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PHYSICAL GEOGRAPHY OF TIBET

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TIBET

PHYSICAL-GEOGRAPHIC CHARACTERISTICS

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B. B. Yusov

(Under the editorship of E. M. Murzayev,  
Doctor of Geographical Sciences)

Tibet is one of the largest regions of China in territorial extent. It is situated on the world's highest and most extensive plateau -- the Tibetan highland. The natural conditions of Tibet, occupying the western, most uplifted part of this upland, are distinguished by extraordinarily unusual and singular contrasts. Suffice it to mention that the elevation above sea level of the northern part of the territory of Tibet, the so-called Changtang Desert, reaches 5,000 meters, and the climate is distinguished by an extraordinarily intense continentality. At the same time, on the southern slope of the Himalaya, partly within the boundaries of Tibet and subject to the action of the moist Indian monsoons, subtropical and tropical vegetation flourishes luxuriantly.

In this book characteristics of the surface structure of Tibet and types of relief are given. Also examined are characteristics of the climate, hydrography, vegetation, and animal world, and physical-geographic regions are delineated and described. The book is of interest not only to geographers and naturalists (botanists, zoologists, climatologists, but also to laymen, since it informs us about one of the least studied regions of the globe.

INTRODUCTION

In this book, presented for the consideration of the reader, are given the physical-geographic characteristics of Tibet, an autonomous region of China that is quite distinct and singular in its natural conditions.

Tibet occupies the western half of the world's highest and most extensive highland, the so-called Tibetan highland, extending into the depths of Asia over an area of two million square kilometers.

The Tibetan highland and all the natural phenomena characteristic of this highland are striking in their uniqueness and grandiosity, not being repeated on such a scale in any other region of the globe. The average elevation of the highland above sea level is 4,500 meters. Beneath its broad hilly plains could be concealed the Alps and the Caucasus, and only the snow-capped peaks of such mountains as Elbruz (5,633 meters) and Kazbek (5,048 meters) would rise somewhat above the surface of these plains.

The scope of tectonic movements on the highland has been unusual, and as a result, a part of the Asiatic continent that is immense in area was lifted to an elevation of 4,500-6,000 meters, although it was still situated at sea level in Tertiary times. No less striking is the speed of these movements, which for the post-glacial era has been around 10 meters per century. Finally, the Tibetan highland is striking due to the extraordinary continentality of the climate of its inner regions, its biological characteristics, and the makeup of its plant and animal population.

A considerable part of the territory of the upland is made up of a rocky desert region, the Changtang, above whose plains rise mountain ranges, chiefly with an east-west orientation, often to heights of 6,000-6,500 meters or more.

Tibet proper (in its administrative boundaries) occupies only a part of the highland, but its territory extends almost 1,400 kilometers from west to east, and for 1,000 kilometers from north to south. It possesses many interesting physical-geographic features. This justifies us in regarding Tibet as an object meriting independent physical-geographic study: it is here that the typical features of the natural conditions of a highland are most clearly and fully expressed.

The principal of these features are these:

1. The territory of Tibet embraces the western, highest part of the highland, having an immense area of internal drainage.
2. The mountain chains of the Himalaya and the Transhimalaya, framing Tibet on the south, in the form of tremendous east-west barriers. These block the path of the warm moist monsoons from the regions of inner Tibet and sharply intensify the continentality of its climate



(an exception are the ranges in the eastern part of the highland which have a north-south orientation, and due to this orientation the monsoons there penetrate unopposed as far northward as 33° N.)

All of this causes a singular development of physical-geographic processes in the territory of Tibet -- climatic, development of the hydrographic system, development of relief, formation and development of vegetation and animal life and, principally, it leaves a firm imprint on all the economic activity of the people.

It was the extraordinary singularity and the inadequacy of previous research work on the natural conditions of this extremely interesting region of our friend, Greater China, that attracted our attention to its study.

Helping in the preparation of this book with their valuable advice were: A. G. Bannikov, G. N. Vitvitskiy, E. M. Murzayev, A. I. Perelman, V. M. Sinitayn, V. M. Fridland, A. A. Yunatov and also the editor L. S. Abramov. The author is grateful to them for their assistance.

#### BRIEF RESUME OF THE HISTORY OF THE EXPLORATION OF TIBET

(Only a brief review is given here of the most important expeditions by explorers who have supplied general geographic information about Tibet. In regard to special research [geological, botanical, etc.], the author felt it was possible to limit himself to using such data in corresponding chapters.)

The history of geographic exploration in Tibet takes in many centuries. Tibet and the Tibetans, already populating the territory of the Tibetan highland in the fourth century, B. C., and bordering on the Chinese, were very familiar to the latter. Chinese science made the principal contribution to the study of Tibetan geography and history, and works of Chinese authors served as source materials from which European scholars for many, many years have extracted information about Tibet. The most ancient document known to us which contains information about Tibet is the chronicles of the Tang dynasty (The Tang dynasty ruled from 618 to 907 A. D.), and of more recent documents -- A State Geography (Translated into the Russian by A. Leyont'yev, St. Petersburg, 1778), in which Tibet is discussed in the chapter "Western Dzan", and the Central Asiatic Geographical Dictionary that was published in Peiping in 1766.

The first references to Tibet in European literature, and that in the form of clouded legend, is found in the works of Herodotus. In the third book of his works Herodotus tells us, evidently in someone else's words, about a country of gold-digging ants. This country is situated

to the north and northeast of Kashmir. By ants are probably meant the gold seekers who wrapped themselves in thick black clothing and worked in pits that were specially dug for the production of gold. They do, in actuality, resemble ants busy digging. The fierce monsters mentioned by Herodotus -- the guardians of this land and its treasures -- are nothing more than huge Tibetan dogs.

With the works of Strabo, information on Tibet becomes more concrete. Ptolemy gives still more definite and reliable descriptions of Tibet; he refers to Tibet as Baut, which resembles the name "Bod" (The origin of the name "Bod" has not yet been explained.), up to that time used by the Tibetans. Ptolemy singles out the marginal mountain ranges of Tibet, the Kunlun and the Himalaya and mentions Tibet's main river, the Tsangpo.

A short report on Tibet can be found in the geographic work Kanon Mas'uda of the outstanding Arab scholar-encyclopedist of the XI century, Biruni.

In the XIII century reports about Tibet began to come into Europe from European travelers who visited China and Central Asia. Of special interest were reports of this country beyond the clouds that came from the remarkable Venetian merchant and explorer Marco Polo, who lived for a long time in China and traveled a great deal through Asia. In The Book of Marco Polo he tells about China, India, and many other countries. His brief but informative reports give the first relatively reliable picture of natural conditions in Tibet and its population. "You can go for a good 20 days through this country," Marco Polo tells us "and there are neither inns nor food; for the entire 20 days it is necessary to supply your own food and fodder for the animals; beasts of prey, daring and mean, are often encountered; it is necessary to take heed of them for they are dangerous. However, there are quite a few castles and villages here." (The Book of Marco Polo 1955, page 134).

Further information about Tibet began to come from emissaries, merchants, and Catholic missionaries who were sent to China and Central Asia by the rulers of Western countries and by the Pope of Rome at a time when the empire of the Mongolian conquerors was at the height of its power.

Monks, traveling to the Mongolian khan or to China, visited Tibet, and some even succeeded in living there for several years.

The first monk to visit Tibet was evidently Mateo Ricchi (1325) or -- which is indisputable -- Odorico of Pordenone, who, having lived three years in Peiping and returning to his homeland through Shensi, entered Tibet in approximately 1325-1326, where he lived for some time

in one of the cities, possibly, it is assumed, in Lhasa. Odorico was almost uneducated, but he loved to travel, was observant, and, together with various fabrications and legends, he noted a great deal that was important and correct, and for this reason his notes remain one of the most important documents about China and Central Asia of that time. After Odorico there were long periods, right up to the XVII century, when there were no Europeans in Tibet.

In 1624-1625, Antonio de Andrada made his way into Tibet from India. He was the first European to climb the Himalaya Range or to visit one of the main sources of the Ganges and also the valley of the upper Suttlej and Lake Manasarowar. In 1625, De Andrada established a religious mission in Tibet that continued to exist for 16 years. The members of this mission, Francisco Asevedo, Esteban Cassella and Juan Cabral, made a series of trips through Tibet, expanding European concepts about these regions of Asia. Also of interest are the Jesuit expeditions and those of the Austrian, Johann Grueber and the Belgian, Albert d'Orville, who in 1661, having left Peiping, passed through the Tibetan highland and past the high mountain lake, Kukuror, to Lhasa, where they lived for a month and a half. As a result of their journeys the geographic location of many places was made more precise, and the map of Asia was substantially improved, and information about the Tibetans was also supplemented.

In 1715, the Tuscan Jesuit Ippolito Desideri and his companions visited Tibet. Their objective was to prevent the activity of the Capuchins who had founded their mission in Tibet in 1708, and to reopen the Jesuit mission, and develop its activity.

Desideri passed through the plains of Tibet from the city of Leh to Lhasa, in which he then lived some time. The missionary wrote a geographical sketch of Tibet, full of precise and valuable observations and notes. This sketch acquaints the readers with Lhasa and many monasteries, with the customs and the way of life of the Tibetans.

During the stay of Desideri in Lhasa, in 1719, thirteen Capuchins arrived there, headed by Francisco Orazio della Penna. Passing more than a quarter of a century in Tibet, della Penna studied the Tibetan's language and country well. He and a member of the Belligati mission left many notes and letters and also pen sketches and paintings of various religious ceremonies and layouts of temples.

Worthy of mention is Van de Putte, a Dutchman, who traveled from India through Lhasa to China in 1724. The traveler compiled a map of the territory between the Brahmaputra and the Ganges, which, although it

was only roughly sketched, was rather precise. Van de Putte's extensive diary was burned after his death, as was his wish, and very scanty information was preserved.

Two French monks, the Lazarists Huc and Gabet, made a long journey through Tibet. From the Chinese city of Sinin they passed Lake Kukumor, the eastern shore of the largest lake in Tibet proper -- Nam Tsho (Tengri-Nur), and in the beginning of 1846 they reached Lhasa. After one and one half months they were expelled from Tibet. A description of this journey was later published in many languages. However, the scientific value of the trip, as several specialists note, was not high: little is said in the book about the geography of the places visited; the information is sometimes vague and confused. N. M. Przheval'skiy did not once make mention of it.

In the second half of the XIX century there were few Europeans who succeeded in visiting Lhasa and Tibet proper in general. The government of China, seeing the undermining activity carried on in Tibet by a majority of the foreigners, forbade the latter to enter the country. Although Tibet had already been visited by many people, making special studies of it, information on natural conditions in the highland remained extremely scanty and sometimes untrustworthy as well. The data collected by the monks was fragmentary and collected at random by people who were often inclined to exaggeration and distortion of the facts, not to mention that the overwhelming majority of the monks did not have specialized preparation in geography and geology, botany and zoology, ethnography and archaeology corresponding to the level of knowledge of their time. Besides, the monk-travelers usually did not have the enrichment of science as their principal goal.

Despite the Chinese government's ban excluding the visit of foreigners in Tibet, many governments, above all the colonial powers, did not stop their activity in the study of this part of the Heavenly Empire. They took advantage of the fact that the Chinese permitted the entrance into Tibet of Buddhists of other countries. The English colonial authorities trained for special investigative work the Buddhists living in regions bordering on Tibet. Trained for topographic mapping and the collection of economic and other information, the Buddhists (pandits) traveled into Tibet in the disguise of pilgrims or merchants and carried on their work in secret. As a precaution they were sometimes only identified by code letters. Among the pandits those of special fame are Nain Singh (A), Kishen (Krishna) Singh (A-k) and Sarat Chandra Das.

Nain Singh, in the course of several years, from 1865 to 1875, made three trips into Tibet. He explored the Ngari-Korsum, the western province of Tibet, then twice surveyed from west to east -- the first time (1865-1866) through the valley of the Tsangpo. (The Tsangpo is

the Tibetan name for the upper part of the Brahmaputra where it flows through Tibet.) The second (1874-1875) was along the route from Lake Pangong to Lake Nam Tsho. Nain Singh also visited Lhasa. He determined the elevation of 33 reference points on the territory of Tibet and collected various geographical materials.

After this successful undertaking the English again dispatched Nain Singh into Tibet together with two other pandits (B and C). In addition to explorations and surveys in the southwestern part of Tibet, it was proposed that they have a look at the gold mines to the east of Rudok and also at deposits of salt and borax. This expedition mapped as it went along for a distance of 850 miles; they determined the elevation of 80 points, the latitude of 75 points and performed other assignments.

A new pandit soon appeared on the scene -- a half-Tibetan, Kishen (Krishna) Singh, known by the letters A-k. In 1868, Kishen Singh mapped as he advanced along to the north of Eastern Nepal for a distance of 1,200 miles. But the most important explorations he made were in 1872-1873. Departing from Kumaon for the city of Shigatse, he mapped the route from Shigatse to Lake Nam Tsho and then visited Lhasa. Then, crossing the Tsangpo, he returned to Shigatse. He mapped for a distance of 320 miles, determined the latitude of the place at several points, and determined elevation at 24 points. A-k made still another journey, a four-year one, in the eastern part of the Tibetan highland, where he also did important work. In particular, he established that the Dikhang, Brahmaputra, and Tsangpo are one and the same river.

Sarat Chandra Das made two journeys into Tibet -- in 1879 and 1881. He studied the Tsangpo valley and its basin. He visited Shigatse, Lhasa and many monasteries and made a whole series of expeditions through southern Tibet, mapped topographically a considerable territory and collected information about the country and its population. After his work a new, considerably improved map of Southern Tibet was compiled in England.

Mention should also be made of pandit L, who mapped the territory between the cities of Shigatse and Tszetan (Chetang), and also the companion of Sarat Chandra Das, the Lamaist U-gyen Gua-tso, who made an independent survey through Southern Tibet.

As a result of the work of the pandits it was possible to plot on the map a considerable part of the territory of Tibet, chiefly its southern regions, those most important in economic respects. They collected varied information on the natural wealth of the country, its economy and population. How great the importance of these materials was is evidenced by the fact that all the activity of the pandits was

conducted in secret and that, for example, the book of Sarat Chandra Das Journey into Tibet in which the southern part of Tibet is described, the part adjoining India, was top secret for more than 20 years. The reports of pandit A-k and others were also not published for a long time.

Sending the pandits into Tibet, the English themselves (and also the representatives of other states) in their turn did not abandon attempts to penetrate the country, and for this purpose, for the most part, they used the northern, western or eastern boundary of Tibet.

Some explorers did not succeed in penetrating into the heart of Tibet proper, and they limited themselves to the study of the countries and territories adjoining it; others, however, succeeded, and reported all kinds of truths and untruths. Thus, in 1811, T. Manning passed through Tibet, visiting Lhasa and Gyangtse. In 1812 Moorcroft was in the southwest of Tibet near Lakes Manasarowar and Rakas. It is believed that he lived in Lhasa for twelve years. Moorcroft's trip was undertaken with private capital, for the purpose of insuring English industry with high quality wool from Western Tibet.

In 1846, H. Strachey was at Lakes Rakas and Manasarowar. He did topographic mapping there and also mapped the region of the passes to the south of Puran that lead to India. A year later Strachey again penetrated into Western Tibet and mapped the province of Ngari-Korsum, and a year later he and his brother, R. Strachey, visited the region of Lakes Rakas and Manasarowar. Together with other work, this time they determined the elevation of Mt. Gurla Mandhata.

In 1855-1857, in the west of Tibet, exploration was carried on by the German Schlagintweit brothers. They visited the basin of the Sutlej, the watershed between the Sutlej and the Indus, Lake Pangong, the Lingzitan Depression, and the northwestern Kunlun.

In 1885-1887, on the border of northern Tibet, the English official Carey, with his companion Dalgeish, made a difficult march from the city of Leh in Kashmir to Keriya in Kashgar. The latter was killed in a skirmish with Tibetans who wanted to keep their country free from undesired intruders. In 1888-1889, the American Lodger twice visited Tibet. He left notes concerning his journeys. Almost at the same time the American diplomat W. Rockhill tried to travel from Eastern Tibet to Lhasa disguised as a Buddhist pilgrim. Two years later, Rockhill made a second attempt to penetrate into Tibet proper. Traveling southwestward from the Tsaidam he passed into Tibetan territory, flanked the western end of the Tanghla (described by Przheval'skiy) and wanted to travel on to Lhasa. But soon the Tibetans discovered him and forced him to turn to the southeast and again return to Eastern Tibet.

The Belgian Bonvalot made a long and difficult journey through Tibet together with Prince Henri d'Orleans. This journey was made in 1889-1890. Departing from Charlyk (to the southwest of Lobnor), they passed over the Altyn-Tagh, and, undergoing numerous difficulties from the great elevation above sea level, from the severe climate, the lack of water and the extreme desert nature of the area, they traveled about 900 kilometers in the direction of Lhasa, approximately along 90° E. At a distance of 180 kilometers from Lhasa, at the demand of the Tibetans, Bonvalot was forced to stop and then go to Chamdo. Although the expedition did not produce important results for geographic science, it passed through virgin territory and gave an idea of the natural conditions of areas along the route, and therefore had considerable value.

In 1891, the captain of Bengal cavalry, Bower, and the botanist Thorold were in Tibet. Departing from Leh, they crossed Tibet from the northwest to the southeast, arrived at Lake Seling and continued on to Chamdo. This expedition, yielding significant results, performed mapping and determined numerous elevations, made profiles of the areas through which it traveled, and collected information on climate, animal life and vegetation.

In 1891-1892, the Englishmen Pauter and Soldate visited Tibet and almost simultaneously with them (1892) their fellow countryman, Dilot, who wrote Diary of a Journey.

In 1892, the Frenchman Dutreuil de Rhins and his comrade Grenard traveled into Tibet. Traveling from Kashgar into the northwestern corner of Tibet, in the region of Lakes Sumchzhi Tsho and Eshil'-kul, they soon were forced to return to Khotan because of insuperable difficulties. De Rhins again headed for Tibet a year later. Leaving from Cherchen, he overcame the desert ranges of the Kunlun and the sterile plains between them with difficulty, and he arrived with Grenard at Lake Dangrayum and later at Nam Tsho. From here De Rhins traveled to Nagchu and further to the east and soon appeared at one of the westernmost sources of the Mekong. Having attained these great successes, Dutreuil de Rhins did not himself succeed in completing his research; he was killed during a skirmish with the inhabitants of Eastern Tibet.

De Rhins and Grenard mapped the area during an expedition of more than 6,000 kilometers. More than two-thirds of this route was mapped along a route that had been totally unexplored. In addition, they made several thousand astronomical, latitudinal and longitudinal determinations and measurements of elevations. They collected a great deal of meteorological information and other data and made geological, botanical, zoological, and ethnographic collections. Grenard later processed these materials, publishing a valuable report in three volumes.

Littledale and his wife were in Tibet in 1895. Leaving the city of Charchen in Kashgar, they crossed the Akka-tagh, and, experiencing great difficulties due to the aridity of the climate, they traveled in the direction of Lake Nam Tsho, occasionally deviating to one side. Only 70 kilometers short of Lhasa they were forced to turn to the Ladak at the insistence of the Tibetans. Littledale accomplished topographic mapping along the entire way. Littledale's report is very brief.

Captain Wellby and Lieutenant Malcolm left from the Ladak a year after Littledale. They traveled an extremely difficult route doing mapping along the northern border of the Changtang, that is, they crossed Tibet where the country is longest. Almost simultaneously with them, Tibet was visited by the English officer Deasy with his comrade Pike. They performed mapping in the northwestern part of Tibet in the region of Lakes Khorpa, Eshil', Aru and Charol.

During these same years the Englishman Lederer (1895) visited Tibet with his family. Later (1896) Wailenkar visited Tibet and wrote notes about his research. In 1897, the journalist S. Lendor visited Lakes Manasarowar and Rakas. He made his way into Tibet from the northwestern provinces of India. For his attempts to penetrate into the heart of the country he was punished by the local inhabitants and expelled from the territory of Tibet.

There were also Japanese in Tibet. The first to penetrate into the country was the bonze Ekon Karagutsi. In 1901 he made his way into the region of Lakes Manasarowar and Rakas, and, traveling through the valley of the Tsangpo, he arrived at Lhasa from where, however, he was soon ejected. The maps and reports produced by Karagutsi do not have great scientific value since a great deal in them is questionable and confused. Simultaneously with Karagutsi, the Japanese Sigeta and Umitatsu were in Tibet.

Among the explorers not visiting Tibet proper but conducting important research in regions adjoining it, one should mention the German Futterer, who in 1898 mapped Eastern Tibet. In 1905, and in subsequent years successful work was conducted here by the German Filchner and the geologist Tafel, whose chief objective was the study of the upper course of the Hwangho and the territory lying to the south of it, right up to Szechwan.

Several participants in the English Army Expedition, Macdonald and Younghusband, penetrated into Tibet in 1904. (This expedition had the objective of capturing the Dalai Lama and pressing a compromising treaty on him. The military intrusion of England, accompanied by severities towards the Tibetans who were defending their country and the looting of the wealth of the country was, in the long run, not accompanied by



the results desired by England, that is, the detachment of Tibet from China. According to the English-Russian agreement of 1907, England was forced to renounce interference in the internal affairs of Tibet and was obliged to thereafter conduct relations with Tibet only through the Chinese government.) The topographers and geodesists who formed part of the personnel of the expedition conducted mapping and triangulation along the entire route of the expedition from the Indian boundary into the heart of the country, measured the elevations, and determined the position of all visible peaks. Thus, Captain Ryder traveled and mapped and studied all aspects of the nature of this region from Shigatse to the sources of the Tsangpo. Such work was also carried on in a sector from the sources of the Sutlej to the boundary of India and also along the Gartang, one of the sources of the Indus.

Even before movement of the main detachment of the expedition to Lhasa, Captain Rawling and Lieutenant Hargreaves explored and photographed the region of the western part of Tibet between the Kunlun on the north and the district of Rudok on the south, the boundary of Tibet on the west and the 84th meridian on the east. They carried on triangulation work connecting the work of the Russian researchers on the north and the English on the south.

A participant on the expedition, R. Landon, published the study An Account of the Country and People of Central Tibet and of the Progress of the Mission Sent There by the English Government in the Year 1903-1904. (Written with the help of all the principal persons of the mission) 1905, London.

In this work he gives striking and precise descriptions of the landscape, for example, of Lake Yamdok, the Chumbi valley, Lhasa, etc. The book was illustrated with numerous photographs and sketches that were made by the author. Also of interest are the book's appendices on natural history and ethnography.

A. Waddell, in his book Lhasa and its Mystery London, 1905, also describes the route in detail, making note of many geographical facts and objects, but he devotes his principal attention to the religious life of the Tibetans and to their customs.

Individual participants in the English expedition collected data on meteorology and geology. These data were used for the climatic characterization of Southern Tibet and a beginning was made on its geological study.

In 1905, the southeastern part of Tibet was visited by the English colonial official Sherring, who visited the region of Mt. Gurla-Mandhata, the city of Taklakot (Puran), the city of Gartok, and the Sutlej valley.

Sherring collected a variety of information. At the same time the region of Lake Pangong was visited by the American expedition of Barrett and Huntington, who went from the city of Leh through the Karakorum to the Tarim Basin in order to make geological and archaeological investigations. The next year the English colonial official Calvert visited Gartok, Rudok, and the gold mines of Tok-Dzhalung.

The Swedish explorer Sven Hedin was in Tibet three times. At the time of his first exploration in 1893-1896 he traveled in an east-west direction only along the northeastern border of Tibet. His second expedition was successful -- in the years 1899-1901 he climbed onto the highland from Kashgar and traveled in the direction of Lhasa to Lake Nam Tsho. At this point the Tibetans stopped Hedin and did not permit him to continue onto their sacred capital. The explorer turned westward and traveled into the Ladak. Thus, covering a great distance, he explored considerable territory in Tibet from north to south and from east to west to an extent greater than anyone else before or after him. The entire journey through Tibet was accomplished in the course of 13 months.

At the time of his third journey into Tibet (1905-1908) Sven Hedin again penetrated into the interior of Tibet (from the Ladak) and also explored extensive territory. This time he established the existence of a tremendous mountain system parallel to the Himalaya, later named by him the Transhimalaya. One should mention, however, by way of clarification, that this mountain system had been seen at various points by Nain Singh and Kishen Singh. N. M. Przheval'skiy saw its eastern part at the time of his Third Central Asiatic Expedition. Przheval'skiy drew the bold and correct conclusion that the range before him was the Nyenchen-Tanghla (the eastern part of the Transhimalaya), which is the watershed range between the areas of internal drainage in Tibet and the Indian Ocean.

Of the research conducted in Tibet by European scholars in recent times, mention should be made of the work done in 1932 by the geologists Ambolt and Norin. They carried on geological research and geodetic measurements in northwestern Tibet, in the region of Aksaychin, Lake Ligten, and between Lake Markham and the main range of the Kunlun (Petermann's Mitteilungen, 1935). In general, however, during recent decades there have been no large foreign expeditions in Tibet.

In speaking of the history of exploration in Tibet, it would be especially desirable to dwell on the services of Russian explorers. The explorations of Central Asia organized by the Russian Geographical Society in the second half of the XIX century included the northern and eastern regions of the Tibetan highland and contributed a good deal to the study of these parts of the earth. The expeditions of G. N. Potanin,

N. M. Przheval'skiy, M. V. Pevtsov, V. I. Roborovskiy, V. A. Obruval'skiy, P. K. Kozlov, G. E. Grumm-Grzhimaylo, and many others crossed Mongolia, Western China and the Tibetan highland, or the mountains adjoining it, and supplied the scientific world with valuable data that is still of importance today.

The explorations of Central Asia and the Tibetan highland by the forces of the Russian Geographical Society were distinguished by a broad scope and a well thought-out plan that was developed by the leaders of the Society headed by the remarkable scholar and superb organizer P. P. Semenov. According to this plan, the routes for the expeditions were laid out in such a way that Central Asia and the Tibetan highland were evenly covered by explorations in accordance with common objectives. A work program was prepared in each individual case. In addition, each expedition was headed by an experienced explorer having all-around preparation in the field of the natural sciences. The latter circumstance was responsible in large part for the success of the expeditions, when you take into consideration that these were reconnaissance parties and, as a rule, did not include many specialists in the various branches of science (geologists, geographers, zoologists, botanists, and others).

Another distinguishing feature of the work of Russian scholars was the method of exploration and geographic description which they developed, beginning with the time of the Tien-shan expedition of 1856-1857 by P. P. Semenov and later fruitfully developed by N. M. Przheval'skiy. This method insured the most complete and systematic collection of factual material about the regions studied and made it possible for scholars to know and understand the geography of Inner Asia better. The Russian geographers did not examine the natural conditions as individual, unrelated elements, but as a unified whole in their inter-relationships and in the interdependence of these elements in their development.

Only a few Russian explorers succeeded in visiting Tibet proper; the majority of them did not find it possible to penetrate the country and worked in other regions of the broad Tibetan highland. Each of them with his data substantially supplemented the information collected by others, and in the long run an immense area of the northern and eastern parts of the highland was explored and described in accordance with the needs of science at that time. The description of the adjoining regions had considerable significance for illuminating the geography of Tibet proper.

Before speaking of the explorations of Przheval'skiy, Potanin, Pevtsov, Roborovskiy, and Koslov, one should mention the contribution made to our knowledge of Tibet by other Russian explorers and scholars.

Of great scientific interest and value are the materials of the remarkable Russian explorer Filipp Efremov, the first of the Europeans traveling through the westernmost outskirts of the Tibetan highland during his Nine-year Wanderings through Asia in 1774-1782. (Filipp Efremov, a non-commissioned officer, served in the military forces on the southeastern boundary of Russia in the Orenburg steppes. At the time of a skirmish with one of the detachments of E. Pugachev, he was wounded and taken prisoner, and later, together with the Ural cossacks who had captured him, he fell into the hands of other cossacks who sold him into slavery at Bukhara. Taking advantage of a satisfactory opportunity, Efremov escaped from slavery and fled to Kashgar from where he went to India, and from India he returned by sea to Petersburg.) Although Efremov did not visit Tibet (in its modern administrative boundaries), he traveled through the territory situated in the boundaries of the present day Kashmir, he used in the compilation of his notes data gained from questioning others, personal observations in the Ladak, and such sources in literature as existed at the time. Efremov left a completely trustworthy general report on Tibet, its population and political structure.

The explorer rather precisely characterizes the geographic position of Tibet, and he mentions its division into parts: Upper, Middle and Lower Tibet. Under Upper Tibet he includes its western part, the Province of Ngari; under Middle Tibet, the central, most populated regions, and under Lower Tibet, evidently, the regions along the Himalaya.

"The vast land of Tibet, whose real size I know not," writes Efremov, "is partly mountainous and partly consists of extensive plains and sandy areas. Air and production correspond to the position of the ground, and therefore there are differences from place to place. Thus it is easy to understand why travelers contradict one another, some saying the land is fertile and others saying it is completely infertile. It is therefore impossible to give a completely clear idea about the nature of the whole country because I traveled only through the Tsang district of the state of Lata or Ladak. (Filipp Efremov. Nine-year Wanderings, 1952, page 43.)

Later the explorer correctly tells of the natural conditions of Northern and Southern Tibet. Speaking about Southern Tibet he writes, ". . . the side of Tibet bordering on Hindustan consists of steep mountains covered with snow and with slopes overgrown with dense forests."

"These mountains are almost completely impassable, and where there are roads they are extremely narrow and are dangerous in many places due to the frightful precipices at whose bottoms water flows turbulently from the mountains with a frightful roar. In many places the mountain abysses are crossed by hanging bridges made from brushwood." About the northern

part in Tibet (he has in mind, evidently, not the extreme north, but the regions bordering on Southern Tibet) he writes that "in comparison with the first, possibly to be considered a high plain, small mountains were only occasionally visible. In several valleys between the rivers grows tolerable grain and in other places live nomadic shepherds who change their abode and tarry always at good pastures for the sake of their cattle." (Ibid.) He speaks about the most widespread wild and domestic animals of Tibet: yak, sheep, wild Tibetan kiang (*Equis hemonius kiang*), the Himalayan musk deer, living in the warmest part of Southern Tibet on the slopes of the Himalaya; he lists the minerals: gold, silver, mercury, iron, copper, sulphur saltpeter, crystal, marble. He mentions medicinal rhubarb, which was exported to other provinces of China and neighboring countries. He is full of warm and sympathetic words about the Tibetans, who, he observed, were "honorable and friendly." He generally correctly describes their appearance, customs, costumes, and religion.

The works of the remarkable Russian scholar N. Ya. Bichurin (1777-1853) are of outstanding significance in the study of Tibet. Bichurin lived in China for many years and studied that country well. On the basis of his own explorations and from numerous Chinese sources he wrote several books about China and its individual provinces, including a report compiled from sources in Chinese literature A Description of Tibet in its Present State, and a History of Tibet and the Kukuror. (N. Ya. Bichurin is also known by the name of monk Jakinf.) Before the publication of this book there was no serious literature on Tibet in the European languages.

In his works Bichurin cites information about the most ancient history of the Tibetans, illuminates their history with numerous events from their later history, administrative division, and the government of Tibet, the economic life of the people and their culture. He tells about inter-relations with the Chinese people and the immense influence of China on the culture and economic development of Tibet. The varied and extensive data cited by Bichurin have still not lost value in our time.

The first abundant and systematized scientific data on the basis of our own exploration in the field, and, to a large degree, corresponding to the modern level of science, came from N. M. Przheval'skiy. To him and to his students and followers -- V. I. Rorobovskiy and P. K. Kozlov, M. V. Pevtsov, G. N. Potanin, G. Ts. Tsybikov -- we are indebted for having studied the northern and eastern parts of the Tibetan highland and its population. The descriptions of natural conditions, the population and the economy of the Tibetan highland that were compiled by Russian scholars represent classical geographical studies.

N. M. Przheval'skiy was a great explorer, possessing a background of varied specialized knowledge, an unusual purposefulness and a love for science. He adopted the new and advanced ideas of P. P. Semenov-Tyan-Shan, which in many respects were close to our modern concept of geography; he expanded and elaborated on his principles of complex geographical observations and the manner for assembling scientific collections, and used his methods of comparative geographical analysis and geographical generalizations.

The great success of the Przheval'skiy expedition is explained by the fact that he was trained in advanced ideas of contemporary scholars and had absorbed a tremendous amount of the scientific legacy of foreign and Russian (especially) researchers who were studying not only the immense territory of their fatherland, representing one-sixth of the earth's surface, but also the surrounding seas and oceans and also conducting research in Europe, Africa, America, on the expanses of the world ocean, and in Antarctica.

Przheval'skiy began to study the Tibetan highland in his First Central Asiatic Expedition of 1870-1873, passing along its northeastern border. Setting out from Kyakhte, he crossed Mongolia in a southeastern direction on the way to Peiping. From there, following the northeastern border of the Ordos, the explorers entered the province of Kansu, the Nan-shan Mountains and Lake Kukur, situated high in the mountains. From Kukur, despite the scanty equipment of the expedition, he succeeded in reaching the headwaters of the Yangtze across the Tibetan highland. However, an inadequacy of foodstuffs and the complete exhaustion of the beasts of burden stopped further advance and forced Przheval'skiy to return along the same route.

Despite the relatively short journey that he made in the highlands, the explorer succeeded in collecting very reliable and systematized data about the natural conditions of the country and its population. As a result of this journey Przheval'skiy was able to write an all-around description of the regions of Central Asia and the Tibetan highland visited by the expedition. This immediately brought the explorer world fame and general recognition.

The Second Central Asiatic Expedition was made by Przheval'skiy in 1876-1877, and although it was brief, it gave outstanding results also. In the first place, Przheval'skiy solved an important geographical mystery, establishing the whereabouts of Lake Lobnor in the center of the Asiatic continent, a lake mentioned by ancient Chinese authors. Secondly, he described the customs, way of life and occupations of the inhabitants near Lobnor so precisely and clearly that this description was esteemed by the most famed scholars as the most attractive and interesting of the ethnographic descriptions that had been written by

recent explorers. Thirdly, he passed along the foot of the gigantic Altyn-Tagh Range, which borders the Kunlun on the north and thus established the northern boundary of the Tibetan highland, which before this time had been placed 300 kilometers further south.

The Third Central Asiatic Expedition made by Przheval'skiy was especially important for its contributions on the area in which we are interested since he succeeded in traveling for quite a considerable distance through the Tibetan highland and through the territory of Tibet proper, considered in its modern administrative boundaries. It is due to the fact that the main work was carried on on the Tibetan highland that this expedition was called the Tibetan Expedition.

The city of Zaysan was the point of departure for the journey. The expedition departed from there at the end of March, 1879. Having explored the lifeless Khami Desert, the expedition reached the Nan-shan, surveyed the Humboldt and Ritter Ranges which they discovered, and then crossing the Shchuga, Kukushili and Dunbure (Dungbure) mountain ranges on the Tibetan highland, they came to the headwaters of the Yangtze and to the Tanghla Range. Later the route lay through the territory of Tibet proper and the way led directly to Lhasa. However, near the city of Bumz, approximately 250 kilometers from Lhasa, the expedition was stopped by representatives of the Tibetan authorities, who blocked the way to their sacred city. Respecting the laws and customs of other peoples, Przheval'skiy advanced no further. But it was not only this reason that caused such a decision: the people and pack animals were exhausted and further movement towards the cherished goal -- Lhasa -- was impossible without the assistance of the local population.

The Second Tibetan, or Fourth Central Asiatic Expedition of the untiring explorer took place in 1883-1885. The expedition departed from Kyakhte and reached the Tsaidam via the Gobi, Alashan, and Kukuror. Having crossed the Burkhan-Budda mountain range and appearing on the Tibetan highland, Przheval'skiy penetrated into the region of the sources of the Yellow River. Here the expedition discovered two lakes -- Orin-nur and Dzharin-nur -- the first he named Russian Lake and the second he named Lake Expedition. The great Chinese river flows through these lakes. The exploration of the headwaters of the Yellow River was a great attainment of geographical science. An important result of the expedition was that by moving along the southern margin of the Tsaidam he then established the orientation and interconnection of the central ranges of the Kunlun (Columbus, Moscow, Przheval'skiy and Tsaidam Ranges). He also succeeded in collecting much new and interesting data on Eastern Turkestan as well, which territory Przheval'skiy crossed while returning to his homeland via the city of Karakol.

Przheval'skiy's Fifth Expedition, as is well known, never materialized. Just before departure on the new long journey the great scientific worker died from typhoid fever in the city of Karakol, later renamed Przheval'skiy.

The services of N. M. Przheval'skiy are not nearly exhausted by enumerating his immense contributions in extending our knowledge of the geography of Central Asia and the Tibetan highland. No less important is the fact that he laid the way for other Russian and foreign pioneers in regions of the Asiatic continent that were unexplored by scholars. Soon extensive "blank spots" on the largest of continents of the globe were erased from the map.

The influence of Przheval'skiy on scholars who were his contemporaries is also seen in the fact that his methods of geographical research were adopted by others to one degree or another, and this, without doubt, facilitated the more rapid development of geography.

Finally, the very special, lively, and clearly written reports of Przheval'skiy and his expeditions, splendid in their literary form, organically connected with a profoundly scientific content, served as a model for the reports of almost all subsequent explorers and won their author both popularity and the unfading affection of the broadest circles of readers; to a significant degree they facilitated the distribution of geographical knowledge -- into the national life -- to use the words of P. P. Semenova-Tyan-Shan.

After Przheval'skiy's death the leadership of the new Tibetan expedition that he had organized was placed under the direction of M. V. Pevtsov, the well-known explorer of Mongolia and Dzhungaria, by the Russian Geographical Society. The territory which the expedition had originally planned to explore was decreased in size. Pevtsov decided to limit himself to work in Kashgar and the Kunlun, that is, in regions adjoining Tibet on the north instead of following Przheval'skiy's proposal to investigate Tibet and visit Lhasa. Pevtsov also planned at the same time to determine the presence of pass routes within Tibet for the next expedition. Pevtsov's expedition, which retained the name "Tibetan," worked during the years 1889-1890. Also participating in the expedition were Przheval'skiy's students, V. I. Roborovskiy and P. K. Koslov, as well as the geologist I. I. Bogdanovich.

A special feature of Pevtsov's work was the more detailed investigations, and, where possible, station research in the regions earlier visited by Russian reconnaissance expeditions. Such work was another step forward in the all-around geographical and more profound study of Central Asia.



Although the expedition concentrated its basic attention to the exploration of Kashgar and Dzhungaria (among the most important results of its work should be mentioned the visit to the broad depression in the center of the Asiatic continent -- the Turfan Depression, of great scientific interest in many respects), one should nevertheless mention the importance of its work for our knowledge of the geography of the Kunlun and the Tibetan highland. Pevtsov and his companions, V. I. Rorobrovskiy and P. K. Koslov visited in different regions of the northwestern border of the Tibetan highland, penetrating southward for a hundred miles from the northern margin of the Kunlun. Exploring and mapping zones in an expanse from the headwaters of the Keriyadar'ya River to the meridian of Lake Lobnor, they became acquainted in its general outlines with the natural conditions of the previously unknown country and they established that this is the most desert-like and lifeless, completely uninhabited and unvisited part of the Tibetan highland. Pevtsov's third companion, the geologist Bogdanovich, laid the beginnings for the geological study of these regions with his geological observations in the Kunlun on the northwestern margin of the Tibetan highland.

The study of the Tibetan highland was continued by V. I. Rorobrovskiy, P. K. Kozlov, and especially by G. N. Potanin.

The outstanding explorer of China, G. N. Potanin, devoted himself to a study of the natural conditions and population of Inner Asia during several decades of his life; he was in Mongolia, in the Chinese provinces of Shansi, Kansu, and Szechwan. In 1885, having previously explored broad regions of the Chinese empire, including the Ordos, Potanin carried on work in Amdo -- a region of northeastern Tibet. And, as was customary for him, the explorer also devoted a great deal of attention to ethnographic observations, history and culture of the Tibetans of Amdo and to the study of Tibetan monasteries.

In the fall of 1892, Potanin, on the orders of the Geographical Society, departed from Kyakhte to China on a new expedition which was to continue the study of the eastern border of the Tibetan highland and the neighboring Chinese province of Szechwan. Due to the serious illness of his traveling companion -- A. V. Potanina -- his wife and assistant -- the explorer could not complete the entire program that had been planned. The extreme western point distant from Szechwan to which the activity extended was the East Tibetan city of Kandin.

The Geographical Society, sending Potanin into Szechwan and Eastern Tibet, at the same time sent V. I. Rorobrovskiy and P. K. Koslov into Central Asia. Rorobrovskiy's expedition wanted to join Potanin in order to connect the investigations of Russian scholars through the Tien-shan, the Turfan Basin, the Nan-shan and further to the northeast, the border of the Tibetan highland in Szechwan. Rorobrovskiy successfully completed a great part of the distance and collected a great wealth of scientific

data. Penetrating further through the Tibetan highland to the south of the Kukuror, Roborovski fell seriously ill in the Amne-macin Mountains, not far from Szechwan, and the expedition, now headed by his assistant, Koslov, was forced to return. Thus, unforeseen and tragic circumstances hindered Roborovski and Potanin from conducting their whole program of planned research. However, science was nevertheless enriched with extensive and valuable data on the geography of the northeastern border of the Tibetan highland, without even mentioning the very important results of these two outstanding Russian expeditions in other regions of Central Asia.

Another of Przheval'skiy's students, P. K. Kozlov, in his first independent Central Asiatic Expedition of 1899-1901, exploring a considerable territory in Mongolia, penetrated into the southeastern region of the Tibetan highland -- the district of Kam. Here he described large mountain ranges to which he gave the names Russian Geographical Society Range, Woodville Rockhill Range, and others. Later Koslov visited the headwaters of the Mekong River, established the basic features of the orography and hydrographic network of the Kam and gave a lively and attractive description of the rich and luxuriant natural conditions of southeastern Tibet.

Koslov, acquainted from former journeys with the severe natural conditions in Northern Tibet, was especially interested in observing the new landscapes opening up before him in the Kam -- full of bright colors and contrasts. To the north of the Hwang-ho and Yangtze watershed, the explorer notes, there is a high, cold plateau running far into the distance. Through this plateau the uppermost headwaters of the Hwang-ho flow placidly, forming lakes in places. A gently rolling plain extends into the distance. To the south of the watershed, in the Kam, the character of the area changes sharply. The river valleys, dark canyons, and ravines alternate with crests which form watersheds, the peaks of which are covered with eternal snows, and the slopes are covered with forest and succulent alpine meadows. Side by side with North Tibetan forms of plants and animals there are also present interesting representatives of more southern species.

In 1907-1909, Koslov was in Eastern Tibet again. After his work in Mongolia, where he discovered a remarkable monument to the former power and culture of the Tanguts (the Mongolian name for the Tibetans) -- the city of Khara-Khoto, and he visited Amdo. Besides the abundant general geographic information and surveys, Koslov's second independent expedition, the Mongolian-Szechwan, yielded abundant data dealing with the history, customs and culture of the Tibetans.

Of the other Russian explorers, it is necessary to dwell a bit on the name of G. Tsybikov, a Buryat by origin, who, as a Lamaist, was able to visit Tibet proper and its capital of Lhasa in 1899. Tibet proper and

Lhasa were also visited by other Russian subjects who were Lamaists: Zayayev, Baza-bakshi, Monkodzhuyev, Norzunov, but the scientific results of their journeys were negligible. Tsybikov, however, compiled a rather detailed report, containing a rich amount of interesting information. When discussing the Russian Lamaists visiting Tibet, we should mention that they brought the first photographs back that showed Lhasa, several monasteries, and portraits of Tibetans. Tsybikov gave the best description of Lhasa and its sights for that time, as well as for the cities of Chetang (Tszetan), Shigatse, and also interesting information about the culture, way of life, and religion of the Tibetans.

A brief review of the contribution of Russian explorers in the study of Tibet and of several Russian printed works about this subject should be ended with a characterization of the excellent work by N. V. Kyuner A Geographical Description of Tibet [Geograficheskoye opisaniye Tibeta], published in 1907-1908.

A Geographical Description of Tibet is an extensive summary of information about Tibet (including Eastern Tibet), compiled on the basis of a careful study of all then-existing sources in literature. The author did an immense amount of work, critically going over the whole mass of reports, books and articles in the periodical literature in many languages, generalizing and systematizing this immense amount of data. The description consists of three parts. The first part includes a review of travels through Tibet, as the author writes "in connection with the development of European acquaintance with that country," and a true geographic description of Tibet. The second part is ethnographic; it deals with a description of the outer appearance of the Tibetans, their physical characteristics, culture, and economy. The third part is historical.

The work of N. V. Kyuner on a number of problems examined, in completeness and fineness of quality of the material included, was unquestionably the best. Although science is now acquainted with many new facts and his treatment of the social side of Tibetan life in a number of cases can cause objections, not one Tibetan explorer can get by without using this work.

In the beginning of the chapter we mentioned the ancient Chinese sources on Tibet that are well known to us, although without question there are considerably more. We do not know, unfortunately, about the works of Chinese scholars that are closer to us in time. We are only able to tell briefly about what has been done since the establishment of the People's Republic of China, when a new stage in the study of Tibet began.

By 1951, the central government of China had dispatched a large research expedition to the Tibetan highland. For a period of two years it conducted work at stations and in the field. This was a large undertaking, for the first time on such a scale and with such objectives in the case of Tibet. The expedition, having before it scientific and practical goals of varied nature, explored an extensive region of the highland -- the region of the headwaters of the three rivers -- the Yangtze, Mekong, and Salween. The workers of the expedition also visited the valley of the Tsangpo, passing westward to approximately 86° E. and the valley of the Chumbi.

This first complex Chinese expedition gave valuable results having great significance for the development of the economy of the Tibetan highland. Li Pu, Hu Shen-sya, and its other members collected new information about the relief of the highland, climate, soils, vegetation, the animal life, minerals, hydro-resources and the economy. They revealed the possibility of an economic utilization of individual regions of the Tibetan highland. They also studied the ethnographic features and the language of the Tibetan population. The expedition compiled a geological atlas of 600,000 square miles, which shows the geological and tectonic structure of an extensive territory of the Tibetan highland

Of considerable significance for the study of Tibet and the better utilization of its natural resources are the works of the Chinese Academy of Sciences that were produced in connection with the work of dividing China into physical-geographic, climatic, soil, geo-botanical and zoological-geographic regions. (In 1957, these works were published in the Russian language by the Academy of Sciences of the USSR under the name Physical-Geographic Regionalization of China [Fiziko-geograficheskoye rayonirovaniye Kitaya] Translated from the Chinese by Ya. M. Berger and others (Collection of articles).

The final delineation of regions is still not ready, but existing drafts sum up the available knowledge of both Tibet and other districts and regions of China. In addition, they contain valuable and factual material which, like the preliminary reports of the participants in the above said expedition, are utilized in this book.

## SURFACE STRUCTURE

### CONCERNING HISTORY OF FORMATION OF TIBETAN HIGHLAND AND TIBETAN RELIEF

In general terms, the Tibetan highland constitutes a colossal plateau-like uplift of a section of the earth's crust, which rises approximately 3,500 meters above the Tarim Basin which adjoins it on the north, and by almost 4,500 meters above the Indo-Gangetic Plain which adjoins it on the south. The northern uplifted shoulder of the highland, falling off sharply to the Tarim Basin, is the Kunlun and the southern shoulder, still more uplifted and also sharply dropping off -- in this case to the Indo-Gangetic Lowland -- is the Himalaya.

In its general layout the highland reminds us of a trapezium with rounded contours, having its maximum width along the meridian of 94° E. In the western, contracted portion, the ranges of the Kunlun, Karakorum, and Himalaya come close together and join with the mountains of the Hindukush, with the Iranian and Pamir highlands, which constitute part of the Mediterranean "mobile" zone which extends further to the west. In the east, however, the highland drops down to the Szechwan Lowland in steps, having the appearance of north-south ranges.

Typical of the surface structure of the highland surface in the boundaries of Tibet are broad plains and (intersecting them) ranges (most commonly with an east-west orientation) with a local relief from several hundred to 1,000-1,500 meters. The base of the highland on which the mountain ranges appear to rest characteristically has a uniformly high level, with variations in local relief over the whole area of 200-300 meters.

At first glance it seems that the surface structure of Tibet is not very complex. However, as will be seen from what follows, this is far from the truth.

The Tibetan highland, together with the extremely large mountain systems framing it -- the Kunlun, the Karakorum, and the Himalaya -- is given the name "High Asia" by V. M. Sinitsyn. It is the largest young uplift on the globe. Genetically all these mountain systems and upland plains are inter-connected.

High Asia arose in the region of the Kunlun-Himalaya mobile zone, which constitutes a part of the whole Mediterranean mobile zone. In its turn the Kunlun-Himalaya zone consists of two branches, separated in the region of Tibet by the central massif of the Changtang and coming together beyond its boundaries -- in the headwaters of the Yarkand-Dar'ya and in the bend of the Yangtze River.

The Tibetan upland did not arise all at once but in the course of several geological periods. The earlier tectonic structures bear clearly expressed traces of the action of consecutive orogenies and neotectonics.

The beginning of mountain formation in the region of High Asia took place in the middle and upper Paleozoic, when the Caledonian and Hercynian orogenic cycles uplifted the Kunlun. In the Mesozoic began the Yanshan (Pacific Ocean) orogeny which led to the uplift of the Karakorum and the Transhimalaya. The Tetis Sea, retreating to the south as a result -- into the Himalayan geosyncline, continued to exist until Tertiary times, when the uplift of the Himalaya began. This immense mountain system rose with exceptional vigor in the Oligocene; it continued to rise in the Miocene, Pliocene, lower Pleistocene and right up to the present day.

As a result of the action of orogenic forces appearing in the course of several geological eras, there arose in the area of the Tibetan highland a series of tremendous mountain systems with an east-west orientation or close to an east-west orientation (northwest-southeast). But in the period of the formation of the Himalaya the whole territory of the Tibetan highland experienced a warping and block movements. They were especially strong at the end of the Neogene and in the Pleistocene. (In the Pre-Kunlun and the Pre-Himalaya arches and also in the Tsaidam thick strata of conglomerates accumulated at that time.)

Tertiary mountain formation exercised the strongest influence even on ancient mountain structures, which were uplifted, broken apart, and dissected into individual parts. This gave to the Kunlun a structure of folded block mountains and an echelon-like arrangement. The Tertiary orogeny created the complex structure of the Tibetan highland, although its principal units for the most part retained their east-west (and northwest-southeast) orientation.

In the Tertiary period, however, evidently in the Oligocene, the northern and eastern regions of the Tibetan highland were finally liberated from the waters of the Tetis Sea which in the Cretaceous period reached as far as  $104^{\circ}$  E. Its central parts, however, were covered by a shallow sea and were freed later from beneath the waters of the sea. Still later, in the Neogene, deeper depressions in the south and southwest of the future highland became dry. The continental period of development of the relief of Tibet began thus from the middle of the Tertiary period.

From the beginning of the continental period of development of the surface of Tibet, high ranges were subjected to denudation, filling with the products of rock destruction the deep intermontane valleys and lake basins, which occupy individual depressions. From the beginning, evidently, this process took place under a more moist and warmer climate in

comparison with the modern climate, and there was drainage to the ocean. One can judge concerning the greater warmth and moisture of the climate in the past, for example, from the deposits in the basin of the Sutlej River. The headwaters of the Sutlej cut through thick Pleistocene alluvial strata of clay, sand, and gravel, in which are found the bones of such animals as the rhinoceros.

In the Quaternary period, together with the continuing growth of young mountain systems in Asia, the Tibetan highland again experienced an uplift as a result of which a broad basin of interior drainage was formed in its territory. A whole series of facts gives evidence of the uplift of the Tibetan highland in the post-Tertiary period. Thus, in the upper Indus at an elevation of 3,800-4,000 meters above sea level, Tertiary peneplanes are present. K. K. Markov writes that in the Min'ya-Gonkar Mountains in Eastern Tibet there are only traces of small ancient glaciation and that the area is characterized by a mixture of subtropical and alpine forms of vegetation. All this can be explained, he notes, only by the fact that the Min'ya-Gonkar during the era of glaciation was lower than now and later it was uplifted. However, the Chinese geologist Li-Sy-Nuan, on the basis of the fact that currents of glacial waters have cut almost 100 meters into their own deposits in these mountains, draws the conclusion that the Tibetan upland is still continuing to rise.

The high uplifted ranges of the Himalaya have made extremely difficult any access of the moist air masses of the Indian Ocean to a large part of the territory of Tibet. Therefore, from the beginning of the Quaternary period the processes of destruction of the Tibetan mountains were now taking place under conditions still more arid than before, with an intensely continental climate and in an immense area in which there was no drainage to the ocean.

The formation of the relief, as can be seen from what we have already said, was complex and did not take place as a process of calm evolution. I. I. Markov notes that Tibet underwent two phases of development: the phase of base leveling (we recall the Tertiary peneplanes at the headwaters of the Indus) and the phase of uplifting of the eroded surfaces.

Clarification of the role of ancient glaciation is extremely difficult, partly because the upland is still poorly studied and very few data of any kind have been collected, and partly because the activity of the glaciers did not everywhere appear with great intensity and in many places its traces may be wiped out as a result of weathering. (Speaking of the absence of traces of ancient glaciation in Central Tibet, E. Trinkler wrote that preglacial erosion did not take place here to such a degree as in the mountains on the border, and therefore troughs and other

forms could not be developed deeply and, in addition, they were filled with younger deposits, as a result of which these valleys now have the appearance of plains.) There is no uniform opinion among researchers about the scale and area of development of ancient glaciation in Tibet. Thus, Sven Hedin felt that glaciation appeared to only a limited extent in Tibet. In his opinion, the temperature in the Pleistocene in the territory of the highland was low and altogether favorable for glaciation, but the high ranges situated to the south of the highland blocked the penetration of moist air masses into the mountain regions of Tibet and they did not cover the high plains since moraines are absent on them.

In the opinion of Ward, basing his evaluation on his many years of observations in Eastern Tibet, only a part of the territory of the highland, situated between 94 and 100° E. and 28 and 32° N., the area still subject to the influence of the moist southeastern winds, was covered by a glacier mantle.

E. V. Kozlov comes to the conclusion that there was no continuous glaciation on the Tibetan highland. On the basis of a study of the ornithology of the Tibetan highland she draws the following conclusion: "The sharply expressed endemism in the ornithology of Tibet, the presence of isolated species and genres of birds, of which the majority live year-round on the highland, gives evidence, as was already indicated, of the ancient -- at any rate, post-glacial -- residence of their ancestors in this country, and, consequently, that they may have survived Quaternary glaciation without leaving the area. From this it necessarily follows that in reality there was no continuous glaciation on the Tibetan highland". (Avifauna of the Tibetan Highland, Its Relationships and History [Avifauna Tibetskogo nagor'ya, eye rodstvennye svyazi i istoriya], Works of the Zoological Institute of the Academy of Sciences of the USSR (Tr. zool. in-ta AN SSR), 1952, Vol IX, publication 4, page 1,026.)

Other investigators hold a different opinion. Thus, a participant in the Chinese Tibetan Expedition of 1951-1953, Hu Shen-su, writes that on the Tibetan highland traces of the activity of ancient glaciation are to be seen everywhere: a mass of debris, u-shaped valleys, moraine lakes. He noted everywhere traces of glacial activity at elevations of 3,000-5,000 meters, but the maximum area of the eroded glacial surface is associated with an elevation of 4,200 meters (Hu Shen-su, 1953). V. M. Sinitsyn, from observations in different parts of the Kunlun and the Tibetan highland, draws the conclusion that ancient glaciation took place in Tibet on an immense scale. (This information as well as some information on iology was kindly sent to us by V. M. Sinitsyn.) Glacial sculptured forms of different degrees of sharpness are observed everywhere here and are easily recognized in every lake valley. In the Kunlun ancient moraines and troughs delimit the boundary where the glaciers



drop down to 3,500-3,300 meters in the west, 4,200-4,000 meters in the central part of the Kunlun and to 3,700 meters in the eastern part. It also reveals the same sequence of regional changes as does modern glaciation.

In the Western Karakorum and the Punjab Himalaya (the southern slope) the glaciers dropped down to an elevation of 2,900-2,800 meters or 300-500 meters lower than the boundary of modern glaciation of this region. In the Nepal Himalaya (also on the southern slope) the difference in elevation of the ends of ancient and modern glaciers is close to 1,000 meters, and in the Assam Himalaya the figure is about 800 meters. V. M. Sinitsyn believes that if the difference in elevation of the ends of ancient and modern glaciers of Tibet is considered to be a minimum of 900 meters, as is recorded for the Central Kunlun, which has much in common with Tibet in the way of orographic and climatic features, then in this case the lower boundary of occurrence of ancient glaciers is 4,600 meters. Consequently, the whole highland of Tibet, for which the figure 4,300 meters is the minimum, in the early Quaternary era was completely covered with a mantle of snow and ice, with the exception of the craggy crests of its inner ranges. And, in actuality, all of the more or less significant valleys of Tibet bear traces of glacial activity. U-shaped valleys are seen clearly both in the mountains and on the plains. Moraines, however, are distributed only along the margins of mountain massifs where there are sharp changes of slope in the longitudinal profile of the troughs. On coming out onto the intermontane plains the speed of movement of the glaciers sharply decreased. This lowered their erosional energy and their ability to transport the products of weathering. In Tibet one does not see glacially deepened valleys, smoothed cliffs and striation. This is due to the relatively thin layers of the masses of ice and their poor mobility. The development of glaciation in Tibet (especially in a horizontal direction) was favored by flat relief with its broad basins without drainage to the outside. In the early stage of glaciation the ice filled all the valleys and basins of the highland, forming in the mountains complexly branching forms but forming sheets in the depressions. Later on there no longer were ice sheets on the plains and the ice became more and more concentrated in the river valleys, forming immense valley glaciers ending blindly in basins without drainage to the outside. With a further retreat of the glaciers, in the depressions freed from ice broad sandy plains arose with large lakes which dried out simultaneously with the dying out of the glaciers in the mountains.

Modern factors of influence in the development of relief in Tibet in the modern period are endogenous processes, appearing in the continuing uplift of the highland (In comparison with the Himalaya and the Kunlun the highland somewhat lagged behind in this process. According to data from V. M. Sinitsyn, this lag amounted to 300 meters (see

Geography of Foreign Asia [Geografiya zarubezhnoy Aziyi], 1956, page 207), that is, if the Himalaya and Kunlun rose 1,300-1,500 meters in post-glacial times, Tibet rose only 1,000-1,200 meters); earthquakes and volcanism; the tectonic structure and lithological composition of the rocks making up the surface; the position of different parts of Tibet above sea level and the erosional base; the absence of drainage to the ocean in the interior regions and the presence of drainage to the outside in border sectors; climatic and biogenous factors.

Endogenous processes appeared in the highland both in remote geological eras and in the modern period. In Tibet clear traces of volcanic activity of Mesozoic and also Tertiary age are preserved. A broad region with typical dissected lava mantling has been discovered and was described by S. Hedin between the Russkiy and the Przheval'skiy Ranges. Here Littledale traced a zone of former volcanic activity from 36° 50' to 33° 50' N. as he moved from north to south approximately along 87° N. In addition, he also discovered the Tongo volcano near Lungnak. The presence of igneous rocks in Tibet is confirmed by data furnished by the Chinese expedition of 1951-1953. It was established that in Tibet there are large areas covered by volcanic rocks. These are especially widely developed to the north of Lhasa as far as the southern part of the lake region in the Transhimalaya.

In the territory of Tibet there are also presently active volcanoes. Thus, in 1951, during the construction in the Kunlun of parts of the road into Tibet by the National Liberation Army, a volcanic cone was discovered from which "there arose smoke and from which rocks were ejected." V. M. Sinitsyn also writes that the Chinese geologist Wan observed a volcanic crater completely untouched by the processes of denudation. It had frozen streams of andesite lava flowing from it. Wan did not note signs of activity in the volcano. According to information from Chinese geologists, an active volcano is situated on the boundary of the southern range of the Kunlun and the Tibetan plateau near the road from the village of Polurin Sin'tszyan to the Keriya-Davan Pass (1954).

That mountain-forming movements in the Tibetan highland have still not ended is evidenced by the occurrence of earthquakes. The most instable zone, in the opinion of M. S. Krishnan (1954) is the Tertiary belt and the zone of contact of Tertiary rocks with those of more ancient formations. Seismism also appears where projecting ancient massifs oppose the forward movement of the folds in the direction of the ancient Indian platform. In the region of the Tibetan highland there are sharply bent sectors of folded arcs that are situated in the southeast near the city of Sadiyya and in the southwest in the region of Gilgit (Kashmir).

Earthquakes are very frequent in the Tibetan highland. Several large earthquakes have been noted during the last decade. H. Harrer describes an intense earthquake which occurred on 15 August 1947 in Lhasa. In the city up to 40 individual shocks were heard and houses trembled strongly as a result. An immense glow appeared in the east. In Assam, writes Harrer, mountains and valleys trembled at this time. The focus of the earthquake was in Southern Tibet where many Tibetan surfaces were rent by cracks into which both buildings and people disappeared. An intense earthquake was noted in 1950 with an epicenter in the region of Bomi; shocks from the earthquake were felt in the north as far as Tszelatszun (to the east of 94° E. on the Tsangpo River). Tibet, as a zone of instability, is also characterized by outflows of hot water -- springs and geysers associated with cracks in the earth's crust.

Exogenous processes have great importance in the formation of the modern relief of Tibet; erosion, mechanical weathering (frost), the activity of the wind, etc. They are most intense in the summer period, when the receipt of solar warmth at the earth's crust is increased and streams become immeasurably deeper and wider.

In respect to erosion, it is necessary to emphasize that its role in the formation of the relief is noticed first and foremost on the borders of Tibet, especially in the Himalaya, and, secondly, on the southern slopes of the ranges which intercept the moisture of the Indian monsoons. The power of water erosion is especially great on the southern slopes of the Himalaya. The rivers here receive an immense amount of water both from the abundant monsoon rains and from the thawing of snows and glaciers. The discharge of water in summer increases many times, and this leads to a sharp increase in the energy of the rivers and their erosional and transport capacity. Using Eri's formula, the weight of the solid material transported by the river is proportional to the sixth power of the velocity:  $p = Av^6$ , that is, if the velocity of flow is doubled, then the weight of the transported material increases 64 times; tripling the velocity, the weight of the transported material is 723 times greater, etc. Thus, it is understandable how great the transport ability of the Himalayan rivers becomes when they carry their mass of detrital material. Digging down deeper as the mountain ranges rose, occasionally using tectonic faults and crevices, they incised canyons and valleys in the mountains that were hundreds or thousands of meters in depth.

Erosion, however, and surface wash in particular, have been strongly weakened by the grass and tree cover on the southern slope of the Himalaya. The role of the vegetative cover, especially the forest cover, increases more and more due to the fact that the maximum rains fall in the zone occupied by forests.

To the north of the crest of the Himalaya, rising far above the main flow of the moisture-saturated air currents, the significance of the monsoon rains in the feeding of rivers drops sharply and the feeding comes essentially from waters of the thawing snows and glaciers. In connection with the general decrease in the amount of water entering the river, its capacity as an agent of erosion is also decreased. But nonetheless the southern slopes of the watershed ranges of the Transhimalaya-Kailas and the Nyenchen-Tanghla, especially the Kailas, are strongly dissected. The absence of a forest cover does not prevent erosion from appearing here with all its force, and only the hard granite rocks of which these ranges consist form an obstacle to their rapid erosion.

In the northern regions of the Transhimalaya and especially in the Changtang, still less rain falls, and the specific weight of water from snow and glacier thaw in the feeding of the rivers increases. However, due to the aridity of the climate there are significantly fewer glaciers and less snow here than in the Himalaya or even in the Kailas and the Nyenchen-Tanghla; therefore, the rivers carry less water and are less vigorous and river erosion is less developed. In addition, these regions do not have drainage to the outside and, consequently, the base level is high. The base level here is local and in absolute elevation is approximately 5,000 meters. Naturally, under such conditions the erosional force of the water currents is considerably less than in those regions that are drained by rivers that flow to the ocean, that is, having a low base level. In addition, due to the absence of drainage to the outside, there has accumulated a mass of detritus which forms an obstacle to deep erosion in the depressions of the relief and in the river valleys.

In the desert regions erosion has special features. For example, the valleys dropping down to the Aksaychin have a canyon-like form or even the appearance of narrow slots. The erosional forms in the basin of the headwaters of the Sutlej River are altogether singular. The Sutlej drains to the ocean. As we have mentioned, this part of the territory of Tibet is characterized by strata of loose deposits with remnants of Pleistocene alluvium -- clays, sands and gravel. These deposits, spread over an area of two thousand square kilometers, rise boldly above the level of the Sutlej. In them we can observe striking erosional forms which are peculiar to arid regions: colossal canyons, hundreds of meters deep, a dense network of V-shaped dry washes gullying the valley slopes and, in addition, the most exotic eolian cities of towers, castles and obelisks.

Whereas river erosion plays an important role in the formation of relief on the southern border of Tibet, mechanical (frost) weathering has an equally significant role in its interior regions, this being true chiefly in the warm season of the year. These regions are characterized by very large diurnal ranges of temperature; sometimes the variations

in temperature are great even during the daytime, since often the weather changes suddenly from warm to cold and the temperature changes from above freezing to below freezing; night freezes are also characteristic. Sharp changes in temperature cause uneven tensions in the rocks and the appearance of cracks. Becoming filled with water or steam, the cracks increase still more in size, especially with the freezing of the water, since at this time the pressure on the walls of the cracks becomes as great as 6,000 kilograms per square centimeter.

No less, and possibly even more intense is the breakdown of rocks on a bright sunny day. In the rarefied and extremely dry Tibetan atmosphere sharp temperature differences occur in the sun and in the shade. When there are high positive temperatures in the sun, not too far off, in the shade, the temperatures will often be negative. As the sun moves through the sky different parts of the earth's surface fall first in the zone of illumination and then in the shadow; thus a state of strong heating is suddenly replaced by cooling; this creates favorable conditions for an energetic mechanical weathering from frost. Several explorers have even noted that they have often heard during the daytime sounds that are similar to a shot, a sound which accompanies the cracking of rocks.

Chemical weathering plays a considerably lesser role in the breakdown of rocks in the Changtang and Transhimalaya since lack of moisture and low temperature impede the solution of materials. The paucity of vegetation is of little assistance to chemical weathering, since plants that liberate organic acids which dissolve minerals are relatively few.

The wind is the most active agent changing the earth's surface in the interior regions of Tibet. It does a tremendous amount of work in the transporting of dust, sand, fine gravel and pebbles; it carries these products of mechanical (frost) weathering from the place they were formed and lays them down in other places, usually in depressions, thus evening out the terrain. In the sandstones, conglomerates, loose continental or alluvial deposits, characteristic of the surface strata of Tibet, wind erosion leads to the formation of special landforms. In some cases a solid armor of pebbles is formed, elsewhere -- sand dunes, in still other cases, as Przheval'skiy says, there is every possible form of strange-shaped hills with towers, fortresses, and cones. This is the result of sand and fine gravel being blown at great speed and destroying and rounding off protruding rocks and the surface of the earth. The sparse vegetation cover of the interior regions of Tibet and the soil, dry and poor or completely loose due to a lack of moisture, impedes but little the destructive activity of the wind.

Significant changes in the earth's surface in Tibet are caused by rodents that live in holes and burrows. If you take into consideration that in some arid regions of Tibet the number of their burrows, according

to Hedin's observations, amounts to several dozen per square meter and that in the course of many thousands of years their numerous progeny dug underground dwellings and passageways and the wind carried away the sand and gravel which they excavated, then it is not difficult to imagine the work accomplished by these animals in the transformation of the earth's surface.

Exogenous forces appear considerably weaker in the cold season of the year. With a decrease in the influx of solar warmth and variations in temperature, there is a decrease in the intensity of mechanical (frost) weathering; the small amount of water in the rivers or their complete freezing results in a stopping of the erosional process; the frozen surface, as if covered with an icy armor, paralyzes the erosional role of the wind; even rodents can not carry on their destructive work, the more so since some of them hibernate.

Despite the tremendous absolute elevation of the ranges of the upland, modern glaciation in Tibet is, in general, weakly and unevenly developed. It is significant only in the Karakorum and in the Himalaya. In the interior part of the highland and in the Kunlun with their sharp continental climate, modern glaciation and eternal snows as well occupy but small areas. In the highland glaciers and eternal snows are distributed primarily in the highest mountain nodes situated in places where ranges with an east-west orientation intersect uplifts having a diagonal orientation.

The development of glaciers is directly associated with the development of a mantle of eternal snows. The lower boundary of the latter in the boundaries of the highland is situated very high, whereas on the slopes of the ranges turned outward from the highland it drops down considerably lower. Thus, whereas the snow line on the southern slope of the Nepal Himalaya is situated at an elevation of about 4,500 meters, on the northern slope, along the Tibetan boundary, its location rises to an elevation of 5,200-5,500 meters.

In the Karakorum the height of the snow boundary on the southern slope is situated at approximately 4,700 meters, and on the northern slope, about 5,900 meters. In the eastern part of the Karakorum, in the territory of Tibet, the boundary of eternal snows goes still higher. In the Kunlun, according to data furnished by G. Sobolevskiy, in the region of the sources of the Khotan River, on the northern slope, the height of the snow line is approximately 4,700 meters and on the southern slope, turned toward Tibet, it is 5,000-5,250 meters. (To the east its elevation increases to 5,000-5,800 meters, and to the west of the sources of the Khotan River, for example, in the ranges of the Kunlun near the Pamirs, N. A. Belyayevskiy quotes a figure for the northern slope of 4,700 meters and for the southern slope a figure of 5,000-5,250 meters.) On the peaks of the interior Tibetan ranges -- in the Duplex, Tanghla

and other ranges, according to Sven Hedin's observations, and according to those made by Bonvalot and Przheval'skiy, the lower boundary of the snows is situated at an elevation of not less than 6,000 meters. Its elevation is also about 6,000 meters in the Ladak Range. Only in the east does it drop down, and at the sources of the Hwang-ho it is situated at an elevation of about 4,900 meters.

Thus, the difference in the elevation of the snowline on the slopes of the ranges along the Tibetan frontier that frame the highland and on the slopes facing it amounts to several hundred to a thousand meters and more. In the highland itself the lower boundary of the eternal snows is situated at the highest elevation.

The same pattern is seen in the development of glaciers. In the ranges bounding the highland one can see thick glaciation in the ends of the glaciers which crop down rather low, and on the other hand, the Tibetan ranges have few glaciers, and these glaciers terminate at a great elevation.

In the Himalaya, blocking with its crests an immense quantity of moisture carried by the Indian monsoons, there are numerous glaciers although their length is not so great. Only in the region of Dzhomolungma and Kanchendzhanga do they attain 19 kilometers (Rongbuk) and 26 kilometers (Zemu and Gangotri). On the southern slope the boundary of the glaciers is situated at an elevation of 3,000-4,000 meters and in the north -- about 5,000 meters.

Very thick glaciation occurs on the southern slopes of the Karakorum ranges that border Tibet on the west. It is associated, as in the Pamirs, with Mediterranean cyclones that bring moisture here during the period of November through April. Here there are such giant glaciers as Siachen -- 72 kilometers, Khispar -- 61, Biafo -- 60, Batura and Baltoro -- 58 kilometers long. The ends of the Karakorum glaciers drop down on an average to the 3,050 meter level. To the east this boundary rises to 5,500-5,600 meters.

In the Kunlun the area of modern glaciation is not as great as in the Karakorum; this mountain range does not receive a large amount of precipitation either from the north or from the south. But here, chiefly in the Western Karakorum, are to be found glaciers with a length of more than 15 kilometers (the glacier of the Nas River -- 15 kilometers, of the Chigmen River -- 16 kilometers). The ends of the glaciers of the Western Kunlun, according to data furnished by G. Sovolevskiy, lie at an average of 4,370 meters, and further to the east, closer to Tibet, their lower boundary, according to N. A. Belyayevskiy, rises to 5,000-5,150 meters.

In Tibet itself the largest modern glaciers have developed on the massif of the Ulugmuztagh in the Kunlun and in the eastern spurs of the Karakorum -- in both cases the glaciers drop down to elevations of 5,500-5,600 meters. Glaciers also exist on the Tanghla Range in its segment entering into the east Tibetan diagonal uplift where the Yangtze and Salween Rivers rise. In association with an increase in the amount of precipitation here, the line of eternal snows and the location of the ends of glaciers also drop down. Przheval'skiy writes that glaciers on the Tanghla Range drop down to elevations of 5,200 meters on the northern slope and to 5,300-5,350 meters on the southern slope.

All that we have said leads us to the conclusion that as a result of the thinness of ice, caused by the aridity of the climate, Tibetan glaciers exercise influence only on the highest parts of the highest mountains, creating such forms of glacial relief as sharp crests and cirques. A large part of the highland and its plains in particular, despite the very great absolute elevation -- close to 5,000 meters, remains untouched by glacial action.

In discussing modern relief-forming factors, it should be noted that the formation of the geomorphological landscape in Tibet takes place amidst a conflict between two contradictory tendencies. The Tibetan border mountain regions -- the Himalaya and the Kunlun (on the northwest), and also the extreme west of Tibet, are associated with basins of rivers that flow to the ocean or that have a low base level, like the north-western Kunlun whose rivers flow into Lake Lobnor. The flow to the ocean and the low base level in these regions determines the energetic pace of erosion, which during the continuing uplift of the highland has formed strongly dissected mountain relief, that is, a rising development of relief is taking place. The interior regions of Tibet -- the Changtang and a large part of the Transhimalaya -- have no outward flow to the ocean and have local base levels that are relatively high. Here there are no such favorable conditions for erosion, the more so since the amount of precipitation is low; the products of the destruction of the rocks are not carried away but remain near the place where they are formed. Consequently, independent of the fact that the highland is rising, a lowering development of the relief is taking place. Regions without drainage to the outside do not have such deep valleys as do regions with drainage to the sea. For the Changtang and for the Transhimalaya, to a significant degree, weakly dissected mountain ranges are characteristic; these rise but little above the high-uplifted plains.

The tendency to a rising type of relief is now getting the upper hand, since its sphere of action is being broadened due to the contraction of areas with a descending type of relief. Interior drainage regions are little by little being included in the systems of rivers that flow to the ocean. This is seen in the example of the Sutlej and the Salween, already penetrating into the southeastern part of the



Changtang; it can also be observed that the Hwang-ho and the Yangtze are driving their sources ever farther to the westward. As this happens the rivers will push ever farther into the depths of the highland and along its borders will broaden the zone which presents the appearance of a strongly dissected mountain country. The loose detrital material covering the broad plains will start being carried away; the former intermontane tectonic valleys to some degree will be reconstructed; new deep V-shaped valleys will appear; the dissection of the slopes will increase and in places the crests will be sharpened.

#### RELIEF

Formerly the Tibetan upland was represented as a gigantic high uplifted pedestal, bounded on the north and south by tremendous ranges and in turn dissected by a series of long east-west (or northwest-southeast) oriented mountain ranges, the Kunlun, Karakorum, Transhimalaya, and Himalaya. Hedin distinguished up to 30 main east-west ranges, in large part parallel to one another.

Researchers in recent years have made substantial corrections to these concepts. V. M. Sinitsyn considers that both in the most ancient and most recent structures, besides the basic east-west (northwest-southeast) system of structuralorographic elements, Tibet also has a system with a northeast-southwest orientation. The combination of these two systems also characterizes the modern structure of High Asia as a whole and Tibet in particular. This structure is made up of a great number of blocks of different sizes and shapes and intermixed to varying degrees. The most uplifted of them are expressed in the landscape by ranges and others in the form of uplifts -- hilly plains occupying a large part of the area of Tibet in comparison with the area occupied by plains. But the northeastern zones of dislocation, with rare exceptions, were not made up of independent structural and orographic units, but constitute complications in the main east-west (northwest-southeast) system (see the sketch map of the tectonic system of High Asia). In the latter, V. M. Sinitsyn distinguishes the following large structural-orographic elements: the Great Himalaya, the depression containing the head-waters of the Indus, the Sutlej and the Tsangpo, the Transhimalaya (Gandisyshan), the depressed region of Northern Tibet lying between the Transhimalaya and the Karakorum-Tanghla Range, the depressed region of Northern Tibet, situated between the Karakorum-Tanghla Ranges and the Kunlun, and the Kunlun itself.

Among the structural-orographic elements with a northeast-southwest (intersecting) direction the most clearly expressed are the following:

1. A zone of dislocation in the Central Kunlun in the segment between the sources of the Keriya-dar'ya and the bend of the Suloho River at Yuymyn' taking on an independent structural and orographic development. In the Northern and Central Tibetan depressions it is associated with the appearance of diagonal ridges forming watersheds, and in the Karakorum, with high mountain nodes.

2. A diagonal zone in Interior Tibet, also having an antiolinal character. Within the boundaries of the depressed zone it appears in the form of a series of crosswise ridges which separate the lake basins. Within the boundaries of the great uplifts of the Tanghla, Transhimalaya, and the Great Himalaya, it appears in the form of tremendous mountain nodes with peaks having an elevation up to 7,000 meters and more. This uplift is one of the principal watersheds of Tibet and serves as a boundary between the region of the sources of the Yangtze River and the basins of interior drainage of Northern Tibet and also the watershed between the Tsangpo River on the one hand and the Sutlej on the other.

Between the diagonal uplifts of the Central Kunlun and Interior Tibet are enclosed broad expanses of plains with lakes that are bounded by hills, ridges and short ranges, these constituting structural orographic units of a lesser scale.

3. There is a large diagonal zone of dislocation in Eastern Tibet that consists of a series of ranges, ridges and mountain outcrops with a northeast-southwest orientation; the largest of them is the Nyenchen-Tanghla. This zone separates the Tibetan highland from the gently sloping to rolling and strongly dissected region of Kam with its alpine landscapes.

The enumerated diagonal zones of dislocation divide High Asia into three main regions: the western flank, embracing the headwaters of the Indus and the Tarim, the Tibetan highland, in the most part an area of internal drainage, and the eastern flank, including Kam and the region of the great canyons. On the flanks a system of northwestern-southeastern dislocations prevails, and these determine the orientation of the main ranges. In Tibet, however, both systems of dislocations -- the northwest-southeast and the northeast-southwest -- are developed approximately the same. As a result, the structural and orographic elements have more of a block than a linear development. Thus, on the flanks there is a predominance of linear forms of highland -- ranges, and in Tibet -- areas of highland, high plains, in respect to which the short ranges situated here are only secondary elements.

Actually, a large part of the surface of Tibet is a plain, especially its northern part. Fen-shen considers that all the territory of the highland to the west of a line from Lake Kukunor to Lake Nam Tsho constitutes a steppe plain -- "tan." "Tan" -- in Tibetan, signifies a

level plain. This is the origin of the name Changtang (Northern Plain) for the huge area occupying the northern part of Tibet proper and part of the north of the eastern half of the highland.

Observations by researchers who have crossed Tibet in the most different parts (from north to south and from west to east) have also confirmed this. All the explorers went a large part of the way through plains which first extended in an east-west direction and then take on the form of intermontane basins.

In the western part of Tibet, in the region of the eastern spurs, the plains are described by Deasy and Bower, who, beginning from Lake Aru, traveled in an east-southeast direction for a period of several weeks through wide open valleys with rounded hills. De Rhins crossed great plains that were 40-50 kilometers in width from north to south as he descended to the north Tibetan plateau from the Przheval'skiy Range. Somewhat to the east of de Rhins, Littledale made the trip from north to south by an almost parallel route. He also traveled through open plains with hilly relief; a somewhat more dissected hilly locality was situated near the Przheval'skiy Range where volcanic rocks were in evidence. Bonvalot crossed Tibet along the line from Lake Ayagkumkul' to Lake Nam Tsho. His route passed through the plateau-like plains that were somewhat higher -- 5,000 meters -- and cut by mountain ranges to the north of the Dupleix Range, plains that were somewhat lower -- up to 4,380 meters -- with chains of hills and lakes to the south of this range. Finally, very large plains expanses with gently-sloping hills and very large lakes (Nam Tsho, Seling, Bam Tsho, etc.) extend to the south from the Tanghla Range.

The surface of the Tibetan Plateau is not uniform everywhere. It is hilly in places and the hills form chains or ridges. Elsewhere it is hilly and gullied. That is its appearance, for example, at the western extremities of the Dumbure and Kukushili Ranges where Littledale and Bonvalot crossed it. Here and there the plains for many tens of kilometers constitute an ideally flat surface -- these are the bottoms of former lakes. As a rule, everywhere on the plains one can encounter numerous lakes, the majority of them situated in relatively shallow depressions with gentle slopes.

One can observe some regularity in the position of the plains areas in relation to sea level. In the northern part of the Tibetan plateau, approximately to the north of 34° N., the plains have been uplifted to a greater absolute elevation than in the south. (To the north of the Przheval'skiy Range the elevations of the intermontane valleys of the Kunlun again drop down, having elevations of about 2,800 meters between the Lower and the Upper Astyn-Tagh.) Thus, the elevation of the Aksaychin depression is about 5,000 meters; the intermontane plains in

the northern part of the Karakorum (in the boundaries of Tibet), according to Deasy's data, is between 4,900-5,000 meters; valleys crossed by de Rhins (to the south of the Przheval'skiy Range), also about 5,000 meters (an average of 5,022 meters). Similar elevations characterize plains situated to the north of the Dupleix Range. However, in this same Karakorum but to the south of 33° N., their elevation above sea level drops down to 4,250 meters, to the south of the Dupleix Range -- to 4,380 meters, and to the south of the Tanghla Range, -- to 4,480 meters.

In addition, on the basis of a comparison of the average elevations of the western and eastern lakes of Tibet, a study made by S. Hedin, it becomes clear that the average elevation of the plains in the western part of Tibet is 200 meters greater than their average elevation in the east.

Plains occupy a large part of the surface of Tibet in respect to area. However, the Tibetan mountains and mountain systems constitute such an important element in the relief that special attention should be devoted to them. It is all the more interesting that in a number of respects, for example, in absolute elevation and extent, they have no equals in the world.

As a result of the aridity of the climate and the slowness of erosional processes, the basic elements in Tibetan orography are largely tectonic, not erosional: tectonic mountain ranges and tectonic intermontane valleys. All the elements of the orography are also extremely closely associated with the geological structure.

E. M. Murzayev, describing the relief of Central Asia, writes that its relief is not only connected with tectonics but also with geological structure as a whole and is often their result. He cites in confirmation of his opinion the conclusions drawn by V. M. Sinitsyn to the effect that the most important elements in the relief and alpine structure are directly associated with one another: anticlinal uplifts are expressed in the relief by mountain ridges and synclinal arches by the intermontane valleys and depressions. The dependence between them finds expression even in the morphological features of the individual units. Thus, for example, the alpine uplifts, not developed from faults, have the form of arches, but the uplifts bounded by pairs of parallel faults have the form of horsts; uplifts of the monoclinical structure type on the earth's surface are found here in the form of monoclinical ridges.

A still deeper connection with structure, in the opinion of V. M. Sinitsyn, is revealed by the mountain systems as a whole. Their sites and orientation were predetermined exclusively by geological factors

and depend on the distribution of the principal geotectonic regions -- "mobile" areas and stable massifs, the development of which took place in the course of many geological periods.

The southern margin of the Tibetan highland is formed by the young Himalaya Mountains, uplifted in the alpine orogenesis, representing as a whole an immense anticline. The principal part of the anticline, also embracing the southern part of Tibet and the Karakorum, consists of alternating zones of pre-Cambrian rocks and granites of different age (coinciding for the most part with the highlands of the Great Himalaya Range, the Karakorum and in part, the Ladak and Pirandzhal Ranges) and zones made up of the most varied Paleozoic and Mesozoic deposits from the Cambrian and Cretaceous inclusive.

Lombard considers that the Himalaya is a slightly uplifted part of the Tibetan block, a feature of whose structure consists in an asymmetrical structure. Its northern slope drops down gently, but its southern slope forms a slightly uplifted precipitous margin. The asymmetry, in addition, is intensified by erosion of differing intensity on slopes having different exposure. On the southern slope, where solar insolation and the amount of precipitation is substantially greater than on the northern slope, the processes of erosion transpire more energetically.

The Himalaya is the highest mountain range in Tibet, since, firstly, it was uplifted by the last and most intense orogenic movements of the alpine cycle and, secondly, the Himalaya is younger than the other mountain systems of Tibet and to a still larger degree has not been subjected to the destructive action of exogenous forces.

The Himalaya, evidently, is still continuing to rise and the processes associated with this uplift outstrip the processes of destruction. Researchers in recent years have established that just after the end of glaciation it rose by 1,300-1,500 meters (Foreign Asia [Zarubezhnaya Aziya], 1956, page 206).

The average elevation of the Himalaya Range above sea level is 6,000-6,100 meters. It constitutes a tremendous mountain arc of four parallel ranges that arch to the southwest. The length of the Himalaya is 2,400 kilometers and it has a width of between 200-350 kilometers. Provisionally its boundaries are considered as follows: in the west, the Indus canyon; on the east, the Dikhang River (the name of the Brahmaputra at the place where it turns from an eastward flowing stream to a southward flowing stream).

The Himalaya is dissected by deep river valleys and canyons into four sections: the Assam Himalaya, the Nepal Himalaya, the Kumaong Himalaya, and the Punjab Himalaya. The term Assam Himalaya is applied to the sector of the Himalaya between the transverse section of the Brahmaputra valley on the east and the Tista River on the west. The length of this sector is 720 kilometers. The principal peaks here are, from east to west -- Namcha Barwa (7,756 meters), Kulakangri (7,554 meters) and Chomolokhari (7,314 meters). The Nepal Himalaya extends for 810 kilometers from the Tista to the Kali River; they are the highest part of the whole Himalaya system. In the Nepal Himalaya is situated the world's highest peak -- Dzhomolungma (8,882 meters; according to the latest data, 8848 meters). Dzhomolungma consists of three peaks of which two rise up next to one another. Besides Dzhomolungma, there are also other 8,000 meter giants here -- like Kanchendzhanga (8,585 meters), Makalu (8,440 meters), Annapurna (8,075 meters), Gozaintan (8,820 meters), Dkhaulagiri (8,172 meters) and Kutang (8,126 meters).

The Kumaong Himalaya, beginning at the canyon of the Kali River, is bounded on the west by the Sutlej valley. Its length is about 320 kilometers and its highest peak is Nanda-Devi (7,816 meters).

The Punjab Himalaya extends for 560 kilometers between the Sutlej and the Indus; it is also called the Pangl Range. Nanga Parbat stands out here with an elevation of 8,216 meters.

Among the four principal mountain ranges of the Himalaya the central one is the most prominent -- the Great Himalaya Range, sometimes called the Main Himalaya Range. This range is striking in its great dimensions, grandiose form, dissected nature and its deep canyons and valleys. The Great Himalaya constitutes a chain of ranges made up of granites, gneisses and crystalline shales (the so-called crystalline axis), forming sharp relief features. In the whole extent of the Great Himalaya gigantic peaks tower up, 11 of them rising to an elevation of more than 8,000 meters.

A characteristic feature of the Great Himalaya Range is the presence of only one crest (not taking into account several lateral offshoots from high massive peaks). Despite the colossal height, the main range is not a major water divide, since in the Kumaong and Nepal Himalaya it is cut through by the Indus, Sutlej, Karnali, Gandak, and Arun Rivers, which receive tributaries in the Ladak Range.

In a number of places the Great Himalaya Range has side branchings. This is observed in the Dkhaulagiri massif where the Little Himalaya branches off from the main range to the west. This range has an average elevation of 3,500 meters and individual peaks go up to 6,000 and even 7,043 meters; side branches also reach out from the main range near the

canyon of the Alaknanda River, the canyon of the Sutlej, and the canyon of the Karnali, where the Zaskar Range goes off in a northwestward direction for a distance of about 1,000 kilometers. A substantial part of the Zaskar is situated within the boundaries of Tibet and the Chinese-Indian frontier passes along it. The Zaskar Range has high individual peaks: Mt. Kamet, situated on the boundary of Tibet and India -- 7,756 meters and Mt. Shilla in the basin of the Spiti River -- 7,026 meters. In a number of places two or more mountain folds pass along the Zaskar. The Kali River flows southeastward through high intermontane valleys; this river rises in the same range. To the east of Dkhaulagiri the bifurcation of the main Himalayan Range is no longer noted.

The main range drops down to the Indus-Ganges Lowland in the form of two great steps. The first of these is the foothill zone with an absolute elevation of 700-1,000 meters, rising 500-800 meters over the Indus-Ganges Lowland. The dissected margin of the step, turned toward the Indus-Ganges plain, is called the Siwalik Range in the west and the Dundwa and Chourigati Ranges in the east.

The second step has an elevation of 3,500-4,500 meters. It also consists of several individual ranges. In the west its dissected margin -- a branching of the main range -- is called the Pirpandzhal Range; further to the east it takes on the names Dauladnar, Nag-Tiba, Little Himalaya and then the Makhabarar and Duari. The latter two ranges do not have a connection with the Himalaya.

Between the second step and the main range is situated a high-lying upland with a width of 80-100 kilometers, which is famed for its rich valleys and gentle climate. At one time these valleys were the beds of lakes. Of special fame are the Vale of Kashmir in India and the Katmandu Valley in Nepal.

The main range towers over the southern Himalaya Range as a gigantic jagged steep barrier, in the upper part completely covered with year-round ice and snow. The southern ranges are strongly dissected and in places are cut through by deep canyons through which movement is difficult. Through these canyons whirl stormy rivers and mountain currents, roaring and covered with white foam.

The strong dissection of the southern slope of the Himalaya is caused by an abundance of precipitation and the steep gradient of the rivers, dropping down to the Hindustan Lowland, which has an elevation of 200 meters or less above sea level.

At the foot of the southern ranges of the Himalaya, receiving an abundance of precipitation brought from the Indian Ocean, grow tropical forests -- jungles; as you go up the slopes of the mountains they change

into an evergreen forest of magnolias and laurel with a scattering of oak and chestnut, and still higher -- into a temperate climate forest and, finally, near the zone of snows, into alpine meadows.

In the direction of the Tsangpo River Valley the Himalaya drops down in a step consisting of the Ladak Range to the west and several other ranges on the east which make up the Nepal-Tibetan watershed. (The Ladak Range is situated between the Indus River and the Sheyok River, but its orographic orientation is maintained up to the regions of Lakes Rakas and Manasarwar.) To the east of them the Nepal-Tibetan watershed begins. Along this watershed, for a great distance, passes the boundary between China and Nepal. The Nepal-Tibetan watershed is separated from the Great Himalaya Range by intermontane lowlands with a width of 80-120 kilometers. Through these lowlands pass rivers such as the Pungchu which have their sources on its slopes and in their turbulent race break through the main range in the south through a canyon. The Ladak (within the boundaries of Tibet) and the Nepal-Tibetan watershed are less intensely dissected than the step of the southern slope of the Himalaya which drops down sharply to the headwaters of the Indus, Sutlej, and Tsangpo. Despite an elevation substantially less than that of the main range, the Nepal-Tibetan watershed serves as the main watershed range. The fact, writes Krishnan, that the main watershed is situated behind the line of the highest peaks of the Himalaya, is usually cited as evidence of the existence of a river system here before the time that the main phase of uplift of the Himalaya mountains took place.

Many peaks of the Ladak and the Nepal-Tibetan watershed rise up to a great elevation. Besides the Gurla-Mandhata massif at 7,728 meters, there are 25 peaks higher than 6,000 meters. The height of the passes exceeds 4,500 meters. (The elevation of the Kharpo Pass in the Ladak is 5,116 meters, Burgi -- 4,784, Medosi -- 5,395, Boga -- 5,952, Aiy -- 5,700 meters. The Nepal-Tibetan watershed in the western part [south of Lake Rakas] has two passes -- 5,212 and 5,547 meters. In its eastern part the height of the passes is Potu -- 4,596 meters, Nola -- 5,060, Sheru -- 5,365, Kura -- 5,456 meters.)

The northern slopes of the Himalaya are more gentle than those facing toward India and are less dissected by the valleys of the river courses. They adjoin the Tibetan Highland, in this place having an absolute elevation of about 4,500 meters, and, therefore, here there are no such immense differences in the elevations of mountain peaks and the plains surrounding them as there are on the southern slope. In addition, the Tibetan climate is considerably drier. All this lowers the intensity of erosional activity of the rivers. The surface of the northern slopes of the Himalaya in many places constitutes a rocky



rolling inclined area with alternating steppes and rocky and Solonchak deserts. On the slope are encountered concealed lake basins, sometimes dessicated.

In the north the Himalaya Range is bounded by a graben, a large tectonic valley that is 70-80 kilometers wide (between the crests of the Ladak and the Kailas), serving as a joint source area for the headwaters of the Indus, Sutlej and Brahmaputra (here called the Tsangpo). The valley stretches out from west to east for a distance of more than 2,000 kilometers. The elevation of its floor drops from 5,000 meters in the region of the Indus and Tsangpo watershed where the area is uplifted by dislocations having a northeast-southwest orientation, to 3,000 meters at the eastern and western ends.

The mountain region of the Transhimalaya (Gandisyshan) is situated in the limits of 29 to 33° N. and from 80 to 96° E. Its length is 1,600 kilometers; its width at the broadest (central) part is 300 kilometers. The Transhimalaya serves as a watershed between the Indian Ocean and Northern Tibet, an area of internal drainage.

In this mountain system of complex Mesozoic rocks the pre-Cambrian base is almost completely covered. Here are developed strata of acid and basic lavas, alternating with the red continental deposits of the Cretaceous and Paleozoic.

The Transhimalaya is a folded mountain country, distinguished by its massive features. To the south it is bounded by the Kailas Range, and on the north by the Aling-Kangri and the Nyenchen-Tanghla. These mountain chains are major ones in their own right. Secondary ranges are situated between them. Although the outer chains of the Kailas, Nyenchen Tanghla and the Aling-Kangri are clearly expressed in the landscape -- they maintain an orographic irregularity and a fixed orientation -- the inner regions of this mountainous country constitute a chaotic group of mountains which often do not form continuous ranges and which rise without any order in the form of steep folds of weathered rock strata. The folds of the earth's crust here are warped, overturned and compressed as if they were subjected to lateral pressure not only from the north but also from the west and east. In many cases one can already make out ranges with a northwest-southeast orientation.

A large part of the mountain country of the Transhimalaya does not have any external drainage. Lakes have been formed in the broad intermontane basins with an average elevation of 4,500 meters. A part of the rivers, flowing down from the southern ranges, flow into these interior lakes; others, however, breaking through the mountains, flow toward the Indus and the Brahmaputra. The rivers flowing from the interior and from the northern ranges of the Transhimalaya feed their waters into the lakes.

Despite the great absolute elevation of the passes (an average of about 5,000 meters -- the Kinla Pass even reaches 5,885 meters), the Transhimalaya is not very difficult to cross. (S. Hedin notes that watershed passes of the first order in the Transhimalaya are at an elevation 500 meters greater than in the Himalaya although in average elevation the Transhimalaya is lower than the Himalaya.)

The Kailas Range, made up of granites, begins in the west at Lake Pangong with Mount Sadzhum which is 6,101 meters in elevation. (Hayden and Burrard assume that the range, after disappearing at Lake Pangong due to a local tectonic downdrop, later continues in a northwestward direction parallel to the Karakorum.) Following the arch of the tectonic lines of the Himalaya, it extends to 84° E. and reaches only a very small distance to the east of this meridian. The width of this range is about 35-40 kilometers, the height of the crest approaches 6,000 meters. The Kailas is most highly developed near Lake Manasarowar where a closeby-packed group of peaks rise up to a height exceeding 6,000 meters. Spurs branch off and make contact with spurs of the Ladak Range. In general, in the region of Lake Manasarowar, where there is a diagonal zone of northeast-southwest dislocations of the Tibetan interior, are situated the highest points of the Ladak, Zaskar and Kailas Ranges -- Mts. Gurla Mandhata, Kamet and Kailas. To the east of this lake the northern slopes of the described range becomes gentler and less dissected than the southern slopes.

Somewhat to the east the northern bank of the Tsangpo is fringed by a chain of other ranges instead of the Kailas. Approximately 85° E., between this range and the string of mountains situated further to the north, lie the sources of the Raga-Tsangpo River, which then flows for 250 kilometers and joins the Tsangpo. In the region of the sources of the Raga-Tsangpo there are peaks more than 6,000 meters high from which the Nyenchen-Tanghla Range branches off towards the east.

The Nyenchen-Tanghla serves as the watershed between the Tsangpo, which eventually drains into the Indian Ocean, and the Tibetan basin of interior drainage. This northern boundary range is the eastern part of the Transhimalaya. Its principal feature is the presence of two systems of dislocations -- east-west (and northwest-southeast) and northeast-southwest. These are present both in the eastern and the western parts of the range. The Nyenchen-Tanghla is also a tremendous range, constituting an almost uninterrupted chain of snowy mountains with high peaks from which glaciers drop down to the north and to the south. The highest of the peaks is the craggy double-peaked Mt. Nyenchen-Tanghla (also called Charemaru or Dzhang-Nyenchen-Tanghla), which has steep slopes. At the same time, for a large part of its length the range is distinguished by a relatively low degree of dissection and by an evenness of its crest.

The elevation characteristics of the range are approximately the same as in the Kailas. It has nine peaks that range in elevation from 6,000 to 7,000 meters. Mt. Nyenchen-Tanghla, however, rises to an elevation of 7,088 meters. Passes in the Nyenchen-Tanghla have an elevation of more than 5,000 meters. (The Kongbo-la Pass has an elevation of 5,151 meters, the Khalamba -- 5,243 meters and Goring Pass -- the high figure of 5,969 meters.)

The Aling-Kangri Range begins near the meridian of 80° E. One hundred kilometers from this point rises the highest point in the range -- Mt. Aling-Kangri, 7,315 meters high. The range extends in a southeasterly direction to 86° E. and forms a range of snowy mountains. Whereas in the Kailas the southern slope is strongly dissected by a network of river valleys and gullies, this is not the case in the Aling-Kangri. Due to the great aridity of the climate, the network of valleys and gullies on its slopes is considerably less developed, excluding the northwestern part of the range. The passes are high, for example, Songchen (Ladung) Pass attains 5,353 meters in elevation.

At 86° E. (along the western shore of Lake Dangrayum) diagonal to the orientation of the Aling-Kangri, passes a ridge belonging to the system of northeastern dislocations. It is crowned by an extremely high peak, Torgot (Torgot-Kangri). This is an isolated massif, towering over the surrounding area. Five glaciers are set deeply into its eastern slope.

To the east of the Torgot-Kangri, in place of the Aling-Kangri, there can be observed ranges and massifs that first have an east-west and later have a northwestern orientation. The lake region of the Transhimalaya is situated here. At the southern tip of Lake Kyaring (Dzharing) a group of peaks, the Gyak-Kharma, rising up to 6,950 meters, stands out sharply. These are parallel to the Torgot-Kangri massif and on the south they adjoin the Nyenchen-Tanghla. The Gyak-Kharma also is part of the system of northeastern dislocations.

The ranges of the broad mountain region, enclosed between the northern and southern boundary ranges of the Transhimalaya, rise up to 5,500-6,000 meters above sea level. Several of them have gentle slopes and rounded shapes but the highest are strongly dissected and crowned by eternal snows. Among the latter are the Lapchung, Kunchung, and Lunkar Ranges. The orientation of many ranges is associated with the northeastern system of dislocations. Interconnected, the main east-west mountain ranges divide the entire interior region of the Transhimalaya into a number of isolated sections with large intermontane basins elevated 4,260 meters above sea level in the east and 4,980 meters in the west. The most depressed of these basins are occupied by large and small lakes.

To the north of the Transhimalaya is situated the Karakorum mountain system whose total length exceeds 1,000 kilometers. The major and highest part of the Karakorum is situated to the west of the boundary of Tibet: in Tibet proper only the low eastern spurs enter which at approximately 82° E. disappear beneath the surface of the plateau. Only a few of them, evidently, appear again, further to the east.

Orographically the Kunlun and the Karakorum are separated by a valley situated to the north of the Buka-Mangna Range and at the southern foot of the Dunbure Range (according to Khaun Ti-tsin'). The boundary between the Karakorum and the Transhimalaya passes through the valley bordering the northern slope of the Aling-Kangri Range. In this valley are distributed Permian-Carboniferous (typically Karakorum) sedimentary limestone rocks. (Some researchers, for example, V. M. Sinitzyn, 1955, consider the Karakorum and the Transhimalaya to be one mountain system. The Karakorum is its western segment; within its boundaries are also situated the sources of the Indus; and the Transhimalaya is its eastern segment -- opposite the east-west valley of the Brahmaputra.)

The Karakorum is the second highest (after the Himalaya) range on the globe. Its average elevation is about 6,000 meters. To the west of the Tibetan boundary it has peaks that exceed 8,000 meters: Chogari (Godwin-Austen) -- 8,611 meters, Hasherbrum -- 8,073, and Hidden -- 8,068 meters.

There are three longitudinal zones in the Karakorum: the southern one has a width of about 90 kilometers and is made up of gneisses and granites; its average width is 50-60 kilometers, made up of sedimentary and metamorphic rocks of Paleozoic and Mesozoic ages (dolomitized limestones, dark shales and sandstones predominate); the northern zone is about 60 kilometers in width and is made up of crystalline shales and Jurassic limestones.

In the western part, outside the territory of Tibet proper, the Karakorum has the appearance of a grandiose mountain system with tremendous craggy peaks, crowned by eternal snows and ice. They are combined with extremely deep valleys and narrow canyons that are especially numerous on the northern slope and also with talus (Karakorum means "Black talus.") The rocky cliffs are a desert. This is a country of glaciers, these being especially developed on the southern slope. (These are the earlier mentioned glaciers, Siachen, Khispar, Batura and others.) The mountain massifs and cliffs often rise up in the form of tremendous extraordinarily singular and picturesque obelisks and towers. The southern slope of the Western Karakorum drops off sharply to the Indus. The northern slopes, turned toward the Rasken-Dar'ye and the Karakash, separating the Karakorum from the Kunlun, have softer contours. The passes in the Karakorum are difficult and are located at a very great

elevation. For example, the most famous, the Karakorum Pass, from Sin'tszyan into Kashmir, is situated at an elevation of 5,575 meters, the Changlung Pass -- 5,764 meters and the Muztagh Pass -- 5,860 meters.

In the eastern, Tibetan, part of the Karakorum, there no longer are any 8,000 meter peaks. But, nevertheless, individual peaks rising in points where east-west (northwest-southeast) and northeast-southwest dislocations intersect are very high: the height of the peak standing at the southwestern shore of Lake Arport is 6,443 meters high, Lhari Peak is 6,407 meters. A great number of lakes are scattered among the east-west ranges that disperse to the east and southeast and which are intersected by heights which have a northeast-southwest orientation. Several of them, Lakes Charol, Pangong, Ligten, Khuping, and others, have complicated shore lines since they are narrow and long, like fiords, and extend embayments into the mountains through valleys and ravines.

The further you go to the east, the lower the ranges of the Karakorum become and the less they stand out amidst the surrounding area. Flat or hilly plains now predominate in the relief, adjoined on the north, south, east and west by short, low ridges. However, among the ranges of varying orientation in the Eastern Karakorum can be pointed out several main mountain ranges with a northwest-southeast orientation: the most northern is the Muztagh-Karakorum (the Tibetan Karakorum), further south -- the Changchenmo, and still further to the south -- the Pangong Range.

The prolongations of the Muztagh-Karakorum and the Changchenmo are not clearly expressed to the east of 82° E.; they are broken and have large ranges with a northeast-southwest orientation that meet them at right angles. It is easier to follow the prolongation of the Pangong Range. It first drops below and then again climbs above the line of eternal snows up to 88° E. where it dies out a little to the north of 32° N. in the Lharikopo-Melong massif, which has an elevation of 6,300 meters.

To the south of the Pangong Range and its eastern prolongation (between it and the Aling-Kangri) a large plateau-like upland plain is situated at about 4,500 meters above sea level, occupying the territory between the Karakorum and the Transhimalaya. Its expanse of steppe is sometimes intersected by low transverse ranges and in the gently sloping depressions are situated flat-bottomed lakes that have no outward drainage.

To the north of the eastern prolongation of the Pangong Range extends the broad Buka-Mangna Range which is parallel to it. Khuan Ti-tsin' assumes that this is a continuation of one of the ranges of the Karakorum. It consists of crystalline metamorphic rocks, originating in the

Hercynian phase of folding. In the west the Buka-Mangna extends approximately along the parallel of 35° N. The highest part of the range in this section is situated in the limits of 84-87° E. Further to the east it drops down sharply and changes orientation to the southeast. Between 88-90° it again climbs sharply and evidently passes into a rather isolated sector of the range called the Duplex Mountains, attaining, so Bonvalot surmises, an immense elevation -- up to 8,000 meters above sea level. The pass of the same name through these mountains is situated at an elevation of 5,462 meters. The eastern end of the range is situated at 92° E. where it is bounded by the headwater streams of the Yangtze: the Drechu River on the south and the Ulan-Murenem on the north. However, one should consider its eastern prolongation to be the watershed between the Mekong and the Yangtze (as Khuan Ti-tsin' proposes).

To the south of the Buka-Mangna Range is located a valley whose floor has an average elevation of 5,022 meters which de Rhins calls the Valley of the Twin Lakes. To the south of it the explorer crossed three parallel mountain ranges of identical height. He considers them to be spurs of the Tanghla Range, being, in the opinion of Khuan Ti-tsin', an eastern continuation of the Muztagh-Karakorum.

As N. M. Przheval'skiy writes, the Tanghla constitutes a broad plateau, possibly one of the highest in Tibet, and it has very gently sloping grades. (From the north the length of the slope is 130 kilometers and from the south, about 80 kilometers. The falloff per kilometer to the north is five meters and to the south, 8 meters.) The Tanghla Range extends along the plateau. It has individual dome-shaped peaks that are eternally snowcapped. Judging from the description by Przheval'skiy, the Tanghla has the appearance of an arched uplift. Its structure, in our opinion, is the result of the appearance of neotectonics on the upland, forming a broad and gently sloping anticline. V. M. Sinitsyn considers that gentle dislocations are generally characteristic of the central massif of Tibet (the Changtang). "Fragmentary data," he writes, "give evidence of the broad development in it (the central massif of the Changtang -- B. Yu.) of gently sloping and not everywhere dislocated deposits from the upper Paleozoic, the Jurassic, Cretaceous and Tertiary systems". (V. M. Sinitsyn, "Principal Features of the Tectonics of China." In the work Problems in the Geology of Asia.)

The name Tanghla, according to Przheval'skiy, can be applied to the entire plateau on which are scattered individual groups of mountains that are topped by eternal snows. The highest peak -- Basudan-ula, is 6,096 meters high. A hilly area is situated between the mountains. In general, however, the Tanghla Plateau constitutes a rolling surface.

The Tanghla Pass through the range and plateau is easily passable and has an elevation of 4,993 meters. The elevation of another pass -- N'yakamarpo -- is 4,950 meters. Above the pass, both to the right and to the left, rise mountains covered with glaciers. They have local relief of 700-1,000 meters, the glaciers flow down from them to the saddle of the pass. Over the valleys of the Mur-Usu and San-Chu Rivers, flowing from the north and from the south from the plateau surface, the passes rise, respectively, 610 and 640 meters in all. The peaks, white with eternal snows, do not stretch out in a continuous line but rise up as islands on a general background of mountains. There are very few cliffs on the range but talus of clayey shale is prevalent.

The eastern part of the Tanghla serves as the watershed between the Indian and the Pacific Oceans. On the northern slope several sources of the Yangtze rise, and on the south -- several sources of the Salween. In addition, in the place where the Tanghla passes into the Dalai-Lama Range, branches of the Mekong River flow from its northern slope.

To the south of the Tanghla, between it and the Transhimalaya, is a broad hilly plain. Its eastern part is occupied by the basin of the headwaters of the Salween. A large part of the streams and rivers that form the Salween rise on the southern slopes of the Tanghla, and considerably fewer, on the northern slopes of the Nyenchen-Tanghla. The western part of the plain is part of the basin of interior drainage and is drained by the Dzichu-Tsangpo, which feeds its waters into Lake Seling. The sources of this river, also rising on the south slope of the Tanghla, are distinguished from the sources of the Salween by gently sloping watersheds and small mountain massifs. Further south, however, the watershed becomes scarcely noticeable and it is formed by a flat plain with a number of large lakes. The plain in the eastern part has the appearance of a plateau with low domelike hills, locally drawn out like small ranges; in the depressions between them there are broad hummocky swamps.

The Kunlun is the lofty uplifted northern edge of the Tibetan upland. This is the largest mountain system of Asia, extending for approximately 2,500 kilometers between 77 and 105° E. The northwestern wing of the Kunlun, facing the Tarim Depression and, in part, the Tsaidam, has an east-west orientation; the southern wing, however, extending from the headwaters of the Hwang-ho to the bend in the Yangtze, has a north-south orientation.

The width of the Kunlun varies from 150 kilometers and less in the west to 300 kilometers in the east. The average elevation of its crest is 6,000 meters. Many peaks rise to 6,700 meters, and individual massifs soar to 7,000 meters and more, for example, the Muztagh massif

is 7,282 meters; the highest point, however, is the pyramidal peak Ulug-Muztagh (in the Przheval'skiy Range) -- 7,723 meters. The height of the passes is up to 5,500 meters.

The Kunlun arose in the early Variscian or Bretonian subcycle of the Variscian orogeny. The ancient Variscian structures were then uplifted, completely transformed, and took on the morphology of typical alpine structures (Khuan Ti-tsin', 1952, page 11). Outflows of lava and volcanic eruptions took place at the time of these transformations. Speaking of the tectonic characteristics of the Kunlun, V. M. Sinitsyn calls our attention to the fact that here are clearly expressed two systems of deep regional faults, reflecting the general block structures of the earth's crust. This northwestern system appears, in particular, in the orientation of the ranges in the Western Kunlun and a northeastern system in the middle Kunlun. Their intersections have the character of terminal connections, and not arched folds as was earlier assumed. These junctions occur in the high mountain plateau of Aksaychin (to the south of Khotan) and at the sources of the Yurun-Kash River.

Like the Himalaya, the Kunlun is continuing to rise and in post-glacial time, chiefly in the Holocene, it rose 1,300-1,500 meters.

The most northern part of the Kunlun (the Tekeliktagh) is made up of metamorphosed shales and sandstones of the Proterozoic, exposed from beneath sloping dislocated strata of the upper Paleozoic. In the ranges situated next to the south (the Kilianskiy, Russkiy, and Marco Polo Ranges) there is found a geosynclinal sandy-slate stratum mostly of the Silurian age. The middle ranges of the Kunlun (Muztagh Karangu-tagh Anne-Machin, Batang) are made up of gneisses and crystalline slates but the southern ranges (Raskemskiy, Kavak-tagh Kukushili) constitute an immense geosynclinal prism formed by thick, complexly warped lower-Paleozoic sandy-shale deposits. Great faults which can be followed for great distances serve as the boundaries for the ranges mentioned.

The Kunlun is divided into the Western, Central and Eastern Kunlun. The Western and the Central are connected together by the Przheval'skiy Range (Arkatagh). The north-south ranges, passing into Yunnan, are called the Sino-Tibetan mountains and are considered the Eastern Karakorum.

K. I. Bogdanovich, studying the Western Kunlun, makes note of its extreme dissection and the impossibility, oftentimes, of determining the orientation of the orographic features since the mountains in some parts are formed by groups of peaks and mountains whose interconnection is difficult to detect. In many places the Western Kunlun breaks down into individual segments which extend in the form of two or three thick folds of 60-90 kilometers in width and forming wild mountain uplifts of difficult access at the points where they come together.



In the Central and the Eastern Kunlun parallel chains are observed that are well-expressed in the relief. They can be traced clearly beginning with the Russkiy (Russian) Range. "The part of the Kunlun in which my research was concentrated" wrote K. I. Bogdanovich "was designated by the general name the Russkiy Range; with extraordinary aptness. . . it was called by the natives by the general name Akkar-chekyl-tagh that is, 'the range of the white snows.' This name accurately describes the character of the range; in the narrowest place along the meridian this range constitutes only a series of sharp crests that rise from 13 to 24 thousand feet (from 3,960 to 7,316 meters) between which turbulent mountain streams flow... The straightness of the orientation of the ranges, their isolation, and the predominance of longitudinal valleys that are joined by wild transverse canyons distinguish the Russkiy Range from the part of the mountains, for example, to the west of Polu (the Keriyskiy Range) and in the Tiznab basin." (Works of the Tibetan Expedition, St. Petersburg, 1889-1890, part 2, page 26 and following.)

Besides the features indicated, the Kunlun Mountains are characterized by an echelon arrangement of their ranges, something also noted by K. I. Bogdanovich.

N. A. Belyayevskiy believes that in the Kunlun there are outer and inner ranges in relation to the Tarim Depression. The southern, or inner ranges are separated from the outer by longitudinal depressions, one following the other, in tectonic respects representing typical synclines.

The range of outer mountains ends in the high Tekeliktagh Range. The southern ranges, framing the Tsaidam from the south, are the main segments of the Central Kunlun -- the Bokalyktagh (Marco Polo Range), the Kolumba, Tolay, Kukushili, Burkhan-Budda and Moscow (Moskovskiy, Achikkol') Ranges.

The northern slopes of the Kunlun, facing the Tarim Depression, are steeper and longer, especially in the western part, than are the southern slopes of the interior ranges which join the high Tibetan upland. The northern slopes are framed by low sterile spurs furrowed by deep river valleys and the dry channels of intermittent streams. For a distance of 65-70 kilometers a desertlike slope drops off from these spurs to the Takla-Makan. This slope is of gravel and pebbles, locally mantled by deposits of waterborne sand. It has been channeled by deep and narrow washes through which flow small streams that dry up in the summer. Areas of this type are called "say" by the local inhabitants. (They also use the same word to refer to intermittent streams.) The plain of the Takla-Makan Desert approaches the slope at an elevation of about 1,350 meters.

The character of the northern slope in the western part of the Kunlun has been adequately described by M. V. Pevtsov near 77° E. The northern outliers of the range, according to Pevtsov, have a north-west-southeast orientation and are distinguished by an unusually intense dissection, sharpness of crests and an extraordinary steepness of slope. Everywhere they are cut up by a labyrinth of narrow, winding, complexly branching valleys and gloomy canyons. The slopes of the valleys and canyons are almost perpendicular and the gradients of the streams have a very steep fall. As a result, after each heavy rain in the mountains, turbulent streams rush downward from the mountains with a deafening roar. Springs are few in number and yield little water and there are no perennial rivers, despite a relatively great quantity of precipitation, since the waters flow off very rapidly onto the adjoining northern plain. However, they disappear on the way into the loess-like deposits on the lower stretches of mountain valleys and again appear in the form of small perennial springs on the plain. The great steepness of the passes, the heavy dissection of the mountains, the great volumes of talus and the turbulent rivers make the Kunlun here an area through which it is difficult to pass.

The heavy dissection of the mountains and their sharply expressed high mountain appearance in this region of the Kunlun are associated with a whole series of causes. First, there is relatively low precipitation here, as evidenced by the bad quality of the mountain pastures and the small spruce and juniper forests situated here mixed with black currant bushes, mountain ash, roses, honeysuckle and willow. Secondly, such a geomorphological character of the Kunlun mountains is characteristic only of those sectors for which Lake Lobnor serves as the local base level. This lake is situated less than 800 meters above sea level. The valleys of the rivers that descend from the Kunlun onto the higher plain at the foot of the mountains and which disappear into the sands are not incised so deeply, although they cut through ranges that have an absolute elevation as great as the former. Finally, sharp forms also are related to the hard Proterozoic sandstones and shales making up the northern ranges of the Kunlun.

Beyond the meridian of Khotan the outer ranges decrease in elevation and gradually disappear, passing over into the so-called Keriyskiy plain, situated at the foot of the mountains and adjoining the foot of the inner ranges on the north. The width of the Kunlun here is considerably smaller. In the sector 80° 30' - 82° E. is a clearly expressed transition to soft rounded peaks and moderately deep valleys that are typical of the eastern part of the range. Glaciers, glacial lakes and moraines of the Raskem type (that is, similar to those found in the basin of the Raskem-Dar'ya River) disappear as you penetrate into the dry interior but the elevations remain great. The principal crest of the interior range has an elevation of about 6,000 meters and the passes lie at an elevation of 5,200-5,300 meters.

To the east of the 82nd meridian the slopes of the Russkiy Range are already turned towards the Tarim Depression. The Russkiy Range is part of the second chain of the Kunlun Mountains, counting from the north. It rises up in the form of a colossal wall beyond a gently slopping desert plain which rises towards the mountains up to an elevation of 1,200-1,350 meters. It is locally dissected by ravines and deeply incised (up to 300 meters near the foot of the mountains) trench-like canyons of the rivers. Its highest snow-covered section with peaks up to 6,626 meters, is situated to the west, although ice and eternal snows also are found in several mountain groups to the east, where Mt. Aktagh, 6,392 meters high, attains the maximum elevation.

The inner chains of the Kunlun are higher than those in the north, and like the Ladak in the Himalaya, serve as the main watershed of the Kunlun. The Yurunkash, Keriya and Cherchen Rivers, flowing from them in deep and impassable canyons, cut through the outer ranges. But, similar to the Ladak, the inner ranges do not serve as a watershed for their entire distance, since in their turn they are cut through in the west by the Yarkendom and Karakash.

The absence of a single watershed for the entire distance of the Kunlun, together with the echelon-like arrangement of the ranges and the high uplifted valleys, confirms abundantly that this mountain country has undergone large-scale post-Hercynian tectonic changes causing an irregular uplift and a mixing of its different parts.

Among the inner ranges, the highest is the watershed range -- the Przheval'skiy (Arkatagh) Range with Mt. Ulug-Muztagh covered by eternal snows and glaciers. However, eternal snows and ice also cover mountain ranges which are a prolongation of the described range to the west of Ulug-Muztagh. This range, having an almost east-west orientation, can be regarded as the backbone of the Kunlun (Foreign Asia [Zarubezhnaya Aziya], 1956).

In the north, in front of the Przheval'skiy Range (between it and the Russkiy Range) a broad expanse is situated occupied by a wild and barren high-mountain plain with an average elevation of 4,500 meters. On this plain are situated disorderly-arranged low mountains and narrow ridges. Low hills of sand and gravel are scattered here and there. Between the ridges and the spurs dry "saw" are oriented towards the northeast, these belonging to the Cherchen Basin. The area is so dug up that it resembles a gigantic plowed field. But at the very foot of the Przheval'skiy Range it takes on the appearance of a rolling plain. This plain on the south is adjoined by parallel or almost parallel (to the main range) mountainous spurs which are separated from one another by longitudinal valleys.

The Przheval'skiy Range in places consists of a series of parallel ranges of which four may be regarded as major. It is not always easy to say which of them is the principal one. There are no gaps in the range, the elevation of the passes is as much as 5,578 meters. The southern slope of the range is considerably steeper than the northern slope and its precipitous spurs are shorter. This slope grades into a rolling surface which on the south joins with the high upland plain of Tibet.

To the south of the Przheval'skiy Range is situated the Kukushili Range with a length of about 900 kilometers. This is the next inner range of the Kunlun. Both ranges are separated by a broad (40-60 kilometers) intermontane valley whose floor has an elevation of 4,900 meters. Individual low mountains and hills arise amidst the valleys. In the depressions between them are situated numerous lakes which are fed by brooks and streams from various directions.

If the northern ranges of the Kunlun, especially in the west, are distinguished by steepness of slope, deep dissection and sharply expressed individual peaks, then the mountain chains like the Kukushili, situated in Tibet's area of internal drainage, are a complete contrast. Local lakes serve as their local base level. These lakes are situated at about 4,900 meters above sea level. Erosion here takes place less forcefully, and the material, due to the absence of drainage to the outside, is not carried away. The Kukushili Range is characterized by gentle slopes, an even and rounded crest, individual domeshaped peaks which rise but little above the crest and an almost complete lack of cliffs; the entire relief is softened by a mass of detrital material. The highest points of the Kukushili Range, for example, Mt. King Oscar, rise up to 6,000 meters. The range rises 300-600 meters in all above the plains which approach its northern and southern foot. In places it is so gently sloping and so weakly expressed on the landscape that you would not immediately regard it as a mountain range. This was the case with Littledale when he climbed the range from the north. To the east the Kukushili passes into the Bayan-Khara-ula Range, which serves as a watershed between the Hwang-ho and the Yangtze.

The range of the Kunlun system next to the south is called the Dunbure (Dungbure). It also maintains a constant orientation. It extends from 87° 30' E. eastward to the headwaters of the Chumar River, that is, for more than 300 kilometers. The Dunbure, so Khuan Ti-tsin' believes, serves as the boundary between the Kunlun and Karakorum rock types: "...to the north of it shales and graywacke of Kunlun phases predominate, but to the south, in the Buka-Mangna and Tanghla Ranges, limestone with organic residues and red banding is the principal rock. It is possible that a part of these limestones is Mesozoic, whereas the

red banding seems to be Triassic and/or Cretaceous. (Basic Features of the Tectonic Structure of China [Osnovnye cherty tektonicheskogo stroeniya Kitaya], Foreign Literature Publishing House, 1952, page 46.)

The distance between the Kukushili and Dunbure Ranges is 50 kilometers. The plain which separates them has a hilly relief and large shallow spring-fed lakes. It drops downward from east to west. Like the Kukushili, the Dunbure Range is gently sloping, strongly depressed, and has soft gentle relief features. A whole series of small streams flowing from the range to the north, east, west and south, emanate from the broad and flat watershed. There are few cliffs in the mountains, but talus is widespread. The highest parts of the crest extend beyond the line of eternal snows in the form of individual peaks and small mountain groups.

There are hummocky swamps on the northern slopes of the range. At the meridian of 95° E. the northeastern spurs of the Dunbure approach the Kukushili and the southeastern spurs approach the Ulan-Ula Range which is part of the system of northeastern dislocations. (It is unnecessary to describe the eastern part of the Kunlun in this work, since it is not situated in the boundaries of Tibet proper.)

In concluding our remarks about the plains and mountains of Tibet it is interesting to cite the following data from Sven Hedin, analyzing the heights of the passes, mountain crests, and valley floors (the latter along the shores of lakes). The explorer came to the conclusion that the crests of the ranges rise above the passes on an average of 300 meters; by approximately the same figure the passes rise above the floors of the valleys and intermontane plains. However, in western Tibet the average elevations of the ranges themselves and the average elevations of the passes are greater than in the eastern part, so the difference, as can be seen from the table, is considerable.

<u>Elevations</u>	<u>Western Tibet, meters</u>	<u>Eastern Tibet, meters</u>	<u>Difference, meters</u>
Passes	5,477	5,189	288
Base	<u>5,109</u>	<u>4,910</u>	<u>199</u>
	368	279	89

Note: For computing mean elevation of the base S. Hedin used the mean elevation of intermontane valleys (along the surface of the water in the lakes).

The average height of the mountain crests in the west of Tibet is 5,800-5,900 meters, and in the east, 5,500 (to be more exact, 5,470 meters, according to Hedin.

## PRINCIPAL TYPES OF RELIEF

From what we have already said, it is evident that the relief of Tibet is complex and is distinguished by a multiplicity of forms which arose as a result of the prolonged interaction of many factors. It has a complex geological history leading to the lifting of this sector of the earth's crust to an immense elevation and its fracture into sectors of various hypsometric levels; a varied lithological composition of the rocks; differences in climatic conditions of individual regions in the territory; uneven intensity of exogenous processes and many others. Nevertheless, according to characteristic shape, relative relief and other factors, especially morphological, all this variety, we feel, can be reduced to four basic types of relief.

- I. High mountain plains, crossed by ranges of moderate height.
- II. A type of relief combining ranges of great and moderate elevations and high upland plains.
- III. High mountain relief.
- IV. Badlands type.

In addition, we can also distinguish the graben-valley of the Indus-Tsangpo (V) separating the Himalaya and the Transhimalaya and constituting a large independent geomorphological element in the relief of Tibet.

The basic types of relief create typical landscape pictures in broad areas. However, in the regions where they predominate within each of these types individual sectors with considerable differences are always encountered. This also makes it possible to distinguish subtypes. Without giving a detailed description of each type of relief, which would lead in large part to a repetition of what we have already presented in this chapter, we limit ourselves to describing their characteristics briefly.

High uplifted plains crossed by ranges of moderate height. This type of relief occupies an immense area in the north of Tibet, situated for the most part in the territory of the so-called Changtang desert, which extends to the north of the Transhimalaya between the meridian  $81^{\circ}$  E. and the boundaries of the region drained by the headwaters of the Hwangho, Yangtze, and Salween. This type of relief is also characteristic of the northern slope of the Great Himalaya Range. At the present time the Changtang has taken on the appearance of a high mountain plateau whose inner regions are without drainage to the outside. The plateau, characterized by a descending type of relief, has a great deal in common with the geomorphological landscapes of the Eastern Pamirs. The same -- or even broader -- valleys are typical here, filled with alluvium and diluvial deposits, separated from one another by low

mountain ridges with several hundred meters of relief in all. These valleys or upland plains are the most characteristic feature of the landscape of the Changtang.

The mountain ranges crossing the plains most frequently from east to west have gentle slopes and weakly dissected crests rising but little above the levels of the passes of the surrounding ranges. Even the peaks covered by eternal snows, with rare exceptions, have domelike contours. The entire appearance of the ranges with gentle, suppressed contours, have features characteristic of a landscape with mountains of moderate height. But in contrast to Central Europe where the concept of middle-sized mountains was first used, the mountains of the Changtang have an extremely great elevation above sea level, are not forest covered, and lack a thick mantle of soil. Their relief is softened by a layer of weathered material made up of large fragments of rocks and gravel that is typical of mountains in regions with a deeply continental location. The plains are hilly in the most widely distributed subtypes of the type being described. But the hills do not conceal the horizon to such an extent that you can not see the ranges in the distance or their high peaks made white by the eternal snows. Such, for example, is the southern part of the Changtang, to the south of the de Rhins and Tanghla Ranges, where travelers can go for weeks in the open upland hilly plains with the horizon stretching far before them, and where the area is easily passable for various kinds of transportation. The hills in large part are gently sloping, dome-shaped or flattened on top, either scattered in the plain or drawn out in east-west ridges. The geological structure and the geomorphology of these hills leaves no doubt that these are not the ruins of formerly high mountains but instead are independent structural elements. We call such relief "open upland hilly plains," subtype I, 1.

The area near the western end of the Tanghla Range looks different. The hills here stand in a close disorderly group, separated by a complex labyrinth of narrow passageways. This relief we call "upland plains with closely spaced hills," subtype I, 2.

The characteristics of the geomorphological landscape in the eastern part of Tibet are unusual. Their singularity consists in the fact that everywhere there are clearly expressed traces of ancient glaciation -- moraine hills, lakes and boulders. These make movement exceedingly difficult. We call this relief "hilly upland plains with clearly expressed traces of glaciation," subtype I, 3.

In the northeastern part of Tibet, between the Przheval'skiy and Dupleix Ranges, the forces of volcanism play a decisive role. Here our attention is drawn to volcanic cones (the volcanoes Ruisbrook, Reclus, Byussi) and hills with a singular structure. These hills, usually

standing close to one another, are similar in appearance to flattened cones. They are made up of reddish sandstone and conglomerate-like rock, covered on top by horizontal strata of black tuff. We call this relief "hilly upland plains with traces of volcanic activity," subtype I, 4.

In the region of the Aksayohin Depression and to the south of Lakes Ligten and Markham, gently sloping and broad ranges are not characteristic. Instead we find those which are low, narrow and difficult to travel through. They have an east-west orientation and are sometimes separated by narrow or broad valleys. We call this type "upland plains with narrow, closely-spaced east-west ranges of low mountains," subtype I, 5.

In the Karakorum and in parts of the Changtang adjoining the Karakorum, together with the east-west mountain ranges, ranges are often encountered with a north-south or a northeast-southwest orientation and bordered by flat intermontane plains. Here has developed an unusual relief with a "cellular" pattern. We call it "upland plains with intersecting ranges having an east-west and north-south orientation," subtype I, 6.

Finally, we can distinguish still another subtype, situated on the northern slope of the Great Himalaya Range. The northern slope of the main range is leeward to the moist winds of the Indian Ocean and, consequently, extremely dry. It drops off gently to the north, passing at an elevation of 4,500 meters into an intermontane depression between the Ladak Range and the ranges of the Nepal-Tibetan watershed on the one hand, and the Great Himalaya Range on the other. The formation of relief here takes place under conditions of an arid climate in the west and an inadequately moist climate in the east and a relatively weak development of erosional processes. On the northern slope there are no such deep valleys and canyons as on the southern slope and the hydrographic network is not very intricate. On the landscape can be seen low east-west ranges with the appearance of "middle-size mountains" (for the most part in the eastern part) and desert-like or steppe-like hilly plains with a rocky or Solonchak surface. They have lakes that have no drainage to the outside; they are bounded on the north and south by low ranges (in the western part). In general, the northern slope of the Great Himalaya Range is very similar to the Changtang (especially in the west). Its distinction, for the most part, consists only in the fact that the northern slope of the Himalaya is drained by rivers, many of which flow to the ocean. We call this relief "upland plains of the northern slope of the Himalaya drained by rivers flowing to the ocean," subtype I, 7.

High mountain relief, in combination with ranges of middle size appearance, is the type of relief characteristic of the Transhimalaya, the Karakorum (the Tibetan part of this mountainous country), and the



region of the Changtang near the Duplex Range. In the region where this type of relief is found, as well as in the Changtang, there are extensive intermontane valleys and flat basins, many of which are occupied by large lakes. But in the morphological landscape ranges of moderate and high relief have very great significance.

The Transhimalaya is uneven in its outer appearance. The middle-sized mountains appearance with soft contours, dome-shaped peaks, shallow intermontane valleys with a mass of weathered debris on the slopes, exists for the most part in the northern and central parts -- the drier parts. But the same picture can also be seen in other places, for example, in the Doktol area on the left bank of the upper course of the Tsangpo (true, there are no barren mountains here; on the contrary, the mountain slopes are covered with succulent pastures). At the same time, high mountain landscapes with sharp peaks, from time to time covered with eternal snows, with steep slopes and deep valleys, predominate in the southern ranges of the Transhimalaya, often, however, also on the northern mountain slopes, especially those like the Nyenchen-Tanghla and the Aling-Kangri. The craggy peaks are crowned by eternal snows and the sharp profiles of the crests can be also seen in several inner ranges -- in the Torgot-Kangri, G'yak-Kharma, Lunkar, Kanchung and Lapchung Ranges.

For the northern and inner ranges of the Transhimalaya, having no external drainage, and situated in a region of predominantly descending relief, the mountain forms are characteristically typical of those in desert regions of interior drainage (without sharp crests and peaks) and to a lesser extent, erosional forms. We call this "relief with a predominance of middle-sized mountains," subtype II, 1.

To the east and to the north of the sources of the Singi River for tens of kilometers there extends a desert area in which the mountains in their morphological features are not altogether similar to typical middle-sized mountains; they do not have rounded contours but are similar to gigantic bells forming what looks like frozen, disorderly-scattered waves. This makes movement extremely difficult in all directions. We call this "relief with unusual disorderly-scattered mountains having a bell shape," subtype II, 2.

The northeastern part of the Transhimalaya can be separated out as a subregion. In this area are situated the largest of the Tibetan lakes -- Seling, Dangrayum, Dzharung and others. Some of them are situated in broad flat basins with low banks, others are surrounded by closely-spaced mountains, some highly dissected and planed off, others with steep slopes and sharp peaks covered by eternal snows -- this we call "medium or moderately high mountain relief with intermontane basins occupied by large lakes," subtype II, 3.

In the lower course of the Singi River and in the southern ranges of the Transhimalaya that are drained by the Tsangpo River and which are experiencing a stage of development of rising relief, high mountain landforms play an important role in the landscape; most common are slopes cut by erosion and valleys which often assume a canyon-like appearance. The upper parts of the mountains, however, carrying a cover of eternal snows and ice, are distinguished by peaks and crests with sharper, more abrupt and dissected forms -- "relief with a predominance of ranges of a high mountain type," subtype II, 4.

The eastern spurs of the Karakorum, situated within Tibetan territory, are also characterized by the type of relief described and, as in the Transhimalaya, ranges of middle-sized mountains predominate over ranges with high mountain landscapes. The intensely reduced and worn-down mountains of the Karakorum have acquired gently-sloping shapes and flattened crests whose passes become swampy in the summertime, as happens in the Tanghla and Dungebure Ranges in the east of Tibet; high mountain landscapes are encountered in the higher ranges, for example, in the Tibetan Karakorum, near Lakes Charol and Arport and in individual high massifs which extend beyond the line of eternal snows. This we call "relief with a predominance of ranges of the middle-sized mountains," subtype II, 5.

As an example the type of relief (II) described in the Changtang, a large mountainous sector situated between the Dupleix and Tanghla Ranges can serve. It is characterized by a combination of two systems of ranges, northeast-southwest (and north-south) and east-west oriented.

High mountain type of relief is characteristic for the most part of the northern and southern borders of Tibet, that is, the Himalaya and Kunlun Mountains, especially the first. The extremely great absolute elevation of the mountains, the nearness of the Hindustan Lowland, and the abundance of moisture brought from the Indian Ocean resulted here in an exceptional development of erosion, dissecting the Great Himalaya Range with extremely deep V-shaped valleys and canyons with a depth of hundreds and thousands of meters. The high mountain appearance of the mountains is formed not only because the Himalaya are in a region of rising relief and subject to intensive erosion but also due to the thick glaciation, which makes possible the appearance of sharp peaks and crests with cirques. We call such relief "high mountain relief with intense glaciation," subtype III, 1.

The high mountain landscapes of the Kunlun are less grandiose since the erosional processes here, due to the greater aridity of the climate, are less intensive, and glaciation has also developed less intensely. The high mountain landscapes in the Kunlun in the territory of Tibet can be divided into the Przheval'skiy Range and the mountains

bounding the Aksaychin valley on the north. They are more developed on the northern slope of the northwestern Kunlun -- beyond the borders of Tibet proper. We call the Kunlun high mountain ranges "high mountain relief with relatively modest dissection and relative relief and weakly developed glaciation," subtype III, 2.

The singular type of geomorphological landscape, the "badlands," has developed in the Sutlej Basin. This type of landscape is characteristic of regions with a special geological structure and an arid or semi-arid climate. As a result of the erosional dissection (due to an inadequacy of moisture), thick strata of horizontally situated ancient lake deposits in the headwaters of the Sutlej have formed deep canyons and a dense network of repeatedly branching canyons with dry washes running into them. The canyons and ravines are often separated by narrow and steep-sloped watersheds with sharp crests almost bare of vegetation. However, the broad watershed areas of the dry steppe are flat and hilly. In its principal features the landscape of the Sutlej Basin is close to a badland -- type IV; the more the dissection is intensified, the more it will resemble a typical badland.

The graben valley of the Indus-Tsangpo. The deep valley of the Indus-Tsangpo is one of the most important elements sharply standing out in the relief of Tibet. The graben separates the Himalaya system from the Transhimalaya system. In the north it is bounded by the Kailas Range and its eastern prolongation and in the south by the Ladak Range and the Nepal-Tibetan watershed. The general orientation of the graben is from northwest to southeast. In the region of Lakes Manasarowar and Rakas the graben is intersected by a young north-south uplift. Its height above sea level is therefore the maximum here -- almost 5,000 meters. To the northwest of this uplift the Gartang River, the left headstream of the Indus, flows through the graben at an elevation of about 4,500 meters and to the southeast -- the Tsangpo River, whose elevation at the headwaters attains an elevation of more than 4,500 meters and in the lower course drops down to 3,000 meters. The distance between the crests of the ranges, bordered by grabens on the north and south, is 30 kilometers and less to the west of the uplift (from the region of Lakes Rakas and Manasarowar), that is, in the sector where the Gartang flows, and 70-80 kilometers (sometimes considerably less) where the Tsangpo flows to the east of the uplift. The width of the graben floor is variable. In some places the outliers of the Kailas and Ladak come so close together that the Tsangpo River flows in a narrow impassable canyon. In other places, however, for example, in the lower course of the Tsangpo, the width of the graben floor is as great as 10-20 kilometers and there is an alternating of widenings and contractions. The presence of lake deposits in the wide places gives evidence that in the past they were occupied by lakes.

The floor of the graben where the Tsangpo flows is flat or hilly. Here and there it is covered by accumulations of gravel, sand hills, or dunes. The spurs of the Transhimalaya and the Himalaya are intensely dissected and sometimes have the appearance of low craggy mountains. Terraces have formed along various parts of the river, and these have a width between several hundred meters to 3-4 kilometers.

In the western part, along the Gartang River, the graben is characterized by exceptional straightness (it is oriented from southeast to northwest) and a true trough-like structure. Its floor is also hilly.

#### CLIMATE

The climate of the Tibetan highland, and especially its western part in which Tibet proper is situated, is characterized by features that are almost without parallel in other parts of the globe, with the exception of the Pamirs. Its most distinctive features are very low mean temperatures during the course of the whole year and great dryness of the air. However, the Tibetan climate was not always like this. G. Austen, on the basis of investigations of fossil bones of the Tertiary period found in Tibet at an elevation of 17,000 feet (about 5,200 meters) came to the conclusion that the climate of Tibet, which now resembles the Arctic, in Tertiary times was warmer and rhinoceroses and other warmth-loving animals could live there (Burrard and Hayden, 1933).

Cooling on the Tibetan highland was due to tectonic causes: the highland was uplifted to a great absolute elevation and blocked off from the influence of the Indian Ocean.

The distinctive features of Tibetan climate are due to the very great absolute elevation and the isolation of its territory. The Himalaya to the south, the Karakorum, Hindukush and Western Himalayan Ranges to the west hinder access of moisture to Tibet -- in the first place from the Indian Ocean, and in the second -- from the Atlantic. All this causes low temperatures and extremely low atmospheric humidity in almost all of the territory of Tibet (only one-quarter of that at sea level). (Atmospheric humidity increases in the summer when the major part of the precipitation falls.) Therefore, despite the fact that Tibet is situated in the same latitude as the southern part of the Mediterranean Sea and the northern rim of Africa, the climate in a large part of its territory is severe, sharply continental, with great annual and diurnal (in summer) ranges of temperature. In addition, the quite intensive cyclogenetic activity causes changeability of weather in the summer. Thus, the climate of Tibet combines features of the climate of an interior Asiatic desert, polar countries, and also a monsoon climate. Hu Shen-su calls it a continental-monsoon climate.

A. I. Voyeykov, discussing the monsoon features of the Tibetan climate, notes that since in Tibet in the winter the winds have almost the same direction as in the summer, deviating only a little to the north, this country can not be considered as belonging completely to the monsoon region; in monsoon regions the winds in summer and winter have opposite directions. But he considers that in Tibet conditions for the distribution of hydrometers is similar to those which characterize the monsoon climates, that is, a moist rainy summer and a dry winter.

Tibet is an arid region, the amount of precipitation dropping off from the southeast to the northwest. A small part of the precipitation, that of winter, is brought into Tibet from the Mediterranean Sea. G. N. Vitvitskiy writes: "It is well known that along the northern border of the subtropical anticyclones there is a movement of cyclones of the temperate latitudes from west to east. Thus the movement of Mediterranean cyclones through Central Asia occurs in a direction towards the Himalaya. Part of them pass to the south of the Himalaya into Southeast China. Some cyclones penetrate into Tibet and Sin'tszyan. The winter precipitation of Kashmir, Tibet and Sin'tszyan is associated with these cyclones." ("The Circulation of Air Over China," News of the Academy of Sciences of the USSR [Izv. AN SSSR], geographical series No 2, 1956, page 36.)

The basic mass of precipitation, however, is brought into Tibet from the Indian Ocean by the monsoons blowing from May through September, although, as is well known, by far the greater part of the moisture of the monsoon falls on the Himalaya and Gandisyshan (Transhimalaya) which stand in its path. The monsoons reach the southern regions of the Changtang so completely exhausted of moisture that they yield little more than 100 millimeters of precipitation (Khuan Fen-shen, 1954), and even less in the center of the Changtang.

In general, rains do not come to Tibet in the springtime but in the second half of the summer, since the monsoons arrive late. They reach the northwestern and central regions of Tibet only on 20 July (Sandberg, 1906).

From the territory of Tibet proper the eastern part of the highland, lying beyond its boundaries, is distinguished by the amount of precipitation. Here, in the east, in the course of three or even four summer months abundant and almost daily rains fall, which in the high mountains are replaced by snowfalls or hail, often with strong thunderstorms. The rains are brought, wrote Przheval'skiy, by southwestern winds into the western part of the highland and by southeastern winds into its eastern parts. The explorer believed that the Indian monsoons bring the moisture to the Tibetan highland.

A. I. Voyeykov explained the origin of the rains in Tibet in the following way: at the foot of the Western Himalaya the moist monsoon blows from the east-southeast and between the northern end of the Bay of Bengal and the Eastern Himalaya its main direction is from the south and south-southeast. Taking into consideration that in the Eastern Himalaya there are deep canyons and the crests of the ranges there are only a little higher and it is locally even lower than in the Tibetan highland, the scientist conjectured that a great quantity of vapor is carried northward from the warm and moist area situated to the south of the Eastern Himalaya. This vapor results in abundant precipitation in the northeastern and southeastern parts of Tibet. The vapor is carried eastward along the Tibetan highland by the predominantly western air currents.

At the present time there are also other explanations.

V. A. Dzhordzhio and M. A. Petrosyants (1950) note that there is an anticyclone in summer over the territory of Tibet. This anticyclone is part of the "subtropical belt of high pressure," girdling the globe at latitudes 25-30° and consisting of individual anticyclones of a different type. The summer Tibetan anticyclone belongs to the type of orographically caused anticyclones that are situated over broad mountain uplifts. The anticyclone is formed as a result of a combination of several unusual factors. First, in summer the air masses over the highland are heated by the high-uplifted underlying mountain surface. The air temperature over the surface of the broad plateau, uplifted 3-4 kilometers above sea level, proves to be considerably higher than in the free atmosphere. "The heating of the air over Tibet" writes G. N. Vitvitskiy, "is accompanied by some drop in pressure in the layers of the atmosphere near the earth's surface and an increase in pressure in the high layers." ("Circulation of Air Over China" "News of the Academy of Sciences of the USSR [Izv. AN SSSR], geographical series, 1956, No 2, page 41.") Second, the deforming influence of the mountain systems of Central Asia on air currents with a westerly movement, as a result of which an orographic ridge is created in the broad current of free air. The third reason for an increase in pressure in the free atmosphere in summer over Southern Tibet and the Himalaya is the additional heating of the air by latent heat of condensation that is liberated in a layer between 3-7 kilometers during the abundant monsoon rains of northern India, which stimulate an uplift of air along the southern slopes of the Himalaya.

The fact that a summer anticyclone exists over Tibet and that rains occur at the same time seems strange and contradicts the generally accepted concept of anticyclonic dry and clear weather. But it is necessary to bear in mind that the Tibetan anticyclone is a high one of a special kind. It has been established that to the east of the anticyclone, approximately between meridians 90-95° E., there is formed a

deep high trough through which a current of cold air masses flows from Siberia. These air masses drive the local Tibetan air upward and thus facilitate the formation of precipitation in the northern parts of the Tibetan highland. Another deep low (from an elevation of 200 to 5,000-8,000 meters), arising to the west of the anticyclone and shifting at an elevation of 5 kilometers from the territory of the Indo-Gangetic plain towards Tibet, plays an important role in the formation of the depression and the appearance of the monsoon over India. Due to this low, in the central and northern part of Tibet rather moisture-rich monsoon air is sucked in at an elevation of 5-8 kilometers. Since it is convectively instable, thunderstorm activity develops in this current, accompanied by abundant precipitation in the form of downpours. They bring the main quantity of moisture to Tibet. The Indian monsoon hardly penetrates to the north of the Kunlun.

The processes of cyclogenesis which occur over the eastern low often lead to the creation of enclosed regions of low pressure in southeastern Tibet -- at the headwaters of the Yangtze, Mekong, and Salween. These regions of low pressure in their turn suck in monsoon air from the Indian Ocean. According to Przheval'skiy's observations, the fall of precipitation extends to the Tanghla, the further path of the moisture-laden winds being blocked by the high continuous crest of this range, thus playing a role as a climatic divide between Tibet proper and southeastern Tibet.

G. N. Vitvitskiy sees the reason for the summer rains in the fact that the western movement in summer shifts northward, the Tibetan highland proves to be outside its mainstream, and the Indian monsoon begins to develop. The abundance of precipitation in July and August in the Chinese-Tibetan mountains, in his opinion, depends on their satisfactory location relative to the zone of convergence or the trade wind front (the line of division between the Indian monsoon and the north-eastern trade winds of the Pacific Ocean) shifting at this time from east to west (1956).

Tibet and the whole Tibetan highland are a region of almost constant winds, in part attaining storm strength with velocities of 70-75 kilometers per hour. The winds blow in winter, spring, and summer almost daily from morning to sunset. The reason for this is the uneven heating by the sun of the surface of the highland across whose plains the air masses can move without restrictions; this is also facilitated by the nearness of the warm Chinese lowlands and the broad desert basins of the Kashgar and Tsaidam type. But the main reason is the intensification of southeastern movement, and especially the nearness of the jet stream.

The indicated extremes and unevenness of the climate are characteristic for almost all of Tibet but in different parts of it they appear to a differing degree. In the desert of the northwest, the continentality, the rarefaction of the air, and the small quantity of precipitation are felt most intensively; to the southeast the severity of the climate is tempered. In Southern Tibet, in the valley of the Tsangpo and the valleys of its tributaries where elevation above sea level is considerably less and where, due to the presence in the Bhutan Himalaya of deep north-south valleys and gaps in the crest, the influence of the Indian monsoon is more strongly expressed and climatic conditions are favorable for the extensive practice of agriculture and gardening.

Tibet can be roughly divided into three climatic regions: Northern Tibet, Southern Tibet, and the Southern Slope of the Great Himalaya Range. The boundaries between them pass along the same place as the boundary between the physical-geographic regions (see later on).

Low mean temperatures are characteristic of Northern Tibet during all seasons of the year; this is due to great elevation above sea level. (With an increase of each 100 meters the temperature drops by approximately  $0.6^{\circ}$ .) Even the mean temperatures for June and July, as can be judged by existing data, are, respectively,  $7-8^{\circ}$  in all the eastern part of Tibet and  $7$  and  $13^{\circ}$  in its western part. (It is impossible to regard the mean figures cited as completely reflecting reality. In the absence of station observations of many years duration it is necessary to use observations taken en route and at best, short-term station observations which include several months in all.)

Voyeykov considers that the mean annual temperature of the Changtang and also the mean temperature of the seven warmest months in the year -- from April through October -- are lower than beyond the Arctic circle in Siberia (1895). The mean minimum temperatures are low. Even in July a mean monthly minimum temperature of  $-4.2^{\circ}$  was observed.

It should be mentioned, however, that as a result of the small amount of moisture and dust present in the air the underlying surface is heated by direct solar radiation to rather high temperatures, due to which the air over the Tibetan highland proves to be considerably warmer than in the free atmosphere at these same elevations. H. Flohn points out that the temperature at levels from 5,000 to 6,000 meters in July and August over Tibet is greater than in other places and the isotherm of  $0^{\circ}$  is situated above 6,000 meters -- something nowhere else noted at such a high elevation. This circumstance creates relatively more favorable conditions for the growing of plants in Tibet and consequently, also for the life of animals.



The North Tibetan summer is brief; there are still heavy freezes in May and summer really begins in June -- although at the end of this month the large lakes are still covered with ice. The summer ends in the second half of August. By this time the growing season for plants ends and the seeds mature and fall out; herbivorous animals get a thick undercoating of wool.

At the very height of summer sharp drops of temperature sometimes occur -- to  $-10^{\circ}$  and even  $-15^{\circ}$ . At the same time, daily temperatures frequently attain  $+20^{\circ}$  and more, in isolated cases  $+30^{\circ}$ , and Captain Weliby in June noted a temperature of even  $40^{\circ}$  in the sun.

Due to the dryness and rarefaction of the air, the earth's surface at night cools off intensely and there are summer frosts at night, and even freezes are a common phenomenon. Variations between day and night temperatures can reach a high figure. Sometimes in June the daytime temperature dropped from  $+12^{\circ}$  in the shade to  $-14.5^{\circ}$  at night. The same reasons explain the great difference of temperature in the sun and in the shade. It is hot in the sun and a man with an uncovered head can suffer sunstroke; in the shade, however, he is penetrated by the cold and his body and extremities grow stiff.

Summer weather can change during the course of the day, the warm and clear air can be replaced by bad weather, rain and thunderstorms or cold weather with a sharp drop in temperature to a negative figure with snowfalls and blizzards, and a layer of snow several centimeters deep can fall at one time.

July and August are the rainiest months in Northern Tibet, but even in these months the total precipitation is 10-25 millimeters in all. The monsoons reach northwestern Tibet towards the end of July and the rains occur here less frequently and less intensely; about 100 millimeters falls in the course of the year.

At the end of the year the temperature begins to drop rather sharply. Whereas in the middle of August the maximum temperature, judging by short-range observations of individual explorers, was  $+20^{\circ}$ , at the end of this month, at the beginning of September, it dropped to  $+10^{\circ}$  with a minimum as low as  $-10^{\circ}$ .

The weather improves as fall approaches. The fall is the best season of the year in the whole highland. The weather remains clear and dry, winds are rare, and the temperature is relatively even. (Nevertheless in 1879 Przheval'skiy observed ten stormy days, the same number as occurred in November. In December he noted 14 days with strong winds.) In this season, and also partly in the winter, the contours of distant objects become clear due to the dryness and transparency of the

atmosphere; the objects themselves seem considerably closer than they are in reality; the horizon seemingly moves off into the distance; the night sky becomes deep, the stars sparkle brightly and the planets on the dark background of the sky shine with a special and unusual luminescence.

In the course of the fall there are almost constant frosts. In October in the eastern, central and western parts of Northern Tibet have been recorded such low temperatures as  $-23$ ,  $-25$ , and  $-29^{\circ}$ , and in November,  $-33.5^{\circ}$ . At the same time Przheval'skiy observed positive temperatures by day:  $+8.2^{\circ}$  in October and  $+6.2^{\circ}$  in November. Winter snow falls by the middle of October.

The fall and also the winter and spring seasons are distinguished by an exceptionally great dryness of the air. Broad swamps, forming at the time of the summer rains, dry up almost everywhere in the fall and the soil cover becomes highly dessicated. The grass dries out to such an extent that it crumbles if trod upon and animals do not chew it but lick at it with their tongues. The dessication of the soil cover during the fall months is expressed in the most negative way on the development of vegetation in the springtime. In addition, the roots of plants are exposed with the dessication of the soil and this also exercises a destructive influence on them. Snow falling in October heralds the rapid approach of winter. The temperatures become low. According to Fan Sin-lin (1954) the mean temperatures in Northern Tibet in December-February amount to  $-14$ ,  $-15^{\circ}$ . Minimum temperatures drop to  $-30^{\circ}$  and below. In northwestern Tibet minima as low as  $-39.4^{\circ}$  have been recorded.

Winter precipitation is evidently insignificant. Przheval'skiy writes that even in years of heavy snows in Tibet only occasionally does a thicker cover fall than the usual (15-30 centimeters) and it remains along the valleys for only a few days. A large part rapidly evaporates under the great dryness of air existing in Tibet and another part is swept away from the level open expanses and into the depressions by the winds. This circumstance makes possible the existence of the numerous hoofed animals of the highland who can freely get to the food underfoot. But due to the absence of an adequate and stable snow cover which can supply the soil with moisture during spring thawing, there are additional unfavorable conditions hindering the development of vegetation.

From the middle of winter strong winds begin to blow more frequently on the highland, primarily westerly winds, but there is deflection to the north and to the south. The strength of the storm is exceptionally great: clouds of dust and sand fill the air and winds sometimes sweep up fine gravel. They attain maximum force at an elevation of 4,500 to

5,500 meters. With the strong Tibetan frosts the winds constitute a real calamity, threatening with destruction or heavy frostbite anyone who does not succeed in sheltering himself from them.

Spring, especially in the northern and western regions of Tibet, comes late, and the snow begins to thaw only in the beginning of May. The spring is cold and the temperatures right up to July fall below 0° at night. Sometimes considerable frosts occur. The rivers are freed from ice only in April. At the beginning of spring when the jet stream shifts northward, the winds intensify, blowing until May or even June. West winds predominate, the same as in winter.

Little precipitation falls in the springtime. Constant, often heavy night frosts, continuing the dessication of the soil under the influence of the intensifying winds, and the very great dryness of the air, causing a high discharge of moisture from plants, create severe conditions for the germination and flowering of plants.

Since the local relief in Northern Tibet attains several hundreds of meters and even 1,000 meters and more, then, naturally, great vertical differences appear in the climate. Hu Shen-su (1953) specifies several vertical climatic zones for the Tibetan highland, of which the following are characteristic for Northern Tibet.

High mountain climate. This climate is typical of regions which are situated from 5,000 meters and more to the snow line, which is situated at an average elevation of 5,800 meters above sea level. The mean annual temperature is always below 0° and precipitation falls predominantly in a solid form. The vegetation develops under extremely unfavorable temperature conditions; therefore only frost-resistant types with a short growing season survive.

The climate of regions situated at an elevation of 5,000 to 3,900 meters and occupying a large part of the highland is called a climate of high mountain steppes. The frost period is also long here but the mean annual temperature is above 0° and in several regions even reaches 5°. Here grow predominantly Tibetan sedge and in the badly drained places -- swamp plants (Eleocharis). In this altitudinal zone there are summer and winter pastures. Besides grassy vegetation small bushes and dwarf fir trees grow on the moist and cold slopes of the mountains, and in some places the population is even engaged in agriculture.

Above Hu Shen-su's high mountain region it is also possible to distinguish a glacial climate -- a lifeless zone where it is possible to encounter nothing more than individual plants hiding in fissures of cliffs or in other sheltered places. The zone of glacial climate occupies the highest crests of the mountain ranges occupied by eternal snows.

Despite the great absolute elevation of the territory of Northern Tibet in comparison with the Eastern Pamirs, its climate as a whole is more favorable than that of the Eastern Pamirs, with the possible exception of the regions to the north of 35° N. This is due first to the large amount of precipitation falling. Relatively better climatic conditions are confirmed, as will be seen from what follows, by the vegetation cover: in a considerable area of Northern Tibet there is a semi-desert or even a steppe vegetation and scattered spots of agriculture; the great number of wild animals in the area also gives evidence of this.

The climate in Southern Tibet is considerably milder than in Northern Tibet, and its continentality and severity decrease from west to east. This is explained in the following manner: first, Southern Tibet is protected by the mountain ranges of the Transhimalaya from the cold northern winds blowing from the highland; second, there are broad surfaces of plains here, and wide valleys and intermontane depressions with lesser absolute depressions than in Northern Tibet and consequently higher temperatures; third, in the eastern part of Southern Tibet the crests of the Himalayan ranges have deep gaps through which moist air masses penetrate from India.

At the same time, in the climates of both parts of Tibet there is a great deal in common. Thus, in Southern Tibet at elevations greater than 3,900 meters it is possible to delineate three vertical climatic zones similar to those that have been described for Northern Tibet. Southern Tibet is also characterized by extremely low atmospheric humidity, especially in the fall, winter and spring. As on the huge North Tibetan plateau, the population of Southern Tibet suffers from cracking of the face, hands, and lips and the fingernails dry out and break; wooden structures deteriorate prematurely. Many inhabitants preserve pillars and doors of structures by wrapping them with felt.

Finally, strong winds are still another common feature of the climate of both parts of Tibet. In Southern Tibet they blow primarily in the spring and winter and most commonly in the western and central regions.

The members of the British military expedition observed the winds in December 1904 and January 1905 at Tun and Gyangtse. The force of the wind was so great that no one dared to go out of doors. H. Harrer noted strong winds blowing in Lhasa daily after midday during March and April (1947).

Blowing the snow cover from the fields, the winds can inflict great damage on farmers. In order to avoid this, the peasants use a simple and clever method -- they flood the fields with water. When the water freezes the soil is covered with an armor of ice and thereby safeguards it from wind erosion.

In comparison with northern regions, the climate of Southern Tibet is distinguished by temperateness. The summer is warm and moist. The winter is dry with little snow, although, for example, the British military expedition in the winter of 1904-1905 observed a snow cover with a thickness of 20-30 centimeters at Shigatse, and this cover was accumulated during five or six snowfalls.

The winter is mild. The large rivers do not freeze every winter and when they do it is for two or three weeks only; only in a few years is the duration of the ice cover longer. (In the winter of 1864-1865 the Dzichu River near Lhasa was ice-locked for six weeks.)

Spring makes itself felt in February. With its arrival the winds begin to blow systematically. Although spring is cool, it is mild: in the eastern part of Southern Tibet the buds begin to open up by the end of March. Farmers cultivate the fields at the beginning of April. In the middle of the month green sprouts show everywhere at altitudes up to 4,250 meters. In April, May, and the beginning of June the area is characterized by great dryness and is striking in its purity and transparency.

In the western part of Southern Tibet the climate is drier and more severe. In the region of Lake Manasarowar it already is but little distinguished from that of Northern Tibet and a large part of the rivers freeze to the bottom during the winter.

In Southern Tibet below 3,900 meters, according to Mu Shen-su, it is possible to delineate two climatic zones.

The arid climate of river valleys, having elevations of from 3,900 to 3,000 meters and subject to the influence of the monsoon. The annual amount of precipitation is 400-600 millimeters; in individual years, however, when the monsoons are strong, the precipitation may be many times greater.

A large part of the precipitation falls in the form of downpours. A considerable part rapidly evaporates; another part, also considerable, flows rapidly along the slopes of the mountains and valleys. Thus, in

the long run, the vegetation suffers from an inadequacy of moisture; this is even more intensified by the fact that generally little precipitation falls in spring. Artificial irrigation is necessary for the successful practice of agriculture.

One can judge the aridity of the climate in the river valleys by the figures for Lhasa, whose climate has been the best studied. (In 1934, the Chinese National Institute of Meteorology opened a meteorological station in Lhasa at an elevation of 3,732 meters.) Acquaintance with the climate of Lhasa is especially interesting because its valley and those of the Nyangchu, Yarlung and others resembling it in its natural conditions are the main economic centers of Tibet.

The temperature conditions of Lhasa are distinguished by great temperateness. Continentality, despite its geographic position in the depths of the continent, is relatively weak. During four years (1935-1938) the absolute maximum temperature was  $28.7^{\circ}$  and the absolute minimum was  $-14.3^{\circ}$ , the daily range of values averaged  $14^{\circ}$ . The winter is warm. The number of days with winter frosts is about 150. In winter a minimum of relative humidity is observed. A secondary maximum is observed in March and April; this is caused by an intensification of the vertical movement of air under the influence of intensifying insolation. The winter is dry; there is almost no precipitation, and there is, therefore, a striking contrast between the abundance of precipitation in the summer, which is associated with the monsoon character of the climate and the absence of precipitation in winter. (Fan Sin-lin, 1954, notes that 90 % of the precipitation falls in the summer.) Warming is observed early and plum trees flower at the beginning of April. The highest temperatures are in June; later they drop since the rains begin and part of the warmth is consumed in evaporation. At the same time a minimum of atmospheric pressure is observed.

In contrast to Northern Tibet where the winters are long and frosts are common in summer, the frost free period in Lhasa extends from June through September. Winds are less common in Lhasa. Of the total number of observations, 49 % showed a calm.

Also, according to Mu Shen-su, one can delineate a climate of forested regions. Strictly speaking, this climate is typical for the East Tibetan region of Kam -- the canyons of the Yangtze, Mekong and Salween, and in Tibet proper it is found in only a very small eastern part of the Tsangpo valley, the valleys of its tributaries, and some other rivers that are subject to considerable influence from the Indian monsoons. The climate here is moist and temperate. Forests grow along the rivers and the slopes of the narrow valleys and canyons; in the broad valleys the forest prefers the northern, cooler slopes. Above the forests and on the southern slopes of the broad valleys which have high temperatures and higher evaporation are found thickets of brush and steppe grasses.

The climate of the southern slope of the Himalaya is in sharp contrast to the climate of Northern and Southern Tibet. We have separated it as an independent physical-geographic region of Tibet -- the region of Men'yuy. The most typical features of the Tibetan part of the southern slope of the Himalaya are observed in southeastern Men'yuy, in Mon-yul. The climatic characteristics of Mon-yul are determined by geographic position, orography and, lastly, by its position on the route of the moist Indian air masses moving to the north.

The southern boundary of the Mon'yul passes along the foot of the Himalaya at an elevation of 200 meters above sea level at the place where there is a transition between its foothills and the Hindustan Lowland, and the northern boundary lies along the transition to the high mountain zone. As a result of this, in the Mon-yul there is a sharply expressed climatic zonality by elevation. The lower part of the Himalaya is in the zone of tropical climate. As you go up into the mountains at an elevation of 900-1,000 meters, the tropical climate is replaced by a subtropical climate which above 2,000 meters changes into a temperate climate: at an elevation of 3,700 meters the temperate climate becomes a high mountain climate and further up yet -- a climate of eternal cold.

Due to the fact that the Mon-yul is oriented to the south, it is entirely subjected to the Indian monsoon from the end of May to the middle of December. At the same time it is influenced by winds of continental origin. As a result, two sharply expressed periods are observed in the Mon-yul: a dry and a wet. The dry period is associated with the dry northeast monsoon -- with winds of continental origin and a wet period, associated with the southwest monsoon -- with winds of oceanic origin. In its turn, the northeast monsoon has two periods -- one of relatively low temperatures and the other, the growing season, with high temperatures.

The wet monsoon is also divided into two periods: the first -- from June through September -- a period of continuous rains falling in all parts of India; a second period -- from October through December -- characterized by a shifting of the rains to the south (A. E. Snegarev, 1926).

Let us use a table borrowed from Snegarev's materials showing the distribution of precipitation (in millimeters) in the eastern part of the Himalaya and the Himalaya foothills (1926, page 158).

Cold period (Jan-Feb)	Hot period (Mar-May)	Moist period (Jun-Oct)	Cool period (Nov-Dec)	Dry period (Jan-May)	Wet period (Jul-Dec)	Annual total
32.3	161.3	1,435.4	7.4	193.5	1,443.5	1,637.3

Period of the north-  
east monsoon

Period of the south-  
west monsoon

Northeast  
monsoon

Southwest  
monsoon

We note that the mountain slopes up to 2,000 meters in elevation are distinguished by maximum wetness, since the quantity of precipitation increases up to this level; above 2,000 meters the quantity of precipitation begins to drop off.

In the zone of temperate climate of Men'yuy winter precipitation evidently falls predominantly in a solid form and often rather abundantly. Heinrich Harrer observed an abundant snowfall in the mountains to the north of Dzhirong in January 1947. However, the snow thawed rapidly.

#### HYDROGRAPHY

The Tibetan highland is known as a mountainous country in which the sources of such Asian rivers as the Hwang-ho, the Yangtze, the Mekong, the Salween, the Indus and the Brahmaputra are located. It is striking, however, that in Tibet proper there is an immense area of internal drainage. Almost all of Northern Tibet, bounded on the south by the Kailas and Nyenchen-Tanghla Ranges, and bounded on the north by the Kunlun is, as it were, blocked off from the world ocean by these high mountain chains and forms an area of internal drainage consisting of isolated enclosed basins situated at various levels. The river system of the area of internal drainage has developed weakly as a result of the geological youth of the upland and the small amount of precipitation, but the above-mentioned rivers rise on its periphery and have still not succeeded in including this territory in their tremendous and multi-branched drainage network. But that moment is not far off-- some peripheral regions of the area of internal drainage will gradually be included in the basins of the large rivers and the area of internal drainage will decrease in size. Thus, one of the sources of the Yangtze, the Chumar River, has already approached right up to the chain of lakes between the Kunlun and the Dunbure Ranges. The watershed, two dozen kilometers wide, will soon be overcome by the regressive erosion of the river and the most eastern of the lakes of this chain will discharge its waters into the Yangtze. Perhaps the Salween is still more rapidly making its way toward the area of internal drainage. The sources of this river have already captured the southeastern part of Northern Tibet and are now situated close to the largest Northern Tibet group of lakes.



Southern Tibet, in contrast to Northern Tibet, has drainage to the outside. It is drained by the Brahmaputra and its numerous tributaries, the Indus with its large tributary, the Sutlej, and several tributaries of the Ganges. These flow into the Indian Ocean. The river system of Southern Tibet is dense and has deeply dissected the mountain chains of the Himalaya and Transhimalaya.

## RIVERS

Northern and Southern Tibet differ from one another in the type of their hydrographic system, type of valleys and the feeding of the rivers. But there are also a number of features in common. Thus, for example, in both regions the water level sharply varies seasonally. The maximum discharge of water occurs in July and August when the rains occur and the maximum temperatures are observed -- thus causing a strong thawing of snow and ice in the mountains. Both regions have two high-water stages. The first occurs at the beginning of the summer when there is a melting of the snow stored up in the mountains and hollows; the second begins with the period of thawing of the mountain glaciers in the middle of summer. The second high water period coincides with the monsoon and, as it were, is masked by rain water. There is also a great similarity in the regime of the small and medium sized streams; they have great variations in level not only seasonally but also diurnally. When the daily temperatures reach the maximum and the thawing of the snows and ice in the mountains is at the maximum, the water in the small streams increases rapidly and in the second half of the day attains its maximum level. At night, however, the level drops down and by morning is at its lowest. As a result of this, the same river can be forded in the morning and in the early part of the day, but after noon it already carries a large and turbulent flow and does not permit fording. (The local inhabitants usually ford the streams in the morning or at night when even such relatively large rivers in Northern Tibet as the Dzichu-Tsangpo, Bog-Tsangpo and Suptsang-Tsangpo are passable.) Rapid rises and falls of the water are more noticeable in Northern Tibet where there are no forests and the grass cover in places is very thin or completely absent. (Sharp variations of level during the course of the day are not observed or are scarcely noted in such large rivers of Southern Tibet as the Tsangpo which have a great length, large basins and a great number of tributaries, the latter frequently with several differences in feeding regime.)

The rivers of Northern Tibet. The special features of the hydrography of Northern Tibet consist in the fact that the river system does not have a fixed pattern and that the direction of the flow of the rivers is often opposite to that of other rivers in the same area. This can be explained first by the fact that there are a great number of local

base levels, those of lakes situated at various hyposmetric levels; secondly, by the formation of reverse slopes in an area due to obstructions formed by sills, something generally characteristic of desert-mountain areas.

In Northern Tibet there are mountain rivers and mountain-plains rivers. The first type of flow is through a mountainous area the entire distance from the sources to the mouth. The second type also usually begins in the mountains. In their upper portions they have the appearance of mountain streams -- a steeply-falling rocky bed, canyon-like valleys and a turbulent flow. But then these rivers discharge onto the flat surface of highland plains and flow placidly along a relatively gentle bed. More often than not their course is through strata of continental or ancient lake deposits which have filled intermontane areas. Some river currents have excavated deep canyon-like valleys in these strata.

The rivers of Northern Tibet can be classified as the type fed by snows and glaciers although precipitation and ground water have a certain significance in their flow. In many cases, as is true for the Eastern Pamirs, the rivers fed by the melted waters of the high mountain snows and glaciers dry up completely in the fall.

In winter the rivers of Northern Tibet, with rare exceptions, freeze to the bottom and the spring and ground water entering them comes out on the surface of the ice, forming broad layers of ice.

The greater part of the precipitation in Northern Tibet comes in the summer months. At the same time, the runoff in the rivers reaches a maximum, coming both from thaw water and rain water. The runoff increases from north to south and reaches a maximum in the Transhimalaya, to the south of 32° N., where the influence of the Indian monsoons becomes greater, the quantity of precipitation increases and snow accumulation and the formation of ice in the mountains is more intense.

Northern Tibet is a desert region with low runoff and a low mean modulus of runoff. Runoff is especially low in the center of the Changtang where about 100 millimeters of precipitation falls annually and the modulus of runoff is approximately 3.2 liters per second per square kilometer. In the eastern, western and southern parts of the Changtang the amount of precipitation increases to 200 millimeters, and in the southern part of the Transhimalaya -- up to 300 millimeters. The moduli of runoff are, respectively, up to 6.3 and 9.5 liters per second per square kilometer.

Although computations of the mean moduli of runoff were made without taking evaporation into consideration, if you compare these moduli with those in the Eastern Pamirs, there is reason to believe that they are very close to reality. The mean moduli of runoff in the Eastern Pamirs (See Sketches on the Hydrography of Rivers in the USSR [Ocherki po gidrografii rek SSSR], Publishing House of the Academy of Sciences of the USSR, 1953) is almost a complete analogue of Tibet -- 2 liters per second per square kilometer and does not exceed 5 liters per second per square kilometer. Somewhat larger moduli of runoff for Northern Tibet can be explained first by the fact that its climate as a whole is moister than that of the Eastern Pamirs and secondly by the fact that computations of the moduli of runoff for Tibet were made, as already pointed out, without taking evaporation into consideration.

The most significant rivers of Northern Tibet, attaining 200-300 kilometers in length, are situated in the Transhimalaya, to wit: Dzichu-Tsangpo, Tichu with its tributary the Ngang, Targo-Tsangpo, Tagra, Paro Tsangpo and Genmar. (The largest of them, the Dzichu-Tsangpo, has a length of 300 kilometers. Four of its upper tributaries rise from glaciers on the southern slopes of the Tanghla Range. The Bog-Tsangpo is 240 kilometers long; the waters of Lake Langbu flow through it into Lake Dagtse. It flows almost parallel to the Dzichu-Tsangpo, but in an opposite direction: to the east-northeast. The Buptsang-Tsangpo River, flowing into Lake Tarok, has a length of 170 kilometers. Its sources lie at the Sam'ye Pass near Mount Lombo-Gangra. Later the river flows to the north-northwest in the valley between the Kanchung and Lunkar Ranges. The Soma-Tsangpo River is 170 kilometers long; it flows into Lake Terinam. Its sources, fanning out northward, are located on the northern slope of the Lapchung and Shuri Ranges; they are covered by eternal snow and ice. The Surnge River is 150 kilometers long; it flows in three branches from the northern slopes of the Kailas Range and enters Lake Nganglaring. Its direction of flow is northeastward. The Targo-Tsangpo River, 140 kilometers long, flows from the northern slopes of the Nyenchen-Tanghla and enters into Lake Dangrayum. The Tagra River, lying near the Targo-Tsangpo and having the same length, flows into Lake Ngangtse. The Paro-Tsangpo and Genmar, somewhat shorter, flow from the Nyenchen-Tanghla to the north into Lake Dzharang. The Tichu River with its tributary, the Ngang, attains a length of 130 kilometers and enters Lake Nam Tsho from the southwest. It rises in the glaciers of the northern slope of the Nyenchen-Tanghla Range.)

Some rivers form channels between the lakes, for example, the channels between Lake Chargut and Seling, Chudun and Nam Tsho, Dzharang and Dzhangok.

In the mountain regions of the Karakorum and the Kunlun (in the boundaries of Tibet proper) the length of rivers does not exceed 120-150 kilometers.

Rivers of Northern Tibet which discharge their waters to the ocean are the Singichu (the right branch of the headwaters of the Indus) (More will be said about the Singichu later on) and the Nagchu (the headwaters of the Salween). The main branch of the Nagchu River is the Dzhangton; it rises on the glaciers of the eastern slopes of a high peak situated a little to the south of the Tanghla. The river receives several other tributaries from the southern slope of this range. Receiving their waters and continuing about 170 kilometers the Dzhangton flows into Lake Amdo-Tsonak. On leaving the lake the river receives the name Nagchu. The total length of the river in the boundaries of Tibet proper is 400 kilometers, the width of the channel is 200 meters at 240 kilometers from the source but the width of the current itself (in winter time) is 40 meters in all.

The economic utilization of the rivers of Northern Tibet at the present time is not very great. In cattle raising regions they serve as a source of fresh water since a large part of the lakes are saline. In the future, as the national economy is developed, the rivers, and especially the channels between the lakes with a naturally regulated runoff, can be utilized for industrial purposes and for production of electric power.

The rivers of Southern Tibet are part of the Indian Ocean basin. In Southern Tibet are situated the headwaters of the great water arteries of Asia: the Indus, the Brahmaputra and the Ganges. More than half of the territory of Southern Tibet is drained by the Brahmaputra (in the headwaters called the Tsangpo); into this river flow a large part of the rivers of Southern Tibet, these flowing from the southern slopes of the Transhimalaya and from both slopes of the Himalaya.

In the main, the principal type of river here is the mountain stream. Their sources almost always lie high in the mountains at the edge of snow fields or glaciers. The longitudinal profile of the river bed is steep, the channel is filled with rapids and the valleys are narrow and canyon-like. In contrast to the rivers of Northern Tibet, the direction of flow here is subject to a fixed regularity. The main arteries -- the Tsangpo and the Indus -- flow in broad tectonic depressions, and their tributaries, as a rule, hold to a north-south direction, cutting the mountain chains of the Himalaya (or Transhimalaya) with deep canyons. The basins of rivers of the second order are bounded by high water divides and the slopes of steep mountains.

Some rivers with their headwaters flow along the northern slope of the Great Himalaya Range through desert steppe landscapes similar to the Changtang and the Transhimalaya. These rivers have a great deal in common with the rivers of Northern Tibet. Dropping down from the glaciers, they flow for some distance with an east-west orientation in strata of loose continental or ancient lake deposits, excavating box-like valleys into them. These are sometimes deep and only in the places where they break through the mountain ranges, for example, during the drop down onto the Indo-Gangetic Lowland to the Brahmaputra, do they acquire a steep gradient and are transformed into roaring mountain currents.

A mixed type of feeding is characteristic of the South Tibetan rivers: rain (or monsoon) type and glacial-snow type. Those situated to the south of the crest of the Great Himalaya Range are considerably larger carriers of water than are those north of the crest. This is due to the fact that the ice fields and snow on the southern slope thaw more intensively and because the range receives a large part of the precipitation coming from the Indian Ocean (1,637 millimeters according to A. E. Snegarev); to the north of the crest of the main range, however, the precipitation is much less: at Lhasa, for example, 500 millimeters, and on the northern slope of this range it is even about 300 millimeters. But in both these cases the runoff is seasonally uneven and this is due to a more intensive entrance of thaw water into the system in the summer period and most of all, it is due to the monsoon character of the climate in which precipitation falls almost completely in the summertime. On the southern slope, during June-October, 1,435 millimeters of precipitation falls, that is, about 90 % of the annual amount; the same percentage of precipitation occurs in summer (about 90 % according to Fan Sin-Lin) to the north of the crest of the main range as well.

The water level in the rivers begins to rise as early as May, from the moment when the thawing of the mountain snows and ice fields begins. In the period of the summer monsoons (especially in July and August) it reaches the maximum.

The modulus of runoff on the southern slope in the period of the monsoons (that is, in June - October), attains 108.6 liters per second per square kilometer (with the annual average being 52.4 liters per second per square kilometer). (Since evaporation on the southern slope of the Himalaya is considerable and amounts to no less than a quarter of the total quantity of precipitation falling the true modulus of runoff at this time will be equal to approximately 81.5 liters per second per square kilometer and the annual average will be about 39.3 liters per second per square kilometer.) In the distribution of the runoff large deviations from this mean index occur in a zone up to 2,000 meters where a rapid increase can be observed in the precipitation brought by

the monsoons. On the other hand, above 2,000 meters there is a noticeably strong deviation in the direction of a decrease, since with height a sharp drop begins in the amount of precipitation.

On the northern slope of the main range the runoff in the summer-time is equal to 9.6 liters per second per square kilometer and in the valley of Lhasa, from 16 to 19 liters per second per square kilometer, but it is necessary to make a correction for evaporation. Due to the aridity of the local climate the evaporation should be considerable. We do not have the data available for such corrections.

The South Tibetan rivers of the greatest interest are the Indus and the Tsangpo with their major Tibetan tributaries.

The Indus rises in Northern Tibet, in the snow fields of the northeastern slopes of the Kailas at an elevation of 5,426 meters. It flows a distance of almost 1,800 kilometers in the mountains. In the territory of Tibet proper is located a segment of the river that is 400 kilometers in length. From the source to the city of Leh in Kashmir, a distance of 700 kilometers, the fall of the river is 1,830 meters, that is, 2.6 meters per kilometer; in Tibet proper, however, it is relatively small, scarcely more than 0.6 meters per kilometer -- beyond the boundaries of Tibet, however, it sharply increases and equals 7 miles per kilometer between Skardo and Bundzhi. The Indus leaves the Tibetan highland at an elevation of 1,400 meters.

The Indus (in Tibetan called the Singichu -- "River of the Lion") between the source and Ranada flows through a broad rock-bottomed intermontane valley incised to a depth of 60-70 meters. Several tens of kilometers from the source the width of the river channel attains 70 meters (in July) and it has a depth of up to 70 centimeters. The river flows slowly through open grassy plains and it can be forded. But from Ranada to the Zaskar River the Indus narrows to 30-50 meters and has a turbulent flow. Further on, up to its confluence with the Sheyok, it is transformed into a turbulent current, whirling through a narrow and constricted canyon.

Three hundred miles from its source the Gartang River flows into the Singichu. After the two rivers join the stream assumes the name Indus. Before this the Singichu receives still another tributary from the left, this having a length of 130 kilometers and flowing further to the north and almost parallel to the Gartang. At its confluence with the Gartang the discharge of water from the Singichu in November, that is, in the intermediate period, was 9.78 cubic meters per second (according to data from Sven Hedin).

The sources of the Gartang lie at an elevation of 5,000 meters on the southwestern slope of the Kailas. From here for a distance of 130 kilometers the Gartang flows directly to the northwest through the tectonic valley between the Kailas and the Ladak Ranges, descending to an elevation of 4,300 meters above sea level at Gartok. The slope of the river bed at Gartok is about 2 meters per kilometer and almost nowhere exceeds 4.7 meters.

In the character of its bed and in its general appearance the Gartang valley is similar to that of the Singichu valley. Having a velocity of flow only half that of the Singichu (near the point where it joins this river), the discharge of water in the Gartang, according to Sven Hedin, is 6.67 cubic meters per second (November). The width of the river near the mouth is about 65 meters and the maximum depth is 0.8 meters. The Singichu bursts turbulently from the Transhimalaya but the Gartang at its confluence with the Singichu flows slowly.

After the two rivers merge, the common river (now called the Indus) flows in the direction of Gartang through a graben valley between the Kailas and the Ladak ranges, that is, between the Himalaya and the Transhimalaya. It is evidently for this reason that a number of explorers have considered that the Gartang is the principal river and the Singichu is its eastern branch. It is also curious that the Indus crosses the Ladak Range three times. We can suppose that the mountain regions through which it flows experienced repeated tectonic disturbances leading to changes in the direction of flow and forcing the river to again and again seek a new route cutting through the mountains rising on this path. (It has been established that the Indus canyon was incised to a depth of 900-1,200 meters.) The first time it crosses the Ladak in a canyon 20 kilometers long at Tangra to the west of the Tibet-Kashmir boundary and it leaves the valley between the Ladak and Kailas Ranges. From here it flows in a broad flat valley between the Ladak and the Great Himalaya Range. Here the river is still fordable, but not at high water when it overflows for up to 6 kilometers. Usually, however, its width is about 1,000 meters and the velocity of flow is 2-3 kilometers per hour. Further to the west the river is constricted in two places and breaks through the Ladak in deep canyons and then flows some distance in its original direction, that is, between the Ladak and the Kailas.

The Sutlej, the largest of all the tributaries of the Indus, flows out of a swamp that is 10 kilometers to the northwest of Lake Rakas. In moist years the lake is fed by the overflow from the swamp. In the boundaries of Tibet the Sutlej flows for a distance of about 300 kilometers. Its width at Tolingmat (Totlin), according to data furnished by Sven Hedin, is 27 meters -- and in places, up to 50 meters. The depth of the river exceeds 1 meter. The slope of the river in Tibet is

equal to 6.5 meters per kilometer, the discharge of water between Dava-Gomba and Tolingmat in the period of the monsoons (August) is about 300 cubic meters per second. In narrows, for example, at Totlin, the river roars and rages, carrying a dirty grey current of water, energetically digging away at the bed and shores. In wide places in the valley there are clearly expressed terraces visible.

Cutting through the Ladak Range at 40 kilometers from the sources, the Sutlej changes direction from northwest to west and hurries through an immense intermontane valley between the Ladak and the Zaskar Ranges. The watershed between them and the Indus is low here -- about 300 meters. The Sutlej and its tributaries are deeply incised in loose deposits and there are difficulties in the use of their waters for irrigation.

At the village of Shipki, near the border of India, the Sutlej, changing its direction of flow to the northwest, consecutively breaks through all the chains of the Himalaya. Here is observed what is probably a picture of beauty and grandeur that is unequalled in the world. The river forms an extraordinarily deep canyon in the Zaskar Range. The bed of the river is situated at an elevation of about 3,050 meters whereas the tremendous peak of Leo-Pardzhal rises to an elevation of 6,791 meters at a distance of 7 kilometers to the north. The canyon of the river also has a magnificent appearance at a point 15 kilometers below Shipki where the right bank is a vertical rocky wall 1,800-2,150 meters in height. In the place where it breaks through the mountain ranges the previously calm Sutlej becomes turbulent and roars turbulently through the deep canyon of the river. Its slope in the Himalaya is 7.4 meters per kilometers.

The mean moduli of flow of the Indus, the Gartang and the Sutlej in the territory of Tibet, evidently, exceeds but little the mean moduli of flow of the rivers of Northern Tibet.

The Tsangpo River rises in a group of snow fields in the Kubi-Kangri Range, forming part of the Ladak Range. The snowfields of the northern slope of the Kubi-Kangri during the period of thawing give rise to small streams, the principal one -- and the true source of the river -- flows from the Brakhmanutra Glacier at an elevation of 4,864 meters.

Within Tibet the Tsangpo flows from west to east between the Ladak and the Kailas and their eastern prolongations in a broad intermontane tectonic valley (graben). About 94° E. it turns sharply to the north-east, makes a large knee-like bend, and assuming a southern direction, it cuts through the Himalaya Range in a very deep and narrow canyon, forming rapids and waterfalls with a height of up to 9 meters. The bed of the river is situated here at an absolute elevation of about 3,000 meters. The tremendous peak Namcha-Barwa rises up above the very



edge of the wild canyon to an elevation of 7,756 meters. At this point one can see the same picture of captivating beauty and grandeur of an extraordinarily deep mountain canyon as we already observed on the Sutlej near Shipki.

Only 30 kilometers from its source the Tsangpo is distinguished by a rapid flow and a deep channel with gentle banks incised in the hard rock of a broad valley. The river is over 20 meters wide. Its slope is relatively gentle, on an average not exceeding 85 centimeters per kilometer. (At Tradum the bench mark at the water's edge is 4,330 meters, at the mouth of the Raga-Tsangpo it is 4,150 meters, at the town of Shigatse it is 3,600 meters and at Tszetan it is about 3,500 meters.)

Approximately near 85° E. the depth and velocity of its flow is already so considerable (although it flows through a broad channel), that crossings are possible only in boats and on rafts. Below this point the river becomes navigable (at least for large boats used by the Tibetans) for the entire length in Tibetan territory with the exception of the sector between the mouths of the Rong and Shang Rivers where it whirls in a deep canyon with rapids and chutes through which only bold spirits dare to navigate their boats.

As the Tsangpo continues to receive tributaries, it becomes ever deeper and broader. At Shigatse where the maximum discharge is 900 cubic meters per second, and at Lhasa, the river has an average width of about 800 meters and breaks down into several channels separated by sandbars and only in places is it constricted in canyons. Somewhat below the mouth of the Dzichu River (Lhasa) its width is 450 meters with a depth of up to 18 meters in individual spots and it has a rapid current.

It is interesting to note that some tributaries of the Tsangpo, right up to their confluence with it, flow in a direction opposite to the flow of the Tsangpo. This is explained by the fact that in the past the Tsangpo flowed from west to east. As a result of tectonic processes, taking place in its basin, it changed its direction of flow but retained its former bed.

A large part of the tributaries, including the largest, flow into the Tsangpo from the left, that is, they flow from the Kailas Range and its eastern prolongation that are windward to the moist air masses of the Indian Ocean. There are few tributaries from the right since the right side of its valley is formed by the northern, leeward to the Indian Ocean monsoon, slopes of the Ladak Range and the ranges of the Nepal-Tibetan watershed.

The sources of the largest left tributary of the Tsangpo -- the Dzichu (called the Blashenstva in Tibetan) or the Lhasa, rise in the snow fields of the Nyenchen-Tanghla. The length of this river is about 350 kilometers. At the point that it flows into the Tsangpo it is equal in width to that river and is also navigable for small boats. The headwaters of one of the sources of the Dzichu approach close to a small tributary of the Nagchu (Salween River). The watershed of the Nyenchen-Tanghla, lying between them, can be easily crossed and over this watershed has been laid out one of the most important roads connecting Tibet with the neighboring provinces of China to the east and northeast. (Of the other large left tributaries, mention can be made of from west to east: the Tsa-chu with a width up to 150 meters, not only almost as large as the main river but unfordable as well, and then the Chorta-Tsangpo, rising in the snow fields in the place where the Kanchung and Lapchung Ranges come together. At 88° E. the main river is joined by the rapid and turbulent Raga-Tsangpo River (called the Dok-ohu in its lower course), whose flow during the entire distance is parallel to that of the main river. Its length is about 300 kilometers, its width near the mouth (according to Sven Hedin) is up to 54 meters, depth up to 1.3 meters, discharge 33 cubic meters per second (April). Twenty-five kilometers below the mouth of this river the Tsangpo is joined by the Shang River (Shiang), flowing from the Nyenchen-Tanghla. In addition, there are several other small rivers.)

The largest of the right tributaries of the Tsangpo are the Yalung (Sak'ya-Tromchu) and the Nyangchu (in Tibetan, the Lakomstv), flowing into the main river near Shigatse. The sources of the Nyangchu are situated in a desert area on the northern slope of the Himalaya but later on its valley becomes fertile, and it is for this reason that the Nyangchu has also received its other name -- the Lakomstv River. This is the only Tibetan tributary of the Tsangpo draining the Great Himalaya Range and the only river which cuts through the Ladak Range to the east of Lake Manasarowar.

To the east of the Nyanchu, another river, the Rong, flows into the Tsangpo. This river has its source near Lake Yamdok. Previously the waters of the lake flowed along this river, now the river does not reach to the lake but this does not necessarily mean that there is no underground connection between them.

In the boundaries of southern Tibet are also situated the sources of rivers flowing into the Ganges and into the lower course of the Brahmaputra. The Karnali River flows from the northern slope of the Zaskar Range (the Karnali in the lower reaches is called the Gogra), a tributary of the Ganges, then flowing to the southeast along the valley between the Zaskar and the Ladak. In its upper course, to the point where it breaks through the Great Himalaya Range, the Karnali flows

along placidly in a valley of about 4,000 meters absolute elevation, but further down, cutting through the main range, it whirls along turbulently in a deep canyon, forming a cascade of waterfalls. At a distance of 200 kilometers the river bed drops down to 3,800 meters, that is, the slope amounts to 19 meters per kilometer. Leaving Tibet, the Karnali passes through a canyon at Kadharnat that is remarkable for its beauty and magnificence: on one side of the canyon there rises the tremendous Gurla-Mandhata massif (7,728 meters) and on the other side -- other high peaks between 6,600-7,000 meters.

The Pungchu River (further on called the Arun) is also a large tributary of the Ganges; it rises from the snow fields on the northern slope of Mt. Gozaintan. For a distance of 240 kilometers it flows through an intermontane valley between the Ladak and the Great Himalaya Range and then, sharply turning to the south, it breaks through the latter a little to the east of the Dzhomolungma massif (Everest), on the way to receiving the small rivers flowing from the northern slope of Everest.

In the eastern part of Southern Tibet are situated the headwaters of the Amo (Torsa) River, flowing through the fertile Chumbi valley, the Kuru River (the headwaters of the Manas) and also the headwaters of the Subansiri River. Their sources lie to the north of the watershed of the Great Himalaya Range and on their way to the lower course of the Brahmaputra they cut through it in deep canyons. Due to the fact that the Indian monsoons penetrate along the valleys of these rivers from the south, the climatic conditions in them are more favorable for the life and the economic activity of the population than in many other Tibetan valleys.

The exploitation of the rivers of Southern Tibet for the time being is by far inadequate. The Tsangpo is used for transportation needs, but only to an insignificant degree and navigation more often than not is in boats made from yak skins and on an irregular basis. Of the other rivers only the Dzichu and the Nyangchu are navigable for a short distance.

The rivers of Southern Tibet are more widely used for irrigation needs. Since the rains here come predominantly in the summer, the soils suffer from an inadequacy of moisture. Aridity is also often experienced in the summer period. Tibetan farmers many centuries ago learned to struggle with the unfavorable aspects of nature in their country. All of their agriculture is based on irrigation. They cleverly convey water from the nearest river or mountain stream to each scrap of land on a river terrace or mountain slope which has good soil and is suitable for cultivation.

In the course of the centuries the immense energy of the rivers has gone to waste. Only in a few places have they adapted it for the turning of millstones powered by water wheels. Possessing huge reserves of power, the Tibetan rivers in the very near future, as the economy is developed in the Chinese People's Republic, including development in Tibet itself, can be used for the production of electric power. A scientific expedition conducting research in Tibet in 1951-1953 searched out and estimated the available reserves of hydroelectric power. The Tsangpo attracted the special attention of the researchers, it being in the basin of this river that the economic life of Tibet is concentrated. According to preliminary calculations, the Tsangpo in its middle and lower course can produce 62 million kilowatt hours of electric power. (The newspaper Druzhba [Friendship], 6 May 1956.) The best prospects of the Tsangpo are two sectors where the river flows in narrows and where it carries large volumes of water and has its maximum energy. The first sector -- Yuetszyue -- is situated somewhat to the west of the city of Chushul (Tsyuyshuy). The discharge of water at low water is here equal to 57.5 cubic meters per second. For a distance of 20 kilometers the slope of the river is almost 90 meters. The Tsangpo possesses still greater power: on an average the discharge is 130 cubic meters per second and the slope in a distance of 40 kilometers is 280 meters. Above these sectors are situated broad sectors of valley which can be utilized perfectly as natural reservoirs. Further to the east at the bend of the Tsangpo (the Bomi Region) conditions for the construction of a hydroelectric station are still more favorable since the climate becomes moister, more moderate and warmer, the velocity of flow and the level of the water in the river become more stable. (For the development of electric power in Tibet the upper courses of the Salween, Mekong and Yangtze Rivers will also take on significance. They are separated by narrow water divides where there are eight suitable sites, which together with one tributary, [the Botuy-Tszanbu], possess [according to preliminary data], a total complex of power of 1,070,460 horsepower. Three sites have a power potential between 30,000-50,000 horsepower, three between 70,000-100,000 horsepower, one -- 130,000 horsepower, one 360,000 horsepower and the Botuy-Tszanbu has 15 suitable sites with a total power of 160,000 horsepower.)

#### LAKES

One of the peculiarities of the landscape in Tibet -- Tibet proper, and not the highland as a whole -- is the numerous scattered lakes which resemble the splinters of a huge mirror scattered throughout its territory.

Some pattern can be observed in the distribution of the lakes. Their number and size increases from north to south, and this is especially true for the eastern part of Tibet.

The lakes are arranged either in broad but shallow basins on the flat plains or in depressions surrounded on all sides by mountains, such as Lakes Charol, Ligten and Dangrayum or they extend in a chain for hundreds of kilometers through the intermontane valleys hemmed in by mountain ranges, such, for example, as the chain of lakes between the Przheval'skiy and Kukushili Ranges.

Describing the Tibetan lakes lying in the midst of the upland plains, Sven Medin notes that in the west their basins as a rule are deeper and those to the east, on the other hand, are more shallow. This pattern, evidently, could be caused by two circumstances. First by the fact that in the eastern part the ancient glacier was thicker and more intensely planed down the relief, and, in the second place, due to the fact that the climate is more humid, the eastern lakes are being filled more rapidly with the products of destruction of the mountains.

The measurement of the maximum depths of the lakes does not reveal very great maximum depths: Lake Ligten, 67 meters, Lake Chargut, 50 meters, Lake Addan, 50 meters, Lake Pangong, 30 meters, Lake Manasarowar, 82 meters.

Origin of the lakes. Almost all of the lakes occupy tectonic depressions. Those of them situated at a level of more than 4,500 meters above sea level, in the opinion of V. M. Sinitsyn, occupy basins which bear clear evidences of glacial activity (Lakes Yamdok, Manasarowar, Pangong, Aksaychin and others). (Some of the glacial lakes were formed due to the damming of river valleys by moraines.)

The opinion is held by some that many lakes are relics of a former broad upper-Tertiary fresh water basin that occupied the highland region. Their premise is that the territory of Northern Tibet had runoff to the ocean, consequently, there were suitable conditions for the drainage of these large lake basins and their transformation into smaller bodies of water. Evidently, one can include Lake Nam Tsho in this type of remnant lakes.

On this conclusion E. M. Murzayev writes: "The reconstruction of the landscape of Tibet in the phase of high level lake waters enables us to speak of a geographical landscape, existing in the past, that is basically different from the present-day landscape. At high levels and under conditions, in general, where low shores prevailed, the area of the Tibetan lakes was far greater than in the present period and this forces us to assume that in the area of Tibet there existed several immense bodies of fresh water.

"It is important to note that in that period, evidently, drainage to the outside did occur and that Western Tibet was not an area of internal drainage. The presence of broad areas of evaporation and the receipt of a large amount of precipitation from the direction of the Indian Ocean provided a different moisture cycle in Western Tibet. The rise of the Himalaya resulted in the dessication of Tibet, a lowering of lake levels, a sharp decline in their areas and depth, their isolation and a consequent mineralization of their waters." (Foreign Asia [Zarubezhnaya Aziya], 1956, page 287.)

Together with the ancient relic lakes there are more modern ones, originating subsequent to the rise of the peripheral mountain systems of Tibet. As a result of the appearance of these mountain systems the territory of Tibet proved to be, as it were, surrounded by a tremendous barrier within which a region of interior drainage was formed, filled with the products of weathering of rocks. Under these conditions, atmospheric moisture, falling in abundance in individual moist periods and flowing off in the form of underground water from the slopes of adjoining ranges, accumulated under strata of loose deposits and then appeared at the surface in the lowest spots. At the same time some basins were also filled with water flowing on the surface, descending as rivers and rivulets from the mountain ranges. It is in this way, perhaps, that Lake Ngangling in the Transhimalaya was formed, as well as Lake Terinam and others, surrounded by low steep-sided and sharp-peaked mountains and having islands from these same mountains. The low elevation and the form of the mountains, possibly, give evidence that there were no glaciers here and that the basins of this mountainous country were filled with flowing water. We can call such lakes "young basin lakes."

Some lakes are intermittent. They exist only in the summertime when the depressions are filled with rain water and thaw water from the snows and glaciers. They dry up in the fall and Solonchaks and marshes remain on their bottoms.

Feeding. The Tibetan lakes receive numerous streams and rivers, rising in the mountain snows and glaciers. This is one of the principal sources from which they receive their water. They are also fed substantially by rains and ground water. The origin of the latter is once again the result of thawing of mountain snows and glaciers and only in part results from the processes of condensation of water vapor in the eluvial-diluvial layers. It may be assumed that underground waters play some role in the feeding of the lakes; this is confirmed by the presence of hot springs or geysers in almost every lake.

Large seasonal fluctuations are observed in the regime of the lakes. In summer their water level is higher, increasing sharply due to incoming water from thawing snows and glaciers and from rains. In fall, however, when the thawing of the snow and ice and the rains cease and the dryness of the air and evaporation increase, the water level begins to drop sharply. At this time the relative significance of ground water and underground water in the feeding of the lakes increases.

Salinity. Almost all of the lakes in Northern Tibet and many in Southern Tibet are strongly mineralized. Sven Hedin calculated that of 37 lakes in the western part of Tibet only eight were fresh water and of the 63 in the east almost all were salty. However, in some of the saline lakes the water is suitable for drinking. In many of them saltiness or freshness is a temporary phenomenon. Some strongly mineralized lakes during the period of rains and the thawing of snows and glaciers become fresh water lakes or only weakly saline; in fall, however, when water no longer enters and evaporation intensifies, they become saline. This is the reason why different explorers give varied reports about the salinity of one and the same lake.

Mineralization results from potassium and sodium salts, soda and borax. Due to their presence the lake water has an extraordinary turquoise color. In several lakes the concentration of salts is so great that with a lowering of the temperature they begin to precipitate, forming on the bottom a thick sparkling layer like a snowy-white tablecloth. When the lake dries up this layer, blindingly white in the sun, is cut by the wind into spheres and pyramids which appear to be the work of human hands rather than a product of nature. The vicinity of many saline lakes gives the appearance of a truly dead desert since the salt carried off by the wind covers the soil of the surrounding area and kills all living things. All the more consoling is the appearance of rare spots of green meadow that are associated with the fresh water basins.

N. K. Kyuner, quoting the Schlagintweit brother, writes that the salt content is not due to the presence of salt rocks in the vicinity. They found that the most highly mineralized lakes are in a region where crystalline rocks were prevalent and the lake salt was qualitatively the same as the ordinary salts of spring and river water. Consequently, the salinity of lakes is due only to the absence of drainage to the outside and the bringing in of salts by surface waters over a period of many centuries. Nevertheless, there is reason to believe that salts enter the lake from rocks lying beneath the bed and also from hot springs and geysers. Lakes with outlets are not saline, for example, in the Changtang, Lakes Pangong (eastern), Aru, Chargut, Addan, and Naktsong.

Dessication of the lakes. All the lakes of the highland, so explorers have observed, show traces of dessication. It is most noticeable in the northwest and less so in the center and especially in the southeast of Tibet. For example, the difference in elevation of the former and modern level of Lake Pangong in northwestern Tibet is 200 meters, at the same time it is approximately 130 meters in the lakes in the center of the Changtang.

The change in the level of the lakes was caused by an intensive, still incomplete rising of the Himalaya Range which to a significant degree has blocked the route to the north of the Indian Ocean monsoon and has made the climate of Tibet more arid than it was formerly. It is difficult to judge at what stage the dessication of the lake is at the present time and whether current climatic conditions are contributing to the dessication. Sufficient data is not available in order to draw a final conclusion. If the Tibetan lakes disappear, this is a natural process, not associated with the climate of the territory described. In Tibet conditions for their preservation, perhaps, are more favorable than in any other area. It is well established that each lake is gradually dying. It is being filled with waste material brought in by the streams and rivers, is growing shallow but is increasing in area. Accordingly, its surface of evaporation is increasing in area and this is bringing closer its day of disappearance. This process is also typical of Tibetan lakes. However, their disappearance here is a slow process since the small amount of precipitation results in a small volume and a low erosive power in the rivers and streams -- the active agents of rock destruction and the transporters of waste material into the lake basins. As a result of their small volume and the low cutting power of the rivers, the process of including Tibetan lakes in the hydrographic network of rivers discharging into the ocean is also proceeding slowly.

The preservation of lakes in Tibet is due to the fact that the intake-loss balance, evidently, is not a negative one, or it is negative to only a small degree. Intensified evaporation of water without compensation is possible only in September and October when there is no thawing of the snow and ice in the mountains, no rain, and when absolute and relative humidity of the air are very low. But this loss is replenished in the summer months when rain and thaw water from snow and glaciers enter into the lake. In winter, however, in the early spring and in the late fall, the lakes are covered with ice, forming an obstacle to any substantial evaporation of water from their surfaces.

Evidence of great dessication of Tibetan lakes is explained by the fact, possibly, by that which E. M. Murzayev has to say in respect to the lakes in Mongolia. "Traces of great dessication" (of Mongolian lakes -- B. Yu.), he writes, "should be attributed to the xerothermal



period which Central Asia experienced, especially after the period of glaciation." (Mongolian People's Republic [Mongol'skaya Narodnaya Respublika], 1952, page 187.)

The largest lakes are situated in Northern Tibet on the Changtang plains and in the basins of the Transhimalaya. It is on the broad plain on the boundary of the Changtang and the Transhimalaya that we find the largest Tibetan lake, Nam Tsho. The name means "Heavenly Lake." Here, however, not far from it, is situated the second largest lake in Tibet, Lake Seling, and others. In the Transhimalaya there are in all more than ten lakes having an area of more than 100 square kilometers each.

AREA AND ABSOLUTE ELEVATION OF THE LARGEST LAKES OF THE TRANSHIMALAYA\*

Name	Area in square miles and square kilometers	Height above sea level, in meters
Nam Tsho (Tengri-Nur)**	950 (2,207)	4,627
Seling	720 (1,673)	4,495
Dangrayum	500 (1,162)	4,724
Terinam	350 (813)	4,684
Dzharing	290 (674)	4,708
Nganglanging	250 (581)	4,748
Ngangtse	250 (581)	4,699
Tank'yung (Naktsong)	230 (534)	4,636
Tarok	180 (418)	4,627
Bam Tsho (Bum)	140 (325)	4,572
Mok'yu	140 (325)	4,572
Tongka	50 (116)	4,572

\* The table is given on the basis of Hayden and Burrard with some additions from Sven Hedin. Hayden and Burrard, evidently, used ordinary (London) miles, equivalent to 1.524 kilometers. In parentheses we have indicated the area of the lakes in square kilometers.

\*\* Lakes Nam Tsho and Seling are located partly in the Transhimalaya and partly in the Changtang, but Hayden and Burrard consider them, evidently, to be Transhimalayan.

Some lakes in the Transhimalaya have outlets and, consequently, are fresh water lakes: Dzharing, Tsikung, Langbu, Chargut, Chudun. Lake Dzharing flows into Lake Tsikung and this in its turn through still another small lake flows into Lake Dzhagok. Lake Chargut, receiving water from the salt lake, Lake Seling, also flows into Lake Dzhagok. Lake Langbu, from which flows a large river, the Bog-Tsangpo, is also a fresh water lake. Lake Chudun flows into Lake Nam Tsho.

The lakes freeze rather late. Thus, Lake Nam Tsho becomes ice-covered only in November and is free from ice in May. The late freezing of this lake is due to its extreme salinity and great area. Evidently it does not freeze every winter. Participants in the Chinese expedition of 1951-1953 write that having arrived on the shores of Lake Nam Tsho in the heart of winter they still observed open water (Around the World [Vokrug Sveta], 1954, No 10). Lakes that are smaller in area and less salty (especially fresh water) lakes freeze somewhat earlier.

There are also rather large lakes to the north of the Transhimalaya: Montcalm, Dzhigitay, Kashum, Markham, Antelope, Red Cliffs, Ligten, Charol, Eshil', Memar, Aru, Khorpa (Arport), Khuping, Kenze, Pangong, Armand David, Sumdzhi and others. They are arranged here, as a rule, in zones or chains in valleys between parallel ranges which are situated far from one another.

If the lakes of the northern part of the Changtang are smaller in area than the lakes of the Transhimalaya, in absolute elevation many of them have no equals in the world. Lake Khorpa, for example, is located at an elevation of 5,465 meters, Lake Armand David at 5,300 meters, Sumdzhi at 5,150 meters and Montcalm at 4,960 meters.

There are also large lakes in Southern Tibet. A large number of them are situated on the gentle northern slope of the Himalaya. These are Yamdok, Tsomotretung, Palgo, Trigutso. Lakes Manasarowar, Rakas and Gunchu (Kongchu) are situated in an intermontane valley (graben) between the Ladak and Kailas Ranges. With the exception of Gunchu, all the lakes enumerated are fresh water lakes. The largest of the lakes of Southern Tibet is Lake Yamdok, and the deepest, according to Swami Pranavanandra, is Manasarowar with a depth of 82 meters.

#### AREA AND ABSOLUTE ELEVATION OF THE LAKES OF SOUTHERN TIBET

Name	Area in square kilometers	Height above sea level, in meters
Yamdok	880	4,374
Manasarowar	520	4,602
Rakas	360	4,589
Gunchu	100	4,877
Trigutso	130	4,724
Pomo	-	4,936

Manasarowar and Rakas are situated close to one another. In years of abundant precipitation Lake Manasarowar, situated to the east of Lake Rakas and 13 meters higher, drains into the latter lake. Lake

Rakas, as indicated above, in some years drains its excess waters into the Suttlej. This will explain how it (and Lake Manasarowar as well) are being drawn into the Suttlej system (L. S. Berg, 1947).

### GEYSERS AND OTHER SPRINGS

On the Tibetan highland, geologically of recent formation, where orogenic processes are still not completed, there are overflows of thermal springs everywhere. There are especially a great many to the north of the Tsangpo -- to 34° N., between 88 and 92° E. The springs are mineralized with chlorides or sulphates, sometimes they contain mixtures of magnesium, iron, sulphur, soda, potash, but there are also fresh water springs.

Often the thermal springs are in the form of rather powerful geysers, ejecting a high fountain of boiling water. For example, 11 geysers, known by the name of the Petin Springs, are situated at a distance of several meters from one another along the bank of the Lakhuchu River (a tributary of the Shang River); they eject a stream of boiling water to a height of 15 meters; the geyser at Lake Nam Tsho ejects to a height of up to 11 meters; the temperature of its water also reaches the boiling point. (At an absolute elevation of 4,627 meters the boiling point is about 83°.)

A large part of the hot springs are situated near the lake, chiefly within the boundaries indicated above. But they are also found in other places. Explorers have encountered them in the river valleys of the Suttlej and the Karnali, on the northern slope of the Himalaya at the city of Dzhirong (Kirong). N. M. Przheval'skiy described the hot springs on the southern slope of the Tanghla, and Bonvalot -- on the northern and southern slopes of Mt. Dupleix.

Despite the high temperature, many springs and geysers freeze under conditions of the severe Tibetan winter. However, they do not entirely cease their activity. Thirty to forty degree freezes suffice only to form a cone or cowl of ice over the geyser within which a hot stream continues to spout; the steam and the spray from the boiling water noisily burst through openings in the walls of the ice towers. The spectacle of geysers shrouded in steam, with the sun's rays playing and refracting in the icicles and drops of water is something unforgettable in its rare beauty. Such geysers, covered with conelike shrouds, were encountered by Bonvalot to the north of Lake Montcalm. The cones had a diameter of 6-7 meters and attained the height of a man. The lake near which they were located Bonvalot called the Lake of the Cones.

T Tibetans long ago noted the curative properties of the hot springs and they have built baths and bath houses in which they undergo a course of treatments. Such, for example, are the bathing basins of Dam-chutszan, 110 kilometers to the north of Lhasa, and bath houses near small geysers on a two-meter high terrace of the Gartang about which Sven Hedin has written, etc.

Swami Pranavanandra notes that the waters of the springs of the Karnali valley and several others contain rhodonite and are radioactive.

#### VEGETATION AND SOILS

Differences in relief and climate and also a complicated history of development have predetermined the singular course of formation and the unusual character of the vegetation and soils of Tibet.

The vegetative cover of Tibet was formed relatively recently since the Tibetan highland is a geologically recent uplift.

"Tibet, especially its eastern part," writes Professor E. V. Vul'f, "as well as the Himalaya, in the Eocene period was still covered by the waters of the Tetis, as a result of which its flora does not have an ancient character". The formation of Tibetan flora began in the second half of the Quaternary Period. "It was formed," writes this same author, "as the result of the penetration into new territory of elements of flora of more ancient mountain systems -- of western China, India and Indonesia". (Historical Geography of Plants [Istoricheskaya geografiya rasteniy], 1944, page 305.)

The vegetative cover of the territory of Tibet is varied; a large part of it consists of a desolate xerophytic alpine zone which results from the immense absolute elevation of the highland and severe climatic conditions. This determines the considerable poverty and monotony of Tibetan flora (in the highland as a whole) and only the deep river valleys of the southeast and of Southern Tibet and the southern slope of the Himalaya, whose natural conditions are sharply different from the natural conditions in the remainder of Tibet, are characterized by a considerably richer flora.

E. V. Vul'f, carefully studying the materials of Ward and other researchers on Tibetan vegetation, writes that the composition of the flora of Tibet is determined first, by its uplift from the bottom of the sea to an elevation of the most tremendous mountain peaks of the globe, and, secondly, by glaciation during the time of the ice age. The ice and snow cover of Tibet and the Himalaya, he writes, isolated the southern peninsula of Asia from its central part. Preglacial vegetation was basically destroyed and only a part of it, pushed southward by

the glacier, was preserved. After the disappearance of the glacier the vegetation of the Tibetan highland was re-established with species coming predominantly from the east, from more ancient heights of Burma and Yunnan (post-Carboniferous but pre-Triassic). The migration of species from the south from the Indo-Malayan region and from the north from Central Asia occurred on a considerably smaller scale. Thus, the flora of Tibet forms part of Sino-Himalayan flora and it would be incorrect to classify it as Central Asiatic. The flora of the Kukuror also is of the Sino-Himalayan type.

Besides the fact that the flora of Tibet, with the exception of the southern slope of the Himalaya, is poor, it also has a depressed appearance in an extensive desolate area. Climatic and soil conditions in Tibet, in its highest parts, are completely unfavorable for the growing of plants. In the natural processes, especially in the Changtang, there is observable a considerable similarity with the Subarctic. Here, as well as in the Subarctic, a limited amount of thermal energy participates in these processes. A negative radiation balance prevails in the course of three-quarters of the year -- fall, winter and spring. In summer, however, in general, the influx of heat is also low, since the daily temperatures even of the warmest month, July, are only 10-15°, more rarely 20° or more. At night, however, as a rule, in the course of the whole summer, there are frosts and the radiation of warmth from the earth's surface is very great due to the rarified atmosphere and the cloudless weather.

Thus, the biochemical processes in the summer also take place with a limited amount of warmth. As a result of this, the process of soil formation proceeds slowly; the activity of soil bacteria is lowered and so also is the assimilation of carbon dioxide, which is an obstacle to the accumulation of chlorophyll. The cold climate is expressed in an exceptionally negative way on higher plants. Also hostile to plants is the excess of ultra-violet radiation.

Plants were first forced to adapt themselves to low temperatures. A. A. Grigor'yev (1956) notes that during droughts and frosts the reactions of plants are similar: in both cases withering occurs. However, during freezing dehydration is the result of the formation of ice crystals in the intercellular spaces (less commonly, within the cells). This process thus amounts to a removal of water from the colloids of plasma. In order to avoid this, plants develop a series of adaptations, change their anatomical structure and the structure of vegetative organs, decrease the size of their leaves, acquire a waxy coating, etc. In the organs there is an increase in the amount of some soluble substances, of the simplest sugars, making difficult both the evaporation of moisture and its crystallization at negative temperatures and at the

same time protecting protein from coagulation. A large amount of sugar increases the resistance of plants to winter conditions, lowering the activity of the organism, for example, of breathing, by two or three times.

This same author writes that another of the adaptations of high mountain plants consists in the appearance from the beginning of the growing season of oxidizing-restorative processes, as a result of which there is an increase in the plants in the amount of mucous substances of hemicelluloses and albuminous nitrogen, vitamins and pigments. Oxidizing-restorative processes in conjunction with an intensification in the production of sugar increase the manufacture of ascorbic acid, that is, of vitamin C.

An intensified exposure to ultra-violet radiation, however (the effect in such quantities in the plant is generally unfavorable), causes the development of vitamin D in the plant organs, having, in particular, the property of strengthening the resistance of animals against disease-causing microbes.

The soils and the conditions for soil formation in a large part of the territory of Tibet are very similar to the soils of the Eastern Pamirs. (L. S. Berg writes: "... the Pamirs (Eastern) -- are an unusual high mountain desert, in their natural conditions constituting a corner of Tibet" (1948, page 220.) For Tibet, as for the Pamirs, mountain ranges are characteristic. Between them are situated gently-sloping or hilly plains with thick strata of alluvial, deluvial and proluvial deposits; the slopes of the mountain ranges are covered with deluvium and their broad flattened water sheds are covered with eluvium. Deposits of both water and non-water borne products in the main consist of coarse, large rubble material which serves as the mother rock for the forming of soils.

As a result of the fact that an immense interior region of Tibet has no drainage to the ocean and is characterized by a dry climate, the soils here have a general tendency to salinity, the more so that the elevation of the local base levels is only a little below the plains surrounding them and the matter in solution is carried into the soil and then into the subsurface waters with great difficulty. To any considerable extent only such easily dissolved materials as chlorides and sulphates are carried away while carbonates, especially calcium carbonate, accumulate in the soils.

Under the conditions of an arid and cold climate the process of soil formation, especially the formation of clayey material and the decomposition of remnants of plants, proceeds very slowly. As a result,

as a rule, the soils of Tibet are largegrained and friable, most commonly they are sandy and usually contain pebbles or gravel (Hu Shen-su, 1953).

Their total thickness, even in steppe areas, is several centimeters and the root system of the grasses rests directly on the hard mother rock. Very rarely, and then only in steppe regions, one can encounter soils whose fine-grained strata will amount to as much as 100 centimeters.

Southern Tibet, situated to the south of the Transhimalaya watershed, has a more dissected relief but absolute elevations lower than in Northern Tibet and a moister and warmer climate. It is characterized by a great variety of vegetation and soils.

These are still more varied on the southern slope of the Great Himalaya Range, since, first, the southern slope of the main range blocks the majority of the moisture of the Indian monsoons; in the second place, due to the southern exposure the temperatures here are higher; in the third place, the absolute elevations from 6,000 meters and more at the crest drop down to 200 meters at the foot of the range, at the point of transition to the Indo-Gangetic Lowland. All this determined not only the variety and wealth of the soil-vegetation cover, but also the clearly-expressed vertical zonality.

Thus, in Tibet we can distinguish four main regions, in each one of which predominates one type or another of vegetation and soil: 1 -- the northern, occupied for the most part by a typical desert-high mountain vegetation on corresponding soils and embracing the northern part of the Changtang; 2 -- the region situated to the south of the first, with a primary distribution of steppe vegetation, on steppe soils, similar to chestnut or chernozem soils; 3 -- the region with vegetation of a meadow-steppe type on meadow-steppe soils and occupying primarily Southern Tibet; 4 -- the region with typical forest and meadow vegetation on forest and meadow soils. This region embraces the southern slope of the Great Himalaya Range and the extreme eastern part of the Tsangpo Basin.

In connection with the fact that in each of these regions there prevails principal types of vegetation and soils, there are individual but important local differences in relief, climate and geological structure, the soil-vegetation cover in reality is substantially more varied, and in addition to the major types of vegetation and soils mentioned there are still others.

To sum up, we can mention these.

High mountain desert. Desert landscapes occupy the major part of the North Tibetan plateau. They are formed under conditions of extreme aridity and continentality of climate and very low temperatures. Desert soils are found here, distinguished by a rather low humus content and a predominance of physical rather than chemical processes of weathering. This is due to their predominantly sandy and pebbly mechanical composition, high gravel content and the scarcely noticeable dissection on the horizon. In these desert soils biological processes are almost completely suppressed, as a result of which they are distinguished by little from rock untouched by soil formation. Often these soils are carbonaceous and sometimes they are of the Solonchak type, especially in the depressions. In regions where these soils are distributed there are expanses covered by a solid completely bare armor of gravel and pebbles. Such "dead land," to use the expression used by M. V. Pevtsov, is especially characteristic of the foothills of the Kunlun ranges. This is in the full meaning of the work a gravel-pebble desert in which it is possible to find only scattered growing plants.

In the desert regions of the Tibetan plateau, plants do not form a continuous cover but are situated a considerable distance from one another. They have a depressed appearance, they are low in size -- from 2 to 5-6 centimeters and only rarely up to 15. In addition, the plants are flattened out and the leaves and flowers are pressed to the ground. Often they form hillocks or pillows. This property of the structure of plants is explained by their desire to safeguard themselves from being torn out of the soil by the strong winds and protect themselves from excess evaporation and cooling. In contrast to the surface organs, the root system is very strongly developed. The roots are usually fleshy or in the form of a massive threadlike tuber.

The entire vegetative cycle from the moment of awakening from winter sleep to the flowering and giving forth of fruit of the plants of the deserts of Northern Tibet takes place with extraordinary rapidity -- in three or four months. Such speed in their development is due to the abundance of sunlight, the strong influence of direct solar radiation on the soil and plants under conditions of great transparency and rarefaction of the atmosphere and also the adaptation of most plants to the short growing season. In several plants, as in the tundra, leaf and flower buds formed in the preceding growing season survive the winter. The freezing of seeds increases their germination but does not influence the continuing development of the plants. (In his time Sandberg expressed the idea that a great stimulating influence on the vegetative cycle is exercised by the action of the intense cold at the roots and the subsurface vegetative part of the plant. This causes a retarded awakening of the plant but creates a latent stimulus for its later rapid development which the sun facilitates.)



Since the Tibetan highland and the Eastern Pamirs are very similar in natural conditions, then, evidently, the vegetation in the desert regions of Tibet as well as in the Eastern Pamirs, develops vegetatively in a way similar to that occurring in the tundra.

The vegetation cover of desert soils consists of occasional bushes of white willow (*Eurotia ceratoides*), gor'kushi (*Saussurea subulata*), feather grass, meadow grass, lyme grass, fescue (*Acantholimon diapensoides*), capsella (*Capsella Tomsonii*), astragalus (*Astragalus Malcolmii*), thermopsis (*Thermopsis inflata*), lousewort (*Pedicularis cheilanthifolia*), wormwood (*Artemisia Wellbyi*) and others. (According to data from Tsyang Chun-shu, U Chzhen-i, Chen'-Chan-du Physical-Geographic Regionalization of China, 1957, and Sandberg).

Despite the very severe natural conditions, writes Sandberg, here, even in the alpine zone, in the passes fine brittle plants with beautiful flowers grow, withstanding severe winds and summer nocturnal frosts. Their stems reach 12 centimeters in length and they climb along the cliffs that shield them from the wind. Poppies are especially fine. The Tibetan horned poppy (*Meconopsis aculeata* and *M. horridula*) has wonderful blue flowers with golden stamens. The stem, leaves and seed pods have thorns. On one stem there are 10-12 luxurious flowers. (For the purpose of safeguarding itself from an excess of ultraviolet rays the Tibetan poppy developed a number of protective adaptations, one of them being that the red flower to which we are accustomed has been replaced by a blue one.) Luxurious and beautiful are also the purple aster (*Aster tibeticus*), strongly smelling Indian nard (*Nardostachis Jatamansi*), yellow iris, Tibetan forget-me-not (*Myosotis alpestris*), the bright blue flowers of which are larger flowers than our forget-me-nots, and *Androsace chamaejasme*.

High mountain steppes. In the southern and eastern parts of Northern Tibet high mountain steppe landscapes have developed. They are typical for the southern and eastern Changtang and for the Trans-himalaya, which have relatively higher humidity. The vegetation cover here is developed considerably better than in the high mountain desert. It forms an almost continuous although most commonly a low-lying cover, with the exception of the valleys in the eastern part of the Trans-himalaya where there are good pastures. Sometimes the generally steppe type of vegetation has features of a meadow vegetation, as was noted by N. M. Przheval'skiy, who wrote about the mixture of steppe and alpine flora characteristic of the Tibetan highland: first steppe vegetation climbs from the valleys up the slopes of the ranges, then alpine types of vegetation drop down into the steppe valleys from the very wet water divides.

The main constituents in the steppe vegetation are various rapidly vegetating varieties of meadow grass (primarily *Poa alpina*, *P. nemoralis*), *Festuca* (*Glyceria*), feather grass (*Stipa pennata*) and sometimes couch grass (*Agropyrum Thoroldianum*). It is on these grasses that wild hoofed animals and rodents feed.

At great elevations (up to 5,800 meters) chiefly on the mountain passes of the steppe zone, giant arenaria (*Arenaria holosteoides*) is found most commonly, forming spherical pillows from 20 to 25 centimeters in diameter, two varieties of *Delphinium* (*D. Brunonianum*, *D. glacialis*), several varieties of wormwood, *Astragalus*, *Saussurea* (especially *S. tridactylus*, *S. glandulifera*), *Microula Bentami*, *Dracocephalum heterophyllum*, and also *Sedum Stracheyi*, *Arenaria Royleana*, *Thermopsis inflata*, *Potentilla polycrista*, *Corydalis tibetica*, *Pedicularis tubiflora* and six varieties of *Oxitropis*. Varieties of *O. chiliophylla* and *O. physocarpae* form large flattened pillows on the ground in the form of a circle. These are perennial plants in which, as the center dies out, new runners grow out, as a result of which a ring-shaped pillow is formed.

As a result of the unfavorable climatic conditions and especially due to the low mean annual temperatures, woody vegetation, requiring a mean July temperature of no less than 10°, grows neither in the desert nor steppe zones. Only on the eastern shore of Lake Nam Tsho is there found a woody juniper (*Juniperus squamosa*). There are few bushes here and those existing are predominantly flat-lying and creeping. The most widespread is the white willow bush (*teresken*), growing almost everywhere on the cliffs. This plant, typical of the rock areas, is rarely met with on saline expanses. Among the bushes there is *Caragana pygmaea* with yellow flowers and thorns and which is a good fuel. Elms grow in spots on drier slopes and oftentimes in the more sheltered valleys. Among other bushes usually growing in thickets on alluvial soils are *Myricaria germanica*, a relative of tamarisk, and also *Tanacetum tibeticum*, honeysuckle -- *Lonicera quinquelocularis* and *L. glauca*, *Ephedra Gerardiana*. Not one of them attains a height of more than 15 centimeters at great elevations. And only on the southern slopes of the southern ranges of the Transhimalaya does the number and size of the bushes increase. Here is found a bushlike juniper (*Juniperus inarva*), a great number of bushes -- *Berberis*, *Caragana jubata* and *C. pygmaea*, *Duddleia tibetica*.

Soils of mountain steppes are richer in humus and heavier than the soils of the highland desert. Depending on the quantity of humus, part of them are similar to chestnut soils and part are similar to chernozems. However, they have a series of specific features -- the coarse composition of humus, its high content in the upper part of the profile and a rapid decline downward in the profile and also the frequent absence of

eluvial-carbonate horizons associated with a weak tempo of weathering and the small thickness of the soil profile. The soils of high mountain steppes are the most fertile on the Tibetan plateau, but due to unfavorable climatic conditions they are not used for cultivation but the regions occupied by them are used as pastures. Agricultural centers exist only in isolated spots -- at the villages of Omba, Sendzha (near Lakes Dangrayum and Dzharang) and Rudok. The lightness of these soils also does not favor cultivation.

Valley steppes. In the valleys of Southern Tibet, having elevations of less than 4,000 meters, steppe vegetation also predominates, but in contrast to the high mountain steppes the grass cover here is considerably higher. This is associated with warmer climatic conditions. The annual total of precipitation in the steppe valleys is greater (500 millimeters and more) than in the high mountain steppes and only high evaporation causes the development of relatively drought-resisting vegetation, not forming a continuous cover and made up (Syao Tsyun'-Chun', 1954) of *Sophora* (*Sophora Moorcroftiana*), wormwood (*Artemisia salsoides*), astragalus (*Astragalus tibetica*) and also *imperata*, *ostrolodka* (*Oxytropis*), barberry, *hyppophae rhamnoides*, on river shoals. Chestnut carbonate soils have developed in these valleys. There is less humus in these soils than in the steppe soils of the Transhimalaya. As the amount of humus decreases they become brown in color.

The zone of steppe chestnut brown carbonate soils is the main agricultural region of Tibet. But even here along the valleys of the Dzichu, Nyangchu and the Tsangpo itself are encountered Solonchaks and saline soils in which feathergrass and some cereals grow easily withstanding drought and saline soils.

Meadow-steppe vegetation. This vegetation occupies a large part of the area of Southern Tibet, the lower parts of mountain slopes and some valleys. As a rule, expanses covered with such vegetation are good natural pastures. At elevations below 4,000 meters moist places are occupied principally by Tibetan sedge and foxtail grass (*Alopecurus pratensis*).

From 4,000 to 4,300 meters on the slopes of the lower mountain spurs where the vegetation cover forms especially rich pastures, there are numerous representatives of varieties of *Melilotus*, *Taraxacum*, *Potentilla*, *Tanacetum*, *Iris* (*I. cumaonensis*), and also *Polygonum*, *Oxytropis*, *Festuca*, *Pedicularis*, *Poa* and, as everywhere, *Carex Moorcroftii*. (In the province of Tszan, for these elevations, Swami Pranavanandra also mentions *Chelidonium dicranostigma*, *Aconitum luridum*, *Papaver undicaule*.)

At an elevation of 4,500 meters are encountered beautiful grassy plots of rose primula, picturesquely bordering snow fields and still higher, more often than others, one encounters Saussurea and Astragal.

Among the South Tibetan pastures the least used are the pastures near Lakes Manasarowar and Rakas and their extensions into the headwaters of the Tsangpo valley. Swami Pranavanandra notes that they remind one of a mottled rug with bright colors (1950). It is interesting to note, however, that climatic conditions in this region change so sharply in a small area that somewhat to one side from these lakes the pleasant picture of flowering pastures somehow disappears at once. In its place depressing landscapes rise before the eyes where brightly-colored alpine flora is replaced by the faded tones of dried grasses which are so hard and sharp that Swami Pranavanandra compares them with knives.

Meadow-steppe vegetation grows on mountain meadow-steppe soils. These soils differ from steppe soils by having a higher humus content in the upper part of the profile, complete leaching of all salts, including carbonates, and a weakly acid reaction.

Mountain meadows. Individual moister mountain chains of Southern Tibet, exposed to monsoon winds, and also the wettest flat peaks in northern regions (the crests of the Tanghla, Dunbure, etc.) have a cover of mountain-meadow vegetation in which the main role is played by *Cobresia tibetica*. Widely distributed are various gentians (*Gentiana*), cinquefoil (*Potentilla*), crowfoot (*Ranunculus*), saxifrage (*Saxifraga*), edelweiss (*Leontopodium*), primroses (*Primula*), rock jasmine (*Androsacea*), stonecrop (*Sedum*), onions (*Allium*) and others. In Southern Tibet below the meadows appear thickets of rhododendrum, forming a transition to the forests.

Mountain-meadow soils have a still more acid reaction than mountain-steppe soils; they have more organic matter in them and the drop in its content downward in the profile is still sharper. Mountain meadows constitute good pastures. Mountain-meadow soils are usually not tilled since here, under conditions of rather high humidity, the warmth is inadequate for the maturing of cultivated crops.

Of a special character are the associations of perennial grassy plants, the so-called mesophytic high grasses, spread through the moistest parts of southeastern Tibet. Making up this high grass complex the most widespread kinds are *Ligularia*, aconite (*Aconitum*), delphinium, salvia, and widely represented are various kinds of umbellate families. The second grassy growth under this high grass is usually very dense. The mountain-meadow soils developing under this high grass are characterized by a considerable thickness of a fine grained layer, deep penetration of humus and an acid reaction.

The temperate climate forest has developed below zones of mountain meadows. They grow on brown forest soils in the extreme eastern part of the Tsangpo Basin and on the southern slope of the Great Himalaya Range in the warm and moist valleys of the Trisuli, Torsa and other rivers and in the Mon'yul.

In the Tsangpo Basin and at an elevation of 3,000-4,000 meters grow unmixed fir forests (*Abies Spectabilis*, *A. Webbiana*) with an undergrowth of rhododendrum. (Here and in the future the list of plants is given according to data from Chinese authors (Physical-Geographic Regionalization of China [Fiziko-geograficheskoye rayonirovaniye Kitaya] 1957, and also Sandberg.) In the lower zone of these forests at elevations of 3,000 meters and less, the main tree is the tsuga (*Tsuga dumosa*), growing together with the fir (*Picea spinulosa*). Larch (*Larix Griffithii*) grows on arid slopes at elevations of 3,500 meters and below.

There is a vegetation of trees in the eastern part of the Tsangpo valley itself and the valleys of its tributaries -- the Nyangchu, Yarlung, Dzichu Rivers and others. Here are found fir, pine, birch, hazelnut; in the region of Lhasa still grow juniper, yews (*Taxus baccata*) and holly. Among the orchard crops of Southern Tibet are the apricot -- the main fruit crop, peaches, walnuts and pears.

On the southern slope of the main range, in the valleys of the Trisuli and Torsa Rivers and in the Mon-yul in the upper zone are found the spruce (*Picea Morinda*) and fir (*Abies Pindrow*); on the upper arid slope grow the larch (*Larix Griffithii*) and further down, the Himalayan cedar (*Cedrus Deodara*) and pine (*Pinus longifolia*) predominate.

The zone of forests in Southern Tibet and the southern slope of the Himalaya are not used for agriculture and only to a slight extent for the raising of livestock. Its economic significance consists in its supplies of valuable timber.

In the western part of Southern Tibet trees grow only in more favored places, continuous stands do not form and the vegetation is distinguished by a suppressed form. According to data from Swami Pranavanandra (1950) such trees are encountered in the Puran valley (headwaters of the Karnali River). These include a low-growing willow and poplar and a variety of *Cedrus Deodara* that is 2-3 meters tall and in which it is difficult to recognize a close kinship with the mighty Himalayan cedar that lifts its magnificent crown to a height of 40-50 meters. Willow and poplar, and these only in sheltered spots, were encountered by Sven Hedin in the Suttlej valley at Tolingmata (Totlin). Hedin even saw apricot trees in rocky sectors at Shipki. Various kinds of low-growing willow and poplar also grow in the headwaters of the Tsangpo valley and along some of its tributaries and on cliffs along the Doktal.

Tropical and subtropical forests of the southern slope of the Himalaya. These forests have developed in the territory of Mon-yul below the temperate zone forests. At elevations up to 900-1,000 meters red and yellow mountain soils have a zone of tropical forest vegetation, and from 900-1,000 to 2,000-2,500 meters there is a zone of subtropical forests.

It is necessary to use Hooker's data (J. D. Hooker, 1907) to characterize the vegetation of the Mon-yul. This pertains, it is true, to the vegetation of Sikkim and Bhutan, neighboring on Tibet. Taking into account that Mon-yul is located in a zone of still greater moisture, it can be assumed that its flora is richer than that of Sikkim and Bhutan. In general, the Eastern Himalaya in botanical respects is even richer than India. Here have been listed 4,000 flowering plants and up to 250 species of ferns and species related to them, of which eight are woody.

In the Eastern Himalaya (of which the Mon-yul is a part) there is a predominance of ten families, arranged below in the order of their predominance.

1. Orchideae, 2. Gramineae, 3. Leguminosae, 4. Compositae,
5. Cyperaceae, 6. Urticaceae, 7. Scrophularineae, 8. Rosaceae,
9. Rubiaceae, 10. Euphorbiaceae.

For the tropical and subtropical forests of the south of Tibet Ward mentions the pine (*Pinus khasya*), not found above 1,500 meters, the Himalayan pine (*P. excelsa*), reaching 2,500 meters, and also the maple (*Acer caudatum* and *A. stachyophyllum*), oaks (*Quercus glauca*, *Q. Griffithi*, *Q. ilex* and others), *Magnolia Campbelli*, *Michelia lanuginosa*.

Swamps and marshy expanses. In all parts of Tibet are encountered areas of swamp and marsh. Some of them are associated with the flat poorly drained watersheds; others with enclosed depressions and riverine terraces. On the flat marshy watersheds, widespread for the most part between 3,900 and 5,000 meters, meadow-swamp soils have developed. In these soils grow sedge, *Eleocharis* and other moisture loving plants. Such vegetation and soil types are encountered in the Tanghla, Kukulshili, Dunbure and Karakorum Ranges. More often than not on the watersheds and gentle slopes of the ranges one can see hummocky swamp (*motoshiriki*), in whose vegetative cover *Cobresia tibetica* predominates.

On the margins of fresh-water lakes meadow-swamp and peat-swamp soils have developed. The vegetative cover consists of crowfoot (*Ranunculus tricuspis*), *Triglochin palustre*, *Cymbalariae*, rushes (*Juncus*

Thomsonii), *Cochleria scapiflora* and others. Areas of peat-swamp soils with corresponding vegetation are found in Southern Tibet at Lakes Yamdok, Tsomo, Palgo and Trigu. Marshy poorly drained soils, especially in Northern Tibet, are often saline.

In meadow soils, forming under conditions of good drainage (along brooks and streams), there is a predominance of sedge, principally *Carex Mucroftiana*.

Broad stretches of land along lake shores, occupied by *Cobresia* and sedge, are used as high-productive pastures and can serve as an extremely important basis for the development of livestock raising.

Vegetation of Solonchaks and marshy areas. On the broad plains of Northern Tibet with interior drainage, Solonchaks and various marshy soils have developed, among which predominate meadow Solonchak soils, but marshy swamp soils also are frequent. Solonchaks occupy broad areas: oftentimes the surface is covered for tens of kilometers with a crust of salts among which ordinary salt ( $\text{NaCl}$ ) and sodium sulphate ( $\text{Na}_2\text{SO}_4$ ) predominate. Most commonly both the largest Solonchaks and salt crusts are encountered to the north of  $33^\circ$  between  $82$  and  $84^\circ$  E. Solonchaks are also found in Southern Tibet, although to a considerably lesser degree, in enclosed valleys shielded by mountain ranges from the influence of the Indian monsoon.

Solonchaks are often completely bare of vegetation; sometimes on them there are encountered clearly obvious salt-loving plants -- niter bushes, etc. The vegetation of marshy meadow and swamp soils is represented by a specific association of plants. With suitable reclamation measures and proper agricultural engineering the marshy soils can be used for the sowing of agricultural crops. At the present time work is already being carried on for the upgrading of virgin lands in the region of marshy soils near Chushula in the Dzichu valley.

Vegetation on the floodplains. Floodplain terraces of the rivers of Southern Tibet have coarse gravelly alluvial soils. Often these flood plains are saline and in such cases they have a vegetation cover with a predominance of tamarisks and other salt-loving plants.

The flat flood plain sectors of the Indus and Sutlej valleys, the alluvial fans of their tributaries and the headwaters of the Tsangpo River, are characterized by an absence of salinity and have dense overgrowths of bushes: burrs, *Hyppophae rhamnoides* and *utesnik* -- *Caragana versicolor*. The bushes grow more than a meter high and differ considerably from the bushes of Northern Tibet.

In ending our description of the natural vegetation of Tibet we should note that some wild-growing Tibetan plants are edible. Thus, the nodular tubers *Codonopsis owata* are boiled, then roasted and made into flour. Also edible are the roots of *Potentilla anserina* (silver weed). Its long and thin starch tubers are roasted in oil. Also used for food are the meaty tubers of *Arenaria*.

**Cultivated vegetation.** Tibetan agriculture is almost completely concentrated in the Tsangpo valley and on the terraces of its most important tributaries. In the western part of the Tsangpo valley there is no agriculture and it begins only to the east of the Ralung Monastery. From here and further downstream on the terraces and alluvial plains of the Tsangpo itself and its tributaries every scrap of land is cultivated that is suitable for this purpose. In general, however, in the western part of Southern Tibet oases are encountered, for example, in the valley of the Gartang River, in the Sotlej Basin and in the valleys of the Karnali and Trisuli Rivers. Agriculture is based on irrigation.

The limits of the vertical boundary of agriculture in Tibet are higher than anywhere else. G. V. Kovalevskiy (1938) considers that this is due to the strong action of direct solar insolation which makes possible a rapid growth of plants and a decrease of the growing season to the minimum.

The farmers of Tibet grow chiefly barley, buckwheat, legumes -- peas (Chinese and Indian) and beans. It has been established that in the case of barley and other cultivated cereals, partly also in the case of leguminous crops, the synthesis of sugar increases very rapidly. In connection with the high sugar content, as mentioned above, there is an increased resistance to frost on the part of the plants mentioned and of grasses as well, which are capable of withstanding temperatures as low as  $-20^{\circ}$  and less. The synthesis, however, of insoluble carbons and proteins drops sharply. The intensified synthesis of sugar, besides increasing the high frost-resistance, increases the nutritive value of cereals and legumes -- and grasses as well. And if this is the case, the fact that so many hooved animals live on the scanty pastures of Northern Tibet, a fact that has surprised all explorers, becomes more understandable.

In Tibet two kinds of barley are grown -- one with a thick husk (soa), used primarily for the feeding of animals, and the other awnless (ne). The latter is very productive and less demanding, bears up under thin soils and shallow plowing, requires little fertilizer and is less sensitive to climatic conditions than is any other cereal.



It even grows at elevations of 4,500 meters, and at Qmba, at an elevation of 4,650 meters.

From the barley ne the Tibetans manufacture tszambu (a flour from overroasted grain) and beer. The barley ne has three varieties: yangma or tukchume -- a fast growing plant, ripening two months after sowing; chkhé-ne -- an average variety and sermo-ne -- the best variety but maturing later than the others.

Buckwheat of two varieties is widely cultivated: *Fagopyrum emargi*, called natum, coarse and cold-resistant and *F. esculentum* -- the best variety, which is grown in the valleys of the Dzichu and Yarlung rivers. The upper boundary of buckwheat reaches 4,270 meters. Wheat is grown everywhere at elevations up to 3,700 meters, but at an elevation above 3,500 meters it often does not mature. Also grown are 60-day oats, millet, maize and rapeseed (for the production of oil and oilcake). Sometimes in the low-lying valleys they sow millet after early barley. The grain harvests are good.

The growing of root crops is widespread in Southern Tibet. The favorites of the Tibetans is the radish, occupying the same area as barley; then turnips and carrots which are only grown in low-lying valleys and are a luxury. There are two kinds of potatoes -- soft white and smooth red, of which many are grown near Lhasa. Onions and garlic also occupy an important position.

The most fertile valleys are the Tsangpo itself (in the eastern part) and its tributaries, the Nyangchu and the Dzichu. However, the valleys of the Yalung (elevation 3,450-3,530 meters) and the Labrak (elevation 3,300-3,400 meters) have the reputation of being the richest. In comparison with other valleys they have a warmer and moister climate.

Lhasa, the capital, is surrounded by green plantations which are carefully tended. In the city itself and in the outskirts, there are flourishing gardens and green parks that beckon with their attractive appearance those mountaineers who come to Lhasa from the deserts of the North Tibetan plateau. The Tibetans are very fond of flowers: in the gardens of Lhasa and in the gardens of the inhabitants of other cities and monasteries scattered along the valleys of the eastern part of southern Tibet there are grown many nasturtiums, asters, marigolds and mallow.

In Northern Tibet cultivated plants are not grown except in isolated places, as, for example, near the city of Rudok and at the villages of Qmba and Sendzha, situated in the basins of the large Transhimalayan

lakes where the inhabitants grow barley. In general, this is the world's highest boundary of agriculture. Barley possesses great resistance to frost and has a short growing season and this is especially important for Northern Tibet.

#### ANIMAL LIFE

The animal life of Tibet, like other elements in the natural landscape, is distinguished by a singular makeup and clear differences in different regions. A large part of the territory of Tibet, that is, the entire North Tibetan plateau, the Transhimalaya and the northern (and especially the upper) parts of the slope of the Himalaya belongs to the Himalayan-Chinese sub-region of the Palearctic zoogeographic region. At the same time, this entire territory is separated into two special provinces. Completely different fauna live on the lower parts of the southern slope of the Himalaya -- that is, below 2,000 meters. This part of Tibet, really only the small territory of Mon-yul, forms part of the Indian sub-region of the Indo-Malayan or Eastern zoogeographic region.

In referring to the animal life of Tibet, we have in mind primarily the fauna of the high plateaus, isolated at the present time from the influence of neighboring countries due to their elevation. It would be proper to begin with the origin and characteristics of this fauna.

The development of the fauna of Central Asia (and consequently, also that of Tibet, the northern part of which forms part of Central Asia) took place, writes E. M. Murzayev, under the special conditions of an intensely continental climate. As a result, it is ecologically extremely diverse and leads to extremely unusual phenomena. Thus, the absence of a forest belt on many desert ranges of Central Asia leads to contact of high mountain, alpine and desert-steppe forms of fauna. The absence of snow results in the gathering of a large number of birds of prey, feeding on rodents that do not hibernate (Foreign Asia [Zarubezhnaya Aziya], 1956).

A. G. Bannikov (1953) considers that a predominance of open landscapes together with the uplifted nature of the country and the extremely continental climate gives rise to the fauna of the cold uplands of Tibet, the rocky Gobi and the sands of the Takla-Makan. However, in Tibet, in contrast to the Gobi and the Takla-Makan, there is a predominance of a high mountain fauna complex whereas there is a desert complex in the Gobi and the Takla-Makan.

In Tibet as well as in the regions of Central Asia adjoining to the north, the continentality and the severity of the climate have caused an impoverishment of a series of animal groups. Here there is a very small

number of amphibians who can only exist in a climate of considerable moisture and high temperatures. There is a small number of reptiles -- warmth-loving animals that are sensitive to low temperatures. Since there are few insects in Tibet due to the cold climate, so also there are few insect eating birds in the fauna, especially those that feed in flight -- fly catchers, swallows, swifts, goat-suckers. Bats are few because they are sensitive to low night temperatures and winds. Finally, as a result of the little snow during Tibetan winters and the pebbly nature of the soil there are few such insectivores as moles and shrews. On the other hand, due to the open nature of the landscapes, the winter with little snow (which permits year-round easy access to food on the ground) and also due to the absence of insects harmful to animals, especially in the north, there are very many hoofed animals, relatively more even than in Central Asia in general, the more so since expanses of Northern Tibet are totally unpopulated and are rarely even visited by hunters.

A large part of the species of wild animals of Northern Tibet, and to a substantial degree also Southern Tibet, belong to desert and steppe fauna. All the animals are well-adapted to severe natural conditions of high-mountain deserts and they form a clearly defined biological complex. But this complex breaks down into two branches which involves a clearly expressed pattern in the places where the individual species live. Thus, the broad plains of Northern Tibet and the northern slopes of the Himalaya are populated with animals loving open landscapes; this enables them to migrate for great distances in search of food and enables them to see threatening danger from afar. This is especially true of several kinds of hoofed animals and birds and animals of prey that are associated with them.

The existence of such an association is explained not only by the modern landscape characteristics of Tibet but also by the fact that open landscapes have prevailed here, since ancient times, despite a series of mountain forming movements. From this it also follows that Tibetan fauna is extremely ancient in its origin.

Among the animals of the open landscapes the most significant and characteristic animal is the yak (*Poephagus grunniens* Gray), which has survived nowhere else in the wild state. The yak is a strong and singularly powerful animal, very tolerant of conditions, superbly adapted to life at great elevations; due to his thick wool he does not suffer from the winds or frosts of Northern Tibet.

As a remarkable animal we can also point out the widespread orongo antelope (*Pantholops hodgsoni*) which usually lives in groups of 5-40 animals but which gather into herds numbering hundreds of head on good pastures. On the south this animal ranges as far as the watersheds of

the Transhimalaya, and on the north to the Russian, Moscow and Tsaidam Ranges. This large and stately animal has long thin legs. Its head is adorned with thin and almost vertical horns up to 60 centimeters long.

Also existing in abundance is another small and extraordinarily graceful antelope, the ada antelope (*Procapra picticaudata*), which grazes in herds of 5-7 animals and ranges to the inner regions of the Himalaya. Like the orongo, the ada antelope easily makes great journeys in search of better pastures.

A typical animal of the North Tibetan plains is the kiang (*Equus kiang*), a primitive horse close to the wild ass. In size and outer appearance the kiang resembles a mule. These keen and trusting residents of Tibet, gathering in herds of 10-50 animals, sometimes even in the hundreds, make extremely long journeys from one pasture to another, the same as do the antelope.

Kiang, yak and antelope gather in immense herds in valleys having abundant fodder. Sometimes there are hundreds or thousands of head. Deasy, for example, writes that he saw a herd of antelope in northwestern Tibet that numbered 15,000 head. Przheval'skiy remarkably describes animal life in Tibet: "Along our way along the river there were constantly seen wild asses, yaks and antelopes. The trusting animals looked with surprise and curiosity at the caravan, almost without fear. Herds of wild asses withdrew only a little to one side, and the whole group, turning as they let us pass by, sometimes even followed behind the camels. Orongo and ada antelope calmly grazed and gambled to one side or ran along the road in front of our mounts; the wild yak who were reclining after having eaten did not bother to get up if the caravan passed them by at a distance of a quarter verst. It seemed as if we had chanced into a primeval paradise where men and animals still did not know of evil and sin..." (From Zaysan through Khami to Tibet.., 1948, page 172).

The most numerous animals in Northern and Southern Tibet are rodents which live both on the plains and in the cliffs and fields of the alpine zone. Among the rodents we can mention two groups: large rodents which dwell everywhere, and small rodents that live amidst the rocks. By day the rodents are active. At night, however, they remain in their burrows due to the frosts. For dwelling places for rodents in Tibet there are favorable sites consisting of thick strata of detrital material in which burrows can be easily arranged. There is a green mass of plants which is adequate for the rodents; that is their only food. The rodents usually dwell in large colonies which consist of unusually great numbers.

The variety of rodents is not great, but on the other hand there are a great many of them. Przheval'skiy in the eastern part of the highland and Sven Medin in its eastern part, in the Transhimalaya and in Southern Tibet, noted an immense number of burrows of these little animals in the soil and ground.

The most widespread are pika or haystackers (*Ochotona*) -- of four types. They received this name because they store hay, accumulating it near the burrows in the form of small haystacks or they make storehouses under the rocks. These are very energetic little creatures who live in steppe regions and in the meadow margins of the mountains. Hundreds of thousands of them wander about in different directions, hastily bounding from burrow to burrow or sit motionless, enjoying the warmth of the sun's rays.

Field voles (*Alticola*) are encountered in great numbers. These are little animals similar to mice but they are downy and grey. They also store away food for winter. Also numerous are large Tibetan marmots (*Marmota*) with thick brown fur. In contrast to the above-mentioned rodents they pass the winter in hibernation in their deep (up to 10 meters or more) many-branched burrows. There are numerous hares as well. It is interesting to note that in the way of adaptation to the severe winter frosts the Tibetan hare, like his brother, the Arctic hare, digs a burrow or, if it is possible, selects as a dwelling someone else's old burrow.

The great number of hoofed animals and rodents living on the North Tibetan plateau and the even on the gently sloping northern slopes of the Himalaya, is associated with the existence here of a group of predators, also preferring the open nature of the area and liking the snowless Tibetan winters. Whereas the absence of snow makes it easy for hoofed animals and rodents to get food, the openness of the terrain enables predators to spot antelope, wild asses or rodents from a considerable distance away and the absence of snow makes easy their pursuit. Among the predators, wolves are the most widespread (*Canis lupus*), principally preying on antelope and marmot, and also Tibetan blue foxes (*Vulpus ferrilatus*) who live in large families. Also numerous are bears (pika eaters) (*Ursus prinosus*), distinguished by small size and dexterity; this bear receives its name from the fact that it feeds on pika which it gets by digging up their burrows. Corsacs (*Canis corsac*) and other animals are common on the plains.

Another branch of the Tibetan fauna complex is made up of animals preferring the mountains over the plains. The most interesting of them are sheep -- the white chested argal (*Ovis ammon*) which graze on gentle mountain slopes. Well-built, with large and shapely bent horns, a bright white chest and a proud gait, the argals, writes Przheval'skiy,

can be regarded as the most magnificent animal of the Tibetan deserts. The kukuyaman (pseudois nachoor) attracts attention by its fineness of line and fine proportions, half-goat, half-sheep, dwelling primarily in the inaccessible rocks of the alpine zone. Besides these, there are also other kinds of goats and sheep.

The form of life of the animals living in the mountains is associated with the seasonal development of natural conditions in the mountains. In contrast to the yaks, wild asses, and antelope which move about in search of food for great horizontal distances, in large part independent of the season of the year, the goats and sheep make vertical migrations: in summer they feed on the succulent high mountain Cobresia swamps and in summer they move to low-lying and warmer valleys. However, the vertical migrations can have a reverse direction when a great deal of snow falls in the valleys. In these cases the animals climb up to places where constant winds blow away the snow, laying bare the pasture.

In the North Tibetan mountains one also can see such interesting representatives of the animal world as the snow leopard (*Felis manul* and others), to the south of the Tanghla Range the white chested musk deer (*Cervus albirostris*), discovered by Przheval'skiy, and in the Transhimalaya, the monkey. Bonvalot also saw small red monkeys with a scarcely noticeable tail in the canyons of the Duplex Range. In Southern Tibet one also finds otter, lynx and leopards.

Lizards, and especially snakes, can be rarely encountered in Northern Tibet, and then only up to an elevation of 4,630 meters, that is, in the less cold zone. There are very few insects. There are butterflies, bees, grasshoppers, etc. Bower encountered butterflies in the Changtang at elevations of almost 5,400 meters. Bees, as he noted, made their dwelling places in the earth.

Fish, living in the lakes and rivers, are in large part members of the salmon and carp family. Fish abound in such large Tibetan lakes as Nam Tsho, Dangrayum, Dzharang, but in very many lakes there are no fish due to supersaturation with salts.

Bird life in Northern Tibet and the northern slope of the Himalaya is represented by few species. Only about 30 species make their home in Northern Tibet. Despite the very severe climate, three-quarters of them live there year-round or migrate within the boundaries of the area. This gives evidence of their high adaptability and the antiquity of the fauna. Almost all the birds make their nests in sheltered spots -- amongst cliffs rocks, in burrows which they excavate themselves as does the

lozhnosoyka (literally: "false jay") (*Pseudopodoces humilis*) or, like the earth finch (*Montifringilla ruficollis*, *M. blanfordi* and others), they use burrows of pika, not at all hindering the latter by their presence.

The majority of birds in Northern Tibet lack bright colored plumage. A distinguishing feature is inability to sing, with rare exceptions, as a result of which the desert plains seem totally lifeless.

Among the birds there are also species associated with open or mountain landscapes and, in addition, with open water bodies.

For open landscapes, including broad river and intermontane valleys and flattened desert ranges, the following birds can be mentioned as characteristic: the red-beaked klushitsa (*Pyrrhocorax pyrrhocorax*), the large chechevichnik (*Carpodacus rubicilla*) which, in contrast to the majority of other birds of the highland, as a rule silent or poor singers, is an excellent singer, the rock dove (*Columba rupestris*), one of the most widespread North Tibetan birds -- the grouse (*Tchangtangia tibetana*), the Mongolian plover (*Charadrius mongolus*), the Tibetan desert lozhnosoyka (*Pseudopodoces humilis*), Taczanowsky's ground finch (*Montifringilla taczanowskii*), the Tibetan short-legged lark (*Calandrella acutirostris*) and the horned lark (*Otocoris alpestris*), lovers of steppe expanses.

The mountain goose (*Eulabeia indica*) lives on high-lying mountain water bodies as do the red duck (*Casarca ferruginea*) and the Tibetan brown headed gull (*Larus brunneicephalus*), and in hummocky swamps, the blacknecked crane (*Grus nigricollis*).

For mountain ranges the ular is typical (also called the "mountain turkey") (*Tetraogallus tibetanus*). This is one of the most remarkable representatives of the Tibetan feathered kingdom. It lives in wild rocky mountains of the uppermost part of the alpine zone and very rarely does it come down lower. It does not fear the cold and happily passes the winter nights in 30° freezes. The ular feeds on the roots of grasses and fresh leaves but it especially loves onion and garlic. Also common in the mountains is the Adams snow finch (*Montifringilla adamsi*), the Brandt mountain finch (*Leucosticte brandti*), the high mountain redstart (*Phoenicurus erythrogaster*), and among the birds of prey -- the white-headed vulture (*Gyps fulvis*), which has powerful wings up to 3 meters in reach and the bearded lammergeyer (*Gypaetus barbatus*) whose wings also have a reach of almost 3 meters, the long-tailed eagle (*Haliaeetus leucoryphus*), which perches for hours on precipices along streams until it has a chance to take a fish away from a gull which has fetched it up from the water.

Due to the fact that Southern Tibet has a milder climate and the vegetation cover is more varied (bushes make their appearance and locally trees as well) the number of bird species, writes E. V. Kozlov, more than doubles. Species appear here which are alien to the major part of the highland. Among them are tropical pheasants, bamboo partridges, timelii, snow doves, blue rock partridges, the solongan, Malayan kingfishers and the Indian chibis.

Whereas all of Tibet constitutes a single province of the Central Asiatic subregion, forming part of the Palearctic zoogeographic region, the Mon-yul, that is, the southern slope of the Great Himalaya Range, in this respect has its special features. Its northern part, situated at an elevation of more than 2,000 meters, is part -- like all of Tibet -- of the Central Asiatic subregion and its fauna is similar to that which was described above for the highland part of Tibet. Its southern part, however, situated at elevations less than 2,000 meters, forms a part, as indicated, of the Indian subregion of the Indo-Malayan zoogeographic region. Because of this the tropical and subtropical zone of the Mon-yul have fauna similar to the neighboring Indian fauna. For the Mon-yul there are characteristic such species not typical of the Tibetan highland as buffalo, boars and panthers. In large numbers are found monkeys, Indian deer, southern bear, etc. It is possible that earlier there were many elephants and rhinoceroses, animals still living in India. Especially remarkable among the birds are numerous representatives of the pheasant family, including peacocks and sertun. There are parrots. They are all characterized by bright plumage which is a peculiarity of birds of hot countries. Finally, very many snakes live here, but relatively few lizards. Insects, like birds, are surprising in their variety and the brightness of their coloring.

Domestic animals bred by the Tibetans include sheep, goats, yaks, ponies and donkeys. Tibetan sheep do not yield a fine and soft wool; their meat, although fatty, is less tasty than the Mongolian. However, their power of resistance is a very valuable quality. They are unpretentious in respect to food and adaptability to life at great elevations. Since sheep suffer less from the thinness of the air than do other animals and since they climb superbly along any mountain trail, the Tibetan population often uses them as beasts of burden: sheep can carry a load of about 10 kilograms. Sheep skins and wool are used in the manufacture of clothing, partly for export.

Long-wooled Tibetan goats are distinguished by a small size, but they yield very good wool -- to be more exact, underwool (fuzz -- "pashmin"), having great demand on the world market. From the fuzz of Tibetan goats are manufactured the wellknown Kashmir shawls. Southwestern Tibet is the main region for the breeding of goats.



One of the most valuable animals in Tibet is the yak. This is a direct descendent of the wild Tibetan yak. The domestic yak is similar to the ordinary domestic ox only the tail is similar to that of a horse and on the bottom of the paunch and on the legs down to the knees wool hangs in the form of fringe that is up to 25 centimeters in length. Yaks are very strong and resistant animals, not demanding in respect to food and conditions for self-preservation. They bear up well under rarified air; despite their seeming clumsiness they climb along the cliffs very cleverly, go through ice and easily ford rivers. Therefore, besides for the cultivation of fields, they are used as the main source of energy for the transporting of burdens and for riding.

The meat of the yak is tasty, although less so than the meat of ordinary cattle; the fat content in the milk is twice greater than the fat content of milk from ordinary cattle and is very tasty. (The milk of a yak cow contains from 6-7 to 10-12 % fat content.) They use the milk to manufacture excellent butter and cottage cheese. In addition, yaks yield long wool and excellent soft underwool. In Tibet they also breed a cross between the yak and the ordinary cow; in Tibetan this cross is called tszo.

Horses are also kept. These are small, very resistant, fast and undemanding animals. They are bred primarily on the Yamdok-Karmalin plain, to the east of Lake Yamdok and near Lake Nam Tsho. In addition, chiefly in the region of the city of Shigatse and Lake Yamdok, mules and donkeys are used in the economy. There are also swine in Southern Tibet.

#### PHYSICAL GEOGRAPHIC REGIONS

The majority of foreign researchers divide the Tibetan highland into three basic physical-geographic regions: Northern Tibet, Southern Tibet and Eastern Tibet. Such a division was also proposed in their time by N. M. Przhneval'skiy and P. K. Kozlov, with E. M. Murzayev being of the same opinion.

In the most recent works of Chinese authors -- Li Pu, Hu Shen-su, Huan Fen-shen and also Chen-hun and Sun Chun-in and others, the highland is divided into the same basic regions although there are also examples of a more detailed regionalization (up to 5-6 regions).

Let us cite several examples of the regionalization of Tibet by Chinese geographers.

Hu Shen-su delineates them as follows: 1 -- The North Tibetan Plateau, the eastern boundary of which he draws through the headwaters of the Hwang-ho, Yangtze and Mekong; 2 -- the Longitudinal Valley, that is, the valley of the Tsangpo; 3 -- the Region of the Canyons, that is, the

eastern part of the plateau where the Tibetan ranges change from a latitudinal direction to the southeastward and then become north-south. Hu Shen-su was guided by relief features and climate when making his regionalization.

Li Pu delineates his regions as follows: 1 -- the Northern Plateau of Tibet -- the region of the Neylukh; 2 -- the Upper Course of the Nutszan (Salween) River -- a region of plateaus and canyons; 3 -- the Eastern Part of the Basin of the Three Rivers -- a mountainous region; 4 -- the Upper Course of the Yalutszyanbutszyan (the headwaters of the Brahmaputra, in Tibetan called the Tsangpo -- a region abounding in mountains; 5 -- the Lower Course of the Yalutszyanbutszyan -- a region of canyons. The basic principle of regionalization used by him was geomorphological features.

Fen-shen in his book (1954) delineates the following regions: 1 -- Ali (southwestern Tibet); 2 -- Tsyantan (Changtang), that is, Northern Tibet; 3 -- Tszan (the basin of the Tsangpo River); he passes its western boundary through the watershed between the basins of the Tsangpo River and Lake Manasarowar; 4 -- An'do (Amdo); 5 -- Kam; 6 -- Men'yuy (the southern slope of the Himalaya Range).

Fen-shen takes into consideration the administrative division, the geomorphological features of the area and also the character of the stream regime (delineation of areas of internal drainage).

Wan Chen-hun and Sun Chun-in (1953) delineated two regions: 1 -- the Plateau of Northern Tibet and 2 -- the valley of Southern Tibet (the Basin of the Tsangpo River).

With an attentive examination of the indicated delineations one can see that in all cases in Tibet proper two parts are delineated into two independent physical-geographic regions -- the northern, occupied by the Changtang and the Transhimalaya (Gandisyshan), and the southern -- a broad tectonic valley occupied by the Tsangpo River and the headwaters of the Indus. In addition, the delineation made by Fen-shen is completely justified in which he separates the southern slope of the Himalaya as an independent region. Such a division completely corresponds to the basic principle of the physical-geographic regionalization which consists, in our opinion, in a consideration first of the orographic features and the climatic and other natural features of the territory that are dependent on them. Despite the fact that the territory of Tibet is very great and that it extends for more than 1,000 kilometers from north to south, it is unfeasible here to delineate physical-geographic regions on the basis of the zonal-latitudinal principle. As a consequence of the extremely great absolute elevation of the mountain complex in a substantial part of its territory, one observes varied

conditions in respect to insolation and radiation of heat and the circulation of air masses different from those of adjoining areas. Consequently, geographical latitude is a factor having decisive significance to the landscape in other places but in Tibet it seems to make no difference. The natural features of one part or another of Tibet depend primarily on orography. Tremendous latitudinal mountain ranges here cause differences in climate and the character of runoff that in the highest degree have influenced and continue to influence the face of the country's landscape, its differences from place to place, the landscape-forming processes and the economic activity of the population. Thus, the southern part of Tibet (to the water divide of the Transhimalaya on the north), still receiving the moisture of the Indian monsoon and distinguished by natural conditions which are most favorable for economic life, has a relief with traces of forceful erosional activity, especially on the southern slopes of the mountains. At the same time, a large part of Tibet, situated to the north of the Transhimalaya and called the Changtang Desert, receives little precipitation and is unsuitable for agriculture. As a consequence of the mountain systems of the Himalaya and the Transhimalaya, blocking off the moist winds coming from the Indian Ocean, and due to the absence of drainage into the ocean, erosional forms in the Changtang have developed somewhat more weakly, the relief is softened by the mass products of weathered rock and by the lowering and levelling off of the surface.

Other factors, to a substantial degree resulting from topography, such, for example, as high or low humidity, can be used only for delineation of differences existing in different parts of the main physical-geographic regions.

Proceeding from what we have already said, and also from the experience of regionalization by other authors, it seemed feasible to divide Tibet proper into these main physical-geographic regions:

1. Northern Tibet.

2. Southern Tibet (the Kailas Range and the Nyenchen-Tanghla serves as the boundary between them) (Eastern Tibet, included in the boundaries of the Tibetan highland, is not part of Tibet proper, and therefore will not be discussed here).

3. Men'yuy -- the southern slope of the Himalaya.

In its turn, in Northern Tibet it is possible to delineate subregions -- the Changtang and the Transhimalaya -- and in the Southern Basin of the Tsangpo -- the Central Subregion and the Southwestern Subregion, Ngari-Korsum, including the basin of the Sotlej.

## NORTHERN TIBET

Under the term Northern Tibet we have in mind the part of Tibet proper located to the north of the watershed of the Transhimalaya. This region occupies a large part of Tibetan territory distinguished by natural conditions that are the least favorable for the life and agricultural activity of the population. On the north the region is bounded by the ranges of the Kunlun, sharply dropping off to the desert basin of the Takhla Makan. The nearness of this desert exercises an unfavorable influence on the natural conditions of the high mountains: it intensifies its aridity and makes possible the penetration of strong winds.

On the south, the boundary of Northern Tibet passes along the high Kailas Range and the Nyenchen-Tanghla, blocking off a large part of the moisture still available after the Indian Ocean monsoons have crossed over the Himalaya. Thus, the region described, in contrast to Southern Tibet, receives substantially less moisture and in the very northern part it is a completely unproductive desert. Another characteristic of its natural conditions is, that blocked off from the west, north and south by young and tremendous ranges it has no runoff to the ocean. Finally, the average absolute elevation of Northern Tibet exceeds that of Southern Tibet, therefore its characteristically greater rarefaction of atmosphere and absolute and mean temperatures lower than in Southern Tibet.

Such are the general features of the natural conditions of this region. Differences in its individual parts are determined above all by the relief, the amount of precipitation which occurs, and the presence or absence of drainage to the outside.

### THE CHANGTANG SUBREGION

The Changtang Desert occupies the major part of Northern Tibet. This is the most elevated part of the highland, located to the east of 81° E. between the Kunlun on the north and the northern outlying ranges of the Transhimalaya on the south. (Some authors, including Chinese, group the Transhimalaya with the Changtang. In nature of relief, soils, vegetation and geological structure, it is more expedient to separate it as a special subregion of Northern Tibet.)

The average elevation of the Changtang above sea level is about 5,000 meters, the area is 500,000 square kilometers (including also its territory situated to the east of the boundary of Tibet proper).

The climate of the Changtang is distinguished by a pronounced continentality. In the warmest months -- June, July -- one observes temperatures here that are 10, 15° (sometimes up to 30° and above) by day and

below zero, sometimes  $-10$ ,  $-15^{\circ}$  at night. The average daily range of temperature reaches  $24^{\circ}$ . The average July temperatures are less than  $10^{\circ}$ , consequently, lower than in the tundra. Summer comes late (the growing season begins only in June) and it is short, the autumn is also short -- in October a permanent snow cover is already present. Autumn weather, relatively good weather with clear days and no wind, is replaced by severe winters and strong cold winds.

As mentioned above, Changtang in the Tibetan language means "northern plain." In general, the Changtang is for the most part a plain which spreads out between widely spaced ranges. These ranges, with a very high elevation above sea level, rise above the highland plains for only a few hundred meters in all, rarely by as much as 1,000-1,500 meters. In the middle of the plain, in their turn, there also rise low ridges and hills. An asymmetrical structure is characteristic of all the ranges of the Changtang: their northern slopes are gentle and the southern slopes are steep.

The mountain ranges and hills in large part have an east-west orientation, but there are also ranges with a different orientation. As a result, the rivers flow in various directions, flowing into lakes which have no outlets.

In the northern part of the Changtang there are many plains which are dismal and completely sterile pebble and detritus covered surfaces of alkaline soil or rock. Here and there on the surface outcrops of dislocated and upturned strata of salts are exposed which the wind has sculptured into queer shapes of pyramids, spheres and cones.

The pebble and detritus covered surfaces were formed as the result of deflation from the soil of particles of fine soil and the accumulation of gravel and pebbles, transforming into a solid polished lustrous armor of sand particles and gravel that is no longer subject to further deflation.

On the best soils there grows a scanty grassy vegetation, primarily from very tough and hard Tibetan reed grass (*Carex Moorcroftii*), occasionally meadow grass or *Festuca sulcata*. There is also dwarf bushes of white willow (*Eurotia ceratoides*) and reamyuriya. *Cobresia* meadow is adapted to the strongly moistened depressions.

In the eastern part of the Changtang and along its southern boundary to the south of  $33^{\circ}$  N. and to the east of  $82^{\circ}$  E., where the amount of precipitation somewhat increases, the surface is partly covered by a steppe or meadow-steppe vegetation with bushes (chiefly *Caragana*) along dry slopes.

In the flat low basins of the Changtang, especially in its southern part, there are scattered a great number of lakes and swamps. However, many swamps contain water, so it appears, only in the summertime, the moist time of the year, and they dry up by autumn.

Judging by the surface deposition in the Changtang and in several other regions of Tibet, the highland was at sometime the bottom of several broad fresh water basins. (Burrard and Hayden consider that on the Tibetan highland and in the regions adjoining it to the west that the following lake basins once existed: Ngari-Korsum -- 800 square miles (1,860 sq. km.), Aksaychin -- 1,200 square miles (2,785 sq. km.), Lingzitang -- 1,000 square miles (2,320 sq. km.), Dapsang -- 500 square miles (1,160 sq. km.), Deosay -- 600 square miles (1,400 sq. km.) The Kheykhe Depression at the headwaters of the Salween can also be included in this group).

Unfortunately, the absence of stratigraphic data does not permit us to determine precisely in what period of geological time the lake basins were formed. It is possible that some of them existed at the beginning of post-glacial times, being fed by the thawing of the glaciers and in part from precipitation brought in by the Indian Ocean monsoon. Other lakes possibly originated in the period between the Upper Cretaceous and glacial times when broad expanses of Eurasia were in the grip of cooling processes. One thing is rather clear: judging from the Pliocene alluvium of the Sutlej basin, by the beginning of Quaternary times many lake basins had already begun to disappear. Orogenic movements played an important role in this process. These occurred in the Tibetan highland and especially involved the uplifting of the Himalaya which by the end of the Tertiary and at the beginning of Quaternary times had attained their present day elevations. The Himalayan barrier blocked the highland off from the moist Indian Ocean monsoons and created a continental climatic regime in its territory. In addition, the crests of the Transhimalaya from the south and the Kunlun from the north created barriers blocking the drainage of interior waters of the highland from outflow to the ocean.

The continentality and aridity of climate with the absence of drainage to the outside determined the direction of development of the landscapes. Interior basins, valleys and lake basins between the chains of mountains and also ancient eroded surfaces, elevated to different levels, began to be filled by a mass of detritus -- products of the weathering of the extremely high mountain ranges. This detritus, due to the absence of drainage to the outside, generally remained in place. Thus, the relief of the Changtang gradually smoothed out and horizontal instead of vertical lines came to predominate. This gave the modern Changtang the appearance of an undulating plain. Only beyond the meridian of Nam Tsho, east of which rise the Yangtze, Hwang-ho and

Salween, does one note a transition from the region of interior drainage to the region of drainage to the outside, to the so-called Chinese-Tibetan Alps. To the west of this line, using Przheval'skiy's words, "is situated a continuous and massive tablelike plateau on whose surface there is a minimum of sharp relief and not having water except in a small part in the east which has drainage to the sea. To the east of the mentioned line, however, all the water flows to the ocean, the area little by little loses its tablelike character and is gradually transformed into a grandiose alpine country in which there are intermingled the systems of the Central Kunlun and the Chinese and Indo-Chinese ranges" (From Zaysan through Khami to Tibet... [Iz Zaysana cherez Khami v Tibet...], 1948, page 149).

The most desertlike northern part of the Changtang is occupied by ranges and intermontane plains of the Kunlun. Their landscapes are dreary, especially within the boundaries of the Sin'tszyan-Uygurskiy autonomous region. The absolute elevation of the plains reaches 5,000 meters. The vegetation almost completely disappears and bare gravel and pebbles predominate. V. I. Roborovskiyy penned a depressing picture of this "dead land." He did exploration there as part of M. V. Pevtsov's Tibetan expedition of 1889-1890.

Climbing up from Karasay (Province of Sin'tszyan) onto the plateau of Tibet and crossing over one of the outlying ranges of the Kunlun, Roborovskiyy headed southward, crossing low and narrow east-west ridges. The height of the plateau was approximately 5,000 meters, vegetation was absent, movement was made difficult by the rockiness and unevenness of the road. Two out of three horses of the expedition perished, not surviving the rarified air, cold and lack of fodder. Proceeding a little more than 100 versts to the south, Roborovskiyy was forced to again return to Karasay.

In his report concerning this journey Roborovskiyy wrote: "On the way through the highland desert we did not see any animals except several weary starved antelope, orongo, moving slowly to the north. They were so exhausted that they paid no attention to us, passing only 50 paces from the caravan. This gave us reason to believe that the above said animals had traveled from afar and that the highland desert in which we met them extends very far to the south. In this same desert we found the skulls of several wild yaks but we found no footprints of these animals. Probably the yaks strayed by chance into this frightful country and perished from the cold."

"At night camp our horses, despite their felt horse blankets, suffered severely from the strong wind and snow and they shivered and shook as if in a fever. It was my first experience in being in such a

wild and frightful desert and the desire to become acquainted with it possibly took me further than I should have gone." (Works of the Tibetan Expedition [Trudy Tibetskoy Ekspeditsii], Vol 3, Saint Petersburg, 1896, pages 40-41.)

The desert landscape also continues to the east. The difference consists only in several peculiarities in the relief. N. M. Przheval'skiy, first of the explorers visiting the northern border of the Tibetan highland, describes the landscape of this high mountain desert. V. I. Bobrovskiy and N. M. Przheval'skiy during the period of these explorations did not enter the territory of Tibet proper, they were somewhat further north of the Tibetan administrative boundary. But their descriptions to a high degree reflect the natural conditions which also lie further to the south, in Tibet proper, and that is why we cite these authors also. Przheval'skiy describes this desert in the following words:

"An extensive broad plain now unfolded before us and passed off eastward beyond the horizon. On the north it was sharply framed by the Columbus Range which in its western part here faces Tibet as a low but extremely steep wall. On the southeast and south we could see the scattered hills and ridges of low mountains; beyond them could be seen the immense range later named for me, with its snowy peaks. Finally, in the middle of the above said plain, longitudinal to it, there spreads out a large lake which, to our surprise, was still not covered with ice. I immediately named this lake Nezamerzayushchoye [never freezing]. (In contemporary books it is called Ayagkumul'). We headed for it through the sterile and gently sloping plain...

"...Three versts from our camp we climbed to the top of one of the principal hills, from which a broad horizon spread out before us. We saw little of a consoling nature for us, however. As far as the eye could see -- to the southeast and the south, extended the same loess hills. They were sterile, and, as usual, dissected in all possible ways: here stood towers, fortresses, cones of various size and shape, bridges, underground passageways, vertical walls, corridors, etc. The average elevation of these hills reached from 300 to 500 feet; some of them rose 800 feet or even a thousand. Then, in the direction of Nezamerzayushchoye Lake this garland of hills dropped off in a vertical wall. In places the loose loess was cemented into a solid mass, in places we encountered small layers of gypsum, on the peaks of the hills, however, and along the bottom of depressions, large pebbles lay on top of the loess.

"Examining the whole vicinity carefully through a spyglass, we were convinced that it was impossible for us to go on. The sterile loess hills lay far to the south; beyond them could be seen mountains



and there rose up a snowy range (Przheval'skiy Range -- B. Yu.)."  
(N. M. Przheval'skiy, From Kyakhty to the Sources of the Yellow River,  
1948, pages 157-158).

In the northwest of Tibet proper in the Changtang is situated a plateaulike intermontane lowland -- the Aksaychin Depression -- bounded on the north by the continuously snow-covered ranges of the Kunlun and in the south by the Karakorum. Mountain spurs dropping off to the Aksaychin have depressed water divides that in many places are dissected by deep channel-like canyons that are typical of interior continental deserts with erosional landforms.

The Aksaychin Depression extends, contracting in width, eastward beyond 80° E. As shown in Wellby's topographic survey, the depression is characterized by long and relatively low folds extending in an east-west direction (severely impeding north-south movement), separated by broad valleys, the floors of which lie at an absolute elevation of about 4,900 meters. Thus, the ranges of the Kunlun rise above the valleys of the depression by a little more than 2,000 meters and those of the Karakorum rise above the depression by 1,500 meters. Lake Ligten is situated on the rocky Aksaychin plain surrounded by high mountains; its shores have fiord-like outlines.

Further to the east and to the east of Lake Markham the relief of the Changtang consists of small east-west ridges that are difficult to cross and which alternate with narrow valleys. The vegetation here is the usual for the Changtang Desert; it is scanty and only in scattered places does it form good pasture. The landscape would be depressingly monotonous if it were not enlivened by the bright variety of colors of the rocks making up the surface of Tibet. (All travelers remark on the bright colors of rocks exposed at the surface in Tibet. S. Hedin noted the intensely bright yellow color of the rocks at Lake Aksaychin and the dark violet, gray-yellow, red and white rocks in the mountains to the south and north of the depression. Yellow-red, fiery red and deep brown rocks were observed by him at Lake Ligten and red and green colored rocks at Lake Markham. Przheval'skiy remarked on the brightly colored rocks in the Dunbure Range and Waddell describes them eloquently on the northern slope of the Himalaya.)

Characteristic of Tibet are rocks of variegated color. This possibly gives evidence of the existence of a moist period in the past and of the calm tectonic conditions prevailing at that time, thus permitting an intensive chemical weathering and the formation of a thick brightly-colored siallite crust from weathering.

To the south of the Aksaychin are situated the Karakorum ranges, among which the chief ones are the Tibetan Karakorum, the Changchenmo and the Pangong. In the western part of Tibet they are the highest and the closest to one another, but eastward they fan outward. The southern of these ranges change their orientation from east-west to southeast-northwest. Although the orography of this part of the Changtang is complicated and intricate, nevertheless, despite the numerous spurs going out from the main ranges, here, so Deasy writes, broad valleys that are separated by broad mountain ranges predominate.

The Karakorum ranges do not reach the heights in this region that they do in the Western Karakorum. However, individual peaks exceed 6,000 meters and the floors of the intermontane plains are situated at 4,900-5,000 meters (and only to the south of 33° N. does the elevation of the mountains and plains decrease: the peaks no longer attain 6,000 meters and the plains are situated at an elevation of approximately 4,250 meters). The ranges in large part remind one of ridges of hills, rising above the level of the plains no more than a few hundred or tens of meters. But the main mountain chains are high -- their individual peaks, and the Tibetan Karakorum most of all, rise to an elevation of 6,443 meters and the crests in many places go beyond the snow line and have an alpine appearance.

The valleys of the part of the Changtang described are trough-shaped with steep slopes and flat floors; the southern slope in large part is steeper than the northern and the profile of their cross section is asymmetrical, something easily seen in the attached sketches. The crest in the western part is rounded and monolithic. In actuality it is furrowed by a great number of gullies, sharply deepening and widening downslope and on the lower part of the slopes they are transformed into deep valleys and canyons. The extraordinary branching network of these deep steeply-sloping valleys and the abundant deposits of rock and talus make the local landscapes similar to the bleak but magnificent landscapes of the Western Karakorum.

At Lakes Arport, Chemen and Aru there is a high mountain landscape. Here one can see steep slopes and craggy peaks carrying a cover of eternal snows, snow fields; glaciers moving downslope and valleys. But in other places, for example, at the Changchenmo River and especially in the eastern part, the Karakorum of Tibet loses its alpine features and reminds us of ruins in their outer appearance. With the exception of the abrupt cliffs, sometimes appearing at the crest, steep slopes, precipices and lofty peaks are rarely encountered here; on the other hand, accumulations of detritus, like a cloak covering the mountains are seen everywhere.

The Changchenmo and Pangong ranges are very similar to the Tibetan Karakorum. Here and there they rise beyond the snow line and glaciers and ice fields are found in their high valleys and canyons. In general, however, these mountains are also, heavily dissected, if not more so, and their low-lying water divides are in many places swampy.

Approximately to the north of  $83^{\circ}$  N., the Changtang has the appearance of a hilly country, the relief of which consists of shallow basins that are separated by low water divides. Sometimes the area is more of a plain, sometimes more mountainous and the mountains or hills are similar to our Mugodzskiy Mountains where their low and gently sloping spurs pass into the plain of Northern Kazakhstan. Ridges of hills and mountains extend in an east-west direction or north-south direction and the depressions between them form something like a large honeycomb. Dry ravines and small valleys drop down from the flat water sheds with their numerous prominences. However, here also there are individual high mountain ranges such as the Dutreuil de Rhins Mountains, in their highest part attaining an elevation of 5,630 meters. One can form an opinion of the landscape of the Changtang from Bower's notes:

"...In the course of several weeks -- writes Bower -- the journey continued through an area completely unpopulated and devoid of fresh water. The nature of the country the whole length of the journey was identical -- rounded hills with broad and open valleys and snow-covered ranges clearly outlined against the sky first here, then there." (Collection of Materials on Asia [Sbornik materialov po Azii], publications 69 and 70, 1893).

Near Kebe-Chung (a little to the north of  $33^{\circ}$  N. at  $86^{\circ}$  E.), Sven dedin described a picture of very close and disorderly-arranged hills, the road winding endlessly among them.

Data supplied by de Rhins gives an idea about the landscape of the Changtang in its least studied central part. He crossed Tibet from north to south between  $86$  and  $87^{\circ}$  N., approximately along the line between the city of Cherchen and Lake Dangrayum. Crossing the Przheval'skiy Range, de Rhins traveled to the south through an east-west oriented plain having a width of 45 kilometers. Its surface is traversed by low mountains and hills. Despite the scantiness of the vegetation, consisting of low-growing grass, he encountered numerous herds of antelope, kiang and yaks. On the south the plain is bounded by a chain of mountains beyond which there extends a plain with large lakes. Further to the south there are mountains again, but they are lower, and the valleys are studded with large lakes. Then the traveler crossed four ridges of high mountains, the highest of which, evidently, was the Buka-Mangna. The most southerly ridge proved to be the highest (with a pass at 5,630 meters) with an abrupt southern slope. It was later named the Dutreuil de Rhins Range.

To the south of this range de Rhins again and again encountered immense mountains. There was a great change in the topography of the region. Instead of the broad valleys, open to the east and west, to the right and left of the traveler mountain chains rose up with narrow valleys between them and with numerous lakes in the depressions. Sometimes the valleys were traversed by north-south ranges, which, so de Rhins concluded, were the northern outliers of the western end of the Tanghla Range. Apparently, in the west it becomes the hilly area that was described by Sven Hedin near Kebe-Chung.

The landscapes of the eastern part of the Changtang were described by Littledale, S. Hedin, Bonvalot and Przheval'skiy. George Littledale crossed the Changtang from the northwest to the southeast along the line between the city of Cherchen and Lake Nam Tsho. The area traversed in the northern part of his journey, described a little further to the east by Sven Hedin, is extraordinarily unusual. At the sources of the Kara-Muren (the northern slope of the Przheval'skiy Range) are scattered numerous hills, as S. Hedin writes "flattened and level cones with jagged sides," consisting in part of reddish and partly of very hard conglomerate-like brick-red rock similar to breccia. The tops of the cones are covered with horizontal strata of black tuff".

These same hills are also found on the southern side of the Przheval'skiy Range. Often encountered here are dry depressions with salt deposits or small lakes. This area in the not distant past was a region of great volcanic activity. In crossing it, Littledale discovered seven volcanoes of which four were of great size. The volcanoes are isolated from one another, having no orographic connection with one another nor with the Przheval'skiy Range situated to the south of them. The peaks and craters of the volcanoes are covered by eternal snows and glaciers. There are also volcanoes on the southern slope of the Przheval'skiy Range. Thus, close to  $90^{\circ}$  E., a large volcano was discovered by Bonvalot who named it Ruisbrook.

The region of development of volcanic forms of relief and volcanic deposits, according to Littledale's observations, is situated between  $36^{\circ} 50'$  E. and  $33^{\circ} 50'$  N., that is, a distance of three degrees of latitude. Besides the seven volcanoes indicated, all three lying to the north of the Przheval'skiy Range, the explorer discovered three other volcanoes with an elevation of about 6,000 meters at  $33^{\circ} 50'$  N. between the meridians of  $87^{\circ}$  and  $88^{\circ}$  E., that is, in the western outliers of the Tanghla Range.

Further to the south of the Przheval'skiy Range, Littledale passed through a desert type but predominantly flat-lying area that was almost devoid of grass. The area was rocky and represented, excluding the volcanic regions, an alternation of flat, east-west oriented valleys

with a great number of lakes and weakly expressed flattened rises, from afar having the appearance of high, eternally snow-clad ranges; close up, however, they proved to be low. En route the explorer crossed several relatively low but steep passes. To the east of the meridian of 87° W., judging by his descriptions, the ranges no longer stood out very clearly.

From Bonvalot's data, recording the journey to the south from Lake Ayagkumkul' to Lake Nam Tsno, it is apparent that the part of the Changtang crossed by him also was of about 5,000 meters elevation or even more. But wherever the eye turned there were snow-covered mountains to be seen. The passes across the mountain ridges for the most part were not difficult. On the plains, covered with lava, were often encountered small lakes, Solonchaks and barchans. Rarely seen were traces of vegetation still surviving from the summer. (Bonvalot traveled in December.) Near the southern slope of the Przheval'skiy Range, as we already mentioned, Bonvalot discovered a large volcano named by him in honor of Ruisbrook. Among other mountain ranges, Bonvalot singles out the Dupleix Range, attaining, in his opinion, an elevation of 8,000 meters above sea level. Glaciers drop down from the slopes of this range, including one which creeps through a broad valley to the Dupleix Pass, situated at an elevation of 5,462 meters above sea level. South of the Dupleix mountains the plateau-like expanses drop down to 4,380 meters. They have the appearance of a steppe plain, intersected by chains of hills with lakes in the depressions; the largest lakes are: Bam Tsho, Darun, Amdo-Tsonak, Yirna. The grass, judging from Bonvalot's description, was quite abundant, despite the fact it was winter. Further to the southeast the relief becomes more dissected.

To the east of Bonvalot's route the system of east-west oriented ranges becomes more noticeable. According to data provided by N. M. Przheval'skiy, this part of the Changtang gives the following impression. On the highland plain with an elevation of about 5,000 meters above sea level, there rise, almost parallel to one another, the Kukushili, Dunbure and Tanghla Ranges. Their local relief is 300-600 meters, the relief features are gentle, slopes are not steep, and ridges and water divides are flat. The peaks of the mountains rise but little over the ridges, are rounded, and only a few of them reach the snow line which is located here at an elevation of about 6,000 meters (it drops down to the eastward). Between the mountain ranges are included plains, more or less broad, sometimes having the appearance of enclosed basins with a hilly or rolling relief.

Since a relatively large amount of precipitation falls in the eastern part of the Changtang, the vegetation here is considerably denser. In the valleys it takes on a steppe-like character and we find grasses

(Gramineae), onion and astragalus. Eurotia and Tamarix also grow in substantial quantity. On moist gentle slopes of mountains and on flat water divides there is an abundance of Tibetan sedge which forms hummocky swamps.

The southwestern part of the Changtang, situated to the south of the Tanghla Range, is drained by the headwaters of the Salween, carrying its waters to the ocean. Crossing the lake region, the Salween captured and drained several lakes and left dry depressions behind in their places. One of them in particular is the Khakhe depression with the city of Atak-Memar. (East of Khakhe, already beyond the boundaries of Tibet proper, the Salween enters a narrow valley that crosses mountainous country. This sector of the Changtang is distinguished by steppes covered with thick grass, especially rich on the right bank of the Salween. In its landscape appearance it is transitional to the alpine landscapes of Kam.)

The climate of the southeastern Changtang is characterized by Li Pu as continental, but thanks to the relatively abundant precipitation it is more favorable for the development of vegetation than is the climate of the northwestern Changtang. The winter is dry, snow falls in the spring, and rain or sleet in the summer. Strong westerly winds blow daily from 1300 to 1800-1900 hours during the months from September through April; these carry off dust and salt particles from the desiccated lake basins. Clear sunny weather usually prevails and the air is so dry and transparent that all the lakes can be seen clearly within a radius of 50 kilometers. In the summer insolation is strong, but in the winter the temperature drops to 30° below zero. The maximum winter temperatures rise to 0°. With the great aridity of the air the fallen snow is rapidly evaporated. The soils here are developed on loess-like material and the farther you go to the east, from the boundary of Tibet, then the better they become because the drainage of the area by rivers belonging to the Salween system also intensifies the carrying off of salts from the ground.

The southeastern Changtang is an important grazing region. Here it is warmer than in the northern Changtang, the vegetation is denser and fresh water is adequate. N. M. Przheval'skiy describes the general picture of the southeastern Changtang (within the boundaries of Tibet) as follows: "On the fifth day after passing through the Tan La we finally dropped down to 14,700 feet above sea level (4,480 meters) from the plateau and came out on the Sanchyu River which flows into the Tan-chyu River, called the Bugyn-gol by the Mongols. The latter flows farther to the southeast and enters the Nay-chyu River or the Khara-usu -- to use the Mongolian name (Salween). On the San-chyu we encountered a camp of nomadic Tibetans whose small black tents stood out helter-skelter here and there along the valley; among them grazed numerous herds of yaks and sheep...

"Our route through the new plateau lay, as before, to the south. The character of the area here was everywhere the same: lowdome-shaped hills, in places levelled out into small ridges and between them a continuous hummocky swamp; at the same time the soil was strewn with large gneiss boulders. The trail was horrible, in particular for camels who had to climb first through rocks and then through the hummocky swamps. Everywhere were encountered the camps of nomadic Tibetans, who, spying on our caravan, usually rode up on horseback and proposed selling us sheep, butter or chur." (From Zaysan through Khami to Tibet [Cherez Khami v Tibet...], 1948, page 202.)

In the southeast of the Changtang are situated the largest of the Tibetan lakes: Nam Tsho (Tengri-Nur in Mongolian), Seling, Dzharang, Naktson, Chargut and others. Several of the lakes are situated on the Changtang plain while others are situated nestled in the mountain spurs of the Transhimalaya which shelter them from the winds. In the case of the largest lake, Nam Tsho, on the west and the east the shores are flat while the hills adjoining it on the west rise no more than 180 meters; on the east, however, between the lake and mountains, a low plain is present.

"Lake Tengri-Nur," write participants in the Chinese expedition to Tibet, "is a broad expanse of water lying at the foot of the Nyenchen-Tanghla Range, the peaks of which are covered by eternal snows. Around the mountains extends a broad steppe which serves as a wonderful pasture for cattle. The Tibetan people call the Tengri-Nur the Nam Tsho, that is, Heavenly Lake, probably because it is situated at a great elevation. We arrived at Tengri-Nur in the midst of winter. The shore of the lake was deserted. The shepherds usually living here had long before moved on to other places. The weather was very cold. For entire days a strong wind blew. Sinister waves rolled along on the surface of the lake. It was necessary to walk sideways in order to move against the wind. Toward evening the wind gradually abated. At this time the lake was especially beautiful. A bright red sunset lit up its calm waters giving it a special charm. It seemed that the white snow, lying on the peaks of the Nyenchen-Tanghla, right then and there would melt into milk." (In the Heart of the Sikang-Tibetan Plateau, Vokrug sveta [Around the World], No 10, 1954.)

Second in size after the Nam Tsho is the Seling Tsho, the northern side of which faces the Changtang; its southern slopes, however, are bounded by spurs of the Transhimalaya. The lake is surrounded by a zone of desert lowland, beyond which to the south rise low mountains with steep slopes at the crests and gentle slopes where they pass into the plains below.

Lakes Chargut and Naktsong, surrounded by the ruin-like Transhimalaya Mountains which approach close to them, are most picturesque than Nam Tsho and Seling Tsho. The surfaces of these lakes are studded with small islands and the shores are sinuous, rocky and locally precipitous.

To the east of the large lakes, beyond the boundaries of Tibet, the Changtang passes over into the typical landscape of mountainous steppe pastures, in Tibetan called "dok". Along the river valleys and along the moist slopes appears a vegetation which includes trees; together with nomadic cattle raising, agriculture and forestry take on significance in the economy (Li Fu).

Having become acquainted with the natural conditions in the Changtang, many authors come to the conclusion that the Changtang is a desert completely unsuitable for the life of the people of the region. This is far from the truth. Even on the northwest the Changtang is not in all places and at all times a lifeless desert. One can cite a series of interesting examples. Thus, Wellby, passing through the Aksaychin depression at the end of May and the beginning of June, saw before him a sterile desert, devoid of grass. The place also appeared to be a desert to Dutreuil de Rhins who passed by Lakes Khorpa and Kenze in September and to Bonvalot, crossing the Changtang from north to south in November and December. But S. Medin, passing through the same places in October through which Wellby had already passed, encountered excellent pastures and relatively frequent fresh water. Bower encountered shepherds in June at a distance of 80-100 kilometers to the east of Lake Aru. He saw shepherds in the valleys of the Karakorum and Bezi. Finally, N. M. Przheval'skiy, crossing the Kukushili, Dumbure and Tanghla Ranges in October, commented on their flat watersheds and the gentle slopes of the still undissected, sedge-overgrown swamps. (One should mention, however, that he traveled approximately 3° further east than Bonvalot, in a region where the climate is moister.)

Apparently the Changtang sharply changes in appearance depending on the season of the year. In summer, when the rains come, and snow and ice melt in the mountains, favorable conditions arise in the Changtang for the growing of grass: the soils are saturated with moisture, the water table rises, some lakes even turn fresh, for example, Lake Aru, according to observations made by Rawling. In the autumn also, when the thawing of the snows and the rains come to an end and the dryness of the air increases, the grass dries out and the landscapes become completely desert-like. It may also be, to be sure, that one traveler was in the Changtang in a year of low precipitation and another traveler -- in a year of heavier precipitation. There have been no systematic observations here.



Fen-shen likewise does not consider the Changtang to be a typical desert but to be characteristic of a large and elevated highland and he explains this by the fact that an adequate amount of precipitation falls on the Tibetan highland.

## TRANSHIMALAYAN SUBREGION

### (GANDISYSHAN')

The mountain system of the Transhimalaya extends for an immense area on the Tibetan highland between the Changtang on the north and the depressions of the Indus and Tsangpo on the south in the limits of 29 and 33° N. and 80 and 96° E.

Despite a number of important features in the natural conditions prevailing in the Transhimalaya, many features of its landscape remind one of the Changtang which justify its conclusion in Northern Tibet. The Transhimalaya is similar to the Changtang both in the predominantly east-west orientation of the ranges which rise over the intermontane plains, and the numerous lakes, situated in depressions, and the absence of drainage to the outside from a substantial part of the area. There is also a similarity in climate and the soil and vegetative cover and, in addition, almost the same processes influence the development of the landscape of both these parts of Tibet. But at the same time there also are substantial differences.

The northern, marginal ranges of the Transhimalaya are formed by the clearly expressed ranges of the Aling-Kangri and the Nyenchen-Tanghla, and the southern -- the Kailas Range and its eastern prolongation. Beyond the bend of the Tsangpo the Transhimalaya passes into the Chinese-Tibetan Alps, whose mountain ranges have a northwest-southeast and north-south orientation. The Transhimalaya serves as a water divide between the Indian Ocean on the south and the Tibetan area of interior drainage on the north. In the western part, this mountain system is cut and drained by the Indus (in the headwaters, the Singichu), and in the east by the Salween.

As a consequence of relatively less dissection the Transhimalaya seems more compact and massive than the Himalaya. The crests of its ranges are more monolithic, the valleys are not so deep as in the Himalaya, the crests of which are sharp and jagged and whose valleys are boldly incised.

In the words of S. Hedin, the Transhimalaya (Gandisyshan') is the only area of its kind where "the mountains do not form continuous chains, but rise as rolls or steep humps of rock, apparently without any order." The mountain ranges are poorly expressed, intermingled and constitute a depressing chaos of mountains.

The absolute elevation of many peaks of the described mountains attains 7,000 meters. The highest individual ranges and massifs rise 2,000-2,500 meters above the plains but the local relief of the greater part of them is a great deal less. The passes are situated on an average of about 5,350 meters and individual passes rise up to 6,000 meters.

The influence of the Indian monsoon on the Transhimalaya is already noted in the ranges extending along the southern bank of the Bog-Tsangpo River, that is, somewhat south of 32° N. It intensifies to the south. Therefore substantial areas of mountain slope and valleys, principally in the eastern part, are covered with a thick mantle of grass, but in the valleys of the southern chains a tree vegetation makes its appearance. Nevertheless, the climate as a whole is very severe. S. Hedin even in May (on the night of the 15th) noted a temperature of -25.8°; on May 24 he saw a frozen waterfall.

The Kailas Range and its eastward prolongation, the first (after the Himalaya) intercepting the moisture still remaining in the monsoons, is strongly dissected, has alpine forms, deep canyons and great variations in local relief. Many of the peaks are covered with white shrouds of eternal snows and glaciers lie in the upper parts of the high valleys.

The northern chains of the Transhimalaya are less dissected than the southern chains. They are strewn with the loose products of weathering, thus softening and levelling out the relief, giving it softer forms. The local relief here is no more than a few hundred meters; glaciers are encountered less frequently. However, such high mountain chains as the Aling-Kangri and the Nyenchen-Tanghla have morphological similarity with the Kailas. The high mountain ranges are separated by broad valleys and basins; the passes between them are in large part easily accessible. Large lakes nestle in the low portions of these valleys and basins.

The western part of the Transhimalaya, where the Aling-Kangri and Kailas ranges come together at a sharp angle, is occupied by the basin of the Singichu River -- the principal source of the Indus. The Singichu rises from the eternal snows at an elevation of 5,426 meters, then flows along a level and open valley framed by green alpine meadows. Dropping down below 5,000 meters, the river enters into intermontane steppe lowlands. The fall of the Singichu is rather steep and at the foot of the Aling-Kangri massif records show its elevation to be 4,500 meters; the peak of the mentioned massif, however, rises 2,800 meters above the valley. A large part of the surrounding mountains, however, has nothing more than the form of low hills. The landscapes of the Singichu basin are similar to the Changtang but are distinguished from it by a relative abundance of fresh water and a denser grass cover which attracts the nomadic Tibetans with their herds of sheep, goats and yaks.

On the east and north from the sources of the Singichu for tens of kilometers a mountainous desert country stretches out which has the appearance of a sea with waves that are seemingly frozen in place and turned to stone, and in appearance they have a bell shape. It is precisely here that a picture of the mountainous chaos that is characteristic of the Transhimalaya makes its appearance. The rock waves of this singular sea are made of rock strata of pale black, red, green, yellow and violet colors. The area is difficult of access; the passes lie at an elevation of 5,000-5,100 meters. There is little vegetation, only occasionally are there encountered stalks of very hard and sharp Tibetan sedge, but, despite such desert characteristics, one encounters kulan (wild ass), hares, partridges, black crows, and around the lakes -- lizards, grasshoppers -- and by the water itself, geese and ducks. The largest of the lakes -- Nganglaring -- is surrounded by low steep mountains made up of yellow and brown colored rocks. Over the water surface protrude mountainous islands, sometimes extending out in the form of small ranges.

To the east of Lake Nganglaring is situated the central part of the Transhimalaya, distinguished by a heavy cover of permanent snows, mountain ranges exceeding 6,000 meters in elevation, and a clear expression of their chaotic arrangement. Besides the Aling-Kangri and the Kailas, the area is characterized by many high mountain ranges oriented in various directions. Of these, a prominent position is held by the north-northwest to south-southeast oriented and parallel ranges of the Lunkar and the Kanchung, separated by the narrow river valley of the Buptsang-Tsangpo. The Lunkar is a tremendous range with a crest covered for almost its entire length by eternal snows. Its highest peak -- Lombo-Gangra (in the Lombo-Gangra Range) rises 7,059 meters above sea level. The Kanchung Range has the same high snowy crest. The area of these ranges carries the traces of ancient glaciation. The existence of large glaciers, descending at one time from the Lombo-Gangra, is evidenced by moraines with granite boulders in the valley. The valley carries a stream flowing southward from the Sam'ye La (Pass).

The area lying along 30° N. in the approximate limits of 84-86° E. is called "Doktol" by the Tibetans. There is no desert or steppe to be seen here such as there is in the Changtang. Wild mountain ridges, deep gullies and hills that are covered by succulent pastures, give picturesque and attractiveness to the landscapes. In the deep valleys of rivers flowing into the Tsangpo, one can encounter individual trees -- willow and poplar. To be sure these are still low-growing and stunted, but among the fauna present are such representatives of mammalia as snow leopards and monkeys.

The Transhimalaya is an imposing picture of a mountainous country, especially in the region of Lake Dangrayum. The lake is surrounded by craggy mountains from which, to the north and the south, rise mountain walls that resemble gigantic waves which have an east-west and also a north-south orientation. Among the latter the Torgot-Kangri Range stands out as it extends along the western shore of the lake. Of the 16 peaks making it up, the greater part are covered with eternal snows which form glaciers; of these, five descend to the east and six to the southwest. In places where the snow cover is absent, base rock of a blue-black color is exposed.

To the east of Lake Dangrayum there is a clearer expression of the east-west orientation of the two main ranges -- the eastern prolongation of the Aling-Kangri and Hyenchen-Tanghla Ranges. The prolongation of the Aling-Kangri for a substantial distance goes beyond the line of eternal snows, since its crest and individual peaks are very high, especially the Dzhang-Kar massif, attaining 6,371 meters. High spurs of the northern slope of the described ridge are strongly dissected by the narrow and deep valleys of the Bog-Tsangpo River and its tributaries. The southern slopes of the ridge, however, drop off to a broad and flat valley that is passable even for the movement of vehicles. This valley has a dense steppe vegetation of meadow grass, *Festuca sulcata*, couch grass (*Agropyrum Thoroldianum*), etc.

Parallel to this ridge on the south the Nyenchen-Tanghla passes here named the Pabla. The highest peaks of the granite crest of the range are covered with eternal snows, the spurs are high and steep, and the climb to the passes is difficult. The northern slope and the depressions of the crest of the Pabla are distinguished by gentle and soft forms, reminding us of the Tien-shan passes. On the other hand, the southern, humid slope has, more than elsewhere in Northern Tibet, energetically incised valleys, sometimes with glaciers in the upper parts, with steep slopes and thalwegs. The northern slope of the Pabla is a desert. The southern slope in its natural conditions however, is more favorable and its landscapes are more beautiful and rich. In valleys of the small streams are found the villages of settled inhabitants, there are encountered sectors of fields sown with barley, and in the mountains wander herds of domestic cattle on the green alpine pastures. There still is no forest vegetation, but in the lower parts of the mountain slopes you can see here and there dark green spots of brush-type juniper.

From the Pabla on the south to the Tsangpo extend mountain chains that have a predominantly east-west orientation and high passes, many of which attain almost 6,000 meters. The topography of the area is strongly complicated by valleys of the river-dissected mountains. It is

It is still more complicated to the north of this range in an area extending to the Aling-Kangri Range. In the lowest part of this territory are located Lakes Ngangtse and Pungpa (Marcanay), receiving tributaries from several directions.

These branching tributaries dissected the principal east-west mountain ranges forming numerous spurs of the second and third order and isolating individual massifs. The orography seems the more confused because here there are also large independent north-south ranges. Among these ranges there stands out a chain of eternally snow-covered peaks, the G'yak-Kharma, extending to the south from Lake Dzharng to the Nyenchen-Tanghla, parallel to the above-mentioned Torgot-Tangri Ranges.

To the east of the G'yak-Kharma peaks the mountain chains in large part extend to the east-south-east, but sometimes one also encounters ranges going at a right angle to them. The highest range here, the Nyenchen-Tanghla, forms a chain of tremendous peaks that are white with snow. The passes through it are few in number and are very difficult. (The Goring-La Pass, leading from the north to Lhasa, has an elevation of 5,970 meters. The trail across the pass goes along the glacier which creeps down from the pass.)

From here to the north and south one can observe a general lowering of the mountains and the beginning of a transitional region from the mountainous country of the Transhimalaya to the plateau-like Changtang. The low and flattened outliers of the Transhimalaya protrude onto the plateau, and the plains sectors of the Changtang in their turn penetrate into the valleys between its spurs.

The eastern part of the Transhimalaya is more subject to the influence of the moist Indian monsoons, therefore significant expanses here are occupied by a dense steppe grass, Glyceria, and other grasses which form good pastures. In individual places, to the south of Lake Dzharng, in the village of Sendzha (Sedzhong) and in the village of Omba (Vompo) near Lake Dangrayum, there is a sedentary population, occupied with agriculture as well as the raising of cattle. They grow barley and some garden crops.

Among wild animals seen near the lakes by the participants of the Chinese Tibetan Expedition were goats, foxes with a fiery red fur, kulang and others.

#### SOUTHERN TIBET

This region is situated to the south of the water divide of the Transhimalaya, extending to the crest of the Great Himalaya Range. In its boundaries is included the graben valley of the Indus-Tsangpo and the

northern slope of the Himalaya and also, as a subregion, the basin of the upper course of the Sutlej. (Thus, in the region are included both Fen-shen's Tszan region and part of his Ali region, that is, the territory of south-western Tibet.) Included here is the Lhasa valley, although it is situated in an intermontane depression of the Trans-himalaya. The climatic conditions of Lhasa are similar to the climatic conditions of the Tsangpo valley and not to those of Northern Tibet, since, in the first place, it is shielded by the Nyenchen-Tanghla Range from the influence of cold winds blowing from the North Tibetan plateau and, in the second place, it experiences the warming action of the Indian monsoon.

Southern Tibet is drained by the Tsangpo River, and also by the Gartang and the Sutlej -- tributaries of the Indus, and, in addition, by the left tributaries of the Ganges and by rivers dropping down from the Himalaya to the Brahmaputra, flowing through the territory of India where the tributaries join. The average elevation of Southern Tibet is 3,900-4,000 meters above sea level, which is significantly less than the average elevation of Northern Tibet.

Warmer and moister than in Northern Tibet, the climate and the connection of the hydrographic network with the world oceans in Southern Tibet cause a significant variety of landscapes and rather favorable conditions for the life and economic activity of the population. Agriculture has developed in the warm valleys shielded from the cold winds of Northern Tibet; there are also gardening and raising of livestock -- not nomadic but by maintenance both indoors and on pastures. However favorable the soil and climatic conditions of Southern Tibet are in comparison with those of Northern Tibet, the agriculture here nevertheless demands irrigation since the precipitation falls chiefly in the summer season and not in the spring when it is necessary for the development of plants.

An overwhelming part of the population of Tibet as a whole lives precisely here, in the valleys of Southern Tibet, in which are concentrated the principal cities and economic centers, since beyond the limits of the valleys natural conditions for the most part are little suitable for settlement. On the upper parts of the mountain slopes and on the plateau-like watersheds are often duplicated landscapes similar to the Changtang: rocky deserts and semi-deserts or steppes with lakes, Solonchaks and swamps. Such a type of landscape, called "tan" in Tibetan, is duplicated to a certain degree on the northern slope of the Himalaya, in a territory adjoining Eastern Nepal and Sikkim -- in the area of Dintsam. This area, situated at an elevation of about 4,600 meters, lacks even a scrub vegetation and is covered with scanty coarse grass. Like the Changtang, it is characterized by broad flat valleys separated

by the ridges of rounded hills. The singularity of this type of landscape "tan" as distinguished from that of Northern Tibet, consists only in the presence of external drainage.

The landscapes of Southern Tibet change sharply as you move from west to east. In the headwaters of the Sutlej and Gartang one can see a picture similar to the Changtang; except, possibly, the mountains and the valleys in the basins of these rivers are more abundant in water and grass. Around Lakes Manasarowar and Rakas and further to the south-east extends a landscape of highland pastures called "dok" by the Tibetans. From here the landscapes change very noticeably. Whereas on the northern slopes and at the heads of the tributaries of the upper course of the Tsangpo there grow bushes and occasional dwarf trees, in the middle course of this river there appears a forest which below Chetang (Tszetan) covers the mountains along both banks with a dense cover, changing over at the eastern boundary of Tibet into magnificent virgin forests, coniferous highest up, mixed forest below, and still lower -- a bamboo thicket. Here are situated the principal forest resources of Tibet proper.

#### CENTRAL SUBREGION

The northern boundary of the subregion passes along the crest of the Kailas and the Nyenchen-Tanghla, the southern, along the crest of the Great Himalaya Range on the east and along the Zaskar crest to the west.

The principal part of the subregion is formed by an intermontane depression-graben separating the Himalaya and the Transhimalaya. At Lakes Rakas and Manasarowar this depression is intersected by a gentle rise of a northeastern dislocation, serving as the watershed between the Indus and the Tsangpo.

The central part of the heights forming the water divide is occupied by Lakes Rakas and Manasarowar. Characteristic of its landscapes are low tablelike mountains with good but sometimes swampy pastures or also low gully-scarred mountains and hills with rocky peaks that surround flat valleys. (The entire territory around Lakes Rakas and Manasarowar is called "dok" by the Tibetans, that is, highland pastures.) Near the sources of the Sutlej and the Gartang the area is a rather flat and slightly rolling surface with scarcely noticeable variations of elevation which do not exceed 200 meters. The headwaters of these streams are separated by very low and gentle watersheds and the headwaters of the Tsangpo are also coming close and it is expected that one of these rivers will capture part of the basin of the other. Apparently, the Sutlej will be the capturing stream since it has the most deeply incised channel and the steepest falling gradient.

The climate of this area is characterized by Swami Pranavanandra as cold and dry, with strong winds blowing from the beginning of November to the middle of May. The monsoons set in late and the rains are not very abundant, although they fall in the form of downpours. A large part of the rivers freeze to the bottom in winter. In summer the water level in the rivers varies sharply: in the morning and during the day they are at low water, but toward evening, due to the thawing of the snow and ice in the mountains, they overflow and become unfordable. Summer weather, as in the Changtang, is very unstable -- good weather is unexpectedly replaced by bad and snow falls instead of rain with thunder. The same author points out that in this part of Tibet there are known such wild animals as the yak, kulang, mountain sheep, musk deer, the snow leopard, lynx and brown and black bears.

Despite the severity of the climate, the area is populated. In the mountain and steppe pastures cattle graziers live a nomadic life with their herds and on the plains and in the valleys are encountered villages of sedentary inhabitants cultivating barley, peas and mustard, and in the gardens -- rapeseed and potatoes.

In the northwest from the watershed heights the Gartang River flows through an intermontane tectonic valley -- the left branch of the headwaters of the Indus. The Gartang is smaller than the Singichu and it flows slowly to its confluence with the latter. On the southwest its valley is bounded by the gloomy steep and desert-like Ladak Range -- a northern outlier of the Himalaya, and on the northeast -- by the reddish Kailas Mountains -- a southern outlier of the Transhimalaya. At Gartok the river flows through a depressing steppe plain framed by desert hills with thinly-scattered little bushes of vegetation on the rocky ridges. Somewhat below this city the Gartang enters into a broad valley, 9-14 kilometers wide, characterized by an unusual straightness and symmetry of structure, thanks to which the entire valley from both ends can be seen for tens of kilometers. It is easy to see the spurs of the Ladak, as far as the eye can see, shaped like an inverted "V", and the canyons of transverse valleys shining between them; on the right side of the Gartang can be seen the hilly ranges of the Kailas, higher than the Ladak.

After the confluence of the Singichu and Gartang, the Indus, as the common stream is then called, flows in a flat valley up to 4 kilometers wide. On both sides of it rise low, gently sloping hills, 60-70 meters high, with sandy slopes. The hills are almost naked and only down below, at the foot, is there a grassy cover which, despite its scantiness, is used by nomadic cattle raisers the year round -- thanks to the snowless winter.



To the southeast of the watershed, through a tectonic valley separating the Himalaya and the Transhimalaya, flows the Tsangpo River. The water divide between it and Lake Manasarowar is a low plateau-like barrier -- an intermontane lowland between the Ladak and Kailas Ranges. The watershed is almost completely flat, weakly expressed and with a local relief that is scarcely noticeable. (Two lakes are situated on the watershed -- Gunchu Tsho at 4,877 meters above sea level and the Tamlung-Tsho. The elevations of the passes leading from the basin of the Tsangpo to the basin of the Manasarowar are relatively small; the Mariamla is at 5,151 meters and the Marniyakla at 5,302 feet.) All this gives reason to suppose, wrote N. V. Kyuner in his time, that in the future the headwaters of the Tsangpo will drain the basin of Lake Manasarowar. From west to east along the watershed there extends a short range that attains 6,065 meters absolute elevation.

In the upper course of the Tsangpo there are clearly expressed traces of erosion: its slopes are steep, strongly dissected, with bare base rock and talus. The river flows in a deeply incised rocky channel with a width of up to 20 meters. From the north it is closely approached by the gradually dropping Kailas Mountains, and on the south, somewhat withdrawn, by the Ladak Mountains. The area is sterile, with the exception of shielded basins and depressions; the population is sparse, and only to the east of Truksum does the population increase. Large herds of cattle graze on the mountain pastures.

Further to the east, approximately to Tradum, along the northern shore of the Tsangpo there rise up small hills of clayey shale, later of red sandstone; on the southern bank of the river, however, at a distance of 25-35 kilometers from it, is situated a high mountain range which serves as the watershed between the basin of interior drainage of Tibet and the Indian Ocean drainage basin. Despite the great number of ice fields and glaciers, this ridge does not drain to the Tsangpo, but sends its streams to the Ganges.

At Tradum the Tsangpo is strongly pinched between mountain chains that come close to one another: in the south they are rounded and low, but on the north they are strongly dissected, often hanging over the river in rocky precipices. For a considerable distance the valley becomes unsuitable for settlement, and even the roads pass it by for more favorable intermontane plains and the valleys of other rivers.

There is no agriculture in the western part of the Tsangpo basin. Tilled areas appear only after approximately 100 kilometers towards the mouth of the Yalung River, flowing in at the city of Lkhadze. The tree-type vegetation, as already mentioned, is also absent, and only on the northern slopes of the mountains and at the heads of side tributaries do dwarf trees and bushes grow.

To the east of the mouth of the Yalung River the landscape begins to change and become more varied: the relief becomes more dissected, the vegetation more abundant, the mountains not so gloomy and desert-like. The valley of the Tsangpo is still constricted and the bare rock of the banks comes right down to the water but where the valley widens out and in the valleys of tributaries, villages are encountered more often, the fields are carefully cultivated and there are scattered small woods; open sectors are covered with thick and succulent grasses. However, after the confluence of the Tsangpo with the Raga-Tsangpo River, the valley widens out and it takes on the appearance of a well-protected, fertile district with broad fields of grain and groves of poplars among which are seen a great number of villages. Only here and there are encountered infertile sandy alluvial plains.

A still more beautiful picture unfolds in the sector between Shigatse and Lhasa. Here stretches the Tibetans' most beloved landscape and the most suitable one for settlement. The Tibetans call it "ron." The mountain spurs abutting on the rivers are dissected by deep gullies and canyons along whose rocky beds noisily flow transparent river currents; in the widenings of the Tsangpo valley, at the mouths and in the valleys of its tributaries, are situated the villages of farmers who sow the fertile alluvial soils with barley, wheat, peas, Indian hemp and who cultivate rapeseed and radishes.

Soon after Shigatse the Tsangpo enters into a narrow canyon with rocky vertical slopes up to 300 meters high and from the mouth of the Shan River to the mouth of the Rong River it becomes unnavigable. Then the canyon widens out and the river with its powerful current breaks into the open. To the south of the Tsangpo, beyond the adjoining "ron" landscape type, extends the higher desert region "tan" of the northern slope of the Himalaya, reminding one of the Changtang in appearance.

At Lake Yamdok the Tsangpo flows at an elevation of 3,600 meters in a narrow valley bounded by high mountains approaching close to the river. Especially striking is the appearance of the Transhimalaya Mountains. High, pointed, and covered with eternal snows, they seem, as Waddell noted, more precipitous and rocky than the crest of the Himalaya. On the north and the south of the river between the river and the mountains sloping terraces gently rise which have a width of between a few hundred meters and 3-4.5 kilometers. Also on them, in the form of terraces, are situated the fields of the farmers; here and there are encountered villages surrounded by poplar or alder groves and orchards of walnut and apricot. Wild-growing flora here is also abundant and varied. In the canyons near the Tsangpo blackthorn clings to the cliffs, wild roses grow, there is bushy rhododendrum and amidst the grasses are masses of wild flowers -- forget-me-nots, crowfoot, rose-lilac daisies, red and lilac mytnik. Among the animals one can encounter kukuyamana, badgers, rabbits and otter.

Even in the upper zone of the mountains, on the high pastures, natural conditions are generous and beautiful. I. Epshteyn, completing a journey by automobile from Lhasa to Shigatse along the new highway and passing through the alpine pastures of the left bank, writes: "...our vehicle passed a canyon between two high red cliffs and we came out on a high mountain pasture near Yanbatszin. Here, under the protection of the snowy range of the Nyenchen-Tanghla, thousands of yaks and sheep graze in a shimmering sea of grass and bushes colored in autumn in purple, scarlet and brown tones. In the course of many hours we did not lose sight of the peak of Dzhomo-Ganga Mountain -- one of the most magnificent peaks in the world with an elevation of 7,800 meters above sea level. It rose up before us, as if an immense sugar loaf, thrusting up into the blue sky, dazzling with its shining snowy peak, sparkling with glaciers. As we approached, frightened antelope leaped headlong in various directions. Huge eagles slowly circled in the motionless air. Once, two meters from the first vehicle of our auto caravan, a large grey wolf ran across the road. ("Travels in Tibet," in the magazine China [Kitay], No 2, 1956.)

Sarat Chandra Das describes this part of the Tsangpo valley in delighted tones: "...from this place (from the Kamba-la Pass -- B. Yu.) I was enthralled with the most magnificent view I had ever encountered in Tibet. The valley of the Tsangpo opened before my eyes, this great river flowed through a deep canyon at the foot of forest-covered mountains. Here and there small settlements were visible, a large part of them consisting of small houses with white walls surrounded by tall trees." (Travels in Tibet [Puteshestviye v Tibet], St. Petersburg, 1904, page 182.)

To the south of the Tsangpo, between the Great Himalaya Range and the Ladak with its eastern prolongation (the Nepal-Tibetan watershed), is situated an intermontane lowland, rather high above sea level, however. Its surface, as well as the northern slope of the Great Himalaya dropping down to it, is a rolling steppe area of "dok" with low east-west oriented mountain ridges between which flow rivers -- in the west, the Lungchu (below Arun), and in the east -- the Subansiri. Having a general west-east direction of flow, the rivers later head southward, bursting through the Great Himalaya Range and dropping down the Hindustan Lowland to the Brahmaputra.

In the basins of the intermontane depressions are situated large lakes without outlets: Lakes Falgo, Tsomotretung, Yandok, Pomo and figu. In addition, one encounters broad flat depressions, apparently the bottoms of ancient dried-up lakes, cut through to a depth of 3-30 meters by the channel-like river valleys. This part of Southern Tibet, locally dropping down to 4,000 meters, has a rather favorable climate and is suitable for settlement. Sterile swampy expanses are rarely encountered, these being replaced by a high-mountain steppe with thickets of

blackthorn, or -- at high elevations -- by alpine meadows with rhododendrum. In the valleys and on the plains near such lakes as Tsanotretung and Yamdok there are good soils suitable for cultivation. The landscapes are enlivened with little villages and monasteries clinging like gigantic birds' nests to the rocky ledges of the mountain slopes; they have the bright green of poplar and willow groves along the course of the rivers and high steep peaks shrouded in snow with juniper clinging to the slopes.

In the zone adjoining the foot of the northern slope of the Great Himalaya Range begins the realm of the desert, which, however, is not devoid of a singular beauty and magnificence, as clearly described by Waddell. The Tibetan landscape, he writes, gives the impression of immense sand dunes, so gentle are the rounded contours of a large part of its unforested uplands in comparison with the part of the Himalaya through which you pass in the north with its surprisingly straight-lined mountains deeply cut by narrow valleys. The coloring of the landscape and the rock exposures of the mountains have a fiery or yellowish tone, with dark red and ashy lilac streaks and are clad with snow and ice. (Waddell examined the Tibetan landscape from the Himalayan side of the Tanla in the wintertime. A. Waddell, Lhasa and its Secrets [Lkhasa i eye tayny], St. Petersburg, 1906.)

The center of the part described of Southern Tibet is the Nyangchu River valley, flowing from south to north into the Tsangpo across east-west ranges. The headwaters of the Nyangchu cross the desert zone of the northern slope of the Great Himalaya Range. Twenty-five or thirty kilometers before the city of Gyangtse the valley loses its desert-like appearance. At an elevation of 4,900 meters one encounters juniper, juniper bushes, elms, and also willow and low yellow birch. Below there extends a bright cover of poison hemlock, arnica, aconite, burdock, rhubarb, nettle, thorny couch grass, fibrous everlastings, veronica, saksigrafiya and other plants, in large part with yellow and blue flowers. Of animals, besides the wild ass (kulan), there are wild sheep and goats. Also living here are wild gazelles and bural, and among the birds, the snowy pheasant.

At Gyangtse the area becomes wooded and one often encounters thickets of raspberry and elm. The width of the river valley attains 18 kilometers. From Gyangtse to Shigatse the valley of the Nyangchu is one of the richest and most fertile regions of Tibet. Each suitable scrap of land is carefully cultivated in millet, legumes, summer wheat and rice. The well settled area extends also to the east of Gyangtse along the road to Lhasa. But conditions for the irrigation of fields are here less favorable and therefore among the sown crops there is a predominance of barley, peas and mustard. On the meadows flourish such flowers as crowfoot, aconite, clematis, primroses, blue hyacinths and cobalt-colored poppies.

Among the lakes situated in the depression between the Nepal-Tibetan watershed and the Great Himalaya Range, Yamdok is the largest. It is situated 600 meters above the valley of the Tsangpo and is separated from it by a twelve kilometer zone of massive, sharply defined mountains up to 5,000 meters high. The lake is framed by rounded, grass covered hills and steppe plains with chernozem soils, excellent for pasture. Especially rich are the pastures of the Yamdok Karmalin Plain, extending to the east of the lake. In the region of the lake, in comparison with areas situated further west, there is a more abundant tree cover. Besides juniper one sometimes comes across willow and poplar here as well as cypress and silver fir, and along the mountain slopes of the valleys of the small rivers running down to the Tsangpo, barberry, wild white roses, heather bushes with yellow flowers, and in the river lowlands, orchards of peaches, plums and walnuts. In the mountains live wild sheep, goats and musk deer. There are also many birds. But it is curious that different from the colorful flowering vegetation the feathers of the birds here, as Waddell notes, are dark and there are almost no bright tones.

The landscapes in the vicinity of Lake Yamdok, according to Waddell's description, remind one very much of Scotland. "The lake, at this place attaining a width of 3-5 miles and lying amidst gently rounded mountains with lilac thickets of pea-like *Pedicularis*, resembled the wild inlets of Scotland to such an extent, even despite their complete absence of trees, that I involuntarily expected that at any moment a steamship would appear around the corner." (Lhasa and its Secrets [Lkhasa i eye tayny], St. Petersburg, 1906, page 240.)

Similar in natural conditions to Southern Tibet is the intermontane tectonic depression south of the main watershed of the Transhimalaya and having Lhasa in its center. This depression is situated between the Nyenchen-Tanghla Range on the north, the eastern prolongation of the Kailas on the south and a series of ranges of various orientations in the east. Li Pu notes the presence here of faults and river valleys penetrating deep into the mountains. The depression occupied by Lhasa, together with the plains accompanying the Dzichu River, due to its tectonic origin, writes Li Pu, forms a staircase, the steps of which rise to the northward from the Tsangpo River. The interior ranges of the territory described rise up 5,000-5,500 meters, but in individual cases their peaks attain 6,235 and 6,136 meters. Above the valley of the Dzichu River (3,650 meters) the highest snowy crests rise 2,000-2,500 meters more. The steepness of the mountain slopes, cut by deep valleys, is considerable; the crests of the ranges are sharply pointed. The southern slopes of the mountains, facing the Lhasa Basin, are often completely bare but the northern slopes are overgrown with scanty low-growing brush.

The climate of the Lhasa Basin, situated at approximately 1,000-1,300 meters lower than the Northern Tibetan Plateau, and shielded from the cold north winds by the Nyenchen-Tangla, is moderate. The average annual temperature is 9°, the average temperature of the coldest month is about 0°, and of the hottest -- July, 17°, the maximum being 28°, the minimum 14°. Since the moist air masses penetrate here from the Indian Ocean, about 500 millimeters of precipitation falls. Sometimes it is two to three times more than that. The frost-free period lasts 140-150 days; this permits the maturing here of many cereals, legumes, vegetables and fruits. Unfavorable for agriculture is the fact that the precipitation falls principally from May through September inclusive and the first months of spring are rainless; therefore agriculture is possible only with irrigation (the more so since winter, as a rule, is snowless).

The Dzichu River carries almost as much as the Tsangpo at their point of confluence. Widely flooding, in a number of places it breaks down into a number of branches and first washes the low sandy or swampy shores, then islands or terraces with grain fields and gardens, then the granite cliffs. In the lowest part the width of the Dzichu valley is 4.5 kilometers wide. Here predominate desert-like sandy alluvial plains which reach up to the foot of the rock banks along whose cliffs and crevices the sand, transported by the wind, is carried to a height of up to 600 meters. The lower parts of the rocky shores, strewn with sand, are overgrown with heather and mytnik; in many places, however, granite outcrops protrude from beneath the sandy surface.

Further upstream the Dzichu loses its desert appearance and thanks to the trees, groves and cultivated fields enlivening it, it takes on a picturesqueness which is occasionally intensified by rocky canyons and precipices. The farmers' fields, however, form only a narrow zone bounded by a zone of sandy plains reaching to the rock slopes of the valley.

Before reaching the Tibetan capital the valley widens out to 10 kilometers. Along the banks of the river there are continual fields, groves and woods. But here also the sands are successful in their battle against vegetation, the cultivated zone is narrow and is soon replaced by sterile sands.

At Lhasa itself "the edges of the valley daringly rise, forming craggy mountain points, their outlines reminding one of the fantastic sketches of Dore..." -- writes Haddell. (Lhasa and its Secrets [Lkhasa i eye tayny], St. Petersburg, 1906, page 240.) On the high and steep cliffs are located monasteries, and everywhere in the valley there are masses of green beyond whose boundaries rise lilac-colored mountains and craggy capes, merging further on with high, eternally snow-clad mountains. Elm, birch, alder, willow, and walnut make up the groves and

woods that cover the bottom of the valley and the slopes of the hills. Together with them the landscape is beautified by orchards of apricot, cherry, pear, apple and other fruit trees. Carefully cultivated fields, intersected with irrigation canals, are sown with oats, barley, peas, wheat, rice and gardens of large turnip-like radishes or potatoes. The vegetation is rich and wild. Among the numerous rivulets one can smell the odor of potentilla and one can see the luster of the brightly colored blue daisies, crimson arum, crowfoot, primroses and hyacinth. On the swampy sectors, however, there appear reeds, rushes, bright marigolds, mytnik, rose colored water lilies, watercress and forget-me-nots. And only the sands adjoining have a scanty vegetation of dry, tough grass and rose and yellow pinpinella. Since this is the most densely populated part of Tibet, the representatives of wildlife are not numerous, more frequently than others one will encounter pika (*Ogotona Kurzoni*) and rabbits; from time to time gazelles are seen.

To the east of the meridian of Lhasa the nature of the Tsangpo valley changes still more notably: to the north and to the south are seen ever higher mountain chains and peaks, the valleys are incised more deeply and the velocity of the currents increases. Here one notes a transition to the southeastern part of the Tibetan highland with its clearly expressed features of a mountain-alpine country. It has great variations in local relief, deep canyons and gorges in which raging mountain currents foam and roar, tremendous mountain ranges, the slopes of which are first rocky and then are covered with forests, farther up passing into succulent alpine meadows.

The valley of the Tsangpo becomes especially beautiful to the east of Samye. This is the part of Tibet that is richest in natural resources, competing in beauty with the landscape of Kashmir. The slopes of the mountains framing the Tsangpo and the deep cool canyons are overgrown with a beautiful coniferous forest. (The average height of the coniferous trees is about 30 meters and individual trees in the Bomi region attain 62 meters in height with a diameter of 1.5 meters.) In the open valleys there are orchards of apricot, walnut and pear trees. The alpine meadows of this part of Tibet, especially the district of Tokpo, are distinguished by succulence and abundance of fodder, therefore the local inhabitants have a great many domestic animals, yaks being the most numerous, there being more here than in any other Tibetan district.

Farther to the east the vegetation becomes still richer. In Kongbo (beyond the boundaries of Tibet proper) are encountered dense bamboo thickets. Apricots grow in such large numbers that they are used to feed swine.

After the Tsangpo leaves the boundaries of Tibet its path is blocked by the northeastern end of the Great Himalaya Range. The river heads to the northeast, it reaches a large basin and turning to the south, it forms a series of rapids and waterfalls, falling for a distance of 30 meters. Then it disappears into a deep narrow canyon with a length as much as 150 kilometers, from which it leaves under the name Bikhanga. Beyond the waterfalls the climate of the valley becomes subtropical. Downstream it is possible to grow cotton, tung and other subtropical crops. The mountain slopes are covered with dense fir forests in which the pointed *Pinus longifolia* predominates. For wildlife, such wild animals as the tiger, mitang (*Bos frontales*) and the squirrel are characteristic. Silk worms are grown and have great economic importance.

To the south of Lakes Rakas and Manasarowar is situated the valley of the Karnali River, a part of the Ganges Basin. The valley of the Karnali in its natural conditions is very similar to the central sub-region. The Karnali has its source on the northeastern slopes of the Zaskar Range and it then flows to the southeast. Its current is placid to the point where it breaks through the Great Himalaya Range, but at the point where the river breaks through the main range it forms a deep canyon with a cascade of raging waterfalls. Leaving Tibet, the Karnali passes through a remarkable canyon along one side of which Mt. Gurla-Mandahata rises to an elevation of 7,723 meters above sea level. On the other side rise peaks of 6,700-7,000 meters absolute elevation.

The valley of the Karnali is a relatively densely populated region of Tibet in which agriculture (the cultivation of wheat and barley) and livestock raising has developed. Important and convenient trade routes from Tibet into Nepal pass through this valley.

#### NGARI-KORSUM SUBREGION

This subregion occupies the southwestern part of Tibet. The southwestern boundary of this subregion passes along the Zaskar Range, the eastern boundary intersects the headwaters of the Sutlej, and the northeastern boundary passes along the southwestern slope of the Ladak Range. A large part of this subregion, located between the Ladak and Zaskar Ranges, in the recent geological past formed a broad lake basin. (These ranges form part of the Central Himalaya which frames the Tibetan highland in the form of gigantic southward facing monoclinical ridges [they are escarpments according to Wadia].) At the present time it has the appearance of an upland plain that is strongly dissected by the Sutlej and its tributaries, this plain having been uplifted to an elevation of 4,500 meters. Its surface is made up of alternating layers of gravel, coarse pebbles and clay, situated parallel to one another and almost horizontally. This former lake basin is, thus, an example of a broad Himalayan intermontane rock valley, filled with alluvium.



Among the landscapes of the subregion the Sutlej River and its valley are distinctive. The river rises near Lake Rakas, flows through the steppe plains around the lake and then cuts through the Ladak Range. Forty kilometers from the source the river receives tributaries which have cut through the range in a direction opposite to the flow of the main river. This evidently gives evidence of recent tectonic dislocations that have changed the hydrography of this region. Later the river comes out onto the broad lake plain of the Ngari-Korsum. Leaving the plain, the Sutlej near Shipki cuts through the Zaskar Range and changes its direction of flow from northwest to southwest. The river canyon has a length of 7 kilometers from the Leo Pardzhal massif, the height of whose peaks is 6,791 meters. The river is located at an elevation of 3,050 meters; the difference of 3,741 meters between the elevation of the Sutlej and the top of the peak is so magnificent and the contrasts between the mountain masses and the deep narrow canyon with the raging and foaming river are so clear that they stagger the imagination.

A striking picture, not comparable in singularity of landscape with other parts of Tibet, is formed by the basin of the Sutlej where the river cuts through the former lake plain. The cross section of this plain, bounded by the Zaskar and the Ladak Ranges, has the form of a curve formed by a tightly stretched cable but drooping somewhat in the middle. Its surface is cut by a labyrinth of deep valleys, similar to abysses, washed by the Sutlej and its tributaries in unconsolidated strata of lake deposits. The Sutlej itself dug a colossal canyon, almost as big as the famed Colorado canyon, having, so Waddell tells us, a depth up to 2,000 feet, that is, more than 600 meters. The valleys of the Sutlej tributaries are incised only a little less. Thus the depth of the canyon of the Yungu-Tsangpo attains up to 375 meters.

In relief features there is a predominance of vertical and steeply inclined lines and only rarely can one see gentle slopes. S. Medin compares such areas excavated into deep valleys and canyons with gigantic Gothic cathedrals turned upside down. In these places on the steep slopes of these valleys and canyons where there are exposed varicolored layers of sand and gravel cut by numerous vertical washes, nature has created an original striped-checked pattern, colored in red and yellow hues.

For all this sector of the Sutlej Basin there are also characteristic forms of relief that are typical for high interior-continental deserts -- isolated masses of standing rock, high towers and huge columns, and an endless number of canyons that resemble cracks in the earth's crust; here and there are blocks of fallen stone which cover the bottom of the gorge or canyon with rubble. All this creates the picture of an enormous and fantastic dead city.

On leaving the river valleys and canyons an assemblage of hills on the surface of the intermontane plain meets the eye. Beyond them one can see on the horizon the flat or cupola-shaped peaks of the Ladak and Zaskar with spots of snow.

The yellow-brown surface of the hilly interfluves and the valleys of the Ngari-Korsum are in large part sterile, especially in the eastern part; only in the upper parts of the valleys do bushes and a scanty grass cover appear, and sometimes meadow as well. In the western part of the basin the vegetation becomes more abundant and more varied. At Tolingmata (Totlin) there are thickets of willow and poplar, and at Shipki one even finds apricot.

In many places in the basin, principally in the west, there are many sectors of alluvial soils that are planted in barley.

Often the fields are situated on terraces, one above the other. Such a method permits an increase in the area under cultivation by using the mountain slopes and, in addition, makes easier the irrigation of the fields -- without which agriculture here is impossible.

The valley of the Sutlej is populated rather heavily in comparison with elsewhere. Some villages, such as Tolingmata, stand at an elevation of 300 meters above the river on a sandstone or loess plateau with vertical walls into which the dwellings of the local inhabitants have been dug.

#### SOUTHERN SLOPE OF THE HIMALAYA (MEN'YUY)

The southern slope of the Himalaya in small part forms part of Tibet and from the crest of the main range to the foot of the mountains it belongs to Tibet only in the east, in the area of Mon-yul. To the west of Mon-yul, however, only small sectors of the southern slope of the Himalaya, occupied by the headwaters of the Trisuli and Torsa Rivers (Chumbi valley) belong to Tibet.

The region of Men'yuy is interesting as a classical place where in a small area one can observe mountain type conditions in all their surprising variety and richness -- from the tropical forests at the foot of the mountains to the cold, icy deserts on their peaks. The Mon-yul displays the most complete combination of features typical of our physical-geographic region.

The width of the Himalayan slope in Mon-yul is a little less than 100 kilometers. Heights from 8,200 meters on the crest of the main range drop down to 200 meters at the foot of the mountains on the Hindustan lowland. Despite the relative steepness of this slope, there is

preserved here the step-like drop that is characteristic of the Himalaya in the form of two or three parallel ranges dropping down to the Hindustan lowland, the so-called Duarow Range which on the east extends to the Dikhang canyon.

The southern slope of the Himalaya is considerably more broken than the northern, and is deeply dissected by V-shaped valleys and canyons. The longitudinal profile of the valleys is steep, but due to the large amount of water carried it is quite graded; this explains the small number of waterfalls encountered along the valleys. The waterfalls possibly appeared at a later time due to the most recent uplifts. Incidentally, the latest tectonic processes have given rise in the Duarow Range to so-called "hanging-valleys," sometimes elevated hundreds of meters above the beds of the principal streams. (The name of the mountain range is associated with the word "duary," which means "doors to the mountains." It was these hanging valleys that resulted in such a name being given to the mountains, for they seem to open the way into the mountains. Besides the erosional river valleys, usually with a north-south orientation, there are also tectonic east-west valleys situated between the Duarow ranges in the Mon-yul.

As is well known, the Great Himalaya Range serves as a climatic divide between the region of tropical monsoon climate in India and the region of sharply continental desert-steppe climate in Central Asia. The Mon-yul is situated in the zone of monsoon climate, where, in the course of five or six summer months there is rain, and in the wintertime, from December through April inclusive, almost no precipitation falls. The amount of precipitation reaches more than 1,600 millimeters (A. P. Snegarev). Rains occur daily. Toward midday the previously clear and open sky is covered with thunderclouds and strong downpours fall, accompanied by hail. The coolest season of the year is in January and February; in these months the temperature in the valleys drops below 15° and at great elevations, even below 0°. The highest temperatures are observed in the second half of the dry period, that is, in March, April and May; at this time in the valleys of the foothills it becomes hot and stifling and the vegetation dries out from lack of moisture.

The area of Mon-yul is not great, but this part of Tibet is distinguished by the greatest variety of natural conditions, caused by the orography of the area and the vertical zonality associated with it. Different from the Tibetan slopes, the southern slopes of the Himalaya from the foot to the snows themselves, are covered with a dense and varied vegetation: farthest down, tropical and subtropical, higher up -- temperate climate vegetation and still higher -- vegetation of the cold high mountains. Up to an elevation of 1,000 meters a tropical forest (jungle) grows on the slopes of the mountains and their foothills. Below, in a swampy zone (in the so-called teray) and on the foothills,

the tropical forest consists of fan palms, gigantic fig, mango, gigantic bamboo, banana, sala, the soapbark tree, the horse chestnut, the laurel tree and magnolias whose trunks are thickly intertwined with lianas. In the underbrush bushes and grasses up to 4-5 meters tall predominate, forming a thicket which is difficult to pass through. Small lakes and swamps are also framed by thickets of tall, thick grass.

The higher in the mountains, the more subtropical becomes the appearance of the forest. Evergreen oaks appear (*Quercus lanata*, *Q. dilatata*), then birch, maple, and in the grass cover -- violets and geraniums. At an elevation of about 1,200 meters the high-trunked palms are fewer but the number of lianas increases. There are many giant bamboo plants and orange and lemon trees. There are wild bananas which prefer moist and shady places, and pandanus, seeking out the bright outskirts of the forest.

In the tropical zone, according to Hooker, one can find 18 kinds of palm, 20 kinds of bamboo, many kinds of ferns, etc., in all, 650 kinds of trees and bushes. Tropical plants go up to an elevation of a little more than 2,000 meters. At a level of 2,250 meters the tropical and subtropical forests begin to be replaced by forests of the temperate zone in which two subzones are distinguished: the lower -- larch, and the upper -- coniferous and rhododendrum. In the first, up to 3,000 meters, a moist forest with oak, magnolia, camphor and maple dominates. Above 3,000 meters the forests consist principally of silver fir (*Abies Webbiana*), spruce, larch, juniper, dense thickets of bamboo and also birches, maple and bush-type rhododendrum and dogrose. Besides the species enumerated, species found in this zone include walnut, apple, cherry and bird cherry trees.

From 3,700 to 4,800-5,000 meters and above there is an alpine zone having about 380 kinds of flowering plants. In the lower zone are still encountered dwarf birches and rhododendrums; in the upper zone, however, they disappear and the realm of grasses and flowers begins: primrose (*Primula sikkimensis* and others), blue poppy, gentian, grasses like *Festuca duriuscula*, meadow grasses (*Poa trivialis*) with a coarse stem and reed grasses (*Carex Moorcroftii*) of types quite ordinary for Tibet. Still higher begins the lifeless zone.

The warm and moist climate of the Mon-yul permits the growing of the most varied crops. In the foothill areas in the teray zone rice is grown and in the drier zones, wheat, corn and also barley. It should be mentioned, however, that as a result of the steepness of the mountain slopes and the deepness and narrowness of the river valleys there are few sectors in the Mon-yul that are suitable for agriculture.

The fauna of the Men'yuy region, the same as the vegetation, is distinguished by great variety. On heights of more than 2,000 meters, there live forms in common with Northern and Southern Tibet: wild mountain sheep and goats, antelope, snow leopards, mountain wolves, the black Himalayan bear (*Selenarctos tibetanus*) and rodents; birds include the turkey and the snow vulture. In the lower zone, however, the fauna is related to that of India: here we can encounter monkeys (thin bodied types and macacos), bears, panthers, tigers, wild boars, buffalo and deer. Among the birds we can find parrots, pheasant, wild chickens and peacocks.

Entering within the boundaries of Men'yuy, the Chumbi valley (in the headwaters of the Torsa River), situated to the west of the Mon-yul, is situated at an elevation of 2,900 meters above sea level, that is, really in the temperate zone. The valley of the Chumbi is famed for the picturesqueness of its landscapes and the healthy mountain climate, which is responsible for the existence here of a great number of sanatoria and the villas of rich townspeople. Its landscapes combine the beauty of the alpine views with the incomparable magnificence of the Himalaya. The rocky mountain slopes of the valley are overgrown by bushes of wild rose and red currant, and above -- with pine forest above whose dark green slope rises the jagged peaks of mountain giants covered with eternal snows and ice. Down in the valley along the rocky bed between meadows of primrose, anemone, sorrel, celandine and wild strawberries runs the source of the Torsa River, rising high in the mountain snows.

In the mountains and forests of the Chumbi valley are encountered kukuyamany, gazelles, musk deer, silver foxes, snow leopards, long-haired rabbits and, among the birds, snow doves, pheasants, larks and sparrows.

The Chumbi valley is one of the densely settled regions of Tibet. Here are situated such cities as Yatung and Laro. These have great significance for the relations of Tibet with India and a whole series of villages is located either close to the river or on the mountain slopes. The population is employed in the raising of cattle and with agriculture, growing wheat, barley, potatoes and turnips in the fields.

On the southern slope of the Himalaya within the boundaries of the Men'yuy region, is also located the valley of the upper course of the Trisuli River. Heinrich Harrer, an Austrian, gives some information about it. He is the only European, he writes, who has visited this locale. Near the city of Dzhiorong (Kirong) the elevation of the valley is 2,770 meters. Along both sides of it rise up the very highest peaks of the river-dissected Great Himalaya Range, among which stands out Mt. Gozaintan -- 8,220 meters. The north-south orientation of the valley

makes easier the penetration of warm and moist air masses into its northern part. Therefore the January temperature at Dzhiromg is a little below 0°, and with a minimum of -10°.

Coniferous forests grow in the mountains that are typical of this zone of the Himalaya. Above the forests there are alpine meadows in the midst of snow fields. At the city of Dzhenka, N. Harrer noted large fields. Down the valley they become broader and orchards make their appearance. In these orchards there are represented almost all kinds of fruit trees and even bamboo grows in the lower part of the valley. In speaking about the fauna, Harrer mentions the panther and monkey as being encountered in the mountains surrounding Dzhiromg; he also mentions wild bees whose honey is collected by the local inhabitants. This, apparently, is the only place where the inhabitants engage in such an occupation; no other traveler makes any mention about the collection of honey elsewhere in Tibet.

### CONCLUSION

The physical-geographic characteristics of Tibet can be summed up in the following way.

1. The study of natural conditions in Tibet is of great independent interest. Tibet occupies only part of the Tibetan highland, but its territory is distinguished by extremely singular natural features, nowhere appearing so clearly and on such a scale as on this highland.

2. Tibet is situated on the world's highest and broadest highland, in its most elevated western part having an absolute elevation of about 5,000 meters. A large part of the area of Tibet, situated to the north of the Transhimalaya watershed, has no drainage to the ocean. This exercises a very strong influence on the course of exogenous processes, on the formation of relief, the hydrographic system, and also on other components of the landscape.

3. The principal features of the tectonics and relief of Tibet -- the block structure, the orientation of mountain ranges, the extremely great absolute elevations, etc. -- were established in the course of alpine orogenesis, or, if you are referring to the Karakorum and the Kunlun, it is neotectonic, elevating these ancient mountains to great elevations. With movements, resulting in fault lines, is also associated the present-day volcanism taking place in the Kunlun, the earthquakes often occurring in the territory of Tibet and the presence of hot springs.

4. The continental period of development of the Tibetan landscape began in the middle of the Tertiary period. The presence of vari-colored and red rocks, making up the surface of broad sectors of the highland, give evidence of the existence in the past, apparently in post Tertiary or early-Quaternary times, of a warmer and moister climate during which time such animals as the rhinoceros may have existed. The disappearance of warmth-loving animals was associated with the cooling off of the climate, caused by an uplift of the highland to an immense height above sea level. The conditions of development of the landscape changed thereafter since with the uplift of the highland and especially the Himalaya to their modern elevations, the climate of Tibet, a region without exterior drainage, became colder, sharply continental and arid.

5. In the modern period in the formation of the relief, erosion by rivers has great significance in the south and southeast of Tibet, together with neotectonics. This is because the rivers here flow to the ocean; in the north, in the region without drainage to the outside, eolian processes are of great significance as well as mechanical (frost) weathering. In this connection, in the south and southeast there is predominantly a rising development of relief and a lowering development in the north. Since the headwaters of the Hwang-ho, Yangtze and Salween are forcefully cutting into the depths of the area of internal drainage, in the future the area of rising relief will also capture the northern regions of the highland.

6. Tibet is situated in the zone of subtropical climate, in that sector subject to the influence of the Indian monsoons. But the large area of interior drainage, blocked off from the influence of the monsoons by the Himalaya and Transhimalaya Ranges, has a dry and sharply continental climate. The very great absolute elevation of this part of Tibet, however, makes possible an intensification of continentality and a lowering of temperatures. This makes the climatic conditions here similar to those of the tundra.

7. The Tibetan lakes have clear traces of shrinkage. But, apparently, their shrinkage took place in a xerothermal period which Central Asia underwent especially after the period of glaciation. At the present time, however, the shrinkage of the Tibetan lakes due to climatic reasons can scarcely occur, since conditions in Tibet are more favorable for their preservation than in any other place on the globe. If there is now occurring a shrinkage in some of them, then this process is a natural dying that is generally characteristic of all lakes in areas of internal drainage.

8. The ancient flora of Tibet was for the most part destroyed in the period of the great glaciation. The beginning of the formation of the modern vegetation of Tibet relates to the second half of the

Quaternary period. It was formed from newly arrived elements of a more ancient flora of the hill lands of Yunnan and Burma and to a small degree from representatives of Central Asiatic flora penetrating into Tibet.

9. Different from vegetation, in the formation of which Central Asiatic flora played a very small role, the fauna of Tibet owed its formation precisely to Central Asiatic desert fauna and only on the southern slope of the Himalaya, in a belt less than 2,000 meters above sea level, is it similar to Indian tropical fauna.

10. The territory of Tibet extends from south to north for more than 1,000 kilometers. Therefore it would be natural to expect in the soil and vegetation the appearance of a latitudinal zonation. However, due to the very great elevation above sea level and the orographic peculiarities in a substantial part of Tibet (excluding the Tsangpo basin and the southern slope of the Himalaya) one can observe similar conditions of insolation and circulation of air masses and in the last analysis there is small difference in the income-outgo heat balance of individual areas, even those latitudinally situated distant from one another. Consequently, such a factor as latitude, usually having the utmost significance in the change of the soil-vegetation cover, is here, so to speak, "levelled out." Differences in the soil-vegetation cover are caused chiefly by orographic features. The mountain ranges of the Himalaya and the Transhimalaya have determined in the northern part of Tibet the singularity of climate and the drainage conditions and, consequently, the soil cover and vegetation, which differ sharply from those prevailing in Southern Tibet and on the southern slope of the Himalaya.

11. Since, as can be seen from the aforesaid, the features of climate depend primarily on orography, and on orography also depends the character and intensity of exogenous processes in various parts of Tibet, the conditions for formation of relief, the hydrographic network, the soil and vegetation cover and the fauna, relief should therefore be selected as the primary consideration in the delineation of physical-geographic regions. Other factors, to a significant degree being produced here by relief, are the amount of precipitation, the degree of continentality, etc. They can be used for distinguishing differences existing at various places in the principal physical-geographic regions.

12. A study of the natural conditions of Tibet shows that a large part of the territory is suitable for the life and economic activity of the population. There no longer should be talk of steppe, semi-desert and even desert regions, with the exception of Tibet's most northern zone, even now used by shepherds. The territory of Northern Tibet will be more intensively utilized by shepherds and in the valleys of the Transhimalaya, where there are already individual farms, the use of



suitable irrigation works will make possible a considerable cultivation of land in agricultural crops. The southern regions of Tibet, however, have all the conditions needed both for the cultivation of wheat and rice and for the growing of valuable subtropical fruit and industrial crops.

13. Future prospects for the economic development of Tibet, in our opinion, are for the most part associated with the development of industry in conjunction with the utilization of the energy in the rivers. Underground wealth can serve as the basis for industry. It has been established that the major accumulation of ores and ore minerals is associated with a folded zone that extends from west to east across the whole of Tibet from the Karakorum to the province of Yunnan. This zone is characterized by intrusions in granites and igneous rocks, a process with which ore formation is associated.

According to preliminary data from a reconnaissance conducted by the Chinese expedition of 1951-1953 in Tibet, more than 30 kinds of minerals were discovered. In the eastern part of the Tsangpo valley were found deposits of magnetite and at Lhasa, deposits of coal and talc. In the Tanghla Range large deposits of iron ore and coal were also discovered, and, in addition, deposits of graphite, asbestos and soapstone. (Newspaper Druzhba [Friendship], Peiping, 6 May 1956.) Besides all this, the expedition discovered deposits of antimony ores, arsenic, molybdenum, copper, lead, zinc and oil-bearing shales. Throughout Tibet there are known to be deposits of gold, both in veins and in streams, and, finally, inexhaustible supplies of various salts, both in the form of deposits and in desiccated lakes -- borax, gypsum, ordinary salt, alum and soda. There are also unlimited supplies of construction materials -- granite, sandstone, limestone, sand and also jade, a semi-precious stone.

The forests of the southeastern part of Tibet also have great industrial significance. According to initial data, the reserves of wood here are estimated at over a hundred million cubic meters. (Newspaper Druzhba [Friendship], 10 February 1957.)

14. For a more successful development of the economy of Tibet, it is necessary to make a broad and detailed study of its natural conditions and to uncover all its natural wealth. One of the important ways to achieve this is the physical-geographic study of the territory of Tibet. Taking into consideration that a large part of it suffers from aridity, especially in the spring, it is expedient to first turn our attention to hydrogeological and geomorphological research, especially in the northern regions of interior drainage. Hydrogeological research makes possible the discovery of resources of fresh ground water. There is no doubt that there is such ground water in the strata of loose deposits which fill the intermontane plains and depressions. The waters can be used,

in the first place, for the raising of livestock. They can bring new regions into use for pasture rotation and, possibly, lengthen the time for use of new and already used natural pastures; in the second place, the solution of the water problem will make easier the solution of the problem of exploitation of deposits of ores and minerals.

Geomorphological study and mapping help to delineate sectors, valleys or intermontane depressions that are suitable for the establishment of reservoirs in which rain water and soil water can be accumulated. These waters are necessary both for industrial purposes and for the production of electric power and for the irrigation of pastures and agricultural lands suitable for cultivation, especially in the Transhimalaya. Geomorphological studies will also be useful for delineation of deposits of placer gold and other minerals and also for road construction.

Geobotanical research is of great value. It can be used for the delineation of the vegetative resources and for compilation of a map of pasture lands.

15. The isolation of Tibet, which has been an obstacle to development of its productive forces, became a thing of the past after the construction of the Sikang-Tibetan, Tsinkhay-Tibetan and Sin'ztsyan-Tibetan highways. Tibet was joined to the remainder of China by reliable routes of communication. The assistance of all the brotherly peoples of free China serves as a solid guarantee of the successful economic and cultural development of Tibet.

The study of the natural conditions of Tibet is associated with considerable difficulties, since up to very recently systematic studies taking in the whole or a large part of its territory did not exist. True, many expeditions visited this lofty region. But they usually did not have among their participants the necessary staff of specialists, as a rule the explorations did not have an all-around and systematic character, nor were station observations made. There are almost no descriptions in which there have been completely generalized materials on geology, orography, hydrography vegetation and animal life in Tibet. We have tried to collect and so far as possible to synthesize and generalize, although fragmentarily in spots, the widest range of data taken from various English, Russian, Chinese, German and other sources. As a result of the lack of uniformity and varying quality of the source materials you can find in the book, undoubtedly, various errors and contradictions. Their elimination will be possible with continuing investigations with the assistance of the remarks and advice of readers. The author will receive such remarks and advice with gratitude.

## DEFINITION OF SOME TERMS IN TIBETAN TOPONYMY

### Nouns

anne -- forefather, ancestor  
bema -- sand  
bznyan (b'nyan, chan, chang) -- north  
gan -- snow  
gan -- highland (gangri, gangri-gan chen') -- snowy mountains  
gomba -- monastery  
dzhi (k'i) -- bliss  
dok -- mountain meadows, pasture  
kan -- country  
la -- mountain pass, gateway  
lin -- monastery  
lkha (khla) -- deity  
lkho (khlo) -- south  
nag -- forest  
nam -- sky  
non -- range  
nubka -- west  
nyan' -- dainty  
po -- river  
ri -- mountain  
ron -- narrow and deep valley  
si -- spring, brook  
singi -- lion  
tan (tkhan) -- steppe, desert; plain, broad valley -- opposite of "ron"  
tog (tkhog) -- upper  
tsan -- plateau  
chzhon -- region  
chu -- river (strictly speaking, water)  
sham -- east  
tsal -- forest  
tsangpo -- river (large)  
tsze -- mountain, peak  
tszon -- city, fortress  
tsva -- salt, grass  
tso -- lake (tsho)  
shon -- range (shan)  
yul -- country  
yum -- turquoise

## Adjectives

kar -- white

mar -- red

machin -- grey

nag -- black

igovo (nen') -- blue

tszan -- clean

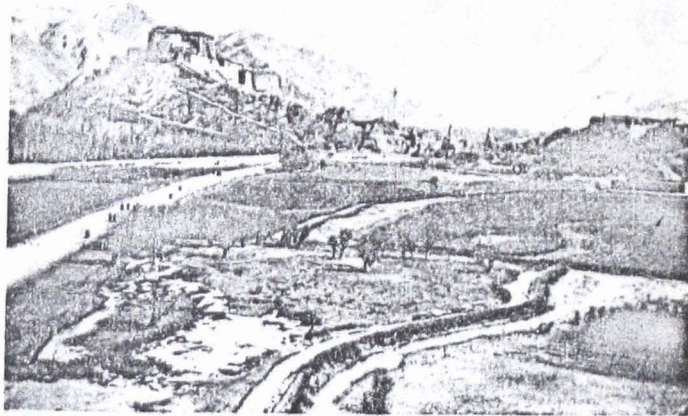
chen' -- large

chun (tan) -- low

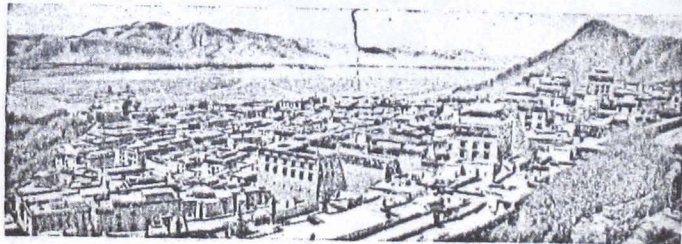
ma -- a particle, showing the word to be of masculine gender.

po -- a particle, showing the word to be of feminine gender.

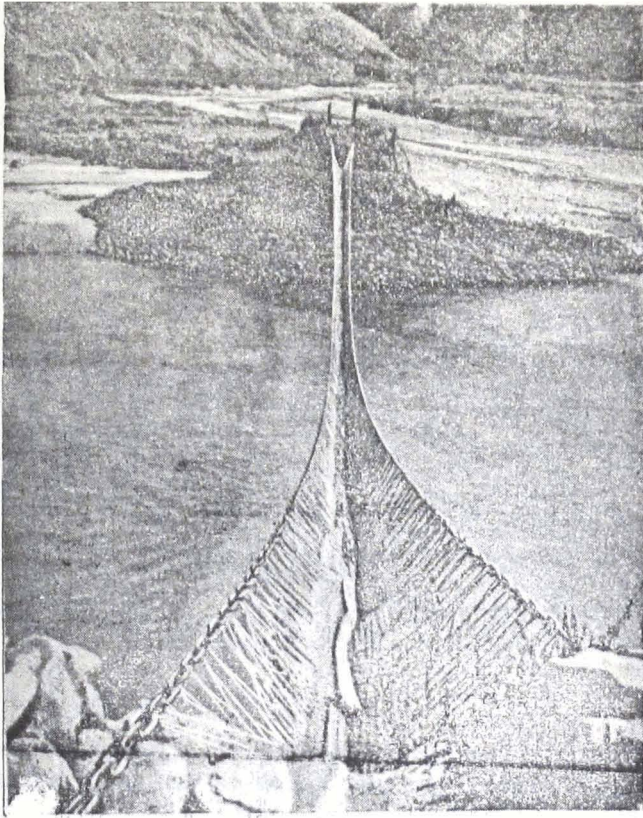
FIGURES



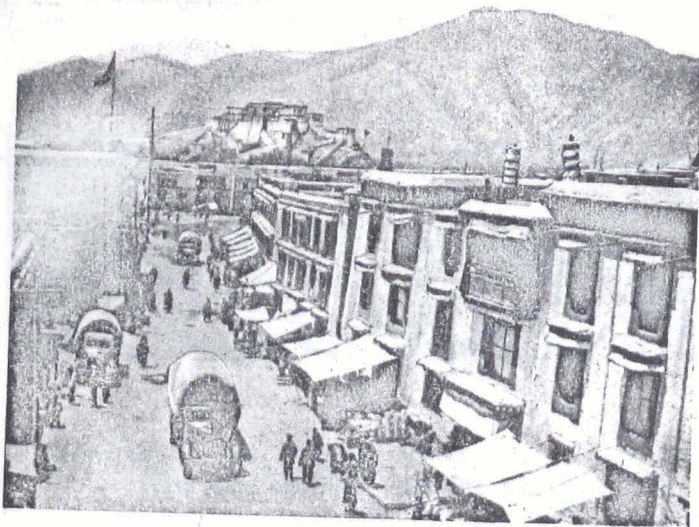
Valley of the Dzichu River in the region of Lhasa. At the left on the hill is the Potala Palace, the residence of the Dalai-Lama.



The city of Shigatse on the right bank of the Tsangpo River. In the foreground is Shigatse and the Tashilupno Palace, the residence of the Panchen-Lama.

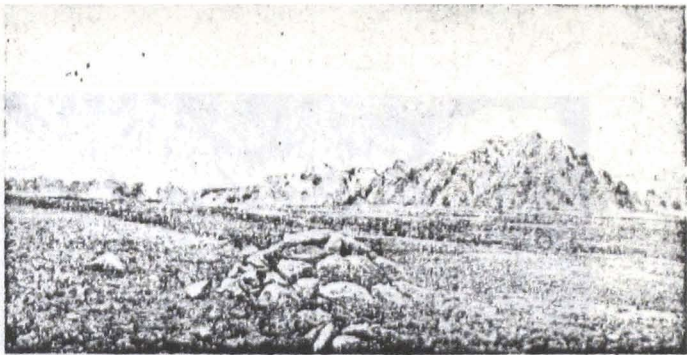


Old type suspension chain bridge across the Tsangpo River.



Street in present-day Lhasa.



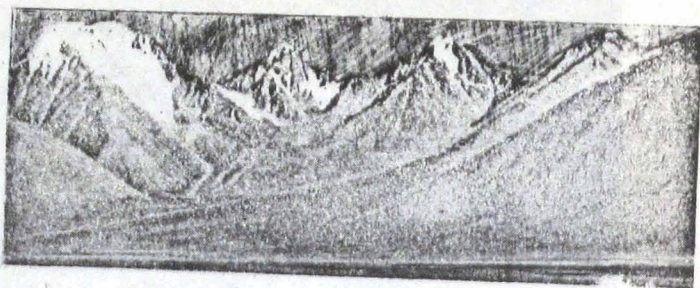


High mountain ranges amidst the plains of southwestern Tibet.

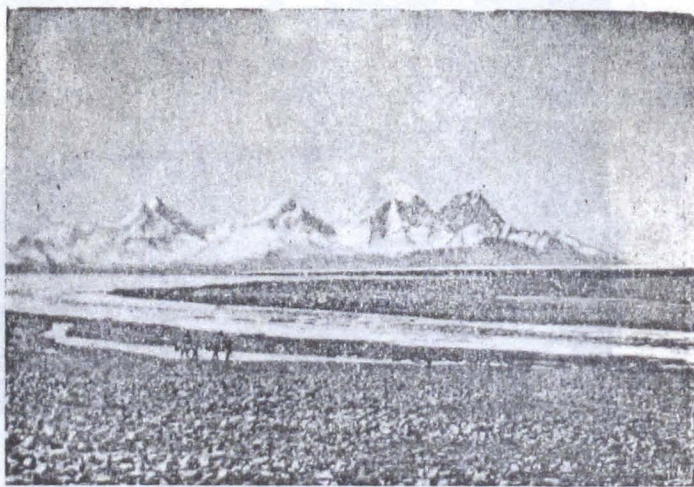
Crest of the Kailash Range



Typical landscape in the central Changtang.



Craggy peaks of the Ladak Range. 2538

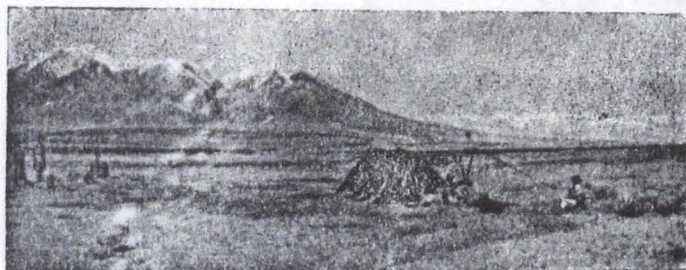


Rocky desert plain on the northern slope of the Himalaya Range.





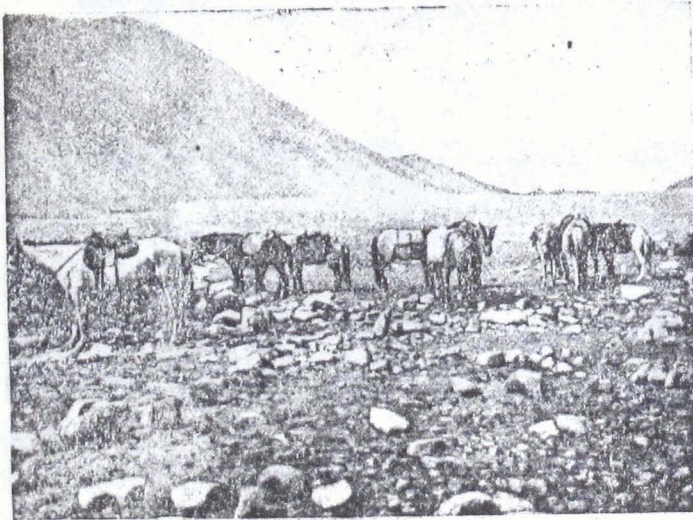
Crest of the Kailas Range.



Snowy peaks of the Torgot-Kangri Range.

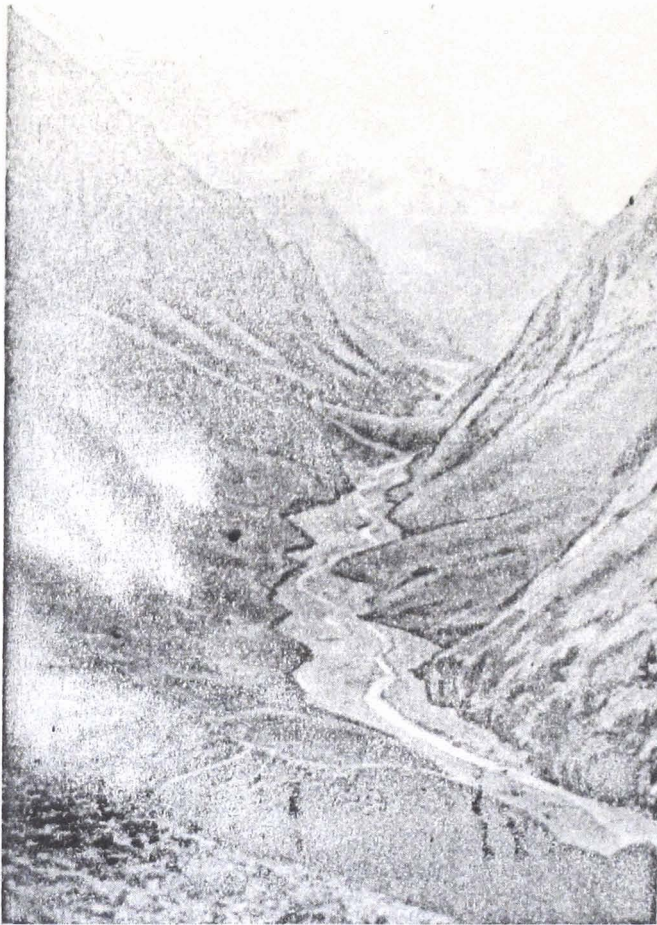


In the southwestern part of Tibet rises Mt Kailas, a symmetrical peak. It consists of world's highest uplifted series of horizontal-laid tertiary conglomerates unbroken by faults (view from the west). In the foreground are nomadic Tibetans.

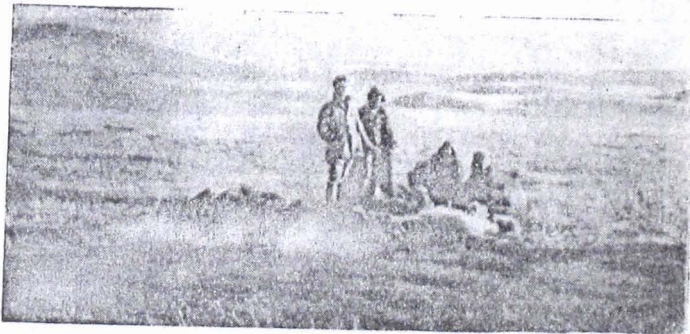


Desert intermontane plain in the Karakorum to the northeast of Lake Pangong.

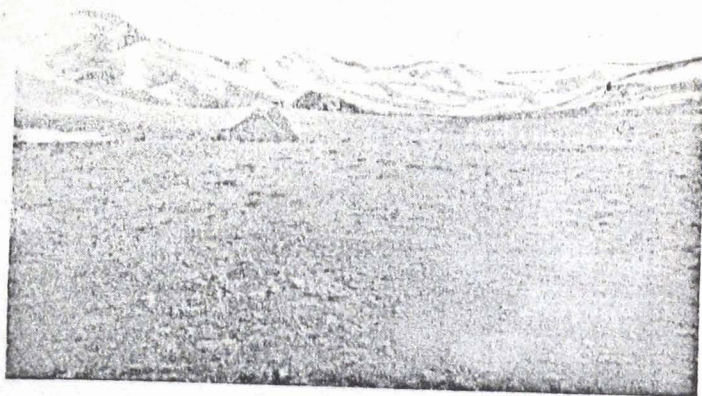




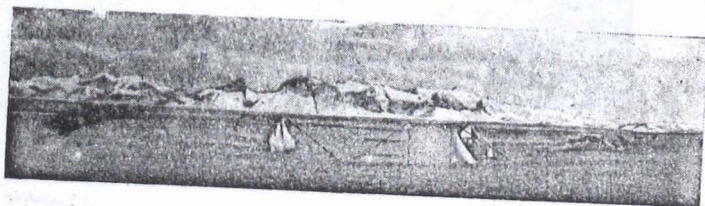
Trough valley of the Kilian River on the northern slope of the western part of the Kunlun.



Northern part of the Changtang in the region to the east of Lake Markham. Low east-west ridges rise up amidst the plain.

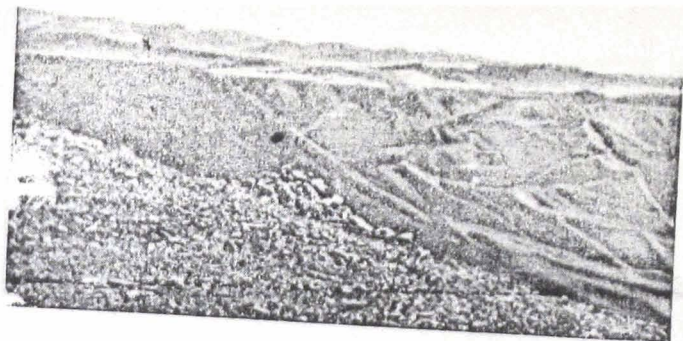


Valley near the Angden-la Pass in the central part of the Transhimalaya.

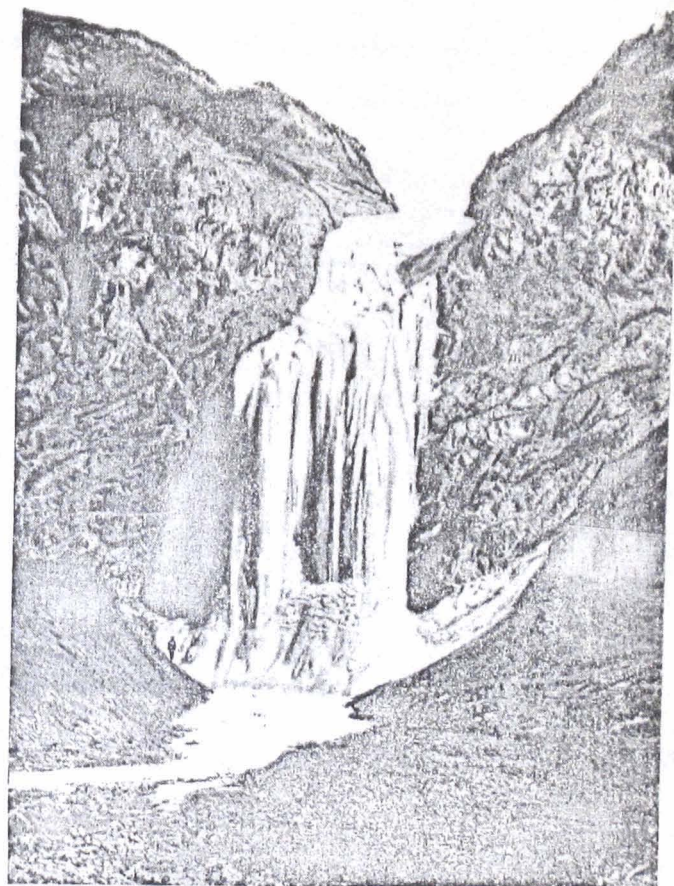


High mountain ranges near Lake Lighten.

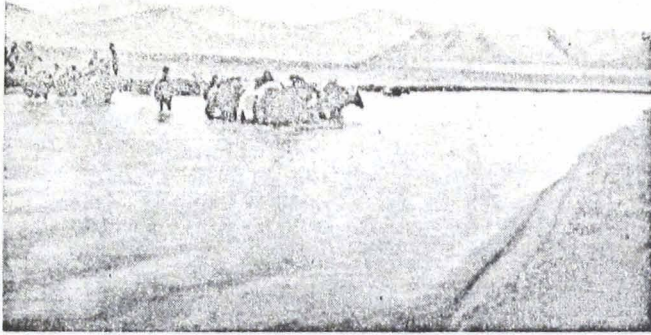




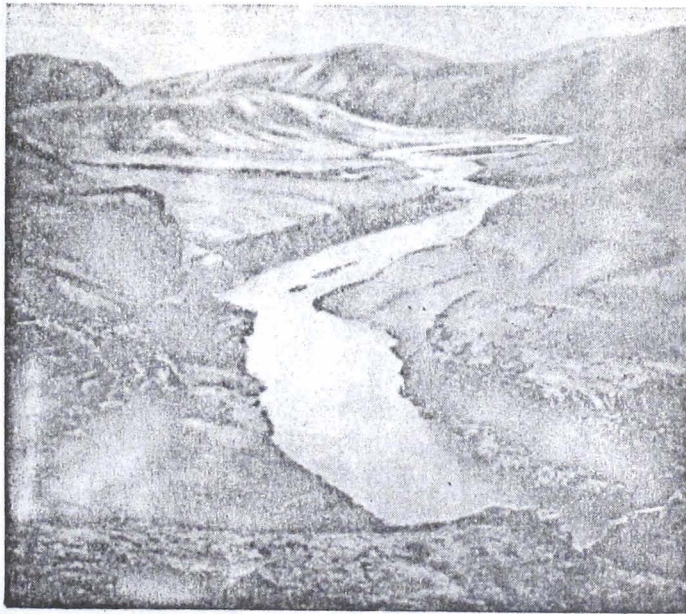
Badland landscape type in the Sutlej Basin.



Frozen waterfall near Farn on the way from India to Lhasa.

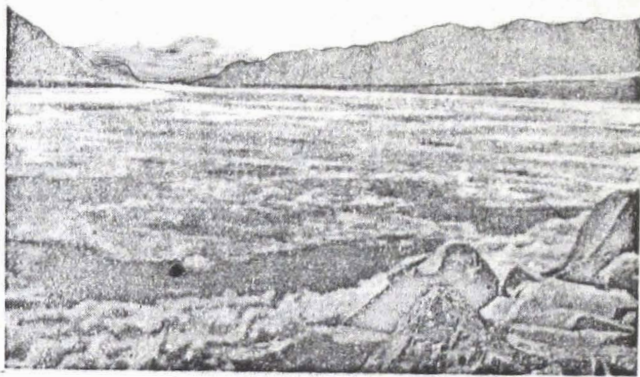


Soma-Tsangpo River in its upper course.



The Sutlej valley -- the largest tributary of the Indus.

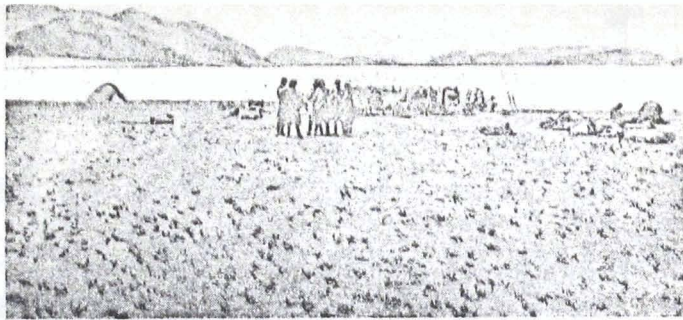




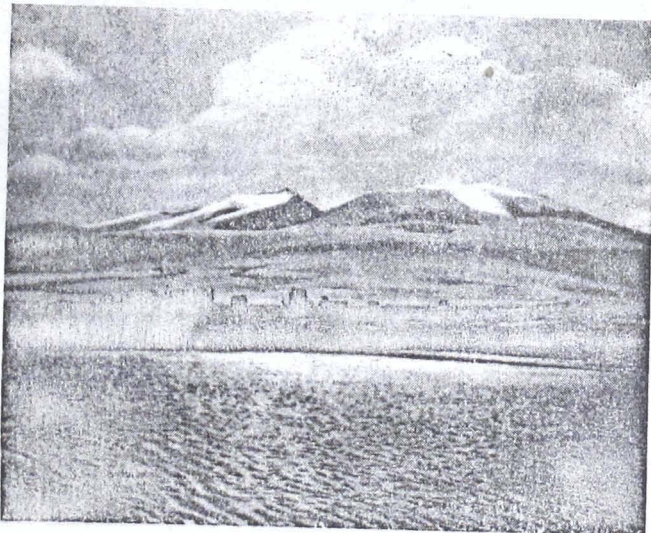
The Tsangpo River 25-30 kilometers upstream from Shigatse.



Lake Nganglaring. Small islands are visible in the center; they are formed by a mountain ridge protruding from the water. Sketch by S. Hedin.

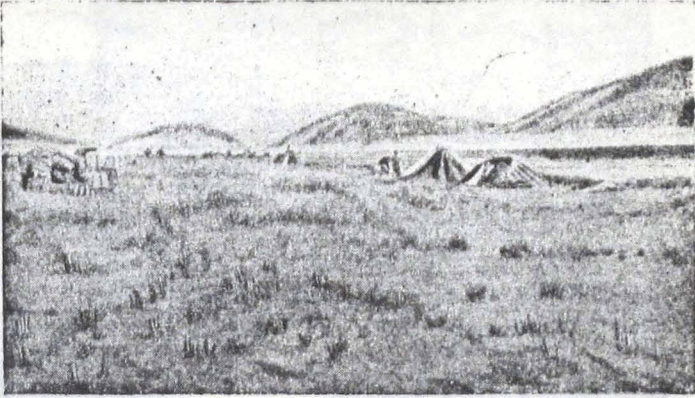


On the shores of Lake Chargut.

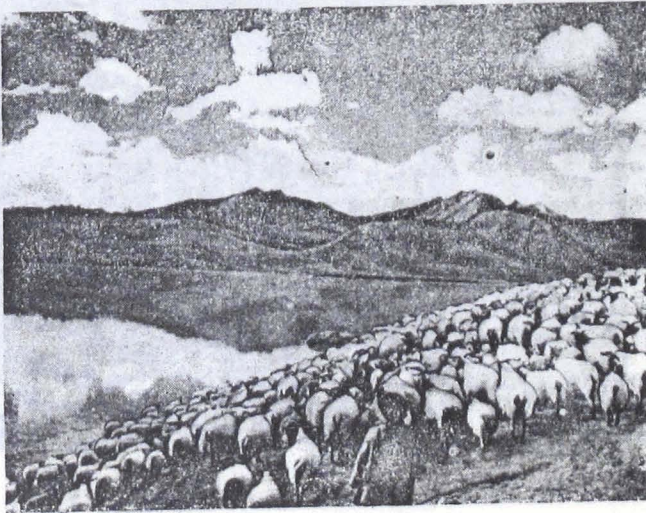


Lake Manasarowar. In the background Mt. Gurila-Mandhata.

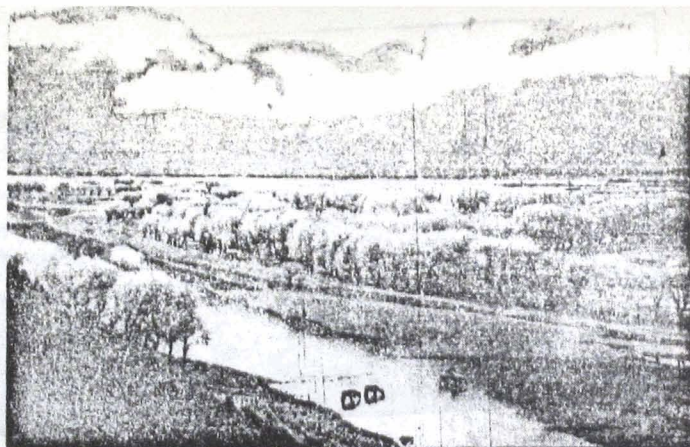




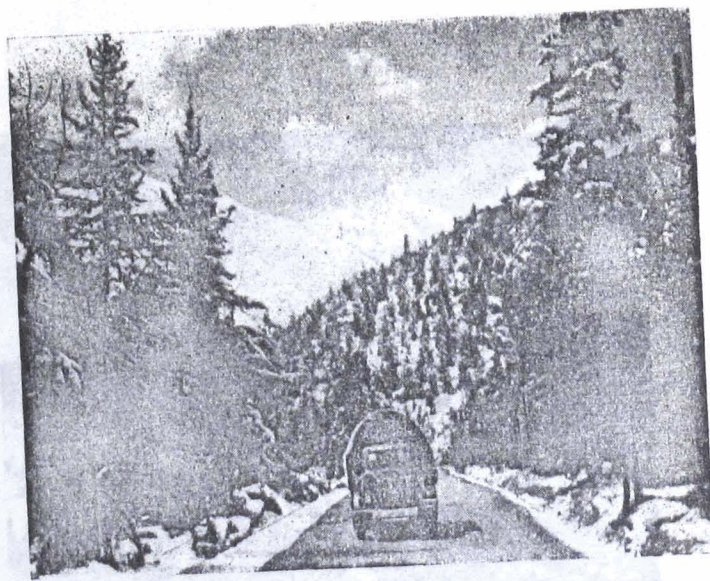
Steppe in the Tsangpo valley near the mouth of the Raga-Tsangpo.



On summer high mountain pasture.

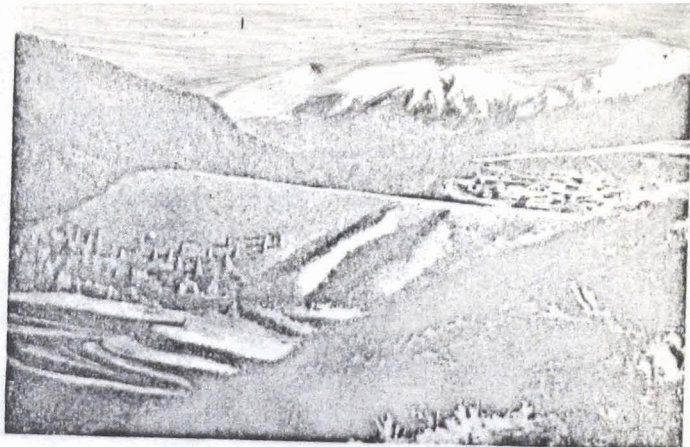


Plantations of trees in the middle course of the Tsangpo River.

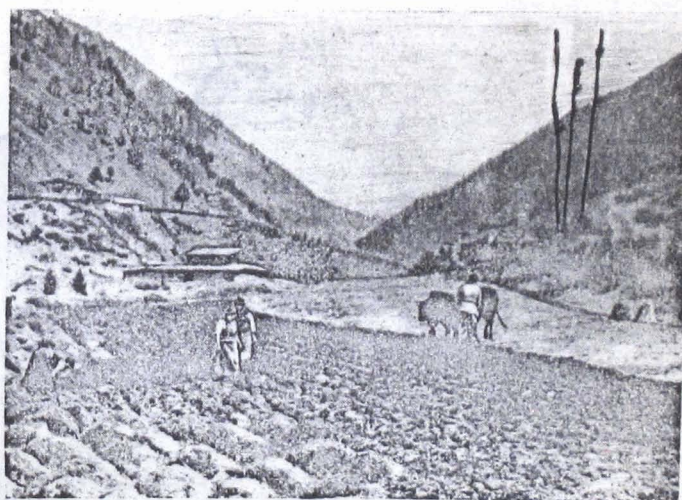


Fir forest in the mountains near Lhasa.

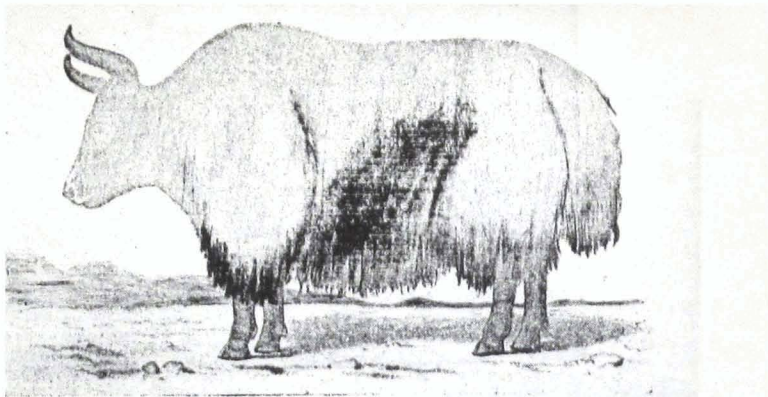




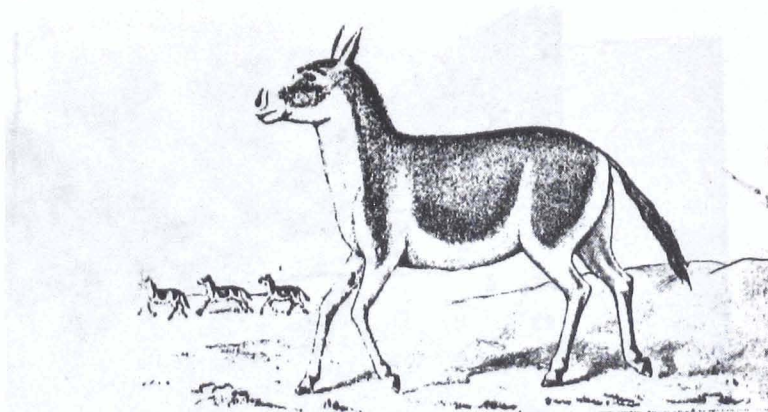
Terraces in the valley of the Yalung River. On the high terrace can be seen a village -- on the lower terraces, irrigated fields.



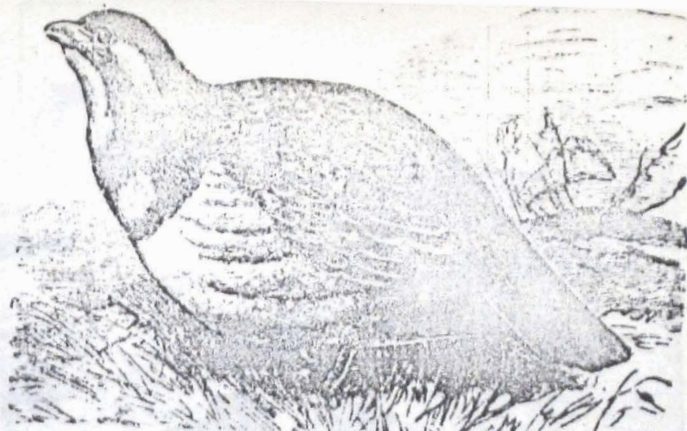
Field of potatoes in Himalayan valley.



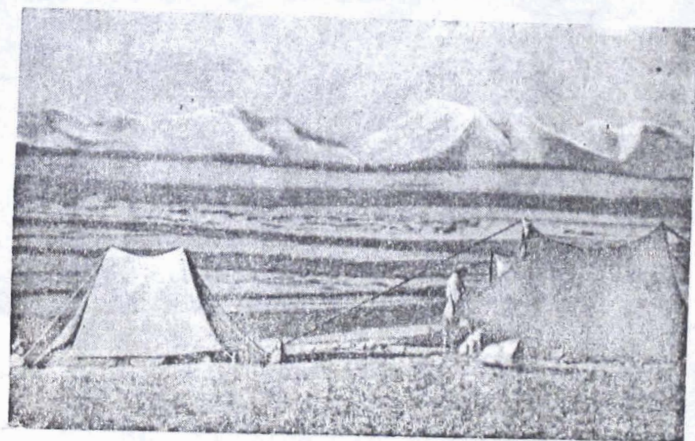
Wild Yak. Sketch by V. I. Roborovskiy.



Kiang. Sketch by V. I. Roborovskiy.



Ular, or mountain turkey. Sketch by V. I. Roborovskiy.



Typical plain in the Changtang.





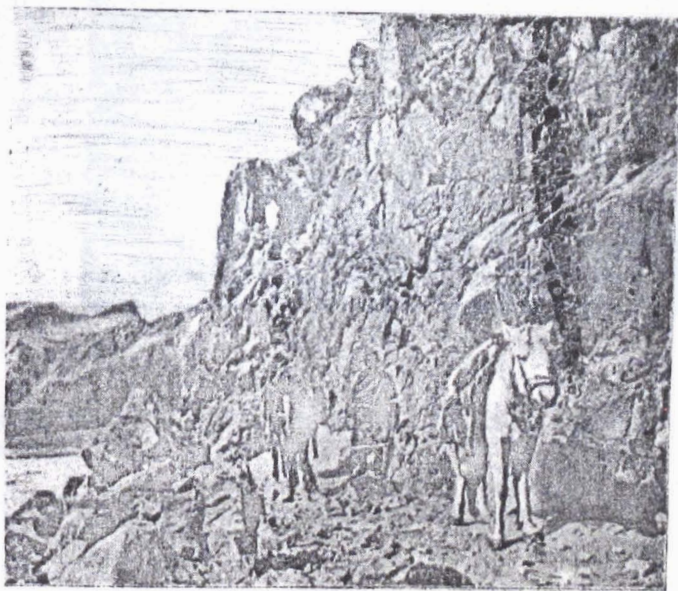
Aksaychin depression. In the foreground a canyon-like ravine.



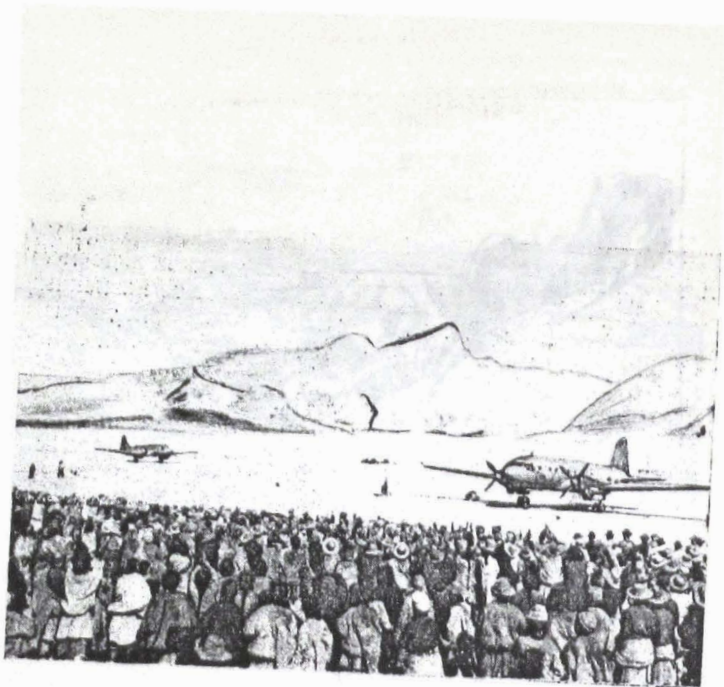
Landscape in the Changtang with typical valley and rolling watershed.



High mountain landscape of the Transhimalaya near Lake Dangrayum.  
Sketch by S. Hedin.



Rocky left bank of the Tsangpo River upstream from Shigatse.

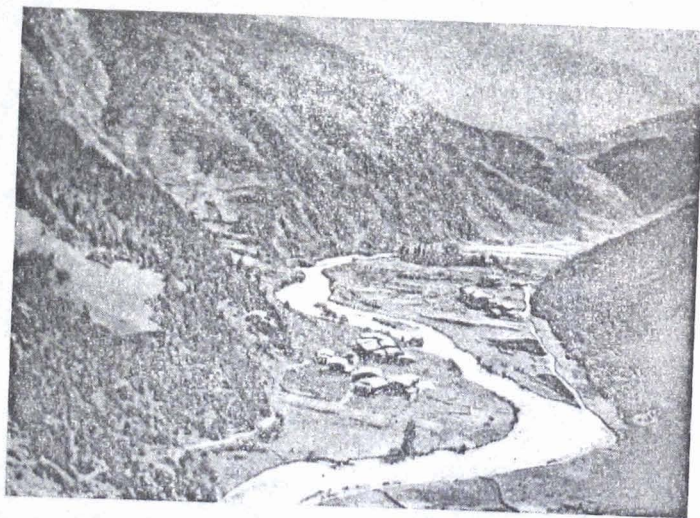


Near Ihesa in the valley of the Dzichu River.





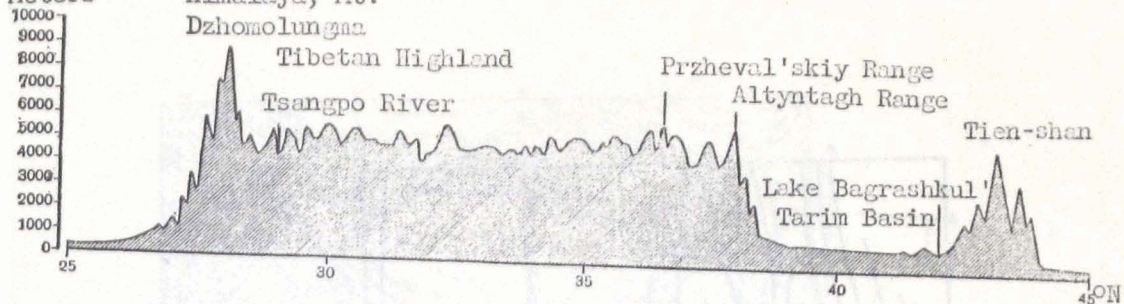
The "Devils' cauldron" in the canyon of the Ngari-Tsangpo River, a tributary of the Sutlej.



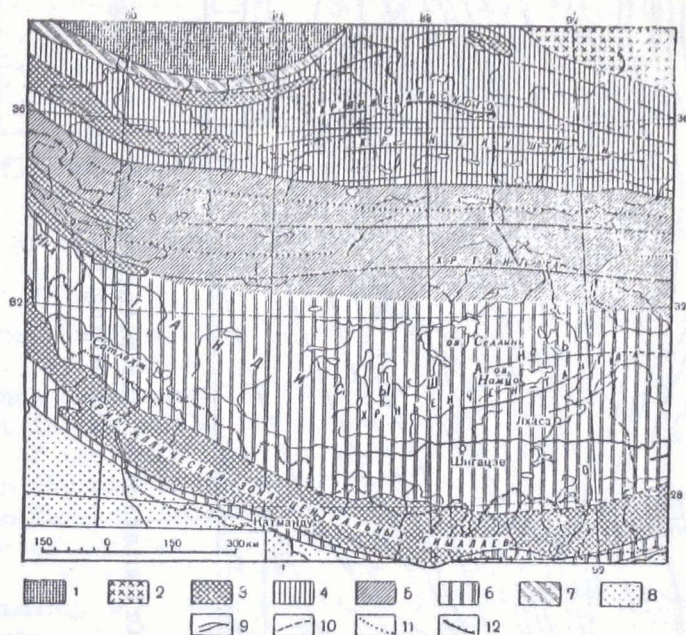
The valley of the Chumbi (headwaters of the Torsa River), famed for its healthy mountain climate.



Height  
in  
Meters

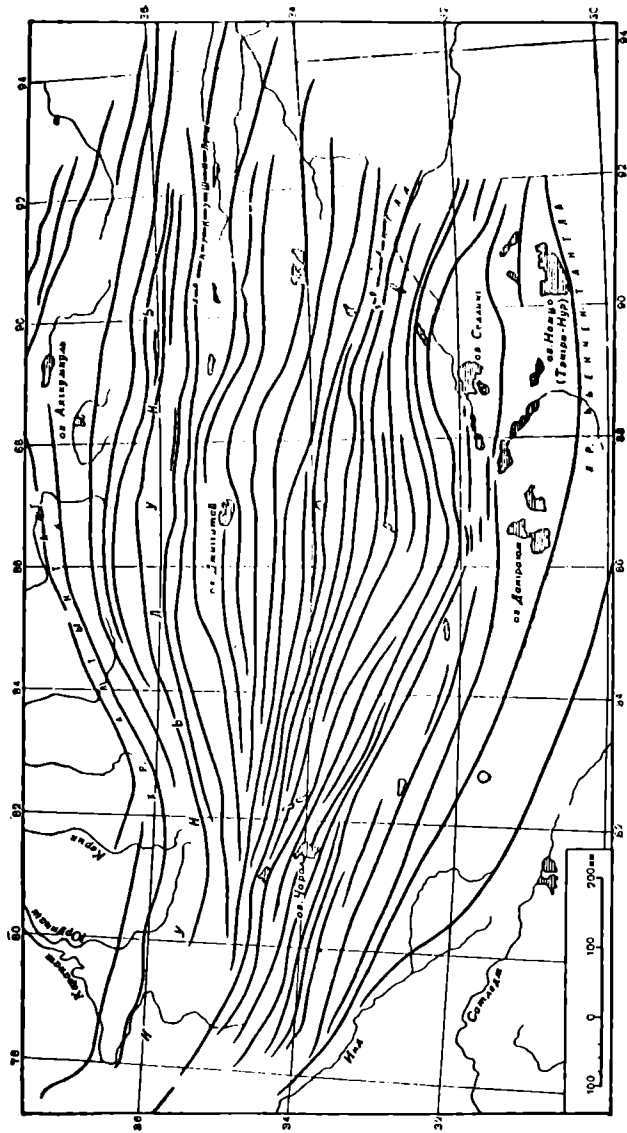


Profile of the Tibetan highland along 87° E.

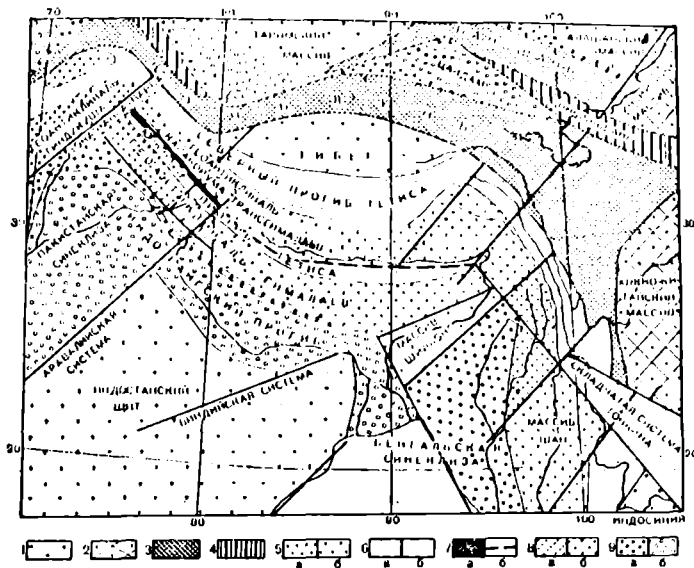


Preliminary tectonic map of Tibet  
(from Khuan-Tu-tsin')

1 -- Pre-Cambrian massifs with Cenozoic cover. 2 -- Crystalline massifs of unexplained age with Cenozoic cover. 3 -- Crystalline axes of various ages (Mostly granite), carried along in mountain building movements. 4 -- variscites generally, including variscites experiencing strong Himalayan movements. 5 -- Yanshanites (Tetis-Himalayan type), experiencing strong Himalayan movements. 6 -- Himalayites generally. 7 -- Himalayites in the form of marginal folds. 8 -- Regions of Tertiary downdrop and widespread development of Quaternary deposits. 9 -- Main structural lines, expressed for the most part orographically. 10 -- Proposed continuation of the main structural lines. 11 -- Proposed synclinoria, separating orographic units. 12 -- Large escarpments.

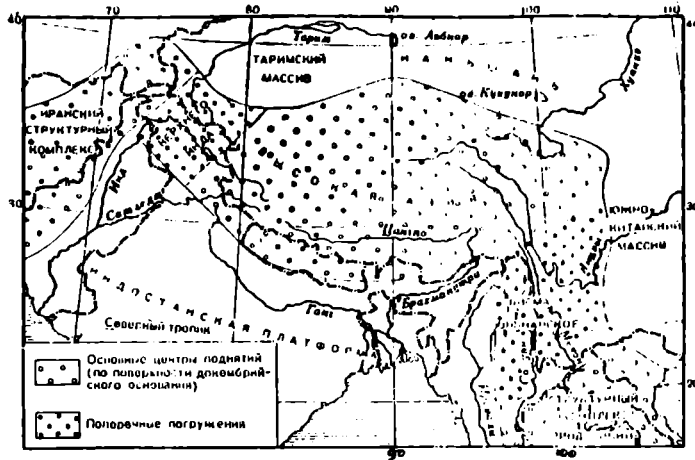


Orientation of the principal mountain ranges of Tibet  
 (according to S. Hedin).



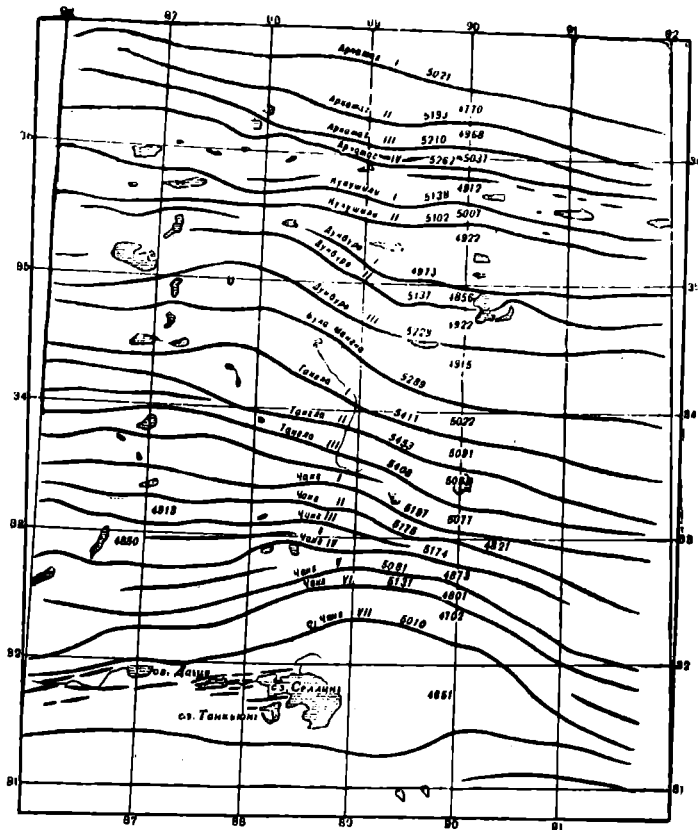
Sketch map of the tectonic pattern of High Asia (according to V. M. Sinitsyn)

1 -- platforms and massifs. 2 -- massifs with a relatively thick Paleozoic cover. 3 -- Paleozoic structures of the Kunlun and the Nan-shan (geosynclinal development in the lower Paleozoic and geoanticlinal development in the middle and upper Paleozoic). 4 -- Post-Paleozoic structures of the Tsin'ling-shan and western Kunlun (geosynclinal development in the middle and upper Paleozoic). 5 -- Mesozoic geoanticline of the Karakorum-Transhimalaya: a -- sector of high mobility, b -- sector of moderate mobility with poorly differentiated tectonic relief. 6 -- Mesozoic arches of the Tetis: a -- sectors of considerable bending, b -- shoals with predominant development of red colored rocks. 7 -- bend of the upper Indus and Brahmaputra (end of the Cretaceous - Paleogene): a -- flysch trough, b -- graben with thin sedimentary cover. 8 -- Alpine geoanticline of the Himalaya: a -- sectors with considerable mobility and a changeable regime of development and alpine-type structures b -- sectors with a stable geoanticlinal regime of development and harman-type structures 9 -- Alpine synclines and marginal folds: a -- sectors subjected to overturning b -- nonoverturned sectors 10 -- the lines indicate boundary lines of fault zones in Pre-Cambrian base rock.



Sketch map of the three main regions of High Asia: the Western Flank, the Tibetan Highland, and the Eastern Flank (according to V. M. Sinitsyn)

(Upper key reads: Main centers of uplift (On surface of pre-chambrian basement); lower key reads: transverse downdrop)



Elevations of ranges and intermontane valleys in the eastern part of Tibet (according to S. Hedin).

## BASIC TYPES AND SUBTYPES OF RELIEF IN TIBET

### I

High upland plains crossed by mountains of moderate height

#### Changtang

I, 1. Relief of open upland hilly plains. I, 2. Relief of upland plains with closely spaced hills. I, 3. Relief of hilly upland plains with clearly expressed traces of glaciation. I, 4. Relief of hilly upland plains with traces of volcanic activity. I, 5. Relief of upland plains with closely spaced narrow east-west ridges of low mountains. I, 6. Relief of upland plains with crossing ranges of east-west and north-south orientation (cellular relief).

## Himalaya

I, 7. Relief of upland plains on the northern slope of the Himalaya, drained by rivers flowing to the ocean.

## II

Type of relief combining ranges of moderate and great elevation with high upland plains.

## Transhimalaya

II, 1. Relief with a predominance of ranges of moderate height. II, 2. Relief with singular disorderly-arranged mountains of a bell shape. II, 3. Moderately high and lofty mountains with intermontane basins occupied by large lakes. II, 4. Relief with a predominance of ranges of lofty mountains.

## Karakorum

II, 5. Relief with a predominance of moderately high mountains.

## Changtang

II, 6. Relief with a predominance of moderately high mountains.

## III

### High mountain type of relief

## Himalaya

III, 1. Maximum development of high mountain relief with intense glaciation.

## Kunlun

III, 2. High mountain relief with relatively less dissection and local relief and less development of glaciation.

## IV

### Badland type

Deep canyons and valleys, dense network of V-shaped dry washes with narrow steep-sloped watersheds between them, poor vegetative cover.



## Graben valley of the Indus-Tsangpo

Key:

TIBET

National boundaries

Boundaries of provinces of China

Railroads

Roads and highways

Intermittent rivers

Spot elevations in meters

Passes

Glaciers

Volcanoes

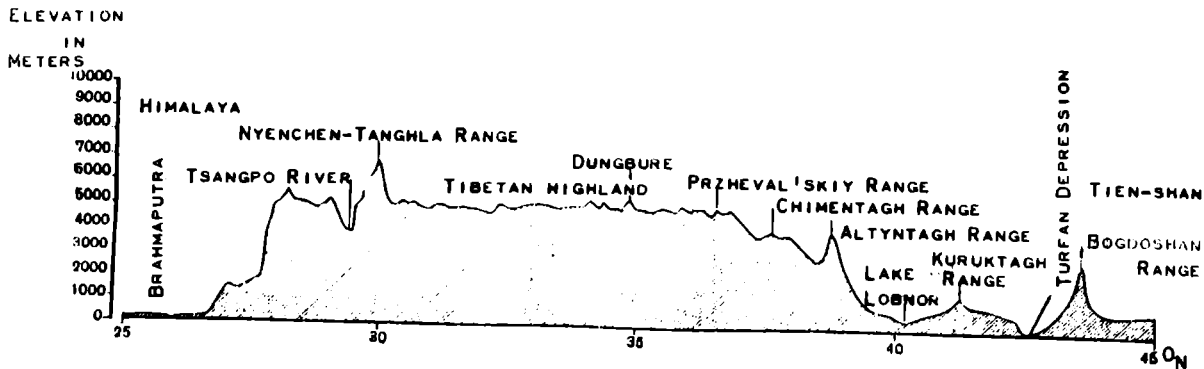
Swamps

Solonchaks

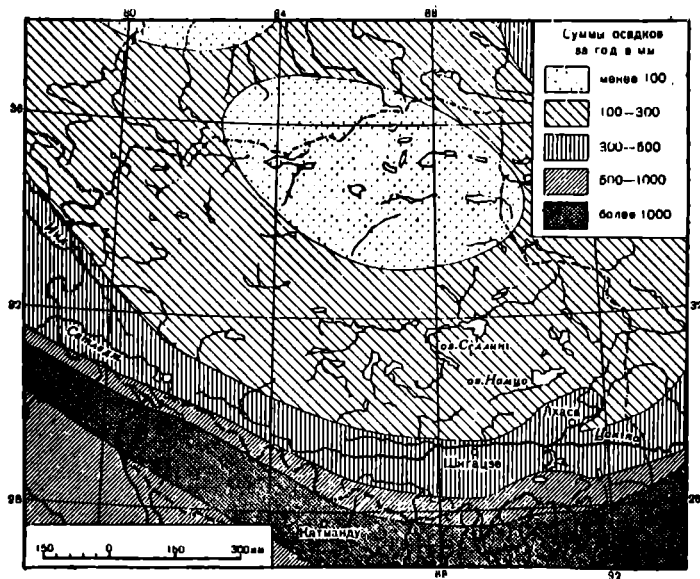
Sands

Boundary of area of internal drainage

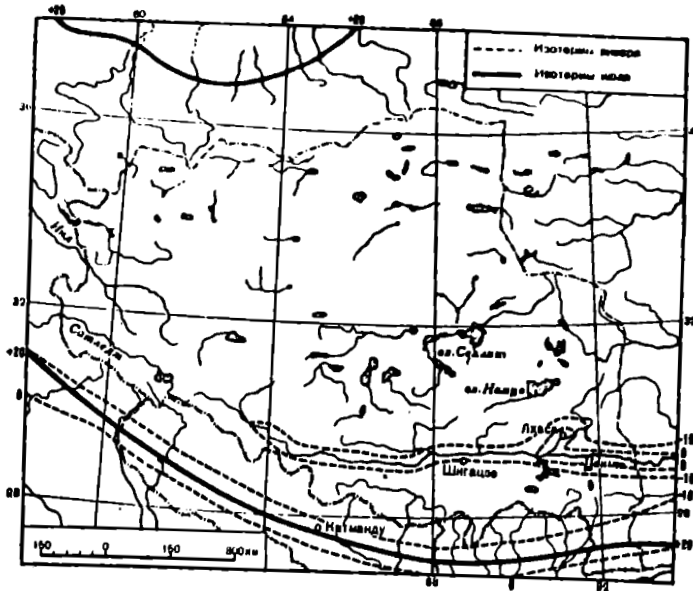
Boundary of relief subtypes



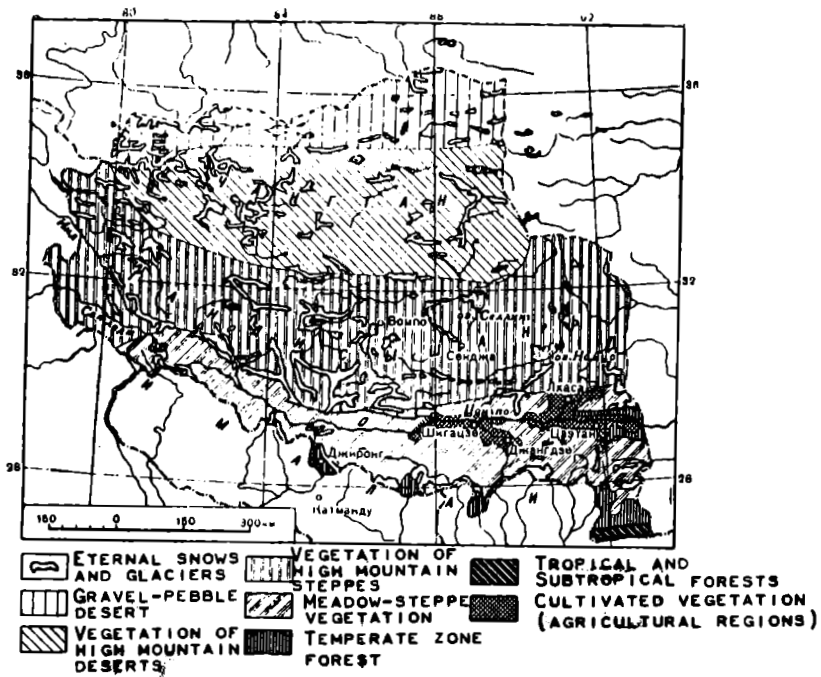
Elevation profile of the Tibetan highland along  $90^{\circ}$  E. The Himalaya Ranges are below the Nyenchen-Tanghla (compare with profile along  $87^{\circ}$  E., page 31)



Annual amount of precipitation (annotations in box read: "Total precipitation per year in mm," "less than 100" and "more than 100")



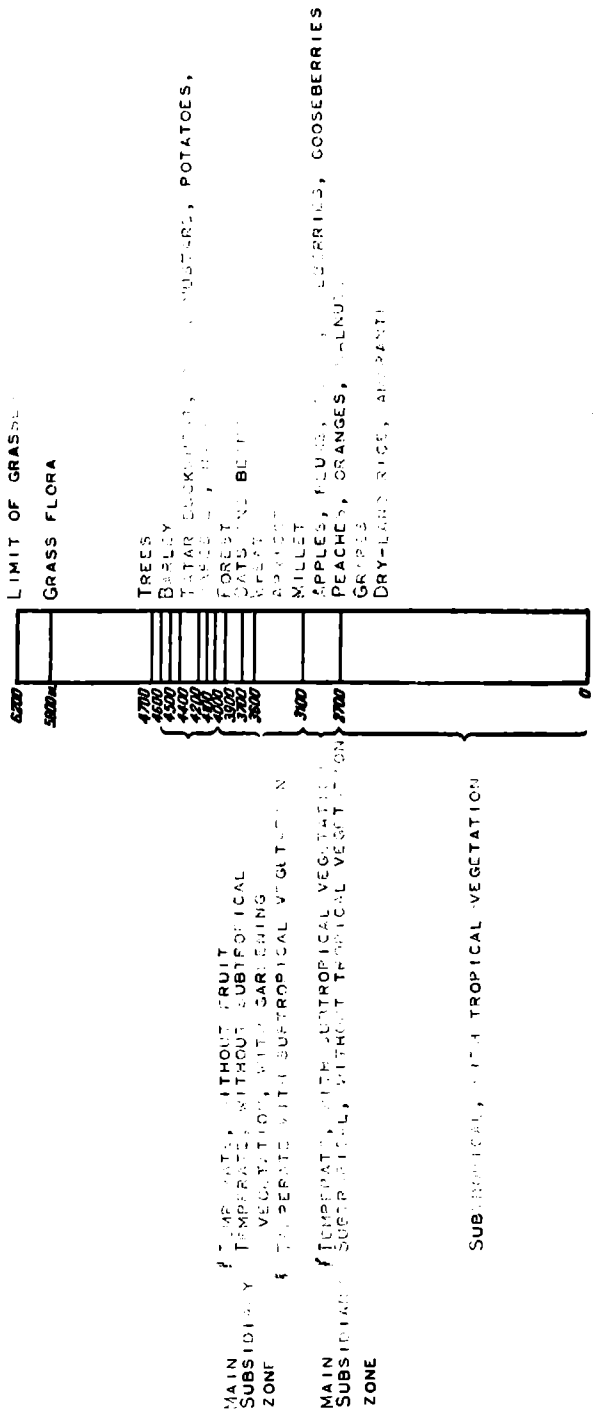
Isotherms for January and July (at the earth's surface) (Annotations read: "Isotherms for January" and "Isotherms for July")



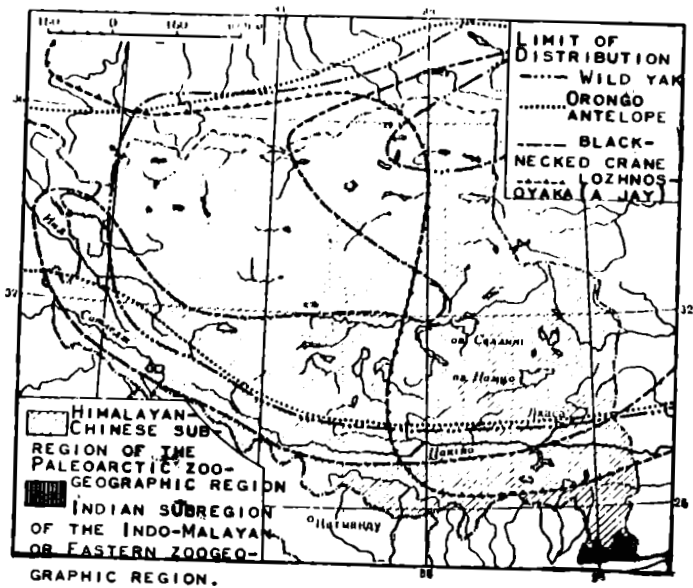
Schematic Map of Distribution of Principal Types of Relief

SKETCH OF THE VERTICAL ZONATION OF PLANTS OF TIBET, NORTHWESTERN AND CENTRAL

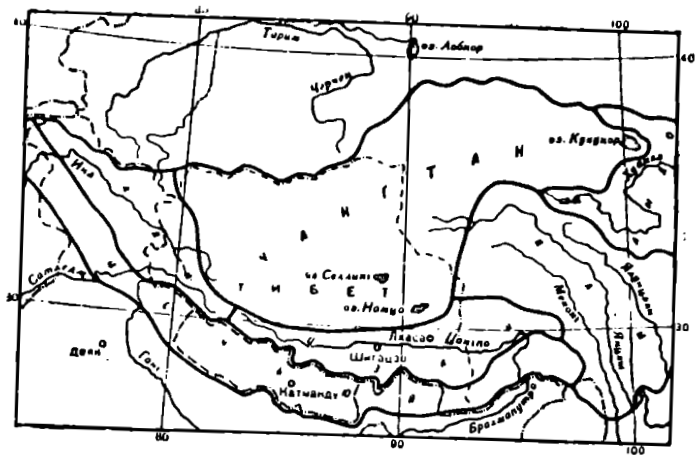
IN HIMALAYA (According to G. V. KOVCHERZHNIK)



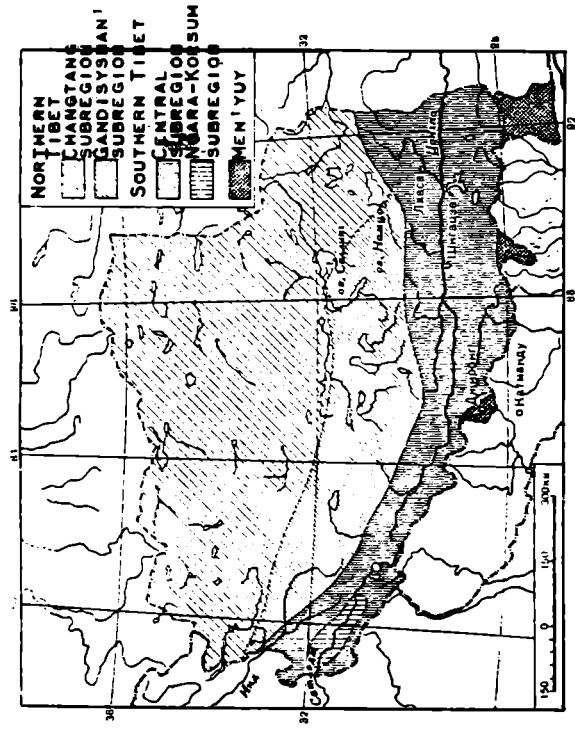
FOR ALL OF THE ENUMERATED GROUPS BELONGING TO THE GROUP OF PLANTS OF THE TEMPERATE ZONE, THEIR HIGHEST UPPER BOUNDARIES OF GROWTH ARE FOUND IN TIBET.



Sketch map of Zoogeographic Regions and Distribution of Several Species of Animals



Regions of Tibet (according to Fen-shen).



Sketch Map of Physical-Geographic Regions



FORMS OF VALLEYS



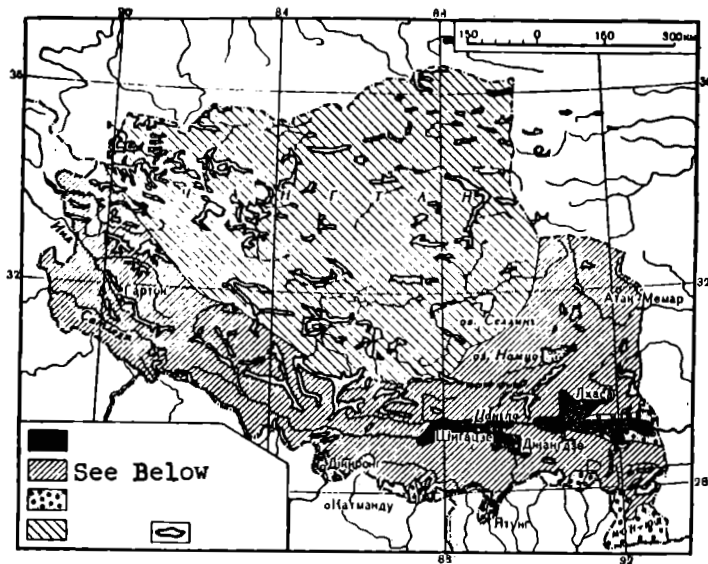
TYPICAL CROSS SECTION OF AN AREA IN  
NORTHERN TIBET








SLOPE OF A FLAT WATERSHED



Cross sections of the Main Elements in Relief of the Changtang (according to S. Hedin)



Special Aspects of the Territory of Tibet (use was made of materials from Sun Tszin-dzhi)

-  Most important agricultural regions
-  Most important regions of livestock grazing
-  Forested regions
-  Barren lands
-  Eternal Snows and Glaciers

TABLE

MEAN MONTHLY AIR TEMPERATURE AT LHASA

MONTHS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN ANNUAL
AVERAGE FOR 4 YEARS	0,0	0,1	6,1	9,6	13,3	17,0	16,3	15,4	14,8	9,1	4,3	0,5	9

MONTHLY TOTALS FOR RAINFALL

MONTHS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN ANNUAL
1935	0	0	0	1	3	26	208	167	43	0	0	—	448
1936	0	—	23	12,5	486	519	2050	1330	619	13	—	0	5033*
1937	0	1	0,2	2,7	12	8	83	235	24	7	0	0	373

RELATIVE HUMIDITY

MONTHS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN ANNUAL
	22	35	27	25	38	48	57	61	54	37	34	30	39

\* STRIKING IS THE IMMENSE AMOUNT OF PRECIPITATION IN 1936 IN COMPARISON WITH OTHER YEARS. THE GREAT DIFFERENCE IN THE PRECIPITATION FALLING IN DIFFERENT YEARS CAN BE CAUSED, EVIDENTLY, EITHER BY INTENSIFIED CYCLONIC ACTIVITY IN THE INDIAN OCEAN WITH OUTBREAKS OF CYCLONES FROM THE BAY OF BENGAL OVER THE HIMALAYA OR IN GENERAL BY A SHARP INTENSIFICATION OF THE INDIAN MONSOONS IN DIFFERENT YEARS, WHOSE DEVELOPMENT DEPENDS ON MANY CAUSES, INCLUDING THE RAPID DEVELOPMENT OF THAWING OF SNOW IN THE HIMALAYA, IF THERE BE LITTLE, AND ON THE INTENSITY OF THE TIBETAN ANTICYCLONE. IT IS POSSIBLE THAT THE MOISTEST YEARS IN INDIA AND TIBET OCCUR WHEN THE CAUSES INDICATED OCCUR SIMULTANEOUSLY.

- E N D -

