JPRS: 3420

20 June 1960

CENTRAL ASIA

PHYSICAL GEOGRAPHY HANDBOOK

by V. M. Sinitsyn

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CSO: 3259-D

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V. M. Sinitsyn

Tsentral'naya Aziya
/Central Asia/
State Publishing House of Geographical Literature, Moscow, 1959, Pages 3-11; 43-122; 151-254; 276-309; 368-425; 448-449; also, seven loose maps inserted on inside back cover
Russian , bk

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FORWARD

(In memory of Vladimir Afanas'evich Obruchev, a pioneer in Central Asiatic studies.)

Central Asia is one of the least-known regions of the earth. Investigation of Central Asia has been strongly handicapped in the past by the extreme continental character of its climate, its broad, waterless deserts, the great altitudes of its mountain ranges, and its remoteness from populated centers. Therefore in Central Asia the period of scientific reconnaissances has extended up to very recent times and still cannot be considered as completed. The systematic and many-sided study of its natural features began very recently and has covered only inconsiderable areas. But investigations are being expanded from year to year, and the time is not far distant when Central Asia will be studied as thoroughly as other parts of the continent.

Up to the present time, working topographic maps have been available for only one fourth of the area of Central Asia with the remaining expanses being shown on maps mainly on the basis of data from the surveys of main routes.

Among the specialized studies of the territory of Central Asia, geological surveys have been the most fully carried out. Geological maps at a scale of 1:1,000,000, and for individual areas at even larger scales, are available for the Mongolian part of Central Asia, for the Western Kunlun, Tien Shan, Dzungaria, the Altay, the Tsaidam basin, and the Kansu corridor. Systematic soil and botanical investigations have been made only in Mongolia, commencing in 1957 in Dzungaria.

The literature on Central Asia is still comparatively small and is composed mostly of reports of a small number of geographical and geological expeditions containing material on the respective exploration areas and also articles devoted to individual questions by members of these expeditions. There is still no description of the natural regions of all Central Asia, unless one counts the famous work of Alexander Humboldt, which is more than a century old, or the brief descriptions of the area contained in textbooks on the geography of Asia.

However, there are regional descriptions, utilizing the results of the most recent work, for many areas of Central Asia. Among them should be named the work on Eastern Mongolia and the still unpublished geographic description of the Nan Shan by V. A. Obruchev, the physical-geographic account of the MPR [Mongolian People's Republic] by E. M. Murzayev, the monographs on the soils and vegetation of the MPR by N. D. Bespalov and A. A. Yunatov, on the stratigraphy of Mongolia by N. A. Marinov, and also the geographical and geological descriptions by the present author of the Ala Shan and Ordos, the Eastern Tien Shan and Pei Shan, Trans-Altay Gobi, Gashun'skiy Gobi, the Turfan-Khamiyskiy depression, and the northwestern part of the Tamir basin.

In preparing the present book, which offers the reader a short physicogeographical and geological study of Central Asia, all the major source materials, both Russian and foreign, were utilized. A considerable proportion of the material presented consists of information obtained through the personal investigations of the author, who has visited all the major regions of Central Asia.

Over the course of many years the author worked under the supervision of former academician Vladimir Afanas'yevich Obruchev and was continually favored by his advice and instructions.

Invaluable assistance was given the author in the course of his field work by various Chinese and Mongolian organizations.

PART ONE

GENERAL DESCRIPTION OF CENTRAL ASIA

Introduction

The term "Central Asia" was introduced into the scientific literature in the second half of the nineteenth century as a result of Alexander Humboldt's classic work on this area of the Asiatic continent.

A. Humboldt gave the name Central Asia to the high plateau which stretches longitudinally between the Altay and the Himalayas and latitudinally between the Great Khingans and the Turan plain.

Later, Ferdinand Richthofen, the famous explorer of China, proposed to call Central Asia that region which does not have an outlet to the ocean, with the exception of the Aral and Caspian basins which lost their outlet to the sea in the recent geological past. Central Asia was similarly defined also by I. V. Mushketov, the specialist on Western Turkestan.

V. A. Obruchev also considered lack of drainage the major characteristic of Central Asia, but, unlike F. Richthofen, he did not include in this area the regions of the Tibetan mountains and Kunlun.

Even among recent authors there is no unanimity of opinion as to the boundaries of Central Asia. For example, A. M. Murzayev, author of the well-known description of Mongolia and Northeastern China, is inclined not to restrict himself to the physicogeographical content of this concept. Instead, in order not to transgress the political boundaries of Mongolia, he proposes to include in Central Asia the basins of the upper courses of the Selenga, Orkhon, and Kerulen rivers which constitute an extension of the Trans-Baykal forest-steppe.

The lack of drainage, which was earlier considered as the main feature in the definition of the boundaries of Central Asia, is undoubtedly an important geographic characteristic of this region, but it is not the only one, nor even the most basic one. Central Asia has other important orographic, climatic, geomorphological, soil, geobotanical, and zoogeographical characteristics which have found expression in specific (Central Asiatic) types of landscapes, indigenous only to this territory and sharply distinguishing it from the surrounding regions.

Orographically, Central Asia is the area of high plains and mountains of the interior of the continent, surrounded by an almost continuous ring of tremendous mountain ranges which serve as climatic barriers.

Climatically, Central Asia is an arid region with an extreme continental climate, lying between areas of the Atlantic and Pacific Ocean circulations and isolated from both.

In relation to the Quaternary cover, Central Asia is characterized principally by the distribution of sands and loesses, a rough overburden of alluvia "gammady," prolluvium on the foothill plains, and colluvial accumulations in the mountains which the weak seasonal torrents are not able to carry off.

As regards its water system, Central Asia represents a region of internal drainage with a very disorganized hydrographic net composed of dry stream beds--"sayry"--grouped around numerous inland basins.

Central Asia is remarkable for the unusual activity of the most recent tectonic movements and for the very slow processes of erosion. Therefore all the young structural forms--uplifts and grabens, block phases of complex structure, "adyrnyye" folds, monoclines, and the inclined plains of the pedestals of mountainous elevations ("beli")--are directly reflected in the relif. The ancient eroded plain, on the basis of which has been formed the modern relief of Central Asia, is well preserved even on the high ranges.

As regards the character of its soils, Central Asia constitutes an enormous block of desert sierozems, bordered only on the periphery by chestnut soils.

Geobotanically, Central Asia is a region of extremely sparse and monotonous vegetation consisting almost exclusively of perennial xeromorphic underbushes and bushes, prominent among which are drought-resistant "stone-lovers" and "sand-lovers" (Ammophila arenaria) and also halophytes.

Zoogeographically, Central Asia is a kingdom of ungulates and rodents. The distribution of the former is aided by the open relief and snowless winters which permit grazing throughout the year. Rodents, however, can endure long periods without water, live nocturnal lives, and become torpid during the summer heat.

Geologically, Central Asia represents one of the most ancient regions of the earth, within the limits of which the continental system has been dominant for a large part of the post-Proterozoic era (in the Lower Sinisian), during the whole Middle Paleozoic, and from the Upper Permian to the present time). As a result of the predominance of uplift movements in Central Asia, its ancient metamorphic foundation is not deeply deposited and emerges to the surface over large areas.

Already in the Upper Jurassic period the climate of Central Asia was becoming arid, and since then its aridity has increased. In general, Central Asia constitutes an inner-continental region of peculiar desert relief forms where an arid climate has prevailed for more than 100 million years.

A major role in the isolation of Central Asia has been played by the newest relief-forming movements, which have created high ranges on its borders. These ranges have served as barriers to air currents. The isolation of Central Asia from moist air currents has resulted in the establishment within it of an arid system. This in turn has caused a sharp reduction in the volume of surface waters in this territory and a weakening of the processes of erosion which now, in consequence of

intensive lifting, are not able to surmount the internal, often quite inconsiderable, orographic barriers which block a flow. Thus, as a result of the steadily intensifying aridity of the climate, Central Asia has been transformed into an area of internal drainage with a primarily dry and disorganized hydrographic network. Associated with the small and seasonal character of the surface flow of water in the presence of weak erosion processes is the predominance in the Quaternary deposits of aeolian and prolluvial types. The composition of the Quaternary cover in turn has exerted a very considerable influence on the formation of the soil cover. The soils in turn have played a very important role as one of the factors determining the nature and distribution of the vegetation cover, and this last has affected the type of fauna.

The border of Central Asia is clearly defined. It consists of mountain ranges bounding the high plains and plateaus of the inner part of the continent which receive less than 200 mm of precipitation annually. On the watersheds of these mountains the desert land forms of Central Asia are replaced by the more eroded steppe reliefs of the border regions with a better-organized river system and a denser and more diverse grassy vegetation cover which has developed on the chestnut soils. Along individual parts the enclosing mountains serve as general or regional watersheds. In consequence, the orographic and climatic boundary of Central Asia is at the same time the hydrographic, geomorphological, soil, geobotanical, and zoogeographical boundary.

The boundary of the arid region of Central Asia lies along the mountain peaks of the southern and northern Tien Shan ranges curving around the Iliyskiy basin, which is open to the west and therefore more humid. Farther, it runs along the meridional ranges of the Pamirs which divide this region into a western moist half and an eastern dry half. Then the border follows the peaks of the Karakorum range and the Trans-Himalayan, Kaylas and N'yenchen-Tangla ranges, and farther along a projection of the diagonal elevation which separates the Tibetan uplands from the Kama and Amdo mountains.

In the Nan Shan the boundary of Central Asia intersects a system of parallel ranges on a powerful lateral uplift which form here a wedge-shaped extension to the west because the eastern part of this mountainous area is protected from the dry winds of the desert and is accessible to moist winds.

In the part between L.nchou and Kalgan the boundary of Central Asia coincides with the broad flat ridges along which the Great Wall of China was erected. Farther, the boundary is formed by the western edge of the Jeho plateau, the southwestern slope of the Darigan range, and the foreland of the Central Khalkhasskiy plateau. Thence it runsalong the summit of the Han-hai, then along the southern slope of the Tannu-Ola range, on into the Mongolian Altay, and to the sources of the Urungu River. In the Altay, skirting the high peaks of the range and its adequately watered slopes, the boundary of the arid region descends to the level plain of the watersheds of the Chernyy Irtysh and Urungu rivers.

Map 1. The borders of Central Asia.

[as keyed in original]: Boundary of Central Asia

Place names: Same as Map 6 [p. 58 of original]

Thence it runs along the peaks of the Saur, Kodzhur, Urkashar, Dzhair, and Mayli to the Dzungarian gates and, passing through the gates, follows along the crest of the Dzungarian Altay around the Borotala trough in the upper reaches of which it joins the Tien Shan section already considered.

Thus within the limits of Central Asia are found the Tarim and Dzungarian high plains, the Eastern Tien Shan, Kunlun, the Eastern Pamirs, and the northern slope of the Karakorum, the Tibetan plateau, the Tsaidam basin and Western Nanshan, the Gobi Altay, the lake plains of Western Mongolia and the southern slope of the Han-hai, Ala Shan and Ordos, Yingshan and the Eastern Gobi with the arid plains of the Chakhar. In width Central Asia extends 3,700 km and in length 2,200 km. Its extreme points are found in the north at 51° N. lat., in the south at 30° N. lat., in the west at 73° E. long., and in the east at 117° E long.

The area of Central Asia is 4,360,000 km^2, or about one ninth that of the Asiatic continent (without islands). Three fourths of the area of Central Asia lies within the boundaries of the Chinese People's Republic and about one fourth inside Mongolia. In the Eastern Pamirs and Southern Tuva the Central Asiatic areas lie within the territory of the Soviet Union. The greatest contrast in natural conditions appears in the south, where only 150 km separates the cold Chang Tang desert from the monsoon area of India with its exceptionally heavy precipitation, high temperatures throughout the year, and diversified ever-flowering vegetation. In the southeast the Central Asiatic desert also borders on hot and moist regions, but here the transitional land forms occupy a larger area because the ranges separating the two areas lie not across the path of movement of moist air masses but rather parallel to it. In the northeast Central Asia borders on an area of mountain-steppe land forms which block the effect of the East Chinese monsoon. Here the ranges lie perpendicular to the main direction of the movement of air masses; therefore its boundary here is sharply defined. In the northeastern part of the boundary the desert land forms of Central Asia border on the Siberian taiga, which is characterized by low winter temperatures and permafrost. Central (Tsentral'nyy) Asia is least sharply distinguished from the similarly desert Middle (Srednly) Asia which borders it to the northwest. But even here the boundary of the more arid Central Asia appears distinct, thanks to the dividing ranges and also to the different seasonal distribution of precipitation, which also influences the types of land forms.

Only in a few areas is it difficult to decide whether or not they belong to the area of Central Asia. Thus it was formerly uncertain whether or not the latter included the Ordos, which embraces the gigantic bend of the Huang Ho and, consequently, belongs hydrographically not to the landlocked regions of Central Asia but rather to the basin of the

Pacific Ocean. But the uncertainty disappeared and the attribution of the Ordos to Central Asia was confirmed when the resemblance of its desert land forms to those of other Central Asiatic areas was established. Moreover, discovered in the interior of the Ordos were typical Central Asiatic landlocked basins.

All other difficulties in fixing the boundaries of Central Asia arise in consequence of the "weakening of the desert land forms in parts lying in the gaps in the mountainous framework through which flow masses of moister air from the outside. Such phenomena have been discovered in parts of Western Kunlun, bordering the Altay trough, on the northern slope of the Tien Shan, in the area of the Nilkhinskiy saddle, and on the southern slope of the Mongolian Altay, which checks the influence of the moist air masses moving along the Trans-Sangskiy depression.

4. Water and the Hydrographic net

There is very little water in Central Asia. From the slight quantity of precipitation which it receives, usually amounting to less than 150 mm a year, hardly one tenth of that falling during showers flows into the surface and underground watercourses. (During slight rains the drops evaporate in the lower levels of the dry air or upon touching the heated surface of the desert.) In winter on the plains of Central sia the snow forms a very thin and discontinuous layer which, as a result of the enormous evaporating capacity of the dry air, lies on the ground for not more than 2 or 3 days. Thus the snow does not substantially add to the reserves of river and underground waters. Therefore the greatest part of the area of Central sia has no permanent water flows. In its dry channels, water appears very rarely and for only a few hours after the very infrequent showers.

Central Asia receives most of its water from the slopes of the high surrounding ranges which block the flow of humid air from the Atlantic, Indian, and Pacific oceans. The main moisture condensers for Central Asia are the Western Kunlun and Karakorum, the southern and northern ranges of the Tien Shan, Nan Shan, the Mongolian Altay, and Han-hai in which originate all the great rivers. On the desert plains the moisture which has accumulated in the mountains again evaporates. Most of the moisture here evaporates in the irrigated fields and terminal lakes.

Another important hydrographic feature of Central Asia is its landlocked character. Only three of its peripheral sections are in areas of a surface flow; the zone of desert plains of Alashan and Ordos which border on the valley of the Huang Ho, the eastern edge of the Tibetan plateau which includes the sources of the Yangtszu, Langtsakiang (Mekong), and Nukiang (Saluen) rivers, and the southern slope of the Mongolian Altay at the sources of the Irtysh River. Most of the territory of Central Asia consists rather of a large number of landlocked basins occupying separate enclosed depressions. Their areas vary from many hundreds of thousands to tens of square kilometers. The centers of flow of the major basins are located in the enclosed Tarim, Dzungarian, Alashan plains--"soty," the plains of Western and Eastern Mongolia, the Tsaidan basin and the Chang Tang plateau, and also in the great intermountain troughs (Turfan-Khamiyskoy, Barkul'skoy, and others). Together, the landlocked basins of Central sia form a special hydrographic system isolated from the surrounding regions of surface flow. A large part of the boundaries of Central Asia lie along watersheds of world significance. The northern part, stretch along the summits of the Han-hai, Tannu-Ola, and Mongolian Altay, serves as a watershed between the landlocked region and the basins of the Arctic Ocean. The Southern part, formed by the Karakorum and Trans-Himalayan ranges, stretches between the landlocked region and the basin of the Indian Ocean. The eastern section stretches along the Jeho plateau between the landlocked region and the basin of

the Pacific Ocean. Only the northwestern section of the boundary, which is formed by the Dzungarian, Tien Shan, and Pamir ranges, does not constitute a general watershed, because here other regions of internal flow (Aral-Caspian and Balkhash) border on the hydrographic net of Central Asia. The Aral-Caspian and Balkhash regions are distinguished from the Central Asiatic area by climatic features and by the fact that until the end of the Tertiary period they maintained an outlet to the ocean.

Landlocked basins. In Central Asia there are hundreds of landlocked basins which are joined on the basis of general orographic features into groups of regional, district, and local significance.

The groups of regional landlocked basins are linked according to the position of terminal water reservoirs within the boundaries of the same valley or intermountain basin and watercollecting areas in the contour of its mountain framework (Map 4). In Central sia there are nine regional groups of landlocked basins: the Tarim (with the basin of the Su-le Ho), Dzungarian, Tibetan, Tsaidam, Turfang-Edzingol', Western Mongolian, Eastern Gobi, Chakhar, and Ala Shan (with the interior landlocked basins of the Ordos). Of these regional groups only the Tarim basin constitutes a more or less unified hydrographical net; all the others are subdivided by inland watersheds into smaller groups of district significance. Thus the Dzungarian regional group is broken up into the Ebinorskiy, Ayrankul'skiy, and Ulyungurskiy district groups, situated in separate enclosed depressions of this plain. But even the district groups usually do not represent a unified river system in their turn being made up of isolated hydrographic elements.

The structure of the hydrographic net of individual basins and groups of basins is very diversified. It depends basically on the relif of the territory of the basin and the distribution of atmospheric precipitation within its limits. In better-watered districts and those with sharper relief, the hydrographic net is more ramified and forms an extensive system through which flow large rivers. However, in the drier districts, especially those where altitude variations are not great, the hydrographic net is less ramified and completely disorganized. And because the better-watered districts of Central sia also have limited altitude variations in the surrounding ranges, it is just these whose river systems are most ramified and in which are found the largest rivers.

A large hydrographic knot is located in the region of the Western Kunlun and the northern slopes of the Karakorum, where originate the chief rivers of the Tarim basin: the Yarkend, Kyzylsu, and Khotan. No less important hydrographic knots are found in the Central Tien Shan (Khantengriyskiy and Irenkhabirganskiy) from which flow the rivers Aksu, Muzart, Khaydyk-Gol (Konchedar'ya), and Manas. Considerable also is the Nan Shan hydrographic knot which embraces the sources of the Edzin-Gol River, the Su-le Ho, and the Datunkhe River.

In the Mongolian Altay the sources of the large rivers are grouped around the main peaks of the Tabyn-Bogdo range (Burchum and Kobdo rivers) and the Munkhu-Tsastu-Khairkhan ranges (Ku-Irtys and Urungu rivers). A mighty hydrographic knot is located in the elevated part of the Han-hai in which lie the sources of such abundant rivers as the Selenga, Orkhon, and Dzabkhana, which radiate from here. In the ranges which lie deep within the arid region of Central Asia, even such high ranges as the Bogdo Shan with the Karlyk Tagh and Gobi Tien Shan, Central and Eastern Kunlun, Altyn Tagh, Gobi Altay, and Lung Shan, the hydrographic net is less ramified and does not possess a single larger river.

Nevertheless, it should be pointed out that the river system of Central Asia, given its extremely dry climate, is considerably ramified and deeply incised into the surface. Even the small desert uplands situated on the Tarim plain (Mazar Tagh, Maralbashiyskiy ridges, Chul' Tagh and Charchak), in the Ala Shan (Bain-Ula, Kharan-Ula, Huhu-Ula), and in the Ordos (Arbiso and Kantageri), with lengths of 15 to 80 km and widths of 1-4 km, are intersected by a network of deep eroded valleys. In their lower parts are found extensive outwash fans which run together on the foothill plain into solid prolluvial deposit strips. A deepening of these valleys now hardly occurs, as is evidenced by the barkhans which line their dry channels. The newest relief forms in these uplands are only wind-eroded(gullies and hollows due to deflation, and sculptured cliffs). There is no doubt that here, comparatively recently, in consequence of an increase in the aridity of the climate, the water-erosion type of dessication has given place to a wind-erosion type. In the period of the formation of the erosion valleys in the desert uplands of Central Asia, sufficient precipitation fell for the development of effective erosion. There was more water at that time in the surrounding ranges on which everywhere there are deep, wide valleys too large for the small rivers which now flow through them. The well-developed river net of the mountains, so unusual for a desert regions, has remained from the preceding period when the climate was more humid.

A great effect on the configuration of the river system of individual enclosed basins is exerted by the relief of the plains within which are located their centers of flow. On the flat plains of the centers the flow is less than on the plains and plateaus with a more dissected relief. Examples of level plains with more organized river systems are those of the Tarim and Dzungarian basins. Examples of plains with differentiated relief and a disorganized hydrographic net are the Ala Shan basin and, in particular, the Tibetan plateau. A more complete river system contributes also to the slope of the plain, the influence of which is particularly noticeable in the Tarim and Dzungarian basins.

The connection between individual hydrographic elements in the landlocked basins of Central Asia appears in various forms and degrees. This is least apparent in the areas of permanent watercourses which in dry and barren Central Asia are rare, shallow, and concentrated in or bordering on the mountainous districts. The rivers of Central Asia usually flow nowhere, suddenly disappearing upon issuing from the mountains and even within the limits of a mountain valley. The underground water courses, into which the failing rivers pour the last of their waters, run farther. Some of them run together in the plains, and as a result become a local or district center of flow. In consequence, the underground hydrographic elements of the enclosed basins are linked somewhat more closely than the surface streams.

The closest connection is found among the dry channels of individual enclosed systems. In the deserts of Central Asia the river channels do not terminate where the surface watercourses disappear, but extend farther deep into the plain for many tens of kilometers, frequently becoming the major stream or terminal reservoir of a given basin. All the large rivers of the southern margin of the Tamir plain, Southern Dzungaria, and Southern Tsaidam have extended dry lower reaches. There has been no water in them for many centuries.

Dry channels--"sayry"--furrow the entire surface of the Gobi plains, particularly close to the mountains and in areas with hilly relief. Individual sayry reach many tens of kilometers in length, have complex ramifications, and possess water-collecting basins of 5,000 km^2. The flow in the sayry rises suddenly during heavy rains, quickly becomes a powerful and turbulent current, and subsides just as quickly. The rainwaters often wash along the sayry into a landlocked basin where for a certain period there arises a small lake ("takyr"), partly absorbed by the coarse, readily penetrable sediments of the channels. Therefore the large sayry frequently have underground flows which disappear only in periods of prolonged drought. The channels of the sayry usually do not form a single connected system for an entire enclosed basin, but rather are combined into separate groups with local centers of flow.

The rivers of Central Asia are also unusual. They flood not in the spring, as in the western and northern regions, but in the summer, during which up to 80% of the annual precipitation falls and there is rapid glacial melting. As a consequence of the "episodic" character of the summer rains and snowfalls, the floods develop unevenly with an alternating sharp rise and fall in water level. The steep incline and bare surface of the mountain slopes contribute to the rapid run-off into the river valleys and to the sudden occurrence in them of turbulent currents which rush along at speeds of up to 8 m/sec,/ carrying along an enormous quantity of rubble. At such times the rivers accomplish an enormous amount of erosion, as a result of which their gorges are deep and narrow. The function of glaciers in feeding the Central Asiatic rivers is inconsiderable due to the fact that the winter periods in which they accumulate moisture are periods of minimum precipitation.

The narrowness of the gorges and the great speed of the currents of the mountain rivers do not facilitate the growth along them of large areas of vegetation. Therefore the mountain rivers in Central Asia do not animate the landscape to the same degree as in other mountainous regions.

At the edge of the desert plains the pitch of the river channels decreases sharply and their speed of flow is correspondingly reduced. In this zone the rivers deposit the main mass of the coarse material they carry from which is formed the thick alluvial fans. In the foothills, as a result of the enormous filtering capacity of the stony deposit strip, all the small rivers disappear and the large ones lose a considerable part of their water. On the open plain, where the gradient of the surface becomes still less, the rivers flow in wide, shallow sandy-muddy channels. Here the seepage of water into the channel bottom is not great but there is a high degree of evaporation.

The rivers of the plains are influenced by even quite insignificant changes in surface incline. Therefore in the parts undergoing uplift their waters flow in a single narrow channel cutting into the alluvial deposits, and in parts which are in the submergence stage the rivers divide into a great number of distributaries and their sediments block up the channels. Along the subsiding parts, as a result of the silting of the channel, the water level in the rivers rises and sometimes becomes higher than the old channel bottom. In such cases the rivers break the dike of their friable, easily-penetrable rocks and resume their old course, moving in another direction, often hundreds of kilometers from their original location. There are many such "roaming" rivers in Central Asia. The Konchedar'ya is a wandering river; it has in its lower reaches three channels with different directions (Ilek, Kokyangak, and Kurukdar'yu), by which it can send its waters into the Chonkul' lowland, the Arganskiye lakes and the Tarim, and, finally, into the Lop Nor. The Dzinchan River on the Dzungarian plain has several arms directed toward various basins. The terminal lake of this river also does not have a constant position and, depending on the distribution of waters along the several channels, is located now in the Ayrankul' basin, now in the Ikhekhak basin.

Another well-known example is the wandering Edzin-Gol River which feeds Lakes Gashun-Nur and Sogo-Nur on the northwestern edge of the Ala Shan desert. In its lower reaches the Edzin-Gol divides into several arms which extend over a strip up to 80 km wide. As a result of the periodic shifts of waters between these arms, Lakes Gashun-Nur and Sogo-Nur regularly change in dimension; more exactly, when the volume of one of them is increased, that of the other is reduced, and vice versa. In the past, a part of the waters of the Edzin-Gol flowed into the Khodun-Khoshu basin which is situated 25 km southeast of the present lakes. The waters of Lake Khodun-Khoshu supplied the ancient city of Khara-Khoto, which was abandoned by its inhabitants in the fourteenth century.

The large rivers of Central Asia, such as the Tarim, Cherchen, Dzinchan, Edzin-Gol, and others which carry great volumes of water and cross extensive plains, are typical transit rivers of the desert. They have no effect at all in moderating the climate of the surrounding area and hardly modify its landscape. This transit character is also manifest by the Huang Ho along the part of its course between Ala Shan and the Ordos.

The rivers of Central Asia have great importance for agriculture as sources of irrigation water for fields without which cultivated plants could not exist here. On the banks of all the large rivers, in the zone where the conglomerate of the foothill deposit strip is replaced by loess and clay soils, there are extensive oases with large tracts of irrigated land. As a result of the abundance of solar heat and light and the fertile loess soils, the irrigated fields of the oases yield rich harvests of grain, fruits, and vegetables. However, the waters of the Central Asiatic rivers are not all used in agriculture; a large part of the water still flows along the channels into the desert without being of use to man. Neither the flood waters nor that part of the waters which the rivers carry in the seasons when the fields are not irrigated is much used. The construction of water reservoirs and new and improved irrigation systems will make it possible to utilize more fully the resources of the river waters--the main wealth of the desert--and to enlarge considerably the areas of irrigated land.

Lakes. In Central Asia there are many lakes which form the terminal water reservoirs for large and small landlocked basins. In the Gobi desert the lakes are situated throughout the open plain at altitudes of 300 to 1,300 m. In Tibet, Tien Shan, Kunlun, and Nan Shan they are found in smaller intermountain troughs and basins with lake-bed altitudes of from 3,000 to 5,400 m.

The lakes of Central Asia are concentrated primarily in its semidesert zone where precipation is somewhat greater, there is less evaporation, and where the waters are collected which flow from the high surrounding ranges. In the desert zone, which receives less than 100 mm of precipitation annually, are found only scattered lakes which are either the terminal water reservoirs of regional basins such as the Lop Nor, Gashun-Nur, and Khalacha, being fed by large rivers, or terminal water reservoirs of basins of district significance like Lake Bodzhante in the Turfanskiy depression and Lake Tagkul' (Shona-Nur) in the Khamiyskiy, which are located near high mountains covered with perpetual snows. Under similar relief and climatic conditions, the sizes and number of the lakes increase outward from the most arid internal districts of Central Asia towards its margins where the landscapes are already semidesert. This regularity is expressed with particular clearness in the location of the lakes of Tibet which are relatively rare and small in the dry Chang Tang and numerous and larger in the better-watered southeastern highlands.

In the past the lakes of Central Asia were more numerous and larger. There is clear evidence of this in the ancient river banks and lake deposits with fresh-water fauna, which are found on the plains far beyond the shores of the present lakes. The latter consequently represent relics of the enormous water bodies of the early Quaternary period. The ancient lakes of the flat Gobi and the very broad depressions of Tibet are distinguished from the water bodies found there now not only in depth but in area, with the latter sometimes exceeding that of the present lake by 6-10 times. For example, the area of the bed of the dried-up Bolshoy Lop Nor Lake is about 28,000 km^2 while that of the lake which remains (plotted on the 1942 topographic map) amounts to only 2,500 km^2. The area of the ancient Lake Edzin-Gol' amounted to 1,400 km^2, while the area of its "heirs"--Gashun-Nur and Sogo-Nur--is 350 km^2 (Map 5). The lakes which were found in the narrow intermountain basins were only a little larger in area than the present ones but had greater depth. In the valley lakes of Tibet the water level was 120-200 m higher than at present. Even in the case of lakes Ebi-Nur and Ubsu-Nur, which were located

Map 5. Edzin-Gol Lakes in the Ala Shan (after Gerner and Chen).

/Legend:/
1--Present lakes;
2--Lakes which have disappeared within the historical period;
3--Ancient lakes with well-preserved shore lines;
4--Probable shore line;
5--Areas of sand dunes;
6--Outcroppings of bedrock.

/Place names:/
7--Lake Gashun-Nur
8--Lake Sogo-Nur
9--Khara-Khoto
10--Muren-Gol River
11--Narin-Gol River
12--Ikhe-Gol River

in large intermountain depressions, the difference in water level amounts to 50-60 m. Many Central Asiatic lakes have dried up completely. There disappeared the enormous lakes of the Tarim plain, lakes which covered it in the area of the Khotan-Keriyskiy watershed, in the area of the junction of the Yarkend, Aksu, and Khotan rivers, and in the Shakh yarskiy lowland. And of the huge ancient Southeastern Tsaidam Lake with an area of more than 20,000 km^2 there remain only a few small lakes which dry up at times.

The lakes located on the plains are not deep (at most only a few meters) and their shorelines change regularly. The mountain depression and valley lakes are deeper and have constant shorelines. The levels of the lakes of Central Asia fluctuate considerably as a result of irregular precipitation and seasonal changes in rates of evaporation. The small lakes exist only in periods of rain and floods, at other times constituting dry or swampy salt marshes. The large area and slight depth of the Gobi lakes makes them efficient water evaporators.

To one degree or another all the lakes of Central Asia are saline. The maximum content of salt is found in lakes situated in the interior of the desert, where less than 100 mm of precipitation falls per year. Moving out towards the margins, the concentrations of salt in the lake waters diminish.

Underground waters. In the deserts of Central Asia, due to poor surface flow, ground waters are of great importance. These are formed on the foothill plains in the zone of coarse and friable deposits. The river waters absorbed by the alluvium form an underground stream which may, under favorable conditions, reach the surface. Most favorable for the issuing forth of ground waters are tectonic benches which cut the water-bearing stratum and guide it to the level of the surface of the lower bench. Ground waters issue forth often and abundantly near high mountains from the slopes of which many rivers flow onto the desert plain. To the extent of the dip into the very dry area of the desert the network of springs quickly thins out, which reduces the flow of water and increases its salt content. Ground waters accumulate also around the relatively low internal elevations in the desert, on which in periods of rain there arise temporary streams. The discharge of springs from interior groups is generally small and varies in accordance with the water-basin area and the height of the hills found within its limits.

The point where ground waters issue forth to the surface and the locations of their shallow pools are marked by growths of Lasiagrostis, reeds, heterophyllous poplars, small species of Carex, and tamarisk. In such "wandering" oases small streams are frequently found with lengths of several hundred meters.

Strangely enough, groups of springs are found also in the dry areas of the desert--in Eastern Dzungaria, in the Kuruk Tagh, Pei Shan, and on the southeastern margin of the Tamir plain, which possesses small reserves of ground water. This paradox is explained by the peculiarities of the geological structure of the areas named, peculiarities which favor the issuing forth to the surface of ground waters. In particular, this is facilitated by the absence or poor development of the absorbing cover.

Springs and "dry" oases having no surface-water flow, are found in clusters extending along fractures. A considerable number of them are found in the southern edge of the Tamir plain at the base of the surrounding foothills, in Southeastern Dzungaria along the boundary with the forward benches of the Tien Shan, in the Turfan depression along the mountain ridge of Tuz Tagh and in other regions.

In the Turfan-Khamiyskiy depression ground water is widely used for the irrigation of fields with the aid of sloping water-conducting conduits ("karysiy"). These are set into the sediment on a level with the circulation of the ground waters. They reach many kilometers in length, and the depth of their leading ends may amount to 80-100 m. In accordance with the reduction in thickness of the coarse water-bearing deposits, the depth to which the karysi are laid is reduced. In sections of wedge-shaped water-bearing lenses, they run on the surface.

Almost completely waterless is the Gashun'skaya Gobi, which receives a minimum of atmospheric precipitation and is isolated from streams of underground waters from other regions in consequence of the relatively high altitude of its surface. Known in the Gashun'skaya Gobi are only individual periodically drying-up springs of mountain-salt water, strewn throughout the completely lifeless desert at distances of 100-200 km from one another.

The water resources utilizable for economic purposes can be increased by tapping the artesian basins of the Yarkendskiy, Kucharskiy, Manasskiy, Turfan-Khamiyskiy, and Tszyutsyuan'skiy foothill depressions which are filled by thick strata of poorly-compressed Mezo-Cenozoic deposits. The areas supplying the artesian basins are located in the foothills of the basins where the Mesozoic and Cenozoic deposits are dislocated, raised considerably, and exposed. In a depression of synclinal structure and in a zone of the thinning out of Neocene-Pleistocene conglomerates (which attain a great thickness only in the foothills) waters under pressure may be obtained.

Development of the hydrographic net and the direction of its growth. The present hydrographic net of Central Asia was formed along with the development of Mesozoic-Cenozoic orogenic processes and in dependence on them. Therefore the position and orientation of its individual elements are determined by the extension and hypsometric relations of the basic structural-orographic units of this region and their relative developments.

The sources of the principal rivers of Central Asia lie in the nascent peaks of the mountain systems. In the Tien Shan these are the peaks of the northern and southern chains, and in the Kunlun the peaks bordering the Tibetan highlands. Along these ancient peaks lie general and regional watersheds. However, the peaks bordering the Gobi plain arose later than the watershed peaks, after the major elements of the hydrographic system had been formed. The major rivers traverse them along narrow valleys. The local elements of the hydrographic net of the bordering ranges correspond to those of the younger peaks.

The opinion is frequently expressed in the literature that the landlocked character of Central Asia constitutes a relic phenomenon and that the process of dismemberment of the landlocked region is being completed with the gradual transition of its individual parts into areas of external flow. However, the facts which would permit the drawing of such a conclusion have still not been established. The orogenic process is in a stage of progressive development and the aridity of the climate continues to

increase. As a result, the "lag" in the denuding processes in relation to the tectonic processes which are forming the orographic barriers continues to increase. Therefore it is unlikely that the landlocked region of Central Asia, which originated in the primary stage of the orogenic process under conditions of a less dissected relief and a moister climate, is now being subjected to dismemberment. It is natural to postulate the reverse, i.e., that the latest stage in the history of Central Asia is accompanied by a further disorganization of the river system in consequence of the fact that the orogaphic barriers which separate the individual basins have been further elevated and erosion has lessened. Examples of the recent isolation of basins are numerous. The most remarkable of them are the separation from the Tarim basin of the Su-le Ho system, the transformation of Lake Kukunor, which formerly flowed into the Huang Ho system and now terminates in an enclosed basin, and the disruption of the previously united southern Tsaidam basin into small parts with independent terminal water reservoirs.

However, along with the continuing disorganization of the river system of Central Asia, there may occur in some localities a uniting of several basins and even the transition of several of them into an area of external flow. But this can only be the result of tectonic movements which have so changed the altitude of the surface of the basins that even the slow processes of erosion have made inevitable their hydrographic combination.

5. Geomorphological Features

Major features of the geomorphology of Central Asia. The geomorphological landscapes of Central Asia are very unusual. This is determined by the great intensity of recent tectonic movements which have resulted in the formation of bold forms of relief and also in the extreme slowness of the erosion and accumulation processes which level it.

Central Asia lies within the boundaries of the inner-continental upheaval which in both area and amplitude of vertical movements is the greatest in the world. Ranges and highlands with altitudes of 3,500-5,000 m are customary, while summits are not unusual which rise to more than 6,000 m. Even the plains have altitudes of 1,000-1,500 m. The absolute magnitude of variations in the altidue of the surface in Central Asia amounts to 7,600 m, the relative magnitude to 5,000 m, while variations in altitude of as much as 1,000-1,500 m are encountered almost everywhere in the mountainous districts.

The aridity of the climate in Central Asia has slowed erosion processes and changed the interrelations among their significant factors. It has sharply reduced the role of the most powerful of these, that of water erosion, and has strongly increased the effectiveness of the least effective of these, wind erosion.

Thus in contrast to the newest tectonic movements which intensify the contrast relief and contribute to the development of erosion and accumulation, the arid climate limits the progress of these processes. In Central Asia, therefore, the relief forms created by the newest tectonic movements are little altered by erosion and have preserved their structural appearance. All forms of new tectonic movements are directly expressed in the landscape and, in particular, the "adyrnyy" upthrusts, monoclines, and peripheral terraces of the foothill zones which arose during that stage of the orogenic process in which the most arid climate was dominant. In the adyrnyy upthrusts, for example, orographic and structural forms sometimes completely coincide, and the angle of incline of the stratum and the angle of decline of the layers in the corresponding fault side are equal, with every change in the angle of incline of the layers in the fold being accompanied by similar changes in the steepness of the stratum slope. The levelling and dying out of the fold is expressed in the relief by the levelling of the stratum and its subsequent submergence to the level of the plain. The form of foothill terraces also precisely reflects their structural form. Usually these are broad, slightly inclined to the surface of the plain, and bordered by a steep and perfectly rectangular bench.

High plains and mountain plateaus are dominant among the landscapes of Central Asia. The former occupy the major part of the Gobi floor, while the latter play a leading role in the relief of the Tibetan uplands. Areas of dissected relief occupy a relatively small area and are located along the borders of the mountainous plateaus of the Gobi plains. For example, a highly dissected mountainous relief predominates in the Kunlun, constituting a tremendous bench between the very high Tibetan and the lower Gobi surfaces. In the Nan Shan and Tien Shan systems the dissected mountainous character is to be observed chiefly on the outer slopes of the bordering ranges which face towards the Gobi plains. These slopes possess the greatest relief energies and have thus checked any strong erosion action. In the interior zones of the Tien Shan and Nan Shan, however, there are extensive plateaus the altitudes of which are a little lower than those of the ranges.

The present relief of Central Asia rose on an ancient denuded plain which had undergone a lengthy period of continental development even before the orogenic process. In the process of orogenesis the ancient denuded plain disintegrated into separate blocks of various sizes which were subjected to differentiated faulting movements. On the least mobile and least differentiated blocks the landscape of the plain has been preserved. However, groups of mobile blocks, whose changes of amplitude were of various magnitudes, formed the mountainous elevations. There is evidence concerning the origin of the mountains of Central Asia from the ancient denuded plain in the broad expanses of surface levelling preserved on the watersheds and sides of the peaks.

The most intensive neotectonic movements occurred in the Paleozoic geosynclinal-folding zones: Tien Shan, Kunlun, Altay, and others, where the ranges of high mountains arose separated by intermountain valleys. The newest tectonic movements were less energetic and differentiated within the limits of stable ranges the present reliefs of whose surfaces represent plains of various types.

Because Central Asia is an enclosed landlocked area, sedimentary materials have been borne into it from other parts of the continent, but the local products of disintegration have not been carried beyond its borders. In consequence of the extreme scarcity of running water in the area, rock waste materials originating as a result of weathering have accumulated chiefly in the mountains close to their points of formation. In the modern epoch sediments accumulate comparatively heavily only in the depressions bordering the peaks surrounding Central Asia, areas in which erosion processes are still sufficiently powerful. In the dry interior of Central Asia, accumulation lags considerably in relation to tectonic relief formation. Therefore to be encountered here are non-compensated depressions which are very unusual for the continent. The best-known example of such an uncompensated innercontinental depression is the Turfan basin. Its surface is 100-154 m below sea level, although it is located at the floor of the Bogdo Shan range whose main elevations attain almost 6,000 m.

Principal Types of Geomorphological Landscapes

Gobi plains. Most of the territory of Central Asia is occupied by high plains which have become adapted to the stable massifs or Meso-Cenozoic depressions which originated on the Paleozoic fold of the base. These plains are divided into three types: denuded-base, denuded-stratified, and accumulative (Map 6).

To the first type belong the plains lying on the thick rocks of pre-Mesozoic origin. These are areas of stabilized blocks and areas of Paleozoic folding which were subjected to lifting and erosion in the Mesozoic and Cenozoic eras, as a result of which their rock base is either completely exposed or has only a thin broken cover of eluvial and aeolian deposits. Such are the parts of the Tarim plain belonging to the "oykhartskiy" upheaval, individual parts of the Ala Shan, the lake district of Western Mongolia, and the Chakhar plain. In the sections of denuded-base plains where neotectonic movements were more intensive, a specific type of landscape rose with "beliye", folded ridges, and hillocks. The plane surfaces called beliye are largely asymmetrical anticlines on the surface of the plain serving as bases for small rocky ridges. The anticlines and rocky ridges are of different ages.

Map 6. Geomorphological diagram of Central Asia

/Legend:/

1--denuded-base plains;
2--denuded-stratified plains;
3--accumulative plains;
4--accumulative and stratified plains (in Tibet);
5--weakly-dissected Gobi mountains with remnants of ancient plain;
6--strongly dissected fault-block and folded mountains

/Place names:/

7--Kashgar
8--Yarkend River
9--Ho-t'ang (city)
10--Ind River
11--Satledzh River
12--Delhi (city)
13--Ganges River
14--Chernyy Irtysh River
15--Urumchi (city)
16--Turfan (city)
17--Tarim River
18--Cherchen River
19--Tsangpo River
20--Ulyasutay (city)
21--Dzabkhan River
22--Khami (city)
23--Lake Lop Nor
24--Lake Kukunor
25--Yang-tzu River
26--Dzachu River
27--Nagchu River
28--Selenga River
29--Orkhon River
30--Ulan Bator (city)
31--Edzin-Gol River
32--Lan-chou (city)
33--Hsi-an (city)
34--Kerulen River
35--Khukh-Khoto (city)
36--Huang Ho (river)

The latter are the primary centers of the elevations which were segregated in the relief even before the dislocation of the peneplain and before the climate of the region became arid. The anticlines were formed as a result of the further (progressive) development of the lifting resulting from the warping of the peneplain. Between the beliye are situated extensive flat submergences --"kholai"--which are occupied by enclosed basins with small lakes and solonchak wastes.

The denuded-stratified type of plains are located in sections of ancient peneplains which have experienced in the course of Mesozoic and partly of Tertiary times a prolonged subsidence accompanied by the accumulation of sediments. In the Neocene period they had already been elevated and subjected to denudation. Therefore the original surface of plains of the denuded-stratified type was composed of sedimentary Pre-Neocene strata arranged in more or less parallel beds. Very recent sedimentary deposits are lacking on them or there is only a thin and discontinuous mantle of eluvium and precipitates of eluvial origin. To plains of the denuded-stratified type in the Gobi layer belong the North Dzungarian, Ordos, and Eastern Gobi. Distributed throughout these plains are flat tablelands (mesas) which rise in solitary fashion among the newest wind- and water- eroded surfaces and which represent mainly

remains of the denuded upper layers of the Meso-Cenozoic sedimentary series. Encountered in parts with a deeper eroded dissection are so-called "aeolian cities"--agglomerates of remnants of diversified, frequently weird shapes. Well known is the "aeolian city" of Orkhu on the Dzungarian plain described by V. A. Obruchev, and that of Sulgassar in the Khamiyskiy desert which was discovered by P. K. Kozlov.

The accumulative plains occupy parts of the foothill basins: Yarkendskiy, Kucharskiy, Manasskiy, Chiu-Chu-an, and others which are still undergoing a powerful submergence. The surface of these plains is covered by thick layers of Neocene and Quaternary alluvial deposits. The accumulative plains are not homogeneous in structure and are breaking down into old parts on which the formation of alluvial cover has ceased and is now subjected to dissection by river valleys and a gully network, and young parts where the thickness of the alluvialcover is continually increasing as a result of the accumulation of sediments. To the first category belong the foothill zones of basins undergoing lifting, and to the second the external sinking zones of these same basins.

A special geomorphological complex is represented by the foothill zones stretching along the borders between the Gobi plains and the forward ranges of the Kunlun, Tien Shan, and Nan Shan. These zones consist of very young structured formations laid down by depositions before and during the Quaternary era. In consequence of their youth and the arid climate, these formations have hardly been affected by erosion. At the present time, the foothills are the most active seismotectonic zones.

The elevations of the foothill zone represent three genetic types: "adyrnyy" strata--anticlines (Artushskiy type), monoclinal crests--cuestas (Kel'pinskiy type), and foothill terraces--piedmonts (Cherchenskiy type). Adyrnyy strata prevail in parts of the foothill zones where there are depressions with thick layers of poorly-compressed Mesozoic and Cenozoic deposits. The monoclinal crests--cuestas--are characteristic for foothill zones located outside the Meso-Cenozoic depressions where the newest movements affect the platform mantle of rather thick Paleozoic deposits, primarily limestones, which had not previously been subjected to dislocation. The foothill terraces are located in parts of the foothill zones where there is no sedimentary mantle and the newest movements have affected the older crystalline or Paleozoic folded base which has outcropped or which is not buried deeply.

Accumulative plains in the foothill zones are found only in the western half of Central Asia where the newest movements are particularly powerful.

The Tibetan highlands represent a special geomorphological region which is distinctive among the other plain areas of Central Asia by reason of its tremendous altitude and very complex relief. Here a plateau rising 4,300-5,200 m alternates with mountainous elevations of various altitudes. The plateau of Tibet is heterogeneous in structure. Its

northern part, located between the Kunlun and Tangla ranges, is a denuded-base plain laid down by the folded complexes of the Paleozoic. Predominant in the southern and central parts of the highlands are denuded-stratified plains formed by the sloping-warping deposits of the Mesozoic. The lower parts of the enclosed troughs (in all parts of the highlands) are covered by Cenozoic sediments and belong to the class of accumulative plains.

The mountains of Tibet are blocks of that same denuded plain (base to the north, stratified to the south), but have a somewhat higher altitude and are more strongly dissected. And although in many ranges of Tibet the ancient level surface has been completely broken up, traces of it have nevertheless been preserved in the homogeneous elevated zone which formed in the distant past a single level surface. The amplitudes of relative altitudes in Tibet are less than in the Gobi strata and usually do not exceed 1,000 m. The character of the dissection of its elevations changes from the dry Chang Tang towards the boundaries of the regions which are affected by monsoons, that is, towards the Himalayas and Kam. While in the Chang Tang the summits of the mountains are massive and depressed and the slopes steep and rocky, in the Gandisy Shan and eastern spurs of the Kukushili and Tangla ranges, along with sharp peaks one frequently finds parts of sloping incline with thick accumulations of outwash and turf covers. The Tibetan relief is still in the stage of rising, as is evidenced by the activity of neotectonic movements and the weakness of leveling processes (erosion and accumulation).

With rare exceptions the mountains of Central Asia constitute the groups of blocks of an ancient peneplain, raised over other groups which constitute the level stratum. As a result of the predominance of tectonic lifting over erosive disintegration, which is weak because of the general aridity of the climate, the mountains have been dissected to only an inconsiderable extent. Therefore unique features are present which are nowhere else so clearly expressed by a fault-block mountain. Everywhere are encountered the remains of the ancient eroded plain, remains which are more numerous and extensive the closer a part of the mountains lies to the arid zone. While in the mountains of the arid internal region plateau surfaces predominate over parts with dissected relief, on the more humid and more intensively dissected bordering ranges they have been preserved only in blocks which are not a prominent part of the relief. But even where the ancient level surfaces have not been preserved, the block-faulted appearance of the mountains is clearly seen in the massive forms of the summits and the homogeneity of their upper levels.

A terraced composite relief is characteristic of the mountains of Central Asia. Individual parts of the plateau, with inclined strata, alternate with rectilinear tectonic benches often several hundred meters high. The benches, as well as the plateaus, are poorly dissected, particularly in areas having a more arid climate. Sometimes they serve as boundaries of various geomorphological zones.

Not only the tectonic benches but also the eroded slopes of the mountains are very steep and bare, conditions which have been favored by the great energy of the relief and the desert-type wind erosion.

The widely adopted division of mountainous areas into morphological types according to altitude (low--up to 1,000 m, medium--up to 2,000 m, and high--over 2,000 m) is not applicable to Central Asia, partly because the general hypsometric level of this region is high and unstable, as a consequence of which the so-called low-mountain type of landscape is encountered at various altitudes up to and including 5,000 m (in Tibet). Moreover, in arid Central Asia the degree and type of dissection of the mountains is completely different from that characteristic of those regions of Western Europe having a much more humid climate where these three types were first differentiated.

In this connection, the vertical zoning of the mountain landscapes of Central Asia is clearly expressed, but the zones lie at different heights the magnitudes of which depend, in particular, on the exposure of the mountains slopes in relation to humid air currents.

In low desert elevations the principal role in the transformation of the tectonic relief is played by temporary currents and winds created by the ramified network of dry eroded valleys and eroded-weathered hollows and basins. The weak degree of dissection, in particular the slight depth of incisions, distinguishes these elevations from similar relief forms in other regions, particularly the Kazakh undulating plains (Fig. 1).

Fig. 1. Undulating surface of ancient peneplain in the Gobi Tien Shan. (Photograph by V. A. Amantov.)

In the medium-mountain zone, river erosion is intensive, dissecting the slopes with deep ravines. These become deeper and more ramified as the altitudes of the mountains increase, and the watersheds are transformed from a compact state to a comblike state. In the high-mountain zone glacial erosion is of special importance, having created troughs with a marine landscape, cirques, and pot holes with hanging valleys and rocky watersheds with small accumulations of firn in crevices. And although the relief of the high-mountain regions of Central Asia (Tien Shan, Kunlun, and Nan Shan) is very similar to Alpine relief, it nevertheless has its special features. This relief is distinguished from the true Alpine type by the massiveness of the watershed peaks and the inconsiderable (for such high mountains) recent glaciation.

The elevation along which run the boundaries of the vertical zones of the mountain landscapes of Central Asia is nonuniform and changes, depending on the latitude of the locality and the degree of aridity of its climate. For example, the lower boundary of the distribution of ancient glacial landscapes descends from an altitude of 4,000-4,300 m in Tibet and the Central Kunlun to 3,000-3,200 m in the Southern Tien Shan and to 2,500 m in the Mongolian Altay and Han-hai range.

6. Quaternary Deposits

The aridity of the climate has exerted influence even on the composition of the Quaternary cover of Central Asia, an influence in which the leading role has been played by various aeolian formations and deposits which form under conditions of the absence of running waters.

There is intensive weathering in Central Asia, although it occurs virtually without the participation of water. The chief factor here is the high daily temperature range which causes the splitting and scaling of rocks. Because there are few streams here, the products of weathering are displaced slowly and usually for only a short distance. Of exceptional significance in Central Asia are the winds, which in the region become both an important agent of erosion and one of the major carriers of the products of rock disintegration.

The composition of the Quaternary cover of Central Asia is very diversified in consequence of the complexity of the structure of its surface and the variegated landscapes. In the plane section (Gobi stratum), which lies within the zone of influence of the Mongolian-Siberian anticyclone, there are eluvial formations widely distributed and converted in one degree or another, and an aeolian complex consisting of two spatially-separated phases: sands and loesses. In the mountainous regions there is a considerable development of talus and glacial deposits. Along the boundaries of the mountain regions, deposits of alluvial-prolluvial groups are extensive in several places.

Eluvial complex of the Gobi. Eluvial formations cover an extensive area in the north, eastern, and, in part, the central parts of the Gobi expanse. Their development is promoted by the flat relief and the scarcity of running water. Because the Gobi eluvium formed in an area having a very continental climate with the inextensive participation of surface and ground waters, it is composed only of the products of the physical weathering of the rocks, so that its physical composition is rather coarse. Its main mass is immovable, and only in parts with dune relief is it slightly transportable as a result of creeping from the slopes and washing by sudden rains.

In the most northerly districts of the Gobi, on the boundaries of the Mongolian-Siberian barometric maximum, where the anticyclonic currents are still very weak, the Gobi eluvium constitutes an undifferentiated formation which has still not been subjected to scattering. In the northern zone of the sandy deserts (the small sand masses of Western and Southern Mongolia), wherein the anticyclonic wind acquires a velocity great enough to exert a strong effect on the loose cover, the eluvium loses its fine particles in considerable measure. However, in the stony desert regions of Eastern Dzungaria, Gashun'-skaya Gobi, and Pei Shan, across which anticyclones frequently reach hurricane force, only the large

rubble constituting the rocky armor of the stony desert is retained. In this region of intensive dispersal the wind action affects even the base rocks, on the outcroppings of which arise groups of sculptured and perforated rocks alternating with hollows and grooved shapes (Fig. 2)

Fig. 2. One of the forms of weathering in granites, Southern Tsaidam Basin. (Photograph by Chzhun Fu-do.)

The aeolian Gobi complex. On the leeward side of the region of widespread scattered eluvium is found the major area of aeolian accumulation, which is broken up into two environmental zones: an inner zone of sandy deserts in which the pulverized fraction is not preserved, and an outer zone of loess accumulation in which the latter is deposited (Map 8).

Within the limits of the inner zone are found the Tarim, Ala Shan, Ordos, Tsaidam, and Dzungarian plains, 60-80% of the surfaces of which are covered by aeolian sands. In these deserts the sands are distributed in zones, with different geomorphological bases, different moisture conditions, and different wind systems. Consequently they are not environmentally uniform.

Three basic types of sandy accumulations are characteristic of the desert of Central Asia: ridges, barkhans, and mounds.

Map 8. Zones of aeolian deposits in Central Asia associated with the action of the Mongolian-Siberian anticyclone.

[Legend:] Regions of intensive scattering: 1--zone of stony deserts; regions of aeolian accumulation; 2--zone of sandy desert; 3--loess zone; 4--mountain regions lying beyond the boundaries of the regions of aeolian accumulation; 5--direction of winds of the Mongolian-Siberian anticyclone; 6--main directions of barkhans.

[Place names:]

7--Kashgar
8--Yarkend River
9--Ho-t'ang (city)
10--Ind River
11--Satledzh River
12--Delhi (city)
13--Ganges River
14--Chernyy Irtysh River
15--Urumchi (city)
16--Turfan (city)
17--Tarim River
18--Cherchen River
19--Tsangpo Rivere
20--Ulyasutay (city)
21--Dzabkhan River
22--Khami (city)
23--Lake Lop Nor
24--Lake Kukunor
25--Yang-tzu River
26--Dzachu River
27--Nagchu River
28--Selenga River
29--Orkhon River
30--Ulan Bator (city)
31--Edzin-Gol River
32--Lan-chou (city)
33--Hsi-an (city)
34--Kerulen River
35--Khukh-Khoto (city)
36--Huang Ho (river)

Sands of the ridged type form present elevations with altitudes of up to 150 m and base widths of up to 1 km. The ridges are separated by longitudinal troughs ("bairi") within which the sandy cover is frequently broken and the base rocks uncovered. Many blocks of ridged sands are called "Kumtag," which in the Uigur language means "sandy mountains." The ridged sands are spread through the eastern half of the Takla-Makan desert and on the western boundary of the Ala Shan desert (Karagobi and Badanchzhareng) belonging to the interior region of the Gobi expanse within which the anticyclonic circulation is not complicated by air currents from other directions.

Sands of the barkhan type have a peculiar crescent-shaped form, heights of 5-10 m, and are grouped in series. As a rule, the masses of barkhan sands are located on the exterior side of the zone of sandy deserts next to the zone of loess accumulation, where the weakened anticyclones are interrupted by strong air currents coming from beyond the boundaries of Central Asia. The alignment of the barkhans does not always depend on the direction of movement of the anticyclone. In the Yarkend plain, for example, a strong effect is exerted on them by the northwestern winds which penetrate here from Middle Asia through the Alayskiy wind gap.

The third type of sandy accumulations consists of separated mounds having conical forms and heights of 1-5 m and forming broad, now very dense, now very sparse clusters. Located on each mound is a thicket of desert vegetation, mostly tamarisks. The sand mounds are formed where the level of the ground water is sufficiently high, e.g., on the boundaries of the valleys of the main rivers (Tarim, Khotan, Edzin-Gol, and others) and also in the vicinity of small temporary lakes ("takyri") and solonchak wastelands.

In part the morphology of the sandy accumulations is defined by the character of the relief of the base surface: eroded plains with an abundance of irregularities promote the development of the ridged type, while the accumulative types, possessing a smoother surface, favor the formation of moving barkhans.

The granular composition of the sands becomes coarser, the closer they approach the zone of rocky deserts.

The aeolian sands of Central Asia, as has been shown by a mineralogical study, were basically formed as a result of the frequent scattering of the lake and river deposits of the Gobi plains and the dispersal of the weakly-cemented sandstones of the Meso-Cenozoic complex, which outcrops in sections of hilly relief. The sandstone sands of Central Asia arose mainly not in consequence of a movement of sands from stony deserts, but as a result of the origin along with them of foci of dispersal and sand accumulation which combined into extensive masses as they increased in size. The appearance, however, of new foci

of sand accumulations was caused by the progressive desiccation of the Gobi, which has manifested itself, in particular, in a contraction of the water balance of the rivers and in a lowering of the ground-water level. As a result, the friable deposits, receiving no water and deprived of a vegetation cover became accessible to scattering action.

The loesses constitute a very small fraction of the aeolian formations of the Gobi desert, that fraction most removed from the sources of their formation. The main masses of loesses are found on the southern margin of the desert, on the leeward side in relation to the Mongolian-Siberian anticyclone where the latter, already extremely weakened, encounters a barrier in the form of high mountains. Corresponding to the two flows of the anticyclone--the western, which blows over the deserts of Takla-Makan, and the eastern, which moves over the Ala Shan and the Ordos--there are also two spatially separated regions of loess development: the Kashgar region embracing the northern slope of the Western Kunlun and the southwestern part of the Tarim plain, and the region of the loess plateau of the Northern Sheng-hsi and Eastern Kan-su with the adjacent slopes of Liu-lien, Ching-lin, Eastern Kunlun, and the southeastern spurs of the Nan Shan. Loess has accumulated in these regions under various climatic conditions and on a different geomorphological base which defines the diversity of its genetic types.

According to their manner of bedding and the relative importance of the aeolian and prolluvial-alluvial formations, the loesses of Central Asia can be divided into three main types: mountain loesses, plateau loesses, and loesses of the alluvial (irrigated) plains.

Mountain loesses cover extensive areas on the northern slope of the Yarkend sector of the Western Kunlun (east of 94° E. long), on the eastern spurs of the Nan Shan, on the northern slope of the Ching-lin, and on the western slope of the Liu-lien. In all the above areas the loess layer covering the ancient broken dissected relief is almost continuous. Only those parts of the steep slope are free from loess on which it is not retained but rather slides off. As a result of the nonuniformity of the surface on which the loess layer lies, its thickness is not constant. It diminishes on steep slopes and increases on gentle slopes, the greatest thickness amounting to 20 m. Analogous changes in the thickness of the loess layer are to be observed also on slopes of different exposure. On the slopes of elevations exposed to anticyclones, the thickness of the loess layer is less than on slopes protected from the wind. Therefore in the Eastern Kunlun the layer of loess is thicker on the eastern slopes and in the Western Kunlun it is thicker on the southwestern.

The areas of mountain loesses are considerably less than those occupied by plateau loesses, a circumstance resulting from the less favorable orographic conditions for loess accumulation on on mountains.

In the Kunlun loess is found only on the northern slopes of the ranges bordering the Gobi desert and is absent from the interior ranges lying beyond this orographic barrier. On the forward ranges loess extends up to the watershed summits, reaching altitudes of 4,000 m or more. Moreover, it covers the sides of the troughs of ancient glaciers and their moraines but does not reach the zone of contemporary glaciation. The content of sand grains and their diameters in mountain loess diminishes in accordance with movement into the interior of the range and towards its watershed summit.

Plateau loess is widely distributed in the Northern Shensi and Eastern Kansu where high, extensive plains, dissected by relatively shallow river valleys, border sandy deserts. The flat relief of the plateaus has promoted the spread of loesses over a large territory and an intensive accumulation (layers 60 m thick in places). In this area the loess in large part extends beyond the borders of Central Asia.

The loess cover of the plateaus is subdivided by Chinese investigators into two forms: sang-meng, consisting of reddish marlaceous loams (red stone loess, in Chinese "hung-shih-tu"), and malang, formed from grayish-yellow loams (typical loams, in Chinese "huang-tu"). The first type is found only within the limits of plateaus and places situated close to the lower-lying alluvial beds of the Pliocene, while the second covers even the slopes of the surrounding highlands. The sang-meng type forms the foundation of plateaus dissected by river and gully systems. Malang loess covers the sang-meng type only on watershed expanses and on the surfaces of upper terraces, while on the benches of plateaus and terraces it covers it with a mantle. The lower terraces of valleys which dissect the plateaus are covered with stratified loesslike rocks of eluvial origin, constituting in part the product of the redeposition of malang and sang-meng loesses.

Loesses of the malang type contain a mixture of sandy particles the volume and sizes of which increase with proximity to the deserts of the Ordos and Ala Shan. On the Ching-lin and Liu-lien boundary, loesses of the malang type change into mountain loesses which do not extend here above 2,000 m.

The loesses of the irrigated plains are distributed only in the western part of the Tarim plain, which is irrigated by the rivers of the Kunlun and Tien Shan. Here they can be traced through a wide zone between the foothill conglomerate diluvial-deposit strips and sandy deserts of Takla-Makan. Here the loesses lie on an ancient Quaternary alluvial layer but have been covered by young barklan sands. Along the foot of the mountains the layer of loess is 30 m thick in places. The loess has irregular stratification and contains lenses of alluvial sands and even gravels. With increasing distance from the mountains, the thickness of the loess layer is reduced, at first to 12-10 m, and to 6-4 m deeper into the plain. In addition, the stratification becomes more regular (parallel), finer, and more distinct, and the fine seams of fine-grained

sands which are a part of it acquire a sheetlike form. This facies composition of the loess layer of the Tarim plain is evidence of its primarily prolluvial-alluvial origin. It is clear that in this region, which is comparatively well-supplied with running waters, part of the aeolian dust carried off the sandy and stony deserts has been subjected to alluvial accumulation.

Loess accumulated during a considerable part of the Quaternary period. This process began soon after the major stage of glaciation, as is evidenced by the mantles of mountain loesses on the old moraines and on the upper terraces of the river valleys which carry fluvial-glacial conglomerates.

The process of loess accumulation is continuing even at the present time. Over the sandy and stony deserts arise thick dust clouds which are constantly in view over the southern areas of the Gobi. The loess dust is held in the air for a considerable time, strongly worsening visibility and hampering breathing. Only with the advent of a lengthy calm or a change in pressure and humidity does it settle, covering everything with a fine layer and coloring the landscape a uniform grayish-yellow color.

Mountain complexes. Completely different is the facies composition of the Quaternary cover in the mountain regions of Central Asia (in the Tibetan zone of relief), where as a consequence of the great variation range of relative altitudes and the steepness of the slopes, physical weathering is very intense. Here is formed much rubble material which sporadically moves down the slopes. Gradually sliding into the valleys, the masses of rubble fall within the sphere of action of ice and running water, which move them farther into the area of accumulation.

In the mountainous regions the character of the most recent sedimentation and the processes which prepare material for it, depend a great deal on altitude. In thebetter-watered high-mountain zone the weathering process, as a result of some participation by water, proceeds more intensively than in the strongly submerged central zone of the mountains. (The landscape of the lower zone of mountains in Central Asia coincides with that of the interior elevations of the Gobi zone.) For the same reason, the portability of the rubble material in the high-mountain zone is greater than in the medium-mountain. In the first the rubble is carried by ice, snowslides, and river waters; in the second it only slides along the slopes under the influence of its own weight or is carried for short distances by temporary water flows. Therefore in the high-mountain zone a leading role is played not only by talus, but also by glacial and alluvial depositions; and in the medium-mountain zone by alluvial and alluvial-prolluvial depositions. Moreover, in the high-mountain zone the accumulation of deposits is facilitated by wide valleys with gentle channel slopes in which rubble can be carried for greater distances and spread over considerable areas. In the medium-mountain zone, where glacial troughs are replaced by narrow erosion valleys, the areas of accumulation of young sediments are sharply reduced.

Beyond the boundary of the distribution of high- and medium-mountain complexes there begins the plain to which the ancient glaciers crept, a plain which within the territory of Central Asia has no definite hypsometric location in consequence of climatic variations.

The Tibetan highlands, on the basis of types of Quaternary accumulations, belong to the high-mountain zone. Landslide and glacial deposits are spread over their ranges, and on sections of the plateaus a thick layer of conglomerates and clays, often finely interbedded, is found. The lower part of the stratified layers of the plateaus accumulated from coarser fluvial-glacial types of sediment; and the upper, from fine limonitic types. In the upper horizons, the layers, corresponding to the most arid period, are found to be composed of saliferous deposits (with borates, potash, etc.).

The moraines on the high plains of Tibet which were also subjected to glaciation (at an early stage) are not widespread, evidently as a result of the fact that the glacial masses which covered them were stationary.

The stratigraphy and geomorphology of Quaternary deposits of various genetic types show the successive advances of mountain glaciers and the gradual assumption of a leading role in the processes of erosion and the accumulation of glacial and river erosion. While on the upper terraces glacial deposits (moraines, fluvial-glacial series) are encountered almost everywhere, on the lower terraces they are distributed only in the upper reaches of valleys, beyond their boundaries being replaced by river alluvial deposits.

Alluvial-prolluvial deposits of the Gobi plains. The sedimentary material which originates in the process of disintegration in mountain regions is carried onto the Gobi plains where it forms a layer of alluvial-prolluvial deposits. The distance to which sedimentary material is carried out onto the plains, like the intensity of the processes of its formation in the mountains, varies in accordance with local climatic conditions. In a similar orographic situation, the disintegration of mountains and the bearing away of sedimentary material from them is more intensive, the more precipitation a given region receives and the greater the abundance of running waters. And because in Central Asia river erosion is strongest in the highest ranges of its mountain framework, the major fronts of the bearing away of sedimentary material are adapted to these ranges. Thick accumulations of alluvial and prolluvial material are found on the foothill plains adjacent to the Western Kunlun, along both slopes of the Tien Shan, and on the foothills of the northern ranges of Nan Shan.

In the eastern half of Central Asia, where the surrounding mountains are lower and their slopes, which have been transformed into desert, are narrow, the accumulation of alluvial and prolluvial materials is inconsiderable. The only exceptions to this are the Yin-chuang, Wu-yuan, and Saradzhiyskaya depressions through which flows the Huang Ho, which forms here a broad alluvial plain.

On the relatively well-watered sections of the foothill plains, the alluvial-prolluvial complex consists primarily of channel conglomerate and sands reaching several hundred meters in thickness. Depending on the degree of movement towards those sections of the plains which lie opposite arid mountains, the leading role is assumed by the carrying power of temporary water courses, whereby the thickness of the accumulation is reduced to a tenth.

The alluvial-prolluvial deposits of the foothill plains reveal clear facies zonality, associated with the successive diminution of the steepness of sedimentary material with increasing distance from the mountains. Along the foothills of the mountains stretches a rocky diluvial depcsit strip consisting of numerous alluvial fans of sediments partly coalescing. The upper parts of the fans are composed of conglomerates and gravels with boulders; and the lower, of sand and gravel. Farther into the depth of the plain up to the border of the sandy desert lies a zone of loess-type loams which represent deposits of broad river bottoms and small temporary lakes ("takyri"). The width of each of these zones changes frequently and within large limits, depending chiefly on the sizes and systems of the water flows which form the fans in a given section.

The boundaries of the facies zones of the alluvial-prolluvial complex of the foothill plains are not stable. A comparison of the stratigraphic reserves of this complex belonging to various sections of the plains shows that the coarse deposits (conglomerates and sands) were located farthest from the mountains in the early Quaternary period. Later, as a consequence of an increase in the aridity of the climate, which caused a reduction of the volumes of water in the rivers, the dispersion area of the coarse deposits began to shrink and its front gradually retreated to the foothills of the mountains. As a result of the movement over them of loess clays, the ancient Quaternary conglomerates and sands were covered in a broad zone and later were even buried in a large area by the aeolian sands which were advancing in the same direction. The subsequent intensification of the aridity of the climate caused also a change in the composition of the coarse-sedimentary facies of the foothill zone. In its lower horizons this zone is composed of alluvial conglomerates; and in its upper horizons, of angular, poorly-sorted prolluvial rubble.

In the period of a relative increase in the humidity of the climate, which came after the main glacial stage, broad lakes were spread over the Gobi plains, lakes which now have either been transformed into small relic water reservoirs or have completely disappeared. These lakes were located in the enclosed lowlands into which even at present the main rivers flow (Bol'shoy Lop Nor--on the lower course of the Tarim; Bol'shoy Ikhekhak--on the lower course of the Dzinchan; Bol'shoy Gashun-Nur, on the lower reaches of the Edzin-Gol; and others).

It has been established on the basis of a study of the largest of them, the Bol'shoy Lop Nor that three stages were present in the development of the ancient lakes; the yardang, corresponding to the Würm stage of glaciation; the prehistoric; and the modern. The yardang stage, in the course of which the lakes reached their maximum sizes, is correlated with a layer 5-10 m thick consisting of gray fine-grained sands interbedded with straw-colored silts. Formed in the prehistoric stage was a layer of brown salts and clays, which has disintegrated and resembles a plowed field. On the bottom of the present lakes there lies a thin salt ooze.

The contours of the lakes at various stages are well expressed geomorphologically, thanks to the embankments and terraces and the stratified arrangement of the beds of the water bodies themselves. In a lake bed the yardang stage is incised less in accordance with the area of the bed than the prehistoric lake, which in its turn encloses a small present-day body of water.

Volcanic rocks. Evidences of Quaternary volcanic action are numerous in the eastern regions of Central Asia: on the Dari-kangki plateau and on the Chakharskiy plain, in the Han-hai mountains and in the Valley of Lakes. Such evidences are noticeable also in the Kunlun (Arka Tagh, region of the sources of the Keriya River, basin of the Karakash River), on the Tarim plain (vicinity of the town of Keriya), and in the Chiu-chiuan depression (west of the oil-bearing deposits of Liao-chun-miao). In some cases lavas occur in the form of streams, having issued from small craters located in groups on fractures; in others, they fill crevices. The composition of the lava varies from basalts to andesites.

The eruptions of uaternary lava occurred at different times: both in the period of loess accumulation in which are found intrusions of tuffaceous elements, and very recently, perhaps in the historical period. Evidence of the youth of the eruptions is the freshness of the volcanic cones, which have not yet been affected by weathering, the position of the lava flows, which in places descend to the lowest terraces and diked valleys, and the placer deposits of tuffaceous sand which lie directly on the surface of the plain.

7. Soils

Characteristics of soil formation in Central Asia. In Central Asia the soil formation process occurs under the conditions of a severely continental climate which results in a predominance of physical weathering over chemical. This results in the formation of specific desert types of soils, poor in organic substances and containing many skeletal elements.

As a consequence of the fact that the surface layer receives almost no moisture in the course of the year, the processes of soil formation here proceed very slowly. They become more active only during the short rain periods which occur in the northern and eastern parts of Central Asia in July and August, and in the southwestern part in May and June. But even during these periods only an insignificant amount of moisture participates in the soil formation process, because the greater part, falling in the form of rain, evaporates and the insignificant portion absorbed by the deposits quickly seeps through them into deeper horizons.

In consequence of the absence of moisture, the mineral mass originating as a result of physical weathering, does not disintegrate; hence the local soils have virtually no fine-grained formations. Neither is the development of soils in Central Asia promoted by its vegetation cover, which is extremely sparse and even wholly absent over large areas. Therefore the sierozem type of soil formation is dominant here, taking place almost entirely without the aid of vegetation and with an insignifically small content of organic substances.

A damaging effect on the soil cover in Central Asia is exercised by the strong winds which in some regions (in the zone of intensive dispersal) blow away its fine-grained particles and in other regions form aeolian deposits on the soil (on the periphery of the anticyclone zone). In the mountain regions of Central Asia the soil-formation process is inhibited by the great steepness and precipitousness of the slopes, on which the products of decomposition of the basic rocks cannot get a footing. In general, the soil cover in Central Asia is broken, thin, and in vertical section poorly differentiated.

The basic zonal type of soils in Central Asia is sierozem, which is formed in rgions where the climate is of maximum aridity. And only on the eastern margin of Central Asia, which has the character of a semi-desert, is the humus content of the soil somewhat increased and sierozem replaced by chestnut soils.

Also prominent among the group of desert soils of Central Asia are saline soils and solonchaks, which cover numerous enclosed depressions. On the high interior uplands mountain chestnut soils are widely distributed and spread throughout the desert group in small islands.

The boundary of the Central Asiatic sierozems and chestnut soils coincides with the line which limits the territory receiving less than 200 mm precipitation annually. To the north this desert-soil mass borders on the chestnut soils of the steppes; and to the south, on the mountain-meadow and mountain-forest soils, beyond which spreads farther a zone of red and yellow soils of subtropical forests and savannahs.

Sierozems. The Central Asiatic mass of sierozem soils is one of the largest in the world. It extends across 35° of latitude and 23° of longitude. The facies of these soils is heterogeneous because they developed in regions with varying relief, on different geological and geomorphological bases, at various latitudes, and in areas which differ in their orientation with respect to the Mongolian-Siberian anticyclone.

The temperature system of these soils varies as a result of the great range of variations in altitude, and is divided into two groups: sierozems of the hot desert, which have developed on the Gobi plains and on the slopes of lower elevations, and the sierozems of the cold desert which are characteristic of the Tibetan zone.

In their turn the sierozems of the hot desert are subdivided on the basis of climatic conditions and geomorphological bases into three types: Dzungarian, distributed through the moderately hot plains of the northern zone (Dzungaria, Trans-Altay Gobi, Khamiyskaya depression), one of intense scattering; Tarim, indigenous to the plains of the southern zone (Tarim plain, Kansu corridor, Ala Shan), lying partly in the zone of aeolian accumulations; and Kyrovyy, found in the interior highlands of the Gobi desert and on the lower slopes of its surrounding ranges (Map 9).

Sierozems of the Dzungarian type are distinguished by a low carbonate composition and unusual skeletal elements originating as a consequence of the blowing off from eluvium of clay and sandy materials. One of the main forms of these sierozems are the stony soils of the "gammady" [stony desert] occupying wide areas in Eastern Dzungaria, Trans-Altay Gobi, and in the Khamiyskaya depression. Their upper layer represents an accumulation of gravel and rubble, covered by a barren sun-blackened film. Only in its lower layer does it possess a thin sandy layer with an insignificant mixture of humus (less than 1%). The layers of Dzungarian sierozems are thin and often broken by upthrusts from the rocky base.

Sierozems of the Tarim type are light and resemble those of a salt flat, containing many carbonates and very little humus. Skeletonization is moderate. Among them clay and sandy varieties predominate, the gravel types being encountered only rarely and near mountains. The main mass of sierozems of the Tarim type are found in areas of the development of prolluvial-alluvial loesses of the foothill plains. Here these soils are somewhat thicker with marks of differentiation into soil horizons. Along the boundaries of the Takla-Makan, Badanchzhareng, and Tyngeri deserts salt-flat type sierozems are covered with aeolian sands.

Kyrovyye sierozems develop on the diluvial cover of desert uplands; therefore they contain many skeletal elements. The carbonate composition is nonuniform and varies from low, in the northern regions, to large, in the southern (Kunlun, Altyn Tagh, Nan Shan). Their humus content is in general inconsiderable but increases somewhat with increasing altitude (up to 2%). The distribution of the soil layer in the regions of Kyrovyye sierozems is broken and insular in places. The sierozems are spread among broad areas of rocky slopes and moving block talus. Their thickness varies but is generally thin. The upper boundary of sierozems of the Kyrovyye type does not have a definite hypsometric position. With increasing climatic aridity and southward movement, the altitude of the upper boundary of the distribution of Kyrovyy sierozems increases. On the dry slopes of the Central Kunlun, Altyn Tagh, Western Nan Shan, and the southern chain of the Tien Shan system it reaches an altitude of 3,000-3,500 m, but on the slopes of the Gobi Altay, the northern chain of the Tien Shan, and the Southern Han-hai it does not rise above 2,000 m.

In areas of the development of plain sierozems of the hot-desert type large areas are occupied by aeolian sands in the deserts of Takla-Makan, Dzosotyn-elisu, Badanchzhareng, and others. The greater part of this is scattered sands, dry and therefore bare. Soil formation takes place only on small masses of brown sands on which, thanks to the high water table, scrub vegetation appears, enriching the soil with salts and humus.

Sierozems of the cold deserts of the Tibetan highlands (Chantan) and Eastern Pamirs are found in large masses only on plateaus and the gentler mountain slopes. However, in parts with alpine relief, constituting here in over-all complexity an enormous area, virtually no soil cover develops.

Sierozems of the high-mountain cold desert contain little humus and few carbonates. Near mountain slopes they are friable and coarsely skeletal, while a little lower on plateaus they constitute sand and loam mixtures with solonchak-meadow soils around lakes. In general, even in the Chang Tang the soil cover is poor; it is thin and broken.

On the boundary of the moist regions of Kama, the Trans-Himalayas, the Western Pamirs, and the Western Tien Shan, sierozems gradually give way to mountain-meadow soils which are considerably leached and contain much humus.

Brown soils. These are distributed throughout the semidesert eastern half of Central Asia. They cover almost all of the Eastern Gobi and Chakhar plain, the lake plains of Western Mongolia, and the eastern half of the Ordos. Brown (and the succeeding chestnut soils) are well developed in that area of Central Asia, particularly as a result of the relatively low height of the bordering orographic barriers of the Han-hai, Heng-te, Bol'shoy Khingan, and Liu-lien, which cause here a gradual change in climate from humid maritime to the arid Central Asia type. In the western half of Central Asia, surrounded by the high ranges of the Kunlun and Tien Shan, the climate changes more sharply. Consequently there the types transitional to its sierozems (brown soils) are poorly developed and in places completely absent.

Soils which develop in the complex with the brown soils include the saline-solonchak group and chestnut mixtures. The former replace them in the lowest sections of the enclosed basins; the latter, on the upper slopes of the mountain elevations and on their summits. The brown soils themselves are heterogeneous in composition and morphological features in consequence of variations in orographic conditions and the geological structure of the substrata on which they have developed. On the slopes of hills and undulating plains these soils represent strongly rubble-filled and sandy varieties poor in fine soil particles. The soil layer here is thin and frequently interrupted by the outcroppings of base rocks. On the plains and lower slopes, brown soils are of the loam types, although they always contain a small amount of skeletal elements. These varieties form a thick eluvium which better facilitates their differentiation.

Found along the edges of enlosed basins occupied by solonchak wastelands are saline varieties of brown soils with a more densely-layered structure in their upper horizon and containing many highly-soluble salts. The humus content of all varieties of brown soils of the Gobi ranges from 0.4 to 0.9%.

Solonchak and solonetz soils. Saline soils are widely distributed in Central Asia, covering up to 15-12% of the surface in some regions. Most of the solonetz and solonchak soils are concentrated in the somewhat more humid zone of the semidesert with brown soils. In the most arid region of Central Asia with its sierozem type of soil formation, solonchak and solonetz soils are rarely found. Here separate, although often very large, masses of them are found in the lower courses of the main rivers (Lop Nor lowland, basin of the Ezdin-Gol lakes, the lower course of the Su-le He) or on the landlocked parts of foothill depressions (Southwestern Tsaidam).

The lower parts of basins and depressions within which the surface and ground waters are in a stagnant condition become saline. The solonchak soils originate in enclosed depressions where even now an excess of ground moisture periodically occurs. In areas, however, where the groundwater level has fallen, solonetz soils are found with clear indications of the salinization of the soil profile and the breakdown of its previous structure. Solonetz soils therefore lie above solonchak soils in the enclosed basins and border them.

In the most arid regions of Central Asia--Gashun'skaya Gobi, Eastern Dzungaria, Khamiyskiy depression, and Pei Shan--solonetz soils predominate over solonchak and in places have displaced them entirely.

Solonetz and solonchak soils contain carbonate, sulfate, and chloride salts in concentrations which often reach 15%. In the interior districts of the Gobi, chloride salification predominates, while in the less arid surrounding regions the soda and soda-sulfate types predominate.

Mountain chestnut soils occupy a large area in the Mongolian and Gobi Altay, on the Dzungarian and Iliyskiy slopes of the Tien Shan, in Western Kunlun, Eastern Nan Shan and Ying-shan. Soil-formation conditions in these mountains are very complex as a result of the sharp dissection of the relief and frequent changes in the depth of the base rocks and their petrologic composition. Therefore in mountainous areas the soil-layer development is noncontinuous, and the thickness and mechanical composition of the soil are subject to considerable fluctuations. On the spurs of slopes and in the valleys which have formed in areas of rock outcroppings very subject to weathering, the soil layers are thicker and contain more fine particles. As the slopes become steeper, the soil layer diminishes and its rubble content increases.

Mountain chestnut soils form a compact sod cover on the slopes. Usually they are grayish-brown in color and have a lumpy texture and shallow beds of carbonate horizons. Their humus content is variable and

changes in accordance with the orography of the locality, exposure of the slope, thickness of the fine-particle layer, and the general altitude of a given mountain massif and its geographical position in relation to the center of aridity of the Gobi desert.

History of the formation of the soil cover. The stages of the continental development of Central Asia include the Cenozoic and Mesozoic and, in some sections, even the Upper Permian period. Therefore the processes of soil formation began here very long ago. However, this prolonged process has not resulted in the formation of a thick, well-developed soil layer because of unfavorable geological and climatic conditions. Above all, the development of the soil cover in Central Asia was hampered by the activity of geological processes. In the zones of subsidence, strong accumulations of sediments systematically buried the soil cover, which had not yet developed successfully, and in the zones of elevation there was intensive denudation, which continually removed the soil. Geological processes were especially active in the orogenetic period which set in with the Oligocene period and has continued to the present.

Nor has the aridity of the climate of Central Asia favored the development of the soil cover. With increasing climatic aridity, the processes of soil formation gradually slowed down. At present they have ceased almost completely. The already formed soils, as a result of active neotectonic movements and the drying of the climate of localities, have been broken down by weathering (Eastern Dzungaria, Gashun'skaya Gobi, and Pei Shan) and erosion (Ordos and the loess plateau of Northern Sheng-hsi).

8. Vegetation

As a consequence of the dominance in Central Asia of a sharply continental and arid climate, conditions for the existence of vegetation here have been very unfavorable. Throughout the entire growing season vegetation here suffers from a serious lack of moisture. The normal development of vegetation is hampered also by wide temperature fluctuations which subject growths either to extreme heat or to extreme cold. Vegetation development is limited also by the considerable skeletal composition and salinity of the soils and the broad expanses of traveling sands on the plains and the bare rocky slopes in the mountains. The main part of the Central Asiatic desert is completely sterile and therefore has no vegetation. Vegetation nestles in the channels of temporary water courses and in various depressions in relief having somewhat more underground moisture.

Only a few types of plants are found in Central Asia; these possess the ability to survive with the meagre soil moisture, to flower quickly in the short period of trifling summer precipitation, and to root in the stony, sandy, and strongly saline soils of the desert.

The prolonged existence of such desert conditions in Central Asia has promoted the emergence and selection of vegetation of the xerophytic type and the appearance of distinctive drought-resistant flora, few in range of species. Xeromorphy can be observed in one degree or another among all the plant families distributed throughout Central Asia. Usually this is expressed in a reduction in the size or the complete loss of leaves, the development of a cover of fine hairs, the distention of the leaves and pedicles, the formation of a branching root system proportionate to the size of the surface parts of the plants, and a considerable development of tissues to protect the individual organs of the plant from burning or drying.

The main forms of Central Asiatic flora are the perennial xerophytic bushes and underbushes belonging to the "kamnelyuby," "peskolyuby," (Ammophila arenaria) and "solelyuby." Annual plants do not play any noticeable role in this area, and only in years of relatively heavy precipitation do they appear in considerable quantity in individual areas, resembling in some degree the spring ephemerals of the Central Asiatic desert.

The exceptional variety of natural conditions creates extreme irregularities and a mosaic quality in the distribution of the vegetation cover of Central Asia and its variegated, frequently sharply varying, species.

The irregularity in the development of the vegetation cover in Central Asia is the result of the following:

(a) solar changes in climatic conditions, associated with variations in the latitude of a locality, which changes by more than 20° between the Ubsa-Nur basin and the Trans-Himalayas;

(b) climatic changes associated with the considerable altitude of the general surface of Central Asia, amounting to an average of 1,200 m in the Gobi and up to 5,000m in Tibet;

(c) differences in seasonal precipitation, which in the eastern half of Central Asia, subject to some monsoon influence, falls primarily in summer; and in the spring on its western margin where, although inconsiderable, some influence on the climate of the regions of Atlantic circulation is felt;

(d) the different exposure of the main mountain chains, which determines the directions of the movement of air masses. Ranges which lie laterally to the air currents block their movement, while mountain chains stretching parallel to them do not. The importance of this factor is clear in the example of the deep penetration ofddesert types of vegetation from the north into the lake plains of Western Mongolia. This is a consequence, on the one hand, of the orographic isolation of this area from regions with comparatively moist climates, and, on the other, its accessibility to air currents from the desert. Exactly the same phenomena explained such paradoxes of Northwest Mongolia (observed by A. A. Yunatov) as the presence of saxaul 2° north of the southern boundary of the habitat of larch and the presence of a dwarf-halophyte desert one degree of latitude from a pine taiga;

(e) the varying exposures of individual mountain slopes with respect to different air currents. The slopes of ranges exposed to hot and dry desert air (for example, the Tien Shan and Kunlun ranges, which face the Takla-Makan desert, or the northern slope of the Nan Shan, which is subject to winds from the Ala Shan desert), are for the most part barren, while the opposite slopes, protected from desert winds and subject to the influence of exterior, more humid air masses, are covered with steppe vegetation and in places with forests.

Fig. 3. Stony desert /gammada/ of Eastern Dzungaria.

And here such paradoxical phenomena are to be observed as, for example, the contact on a watershed of a range of an alpine meadow and a desert steppe;

(f) the salification of soils in enclosed basins. In Central Asia all types of soils are saline to one degree or another, as are some Quaternary beds and Tertiary and Cretaceous deposits. This exceptional salinity of the substrata is reflected in the species of local plants among which halophytes are prominent. The island character of the distribution of the strongly saline soils is one of the major reasons for the mosaic quality and variety of the vegetation cover of Central Asia.

However, despite all this, regional zones appear in the vegetation cover of Central Asia. Towards the boundaries of the arid region the extent of the vegetation cover increases as does the importance therein of the less drought-resistant types. This concentric zonality reflects the landlocked character of the arid region of Central Asia and its location in relation to areas with humid or only moderately dry climates.

In Central Asia three major types of desert can be distinguished: hot deserts, encountered within the Turkestan climatic province; moderately hot deserts of the Dzungarian climatic province; and cold deserts in Tibet. Each of these major types of desert is in turn divided into stony deserts ("gammady"), mountain (rocky), sandy, and clay deserts (Map 10).

Stony deserts /"gammady"/ are one of the most typical types of Central Asiatic deserts, distributed over broad expanses of both the hot Turkestan province and the moderately hot Dzungaria and Ala Shan. Stony deserts occupy particularly large areas in the Nomin-Gobi, Turfan-Khamiyskiy basin, and in the intermountain valleys of the Pei Shan.

"Gammady" occupy the most arid regions in Central Asia and those most subject to storms. The dry, hot, and windy climate is unfavorable for the development of vegetation on these stony deserts, which are very strongly dissected and monotonous. The greater part of a stony desert is either completely barren or colonized by isolated, strongly stunted species (Figure 3). The vegetation is concentrated primarily in the dry beds of temporary streams, which comparatively often are found around elevations but rarely on the plains. On the latter one may sometimes travel tens of kilometers without encountering a single high plant.

The most common and, in places, the only, living plant forms of the stony deserts are xeromorphic bushes and underbushes. Widely distributed throughout the stony deserts of the Djungarian climatic province is saxaul, which forms distinctive saxaul deserts (Map 11). On these deserts saxaul grows in bushes 0.5 to 1.5 m high, spread thinly in broad, flat hollows where ground waters are found rather close to the surface. The usual companions of saxaul on stony substrata are Ephedra Przheval'skiy; on sandy substrata, "kharmyk" (Nitraria Sibirica); along the boundaries of barren gammady, Reaumuria and annuals of the halophytic type.

Map 11. Range of distribution of saxaul in Central Asia.
Legend: 1--Range of saxaul.
/Place names: Same as Map 6./

Found on the stony deserts of the Turkestan climatic province are clusters of bushes with variable dominants. In both the bushy and saxaul deserts, vegetation nestles only in the best-watered depressions of the relief and is lacking in dry, elevated areas. The flora of the bushy deserts are also monotonous. Usually there are encountered various (as a rule, two or three-member) combinations of Ephedra Przheval'skiy, species of Nitraria (selitryanka vzdutoplodnaya) and Zygophyllum (parnolistnika zheltodrevesinnaya), xeromorphic elms, treelike saltwort plants, and short-leafed blackberry bushes.

A distinctive feature of the stony deserts of Eastern Dzungaria, Gashun'skaya Gobi, and Pei Shan are oases--small islets of magnificent vegetation standing out distinctly against the surrounding desert. The oases are located in "sayry" or on piedmont plains near large fractures where the ground-water table is high enough to reach plant roots.

At some distance from the springs are located groves of heterophylous poplars ("togaka) with a mixture of wild olives (Elaeaghus angustifolia); still farther come thickets of rough grasses (Lasiagrostis splendens) and Alhagi pseudoalhagi; and on the borders of the oases, densely growing bushes of tamarisk and saxaul (Fig. 4).

Fig. 4. Oases in Eastern Dzungaria.
(Photograph by V. A. Amantov)

Sandy deserts. These are even more widely distributed than stony deserts and occupy a major part of the Tarim, Dzungarian, Ala Shan, Ordos, and Tsaidam plains. Among them are to be distinguished true deserts, on which over large areas there are no high plants, and moderate deserts with oases of vegetation. The true deserts are sandy masses lying on denuded plains (peneplains) and on the piedmont (elevated) areas of alluvial plains where the ground-water table is lowest. To this group belong most of the sandy basin of Takla-Makan, the Kum Tagh sands in the foothills of the Kunlun, the sandy masses of Karagobi and Badanchzhareng in the Ala Shan, and the northern half of the Dzosotyn-elisu area on the Dzungarian plain. Peculiar to moderate deserts are sands lying on young

alluvial plains with a higher ground-water level. Examples of this type are the southwestern boundary of the sandy basin of Takla-Makan and the southern half of the Dzosotyn-elisu area. The vegetation cover is best developed and most diversified on the sands of the Eastern Ordos, Chakhar, and Southern Mongolia, which are already in the semidesert zone.

The vegetation of a sandy desert represents a completely distinctive grouping of psammophytes capable of enduring the instability of the free-flowing sandy substrata, the masses of which during a storm begin to shift and either bury the vegetation or uncover its root systems. The major representatives of this vegetation classification are tamarisks, calligonums, "kharmyk" (Nitraria sibirica), Reaumuria, and, in the north, saxaul. Tamarisks and calligonums grow abundantly on the sand alluvial plains with high ground-water levels, and also on the sands lining the valleys of the main rivers and oases. In the latter two cases they are combined with strongly stunted reeds and low-growing poplar. A landscape of sand dunes is associated with the main areas of tamarisk. On bare sands tamarisk is found growing in isolated bushes which anchor the slopes of barkhan ridges in the less windy areas. "Kharmyk" and Reaumuria are distributed in considerable number only along the edges of sandy deserts where the latter border stony deserts. On "kharmyk" habitats there is formed a special type of sandy-desert landscape which has been named the "heaped sands" (V. A. Obruchev).

Sands located in the semi-desert zone are subject to almost no shifting, being anchored by plants to a considerable extent. Here grow separate masses of saxaul, calligonums, and elms (Ulmus densa) which here are associated with sand-loving species of wormwoods and grasses.

Vegetation of the "tugay" forests. Extensively associated with sandy, and partly with stony, deserts are tugay forests, which stretch in narrow, sometimes interrupted, belts along the valleys of the main rivers.

The largest tugay forests are found in the valley of the Yarkend and Tarim rivers and in the valleys of the Ho-t'ang and its tributaries the Karakash and Yurunkash, along which the forest belt sometimes reaches 30 km in width. Frequently tugay forests are located directly on the alluvial plain along the foot of the boundary foothills where there is an abundant outflow of ground water. Tugay forests of this type are widespread along the southern edge of the Tarim plain and particularly between Niya and Cherchen.

Tugay forests receive much solar light and heat and grow on well-moistened soils which are periodically enriched during floods by silt deposits. Harmful to them are the seasonal inundations of the rivers, destroying the vegetation growing close to their channels, and also the sharp drops in the ground-water table in dry years, which seriously damage sections of the forest strip bordering the desert. But the greatest catastrophe of all for tugay forests are changes in the course of river channels, which are rather common on the plains of Central Asia.

In such cases tugay forests quickly dry up and become covered by sand along the old channels. However, later, along the banks of the new river channel young trees spring up no less luxuriantly than on the old site. The main type of tree in tugay forests is the efratskiy poplar, forming now dense growsths of small trees, now sparse forests of large individuals. Mixed with tograks are oleasters or wild olives--small, bushy trees with thin branches sloping towards the ground. Tograks and oleasters are thickly intertwined with lianas. On the boundary between a tugay forest and the desert are found tamarisks, Hippophae, and alhagi (Alhagi camelorum); and opposte the lacustrine flood-plains of rivers and swamps, willows and reeds.

Stony mountain deserts are characteristic of the interior elevations of the Gobi and the lower (hot) zone of the mountains surrounding it. Such deserts occupy large areas in the Gobi Tien Shan, Pei Shan, and Chol Tagh; in the Gashun'skaya Gobi and Kuruk Tagh, Altyn Tagh, and Western Nan Shan; in the southern foothills of the Tien Shan and on the forward peaks of the Kunlun. On these deserts are found broad, rocky surfaces and block, at times moving, talus, virtually bare of vegetation. The vegetation is concentrated mainly along the channels of temporary watercourses where usually to be found are ephedra, bayberries, white willow, elms (Ulmus densa), "kharmyk", tamarisks, and also kupets and polyni. In the extent of the development of vegetation mountain deserts do not much surpass stony deserts.

On the hot lower mountain slopes, as a result of the complex relief, the diversity of vegetation is clearly revealed. Under the influence of changes in the exposure of the slopes, the soil composition, and the amount of moisture they receive, the vegetation groupings replace one another sharply and frequently. The upper boundary of the hot (Gobi) subtype of mountain desert does not lie at a fixed altitude. In the forward ranges of the Middle Kunlun and in the Western Nan Shan it reaches an altitude of about 3,500 m, on the Tarim slope of the Tien Shan range and on the Chol Tagh range it does not rise above 2,600 m, and on the Dzungarian slope of the Tien Shan it does not reach 1,500 m.

In the Western Kunlun and Eastern Nan Shan, which receive more atmospheric moisture, mountain deserts 2,000-3,500 m in altitude are replaced by dry, grassy steppes.

Clay deserts are found in the zone of accumulation of prolluvial loess soils and loess-type clays. Their soil is barren which prevents the development of the root systems and anchoring of plants.

In climate and underground moisture, clay deserts are not distinguished to any considerable degree from sandy and stony deserts. They too are bare and sterile. Only on the very western edges of the Tarim plain (Kashkar and Yarkend districts), which are under the influence of the Middle Asiatic climate (in Middle Asia precipitation occurs mainly in the spring), are noticeable roles played in the vegetation of the clay desert by ephemerals which rise in the spring and die with the onset of the dry summer. In consequence of the increased salinity of the soils of the clay desert, halophytes are of increased importance in its vegetation.

Special features of the vegetation of Dzungaria and Ala Shan. On the cooler and less arid deserts of the Dzungarian climatic province the vegetation cover is less sparse. Underbushes play a somewhat more important role in comparison with bushes, and relatively diversified halophytes are widespread.

The deserts of this province are divided in their turn into two types: western, found in Dzungaria; and eastern, situation in the Northern Ala Shan and Eastern Gobi. They are separated by a region of intense weathering running along the main watershed of Central Asia.

In the Eastern Gobi and Ala Shan the "borbudurganovyy" grouping is most common, the main member of which is sparrow saltwort. On the pedestal elevations with less solonetz and more rubble-filled and carbonate soils the "borbudurganovyy" grouping is replaced by the "baglurovyy," whose chief members are saltwort underbushes--short-leafed annuals growing in scattered low small bushes. Towards the lower section of the depressions occupied by solonchak scrub, in the "borbudurganovyy" grouping appear Dzungarian Reaumuria and well-shaped saltwort bushes. In both the "borbudurganovyy" and "baglurovyy" groupings are found also permanent grasses--Gobi feather grass.

Map 12. Distribution range of tree species in Central Asia.
1--Heterophylous poplar;
2--Low-growing elm;
3--Shrenka spruce
a--Tien Shan
b--Nan Shan
4--Siberian larch
5--Poplar (Populus laurifolia)
6--Southern boundary of ancient distribution of Siberian poplar.

[Place names: Same as Map 6.]

The vegetation cover of Dzungaria, while in general resembling that of the Ala Shan, reveals many distinctive features. First of all, it should be noted that there is lacking in Dzungaria one of the most common plants of the Eastern Gobi and Northern Ala Shan--sparrow saltwort, while frequently found in its place are underbushes of dwarf hedgehog plants or "tar," which is lacking in the east. Moreover, in the vegetation cover of Dzungaria, especially in areas bordering the Trans-Sanskiy and Ebinorskiy gaps "polyni" are of great importance in the surrounding mountains and here is one of the most common species.

Variations in the nature of the vegetation of Dzhungaria and the eastern areas of the Gobi are shown also in the tree species, which are represented in the former by heterophylous poplars (oases near the Tien Shan) and Populus laurifolia (valleys of the Urungu and Irtysh), and in the latter by low-growing elms (Map 12).

In the eastern Gobi and the foothills of the Han-hai region the climate is somewhat more moderate, with the result that the landscape becomes semidesert. Here the main type of vegetation is sparse underbush-grassy desert-steppes species modified by short feather grasses with "polyni" and tansy (Tanacetum vulgare). The composition of the flora of the feather-grass desert steppes changes in accordance with the substrata. In areas with sandy soils the importance of Chinese snakeweed and xeromorphic tansy is greatly increased, these sometimes becoming the dominant species. However, the increase in the salinity of the soils results in increased numbers of leeks and underbush saltworts--short-leafed Echinocloac and sparrow saltwort. On the boundaries of the Gobi depressions where there is more gravel and rubble in the soils, bushy feather-grass steppes are widely distributed with growths of elms (Ulmus densa), Eurotia bushes, and a species of Zygophyllum ("zheltadrevesinnyy").

On the Central Khalkhasskiy plateau and the Darigang massif the semi-desert vegetation is gradually giving way to steppe vegetation. Xerophytic species have virtually disappeared. The vegetation cover is becoming denser and with more varied grasses, and although its composition continues to remain primarily grassy, the leading role is already played not by the small plumed feather grasses but by Agropyrum ramosum which forms a coarser turf.

Vegetation of the Chang Tang cold desert. In the Chang Tang low temperatures continue for almost 10 months of the year. Therefore there can exist here only a few species, those which have developed the capacity to vegetate after the cold and dry spring and brief summer period and to endure the night frosts which continue during these seaons. Over the broad territory of the Chang Tang are found only a little more than 50 species of flowering plants, of which 10 are native to this region. The poverty of species among the flora of the Chang Tang is explained by the fact that the soils there are still poorly developed and a snow cover is lacking which could protect the plants from the winter cold and the strong solar radiation.

In the Chang Tang, as in polar regions, the thin atmospheric layer which heats the warmer soil forces the vegetation to develop its shoots not in a vertical but in a horizontal direction and to develop creeping and pillowlike forms. Under the constant force of strong winds the plants of the Chang Tang have developed strong root systems which penetrate the thin soil layer and anchor in rocky crevices.

A major part of the Chang Tang cold desert, as in the hot Gobi, is a stony desert (gammada) either completely bare or supporting scattered low underbushes, chiefly Eurotia. Only a small area is occupied by turf, which extends along mountain slopes and valley floors protected from the wind and receiving more moisture. Growing on the dry slopes are Tibetan sedges with meadow grass, fescue, and Reaumuria; and in the depressions with standing water, mound meadows and swamps with Cobresia cappilifolia.

This stony desert covers the entire Chang Tang as far as the Central Tibetan diagonal uplift to the east, and the Aling-Gangra mountain chain to the south which blocks the penetration of the remaining moisture carried by monsoons. In the eastern part of the Tibetan highlands, where lie the sources of the great Chinese rivers, and in the interior valleys of the Trans-Himalayas, the climate is somewhat milder and there is a rather dense steppe vegetation with a predominance of steppe grass (fescue), coutch grass, bearded oats, Poa, and meadows of Carex and Cobresia cappilifolia.

Beyond the successive orographic barriers formed by the Kaylas and N'enchen-Tangla ranges, the climate becomes still more favorable. In the valleys of the Kama and Brakhmaputra rivers lying beyond these ranges are found meadows of various grasses, bushes, and coniferous forests. Here it is possible also to ripen cereals and fruit trees.

The number of plant species in these regions is more than 10 times greater than in the Chang Tang.

On the history of the formation of the desert flora of Central Asia. The climate of Central Asia began to become arid already at the end of the Jurassic. The nucleus of the future desert was formed by the Gashun'skaya Gobi and Pei Shan and adjoining areas of the Tarim, Dzungarian and Ala Shan basins. In the Cretaceous and Tertiary periods this region continued to increase in aridity and to spread throughout the territories named. Evidence of the progressive desiccation of Central Asia in the Upper Mesozoic and Cenozoic periods are the changes in the composition of deposits laid down in these times. Beginning with the Upper Jurassic, these deposits became mostly red in color with salts and gypsums and there occurred the disappearance of such characteristic indications of the humid conditions of sedimentary accumulation as coal, bauxite, and sedimentary ferromanganese ores. Finally, there is evidence of the intensification of the climatic aridity of the Mesozoic and Tertiary periods in the discovery in the deposits of these periods of fossils of vegetation and fauna characteristic of arid regions. The replacement of the forest landscapes which had predominated here since the Middle Jurassic by the barren stony and sandy deserts of the present time took place successively through a series of intermediate landscapes--steppes of various kinds, semideserts, and modified deserts.

The gradual thinning out of vegetation and the reduction of the volumes of growing organic material in the arid region of Central Asia are revealed with particular clarity in the successive displacement of the zones of coal formation from within its boundaries to the edges of the continent. In the Lower and Middle Jurassic, coal deposits were found in all the territories of Central Asia; in the Upper Jurassic and Cretaceous, only in Eastern Gobi and Southern Tibet; and in the Tertiary, only in the regions lying beyond the Bol'shoy Khingan and Sino-Tibetan Alps.

The desiccation of Central Asia increased sharply in the Neocene and Quaternary as a result of an increase in the mean elevation of the land surface to almost 1,200 m in the Gobi and 5,000 m in the Chang Tang and the emergence on its boundaries of high mountain ranges which isolated the region from moist air currents. The atmospheric-moisture content of Central Asia was still relatively high at the beginning of the Quaternary period, as is evidenced by the considerable magnitude of the ancient glaciation. The post-glacial period was the most arid in the history of Central Asia, for during this time the climatic aridity increased with particular rapidity and effectiveness.

The duration and stability of the arid climate in Central Asia could not help but contribute to the appearance here of native species of plants despite the low rate of species formation under such conditions. The largest number of such species are found in the barrenmost area of Central Asia where arid climatic conditions have endured the longest. However, in the regions surrounding it, where the climate had become arid only in the Quaternary period, the basis of the vegetation cover consists of xerophytic representatives of the less drought-resistant earlier flora. The process of the development of xerophytic varieties of earlier flora on the boundaries of the arid region is occurring even at the present time, as has been shown by investigations in Southeastern Tibet and Eastern Mongolia.

The migration of plant species in Central Asia as a result of progressive desiccation and the steady expansion of desert areas has proceeded in only one direction--from the arid region into the adjacent territories. Migration in reverse direction is noticeable only in regions which experienced Quaternary glaciation, particularly in Southeastern Tibet, only recently colonized by species which have penetrated here from Burma and Yunan, and in the Western Nan Shan where several representatives of Kansu flora have become established.

9. Fauna

The fauna of Central Asia is also unique. The predominance of the open landscapes of high desert plains, the scarcity of water and its high mineral content, the exceptional sparsity and poverty of vegetation, the severe winters with but little snow (in the course of which part of the land surface remains bare, thus making it possible to obtain forage), the strong heating of the soil and air in summer, and the steady, intense evaporation create here special conditions for animal life. The long continuance of such conditions has promoted a high specialization of the animals of Central Asia, the emergence among them of distinctive drought-tolerant species which easily endure heat and lack of water.

The open landscapes with their sparse vegetative cover and winterbare earth have facilitated the spread of ungulates which can cover considerable distances in search of water and forage. The barenness of vast areas of the desert has been favorable also for the distribution of jumping rodents (jerboas) and birds which prefer running to flight (stilts, sandpipers).

The poor development in desert plants of vegetative parts and the presence of a strong root system has promoted the spread among rodents of, on the one hand, species which feed primarily on seeds, fruits, and, in part, insects (jerboas), and, on the other hand, of species which feed on the underground parts of plants (blindsnakes).

In the process of adaptation to their environment, the animals of the Central Asia deserts have acquired the ability to survive on the moisture obtained from food. The rodents and lizards rarely or never drink, and even the gazelle (Gazella subguttuyosa) can get along for a considerable time without water. Moreover, among several of the inhabitants of the hot desert (gerbils, jerboas) the deficiency of water in the organism is compensated for by the moisture formed in the course of the oxidation of substances (fat). The retention of moisture in the organisms of some desert animals is facilitated by the weak development or complete absence of sweat glands (carnivores, rodents).

Characteristic for animals of the desert, particularly ungulates, are seasonal and irregular migrations within their general habitat. Desert animals--antelopes and koulans (Equus asinus ferus)--migrate during the hot summer to areas well supplied with water and rich fodder. By winter they return to the warmer zones of the desert where, due to the absence of snow, it is easy to find fodder. Mountain goats and sheep migrate in summer to alpine meadows; and in the autumn, when snow falls there, they descend to the warmer lower mountain levels.

Some of desert animals pass the hottest part of the day under bushes or rock ledges; others, in burrows. There is more life in the desert at night than by day, because part of its inhabitants, of which the most numerous and mobile are jerboas, lead nocturnal lives. Active also at night, in consequence, are carnivores which feed on the jerboas. Some species of jerboas and gophers pass the period of summer heat in a torpid state.

A noticeable effect on the composition of the fauna of Central Asia and on the biological characteristics of its individual representatives is exerted by the winds, which reach hurricane force during the cold half of the year. Very likely the greatest effect of the winds is exerted on insects, among whom there are few flying and comparatively many creeping species. The flying insects live only in the tugay forests and reed beds impenetrable even to strong winds. The creeping insects, able to conceal themselves in any surface irregularities in the ground, are found also in areas with sparse vegetation.

The birds build their nests out of reach of the wind in abandoned burrows or fissures in rocks.

Fig. 1. Animals and birds of the Gobi plains:

1--Przhevalski's horse
2--dzeren
3--koulan (Equus asinus ferus)
4--steppe antelope
5--camel
6--seminocturnal gerbil
7--boar
8--gazelle (Gazella subgutturosa) ("dzheyram")
9--small jerboa
10--tridactyl jerboa
11--fine-toed suslik
12--large gerbil
13--Gobi jerboa
14--saxaul jay
15--Srrrhaptes paradoxus

Almost all the Central Asia rodents store food. In the dry air, under the burning rays of the sun, a portion of the plants used by the rodents for food quickly wither and dry up, and, becoming brittle and fragile, are carried away by the winds. In the course of the struggle for food caused by the resulting lack of fodder, the rodents--Leptopoecile sophiae, field mice, gerbils--have developed the habit of gathering plant shoots when these are still fresh and green. These they heap as a food reserve near their burrows protected from the wind in rock crevices, or, if the burrow is situated in the open, they weight them down with pebbles.

Fig. 2. Animals and birds of the Tibetan plateau and high mountains:

1--yak
2--koulan (Equus asinus ferus)
3--"orongo" antelope
4--kuku-yaman (Pseudois nayaur)
5--Central Asiatic sheep
6--mountain goat
7--Leptopoecile sophiae
8--mountain gosse
9--pseudo-sparrow
10--horned lark
11--Syrrhaptes paradoxus /type of sand grouse/
12--Tibetan turkey (Tetraogallus)

As a whole, the fauna of Central Asia is monotonous, since only a relatively few animals can adapt themselves to the dry climate of this region. But, on the other hand, there are many individually distinct species.

The distribution of animals throughout Central Asia is far from uniform. Many of them inhabit areas having abundant water and food which are distributed like islands among the broad expanses of stony and sandy deserts completely lacking in fauna. And because the number and size of such islands increases in proportion to the distance from the interior desert areas of Central Asia to its semidesert boundaries the fauna correspondingly becomes more numerous and varied.

The ranges of the distribution of individual animal species depends in considerable measure on the altitude of the locality, variations in which result in sharp changes in climate and living conditions. Therefore there exist in Central Asia two faunal complexes and two zoogeogrphic regions--the Gobi and the Tibetan (Fig. 1, 2), corresponding to two major relief zones with a difference of 3,500 m in altitude between them. The first of these (altitude 1,000-1,500 m) is a hot desert, where atmospheric pressure is close to normal; in consequence of greater altitude (4,500-6,000 m) the second is a cold desert with very thin atmosphere.

Each of these fauna complexes comprises typical specimens of ungulates, rodents, and carnivores. Only one koulan is found equally in both complexes, but even it is represented by different races: the kiang in Tibet and the "dzhigetay" in the Gobi, which differ in size and coloration.

The animals of the Gobi and Tibetan fauna complexes, even those belonging to the same genus and family, differ considerably in size, body structure, coloration, and mode of life. For example, the Gobi antelopes (gazelle, dzeren, and Przhevalski's antelope), especially speedy in flight, possess relatively small bodies with long and well-shaped hoofs; while the Tibetan antelopes ("orongo" and "ada"), which live in a region of thin atmosphere, have a better-developed thorax and larger body.

The protective coloration of the animals of Central Asia, which enables them to blend with the landscape, depends above all not on the color of the vegetation, which is here very sparse, but on the color of the soil. Because the latter varies from grayish-yellow to brown, the protective coloration of the animals changes within the same range of colors. On the Gobi plains light-colored sands and loess-type clays are most prominent on the landscape, while on the Tibetan plateau relatively dark gravel deposits alternate with stony outcroppings. The result is that the coloration of the fauna inhabiting the Gobi plains is lighter than that of the animals of Tibet.

Gobi fauna complex. The most remarkable animal of the Gobi desert is the wild camel, which inhabits the hottest, driest, and most isolated parts. At present wild camels are found only in the Trans-Altay and Gashun'skaya Gobi, which evidently constitute isolated ranges. The Trans-Altay range is bounded on the north by the Ederengiin-Nor range, on the west by the meridian of Mt. Shivetiin-ulan-ula, and on the east by the meridian of the Ekhin-gol oasis. The Gashunskaya Gobi range lies between Chol Tagh, Western Kuruk Tagh, the Lop Nor lowland, and the Eastern Pei Shan. The isolation of these ranges has come about in the last decade, clearly as a result of the increase in transportation movements on the Pei Shan section of the Lanchow-Sinkiang route and railroad construction.

In recent times, as a result of man's penetration into the desert, the Gobi range inhabited by the wild camel has been sharply reduced. At the end of the nineteenth century wild camels were still encountered throughout the entire arid region of the Gobi. They were found along the lower course of the Keriya River and on the sands of the eastern part of the Takla-Makan desert, in the Altyn Tagh and Tsaidam basin, on the sands of the Kum Tagh, throughout all of the Pei Shan, and in the Nomin-Gobi desert (Map 13). At the present time, however, according to the reports of hunters, wild camels gather in herds of up to 20 individuals, but only in the Lake Toli area in the G shun'skaya Gobi, evidently a special habitat of these animals, are they found in herds of 100-200 head.

Map 13. Distribution range in Central Asia of the wild and domestic camel.
1--Present limits of the range of the wild camel (I--Gashun'skaya Gobi, II--Trans-Altay Gobi);
2--Distribution range of the wild camel in the 19th century;
3--Distribution range of the domestic camel.
/Place names: Same as Map 6./

They graze primarily in the morning and evening, resting during the day lying under saxaul bushes. They rarely seek water; in periods of not very hot and dry weather they can get along without water for 2 weeks or more. Their food consists of feather grasses, leeks, "polyni," and halophytes, and twigs of saxaul and poplars.

The wild camel has very keen senses, possessing superior hearing, smell, and vision. In the picturesque words of one of the best-known local hunters, "The eyes and ears of this animal are worth more than the legs of a gazelle." Its keen senses permit the wild camel to escape encounters with man. nd this strong camel does not fear carnivores. It moves rapidly and tirelessly, covering great distances in the course of a day.

According to the local inhabitants, it appears that the wild camel is noticeably different from the domestic camel. Its back is straight, the humps very small, the snout narrow, the hoofs slender and well formed, the crupper not as large, the head crest hardly evident, the mane, neck, and shoulder hairs short and sparse.

Another typical Central Asiatic ungulate is the koulan which in appearance and size resembles a mule. The koulan inhabits both the Gobi and Tibet, but is represented by different races: in the former the "dzhigetay" and in the latter the kiang. The kiang is somewhat larger and darker colored. The "dzhigetay," like the wild camel, roams the most barren stretches of the desert to which they migrate in the cold season when their water requirements are less and water can be obtained from hoarfrost, the rare snowfall, and ice on saline springs. In summer, however, they graze the foothills and in the mountains where there is more water and green pasturage.

The favorite habitat of the kiang is a few valleys in the Western Nan Shan and Chang Tang which are protected from cold winds and seldom frequented by cattle raisers. In these valleys, in the course of a single day, one may encounter dozens of herds of horses, with a hundred or more head in each. The kiang, which is considered a sacred animal by the Tibetans, is hunted less than the Gobi dzhigetay and consequently is more numerous and less timid. Herds of them may often be seen grazing along with domestic animals near Tibetan yurts.

Koulans previously had a larger range than at present. There are reliable reports of the occurrence of these animals in the nineteenth century in Eastern Mongolia and Chakhar, in Dzungaria, the Western Kunlun, and Southern Tibet, areas where now they are never or rarely encountered. In the still more distant past koulans were found throughout the whole zone of semideserts and dry steppes. The reduction of their ranges and the restriction of them to the most barren desert areas were caused by man's conquest and settlement of the steppe and, partly, of the semidesert, by a reduction in the pasturage and water sources available to wild animals, and by the hunting of them for hides and meat.

Przhevalski's horse is a rare animal known only in Central Asia But it cannot be called a typical desert animal, since it inhabits the steppe areas bordering the desert region near the latter's northern boundary. Przhevalski's horse is now found in the Takhiin-sharanuru and Khab Tagh mountains surrounding the Dzungarian desert (Map 14). As recently as 20 years ago in these mountains herds of 50 and even 100 of these horses were to be found. Later they were extensively hunted and almost completely exterminated.

Map 14. Distribution range of large ungulates in Central Asia.
1--Gobi wild ass (dzhigetay)
2--Tibetan kiang
3--Przhevalski's horse
4--wild yak
/Place names on map: Same as Map 6./

Now that hunting Przhevelski's horse has been prohibited, the breed has re-established itself rather quickly. The observations of an investigator of the Mongolian region, Dorzhin Eregden Dagva, show that Przheval'ski's horse leads a migratory mode of life and does not remain long in one place. It feeds on various cereals, polyni, leeks, and cane leaves. It moves to waterholes once every 2-4 days. It feeds mainly at dawn.

The antelopes of the Gobi plains--the dzheyran, dzeren' and Przhevalski's antelope--are swift and hardy animals which roam in herds the size and compositions of which varies with the season of the year. Their coloration is light grayish-yellow in the light of the surrounding landscape. Searching for water and fodder, they may cover severals hundreds of kilometers daily. Antelopes feed on polyni and various cereals, saltworts, and saxaul twigs; they can go without water for a long time, contenting themselves with the moisture contained in their food. They inhabit open expanses with groups of small rolling hills; in the mountains they are not found above 1500 m. Most adapted to desert life is the dzheyran (gazella subgutturosa) whose range includes the semidesert zone and adjoining less barren desert areas.

Map 15. Distribution range of antelopes in Central Asia:
1--dzeren
2--dzheyran (Gazella subgutturosa)
3--Przhevalski's antelope
4--ada antelope
5--orongo
6--saiga
[Place names on map: Same as Map 6.7]

They are absent only from the completely barren parts of the Takla-Makan and Gobi deserts (Map 15).

The dzeren is found in the less arid region of Northern and Eastern Mongolia whose vegetation is that of the dry steppe type and transitional to the semidesert type. Przhevalski's antelope inhabits the southeastern boundary of the Central Asia desert where areas of mountain-meadow vegetation are comparatively extensive.

On the lake plains of Western Mongolia is found the saiga which, like the dzeren, prefers the less arid regions of the desert In the past it was also distributed throughout Dzungaria, where it was almost completely exterminated because the antlers of the males were in demand in Chinese national pharmacology.

Rodents in the Gobi are not very diversified but they are large in number. Species vary in accordance with local conditions. Characteristic for the clay and sandy deserts are various species of jerboas, gerbils, small-toed susliks, hare-gerbils, and blindsnakes. In the semideserts the major rodent forms are various species of susliks, while the jerboas and gerbils are considerably lesser in number (Map 16).

Map 16. Distribution range in Central Asia of various groups of rodents.
1--Mountain-meadow-steppe group (a--with dense population; b--with sparse population and limited numbers of species);
2--Semidesert group;
3--Desert group.
[Place names on map: Same as Map 6.7]

Rodents are most diversified and numerous in the dry steppes bordering the Gobi deserts. Particularly numerous here are field mice, hamsters, leptopoecile sophiae, and marmots. There are no jerboas or gerbils, and susliks are represented by special steppe species (long-tailed susliks and others). The leading role in the steppe zone is played by field mice.

As a result of the abundance of rodents in the Gobi and adjoining areas, there are many quadruped and feathered predatory animals. Everywhere are found wolves, foxes and Tartar foxes and also eagles, hawks, and falcons. The carnivores live largely in the semideserts and steppes, which are the main habitats of rodents.

Birds are comparatively numerous in the Gobi only in the tugay forests and in those sections of the desert and semidesert covered with bushes. Typical of the latter are the saxaul jay, lark, saxaul sparrow, chekan, desert jay, and pale shrike. On the solonchaks are ordinarily found desert "zuyki." A Mongolian grouse (Syrrhaptes paradoxus) is found throughout the whole semidesert zone and adjoining districts. On the lakes are many ducks, geese, pelicans, and cormorants.

The most numerous vertebrate animals in the Gobi, according to the determinations of A. G. Bannikov, are lizards (Phryndcephalus, Agamida). They live in deserts of all types: sandy, clay, and stony. In places their number can amount to 1,500 per hectare.

A very special fauna complex in the Gobi zoographic region is represented by the population of tugay forests growing in the valleys of the main rivers. In these forests there are many boars and sometimes Siberian stags. Among the carnivores, in addition to wolves and foxes, the reed cat is widespread and it is surmised that tigers remain in the valley of the Tarim River.

The bird fauna of the tugay forests is considerably more numerous and diversified than in the surrounding desert. Here, in addition to the desert birds, are found species which live near rivers and lakes. A typical bird species in the tugay forests of Dzungaria and the Ala Shan is the pheasant, large numbers of which inhabit the thorny bushes along river banks.

The Tibetan fauna complex, like the Gobi, was formed under conditions of a severe continental climate; thus they have several features in common. In particular, the fauna of both regions is monotonous and sparse and desert species are the most common in both of them. However, Tibet and the Gobi lie at different altitudes, which causes great variations in their thermal systems and atmospheric density. The Tibetan uplands, with a mean elevation of 3,500 m above the Gobi plain, have low temperatures even in summer and the air is very thin. Although the same groups of animals are found here as in the Gobi--ungulates, rodents, and carnivores--their representatives as a rule are of different species and races. Antelopes in Tibet are represented by two species, the Orongo and "ada," which are as capable as the Gobi gazelle and dzeren of moving across the desert plain in search of food and waterholes. In addition, they are inured to high altitudes and constant cold.

Occurring throughout all of the Chang Tang and Western Nan Shan, as well as in the Central and Eastern Kunlun, is the wild yak, a powerful animal of the subfamily of oxen, having a heavy body with a short neck and short, strong legs. The wild yak is covered with long, thick black hair. In size and strength it is considerably superior to its domesticated kin. The favorite habitat of the wild yak is the small alpine meadows on the plateaus of mountain slopes not far from the snowline. Large herds of wild yaks are particularly frequently encountered along with kiangs and antelopes in the Western Chang Tang where even a nomad population is lacking and where hunters rarely go.

A special group in the Tibetan fauna complex is formed by the inhabitants of regions with dissected relief--mountain goats and sheep. While antelopes and kiangs prefer the open landscapes of the highlands, the goats and sheep (teke, arkhar, and kuku-yaman) live in the mountains, particularly on the steepest slopes covered with rocks and precipices; and arkhars, on steep slopes and syrts. Kuku-yamany, occupying a position in the genetic order between goats and sheep, also recall both.

Rodents are very widely distributed throughout Tibet. Colonies of them can be seen in all the lake beds of the uplands and are particularly large in young basins with mountain-steppe relief. Among the rodents of Tibet only those are found which are active during the day and become torpid in winter. These characteristics were developed among them in the process of adaptation to the low winter temperatures and the cold summer nights.

The principal ground animals in Tibet are the Leptopoecile sophiae, represented here by four species. In the basins of the mountain-steppe zone, in areas where colonies of L. Sophiae are to be found, the turf cover seems to be plowed up--there are so many of these creatures. Just as numerous in the Chang Tang are the small mountain field mice and large marmots, covered with thick brown fur.

Possibly the most interesting of the carnivores of Tibet is the small black "medved'-pishchukhoyed." In Tibet there are many red wolves and tricolored foxes which also feed on rodents.

Among the birds of the Chang Tang there are about 30 species, the greater part of which, despite the very severe climate, live there the year round. They nest in rock crevices, in abandoned rodent burrows, or in burrows they themselves dig.

Typical for the Chang Tang are the Tibetan grouse and Tibetan "ular," the red-beaked gull, horned and small-toed larks, the pseudo-sparrow ("lozhnosoyka"), and ground finches. As one approaches the Kama River and Southern Tibet, the number of birds and bird species increases considerably because of the milder climate.

Map 17. Distribution range of grouse in Central Asia.
1--Mongolian;
2--Tibetan.
/Place names on map: Same as Map 6./

On the history of the formation of the fauna of Central Asia. Central Asia is one of the oldest areas of the earth and one of the principal world foci in the formation of continental fauna. There have been discovered on the territory of Central Asia many fossils of various Triassic, Jurassic, and Cretaceous reptiles and of the still more varied mammals of the Tertiary period.

Ungulates, rodents, and carnivores were widely distributed throughout Central Asia already at the beginning of the Neocene. Later, however, as a result of the intensification of the climatic aridity of Central Asia, it became poorer in fauna. In accordanc with the increase in desert areas and the disappearance of forest-steppe landscapes, the animals characteristic for these landscapes also died off. Already in the Pliocene, in various parts of the Gobi where barren sandy and stony deserts now stretch, there roamed giraffes and ostriches, hipparions and gazelles, mastodons and deer. Since those times many of these animal species have become completely extinct while others have survived only in small areas here and there along the boundaries of the desert (deer). Only a comparatively few species have been able to adapt to the new, more arid conditions of life (horses, antelopes, camels).

In the historic period the reduction in the range of some animals, particularly horses and antelopes, and the transformation of these animals from steppe to desert dwellers, has taken place also under the influence of man, who has settled and cultivated the steppe or transformed it into pasturage for domestic cattle. In the past the animals of the Gobi were less adapted than now to life in the desert.

The long predominance in Central Asia of an arid climate has resulted in the formation of an independent drought-tolerant fauna.

10. Mineral Resources

Just as the geological structure of Central Asia is heterogenous, so also are its mineral deposits. In the active zones are found the deposits of various metals, and in the regional depressions of honeycombed blocks are found great seams of coal and oi-bearing rocks.

Metalliferous deposits. Each zone of the region of Paleozoic and Mesozoic folding and the activated areas of platform and middle massifs is characterized by definite metallogenetic features which formed in the process of geological development. In zones which were subjected to prolonged upheaval and had great masses of granites, usually to be found are deposits of rare metals, tin, tungsten, and molybedenum. Distributed in zones which were subjected to prolonged warping and almost entirely free of granite intrusions, but having thick volcanogenic series, are deposits of polymetallic ores, while in their exterior sections, adjoining the honeycombed blocks, are found mainly copper ores. In the interior sections bordering the crystalline axes of the mountain systems there are lead-zinc ores.

The ore bodies of rare metals are adapted to areas of the outcroppings of ancient metamorphic series which were subjected to considerable activization in the Paleozoic and Mesozoic. In zones bordering the broad areas of ancient dry lands iron deposits are found.

The specific system of the geological development of an individual zone and its stability over the course of considerable periods of time have resulted in the long-continued accumulation in them of some elements which achieve concentrations many times exceeding the average Clarke contents [= average contents of an element in the earth's crust]. These elements become the primary ones in a given zone, defining its metallogenic profile. In turn the metallogenic zones are distinguished by the nonuniform distribution of concentrations of primary elements, which reflects the unevenness of the manifestation in them of geological processes facilitating the migrations of atoms.

In areas where the geological processes favoring ore formation have operated particularly energetically, ore beds and regions have risen in which are concentrated the largest and most numerous deposits.

Such accumulations of metallic deposits are controlled in some cases by fractures, in others by uplifts and adaptive ore-bearing intrusions. In still others they coincide with areas of the distribution of sedimentary strata enriched by ore components, movable under conditions of hypergenesis, and capable during the activization of the environment, in particular under the influence of granitic intrusions, of creating ore concentrations. On the basis of the extent of the zone lying outside the sphere of action of the specially favorable factors resulting in the concentration of elements, its specific elements remain in a dispersed condition.

The two most important epochs of endogenic ore-formation have been established for Central Asia: the Hercynian, manifest in the regions of Paleozoic folding, and the Yen-Shang, the main epoch for the regions of Mesozoic folding and for areas of the Mesozoic activization of the Sinisian shield. The primary elements in these two differently developing regions of endogenic ore-formation are identical: represented in both of them are rare-metal, rare-element, polymetallic, and iron-ore zones (Map 18).

Regions of rare-metal mineralization. The phenomenon of the rare-metal mineralization of the Hercynian age has been established in the Kavak Tagh range of the Western Kunlun, in the basin of the Borotala River of the Northern Tien Shan, and along the watershed area of the Mongolian Altay belonging to the axis zones of anticlinoria with large bodies of Upper Paleozoic granites. The main deposits are usually found at the contact point of granites and hornblende schists and sandstones and represent groups of small quartzitic seams with the impregnation of ore minerals. In river valleys, somewhat below these ore-bearing contact points, placer deposits are found

Map 18. Diagram of the mineral-geochemical provinces of Central Asia.
1--rare element ores;
2--rare metallic ores (Sn, W, Mo);
3--gold-molybdenum zone of Hangaya and Kentey;
4--polymetallic ores (Pb-Zn, partly Cu);
5--copper-bearing ores (in places with Cr);
6--iron ores;
7--area of Meso-Cenozoic mantle, essentially not affected by processes of hypogenic mineralization;
8--regions which have not been prospected for metals.

/Place names shown on map Same as Map 6./

The mineral compositions of the Hercynian regions of rare-metal mineralization are dissimilar: characteristic for the Kunlun are monomineral tin-ore deposits; in the Borotala River valley there are large deposits of tungsten and tungsten-tin ores; in the Mongolian Altay there are deposits of wolfram-molybdenum ores.

Rare-metal deposits of the Yen-Shang age are known in the Eastern Gobi and in the Karakorum. In the former they are grouped in two belts: the northern, manifest on the Central Khalkhasskiy plateau and the basin of the Kerulen River, and the southern, adapted to the Totoshan'-Nukutdabanskiy series of elevations. Both belts coincide with active uplifts of the Mesozoic structure in which are localized major centers of Jurassic volcanic activity and Yen-Shang granites. The ore bodies are mineralized quartzitic veins sometimes fringed with greisens. In the northern belt the most important ore-forming elements are tin and tungsten; and in the southern, tungsten and molybdenum.

In the Karakorum rare-metal mineralization with tin and tungsten has been discovered in the axial zone of the geoanticline of this range between the headwaters of the Yarkend and the Pamirs.

Zone of lead-zinc mineralization. The zone of ore mineralization with a distinctly expressed lead-zinc profile extends along the Southern Tien Shan and the adjoining areas of the Tarim massif, along the ranges enclosing the Iliyskiy depression, along the forward ranges of the Western Kunlun, the upper course of the Yangtze River, and the southern boundary of Tibet. Moreover, evidences of lead-zinc mineralization have been observed in the southern ranges of the Nan Shan, in the Pei Shan and the Gobi Altay. In the Tibetan zones mineralization is of the Yen-Shang age; in all the other regions, the Hercynian.

The conditions of the localization of lead and zinc deposits in Central Asia are more or less homogeneous and are expressed in their adaptation to zones of fractures separating the zones of different tectonic systems within the region of submergence. The link between this type of ore deposits and the regional fractures is explained by their more linear (zonal) development in comparison with the deposits of rare metals, whose localization is determined in considerable measure by a magmatic factor.

In the zones of lead-zinc mineralization the deposits are localized in ore bodies located at the contact points of zones of the fractures of various strikes. The rocks enclosing the ore bodies of lead-zinc deposits usually are limestones and volcanic-sedimentary blocks.

Regions of copper mineralization. Ore manifestations with copper as the leading element have been observed in large numbers in the Kel'pinskiy region of the Tarim massif and along the entire area of the Dzungarian massif, the Ordos, and the Nan Shan depression area. The age of mineralization in these regions is mostly Hercynian; the only exceptions are the Ordos region, where it is most likely of the Yen-Shang age, and the Kil'pinskiy ridge of the Tarim massif, in which mineral formation evidently took place in the Alpine epoch.

The regional factor which favored the development of copper mineralization in all the areas named is represented by the regional fractures of the central and inner platform massives which allowed the egress to the surface of lavas of basic and neutral composition and which served as the receptacle for intrusions of ophiolites.

Deposits of copper-bearing minerals are usually observed in the form of scattered impregnations and small veins in fractured rocks, only rarely forming seams of continuous pyrite masses. In the Kel'pinskiy region of the Tarim massif and in the Shansi mountains, mineralization occurs mainly in Cambrian-ordovician limestone; in the AltynTagh in the Semenov range; in the Ho-lang-shang, in blocks of serpentine ultrabasic rocks laid down in the metamorphic complex, and also in Cambian-Ordovician limestone; in Dzhair and the Bogdo Shan and Richthofen ranges, in igneous sedimentary layers of the Silurian and Devonion. In deposits associated with layers of basal lavas and blocks of ultrabasic rocks, copper is frequently accompanied by chromium.

Regions of rare-element mineralization. Deposits of rare elements occur on the southern slope of the Mongolian Altay and in the Ying-Shang. The first of these regions constitutes part of the ancient Dzungarian massif, which was activated by Hercynian movements and by numerous Hercynian rock intrusions. The second is a part of the Sinisian shield which was subjected to activization in the epoch of Yen-Shang tectonic genesis.

In both regions the ore-bearers are pegmatite strata which form accumulations in the contact zones of granite blocks and in the large buttes on the top.

Regions of the distribution of iron-ore deposits. Belonging to the metallogenic regions with iron-ore profiles are the interior zones of the Eastern Tien Shan and Nan Shan, the Eastern Gobi, and the upper basin of the Lantsatszyan (Mekong). In all these regions the iron mineralization gravitates towards the Sinisian and Tibetan shields, which constituted for a prolonged period of time level dry land on which, under the conditions of a hot and moist climate, the processes of chemical weathering occurred intensively. The atoms of iron concentrated during these processes were carried by running waters to the coastal zone of the sea, where they accumulated in large quantities. High concentrations of iron are to be observed in the coastal deposits of the Sinisian system, the Silurian, Devonian, Carboniferous, and Permian, and also in the lake deposits of the Jurassic. A part of these deposits are brown hematites which have fully preserved the characteristics of sedimentary formation; other deposits, of more practical value, are the result of the metamorphosis (secondary enrichment) of ferrous deposits and sedimentary deposits and ores under the influence of granite intrusions and hydrothermal processes.

Gold-bearing ores. In Central Asia gold is widely distributed, occurring under a diversity of geological conditions. It is found in the alluvial deposits of the various metallogenic zones of the Altay, Han-hai, Dzhair, Eastern Tien Shan, Kuruk Tagh, Kunlun, Altyn Tagh, Northern Tibet, and Nan Shan. The main sources of placer gold are ancient metamorphic strata, sandstone-slate complexes of the Ordovician and Silurian, and conglomerates of the Neocene.

In antiquity the Kunlun, Altyn Tagh, and Nan Shan were among the main regions of the world in gold extraction.

Map 19. Coal-bearing provinces of Central Asia:
1--Carboniferous; 2--Lower Permian;
3--Upper Permian; 4--Jurassic;
5--Jurassic-Cretaceous; 6--Lower Cretaceous.
/Place names shown on map: Same as Map 6./

Coal deposits. Five periods of coal formation have been established within the territory of Central Asia: the Carboniferous, appearing in Dzungaria, the Nan Shan, the eastern Ala Shan depression, and the Ordos; the Lower Permian, with which are associated the carboniferous deposits of Western Mongolia and the Northeastern Gobi; the Upper Permian, coals of the area of the upper course of the Yangtze River; the Jurassic, appearing in all the Mesozoic depressions; and, finally, the Lower Cretaceous, the coals of which are distributed in the Eastern Gobi and Southern Tibet (Map 19).

The coal-bearing deposits of the Carboniferous and Permian periods were laid down on the flat coastal plains. Their distribution shows the successive stages of the drying of the territory of Central Asia, which was flooded by the Paleozoic sea. The coal-bearing deposits of the Jurassic and Lower Cretaceous were formed under continental conditions; their localization is determined to a considerable degree by climatic factors.

In the Carboniferous the sea receded from Eastern Kazakhstan, Dzungaria, and Northern China, in which regions coal formation occurred at that time. Coal-bearing deposits of the Carboniferous are found in the Lake Ulyungur region, in the Baytyk-Bogdo mountains, the Mechin-Ula range, the northern ranges of the Nan Shan, in the Kholan Shan and Ying Shan, in the Ordos, and also in the Taiwan trough and the Ho-pei sineclise beyond the boundaries of Central Asia. In this broad Asiatic zone of Carboniferous coal-accumulation the age of productive seams changes in direction from west to east, from the Visean in Kazakhstan and Dzungaria to the Middle Carboniferous in the Nan Shan and the Upper Carboniferous in the Ordos and Ho-pei sineclises.

Coal-bearing Lower Permian deposits are distributed in the northern Altay region (Kobdoskiy) downwarping and the Mandal-Gobi synclinorium.

Coals of the Upper Permian are found in Southern China and Eastern Tibet (upper courses of the Yangtze River). Here the productive stratum is interbedded with marine sediments and is thus associated only with the temporary drying of this territory.

In the Jurassic, coal-formation occurred in the interior continental basins, distant from the sea. The seams of coal-bearing deposits were laid down in all the lowlands of the Jurassic relief, a process which evidently was facilitated by the climatic conditions in this period.

In the Lower Cretaceous, coal was laid down only in the Eastern Gobi and Southern Tibet. Still nearer to the ocean littoral, the zone of coal-accumulation was formed in the Upper Cretaceous and Tertiary periods. The cause of this displacement was the progressive development of the Central Asiatic arid region.

Types of coal field in Central Asia. Among the coal fiels of Central Asia are found three major genetic types characterized by a definite series of tectonic, paleographic, and facies features:

(a) fields adapted to sineclises (Ordos) and to depressed central massives (Dzungaria);

(b) fields of piedmont depressions (Kucharskiy, chiu-chiu-an, Yarkend-Ferganskiy, Tsaidam);

(c) fields of intermountain basins (Kungesskiy, Karasharskiy, and Turfanskiy in the Tien Shan; Yangidavanskiy and Naychingol'skiy in the Kunlun; Mominskiy in the Pei Shan; and others).

Fields of the first type are characterized by large size, a more or less isometric form, and a mantlelike development of coal-bearing deposits, which are evidence of the weak structural differentiation of these regions. Such subsidence of Sineclises and central massifs occurred uninterruptedly during the course of many geological epochs, and their cross-section frequently shows not one but two coal-bearing strata. In the Ordos, for example, the Carboniferous and Jurassic are productive in this respect.

In fields of this type the coal beds were laid down not over all their enormous area but only along the boundaries of active upheavals; along the Liu-lien and Ching-lin in the Ordos, and near the Tien Shan and Dzhair ranges in the Dzungarian massif. Farther from the active uplift, coal beds become thinner or completely disappear. The coals in these types of basins are the least metamorphosed.

Fields in the foothill depressions are distinguished by somewhat smaller dimensions and extension in the direction of the trend of the rear mountain system. Observable in them is a unilateral facies zonality of types of sediments and coal beds. The latter are expressed in a successive change from a zone of heavy coal impregnation extending along the mountains to a zone of moderate and then weak coal impregnation lying along the level flank of the basin. Characteristic for fields of intermountain troughs is an abundance of conglomerates which are absent in the basins of sineclises.

While the last-named basins and those of foothill depressions belong to regions of prolonged submergence, the basins of intermountain troughs are areas of temporary submergence in a region of general uplift. They are relatively smaller in area and have a more complex structure. Coal beds in fields of this type usually occur over their entire area. The degree of metamorphosis of their coals is very high.

The possible coal reserves of the basins of sineclises, depressed central massifs, and foothill depressions amount to tens of billions of tons, and the reserves in intermountain troughs and individual basins are estimated to contain many hundreds of millions of tons.

The coals of the Carboniferous and Permian periods are bituminous; those of the Jurassic, bituminous and lignite; of the Cretaceous, lignite only.

Petroleum and natural gas fields. Central Asia, with its many large Meso-Cenozoic depressions, is a very favorable area for petroleum and natural gas fields. However, prospects have been poorly verified up to the present time by geological surveys.

Oil and gas deposits of industrial importance have been discovered in the southern and western margins of the Dzungarian massif in the depressions of the Kan-su corridor, in the Tsaidam basin, and in the Eastern Gobi. Abundant evidences of petroleum are known in both regional downwarpings of the Tarim massif, in the Turfan-Khamiyskiy depression, and in the Ordos; isolated indications of oil have been noted in the depression of the Nomin-Gobi and in the Mesozoic downwarpings of Tibet (Map 20).

Conditions of the occurrence of petroleum and gas in the basins of Central Asia are very diverse. In the western group of basins, including the regional downwarpings of the Tarim massif, and also in Dzungaria, the Turfan-Khamiyskiy depression, the Tsaidam basin, and the Kansu corridor, all of which underwent powerful submergence in the Cenozoic (as a result of which sedimentary layers 2,000 to 5,000 m thick were laid down here), the main oil-bearing horizons conform to the Paleocene. In the eastern group, however, comprising the Eastern Gobi basin, the Ordos, and the Tibetan basins, the submergences of which were completed in the Upper Cretaceous, the oil-bearing horizons are located in various systems of the Mesozoic: in the Eastern Gobi, in the Lower Cretaceous; in the depressions of Chao-shui and Ming-ho, in the Jurassic; and in the Ordos, in the Jurassic and Triassic.

Differences between these groups of basins are manifest also in the structural forms governing oil and gas deposits. In the western group such forms are the so-called Adyrnyye folds /from "adyry," groups of small hills in Turkestan and Kazakhstan/--asymmetrical and folded anticlines formed by thick layers of the Tertiary system and directly expressed in the relief as mountain chains of corresponding morphology.

Map 20. Oil-bearing districts of Central Asia:
1--with verified oil-bearing seams;
2--with probable oil-bearing seams.
/Place names shown on the map: same as Map 6./

In the eastern group of basins, filled with sediments of moderate thickness, the typical structural forms are upthrust anticlines with shallow Paleozoic cores, walls, and buried uplifts.

Salt deposits. Salts constitute specific useful minerals of Central Asia associated with the repeated occurrence in its history of an arid climate. There are salt-bearing deposits of the Sinisian, Lower Cambrian, Middle Paleozoic, Upper Permian, Triassic, and finally, of the Upper Mesozoic and Cenozoic. Of the greatest extent are the Quaternary salts which accumulated in lake-evaporators--the Lop Nor, the Dabasun-Nor in the Tsaidam Basin, Ikhekhak, and Gashun-Nur. In the Gobi strata Glauber and rock salts predominate; and in Tibet, along with these, potash and borates.

Underground water. Of significance as mineral resource in the desert of Central Asia is underground water: interstitial water in mountainous elevations composed of dense Paleozoic rocks, and water occurring below the petroleum layer in the foothill and intermountain basins filled by the gently dislocated deposits of the Meso-Cenozoic. Because underground waters are formed mainly as a result of the seepage of atmospheric precipitation, ground water reserves are determined to a considerable extent by the regional climatic zones. Underground water resources are considerable in the hydrogeological massives of the Mongolian Altay, Han-hai,

Liu-lien, Eastern Nan Shan, Eastern and Western Kunlun, Karakorum, and the high part of the Tien Shan, all of which occupy peripheral positions in the arid region of Central Asia and receive annually up to 300 mm of atmospheric precipitation. However, elevations in the most arid part of the Central Asiatic desert, even such high areas as the Central Kunlun, Altyn Tagh, Western Nan Shan, Kuruk Tagh, Chol Tagh, and Gobi Tien Shan, are poor in underground waters. Springs of such waters are rarely encountered in these areas, and the discharge is not great.

Map 21. Hydrochemical diagram of Central Asia.
1--regions of hydrocarbonate and hydrocarbonate-sulfate waters;
2--regions of chloride and chloride-sulfate waters.
/Place names shown on the map: same as Map 6./

All the Mesozoic and Meso-Cenozoic depressions of Central Asia are artesian basins which in the course of many geological epochs have accumulated waters received from surrounding elevations. Such water is most abundant in those basins or the parts of which that received a flow from high surrounding ranges. For example, Dzungaria, which is bordered by snow-covered ranges, is apprently richer in artesian waters than the neighboring basin of the Nomin-Gobi, which lies among desert uplands. And the western part of the depressions adjoining the Kunlun range, into which flow streams from the slopes of the Karakorum and the mountain knots of Kungur and Muztagat, has more underground water than the eastern part of the same depression bordering the dry Central Kunlun.

Central Asia constitutes primarily an area of the distribution of saline chloride and chloride-sulfate waters, the mineralization of which is facilitated by intense evaporation, the abundance of salts in the enclosing rocks, and the very slow movement of waters along the broad sloping parts of the Meso-Cenozoic depressions. Fresh hydrocarbonate and hydrocarbonate-sulfate waters are found mainly near the bordering uplands (Map 21).

PART TWO

DESCRIPTION OF INDIVIDUAL REGIONS OF CENTRAL ASIA

For purposes of systematic description Central Asia has been divided into eleven regions (Map 36).

1. Eastern Tien Shan
2. Tarim plain
3. Dzungaria
4. Gashun'skaya Gobi, Pei Shan, and Kansu corridor
5. Ala Shan and Ordos
6. Mongolian and Gobi Altay
7. Lake plains of Western Mongolia and the southern slope of the Han-hai
8. Eastern Gobi and Ying-shan
9. Nan Shan, Altyn Tagh, and Tsaidam basin
10. Western Kunlun, Eastern Pamirs, and northern slope of the Karakorum
11. Eastern Kunlun and Chang Tang

This division, however, should not be considered as a physico-geographic regional breakdown of Central Asia, because in determining the regions to be described consideration was taken not only of features of the landscapes but also those of a structural nature. Also, there was the particular aim of generalizing the material as much as possible.

Some of the regions chosen, such as the Tarim plain, the Eastern Tien Shan, Dzungaria, the Mongolian and Gobi Altay, actually represent special physicogegraphical regions which must also figure in the special pattern of regional breakdown. Other regions, however, consist of two or three physicogegraphic regions with similar landscape features. Examples of the latter group are the Ala Shan and Ordos or the Nan Shan, Altyn Tagh, and Tsaidam basin, each of which sonstitutes a separate physicogeographic region.

Map 36. Major physicogeographic regions of Central Asia.

I. Eastern Tien Shan
II. Tarim plain
III. Dzungaria
IV. Gashunskiy Gobi, Pei Shan, and Kansu corridor
V. Ala Shan and Ordos
VI. Mongolian and Gobi Altay
VII. Lake plains of Western Mongolia and the southern slope of the Han-hai
VIII. Eastern Gobi and Ying-shan
IX. Nan Shan, Altyntag, and Tsaidam basin
X. Western Kunlun, Eastern Pamirs, and northern slope of Karakorum
XI. Eastern Kunlun and Chang-tang

1--Borders of physicogeographic regions.

/Place names shown on map: same as Map 6./

The Kunlun mountain system, extending 2,500 km and having different structures in the west and east, is divided into two sections which are considered in different sections: one section is devoted to the western part of the Kunlun, the Eastern Pamirs, and the northern slope of the Karakorum; the second, to the eastern part of the Kunlun system and Chang Tang. In the latter case the degree of investigation is considered which has been undertaken in each of these territories. The better-investigated Western Kunlun can more conveniently be treated along with the Eastern Pamirs; and the less-investigated Eastern Kunlun, along with the no more intensively investigated Chang Tang region.

1. EASTERN TIEN SHAN

General Characteristics of Orographic Regions

Only the eastern half of the Tien Shan mountain system lies within the boundaries of Central Asia, where it bounds the Tarim and Dzungarian plains. In this part of the Tien-Shan three series of ranges can be distinguished: the high northern and southern chains and the interior zone separating them and characterized by relatively low ranges and large intermountain basins. The western Tien Shan is being transformed into a broad mountain system, and, as a result of the tapering of the Tarim and Dzungarian plains, it is drawing closer to the Kunlun and the Dzungarian mountain region. To the east, however, the Tien Shan gradually disappears. The ranges of the southern chain disappear first, terminating already before reaching the Bagrashkul' basin. The interior ranges reach 90° longitude, while those of the northern chain extend into Mongolia, reaching the junction with the Gobi Altay which cuts them at an angle (Map 38 [not included]).

As a whole the Tien Shan mountain system lies approximately on an east-west axis, although individual ranges depart from it considerably. In the Central Asiatic part of the system the ranges are oriented mainly in two different directions: northwest (290-295° NW), characteristic for the Borokhoro, Chol Tagh, and Karlyk Tagh; and northeast (60-75° NE), as in the Maydan Tagh, Kokshaal-Tau, Khalyktau, and Narat ranges.

All the Tien Shan ranges extend in conformity with the parts lying opposite them of the contours of the Tarim and Dzungarian massifs, thus reflecting the regional structure which was already formed in early geological epochs.

Between 85° and 86° longitude, where the Tarim and Dzungarian massifs reach their maximum widths, the Tien Shan ranges form a cluster of peaks in which is found one of the largest mountain knots of the system--the Iren'khabirganskiy, forming the watershed of the Ili and Knaydyk-Gol rivers. From this cluster the ranges of the Eastern Tien Shan extend in both directions.

Northern chain of the Tien Shan. The northern chain of the Tien Shan, bordering the Dzungarian plain, includes the Borokhoro-Uken, Dzharges, Bogdo Shan, and Karlyk-Tagh ranges and the so-called Gobi Tien Shan, separated either by transverse saddles or lying along different sides of the mountain knots.

The trend of the chain is generally northwest: its length is about 2,000 km; width 35-50 km; altitude in the main groups 5,000-5,500 km. The saddles which divide the ranges reach 1,700-2,500 m.

The northern chain begins with the Bedzhintau range, a small link between two arms of the Dzungarian basin: the tectonic valleys of the Borotala and Khustay. The length of the range is 240 km, its maximal altitude (in the Kokdzhet mountain knot) 5,000 m. The Bedzhintau ends in front of the basin of Lake Ebi-Nur.

The Borokhoro and Uken ranges, which come together in the Irenkhabirganskiy mountain knot, constitute the principal trunk of the northern chain. The more westerly of these two ranges, the Borokhoro, has a length of about 450 km, while the eastern range, the Uken, extends for only 200 km. The Borokhoro range in its middle section (lying opposite the zone of the greatest subsidence of the Dzungarian plain) is now undergoing subsidence, so that its altitude varies from 2,500 to 3,000 m. To the east and west the altitude of the range quickly increases and for a considerable distance remains 4,500-5,000 m. In the Irenkhabirganskiy mountain knot it reaches 5,500 m. Extending here from the northern chain are high spurs with a northeasterly trend, serving, as it were, as a continuation of the orographic direction of the Narat range which joins it in this area. The Borokhoro-Uken chain is asymmetric because the Dzungarian plain which borders it to the north is 1,000-1,500 m lower than the intermountain basins south of the chain. Therefore the northern slopes of the Borokhoro and Uken ranges are longer, higher, and more complexly dissected than the southern. Moreover, the northern slope in many sections is complicated by local uplifts in the form of ridges extending in conformity with the trend of the range and rather well distinguished orographically, thanks to the longitudinal tectonic valleys which border them on both sides.

The relif of the Irenkhabirganskiy knot and of the adjoining parts of the Borokhoro and Uken ranges is typically alpine. The ranges have sharp, clearly-outlined peaks and summits, mostly covered with permanent snows.

Near the town of Urumchi, the northern chain of the Tien Shan is cut by a mighty diagonal depression zone which causes a sharp drop in altitude to 1,500-2,000 m. Here the northern chain is formed by the low ridge of the Dzharges which separates the Davanchinskiy and Turfan basins.

Beyond the diagonal depression zone the Bogdo Shan range ceases to be a direct continuation of the Borokhoro-Uken range, becoming a link displaced somewhat to the north. It begins near the town of Urumchi with the low ridges of the Tun Shan, and only 20 km to the east, after

a few successively rising benches, it reaches an altitude of 3,800 m. Still farther on, its summits reach the zone of permanent snows. The western part of the range is crowned by the Bogdo-Ula massif with an altitude of 5,456 m, from the distance appearing to have the shape of a trapezium prevailing over the remaining range. The Bogdo-Ula trapezium has been dissected into three groups of peaks, almost half of whose slopes are covered with permanent snow.

From the eastern face of the trapezium the altitude of the range sharply diminishes to 4,400 m. Its watershed here is rocky and has individual insignificantly rising groups of snow-covered peaks. Approaching the next diagonal depression zone, in which lies the Tsigechintsze basin, the Bogdo Shan gradually becomes lower, becoming transformed first into a barren ridge and then into a group of undulating plains with low hills.

East of the lateral depression zone, from the Tsigechintsze basin the northern chain again rises in the Barkul Tagh range, which for the first 30 km still has the form of a rocky, barren ridge, only farther on being transformed into a true mountain range rising more than 1,000 m over the surrounding region. In the middle section the altitude of the Barkul' Tagh increases to 4,200 m. Here its relief is alpine, with the characteristic alpine combination of snowy peaks and broad glacial cirques divided by narrow, jagged crests. The slopes of the range consist of several longitudinal terraces which descend successively to the Barkul'skiy and Khamiyskiy basins and terminate at the boundary in rectilinear terraces. Here and there on these terraces large remnants of the ancient denuded plain remain.

At the meridian of the town of Khami, the Barkul' Tagh narrows sharply and descends; later it is cut by a diagnonal tectonic trough originating from the southeastern corner of the Barkul'skiy basin.

Farther on follows the Karlyk Tagh range, a large and complex upheaval consisting of a large number of wedge-shaped block terraces. Only the watershed ridge of the Karlyk Tagh which reaches an altitude of 4,900 m, constitutes a sharp, strongly incised rocky ridge. However, its lateral terraces, and both ends of the main terrace, have the character of a mountain plateau weakly incised by river valleys.

Fig. 7. Mountain massif of Ates-Ula in the Gobi Tien Shan. (Photograph by V. A. Amantov)

The southern slope of the Karlyk Tagh, which faces the lower Khamiyskiy plain, is higher than the northern, more strongly dissected, and more barren. Large glaciers are found only in the main mountain group of the range, its other summits rising only a little above the snowline thus there is little snow on them which lies only in the ravines and in crevices among the rocks.

At about the 96th meridian the northern chain of the Tien Shan is once again intersected by a diagonal depression zone, a continuation of the Nomin-Gobi. In this zone the altitude of the range descends almost to the level of the surrounding area. To the east of this low section stretch the mountain peaks of the Gobi Tien Shan, separated by the numerous depression zones of the Altay (northwestern) strike from several isolated mountain massifs lying on a common base. In individual segments of the Gobi Tien Shan there are as many as five parallel ridges, but the major strata are the two northern ones bordering the Dzungarian basin. On the northernmost ridge are found the mountain massifs of the Ates-Ula (1,900 m), Atas-Ula (2,702 m), Chingis-Ula (2,154 m), Tszara-Khairkhan, and Ikhe-Khebtsagay (1,540 m). The second high ridge consists of the massifs of Toroyn-Khundey, Tumartin-Nuru, and Tsagan-Bodgo-Ula (2,380 m). These major ridges of the Gobi Tien Shan are separated by a broad tectonic valley, and only in a few places do they run close to one another.

Fig. 8. Mountain massif of Tszara-Khairkhan in the Gobi Tien Shan. In the foreground is the wide channel of a dry river bed.

The asymmetry of the system is retained in the Gobi Tien Shan, the northern slope of which is considerably higher and steeper than the southern.

The strike of the Gobi Tien Shan as a whole is latitudinal and only in individual sections, where the influence of Altay elements is particularly strong, does it trend to the northwest. Almost all the mountain massifs and crests of the Gobi Tien Shan possess developed bases in the form of anticlinelike curved piedmont plains.

Farther to the east, the Nemegetu and Tostu mountains, although also lying on a continuation of the Gobi Tien Shan and retaining its characterisitc latitudinal strike, are nevertheless already within the limits of the Altay zone. The influence of the Tien Shan is apparent not only on the Nemegetu and Tostu mountains but also on other sections of this part of the Gobi Altay, with the sole exception of the Nomgon and Gurban-Saykhan ranges, which extend in a northwesterly direction. The influence of the Tien Shan is manifest even on the boundary of the Eastern Gobi depression in the latitudinal strike of the Sharakhatszar and Shang-Lai mountains.

Southern chain of the Tien Shan. The southern chain of the Tien Shan system extending along the boundary of the Tarim plain consists of two branches separated by the tectonic valley of the Taushkandar'ya (Kokshaal) River. The eastern branch is formed by the Kokshaal-Tau and Khalyktau ranges which unite in the Khantengriyskiy mountain knot, while the western branch is made up of three separate orographic complexes with different trends; the Maydan Tagh range, a continuation of the Kokshaal-Tau beyond the valley of the Taushkandar'ya; the Koktun mountains, which represent the southeastern extremity of the Fergana range; and the Uchchat mountains, including the Terektau range, belonging to the Alayu.

The orographic center of the western branch is the Sulutorekskiy mountain massif, whose main summit rises to 5,300 m. Its highest part, strongly dissected, is covered by glaciers and snow banks. Adjoining the Sulutorekskiy massif on the northwest is the Uchchat mountain plateau rising 3,900-4,100 m and cut by deep river valleys. Rising still farther on is the Terektau range which has the northeast trend typical for this part of the Alaya. Despite its considerable altitude (4,500-4,800 m) there are no firn fields or glaciers in the range; its summits are flat and rounded and there are many meadows on the comparatively weakly incised slopes.

The Koktun mountains, which extend the Fergana range into the territory of China and which also have a northwest trend, appear to be wedged in the ranges of the northeastern system to which belong the Terektau with the Uchchat and Maydan Tagh. The Koktun mountains are separated from both of the last-named ranges by wide ridges extending along the valleys of the Suek and Terekta. The highest part of the Koktun mountains is the western, bordering the Sulutorekskiy massif, where there are peaks 4,200 to 4,300 m high. In contrast to the Uchchat and Maydan Tagh, level relief is lacking in the Koktun mountains, but there are many rocky crests alternating with deep, narrow valleys.

The Maydan Tagh range, which has a general northeast trend (70°NE), is a complex block upheaval composed of several equally extended ridges--horsts separated by narrow valleys, and grabens or river gorges which have been formed on the faults. As a result of some variance in the trends of the main system of ridges and of the orographic axis of the upheaval, the ridges are diagonally crossbedded. There are basins on both flanks of the Maydan Tagh; the Toyunskiy, Aksayskiy, and Taushkandar'inskiy to the north; the Kylka, Dzhangal, and Chul'tala to the south. As a result of the difference in altitude of the floors of these depressions, the profile of the Maydan Tagh range which they surround is asymmetric. Its southern slope is high, steep, and consists of a series of terraces successively descending towards the piedmont. The amplitude of variations in its altitude in places reaches 2,000 m. The northern slope of the Maydan Tagh is comparatively gentle and merges with the floor of the Aksayskiy depression. Here the range is only 700-1,000 m higher than the piedmont plain.

Along the range there is a broad, flat, and still weakly dissected watershed. Its main summits reach 4,300 m.

From the Maydan Tagh a diagonal ridge intercepts the Karateke mountains, which represent an anticlinelike upheaval rendered complex by block forms. The summits of the Karateke mountains are flat, but in places the slopes have the character of benches. Its highest summits are 3,500-3,600 m high, which with the elevation of the surrounding depression of 1,700-2,000 m, gives a range of variation in the relief of up to 1,500 m.

The eastern branch of the southern chain of the Tien Shan originates from the branching of the Aksayskiy and Taushkandar'inskiy depressions and extends in a latitudinal, then in a northeasterly, then again in a latitudinal, direction to the Bagrashkul'skiy basin. Its trend changes sharply in the region of the Dankov peak and in the Khan-Tengra mountain knot. The latter divides this spur into two ranges: the Kokshaal-Tau (western) and Khalyktau (eastern). The watershed ridges of these ranges for the most part rise above the snow line, reaching 5,982 m on the Dankov peak (Kokshaal-Tau) and 6,877 m on the Tamgatash peak (Khalyktau). But the maximum height of the southern chain of the Tien Shan is reached in the Khan-Tengra mountain knot, where its main peak, the Pobeda, attains 7,439 m. The southern slopes of the Kokshaal-Tau and Khalyktau, which face the Tarim plain, whose altitude at their foot is 1,800-1,500 m, are considerably higher and longer than their northern slopes which descend to the intermountain valleys of the Myudyuryum, Akshiyzyak, Agiyaz, and Koksu with altitudes of 2,500-3,000 m. Thus from the south they have the form of a gigantic mountain chain, but appear less vast from the north.

Thus the southern chain, asymmetrical structurally, possesses a profile opposed to that of the northern chain, along which the northern slope, bordering the Dzungarian plain, is the more strongly developed.

The closer one approaches the Khantengriyskiy mountain knot, the more the longitudinal intermountain valleys lying north of the Kokshaal-Tau and Khalyktau narrow, whereas their altitude increases, as a result of which the southern chain joins the Terskey-Alatau and Narat ranges which already belong to the interior zone of the Tien Shan.

For almost their whole length the Kokshaal-Tau and Khalyktau ranges possess an alpine relief with a characteristic combination of sharp ridges and peaks, strongly incised rocky slopes, and deep valleys with glaciers in their upper reaches. In many places the Kokshaal-Tau and Khalyktau ranges are cut by lateral terraces, deep mountain passes, river valleys, and even continuous gorges. Especially large lateral gaps are found on the boundary between the Khantengriyskiy mountain knot and the Kokshaal-Tau (the Sarykzhaz continuous gorge) and Khalyktau (the valley of the Muzart River with the deep mountain pass of the same name).

To the east the southern chain of the Tien Shan descends now gradually, now in terraces, while the prominence in its relief of rocky forms diminishes and glaciers and large accumulations of firm disappear. At the same time, the trend of the range changes from northeastern to latitudinal; and still farther on, to southeastern. The latter trend begins at the headwaters of the Kucha River where the range is cut by diagonal faults. The southeastern spur of the southern chain is the Kokteketau range which does not reach the zone of perpetual snows. It has a broad plateau-shaped watershed and weakly incised slopes. Towards the Bagrashkul'skiy basin the Kokteketau becomes a small barren ridge

bluntly cutting off in one of the transverse faults. East of the Bagrashkul'skiy basin, on the continuation of the eastern chain of the Tien Shan, lies the Gashunskaya Gobi--a region with a special type of relief and structure.

Interior zone of the Tien Shan. Between the northern and southern chains of the Tien Shan there is a vast region of interior ranges and basins, broad in the Iliyskiy basin and along the boundary of the Gashunskaya Gobi and suddenly narrowing in the region of the headwaters of the Khaydyk-Gol River. The major positive relief forms of this zone are the Ketmen', Avral, Narat, Saarmin, Tashkar Tagh, Chol Tagh and other ranges; negative forms, the Iliyskiy, Kashskiy, Kungesskiy, Tekesskiy, Turfan-Khamiyskiy, Kumyshtalinskiy, and Bagrashkul'skiy basins.

The ranges of the interior zone of the Tien Shan are comparatively small; their altitude usually does not exceed 3,500 m. In the Iliyskiy basin the largest of them is the Narat range, which borders on the southern chain and which, like it, has a northeasterly trend. It begins in the Khantengriyskiy mountain knot and ends along the sources of the Kunges River. The orographic axis of the Narat range is displaced towards the Agiyaza and Koksu basins, which are higher than the valleys of the Tekes, Dzhargelan, and Tsanma, bordering it on the northwest. Thus its southeastern slope is shorter and lower than the northwestern. Despite the considerable absolute altitude of the Narat (individual summits reach to 4,000 m), sharp rocky forms are here comparatively rare.

Another range of the interior zone--the Ketmen'--lies equally distant from both chains of the Tien Shan, so that their influence is not experienced. The Ketmen' range is situated between the Tekesskiy and Iliyskiy basins and, like them, extends in a latitudinal direction. The northern slope of the Ketmen' range, linked to the deeper Iliyskiy basin, is higher and longer than the southern, which borders the valley of the Tekes. This range has its maximum altitude on the border between the USSR and CPR [Chinese People's Republic], while to the east it descends and narrows. Lacking high elevations, the watershed of the Ketmen' range is broad and gently undulating, and its slopes are steep and denuded to a considerable degree.

The Avral range borders the northern chain, thus having the latter's characteristic northeastern trend. It arises along the division of the Iliyskiy plain into the Kashskiy and Kungesskiy depressions and extends to the Irenkhabigranskiy mountain knot, gradually rising and broadening. Its relief is complex.

In the section of the interior zone of the Tien Shan situated east of the sources of the Khaydyk-Gol River, the most important range is that known in various of its segments under the names Tashkar Tagh, Bortoul, and Chol Tagh. This range arises on the boundary of the high-mountain plain of the Malyy Yuldus and extends southeast to the interior districts of the Gashunskaya Gobi. On its western segment (Tashkar Tagh) it is crowned by a rocky crest with summits up to 4,200 m. On the boundary of the middle segment, called the Bortoul, the range forms a

transverse bench along which it drops sharply, and changing its morphological features. The Bortoul range and its continuation beyond the Agyrbulak pass, the Chol Tagh range, constitute an asymmetric arch with a long and high northeastern slope descending towards the Turfan basin, the surface of which lies at or below sea level, and a short and narrow southwestern slope facing the Kyumyshtal basin (whose altitude is not much above 700 m). The character of the erosive dissection of the slopes of the Cholta range is varied. Its northeastern slope is incised by deep gorges and has many sharp peaks, while the southwestern slope consists of a series of conical hills of medium height separated by broad and shallow clefts. Approaching the Gashunskaya Gobi, the range gradually descends in altitude from 3,500 to 2,900 m in the Bortoul range and from 2,900 to 1,300 in the Chol Tagh. Within the boundaries of the Gashunskaya Gobi the range is cut by lateral terraces which descend to the level of the surrounding terrain.

The Saarmin range arises between the high-mountain plain of the Malyy Yuldus and the valley of the Khadyk-Gol River. Its trend is latitudinal, with altitudes to 4,500 m. In front of the Bagrashkul'skiy basin the range forms a transverse terrace and descends steeply; from a high snowy crest it is transformed into a medium-sized barren ridge joining the southern slope of the Tashkar Tagh. On the east a continuation of this ridge is formed by the rocky mountain blocks of the Ala Tagh and Kyzylt Tagh, which extend to the Gashunskaya Gobi. And although in the Gashunskaya Gobi, on a continuation of the ranges of the interior zone of the Tien Shan, there are still elevations supposedly connected with these ranges, these elevations are actually of another orographic series not possessing the linear development characteristic of the Tien Shan and constituting, together with the Pei Shan, a broad flat uplift rendered complex by block forms.

Intermountain basins occupy a large area in the interior zone of the Tien Shan. Particularly prominent in the west of the Tien Shan is the Iliyskiy basin, the width of which on the USSR-China border is about 120 km. Thence to the east it narrows into a wedge shape and its floor gradually drops. On the 82nd meridian the Iliyskiy basin divides into two parts: the Kashskiy and Kungesskiy, each up to 20 km wide. But even in the branches the surface continues to rise towards the east, and in the area of the Ili and Khaydyk-Gol watershed its altitude is about 2,060 m.

Along its continuation eastward in the tectonic valleys of the Djirgalan and Tsang-ma, the Tekesskiy basin constitutes another large zone of relative submergence, separated from the Iliyskiy basin by the Ketmen' range. The floor of this basin descends from south to north and from the margins towards the center, where the Tekes River cuts through the Ketmen' range, which is considerably reduced in altitude there. Inclined to the north also are the floors of the tectonic valleys of the Agiyaza and Koksu, which are transformed in the east into the high-mountain basins of the Bol'shoy and Malyy Yuldus rivers.

Situated in the eastern part of the Tien Shan is the very large Turfan-Khamiyskiy basins bordered by the Bogdo Shan and Karlyk Tagh ranges in the north and the Chol Tagh range in the south. Its length is about 600 km; its width, 70-80 km. In the west the basin rises steeply and is transformed into a gently undulating mountain plateau; in the east it narrows, descends to 1,400 m, and is divided into several branches which extend in the direction of the Edzin-Gol lakes. A flat transverse uplift with the sandy massifs of the Kum Tagh divides the basin into two parts: the Turfan and Khamiyskiy. The former is the most downwarped part of the basin. It consists of three major elements: the Chi-chang declivity, the Ass lowland, and the Tuztag ridge which separates them. The Chi-chang declivity occupies the northern part of the basin bordering the Bogdo Shan range. It is a plain gently inclined to the south and up to 30 km wide. The elevation of the declivity varies from 1,300-1,000 m near the Bogdo Shan to 200 m in front of the Tzy Tagh ridge. It is entirely covered by a thick, coarse alluvial deposit furrowed by dry channels and constitutes a stony desert.

On the southern border of the Chi-chang declivity there is a chain of elevations of which the most important is the Tuz Tagh ridge which rises 500-800 m over the surrounding terrain. These elevations extend with small breaks for 200 km. As a result of the different elevations of the plains which border them, their profiles are asymmetric. For example, along the Tuz Tagh ridge, the piedmont of the northern slope, which faces the Chi-chang declivity, is 200-300 m higher than that of the southern slope which descends to the Ass lowland.

The Ass lowland occupies the southern part of the Turfan basin. This plain, which lies below sea level, is gently inclined towards the Chol Tagh. Situated in its lowest part (-154 m) is the Bodzhanteshor solonchak [salt marsh] with transitory lakes.

Fig. 9. Sands of the Kum Tagh in the Turfan-Khamiyskiy basin. Aerial view.

The Kum Tagh vault, which separates the Turfan and Khamiyskiy parts of the basin, is covered with barkhan sands (Fig. 9). Over the Ass lowland it rises to 600 m, but over the T'an-chuang basin bordering it in the east its elevation is only 200-300 m. It is separated from the Chol Tagh and Tuz Tagh by longitudinal tectonic valleys several kilometers in width.

The Khamiyskiy part of the basin also represent an inclined plain descending from 1,700 m along the foothills of the Karlyk Tagh to 300-800 m on the border of the heights of the Gashunskaya Gobi. The Khamiyskiy plain descends gradually with terraces up to 60 m in elevation. Flat transverse submergencies divide its most downwarped part into three landlocked basins: T'an-chuang, Shonanorskiy, Kokchal'skiy. The area of the largest of these, the Shonanorskiy (250-m contour lines) exceeds 600 km^2. Toward it flow the waters from the southern slope of the Karlyk Tagh and the northern ridges of the Pei Shan. The center of these flows is Lake Shonanor (T gkul'), which lies at an altitude of 81 m. On the flat heights of the Khamiyskiy plain are frequently found residual forms of wind-eroded relief, one of the series of which has been described by P. K. Kozlov under the name of the aeolian city of Sulgassar.

Fig. 10. Solonchak scrub in the intermountain Kumysh-tal depression. (Photograph by E. Norin.)

The northern edge of the Turfan-Khamiyskiy basin, formed by the Pei Shan and Karlyk Tagh ranges, consists of high, rectilinear mountain slopes of tectonic origin. The southern edge, a slope of the gently vaulted upheaval of the Gashunskaya Gobi, merges gradually with the basin floor.

Between the ranges of the interior zone of the Tien Shan, the Chol Tagh and the Kyzyl Tagh lies the Kumyshtal basin, whose middle part is 25 km wide and whose floor has an elevation of 600-800 m. The margin of the basin is covered with a stony prolluvial deposit, while its center is occupied by solonchaks (Fig. 10). In the zone of northeast faults which borders the Chol Tagh the Kumyshtalinskiy basin also terminates.

Still farther south is found the Bagrashkul'skiy basin, which is bordered in the north by the Tashkar Tagh, Saarmin, and Kyzyl Tagh mountains, and in the south by the Karatekenul range. The length of the basin is about 250 km, its maximum width 60 km, its minimum elevation 1,030 m. Its deepest central part is occupied by Lake Bagrashkul', the largest fresh-water lake in Central Asia. In the west the basin becomes the tectonic valley of the Khaydyk-Gol River, through which it is joined to the high-mountain basin of the Bol'shoy Yuldus. In the east it becomes a gently undulating plateau with an altitude of 1,360-1,500 m.

Fig. 11. Peneplains of the Eastern Tien Shan (photograph by E. Norin).

In the narrowest part of the Tien Shan, between the depressions of the western and eastern groups, are situated the high-mountain troughs of the Bol'shoy and Malyy Yuldus. The first lies at the junction of the tectonic valleys of the Koksu and Khaydyk-Gol; and second, in the general area of the Turfan-Khamiyskiy and Kungesskiy basins. The altitude of the Malyy Yuldus is 2,450-2,700 m, that of the Bol'shoy Yuldus 100-150 m less. The Yuldus troughs are surrounded by high snow-covered mountains and are well watered by the sources of the Khaydyk-Gol River. Their surface is covered by broad meadows and swamps with a rich grass vegetation.

Characteristic for the Tien Shan system as a whole is the wide distribution of plateau surfaces and rectilinear benches which are particularly well preserved in the ranges which lie near the deserts of the Gashunskaya Gobi and Takla-Makan and in which erosion is thus slight (Fig. 11, 12). Complex dissection of the alpine type is observed only in the mountain knots and in the ranges of the northern and southern chains which rise beyond the snow line. These high-mountain sections of the Tien Shan are possibly its most ancient elements, uplifted over the peneplain even before the dislocation.

Climate, Glaciation, and Irrigation

The climate of the Tien Shan depends to a considerable degree on its orography. The divergence of the high ranges of the northern and southern chains towards the west, their later junction along the headwaters of the Khaydyk-Gol River, the successive descent towards the Gashunskaya Gobi--all this favors the penetration into the Iliyskiy basin of moist air masses moving in from the west, and, on the other hand, blocks the movement into them from the east of dry winds off the Central Asiatic deserts. This is a contributing factor to the moderate climate, not characteristic of Central Asia, in the Iliyskiy basin and on the high-mountain plains of the Yuldus rivers. About 400-450 m of precipitation fall annually in this region.

The territory of the Eastern Tien Shan lies on the exterior side of a triangle formed by the convergent snowy ranges of the northern and southern chains. It is thus affected by the hot, dry winds of the Takla-Makan and Gobi deserts and receives not more than 200 m of precipitation a year.

Moreover, the northern chain of the Tien Shan serves as an important climatic boundary between the moister and relatively cool Dzungaria, exposted to the climatic influence of Siberia, and the drier and hotter Kashgariya, which belongs to the Turkestan climatic province. Thus the northern slope of this chain, which faces Dzungaria, has more precipitation and running waters than its southern slope or the mountains which lie still farther south. On the Dzungarian slope of the northern chain, the vertical zonality of the landscape and vegetation is clearly evident. Along its foothills stretch deserts which, as they approach the mountains, aare replaced by steppes. The middle slope is covered by permanent meadows and forests; higher there are alpine meadows, and still higher the bare rocky crests of a watershed. In the southern ranges, which are exposed to hot, dry desert winds, a vertical zonality is less distinct, in part virtually disappears in a more or less monotonous desert.

In conformity with this climatic differentiation of the Eastern Tien Shan, the altitude of the snow line and the lower boundary of the descent of glaciers on its territory are not constant. They are highest in the region of the Suluterekskiy massif, in which, according to preliminary investigations, the snowline lies at an altitude of 4,800-4,900 m and the lower boundary of present-day glaciation at 4,100-4,200 m. From here they descend to the west, north, and east. In the Mayden Tagh which reaches an altitude of 4,300 m, there are now no glaciers or perpetual snows, but ancient glaciers occupied the upper reaches of all troughs lying above 3,500 m in the western part of the range and those above 3,200 m in the eastern. In the Kokshaal-Tau the snowline descends to 3,700-4,000 m, the present-day glaciers to 3,300-3,500 m, whereas the level of ancient

glaciers was 2,700-2,900 m. The snowline and the boundaries of ancient and recent glaciation lie at about the same altitude in the Narat and Barokhoro ranges. However, approaching Lake Issyk-Kul', they descend still farther: the snowline to 3,500 m, the boundary of recent glaciation to 3,000 m, and that of ancient glaciation to 2,400-2,500 m.

In the southern chain of the Tien Shan about 200 glaciers have been counted, many of which have lengths of 10-12 km--a few even 30-35 km. In the northern chain, where there are fewer summits lying above the snowline, there is less glaciation. Here the total number of glaciers does not amount to even 100, and the length of the largest of them does not exceed 12 km.

Deeper into the interior of the Tien Shan, in the semiarid areas of the Gobi, the snowline and glaciation boundaries rise sharply. In the eastern part of the Khalyktau and in the Tashkar Tagh the snowline runs at an altitude of 4,300 m, while the relief forms created by ancient glaciation descend to 3,200 m. On the northern slope of the Bogdo Shan and Karlyk Tagh ranges the snowline lies at an altitude of 3,700-3,800 m, the boundary of recent glaciation at 3,200 m, and that of ancient glaciers at 2,000-2,100 m.

Just as the distribution of precipitation in the ranges of the Tien Shan depends on their location, so in turn do the degree of the watering of its individual territories and the character of the hydrographic system depend on the precipitation. Best watered in the Eastern Tien Shan are the Iliyskiy basin and the high-mountain plains of the Yuldus rivers, which are exposed to the currents of moist air masses and thus receive the heaviest precipitation. Within the Iliyskiy basin are found the largest rivers of the Eastern Tien Shan: the Tekes, Kunges, and Kash which unite to form the abundant waters of the Ili River. The Khaydyk-Gol, whose waters flow into the arid regions of Central Asia and feed two large lakes, the Bagrashkul' and Lop Nor, begins on the high-altitude uplands of the Bol'shoy and Malyy Yuldus which also belong to the better-watered western province. In the Bagrashkul' basin the Khaydyk-Gol has a small tributary, whereas on the Tarim plain its continuation--the Konchedar'ya River--is entirely without tributaries.

Among the best-watered regions is also the Dzungarian slope of the northern chain. However, the remaining parts of the mountain system, lower or bounded by deserts, have few and short streams or none at all.

The largest and deepest rivers flow through the broad tectonic troughs of the interior zone of the Tien Shan in a latitudinal direction, partly westward towards Lake Balkhash, partly eastward into the landlocked intermountain basins. Their sources lie in the Irenkhabirgansky and Khantengriyskiy knots, towards which the floors of the tectonic depressions rise. Of the rivers which flow along the gradient of the slopes, only a few are large streams, in particular the Manas, Khotubi, Dzhergalan, and Muzart. All these flow on the slopes of the highest parts of the northern and southern chains of the Tien Shan where, covered with permanent snow, are located the main groups of summits.

The rivers of the Eastern Tien Shan are fed by the glaciers and snows of the high-altitude zone; they thus flood in July and August, when there is rapid thawing of the snows in the mountains.

In a hydrographic sense the territory of the Eastern Tien Shan is divided into four large landlocked basins: the Tarim, embracing the ranges of the southern chain; the Balkhash, in which is found all the territory watered by the Ili River; the Dzungarian, which includes the northern slope of the northern chain; and the Turfan-Khamiyskiy, within which lie the eastern spurs of the ranges of the interior zone and the southern slope of the Bogdo Shan and Karlyk Tagh ranges.

The relative significance in the individual basins of the Eastern Tien Shan of various erosion factors varies in accordance with the amount of precipitation which they receive. In the high-altitude zone, especially in the western part, which receives the heaviest precipitation, glacial processes play the leading role in the dissection of the relief; while below the snowline fluvial erosion is of major importance. In the east, where the mountains are lower and running streams are fewer, fluvial erosion is weaker and is here accompanied by weathering as a significant denuding factor.

Flora and Fauna

The phytogeography of the Eastern Tien Shan reflects in its major traits the climatic zonality of this area--both regionally and altitudewise.

Vegetation is most developed in the Iliyskiy basin and in the Yulduses, which are distinguished by a moderate climate. It is less dense and varied on the Dzungarian slope of the northern chain and very insignificant on the Tarim slope of the southern chain and on the eastern spurs of all the Tien Shan ranges exposed to the scorching winds of the desert.

Tree growth in the Eastern Tien Shan is of both the coniferous and leafy types. Particularly widespread among the first group is the Tien Shan spruce which forms in the mountains of the Iliyskiy basin and on the Dzungarian slope of the northern chain large forests at altitudes of 1,300 to 2,500 m. Just as widely distributed is the larch, which borders the Tien Shan spruce in the dry parts of the forest zone and replaces it in the east. Forests of spruce and larch as a rule do not form large, dense stands but instead are separated into individual forest belts lying along the northern slopes, which are better shaded and watered than the southern. To the east the zone of coniferous trees gradually narrows and becomes still more broken, while its lower border rises to 1,500 m and its upper to 2,900 m. The zone of coniferous forests generally does not extend east of the Karlyk Tagh range.

Leafy trees do not form large forests in the Eastern Tien Shan. In the west and north of this region they are represented by two complexes--"tugay" and mid-altitude. The major representative of the tugay complex is Populis diversifolia (tograk), which forms dense stands in the river valleys, along the channels and on the lower terraces. A noticeable role

in this complex is played also by the wild apple tree, the greengage plum tree (Crataegus monogyna), and the mountain ash (Sorbus aucuparia). Willow shrub, dog rose (Rosa canina), barberry (Berberis vulgaris), and several other species form bushy undergrowth.

The mid-altitude complex of tree growth is also concentrated in the river valleys, not along the channels or lower terraces but rather on the upper terraces and bordering slopes. In this complex are found the stunted Tien Shan birch (Betula), common poplar (Populus), and aspen (Populus tremula). The mid-altitude complex is distributed only in the northwestern regions and is lacking in the rest of the Eastern Tien Shan. Grassy and underbush vegetation are richly represented in the steppe zone and in the zone of alpine meadows.

The alpine-meadow zone coincides approximately with the zone of the distribution of ancient glacial landscapes. It begins in the coniferous-forest zone, ascending to 2,000-3,200 m. Broad alpine meadows with luxurious vegetation are found in the mountains of the Iliyskiy basin, in the basins of the Yulduses, and also on the Dzungarian slope of the northern chain. In the eastern spurs of the latter and in the ranges of the southern chain the alpine-meadow zone narrows sharply and is located at a higher level. Here the vegetation is sparser and poorer. Still closer to the desert zone, alpine vegetation discontinues and stunted forms begin to appear.

The steppe zone, like the alpine, does not occupy a definite altitude range; it descends and widens to the west, rising, and at the same time narrowing, to the east. In the Iliyskiy basin it covers the entire lower slope of the mountains and peripheral areas of the intermountain basins. On the Dzungarian slope it runs along the lower slope of the mountains, but on the eastern spurs and the Tarim slope it is cut off by the desert in the complex-mountain area. "Polynnyye," "kiptsovyye," and feather-grass species represent the dominant form of vegetation among the steppes of the Eastern Tien Shan.

The zoogeography of the Eastern Tien Shan is also defined by climatic and geobotanical zonality. Situated in the alpine-meadow zone, closer to the rocky peaks, is the habitat of the mountain goat, the "teke"; and somewhat lower, that of the mountain sheep. Among the carnivores, snow panthers are found here. The characteristic bird species is the pheasant (phasianid). Deer and bear live in the forest zone. On the steppes there are many gazelles (Gazella subgutturosa), wolves, foxes and rabbits. Roaming in the tugay forests and also in the reed beds along the rivers and lakes of the Iliyskiy basin and the Khaydyk-Gol River are wild boars. In the dry mid-altitude area there are stone partridges; along the rivers and lakes, ducks and geese; and in the drier parts of the valleys, pheasants.

Geological Structure

The geological structure of the Eastern Tien Shan is characterized by a linear development and sharply defined zones. The region of the interior ranges and basins of the Eastern Tien Shan represents part of the pre-Caledonian shell of this mountain system; and the northern and southern chain of ranges situated on its flanks, Caledonian geosyncline-fold formations. The boundary ranges lying on the exterior sides of the northern and southern chains are Hercynian formations, while the piedmont ridges rising on the edges of the Dzungarian and Tarim plains were created by alpine movements.

Interior zone of the Eastern Tien Shan. This zone constitutes a continuation of the Caledonian uplift, embracing within the territory of the Soviet Union the ranges of the Terske- and Kungey-Alatay, the Trans-Iliyskiy Alatay, and the Ketmen', and also a considerable part of the Iliyskiy basins. Approaching the sources of the Khaydyk-Gol River, the interior zone narrows into a wedge shape, diminishing in width from 200 km to 30 km. Past this watershed it again widens, attaining a width of 70 km on the Gashunskaya Gobi boundary.

In the Lower Paleozoic the zones of the northern and southern chains were submerged, and sedimentation processes operated actively within them. The interior zone, on the other hand, was an uplift which had been subjected to erosion.

In the Lower Devonian the geosynclinal downwarpings of the northern and southern zones, which are filled with strata of the Ordovician and Silurian, warped into folds and later uplifted into a zone of erosion. At this time the interior zone sank, and over it advanced the sea, whose transgressions reached a maximum in the Visean stage. In the Upper Carboniferous and Permian local uplifting intensified, and sedimentary accumulation continued only within the relatively small area in the region of the modern Avral range and in the western part of the Turfan-Khamiyskiy basin.

Separate parts of the interior zone sank also in the Mesozoic and Cenozoic. This was particularly intensive in the Iliyskiy and Turfan-Khamiyskiy basins which even now lie at a low hypsometric level.

Despite the repeated subsidence of individual parts of the interior zone, the Pre-Cambrian metamorphic base within its limits is comparatively shallow and is sometimes exposed on the surface.

The largest outcroppings of metamorphic rocks of the Pre-Cambrian are found on the boundary of the southern zone of the Caledonian, in the region of the Ili-and Khaydyk-Gol watershed, and in the Chol Tagh range (Map 37) [not included]. Among them two complexes can be distinguished according to composition and degree of metamorphosis: a gneiss-schist, probably Archean, and a quartzite-marble-phyllite, probably belonging to the Proterozoic. The first is composed of quartzbiotite schists: and paragneisses containing sillimanite, granite, cordierite, and other minerals of the deep metamorphic zone. Considerably less frequent in this

complex are amphibolites, marbles, quartzites, as well as granite orthogneisses. The quartzite-marble-phyllite complex is much more widely distributed. In the lower part it is composed of mica schists and mica quartzites; in the upper, of quartz sericite and quartzchlorite phyllites with blocks of marble.

In the interior zone of the Eastern Tien Shan the Paleozoic is represented by the Upper Devonian, and also by the Visean in places lying directly on metamorphic rocks of the Pre-Cambrian. The main regions of the distribution of Paleozoic deposits (Epi-Caledonian depressions) are the Iliyskiy basin and the region adjoining the Turfan-Khamiyskiy basin.

Laid down in the Iliyskiy basin on a foundation of Paleozoic rocks was an effusive-tuffaceous stratum of the Upper Devonian-Tournaisian (D_3 / C_1^t) composed of quartz porphyrites and felsites with dacite and andesite porphyrites, variegated tuffs, and also siliceous schists and siltstones, tufogenic graywacke and polymignite sandstones, and calcareous-argillaceous schists with lenses of limestones. The thickness of the beds varies from 2,000 m to 3,500 m. In the seams of schists and limestones various species of Retzia have been discovered.

The effusive-tuffaceous stratum of the Upper Devonian, the Tournaisian, occurs unconformably on the Pre-Cambrian metamorphic foundation, both along the boundary of the northern zone and on the Lower Paleozoic. Higher there follows a straum of the Visean and bases of the Middle Carboniferous (C_2^1-C_1^1), composed of various sandstones, schists, conglomerates, and, to a lesser degree, limestones, tuffs, and lavas. The sandstones and conglomerates of this stratum are polymignites, partly tufogenic; the schists are siliceous-argillaceous and calcareous-argillaceous. Sometimes found are rather thick limestone blocks with many fossils of spiriferids, productids, and corals. Lavas and tuffs form thick blocks in places; their composition varies from felsite and quartz porphyry to pyroxene porphyry. The beds are 1,000-2,000 m thick. In the Iliyskiy basin this stratum occurs unconformably on deposits of the Upper Devonian and Tournaisian, and in the eastern regions it transgresses on the metamorphic complex of the Pre-Cambrian.

Deposits of the upper part of the middle and lower stages of the Upper Carboniferous (C_2^2 / C_3^1) are represented in the Iliyskiy basin by a sandstone-schist series; and in regions east of the basins of the Yulduses, by a series of calcareous-argillaceous schists and stratified limestones.

Still higher there is a volcanic-sedimentary layer of the Upper Carboniferous and Lower Permian (C_3^3 / P) composed of neutral and acid lavas, tuffs and tuff-conglomerates of siliceous siltstones and schists, graywackes, polymignite sandstones and schists with layers of limestones containing brachiopods, corals, and foraminifers. The stratum is up to 1,500 m in thickness. Usually it lies on deposits of the Middle Carboniferous, sometimes even on older rocks.

In the Avral range and in the Turfan basin outcroppings of Upper Permian deposits are known composed of conglomerates, sandstones, and argillites. Conglomerates and coarse sandstones occur primarily in the lower level of the stratum, fine-grained sandstones and argillites occurring in the upper level. Floral remains are found in the argillites.

The lithological composition of the Epi-Caledonian complex of the interior zone of the Tien Shan is highly variegated and diverse. An important role is played by lavas, tuffs, and also by conglomerates. Characteristic are frequent and sharp changes in the thicknesses of, and local unconformities between, individual strata; some unconformities appear regionally. All this is evidence of the intensity of tectonic movements in the interior zone in the Paleozoic and the complex structure of its relief. The relief of the interior zone was most differentiated in the Upper Devonian and Tournaisian, and also in the Upper Carboniferous and Permian, the deposits of which reveal an especially complex picture of facies changes and a high concentration of volcanic rocks. The beds of this age did not accumulate over the entire territory of the zone, but in separate depressions often considerable in dimension.

In the Visean and the beginning of the Middle Carboniferous, the surface of the interior zone was relatively level, which explains the broad range of the deposits of this age, the relative uniformity of their composition, the predominance of thin-fragmental rocks, and the minimal content of volcanic products.

Basic elements of the structure of the Paleozoic strata of the interior zone of the Tien Shan are groups of large anticlinal and synclinal folds, several tens of kilometers in length and 3-8 km wide. These folds were reflected in the Paleozoic relief in the form of local uplifts and submergences and influenced the facies zonality of the deposits. The Paleozoic is more fully represented in the synclinal folds, and here there is a larger content of fine-grained rocks; whereas in the anticlinal folds deposits of coarse composition predominate and local degradations and unconformities are observable.

Moreover, the Paleozoic strata form a smaller series of folds associated with the nonuniformity of the structure of the large folds.

In general the fold structure of the Paleozoic strata of the interior zone is relatively simple. Its individual elements have large dimensions and moderately steep walls. The only exceptions are parts which butt onto large faults where the layers lie very steeply, rendered complex by minor folding, and are even subjected to shearing.

In the Mesozoic and Cenozoic the Iliyskiy, Kungesskiy Tekesskiy, Turfan-Khamiyskiy, and Bagrashkul'skiy basins, constituting the greatest part of the territory of the interior zone, sank. Within them the Mesozoic-Cenozoic profile usually begins with red conglomerates and sandstones of the Triassic up to 350 m thick. Above follow Jurassic deposits, usually divided into two formations: productive and variegated. Both are conglomerate-sand-argillite, but the deposits of the first are mainly gray-green and contain coal, while the deposits of the second are primarily red.

Fig. 13. Valley of Demons. Aerial view. The dark strip is an outcropping of red strata of the Cretaceous and Upper Jurassic in an easterly continuation of the Chiktymskiy monocline. The light-colored strips are dry channels (sayry). (Photography by A. A. Shneyder.)

In the productive series there are vegetation imprints which are evidence that they belong to the Lower and Upper divisions of the Jurassic system. In the variegated series of the Turfan-Khamiyskiy basin there is a thin layer of lake limestone with shells of the mollusk "Ferganokonkha," characteristic of layers in the transitional stage from the Middle to the Upper Jurassic. The over-all thickness of the Jurassic deposits in the basins of the interior zone varies from 600 to 1,500 m.

At the end of the Jurassic, the relatively small Kungesskiy and Tekesskiy basins experienced a change of the tectonic cycle and butted against the underlying parts of the Tien Shan. The Iliyskiy and Turfan-Khamiyskiy basins submerged also in the Cretaceous and Tertiary periods and continue to sink in the present day. In these basins the Cretaceous and Paleocene are represented by a red-colored series which occurs on the Jurassic deposits. In the Iliyskiy basin, which in the Cretaceous was the best-watered basin of the eastern group, the red series consists primarily of conglomerates and coarse sandstones; while in the Turfan-Khamiyskiy basin it is composed mainly of sandstones with a layer of anhydrite. The thickness of the red series varies from 400-500 m in the east to 1,000 m in the west.

The Neocene and the oldest deposits of the Quaternary system are represented by straw-colored sandy-clay and gray conglomerate series with a total thickness of 200-400 m.

In thickness of deposits of the Mesozoic and Cenozoic, the interior zone of the Tien Shan lags considerably behind the deposits of the same age in the piedmont downwarpings found on the Dzungarian and Tarim massifs. This is a result of the more intensive and prolonged submergence of the latter.

The Mesozoic-Cenozoic deposits of the basins of the interior zone have been gently dislocated. Each basin represents an enormous syncline with steep walls and a broad, flat floor within the ranges of which the layers are virtually undisturbed. Only in the Iliyskiy and Turfan-Khamiyskiy basins are internal dislocations to be observed: walls and monoclines connected with block displacements of the base.

Granites are widely distributed in the interior zone of the Tien Shan, forming large blocks among the ancient complexes and small bodies in the upper structural zone (Carboniferous). Most often encountered are young Hercynian light-gray biotite granites forming active contacts with the Carboniferous. Individual bodies are of Pre-Visean and even Pre-Upper Devonian age. Also found among the rocks of the metamorphic complex are small blocks of gneissoid granites which evidently formed before the onset of the Paleozoic era.

Northern zone of the Tien Shan. This zone is a Caledonian geosynclinal-folded prism, located between the ancient shell of the system (interior zone) and the Dzungarian massif.

In the Ordovician and Silurian, when the interior zone of the Tien Shan and the Dzungarian massif rose, the northern zone sank and sediments accumlated strongly within it. At the end of the Silurian, in the northern zone the strata of Ordovian and Silurian deposits were subjected to warping and metamorphization. From this time on, the northern zone, with the exception of individual boundary areas and regions of diagonal downwarpings, began to rise. This process was particularly intensive in the Middle and Upper Paleozoic, when large granite blocks developed in its Ordovician-Silurian strata.

Intensive upheavals are characteristic also of the most recent geological epoch, during which blocks of Caledonian geosynclinal prisms have formed high ranges.

The Ordovician deposits in the ranges of the northern chain of the Tien Shan form several outcroppings adapted to large anticlinal zones. They represent alternating layers of gray-green schists and fine-grained sandstones converted to phyllite to a considerable degree. Limestones and also coarse sandstone, in a form transitional to conglomerate, are found only in individual seams. Organic remains have been discovered only in the upper horizons conforming to the Upper Ordovician.

Silurian deposits are considerably more widespread than Ordovician and exceed them in total thickness. As a whole the Silurian of the northern chain is an enormous terrigenous stratum folded with calcareous-argillaceous and siliceous-argillaceous shales converted to phyllites and interbedded with quartz and graywacke sandstones. The lower level of the stratum contains many light limestones, sometimes marbelized and silicified. In places the content of limestones in the lower layers of the Silurian stratum is so great so that they separate into a distinct series. In the center of the Silurian stratum there are andesite and diabasic porphyrites and tuffs. In individual parts the concentration of vulcanic rocks is sufficiently great for them to separate into a distinct series.

In many places in the limestones and schists of the Silurian stratum the remains are found of fauna characteristic of the Llandoverian and Wenlock series.

The Ordovician and Silurian strata of the northern zone of the Tien Shan are strongly warped. They form small, steep folds complicated by numerous fractures. The prevailing dip of the layers of the bed to the south is evidence of the general incline of the whole folded system of the Caledonian of the northern zone towards the Dzungarian massif.

On the boundary of the interior zone the Caledonian layers of the northern zone are accompanied in places by piedmont downwarpings. One of these is found on the southern slope of the Borokhoro range where the Silurian shales and sandstones are conformably covered by a red sand-shale series up to 1,200 m thick, which in turn alternates with a still thicker

series composed of alternating sandstones and shales with blocks of acidic lavas and tuffs. The age of the red and volcanic-sedimentary series has not been established: provisionally it is assigned to the Upper Silurian-Devonian.

On the Dzungarian slope of the northern chain, the Silurian deposits are unconformably covered by marine beds of the Upper Paleozoic, while in the outcroppings in the mountain zone basal layers of the Upper Paleozoic complex belong to the Middle Carboniferous, and those in the outcroppings of the foothills zone to the Visean. The Visean deposits consist of siltstones, sandstones, and siliceous-clayey and limestone-clayey shales, the latter with limestone blocks containing many brachiopod and coral fossils (1,000 m). The Middle Carboniferous deposits consist of limestones with blocks of shales and siltstones; and, higher, sandstones and shales with single seams of limestones containing many faunal fossils. The Upper Carboniferous deposits consist of sandstone and shale in places, conglomerate, limestone, porphyrite, porphyry, and tuff. The thickness varies from very thin to 1,500 m. Lower Permian deposits are found in small areas and are composed of variegated conglomerate with pebble effusive rock, blocks of gray sandstone, and dark argillites with limestone seams. In the argillites and sandstones there are imprints of crossopterygian and ganoid fishes; in the limestones those of pelecypods. Other sandstone seams contain many plant imprints.

The facies composition of the Upper Paleozoic deposits of the Dzungarian slope of the northern chain fluctuates. It changes expecially in the direction of the trend of the mountain system. For example, eastward the content of volcanic and continental formations increases while marine formations disappear almost completely.

In Hercynian structure the northern chain represents a large asymmetric anticlinorium whose core is composed of a Caledonian geosyncline - fold complex exposed on the surface in the high-altitude zone; and whose sides are composed of blocks of Middle and Upper Paleozoic deposts constituting the slopes of the ranges on the boundary of the interior zone and the Dzungarian plain. In the northern side the Hercynian sedimentary complex is of increased thickness and is represented primarily by marine facies; it is steeply folded and often tilted toward the north.

In the region of the southern side of the anticlinorium which butts onto the interior zone, the Hercynian complex is thinner and contains many volcanic rocks and continental depots. The forms of folding here are rather simple.

Granite is distributed unevenly in the northern zone of the Tien Shan It forms large bodies in the eastern Borokhoro range, the Karlyk Tagh, and the Gobi Tien Shan but is completely lacking in the Uken and Bogdo Shan ranges. The granite blocks of the northern zone are divided into two groups according toage: the old Hercynian, which form active contacts with the Devonian but are covered by transgression of the Visean,

and the young Hercynian, which metamorphose the Paleozoic rocks of this zone up to and including the Upper Carboniferous. Young Hercynian granites predominate, while the old Hercynian form only individual blocks. Both groups consist of light gray biotites and, less often, biotite-hornblende schist varieties.

Southern zone of the Tien Shan. This zone is divided by the tectonic trough of the Taushkandar'ya into two differently structured branches: the eastern (Khalyktau and Kokshaal-Tau ranges) and the western (Maydan Tagh, Koktun, and Uchchat ranges).

Eastern branch. This is a Paleozoic geosynecline-fold region resembling the northern zone in its geological history. Its lower structural series is formed by thick Ordovician and Silurian strata exposed in the high-altitude zone. The Ordovician usually begins with arkosic sandstones which lie on metamorphic rocks and ancient granites. Higher follow alternating layers of clayey and limestone shales, siltstones, sandstones, and also limestones which sometimes form thick blocks. Remnants of fauna are not found in these deposits, but their stratigraphic position between the metamorphic complex and the Silurian makes it possible to assign them to the Ordovician.

Silurian deposits are considerably more widely distributed than the Ordovician. They are represented in the Aksuyskiy uplift by metamorphosed limestones interbedded with mica-carbonate schists, and to the west and east of this uplift by a sand-shale layer with rare limestone blocks. In some places in the Silurian stratum there are greenstone rocks which formed from spilites and basic tuffs. In regions with greenstone series various siliceous rocks occur in large quantities. The general thickness of the Silurian stratum, according to a preliminary estimate, amounts to 2,000-3,000 m. In the limestones of the sandy-shale stratum there have been found corals and brachiopods from the Silurian and the Lower Devonian.

Within the main territory of the southern chain the Silurian and Ordovician occur conformably, constituting a single sedimentary complex, but on the boundary of the interior zone, within the limits of the Aksuyskiy uplift, and on the eastern extremity of the chain, the Silurian lies unconformably, usually accompanied by arkosic sandstones and also conglomerates.

The complex of deposits of the Ordovician and Silurian of the southern chain of the Tien Shan has formed into strongly compressed folds with some displacement of the mass towards the interior zone and with distinct tilting of the folds and thrusts towards the Tarim massif. The angular unconformity of this complex with the deposits of the Middle and Upper Devonian shows the Caledonian age of its folding.

The Hercynian structural core in the southern zone of the Tien Shan developed on the boundary of the eastern zone (Khaydyk-Gol subzone) and the Tarim massif. In the first of these it is represented by the Devonian and in the second by the Carboniferous and Permian. Along the eastern extremity of the southern chain these two disconnected zones are joined.

In the Khaydyk-Gol subzone the Hercynian complex is composed of two thick strata connected by transitional layers: the lower by sand-shale, and the upper by limestone. The lower stratum consists of gray and gray-green clayey and sileceous schists, siltstones, and graywackes with separate mantles of spilites. Its age is thought to be Upper Silurian-Lower Devonian. The upper stratum is composed of gray silicified limestones in the upper part containing fossils of the fauna of the time, transitional from the Givetian stage to the Frasnian; in the upper part, from the Famennian. Along the headwaters of the Khaydik-Gol River the thickness of the Devonian limestones attains 1,500 m, but towards the southeast it diminishes to 500-300 m while among the limestones there appear blocks of red marls, sandstones, and conglomerates.

In the region of the eastern submergence of the southern chain (Koktepstau range) the Carboniferous transgresses on the limestones of the Devonian, beginning with basal conglomerates which higher are replaced by arkosic sandstones, and, still higher, by a thick sand-schist series with limestone seams containing fauna from the Upper Visean to the Upper Carboniferous. The Devonian and Carboniferous deposits occur comparatively undisturbed, forming broad, gentle folds. Only in the proximity of faultings do their strata become steep.

In the region of the Tarim flank there have developed thick sand-schist and limestone strata of the Carboniferous and Permian. The latter contain many volcanic formations and thick accumulations of conglomerates. Steep and asymmetric, the folds of these strata are complicated by thrust displacements in the direction of the Tarim plain.

In Hercynian structure the eastern branch of the southern chain of the Tien Shan represents a large anticlinorium with unequal limb development. In its core the Caledonian folded complex outcrops onto the surface and consists of sand-shale and limestones strata of the Ordovician and the Silurian, exposed in the high-altitude zone. The limbs were formed by the Hercynian complex, which is expressed in the Khaydyk-Gol subzone by a sand-shale stratum of the Silurian-Devonian and by a limestone stratum of the Middle and Upper Devonian; and in the region of the Tarim flank by geosynclinal strata of the Upper Paleozoic with a complex structure. Thus the orientation of the structural elements of the southern and northern zones of the Tien Shan, having developed asymmetrically, is reversed, which is the result of the movement of the blocks in different directions in the process of folding--toward the Dzungarian and Tarim massifs.

Granites in the eastern branch of the southern zone, just as in the northern zone, are represented by two groups of different ages: the ancient Hercynian, not already acted upon by deposits of the Visean, and the young Hercynian, metamorphosed by deposits of the Upper Paleozoic.

The granites of both groups, similar in composition, are represented primarily by block porphyritic biotite varieties frequently transitional to biotite-hornblende schist granodiorites. The area of the outcroppings of granites in the southern zone of the Tien Shan is not great; the major accumulations of granite bodies are found in the Khalyktau range.

Western arm. Between the Caledonians of the Southern Tien Shan and the Tarim massif lies a zone of Hercynian geosynclinal structures. The Hercynians are particularly developed in the Maydan Tagh and Muzduk ranges where they are divided into two structural facies subzones: the Maydan Tagh, which conforms to the downwarped section which butts against the ancient structures of the Tien Shan and which has undergone intensive submergence, and the Muzduk, the less mobile part bordering on the Tarim massif. In the first there developed a sand-shale complex of the Middle and Upper Carboniferous (thickness about 4,000 m), and in the second all the stratigraphic horizons of the Carboniferous from the Visean to the Lower Permian inclusive (total thickness, however, not more than 1,200 m). The boundary of these subzones is formed by a zone of large faults in which the sand-shale complex is replaced by a stratum of limestones.

The sand-shale complex of the Maydan Tagh is a polyfacies flysch formation. It is composed of fine- and medium-grained sandstones, siltstones, and shales. In the lower part of the complex, siltstones and shales predominate: in the upper, sandstones. A comparison of horizons of the Upper Paleozoic flysch from various parts of the Maydan Tagh shows the coarsening of the fragmental material of its deposits from south to north, culminating finally in the submergence of conglomerates along the northern boundary. Thus the uplift of the Central Tien Shan, bordering it in the north, served as the region of the feeding of the flysch trough of the Maydan Tagh. The limestone Muzduk complex is located on the southern spur of the slope of the submergence between the flysch trough and the Tarim massif. In the large synclinal structures it is underlain by limestones and conglomerates of the Lower Carboniferous and in the anticlinal structures it lies nonconformally on the sand-shale series of the Silurian-Devonian.

Corresponding to the Lower Carboniferous in the Muzduk subzone is a series of limestone conglomerates including beds of red sandstones (500 m), a series of dark-gray and black limestones interbedded with gray-yellow calcareous sandstones, (400 m), and a series of gray block limestones (350 m).

The Upper Paleozoic is represented almost exclusively by limestones: in the lower part by gray thin-bedded blocks, and in the middle and upper parts by white blocks. Throughout the whole horizon in the limestones are found the remains of brachiopods, corals, bryozoan, and foraminifers which permit dividing the Visean, Middle and Upper Carboniferous, and Lower Permian. The horizon of the Upper Paleozoic in the Muzduk subzone ends with a sand-shale series (300 m) containing plant remains of the Lower Permian.

On the boundary of the Tarim massif, limestones of the Muzduk type are replaced by a stratum of limestones, sandstones, and marls of the platform facies, the thickness of which, despite the large number of horizons (from the Visean to the Lower Permian inclusive), does not exceed 120 m. The Muzduk type of horizon of the Upper Paleozoic is replaced by a platform type in the narrow zone of faults serving as the northern boundary of the Tarim massif.

In the region of the Aksuyskiy uplift, the Upper Paleozoic downwarping narrows sharply and diminishes in depth. Therefore, approaching it, the Maydan Tagh flysch is replaced by limestones of the Muzduk type along the trend of the zone. On the other side of the Aksuyskiy uplift, in the Upper Paleozoic submergence, there again appear thick sand-shale and limestone strata of the Lower and Middle Carboniferous, and the thickness of the Upper Carboniferous and Permian deposits increases considerably. In the eastern part of the downwarping the Permian contains many volcanic rocks and conglomerates.

The most active zone of the Upper Paleozoic downwarping of the Southern Tien Shan, the Maydan Tagh flysch trough, experienced a reduction in the tectonic system earlier than the Muzduk zone, where sedimentary accumulation contined even in Lower Permian times. The sand-shale complex of the Maydan Tagh forms a system of small asymmetric folds dipping to the south. In the Muzduk subzone the limestones of the Paleozoic, together with the underlying deposits of the Lower Carboniferous, warped into large folds boxlike in form. Nearer to the Tarim massif, their folding becomes complex and steep asymmetric forms begin to predominate, dipping still more to the south.

A special position in the structure of the Southern Tien Shan is occupied by the Kashgarskiy knot in which are united the northeastern structures of the Alayskiy range, the southeastern Ferganskiy, and broad structures of the Kingtau, belonging to the Kunlun system. The center of the knot is the Sulutereksiy block, a broad ridge of the Pre-Cambrian base.

Forming a part of the Fergana zone of dislocation in this mountain knot are the Koktun Mountains situated on the eastern boundary of the Sulutereksiy block. Two zones can be distinguished in the structure of the Koktun Mountains: the Kercynian, which crops out in the form of small blocks, and the Yen-shang, of which these mountains are primarily formed.

The Hercynian zone consists of variegated sand-shale strata of the Silurian-Devonian, limestone-shale strata of the Middle and Upper Devonian, and an Upper Paleozoic series of limestones, shales and sandstones, which are also subdivided into several strata. These deposits are of great thickness and complexly warped. The trend of the Hercynian structures in the Koktun Mountains is northeasterly.

The Yen-shang zone in the Koktun Mountains is composed of a series of gray sandstones and siltstones with carbonaceous seams (100 m) and a series of red conglomerates (250 m), possibly Triassic; a series of gray conglomerates (500 m) and gray sandstones interbedded with siltstones and argillites (1,100 m) of the Lower and Middle Jurassic. The Triassic and Jurassic deposits form groups of large uneven folds whose axes are gently bent from 340° NW in the southern terrace of the mountains to 310° NW near the Soviet-Chinese border.

A decrease of tectonic movements in the Mesozoic depression of the Koktun Mountains evidently occurred in the Upper Jurassic deposits from which are not represented in the Yen-shang complex whereas the Cretaceous lies nonconformably on them.

To the Alayskiy structures belong the anticlinal mountains of Terektau and the synclinorium of the western Uchchat Mountains which lie on the western boundary of the Suluterekskiy block. The Terektauskiy anticlinorium is composed of a thick folded and warped sand-shale stratum of the Silurian, overlapped on the sides by limestones of the Middle Devonian and Lower Carboniferous. Within the limits of the western Uchchat synclinorium there have developed limestones and shales from all divisions of the Devonian and Lower Carboniferous, a thick sand-shale stratum of the Middle Carboniferous, and limestones of the Upper Carboniferous and Lower Permian. All these deposits of the synclinorium are strongly folded, particularly the sand-shale series.

In the Uchchat Mountains, in the trend of the structural elements of the Alayskiy zone there is a sigmoidal bend with successive alteration from 60° NE to 20° NE and again towards 60-70° NE. In the eastern part of the mountains, on the ancient peneplain, which has been broken into blocks, lie gently dislocated deposits of the Mesozoic represented by a series of conglomerates, sandstones, and argillites of the Middle Jurassic (130 m), gray-violent sandstones and conglomerates of the Upper Jurassic (130 m), and brown-red sandstones and conglomerates of the Lower Cretaceous (470 m).

The Suluterekskiy block, which is mantled by the folds of the Koktyn and Uchchat mountains, represents part of a large ancient uplift to which belong also the Kunlun blocks of the Muz Tagh and Kongur. The Suluterekskiy block was isolated from the Kunlun parts of the uplift in the Upper Paleozoic, when a broad downwarping originated in the region of the Kingtau range. Belonging to this block, besides the outcroppings of crystalline schists and gneisses in the headwaters of the Suluterek and Dumdzheylo rivers, are also the southeastern part of the Uchchat Mountains, composed of gently-dislocated quartzites and phyllites of the Upper Proterozoic, and the structural block in the group of Artushskiy folds formed by Tertiary strata and on which rests the broad, Kushuyko flat depression.

Igneous rocks are rarely found in the Hercynian folds of the Southern Tien Shan and are represented by small bodies. They divide into young Hercynian and alpine. To the former belong the thin blocks of alaskites and granite-porphyrites which are concentrated mainly in the central part of the Maydantag range. The latter types are represented by blanket deposits and dikes of teschenite, camptonite, Okasite, kersantite, monchiquite, shonkinite, and bekinkinite which lie in the Jurassic stratum of the Koktun Mountains and in the Cretaceous red beds of the Toyunskiy depression.

Mineral Resources

The mineral resources of the Eastern Tien Shan have been investigated very little. Known at present are deposits of lead and zinc; evidences of tin and molybdenum in various ranges; copper on the northern slope of the Borokhoro range and in the western Khalyktau; iron in the ranges of the northern chain, primarily in the interior zone of the Tien Shan; and also deposits of coal in the Mesozoic basins of the interior zone.

Lead and zinc. Deposits of lead and zinc are the most widespread and clearly of the highest potential economic value. They are distributed zonally, extending mainly towards the fracture zones which separate individual structural-facies zones. One zone of lead-zinc deposits extends along the southern slope of the Borokhoro range along the boundary of the Caledonian folds of the northern chain and the Hercynians of the interior zone. Another zone of lead-zinc deposits and ore manifestations has been traced on the boundary of the Maydan Tagh flysch trough with limestones of the Muzduk zone. A third zone of complex mineralization is found in the zone of northwest fractures on the boundary between the Koktun Mountains and the Suluterekskiy block. A fourth zone of lead-zinc ore indications runs along the northern slope of the Ketmen' range. A fifth runs on the boundary between the interior zone and the eastern spurs of the southern zone of Caledonian foldings (Tashkar Tagh, Igerchi Tagh, Ala Tagh, and Kyzyl Tagh).

In the individual zones the deposits and ore indications are grouped in joints which occur in areas cut by faults running in various directions. For example, the well-known Kan-sui ore joint containing the Sarytash, Uraken, Karaboktor, and other deposits is located in the region of the junction of the northwestern fractures of the Fergana range and the almost-latitudinal fractures of the Maydan Tagh; the Dzhaytyubinskiy ore joint containing the Khoshbulak, Kokyar, Kokterek, and other deposits is situated where the latitudinal and northeastern fractures of the Maydan Tagh are cut by the northwestern fractures of the Maralbashiyskiy zone.

In the southern zones of polymetallic mineralization, deposits are most frequently found in beds of the Devonian and Upper Paleozoic. These are metasomatic beds in limestones, or the impregnation of sulfides in quartz-calcite and quartz-barite veins, or ore veins and crossveins in the mineralized zones of granulation. Of greatest potential value are the metasomatic beds to which category belong the main ore bodies of the Sarytash and Khoshbulak deposits which have metal reserves of industrial significance.

In the northern zones of polymetallic mineralization, lead-zinc ore indications are found primarily in the volcanic-sedimentary stratum of the Middle Paleozoic and can be traced to the filling of minor tectonic fissures. The ore is found in impregnations of sulfides in quartz-calcite and quartz-barite veins. In these zones large deposits have still not been discovered.

Molybdenum and tin. Rare-metal mineralization appears in limited areas and as yet has no economic significance. It is found in the central Borokhoro range in the main granite blocks. Ore indications are found in the contact zones of granite blocks and represent groups of thin quartz veins with the impregnation of sulfides of copper and molybdenum.

Cassiterite has not been found in the basic strata but is found in many schlichs of alluvial sediments on the northern slope of the Borokhoro range.

Another region of rare-metal mineralization is found in the basin of the Southern Muzart range, where outcroppings of pegmatites containing cassiterite have been noted.

Copper. Ore indications with copper as the leading components are distributed rather widely and are to be found in all parts of the Eastern Tien Shan, mainly in areas where volcanic activity has been most intense. Such indications are found in the northern zone of Caledonian foldings along with the outcroppings of basic rocks and tuffs in the Ketmen' and Avral ranges in which are found volcanic formations of the Middle Paleozoic. Usually the mineralization takes the form of a thin scattered impregnation of copper pyrite and chalcopyrite converted by oxidation into hydrocarbonate compounds of copper (malachite, azurite). These compounds occur in fractured rocks in the form of very thin veins and layers. Industrial deposits are as yet unknown.

Iron. Iron ore indications are found in the Tien Shan mainly in the interior zone where they are represented by skarn and sedimentary types. The latter are found more frequently and are evidently of greater industrial value.

Sedimentary iron ores are found in the Jurassic deposits of Mesozoic basins. These are brown hematites and siderites which occur in clays in the form of nodules, lenses, and short seams up to 15 cm thick.

The skarn type is foundaat the contact points of granite intrusions and limestones which in the interior zone of the Tien Shan are most often of the Visean age. Iron ore skarns are observed in the form of seams conforming to the enclosing rocks or the contact face of an intrusion. The sizes of known seams are not large. In composition the skarns are magnetite-epidotic and magnetite-garnet, sometimes transitional to continuous deposits of magnetite. The skarn and sedimentary types of iron mineralization, as well as formations of hematite veins in hornstones, have been discovered in all parts of the interior zone of the Tien Shan: in the Iliyskiy basin, in the Karashar region, in the Chol Tagh and Gashun'skaya Gobi, all of which can thus be considered as mineral provinces with an increased content of iron which tends to form concentrations.

Coal. Coal-bearing areas in the Eastern Tien Shan are the Mesozoic basins of the interior zone, among the deposits of which are found sand-argillite series of the Jurassic with coal beds. Among them are the Iliyskiy, Kungesskiy, and Tekesskiy Turfan-Khamiyskiy basins, each constituting an independent coal field.

Coal is found in all horizons of the Jurassic; however, beds of workable thicknesses are concentrated in the deposits of the Lower and Middle Jurassic. Coal beds can be counted by the dozens, but usually only three to five beds are suitable for working. The beds are lenticular in form; thickness varies from a few centimeters to 14 m. Some beds extend for tens of kilometers. As a rule the coal beds do not lie deeply; therefore they can be worked by stripping.

Among the coal beds of the interior zone of the Tien Shan occur long-flame coals, those transitional to gaseous coals, and gaseous, and those transitional to bituminous. The ash and sulfur content is not large in coals of the Eastern Tien Shan.

2. TARIM MASSIVE

General Description of Orographic Regions

The Tarim massif is a large, relatively stable section of the earth's crust enclosed between the active zones of the Tien Shan and Kunlun.

Its relief is that of an upheaved plain with altitudes of 780-1400 m. In comparison with the high ranges of the mountain systems surrounding it, it appears to be the floor of a deep depression. However, the boundaries of the Tarim massif and plain do not coincide completely. To the Tarim massif belong also the groups of heights which butt onto the Tien Shan (Artyshskiy ridges, Kel'pinskiy mountains, Chult' Tagh and Kuruk Tagh ranges) and the mountain massif of the Tekelik Tagh which is orographically linked with the Kunlun.

Tarim plain. The Tarim plain has the shape of an oval the axis of which coincides approximately with the 40th parallel. The apex of the western arc of the oval is located near the town of Kashgar on the 76th meridian, and that of the eastern arc lies to the east of Lake Lop Nor on the 91st meridian. The Tarim plain is surrounded by mountains, and only in the east is there a corridor about 70 km wide through which it is joined with the deserts of the Ala Shan. The Tarim plain extends 1,300 km from east to west and 500 km from north to south; its area is 390,000 km^2.

The Tarim plain is inclined gently to the north and east, and in these directions its altitude diminishes from 1,400 to 1,000 m and from 1,200 to 780 m. In consequence of the incline of the plain to the north, its main water artery, the Tarim River, flows along the Tien Shan boundary, and as a result of the incline to the east, the center of its landlocked basin--Lake Lop Nor--lies on its eastern boundary.

The Tarim plain is divided into several types of landscapes: (a) the stony desert of the piedmont prolluvial-alluvial strip; (b) loess plains; (c) "yardangi," constituting a special type of denuded-remnant relief originating as a result of the scattering of the horizontally bedded ancient lake deposits; (d) the Takla-Makan sandy desert in which three types of accumulations are distinguished: ridge, barkhan, and mound; and (e) the interior mountain ridges of the Tarim plain, to which belong the Mazar Tagh and Maralbashiyskiy heights.

The piedmont prolluvial-alluvial strip (stony desert) is well developed only on the boundary of the Kunlun, where in places it attains a width of 15-20 km. Along the foot of the mountain ridges bordering the plain in the north and southeast (Altyn Tagh), its width usually does not exceed 1.5-2 km. The prolluvial -alluvial deposit strip consists of outwash fans of varying size cut by numerous dry stream channels.

The loess plains are located between the stony desert of the piedmont zone and the sandy desert of Takla-Makan. The incline of its surface is not great; the ground-water table is relatively high, so that vegetation grows here and there on it.

Fig. 14. Sands of the Takla-Makan desert (photograph by A. Steyn).

Fig. 15. Sand dunes on the southern boundary of the Takla-Makan sandy desert (photograph by A. Steyn).

Fig. 16. Remains of human dwellings a thousand years old among the mound sands of the southern Takla-Makan desert (photograph by A. Steyn).

The "yarangi" are widely distributed in the Lop Nor lowland and in the area between the Ho-t'ang and Keriya rivers, which were once filled by broad ancient Quaternary lakes. These are either numerous crests separated by wind gaps, or hills separated and grouped in small chains (recently crumbled crests) scattered on the denuded plain. The altitude of the crests and hills fluctuates, in accordance with the extent of the erosion of the lake stratum, from fractions of a meter to 10 m.

The Takla-Makan sandy desert is divided into two parts: the coarse sands of the main basin of the desert in its central and northeastern parts, known by the name Kum Tagh; and the barkhan sands of the southwestern part of the desert, called the Bel'kum.

Characteristic of the Kum Tagh is a combination of ridges and the broad hollows between them--"bairi," covered by a thin layer of coarse sand broken in places by outcroppings of the substratum. The ridges attain 180 m in altitude and a width of 1 km at the base; their extension is northwesterly, approaching the meridional (Fig. 14, 15, 16).

The sands of the Bel'kum constitute barkhans, mostly individual dunes on the desert boundaries, and joined in chains in the depth of the desert. Their average height is 5-8 m, their width at the base 30-40 m.

In addition, sandy-loess mounds occur with heights of 1-5 m and widths of 5-10 m, located 10-50 m apart. A bush of desert vegetation crowns each mound. A few mounds preserve a true conical form; usually, however, in consequence of the dying out of the undergrowth which anchor the sands, the mounds scatter. At first small depressions form on the slopes of the mounds, then large niches; finally there remains of the mound only a formless sand heap with the projecting roots of the plants which previously grew on it. The sands blown from the mounds form separate barkhans here, however, sometimes even forming large barkhan fields with the numerous remains of scattered mounds. Mound sands are widespread on the low parts of the plain near the large rivers, where the ground-water table is comparatively high.

The Tarim plain is not monolithic: numerous fractures with different trends divide it into slightly displaced blocks of various size and form. Displacement of several dozen meters, as a consequence of the size of the individual blocks, are not visually perceptible but are readily revealed by changes of the most recent deposits, by the movement of surface and ground waters, and by the distribution of various plant complexes.

Relatively elevated blocks in the Kashgar sector of the plain, the sands of the Bugarakum and Tograkkum are waterless and thus uninhabited expanses where between the barkhans there frequently outcrop horizons of the Pleistocene stratum. Another relatively elevated block is the Kumsaga plain to the south of the settlement of Astyn-Artush and constituting a waterless desert with barren solonchak-loess soil. The Kyzylsu and Artushdar'ya rivers form along this block sharp bends in various directions, and where their valleys lie beyond the boundary of this block, their numerous tributaries flow together in a single channel. A relatively depressed block is the territory of the Kashgarskiy and Fayzabadskiy oases where the rivers flow in open valleys and have many tributaries. Favored by the comparatively high ground-water table under this block, vegetation is found here, mainly "tograk" and tamarisk.

Among the highest parts of the Tarim plain is the northwestern sector of the Takla-Makan desert, where there are high-lying areas. Here the desert sands lie directly on rocks which lie in their original position. To this elevation belong the Mazar Tagh mountain ridge and those of the Maralbashiyskiy group.

The Mazar Tagh mountain ridge is situated in the western part of the Takla-Makan desert between the valleys of the Ho-t'ang and Yarkend rivers. It has the shape of an arch rising towards the southwest. It is 140 km long, 1.5-4 km wide, and 1,200-1,500 m high. This ridge constitutes a fold situated on the boundary of the Yarkend depression and the interior uplift of the Tarim massif. It rises an average of 300-350 m above the surface of the Yarkend depressions, but only 50-120 m over the interior uplift of the massif. Thus, from the south it appears as a rather high ridge, whereas from the north it is hardly distinguishable among the sandy elevations of the desert which rise to almost the same height.

The Maralbashiyskiy heights are located on the northern boundary of the Tarim plain in the vicinity of the Kal'pin Tagh with which they have many genetic and morphological features in common, although they are distinguished from it in extent. In the Maralbashiyskiy group are included nine separate ridges of various size comprising three approximately parallel chains with a northwesterly trend: the western (Vasig' Tagh and Mazar mountains), northern (Choku Tagh, Davan Tagh, Oshurmazar Tagh, Bel' Tagh, and Koral Tagh mountains), and eastern (Laal Tagh and Tumshuk Tagh).

Individual summits of the longest of these ridges rise to 1,600-1,700 m; the elevation of the surrounding locality, however, is 1,500 m. Only the Mazar and Laal Tagh mountains have the character of rolling hills; the other seven elevations are monoclinal ridges with a precipitous southwestern and moderately steep northwestern slope.

The region to the south and east of the Mazar Tagh has experienced subsidence. Within it, under barkhans and over broad areas free from sand, lies a stratum of lake sediments up to 6 m thick. Towards this ancient lake flowed the Karakash, Yurunkash, and Keriya rivers, and the dry channels of numerous rivers of the Gumiyskiy region now extend in the same direction. It is possible that even now underground sources of rivers of the Gumiyskiy group reach the former lake basin. The grounds for such a conjecture is the abundance in this area of ground waters, lying at depths of no more than 2m.

Thanks to the high water table, poplar, wild olive, (Elaeachus angustifolia), and tamarisk are widely distributed and sometimes cover a considerable area. As is shown by the history of the lost settlements of Dandanulek and Karadonk, which were situated on the southeastern boundary of an ancient lake until the third to fifth centuries, it was even possible to carry on agriculture here.

Large lowlands are found also on the northern boundary of the plain where the Tarim River flows One of these occupies the region of the junction of the largest rivers of Western Kashgariya--the Kyzylsu, Yarkend, Aksu, and Ho-t'ang--and many small streams originating on the slopes of the Khantengriyskiy mountain knot (Derensu, Ulugyarsu, vatsu, and others).

The surface of this lowland consists of broad, bare clayey parts and solonchak scrub with masses of mound sands.

A second large lowland of this zone covers the area between Shakh'yar and Chiglyk (260 km) within which the currents of the Tarim, Muzart, and Konchedar'ya sharply decelerate and the rivers divide into a multitude of meandering channels part of which form flowing lakes and marshes, sometimes even terminating in them. Below Chiglyk all the branches of the Tarim and Muzart rivers flow together in one channel which is deeply incised into the alluvial plain.

Between these depressions is found an upheaved sector of the plan through which the Tarim River flows swiftly in a narrow canyon bounded by scarps.

In the southern part of the Tarim plain, between the Tulankhodzha and Cherchen rivers, there extends a broad lowland occupied by a "tograk" forest which stretches 60-80 km into the Takla-Makan desert. The soil here is solonchak; the sparse vegetation consists of reeds, tamarisk, licorice (Glycyrrhiza glabra), and calligonum. Ground waters lie not more than 2 m below the surface.

The largest and most important submergence in the Tarim plain is the Lop Nor lowland, where is found the terminal lake of the landlocked basin of Lake Lop Nor. It is a broad desert plain bounded on three sides by the equally desert heights of the Kuruk Tagh, Pei Shan, and Altyn Tagh. In the west the Lop Nor lowland joins the Tarim plain, and here its boundary is formed by the eastern edge of the sandy area of the Takla-Makan. The area of the lowland covers approximately 20,000 km^2; its altitude in the area of the lake basin varies from 780 to 795 m, and on the boundary of the surrounding mountains from 810 to 900 m. To the east of the Lop Nor lowland emerge two grabens each 20-25 km wide. The northern (Yardangla) extends between the Pei Shan and the Kuruk Tagh, and the southern (Achiktala) separates the Pei Shan and the Altyn Tagh.

The Lop Nor lowland has a complex microrelief. There are three types of landscape, lying at different heights. On the margins arefound terraced benches 20-30 m high cut by transverse dry gullies descending from the neighboring heights. The benches are not infrequently broken up into separate tablelike hills which, approaching the lake basin, become smaller and then disappear. These benches are extended to the northeast, conforming to the trend of the faults which border the mountain blocks.

The second type of landscape, situated at a lower elevation, constitutes fields of "yardangi" which are particularly numerous in the northern half of the lowland The crests and small chains in the yardangi fields extend to the northeast, conforming with the dominant direction of the winds in this region.

The third type of landscape is the floor of the dry lake bed of the pre-historic Lobnor, covered by the compact hillocks of a solonchak (Fig. 17 /not included/).

From the Lop Nor lowland towards the mountain blocks of the Kuruk Tagh, Pei Shan, and Altyn Tagh, the Tarim plain rises by stages in low but steep and rectilinear benches along the bases of which spring waters intermittently gush forth. The largest of these stages of ascent is the sloping stony and sandy desert of the Kum Tagh, which lies in front of the Altyn Tagh. Near the Lop Nor lowland (Achiktala) the Kumtagskiy terrace ends in a bench 50-100 m high, along which extends a strip of dense vegetation (reeds, tamarisk, halophytes) abundantly fed by ground waters. The surface of the terraces is cut by deep, dry gullies and covered by sand ridges: its altitude approaching the Altyn Tagh increases from 900 to 1,500 m. To the northeast the Kumtagskiy terrace drops and is transformed into a sloping ridge which separates the lake basins of the Lop Nor and Khalach. To the southeast, on the other hand, the Kumtagskiy terrace rises, and on its surface there appear high, rocky ridges which farther along in this direction are gradually free of sands.

South of the Lop Nor, in consequence of the intensive upheaval of the Kum Tagh terrace and its transformation from the base of a range into a mountain ridge, there appears on the plain next to the Kum Tagh a new bench with a rectilinear terrace 20-30 m high. The surface of this new bench also slopes gently towards the Lop Nor lowland and is waterless and barren. Along the base of its terrace are many alkaline springs, around which grow reeds and tamarisks. At the stage when the "yardangi" originated the mouths of the ravines dissecting the terrace facing the Kum Tagh were filled with the waters of Lake Lop Nor, which deposited sediments in them.

West of the meridian of Lake Lop Nor, the terrace facing the Kum Tagh rises and on its surface there appear outcroppings of coarse prolluvial deposits with masses of barkhan sands. Rising in the Charklyk area, on a continuation of this terrace, is a high rocky ridge constituting the forward part of the Altyn Tagh.

The eastern Takla-Makan desert occupying the lower course of the Tarim River and the Cherchen River valley is apparently rising; evidences of this are the fact that it forms a watershed, and the distribution here of ridge sands. The shifting of the main channel of the Cherchen to the south, of the Tarim to the east, and of the Niya and Endere rivers to the west may have been caused by an increase in the dimensions of this upheaval in the Quaternary period.

Elevations of the Tarim massif butting onto the Tien Shan. Artushskiy group. The Artushskiy group unites the ridges of the Kashgarskiy sector of the foothill zone of the Tien Sham, the relief of which ridges reveals the large-scale foldings of Mesozoic-Cenozoic strata. The mountain ridges correspond to anticlines, and the longitudinal valleys to synclines. On the southern ridges (Mynyul'skiy and Artushskiy), which are younger and less dissected, orographic and structural forms coincide almost completely. On the northern ridges (Arpalykskiy), which was subjected to more prolonged and intense erosion, indications can be observed of a change in the relief. With the uncovering in their cores of weakly cemented sand-clay strata of the Neocene and Paleocene, the process of denudation proceeded farther here than in the sides, which are composed of conglomerates of the Pliocene-Pleistocene. In the central parts of the anticlines there thus arose the rolling-hill type of badlands, while on their sides high, rocky crests formed.

The rtushskiy anticlines are structurally folded ones with uneven development of the slopes. Their southern slopes facing the Tarim plain are 100-200 m higher than the northern, which descend towards the interior depressions. The trend of the ridges is latitudinal, sometimes northeasterly. In length the individual ridges of the Artushskiy group attain 180 km; the width varies from 4 to 8 km and the altitude from 2,100 to 3,000 m.

In the east the Artushskiy ridges become the Kel'pinskiy ridges.

Kel'pinskiy ridges. The Kel'pinskiy group unites the monoclinal ridges of the Kel'pin Tagh, Imgantau, Ozytartau, Kozek, Karabashil, and others. The monoclinal ridges constitute comparatively narrow and very elongated rocky elevations with steep southern (southeastern) and gentle northern (Northwestern) slopes. The ridges are separated by extensive areas of plain, largely stony deserts. All the ridges are composed of the same series of deposits dipping in the direction of the gentle northwestern slope. This structural feature of the Kel'pinskiy ridges is expressed in their cuesta type of morphology. The trend of the ridges to the south of the town of Maralbasha is latitudinal; to the east of it, northeasterly. The length of the largest ridges of this group, the Kel'pin Tagh and Imagantau, is 200 km, the width 8-10 km, and the relative elevation 1,000 m.

Located between the towns of Kel'pin and Aksu, on an extension of the southern group of ridges, is the extensive upheaval of the Bitammatau Mountains, complicated by concentric faults. The northeastern part of the upheaval (Kurukuzhum) has collapsed and has a plain relief with a stony desert landscape, while the eastern, southern, and western parts corresponding mainly to the sides of the upheaval, rise in rocky ridges. The trend of the ridges changes in conformity with the direction of segments of the contour of the upheaval: the eastern ridge, the Azambulak Tagh, trends 40-55° NE; the southern ridges, the Tastar Tagh and Mechetiin Tagh, 295° NW; and the western, the Bitammatau itself, 40° NE. Morphologically, the eastern and southern ridges represent cuestas sloping towards the Tarim plain. In altitude the Azgabulak Tagh is 1,600-1,850 m, the Mechitiin Tagh 2,700 m, and individual summits of the Bitammatau 3,200-3,400 m. The relative altitude of the ridges reaches 1,300 m.

Elevations of the Kucharskiy sector. Located east of the town of Aksu, along a continuation of the Kel'pinskiy Mountains, is the Chul Tagh mountain ridge, similar in structure and morphology to the ridges of the Artushskiy group.

The Chul' Tagh ridge is a young asymmetric anticline prominent in the relief and having a northeasterly trend. It is 190 km long; its average width is about 10 km; the altitude of the watershed increases to the northeast from 1,600 to 2,340 m. As a result of the differences in elevation of the Tarim plain (1,000-1,050 m) which butts on to it and those of the Bayskiy depression (1,240-1,280 m), situated to the north of it, the relative altitude of the southern slope of the Chul' Tagh is 200-250 m higher than that of the northern. The Chul' Tagh ridge is broken and complexly dissected (badlands type), and its surface is entirely barren.

The Bayskiy depression lying between the Chul' Tagh ridge and the bench of the Tien Shan has a plains relief only in the southern part, whereas in the northern part it is a hilly region with extensive badlands.

The surface of the depression is inclined to the south, as a consequence of which its main water course, the Muzart River, flows for a considerable distance along the southern edge near the Chul' Tagh ridge. In the southern part of the depression two relief formations are found: the main surface of an alluvial plain with the landscape of a stony desert, and the broad floors covered with loess clays, of the river basins which cut through it. In the valleys there are settlements with gardens and fields.

Kuruk Tagh. Under this name is included the series of elevations in the northeastern part of the Tarim massif. The Kuruk Tagh begins at 85°30' E long. with the Borokhotan ridge which borders the Tien Shan range of the Kokteketau. Along the gorge of the Konchedar'ya River the Kuruktag diverges from the Tien Shan and extends up to the 91st meridian in the form of a completely separate elevation. As a whole, the Kuruktag constitutes a broad flat dome insignificantly rising over the depression zone which separates it from the Tien Shan, but appearing rather high from the side of the Tarim plain despite the fact that it descends in this direction. The breadth of the Kuruk Tagh varies from several kilometers up to 90 km. In the narrow western part it consists of one horst-shaped ridge, but in the northern and eastern parts which are broader, it divides into a series of oblique horsts and grabens which descend successively towards the Tarim plain.

Fig. 18. Sharachaktal valley and ridge of the Moren-ulan-Ula in Western Kuruk Tagh (photograph by E. Norin).

In the Kuruk Tagh two basic types of elevations are distinguished: the northern (Borokhotan, Karatekenula, Yumuluk Tagh ridges) and the southern (the smaller massifs of the Kurbanchik Tagh, Shindi Tagh, Kok Tagh, and Olontementuula) which are separated by an extensive graben with a rocky cover. The surface of the graben lies 500-800 m lower than the summits of the northern series of elevations and only 150-300 m lower than those of the southern series. The Borokhotan and Karatekenula represent parts of one mighty ridge cut through by the valley of the Konchedar'ya River. The western part, the Borokhotan, rises from the piedmont plain and within a few kilometers attains a relative altitude of 1,000 m. It is separated from the Tien Shan range of Kokteketau by long longitudinal valleys developing along the marginal fault. The Borokhotan is as high as 2,300 m in altitude; its breadth does not exceed 6 km; it is brokenly dissected and barren. Besides the numerous local ravines, the Borokhotan is cut by valleys the upper reaches of which lie in the Kokteketau. Its eastern continuation, the Karatekenula range, extends to Zenger (88°40'), then is replaced by small extinct volcanoes, beyond which it rises in the mountain massif of the Yumuluk Tagh, the last considerable elevation of the northern chain of the Kuruk Tagh.

Near the Konchedar'ya River the Karatekenula constitutes a horst bounded by rectilinear terraces. East of it appear additional fractures, creating alongside the main stem of the system small wedges rising and dying away independently of one another. Thus the width of the range increases from 5 to 25 km and its boundaries here become irregular. A rocky plain is strongly imbedded in the range and almost reaches its watershed line. The elevation of individual summits of the mountain massifs situated in the central upheaval zone exceeds 2,500 m. The trend of the ridges of the northern chain of the Kuruk Tagh is approximately latitudinal throughout.

The depression zone running between the northern and southern chains of the Kuruk Tagh contains the intermountain troughs of the Tementologoytala, Shinditala, Gentigentograk, and Buruntubulak, which are separated by lateral slopes and small ridges. The breadth of these troughs varies from 8 to 25 km; their relief is level, their surfaces slope toward the south. The troughs carry a broken mantle of slightly-rounded gravel. In the area of lateral submergence causing a temporary break in both chains of the Kuruk Tagh, is found the Gentigentograk plain with extensive solonchak wastes. The absolute elevation of points in the depression zone diminishes from north to south and from west to east from 1,600 to 1,100 m.

The southern chain of the Kuruk Tagh consists of a group of comparatively low mountain blocks extended latitudinally. In the west it begins with the Sugetbulak Tagh, a weakly denuded horst with rectilinear and almost perpendicular sides. In the middle part the width of this horst is about 15 km, its elevation over 2,100 m. It descends to the east of a continuous canyon, divides into several parallel ridges, and then terminates in a stony hilly plain. The next link in the southern chain is the Shindi Tagh mountain massif which extends in a latitudinal direction for 90 km. It is also bounded by rectilinear terraces with relative elevations of 300-350 m. The highest is the northwestern part of the massif where there are summits 2,200-2,300 m high. To the south and east the Shindi Tagh descends to 1,500-1,700 m and at 88°15' E long. it merges with a plain. In the segment lying opposite the solonchak plain of Gentigentograk the southern chain is not prominent at all, and only farther on do the sharp rocky ridges of the Olontementuul rise to an elevation of 1,230 m. The relief of these mountains varies, depending on the lithological composition of the rocks and their structure Narrow rocky ridges correspond with outcroppings of limestones, and broad hollows and parts with rolling hilly relief correspond with thick sandy-shale bodies.

Fig. 19. Barren ridges of the Kuruk Tagh (photograph by E. Norin).

The directions of the ridges and hollows are defined by the trend of the limestone-sand-shale stratum, and their sizes by the thicknesses of the individual bodies (Fig. 19).

Located on the Tarim plain between the Kuruk Tagh and Kumdar'ya is the Charchak Tagh ridge, a barren, rocky crest up to 20 km long, 1.5 km wide, and having a relative elevation of 150-200 m (maximum absolute elevation 1,250 m). The ridge is curved like a bow. In the central (highest) part its trend is 130° SE; in the western, latitudinal; and in the southern, 155° SE. As a result of its position on a plain, considerable elevation, and light coloration, the Charchak Tagh stands out sharply against the surrounding relief.

Elevations of the Tarim massif orographically linked with the Kunlun. Tekelik Tagh. South of the Khotan, in the triangle between the converging mountain-fold zones of the Western and Central Kunlun, is found a mountain block named for its major summit, the Tekelik Tagh.

This massif is orographically closely linked with the Kunlun, but in accordance with the conditions of its geological development it belongs to the Tarim massif.

The elevation of the main summit of the Tekelik Tagh is 5,440 m, that of other major summits varies from 4,300 to 5,400 m. It rises 3,500 m over the boundary of the Tarim plain, and 1,500-1,800 m over the floors of the river valleys which cut through these mountains. The heights of the Tekelik Tagh are rocky, barren, and for the most part difficult to approach.

Hydrographic Net

The Tarim massif is situated within the landlocked basin of the same name. This basin is the largest in Central Asia. It is watered by the rivers of the Kunlun, of which the largest are the Yarkend, Khotan, Keriya, and Cherchen, and by the rivers which flow from the slopes of the Tien Shan, in particular the Kyzylsu, Aksu, Muzart, and Konchedar'ya.

The largest river of the Tarim basin, the Yarkend-Tarim, begins among the glaciers of the northern slope of the Karakorum and cuts a deep gorge through the ranges of the Western Kunlun, where it receives many large tributaries. On the Tarim plain the Yarkend flows first in a longitudinal direction and then, towards its northern boundary, bends sharply to the east to flow along the Tien Shan a short distance from its foothills. The Yarkend receives as left tributaries only the Aksu, Muzart, and Konchedar'ya rivers, and these only because their waters, due to the position of the Yarkend on the northern edge of the plain, need flow through the desert for not more than 100 km and hence do not evaporate completely or seep into the ground. Of the rivers flowing from the Kunlun, the Yarkend receives only the Khotan, but only in times of flood. All the other right tributaries have long since lost their connection with it and terminate either in the piedmont zone or in the sandy desert of the Takla-Makan.

Below the junction with the Aksu and Khotan the Yarkend River is called the Tarim and terminates in the marshes and lakes of the Lop Nor lowland. The over-all length of the Yarkend-Tarim River is about 2,000 km.

On the Tarim plain the river valley does not have clear boundaries, gradually merging with the surrounding region. In parts which have undergone subsidence (for example, between Shakh'yar and Chiglyk) the river has built up extensive alluvial plains on which it forms a labyrinth of complexly braided channels. In parts which have undergone upheaval, its waters flow in a single channel and run somewhat more swiftly. The channels of the Yarkend-Tarim are bordered by sandy and loess banks covered with vegetation. In the flood period the river fills the small basins adjoining its valley, forming in them numerous lakes which remain sometimes for several years. On the plain the channel of the river is sandy and oozy, in places muddy; it is 30-100 m wide and up to 10 m deep. Extending along the entire course of the river is a broad strip of tugay forests (Fig. 20).

Fig. 20. Tugay forests along the Tarim River (photograph by A. A. Shneyder).

The Ho-t'ang River forms in the Takla-Makan desert as a result of the junction of the large Karakash and Yurunkash rivers which begin on the high-altitude plains of Northern Tibet and cut through the ranges of the Kunlun. The Khotan flows through the desert in a sandy channel about 1 km wide in a broad flat valley. Between flood stages the Ho-t'ang remains a permanent river only up to the Mazar Tagh; below this range it divides into separate stretches which become shorter and lesser in number approaching the north. But in sandy deposits along the entire channel, water continues to ooze out. This water is used by the caravans crossing the desert along this valley. In summer the caravans do not follow this route because of the fierce heat and the abundance of gadflies.

Penetrating just as deeply into the desert is the other Kunlun river, the Keriya, whose waters in flodd stage reach the extensive solonchak waste in the sands of the Takla-Makan 300 km from the mountains. But at low water (fall and winter) the river has a permanent flow only in the piedmont zone, in the lower stretches being divided into individual stretches.

The Cherchen River begins on the Tibetan plateau and, before reaching the Tarim plain, runs through the Kunlun ranges. Alone among the Kunlun rivers, it flows across the plain not in a longitudinal direction but rather northeasterly, towards the Lobnor lowland where here and there it joins the Tarim River.

The Kyzylsu River, which feeds the Kashgarskiy oasis, the largest on the Tarim plain, collects its waters from the area of convergence of the Kunlun and Tien Shan ranges. The Kyzylsu flows in a latitudinal direction. Most of its waters irrigate the fields of the Kashgarskiy and Fayzabadskiy oases, and only a small part reaches the Maralbashiyskiy oasis. However, the river channel extends still farther eastward to the Aksuyskiy depression, where it joins the Yarkend.

The sources of the Aksu River collect waters from the Kokshaal-Tau and the western part of the Khantengriyskiy mountain knot. The river is fairly full throughout the year and, despite considerable diversion of its waters in irrigating the Aksuyskiy and Avatskiy oases, it maintains a permanent flow until it joins the Yarkend River.

The Muzart River collects waters from the Khalyktau range and the eastern part of the Khantengriyskiy mountain knot. It feeds the oases of the Bayskiy basin and, on the Tarim plain, the Kucharskiy and Shakh'yarskiy oases. In the Muzart depression the river divides into many arms and flows parallel to the Tarim. These arms converge only in the Chiglyk region on the eastern boundary of the depression. Here some channels separate from the Muzart and join the Konchedar'ya.

The Konchedar'ya constitutes a continuation of the Khaydyk-Gol River below the outlet lake of Bagrashkul'. Part of the waters of the Tarim and Muzart intermittently flow in the beds of the Konchedar'ya as a result of temporarily functioning channels. The main channel of the Konchedar'ya lies along the foot of the Kuruk Tagh and enters the Lop Nor lowland from the northwest, while the Tarim enters from the southwest. Some channels branch off from the middle course of the Konchedar'ya and run in the direction of the Chonkol'skiy marsh and the lakes of the Arganskiy group.

High water in the rivers of the Tarim basin occurs in July and August when the mountain snows melt most rapidly. However, it does not occur at the same time in all its rivers. As a result of the fact that in the Kunlun system the altitude of the snowline increases from west to east, the eastern rivers (Keriya, Niyadar'ya, Tulankhodzha, Cherchen, and others) flood later than the western rivers (Yarkend, Khotan, and Kyzylsu).

The Tarim and all its tributaries are typical transit rivers of the desert and do not affects its climate.

Lake Lop Nor is the terminal reservoir of the Tarim landlocked basin and is well known in the geographical literature as an example of a "migrant" lake. A dispute over the location of this lake long raged between N. M. Przheval'skiy and F. Richthofen and, later, among their students.

The present Lake Lop Nor does not have a permanently-defined location and definite boundaries. In the seventh century, according to Chinese sources, Lake Lop Nor was located in the northern part of the old lake basin near the mouth of the Konchedar'ya. Later, for a thousand years it was situated south of this in the Kara-Koshun tract near the mouth of the Tarim River, where it was seen by N. M Przheval'skiy, M. V. Pevtsov, and P. K. Kozlov. At the beginning of the present century, the southern Lop Nor (Kara-Koshun or Przheval'skiy Lop Nor) dried up, with the result that a large part of the waters of the Tarim River flowed into the lakes of the Arganskiy group. In 1923 the large Kondar'ya River, which until then had flowed into one of the channels of the Tarim, returned to its old bed, which is known among the local population by the name Kurukdar'ya (dry river) and Kumdar'ya (sandy river) and had been dry for a millenium.

The diversion of the main waters of the Konchedar'ya into the old channel (the Kurukdar'ya) resulted in the drying up of the Arganskiy lakes which had been fed by a branch of it (the Ilek) and in the regeneration of the northern Lop Nor, which received water from the Kurukdar'ya.

At the time of the sojourn on the Lop Nor lowland of a Swedish-Chinese expedition (1928-1931) the lake had an area of about 2,000 km^2 and extended in a longitudinal direction. In those years the western shore of the Lop Nor lay 20 km east of the 90th meridian, while the eastern shore reached longitude 90°45', where the lake ended in a broad bay. As is shown by the most recent topographic map, make in 1942, Lake Lop Nor had by then changed considerably: the area of the lake had increased to 3,000 km^2 and had become nearly oval in form, extending to the northeast (Map 39). The western shore of the lake was shifted 30-35 km to the west, past the 90th meridian, while on the site of the former southeastern bay a solonchak had formed.

Map 39. Lake Lop Nor.
1-- Mountainous surroundings of the Lop Nor lowland;
2-- Tarim plain;
3-- deposits of the lake at the "yarganda" stage;
4-- bed and sediments of the prehistoric stage;
5-- Lake Lop Nor at the time of N. M. Przheval'skiy's expeditions (1876-1885);
6-- Lake Lop Nor at the time of the Swedish-Chinese expedition (1928-1931);
7-- Lake Lop Nor on most recent topographic map (1942).

/Place names on the map:/
1-- Kuruk Tagh range
2-- Konchedar'ya River
3-- Tarim River
4-- Lou-lang
5-- Abdal (city)
6-- Charklyk (city)
7-- Altyn Tagh (range)
8-- Pei Shan (range)

In 1950, according to Ye. P. Tsyplenkov, there was no water in Lake Lop Nor other than that of small ponds. This investigator found only salt beds on the site of the lake.

At the time of our visits to the Lop Nor lowland in 1952 and 1954 there was neither a northern nor a southern Nop Nor lake. The waters of the Tarim and Konchedar'ya rivers were retained mainly in the Chonkul' depression where there had previously been extensive marshes and solonchaks but where a large lake has now formed.

In 1954 in Argan we met an 80-year-old man, Atek Dadi, who had worked for Sven Gedin and remembered the oldest student of Lake Lop Nor, Kunchikan-bek, with whom N. M. Przheval'skiy had stayed during his second and fourth expeiditions. Atek Dadi related that in 1926 the waters of the Konchedar'ya and Inichkedar'ya (the northern channel of the Tarim, which was connected to the Kurukdar'ya) flowed in the Kurukdar'ya channel into the northern Lop Nor lake basin. In the lower Tarim there was no water at all. The population of the settlements located along the Ugendar'ya and Ilek had to buy water from the beys who owned the land through which flowed the regenerated Kurukdar'ya. Much land was abandoned and once-prosperous settlements deserted. In 1949-1950 the people's authorities of Sinkiang, on the petition of the impoverished population of the lower Tarim area, decided to build a dike across the dry channel of the Konchedar'ya and Inichkedar'ya rivers and divert their water into the higher channel of the Ugendar'ya, which fed the largest oases of the region. As a result the Kurukdar'ya and its terminal reservoir, the northern Lop Nor, again dried up. However, this did not effect a regeneration of the southern Lop Nor, because the diverted waters began to fill up the broad Chonkul' depression and only a small part found their way to the channel of the Ugendar'ya. There was now so little water in the Ugendar'ya that it evaporated or seeped into the channel sediments before reaching the Kara-Koshun lake basin. As the Chonkul' depression filled, the water level in the Ugendar'ya rose. It is probable that in the next few years the basin of the Kara-Koshun (Przheval'skiy Lop Nor) will begin to fill with water and a lake will again form there.

Lake Lop Nor is a shallow body of water which in its basin, during river flood stages, rises to the level of the surrounding plain. It has no definite shoreline; it is lost in the solonchaks bordering the lake and regularly shifting from one side of the lake to another, depending on fluctuations in the flow of water and seasonal changes in rates of evaporation.

The displacements of the lake in the Lop Nor lowland and its periodic drying up are caused by shifts in the flow of water along the channels of the Tarim and Konchedar'ya. When the main waters flow into the Lop Nor lowland along the channel of the Konchedar'ya (Kurukdar'ya), the nothern Lop Nor exists. The Kara-Koshul basin fills with waters from the Tarim (Ugendar'ya). In periods when a considerable part of the waters of the Tarim and Konchedar'ya is retained in the lakes of the Arganskiy group or in the Chonkul'skiy depression, the lake dries up temporarily.

Water is one of the most important natural resources in the deserts of Central Asia. The fertility of the loess soils in areas where there is much solar heat and light permits, under irrigation, abundant harvests of valuable agricultural crops. But this resource is still being insufficiently

exploited. Enormous volumes of water are still carried by the rivers into the desert and are lost to man. The proper utilization of this water could result in a considerable expansion of the sown areas, particularly in the Tarim basin, which is the best watered and which possesses extensive areas of valuable land with fertile loess soils.

Fig. 21. Gammada /stony desert/ of the northeastern edge of the Tarim plain (vicinity of the Charchak Tagh mountain ridge (Photograph by E. Norin).

Flora and Fauna

Due to the extreme aridity of the climate, a large part of the Tarim plain is a desert bare of vegetation. Such are mainly the areas of sand ridges, completely bare, on which even isolated tamarisk bushes are only rarely found. The vegetation cover is very sparsely developed also in the zone of the piedmont alluvial strip of whicha bare stony desert occupies a large part. Only in crevices and hollows is sparse vegetation to be found (ephemerals, calligonum, and a few halophytes).

Vegetation is rich (for a desert) in the zone of loess soils, where ground-water table is relatively high. Concentrated in this zone are the largest oases and areas of arboreal vegetation. But even here the watered soil does not extend over a continuous strip but rather is found in isolated areas separated by wider expanses of desert. These parts, having oases and large stands of arboreal vegetation, are found along the rivers and in the large secondary outlets of ground waters. They are large and numerous in the western half of the Tarim plain, less frequent and smaller in the east.

Map 40. Areas of the distribution of tugay forests and mound-sand vegetation on the Tarim plain which disappeared during the most recent period as a result of a fall in the ground-water table.

/Place names on map:/
1--Kashgar (city)
2--Yarkend (city)
3--Khotan (city)
4--Tarim plain
5--Tarim River
6--Cherchen (city)
7--Lake Lop Nor

In the river valleys there are tugay forests of Yevfratskiy poplar, wild olive, willow, and tamarisk, forming in places impenetrable groves. On the main surface of the plain extensive areas are occupied by sparse forests of Yevfratskiy poplar with a low zone of tamarisk growing on the loess hillocks, with reeds occupying the solonchak depressions between them.

In the recent past, poplar-tamarisk forests formed a virtually continuous green ring around the Takla-Makan desert. In the course of the last 1,500 years extensive areas of forest in many parts of this ring have perished, there remaining only isolated trunks of poplars, arising among the barkhans and dead tamarisk roots on the site of shifting mounds. An especially large amount of arboreal vegetation perished in the Gumiyskiy part of the desert, in the area between the Keriya and Niyadar'ya rivers and on various sites in the foothill zone of the Tien Shan (Map 40).

Large stands of sparse poplar-tamarisk forests are found in the interior of the Takal-Makan desert on the site of an ancient lake, called in legends the Yashil'kul'. In the eastern half of the Tarim plain, as a consequence of a general fall in the ground-water table and an increased sand content of the soil, saxaul and "kharmyk" appear and the range of tamarisk simultaneously diminishes.

In the best-watered parts of hollows having stagnant waters and solonchak soils, peculiar meadows of halophytes, reed grasses, and reeds are found. Similar meadows occupy large areas in the Muzartskiy depression of the Tarim plain, along the lower courses of the Tarim and Cherchen rivers, and on the southern boundary of the Lop Nor lowland along the base of the Kum Tagh terrace.

Fig. 22. Vegetation of the loess plain on the southern boundary of the Takla-Makan desert (photograph by A. Steyn).

Agriculture is possible on the Tarim plain only with irrigation. The main bodies of cultivable soils are found in the loess zone, mainly on the boundary of the piedmont rocky strip, where the rivers still retain a good deal of water and the slope of the plain's surface permits gravity-flow irrigation. At the same time, approaching the Takla-Makan desert, the quality of the soils worsens in consequence of an increase in their sand and salt content.

On the oases of the Tarim plain corn, wheat, rice, barley, and several types of millet are grown, as well as cotton, sesame, and various vegetables. On the western oases, on a part of the land, two harvests a year are gathered: first winter wheat or spring barley ripening early in June, then corn, harvested in October. Growing in the gardens of the oases of the Tarim plain are grapes, apricots, peaches, apples, pears, cherries (Cerasus avium and C. prunus), quinces, pomegranates, figs, mulberry trees, and walnuts.

Of the animals of the Tarim plain the most common are gazelles (Gazella subgutturosa), occurring mainly on the open expanses of the foothill zone, and boars, numerous in the reed growths and tugay forests of the river valleys. Among the rarer animals are Siberian deer (Servus canadensis asiaticus), which are found all along the valleys of the Yarkend and Tarim rivers, and the wild camel, which sometimes occurs in the sands of the Kum Tagh near the Altyn Tagh. As recently as the end

of the last century, camels lived in the eastern and central parts of the Takla-Makan desert as far as the Ho-t'ang River. Among the carnivores are wolves, reed cats, and foxes which inhabit the tugay forests, sparse poplar forests, and the foothill zone. In the valleys of the Tarim, Ho-t'ang and Cherchendar'ya rivers, tigers were still found at the beginning of this century.

Geological Structure

The Tarim massif is a relatively stable part of the earth's crust lying between the active zones of the Tien Shan and Kunlun. It has an irregular diamond shape bordered on all sides by zones of regional (deep-seated) faults, in conformity with which trend the structural-facies zones, folds, and ranges of the Tien Shan and Kunlun mountain system which surround it.

The movements of the Tarim massif were distinguished by a weak differentiation, by slow speed, and small amplitudes of displacement, as a result of which its sedimentary mantle is thin and surprisingly constant in litholitic composition in individual horizons. The strata of the Tarim massif either have an undisturbed bed or reveal local folded dislocations. Their sedimentary material has not undergone changes other than diagenetic; therefore even in the ancient systems of the cover it is found in a condition of compression characteristic for argillite. Deep-seated and volcanic formations in the Tarim massif are rare and represented exclusively by shallow fractured bodies and blanket deposits.

The composition of the deposits on the massif and their facies changes attest that the relief of this region was flat and weakly differentiated already at the end of the Proterozoic. The movements of the Tarim massif had an epeirogenic character and were not accompanied by distortion of the strata. Therefore, in its mantle, despite numerous and extended discontinuities in depositional accumulation and infrequent changes in the facies types, there are no angular unconformities. The platform system of development of the Tarim massif began even before the Sinisian epoch, deposits of which still enter into the composition of the sedimentary mantle.

At present the Tarim massif is for the most part an elevated plain appearing to be the floor of a basin among the high ranges of the Tien Shan and Kunlun. The study of the structure of the Tarim massif is hindered by the unbroken mantle of Quaternary deposits (loesses and sands) which has developed on its plain surface. Ideas concerning the structure of the massif are based mainly on geological data on the bordering areas, which have been affected by the most recent movements and which have a mountain relief, and also on data from geophysical investigations carried out by Soviet and Chinese scientists.

The foundation of the Tarim massif, which outcrops in the Aksuyskiy upheaval, the Kuruk Tagh, and the Tekelik Tagh, is formed by ancient metamorphic strata and granites. Among them two series may be distinguished according to degree of metamorphosis: a gneiss-schist, possibly Archean, and a quartz-schist, provisionally assigned to the Proterozoic. The Archean series is composed of various gneisses and crystalline schists with bodies of amphibolites and also small bodies of orthogneisses. The composition of the Proterozoic series includes quartzites, marbles, and metamorphosized sandstones, quartz-mica, and quartz-chlorite schists.

On the Tarim plain the metamorphic strata of the foundation are found at various depths. In the eastern half of the plain, judging from the structure of the adjoining heights of the Kuruk Tagh and Altyn Tagh, the Pre-Sinisian foundation of the massif lies under a thin layer of Late Tertiary and Quaternary deposits. In the southern part of the plain, and also in the Tekelik Tagh, over considerably areas it is covered by Upper Paleozoic deposits about 500 m thick, and then by Cenozoic deposits 300-400 m thick. Most depressed is the northwestern section of the massif in which, as may be concluded from the structure of the Kel'pinskiy ridges, the thickness of the sedimentary mantle is about 2,500-3,000 m and it is especially fully represented.

The sharp difference in degree of metamorphorphism of the strata of the foundation and mantle of the Tarim massif, strong in the former and absent almost altogether in the latter, and the clear angular unconformity between them, are evidence of an extremely long period of denudation during which the tectonic development of this region changed from highly active to completely stable. The continental period evidently embraced a considerably portion of the Proterozoic.

In the Sinisian and Lower Paleozoic the Tarim massif was already hardly active and possessed a weakly differentiated plain relief. But even in this period a considerable part of its territory continued to rise and to undergo denudation. Large downwarpings filled with sediments are found only on the northern boundary of the massif, on the Kuruk Tagh and the Kel'pinskiy ridges.

In the Kuruk Tagh the Sinisian deposits begin with the P-i-i-hsi series, composed of poorly sorted products of the weathering of Archean gneisses. The higher Altyngol series, which corresponds to a period of intense volcanic activity, consists of acid lavas and pyroclastics, alternating with arkoses, quartzites, and schists. The following series, the Terekenskiy, is composed of schists and marls interbedded with tillite-type rocks and spilites (700 m). Still higher is found the Yukkengol'skiy series, an interbedding of sandstones and siltstones of quartz and graywacke composition (700 m).

In the Kel'pinskiy region the Sinisian is represented only by a stratum of gray-green quartzite and graywacke sandstones with conglomerates and spilites (600 m), which stratum occurs in a metamorphic series and is covered with red sandstones provisionally assigned to the Lower Cambrian.

The Kuruk Tagh and Kel'pinskiy Sinisian downwarpings include only a narrow zone of the Tarim massif bordering on the Tien Shan. The southern ridges of the Kuruk Tagh and those of the Azgambulak Tagh in the system of Kel'pinskiy heights are located beyond the limits of the downwarpings, and in them a marine series of the Cambrian-Ordovician lies on a metamorphic foundation.

Evidently corresponding to the Lower Cambrian in the Kel'pinskiy downwarping is the stratum of red saliferous sandstones and basic lavas (200 m) located in the Bitanmatau Mountains and in the Maralbashiyskiy heights (Vazir' Tagh). In the Kuruk Tagh the Lower Cambrian is evidently lacking, but the Middle Cambrian is represented by variegated flints up to 40 m thick which occur mainly on the Paleozoic series.

In the Middle Cambrian the sea flooded the entire northern half of the Tarim massif. The transgression continued until the end of the Ordovician. In the Kuruk Tagh, the marine deposits consist of the Tursuk Tagh series of block limestones and calcareous schists (500 m) containing triolobites of the Cambrian, and the Charakskiy series of schists, siltstones, and limestones (300 m) containing Ordovician graptolite fossils.

In the Kel'pinskiy and Maralbashiyskiy regions, deposits of the Cambrian-Ordovician transgression are represented by the Chul' Tagh stratum of limestones and dolomites (1,200-1,300 m) and the Subashiyskiy limestone argillite series (150 m). To the Cambrian belongs the lower part of the Chul' Tagh limestones having a thickness of 600-700 m, in which are found the thickest blocks of dolomites and red marls. To the Ordovician in this horizon belong the upper part of the Chul' Tagh stratum and the Subashiyskiy series, which contains fossils of various fauna, mainly orthoceratites and trilobites.

Changes in the facies composition and thickness of the Chul' Tagh stratum are evidence of the presence in the northwestern part of the massif of two horizontal upheavlas: the Maralbashiyskiy and the Aksuyskiy. In the region of these upheavals the thickness of the Chul' Tagh straum is minimal (less than 1,000 m). It contains many dolomites, calcareous conglomerates, and red marls, which attest the presence in these areas of the Cambrian-Ordovician sea of broad shoals which were intermittently transformed into dry land and subjected to erosion. In the Chilanskiy zone, which separates the Maral bashiyskiy and Aksuyskiy upheavals, the content of dolomite and fragmental limestone in the Cambrian-Ordovician stratum sharply diminishes but the thickness of the stratum increases to 1,500 m. Also occurring in this zone are thin laminated limestones and limestone argillites of the Subashiyskiy series, which are absent in the uplifts.

At the end of the Ordovician, the Tarim massif was upheaved and almost all of it became dry land. A Silurian sea with geosynclinal conditions of sedimentary accumulation existed on the territory of the Tien Shan and Kunlun mountain systems. A zone of epicontinental shoal waters, within which was laid down a thin stratum (200 m) of red sandstones and

argillites, extended across the area of the Kel'pinskiy ridges and the forward ranges of the Western Kunlun. The red stones of the Silurian lie on different horizons of the Cambrian-Ordovician, but with parallel unconformity. Among the organic fossils in them, gastropods have been discovered. On the main territory of the Tarim massif, which evidently represented a weakly elevated plain, Silurian fossils did not accumulate.

The next advance of the sea over the Tarim massif occurred in the Middle and Upper Devonian. As in the preceding epoch, it flooded only the northern lower boundary of the massif.

Belonging, in the Kel'pinskiy region, to the Middle and Upper divisions of the Devonian is the series of gray-green calcareous argillites and fine-grained sandstones with seamsof argillaceous limestones which cover conformably the red stratum of the Silurian. The thickness of these deposits increases to several hundred meters towards the geosynclinal region of the Tien Shan, while there is a sharp increase in limestones containing fossils of brachiopods, corals, bryozoans, and stromatoporoids of the Givetian and Frasnian stages.

In the Tournaisian stage of the Lower Carboniferous, the sea receded from the Tarim massif, with the result that in the Kel'pinskiy region and in the forward ranges of the Kunlun crossbedded red sandstones and gravels were laid down, representing the sediments of river deltas. Closer to the Tien Shan, the thickness of the Tournaisian red strata increases from 150 to 400 m. long the Chonmuzdukskiy fault, the boundary between the Tarim massif and the geosynclinal downwarping of the Southern Tien Shan, the red strata are replaced by a stratum of marine limestones, schists, and conglomerates about 1,000 m thick. The deposits of the Tournaisian are similarly changed also on the boundary between the Tarim massif and the Western Kunlun.

In the Takla-Makan desert and Tekelik Tagh the Tarim massif remained dry during the whole Middle Paleozoic and was not mantled by sediments. In the Kuruk Tagh, deposits of the Middle Paleozoic are found only in the marginal ridges northwest of Lake Lop Nor where they exist in variegated strata of sandstones and siltstones with seams of basic tuffs and lavas.

In the Visean, tectonic movements were rather strong on the Aksuyskiy, Maralbashiyskiy, and North Kurug Tagh upheavals, on the boundary of which the sedimentary mantle of the massif was subjected to weak folding. Local angular unconformities thus originated here between the Upper Paleozoic limestones, which contain in the basal layers fossils of fauna of the Upper Visean or Middle Carboniferous, and the red strata of the Tournaisian. In the depressions which lie between these upheavals there were no dislocations; thus here the Paleozoic limestones lie conformably on the Tournaisian red strata.

The Maralbashiyskiy upheaval incoudes the heights of the same name, the part of the Kel'pinskiy ridges lying opposite them, and the northwestern part of the Takl-Makan desert as far as the Mazar Tagh ridge.

The center of this upheaval is the dome of the Mazar mountain, whose core was formed by the gently dislocated strata of red sandstones and siltstones of the Lower Cambrian, and whose sides by Cambrian-Ordovician limestones and dolomites. In the arch part of the dome there are numerous dikes of diabases and camptonites with a northwesterly trend, and a mixture of differentiated blocks of syenites with an annular structure.

The Aksuyskiy upheaval is largely a level or gently rolling plain bearing a mantle of Neocene-Pleistocene and very recent deposits. Only in the Azgambulak Tagh and Bitammatau mountains can the structure of this upheaval be seen. In the central region there is an outcropping of a metamorphic stratum and deposits belonging to the Sinisian system. On the slopes of the upheaval there are outcroppings of limestones and dolomites of the Cambrian-Ordovician which rest on various horizons of the oldest complexes.

In the Paleozoic structure of the Kuruk Tagh three major zones can be distinguished: a northern downwarping, which lies along the boundary of the Tien Shan; a southern downwarping, which includes the marginal ridges in the vicinity of Lake Lop Nor; and a central upheaval, which lies between them. Occurring in the northern downwarping are Sinisian and Cambrian-Ordovician strata which form a complete horizon without internal unconformities. In the southern downwarping and on the slopes of the central upheaval, the Cambrian-Ordovician series occurs on Pre-Sinisian rocks. In the broad arched part of the central upheaval, Pre-Cambrian crystallized schists outcrop.

In the Upper Paleozoic the sea covered a considerable part of the Tarim massif. The only areas which remained dry were small areas in the arched parts of the Maralbashiyskiy, Aksuyskiy, and Kuruk Tagh upheavals. The flooding of the Tarim massif by the Upper Paleozoic sea occurred gradually, reaching a maximum in the Lower Permian. The sea advanced from the depressions in which the horizon of its sediments is thickest towards the vaults of the upheavals in which direction the importance in the horizon of continental elements increases and its thickness diminishes.

In the Chilanskiy depression, lying between the Maralbashiyskiy and Aksuyskiy upheavals, the Upper Paleozoic complex consists of limestones, calcareous sandstones, and marls, represented in which, despite their total thickness of only 190 m, are all the divisions of the Carboniferous and Permian. In the Permian horizon of the stratum there are deposits of basalt and tuffs (30 m).

Approaching the Aksuyskiy and Maralbashiyskiy upheavals, the lower horizons of the Upper Paleozoic complex disappear: first the limestones of the Upper Visean and later the Middle Carboniferous. The farthest penetration in the upheavals was made by deposits of the Upper Carboniferous and Lower Permian, among which a considerable role is played by red rocks. The total thickness of the deposits of the Upper Paleozoic in the Kel'pinskiy region varies from 200 m (in the downwarping) to 40 m) (on the slopes of the upheavals).

In the Upper Paleozoic, transgressions first occurred on the southern boundary of the Tarim massif along the Kunlun. In this part of the massif, the Upper Paleozoic is represented by strata of comparatively uniform light-gray limestones 200-250 m thick belonging to the Middle and Upper divisions of the Carboniferous and the Lower Permian, and a sand-schist stratum with conglomerates probably belonging to the Upper Permian.

Belonging to the Upper Paleozoic in the Kuruk Tagh are red sandstones, argillites, conglomerates, and effusive rocks with blocks of limestones laid bare in the Pochentsze and Gentingentograka synclines (200-400 m). In this stratum fossils of marine organisms from the Upper Visean to the Lower Permian have been found.

Deposits of the Upper Paleozoic in the Tarim massif occur in various complexes: on the southern boundary (Tekelik Tagh) they are laid down on a Pre-Cambrian metamorphic base; on the Maralbashiyskiy upheaval they rest on Cambrian-Ordovician limestones; and in the Chilanskiy downwarping they are underlain by red strata of the Tournaisian. Only in parts which were envloped by ancient Hercynian movements do the Upper Paleozoic deposits cover the lower-lying strata unconformably. Usually, however, even in cases of considerable breaks, they lie parallel to the ancient layers.

On most of the territory of the Tarim massif the sedimentary mantle ends with Upper Paleozoic deposits, and only in the downwarpings near the Tien Shan and Kunlun are there found Mesozoic-Cenozoic strata lying with parallel unconformity on the Paleozoic.

In the beginning of the Upper Permian, the Tarim massif was upheaved and became dry. The sea remained for some time along the foot of the Hercynian structures of the Tien Shan and Western Kunlun, but later receded even from these.

Alpine piedmont downwarpings formed in the Permian and Triassic periods: the Kucharskiy depression, which lies along the foot of the Central Tien Shan, and the Yarkend, which is located on the boundary of the Western Kunlun.

The deposits which filled these downwarpings begin with stratum of brown conglomerates and sandstones (500-600 m), which contains pebbles of "shvagerinovyye" limestones. The Traiassic is represented by red-violet sandstones with layers of clay and gravels (200-300 m) which lie on conglomerates of the Upper Permian. Higher follow gray-green coal-bearing deposits of the Rhaetic and Jurassic with an abundance oof plant remains. They contain a considerable amount of coarse sandstones and conglomerates up to 2,500 m thick. The unilateral facies zonality of the Rhaetic and Jurassic deposits of the regional downwarpings of the Tarim massif reflects the movement into them of fragmental material only from the regions of active upheavals of the Tien Shan and Kunlun. The interior regions of the Tarim massif, however, evidently constituted a slightly elevated plain on which neither denudation or sedimentary accumulation could occur intensively.

At the end of the Jurassic the boundary zones of the downwarpings which butt on the Kunlun and Tien Shan experienced a change of the tectonic system and began to upheave. In addition, the region of the submergence and accumulation of deposits was somewhat shifted towards the interior parts of the Tarim massif.

The Yarkend downwarping, one of the largest in Central Asia and territorially and genetically closely linked with the Kunlun upheaval, in relation towhich it is a frontal basin, began to develop in the Cretaceous period. The boundaries of this downwarping in the south are the fractures of the forward terraces of the Kunlun, and in the north the Mazar Tagh fault which separates it from the upheaved regions of the massif (Oykhartskiy upheaval). However, the boundaries of the intensively subsiding part of the downwarping, where deposits were mainly accumulated, regularly shifted. Cretaceous deposits, for example, occur to a considrable degree only in the northwestern part of the downwarping in the Fergana zone of northwestern fractures. Here, in the base of the Cretaceous system, is to be observed a coarse conglomerate lying on Paleozoic rocks and containing them in pebble form. Higher come brick-red sandstones with seams of red-brown clays. Still higher are found red-violet clays and marls covered by marine limestones and gypsums. The thickness of the Cretacious deposits in the southwestern part of the Yarkend downwarping in places attains 850 m. To the east of the Fergana zone of fractures the marls, limestones, and gypsums disappear, and in the horizon of the Cretaceous there remain only red sandstones and clays 300-400 m thick. The same continental sandstones and clays of the Cretaceous are represented also in the Kucharskiy downwarping, but the thickness of the Cretaceous red strata here is 800-900 m.

The Tertiary system, closely linked with the Pleistocene, is divided into two series in the Tarim massif. These differ in the composition of deposits: a red series of the Paleocene and a pale yellow-gray series of the Neocene-Pleistocene.

Deposits of the Paleocene, which in general lie conformably to the Cretaceous, are found with the latter, that is, in the Yarkend and Kicharskiy depressions, but are lacking in the Oykhartskiy upheaval. Deposits of the Neocene-Pleistocene, however, cover a larger area, including part of the Oykhartskiy upheaval (in the Kel'pinskiy region and the Lop Nor lowland).

In the Yarkend depression the Paleocene is represented primarily by marine and lagoon deposits divided into three series:

1. Red sandstones with seams of brown clays and blocks of gypsums in the foundation (130-250 m). The clay seams of the upper part of the series contain fossils of oysters of the Paleocene epoch.

2. Gray marls, calcareous sandstones, and limestones containing fossils of oysters of the Eocene epoch (100-200 m).

3. Rose-gray gypsiferous sandstones, clays, and gravels containing in the lower horizons fossils of Oligocene fauna (1,000-2,000 m).

Marine deposits of the Paleocene are found only in the Fergana zone of fractures and to the west of it. In the eastern part of the Yarkend depression the Paleocene sediments are primarily continental. Marine deposits have been observed only in its lower part, which contains a bed of limestone with fossils of oysters, calcareous sandstones, and blocks of gypsiferous clays. In the Kucharskiy downwarping the Paleocene is represented by continental and lagoon sediments which are divided into two series:

1. Brown-red and gray-yellow sandstones, marls, and clays, including in places seams of gypsum and rock salt, and, in a part to the west of the town of Aksu, also a bed of gray limestone with small freshwater gastropods (200-300 m).

2. Brown-red sandstones and small-pebble conglomerates (1,700 m).

The first series lies parallel with the marine deposits of the Paleocene and Eocene of the Yarkend downwarping; the second, with redstones of the Oligocene and Miocene which lie above.

Deposits of the Neocene and Pleistocene in the piedmont downwarpings of the Tarim massif are represented by straw-coloured sand-clay and gray conglomerate strata which were laid down in the period of the intensive growth of the Tien Shan and Kunlun ranges. The straw-coloured stratum is composed of alternating layers of sandstones, siltstones, clays, and marls. It attains a thickness of 2,500 m in the Artushskiy ridges and in the Yarkend sector of the Kunlun foothills. In its beds have been found fossil plants of the Pliocene.

The gray conglomerate stratum is located in the foothill zone of the downwarping where it attains a thickness of 1,500-2,000 m. Closer to the mountains, the conglomerates in it are replaced by gravels; and later by sandstones which are in turn displaced by siltstones and clays, while the thickness of the stratum diminishes to 300-400 m. The bones of camels, deer, and gazelles have been found in the lower part of the stratum.

Both the alpine downwarpings of the Tarim massif have a sloping form which can be related to the deeper subsidence of their foothill parts. The total thickness of the Mesozoic-Cenozoic deposits in the piedmont zones of these downwarpings, in conformity with the amplitude of their submergence, amounts to 4,500-7,000 m, that is, approximately the same as the height of the Tien Shan and Kunlun systems.

Approaching the Oykhartskiy uplift, the foundation of the Yarkend and Kucharskiy downwarpings rises to the surface and the thickness of the Mesozoic-Cenozoic deposits diminishes. At the same time, the amplitude of submergence of the downwarpng s diminishes and in alignment they extend from the central parts towards the flanks.

Among the strata of sediments which filled the young basins of the Tarim massif the thickest are the straw-colored and gray series of the Neocene-Pleistocene which formed in the period of intensive neotectonic movements of the earth's crust. The straw-colored stratum constitutes the deposits of lakes and plain rivers; the conglomerate stratum, the deposits of the broad outwash fans bordering the foothills of the Tien Shan and Kunlun.

Beyond the limits of the Kucharskiy and Yarkend downwarpings, Neocene and Pleistocene deposits are widely distributed on the piedmont plains of the Altyn Tagh and Kuruk Tagh where they are represented by lower and higher series of "relic hills"; brown-red and gray-yellow gypsiferous sandstones and clays which accumulated in the transitory lakes and the dry deltas of temporary watercourses (100-150 m).

The most recent Quaternary deposits are found over all the Tarim plain. They are represented in the mountain zone by pebbles of the alluvial-prolluvial deposit strip; in the zone of oases by loesses and loess-type loams; in the Takla-Makan desert by windblown sands of various morphological types; and in the Lop Nor lowland (Fig. 23) and Khotan-Keriyskiy interfluve by lake sands and clays.

Besides the large vertical displacements which resulted in the formation of the Kucharskiy and Yarkend downwarpings and which divide them from the Oykhartskiy uplift, the Tarim massif experienced dislocations on a lesser scale. These are revealed in the differentiated movements of blocks along fractures and in local distortions of the beds of its sedimentary mantle.

Alpine structural formations are prominent in the relief which have also been slightly changed by erosion. The types and forms of the structural formations created on the Tarim massif by the most recent movements depend on the depth of the foundation and the thickness of its sedimentary mantle. Three basic types may be distinguished among them:

1. Anticlines and folded anticlines in the thick Mesozoic-Cenozoic deposits of the Kucharskiy and Yarkend downwarpings (Adyrnyy type).

2. Monoclinal structures in the Kel'pinskiy region which constitute part of the Oykhartskiy uplift, characteristic of which is a thin Mesozoic-Cenozoic mantle and a shallow occurrence of the denser Paleozoic strata which earlier were not subjected to folding.

3. Coarse-stone forms of diverse morphology in the regions of the shallow occurrence of the metamorphic foundation (Kuruk Tagh and Tekelik Tagh).

Fig. 23. Deposits of an early stage of the Great Lop Nor on the boundary of the proluvial deposit strip of the Altyn Tagh (east of the Miran settlement).

The displacements of the foundation of the Tarim massif, which were accompanied by dislocations of the sedimentary mantle, were most intense on the boundary of the Tien Shan where a wide strip emerged of young fold-anticlinal and monocline structures. The massif near the Kunlun was less disturbed; in this area there are only separate folds which do not form a unified system.

To the Adyrnyy type belong: in the foothill zone of the Southern Tien Shan, folds of the Artyshkiy group, and also the Chul' Tagh, Adyr Tagh, and Ishtalinskiy folds; and in the foothills of the Western Kunlun, Yangigissarskiy, Bora, Sandzhu, and Duvakyr folds. In these fold systems are found both anticlines, apparent in the relief of mountain ridges, and synclines, apparent in the relief of intermountain troughs and basins. The anticlines which lie closer to the mountains arose earlier and thus are more strongly dissected; tectonic and orographic forms do not fully coincide in them. In the core of these folds deposits of the Cretaceous and Paleocene have been discovered. However, the folds occurring on the boundary of the Tarim plain are younger and less eroded; in these the forms of structure and relief coincide almost exactly. In the peripheral folds, deposits of the older straw-colored series of the Neocene usually do not appear on the surface.

The Adyrnyy folds are as a rule asymmetric: one limb is long and steep, the other is short and gently sloping (flexure-anticlines). Usually the long, steep limb among the folds of the Tien Shan foothills is the southern, while, on the contrary, among the folds of the Kunlun it is the northern. The Adyrnyy folds are 3-10 km wide and hundreds of kilometers long.

In the foothills of the Kunlun the Adyrnyy type is represented by the Yangigissarskiy structure--a young anticline directly observable in the relief and composed of conglomerates and sandstones of the Neocene and Pleistocene. The strike is almost latitudinal (270-250° NW) and lies at an angle to the main northwestern structure of the Kunlun. The dip of the beds in it varies from 5 to 50°. To the same type belongs the flat Bora arch which is recognizable in the relief by a broad ridge. The Bora arch contains the upper horizons of a conglomerate stratum of the Pliocene and Pleistocene inclining towards the slope facing the Tarim plain 2-3° N and towards the foothills of the Kunlun 1-2° S.

Between the Bora arch and the Paleozoic terrace of the Kunlun there is an enormous flat-bottomed syncline which extends from the valley of the Yarkend River to the meridian of the town of Ho-t'ang, attaining a width of 20-25 km. According to geophysical data, the thickness of the Mesozoic-Cenozoic deposits in this syncline is 6-7 km and over a considerable expanse they lie almost horizontally. The southern limb of the syncline is complicated by longitudinal fractures and additional curvatures as a result of which the Mesozoic Cenozoic strata (up to and including the Jurassic) outcropping therein lie vertically or are even overturned. At the eastern end of the Duvakyr syncline the Pliocene-Pleistocene deposits are more steeply dislocated, rise higher over the Tarim plain, and are better exposed.

In this section there is an outcropping in the syncline of rocks of a straw-colored series forming an undulating plain in the relief. In the core there are erosion-resistant conglomerates of the higher-lying strata forming stony uplands.

In the Takla-Makan desert, on the boundary of the Yarkend downwarping and the Oykhartskiy uplift, there is the folded Mazar Tagh ridge which extends in a gentle curve from the valley of the Ho-t'ang River almost to the bend of the Yarkend. The high side of the fold butts against the Oykhartskiy uplift, and the low side butts against the alluvial plain of the Yarkend downwarping. On the upper slope of the fold there is a longitudinal fracture along which it rises and tilts over the northern side by as much as 150 m On the slope of the Mazar Tagh fold Cenozoic deposits are exposed from gypsums of the Bukhurskiy series to sandstones of the Pleistocene. Along the entire ridge the beds dip monoclinally to the southwest at an angle of 25-50°. In the sides of the fold the beds lie almost horizontally, while in the northern side (Oykhartskiy) Mesozoic-Cenozoic deposits are lacking with the exception of thin blocks of red sandstones of the Paleocene.

At the base of the Mazar Tagh dislocation there is a deep fault which has formed a steep ledge in the Pre-Cambrian foundation. This ledge extends beyond the limits of the Tarim plain and continues in the foothill zone of the Southern Tien Shan where it connects with the submergence of the Kel'pinskiy monoclines which are replaced along the trend by the Artushkiy folds. The anticlines and flexure-anticlines of the Mesozoic-Cenozoic strata of the Kucharskiy and Yarkend downwarpings and the monoclinal structures of Paleozoic strata representing a continuation of them in the Kel'pinskiy region constitute a peculiar seamed dislocation formed by the fractures which divide the Pre-Cambrian foundation into variously displaced blocks.

To the Kel'pinskiy type belong the monoclines which replace the Artushskiy folds on the Oykhartskiy upheaval as a result of the fact that the Mesozoic-Cenozoic deposits are lacking here and the upper layer of the sedimentary mantle is formed by strata of more competent Paleozoic limestones and red sandstones deformed not into folds but into monoclines adapted to the fractures.

The Kel'pinskiy monoclines are observable in the relief in the form of cuesta ridges in which the structural and orographic forms conform in general features. All the Kel'pinskiy ridges are similarly constructed. On their steep southern (southeastern) slope, which butts against the fracture, Cambrian-Orodovician limestones are exposed along with redstones of the Middle Paleozoic and a sand-limestone series of the Carboniferous and Permian which inclines into the depth of the slope. Outcropping on the northern (Northwestern) slope are straw-colored and conglomerate strata of the Neocene and Pleistocene. Near the fracture, the beds dip very steeply, sometimes even vertically;

farther away they are gentler and lie at an angle of 5-10° at the boundary of an intermountain trough. The width of the Kel'pinskiy monoclines is 4-6 km, the length up to 200 km, the trend northeasterly. In the Maralbashiyskiy group of heights, the monoclines have a northwest trend and are faulted transversely into short crests. The same transverse ridges can be observed in the Mechetiin Tagh which lie on the southern boundary of the Aksuyskiy upheaval.

The coarse-rock type is distributed in the Kuruk Tagh and in the Tekelik Tagh massif which butts onto the Kunlun. The former is a broad, flat upheaval rising only slightly over the Bagrashkul'skiy depression but appearing rather high from the side of the Tarim basin. In its narrow western part the Kuruk Tagh consists of a horst ridge, while in the central and eastern parts, where its width increases to 90 km, it is divided into several horsts and grabens which successively descend towards the Tarim plain. In the Kuruk Tagh two basic series of horsts can be distinguished: the northern (Borokhotan, Karatekenula, and Yumuluk Tagh), and the southern (the smaller mountain massifs of the Kurbanchik Tagh, Shindi Tagh, Kok Tagh, and others). Between the horsts lies a chain of grabens the stony floors of which lie 500-800 m lower than the summit of the northern series and 150-300 m below that of the southern.

Two systems of regional faults are clearly visible in the southern surroundings of the Tarim massif: a northwestern, defining the strike of the structural-facies zones, folds, and ranges in the Western Kunlun; and a northeastern, defining the direction of main elements of the geological structure and relief in the Central Kunlun. The northwestern and northeastern structural-orographic zones converge to the south of Ho-t'ang. In the region of their junction the Tarim massif forms a terminal wedge-shaped terrace to which belongs the high-altitude Tekelik Tagh massif.

In the Tekelik Tagh the Tarim massif forms two vast arches which are separated by a flat depression about 40 km wide. The latter retains a sedimentary mantle consistng of limestones of the Carboniferous and Lower Permian (240 m), sand-schist series of the Upper Permian (300 m), red sandstones and argillites of the Triasssic(200 m), a gray series of sandstones and argillites of the Jurassic (250 m), and a variegated stratum of sandstones, marls, and clays of the Upper Jurassic, Cretaceous, and Paleocene (500 m). Exposed on the vaults are metamorphic complexes of the Archean and Proterozoic with rare bodies of Pre-Paleozoic granites. The slopes of the vaults retain remnants of the ancient denuded plain which constitutes the surface of the base of the Tarim massif and on which lies a sedimentary mantle. Before the valley of the Chira River, the northern arch descends sharply and terminates and the synclinal depression merges with the Chakar depression. The Tekelik Tagh massif is separated from the plain part of the Tarim massif by faults of a latitudinal trend to which high rectilinear benches can be related in the relief.

Volcanic rocks are found on the Tarim massif only in the piedmont zones (mostly in the northern), which have been affected by Paleozoic and the most recent tectonic movements. They are divided into Sinisian, old Hercynian, young Hercynian, and alpine groups.

The Sinisian group is represented by keratophyres, quartz porphyries, and andesite porphyrites which are constituents of the Altyn Tagh series of the Kuruk Tagh.

The old Hercynian group is widely distributed on the Maralbashiyskiy upheaval. To it belong dikes and intrusive seams of augite porphyrites, diabases, and camptonites, some of which are contained in deposits of the Lower and Middle Paleozoic, but mainly in Cambrian-Ordovician limestones.

The young Hercynian group invludes volcanic and intrusive formations. The former are represented by mantles of fine-grained basalt and basic tuffs, which are found in various parts of the Kel'pinskiy ridges among deposits of the Permian; the latter are represented by the syenite dome of the Mazar mountain in the Maralbashiyskiy heights. The latter is found in the core of a brachyanticline, apparently bounded by annular fractures. It consists of three types of syenites composing the surrounding concentric zones.

To the young alpine group belong the dikes of Sogunkaraul and the volcanic rocks in the vicinity of the town of Keriya. The former, cutting Tertiary sandstones and Clays, are composed of fine-grained dolerites. The basalt mantles and tuffaceous sands of the Keriya region lie on Quaternary pebbles of the valley at the foot of the mountain and on the terraces of the Keriya River.

Mineral Resources

The most important mineral deposits in the Tarim massif are concentrated along its boundaries, particularly in the tectonically most active zone closest to the Tien Shan. These deposits are of polymetallic ores, copperbearing sandstones, petroleum, coal, and sulfur.

The following mineral provinces can be distinguished in the Tarim massif:

(1) the polymetallic provinces of the Kel'pinskiy ridges, the Kuruk Tagh, and the Tekelik Tagh;

(2) the Kashgarskiy and Kucharskiy provinces of copper-bearing sandstones;

(3) the Kashgarskiy and Kucharskiy oil-bearing provinces;

(4) the Kucharskiy and Yarkendskiy coal fields.

The polymetallic provinces belong to the relatively upheaved parts of the Tarim massif, while the provinces of copper-bearing sandstones, oil, and coal fields belong to the Mesozoic-Cenozoic zones of submergence.

The Kashgarskiy polymetallic province, in which more than a dozen ore deposits have been found, occurs on the part of the Oykhartskiy upheaval which joins the active zone of the Tien Shan. The clefts which divide this part of the massif, have facilitated the egress from the depths of active metal compounds and their accumulation in the rocks of the deformed sedimentary mantle. Mineralization in the deposits of this province occurs in the form of thin lodes, nodules, and zones of impregnated and cross-vein ores, which are present in the fissured Cambrian-Ordovician limestones near large fractures. The leading elements here are lead and copper, which are found both together and separately. Zinc and antimony are of lesser importance. The latter is present in considerable quantity only in the Koguzhun Tagh deposit. The polymetallic ore deposits of the Kel'pinskiy province generally are not large and the ores are poor; therefore most of them are not of industrial importance. The Kel'pinskiy province represents, as it were, the southern arm of the broad polymetallic zone of Northern Kashgariya, which comprises the Southern Tien Shan and the adjoining border of the Tarim massif. In the northern arm of this zone, which lies in the Tien Shan, lead ores predominate with higher concentrations of metal.

In the Kel'pinskiy region there are also large deposits of sulfur--ko-nieh-kang and Yang-ki-kang. These are veined and pipe-shaped bodies imbedded in limestones and argillites of the Ordovician.

In the Kuruk Tagh province, which is still poorly investigated, only two lead deposits are now known: the Chaopishanskiy, contained in graywacke sandstones and calcareous schists of the Sinisian; and the Altmyshbulakskiy, found in outcroppings of limestones of the Cambrian-Ordovician on the mountain ridge north of Lake Lop Nor.

The similarity between the Kuruk Tagh and the Kel'pinskiy region in geological development and type of ore mineralization makes it possible to separate in it a metallogenetic province similar to the Kel'pinskiy.

The Tekelik Tagh block is apparently also a region manifesting indications of polymetallic mineralization. One lead-zinc deposit has been found there-the Lyangar-Otrakyr, a system of thin veins of galenite and sphalerite cutting Pre-Cambrian crystalline schists.

The Kashgar and Kucharskiy provinces of copper-bearing sandstones belong to young depressions along the foot of the Tien Shan. Conforming to the configuration of these depressions, which are separated by the Kel'pinskiy ridge from the Oykhartskiy upheaval, the zone of copper-bearing sandstones of Northern Kashgariya is divided into two provinces: the Kashgarskiy and the Kucharskiy. Dozens of deposits have been discovered in each of these provinces. The largest deposits of the Kashgarskiy province are the Chonkan, Tonguzakzy and Kang-ju-kang. The best known deposits of the Kucharskiy province are the Chorgo, Onbashi, and Myskan. In the past many deposits of copper-bearing sandstones were worked. In the individual deposits the ore horizons of copper-bearing sandstones lie conformably with the stratification, and only a comparison of the horizons of various ore-bearing areas reveals the occurrence of them on different

stratigraphic levels. Copper-bearing sandstones are found in deposits of the Upper Cretaceous in all series of the Paleocene and in the lower horizons of the Neocene. Usually the mineralization bears practically no relationship to the lithologic composition and structure of the enclosing rocks. The position of the ore areas along the fractures shows their relationship to intrusive sources. It is possible that the ore entered the zone of sedimentation along these fractures and became enclosed in the accumulating sediments.

Ore minerals in the deposits of copper-bearing sandstones are represented mainly by malachites; found less frequently are azurite, cuprite, native copper, chalcocite, and bornite. Areas with metal concentrations sufficient for development are in general not large.

Oil provinces. Oil accumulations are also found in the same young depressions on the northern boundary of the Tarim massif. They are revealed in the flexure-anticline complex of thick strata of poorly cemented sandstones, clays, and marls of the Cretaceous and Tertiary systems. These folds constitute seamed structures which reveal in the thick sedimentary mantle the massive displacements of the foundation. The flexure-anticlines are complicated by longitudinal and transverse fractures which are particularly numerous in those anticlines which butt onto the Paleozoic massifs of the Tien Shan. The latter are also the most eroded. These special features of the structure of the folds of the interior zone of the foothill area explain the fact that here occur all the known appearances in the region of petroleum on the surface. In the folds of the exterior zone of the foothill area (Myn"yul'skiy in the Kashgar province and Ishtalinskiy in the Kucharskiy province) there are no large continuous fractures, and the existing ones in consequence of their relative youth are only slightly eroded. These folds are probably the most favofable structures for oil bearing.

Coal basins. To the south of the territory of the Kucharskiy and Yarkend depressions, thick gray conglomerates, sandstones, and argillites have accumulated with seams of coal. Evidences of coal seams do not occur in the entire horizon of the Jurassic but are concentrated in the strata of the Upper Lias and Lower Dogger. The greatest coal formation is found in the outcroppings of Jurassic deposits bordering the Paleozoic massifs where the coal-bearing strata contain 5 to 10 seams of workable thickness. Farther away from the mountains, the number of coal seams and their thickness diminish. In the Kucharskiy depression, outcroppings of coal seams of the Jurassic extend along the northern boundary for 200 km. How far the coal seams of the Jurassic extend into this depression under the Cretaceous and Tertiary deposits is not known. If the width of the zone of coal-bearing deposits in the Kucharskiy depression is taken as 20 km, then the area of the basin amounts to 4,000 km^2 and the reserves consist of several billion tons.

In the Yarkend basin, outcroppings of coal seams of the Jurassic extend for a distance of more than 100 km along the trend of the depression and for 10-15 km laterally. The geological reserves of coal in this basin are very considerable. The coals of the Kucharskiy and Yarkend basins are primarily of the low-ash type; in some deposits, of the clinkering type.

3. THE GASHUN'SKAYA GOBI, PEI SHAN, AND THE KANSU CORRIDOR

General Description of Orographic Regions

The Pei Shan, together with the Gashun'skaya Gobi, constitutes an extensive but generally rather low upheaval between the Tarim and Ala Shan sandy deserts. In some places it has the character of a hilly plain, in others, that of groups of rolling hills with individual rocky ridges.

The peculiar features of the orography and tectonic structure of the Gashun'skaya Gobi and Pei Shan which sharply distinguish these regions from the adjacent mountain systems, arise from the fact that on their territories are found two differently oriented systems of faults which occur here with equal force. These are a northwestern system, extending from the Tien Shan and Nan Shan; and a northeastern system, common with the fracture zone of the Central Kunlun. Thus in the Gashun'skaya Gobi and Pei Shan the elevations and structural elements have a block rather than linear development and are distinguished by frequent and sharp changes in trend reflecting the local relationships of the major system of faults.

The Gashun'skaya Gobi and Pei Shan are among the most arid regions of Central Asia, their barrenness exceeding even that of the Takla-Makan desert. Their main landscape types are hilly and stony deserts.

Situated on the southern flank of the Pei Shan is the Kansu corridor, a desert plain possessing in various parts mountain ridges and groups of small volcanoes. In landscape forms the Kansu corridor is more closely related to the Pein Shan than with the Nan Shan, which bounds it in the south.

The Gashun'skaya Gobi is the name for an extensive area of gentle, undulating relief with rocky crests rising here and there. This expanse separates the southeastern spurs of the Tien Shan and Kuruk Tagh from the Pei Shan Its western boundary is a zone of strong faults with a northeasterly trend which create lateral terraces in the relief, to which belong the Kataryulgun, Shaldranbulak, and Iltyrganbulak springs.

These faults intercept the Chol Tagh and enclose the Kyumyshtala intermountain basin The boundary between the Gashun'skaya Gobi and the Pei Shan is also formed by tectonic benches with a northeasterly trend, among which the relief of a hilly plain is replaced by mountain relief.

Although it appears from afar as an ideal peneplain, the surface of the Gashun'skaya Gobi is nevertheless broken, but not deeply dissected. It constitutes a complex labyrinth of broad ravines separated by level hills or rocky crests belonging to outcroppings of the more resistant rocks. The ravines converge on interior closed basins with solonchak wastes or empty into the Khamiyskiy depression and the Lop Nor lowland. The relative elevations of the rocky crests reach 100 m in rare cases, but in the groups of hills do not rise more than 50 m The primary extension of the crests in the western Gashun'skaya Gobi is northeasterly, northwesterly in the center, and again northeasterly in the east

Relative to the Khamiyskiy basin, having elevations of 100-300 m, and the Lop Nor lowland with elevations of 900-1,000 m, the Gashun'skaya Gobi, with its elevation of 1,200-1,400 m, constitutes an upheaval which from the direction of the former appears to be a high mountain dome, but from that of the latter only a slightly elevated hilly plain. The northern flank of the upheaval of the Gashun'skaya Gobi, where the elevation of the relief changes from 300 to 1,100 m, is dissected by extended, deeply incised gorges which narrow in their lower stretches, acquiring the character of canyons. The ravines descending to the Lop Nor lowland are distinguished by shallow incisions and moderate slope.

Areas of internal drainage are found mainly in the northern Gashun'skaya Gobi opposite the Lop Nor lowland and the Shonanorskiy basin. Here on its dome there is a broad, flat saddle with elevations 200-300 m less than those in the parts bordering the Kuruk Tagh and Pei Shan.

The gently sloping vault of the Gashun'skaya Gobi connects the interior chain of the Tien Shan with the Pei Shan. In the south it is bounded by an unclearly defined depression zone which constitutes the southeastern continuation of the Kyumyshtala intermountain basin. In the center of the Gashun'skaya Gobi, where its dome is cut by a lateral saddle, the depression zone merges with the Lop Nor lowland.

The Pei Shan constitutes the most upheaved and active part of a vast flat dome on the earth's surface situated between the Tarim and Ala Shan plains. Because of increased activization, the block structure in the Pei Shan is very prominent. The highest blocks form short mountain ridges, while the lower form broad intermountain troughs. In the Western Pei Shan the trend of almost all the mountain ridges and of the troughs separating them is northeasterly, while in the Eastern Pei Shan it is northwesterly The trend break in the orographic and structural elements of the Pei Shan occurs in its highest part, coinciding approximately with the line of the railroad. In this axial zone of the Pei Shan individual ridges rise to 2,800 m, while the intermountain troughs lie at an elevation of 1,800 m. To the west and east, the altitude of the ridges diminishes from 1,800 to 1,600 m, and that of the troughs to 1,500-1,400 m. The relative elevations of the ridges over the troughs in the axial zone of the upheaval attain 400 m or more, while in its spurs they usually do not exceed 200 m. In the axial zone the Pei Shan ridges converge, diverging farther away from it, with the breadth of the troughs between them increasing from 5-7 to 20-40 km.

The ridges of the Pei Shan are grouped into five completely separate chains having a common base and separated by longitudinal troughs which continue along the entire extent of the mountainous region. These chains, which are named for their main ridges are the following (from north to south): Tsigechintsze, Ma-tsung-shan, Syaomodzunshan', Ying-wang-shan, and Po-hsiang-tse. The grouped Pei Shan chains are coulisse-like in form and developed simultaneously relative to the axial zone of

the upheaval. Some of them run far into the Ala Shan desert; others, however, extend long spurs in the direction of the Tarim plain and then terminate quickly to the east. The northern chains, which butt onto the Khamiyskiy depression, are shorter than the southern chains, which border the Kansu corridor.

The Tsigechintsze mountain chain arises on the boundary of the Gashun'skaya Gobi and terminates in the Karagobi sandy desert a considerable distance from the valley of the Edzin-Gol River. It appears as a stretch of small volcanoes rising 600 m over the surface of the Khamiyskiy depression and less than 150 m over the Yeh-ma-chuan intermountain trough. However, with a girth of 20-30 km and the gentle dip of the slopes of the chain, this difference in elevation is hardly noticeable. The Tsigechintsze is composed mainly of three ridges or groups of hills separated by broad ravines and strips of stony plain. It attains its greatest elevation in the axial zone of the Pei Shan, where the mountain passes reach 2,260 m and the summits of the largest conical hills 2,400 m. Here on the northern ridge is found the small Fochentsze mountain block, whose absolute elevation is about 2,600 m and relative elevation as much as 750 m.

The Tsigechintsze mountain chain is widely but not deeply dissected, The range of variations of its elevation comprises a few dozen meters.

Lying south of the Tsigenchintsze is the Yeh-ma-chuan intermountain trough, a stony plain with a scattering of flat hills, erosion and deflation basins with solonchaks in the centers, and inrunning broad, dry channels. This trough narrows and rises as it approaches the axial zone of the Pei Shan. In the west its width is about 40 km, and its elevations somewhat less than 1,600 m; towards the axial zone its width diminishes to 15 km, while its elevation increases to 2,100 m. Beyond the axial zone the trough again widens to 25 km and its elevation drops to 1,000 m. Moreover, the elevationof the trough increases from the northern edge towards the southern. Therefore the main dry channel is found along its relatively low northern side.

The next mountain chain, the Ma-tsun Shan, also consists of a group of rocky ridges and crests separated by longitudinal erosion hollows. The total width of the range ranges from 12 to 15 km; the elevation of its mountain passes increases towards the axial zone to 2,200 m. The chain rises sharply in the area where the trend changes from northeasterly to northwesterly, its relative elevation attaining 700-900 m and its absolute elevation about 3,000 m. Here oblique tectonic troughs break it into short ridges. The slopes of these ridges are rocky, dissected by deep, narrow gorges, and only in the upper parts of the gorges are there some more or less gently sloping areas with meadows and even forests. The Ma-tsun-shan ridges maintain their high elevation for a distance of only 80 km; beyond this, they descend to the east and terminate on the boundary of the Karagobi.

In the south the Ma-tsun Shan chain is bounded by the Ma-lan-chuan mountain trough, a slightly hilly plain with an almost continuous rubble cover. The breadth of the trough in the western and central Pei Shan is 10-12 km; in the eastern part, 20-25 km. Its elevation increases from the west towards the axis from 1,700 to 1,980 m, but on the other side of the axis it decreases to 1,200 m.

The third zone of heights, grouped under the general name Syaomadzun Shan, begins not far from Lake Lop Nor with the Igiz Tagh group of low ridges having a northeasterly trend and separated by broad tectonic troughs. These ridges are rocky, strongly dissected, and have several crests. The profile of the boundary ridges of this group, bordering the Yardangla and Achiktala, is asymmetric: their exterior slopes are higher and steeper than the interior. The floors of the intermountain troughs are gently sloping plains with infrequent dry channels. Alongside the ridges they are hilly; the lowlands in the center are occupied by solonchaks and salt flats. The elevation of the Igiz Tagh ridges varies from 1,450 m to 1,760 m; the elevation of the troughs spearating them ranges from 1,200 to 1,300 m.

The next ridge to the east of this chain, the Sulussiin Tagh, does not have a uniform trend. Its western part follows the trend of the Tien Shan (NW), and its eastern that of the Altyn Tagh (NE). In both parts the Sulussiin Tagh is divided into parallel crests and ridges. Still farther to the east, the Syaomadzun Shan constitutes an arched upheaval with an absolute altitude of 1,700-1,800 m and scattered groups of hills and rocky slopes rising 80-150 m over its surface. This elevation is not a uniform crest, although the general northwesterly trend of its individual elements is clearly defined. The Syaomadzun Shan mountain chain extends to the valley of the Edzin-Gol River, even crossing to its eastern bank (Kukuula ridge).

The still more southerly chain of the Pei Shan, the Ying-wang Shan, also does not constitute a uniform mass but is divided into a large number of hills and rocky crests with relative elevations of 100-150 m located on a common base.

The Ying-wang Shan originates on the meridian of the town of An'si and extends to the Edzin-Gol valley, before which it is cut off. It is separated from the Syaomadzun Shan by a narrow lowland filled with low flat-topped hills between which run dry channels and small basins with smooth clay areas of salt flats or hilly solonchaks. To the south the Ying-wang Shan spreads into a stony plain somewhat hilly near the mountains but perfectly smooth farther from them. The breadth of the plain is 50 km in some places.

The most southerly ridge of the Pei Shan, the Po-hsiang-tse, beginning north of the town of Yui-meng, quickly transforms into an extensive zone of heights possessing in the northern part rocky slopes up to 240 m high, and in the southern part rolling and flat-topped hills. The slopes, consisting of seams of hard rocks, are separated by deep depressions now

broad and open, now narrow and closed. The floors of the depressions are covered with rubble and loam. The Po-hsiang-tse gradually descends towards the Kansu corridor and on the boundary of the latter becomes a series of low hills with an absolute elevation of 1,350 m. Towards the Edzin-Gol valley the Po-hsiang-tse becomes a small rocky elevation finally terminating here.

The Lung Shan range occupies a special position in the system of heights of the middle of Central Asia. Because this range is found to the north of the Kansu corridor, which is taken as the boundary of the Nan Shan and Pei Shan, it is assigned to the latter. Actually, however, the Pei Shan extends eastward only to the valley of the Edzin-Gol River, while the Lung-shan originates beyond the Edzin-Gol and extends to the town of Shuykhe. Moreoever, the western spurs of this range cut the Kansu corridor obliquely and approach closely the foothills of the Nan Shan. However, the landscape of the Lung-shan is more similar to that of the Pei Shan, due to their common proximity to the Ala Shan desert.

The Lung Shan constitutes a comparatively small upheaval on the boundary between the Ala Shan massif and the Kansu corridor, and consists of two, three, and even four low chains, completely bare and rocky and extending from NW to SE. The width of the Lung Shan upheaval varies from 20 to 25 km. Its ridges are separated by spacious tectonic valleys which branch off the Kansu corridor. The southern ridge is the highest, rising in the area of the town of Chan-yeh with summits attaining up to 3,650 m. In the Lung Shan there are many broad plateaus with steep sides cut by canyons; only the highest ridges are crowned by rocky crests. Towards the Edzin-Gol valley and the sands of the Tyngera, the Lung Shan descends sharply and is transformed into broad rocky slopes.

The ridges of the Lung Shan protect the oases of the Kansu corridor from the dry winds of the Ala Shan desert.

Kansu corridor is the general name for a chain of basins between the Nan Shan and Pei Shan, through which a famous silk route formerly ran from China to the Mediterranean countries and Byzantium, and through which a railroad to Sinkiang and Alma-Ata now runs. In the Kansu corridor are found many large oases fed by the streams flowing off the slopes of the Nan Shan.

The western part of the Kansu corridor, the most barren, has a latitudinal direction and serves as a connecting link between the Tarim and Ala Shan plains. Here it constitutes a flat tectonic trough 40-60 km wide. In the vicinity of An-hsi and Yui-meng it is much constricted by hills and ridges which wedge it in on both sides. The hills form an interior watershed forcing the Su-le Ho to turn to the west, and the tributaries of the Edzin-Gol to alter their course to the east.

The middle part of the Kansu corridor, which is separated from the western by the spurs of the Lung Shan, has a northwesterly trend, conforming to the direction of the ranges which border it. It butts onto the very high and snowy mountain group of the Nan Shan and is therefore better watered. In this part of the basin there are two expansions: one in the direction of the town of Chiu-chiu-an, the other towards the town of Chan-yeh, where its breadth approaches 60 km. Between the two broadenings, expanded ridges rising before the Nan Shan constrict the basin to 20-25 km.

Beyond the town of Wu-wei follows the part of the Kansu corridor which is almost completely mountainous; there remains free from mountains only a narrow pass about 10 kilometers wide running along the Lung Shan side. From this (Yung-chan) mountain link there begins the eastern part of the Kansu corridor, which butts onto the valley of the Huang Ho. Here the depression merges in the north with the gently rolling Ala Shan plain, from which direction there is an intrusion of the barkhan sands of the Tyngera. The eastern Kansu corridor is barren because it lies along the foot of the snowless spurs of the Nan Shan, from which little water flows, and is not protected from the dry winds of the Ala Shan.

The entire surface of the Kansu corridor is gently inclined toward the north, toward the less powerful upheavals (Pei Shan and Lung Shan). This slope causes a zonal pattern in its landscapes. Along the Nan Shan stretches a broad zone of pebbles of an alluvial-prolluvial strip--a stony desert. Farther follows a zone of loess-type loams with semidesert and dry-steppe vegetation. Here there are oases along the main rivers. In the lowest part of the basin there are solonchak wastes and broad alluvial flood-plains.

The Gashun'skaya Gobi, Pei Shan, and the western Kansu corridor, together with the adjoining eastern parts of the Tarim plain and Dzungariya, constitute the most arid region of Central Asia. They also constitute a peculiar climatic line dividing the western half of Central Asia, which is affected by the Atlantic air current, and the eastern half, which is affected by the Pacific air current. Here only a few dozen millimeters of precipitation fall annually, with the result that there is not a single permanent watercourse, springs being small and very rare.

The large number of rocky outcroppings on the territory of the Gashun'skaya Gobi and the Pei Shan, the abundance of solar light and heat falling on their surfaces, and the absence of a vegetation cover facilitate a rapid heating of the lower layers of the atmosphere and a rise in the barometric minimum. This causes a disturbance of the atmosphere, particularly strong during the active periods of the Mongolian-Siberian anticyclone.

The Gashun'skaya Gobi, Pei Shan, and adjoining areas of the Kansu corridor, Lop Nor lowland, and Dzungaria constitute an area of intensive weathering. The finely fragmented products of weathering do not accumulate in this region but are gradually carried by the wind into other areas: sandlike particles into the sandy-desert zone of the Tarim

and Ala Shan, and dust particles into the loess zone lying to the south. Due to the extreme aridity, erosional dissection of the surface of the Gashun'skaya Gobi and Pei Shan is minimal. The principal factor in denudation here is deflation, caused by the strong steady effect of wind on the original rocks and the products of their disintegration. As a result of the large temperature variations which cause first expansion, then contraction, of the rocks, they split and disintegrate. The fragments separated from the rocks are scattered over the surrounding area, in some places burying the rocks themselves. The wind sorts this "mountain waste," lifting and carrying the fine particles and leaving in their place the rubble from which originates the stony armor of the desert. Such stony deserts (gammady) cover large areas throughout the Gashun'skaya Gobi and Pei Shan.

The prominent role of deflation in this region results in the formation of a peculiar form of relief--enclosed basins and holbws on the outcroppings of soft, easily weathered rocks and rocky ridges; and on the outcroppings of hard rocks, resistant to desert weathering. Widely distributed here also are sculptured rocks, niches, potholes, and other forms of microrelief found most frequently on the outcroppings of granites and gneisses. In the Gashun'skaya Gobi and Pei Shan the lithological composition of the rocks, which determines the degree of their resistance to the processes of deflation, is of very great importance, because in the final analysis the type of microrelief depends on it.

In the Kansu corridor the aridity moderates toward the east. Still widespread in the western part of the depression are flat-topped hills, small ridges, and trenches, which recall the yardangi of the Lop Nor lowland. In the central part there are no longer any deflated forms, and here small masses of shifting sands appear. From the town of Chan-yeh there stretches a zone of loess accumulation, first in the form of separate fields separated by eroded areas, farther a continuous loess cover of gradually increasing thickness.

Hydrographic Net

The hydrographic net of the Gashun'skaya Gobi and Pei Shan consists of numerous dry channels ("sayry") in which water appears only after strong downpours, which occur here only at intervals of several years. The sayry run in various directions towards the nearest large lowlands and form several extensive landlocked basins. The largest of this are the Shonanorskiy enclosed basin, which takes in the northern parts of the Gashun'skaya Gobi and Pei Shan; the Edzingol'skiy basin, to which belongs the eastern half of the Pei Shan up to its axial zone, which serves as the main watershed of this mountainous region; the Lop Nor basin, located on the southern edge of the Gashun'skaya Gobi and the southwestern spurs of the Pei Shan; and the basin of the Su-le Ho, including the southernmost ridges of the Pei Shan. There are no permanent surface watercourses in the Gashun'skaya Gobi and Pei Shan. Only on the Ma-tsung Shan ridge, whose individual summits reach to nearly 3,000 m, do streams flow for

short periods after rains. Here, along the foot of the ridge, springs appear which water small meadow tracts. In the Gashun'skaya Gobi and Pei Shan springs are small and are rarely encountered. They are also seldom encountered in the highest axial zone of the Pei Shan, along which run a motor road and railroad, and are scattered in the remaining territory. For example, in the Gashun'skaya Gobi, with an area of more than 20,000 km^2, only a few dozen small springs and wells are known, these with strongly mineralized water usually unfit for drinking. And even these are so small that after each passing caravan they remain dry for many hours.

The Kansu corridor is watered by streams flowing down the slopes of the Nan Shan and forming three large rivers--the Su-le Ho, Edzin-Gol, and Shui Ho, which belong to different landlocked basins.

The Su-le Ho, which turns to the west immediately after issuing forth from the Nan Shan, flows along the Kansu corridor for a distance of 320 km to the dry Ta-shih-hu lake basin, which borders the Lop Nor lowland and is separated from it by a low eastern spur of the Kum Tagh terrace. In the Pleistocene, when the lake was filled with water and the spur of the Kum Tagh was lower, the Great Lop Nor and the ancient Lake Ta-shih-hu constituted one reservoir. Now into the basin of the latter there runs only a dry channel of the Su-le Ho, its waters remaining in Lake Khalachi.

Between the town of An-hsi and Lake Khalachi, the Su-le Ho flows slowly in a broad, flat valley bounded by solonchaks. In this part of the valley there is also a large lake reservoir (the ancient Lake Khalachi) which is of the same age as the Great Lop Nor (Fig. 24).

The Edzin-Gol River is formed by the junction of the Hei Ho and the Lin-shui which collect water from the central, highest, and most snow-covered part of the Nan Shan. In the Kansu corridor the Lin-shui forms only a short bend, but the Hei Ho flows through its plains along the northern edge for about 200 km.

Fig. 24. Ancient lake deposits in the valley of the Su-le Ho. (photograph by A. Steyn).

These rivers come together in a tectonic valley between the western spurs of the Lung Shan and Pei Shan. The Edzin-Gol River, which is thus formed, flows northeast along the boundary of the sands of the Badan-Dzhareng to an extensive lowland on the northern margin of the Ala Shan desert, where it separates into several channels and then terminates in lakes Gashun-Nur and Sogo-Nur.

The Shui Ho is formed in the Kansu corridor from a large number of streams flowing from the eastern spur of the Richthofen range. Despite a considerable diversion of its water for irrigation purposes, the Shui Ho nevertheless flows for a long distance within the Ala Shan desert and forms in it Lake Khara-Nur, as much as 30 km in circumference.

Flora and Fauna

In the Gashun'skaya Gobi, Pei Shan, and western Kansu corridor there is only a very sparse vegetation cover. It is concentrated in hollows, enclosed basins, along dry channel arms, and in river valleys. Usually very stunted, permanent xerophytic bushes and underbushes predominate. Annuals are of scant importance, and there are no ephemerals at all.

Predominating in the Gashun'skaya Gobi and Pei Shan are bare outcroppings of basal rocks covered with rubble with a sun-blackened desert cover. Only in the depressions do there appear ephedras, clumps of saxaul bushes, kharmyk, yellow-wood Zygophyllum, Nitraria, halophytes; along the dry channels there are also tamarisk, reeds; and in the Pei Shan these and African millet.

On the solonchak deserts, which occupy extensive areas in the valley of the Su-le Ho and in the landlocked basins of the Gashun'skaya Gobi there are various halophytes, small reeds, and solitary bushes of stunted tamarisk .

In the desert area of the Gashun'skaya Gobi and the Pei Shan there is forest and meadow vegetation only on the Ma-tsung Shan ridge. Growing in the upper valleys which cut through the northern slope of this ridge are spruce forests with birch, mountain ash, and buckthorn. In spring-watered areas there are small meadow tracts with clusters of tograks.

In the Kansu corridor large areas are occupied by oases bounded in the west by solonchak and mound sands and in the east by a grassy steppe.

Animals are comparatively numerous and diversified in the Gashun'-skaya Gobi and Pei Shan despite the extreme poverty of food sources and the lack of water. In the Gashun'skaya Gobi, animals are little hunted by man. Thus preserved here is a rare representative of Central Asiatic fauna--the wild camel, individual herds of which even now are composed of 50-60 individuals. In the Pei Shan koulans and gazelles are encountered. In the Kansu corridor, where there are many roads and populated oases, almost no ungulates remain.

Geological Structure

The Gashun'skaya Gobi and the Pei Shan have been covered only by sketchy route surveys, so that their geological structure can be depicted in only the most general terms. The Kansu corridor has been more investigated in connection with oil surveys.

In the Gashun'skaya Gobi and the bordering spurs of the Pei Shan there are four geologically different zones:

(1) a crystalline zone embracing the southern slope of the upheaval of the Gashun'skaya Gobi and a considerable area of the western spurs of the Pei Shan, within which are found primarily metamorphic strata and Pre-Cambrian granites;

(2) the Chol Tagh zone, also found in the northern part of the Gashun'skaya Gobi, distinguished by the formation of a thick, complexly warped stratum of the Ordovician and Silurian;

(3) the Inkikaran Tagh zone of ancient Hercynian formations, located on the mountain ridge of the same name and characterized by a folded Middle Paleozoic formation;

(4) the Kumyshtalinskiy zone of the southern Gashun'skaya Gobi, where Middle Paleozoic deposits are found.

In the Pei Shan two zones of metamorphic rocks are distinguished in which are also found very large blocks of granites. In the center zone of the Pei Shan are found mainly Paleozoic rocks of two different structural series: the Caledonian (Ordovician-Silurian) and the Hercynian (Carboniferous). In the eastern part of this zone Jurassic and Cretaceous deposits lying unconformably on the Paleozoic are widely distributed.

The Kansu corridor constitutes a region of young submergence composed of a large number of blocks which have sunk to different depths. Its primary structural elements are the Chiu-chiu-an, Chan-yeh, and Chao-shui basins, in which the Mesozoic-Cenozoic sedimentary complex attains a maximum thickness. These basins are separated by upheavals in which the Pre-Mesozoic foundation either outcrops or lies unconformably under a thin mantle of late-Tertiary deposits.

Gashun'skaya Gobi. The crystalline zone of the southern Gashun'skaya Gobi and adjoining western spurs of the Pei Shan lies on a continuation of the ancient foundation of the Tien Shan. Among the ancient rocks of this zone two complexes are distinguished according to degree of metamorphosis: a gneiss-schist, possibly Archean; and a schist-marble-phyllite, Proterozoic.

The gneiss-schist complex is composed primarily of quartzmica schists and paragneisses containing garnet, sillimanite, and other minerals of the deep zone of metamorphosis. Found less often are hornblende schists and quartzites, forming bodies several meters thick in the schist-gneiss stratur .

The schist-marble-phyllite complex is considerably more widely distributed than the gneiss-schist. Two strata can be distinguished in the former: a lower, composed of dark-gray biotite and micaceous thin-layered schists; and an upper, an alternation of bodies of thin-seamed marbled limestones and dolomites with fine-grained quartzites and sericite-chlorite phyllites, and sometimes with green schists. The metamorphic strata are impregnated with small bodies of granites, granodiorites, and diorites of various forms which in volume sometimes predominate over the enclosing metamorphic rocks. The composition of individual bodies depends on the enclosing rocks. In those cases in which intrusions occur among marbles or green schists, present in their endo-contact points are gabbro-diorites alternating deeply in the block with quartzitic diorites and tonalites. The intrusive bodies lying among phyllites are granite and granodiorite in composition. In the neighboring Kuruk Tagh the intrusive bodies of this group are covered by deposits of the Cambrian-Ordovician, and their Proterozoic age is beyond doubt.

The crystalline zone of the Gashun'skaya Gobi and the western spurs of the Pei Shan upheaved mainly in the Paleozoic and Mesozoic-Cenozoic. Thus on its territory blocks of the ancient metamorphic foundation either outcrop or lie shallowly under a volcanic stratum of the Upper Paleozoic and red Tertiary deposits.

The northern zone of Caledonian formations is a continuation of the Lower Paleozoic geosyncline of the Chol Tagh. Located within it is a thick and strongly warped stratum of the Ordovician-Silurian composed of gray-green sandstones, siltstones, and shales. In places this straum contains bodies of greenstone spilites and porphyritic tuffs, and there are also individual beds of marbled limestones.

The succession of bedding in the sandy-shale stratum is not apparent. However, the predominance of limestones and calcareous-argillaceous shales in its southern outcroppings bordering on the old strata of the crystalline zone, and of siliceous rocks and spilites in the northern outcroppings extending to the zone of the Upper Paleozoic, permits surmising that the former belong to the lower half of the stratum, and the latter the upper half.

The sand-shale stratum forms steep folds with a usual dip of the beds of 60-80° and a trend of 290-300° NW in the Gashun'skaya Gobi and 60° NE in the western Pei Shan.

Lying unconformably on the Ordovician-Silurian stratum is an Upper Paleozoic complex of variable composition. In the western Gashun'skaya Gobi, in the part which belongs to the dome of the upheaval, there is found at the base of the Upper Paleozoic complex conglomerate with red calcareous-argillaceous cement, above which there are limestones with fossils of the Upper Visean. Still higher follows a series of gray and gray-brown sandstones interbedded with argillaceous schists.

On the northern slope of the upheaval of this same western part of the Gashun'skaya Gobi, the deepest layers of the Upper Paleozoic complex are represented by a body of gray and gray-brown sandstones and siltstones with thin seams of limestones containing remains of Upper Visean fauna. Higher follow gray-green siliceous and tuffaceous graywackes with individual beds of spilite and basic tuffites. Still higher lie tuffaceous sandstones interbedded with andesite and pyroxenic porphyrites, tuffs of porphyrites, breccia, and limestones, and containing fusulinids and corals of the Middle and Upper Carboniferous.

The upper horizons of the Upper Paleozoic complex contain so much volcanic rock that sedimentary formations (siliceous siltstones and graywackes) play a secondary role. In addition, also found among the volcanic rocks are acid varieties: for example, dacite and quartzite porphyries and felsites gradually supplanting augite and andesite porphyrites. The highest level of the complex is composed of acid lavas and tuffs, among which rhyolites and obsidians are frequently encountered.

In the eastern Gashun'skaya Gobi and in the western spurs of the Pei Shan the thickness of the Upper Paleozoic complex is less and consists almost entirely of volcanic rocks.

In the zones extending to the large faults, the Upper Paleozoic complex forms steep folds; usually, however, it lies gently in the form of depressions complicated by interior distortions.

In the Ying-ki-kara Tagh zone there is a sand-shale stratum steeply folded and having a northeasterly trend. The lower horizons of this stratum are composed of gray and gray-green sandstones and siltstones; the middle, of gray sandstones, siltstones, and gravels of quartz and mixed composition; and the upper horizons, of conglomerates, bodies of brown-red shales and siltstones, siliceous rocks with lenses of limestones and graywackes. The total thickness of the Ying-ki-kara Tagh horizon is about 2,000 m.

Fauna remains have not been found in the deposits of the Ying-ki-kara Tagh zone. The lithological resemblance of these deposits to the sand-shale strata of the interior Tien Shan and Nan Shan makes it possible to conditionally assign them to the Lower Paleozoic (Cambrian-Ordovician).

In the Kumyshtalinskiy zone are found Silurian and Devonian deposits in facies typical for the interior Tien Shan. The Devonian stratum of this zone includes brown-red sandstones, black argillaceous shales, and siliceous siltstones alternating with bodies of gray limestones and greenish-gray calcareous-argillaceous shales. In the upper level of the stratum limestones predominate containing the remains of various fauna of the Devonian. Over most of this zone the deposits of the Silurian and Devonian lie relatively sloping (20-35°), and only near the faults, particularly the marginal, do they lie steeply with frequent changes of direction and dip.

In the Gashun'skaya Gobi several large Paleozoic granite blocks have been found with diameters of 10-25 km. The granite blocks lie mainly among the metamorphic strata of the crystalline zone, but in places they intrude into the sand-shale stratum of the northern zone of the Gashun'skaya Gobi. Among the most widely found varieties of rocks in these blocks are adamellites and perthitic granite.

Pei Shan. As a while the Pei Shan is a broad dome in the western (sharply constricted) part of the Sinisian shield between its Tarim and Ala Shan massifs. The slopes of the dome facing towards the Kansu corridor and the Khamiyskiy basin constitute sloping plains with scattered tableland heights composed of red Tertiary sandstones and clays. The vault of the Pei Shan dome, 125 km in diameter, is broken by faults in the northeastern and northwestern directions into separate blocks with different heights. The highest blocks form low mountain ridges, and the lower blocks form intermountain troughs.

The profile of the Pei Shan dome is asymmetric: the height of the base of its southern slope is 1,100-1,150 m, and that of the northern is 500 m or less.

The heights of the Pei Shan are composed primarily of ancient metamorphic rocks and granites and, to a lesser degree, of an Upper Paleozoic stratum in which a considerable role is played by various volcanic formations. In conformity with the location of the outcroppings of these rocks, a northern and a southern crystalline zone are distinguished in the Pei Shan, as well as a region of Paleozoic submergence separating them and filled with Ordovician-Silurian and Carboniferous strata.

The northern crystalline zone of the Pei Shan, embracing a group of mountain ridges and chains with the general name of Tszingechintsze, is distinguished by granites and ancient metamorphic rocks. Particularly widespread are gneisses, represented by a dark variety with a high mica content, and a gray-rose variety composed of quartz, muscovite, feldspar, and garnet. Migmatites are found in the zone of intensive granitization The gneisses are interbedded in strips of varying width with quartzitic-micaceous, amphibolic, and quartzitic-chlorite schists sometimes containing bodies of marbles. The trend of the metamorphic series in the western half of the Pei Shan is 70-55° NE , and in the eastern 300-280° NW.

The metamorphic stratum is impregnated with small but numerous bodies of granitoids extremely varied in texture and composition. These change from leucocratic granite to diorite. Characteristic is an abundance of dikes of diabases extending in the northeasterly and northwesterly directions.

The Paleozoic zone includes the central group of ridges and crests of the Pei Shan, including the Ma-tsung Shan. Within it there predominate rocks not subjected to metamorphosis and usually separated into two complexes: a sand-shale with limestones, and a volcanic-sedimentary. The latter is undoubtedly of the Carboniferous period, while the former clearly is similar in age to the Ordovician-Silurian strata of the Tien Shan and Nan Shan systems. The sand-shale complex, supposedly of the Lower Paleozoic, is found in the north of this zone (ridges of the Madzunshanskiy chain), with the volcanic-sedimentary complex to the south of it (ridges of the Syomadzunshanskiy and Ying-wang Shan chains). Across individual parts of these different-aged complexes lies a zone of metamorphic outcroppings with intrusions of granites and diorites. The Lower Paleozoic complex on the lower level is composed of dark-gray blocks of limestones containing in some horizons seams and lenses of black flints. In the middle level the Lower Paleozoic is represented by alternating yellow-gray blocks and dark-gray thin-bedded limestones, usually strongly silicified. Its upper level is composed of quartz sandstones, siltstones, and argillaceous-siliceous schists. The thickness of the limestones is about 500-600 m; the sandstone-shale mantle which covers them is of the same thickness. The Lower Paleozoic complex forms large asymmetric folds in which the beds usually dip no more steeply than 35°. The area of the distribution of the Upper Paleozoic is comparatively narrow in the western and watershed parts of the Pei Shan, but broadens rapidly to the east. Before the valley of the Edzin-Gol River all the mountain chains of this system consist mostly of the Upper Paleozoic complex, which here is

thicker and more complete. In the eastern spurs of the Pei Shan the Upper Paleozoic complex begins with a Visean stratum of limestones alternating with sand-shales. Above follows a volcanic-sedimentary stratum composed of lavas of quartz and dacite porphyries, felsites, and andesite porphyries, between which lie beds of acid and mixed tuffs, and also bodies of sedimentary rocks: tuffaceous sandstones and conglomerates, siliceous siltstones and shales. The total thickness of the deposits of this group is about 2,000 m.

In the western and watershed parts of the Pei Shan, the Upper Paleozoic complex is represented only by a volcanic stratum several hundred meters thick. The dislocation of the volcanic-sedimentary stratum is nonuniform: near the faults its beds lie steeply, but comparatively gentle sloping in the areas between faults.

In the Paleozoic zone of the Pei Shan are found several grabens with a Jurassic coal-bearing sandy-argillite stratum and broad depressions filled with Cretaceous deposits: conglomerates and red sandstones with seams of brown and yellow-gray clays.

The southern crystalline zone of the Pei Shan includes a group of mountain ridges and small volcanoes with the general geographic name of Po-hsiang-tse. In the southernmost ridges bordering the Kansu corridor are found mainly biotite and biotite-hornblende schist granites dissected by numerous dikes of granite-porphyries, porphyries, and aplites. Occurring to the north, besides granites, are granite gneisses and biotite paragneisses to which are joined still farther north quartz-mica schists alternating with blocks of marbles and mica-carbonaceous and amphibolic schists. The trend of the rocks of the metamorphic series is latitudinal and NW to 285°; the dip is steep, mostly to the north. In the northern ridges the groups of the Po-hsiang-tse again form considerable granites and their vein derivatives, while the degree of metamorphosis of the Pre-Cambrian rocks increases and among them gneisses with abundant aplite injections again appear.

The Po-hsiang-tse is separated from the central chains of the Pei Shan by the broad Dolonmodo intermountain trough, a stony desert studded with flat hills on whose slopes in some places horizontal beds of brown-red sandy Tertiary clays outcrop from under the rock debris.

Lung Shan. Two major structural-facies zones are distinguished in the Lung Shan. One of these comprises its northwestern ridges butting onto the Pei Shan; to the other zone belongs its main ridge rising on the meridian of the town of Chuan-yeh and extending eastwards to the Chao-shui basin. The zones differ in the composition of the rocks underlying the Upper Paleozoic volcanic-sedimentary stratum: in the northwestern zone gneisses and schists of an old metamorphic series, and in the southeastern zone a strongly dislocated sand-shale stratum of the Lower Paleozoic.

Kansu Corridor. The Kansu corridor constitutes a Mesozoic-Cenozoic downwarping facing the Nan Shan and separated by interior upheavals (between Gaotayem and Chuan-yeh and in the Yung-chang region) into the separate Chiu-chuan, Kan-chou, and Chao-shui basins.

The foundation of the Kansu corridor, outcropping on the Lung Shan in the foothill ridges of the Nan Shan, and on the interior upheavals, is formed by a Pre-Cambrian metamorphic series and a Lower Paleczoic complex. The first is composed of gneisses, quartz-mica schists, quartz-serite-chlorite phyllites, and numerous small bodies of old granites of varied composition; the second is composed of gray-green sandstones and shales which here and there enclose layers of limestones. The Lower Paleozoic complex of the Kansu corridor is sharply distinguished from deposits of the same age in the Nan Shan: within it there are no volcanic elements, it is comparatively thin, and is warped into simpler folds whose formation was not accompanied by dislocations of metamorphic sediments.

Along the southern boundary of the Kansu corridor there stretches a zone of outcroppings of variegated deposits of the Silurian, Devonian, and Tournaisian, laid down in the foothill downwarping of the Nan Shan (Richthofen range). In this zone the Silurian is represented by yellow-gray, green, and red shales and sandstones with beds of limestones (1,000 m); the Devonian, by a series of red-brown and violet sandstones, gravels, and shales (500-600 m); and the Tournaisian (found in separate parts) by variegated conglomerates and bodies of red sandstones and mantles of andesites (1,000 m). The succeeding Upper Paleozoic series is found along the entire corridor but is not everywhere represented with uniform completeness. In the part of the corridor facing the Nan Shan, from where a transgression developed, the basal layers of the series are composed of sandstones, shales, and limestones with Visean products (200 m); and its other parts are composed of crinoid limestones, quartz sandstones, and argillaceous shales of the Middle Carboniferous (50-100 m). The Upper Carboniferous, which is present everywhere, is represented by gray fine-seamed limestones, brown sandstones, and dark shales with beds of coal. The Permian, like the Visean, is found only along the south of the corridor. In the lower horizons it is represented by gray-green, yellow, and white quartz-mica sandstones and shales (350 m), and in the upper by videt sandstones and shales (370 m).

Large areas in the heights of the Kansu corridor are occupied by granites intruding into the Lower Paleozoic deposits but not affecting the coal beds.

The sea covered the Kansu corridor for the last time in the Permian period; later there began here a long-continued period of continental development during which there was laid down a thick series of Mesozoic-Cenozoic deposits filling the Chiu-chuang, Kan-chou, and Chao-shui basins. Beneath the Mesozoic-Cenozoic series is found a stratum of red-violet sandstones and conglomerates of the Triassic up to 800 m thick. The Triassic sediments were laid down near the area of drift, and are thus poorly sorted, oblique stratification being often found.

Higher lies a Jurassic stratum of gray-green sandstones, siltstones, and argillites with thick bodies of conglomerates and coal beds (1,000-2,000 m). In the upper horizons of the Jurassic stratum there are red argillites and sandstones with gypsum. The Cretaceous begins with a series of dark-gray argillites with beds of argillaceous limestone (150 m) covered in the central parts of the basins by paper shales rich in organic substances (10 m), which on the boundaries are replaced by red argillites and sandstones. Still higher lie gray argillites and sandstones in which are found the remains of insects and fishes (450 m). The horizon of the Cretaceous system is topped with red-gray sandstones and conglomerates (200 m).

The Tertiary deposits of the Kansu corridor are clearly separated into two strata: a lower, composed of orange sandstones and clays evidently belonging to the Paleocene and Miocene (600-700 m); and an upper, formed of gray-yellow Pliocene conglomerates and sandstones (1,000 m). To the Quaternary system belong the pebbles of the foothill deposit strip and the loess-type loams covering the surface of the depression.

The southern areas of the Kansu corridor depression, bordering the higher Nan Shan have sunk more deeply than the northern areas which border the less-upheaved Pei Shan and Lung Shan. Thus the Carboniferous and Permian seas were located along the Nan Shan, while towards the Pei Shan and Lung Shan the marine sediments are gradually being replaced by continental sediments. The Mesozoic-Cenozoic series along the Nan Shan boundary are thick and composed of coarser sediments.

In the central parts of the basins, in the Mesozoic-Cenozoic deposits there are no noticeable breaks and unconformities, but alongside the Nan Shan and Pei Shan, and also on the boundaries of the interior upheavals, there appear in these deposits large-scale breaks and transgressive overlappings of the older rocks of the foundation by young sediments. The Chiu-chu-ang, Kan-chou, and Chao-shui basins are in turn broken up into smaller blocks displaced to diverse extent. The block structure of the foundation of these basins can be seen in their Mesozoic-Cenozoic sedimentary mantle in the form of the flexure anticlines forming on the terraces of grabens and domes the cores of which are composed of the horst-shaped active wedges of ancient rocks.

The western Kansu corridor, shut off from the Chiu-chuan basin by the spurs of the Lung Shan, originated in the Tertiary period. Here are found only the deposits of the Neocene and Quaternary periods, which together constitute a mantle several hundreds of meters thick under which there are metamorphic rocks and in places Upper Paleozoic strata.

Mineral Resources

Data on the useful minerals of the Gashun'skaya Gobi and Pei Shan are comparatively meager in consequence of the limited investigation of these regions. However, there are evidences of iron, polymetallic ores, gold, optical quartz, and coal.

Iron. In the Gashun'skaya Gobi, in the zone of the occurrence of metamorphic strata, indications of iron mineralization have been discovered in the form of veins and nodules of hematite and magnetite in quartzes, marbles, and crystallized schists. These signs of iron mineralization are of mineralogical interest and are important as indications of the possibility of finding industrial iron ore deposits in the Proterozoic stratum, particularly near its contact points with granites.

Lead, zinc, silver. In the reports of the first investigators of Central Asia are found statements on the working of lead-silver ores at a number of points of the Pei Shan. However, these were lacking a descriptio of the workings and the ores which were here extracted. The long-abandoned mines of the Pei Shan have not been investigated by experts. All the deposits of silver-containing lead ores plotted on maps are found in the central zone of the Pei Shan where Paleozoic strata predominate.

Gold. The same reported data contain statements also on the mining of gold in the northern and southern ridges of the Pei Shan, which are composed of metamorphic rocks. Gold has not been mined in the Pei Shan for a long time; there are no geological data on gold deposits.

Optical quartz. In the northern part of the Gashun'skaya Gobi, small veins with mountain crystal suitable for optical quartz have been found. The crystal-bearing veins are found in the Lower Paleozoic sand-schist stratum and in the intrusive granites. In the latter they constitute small quartz pockets with a pegmatite fringe. In the cores of these bodies there are large, well-enclosed, non-fractured, completely transparent quartz crystals.

Coal. Two coal deposits are known in the central zone of the Pei Shan, in grabens with a Jurassic sand-argillite stratum. Only the eastern is being worked, not far from the town of Ting-hsin (on the Edzin-Gol River).

In the Kansu corridor the major mineral deposits are coal and petroleum, found in its most submerged sections: the Chiu-chuang, Kan-chou, and Chao-shui basins. The coal-bearing strata are of the Middle and Upper Carboniferous, Lower and Middle Jurassic, and Lower Cretaceous, but only the Jurassic deposits are of industrial importance. A considerable stratum of Jurassic coal deposits is being developed in the southern parts of the Kansu corridor butting onto the Nan Shan. Closer to the Lung Shan, however, the number of coal seams and their thickness diminish. In the Jurassic stratum of the Kansu corridor there are several workable coal seams 3-5 and even 10 m thick. The structure of the seams is complex: usually they are veins in which the coal is separated by layers of argillite.

In external features the coals of the Kansu deposits are similar to Sinkiang coals, of the same age but more thoroughly investigated. This similarity provides a basis for conjecturing that the Kansu coals also possess a high calorific value, contain little sulfur, and that some varieties of them can be coked.

The Jurassic coal stratum is exposed only along the boundaries of the corridor, in its center being covered over a broad area by thick Cretaceous, Tertiary, and Quaternary sediments. The potential industrial value of the Jurassic coal fields of the Kansu corridor is very great.

Oil. There are oil-bearing strata in the most submerged parts of the Kansu corridor where the thickness of the Mesozoic-Cenozoic deposits reaches many thousands of meters. Petroleum accumulations belong to the asymmetric anticlines, flexure anticlines, flexures, and cupolalike anticlines of the Mesozoic-Cenozoic strata in which massive displacements of the foundation are apparent. These structures formed intermittently throughout the Mesozoic and Cenozoic. The oil-bearing structures grew most intensively in the Quaternary, during which they were apparent in the relief in the form of elevations. As yet only individual structures have been investigated. Oil has been discovered among Tertiary, Jurassic, and Permian deposits; in the Liao-tsung-miao deposit, the largest in the province, the major oil-bearing horizon belongs to the Tertiary stratum.

The oil deposits in the Kansu corridor are among the most promising in China.

5. DZUNGARIA

General Description of Orographic Regions

Dzungaria is a flat region with groups of mountain ridges and rolling hills situated between the Altay and the Tien Shan. The western boundary of Dzungaria is a vast upheaval which stretches in a northeasterly direction from the end of the northern chain of the Tien Shan and the ranges of the Dzungarian Altay to the mountain knot of Tabyn-Bogdo in the Altay and farther into western Tannu-Ola. Within the zone of this oblique upheaval lie the ranges of the boundary of Dzungaria: the Mayli, Barlyk, Dzhair, and Urkashar, all extending in a northeasterly direction, and also the Saur range and the group of small heights which walls off the Irtysh depression along the Burchum. In this upheaval there are three gaps: the Dzungarian gates, the Dyam-Emel'skiy saddle, and the Irtysh depression. These gaps divide the upheaval into separate mountain massifs and through these Dzungaria is linked with the plains of Eastern Kazakhstan.

Dzungaria has the shape of an unequal triangle, broadest in the west, where the ranges of the Tien Shan and Altay diverge, and narrowing in a wedge shape to the east, where these ranges converge. Dzungaria covers an area of about 300,000 km^2.

Structurally and orographically, Dzungaria is nonuniform. Three completely separated areas are distinguished in it: the mountains of the boundary area of Dzungaria, the Dzungarian plain, and the heights and depressions of Eastern Dzungaria.

Pogranichnaya Dzungaria. After the investigations of V. A. Obruchev, this name was adopted for the mountainous region situated on the western flank of the Dzungarian plain and constituting an independent structural-orographic group belonging to neither the Tien Shan nor the Altay and having a trend different from each of them. The following ranges are included in the Pogranichnaya Dzungaria group: Barlyk, Mayli, Dzhair, Urkashar, Semistay, and Kodzhur, separated by tectonic troughs. Closely adjoining are the Tarbagatay and Saur ranges which constitute, together with the Chingiz in the west and the ranges of the Baytykskiy chain in the east, a completely separate structural-orographic zone. In the eastern part this zone separates the Dzungarian massif and the Trans-Ysanskiy synclinorium, the latter closely connected to the Altay.

The mountains of Pogranichnaya Dzungaria are typical block upheavals which originated during the process of the warping, cleavage, and differential displacements of the ancient denuded plain. Their forms were determinred by a combination of faults with northeasterly and northwesterly trends. More strongly apparent are the faults with a northeasterly trend, which is primarily that of the mountains of Pogranichnaya Dzungaria. Only in the Tarbagatay, Saur, and Semistay ranges do northwesterly (here almost latitudinal)faults predominate, contributing to the linear development of these ranges in a corresponding direction. The

elevations of Pogranichnaya Dzungaria usually constitute short ranges and massifs having the aspect of a complex mountain plateau composed of groups of block-terraces with various altitudes. They are grouped into two chains with northeasterly trends, separated by the Kup and Mukurtay tectonic troughs. The Mayli, Dzhair, Kharaarat, and Salburty ranges form the eastern chain, and the Barlyk, Urkashar, and Kodzhur ranges the western.

The eastern chain is considerably developed only in the Mayli and Dzhair ranges, each of which constitutes a complex horst consisting of three or four stepped terraces. There are summits here up to 2,300 m which serve as a watershed between the Dzungarian and Alakul'skiy basins. High on the Mayli and Dzhair ranges extensive remnants of the ancient denuded plain are preserved; their lower levels are more strongly dissected and here the relief is of the small-volcano type. The Kharaarat and Salburty mountains, which are continuations of the eastern chain beyond the Dyam River valley, comprise groups of small volcanoes with individual ridges rising several hundreds of meters over the surrounding relief.

The western chain is higher, rising 2,300-3,000 m. It is composed of the tightly enclosed Urkashar and Kozzhur massifs and the Barlyk massif, which is separated from them by a lowland. In the transverse lowland the western chain takes the form of narrow ridges--the Karnyntau and Dzhel'dykara horsts which rise only 100-250 m above the plain.

The mountain massifs of Barlyk and Urkashar are complex upheavals composed of tectonic block terraces of different elevations, cut by river valleys, but still preserving small remnants of the ancient plain. In these massifs, in the parts lying higher than 2,700 m, there are narrow crests with sharp, rocky summits and deep saddles resembling corresponding forms of the alpine type of relief. Signs of ancient glaciation can be observed in them.

Joining the Urkashar from the east is the broad Semistay range, consisting of two block-terraces dissected into rolling hills. The Saur range is a complex and asymmetric horst with a long and gentle northern slope complicated by longitudinal benches, and a short steep southern slopes. The watershed of the range is broad and flat, and in the Muztau group rises above the snowline (3,600-3,750 m). Towards the Dzungarian plain the Saur range descends sharply and is broken up into small ridges. In the high part of the Saur range there are remnants of the ancient denuded plain.

The mountain massifs and ranges of Pogranichnaya Dzungaria are separated by extensive plains. The largest of these are the Emèl'skiy trough, running between the Barlyk, Urkashar, and Tarbagatay; the Kobu trouch, bordering the Saur and Semistay ranges; and the Kup-Murkurtay trough, which separates the eastern and western mountain chains. The altitude of the intermountain plains fluctuates between 425 and 700 m. Closer to the mountains, the surface of the plains becomes rolling or hilly and is dissected by dry channels.

Dzungarian plain. The interior of Dzungaria constitutes a desert plain, inclined to the northwest, in which direction the altitude of its surface decreases from 600 m in the south (foot of the Tien Shan) and 800 m in the east (Borten'-Gobi) to 250-400 m along the western boundary, where there are a series of closed lake basins.

The main surface of the plain is covered with barkhan sands, largely barren and anchored by vegetation only in individual parts. The orientation of the barkhans in the sandy masses of the Dzungarian desert is gradually shifting from latitudinal in the southeast to northwesterly in the central part and almost longitudinal in the northeast. The horns of the barkhans face north and east; their height varies from 5 to 12 m.

The northern boundary of the plain, joined to the valley of the Urungu River, is uneven with its many benches and flat hills consisting of loose horizontal Tertiary deposits. The benches and slopes of the hills, rising to 25 m, are dissected by gullies. In the larger groups of hills there are in places closed basins with small temporary lakes.

The southern edge of the plain, joined to the Tien Shan and having a gentle incline to the north, is divided into two major landscape zones: that of the piedmont alluvial-prolluvial strip, and that of loess-type loams, beyond which lies a sandy desert. The former consists of separate outwash fans, dissected in different directions by numerous dry channels; its surface is stony and virtually bare of vegetation. Above thiis stony surface rise bare mountain ridges composed of poorly cemented Tertiary sandstones and clays. The ridges extend in a latitudinal direction for several dozen kilometers with girths of 5-10 km and relative altitudes of 250-500 m. They are traversed by the river valleys which cross the Dzungarian plain from the Tien Shan.

Farther from the mountains, the alluvial strip is replaced by loess-type loams. On the boundary between these zone, as a result of the change in composition and thickness of the Quaternary deposits, ground waters approach the surface, contributing to the development in some places of a rich vegetation. Here are concentrated the main areas of cultivable lands and the largest settlements in Dzungaria.

Still farther from the mountains, the slope of the Dzungarian plain continues to diminish and the rate of flow of the ground waters becomes almost stagnant, which under desert conditions promotes the salinization of soils. Thus in the zone of loess-type loams, just beyond the oasis belt, there is a strip of solonchak wastes and swamps, especially extensive in the parts opposite the Dzinchan and Khotubi Rivers. Sandy masses appear still farther north, 50-60 km from the oasis belt.

The western boundary of the plain, joined to the mountains of Pogranichnaya Dzungaria, is the lowest. Here are found the Dzhergalan, Ikhekhak, Mukurtay, and Ulyungurskiy basins, towards which waters flow from the Dzungarian drainage area. These landlocked basins extend in a northeasterly direction; some of the are separated by narrow cusps into more

depressed areas. The floors of the basins are covered with sands and clays; in places they are converted into solonchaks. In some parts they are barren, in others they are covered by reeds and sedges. The altitude of the Dzhergalanskiy basin is 190-200 m, that of the Ikhekhak basin 250-270 m, that of the Mukurtay 490 m, and that of the Ulyungurskiy 470 m.

Eastern Dzungaria. This is a region of mountains and plains. Its heights, like those of Pogranichnaya Dzungaria, constitute block upheavals which rose on the ancient denuded plain and were subjected to differential displacements along the faults in latitudinal and northwesterly directions. In conformity with the trend of these two dominant systems of dislocations, the heights of this region are combined into several groups (chains) extending in latitudinal and northwesterly directions and separated from each other by basin zones. The northern latitudinal chain is composed of the Naymechu, Baytyk-Bogdo, Ikhekhabtak, and Takiin-shara-Nuru ranges, separated from the Altay by the Barun-Khuray depression. The southern group, with a latitudinal trend and consisting of the Kuarchatau, Tugurtyube, and Mechin-Ula mountains, is separated from the Tien Shan by the Barkulya and Yanchi depressions. Included in the middle group, situated in the lowest part of the region, are the small-volcano massifs of the Kara-Mayli, Kokserke, and others. The mountain massifs are also echeloned in diagonal series, parallel to the direction of the Altay system and butting angularly onto the ranges of the Tien Shan. Most clearly apparent are the diagonal series composed of the Armanty Mountains, the Baytyk-Bogdo range, the Kokserke small-volcano massif, and the Mechin-Ula range; and the series extending from the Adzh-Bogdo towards the highest summit of the Bogi Tien Shan--the Atys-Ula. The first of these series separates the submergence of the Nomin Gobi from the Dzungarian plain, while the second creates a barrier between the Nomin Gobi and the Narinkhukhu Gobi.

The heights of Eastern Dzungaria constitute wedge-shaped blocks with different altitudes and worn by erosion to varying degrees. They acquire the form of peaks only in parts where one system of faults predominates sharply over others, while in parts with a uniform development of several systems they have the character of mountain massifs. Preserved on almost all of these are remnants of the ancient denuded plain, worn by erosion in varying degrees and sometimes virtually unrecognizable.

The northern latitudinal group does not constitute a continuous range with a single crest. Each of these ranges is an orographically distinct block, separated from its neighbors by a bench or diagonal graben. They have in common the base on which they are situated, and also the linear echeloning determined by the single system of latitudinal faults. The ranges of this group, in consequence of the considerable diversity in the altitude of the basins located on their flanks (in the south the Nomin Gobi, in the north the Barun-Khuray) do not have uniform slopes. Toward the first basin they become steep rectilinear terraces up to 2,000 m in relative altitude, and on the boundary of the second basin are accompanied by a zone of small volcanoes, towards which the terraces descend with an altitude of not more than 1,000 m.

The southern latitudinal group does not have a uniform trend; its orographic similarity is apparent only in relation to the surrounding depressions.

The Mechin-Ula is the longest and highest range in Eastern Dzungaria. It is about 200 km long and the altitude of its main summits is 3,600-3,900 m. The range is composed of a large number of tectonic wedge-terraces with a northwesterly trend and various altitudes. In the western (highest) part it is composed of five steps bordered by rectilinear benches. The interior terraces of the Mechin-Ula preserve large remnants of the old peneplain, with the result that from a distance its watershed appears completely level. In the central part the two southern steps of the Mechin-Ula, which have undergone contraction and sinking, incline towards the Karlyk Tagh and the Yanchi depression has formed on the base of the submerged third step. Only two terraces continue to the east: the watershed and the northern, which here become broader and lower. Facing the valley of the Nom-Gol River, the completely sunken Mechin-Ula is broken up into a series of isolated ridges which terminate on the boundary of the diagonal submergence extending from the Nomin Gobi. On the northern slope of the western part of the Mechin-Ula there are small glacial troughs with moraine fills, and also fresh cirques. The lower boundary of the extension of glacial relief coincides approximately with the 2,700-m line.

The Kuarchatau and Tugurtyube mountains constitute complex horsts without definite direction and with the surface of a moderately worn plateau dipping towards the northwest. On their southern boundary, butting onto the Tien Shan, the altitude fluctuates from 2,000 to 2,450, while on the northwest boundary, which faces towards the Dzungarian plain, it is only 1,500 m with a relative altitude of not over 300 m.

The southern group of heights is separated from the Tien Shan ranges of the Bogdo Shan and Karlyk Tagh by a zone of depressions, of which the main one is the Barkul'skiy trough-graben, with a length of 150 km and a width of 20-25 km. This graben has its lowest altitude in the vicinity of Lake Barkul', from which the surface rises in both directions up to 2,000 m. The floor is covered by a layer of loess-type loams and the pebbles of a piedmont strip (the latter occurs only along the foot of the Tien Shan ranges).

Fig. 27. Wastes of the Narin-khukhu-Gobi (Eastern Dzungaria). (photograph by V. A. Amantov).

The central group of heights constituting an interior upheaval on the Dzungarian plain is apparent only in the main diagonal series, which are situated opposite the western and eastern ends of the Nomin Gobi desert. In the western series it is represented by the heights of the Kara-Mayli and Kokserke, composed of rocky ridges alternating with small volcanoes, flat-topped heights, and sectors of undulating plain. In the eastern series it consists of the Arslan-Khayrkhan, Dobkhurkhara-Nuru, Isagtu-sayriin-Khundey, and other heights having the appearance of short rocky ridges extending in the northwesterly and latitudinal directions.

The interior heights of Eastern Dzungaria are of relatively low altitude, varying from 1,500 to 850 m. They are dissected by a multitude of shallow, dry gullies which introduce some variety into the desert landscape.

The plains of Eastern Dzungaria are separated by main diagonal rows of heights into three separate parts: Borten'-Gobi, Nomin-Gobi, and Narin-khukhu-Gobi. The Borten'-Gobi represents the eastern terminus of the Dzungarian plain, which is here sharply constricted and rises gently towards the Tien Shan and the Kara-Mayli Mountains, in the vicinity of which it has a rocky prolluvial mantle. The Nomin-Gobi is an enclosed basin with a plain surface covered by rocky diluvial deposits and with its rocky foundation exposed over large areas. Through the center of the Nomin-Gobi runs a narrow trough with solonchak wastes, towards which the terrain descends smoothly in both directions from 1,000 m in the foothills to 360 m in the trough itself.

The Narin-khukhu-Gobi is situated between the eastern diagonal series of heights and the area of the junction of the Tien Shan and Altay ranges. It too is an enclosed, landlocked basin with gently rolling relief. In places its breadth reaches 50 km; the lowest elevation marks are somewhat below 700 m (Fig. 27).

The Nomin-Gobi and the Khukhu-nomin-Gobi are the most barren parts of Eastern Dzungaria, virtually waterless and without vegetation.

Hydrographic Net

In Dzungaria the degree of the continental climate increases from west to east, not steadily but in zones along the orographic barriers. The mountains of Pogranichnaya Dzungaria lie in the path of westerly air masses, on which they exert, despite their relatively insignificant altitude, a retarding effect and retain part of the moisture borne by the winds. The difference in the amount of precipitation falling on either side of the mountains is so considerable that along here runs the boundary between the dry steppes and semidesert of Northeastern Kazakhstan (to which belongs also the basin of the Emel' River in Sinkiang) and the true desert of Dzungaria. On the western flank of the mountains of Pogranichnaya Dzungaria the annual precipitation approaches 300 mm, while on the Dzungarian plain it is less than 200 mm, its western parts receiving somewhat more than its eastern. The deserts of the Nomin-Gobi and the Narin-khukhu-Gobi, which are situated beyond the next diagonal barrier, belong to the most arid region of Central Asia, in which the annual precipitation is less than 100 mm.

In the plains and low-altitude parts of Dzungaria so little precipitation falls that they cannot maintain permanent watercourses. Water for Dzungaria is collected in the ranges of its bordering mountains, particularly the northern chain of the Tien Shan. Best watered, therefore, is

the southwestern border of the Dzungarian plain, through which flow waters from the snowy summits of the Borokhoro, Iren-Khaberga, Uken, and Bogdo-shan' ranges. The eastern half of the basin, which is bordered by barren spurs of the Tien Shan and Altay systems, is poorly watered.

The hydrographic net of Dzungaria is broken up into a multitude of enclosed basins which can be grouped into six major landlocked regions aligned along the main watersheds: Ebinurskiy, Ayrankul'skiy, Ulyungurskiy, Nomingobiyskiy, and Tsenkherkholyskiy.

To the basin of Lake Ebi-Nur belong the Borotala, Dzhergalan, and other rivers, whose catch basins include the slopes of the Dzungarian Ala Tau, Bedzhin Tau, Borokhoro, and Mayli ranges, all of which face the Dzungarian basin. The main water reservoir of this basin, Lake Ebi-Nur, has the form of an irregular ellipse, with its long axis northwest-southeast. It is 55 km long and 23 km wide. The southeastern half of the lake is bounded by marshes, which farther on are displaced by solonchak wastes. The northeastern shore, which borders the base of the Mayli range, is separated from its foothills by a 4 km strip of low lake plain. On the northwestern shore, rocky ridges come up to the lake itself. Preserved on the northern shore are beaches which were formed by deposits of the old lake, which was larger than the present Ebi-Nur. The water in the lake is alkaline.

In the Ebinurskiy basin the absolute elevation is 190 m, the lowest for all of Dzungaria and Eastern Kazakhstan.

The Ayrankul'skiy basin is fed by water collected in the region of the Irenkhaberganskiy mountain knot of the Tien Shan, by the Dzinchan (Manas) and Khotubi rivers, and by water carried by the Dyam River from the Urkashar and Dzhair ranges. The center of flow of this basin is the enclosed depression on the western boundary of the Dzungarian plain. This depression extends in a northeasterly direction and is separated by a narrow, deeply jutting spurs into two parts: the western, with the Ayrankul' solonchak; and the eastern, with the Ikhekhak solonchak. The flat floor of the landlocked basin has an elevation of 250-270 m and an area of about 3,500 km^2 (in 280-m contours).

Map 41. Lake Ikhekhak on the Dzungarian plain.
1--present lake;
   a. regenerating Ikhekhak; and
   b. dry Ayrankul';
2--floor of old lake (follows 280-m contour line);
3--Dzungarian plain;
4--Dzhair mountains and piedmont hilly zone;
5--active channels;
6--dry channels

/Place names on map:/
1--Dzhair range;
2--Lake Ayrankul';
c--Chugoy (city);
4--Dagoy (city);
5--Dzinchan River;
6--Dzungarian plain;
7--Dyam River;
8--Khobuk River;
9--Lake Ikhekhak.

In the recent past this entire basin was filled by a vast fresh-water lake, which later shrank and became salty (Map 41). Evidence of the existence of this lake are the lake deposits which lie on the floor of the basin, and the morphology of its slopes, which are of the shore terrace type (Fig. 28). In the past, the flow of water into the basin was much greater than at present. It received the waters not only of the Dzinchan River but also those of the Khutubi, which now seeps into the sands of the Dzungarian desert.

The Dzinchan River, which feeds the present lake, divides within the basin into a multitude of channels, some of which lead into the western half to the Ayrankul' solonchak, while others turn towards the east to the Ikhekhak solonchak. The present lake therefore does not have a constant location and, depending on the distribution of water between these channels, is located now within the territory of the Ayrankul' solonchak, not within that of the Ikhekhak solonchak. At the end of the nineteenth century and in the first half of the twentieth, according to evidence collected by the Russian explorers M. V. Pevtsov and V. A. Obruchev, the lake was located in the Ayrankul' area, while the Ikhekhak was a dry solonchak towards which water flowed in only one small channel, the Kupyr, or Khol, which quickly ran dry. At the present time, however, the main waters of the Dzinchan River flow in channels running in the direction of the Ikhekhak solonchak, where a new lake has arisen. The Ayrankul', deprived of any in-flow, has dried up and become transformed into a solonchak.

Fig. 28. Terraces of Tertiary deposits on the boundary of the ancient Ikhekhak lake basin on the Dzungarian plain (photograph by A. A. Shneyder).

The Ikhekhak considerably surpasses the Ayrankul' in size and salt reserves. This supports the conclusion that the Ikhekhak is the main terminal reservoir of the Dzinchan River, and that the periods during which lakes existed on the site of the Ayrankul' solonchak were relatively short and infrequent. The shifting of the lake from the Ayrankul' solonchak to the Ikhekhak, and vice versa, evidently occurred repeatedly, being caused primarily by the deposition of sand and silt in the active channels. The deposits raised the level of the water, which as a result overflowed into the old channels which lay at a lower level. It is possible that there were also periods in which the Ikhekhak and Ayrankul' lakes existed simultaneously.

The Ulyungurskiy basin includes a small part of the southern slope of the Mongolian Altay in the border zone of the CPR [Chinese People's Republic] and the MNR [Mongolian People's Republic] and the northern edge of the Dzungarian plain. The terminal lake of this basin is Lake Ulyungur, located in the basin between the spurs of the Saur range at an elevation of 468 m. The southern terminus of the basin is occupied by Lake Baga-Nur, which is 2 m higher than Lake Ulyungur and is connected with it by a channel. The northern end of Lake Ulyungur nearly reaches the valley of the Chernyy Irtysh, from which it is separated by a flat neck of land 2 km wide. At the present time, the level of Lake Ulyungur is 5 m lower than that of the water in the Irtysh. But in the recent past the lake was not confined to the Ulyungurskiy depression but also extended across the adjacent part of the Irtysh valley and the lower Kran River. This was a large lake, with dimensions no less than those of the present Lake Zaysan and constituting, like it, a running lake.

The Urungu River, which feeds lakes Ulyungur and Baga-Nur, runs across all of Northern Dzungaria without receiving a single tributary. All the water it carries into the lake basin is collected in the Altay Mountains.

The basin of the Nomin-Gobi, besides the basin proper and the surrounding mountain area, includes a considerable part of the northern slope of the Karlyk Tagh. Its hydrographic net is composed mainly of extended dry channels which furrow the rolling hills and plains of the desert. Only on the northern slope of the Karlyk Tagh and in the Mechin-Ula range are deep valleys found with turbulent currents. In the entire basin, about 60,000 km^2 in area, only one river of any considerable length is found--the Nom-Gol, which carries its waters to the solonchak wastes which occupy the deepest part of the basin. The Nomin-Gobi basin does not have a single center of flow. Within it separate groups of channels terminate in small basins of tectonic and deflation origin.

The Narin-khukhu-Gobi is divided into two landlocked basins which lie in enclosed depressions separated by a spur of the Ederengiin-Nury range.

Fig. 29. Dry channel (sayr) in Eastern Dzungaria (Trans-Altay Gobi) (photograph by V A. Amantov).

The severely continental climate of Eastern Dzungaria is the primary cause of the poverty of its water resources.

Of the meager precipitation (50-80 mm a year), only an insignificant part, which falls in heavy downpours, reaches river channels or feeds underground sources. The light rains are ineffective as regards infiltration, because their moisture evaporates while passing through the lower levels of dry air or upon touching the hot surface of the desert. Snow rarely falls in Eastern Dzungaria, and after falling quickly evaporates.

The sparse and intermittent precipitation gives the hydrographic net of Eastern Dzungaria a peculiar character. Its main elements are dry channels--sayry, filled with water only for a few hours during rare and brief downpours. Large sayry reach lengths of dozens of kilometers and have many side channels; the area of their collection basins sometimes

amounts to 2,000-5,000 km^2. On the bordering ridges sayry frequently form continuous valleys (Fig. 29). Water appears suddenly in the sayry, flows torrentially, and quickly disappears. Most of the run-off is carried into landlocked basins where it forms small lakes (takyr), a part seeps into the coarse, porous channel deposits, and a certain amount evaporates. In the periods between heavy downpours, the channels of the large sayry are dry, but downstream, along the boundary between the channel deposits and the rocky bottom, a slow current of water is maintained, supplied from alluvial deposits and fissured rocks throughout the entire area of the basin. The sayry most likely to carry water are those whose basins contain high elevations which retain atmospheric precipitation.

In water-carrying sayry an underground source is usually located at a depth of 1 to 6 m. The volume of flow is irregular, lessening and sometimes even completely disappearing, in periods of prolonged drought. The main sources of water are a limited number of springs and wells.

Springs are irregularly distributed, being concentrated on the boundaries of the Gobi Tien Shan and the Altay ranges. Almost all of them are located in sayry in parts where the latter are dissected by tectonic benches.

A rise of the water table to the surface, and also sites in which it lies close to the surface, are disclosed by thickets of rough grasses (Lasiagrostis), reed, poplar, sedge, willow and tamarisk. Such oases are one of the features of Eastern Dzungaria associated with the poor development of a porous sedimentary cover and the occurrence of continuous fractures which favor the outflow of water onto the surface. The spring water is fresh, but that of the wells often contains salt. In wells located close to the mountains and there fed by running water, mineralization is minimal, whereas in wells in basins which streams do not reach, mineralization is very strong, rendering the water unfit for drinking.

Flora and Fauna

The location of Dzungaria in the northern half of Central Asia on the same latitude as that of the deserts and semideserts of Kazakhstan and Mongolia connects it on the basis of physicogeographical conditions with the latter, and at the same time distinguishes it from the desert of the southern zone situated on the other side of the Tien Shan and belonging to the hotter Turkestan climatic province. Considerable variations are observed also in Dzungaria itself, particularly between its western and eastern regions, which are distinguishable in climatic conditions, types of soil, and degree of soil moisture.

As a whole, the climate of Dzungaria is unfavorable for the growth of vegetation. The extreme dryness of the air and of the soil, the great variations in temperatures, and the strong salinity of the soils create extraordinary restrictions on vegetation There is virtually no spring here, and the hot, dry summer begins very soon after the very cold winter.

The lack of moisture is felt during the entire growing season. Under such conditions only a very few permanent bushes and underbushes can grow--those which can manage with a minimum of soil moisture grow during the entire warm period of the year, and can withstand the increased salt content of the soil. This results in the extreme monotonousness in the appearance of the vegetation and gives it an xerophytic aspect. Vegetation cover in Dzungaria is very scattered and completely lacking over large areas.

Several types of plants grow in Dzungaria.

The vegetation of sandy deserts is characteristic of the interior regions of the Dzungarian plain. The plants consist mainly of bushes of saxaul, tamarisk, and calligonum, scattered among the bare sands.

Solonchak vegetation is found on the southern boundary of the Dzungarian plain and in the low parts of some enclosed basins. The main representatives of this complex are various halophytes, and also stunted tamarisks and reeds.

Vegetation of the semidesert and dry steppes is distributed through the northern part of Dzungaria. Here, in accordance with orographic conditions and the ground-water systems, there appear either polyn-saltwort or polyn-grass complexes.

Vegetation of the stony desert with a very scattered vegetation of bushes and underbushes is characteristic of Eastern Dzungaria. The vegetation cover in deserts of this type develops in isolated parts alternating with bare areas. The thinnest vegetation cover is observed along the boundaries of the basins and on the bases of heights: here vegetation is found only in ravines. Here the main representatives are ephedras, low, strongly stunted saxaul, and Nitraria.

Whole deserts occupy large areas of the Nomin-Gobi. They constitute the bare outcroppings of jagged Paleozoic rocks and semiporous Tertiary deposits, with a thin mantle of rubble with a sun-blackened layer. Only in the dry channels do there appear groups of saxaul bushes.

Mountain deserts are a type of true desert, bare of vegetation on their main surface. To this type belong almost all the ridges and hilly areas of Eastern Dzungaria. The slopes of these heights are bare and sterile; vegetation nestles only along the sides of the dry channels, where may be found saxsaul, ephedra, yellow-wooded Zygophyllum, and elm.

The tugay forests in the large river valleys (Dzinchan, Khutubi, Nom-Gol, and others) and oases consist of togaks, two varieties of wild olives, and osiers. Tamarisk grows on the edges. The largest areas of tugay forests are found in Southwestern Dzungaria

Despite the scarcity of water and food, the fauna of Dzungaria is comparatively varied. Still to be found in the eastern regions may be the wild camel, Przhevalski's horse, and the Circassian koulan, which as late as the end of the nineteenth century occurred throughout the whole territory. And even at the present time there are numerous herds of gazelles on the piedmont plains and boars are found in the reed growths of the lower rivers and around springs.

Among carnivores, the red wolf, reed cat, fox, and Tartar fox are found in Dzungaria.

Geological Structure

Dzungaria is heterogeneous in the geological sense. Its plain area constitutes a weakly-active massif enclosed by the geosynclines of the Tien Shan, Altay, and Eastern Kazakhstan. Structurally, the western part of the massif is weakly dissected, with the result that its movements have been only slightly differentiated, inconsiderable in range, and slow. Its sedimentary mantle was only partly dislocated. The eastern part of the massif, within which are found the deserts of the Nomin-Gobi and numerous groups of rolling hills, has been subjected to considerable activation under the influence of the converging active zones of the Tien Shan and Altay. It is dissected by fractures into a great number of blocks which have undergone various displacements, with the result that its covering is dislocated throughout the entire area. Pogranichnaya Dzungaria represents a part of the Hercynian folded region of Eastern Kazakhstan.

Heights of Pogranichnaya Dzungaria. Pogranichnaya Dzungaria is separated into four major structural zones: Mayli-Dzhairskiy, Barlyk-Urkasharskiy, Emel'skiy (Emel'skiy block) and Eastern Tarbagatayskiy, distinguished by the histories of their geological development.

The Mayli-Dzhairskiy zone is a short but broad geosynclinal prism bordering directly on the northwest edge of the Dzungarian massif. Within it two structural strata are distinguished: a lower, formed by the thick sand-shale strata of the Ordovician and Silurian, forming a system of warped folds with a northeasterly trend; and an upper, composed of the volcanic-sedimentary stratum of the Lower Carboniferous lying on Caledonian folds with sharp unconformity. The main stratum is the Caledonian, developed throughout the entire zone and outcropping on the surface over most of its area. The ancient Hercynian stratum (Lower Carboniferous) developed only in the central part of the zone, which underwent subsidence in the course of this stage. Serving as the boundaries of the Mayli-Dzhairskiy zone are the faults with a northeasterly trend running along the edge of the Dzungarian massif and on the edge of the Kup-Mukurtay graben. This zone extends ina southwesterly direction to the lateral faults of the Dzungarian gates, and in a northeasterly direction to those bordering the Trans-Ysanskiy synclinorium.

The Caledonian complex of the Mayli-Dzhairskiy zone is divided into three strata: the lower, a sand-shale with subordinate bodies of silicified dolomites and schist breccia; a middle, effusive-schist composed of tuffaceous schists and sandstones, basic tuffs, and lavas with beds of variegated jaspers and limestones; and an upper, sand-shale with a high content of siliceous rocks.

The lower stratum, the thickest and belonging to the Ordovician, is exposed on the southern terraces of the Dzhair range and in the higher terraces of the Mayli range. The middle and upper formations, belonging to the Silurian, are developed primarily near the watershed of the Dzhair range, but also in the lower terraces of the Mayli. The eastern boundary of the Silurian strata is formed by the Dorbutinskiy fault which runs along the entire extent of this zone. To the Dorbutinskiy fault belong the outcroppings of ultrabasic rocks, a narrow zone of Permian-Triassic conglomerates, and also benches and rivery valleys of the present relief.

Frequently found at the base of the Silurian part of the horizon is a conglomerate containing pebbles of green and crimson schists of the Ordovician stratum. In places the bedding of the Silurian strata on the Ordovician is unconformable.

The Ordovician and Silurian deposits of the Mayli-Dzhairskiy zone form small folds with a northeasterly trendof 55-65°. There is no noticeable difference in the degree of dislocation of the Ordovician and Silurian strata. The age of their folding is Caledonian, as is evident from the angular unconformity with the old Hercynian complex.

The old Hercynian stratum in the Mayli-Dzhairskiy zone constitutes a volcanic-sedimentary stratum of the Tournaisian composed of variegated porphyrites, felsites, quartz porphyries, and tuffs of mixed composition, alternating with bodies of siliceous-argillaceous shales and sandstones, in some seams transitional to conglomerate. In the northern terrace of the Mayli range, in the vicinity of the Barlyk-Urkasharskiy zone, a sand-shale series of the Middle Devonian transgresses on the Caledonian folds, and in the Kharaarat Mountains lies a volcanic-sedimentary stratum, evidently of the Upper Devonian. The folds of the strata of the old Hercynian series are considerably larger and more slantingly folded than the Caledonian substratum; their trend is also northeasterly (50-65°).

Granites in the Mayli-Dzhairskiy zone are represented by biotite and biotite-hornblende schist varieties forming bodies of elliptical form with diameters up to 25 km. In the Kozhurtayskiy massif the biotite granites are intruded by more recent alaskite and bordered in the southeastern contact zone by mountain blends. The active contacts of these granite blocks with the Tournaisian are evidence of their Hercynian age.

The Barlyk-Urkasharskiy zone is characterized by the development of a thick, strongly folded stratum of the Middle Devonian consisting of an alternation of tuffaceous, graywacke, and quartz sandstones, argillaceous and siliceous-argillaceous shales, and individual bodies of limestones, spilites, and basic tuffs. The limestones and some seams of the sandstones contain abundant fossils of brachiopods, bryozoans, and corals of the Eifelian and Givetian series. The Middle Devonian stratum is made up of steep, mostly small, folds of irregular trend. In the Barlyk a northwesterly trend (320° NW) predominates; in the Kertau Mountains, a northeasterly (50-70° NE); in the Semistay and Saur ranges, a latitudinal.

In the Barlyk and Semistay the Middle Devonian stratum is covered by volcanic-sedimentary strata of the Upper Devonian and Tournaisian, comprising the upper structural series of this zone. The Upper Devonian and Tournaisian strata are distinguished by their constituent lavas and tuffs. In the first they are represented almost exclusively by porphyritic varieties, and in the second mainly by derivative acid magma. In the Upper Devonian stratum, besides lavas and tuffs, there are siliceous-argillaceous shales, sandstones, conglomerates, and individual seams of limestone with fossil fauna of the Frasnian series. In the stratum of the Lower Carboniferous, sedimentary formations are also found in large numbers and are represented by various shales, sandstones, and conglomerates. In the shale bodies there are seams of argillaceous limestones containing fossil fauna of the Tournaisian. The volcanic-sedimentary stratum of the Tournaisian is developed in the northern ridges of the Barlyk, forming together with the Dzhairskiy outcroppings an extensive synclinal structure with a northwesterly extension. Within this syncline the strata of the Tournaisian form steep folds of brachyclinal form with a distinct northwestern trend. In the fault zones the folds are steep and complex, but elsewhere are comparatively sloping and simple.

A second large area of the accumulation of Tournaisian volcanic-sedimentary stratum was the Kup-Mukurtayskiy zone of northeasterly faults extending along the boundary of the Caledonian formations of the Mayli-Dzhair and the old Hercynian formations of the Barlyk-Urkashar. In this zone the Tournaisian stratum is dislocated in a northeasterly direction, conforming with the trend of its faults. Also belonging to the Kup-Mukuratayskiy zone are outcroppings of the Upper Paleozoic, represented by a stratum of variegated conglomerates and sandstones up to 1,000 m thick lying on the various horizons of the Devonian and Tournaisian. The conglomerate stratum forms incomplete synclines up to 3 km in width butting against the large faults.

Granites in the Barlyk-Urkasharskiy zone are not extensive; they form individual blocks of moderate size. In composition they are of the same types as the Dzhairskiy.

The Emel'skiy block in the contemporary relief constitutes a plain on which the foundation rocks have been covered by a continuous mantle of loess-type loams. An idea of its structure can be obtained only from the outcroppings of the Paleozoic in the heights along the foothills of the Tarbagatay to the west of the town of Chuguchak. Exposed in these heights are rocks of the Lower Cambriam subdivided into two series: a lower, composed of sealed jaspers and quartzites alternating with bodies of sheared spilites; and an upper, composed of sheared diabasic porphyrites and basic tuffs. The series of the Lower Cambrian lies in steep linear folds with a northwesterly trend. Lying sharply unconformably on them is a volcanic-sedimentary stratum of the Upper Devonian, which forms moderately steep brachyclinal folds. Similar geological relationships with the combination of a geosynclinal Lower Cambrian in the capacity of a lower structural series and a volcanic-sedimentary stratum of the Upper Devonian

as an upper series is evidently maint ined over the entire extent of the Emel'skiy block up to the boundaries of the Barlyk and Urkashar. During the Caledonian and Hercynian movements the Emel'skiy block formed a middle block which separated the active zones of Pogranichnaya Dzungaria and Tarbagatay.

The eastern Tarbagatay zone lying between the Emel'skiy block and the Trans-Ysanskiy synclinorium is characterized by the more or less latitudinal trend of its structures. Within it two structural series are distinguished, forming a surface of regional unconformity: a lower, formed of a thick stratum of phyllite-type schists, sandstones, and siliceous siltstones of the Silurian; and an upper, composed of Upper Devonian and Tournaisian volcanic-sedimentary strata similar in composition to strata of the same age in the Barlyk and Dzhair ranges.

The lower series is present on the watershed ridge of the range, while the upper lies on its slopes and partly on the watershed in the zones of lateral submergences. Besides differences in the facies and lithological composition of the rocks, the lower and upper structural series are distinguished further by the character of their dislocations: the strata of the lower series lie in steep linear folds, while those of the upper series form large forms, complex and acquiring linear form only in the vicinity of faults.

In the mountain massif of Kodzhur and the Semistay range there occur latitudinal dislocations originating from the Tarbagatay, and northeasterly dislocations from the Barlyk-Urkasharskiy zone. Predominating is the latitudinal Tarbagatay direction to which in this region conform all the most important fractures, folds, and major orographic elements. The Kadzhur and Semistay are distinguished from the adjoining Tarbagatay mountains by the fact that in the former the upper structural series, formed by strata of the Upper Devonian and Tournaisian, does not lie on the Lower Paleozoic but rather on the Middle Devonian geosynclinal formations of the Barlyk-Urkasharskiy zone.

Granites are represented in Eastern Tarbagatay by a large block of elliptical form extending in the direction of the main trend of the regional structures. The block belongs to the area of maximal upheaval of the Eastern Tarbagatay zone and is found enclosed in strata of the Lower Paleozoic.

The eastern Saur range, butting onto the Ulyungurskiy basin, is situated at the junction of the Barlyk-Urkasharskiy zone which extends in a northeasterly direction, latitudinal to the Eastern Tarbagatay zone and the Trans-Ysanskiy synclinorium, which are characterized by the northwestern trend of their structural elements. Evidence that the Eastern Saur range belongs to the Barlyk-Urkasharskiy zone is the presence in it of a thick sand-shale stratum of the Middle Devonian as a lower structural series. Elements of the Trans-Ysanskiy synclinorium in the Saur range are a sand-shale stratum of the Upper Visean and Middle Carboniferous (Naryn-Kara) and a volcanic stratum of the Middle and Upper Carboniferous, constituting the eastern spurs of this range. The influence of the

Eastern Tarbagatay zone is apparent in the development here of thick latitudinal faults and in the general latitudinal trend of the range. The folds of the Devonian and Carboniferous strata in the eastern Saur range do not have a uniform trend but extend in each individual part in conformity with the trend of its boundary faults. Dislocations are found alike in the Saur in northwestern, northeastern, and latitudinal directions, and join one another at angles

The northeastern zone of dislocations of the Barlyk-Urkasharskiy zone reaches the Trans-Ysamskiy synclinorium and occurs in it as a lateral uplift, in connection with which there appear on the plain in the area of the town of Burchum numerous heights which reach almost to the Altay edge of the synclinorium. These heights are composed of an Upper Paleozoic stratum of acid lavas and tuffs interbedded with tuffaceous sandstones and intruded by small bodies of rose-colored microperthites.

Eastern Dzungaria. In Eastern Dzungaria, faults appear equally in the northwestern, latitudinal, and northeastern directions; thus its structural formations have not undergone a linear development and are primarily of the block type. This explains the mosaic structure of Eastern Dzungaria and the variability in the trends of its structural elements. However, in the mosaic structure of Eastern Dzungaria there appear large complexes of blocks related to the totality of the geological development. A major structural complex is the diamond-shaped mass of the Nomin-Gobi, which is separated from the Dzungarian massif proper by a diagonal zone of complex folds in which lie the Nemeychu and Karak-Mayli, Kyarchatau and Kokserke, Tugurtyube and Mechin-Ula mountains.

A special feature of the geological structure of the Nomin-Gobi consists in the absence or slight development of deposits of the Lower and Middle Paleozoic, connected with the active movements of this mass in the Caledonian and early Hercynian stages of history, and with the wide distribution of deposits of the Upper Paleozoic (with the Upper Visean at the base) and Mesozoic-Cenozoic during the formation of which the mass of the Nomin-Gobi underwent a subsidence. In the zones of complex folding which border the Nomin Gobi, on the other hand, there developed thick strata of the Silurian, Devonian, and Tournaisian series of the Lower Carboniferous, while deposits of the Upper Paleozoic and Mesozoic-Cenozoic are absent. Thus the movements of the mass of the Nomin-Gobi and of the active zones which lie on its flanks were mutually opposing.

The metamorphic foundation of the Nomin-Gobi is exposed only in the bordering parts which were included in the upheaval. They have been noted on the northern ridges of the Mechin-Ula, in the Ates-Ula and Atys-Ula massifs of the Gobi Tien Shan and at the eastern end of the Khara-sayrin-Kundey intermountain trough Represented in these outcroppings are quartz-mica, quartz-sericite-chlorite, and green schists, quartz, and marbles, probably of the Proterozoic age. Above lies an Upper Paleozoic structural series occurring throughout the entire area of the Nomin-Gobi and formed of two strata: a sedimentary, belonging to the Visean and to the early Middle Carboniferous; and a volcanic, belonging to the Middle and Upper Carboniferous.

The sedimentary stratum is exposed only on the northern and southern margins of the massif. In the northern outcroppings, the most extensive (Dobkhur-Nuru, Erien, and Dobiin-Nuru mountains), they increase in thickness and have a higher content of beds of marine origin. Here its horizon begins with a layer of large-pebble conglomerates with glacial boulders. Higher follow sandstones, at first coarse with layers of gravels, then fine-pebbled and interbedded with siltstones. Still higher there is a thick body of siliceous siltstones with sandstones and coverings of andesite porphyrites. In the cores of the large synclines this body is covered by limestones; in the lower part by dark gray coarsely-bedded ones and in the upper part by light-colored, fine-seamed ones. The thickness of the limestones attains 200-250 m in places and the strata generally are 1,000 m thick. Some layers of limestones represent organic formations: crinoidal, crinoid-bryophytic, and brachiopod. The fauna contained in them are evidence that this stratum belongs to the Visean and lower levels of the Middle Carboniferous.

In the southern group of outcroppings (Mechin-Ula range and Barkul'skiy trough) the described strata contain continental elements in the form of carbonaceous rocks and redstones with limestones almost entirely absent. Here its horizon begins with coarse conglomerates which higher become fine-pebbled and then are replaced by sandstones and siltstones. Farther follows a series of complex lithological composition with an interbedding of sandstones, conglomerates, and andesite porphyrites. To this series are subordinated beds of red sandstones, variegated marls, and carbonaceous argillites. The upper level of the stratum is composed of sandstones, siltstones, and shales, mainly siliceous and only in individual blocks having a clay and lime matrix. Now and then small ledges of crinoid limestones are found in such blocks.

A volcanic stratum comprises the extensive small-volcano massifs of the interior of the Nomin-Gobi. Its composition includes variously colored quartz porphyries and felsites, dacite and andesite porphyrites, acid and mixed tuffs, and tuffaceous sandstones. The succession of bedding in the stratum changes often and sharply, evidently due to the fact that in the various parts it constitutes formations of different volcanoes.

In the Nomin-Gobi the volcanic stratum is underlain by deposits of the Visean, but in the zones surrounding it the former lies on a sand-shale stratum of the Silurian and also on Pre-Cambrian metamorphic rocks. The thickness of the volcanic stratum varies from 200 to 600 m. The possibility is not ruled out of discovering in the Nomin-Gobi deposits of the Permian period also; these occur in the vicinity of the Borten'-Gobi and also in the Gobi Tien Shan and Mongolian Altay.

The strata of the Upper Paleozoic structural zone of the Nomin-Gobi form broad slanting folds with angles of dip of usually not more than 15° and lying virtually undisturbed over extensive areas. Only in the vicinity of the Mechin-Ula, the Baytukskiy ranges, and the Adzh-Bordo do the folds become narrow and steep.

As a whole, the Nomin-Gobi has a synclinal structure, in connection with which the lower strata of its cover outcrop on the margin while the upper are localized in the interior regions.

Jurassic and Cretaceous deposits have been noted in the Nomin-Gobi in the areas of the Shih-to-mei and Shih-t'an-yeh deposits. It is possible that under the mantle of Tertiary sediments they extend over the entire area of the most depressed parts of this mass: the Nomskiy and Loyemegobiyskiy. In the area of the Shih-to-mei deposits the Jurassic is represented by an alternation of gray, white, and gray-green, and above by brown and brown-red, sandstones, siltstones, fine-pebbled sandstones and argillites with seams of coal and siderite gneisses. The kaolinic argillites occurring with coal beds contain plant fossils.

The Jurassic coal-bearing deposits are covered by a series of red-brown conglomerates and coarse sandstones, possibly of the Cretaceous period.

The level areas of the Nomin-Gobi are covered with thin Tertiary deposits. At the base of the Tertiary mantle are found brown-red and orange gypsiferous sandy clays with lenses of sand. Above lie yellow and light gray sands and clay which are in turn overlain by white, lumpy, compact marls and argillaceous clays with seams of quartz sands. In the vicinity of the Mechin-Ula a horizon of the Tertiary stratum is topped by prolluvial pebbles apparently analogous to the thick conglomerates of the Pliocene-Pleistocene which are present in all the large foothill depressions of Central Asia.

The Jurassic and Cretaceous strata have undergone steep dislocation along the faults, while the Tertiary deposits take part only in the block displacements, which explains their location at different hypsometric levels. Dislocations apparent in bendings of the beds are not observed in them.

Granites are lacking in the territory of the Nomin-Gobi.

The diagonal zone of heights separating the Nomin-Gobi from the Dzungarian plain and the ranges of the Baytykskiy arm. A primary feature of the geological structure of these heights is the presence of a sand-shale stratum of the Ordovician-Silurian, not present on the Dzungarian massif or in the Nomin-Gobi. This stratum is of the same age as deposits in the northern chain of the Tien Shan, Altay, and Dzhair and is composed of typical geosynclinal formations. It is distinguished by lesser thickness, the absence of basic lavas and tuffs, and by only slight dislocation of the metamorphic rocks. Moreover, the Ordovician-Silurian stratum of Eastern Dzungaria reveals local differences connected with the unequal activeness of individual parts. In the Mechin-Ula and Akdzhala, which belong to the diagonal zone of heights, the Ordovician-Silurian stratum consists principally of quartz sandstones and siltstones with accompanying argillaceous and calcareous-argillaceous shales. Its thickness here does not exceed 100 m. In the Ikhe-Khabtak and Nemeychu, along with

quartz sandstones and argillaceous shales there are considerable developments of graywacke sandstones and gravels, and siliceous-argillaceous, argillaceous-chlorite, calcareous-argillaceous shales with individual seams of limestones. The thickness of the sand-shale stratum in these heights increases to 2,000 m.

All the outcroppings of the Ordovician-Silurian stratum possess a complexly folded structure The trend of its folds is latitudinal in the ranges of the Baytykskiy arm, NW 300-325° in the diagonal zone of heights. Deposits of the Middle Paleozoic form unconformities with it.

On the northern slope of the ranges of the Baytykskiy arm, which face towards the downwarping before the Altay, the Ordovician-Silurian stratum is covered by deposits of the Devonian and Tournaisian, which are here represented by the following series:

A lower siliceous shale series with alternations of thick blocks of siliceous siltstones and shales and blocks of argillaceous shales and sandstones, enclosing beds of gravels and limestones. In the latter there are brachiopods, which indicates that these deposits belong to the upper Middle and lower Upper Devonian.

A volcani-sedimentary series, consisting of pyroxenic and andesite porphyrites, tuffs, mixed and graywacke sandstones, and various siliceous rocks from schists to gravels inclusive.

A sand-shale series, composed in the lower level of argillaceous and calcareous sandstones and siltstones with seams of limestones containing brachiopods of the Famennian stage of the Devonian; and in the upper level of sandstones and shales with individual layers of fine-pebbled conglomerates, argillaceous limestones, and coals. In the sandstones of this body there are found plant fossils of the Tournaisian stage.

An upper siliceous sand-shale series, containing in separate seams a variety of fauna of the Upper Tournaisian age.

The Devonian and Tournaisian deposits of this zone are everywhere dislocated, but to different degrees in individual parts. In the vicinity of large faults they form a steep and close warping, but in parts more distant from the faults they are bent into wide sloping folds with angles of dip of not more than 35°.

In the heights of the diagonal series extending between the Nomin-Gobi and the Dzungarian plain, Devonian and Tournaisian formations are absent. Here, on the Ordovician-Silurian sand-shale stratum lie deposits of the Visean and a stratum of volcanic origin of the Middle and Upper epochs of the Carboniferous, to which is joined in the P'a-t'a-shan hills a Lower Permian sandy-conglomerate stratum with seams of limestones.

Granites are lacking in the ranges of the Baytykskiy arm but are found in the heights of the diagonal series. In the latter they are localized in parts where the diagonal upheaval interferes with the upheaval of the Baytykskiy zone (Nemeychu and Kara-Mayli) and with the upheaval of the Eastern Tien Shan (Mechin-Ula, Tugurtyube). The blocks of both groups are composed of light gray and pink medium- and large-

grained granites with microperthitic potassium-sodium feldspar. Usually they lie in strata of the Lower Paleozoic and Devonian, but cases have been noted of active contact with a volcanic stratum of the Upper Paleozoic, on the basis of which a young Hercynian age is assigned to them.

Dzungarian plain. With the exception of its northern hilly area, this plain is closely connected with the Altay. It is a region of lengthy and persistent subsidence, which began in the Middle Paleozoic and has continued to the present. Thus the plain part of the Dzungarian massif bears a thick mantle of deposits of the Upper Paleozoic and Mesozoic-Cenozoic which are exposed only in the bordering heights, while most of the expanse is covered by Quaternary loams and sands.

The foundation and lower levels of the sedimentary mantle of the Dzungarian massif have submerged to a great depth with the result that their structure remains unknown, although in the western and eastern corners of the Dzungarian triangle (on the Bedzhintau range and in the Kuarchatau)small volcanoes outcroppings have been identified of Pre-Cambrian metamorphic rocks, apparently representing "ottorzhentsy" of the stable massif moved by the upheaval of the Tien Shan. In the Bedzhin Tau the basal layers of the sedimentary series belong to the Middle Devonian, and those on the Kuarchatau hills are Visean. This provides grounds for supposing that Lower Paleozoic deposits are absent from the Dzungarian massif, as from the Nomin-Gobi. In the eastern parts the massif includes the divisions from the Middle Paleozoic to the Tournaisian inclusive.

The sedimentary strata covering the Dzungarian massif are most exposed in the foothills of the Tien Shan and in the P'a-t'a-shan hills, where the Mesozoic and most recent movements were particularly strong. Here the mantle is composed of the following formations:

The Visean, represented in the lower level by conglomerates and "gravelity" interbedded with coarse sandstones; in the middle level by sandstones, siltstones, and shales, partly siliceous; and in the upper level mainly by siliceous sandstones and shales with numerous layers of basic lavas and beds of tuffs. The limestones and seams of calcareous sandstones, which extend to the lower level of the stratum, contain fossil fauna of the Visean. Some seams of sandstones contain fossil calamites.

The Middle and Upper Carboniferous are represented mainly by sedimentary formations: sandstones, shales, and limestones. Lavas and tuffs are here almost entirely of basic composition (andesite and pyroxenic porphyrites) and are found in individual sills and bodies, thinning out upwards in the horizon. Along with the volcanic rocks there are thick blocks of siliceous siltstones and schists. The seams of crinoidal limestones of the upper level of the horizon contain brachiopods and bryozoan characteristics of the Upper Carboniferous.

The Permian period is represented in the lower level of the horizon by fine-grained graywackes interbedded with porphyritic tuffs, siliceous sandstones, siltstones, and calcareous-argillaceous argillites. The argillites contain corals of the Lower Permian age and the sandstones floral detritus. The upper level of the horizon is formed by brown and gray sandstones and black argillites, with individual layers of oolitic limestones. The sandstones contain the remains of lepidodendroids, cordaitaleans, and calamites, and in the upper seams of argillites the scales of ganoid fishes are found. Higher follows a Mesozoic-Cenozoic complex of continental deposits, in which the Triassic is represented by a series of red conglomerates, sandstones, and argillites containing bony reptile fossils. The redstones of the Triassic are found only in Eastern Dzungaria, mainly in the foothills of the Bogdo Shan range, where they reach 1,000 m in thickness.

The Rhaetic stage and the Jurassic period are represented throughout the entire basin. Everywhere they are divided into two series: a coal-bearing, composed of gray and gray-green argillites, aand stones, and conglomerates with beds of coals; and a variegated series, also composed of argillites, sandstones, and conglomerates, but primarily red and brown in color. The proportion of individual types of rocks, particularly of conglomerates, in the coal-bearing and variegated strata changes directly in accordance with the Paleozoic landscapes, reaching the greatest thickness near the river valleys. There are parallel changes also in the thickness of the series: the coal-bearing from 1,200 to 3,500 m, and the variegated from 50 to 700 m.

Some seams of the coal-bearing series abound in the floral remains of ferns, ginkgo trees, cycads, and Bennettitaceae. Variegated series have been found containing the silicified trunks of ancient conifers and fossils of dinosaurs.

In comparison with the Jurassic, the Cretaceous has a very limited distribution, being absent, for example, on the eastern edge of the depression. On the lower level of the Cretaceous system lie light-colored conglomerates (100-200 m); above follow light-colored sandstones with blocks of conglomerates (up to 500 m). Still higher there is a series of brown and red clays with seams of sandstones (700-1,000 m). In the clays are found fossils of fishes, tortoises, and also pelecypods, ostracods, and estherians. The horizon of the system is completed by a series of red clays and sandstones with layers of conglomerates (100-700 m). The facies and thickness of the individual levels of the horizon of the Cretaceous system change quickly and sharply along the trend.

Tertiary deposits are most fully developed in the southern half of the depression (south of the Urumchi-Karamay zone of deep faults). Here they are separated into five series: a lower green of the Oligocene epoch, consisting of clays with infrequent layers of sandstones and conglomerates (180-350 m); a brown of the Lower Miocene, consisting of clays with layers of sandstones (100-750 m); an upper green of the Lower Miocene,

represented by interbedded stratified clays, fine-grained sandstones, and marls (40-450 m); a pale yellow of the Lower Pliocene, including sandy and marl clays, sandstones, and in the upper horizons conglomerates (500-1,600 m); a conglomerate of the Pliocene-Pleistocene, with a thickness of 200-1,200 m west of the Manas River and 300-800 m east of it.

All the horizons of the Tertiary stratum contain fossils of mollusks and ostracods. The Oligocene and Miocene also contain the remains of fishes and river turtles, and the Pliocene the remains of elms, poplars, willows, and other plants.

Unconformities in the sedimentary mantle between the Paleozoic and Mesozoic-Cenozoic groups, and also within these groups between individual series, are to be observed only on the margins which have been effected by the upheavals of the Tien Shan and Dzhair ranges. In the direction of the Dzungarian plain the unconformities become less distinct and are replaced by normal bedding.

The sinking of the Dzungarian massif in the Mesozoic-Cenozoic era occurred unevenly: most submerged was its southern part bordering on the Tien Shan, in which part the total thickness of the Mesozoic-Cenozoic group of deposits probably amounts to 7,000-8,000 m. To the north, the foundation of the massif approaches the surface in benches, and the thickness of the Mesozoic-Cenozoic sediments dimishes to 1,000-2,000 m.

In facies composition the Mesozoic-Cenozoic complex manifests great changes which are apparent(uniformly in all series) in the subsidence of the deposits approaching the mountains, the Tien Shan in particular.

The sedimentary cover of the massif underwent dislocation only in the vicinity of the active zones of the Tien Shan, Dzhair, and the heights of Eastern Dzungaria. On the boundary of the Tien Shan the width of folded outcroppings of the Mesozoic and Cenozoic attains 50 km. However, strong warping is evident only in a narrow zone several kilometers long. Farther, towards the Dzungarian plain there are large, gentle folds. Running between zones of strong dislocations and folds is a depression, the strata of which lie almost unbroken. The flexure anticlines situated between this depression and the Dzungarian plain, are extended latitudinally, parallel to the ranges of the Tien Shan. They are echeloned in the shape of coulisses and are submerged on both sides; their sides are sloping, and the binding crests are smooth, without complicating bends or breaks. However the folds butting onto the Tien Shan possess strongly warped cores, broken along the axial surfaces by faults along which the southern sides are thrust somewhat against the northern.

In the foothills of the Bogdo Shan, Permian deposits are included in the folds of the Mesozoic-Cenozoic complex. Here are observed two large synclines separated by a narrow anticlinal graben exposing the Permian stratum. The internal syncline, directly butting onto the Bogdo Shan range, is composed mainly of Upper Permian deposits. Outcropping in the most submerged parts of the syncline is the Jurassic the horizon of which lacks the productive series of the middle level and the variegated series of the upper level. Thus the interior syncline belongs to that zone of foothills

which was already made a part of the upheaval of the Tien Shan before the laying down of the productive series. The exterior syncline, which borders on the Dzungarian plain, is composed mainly of the Jurassic, in the horizon of which a productive series is present.

On the boundary of the Kara-Mayli Mountains the sedimentary cover of the Dzungarian massif forms flat domes and terraced steps, on the arches of which Paleozoic strata are usually present. Analogous dislocations have developed also along the foot of the Dzhair and Semistay ranges, with the sole difference that here the strata of the Jurassic and Cretaceous series on the sides of the domes and on the steps of the structural terraces manifest steeper dips.

A prominent role in the geological development of Dzungaria was taken by the fault zone which extends in a northeasterly direction from the town of Urumchi to the bend of the Urungu River. Repeatedly originating on these faults were transverse benches which separated regions having different paleogeographic conditions. In the Permian and Triassic the eastern part of the massif (Borten'-Gobi) was submerged, and in this part there are mainly the localized deposits of these systems. Beginning with the Upper Jurassic the hypsometric relations of the western and eastern blocks of the massif were reversed: the western block began to sink more actively and Upper Jurassic, Cretaceous, and Paleocene deposits accumulated extensively on it, though they were absent on the eastern block. In the present-day relief the sudden extinction of the Bogdo Shan range and the Nemeychu and Kara-Mayli mountains have, as it were, become adapted to the Urumchi zone of northeasterly faults.

Mineral Resources

The most important mineral resources which have been discovered in Dzungaria up to the present time are petroleum, coal, and gold.

Petroleum is found along the southern and western margins of the Dzungarian plain and in the Nomin-Gobi to the west of the settlement of Nom. The oil strata belong to the most submerged parts of the Dzungarian massif, in which deposits of the Mesozoic and Cenozoic are of maximum thickness and have undergone dislocation in connection with the most recent movements. The oil is contained in large asymmetric anticlines and folded anticlines, apparent in the contemporary relief in the form of mountain ridges. In depth these folds pass over into block displacements of the foundation along faults.

Coal is located in Jurassic deposits of the boundary areas of the Dzungarian massif and the adjacent Mesozoic basins of Pogranichnaya Dzungaria and the Nomin-Gobi. The main coal-bearing horizons belong to the Middle Jurassic, which is represented by interbedded sandstones, argillites, and conglomerates. The largest coal-bearing Jurassic strata are observed along the boundaries of the Tien Shan and Pogranichnaya Dzungarian ranges. Towards the Dzungarian plain the number of coal seams

diminishes and the seams become thinner; in addition, the coals become ashy and are transitional to carbonaceous argillite. The degree of coal-impregnation of the Jurassic stratum changes also along the strike of the basin. Increased coal-impregnations distinguish the Urumchi region where, in addition to numerous beds and seams of coal 1-2 m thick, there are coal beds 11-14 and even 30 m thick.

A predominance has been noted in the western side of the basin of thin coal beds with considerably less veins of workable thickness. The coal veins in this case, even when less than 1 meter in thickness, are characterized by a complex structure in consequence of their seams of carbonaceous argillites. The ash content of the coal varies from 1 to 2% in shiny varieties, and 20 to 25% in dull varieties. The sulfur content is not great and usually does not exceed 0.55%. The volatile content varies. Clearly evident in the southern part (next to the Tien Shan) of the field is a tendency towards an increase in the degree of metamorphosis of the coal in an eastward direction. In the fields to the west of the Urumchi group, the coals contain many volatile substances and belong to the group of fatty and long-flame coals. In the Urumchi deposits the content of volatile materials diminishes to 33% (of the combustible mass), and in some of them (for example, the Po-ta-wang) the coal is of the coking variety.

The Jurassic coal-bearing stratum is exposed only in the foothills on the periphery of the Dzungarian field in an area which underwent a conversion of the tectonic system even before the depositing of the Tertiary complex. On the plains of Dzungaria, which were not subjected to this tectonic conversion, the Jurassic lies at a considerable depth under strata of the Cretaceous and Tertiary systems. The Jurassic coal-bearing deposits are dislocated in the foothills. Usually they form broad, gently sloping folds, and only in the vicinity of large fractures are they compressed into narrow steep folds extending for many tens of kilometers along the strike.

The coal reserves of the Dzungarian basin have been estimated at several tens of billions of tons.

Gold is widely distributed in the mountains of Dzungaria. Especially rich in gold is the Dzhair range in which have been observed old workings which can be traced over a large area. Almost all the gold mines and placer deposits are located in outcroppings of the Lower Paleozoic, mainly in parts where there are many basic volcanic rocks. The gold has been worked in quartz veins and placer deposits.

The gold-bearing quartz veins of the Dzhair and Mechin-Ula ranges are characteristically thin (rarely exceeding 1 m), several dozen meters long, and occur along sharply dipping crevices dissecting the enclosing schists and sandstones in various directions. Some gold-bearing veins reveal a beaded structure and are accompanied by zones in which the schists have been perforated by small quartz injections. The quartz of the ore veins is white and coarsely crystalline and contains infrequent impregnations of sulfides.

Placer gold is found in various valleys of the Dzhair and Mechin-Ula ranges. Its economic importance is not great, due to the insufficiency of water in these heights.

9. NAN SHAN, ALTYN TAGH, AND TSAIDAM

General Description of Orographic Regions

Situated between the desert plains of the 40th parallel and the Kunlun is an extensive and structurally varied expanse of mountainous country which combines several orographic groups. The ranges of the Nan Shan, trending in a northwesterly direction, and the range of the Altyn Tagh, extending to the northeast, resemble a bow curving to the north. Inside this bow is contained the high plains of the Tsaidam and Kul'tala, separated by the Chimen Tagh, which, like the Nan Shan, has a northwesterly direction.

Nan Shan. The eastern, more strongly developed side of the arch in front of the Kunlun, known under the name of Nan Shan is composed of from five to seven large ranges separated by broad longitudinal troughs. (In recent years Chinese scientists have favored the name Chi-leng Shan, from the district center Chi-leng in the valley of the Ta-t'ung Ho in the Eastern Nan Shan.) Although the trend of the Nan Shan is not uniform, the northwesterly trend strongly predominates, and all the most extended mountain chains have this trend. At both ends the ranges of the Nan Shan are cut by strong northeast faults, with the result that they are either broken off steeply towards the plains, or thrust against the mountain ridges which extend laterally across them. Between these zones of lateral distortions the length of the system is about 800 km and its breadth 320 km.

Fig. 31 Southern slope of the Richthofen range in the basin of the Woo-ta-kuo-woo River (photograph by Chun Foo-do).

The system received the name Nan Shan ("southern mountains") from the inhabitants of the oases of the Kansu corridor which it surrounds in the south.

The northern part of the Nan Shan is formed by the snowy Richthofen range and its snowless eastern spur, the Ma-ling Shan. Both ranges appear strongly asymmetric, in connection with the different elevations of the plains lying at their flanks. The northern slope of the chain, facing the plains of the Kansu corridor which lie at an elevation of up to 1,500 m, is very high and extended. Its elevations attain 4,500 m and its overall breadth amounts to 30-40 km. In places, the narrow continuous troughs, which originate on the faults, divide it into separate benches and ridges. The southern slope of the Richthofen range, inclined towards the valley of the Hei Ho (with elevations of 3,600-3,800 m) is short and lower. Its breadth is only 12-15 km and its relative elevation less than 2,000 m. The main crest of the range is broad, massive, and dissected by deep river valleys into groups of snow-covered summits with absolute elevations of 5,700-6,000 m. The summits are flat or rocky, changing into winding spurs. The ranges are difficult to approach; the few passes through them are situated in lateral tectonic troughs. A part of the range covered by perpetual snow extends for a distance of 220 km between the disrupting valleys of the Ling-shui and Hei Ho. West and

of these lateral valleys the Richthofen range descends, dividing into separate spurs. The western spurs of the range slope down to an arid region, are weakly dissected, and preserve remnants of the ancient denuded surface; while the eastern spurs are less rocky though more dissected. The relief of the slopes here is subdued by the soil cover and loess accumulation.

The longitudinal valley which separates the Richthofen range from the following chain of the Nan Shan is named the Hei Ho from the river which flows in it for a distance of almost 200 km. The breadth of the Hei Ho valley varies between 10 and 18 km; its elevation varies from 3,500 to 3,800 m. In the Hei Ho there are two relief zones: the main surface, and the broad bottoms of numerous gullies which incise it to a depth sometimes of dozens of meters. In places the valley is divided by sloping transverse ridges, which form interior watersheds.

The second chain of the Nan Shan is the high Tkholo Shan range which has snow-covered summits only in the western half of the system where it rises 5,000-5,200 m. The passes here lie at elevations of 4,100-4,200 m. The crest of the range is narrow and rocky, divided in many places by broad saddles into separate blocks. The longitudinal troughs bordering the Tkholo Shan range have equal elevations. In consequence, the slopes of the range are more or less symmetric. The Tkholo Shan receives somewhat more precipitation than the Richthofen range, which is affected by the Ala Shan desert. Thus the former is also more strongly dissected.

An independent mountain chain the Tkholo Shan range extends only to the longitude of the settlement of Chi-leng, where in connection with the tapering out of the Hei Ho valley it merges with the eastern spurs of the Richthofen range.

A second longitudinal valley extends along the entire expanse of the Nan Shan. In it are found the Ling-shui and Ta-t'ung Ho, which flow in opposite directions. From both sides, lateral coulisses of the ranges intrude into the valley with the result that its breadth changes frequently and sharply. The elevation of the valley from the main watershed of the Nan Shan to the flanks of the system gradually decreases from 3,600 to 3,300 m. The valley's surface over almost its entire length constitutes a grassy-bushy steppe with sandy-pebbly soil

The third mountain chain of the Nan Shan is not continuous. In the area of the system's main watershed it is divided into two separate branches: a western, the Ta-hsueh Shan; and an eastern, the Ching-shih-ling range. The former is a high rocky ridge, fringed on the northern slope by two or three zones of piedmont terraces in the form of sloping plateaus gently inclined toward the To-loi Ho valley. On the northern slope the entire crest of the range is covered by snow, but on the southern slope snow covers only individual summits. In a westerly direction the range becomes less dissected, the pyramidal stony peaks on the crest being gradually replaced by flat-domed summits situated at about the same level. In the western part the range is dissected by the continuous valley of the Su-le Ho.

The Ching-shih-ling range rises to an elevation of only 4,500 m and nowhere reaches the snowline, although more of its relief has an alpine character than is the case with the Ta-hsueh Shan. The northern slope of the former range (above 3,700 m) is covered in the upper zone by alpine meadows, which lower are replaced by bushes, and still lower by forests. The watershed ridge is sharply displaced in the direction of the northern slope, which is therefore short and steep. The southern slope, which faces the Kukunor depression, is gently sloping and long. It is divided into a series of sloping plateaus, elevated along longitudinal faults.

The third longitudinal trough bearing the upper reaches of the Su-le Ho, is developed only in the Western Nan Shan. In the area of the main watershed it is closed by a diagonal spur of the Zyussa range. This is the highest longitudinal trough of the Nan Shan: its absolute elevation falls within the range of 3,700-4,000 m. The floor of the trough is a gently rolling plain. In the eastern part it becomes swampy and contains many small lakes, while in the western part it is a dry steppe with separate groups of barkhans up to 12 m in height (Fig. 32).

The fourth mountain chain of the Nan Shan, the Zyussa range, like the valley of the Su-le Ho, is developed only in the western part of the system. In the zone of the main watershed it changes its trend abruptly from northwest to northeast and butts onto the ching-shih-ling range. The Zyussa range is the highest chain of the Nan Shan: its base rises 4,500 m and the crest of individual summits reaches 6,000-6,300 m. The slopes are covered with snow for almost 1,000 m along the vertical, but not everywhere. In the zones of transverse distortions the range descends below the snowline. In the high parts it constitutes a narrow ridge with pyramidal and conical summits and extensive firn fields on the slopes. Glaciers radiate from the major summits.

Fig. 32. Upper reaches of the Su-le Ho valley (Sulenor tract) and Zyussa range (photograph by Chun Foo-do).

The fourth depression zone extends through the entire Nan Shan system. Within it lie the Sharagol'dzhin valley, the Kharanur basin, and the basin of Lake Kukunor, separated by lateral upheavals. To the same depression zone belongs also the valley of Hsi-ning Ho, which is separated from the Kukunor basin by a low diagonal ridge. Hilly, undulating relief prevails within the territory of the depression zone, being replaced in the direction of the lateral upheavals by low mountains. The elevation of the main surface in the Kharanur basin is 4,000 m or somewhat more. Along the course of the Sharagol'dzhin towards Lake Kukunor, however, it drops to 3,200 m.

The fifth chain of the Nan Shan comprises the Humboldt and Southern Kukunor ranges, which are separated in the Kharanur basin sector by a zone of complex mountains without clear orographic direction.

The Humboldt range rises above the snowline only in the eastern part, rising here to an elevation of about 5,400 m. The crest of the range is not deeply incised, with the result that the passes running through it, even in the western part traverse it at elevations of not less than 4,700 m. The weak dissection of the range explains also the predominance in it of truncated-pyramidal summit forms. In the south the Humboldt range is bounded by the desert plains of the Syrtyn- and Khaltyn-Gol, which are situated on its northern flank 500 m lower than the Sharagol'dzhin valley. In connection with this, the southern slope of the range is somewhat higher and steeper than the northern.

The southern Kukunor range is orographically distinct only along the 98th meridian of longitude, where on its northern flank appears the valley of the Pu-heng-Gol. It extends to the eastern edge of Lake Kukunor as a narrow mountain chain, rising in terraces above the flanking plains. Several groups of summits of the western part of the range are covered with perpetual snow. Opposite the eastern margin of Lake Kukunor the range abruptly descends and is transformed into a flat dissected ridge. In profile the southern Kukunor range displays asymmetry, which is reflected, in contrast to the northern ranges of the system, in the greater elevation and steepness of the southern slope, which faces towards the lower Tsaidam On the northern slope the southern Kukunor range is still strongly affected by a monsoon, with the result that here may be seen large areas of forest and meadow vegetation. The southern slope of the range, however, is completely barren.

On the continuation of the southern Kukunor range, beyond the low-mountain zone of the basin of the Ara-Gol River, rises the Ama-Surgu range which, although not high, is strongly dissected and has thus received the name "Sinisian Alps."

The southern ranges of the Nan Shan do not form continuous chains nor maintain a uniform trend. The small extent of these ranges divides them in some cases into similar mountain massifs.

The Ritter range is the highest in this group and probably more than any of the others resembles a mountain massif. Despite its enormous elevation, many summits exceeding 5,000 m and with a breadth of up to 50 km, it extends only for a distance of 100 km. The range has several crests which converge in two snow-covered knots.

Situated on a continuation of the Ritter range to the south of the Kaktyn-Gol valley is the Kurlyk-Daban range, which has a northeasterly trend. The range rises 5,000 m and is snow-covered in the southwestern half. Its crest is sharp-toothed, and on the flanks there are flat and conical summits separated by high saddles... Both slopes of the range are steep and rocky.

To the southeast of the Kurlyk-Daban range follows the Sarlyk-Ula mountain ridge and the Semenov range, which together constitute a mountain chain rising in an easterly direction. Along the headwaters of the Chang-ke-Gol (a left tributary of the Huang Ho) the Semenov range rises above the snowline.

The northern slope of this chain is rectilinear, steep, and short, although the difference in elevation between its foot and crest is greater than on the southern slope, which is gently sloping and long. The western part of the mountain chain, butting onto the Tsaidam, is completely barren. The eastern half, however, belonging to the basin of the Huang Ho is less desolate, and along it, among stony slopes, there are meadows and forests of juniper trees.

On the Tsaidam boundary the Nan Shan is edged by a group of short rocky crests and ridges trending in a northwestern direction, now nearly latitudinal, now almost longitudinal. The crests and ridges are separated by broad valleys which are divided by low transverse hills into enclosed basins with lakes and solonchak wastes. The relative elevations of the ridges are not more than 500 m. Their southern slopes, inclined towards the Tsaidam plain, are higher, steeper, and less dissected than the opposite slopes. The entire zone of the southern foothills of the Nan Shan, like the neighboring Tsaidam plain, is a desert.

Speaking of the Nan Shan as a whole, mention should be made first of all of the differences in the structure of its western and eastern parts. In the western half, the ranges are larger and higher than in the eastern. This is especially noticeable on the basis of the location of the snowy mountains, which are almost exclusively found in the western half of the Nan Shan, despite its increased aridity and the higher level of the snow-line. The boundary between the western and eastern parts of the Nan Shan coincides with the zone of strong transverse faults in which lie the Kurlyk-Daban and Zyussa ranges, which are unusual for this system in being extended in a northeasterly direction. Coinciding with this same fault zone is the main Nan Shan watershed, from which the rivers flow in longitudinal valleys in opposite directions. The linear development of the ranges is maintained for the entire extent of the mountain system only by the northern chains, the southern chains being broken up into short ranges and mountain massifs which are not always extended in the same direction.

The peripheral ranges of the system have unequal slopes, and their asymmetry is mutually opposed: in the ranges of the northern chain the northern slope, dipping towards the Kansu corridor, is distinguished by the greatest steepness and elevation, while in the range of the southern group the southern slope, facing towards the Tsaidam, is more strongly developed. The descent of the Nan Shan ranges to the east and the appearance among them of intermountain troughs (Kukunor and Ta-t'ung Ho), which open in the same direction, facilitates the penetration into the interior zone of the mountain system of the warm and moist monsoon from Southern China. At the same time, the high peripheral Richthofen, Humboldt, and southern Kukunor ranges check the dry winds blowing from the Ala Shan, Tarim, and Tsaidam deserts The interior of the Nan Shan, protected from the desert but accessible to the monsoon, receives more than 200 mm of precipitation a year. Thus climatically it does not represent a Central Asiatic region. Whereas the exterior slopes of the peripheral ranges, exposed to the hot, dry air of the desert, are completely barren, in the

ranges and valleys of the interior Nan Shan all the more or less sloping surfaces are covered by meadow or steppe vegetation and, in places, by forests. But observable even within these climatic zones of the Nan Shan (which are determined by the exposure of individual ranges to various wind currents) are general regional changes in climate and landscape along the trend of the mountain system, depending on distance from the desert of Central Asia and proximity to the region actively affected by the monsoon. This regional regularity is reflected in the gradual weakening of desert landscape features towards the southeast and their complete disappearance in the regions lying to the east of Lake Kukunor.

The "Western Nan Shan," writes M. E. Murzayev,"receives a small quantity of precipitation. Therefore it is dry, stony, rocky; the soils are gravelly, the vegetation sparse. . . Despite the considerable amount of firn and ice, few rivers originate in the Western Nan Shan and there is considerable surface evaporation. The majority of the streams which originate in the zone of snow and ice disappear in the middle or lower parts of the mountain gorges, down which temporary streams flow torentially, accumulating along the foot of the ranges enormous masses of outwash material. . ."

"Central Asia," says the same author, "is a transitional area. It has mountain-steppe landscapes, although even here the intermountain troughs have a desert appearance.

In the Eastern Nan Shan there are no perpetual snows, but the alpine zone occupies a large expanse. On the northern slopes of the mountains there are extensive forests of Tien Shan spruce. Beginning with the longitude of Lake Kukunor, loess appears in the Nan Shan, covering its heights with an unbroken mantle moderating the microrelief.

The tendency towards lessened aridity towards the east is apparent also in the reductionof the snowline and of the boundary of descent of glaciers, as well as in a general reduction in the extent of glaciation. Snow and glacial cover is extensive only in the Western Nan Shan, where the crests of the ranges rise 5,000-6,000 m over considerable areas. Snows and glaciation are greatest on the Zyussa and Ta-hsueh Shan ranges, which are located in the interior zone of the system and receive the greatest amount of precipitation. On these ranges firn basins lie along the slopes in a strip of almost a thousand meters, while the glaciers, despite the great steepness of the troughs, reach lengths of 4-5 km. In these parts of the crests perpetual snows do not descend below 5,200 m, while in the eastern they begin as low as 4,600 m. Glacier tongues descend in some cases to 4,400 m.

Ancient glaciation was considerable in the Nan Shan. Enormous masses of ice and firn were concentrated in its longitudinal troughs, where were found glaciers as long as 100-200 km. Along these troughs the glaciers descended to an elevation of 3,000 m. Even on the northern slope of the Richthofen range, which was subject in the past to the effect of the arid climate of the Ala Shan, traces of ancient glaciation in the form of cirques and troughs with lakes and swampy plains are still to be observed even at an elevation of 3,300 m (Fig. 33).

In the longitudinal troughs of the Nan Shan are distinguished several zones of ancient glacial relief, of which two are particularly clearly apparent: a very high trough, which occupies the entire expanse between the rocky crests of the ranges; and a very low trough, containing a river channel. The glaciers in the longitudinal troughs of the Nan Shan did not disappear simultaneously. The glacier remained longest of all in the upper course of the Su-le Ho (Sulenor tract) in which even now there exist layers of subsurface ice which take the form of blister-like mounds.

Fig. 33. Glacial basin with lake on the northern slope of the Richthofen range (photograph by Shen Nai-sheng).

Hydrographic net of the Nan Shan. A large part of the Nan Shan belongs to the region of interior flow, and only that part which includes the tributaries of the Huang Ho belongs to the Pacific Ocean basin. The region of interior flow of the Nan Shan is in turn subdivided into two types: local landlocked basins, the terminal lakes of which are located within the mountain system (for example, Kukunor and Kharanur); and enclosed basins, the centers of flow of which are located beyond the limits of a given mountain system (for example, the Edzin-Gol and Su-le Ho).

A prominent feature of the hydrography of the Nan Shan is the parallel upper courses of the rivers, which run in longitudinal valleys.

The Hei Ho, Ta-t'ung Ho, Su-le Ho, Sharagol'dzhin, and Khaltyn-Gol flow in perfectly straight courses for distances of 150-250 km, joined along the way by the numerous but short tributaries from the bordering ranges of the valley. Lower along these parts, the rivers bend onto the plain of the Kansu corridor or toward the valley of the Huang Ho, traversing the ranges along one of the zones of diagonal dislocations. Whereas in the longitudinal valleys the rivers flow slowly in shallow, broad beds divided into channels, in the continuous canyons they form turbulent currents. A somewhat different pattern distinguishes Pu-heng-Gol and Hsi-ning systems, which flow through a broad depression zone. These systems, besides the trunk river, which flows in the direction of the extension of the ranges, have many large, extended side tributaries.

The main watershed of the Nan Shan is the diagonal upheaval extending from the Kurlyk-Daban range through the eastern Zyussa range toward the town of Chan-yeh. Rivers flow in opposite directions from it down longitudinal valleys. Largest are the Hei Ho, Li-shui, and Su-le Ho whose headwaters lie in the most elevated and snow-covered parts of the mountains. These rivers are fed almost entirely by snow and glaciers. The rivers of the Eastern Nan Shan--the Ta-t'ung Ho, Hsi-ning Ho and others--also carry large volumes of water, although they flow among snowless ranges. They are fed largely by ground waters and precipitation.

A large proportion of the waters which collect within the territory of the Nan Shan flow north and west towards the plains of the Kansu corridor; at whose boundary are observed the maximum variations in the elevation of the relief. Towards the Tsaidam, the surface of which lies

1,000 m higher than the plains of the Kansu corridor, the flow of waters is small. Besides, the greater part of the water which flows in that direction does not reach the Tsaidam but is held in the basins separated from it by low, barren ridges. In these basins the waters form small lakes: Kurlyk-Nor and Toson-Nur, I-ho-Tsaidam, Baga-Tsaidam, and others, which are saline in various degrees

Lake Kukunor (in Chinese "Ching-hai") is situated in the eastern Nan Shan, in the broad depression between the southern Kukunor and Ching-shih-ling ranges. The lake lies at an elevation of 3,205 m. In the south a slope of the southern Kukunor range approaches close to it, while to the north stretches an area with gently rolling hills and broad valleys. On the southern shore of the lake there are two terraces, which are evidence of higher levels of the lake: the upper of these is covered with as much as 0.5 m of loess. The waters of the lake are brackish; in salt content sodium chloride predominates. Into Lake Kukunor flow about 10 small rivers, of which only the Pu-heng-Gol, which begins in the eastern Zyussa range, carries much water The small Ara-Gol River flows into the lake from the west along a gently sloping valley separated by a flat elevation from one of the tributaries of the Huang Ho. It is probable that even a modest rise in the level of Lake Kukunor would re-establish the lake's connection with the ocean through the valley of the Ara-Gol.

Lake Khara-Nur lies in the same depression with Lake Kukunor. It has an altitude of 4,048 m; it is 36 km long and 15-20 km wide. Its waters are alkaline. The shoreline is indistinct, especially along the southern edge, due to the swampiness of the low shorelines and fluctuations in the level of the lake depending on changes in climatic conditions. Scattered along the eastern shore are sandy barkhans up to 30 m high.

The vegetation of the western part of the Nan Shan, which is subject to the effect of dry, hot desert winds, is different from that of the eastern part of the mountain system, which is exposed to the warm and moist monsoon. In the Western Nan Shan vegetation is sparse and uniform, just as in the neighboring deserts. Here the slopes of the mountains and the floors of the longitudinal valleys are either completely bare or have only scattered drought-resistant bushes. The coloration is thus determined more by that of the outcropping rocks than by the vegetation cover.

In the Western Nan Shan, desert vegetation--tamarisk, saxsaul, "kharmyk," Reaumuria, and others--is found up to an elevation of 3,000 m. Higher the vegetation is replaced by a zone of dry steppes with feather grass (Stipa), Lasiagrostis, white willow, and others. Above 3,500 m begins the alpine zone with a rather dense plant cover of various vetches, leeks, and cereal grasses, which grow only on the watered parts of the slopes. At elevations of 4,000-4,100 m the alpine zone gives way to a strip of loose, rocky ground and crags, which continues up to the snow-line. On the boundary of the rocky ground the plant cover becomes very sparse and only scattered species reach higher. In an easterly direction, approaching the regions of monsoon climate, the vegetation becomes richer and more varied on the mountains of the Nan Shan while the boundaries of its vertical zones gradually descend.

In the Eastern Nan Shan the alpine zone is well developed, beginning here at 3,000 m and rising to the rockiest crests, covering 1,200-1,300 m of vertical slope. In it can be discerned a lower bushy and an upper grassy strip. Predominant among the grasses are leeks, vetches, and cereal grasses. Common among the bushy plants are rhododendron and alpine species of elm; encountered somewhat less often are low willows, buckthorn, barberry, and dog rose. On the less well-watered parts of the slopes of the bushy strip, millet (Eleusine cogacana, Gaertn.) and white willow are encountered.

Forests grow along the northern slopes of the ranges. They usually do not rise above 2,800 m, and only the more resistant juniper trees reach the bushy strip of the alpine zone and, in some cases, extend into it.

Forests grow only along the shady slopes of the mountains and in the river valleys. Most often found in the forests are Himalayan and white birch, aspen, spruce, pine, poplar, and mountain ash; and among the bushes, which form thickets along the river banks, honeysuckle, currants, jasmine, and buckthorn.

The fauna of the Nan Shan varies in different parts of the system. In the Eastern Nan Shan, despite favorable natural conditions, large mammals are few, because here there is a rather dense human population. There are few rodents here, since the increased soil moisture does not favor their distribution.

Occurring in the alpine zone of this part of the Nan Shan are Kuku-yaman (Pseudois nayaur) and marmots, and in the forests--bears, deer, roe deer, musk deer, wolves, badgers, and foxes. The Eastern Nan Shan is also rich in birds, among which are hundreds of species, for the most part not indigeneous to Central Asia but found throughout Eastern China. Among the flesh-eating birds in these mountains are griffon vultures, eagles, and hawks; among the fowl, partridges, pheasants, and guinea hens.

In the Western Nan Shan there are many wild yaks and koulans, which form herds of 100-200 head. Here there are also addaxes and Kuku-yamany, many small rodents, some pandas, and eagles and hawks. Of the carnivores the most common are wolves, which is explained by the abundance of ungulates.

Altyn Tagh. This is the name given to the group of ranges and ridges with a northeasterly trend extending between the Tarim and Tsaidam massifs for a distance of about 1,000 km. A strong effect is exerted on the relief of the Altyn Tagh by the northwestern dislocation system which stretches from the Nan Shan, Tsaidam, Chimen Tagh, and Kul'tala. In accordance with the nature of the effect of the transverse system, three basic sections are distinguished in the Altyn Tagh: a northeastern, bordering on the Nan Shan; a central, opposite the Tsaidam; and a southwestern, butting onto the Chimen Tagh and Kul'tala.

The northeastern section of the Altyn Tagh is not a continuous chain: powerful northwesterly faults, coming from the Nan Shan, cut it into short blocks extending in the "Altyn Tagh" (northeasterly) direction. A better linear development is displayed by the piedmont ridges and benches which stretch along the boundary of the Tarim plain and the Kansu corridor. On these ridges, probably as a result of a certain remoteness from the Nan Shan, the effect of the lateral distortions is apparent to a lesser extent. The mountain massifs of the Northeastern Altyn Tagh, lying on a continuation of individual Nan Shan ranges, have undergone the greatest upheaval. Some of their summits are even snow-covered, for example, the Anembar-Ula massif, located in the same zone as the Ritter range. On the other hand, the parts of the Altyn Tagh lying opposite the longitudinal valleys of the Nan Shan are generally depressed and have river valleys running through them. In the central part, which is affected by the Tsaidam, the Altyn Tagh abruptly descends and narrows; here its elevation does not exceed 4,000 m, while the breadth varies between 25 and 40 km. Although in this part the Altyn Tagh extends in a northeasterly direction, its block structure is clearly evident, partly in the alternation of blocks of different heights, partly in the angular advances of some blocks onto the Tarim and Tsaidam plains.

In the southwestern part, which is influenced by the Kunlun, the Altyn Tagh develops into a mighty mountain system consisting of two or three parallel chains covered by perpetual snows, the chains being separated by longitudinal valleys. The Toguz-Davan range forms the exterior chain of the Altyn Tagh. It rises over the Tarim plain in a wall 3 km high, and 1-1.5 km over the longitudinal intermountain valley. Both slopes of the range are dissected by deep gorges, are extremely rocky, and on the less steep parts covered by talus The Toguz-Davan range is traversed by the valleys of several rivers which feed the oases of the Tarim plain.

The second chain may be called the Yusupalyk Tagh from its highest part, which is crowned by a snow-covered crest. To the west and east the range descends and is broken in a number of places by lateral grabens in which lie similar mountain passes. The slopes are developed nonuniformly. The southern slope, which faces the fault valley of the Yusupalyk River, is short and steep, in places having terraces; while the slope which descends towards the northern longitudinal valley is broad and dissected by river gorges into narrow rocky ridges.

The longitudinal valley extending between the Tonguz-Davan and Yusupalyk Tagh ranges is narrow (not more than 10 km in width), but in the basin of the Dzhakhan River it suddenly broadens to 30 km. In this valley there are few level parts. Its surface is strewn with hills or dissected by lateral and diagonal ridges descending from both mountain slopes.

In general, the Altyn Tagh, when seen from the side of the Tarim plain, appears to be a high range, the relative elevations of which, even in the middle part, are not less than 2,000 m. From the Tsaidam, however, which is located 1,500 m higher, it gives the impression of a moderately elevated ridge. Watercourses are observed only in the eastern and western parts of the Altyn Tagh butting onto the Nan Shan and Kunlun. In the middle part of the mountains opposite the Tsaidam there are no watercourses. Vegetation is poor all over the Altyn Tagh. Only in the longitudinal valleys and gorges are there found ephedras, stunted saxsaul and tamarisk bushes, reeds, and several species of halophytes. Animal life is also sparse in the Altyn Tagh. Only in the mountains bordering the Nan Shan and Kunlun do there appear at times wild yaks, "orongo" antelopes, and "kuku-yamany." In the lower and more barren middle part of the range, wild camels were found until recently which had strayed from the sands of the Kum Tagh.

Tsaidam. The Tsaidam is a high plain enclosed between the ranges of the Nan Shan and the Altyn Tagh dome in the north and the Kunlun ranges in the south. Along with the Tsaidam within the frame of these ranges is another, still higher plain--the Kul'tala, which is separated from the Tsaidam by the Chimen Tagh range.

Map 42. Boundaries of the Tsaidam Ta-pa-sung-Nur lake in the past and at present.

Legend:

1--surrounding mountains of the lake basins;
2--plain of Northwestern Tsaidam;
3--peripheral parts of ancient glacial basin not covered by the waters of the lake;
4--bed and sediments of the ancient lake;
5--residual lakes.

/Place names on map:/

1--Batyrantu River;
2--Khadzhar (city);
3--Tsaidam;
4--Lake Divsan-Nur;
5--Naychi-Gol River;
6--Takalgan (city);
7--Tatlyn-Gol River;
8--Lake Khollosun-Nur;
9--Pa-yang-Gol River;
10--Bulangir-Gol River;
11--Dzun (city);
12--Golmo (city).

The Tsaidam itself has the shape of a horn widening towards the Altyn Tagh, in this part having a northwestern direction, while in the narrow eastern half it acquires a latitudinal direction. The Tsaidam extends for 600 km in a latitudinal direction and 100-200 km longitudinally. In landscape forms it is divided into two parts: a southeastern, narrow, almost completely covered by solonchaks; and a northwestern, a broad clay and sandy desert very hilly in places. The former part lies at an altitude of 2,600-2,700 m; the latter, 2,700 to 3,000 m. These parts of the Tsaidam are separated by a low bench. The northwestern part is framed by barren mountains from which little water flows. The surface here is without vegetation, and only along the dry channels which collect the insignificant rain waters may scattered white willow, Tydapzassor and Reaumuria bushes be encountered.

The southeastern part of the Tsaidam is bordered in the south by the Kunlun ranges, in which originate several large rivers which often penetrate far into the basin and terminate in salt lakes. On continuations of the rivers which dry up in the foothills, beyond the last barren benches there appear numerous springs which water the soil and make possible an abundant growth of cane, sedge, and several cereal grasses. In less well-watered parts appear thickets of tamarisk and "kharmyk" with low growths of cane, calligonum, and "sugak." This is the best area in the Tsaidam and extends in an almost unbroken strip 10-20 km in width. Farther on, up to the most northerly boundary of the basin, the Tsaidam is covered by brown solonchaks in which vegetation is completely lacking. In the recent geological past this part was the bed of an enormous lake, and still earlier the bed of a piedmont glacier (Maps 42, 43).

Map 43. Tsaidam in the glacial period.
1--rocky crests of ranges rising above the ice cover;
2--glaciers;
3--parts of the plain not covered by ice.
/Place names on the map:/
1--Altyn Tagh
2--Nan Shan (system)
3--Kunlun (system)

The hills and ridges of Northwestern Tsaidam are grouped into two zones situated at some distance from the Chimen Tagh and Mushketova range and parallel to them. The zone of interior heights of the Tsaidam joins the Altyn Tagh at almost a right angle. In the largest of these zones--the western--there are more than 10 ridges with lengths of 4-15 km and with relative elevations of 60-250 m. Separated from the Tsaidam by these ridges is a strip of piedmont plain running along the foot of the Chimen Tagh and containing extensive solonchak wastes, including the Gaskul' solonchak with the salt lake of the same name.

In the northeast the Tsaidam is joined with the Syrtym plain, which is essentially an orographic element of the Nan Shan. This plain originates on a continuation of the steeply descending Ritter range from the longitudinal mountain valleys which lie along its flanks. Onto the Syrtym plain from the Nan Shan flows the Khaltyn-Gol River, which forms in the western part of the plain a salt lake, the Su-hain-Nur, which is framed by a strip of solonchaks and spring tracts.

The Chimen Tagh and Kyakdyg Tagh ranges, which separate from the Tsaidam the still-higher mountain plain of the Kul'tala, extend parallel to the ranges of the Nan Shan. On the western rim they descend to the valley of the Yusupalyk River, and on the eastern to the edge of the Tsaidam. The ranges are separated by a valley in which flow the Khatynzana and Bayan-Gol rivers: the first northwesterly toward the Yusupalyk, the second in the opposite direction into the solonchaks of the Southern Tsaidam. The westerly of these ranges, the Chimen Tagh, lies in general below 5,000 m, while the eastern range, the Kyakdyg Tagh, which borders on the higher Kul'tala, rises 500-1,000 m higher, in some places above the snowline. Both ranges are dissected by deep branching troughs, although they still preserve remnants of the ancient peneplain. There are few rocks on the slopes but much loose talus. The ranges are everywhere arid and barren.

The Kul'tala plain has the shape of a miniature Tsaidam and, like the latter, is narrow and elongated in the eastern part and broad in the western. The elevation of the plain varies between 3,500 and 4,500 m. Around lakes Ayagkumkul' and Achikkul' the plain has no irregularities, but elsewhere, especially facing the Przheval'skiy range, it is covered with hills and low ridges of soft rocks in which the wind has created microrelief forms reminiscent of towers, fortresses, bridges, and cones. These hills are usually 100-150 m high, but some reach 300 m. The Kul'tala plain, according to N. M. Przheval'skiy, constitutes a desert not of the Tibetan, but rather of the Western Nan Shan, type. Besides stunted halophytes, in the watered areas there are species of carex, and in pebbly areas there are also "polyn," Eurotia, and Reaumuria. Among the animals there are koulans and "orongo" antelopes; these occasionally stray into this area.

In the southern part of the Kul'tala the two mighty knots of the rka Tagh range rise as high as 7,720 m. In these knots there are extensive fields of firn and large valley glaciers which feed numerous rivers. These rivers flow mainly into the Kul'tala plain and there form two large lakes: the Ayagkumkul' and Achikkul'. Both are alkaline lakes.

Geological Structure and Mineral Resources

Three main structural-orographic complexes can be distinguished within this region:

1. The Nan Shan active zone, composed of a series of zones of different age and structure which have developed in the northwesterly direction.

2. The Tsaidam and Kul'tala, representing two parts of a slightly-active block of the earth's crust, separated by the interior upheaval of the Chimen Tagh range.

3. The Altyn Tagh, an inner-platform zone of block dislocations of northeasterly strike, which divides the Tarim and Tsaidam massifs.

Nan Shan. The Nan Shan lies in the zone of northwesterly faults which divides the Ala Shan and Tsaidam massifs. Due to these faults the structural formations of the Nan Shan have a clearly expressed linear development and zonal structure.

The Nan Shan is divided into the following five structural-facies zones, which differ in age and type of dislocation:

(a) the zone of the Richthofen range, which is distinguished primarily by the development of geosynclinal strata of the Ordovician and Silurian;

(b) the crystalline axis of the system, which includes the Tkholo Shan, Ta-hsue Shan, and Zyussa ranges in which ancient metamorphic rocks and granites outcrop;

(c) the Kukunor zone, which is characterized by the development of deposits of the Upper Paleozoic and marine Triassic;

(d) the zone of the Ritter range, a remarkably enormous area of deposits of the Silurian and Devonian of the geosynclinal type;

(e) the zone of the Mushketov range, which is transitional to the Tsaidam Basin and represents an area of the latter which was activated in conjunction with the Nan Shan. In this zone there are ancient metamorphic rocks and dislocated deposits of the platform mantle, primarily Devonian and Carboniferous.

The structural-facies zones of the Nan Shan which have been listed can be followed along the entire extent of the mountain system but are sharply cut off in its northwestern and southeastern termini on the line of encounter with the strong transverse faults originating from the Altyn Tagh and the region of the upper course of the Huang Ho.

The zone of the Richthofen range is a Caledonian geosynclinal prism formed by powerful and intensive warpings of deposits of the Ordovician and Silurian. The horizon of the latter deposits, however, is not uniform and reveals considerable changes both along the strike of the zone and transversely. In the watershed region of the range, which is the most active part of the zone, the complex of Ordovician-Silurian deposits possesses maximum thickness (about 4,000 m), the most complex warping, and strong dislocation of the rocks by metamorphosis. Here it is composed of the following elements: a lower stratum of gray-green argillaceous phyllite-type schists with an abundance of new formations of sericite and chlorite and also siltstones and fine-grained sandstones of quartz-feldspar and graywacke composition; a middle stratum of gray siliceous

and siliceous-argillaceous shales, siltstones, and fine-grained sandstones; an upper stratum of gray-green sandstones and schists to which are subordinate thick blocks of porphyrites and porphyritic tuffs, tuffaceous conglomerates, breccias, and variegated jaspers.

In places in the lower stratum there are blocks of limestones containing fossils of fauna of the Middle Ordovician. Characteristic for the central part of the northern slope of the range, the subsidence of which was moderate, is the development of limestones in general not very sharply dislocated and not manifesting signs of dislocated metamorphism. The limestones are gray and white, in some blocks massive, in others stratified, sometimes strongly silicified. On different stratigraphic levels of the limestone stratum there are blocks of calcareous-argillaceous and siliceous shales. The total thickness of the Ordovician-Silurian horizon of this type does not exceed 1,500 m.

In the lower part of the northern slope of the range, which borders the Kansu corridor, the same complex is represented by sandstones and shales: in the base strata by argillaceous and calcareous-argillaceous, and in the upper by siliceous-argillaceous shales. In this horizon the sandy-shale stratum is not more than 1,000 m thick, although it is rather sharply dislocated and its rocks have undergone phyllitization. Here only the Silurian is represented without the Ordovician, and perhaps even the Lower Devonian enters here, because higher follows a conforming stratum of red-brown sandstones and shales undoubtedly of the Middle Devonian (thickness 400-500 m). It is clear that the part of the Caledonian downwarping to which the watershed ridge of the Richthofen range belongs originated somewhat earlier, underwent a more active submergence, and began to rise correspondingly earlier. The northern edge of the downwarping, on the other hand, sank later and remained so longer than the others. At the end of the Silurian and in the Devonian the now high-altitude part of the Richthofen range constituted an upheaval, while the lower part of the northern slope, in the area of the outcropping of redstones of the Devonian, was at that time a front downwarping.

The Hercynian structural series in the Richthofen range is developed only in narrow grabens. On the boundary of the Kansu corridor it is represented by a stratum up to 100 m thick, composed half of limestones with marine fauna of all divisions of the Carboniferous and Lower Permian, and half of continental sandstones and argillites with coal seams. On the southern flank of the range and in the interior grabens there remain only the continental deposits of the Middle and in part of the Upper Carboniferous in the form of conglomerates and argillites with beds of coal of workable thickness.

In the longitudinal graben which lies between the watershed and the forward ridges of the range, the coal-bearing Carboniferous is covered conformably by a stratum of red and yellow-gray conglomerates and sandstones to a thickness of about 600 m. The middle and upper parts of this variegated stratum belong to the Triassic, and the lower (on the basis of discoveries of plant fossils in analogous layers of the Eastern Nan Shan) to the Upper Permian.

In the high-altitude zone of the Richthofen range, which is characterized by a thick development of porphyritic lavas and tuffs, small bodies of ultabasic rocks are widely found, usually strongly serpentinized. These bodies belong to marginal, intrazonal, and diagonal fractures. With the exception of individual and small dikes, granites are not found in the Caledonian geosynclinal zones of the Richthofen range.

The folding of the Ordovician-Silurian complex in all the subzones of the range is strong, in places having a distinct tilting of the masses in the direction of the Kansu corridor, expressed in the dip of the beds to the southwest. Although the deposits of the Carboniferous and Permian-Triassic lie on the Ordovician-Silurian complex with angular unconformity, they are no less sharply dislocated in connection with their position in the vicinity of marginal and intrazonal fractures.

The crystalline zone of the Nan Shan appears in its highest ranges: the Tkholo Shan, Ta-hsue Shan, and Zyussa, and also in their easterly continuation--the Ching-shi-ling range. A special feature of this zone is the high hypsometric level of the metamorphic foundation, a large part of which appears directly on the surface. In the Caledonian and Hercynian stages of the development of the Nan Shan this zone underwent upheaval in connection with which deposits of the Lower and Middle Paleozoic are lacking in it. Its upheaval explains also the location here of granitoids of various ages. In the Mesozoic the crystalline zone was subjected to partial sinking, as a result of which continental deposits are found in it from the Triassic and Jurassic.

The Pre-Sinisian complex in the crystalline zone of the Nan Shan is composed of three strata differing in composition and degree of metamorphosis: a lower (quartz-schist), middle (primarily schist), and an upper (phyllite). The lower stratum consists mainly of coarse-grained compact white and light-gray quartzites which form bodies several meters to 50 m thick. Bodies of light micaceous schists and, now and then, dark amphibolites 2 to 15 m thick alternate with the quartzites. The middle stratum is composed of micaceous schists and gneissoid rocks containing a buried structure of sandstones and gravels. In some bodies of this stratum there is a large quantity of black hornblende schists, whereas in others quartzites predominate. The upper stratum is probably the thickest and includes micaceous-chlorite phyllites, thin lamellar-structured micaceous schists, and green schists with abundant formations of actinolite. In the crystalline zone the metamorphic complex forms an enormous anticline, the core of which (with outcroppings of the lower stratum) reaches to the Ta-hsueh Shan, and the limbs (composed primarily of the upper members of the metamorphic complex) to the Tkholo Shan and Zyussa ranges. In the rocks of the metamorphic complex ptygmatic folding appears everywhere, but at the same time the strata of this complex do not always lie steeply and there are many parts, particularly in the arch of the anticline, where the beds dip very gently.

The Sinisian deposits in the interior zone of the Nan Shan cover a great area. Their outcroppings can be traced in the Zyussa range, in the valleys of the upper courses of the Su-le Ho and Ta-t'ung Ho and in the Tkholo Shan range. The base beds of the Sinisian strata are composed of multicolored quartzes alternating with marls. Higher follow gray-green graywacke and quartz-plagioclastic sandstones and schists with blocks of light gray limestones and porphyrite tuffs which have undergone a greenstone change. The upper level of the strata is composed of gray and white limestones, in some blocks massive, in others thin-bedded and always silicified to one degree or another. The limestones are interbedded with marls and calcareous-argillaceous schists. The age of the stratum has been determined on the basis of finds of algae usual for the Sinisian system of Northern China. In the Zyussa and Ta-hsueh Shan ranges the Sinisian deposits form large, strongly compressed ridges, but in the valley of the Su-le Ho they lie undisturbed in broad gentle folds. In places Cambrian-Ordovician deposits are included in the Sinisian stratum and represented by limestones with sandy-shale blocks. In the limestones trilobites of the Cambrian age have been discovered.

In the longitudinal valley which contains the upper courses of the Lin-shui and Ta-t'ung Ho there is a coal-bearing sandy-argillite series of the Carboniferous containing thin layers of gray limestones with fusulinids. Alternating with elements of the stratigraphic horizon of the crystalline zone of the Nan Shan is a red stratum of the Triassic and a coal-bearing seam of the Jurassic, which are exposed over considerable areas in the Ta-hsueh Shan, Zyussa, Ching-shi-ling ranges, and also in the valley of the Su-le Ho and in the headwaters of the Bukhin-Gol. The Triassic stratum is composed of brown-red sandstones, in the lower level coarse and transitional to conglomerates, and in the upper level fine-grained varieties. The Jurassic stratum represents an interbedding of sandstones, siltstones, and argillites, while in places there appear in it thick blocks of conglomerates and also seams of coal. Each stratum is hundreds of meters thick. Along the foot of the ranges where there are strong faults, the deposits of the Triassic and Jurassic display complex dislocations; on the remaining parts they lie on a comparatively gentle slope.

Concentrated in the crystalline zone of the Nan Shan is an enormous number of plutonic rocks of differing composition and age. The oldest of these are small bodies of aplite orthogneisses and augen granite-gneisses enclosed in a metamorphic complex. Somewhat younger that these is the block of rapakivi granite which is exposed along the headwaters of the Su-le Ho in the core of the broad flat dome formed by the Sinisian stratum.

The most common type of granite in this zone is a gray biotite variety with a distinct gneissoid structure, forming large blocks in the Ja-hsueh Shan, Zyussa, and Ching-shi-ling ranges. The age of the gneissoid granites is unknown; if they belong to the Paleozoic group, they constitute its oldest members. Among the gneissoid granites are found small bodies of leucocratic block granites which can be assigned to the Hercynian.

The Kukunor zone extends across the entire Nan Shan from the vicinity of the town of Hsi-ning to the lower end of the mountain valley of the Sharagol'dzhin River. This zone is distinguished by the widespread occurrence of the Carboniferous and Permian conformably underlain by thin and mostly red-colored deposits of the Middle Paleozoic.

The Paleozoic downwarping of the Kukunor is wider in the eastern than in the western part, and its axis is displaced towards the southern edge. This asymmetry of the downwarping became apparent in the gradual increase in the thickness of all series of the Middle and Upper Paleozoic from north to south, and in the simultaneous replacement of the continental and littoral facies of sediments by deposits from the open sea.

In the eastern part of the Kukunor depression a cross-section of the deposits shows the following succession. On the northern border the entire complex of deposits from the Devonian to the Triassic inclusive is only about 300 m thick, while the lower part, which belongs to the Devonian and partly to the Lower Carboniferous, is composed of red sandstones--in the basal layers, coarse, with cross-bedding; and higher, fine-grained with parallel bedding, alternating with blocks of variegated marls. The middle part, belonging to the whole Upper Paleozoic, is composed of light-gray block limestones interbedded in the foundation with variegated marls and red sandstones, and, closer to the top, of gray sandstones and siltstones. And, finally, the upper level of the complex, which belongs to the Triassic, is composed of gray, mostly fine-grained sandstones containing thin seams of argillites and argillaceous limestones with goniatites and pelecypods. Southward from here there extend only the outcroppings of the Middle and Upper Paleozoic divisions of the complex, all the horizons of which are of greatly increased thickness.

Farther from the axis of the downwarping (to the broad valley of the Bukhin-Gol River) red sandstones are preserved in the Middle Paleozoic level of the complex, and their thickness increases to 250-300 m. The higher-lying block of variegated marls and sandstones is replaced by a series of gray argillaceous, siliceous, and calcareous sandstones and siltstones with frequent but thin interlayers of limestones (200-300m). The Upper Paleozoic level of the complex increases in thickness to 400 m and acquires an exclusively carbonaceous composition. Conformity of stratification is still preserved between the Middle and Upper Paleozoic parts of the complex in this area of the downwarping.

In the axial zone and on the southern edge of the downwarping is a Middle Paleozoic stratum of siliceous sandstones and siltstones of gray-green and gray-violet color with interlayers of olive-green and multi-colored jasperlike schists, and also a higher-lying stratum of gray-green argillaceous and calcareous-argillaceous shales with blocks of gray fine-bedded limestones. The over-all thickness of these strata exceeds 2,000 m. Both beds are strongly dislocated. The Upper Paleozoic is here represented by two series of different limestones: the lower by limestones of gray color, distinctly stratified (200-300 m); and the upper by gray and white limestones, almost exclusively of the block type (400-600 m). The Upper Paleozoic limestones lie on sandy-shale strata

of the Middle Paleozoic (Silurian-Devonian) with distinct angular unconformity. In this same part of the zone there again appears a sandy-shale stratum of the Triassic of marine origin, and in places also a continental sandy-argillite stratum of the Jurassic with indications of coal-bearing.

The folding of the Paleozoic deposits in the Kukunor zone is gentle and characterized in general by large brachyanticlinal forms of the trunk type. The main background is formed by the flat domes of the anticlines and equally flat synclinal slopes, in which the layers lie at an angle of not more than 10-15°, Only in the narrow limbs of the folds do they acquire an incline up to 40-50°. Approaching the boundaries of the zone, the system of faults which breach its foundation is compressed, in connection with which the folded structure of the strata of the surface becomes more complex. In these boundary parts of the zone the dip of the beds is usually 40-50° The Middle and Upper Paleozoic structural series reveal conformal dislocations only on the spur of the northern limb of the depression, while in the southern limb, where they depart to the surface of an angular unconformity, the deposits of the Middle Paleozoic (Silurian-Devonian) have undergone dislocation up to the limestone deposits of the Carboniferous. The folds of the Middle Paleozoic strata are distinguished by a fairly steep and linear development, resembling in this connection the folded formations of the zones of the Ritter range to the south.

Intrusive rocks are lacking in the Kukunor zone.

The zone of the Ritter range, unlike the Kukunor, is more developed in the west than in the east. It is composed of the Ritter range, the watershed ridge of the Southern Kukunor range, and the mountain ridges on the left bank of the broad valley of the Bukhin-Gol River.

The zone of the Ritter range is remarkable for the exceptional development of deposits of the Silurian and Devonian. These are of great thickness and reveal complex forms of compression.

The stratigraphic horizon of the Silurian-Devonian complex of this zone has not yet been thoroughly investigated. It is known only that it includes gray and gray-green sandstones, siltstones, and shales, in some blocks substantially siliceous, in others argillaceous and calcareous-argillaceous. On various stratigraphic levels of the complex there are limestones containing fossils of the Silurian and Lower Devonian. The thickness of the complex has been estimated as approximately 2,500-3,000 m The folding of the Silurian-Devonian complex is very strong; a dip of the beds of 65-70° is usual here. Granite blocks have been observed in the zone of the Ritter range, but in limited number.

The zone of the Mushketova range is essentially a part of the Tsaidam massif which has been activated along with boundary of the Nan Shan. Located in this zone are the Kurlyk-Daban and Mushketova ranges, the southern slope of the Southern Kukunor range, all the troughs lying between these ranges, and also the mountain ridges rising on the edge of the Tsaidam basin. The ranges and ridges are composed of an old metamorphic series whose composition include gneisses, mica schists, quartzites,

phyllites, with Tertiary deposits in the troughs between them. In the foothills there are limestones with fossils of the Lower Carboniferous and Devonian, and also sandstones and conglomerates, partly red-colored. The total thickness of the Devonian and Carboniferous in this zone is computed at several hundred meters.

Recent evidence has been presented of finds in the southern foothills of the Nan Shan of deposits of the Sinisian and Cambrian-Ordovician in facies which recall those of the Kuruk Tagh. The tertiary deposits in the southern foothills of the Nan Shan reveal several types of horizons. In the valleys distant from the Tsaidam they are not very thick and are represented in considerable party by upper horizons (Neocene-Pleistocene), while in the valleys lying between the peripheral ridges they have a full and thick horizon similar to that of the Tsaidam.

In the zone of the Mushketova range the main axes of the dislocations do not reveal the same linearity as in the rest of the Nan Shan. In this range the foundation is separated into several comparatively short wedge-shaped benches which are apparent in the relief as ranges and ridges which do not extend uniformly, sometimes even an angle to one another. The Mushketova, Southern Kukunor, and Semenov ranges extend NW 300°; the mountain ridge lying between the Tsaidam and the basin of lakes Ikhe-Tsaidam and Baga-Tsaidam, trends northwest (340°); while the Kurlyk-Daban and Imnik-Ula ranges trend in a latitudinal direction. The sedimentary strata appearing in conjunction with these ranges and ridges trend similarly.

Intrusive rocks are found only in the Southern Kukunor and Kurlyk-Daban ranges, where there have been observed several large masses of biotite granites transitional along the contact line with the enclosing rocks into granodiorites, and in places also into quartz diorites.

The present structure of the Nan Shan, apparent in its present relief, began to be formed as early as the Cretaceous. Clearly defined even then were all the ranges and longitudinal valleys of the Nan Shan, although as yet they did not constitute a high-mountain region but were located at an altitude close to sea level. In this original stage of development of the present structure of the Nan Shan, which continued until the close of the Paleocene, strata of red sandstones, marls, and conglomerates were laid down in the longitudinal valleys. In the course of the Neocene and the Quaternary the entire Nan Shan system underwent an intensive upheaval which transformed it into a high-mountain region. In this period not only the ranges but also the longitudinal valleys were subject to denudation, with the result that sedimentary accumulation within the territory of the Nan Shan ceased almost completely. Despite the absence in the Nan Shan of a mantle of young sediments, the forms of its present structure are easily identifiable in the relief from the weakly denuded rectilinear terraces of the slopes and from the position of the remains of the ancient peneplain.

Among the mineral resources now known in the Nan Shan are iron, chromium, copper, lead, zinc, gold, and coal. Mineral resources have been investigated to one degree or another only in the Richthofen range, on the approach from the Kansu corridor, and the marginal mountains of the Southern Nan Shan fronting the Tsaidam basin. As yet almost nothing is known concerning the mineral resources of the interior ranges of the system.

The Richthofen range constitutes an unusual metallogenic province clearly recalling the province of the greenstone rock zone of the Urals. In numerous bodies of ultrabasic rocks in the former, indications are clearly discernible of titanium-magnetite and chromite mineralization. In the Silurian stratum of siliceous shales, porphyritic lavas, and tuffs, impregnation has been noticed in many places of copper-bearing sulfides and even small pyrite deposits. This same zone serves as a primary source of placer gold, which in the past was recovered from placer deposits in the river valleys.

In the lower part of the northern slope of the Richthofen range indications of iron have been found, and among them is one deposit of commercial importance. These ore indications are found in outcroppings of old metamorphic rocks in the northern limb of the Caledonian geosyncline in which the Ordovician-Silurian complex is of reduced thickness and interrupted along the faults by terraces of the foundation

The zone of the Mushketova range appears to be a polymetallic province. In it are evident many ore indications with lead, zinc, and copper as the primary elements. Some of these ore indications seem of great potential commercial significance and are being surveyed at the present time. All the polymetallic deposits of any significance in this zone are found in outcroppings of ancient metamorphic rocks: gneisses, crystalline schists, and marbles. It is interesting to note that in this same zone (the Semenov range) outcroppings of ultrabasic rocks with chromites have been identified (the Shen-ye deposit).

The coal deposits in the Nan Shan are associated with the Carboniferous and Jurassic. Carboniferous coals are found in the area of the Richthofen range, and Jurassic coals in the interior cyrstalline zone.

In the Richthofen range coal beds are known in all the grabens which contain Carboniferous deposits. However, the most valuable coal deposits are found only in the Wu-ta-kuo-wu graben between the watershed and the forward crests of the range. Here the Carboniferous is represented almost exclusively by continental deposits, among which are contained several seams of coal of good quality. The thickness of the primary workable seam of the graben amounts to 3 m. In the grabens of the lower area of the northern slope of the range and in the Hei-ho graben the Carboniferous is frequently represented by marine facies, and in it coals are observed only in the form of thin seams among carbonaceous argillites.

Deposits of Jurassic coals of the interior crystalline zone were discovered in very recent years but have still not been fully investigated. The most promising of them is the coal-bearing area on the headwaters of the Bukhin-Gol River, where several seams of workable thickness have been established.

Altyn Tagh. The geological structure of the Altyn Tagh is known only in the parts traversed by the main roads in the Tsaidam basin and in its margins descending to the Tung-huang and Ansi oases. Some idea of the character of the rocks which compose the Altyn Tagh is provided also by the prolluvial strip encircling the foot of this range along the edge of the Tarim plain. Along this foot of the range ran the ancient silk route, which has been travelled by a number of investigators. The impression has been formed that the Altyn Tagh is composed to a considerable degree of an old metamorphic complex whose composition includes gneisses, granulites, various crystalline schists, and also phyllites, quartzes, and marbles. In places the metamorphic complex encloses blocks of light mica granites which appear to be old and which contribute a dense fractioning, a strong cataclase and inclination to the gneissoid structure.

On the part of the Altyn Tagh lying opposite Lake Lop Nor, extensive outcroppings have been noticed of gray Cambrian limestones. In the longitudinal tectonic valley separating the outer and the Yusupalyk Tagh chain of the range, there are limestones and sandy-shale series of the Upper Paleozoic. The Cambrian limestones of the Altyn Tagh are similar to those of the Kuruk Tagh, while the Upper Paleozoic resembles the deposits of the same age in the Khotan terrace of the Tarim massif (Tekelik Tagh). The dislocation of the strata of the Cambrian and Upper Paleozoic is gentle and simple and not accompanied by any metamorphic changes in the constituent rocks. Neither have granite impregnations been noticed in the strata of the Altyn Tagh.

All this is evidence that the structure of the Altyn Tagh is in now way distinguishable from that of the Tarim and Tsaidam massifs separating it and, like these massifs, belongs to the ancient platform. However, the Altyn Tagh represents a special part of the platform, which after the Upper Paleozoic transgression underwent a steady and powerful upheaval. This distinguishes it from the Tarim and Tsaidam massifs the movements of which were so moderate that they never disrupted the plain character of their relief. Moreover, in the Mesozoic and Cenozoic, considerable areas of the Tarim and Tsaidam massifs, parallel with the upheaval of the Altyn Tagh, underwent strong subsidence and were covered by thick layers of sediments.

Concerning mineral resources in the Altyn Tagh, there is evidence only of the occurrence in this range of lead-zinc mineralization and chromites in the serpentinized ultrabasic rock.

Tsaidam, Kul'tala, and Chimen Tagh. The Tsaidam basin, together with the Kul'tala region and the Chimen Tagh which separates them, constitutes a strongly faulted structure of the earth's crust in the form of an isosceles triangle along the sides of which extend the eastern Kunlun, Nan Shan, and Altyn Tagh. Like the Tarim and Dzungarian massifs, this block is less dissected and differentiated than the surrounding mountainous regions.

Lagging behind the Nan Shan and the Kunlun in general uplift, the Tsaidam block formed the floor of a basin, despite the fact that it reached an altitude of 3,000 m. The tsaidam occupied this relatively low hypsometric position during the entire Mesozoic and Cenozoic and was consequently a region of the accumulation of the sediments of these periods.

The horizon of the Mesozoic-Cenozoic in the Tsaidam is divided into six individual parts with different developmental histories The solonchak plain of the Southeastern Tsaidam and the Gaskul'skiy depression running along the foot of the Chimen Tagh, as well as the plain of the Syrtiy, are comparatively young, expanding basins. In these parts the sedimentary mantle consists only of Quaternary and Late Tertiary deposits here underlain by Paleozoic rocks.

The northwestern part of the Tsaidam basin was in the past the nucleus of a depression. It is filled with Jurassic, Cretaceous, and thick Tertiary deposits, not to mention Triassic deposits, which are usual for the Mesozoic-Cenozoic basins of Central Asia. Three structural-facies zones with a northwest extension have been noted in this part of the Tsaidam: the depressions bordering on the Chimen Tagh and Nan Shan ranges, coinciding approximately with the western and eastern zones of the intra-Tsaidam heights, and a central upheaval extending between them and apparent as a plain in the relief. In the depressions the Mesozoic-Cenozoic complex has increased thickness and a coarser sedimentary composition, while in the central upheaval it has moderate thickness and a predominance of fine-grained and parallel-bedded sediments among which are considerable accumulations of salts.

In the Tsaidam the Mesozoic-Cenozoic complex lies on rocks of different ages. In the depression fronting on the Chimen Tagh it is underlain by limestones, shales, siltstones of the Cambrian-Ordovician and a calcareous-shale-sandstone stratum of the Visean; in the depression fronting on the Nan Shan, by red sandstones and siliceous shales of the Devonian and a carbonate-terrigenous series of the Carboniferous; in the central upheaval, by a Pre-Sinisian metamorphic complex. In both depressions the horizon of the Mesozoic-Cenozoic begins with the Jurassic, which forms disconnected outcroppings along the margins of the basin. Its lower part is composed of conglomerates and coarse sandstones, its middle of gray-green sandstones and argillites, and its upper of red-violet and, in part, gray-green sandstones and argillites. The total thickness of the Jurassic in well-exposed horizons is as much as 3,000 m. Lying unconformably on the Jurassic is a Cretaceous stratum of gray-brown

conglomerates with sandstones and seams of marls and fine-grained limestones (700-800 m) Above follow red sandstones, mainly fine-grained, interbedded with argillites and marls; the last-named are especially numerous in the lower part of the stratum (thickness 400-500 m). The marls contain ostracods typical for the Paleocene of Central Asia. Above are found the same redstones, but coarser and with frequent seams of conglomerates, although in these clays and marls and even oolitic limestones continue to be found (1,700 m).

The next element of the stratum is a series of gray-yellow sandstones and clays coarsening towards the top; above, the clays disappear and numerous seams of fine-pebbled conglomerates appear (600 m). These deposits are indented by a pale-yellow series of the Tarim basin and Dzungaria belonging to the Lower Neocene.

The horizon of the Mesozoic-Cenozoic complex of the Tsaidam, as everywhere in Central Asia, is topped by a stratum of gray conglomerates, in general poorly rolled and sorted, constituting the formations of the ancient alluvial fans (200 m). Further from the Chimen Tagh and Nan Shan there occurs in all the strata of the Mesozoic-Cenozoic complex a rapid pulverization of the fragmental material of the sediments, which is apparent in the replacement of conglomerates by sandstones and later by clays. At the same time, the stratification changes from sloping near the mountains to parallel in the central regions of the basin. The total thickness of the Mesozoic-Cenozoic complex is reduced by a third towards the central upheaval.

In both foothill depressions of the Tsaidam, deposits of the Mesozoic-Cenozoic complex form groups of large anticlinal folds with elliptical forms, all extending in a northwesterly direction The anticlines are apparent in the relief as ridges of various heights; here synclinal folds, however, are usually not apparent, because the strata beyond the anticlines immediately acquire a horizontal bedding. A majority of the young anticlines of the Tsaidam have a naturally asymmetric structure. In the group near the Chimen Tagh, folds predominate with a steep eastern limb, while in the group near the Nan Shan folds the steep limb of which is turned westward are more frequently observed. In both groups the anticlines of the Mesozoic-Cenozoic complex are echeloned in small chains which lie opposite the large lateral dislocations in the Altyn Tagh.

On the boundary of the ltyn Tagh one may often see peculiar "structural noses" which represent the projections of old rocks toward the basin and are bordered by the sediments of the latter These "structural noses," like the position of the small chains of anticlines on the lines of the northwesterly dislocations which appear in the Altyn Tagh, are evidence of a connection between the Tsaidam folds and the deep-seated dislocations of the foundation of the basin.

The Kul'tala can assuredly be considered the western part of the Tsaidam massif, being separated from it by the Chimen Tagh and by an elevation 1,000 m higher. Nothing is known concerning the geological structure of the Kul'tala other than indications of the widespread distribution in it of Cretaceous and Tertiary deposits

Neither has the geology of the Chimen Tagh been investigated much. Its location between the Tsaidam and the Kul'tala, on the edges of the large triangle formed by the Kunlun, Nan Shan, and Altyn Tagh, permits considering it as an interior upheaval of a shield similar to the Altyn Tagh in structure and developmental history.

In the high-altitude zone, the Chimen Tagh is composed of gneissoid granites and partly of metamorphic rocks. On the Tsaidam flank of the range there is exposed a Visean stratum of limestones with bodies of sandstones and shales.

From the Chimen Tagh a zone with outcroppings of gneissoid granites extends along the trend into the foothills of the Kunlun and along them up to the eastern end of the Tsaidam.

10. THE WESTERN KUNLUN, EASTERN PAMIRS, AND THE NORTHERN SLOPE OF THE KARAKORUM

General Description of Orographic Regions

Rising on the boundary between the Gobi and Tibet are the Kunlun ranges--one of the highest mountain systems in the world. The Kunlun mountain system extends almost 2,500 km in an east-west direction. Over this enormous extent it repeatedly changes trend and passes through various climatic regions. In the orographic and geomorphological senses the Kunlun is divided into two parts: the western and eastern, the boundaries of which, however, have not been agreed upon and are shown differently by various investigators. There is often less similarity between remote parts of the Kunlun than between any of its parts and the adjoining ones of some other geographic region, the Karakorum, for example

Therefore it is advisable to describe the Kunlun not as a whole but according to individual parts, together with their respective adjoining regions, and, in particular, to examine the Western Kunlun together with the Eastern Pamirs and the northern slope of the Karakorum, all of which are closely related as regards orographical and natural conditions.

Eastern Pamirs. The Eastern Pamirs constitute a high upland similar to the Tibetan. They are bounded almost everywhere by high snowy ranges: in the north by the Trans-Alayskiy, in the east by the Sarykol'skiy, in the south by the Kindu Kush, in the northwest by the longitudinal Zulumart range. Only in the southwest do they lack a well-defined boundary, since here their boundaries are conventionally assumed to run athwart broad ranges and valleys in the direction: Usoyskiy barrier--Lake Yashil'kul'--Bakchigir mountain massif and the junction of the Pamir and the Vakhandar'ya rivers.

The Eastern Pamirs are sharply distinguished from the Western, which possess a more complexly differentiated surface and receive more precipitation. Despite their enormous absolute elevation of 5,000-5,500 m, the relief of the Eastern Pamirs has a complex-mountain character. Within their limits are found the eastern spurs of the Muzkol, Bazarkdarinskiy, Southern Alichurskiy, and Vakhanskiy ranges which rise not more than 1,500 m over the surrounding region. The mountains of the Eastern Pamirs are distinguished by subdued contours: their summits are depressed, their slopes moderately steep and weakly dissected, rocky relief is rare and not extensive. Active physical weathering of the rocks has produced an enormous quantity of fragmented material which because of the limited watercourses moves over the slopes very slowly, everywhere forming vast accumulations which contribute to the softening of the relief. Between the ranges at an elevation of 3,700-4,200 m run broad troughs in which are contained the wide meandering channels of rivers. The channels are filled to a great depth by alluvial deposits which cover all the irregularities of their bottoms.

The dominant landscape types in the Eastern Pamirs are glacial. There are ancient and recent glacial troughs, firn basins recently fr ed of snow, moraines with hilly relief, fluvial glacial plains and, finally, diverse forms of microrelief in the permanently frozen ground, which begins here even at elevations of 3,800 m.

Towards the Western Pamirs, the vertical dissection of the country becomes more complex: the slopes of the mountains become steeper and more rocky and the river valleys deeper and narrower. The ranges cquire sharp crests and on their watersheds appear pointed summits and peaks. The occurrence of erosional relief forms increases in the Western Pamirs, and they come to predominate. Glaciation is evident in the Eastern Pamirs only over very small areas, in consequence of the aridity. The snowline occurs at elevations of 5,000-5,100 m, and only near the Beik pass does it descend to 4,800 m. Small firn fields and glaciers can be observed only along the watershed ridges of the ranges. And the basin of the Murgab River, which comprises almost half of the Eastern P-mirs, is completely untouched by recent glaciation. Even the ancient glaciers in this region were of moderate size, because here the descent of the snowline, according to R. D. Zabirov, amounted to only 350-450 m. In the Western Pamirs, which receive more precipitation, the snowline descends to 4,000-4,500 m, and the scope of glaciation increases sharply as a consequence. On the slopes of the ranges of the Western Pamirs there are vast firn basins and extended valley glaciers. The ancient glaciation was still more gigantic when the snowline came 700-900 m below its present level.

The noticeable differences in landscape types between the western and eastern parts of the Pamirs can be explained mainly by peculiarities of the orographic structure of this mountain region. The Western Pamirs are open to the influence of the moist air currents from the Mediterranean Sea and the Atlantic Ocean. Its ranges, having an approximately latitudinal trend, do not obstruct the penetration of moist air masses deep into the mountainous regions.

In the axial zone of the Pamirs, in the northern part, rise the longitudinal "Academy of Sciences" and Zulumart ranges topped by summits 6,000-7,000 m in altitude. Almost all the moisture from the western air masses is held on these ranges. The longitudinal ranges end south of the valley of the Bartang, and in this same direction there arise the vast spurs of the Rushanskiy, Southern Alichurskiy, and other ranges, which perform the same function as a climatic barrier. Only the broad Alayskiy trough does not obstruct the penetration of moist western air far into the Sarykol'skiy trough and the Kingtau range of the Kunlun system. But the Eastern Pamirs are isolated from this climatically favorable region by the Sarykol'skiy range.

The small amount of precipitation which falls within the territory of the Eastern Pamirs explains its poorly developed hydrographic net. The largest river is the Oksu, which drains almost half the area and belongs to the basin of the Amu-Dar'ya. A small part in the north is watered by the Markansu River, which flows into the Tarim basin. The rest of the Eastern Pamirs is divided between local landlocked basins and lakes. The rivers have a plain character: they flow in broad valleys with slight slopes, are strongly meandering, and branch into numerous channels. Upon issuing forth from the snow ranges, many small streams quickly dry up, but extend their dry channels over a great distance.

The lakes of the Eastern Pamirs, like the Tibetan lakes, are among the highest lakes on earth. Among them two types are distinguished: lakes situated in flat basins of tectonic origin (Karakul' and Rangkul'), and lakes enclosed in river valleys blocked by landslides (Sarezskoye and Yashil'kul').

"The climate of the Eastern Pamirs is characterized by extreme aridity, by below-freezing mean annual temperatures, by short frost-free periods, insignificant cloudiness, long winters with little snow and strong winds" (R. D. Zabirov). Characteristic are sharp daily, seasonal, and annual temperature fluctuations. Annual precipitation in the valleys of the Eastern Pamirs does not exceed 100 mm, of which about 90% falls in the form of snow. All these factors have very unfavorable consequences for the development of vegetation, which is represented by a few species of underbushes and permanent grasses. On the stony soils of gentle slopes underbushes of salsola and Eurotia are widely distributed together with dwarf "polyny," Oxytropis, astragalus, and an eastern species of feather grass. Vegetation is very sparse and hugs the surface of the high-altitude stony desert as a result of the energetic growth of plants in a horizontal direction along the level of the warmest layer of air just above the soil. Occurring on hillocks along the rivers of the Eastern Pamirs are hilly bamboo meadows and Carex, cereal grasses, and Cobresia capillifolia. The upper level of distribution of vegetation is somewhat above 5,300 m.

The major fauna group in the Eastern Pamirs are the ungulates. Especially common are "arkhary," which occur in large herds on well-watered mountain slopes near the snowline. A typical animal of the Pamirs is the domestic yak.

Western Kunlun. On the boundary of the Tarim massif the Kunlun forms an enormous dome with its crest in the vicinity of the town of Ho-t'ang. In this dome the trend of the ranges changes from northwesterly (320-340° NW) to northeasterly (70-80° NE).

The Western Kunlun is the name given to that part of the dome extending from the Ho-t'ang crest to the Pamirs and characterized by a northwesterly trend. Kunlun is about 600 km long, and its width in various directions approaches 200 km.

The Kunlun constitutes, as it were, the northern wing of the gigantic upheaval of mountainous Asia, of which the Tibetan highlands form the dome part. However, as a result of steady narrowing towards the west, the Tibetan highlands are closed off in the region of the headwaters of the Karakash and Raskemdar'ya rivers and the Kunlun butts onto the Karakorum ranges. In the Eastern Pamirs a highland of the Tibetan type again arises, diverting the ranges of the Kunlun and Karakorum in different directions. The position of Western Kunlun in the zone of the crowding together of the ranges between the Tibetan and Eastern Pamirs highlands determines its exceptional compactness. It is completely without broad intermountain basins such as are usually seen in the Eastern Kunlun and particularly in the Tien Shan.

Three parallel chains of ranges are distinguished in the Western Kunlun, of which the two main ones extend over its entire length. The southern chain, butting onto the Karakorum, and bordered on the flanks by the highlands of the Eastern Pamirs and Tibet, comprises the Sarykol'skiy, Tashkurgan Tagh, Agyl, and Suget Tagh ranges. The interior chain is formed by the ranges and mountain massifs of the Kingtau, Kungur, Kandar Tagh, Takhtakorum, and Karangu Tagh. The northern chain, the shortest, consists of the Tiznaf and Sandzhu Tagh ranges. The southern and interior chains of the Western Kunlun are separated by longitudinal tectonic valleys, in which rivers flow for distances of tens and sometimes even hundred of kilometers and similar passes are located. The northern chain is separated from the interior by a system of benches and "dry" grabens. The ranges of the main chains are separated by the continuous valleys of the large rivers which originate on the Tibetan highlands or in the Karakorum.

The altitude of the Western Kunlun varies. The main centers of upheaval are located in the western and eastern parts where there are summits 7,000 m in altitude. The middle part in which is located the valley of the Yarkend River, is the lowest part of the mountain system. Here the summits do not attain elevations of even 6,000 m. In the middle part the ranges rise steeply from the Tarim plain and attain their maximum elevations on the boundary of the Karakorum. In the western and eastern parts they rise in a gigantic terrace over the plain, and even in the forward chain have summits more than 6,000 m in altitude. The elevation of the longitudinal valleys of the Western Kunlun increases farther away from the Tarim plain, therefore all its ranges are developed asymmetrically.

Their Tarim slopes are higher, longer, and more dissected than the opposite ones. The degree and type of dissection of the Kunlun ranges changes from west to east with a decrease in precipitation. In the westernmost part of the mountain system the influence is noticeable of the moist northwesterly winds which penetrate here through the Alayskiy valley. Consequently the network of eroded valleys is denser and the divides separating them are sharper and rockier. In the eastern part, which is more arid, there are fewer valleys on the mountain slopes and the watersheds are more massive and lack conical summits. In the Ho-t'ang sector the mountain massifs are extensively developed and have very steep slopes and depressed summits. In the peripheral ranges of the middle (Yarkendskiy) sector of the Western Kunlun, loess covers large areas with an unbroken mantle on the dissected mountain relief, somewhat subduing its forms.

The erosion base for the Western Kunlun is the Tarim plain, over which the latter rises by 4,100-5,500 m. Despite the aridity of the climate, the depth of incisions by erosion in the Western Kunlun is exceptionally great and canyons 2-3 km deep are common. In places such canyons are bounded by sheer walls, the sun shining in them for only a short period each day.

The longitudinal valleys which run between the ranges of the Western Kunlun constitute mostly narrow grabens. Only where lateral branches join the tectonic valleys do they broaden into intermountain basins 15-20 km across. All the bestknown basins of the Western Kunlun, such as the Sarykol'skiy, Tagarminskiy, and Vachinskiy, are situated between its interior ranges at elevations of 3,500-3,700 m. The basins have a plain relief; it is hilly, with a barren landscape of the Eastern Pamirs type, only along the mountains.

The Western Kunlun as a whole lies within the Tarim landlocked basin, the boundaries of which coincide in part with the watershed crests of the ranges of the southern chain. The Sarykol'skiy range serves as the boundary between this basin and the Amu-Dar'ya basin, while the Karangu Tagh range serves the same function at the junctionwith the landlocked basins of Northern Tibet. Only in the middle part of the Western Kunlun is the boundary of the Tarim landlocked basin displaced beyond the limits of this mountain system; here it runs along the Karakorum range.

The hydrographic system of the Western Kunlun is composed of elements of two types: major rivers, whose basins occupy the entire interior high-altitude region of the mountain system and transect the continuous valleys of the peripheral ranges; and numerous small rivers, which water only the peripheral ranges. The main rivers of the Western Kunlun--the Gyoz, Yarkend, Karakash, and Yurunkash--begin either on the margins of the Tibetan and Eastern Pamirs uplands, or in the Karakorum. In the Kunlun itself they form extended twisting valleys composed of northwesterly parts (in the east almost latitudinal), which conform to the longitudinal tectonic valleys, and northeasterly (in places north-south) parts which cross the ranges transversely to their trend. The northwesterly parts of the river valleys are long (frequently as much as 200 km), broad, and open; the

northeasterly parts, on the other hand, are short and narrow canyons which remain half dark during the day. In the longitudinal valleys the rivers flow quietly in broad pebbly channels bounded by still broader bottom lands. In the lateral canyons the rivers form turbulent currents bubbling among the rocks and large blocks which here and there have fallen from their walls. In the longitudinal valleys four river terraces can be clearly traced; in the lateral canyons, however, terrace remains have not been preserved.

The small rivers, which begin on the bordering ranges, are usually short, mostly not over 80 km, form a dense network on the slopes, and run more or less uniformly in the direction of dip of the Tarim slope of the ranges. The bordering ranges of the Kunlun on the boundary of the Tarim plain are 4,500-4,500 m high with relative elevations of 3,000-3,500 m. Consequently the energy of the relief is very considerable here and conditions are thus most favorable for erosion. These small rivers, despite their short lengths and generally insignificant volumes, carve deep, narrow valleys that are mostly impenetrable. The basins of the boundary ranges are still more complexly and deeply incised than in the areas drained by the large rivers. Describing one of the peripheral ranges of the Western Kunlun, the Topa Tagh, M. V. Pevtsov writes: "The Tapa Tagh mountains are distinguished by unusual dissection, the sharpness of their crests, and the extreme steepness of their slopes. They are furrowed everywhere by a whole labyrinth of narrow, winding valleys and dark gorges. These deep valleys and gorges in turn branch into a multitude of still narrower lateral valleys, ravines, and slits. The walls of all the valleys are very steep, and the walls of the gorges are sheer almost everywhere. The gradients of these and other gorges are extraordinarily steep. Thus after each heavy rain numerous streams flow from these mountains with deafening roars, drying up quickly after the downpour stops." (66).

This strong dissection of the boundary ranges of the Western Kunlun took place mainly in early Quaternary times, when large amounts of sediment accumulated on the mountains and river erosion was greatest. Evidence of the age of the relief is the diluvial bedding of the loess, which at the present time, due to the exceptional aridity, is hardly disturbed.

Glaciation exerted a great influence on the present and particularly on the ancient landscape forms of the Western Kunlun. On the ranges of this system the snowline presently exists at a very high elevation, in addition displaying a tendency to rise steadily towards the southeast. In the part of the Kunlun near the Pamirs, it exists at an altitude of 4,700-4,900 m on the northern slopes and at 5,000-5,200 m on the southern slopes, while in the Ho-t'ang sector it lies at 5,300 and 5,700 m respectively. Thus perpetual snows are found east of the Yarkend River only on the watershed ridges of the ranges, where they cover them not completely but only in the clefts.

Large-scale contemporary glaciation is evident in the Western Kunlun only in the part near the Pamirs and in the Kungur and Muz Tagh massifs, where there are many dozens of glaciers, each 2-15 km long. On slopes with a northern exposure the glaciers terminate at elevations of 3,900-4,700 m, and on slopes with southern exposure at elevations of 5,000-5,200 m. In the remainder of the Western Kunlun glaciers are found only on mountain ranges with elevations of 6,000 m or more. The number of such glaciers is not great and they are small in size. The Kunlun glaciers are of the Turkestan type, characteristic for regions with a continental climate, and are extreme representatives in which the occurrence of firn fields is minimal. Among the glaciers of the Kunlun the firn field has a disproportionately small area in comparison with the size of the glaciers and sometimes is absent completely.

The ancient glaciation of the Western Kunlun was greater than the present. The extent of the ancient moraines and troughs is marked by the lower boundary of the descent of ancient glaciers at the 3,300-3,400 m level in the part near the Pamirs and 3,700-3,900 m in the Ho-t'ang sector. These reveal the same succession of regional differences of elevations as occurs with the modern glaciation. A comparison of the lower boundaries of the descent of ancient and modern glaciers for individual mountain ranges shows that the difference in their hypsometric levels is everywhere the same, approximately 700 m. Small valley glaciers were found in the past at the heads of all valleys of the high-altitude zone. The largest of these were located in the longitudinal tectonic valleys which separated the ranges of the various chains. These glaciers had lengths of as much as 150-200 km and descended considerably lower than the general boundary of glaciation. For example, the Karakashskiy glacier, which was located in the valley between the Suget Tagh and Karangu Tagh ranges and was more than 150 km long, reached the area of the Shakhidull station at an elevation of 3,650 m, at a time when the glaciers on the surrounding slopes terminated at elevations of 3,900-4,000 m. The rise in the level of the ancient snowline and the boundaries of the descent of glaciers in the direction from the Pamirs towards the Ho-t'ang sector shows that in the past atmospheric precipitation was carried to the Western Kunlun mainly by northwesterly air currents.

The amount of moisture received by the mountains of the Western Kunlun is clearly reflected in the development of vegetation, which becomes sparser towards the southeast. In the part of the Kunlun near the Pamirs, on mountain slopes protected from the dry winds of the Takla-Makan desert, there are spruce and juniper forests with bushes of ash, willow, wild rose, honeysuckle, and black currant. Here the forest zone lies between 3,200 and 3,700 m. On the spurs of the northeastern slopes, where forests are lacking, there are rough grasses (Lasiagrostis), virgin's bower (Clematis orientalis), bayberry, and also the most important fodder plants of these areas: "kipets" and oats. Immediately beyond the Kungur and Muz Tagh ranges the forest zone begins to abruptly rise to the 3,500-4,200 m level and breaks up into small sparse groves, while spruces gradually disappear

from the forest. In the east, coniferous forests extend to the Sandzhu and Duva valleys, where they consist only of juniper trees. In the mountains of the Ho-t'ang sector, forests grow only in the river valleys, where they are composed of the tugay complex with poplar, wild olive and tamarisk. In the Ho-t'ang sector of the Kunlun the forest does not reach even the mountain-steppe zone, which replaces the semidesert zone with a very thin cover of drought-resistant plants (the polyn-halophyte complex).

In the Kunlun part near the Pamirs there are many mountain sheep. Tibetan bears are also encountered, and on the meadow slopes there are marmots. Among the birds which nest here there are various species of eagles, turkeys, (Tetraogallus), rock partridges, pigeons, and various representatives of sparrow types.

Approaching the Ho-t'ang sector, the fauna in the mountains of the Kunlun gradually decrease in number as a result of the worsening of natural conditions. Animals are encountered here less and less frequently.

Northern slope of the Karakorum. The Karakorum is one of the highest ranges in the world, some of its summits rising more than 8,000 m (including the second highest mountain in the world, the Chogori peak, or Mt. Godwin-Austen, 8,611 m). In the enormous cluster of ranges, rising between the highlands of the Pamirs and Tibet, the crest of the Karakorum is the highest and constitutes the main watershed of this part of Asia. And here it is not the Himalayas, but the Karakorum, that constitutes the main climatic divide, along which runs the boundary between the monsoon-climate region of India and the arid region of Tibet and the Kunlun.

In the area of the Chogori peak the Karakorum constitutes a single vast range divided toward the west and east into a series of narrow and less-elevated parallel ranges These spur ranges do not rise higher than 7,700 m. Passes into the Karakorum lie at elevations of 5,575-5,800 m.

The slopes of the Karakorum range are not developed uniformly: the southern, sloping towards the longitudinal tectonic valleys of the Ind and Shayok rivers, is long and steep; while the northern slope, which faces the Tibetan highlands and the Kunlun, is short but also steep. While on the southern slope of the range the relative altitude of the main crests of the watershed is 5,000-6,000 m, on the northern slope it is not more than 3,000-3,500 m. The southern slope of the Karakorum, which is exposed to the monsoon, is strongly dissected and covered by snow and ice. According to G. I. Sobolevskiy, on this southern slope there are entire valleys filled with ice and having numerous tributaries, the heads of each of which end in a firn field. The glaciers even cross the watershed line, as, for example, in the Khispar-Biafo system. Only individual particularly rocky peaks emerge above the general, almost continuous region of glaciation. The remainder are covered by fields of firn The glaciers meet to form complex systems bounded by firn fields.

Both the regions of glacial feeding and the firn areas frequently lack a clearly expressed slope. This is a maximum glacial development which recalls somewhat a continental ice sheet and owes its origin to a combination of the most favorable orographic and climatic conditions The glaciers of the southern slope of the Karakorum descend to elevations of 2,900-3,500 m, depending on their size. But towards the east, in connection with the weakening of the effect of the monsoon, the snowline rises and the glaciation becomes less intensive. The complex glacial systems break up, giving place to the usual valley glaciers, and the latter to small glaciers on the mountain slopes and summits.

On the northern Karakorum slope, which belongs to the arid Central Asiatic climatic province, there is quite a different picture. Here the snowline lies at elevations of 5,800-5,900 m; snow accumulation is not great, and the glaciers fed by it are inconsiderable in size. The mountains in the region of this slope are rocky and almost completely bare of vegetation. Thus they, like the ranges of the neighboring Kunlun, give the impression of a cold high-altitude desert.

Geological Structure and Mineral Resources

The Kunlun and Karakorum mountain systems belong to one of the most active zones of the earth--the Mediterranean. In the former, the cycle of active development, expressed in the laying down of thick strata of geosynclinal sediments and the formation of enormous bodies of granites, took place in the Paleozoic; and in the latter, mainly in the Mesozoic. The Pamirs are the only geographic region in which is found a continuation both of the Paleozoic structures of the Kunlun and the Mesozoic structures of the Karakorum.

Western Kunlun. In the Western Kunlun, which lies in the zone of regional northwesterly faults, there are three major structural zones with different geological histories. These zones are the crystalline axis of the Kunlun, which emerges in the ranges of its interior zone; the Paleozoic depression of the Tarim flank, comprising the forward ranges of the mountain system bordering on the Tarim massif; and the Paleozoic depression of the Karakorum flank, situated in the region of the ranges bordering the Karakorum and Tibet.

The crystalline axis represents the ancient core of the Kunlun upheaval which underwent activation during the Paleozoic and Mesozoic-Cenozoic stages of its development. Within it Pre-Cambrian metamorphic strata and Hercynian granites were thus widely developed. The girth of the crystalline axis of the Western Kunlun amounts to 70-120 km in places. The main structural element of this zone is the metamorphic complex, which can be divided, according to lithological composition, into three groups of rocks, each possibly with independent stratigraphic significance.

The most common is the group of crystalline schists and gneisses complicated by mica varieties containing in varying amounts garnet, sillimanite, kyanite, cordierite, and hornblende. The next, the schist-marble group, is characterized by a combination of mica, mica-garnet, and hornblende schists with marbles. The third group, quartzitic-marble, the most varied in composition, constitutes an alternation of blocks of quartzites, mica schists, amphibolites, and marbles. Frequently found among the latter are skarn varieties containing diopside, herdenbergite, garnet, tremolite, wollastonite, and phlogopite. The original material for the rocks of the metamorphic complex were various terrigenous and carbonaceous sediments and also effusive rocks of basic composition.

Concentrated in the crystalline zone are the main plutonic formations of the Kunlun, among which three groups of different age can be distinguished: (a) granite orthogneisses, which compose the great block in the Muz Tagh mountain knot; (b) gneissoid granites and granodiorites, which are found in all parts of the zone in blocks up to 20 km wide; (c) massive and porphyritic granites, also found throughout all parts of the zone, but encountered less often than the gneissoids and forming bodies of small dimension. The orthogneisses are undoubtedly of the Pre-Cambrian age, whereas the gneissoid granites and ganodiorites of the second group are Caledonian or early Hercynian, because they intrude on Silurian deposits but are enclosed in the form of halites in conglomerates of the Lower Carboniferous. The massive and porphyritic granites composing the third age group were formed at the close of the Upper Paleozoic, as is evidenced, on the one hand, by their active contacts with deposits of all divisions of the Carboniferous, and on the other by their occurrence in halites in the basal conglomerates of the Jurassic stratum.

All the blocks of granites, both Paleozoic and the older blocks, extend uniformly in a northwesterly direction in conformity with the trend of the primary elements of the regional structure.

The depression of the Tarim flank existed during the entire Paleozoic but not within fixed boundaries. As the Kunlun upheaval grew, it was displaced on the margin of the Tarim massif. Participating in its formation were three complexes of rocks of different ages divided from one another by angular unconformities and in large part separated in spatial development. The oldest of these, the Kilianskiy sand-schist complex, belonging basically to the Ordovician, forms vast outcroppings in the vicinity of the crystalline zone. The next oldest complex, composed of Upper Silurian and Devonian deposits of varying facies composition, developed in the peripheral ranges of the Kunlun. The third complex, combining deposits of the Carboniferous and Permian, is exposed in the foothills.

The Kilianskiy complex is separated into three series: a sand-conglomerate series lying on the foundation; a series of phyllite-type schists lying higher; and a calcareous-schistose, topping the horizon. The sand-conglomerate series lies with sharp angular unconformity on the metamorphic strata of the Pre-Cambrian. Its lower level is formed of

coarse conglomerates including lenticular layers of coarse cross-bedded sandstones deposited under surface conditions. The thickness of the sand-conglomerate series is calculated at approximately 1,500-1,800 m. The series of phyllite-type schists is composed of sericitic and sericite-choloritic varieties interbedded in its lower part with sandstones, and in its upper with thin interstitial seams of crystalline limestones. Discovered in the upper half of this series were problematic organic remains bearing some resemblance to graptolites. The thickness is 2,200-2,500 m. The calcareous-schist series constitutes an interbedding of crystalline limestones and phyllite-type calcareous-argillaceous schists with abundant precipitations of sericite and chlorite. In the upper part, in schist blocks, there are mantles of basic effusive rocks which have undergone a greenstone change. In the limestones there have been found the poorly preserved remains of brachiopods and corals. The thickness of the argillaceous-schistose layer is as much as 3,000 m. The total thickness of the Kilianskiy complex amounts to 6,000-7,000 m. Organic remains have not been identified in the Kilianskiy complex; but the Lower Paleozoic age of the complex is certain, since in lithologic composition and stratigraphic alignment this complex is identical with the sand-shale complex of the Central Tien Shan and Mongolian Altay, the age of which has been established from fossil fauna.

The Middle Paleozoic is represented in the northern depression by two strata: a red, evidently Silurian; and a calcareous, which contains the faunal remains of the Middle and Upper divisions of the Devonian. The red stratum, about 500 m thick, is composed of carcareous conglomerates, sandstones, largely quartzitic; and shales, argillaceous and partly calcareous. The limestone stratum is bedded conformably on the red straum and has a thickness of 1,600 m. It is composed of light-gray and siliceous cream-colored limestones containing brachiopods and stromatoporoids. On the boundary of the Khotanskiy block, the limestone stratum is replaced to a considerable extent by effusive and accompanying siliceous rocks: tuffs and tuff-conglomerates. In the lower part of the effusive stratum only spilites are developed, while in the upper, andesite and dacite porphyrites are represented in large quantities, as are also porphyries. In the seams of siliceous shales underlying the effusive stratum radiolarians are found.

The Lower Carboniferous is represented in the northern depression of the Kunlun in marine and continental facies. The former is found in the Yangigissarskiy and Yarkend sectors of the depression and the latter in the Gumiyskiy sector, where the depression is undergoing closing. The most complete horizon of marine deposits of the Lower Carboniferous is to be found in the Yangigissarskiy sector in which, besides a widely distributed stratum of the Visean, there are sediments of the Tournaisian. Here the Tournaisian is represented by a series of gray sandstones, conglomerates, and limestones bedded on a dislocated and eroded straum of the Upper Devonian. In the limestones of this series various brachiopods, typical for the Tournaisian stage have been collected. In a southeasterly

direction the marine deposits of the Tournaisian are replaced by red sandstones and conglomerates of the Tiznafskiy series. The Visean is represented by dark limestones with abundant fossil fauna. In the Yangigissarskiy and Yarkend sectors of the depression the Visean is fully represented, having a thickness of about 400 m. In the southeastern part of the depression only the Upper Visean is present, having a thickness of several dozen meters and lying on red sandstones and conglomerates of the Tiznatskiy series, and, where the latter dips below the horizon (east of Sandzhu), directly on the Pre-Cambrian.

The continental facies of the Lower Carboniferous, distinguished by de Terra under the name "Tiznafskiy series," is found in the Gumiyskiy sector and the eastern part of the Yarkend. The Tiznafskiy series is composed of red sandstones and fine-grained conglomerates with pebble quartz and effusive rocks. The Tiznafskiy series is bedded unconformably on an effusive series of the Devonian and is covered conformably by limestones of the Visean. The maximum thickness of the Tiznafskiy is attained in the valley of the Yarkend River (1,400 m). In a westerly direction it is replaced by marine deposits of the Tournaisian, while in the east it gradually decreases in thickness and disappears from the horizon.

In the northern ranges of the Kunlun, the Upper Paleozoic is widely distributed. It can be divided on the basis of numerous fauna remains into the Middle and Upper divisions of the Carboniferous and also the Lower and, in part, the Upper Permian. The facies composition of the Upper Paleozoic complex is not stable. In the northwestern part of the depression near the Pamirs it is composed of sandstones, argillaceous and siliceous shales, lavas of basic and neutral composition, tuffs and tuff-conglomerates. In the southeastern direction the content of volcanic rocks in the horizon of the Upper Paleozoic quickly decreases and then disappears completely, but at the same time limestones appear in large quantities. In the Yangissarskiy and Yarkend sectors this complex constitutes an alternation of thick sand-shale and limestone blocks. Farther on, the Gumuyskiy sector is composed almost entirely of limestones. The thickness of the Upper Paleozoic complex, in connection with changes in its facies composition, gradually decreases from the 4,000-5,000 m which it has in the area of the sand-shale strata and effusive rocks, to 1,000 m in the area of the Carboniferous horizon. In the foothills of the Kunlun, the horizon of the Upper Paleozoic is topped by variegated deposits belonging to the Upper Permian. In the western parts of the depression, the lower level of this series is composed of sandstones, argillites, and marls with seams of limestones, while red sandstones predominate in the upper level of it. In the sand-argillite blocks there are seams with carbonized plant detritus and the imprints of calamites. The limestone veins contain typical brachiopods of the Upper Permian. In the southeastern part of the depression, the variegated series is replaced by a conglomerate-sandstone series the laying down of which occurred under continental conditions. The complete closing off of the northern depression of the Kunlun is assigned to the end of the Permian.

The trend arrangement of the strata of various periods in the northern zone and the whole picture of changes in their facies composition and thicknesses are evidence, on the one hand, of a successive displacement of the boundaries of the depression from the crystalline core of the Kunlun towards the Tarim massif, and, on the other hand, of a reduction in its depth and, later, also a complete tapering out in the southeasterly direction, in which the marine deposits are replaced by lagoon and continental deposits, with a reduction in the thickness of the individual strata series and a simplification of their folded structure. In the western parts of the depression, where it formed thick sand-shale strata, the folding is close and steep with clear indications of the tilting and overthrust folding of the mass in the direction of the Arim plain. In the southeastern continuation of the depression, the folds are larger and with almost no complex form in the lower series.

The depression of the Karakorum flank is structurally less clearly expressed than the depressions which border the Tarim mass. However, the deposits which fill it are to a considerable degree similar to the series of the northern depression not only stratigraphically but also lithologically. For example, widely distributed in the depression of the Karakorum flank is a Lower Paleozoic sand-shale complex which attains a great thickness (3,500-4,000 m) on the boundary of the crystalline core of the Kunlun and reveals a complex warping. Towards the Karakorum the thickness of this complex diminishes and its folding becomes weaker. The southern ranges of the Kunlun and the northern margin of the Tibetan highlands are composed of rocks of the Lower Paleozoic complex.

In the southern depression, as well as in the northern, the Middle Paleozoic is represented by a red Silurian-Devonian stratum and a limestone stratum of the Middle and Upper Devonian which is exposed in the Agyl Mountains. The red stratum is composed of quartz sandstones and argillaceous shales, to which conform bodies of various marls and seams of limestones. The lower level of the red stratum belongs to the Upper Silurian, and the upper to the Lower Devonian. Its apparent thickness amounts to 430 m. The limestone stratum lies on the red without visible unconformity; its thickness reaches 1,500 m. In the upper level of the Devonian horizon there appear in large quantity various tuffs, tuff brecias, tuff-conglomerates, tuffites, and siliceous rocks. In the Agyl Mountains there is also a stratum of red sandstones and conglomerates which bears an analogy to the Tournaisian redstones of the northern depression, known under the name "Tiznafskiy series." The Visean series is represented here by gray and yellow limestones. The apparent thickness of these limestones is 500 m.

Deposits of the Middle and Upper divisions of the Carboniferous and the Lower Permian, which constitute a continuous complex, are represented almost exclusively by limestones. Belonging to the Middle Carboniferous is a series of gray, largely siliceous limestones 500 m thick; belonging to the Upper Carboniferous are red and gray stratified limestones 400 m thick. The Lower Permian is represented by limestones with bodies of marls and schists 300 m thick.

The southern depression, like the northern, has been successively displaced away from the crystalline core of the Kunlun and closed off in a southeasterly direction (in the region of the headwaters of the Karakash River), in which all the Paleozoic strata diminish in thickness and some disappear completely from the horizon.

The Mesozoic-Cenozoic stage of the geological history of the Kunlun is characterized by geo-anticlinal tendencies in its development. Beginning with the close of the Permian, the Kunlun constituted an upheaval with boundaries closely paralleling those of the present. Within the boundaries of this upheaval denuding processes predominated and became especially active in the Neocene and Quaternary periods. Sedimentary accumulation appears on an inconsiderable scale and only in small interior basins (Tagarminskiy and Vachinskiy) with mantles of late Tertiary pebbles and sands.

Absent in the Kunlun are any larger remnants of the ancient peneplain, such as are characteristic for many regions of Asia (Tien Shan, Altay, and others), a circumstance which is probably connected with its prolonged upheaval and denudation.

Karakorum. The Karakorum is located in a zone of Mesozoic structures extending between the Paleozoic of the Kunlun and the alpine of the Himalayas. In the Mesozoic this zone constituted two depressions of unequal size separated by the geoanticline of the Karakorum and Trans-Himalayas. The more northerly of these two depressions comprised the region of the Agyl and Lokzun ranges and the southern boundary of the Chang Tang plateau, while the southern and smaller depression was located within the territory of the valleys of the Ind and Brakhmaputra rivers and the facing slope of the Himalayas.

The geo-anticline of the Karakorum is characterized by extensive outcroppings of crystalline schists of the Pre-Cambrian and strata of phyllites, possibly of the Sinisian system. On the slopes of the geo-anticlines, the Pre-Cambrian metamorphic complex is transgressively covered by sediments of the Upper Paleozoic. The axial zone of the geo-anticline contains batholytic bodies of alpine granites.

The northern depression, which constituted the primary branch of the Tetis, existed long before the Mesozoic movements. Present in it, besides the geo-synclinal strata of marine sediments of the Trassic, Jurassic, and Cretaceous, are deposits of the Upper Paleozoic, represented by various terrigenous and carbonaceous series. The Paleozoic deposits are distinguished by moderate thickness, facies regularity in individual strata, and the absence in the horizon of regionally-appearing unconformities, all of which attests the inconsiderable activity of this depression in the Paleozoic and the weak differentiation of its relief. The thick complex of Mesozoic sediments lies conformably on the Paleozoic.

In the horizon of the Upper Paleozoic group, four series are distinguished according to lithologic features: a lower, of limestone about 1,000 m thick belonging to the Carboniferous (from the Visean to the upper division inclusive); a series of dark argillaceous shales with limestone seams, in the upper horizons of which there are various foraminifersa, which indicates the Lower Permian age of these deposits (500 m); a series of light gray and dark gray stratified limestones of the Middle Permian (600 m); an upper sand-shale series up to 1,000 m thick, containing Upper Permian fauna in seams of conglomerated limestones.

The lower series, primarily of the Carboniferous, developed in the northern part of the depression bordering on the Kunlun. The area of the development of Permian deposits, on the other hand, was displaced in the direction of the Karakorum, where these deposits lie directly on metamorphic Pre-Cambrian rocks.

In the Mesozoic, in connection with an intensification of movements, the conditions of sedimentary accumulation in the Tetis became more complicated. The region of the most active sedimentary accumulation was the western part of the depression (Agyl and Lokzun ranges) in which the Mesozoic is represented almost entirely by limestones and shales of marine and lagoon origin lying on the Upper Paleozoic with parallel unconformity. In the Triassic of this region N. A. Belyaevskiy distinguished the following elements:

1. Sandstones with fine-pebbled conglomerates (150 m). Organic remains are represented by goniatitoids and pelecypods not subject to precise identification (probably Lower Triassic).

Ladinskiy series

2. Gastropod and bryozoa limestones (500-700 m).
3. Calcareous shales (120 m).
4. Argillaceous and calcareous shales interbedded with pelecypoda limestones. In the seams of schists are found fish scales (200 m).
5. Sandstones, shales, limestones (100 m).

Karniyskiy series

6. Gray marl limestones with shynchonellids (100 m).
7. Gray limestones (300 m).

Noriyskiy series

8. Siliceous and dolomitized limestones with numerous false yews (300 m).

Reticheskiy series

9. Block limestones with megalodontids (500 m).

In the Jurassic the same investigator disguishes:

Lower division 1500 m

1. Conglomerates, replaced above by sandstones. In the latter are seams of tuffaceous sandstones and one bed of limestone with belemnites.

2. Sandstones and shales with plant imprints.

Upper division 260 m

3. Block and stratified limestones with numerous but poorly preserved small brachiopods, pelecypods, sponges, and, more rarely, ammonites.

4. Gray and green marls.

The deposits of the Lower and Middle Jurassic are exposed along the headwaters of the Karakash and Yarkend rivers in isolated tectonic blocks. Their relation to the sedimentary complexes lying above and below them thus remains unclear.

The deposits of the Upper Jurassic and Lower Cretaceous, closely associated with each other, extend along the southwestern slope of the Agyl range and the northeastern slope of the Muz Tagh-Karakorum range. They constitute three series:

(1) a red conglomerate-sandstone, lying unconformably on the Permian stratum; this series is assigned to the Upper Jurassic on the basis of its resemblance to such formations of the Eastern Pamirs (340 m);

(2) a carbonaceous, consisting of block limestones with sponges; the lower level of the series belongs to the Upper Jurassic and the upper to the Cretaceous (Valanginian); thickness 200 m;

(3) a series of sandstones with remains of sea urchins (200 m).

On the boundary of Tibet, in the Mesozoic sedimentary complex, there is a sharp reduction in the thicknesses of all the strata and the appearance in its Triassic part of red rocks, which replace limestones and shales. In the Tibetan part of the Tetis the Triassic is represented by redstones in places dipping completely out of the horizon; and a Jurassic, by a marine series of black shales, limestones, and quartzites, the outcroppings of which, despite their thinness, are widely distributed in Southern Tibet.

The reduction of the northern depression of the Tetis, accompanied by a warping of its sedimentary strata, occurred at the close of the Lower Cretaceous The deposits of the Valanginian, which developed in the Kokzun range and in Western Tibet, still belong to the prefolded complex, but the deposits of the Senomanian stage are separated from it by an unconformity.

However, in the Upper Cretaceous the eastern parts of the Mesozoic folded zone of the Karakorum adjoining Tibet were envloped in the movements which had begun and subjected to transgression.

In these parts the Upper Cretaceous, according to N. A. Belyaevskiy, is represented by:

Senomanian

1. Red conglomerates and sandstones (100-150 m);

2. Variegated limestones with rudistes (200 m);

Turonian

3. Brick-red and gray fragile calcareous sandstones and argillites, Bordeaux marls, yellow and gray oolitic limestones with small oysters, conglomerates with limestone pebbles (600 m).

Senonian

4. Gray and black limestones with bryozoans and oysters in blocks of red sandstones and marls.

The upheaval which occurred in the Danian epoch resulted in the drying of the Karakorum zone and slowed the processes of sedimentary accumulation, which were later confined to the limits of the small interior basins. In one of these basins, comprising the middle part of the watershed area of the Agyl range, Tertiary deposits are represented by two series: a siltstone-shale with lenses of fresh-water limestones in which have been found poorly preserved shells of pelecypods and gastropods probably of the Eocene (130 m), and, lying above this, a conglomerate series containing in pebbles limestones of the Jurassic and Triassic (600 m) -- Miocene (?).

The folding of the Mesozoic deposits is complex only in the Karakorum area, where they possess great thickness and are represented in marine facies. On the boundary of Tibet the folded structure of the Mesozoic series becomes sharply simplified and acquires a mixed character. Here there occurs also a change in the primary trend of the Mesozoic folded system of the Karakorum from a northwest--typical for the region of the headwaters of the Karakash and Yarkend rivers--to an almost latitudinal trend, which predominates in Tibet.

With respect to the mineral resources of the Kunlun and Karakorum we have at our disposal very scanty data, since they have been little investigated. The existing information, however, permits noting the special features of the distribution of ore indications in the structural-facies zones of the Kunlun and Karakorum, and thereby furnish a basis for a preliminary evaluation of prospects for finding mineral deposits in these zones.

In the Kunlun two metallogenic zones are clearly defined: a polymetallic, belonging to the Paleozoic depression of the Tarim flank, within which are concentrated dozens of small deposits and ore indications which were exploited in the past by primitve methods; and a rare-metal zone (mainly tin) belonging to the axial zone of the Hercynian anticlinorium of the Western Kunlun, within which are distributed enormous bodies of Upper Paleozoic granites.

In this zone many tin-bearing placer deposits are known, as well as a few primary ore indications. Mineralization is represented by the quartz-cassiterite type, which is known not to produce good main ore deposits but facilitates the formation of rich placer deposits. In this same zone wolframite and beryl (in pegmatites) have been found.

In the Kunlun there are gold deposits which continue to be mined up to the present. The gold is taken from placer deposits in the river valleys which cut through the metamorphic strata and the sand-shale complex of the Lower Paleozoic. The Kunlun gold area, on the basis of mineralized area, is evidently the largest in China. Of nonmetallic minerals, rock crystal, jade, and diamonds are known. The age of the Kunlun mineralization is Paleozoic or older.

Of the Karakorum there is information concerning tin-tungsten mineralization, occurring in the main geoanticlinal zone, and also placer gold the sources of which are the old metamorphic strata which occur in this same geoanticlinal zone. Tin mineralization is represented by both quartz-cassiterite and sulfide-cassiterite types. Ore surveys have shown that the cassiterite in the placer deposits of the geoanticlinal zone is present along a stretch of 100 km between the upper courses of the Yarkend River and the Pamirs.

The mineralization in the zone of the Karakorum is of the Yen-shan age.

Pamirs. On the basis of their geological structure the Pamirs can be divided into four major zones which in general trend latitudinally, but somewhat curved to the north.

The first zone comprises the Southwestern Pamirs and adjoining parts of northeastern Afghanistan. The northern boundary of the zone runs from Lake Zorkul' to the northern course of the Bartang River, where it turns southwest and then extends into the vicinity of the town of Khorog, traversing the valley of the Pyandzh River. The Afghanistan extension of the zone has been investigated very little.

This zone of the Pamirs is one of the largest and most long-developed upheavals of the active Mesozoic zone of Southern Asia. Almost its entire area comprises a Pre-Cambrian metamorphic complex complicated by gnesisses, various crystalline schists, amphibolites, and marbles. Its main structural element is the megaanticline of the Shakhdar'inskiy and Vakhanskiy ranges in which are exposed very old members of the metamorphic complex. Prominent in the structure of this zone also are blocks of granites, mainly of the Yen-shan age, concentrated in the Shugnanskiy and Alichurskiy ranges. On the boundary of the zone of Paleozoic folding, where the movements were particularly intensive and opposing, there is a wide distribution of pegmatites and gneissoid granites of various ages from the Pre-Cambrian to the Yen-shan inclusive.

The second zone borders the first in the north and extends farther to the Murgab settlement--Tanymas mouth--Rushan settlement line. This zone also belongs to the active Mesozoic zone and is a continuation of the structures of the Karakorum. In it two parts can be distinguished very clearly--an eastern and a western. The eastern part (Murgabskiy) is characterized by a thick and rather complete horizon of the Upper Paleozoic and Mesozoic, while the western has a reduced horizon, in places of the Jurassic only, to a considerable degree volcanic in origin and lying directly on strongly metamorphosed deposits of the early Paleozoic.

In the eastern part of the second zone of the Pamirs the Upper Paleozoic begins with a thick stratum of quartzite-type sandstones and siliceous and argillaceous shales with blocks of limestones containing fossil fauna of the Upper Carboniferous (2,000 m). Higher follow shales, then limestones, and again shales with tuffaceous rocks. This shale-limestone stratum with

a total thickness of about 1,000 m contains all divisions of the Permian. The Triassic lies on the Permian with clear evidence of erosion, although unconformities between them, other than local and weakly expressed ones, have not been established. To the Triassic belongs a sand-shale stratum 1,500 m thick in which limestones are numerous in some places.

The Jurassic is represented by two complex divided by an unconformity. The lower complex, belonging to the Lias and Dogger, is composed of limestones and shales alternating with thick bodies of conglomerates and tuffaceous and volcanic rocks (2,000 m). The upper complex, belonging to the Malm (Valanginian), consists of light-gray block limestones underlain by red conglomerates and sandstones (1,500 m). In the Kyzyl-Rabat region there is a stratum of conglomerates and tuffs with blocks of sandstones and limestones which perhaps belong to the Upper Cretaceous.

In the western part, the zone of Upper Paleozoic and Mesozoic deposits is broken up by internal upheavals into separate areas. In the largest of these, the Bartangskiy, the sedimentary series runs from the Upper Permian to the Valanginian inclusive and in its primary features is similar to the horizon of the Murgabskiy part, although thinner. In the Rushanskiy area there is only the lower complex of the Jurassic, composed primarily of volcanic formations.

Intrusive rocks occur to a lesser extent in the second zone than in the first zone of the Pamirs; moreover, most of their outcroppings are concentrated in the southeastern (Rushanskiy) part, which underwent upheaval at the base. They are represented mainly by granites of the Hercynian and partly of the Yenshan periods.

The dislocations of deposits of the Upper Paleozoic and Mesozoic in this zone are in general conformable. Over the greater part of the zone they are rather simple: the folds are broad and sloping, and fractures are few and warpings inconsiderable. Only along the northern boundary of the zone (Akbaytal, Pshart, Rakharv) do powerful faults appear close together, in connection with which the folded structure of the Upper Paleozoic and Mesozoic strata is strongly complicated.

The third zone, embracing the Central Pamirs, constitutes a continuation of the masses and structures of the Western Kunlun. In a northerly direction it extends to the watershed crest of the Trans-Alayskiy range. In the axial part of this zone there are strongly metamorphosed schists and quartz-type sandstones of the Lower Paleozoic, while younger strata are localized on its flanks. On the southern flank (Vanch-Yazgulem) this sand-shale-limestone complex is more than 2,000 m thick, and in it there can be traced virtually uninterrupted horizon from the Ordovician to the Upper Devonian inclusive; while on the northern flank (Trans-Alayskiy Darvas range) there is a thick stratum of basic lavas and tuffs of the Upper Paleozoic. Widely found in this zone are Hercynian granitoids, which form enormous bodies extended along the trend of the folded structures.

The structure of the zone is complex, particularly on the northern margin and in the strip of outcroppings of the Lower Paleozoic. Characteristic of the former is a distinct tilting of the folds in the direction of the alpine depression of the Trans-Alayskiy range.

The fourth zone of the Pamirs, the most northerly, comprises the "Peter I" range, the northern slope of the Trans-Alayskiy range, and the eastern spur of the latter (Kazyart range). It represents the youngest formation of the Pamirs, originating on the site of the alpine depression. The structure of the zone includes volcanic-sedimentary strata of the Permian and early Mesozoic, a saliferous and gypsiferous stratum of the Upper Jurassic and a red sandstone-conglomerate series of the Cretaceous and Tertiary. The total thickness of the Mesozoic-Cenozoic complex of the zone is as much as 10,000 m. There are many volcanic rocks in this zone, but intrusive rocks are represented only by individual and very small bodies of post-Jurassic quartz diorites.

The folding of the deposits of the Mesozoic-Cenozoic in the northern zone is exceptionally strong. Their folds are steep, complicated by bends and fractures usually thrust back to the north in the direction of the Alayskiy trough. Along both boundaries of the zone run large thrusts the surfaces of which dip gently to the south.

CONCLUSION

In conclusion it should once again be emphasized that Central Asia is characteristically a region of specific desert landscapes surrounded on virtually all sides by high mountain ranges.

The climate in Central Asia began to become arid as early as the close of the Jurassic period. In the Cretaceous and Paleocene savannahs predominated here. The orogenic process, which began in the Neocene and has continued to the present time, resulted in a sharp increase in the desert conditions of Central Asia. Because the factors which led to the formation of deserts in Central Asia, in particular the rise of the peripheral mountain chains and the general upheaval of the region, continue to exert their effects, the process of the dessication of Central Asia has not yet halted, although at the present time it is occurring less efficiently than earlier.

The natural conditions in Central Asia are very severe and unfavorable for man's economic activities. However, the existing possibilities are still not being fully or systematically exploited. This refers above all to water--the most valuable resource of nature under desert conditions. With the abundance of solar light and heat, the fertile loess soils will furnish abundant harvests of very valuable agricultural crops. Nevertheless, the amount of land under cultivation here is small because of a lack of the water needed for irrigation.

But even with the available water supply, the sown areas could be expanded considerably, if measures were taken for the collection and storage of the uselessly-lost flood waters and the waters not used in the periods when the fields are not being irrigated.

These waters are carried by the rivers into the desert where they evaporate without advantage to man.

An increase in the volume of water available for economic purposes can be achieved only by means of a reduction in the seepage of channel waters into the zone of the piedmont alluvial strip, particularly by the construction here of concrete floodgates. However, the major branch of the economy of the regions of Central Asia in the next few decades will evidently remain the mining industry, on which the negative effect of the arid climate is of almost no importance.

The numerous and diverse deposits of minerals already established in Central Asia, despite the still very limited geological investigation of the region, support a favorable assessment of its mineral prospects.

The railroad and industrial construction which has already been carried out by the Chinese and Mongolian people in various regions of Central Asia will contribute to an ever more rapid exploitation of its natural resources, and this in turn will provide an impetus for a planned and many-sided investigation of its territory.

The author will be happy if the book which he has written proves useful in the carrying out of these new investigations of Central Asia.

/SEVEN LOOSE MAPS INSERTED ON INSIDE BACK COVER OF BOOK

Notes

1. Numbering of place names on map. This has been done in blue ink from top to bottom, left to right. The numbers continue those of the legend, or an original series of numbers is begun.

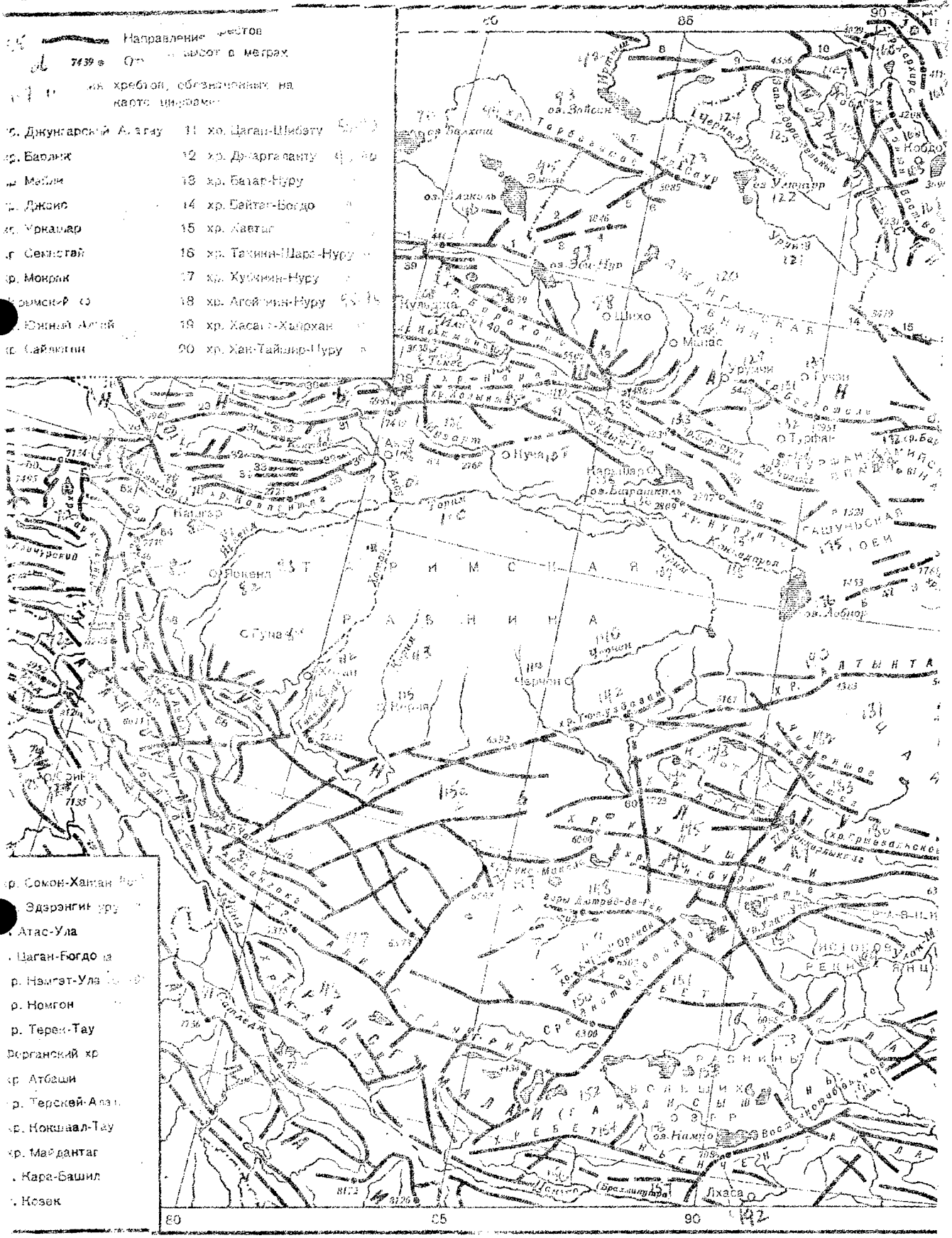
2. Locating items on map. The latitude and longitude of the SW corner of each square on the map precedes the listing of the place names for each such square.

3. Numbering of long names extending over several squares. Numbers are used but once, to the left of or near the first letter of the name.

4. Spelling. The most common conventional spellings are used where standard names exist, e.g., Himalayas, Tien Shan. Transliteration based on the "Russian-English key to Chinese names" was used wherever appropriate. In cases where no help could be obtained from this key, transliteration according to the Board on Geographic Names was used./

APPEND A^L HERE

Орографическая схема Центральной Азии


Направление хребтов
7439 м Отметки высот в метрах
Номера хребтов, обозначенных на карте цифрами
1 хр. Джунгарский Алатау
2 хр. Барлык
3 хр. Майли
4 хр. Джаис
5 хр. Уркашар
6 хр. Семистай
7 хр. Мокрый
8 хр. Юрмский
9 хр. Южный Алтай
10 хр. Сайлюгем
11 хр. Цаган-Шибэту
12 хр. Джаргасанту
13 хр. Батар-Нуру
14 хр. Байтаг-Богдо
15 хр. Хавтаг
16 хр. Тахкин-Шара-Нуру
17 хр. Хухэмин-Нуру
18 хр. Агойтин-Нуру
19 хр. Хасагт-Хыроган
20 хр. Хан-Тайшир-Нуру
хр. Сомон-Хангай
Эдэрэнгин Нуру
Атас-Ула
Цаган-Богдо
р. Нэмэгэт-Ула
р. Номгон
р. Терен-Тау
Ворганский хр
хр. Атбаши
р. Терскей-Ала
хр. Кокшаал-Тау
хр. Майдантаг
Кара-Башил
Козек
Г О Б И
Т А Р И М С К А Я
Д З У Н Г А Р С К А Я
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Ю Ж Н О - Д З У Н Г А Р С К

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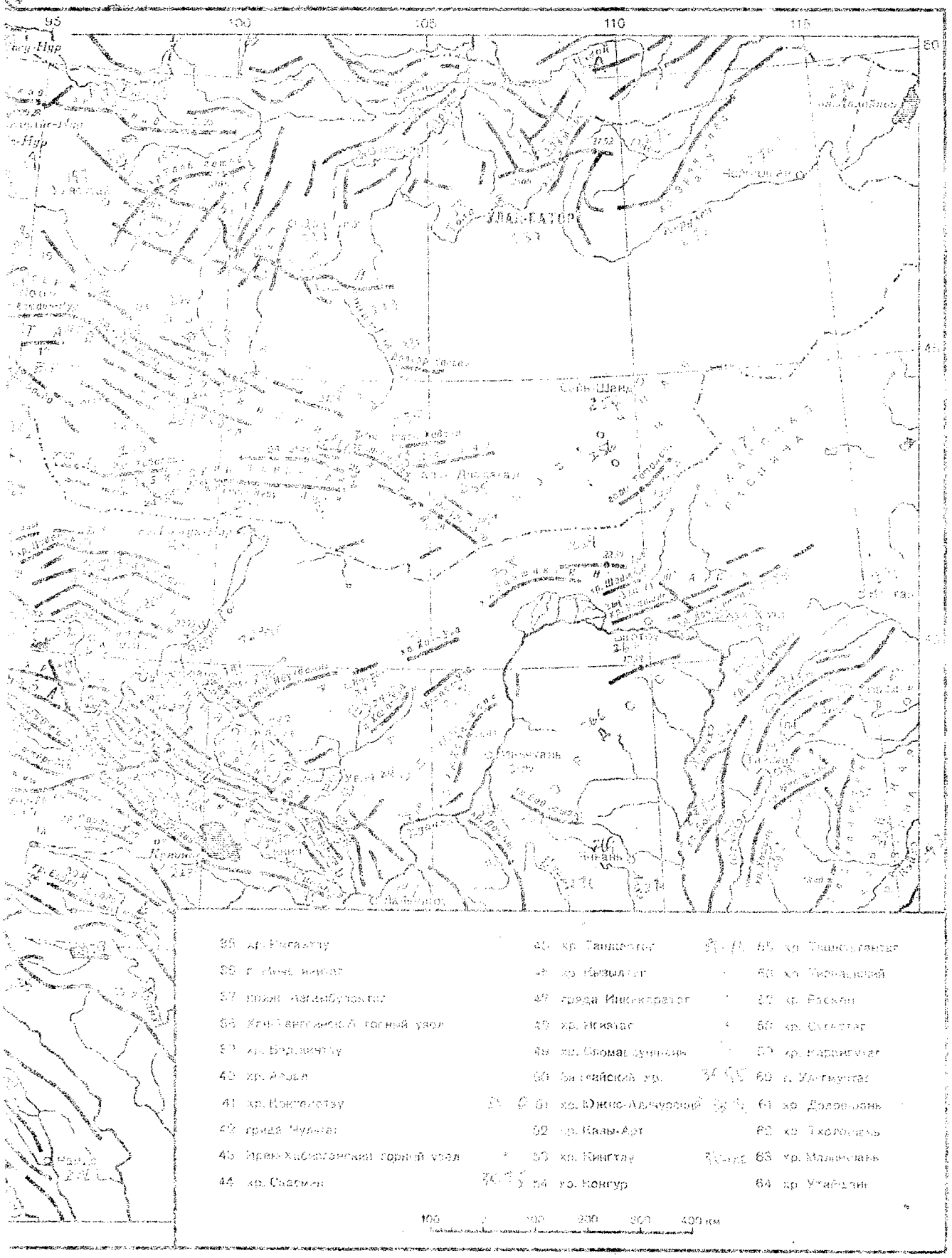

95
100
105
110
115
80
УЛАН-БАТОР
Сайн-Шанд
Чинань
35 хр. Кигаэтау
36 г. Ивчь-Кингат
37 пожн. Ангамбулактаг
38 Хан-Тенгринский горный узел
39 хр. Бадлинтау
40 хр. Аэрал
41 хр. Кокгелетау
42 гряда Чулытаг
43 Ирен-Хабирганский горный узел
44 хр. Свармин
45 хр. Ташкентаг
46 хр. Кызылтаг
47 гряда Инкекаратаг
48 хр. Игиатаг
49 хр. Сломаг-Сунгиань
50 Байгайский хр.
51 хр. Южно-Альчурский
52 хр. Казы-Арт
53 хр. Кингтау
54 хр. Конгур
55 хр. Ташкургантаг
56 хр. Тиснацкий
57 хр. Раскан
58 хр. Сугаттаг
59 хр. Карангутаг
60 г. Улугмуртаг
61 хр. Долоншань
62 хр. Тхолошань
63 хр. Малинчань
64 хр. Утайдзин
100 0 100 200 300 400 км

MAP A

OROGRAPHIC DIAGRAM OF CENTRAL ASIA

Legend:

1 Dzungarian Altay range
2 Barlyk range
3 Mayli range
4 Dzhair range
5 Urkashar range
6 Semistay range
7 Monrak range
8 Narymskiy range
9 Southern Altay range
10 Saylyugem range
11 Tsagan-Shibetu range
12 Dzhargalantu range
13 Batar-Nuru range
14 Bay Tagh-Bogdo range
15 Khav Tagh range
16 Takhiin-Shara-Nuru range
17 Knubchiin-Nuru range
18 Agoytiin-Nuru range
19 Khasagt-Khayrkhan range
20 Khan-Tayshir-Nuru range
21 Somon-Khayrkhan range
22 Ederengin-Nuru range
23 tas-Ula mountains
24 Tsagan-Bogdo-Ula mountains
25 Nemget-Ula range
26 Nomgon range
27 Terek-Tau range
28 Ferganskiy range
29 Atbashi range
30 Terskey-Alatay range
31 Kokshaal-Tau range
32 Maydan Tagh range
33 Kara-Bashil mountains
34 Kozek mountain
35 Imgantau range
36 Mechetiin Tagh mountains
37 Azgambulak Tagh mountain ridge
38 Khan-Tengrinskiy mountain knot
39 Bedzhintau range
40 Avral range
41 Kokteketau range
42 Chul' Tagh ridge

43 Iren-Khabirganskiy mountain knot
44 Saarmin range
45 Tashkar Tagh range
46 Kyzyl Tagh range
47 Inkikara Tagh range
48 Igiz Tagh range
49 Syamatszun Shan range
50 Trans-Alayskiy range
51 Southern Alichurskiy range
52 Kazy-Art range
53 Kingtau range
54 Kongur range
55 Tashkurgan Tagh range
56 Tiznafskiy range
57 Raskem range
58 Suget Tagh range
59 Karangu Tagh range
60 Ulugmuz Tagh range
61 Doloye Shan range
62 Tkholo Shan range
63 Malin Shan range
64 Utay Shan range
65 Bearing of ranges
66 Altitude in meters
67 Names of ranges numbered on map:

Place names on map:

40-70 68 Tien Shan (system)
35-70 69 Kyzylsu River
70 Sarykol'skiy range
71 Northern Alichurskiy range
72 Karakorum (system)
73 Ind River
30-70 74 Himalayas (system)
45-75 75 Srinagar (town)
76 Lake Balkash
40-75 77 Kokshaal R.
35-75 78 Kyzylsu (town)
79 Kalpin Tagh range
80 Kashgar (town)
81 Yarkend River
82 Yarkend (town)
83 Tarim plain
84 Guma (town)
85 Kunlun (system)
86 Agyl mountains

30-75	87	Ladan range
	88	Chang-Chenmo range
	89	Pangong range
	90	Ind River
	91	Satledzh River
45-80	92	Irtysh River
	93	Lake Zaysan
	94	Tarbagatay range
	95	Emel' River
	96	Lake Alakol'
	97	Lake Ebi-Nur
40-80	98	Shikho (town)
	99	Borokhoro range
	100	Kul'dzha (town)
	101	Ili River
	102	Kelten' range
	103	Tekes River
	104	Narat range
	105	Khalykta range
	106	Muzart River
	107	Kucha (town)
	108	Aksu (town)
	109	Aksu River
	110	Tarim River
	111	Ho-t'ang River
	112	Ho-t'ang (town)
	113	Keriya River
	114	Cherchen (town)
	115	Keriya (town)
	115a	Chang Tang (region)
	116	Tekelik Tagh (range)
30-80	117	Aling-Gangri range
	118	Trans-Himalaya (Gandisu Shan) (system)
	119	Kaylas range
45-85	120	Dzungarian plain
	121	Urungu River
	122	Lake Ulyungur
	123	Saur range
	124	Chernyy Irtysh River
	125	western watershed
	126	Mongolian Altay (region)
	127	Kobdo River
40-85	128	Manas (town)
	129	Urumchi (town)
	130	Ku-cheng (town)
	131	Bogdo Shan range
	132	Turfan (town)

	133	Bortoula range
	133a	Khaydyk-Gol River
	134	Chol Tagh range
	135	Karashar (town)
	136	Lake Bagrashkul'
	137	Kuruk Tagh range
	138	Konchedar'ya River
	139	Tarim River
35-84	140	Cherchen River
	141	---
	142	Tokuzdavan range
	143	Kul'tala (region)
	144	Arka Tagh range
	145	Kukushili range
	146	Dungbure range
30-85	147	Buka-Mangna range
	148	Dyutryoy-de-Ren mountains
	149	"Anri-d'Orlean" mountain
	150	Central Tibetan upheaval
	151	Tangla range
	152	Gandisy Shan (see 118)
	153	Plains of Great Lakes
	154	N'enchen-Tangla range
	155	Lake Namtso
25-85	156	Tsangpo River
	157	Brahmaputra River
50-90	158	Tannu-Ola range
	159	Lake Ubsu-Nur
45-90	160	Kharkira range
	161	Basin of Great Lakes
	162	Khan-Khukhzy range
	163	Lake Khirgis-Nur
	164	Lake Khara-Us-Nur
	165	Kobdo (town)
	166	Delyan range
	167	eastern watershed
	168	Shargyn Gobi (region)
40-90	169	Adzh-Bogdo range
	170	Nomin Gobi (region)
	171	Mechin-Ula range
	172	Barkul' Tagh range
	173	Karlyk Tagh range
	173a	Turfan-Khamiyskiy basin
	174	Khami (town)
	175	Gashun'skiy Gobi
	176	Lake Lop Nor
	177	Sulyssiin Tagh range
	178	Tien-shan-tse range
	179	Ushan' Ala Shan (system)

35-90	180	Altyn Tagh range
	181	Tsaidam (basin)
	182	Chiten Tagh (range)
	183	Kyakdyg Tagh (range)
	184	Khaltyn-Col River
	185	Mushketova range
	186	Przheval'skiy range
	187	Chonkarly Tagh (range)
30-90	188	Ulan-Ula range
	189	Plains of the headwaters of the Yang-tse River
	190	Ulan-Muran (Yang-tse) River
	191	East Tibetan upheaval
25-90	192	Lkhasa (town)
45-95	193	Tes River
	194	Bolnay range
	195	Tarbagatay range
	196	Khangay (region)
	197	Ulyasutay (town)
	198	Altain-Nuru range
	199	Gichgene-Nuru range
	200	Valley of Lakes
40-95	201	Gobi Altay (region)
	202	Bayan-Under range
	203	Ikhe-Khabtsagay (range)
	204	Gobi Tien Shan (system)
	205	Lake Gashun-Nur
	206	Tsigechintszu range
	207	Ta-ma-tsung Shan range
	208	Sulekhe River
	209	Po-hsiang-tse mountain
	210	Yui-meng (town)
	211	Edzin-Gol River
	212	Kansu corridor
35-95	213	Chiu-chiu-an (town)
	214	Richthofen range
	215	Nan Shan (system)
	216	--
	217	Zyussa range
	218	Ritter range
	219	Kurlyk-Daban range
	220	Southern Kukunor range
	221	Ching-shek-ling range
	222	Sarlyk-Ula range
	223	Lake Kukunor
	224	Barkhan-Budda range

30-95	225	Yang-tse River
	226	Huang Ho
	227	Dzachu (Mekong) River
	228	Chamdo (town)
	229	Nagchu (Saluen) River
45-100	230	Selenga River
	231	Bulgan (town)
	232	Tsetserleg (town)
	233	Ongin-Gol River
	234	Delger-Khangay (range)
40-10	235	Shara-Khadzar (range)
	236	Gurvan-Saykhan range
	237	Shang-hai (town)
	238	Tost-Nuru range
	239	Khan-Ula range
	239a	Ala Shan
35-100	240	Ibula Shan
	241	Hei-ho (range)
	242	Chang-yeh (town)
	243	Yabaray mountain
	243a	Richthofen (range (= 214)
	244	Ta-t'ung Ho
	244a	Khara-Ula mountains
	245	Hsi-ning (town)
	245a	Wu-wei (town)
	246	Hsi-ning Ho
	247	Lang-chou (town)
	248	Huang Ho
50-105	249	Chikoy River
45-105	250	Orkhon River
	251	Kheytey range
	252	Ulan B tor (town)
	253	Tola River
40-105	254	Sayn-Shand (town)
	255	Dalan-Dzadagad (town)
	256	Eastern Gobi (region)
	257	Khurkhe-Ula range
	258	Lang Shan range
	259	Ying Shan (region)
	260	Sheyten-Ula range
	261	Ula Shan range
	262	Pao-tow (town)
35-105	263	Bayan-Ula range
	264	Kholan Shan range
	265	Yin-chuan (town)
	266	Ordos (region)
	267	Pai-liu Shan range

	268	Lo Shan range
	269	Yang-an (town)
	270	Lo Ho
	271	Ching Ho
45-110	272	Onon River
	273	Erh-en-ta-pa range
	274	Choybalsan (town)
	274	Kerulen River
40-110	276	To-mo-shan mountain
	277	Chakhar plain
	278	Ta-ching Shan range
	279	Khykh-Khoto (town)
35-110	280	Huang-hua Shan range
	281	Heng Shan range
	282	Huang Ho
	283	T'ai-yuan (town)
	284	Mien Shan range
	285	Liu-liang range
	286	Feng Ho
	287	Ho Shan range
	288	T'ai-hang Shan (range)
	289	Ho-peh plain
45-115	290	Lake Dalaynor
40-115	291	Kalgan (town)
35-115	292	Pao-ting (town)
	293	Wei Ho

MAP B

QUATERNARY DEPOSITS IN CENTRAL ASIA

Legend:

1 High mountain complex. Disconnected parts of diluvial and glacial formations among rocky outcroppings of Pre-Quaternary rocks.

2 Fluvio-glacial deposits covering high-altitude plains.

3 Central mountain complex.
a. within the arid region (discontinuous alluvial cover on slopes and in valleys);
b. outside the arid region (more continuous alluvial cover on slopes and in valleys).

4 Very mixed flood(deluvial) deposits in region of stony deserts.

5 Less intensively mixed deluvial deposits in region of sandy deserts.

6 Unmixed alluvial deposits of plains and hills outside the arid region.

7 Bare mixed sands.

8 Sands partly covered by vegetation.

9 Mountain loesses.

10 Plateau loesses.

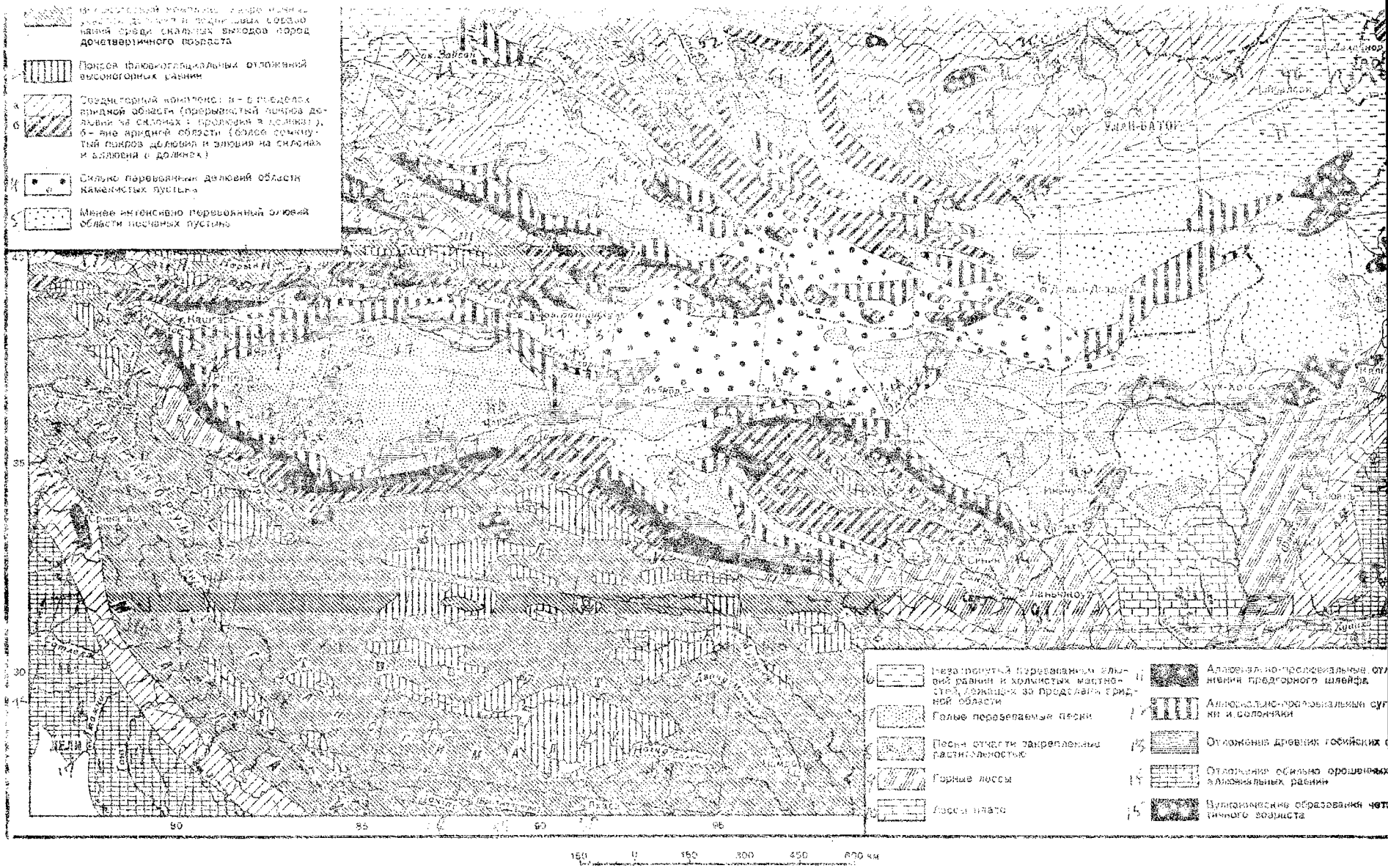
11 Foothill deposit strip.

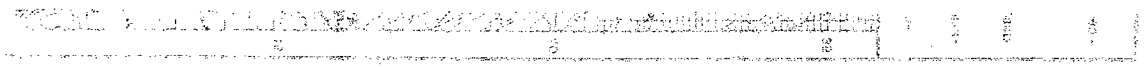
12 Clays and solonchaks.

13 Deposits of ancient Gobi lakes.

14 Deposits of well-watered alluvial plains.

15 Quaternary volcanic formations.


Ховд
Улан-Батор
Дзамын-Удэ
Ханхонгор
Дзун-Хара
Дзелин
Сайншанд
Баотоу
Хух-Хото
Ордос
Ланьчжоу
Синин
Хух-Нур
Цайдам
Нарын-Хара
Ала-Шань
Гоби
Тенгер
Алашань
Ордосская
Тенгерская
Гобийская
Алашаньская
Цайдамская
Нарын-Харинская
Ланьчжоуская
Сининьская
Хух-Норская
Ордос



Place names on map:

40-70	1	Tien Shan (system)
35-70	2	Kyzylsu River
	3	Ind River
40-75	4	Naryn River
	5	Kokshaal River
35-75	6	Kashgar (town)
	7	Yarkend River
	8	Yarkend (town)
	8a	Kunlun (system)
	9	Karakash (town)
	10	Yurunkash River
	11	Karakorum (system)
	12	Ku-ma (town)
30-75	13	Srinager (town)
	14	Ind River
	15	Himalayas (system)
	16	Satledzh River
25-75	17	Delhi (town)
	18	Dzhamna River
	19	Ganges River
45-80	20	Irtysh River
	21	Lake Zaysan
	22	Emel' River
40-80	23	Kul'dzha (town)
	24	Tekes River
	25	Aksu River
	26	Aksu (town)
	27	Muzart River
	28	Koo-cha (town)
	29	Khaydyk-Gol River
	30	Tarim River
	31	Ili River
35-80	32	Khotan River
	33	Keriya River
	34	Ko-t'ang (town)
	35	Cherchen (town)
	36	Yurunkash River
30-80	37	Tibet (region)
	38	Trans-Himalayas (region)
45-85	39	Mongolian Altay (region)
	40	Chernyy Irtysh River
	41	Urungu River

40-85	42	Urumchi (town)
	43	Turfan (town)
	44	Lake Bagrashkul'
	45	Konchedar'ya River
35-85	46	Cherchen River
	47	Cherchen (town) = 35
25-85	48	Tsangpo River
	49	Brahmaputra River
50-90	50	Lake Ubsu-Nur
45-90	51	Dzabkhan River
	52	Kobdo River
	53	Kobdo (town)
40-90	54	Khami (town)
	55	Lake Lop Nor
35-90	56	Tsaidam (basin)
30-90	57	Dzachu (Mekong) River
	58	Ulan-Muren (Yang-tse) River
	59	Nagchu (Saluen) River
25-90	60	Lkhasa (town)
45-95	61	Ulyasutay (town)
40-95	62	Su-le Ho
	63	Yui-meng (town)
	64	Edzin-Gol River
35-95	65	Chiu-chiu-an (town)
	66	Hei Ho
	67	Huang Ho
30-95	68	= 58
	69	Chamdo (town)
45-100	70	Selenga River
	71	Orkhon River
	72	Bulgan (town)
	73	Tsetserleg (town)
	74	---
	75	Ongin-Gol River
40-100	76	Dulan-Dzadagad (town)
35-100	77	Ta-t'ung Ho
	78	---
	79	Hsi-ning (town)
	80	Hsi-ning Ho
	81	Lang-chou (town)
	82	Lake Kukunor
	83	= 67
45-105	84	Tola River
	85	Ulan Bator (town)

35-105	86	Yin-chuan (town)
	87	Lo Ho
	88	Ching Ho
45-110	89	Onon River
	90	Choybalsan (town)
	91	Kerulen River
40-110	92	Khukh-Khoto (town)
	93	Kalgan (town)
35-110	94	T'ai-yuan (town)
	95	Feng Ho
	96	= 83
	97	Wei Ho
45-115	98	Lake Dalaynor

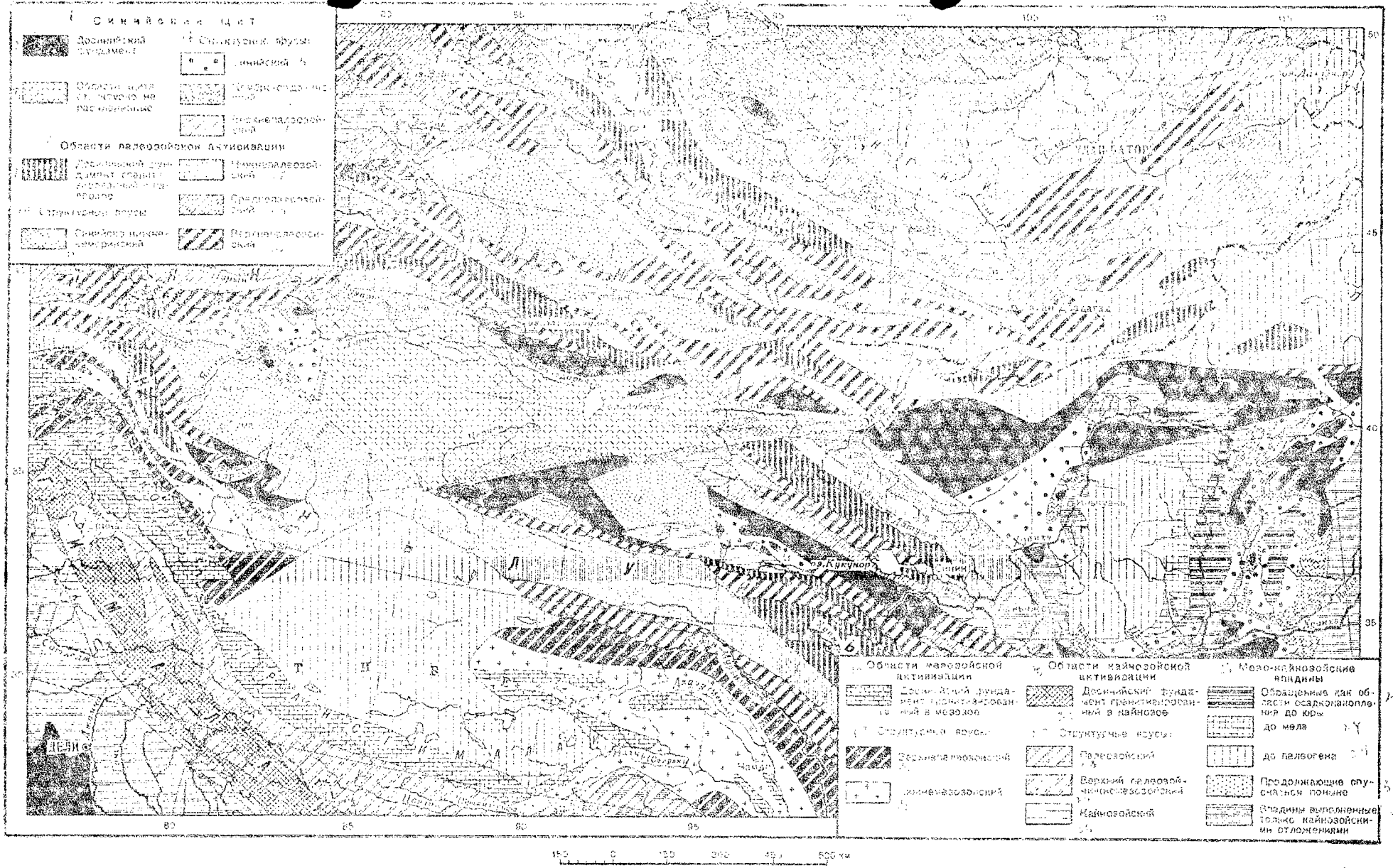
MAP C

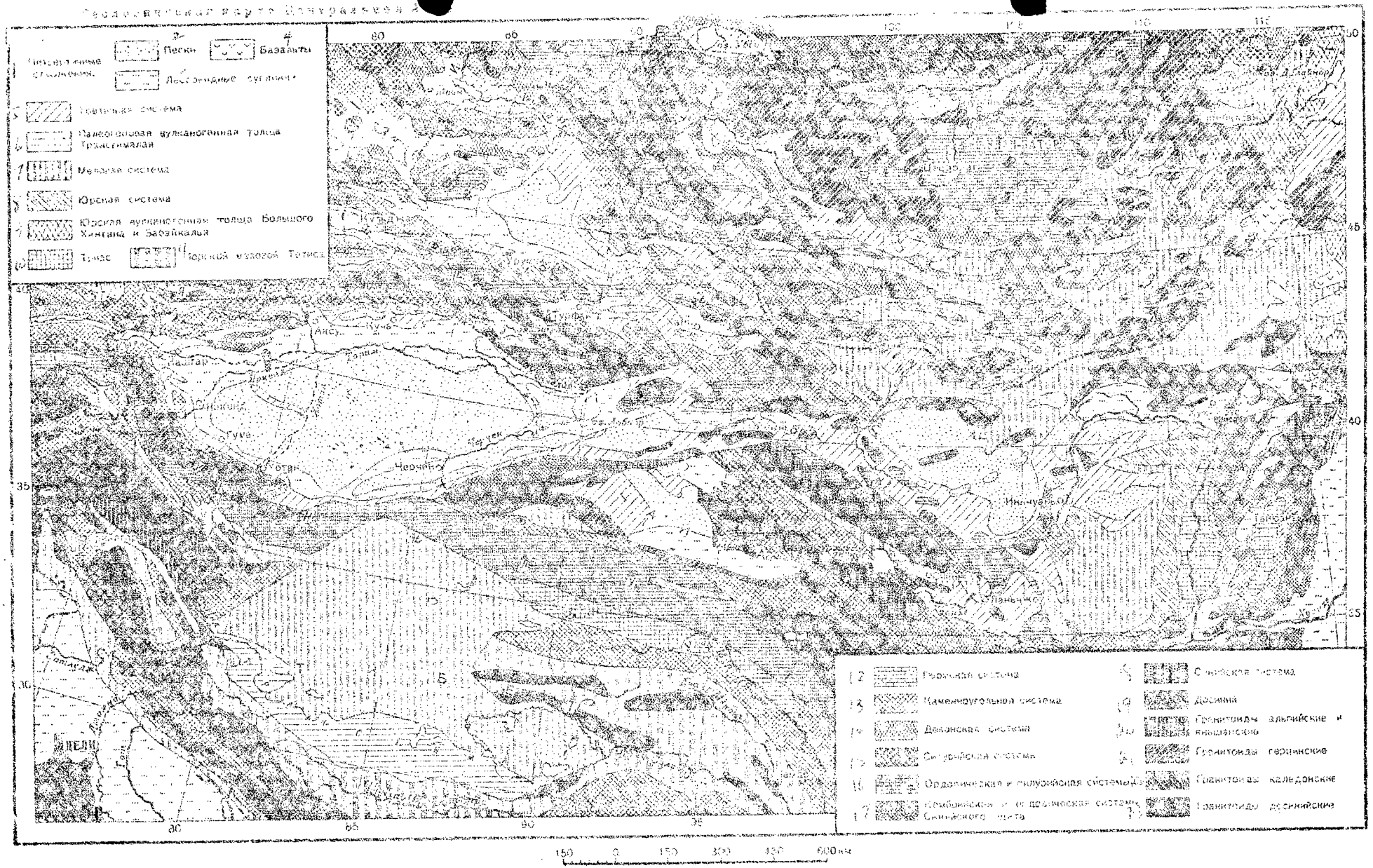
GEOLOGICAL MAP OF CENTRAL ASIA

Legend:

1 Quaternary deposits
2 Sands
3 Loess-type clays
4 Basalts
5 Tertiary system
6 Paleocenic volcanic stratum of Trans-Himalayas
7 Cretaceous system
8 Jurassic system
9 Jurassic volcanic stratum of Greater Khingans and Trans-Baikalia
10 Triassic
11 Marine Mesozoic of Tetis
12 Permian system
13 Carboniferous system
14 Devonian system
15 Silurian system
16 Ordovician and Silurian systems
17 Cambrian and Ordovician systems of Sinisian shield
18 Sinisian system
19 Pre-Sinisian
20 Alpine and Yen-shan granitoids
21 Hercynian granitoids
22 C ledonian
23 Pre-Sinisian

Place names on map: Same as Map B.


Синийский щит
Докембрийский фундамент
Области щитов со слабо или не расчлененным
Области палеозойской активизации
Структурные зоны
Структурные зоны:
Синийский
Каледонидный
Герцинидный
Каледонский
Среднепалеозойский
Верхнепалеозойский
Области мезозойской активизации
Области кайнозойской активизации
Мезо-кайнозойские впадины
Докембрийский фундамент
Палеозойский
Верхний палеозой-мезозойский
Кайнозойский
Обращенные как области осадконакопления до юры
до мела
до палеогена
Продолжающие опускаться поныне
Впадины выполненные только кайнозойскими отложениями
Ляохэ
Ляодунский
Ляохэ
Ляодунский
Ляохэ
Ляодунский



Пески
Базальты
Лессовидные суглинки
Третичная система
Палеогеновая вулканогенная толща Трансгималая
Меловая система
Юрская система
Юрская вулканогенная толща Большого Хинганa и Забайкалья
Триас
Норской мезозой Тетиса
Пермская система
Каменноугольная система
Девонская система
Силурийская система
Ордовическая и силурийская системы
Синийская система
Досиний
Гранитоиды альпийские и яньшанские
Гранитоиды герцинские
Гранитоиды каледонские
Гранитоиды досинийские
150 0 150 300 450 600 км

MAP D

TECTONIC MAP OF CENTRAL ASIA

Legend:

1 Sinisian shield
2 Pre-Sinisian base
3 Region of shield not structurally dissected
4 Structural series:
5 Sinisian
6 Cambrian-Ordovician
7 Upper Paleozoic
8 Regions of Paleozoic activization
9 Pre-Sinisian base granitized in Paleozoic
10 Structural series:
11 Sinisian-Lower Cambrian
12 Lower Paleozoic
13 Middle Paleozoic
14 Upper Paleozoic
15 Regions of Mesozoic activization
16 Pre-Sinisian base granitized in Mesozoic
17 Structural series:
18 Upper Paleozoic
19 Lower Mesozoic
20 Regions of Cenozoic activization
21 Pre-Sinisian base granitized in Cenozoic
22 Structural series:
23 Paleozoic
24 Upper Paleozoic-Lower Mesozoic
25 Cenozoic
26 Mesozoic-Cenozoic basins
27 Formed as a region of sedimentary accumulation before the Jurassic
28 Before the Cretaceous
29 Before the Paleocene
30 Continuing to subside at the present time
31 Plains of only Cenozoic deposits

Place names: Same as Map B.

MAP E

HYDROGRAPHIC DIAGRAM OF CENTRAL ASIA

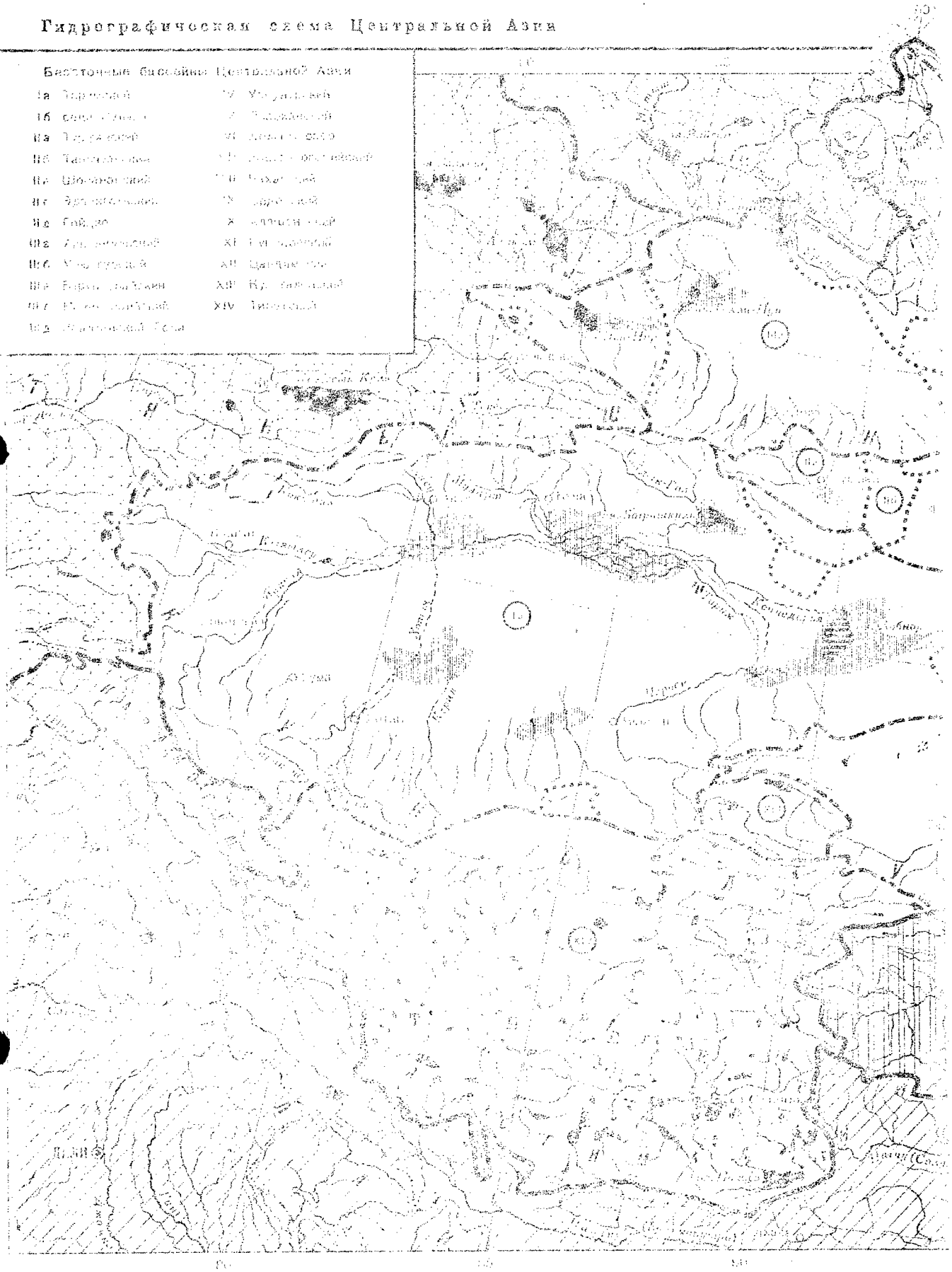
Legend:

1 Landlocked basins of Central Asia

Ia Tarim
Ib of the Su-le Ho
IIa Turfan
IIb T'an-chuang
IIc Shonanorskiy
IId Edzin-Gol
IIe Goydzo
IIIa Ayrankul'skiy
IIIb Ulyungurskiy
IIIc Barunkhurayskiy
IIId Nomin-Gobi
IIIe Trans-Altay Gobi
IV Ubsunurskiy
V Dzabkhanskiy
VI Valley of Lakes
VII Eastern Gobi
VIII Chakharskiy
IX Ordos
X Ala Shan
XI Kukunor
XII Tsaidam
XIII Kul'talinskiy
XIV Tibetan

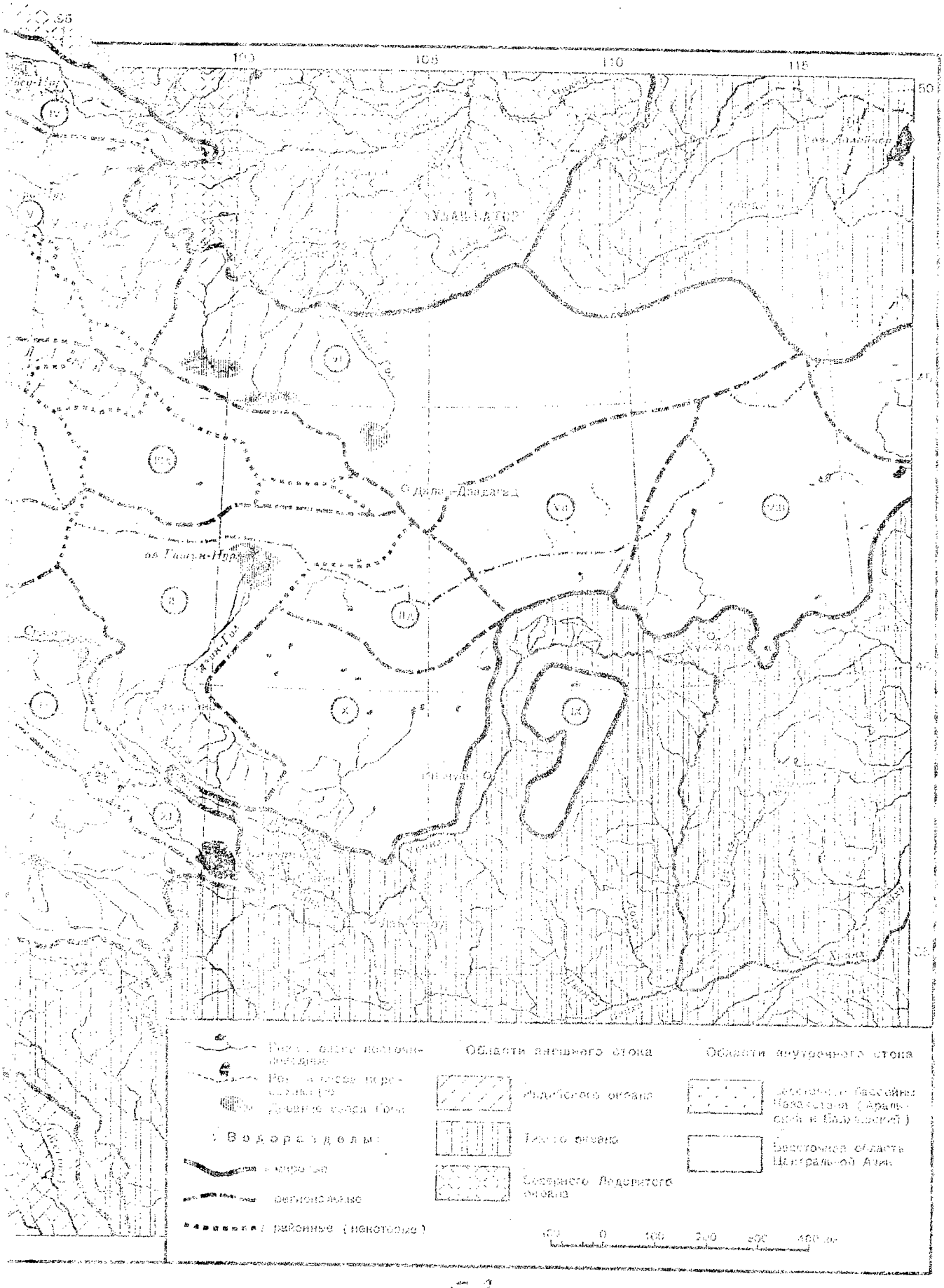
2 Permanent rivers and lakes
3 Intermittent rivers and lakes
4 Ancient lakes of the Gobi
5 Watersheds:
6 General
7 Regional
8 District (selection)
9 Regions of external flow
10 Indian Ocean
11 Pacific Ocean
12 Arctic Ocean
13 Regions of internal flow
14 Landlocked basins of Kazakhstan (Aral Sea and Lake Balkash)
15 Landlocked region of Central Asia.

Гидрографическая схема Центральной Азии



E'

APPEND E' HE



Области внешнего стока
Области внутреннего стока
Индийского океана
Тихого океана
Северного Ледовитого океана
Бессточная область Центральной Азии
Водоразделы:
районные (некоторые)

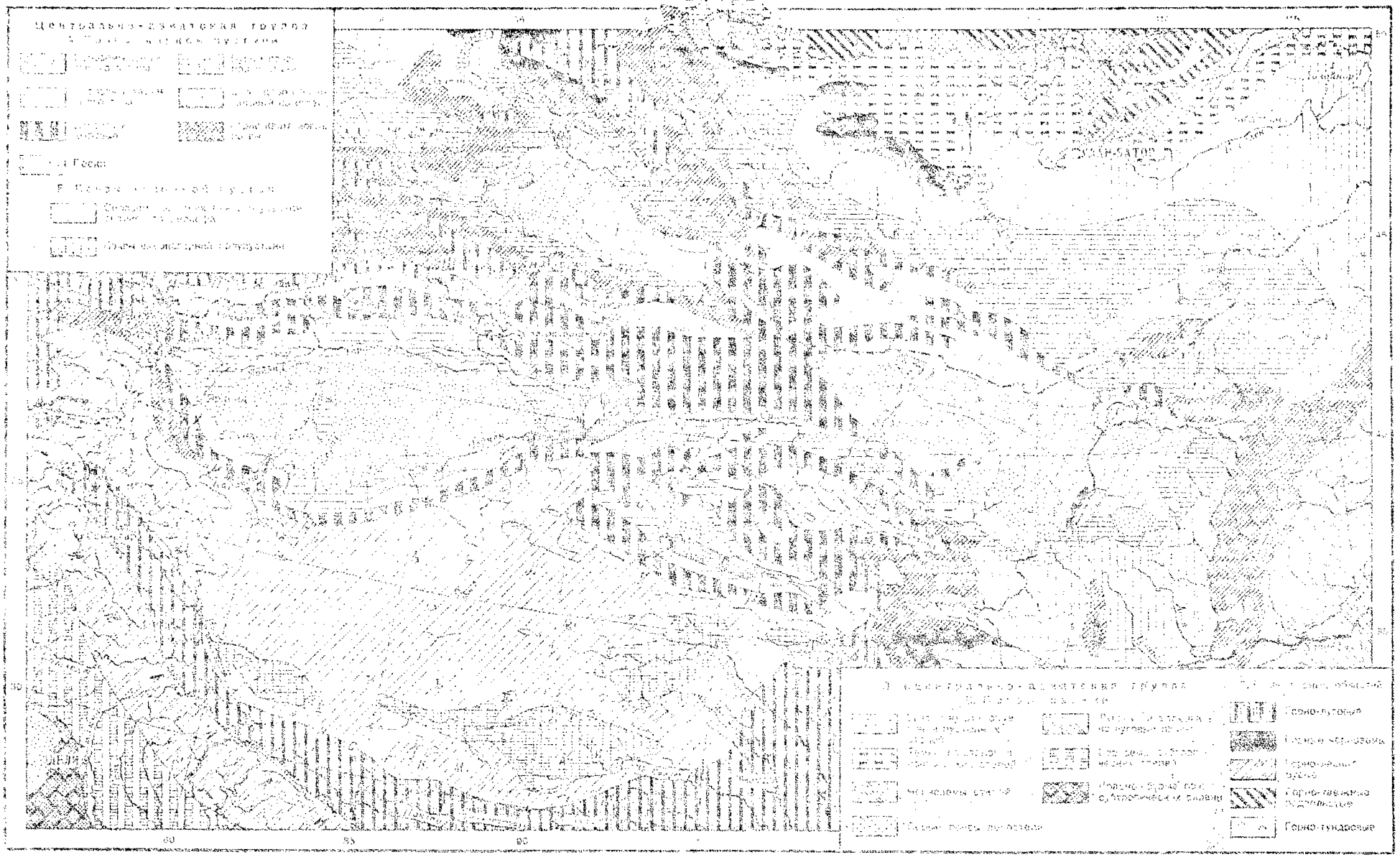
Е 2

Place names on map:

40-70	1	Tien Shan (system)
	2	Syr-Dar'ya River
	3	Naryn River
35-70	4	Karakorum (system)
	5	Ind River
45-75	6	Lake Balkhash
40-75	7	Chu River
	8	Lake Issyk-Kul'
	9	Kokshaal River
	10	Aksu River
35-75	11	Kashgar (town)
	12	Kyzylsu River
	13	Yarkend River
	14	Yarkend (town)
	15	Ku-ma (town)
	16	Karakash River
30-75	17	Srinagar (town)
	17a	Himalayas (system)
	18	Ind River
	19	Satledzh River
25-75	20	Delhi (town)
	21	Dzhamna River
	22	Ganges River
45-80	23	Irtysh River
	24	Lake Zaysan
	25	Emel' River
	26	Lake Iakol'
40-80	27	Lake Ebi-Nur
	28	Kul'dzha (town)
	29	Ili River
	30	Tekes River
	31	Khaydyk-Gol River
	32	Koo-cha (town)
	33	Muzart River
	33a	Aksu River
	34	Aksu (town)
	35	Tarim River
	36	Ho-t'ang River
	37	Ho-t'ang (town)
	38	Keriya River
	39	Yurunkash River
30-80	40	Tibet (region)
	41	Trans-Himalayas (region)

45-85	41a	Mongolian Altay (region)
	42	Chernyy Irtysh River
	43	Lake Ulyungur
	44	Urungu River
	45	Lake Tekli-Nur
40-85	46	Urumchi (town)
	47	Turfan (town)
	48	Lake Bagrashkul'
	49	Konchedar'ya River
	50	= 35
35-85	51	Cherchen River
	52	Cherchen (town)
30-85	53	Lake Selling
	54	Lake Namtso
25-85	55	Tsangpo River
	56	Brahmaputra River
45-90	57	Lake Ubsu-Nur
	58	Kobdo River
	59	Lake Khirgis-Nur
	60	Lake Khara-Us-Nur
	61	Kobdo (town)
	62	Lake Khara-Nur
40-90	63	Khami (town)
	64	Lake Lop Nor
35-90	65	Tsaidam (basin)
30-90	66	Ulan-Muren (Yang-tse) River
	67	Nagchu (S luen) River
25-90	68	Lkhasa (town)
45-95	69	Tes River
	69a	Khangay (region)
	70	Ulyasutay (town)
	71	Dzabkhan River
40-95	72	Lake Gashun-Nur
	73	Su-le Ho
35-95	74	Chiu-chiu-an (town)
	75	Hei Ho
30-95	76	= 66
	77	Huang Ho
	78	Dzachu (Mekong) River
	79	Chamdo (town)
45-100	80	Selenga River
	81	Bulgan (town)
	82	Tsetserleg (town)
	83	Ongin-Gol River
40-10	84	Dalan-Dzadagad (town)
	85	Edzin-Gol River

35-100	86	Ta-t'ung Ho
	87	Lake Kukunor
	88	Hsi-ning (town)
	89	Hsi-ning Ho (river)
	90	Lang-chou (town)
50-105	91	Chikoy River
45-105	92	Ulan Bator (town)
	93	Orkhon River
	94	Tola River
35-105	95	Yin-chuan (town)
	96	Huang Ho
	97	Lo Ho
30-105	98	Ching Ho
	99	Wei Ho
45-110	100	Onon River
45-115	101	Lake Dalaynor
45-110	102	Choybalsan (town)
	103	Kerulen River
40-110	104	Khukh-Khoto (town)
	105	Kalgan (town)
35-110	106	T'ai-yuan (town)
	107	Feng Ho
35-115	108	= 99
	109	= 96



MAP F

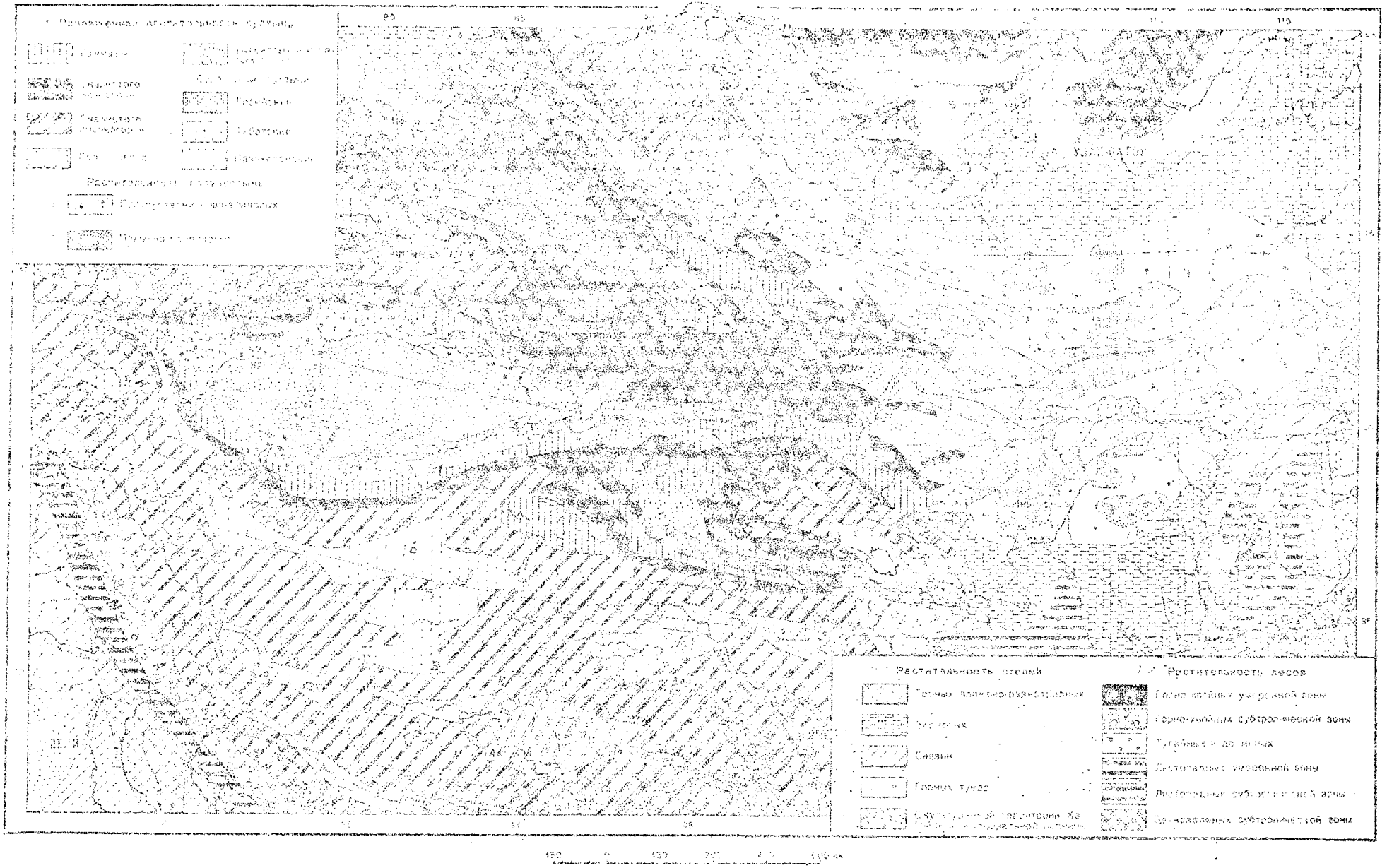
SOILS OF CENTRAL ASIA

Legend:

1 Central Asiatic group
2 A. Soils of the hot desert
3 Sierozem soils of the Dzungarian type
4 Sierozem soils of the Tarim type
5 Kyrovye
6 Sands
7 Brown soils of the semidesert
8 Saliferous-solonchak complex
9 Mountain-chestnut soils
10 B. Soils of the cold desert
11 Sierozem soils of high plateaus and rocky relief
12 Soils of the high-altitude semidesert
13 Non-Central Asiatic group
14 C. Soils of plains
15 Light chestnut soils of the desert steppes
16 Dark chestnut soils of the dry steppes
17 Steppe chernozem soils
18 Gray soils of the forest-steppe
19 Meadow and alluvial-meadow soils
20 Sierozem soils of the sub-tropic steppes
21 Red-brown soils of subtropical savannahs
22 D. Mountain soils
23 Mountain-meadow
24 Mountain chernozem
25 Mountain-forest brown
26 Mountain-taiga podzol
27 Mountain-tundra

Place names on map: Same as Map B.

Растительность Центральной Азии



MAP G

VEGETATION OF CENTRAL ASIA

Legend:

1 Sparse desert vegetation
2 Stony deserts
3 Rocky low-mountain
4 Rocky high-mountain
5 Bare sands
6 Hill and dune sands
7 Saliferous deserts
8 Gobi
9 Tibet
10 Kazakh
11 Vegetation of the semidesert
12 Underbush-grassy
13 Polyn and salt desert
14 Vegetation of the steppes
15 Mountain cereal-grass
16 Grassy
17 Savannahs
18 Mountain tundra
19 Cultivated area of the Ho-peh alluvial plain
20 Vegetation of forests
21 Mountain-coniferous of the moderate zone
22 Mountain-coniferous of the subtropical zone
23 Taiga and valley
24 Deciduous (moderate zone)
25 Deciduous (subtropical zone)
26 Evergreens of the subtropical zone

Place names on map: Same as Map B.

5031

END