Symposium on
Qinghai-Xizang(Tibet) Plateau
Beijing, China

# *A Scientific Guidebook to South Xizang (Tibet)*

June 2-June 14, 1980

Organizing Committee
Symposium on Qinghai-Xizang(Tibet) Plateau
Academia Sinica

# Contents

Preface

A. Geography

I. Introduction ······ (1)
II. A brief account of physical geography of South Xizang ······ (3)
III. Important stops ······ (6)

B. Geology and Geophysics

I. General Features from Lhasa to Nyalam ······ (17)
II. The Geothermal Fields and the Quaternary in Yangbajain District ······ (34)
III. Kangdese Magmatic Rock Belt ······ (44)
IV. Yarlung Zangbo Ophiolite Belt ······ (53)
V. The Pliocene and the Quaternary in Nyalam District ······ (69)
VI. The Paleozoic and the Mesozoic in Nyalam District ······ (81)
VII. High Himalaya Metamorphic Rock Series in Nyalam District ······ (95)

References ······ (106)

Appendix: Geological Map of the Lhasa-Nyalam Area, Xizang (Tibet), The People's Republic of China

# PREFACE

*A Scientific Guidebook to South Xizang* edited purposedly for the Lhasa-Nyalam excursion includes 2 parts: A. Geography and B. Geology and Geophysics.

The route of the excursion begins from Yangbajain near Lhasa roughly along the highway from China to Nepal through the south wing of the Nyainqentanglha Range and the Xizang Himalayas to the border town Zham in Nyalam County, ending at the Friendship Bridge at the Sino-Nepalese border. The distance approximates 930 km.

The physical environments, biologic features, and the unique geologic developments of the region have long attracted the attention of scientists. From the end of the 19th century to the eve of the founding of the People's Republic of China, a number of scientific researches have been made. During 1903—1904, H. H. Hayden made a reconnaissance survey from Ya-dong passing Gyanze to Lhasa. Later, as members of British Mountaineering Expedition of Mt. Qomolangma (Mt. Everest), A. M. Heron, N. E. O'dell, L. R. Wager et al. studied in the 20s and 30s the north slopes of Mt. Qomólangma. Xu Jin-zhi, Luo Wen-bo and Liu Shen-e surveyed the east part of this region.

Since the founding of the People's Republic of China, deep concern by the Chinese Communist Party and Government for the benefit of the Xizang people has led to many scientific investigations to the plateau. Among them may be mentioned The Working Team to Xizang, the Government Administration Council, 1951—1953; Scientific Investigation Team of Chinese Mountaineering Expedition to Mt. Qomolangma, 1959— 1960; Multi-disciplinary Scientific Investigation Team to Xizang, Academia Sinica, 1960—1961; Chinese Scientific Investigation Team of Mountaineering Expedition to Mt. Xixabangma, 1964; Scientific Investigation Team to Xizang, Academia Sinica, 1966—1968, and Multi-disciplinary Scientific Investigation Team of Qinghai-Xizang Plateau, Academia Sinica, 1973—1979; all these were of comparatively large scale. Based on the geologic and geophysical data already obtained, a demarcation line may be made along the Yarlung Zangbo ophiolite belt, separating the area into north and south parts, which differ significantly from each other in history as well as in structure. To the south is a part of the Indian Plate or the Gondwana with Himalaya structure, to the north is a part of the Eurasian Plate with Kangdese Nyainqentanglha structure. The Yarlung Zangbo valley, where the intermediate-acid magmatic belt (Kangdese magmatic belt) trends W-E, parallels to the Yarlung Zangbo ophiolite belt. In the Xigaze region, the central crystalline belt of the Himalayas is mainly composed of medium metamorphic rocks. In the lower part are schist and gneiss; and in the upper, migmatites. Many thrusts indicate the possibility of a nappe toward the south. Combined with the numerous nappes on the south slope of the Himalaya including Nepal this may offer evidences for the mechanism of a force from the north, conforming with the stress fields generated by the collision of the Indian and the Eurasian Plates.

The geologic researches in the Himalaya and the Kangdese-Nyainqentanglha well reveal the mysteries of the plate motion. In recent years, many researches have been made at the south slope of the Himalaya extending through Nepal, Pakistan, India, and other countries. It is hoped that this Symposium and the post-Symposium excursion will contribute to the understanding of the Qinghai-Xizang Plateau, and will lay a good foundation for further researches.

The high altitude of the Qinghai-Xizang Plateau raises interesting problems in the fields of physical environments, fauna and flora, as well as in agriculture, forestry, animal husbandry and human adaptability. This Guidebook fails to go into the details of every field, it is only an attempt to provide a background for field discussions.

For the compilation of this Guidebook, the results of the former investigations have been consulted and a reconnaissance survey was made from May to August, 1979 along the excursion route. The compilation group is indebted to the Government organizations, the Scientific and Technological Commission, and the Bureau of Geology of the Xizang Autonomous Region for their hospitality and supports.

The compilation group of *A Scientific Guidebook to South Xizang (Tibet)*

## Compilers of A, Geography

ZHANG RONGZU — *Chief Compiler (Institute of Geography, Academia Sinica)*

ZHENG DU — *(ditto)*

YANG YICHOU — *(ditto)*

SUN HONGLIE — *(Integrated Survey Commission of Natural Resources, Academia Sinica)*

LI MINGSEN — *(ditto)*

CHEN CHUANYOU — *(ditto)*

ZHANG YIGUANG — *(ditto)*

HAN YUFENG — *(ditto)*

WU SUGONG — *(Kunming Institute of Botany, Academia Sinica)*

WANG JINTING — *(Institute of Botany, Academia Sinica)*

FENG ZUOJIAN — *(Institute of Zoology, Academia Sinica)*

FAN YUNQI — *(Nanjing Institute of Geography, Academia Sinica)*

ZHENG BENXING — *(Lanzhou Institute of Glaciology and Cryopedology, Academia Sinica)*

## Compilers of B, Geology and Geophysics

YIN JIXIANG — *Chief Compiler (Institute of Geology, Academia Sinica)*

CHANG CHENGFA — *(ditto)*

DENG WANMING — *(ditto)*

ZHANG QI — *(ditto)*

ZHENG XILAN — *(ditto)*

PAN YUSHENG — *(ditto)*

WU HAORUO — *(ditto)*

SUN YIYIN — *(ditto)*

TENG JIWEN — *(Institute of Geophysics, Academia Sinica)*

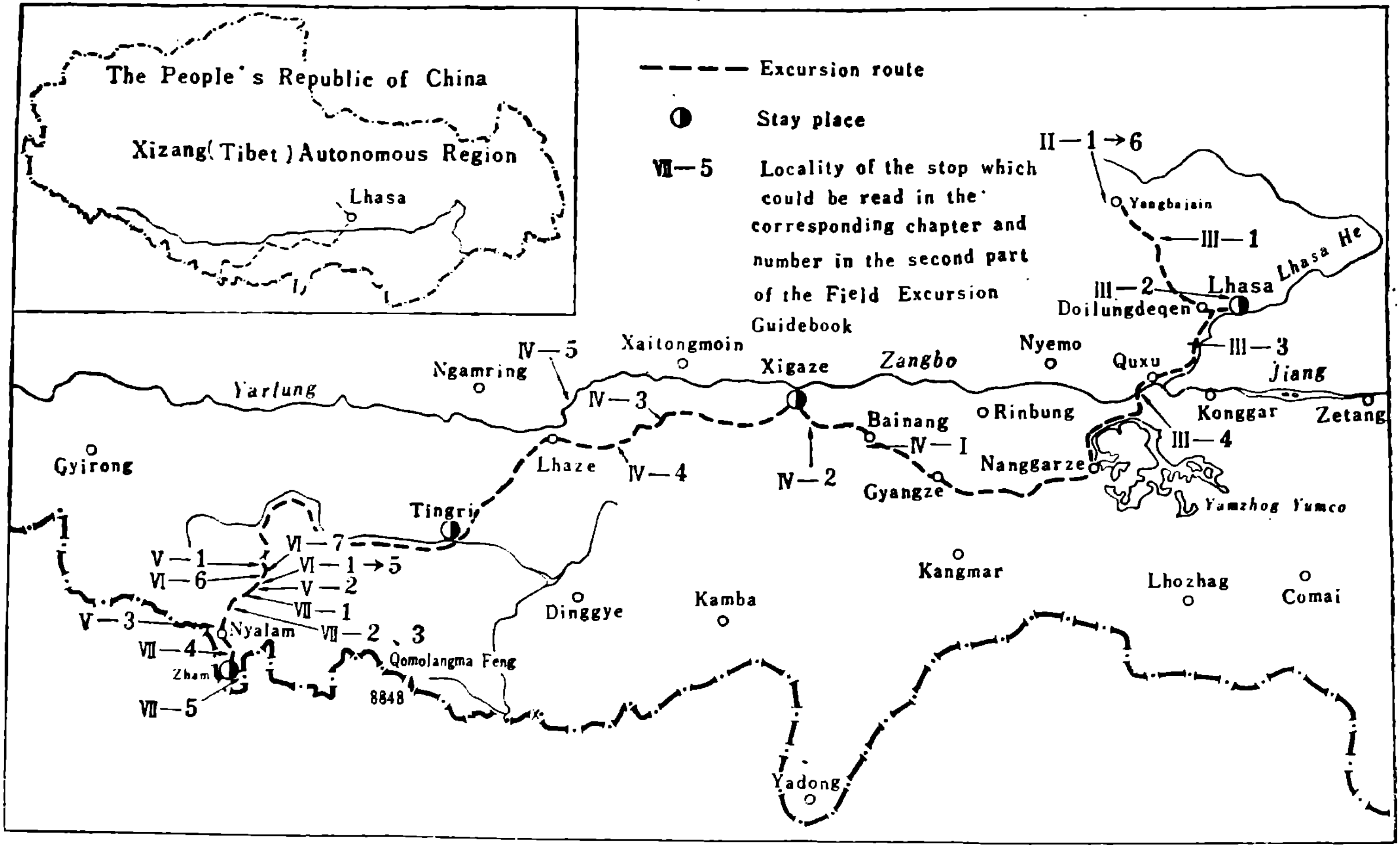
WEN SHIXUAN (*Nanjing Institute of Geology and Paleontology, Academia Sinica*)

ZHANG YUQUAN (*Institute of Geochemistry, Academia Sinica*)

WANG FUBAO (*Nanjing University*)

ZHANG ZHIFEI (*Beijing University*)

ZHANG QINGSONG (*Institute of Geography, Academia Sinica*)



The People's Republic of China
Xizang (Tibet) Autonomous Region
Lhasa
Excursion route
Stay place
Ⅶ—5
Locality of the stop which could be read in the corresponding chapter and number in the second part of the Field Excursion Guidebook
Ⅱ—1→6
Yangbajain
Ⅲ—1
Lhasa He
Ⅲ—2
Lhasa
Doilungdeqen
Ⅲ—3
Nyemo
Quxu
Jiang
Zangbo
Xigaze
Xaitongmoin
Ⅳ—5
Ngamring
Yarlung
Ⅳ—3
Konggar
Zetang
Rinbung
Bainang
Ⅳ—1
Ⅲ—4
Nanggarze
Ⅳ—2
Gyangze
Yamzhog Yumco
Lhaze
Ⅳ—4
Gyirong
Tingri
Ⅵ—7
Ⅴ—1
Ⅵ—1→5
Ⅵ—6
Ⅴ—2
Ⅶ—1
Ⅴ—3
Nyalam
Ⅶ—2, 3
Ⅶ—4
Zham
Ⅶ—5
Qomolangma Feng
8848
Dinggye
Kamba
Kangmar
Lhozhag
Comai
Yadong

# A. GEOGRAPHY

## I. Introduction

The Qinghai-Xizang Plateau borders the Kun-lun mountain and the Qi-lian mountain on the north, the Himalayas in the south, the state boundary on the west, and the so-called Heng-duan mountain comprising a group of north-south ranges on the east. Occupying about one fourth of the country in area, the plateau averages over 4,000 m in elevation, worthy of the name the "World's Roof".

The Xizang Autonomous Region is situated in the south part of the plateau, extending from 78°25′ to 99°05′E, and 26°50′ to 36°30′N with an area of about 1.2 million $km^2$.

The topography is by no means even. The west to east trending ranges reflect the geological control; they are from north to south the Kun-lun, the Karakorum-Tanggula, the Kangdese-Nyainqentanglha, and the Himalaya. In the east, however, the Hengduan ranges trend north to south and, from west to east, they are the Boshula, the Taniantaweng, and the Ningjing with respectively the Nu-jiang, the Lancang-jiang, and the Jinsha-jiang gorges in between. On these ranges, peaks rise as high as 5,500—7,000 m, where glacial and periglacial landforms, actual as well as ancient, prevail.

In the north part of the Xizang Autonmous Region, the relief of Chang Tang plateau fluctuates between 4,500—4,800 m with numerous lakes and ponds on the surface, being a vast expanse of interior drainage. In east Xizang where the climate becomes relatively moister, mountains and gorges signify the intense dissection of the land, while the steep slopes plus deep valleys render all kinds of transportation difficult. The valley may reach as low as 200 m, with the utmost even down to 150 m. The plateau as a whole inclines from northwest to southeast.

This enormous plateau being almost 1/3 as high as the tropopause, the oxygen pressure amounts to half of that over East China. People first visiting Xizang are apt to suffer from the so-called "Alpine reaction", breathing rapidly and feeling strengthless. The warming effects of the plateau mass help elevate the air temperature higher over Xizang than anywhere of the same latitute and altitude, contributing to Xizang 'a favorable eco-environment.

In the winter half year, westerlies prevail over the Plateau; in the summer half, however, a low center develops over the ground against a high in the sky. The shifting of winds forms some kind of monsoonal system on the plateau itself so that a dry season befalls from October to May inclusive with clear sky and strong winds, and a wet season June to September. Since the warm moist air from the Indian Ocean blows northwestward, a succession of natural belts arranging in the direction represented by forest-meadow-steppe-desert differentiates the environment, as well as the land use.

## II. A brief account of physical geography of South Xizang

South Xizang is used to indicate the region to the south of the Kangdese-Nyainqentanglha range, including the Yarlungzangbo and the Pum-Qu river systems. The Yarlungzangbo (or the upper stream of the Brahmaputra) along the great fault valley at the southfoot of the said range is a large river of the greatest altitude in the world. In its middle stream, gorges alternate with depressions. In the latter, several steps of terraces may occur, as may the deposits of aeolian sands. The middle Yarlungzangbo plus its larger tributaries such as the Nyang-Qu and the Lhasa-He is the main farming area of Xizang with concentration of population and urban centers. The elevation is about 3,500—4,200 m.

The Pum-Qu valley, smaller than the Yarlungzangbo, is situated in the west part of South Xizang. The depressions in the upper and lower streams average over 4,000 m in elevation. The major lakes in South Xizang including from east to west the Yamzhog Yum Co, Puma Yum Co, Dogen Co, and Baiku Co etc. are without an outlet but with fresh or slightly salt water in them. Most lake basins, actual and ancient, are of fault origin. The *Hipparion* fossils in the lacustrine deposits remind us of the Pliocene forests or forest-steppes replaced by the present alpine steppes.

The Himalaya range, bordering the Plateau in the south and having uplifted only since Miocene, is highest in its middle stretch with numerous ice pinnacles and rugged peaks. Besides Mount Qomolangma (known to the Western world as Mount Everest, 8,848 m), five peaks rise above 8,000 m and all these high peaks provide an excellent ground for glacial actions.

On the southern slopes of the Himalayas, the natural landscape differs greatly from what has been described to the north. Here the steep slopes signify the strong fluvial erosion by gorges and cataracts consequent to the cuesta-like upheaval. The mountains rising abruptly from the Ganges plain, the physical phenomena are differentiated clearly in vertical zones within short distance. Timber resources abound in the great variety of forests.

The climate of South Xizang is semi-arid, rains fall about 200—500 mm in the year decreasing toward the west. The warmest month of 10°C—16°C plus the coldest of −10°C average 2—8°C for the annual temperature. Solar radiation is so strong that bathrooms have been established for public service in Lhasa, using solar energy alone. Lhasa has been known as the "City of Sunlight".

Alpine steppe and montane shrubby steppe form the vegetation. The former consists of *Stipa purpurea* and *Artemisia* spp., and the latter *Sophora moocroftiana* and *Aristida triseta*; their calcareous soils are respectively Baga Soil (Alpine steppe soil) and Aga Soil (Montane shrubby steppe soil).

Winter wheat, Qing-ke (highland barley) grows well in

## Table of Climatic Elements

| | Location / Climatic elements | Lhasa | Xigaze | Nanggarze | Gyangze | Tingri Xeger | Tingri | Nyalam |
|---|---|---|---|---|---|---|---|---|
| June | Mean Temperature | 15.5 | 14.6 | 9.6 | 12.7 | 11.1 | 9.8 | 9.2 |
| | Precipitation mm | 75.6 | 71.7 | 64.8 | 45.0 | 47.3 | 13.3 | 66.6 |
| | Relative humidity % | 53 | 51 | 60 | 52 | 51 | 53 | 79 |
| | Mean wind velocity m/s | 2.2 | 2.1 | 2.3 | 2.6 | 2.6 | 3.1 | 4.4 |
| Annual | Mean Temperature | 7.5 | 6.3 | 2.4 | 4.8 | 2.7 | 0.7 | 3.5 |
| | Precipitation mm | 443.6 | 434.1 | 372.9 | 288.4 | 322.3 | 236.2 | 614.8 |
| | Relative humidity % | 45 | 41 | 44 | 41 | 39 | 45 | 62 |
| | Mean wind velocity m/s | 2.1 | 1.8 | 2.9 | 2.7 | 2.8 | 2.6 | 4.2 |

South Xizang. The highest wheat yield having reached 1,700 jin/mu, the upper limit of wheat goes as high as 4,200 m, and that of Qing-ke 4,700 m, recording the world's highest upper limit of cultivation. Xizang sheep and yak find their excellent pastures in the plateaus, mountains, and lacustrine flats. Livestock farming constitutes an important part of the Autonomous Region's economy. It is only natural that the region's economic and cultural centre lies in South Xizang.

This trip will follow the route from the south slope of the Nyainqentanglha range, through the Yarlungzangbo valley, up to South Xizang Plateau and the Himalaya Range, before turning to the south slopes of the Himalayas. Some typical spots will be chosen from each major region.

## III. Important stops

**1. Lhasa.** Lhasa city (3,658 m), the capital of the Autonomous Region, is situated in the middle stream of the Lhasa-He, a tributary to the Yarlungzangbo. At their junction, rivers braid and swamps spread over a vast expanse, unfavorable to settlements. This helps to realize why Lhasa gets away from the water course, so unlike a riverine port, but retreats to the hillside. Some limestone hills rise about 100 m above the valley bottom, and the magnificient monastery the Potala Palace tops one of them. Ancient karst topography awakes to the former moister climate. On the north side of the valley, steep slopes of granites under strong mechanical weathering are almost deprived of vegetation.

The June temperature approximates 15.5°C, the January −2.2°C and the annual 7.5°C. The precipitation amounts to 440 mm in the year and the rainy season starts early in June, when the air moisture significantly increases. Night rainfall counts up to about 80%. Agriculture develops well on irrigation.

The old city has extended to the new one with an urban population about 100 thousands.

**2. Yangbajain-Damxung Doiling.** The district lies at the north hillsides of the Nyainqentanglha range along a northeast trending valley. Neotectonic movements are strong. The Yangbajain thermal fields in the center of a depression of the same name diffuse the geothermal heat in various forms including boiling springs, hot springs, thermal springs, and a thermal lake, etc. Once, a drilling led to a thermal explosion of geysers; now the No. 7 Geyser explodes once every 12 minutes. The thermal lake, of oval shape and 7,350 $km^2$ in area, measures 16.1 m deep. The water is clear and the temperature up to 50°C, vapours all over the surface, producing an area of heat anomaly about 7 $km^2$ and a total heat diffusion 116,000 Cal/sec. (see Geology Guide-book)

Doiling is situated in the valley by the south foot of the Nyainqentanglha range. Most pointed peaks rise above 6,000 m, the highest being 7,111 m, through which wind the glaciers. Cirques are found. On the southeast slopes of the Nyainqentanglha are several steps of ancient platforms of glacial accumulation, lower down, are platforms and fans of fluvio-glacial origin. 2 or 3 sets of valley in valley, demonstrating the actual dissection by the V-valley into the U-valley. In Quaternary, at least 3 glaciation occurred, the greatest one reached as far as down the valley bottom, forming foot-hill glaciers with moraines and erratic boulders.

**3. Quxu-Kambala pass.** The city of Quxu (3,600 m) is on the north bank of the Yarlungzangbo. After the liberation, a bridge over the Yarlungzangbo has been built. The river is here about 6 m deep in the flood season and about 2 m in the dry season. Below the bridge, the river branches between sand bars with which the prevailing west winds blow sand dunes along the river or sand covers over the slopes.

To the south of the Yarlungzangbo, the road goes up the Kamba La pass (4,794 m). Shrubby steppe, shrubby meadow steppe, and alpine meadow are found. The well-known lake Yamzhog Yumco lies at the south foot of the pass.

**4. Yamzhog Yumco.** The lake ramifies westwards. Evidences are that a tributary led it to the Yarlungzangbo, before it was dammed into an enclosed lake.

The lake, 4,441 m in elevation, measures 678 $km^2$ at the surface with an drainage area of 6,100 $km^2$. All the rivers entering the lake are short ones, more from the south, the longest of which, the Kadongjia, is 75 km long. Pluvial supply is general the case except the Ka-lu-xiang-qu, which is fed by melt water.

The depth averages 20—40 m, the deepest measurement being 59 m. The 20 m isobath is within 300 m from the bank, reflecting the steep sides. The water volume amounts to 1.51 bill. $m^3$, with very slight change in the stage, only 4.3 m for the last 100 years. *Gymnocypris wadellii* abound.

**5. Karila.** The Karila pass, 5,045 m, is to the southwest of the Yamzhog Yumco, about 30 km from the lake city of Nanggarze, being the highest pass on the motorable road to Gyangze. The pass is a part of a morainic platform in an ancient glaciated U-valley bordered by lateral moraines and ended with terminal moraines plus fluvio-glacial terraces. Striae on the valley walls and ancient cirques on the heights are clear.

To the north of the pass is Mount Noijinkangsang (7,191 m) and to the south, Mt. Ka-lu-xiong (6,647 m). The snowline in the vicinity reaching 5,900 m, numerous cirque glaciers and hanging glaciers nourish the streams that flow westwards and northwards through the Nyang Qu and the Main Qu to the Yarlungzangbo.

To the northwest of the Karila pass a hanging glacier comes from the south slope of Mt. North in Noijinkangsang down as low as 5,233 m. Crevasses help avalanches. In the years 1957, 1963, 1978, avalanches occurred in large scale and blocked the road.

South of the road, comes down the Qiang-yong glacier, which, being a continental cirque glacier, moves at a rate of 30 m/year (1975). It bifurcates in the lower stretch, the east branch extends as below the snowline to 5,132 m and the west one even to 4,980 m. At the terminus of the glacial tongue, a lake is formed by terminal as well as lateral moraines. From 1975—1979, the tongue advanced 12.5 m.

The periglacial landformes above 5,000 m include rock pinnacles, polygonal sols, and solifluctions. Skirting the mountain-sides are taluses and aprons of angular boulders, as are the frozen mounds on the morainic platforms at the ontlets.

Alpine meadows are the main type of vegetation in the vicinity of Karila, with only single plants on the moraines and the taluses.

**6. Gyangze.** Gyangze is an important town of South Xizang, situated at 4,000 m above sea level in a depression in the middle stretch of the Nyang Qu valley on the north side of the Karila pass. The Nyang Qu is the largest tributary to the Yarlungzangbo on the right side, draining northwestwards an area of 11,100 $km^2$. The valley is broad around Gyangze where several isolated hills remain. Vegetation is scarce, and the alluvial fans are spotted with some *Sophora moocroftiana.*

Crops on the several steps of terraces and on the major river bed furnish the cereals. Although the annual rainfall amounts only to 290 mm, abundant supply of melt water meets the needs of sufficient irrigation and promises the good growth of Qing-Ke (highland barley), peas and oil-seed, etc. The introduction in the early 70 s of winter wheat has brought good harvests. The climate seems to satisfy the wheats particularly well, the experimental station of agriculture at Xigaze has recorded the yield of over 1,700 jin/mu.

Atop one of the hills stand the remnants of fortifications against the British invasion in 1904; a monastery the Ba-jiao-qu-deng temple is at the foot of the same hill. Gyangze has a long history of her fabric industry, famous of producing tapestries and rugs.

**7. Xigaze.** Xigaze meaning "fine manor", is Xizang's second largest city (only next to Lhasa), situated 3,836 m at the junction of the Nyang Qu and Yarlungzangbo. The valley is here wider than in Gyangze and the lacustrine deposits on the terraces locate the once Pleistocene lake.

The semi-arid climate flourishes adequate farming in the suburbs with relatively dense population, although rocky hills with poor soils surround the city proper. Shrubby steppes represent the natural vegetation; trees are very rare. However, rows of willows and poplars are cultivated along the rivers.

Streets are neat. Urbanization comes only after Lhasa. The Holy Monastery the Zhaxilhunbo temple on a hill north of the city may be compared to the Potala Palace both in arts and structure.

**8. Dagzhuka.** This important ford is about 90 km below Xigaze along the Yarlungzangbo, 3,750 m in elevation. The valley broadens above the ford, but narrows below it. Despite the low temperature, water flows smoothly in winter without freezing. Blown sand covers some of the steppes.

The greatest width of the valley may be 8—10 km, where the river braids. Croplands on the terraces and river bars make it one of the agricultural bases of Xizang. Natural plants such as *Sophora moocroftiana, Oxytropis, Pennisetum, Orinus, Stipa* spp. etc. provide adequate pastures for life-stocks.

Below the Dagzhuka ford, begins the To-xia gorge which stretches 80 km long in a series of rapids with a total fall of more than 100 m, being a rich resource of future water power development.

**9. Gyaco La.** Further west, the road crosses several tributaries (the Bu-qu, Re-qu, Sagya Chumqu) and several low passes before reaching Lhaze, 145 km from Xigaze. The town is located on the alluvial plain at 4,100 m. The landscape, as well as the farming and pasturing activities are similar to that in Gyangze and Xigaze.

Not far from Lhaze to the west, rises the Lhagoi Kangri Range, where alpine meadows appear above 4,500 m. The Gyaco La pass is on the range, broad and flat at 5,250 m, representing the remnants of an ancient peneplain. The climate is rather cold and slightly moist. Among the components of the alpine meadow are *Kobresia Pygmaea* and *Kobresia* spp.

Immediately south of the pass are morainic materials from Mount Lhagoi Kangri (6,457 m). Down the road well preserved U-valleys are on the east side spread over on the bottom by granitic moraines. Swampy meadows of *Kobresia littledalia* develop on the fluvio-glacial fans.

**10. Tingri and Kung Co.** The Lhagoi Kangri range divides the Yarlungzangbo from the Pum Qu, the latter being the second largest river in South Xizang. The town

Tingri is on the largest tectonic basin of the upper stretch of the Pum Qu valley. The basin measures 20 km from north to south and 10 km from west to east, about 4,300—4,500 m in elevation. It borders the Himalayas on the south, and the immediate mountains average over 5,000 m above sea level. The east-flowing Pum Qu river crosses through the basin before turning south to cross the Himalayas.

Skirting the south slopes of the basin are enormous glacio-fluvial fans. On the alluvial center, rise some isolated hills 80—100 m high. Small sand bars split the water course. Tingri leans on the east foot of a hill, dominating the China-Nepal highway.

The basin is under the shadow of the Himalayas. Of the semi-arid steppe, the dominants comprise *Peninsetum flaccidum, Orinus thorodii, Stipa* spp., and *Artemisia spp.* Animal husbandry develops in addition to some farmlands.

To the west of the Tingri depression is the Kung Co depression in sight of Mount Qomolangma. U-valley and morainic forms are seen to the east. Swampy meadows of *Kobresio* develop on the lowlands.

**11. Yagru Xongla.** Yagru Xongla is another platformlike remnant of the 5,200 m peneplain. It divides the Pum Qu river into several minor systems draining to the south of the Himalayas. This means the World's highest mountain system is cut into several places by small streams. Where the China-Nepal road is, the pass measures 7—8 km wide and 5,100 m in elevation. Mount Xixabangma, 8,012 m, rises abruptly to the southwest, topped with snow and dissected by glaciers.

Vegetation on the platform is dominated by cushion-like herbs and grasses including *Androsace tapete, Arenaria musciformis,* and *Astragalus* spp.

Down south from the pass outcrop the lacustrine deposits, 510 m thick, of Pliocene, fossilizing lamellibranchia gastropods, and ostrocods. Also found are *Hipparion* in a layer of white-grey sands at 4,950 m. Sporo-pollen analysis shows that 4 palaeogeographical stages may be divided in the course of the upheaval of the Plateau, changing the warm moist environment gradually to cool aridity.

Further south, the road goes down the Bo-Qu valley, where the landscape rapidly changes. Retrograding erosion by the antecedant streams on the south slope of the Himalaya cuts through the grand mountain range. The ancient lake basin ends in a gorge.

**12. Yarleb.** The village Yarleb is sited at 4,300 m on the east side of the Bo-Qu valley, where sinter courses out from the Ordovician limestones. The rocks are compact and oblique. In the sinter are found artifacts of all sorts of mio-lithic or neolithic age, as are fossils of *Rhododendron, Lonicera, Salix,* and *Viburnum.* Communities of similar plants at present are located much lower in elevation, such as those further south in the Quxam district, 4,300—3,880 m above sea level. The formation of the crust, therefore, should have been under a warmer and moister climate (probably 2—3°C warmer than at present), and the artifacts here may be compared to the Yangshao culture of East China of Holocene (Neolithic), a period with favorable climate.

**13. Nyalam.** Nyalam is an important post on the road, situated at the junction of the Po Qu and the Fu-Qu, 3,810 m in elevation. Several terraces are of morainic origin with huge boulders seemingly laid down by the former glaciers from Mount Xixabangma.

An annual temperature of 3—5°C combined with precipitation of 600 mm makes the climate subhumid, subalpine frutescent meadows being all around. Sunny slopes contrast rather markedly with the shade ones. Meadows on the former are with *Sabina squamata* and *S. wallichiana;* on the latter, with *Rhododendron companuatum*. While those on the morainic platform are with *Androsace tapete, Cassiope fastigiata,* and *Artemisia* spp.; and in well-watered spots, with *Primula sikkimensis*.

**14. Zham.** Zham is a local trading post with Nepal, 30 km south of Nyalam. The settlement is scattered over the steep slopes on the left side of the Bo-Qu with 2 main streets at 2,300 m. 20 km further down the valley is the Friendship bridge, crossing the center of which lies the Sino-Nepalese boundary. Between these 20 km, the elevation falls 2,200 m (3,800—1,600) in a gorge all through at a gradient of 110 m/km resulting from strong erosion.

Forests are everywhere from Zham up to Nyalam, 3 belts may be recognized. They are from Zham upwards: 1) Montane evergreen broad-leaf forest (1,600—2,500 m); 2)

Montane mixed forest (2,500—3,100 m); 3) Montane coniferous forest (3,100—3,900 m).

The June temperature averages 16°C and the frost-free period about 250 days in the year. The annual rain of 2,000 mm or so falls from May till October, more often in topographical or convectional forms.

In the subtropical forest around Zham plants are of great variety, *Fagaceae* and *Lauraceae* dominating. Climbers and epiphytes are seen all the way from Zham to the timber-producing area near Li-xin village; bamboos are no little. Wild animals include *Presbytis entellus, Mucaca assamensis, Hystris hadgsons,* and *Petaurista* spp. *Ailurus fulgens* also appears.

Maize, wheat, Highland barley are the main crops. In recent years, tea has been introduced to the gentle slopes below 2,500 m and the growth is coming on splendidly.

From Zham, the path winds 7 km (straight distance 3 km) to the Friendship bridge 1,600 m in elevation. A stone statue of an elephant by the bridge symbolizing the Sino-Nepalese friendship. The Nepalese capital Katmandu is 118 km from the bridge.

# B. GEOLOGY AND GEOPHYSICS

## I. General Faetures from Lhasa to Nyalam

On the Qinghai-Xizang Plateau, 4 mountain W—E trending ranges, namely, the Kunlun, Tanggula, Kangdese-Nyainqentanglha, and the Himalaya, lie from N to S, representing respectively 4 structural units separated by deep faults. The Kunlun Mountain is the product of the Hercynian Movement (240—280 m.y.), the Tanggula, of the Indo-china Movement (107—210 m.y.), the Kangdese-Nyainqentanglha, of the Yenshanian Movement (65—119 m.y.) and the Himalaya, of the Himalayan Movement (10—55 m.y.).

In the Lhasa district in the southern part of the Kangdese-Nyainqentanglha tectonic region, Precambrian parametamorphic series and the fossiliferous beds of Carboniferous, Permian, Triassic, Jurassic, and Cretaceous occur. Volcanics of Cretaceous—Early Tertiary has a wide distribution to the north of the Nyainqentanglha plutons (Table I-1).

In the southern part of the district or to the north of the Yarlung Zangbo river, extends an intermediate-acid magmatic belt of the Yenshanian and Himalayan movements in interrupted outcrops called here the "Kangdese magmatic belt". Most intrusive bodies are hornblendes, grano-diorites and a few are diorites and granites which intruded and altered the Mesozoic beds, causing a metamorphic zone tens to

**Table I-1 The Stratigraphic Scale in Lhasa District**

| Time | | Names of strata | Lithology and thickness | Chief fossils |
|---|---|---|---|---|
| Q | | | fluvial, lacustrine and glacial sediments, (thickness unknown) | |
| $K_2$-R | | | andesite, sandstone and shale | |
| K | $K_2$ | Lingzizong fm. | andesite, rhyolite intercalated with red beds, 1,560m | *Homalocephale* cf. *calathoceros* (Maryanska) |
| K | $K_1$ | Takena fm. | marlite intercalated with purple red clastic rock, 1,000m | *Orbitolina tibetica* Cotter *Acanthoplites* sp., *Ubligella* sp. Neithea quinquecostata (Sowerby) |
| K | $K_1$ | Chumulong fm. | thick bedded quartz sandstone intercalated with slate, 900m | |
| K | $K_1$ | Lingbuzong fm. | coal-bearing clastic rock, 1,600m | *Weichselia reticulata* (Stokes et Webb), *Elatides curvifolia* (Dunker) *Klukia browniana* (Dunker), *Onychiopsis elongata* (Geyler) |
| J | | Duodigou group ($J_3$) | dark gray limestone, 300m | *Cossmannea* sp., *Ptygmatis* sp. *Lochmaeosmilis* sp. |
| | | fault | | |
| T | $T_3$ | Mailonggang group | sandstone, limestone, shale, 1,000m | *Myophoria* (*costatoria*) sp. *Palaeocardita* sp., *Halobia* sp. *Montlivaltia* sp. |
| | | fault | | |
| T | $T_{1+2}$ | Chaqupu group | crystalline limestone, andesite, 1,130m | *Paraceratites trinodosus* (Mojs.) *Reifingites euginiae* Arthaber *Acrochordiceras carolina* Mojs. |
| | | fault | | |
| | $P_1$ | Lielonggou fm. | limestone, siliceous rock | *Guizhoupecten* cf. *regularis* Chen |

| | | | | | |
|---|---|---|---|---|---|
| P | $P_1$ | Lobadoi fm. | Lobadoi reservoir member | limestone intercalated with intermediate-basic volcanics, 400m | *Yabeina shiraiwensis* Ozawa<br>*Y. multiseptata* (Deprat) |
| | | | Majula member | gray massive limestone, 460m | *Neoschwagerina globularis* Wang Sheng et Zhang<br>*Luntschichites minimus* (Chen)<br>*Iranophyllum minor* Wu<br>*Wentzelellites* sp. |
| | | Urulung fm. | | thin bedded limestone, intercalated with black slate, 40—50m | ? *Stepanoviella flexuosa* Waterhouse, *Stenoscisma timorensis* Hayasaka et Gan |
| C | | Pondo group ($C_3$) | | pebbly mudstone sandy slate, siltstone and limestone (thickness unknown) | *Bandoproductus hemiglobica* Ching et Sun, *Chaoiella latisinuata* Ching et Sun |
| | | fault | | | |
| AnЄ | | Nyainqentanglha group | | granitic gneiss and hornblendite, 3,000m | |

1) Paleocene foraminifera and algae (*Keramosphaera tergestina* Stache, *Furcoporella diplopora* Pia, *Distichoplax biserialis* (Deitrich)) in a limestone rubble were found in the Niumagou coal mine in the vicinity of Painbo farm of Lhunzhub county;

2) Cretaceous Xigaze group sediments are unconformable on the Kangdese magmatic rock belt and Early Cretaceous (?) volcanics, from bottom up the succession is:

Xigaze group ($K_2$):
- Ngamring formation sediments of turbid currents with *Mammites* sp., 1,000m
- Sangzugang formation gray bioclastic limestone with *Orbitolina* sp. 100—200m
- Qiabuling formation purple red, grayish yellow conglomerate intercalated with sandstone, containing *Equisetites*., sp., *Trochuctaeon* sp., 150—500m
- Qiuwu formation purple red conglomerate and coal-bearing sandstone and shale containing *Eucalyptus* sp., *Ficus* sp. 200—1,000m

hundreds of meters in width. In the grano-diorites are dioritic xenoliths in definite orientations. In some places, the Kangdese magmatic belt is covered by Late Cretaceous and Tertiary sandstones and conglomerates. North of the belt, occurs also a Late Cretaceous—Early Tertiary volcanic belt. Fluvial, lacustrine, and glacial accumulations of Tertiary and Quaternary fill some of the fault basins.

The Kangdese-Nyainqentanglha and the Himalaya tectonic units are separated by the Yarlung Zangbo ophiolite belt. To the west it connects the Indus ophiolite belt in India and to the east, the ophiolite belt of the Indian-Burmese border. The Yarlung Zangbo ophiolite belt is interpreted as the geosuture between Eurasia and South Asia. The ophiolites roughly have a succession from ultrabasic rocks, basic rocks, basalts, pillow lavas to Cretaceous radiolarian cherts. Faults exist on both sides of the ophiolites, Late Cretaceous flysch (Xigaze group) to the north and Triassic beds to the south. The ultrabasic rocks generally dip to the south, brecciation and schistosity are found without hypothermal metamorphism. Some melanges have occurred during the tectonic emplacement of the ophiolites. To the south in Triassic beds, are some exotic blocks of Permian limestones.

On the basis of the differences of sedimentary features and tectonic deformation, the Himalayan tectonic division can be divided into Tethys-Himalayan and High-Himalayan belts. In Xigaze district, they are demarcated tentatively along the line from Kangmar—Sagya. Tethys-Himalayan belt can also be subdivided into North and South sub-belts. Late Paleozoic sediments of the North sub-belt are similar to those of the South, while its Mesozoic flysch are characterized by local intercalation of intermediate and basic volcanics and radiolarian rock which differ from those of the Southern sub-belt (Table I-2 The Marine Stratigraphy of Tethys-Himalayan Northern Sub-belt in Xigaze District). In the Northern sub-belt, the thick Mesozoic metamorphic beds in some districts are strongly folded, forming southward isoclinal folded zone, while in Yamzhog Yumco lake district it becomes an asymmetric geosynclinorium with east-west axis, associated with faults in nearly an east-west direction. Most of the faults manifest the character of thrusting from north toward south. The Southern sub-belt is mainly composed of nearly continued fossiliferous marine beds from Sinian to Eocene, except that the Sinian-Cambrian beds are slightly metamorphosed. Among them the Carboniferous and the Permian consist of beds of Gondwana facies (e.g. glacio-marine diamictite, *Stepanoviella* fauna and *Glossopteris* flora), (Table I-3 The Marine Stratigraphy of Tethys-Himalayan Southern Sub-belt in Xigaze District).

The High-Himalayan belt (or central crystalline belt) is composed of Nyalam group of medium-degreed metamorphic rocks, the lower part invertedly metamorphosed. It might be mainly composed of a series of parametamorphics, including gneiss, schists and migmatite of about ten thousand meters in thickness; strong migmatization and

**Table I-2 The Marine Stratigraphy of Tethys-Himalayan Northern Sub-Belt in Xigaze District**

| Time | | Names of strata | Lithology and thickness | Chief fossils |
|---|---|---|---|---|
| K | $K_2$ | Zongzhuo formation | olistostrome or mélange flysch-like containing siliceous rock intercalated with pelagic limestone, 1,100m | *Globotruncana linneiana tricarinata* (Quereau) |
| | $K_1$ | Jiabula fm. | grayish black shale, calcareous shale and siliceous shale, 1,100m | *Thurmanniceras grandium* Chao<br>*Calliptychoceras walkeri* (Uhlig)<br>*Hibolithes jiabulensis* Yin |
| J | $J_3$ | Weimei fm. | alternation of beds of silty shale and sandstone, 700m | *Himalayites* sp., *Haplophylloceras* (Blanford), *Belemnopsis elongata* Yin |
| | $J_2$ | Gyangze fm. | thin bedded limestone and laminated marlite, thin bedded tuff 200m | *Delecticeras* sp. |
| | $J_{1-2}$ | Jiazhong flysch | cyclothems of fine sandstone, siltstone and shale intercalated with dacite, 500m | |
| | $J_1$ | Ritang fm. | grayish black calcareous mudstone and marlite, 350m | *Psiloceras provincialis* (Quenstedt)<br>*Prodactylioceras enodum* (Quenstedt) |

| | | | |
|---|---|---|---|
| T | Chogar group.* ($T_1$–$T_3$) | grayish black siltstone, calcareous slate intercalated quartz-sandstone, marlite, 870m | *Placites* sp., *Daonella indica* Bittner, *Anasibirites* sp., *Claraia griesbachi* Bittner |
| P–$C_3$ | Baidingpu fm. | crystalline limestone, 250m. | *Neospirifer kubeiensis* Ting emend. Chang, *Chonetella nasuta* Waagen *Spiriferella* cf. *qubuensis* Chang *Tachylasma* sp. |
| | Kangmar fm. | black slate, 100m. | |
| | Kewoxika fm. | dark gray diamictite intercalated with quartz-sandstone 200m | |

* At the northern side of this sub-belt, there occurs a suite of mottled siliceous shale, calcareous shale intercalated with radiolarian cherts, sandstone and limestone; the thickness is greater than 1,000m, named Gyirong group, containing *Monotis salinaria* Bronn.

**Table 1-3 The Marine Stratigraphy of Tethys-Himalayan Southern Sub-Belt in Xigaze District**

| Time | | Names of strata | | Lithology and thickness | Chief fossils |
|---|---|---|---|---|---|
| E | | Zebu Ri formation | | massive limestone, shale intercalated with marlite | *Orbitolites cotentiensis* Lehmann<br>*Fasciolites ellipsoidalis* (Schwager)<br>*Assilina dondotica* Davies,<br>*Discocyclina sowerbyi* Nuttall |
| E | | Zongpu group | | massive limestone intercalated with shale, 383m | *Nummulites parvulus* Sheng et Zhang<br>*Orbitolites complanatus* Lamarck<br>*Miscellanea miscella* (d'Archiac et Haime)<br>*Campanile brevius* Douvillè<br>*Keramosphaera tergestina* (Stache) |
| K | $K_2$ | Jidula fm. | | quartz sandstone intercalated with limestone, 188m | *Uroleberis inflata* Morellet,<br>*Cymopolia tibetica* Huang,<br>*Neomeris cretacea* Steinmann,<br>*Acicularia antiqua* Pia |
| K | $K_2$ | Zongshan fm. | | limestone intercalated calcareous shale, 278m | *Omphalocyclus macroporus* (Lamarck)<br>*Orbitoides media* (d'Archiac),<br>*Globotruncana linneiana tricarinata* (Quereau),<br>*Neithea quadricostata* (Sowerby),<br>*Bournonia haydeni* Douvillè,<br>*Hemipneustes compressus* Noetling |
| K | $K_1$ | Kangpa group | Gangbacunkou fm. | gray shale, calcareous shale intercalated with marlite, 530m | *Hemiaster front-acutus* Stoliczka,<br>*Neoflabellina* cf. *ovalis* Wedekind,<br>*Camptonectes curvatus* (Geinitz),<br>*Calycoceras newboldi* (Kossmat) |

| | | | | | |
|---|---|---|---|---|---|
| K | $K_1$ | Kangpa grouy | Chaqiela fm. | grayish black shale intercalated with sandstone, calcareous shale, 240m | |
| | | | Gangbadongshan fm. | black shale intercalated with marlite, 530m | *Mortoniceras* sp. *Parahoplites* sp., *Pterolytoceras* sp. |
| J | $J_3$ | Menkadun fm. | | grayish black shale intercalated with sandy shale | *Himalayites* sp., *Blanfordiceras* sp., *Virgatosphinctes denseplicatus* (Waagen) *Aulagosphinotoides smith-woodwardi* (Uhlig) *Buchia blanfordiana* (Stoliczka) |
| | $J_2$ | Niehnieh Hsiungla fm. | | gray limestone and grayish white quartz-sandstone, 1,565m | *Macrocephalites* sp., *Erymnoceras* aff. *coronoides* (Quenst.), *Witchella tibetica* Bukman, *Dorsetensia haydeni* Arkell |
| | $J_1$ | Pupuga fm. | | sandstone, shale and limestone, 495m | *Nyalamoceras nyalamense* Wang, *Schlothemia* sp., *Orbitopsella praecursor* (Gümber), *Entolium nieniexionglaense* Wen |
| T | $T_3$ | Derirong fm. ($T_3^{2-3}$) | | light grayish white quartz-sandstone, occasionally intercalated with coal seams 591m | *Palaeocardita mansuyi* Reed, *Nuculana yunnanensis* Reed, *Indopecten margariti-costatus* (Diener), Myophoria (Neoschizodus) *laevigata* Ziethen |
| | | Qulonggongba fm. ($T_3^{2-2}$) | | dark gray shale, sandy shale intercalated marlite, 465m. | *Distichites tingriensis* Wang et He *Cyrtopleurites socius* Mojs., *Indojuvavites angulatus* Diener, *Himalayasaurus tibetensis* Dong, *Indopecten himalayensis* Wen et Lan, *Palaeocardita rhomboidalis* Wen et Lan |

(*To be continued*)

**Table I-3(1)** *(Continued)*

| Time | | Names of strata | | Lithology and thickness | Chief fossils |
|---|---|---|---|---|---|
| T | $T_3$ | Tulung group | Dashalong fm. ($T_3^{2-1}$) | gray limestone intercalated with sandy shale, 179m | *Gaiesbachites pseudomedleyanus* Diener<br>*Gonionotites tingriensis* Wang et He<br>*Nodotibetites nodosus* Chao et Wang<br>*Burmesia lirata* Healey |
| | | | Zamure fm ($T_3^1$) | bioclastic limestone intercalated with sandy shale and fine sandstone, 99m | *Parahauerites acutus* Wang et He<br>*Hoplotropites circumspinatus* (Mojs.)<br>*Halobia comata* Bittner,<br>*Lilangina nobilis* Diener |
| | $T_2$ | | Laibuxi fm | upper part limestone intercalated with dark gray shale 133m | *Protrachyceras ladinum* Mojs.<br>*Joannites kossmati* Diener<br>*Daonella indica* Bittner |
| | | | | lower part alternation of dark gray shale and sandy limestone, 126m | *Ptychites rugifer* (Oppel)<br>*Anacrochordiceras nodosus* Wang et He<br>*Japonites magnus* Wang et He |
| | $T_1$ | | Kangshare fm. | upper part limestone, argillaceous limestone, 40m | *Procarnites xizangensis* Wang<br>*Anasibirites kingianus* (Waagen)<br>*Owenites* sp. |
| | | | | lower part dark shale and limestone, bottom dolomite 63m | *Gyronites psilogyrus* (Waagen)<br>*Ophiceras* (*Lytophiceras*) *sakuntala* Diener<br>*Otoceras latilobatum* Wang |

| | | | | | |
|---|---|---|---|---|---|
| P | | Selung group | Chubujeka fm | siltstone intercalated with bioclastic limestone and shale, 375m | Chonetella nasuta (Waagen), *Calliomarginatia himalayensis* Ching, *Taeniothaerus* cf. *subquadratus* (Morris), *Lytvolasma asymetricum* Soshkina |
| P | | Selung group | Chubuk fm. | quartz-sandstone intercalated dark gray shale, 20m | *Glossopteris communis* Feistm., *G. angustifolia* Bgt., *G. indica* Schimp., *Dizeugotheca qubuensis* Hsü, *Raniganjia qubuensis* Hsü |
| C | $C_3$ | Gilung fm. | Chaya quartzose sandstone member | quartz sandstone, 700m | |
| C | $C_3$ | Gilung fm. | *Stepanoviello*-bearing sandy siltstone member 1 m | | *Stepanoviella gracilis* Ching, *Empodesma* sp. *Attenuatella convex* Armstrong |
| C | $C_3$ | Gilung fm. | Chataje diamictite member | glacio-marine sediments about 30m | only brachiopod fragments are found |
| C | $C_{1+2}$ | Naxing formation | | gray shale intercalated with quartz sandstone and a little marlite, 1,888m | *Sanguinolites omalianus* (Koninck) *Streblopteria hemisphaerica* (Phillips) *Fusella yaliensis* Ching *Marginirugus* cf. *magnus* (Meek et Worthen) |
| C | $C_{1+2}$ | Yali formation | | alternations of beds of marlite and shale, 60m | *Imitoceras orientale* Liang, *Gattendorfia yaliana* Liang *Pseudosyrinx keokuk* Weller |

(*To be continued*)

**Table I-3(2)** *(Continued)*

| Time | | Names of strata | | Lithology and thickness | Chief fossils |
|---|---|---|---|---|---|
| D | $D_{2+3}$ | Pochu group | upper fm. | grayish black shale intercalated with sandstone 66m | *Paracyclos* cf. *dubia* Beus<br>*Metriophyllum* sp. |
| | | | lower fm. | light gray quartz sandstone 12.56m | |
| | $D_1$ | Liangquan fm. | | dark gray shale, 40m | *Nowakia acuaria* (Richter), *Guerichina rizangensis* Mu, *Neomonograptus atopus rigidus* Mu et Ni, *Monograptus thomasi* Jaeger *M.* cf. *yukonensis* Jackson |
| | $S_{2+3}$ | Pulu group | | quartz sandstone intercalated with calcareous shale and limestone, 46m | *Monograptus vomerina subgracilis* Pribyl<br>*Pristiograptus dubius* (Suess)<br>*Michelinoceras* (*Kopaninoceras*) *jucundum* (Barrande) |
| | $S_1$ | Shiqipo formation | | sandstone, graptolithic shale and limestone, 90m | *Climacograptus normalis* Lapworth<br>*Streptograptus lobiferus* (M'Coy)<br>*Monograptus prioden* (Bronn) |
| O | $O_3$ | Hongshantou fm. | | brown shale intercalated with fine sandstone, 70m | |
| | $O_2$ | Chiatsun group | upper fm. | purple red argillaceous limestone, 97m | *Sinoceras chinense* (Foord), *S. densum* (Yü)<br>*Beloitoceras rizangense* Chen,<br>*Maclurites* sp. |

**Table I-4 The Stratigraphic Scale of Tethys-Himalaya from Oligocene-Quaternary in Xigaze District**

| Age | | Glacial age and inter-glacial age | | Stratigraphic units | Lithology and thickness (m) | Chief fossils | Isotopic age y. |
|---|---|---|---|---|---|---|---|
| Holocene | $Q_4^3$ | Neo-glacial age | | | moraine, fluvioglacial, fluvial, alluvial sediments and eolian accumulations, 30—100 | | B. P. 1700−1900<br>B. P. 2980±150 |
| | $Q_4^2$ | Yali age | | beds of lacustrine facies | clay, clayey soil, diatomite, peat, sinter, pluvial sands and gravels, silt soil, 10—40 | *Ochotona curzoniae*, *Marmota himalaya*, *Cervus albirostris*, microlith (stone nuclei, stone leaves flakes and round scrapers) | B. P. 3050±105 −7010±150 |
| | $Q_4^1$ | age turning warm | | | beds of sand and gravel and sludge, 10—20 | | B. P. 8000−1200 |
| Late Pleistocene | $Q_3^3$ | Qomolangma glacial age | Rongbuk glacial age | | moraine, fluvioglacial, and alluvial sediments, lacustrine sands, gravels and clay 10—100m | | B. P. 23500±1200 |
| | $Q_3^2$ | | interglacial age | Yarlung Zangbo river lacustrine beds | lacustrine, alluvial silts, sands, gravels 10—50, brown earth (residuum), 0.2—0.5 | *Bios* sp. | |
| | $Q_3^1$ | | Jilong glacial age | | high lateral moraine, fluvioglacial and lacustrine sand gravel beds, 10—300 | | |
| Middle Pleistocene | $Q_2^2$ | greater interglacial age (Jiabula interglacial age) | | Jiabula lacustrine beds | lacustrine silts, clay, sands and gravels pluvial gravel bed, 300—200, red brown soil (residuum) 0.5—1.2 | *Sabina recurva* (Buch-Hamit) Antoina, *Pecea spinulosa* (Griff) Henery | |
| | $Q_2^1$ | Nyalam glacial age (Nieh-nieh Hsiungla glacial age) | | | piedmont moraine, fluvioglacial and fluvial sands, gravels 50—300 | | |
| Early Pleistocene | $Q_1^2$ | interglacial age | | | lacustrine silt, clay and sand, gravel beds, greater than 20, calcium rich red soil 0.5—2 | | |
| | $Q_1^1$ | Xixabangma glacial age | | Gongba conglomerate | calcium-rich coarse conglomerate, sand bed and clayey soil, fluvioglacial gravel bed, 120—300 | *Condona* sp., *Condoniella* sp. *Leucocythere* sp., *Leucocytherella* sp. | |
| Pliocene | $N_2$ | | | Yebokanggale group: Woma fm, Date fm | gray and gray yellow silty clay rock intercalated with sand and gravel bed bearing layers of ferruginous sandstone, in the lower part bearing lignite beds, 500—1,000m | *Hipparion gyirongensis* Hsu, *Chilotherium xizangensis* Huang *Metacervulus caprolinus* Teilhard et Trassaet, *Palaeotragus microden* Koken, *Gazella gaudryi* Schlosser, *Quercus semioarpifolia* Smith *Q.* cf. *pannosa* Hand-Mzt. *Q.* cf. *senescens* Hand-Mzt | |
| Miocene \| Oligocene | $E_3-N_1$ | | | Liuqu conglomerate | mottled sandstone, conglomerate and shale greater than 500 | | |

| | | | | | |
|---|---|---|---|---|---|
| O | $O_1$ | Chiatsun group | lower fm. | limestone intercalated with dolomitic limestone and calcareous sandstone, 726m | *Tropidodiscus chiatsunensis* Yu<br>*Paradnatoceras yaliense* Chen<br>*Pomphoceras nyalamense* (Chen)<br>*Wutinoceras remotum* Chen,<br>*Maclurites* cf. *acuminatus* (Billings),<br>*Aporthophyla perelegans* Liu |
| | | Rouqieun formation | | striped and laminated crystalline limestone, marble 237—48m | |
| Є-Z | | North Col fm. | | phyllite, quartzite, marble, biotite quartz schist, greater than 1,000m | |
| | | | | ———fault——— | |
| AnZ(?) | | Nyalam group | | kyanite schist, staurolite schist, sillimanite gneiss, marble, ocular and striped migmatite, greater than 10,000m | |

granitic intrusions are mostly present in the upper part of the succession. The rocks originally were argillaceous—sandy, feldspathic sandstone, calcareous rocks and a small amount of basic volcanics. The metamorphic degree reaches hornblendite facies. Overthrusts toward the south is one of the characteristics of the High-Himalayan belt.

High Himalayan belt is separated from the overlying Tethys-Himalayan sedimentary sucessions by low angle thrusts, strongly dynamo-metamorphics and cataclastic muscovite granitic gneiss at the northern slope of Mt. Qomolangma, but in Zangdong-Jangling district of Nyalam it is separated by granites probably intruding in along the fault zone. This thrust fault, fault zone are tentatively called "The Main Northern Thrust".

At the northern slope of Himalayas occur a series of fault basins and valleys filled with Pliocene lacustrine clay siltstone of several hundred meters in thickness. Since Quaternary, as the global climate turned cold and Qinghai-Xizang Plateau rose, successive glacial and interglacial deposits developed in the mountain areas, while in basins and valleys, Quaternary beds of lacustrine, fluvial, glacio-fluvial origin were accumulated. (Table I-4 The Stratigraphic Scale of Tethys-Himalaya from Oligocene-Quaternary in Xigaze District). South of the Yarlung Zangbo ophiolite belt, variegated molasse of several hundred meters thick develops, in which gravels of basic volcanics, red siliceous rock and gravels of the ultrabasic rock of the ophiolite series are frequently seen, the age of the molasse is inferred as Oligocene—Miocene.

Himalayan granitoids have a wide distribution in High-Himalaya belt. These intrusive bodies are almost entirely composed of massive to gneissic tourmaline-muscovite granitoids. Besides, aplite and pegmatite are often found. These granitic bodies always accompany with major thrust faults which implicates that they were the products of partial melting of the shallow crust during the process of the intensive Himalayan movement. But most of the Himalayan granitoids occur as small sills, with contact metamorphism of the wall rocks.

Hundreds of hydrothermal active regions are seen along the two sides of Sengge Zangbo—Yarlung Zangbo rivers. Among them, including 10 and more hydrothermal explosion regions, which are rarely seen over the world, and 4 geysers. Besides, there are also tens of intensively active hydrothermal regions such as fountains and boiling springs. According to the dense distribution of these intensive hydrothermal regions, the Himalayan geothermal belt can be classified.

For the purpose of exploring the deep crustal structure of Qinghai-Xizang Plateau and the plateau uplift, a seismological station and a geomagnetic station were installed by Institute of Geophysics, Academia Sinica, at Lhasa in 1957. Since then, geophysicists along with the alpinists of State Mountaincering Expedition to Mt. Qomolangma have made some reconnaissance gravity surveys and later some surveys on geomagnetic elements in that area for several times.

Since 1975, seismological stations have been established at Biru, Nyingchi, Yadong and Zayu and provisional short-cycle seismological station network were established in Zhamog and Damxung districts to study the activities of earthquake and the state of stress field in the plateau region.

During the past two decades, various seismologic and geomagnetic instruments have recorded incessantly and accumulated a great amount of valuable data. A preliminary investigation shows that the earthquakes here can be referred to shallow earthquakes, the depth of the seismicity has a lower limit not more than 70 km, and the Q value is very low. The major axis of compressional stress is oriented nearly in north-south direction, which changes with the directions of the strikes of arc mountain ranges.

The aeromagnetic surveys demonstrate that a strong magnetic anomalous belt lies along the Yarlung Zangbo river and the anomalous values reach 150—450 high, which are responses of the ophiolites. The geomagnetic field distributes and extends in a belt-like shape between the Yarlung Zhangbo river and Himalaya. The loci of the paleomagnetic pole shifts show that the area north of the Yarlung Zangbo river belongs to Eurasian plate, while the area south of the river to Indian plate.

The isostatic anomaly in Himalaya is +120 milli-gal, which shows that it has not reached an isostatics and the Himalaya mountain is still uplifting. Nevertheless, in the area between the Yarlung Zangbo river and the Ganges plain, the value trends to 0. In the central part of the plateau, Bouguer gravity anomaly has the largest negative value of the country, i.e. −550 milli-gal.

The excitative elastic wave of subwater explosion of 40—50 m depth succeeded in its first try in the largest lake Nam Co and also lakes Yamzhog Yumco and Namu on Xizang plateau, the highest plateau in the world. Studies on the structure of the crust and the upper mantle and distribution of velocity have shown that the crust of the plateau is composed of alternated layer media of high and low velocities. North of the Yarlung Zangbo river, the thickness of the crust is 70—74 km, while south of the river it is 68—45 km and gradually tilts toward the south. Also, it is in this area low velocity channel is discovered in the lower crust. Besides, the crust structure of the plateau is also reflected by the group velocity and facies velocity of teleseismicity gravity survey and magnetotelluric deep-sounding survey. A crust of such a great thickness is not a simple double-crust as someone holds.

Here, what we particularly would like to mention is the geothermal features of Yarlung Zangbo-Himalaya region, where intensive hydrothermal activities occur. However, up to now, no recent volcano has been found. In hydrothermal regions, not only seismicity is frequently measured, but also turning locations of high-gradient change of the gravity field and the change of crustal structure are found. The crustal media of the plateau and its southern margin have strong absorptive property to the energy of seismic wave and the Lg wave is relatively weak and gradually vanishes.

Furthermore, on the basis of the fact that low velocity layer exists in the lower crust, it is argued that remelting or partial remelting as well as magma pocket exist in the crust here.

Anomaly features of the geophysical field and the formation of an excess of thick crust in the plateau area show that the formation of Qinghai-Xizang Plateau has been strongly controlled and effected by the collision between the Eurasian and Indian plates and Himalayan belt has been the transitional area of collision and compression of continental collision. Nevertheless, the intensive deformation has not consumed all the energy of collision, but it propagates through the plateau and affects the pattern of the whole tectonics and stress field of our country or even propagates far to the north to the rift valley of Lake Baikal.

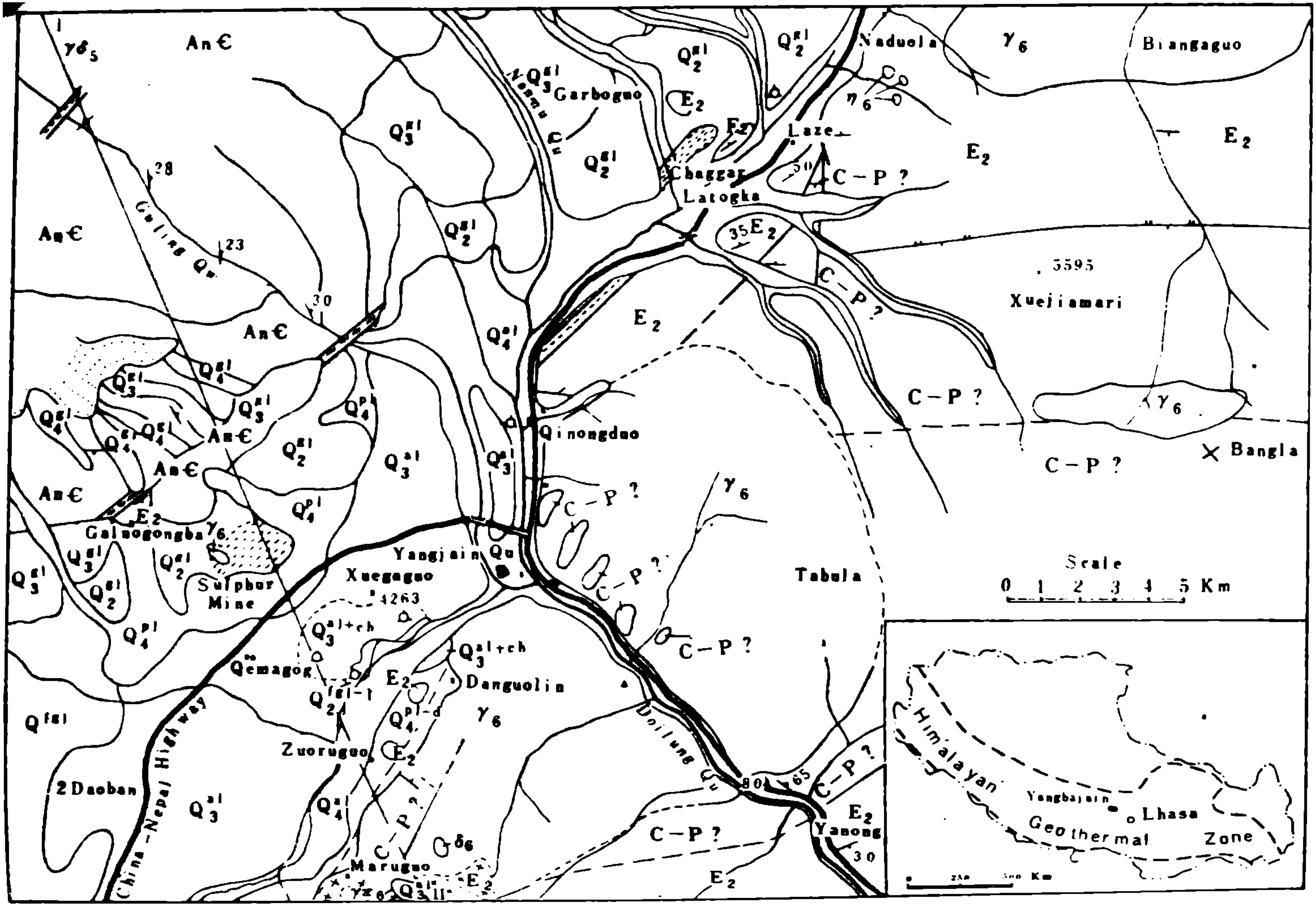
## II. The Geothermal Field and the Quaternary in Yangbajain

### *Yangbajain geothermal field*

Yangbajain geothermal field is situated in the middle of Yangbajain basin, 90 km northwest of Lhasa. This is one of the Nyainqentanglha piedmont paternoster fault basins. Nyainqentanglha mountain composed of granitic gneiss lies at the northwest of the basin, demarcated by the Nyainqentanglha major fault. To the southeast of the basin lies Tang mountain composed of Carboniferous-Permian slightly metamorphosed beds, Cretaceous red beds and volcanics and Yangbajain granite demarcated with the basin by Marugo-Danguolin fault and Qilongduo-Chaggar fault (Fig. II-1).

In Yangbajain fault basin, Pleistocene moraine, glaciofluvial sediments and fluvial, lacustrine sediments are accumulated, the greatest thickness of which can reach 500 m forming the shallow layered reservoir and cap rock of the geothermal field. In the greater depth of the crust below the basin or its adjacent area, relatively recent magmatism may occur(?) forming a strong thermal source of the geothermal field and a hydrothermal convection system is formed in the middle part of the basin. Thus, since the middle period of Pleistocene, Yangbajain geothermal field has gradually formed.

Yangbajain geothermal field is one of the 40 high temperature hydrothermal regions in the Himalaya geothermal belt. Starting at Ngri from the west to the Hengduan Mountain at the east, then turning south to the western part of Yunnan, the Himalaya geothermal field extends 2,000 km or more. The southern border of the geothermal belt approximately corresponds to the backbone line of Himalaya and its northern border roughly extends along the northern slope of Kangdese-Nyainqentanglha mountains. To the west passing Kashmir district, the belt connects with Mediterranean geothermal belt and to the south passing Burma, Malaysia and Indonesia connects with circum-Pacific geothermal belt. It is a section where lies the


Bianguo
Naduola
Garboguo
Chaggar
Latogka
Laze
Xuejiamari
5595
Bangla
Qinongduo
Tabula
Yangjain Qu
Xueguguo
4263
Qemagog
Danguolin
Zuoruguo
Maruguo
Galsogongba
Sulphur Mine
2Daoban
Doilung Qu
Yanong
Geling Qu
Nonmu Qu
China-Nepal Highway
Scale
0 1 2 3 4 5 Km
Himalayan
Yangbajain
Lhasa
Geothermal
Zone

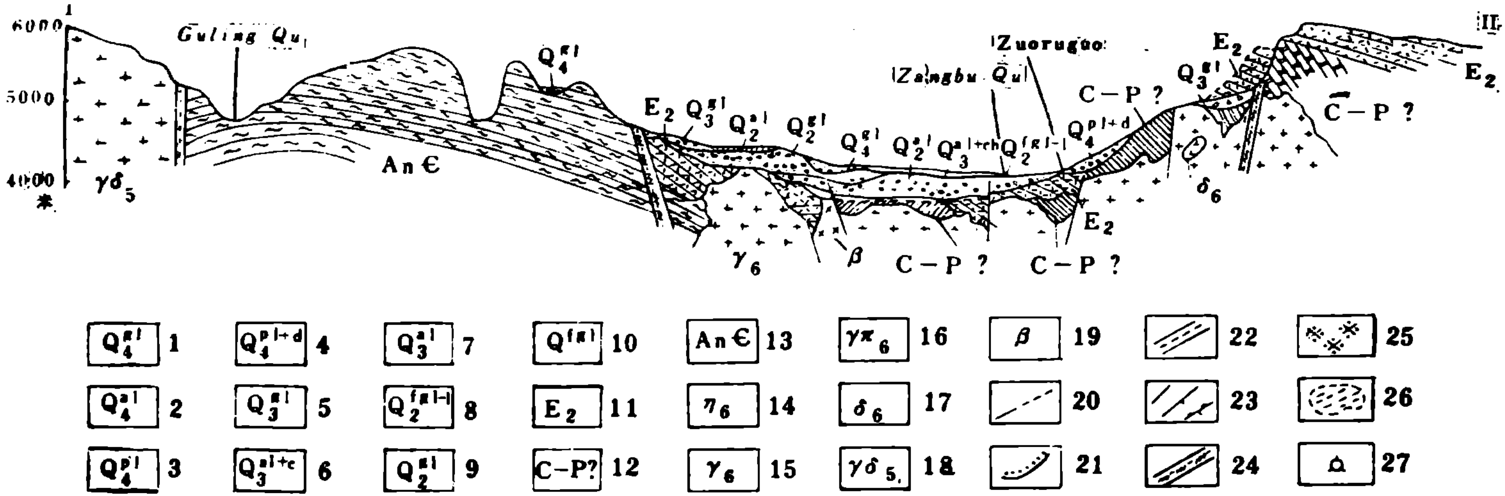



Fig. II-1 The Geologic Map of Yangbajain Geothermal Field

1. Holocene moraine bed; 2. Holocene alluvial bed and swamp deposits; 3. Holocene pluvial bed; 4. Holocene pluvial and talus accumulation; 5. Late Pleistocene moraine bed; 6. Late Pleistocene alluvial bed and sinter; 7. Late Pleistocene alluvial bed; 8. Middle Pleistocene fluvioglacial deposits and lacustrine deposits; 9. Middle Pleistocene moraine bed; 10. Pleistocene fluvioglacial deposits; 11. Eocene volcanic tuff, dacite, trachyte, volcanic breccia; 12. Cabroniferous-Permian slate, quartz-schist, marble; 13. Pre-Cambrian biotite gneiss, migmatite; 14. alkali-intrusive rock of Himalayan period; 15. granite of Himalayan; 16. granite porphyry of Himalayan; 17. diorite of Himalayan; 18. granitic diorite of Yenshanian Period; 19. basic hypabyssal rock of Late Himalayan Period; 20. geologic boundary (surveyed and deduced); 21. angular unconformity; 22. fault fractured zone; 23. fault, normal fault, thrust; 24. mylonitization zone; 25. contact metamorphic zone; 26. hydrothermal alteration zone; 27. geothermal manifestation spots.

most active and largest geothermal belt in the world.

The thermal manifestation on the surface of Yangbajain geothermal field can be divided into two regions. One parallels with the hydrothermal alterative belt extending as a piedmont fault of Nyainqentanglha mountain, and the other is various hydrothermal regions spreading along the Zangbuqu river valley.

"The hydrothermal alterative belt of Nyainqentanglha piedmont major fault" crops out along the sulphur mine, nearly 2.5 km long. The original rock of the alterative belt is mainly moraine containing granitic and gneiss gravels undergoing alumitization, silicification and kaolinization. In the alterative rock fissures and pores, natural sulphur of euhedral crystals are deposited. Furthermore, brine sinter of mainly double sulfate consisted of potash-alumite, soda-alumite alunogenite is deposited. It is worthy to be noted that the surface of the upper end of the thermal groove is very hot and the temperature at the depth of 0.4 m below the surface may reach 84°C. $H_2S$ gas steams out from rock fissures in many places and natural sulphur deposits continually. The analyses of sulphur isotope show that the fluctuation range of $\delta^{34}S$ is narrow and approaches the value of the standard sample — Cayon-Diablo troilite, which indicates the sulphur directly comes from depths of the crust or even the upper mantle.

A variety of thermal activities distribute along Zangbuqu. Hydrothermal explosions and geysers are often seen in strong hydrothermal regions in the world and over 10 hydrothermal explosion regions are found in Himalayan geothermal belt and Yangbajain is one of them. Despite of no geyser has been found in Yangbajain district, yet a typical geysering well occurs. The well erupts once for every 12 minutes and before erupting, it overflows 2 and odd minutes. The eruption may last 3 minutes to a height of 30 m and the volume of the water erupting out approximates 2.9 $m^3$. At the original Yangbajain hole no. 1, in the afternoon of Dec. 4, 1977 from 2:25—2:28 p.m., a hydrothermal explosion related with drilling broke out. At first, the cement platform sealing the well suddenly swelled up and broke, erupting out the steam and then with a tremendous great noise, a thick and dense column of smoke soared up to the sky reaching some 50 m, stones of 25—30 cm in diameter projected 50 m far and mud and sand spread over an area of 300 m in radius. The pit left after the explosion was 10 m in diameter and 12 m deep. At the bottom of the exploded pit only a little water gathered, but a night after, the pit was full of water. Today, the diameter of the pit has expanded to 15 m and the pit is full of water of a temperature above 50°C. The overflow is slow and no anomaly is found. Another interesting example which is worthy to be mentioned is the hot water lake in Yangbajain situated at the northeast end of the thermal field in a ellipse shape with an area larger than 350 $m^2$. The maximum depth of the lake water reaches 16.1 m and the temperature of the water is around 50°C. The water is green and clear and above the lake heavy mist and vapor spread all over.

In fine and windless days the white vapor column may curl upwards to a height of 50 meters or more and the scene is magnificent. The lake lies on the terrace of the second grade and the deepest part of the lake bottom is 5—6 m lower than the bed of Zangbuqu river. It is interesting to explore the genesis of the lake. It might be a large pit produced by a great hydrothermal explosion in the past and later the pit has gradually expanded to the present shape through incessant activities of hot springs. The hydrothermal explosion of Yangbajain hole no. 1 mentioned above provides a proof for such an speculation.

In addition, hydrothermal phenomena of eruptive fountain, boiling spring, thermal spring and steaming ground scatter along the two sides of Zangbuqu river.

The area of the thermal field circled by the geoelectric exploration, plant manifestation, temperature measurement in shallow holes approximates 15 $km^2$ and heat discharge is estimated as 116,000 Cal/second. The temperature below the thermal field estimated by the geochemical thermal metric scale is 200—220°C and the highest may reach 275°C. The highest temperature actually measured up to present below the well is 172°C (measured at the depth of 130—288 m below Yangbajain well no. 14 of the northern part of the thermal field).

Yangbajain thermal field can be referred to high temperature hot water geothermal field or wet steam type geothermal field. The chemical type of hot water is mainly sodium chloride type and the mineralized degree is 1—2 gram litre$^{-1}$, which is similar to the hydrochemical type of the major geothermal fields in the world and rich in components of B, As, Li, Rb and Cs.

The cover of the southern part of the geothermal field is composed of alluvial deposits, sinter-cemented sandstone and glacial varve and its thickness is around 40 m. Below the cover is the thermal reservoir layer of relatively loosened gravel pores, 30 m thick and the temperature actually measured is 149—100°C which is the first thermal reservoir layer. The second thermal reservoir layer is a silified sandstone-conglomerate fissure one, which is mainly distributed along a belt of north-south direction starting from Yangbajain well no. 2. The northern section is below the cover of mud and gravels, deeply buried in the depth of 130 m or more and the thickness of this thermal reservoir layer is 100 and odd meters with a temperature of 172°C. The southern section is below the first thermal reservoir layer (separated by thin bedded clay) buried deeply below 60—80 m with a thickness of tens of meters, the temperature around 165°C.

Since 1975, 10 and more wells and holes for the purpose of exploration and production have been drilled one after another. Yangbajain well no. 4 is a production well for experimental power plant. In 1977, an experimental power station of 1,000 kw was established. Now an extension project of 6,000 kw generating system is under way, which will be the main power supply base for Lhasa city in the near future.

Visiting spots

no. 1. The sulphur mine, the thermal groove, looking down at a full view of the thermal field;

no. 2. Hot water lake, viewing Shaxintan eruptive fountain and far to the geysering eruption of Yangbajain well no. 7;

no. 3. Visiting the original hydrothermal explosion pit of Yangbajain well no. 1, the geysering eruption of Yangbajain well no. 7 and the equipments and tubes at the entrance of the production well;

no. 4. Visiting the geothermal power plant;

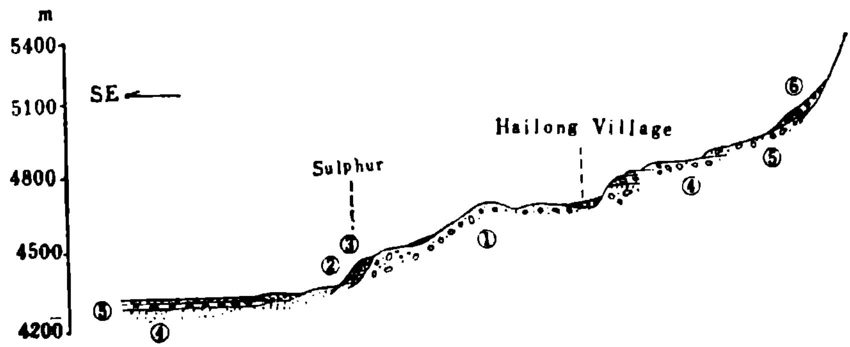



Fig. II-2 Section of the sulphur mine at Yangbajain-Hailongcun, Damxung county at the southern foot of Nyainqentanglha mountain:

6) Moraines of recent glacial age and minor ice-age;

5) Moraines and lacustrine sediments of Gujinla (30m thick);

4) Moraines and glacioaqueous sediments of Hailongcun ice age;

3) Loess-like siltsoil accumulated materials of slope wash and pluvial facies of an age corresponding to Hailongcun ice age, several—20m;

2) Gray gravel-containing siltstone which is the pluvial-lacustrine sediments of erosion depression of piedmont moraine in an early ice age, 0—25m thick;

1) Moraines of Yangbajain ice age forming piedmont moraine and pediment moraine platforms or moraine hills.

*Visiting spot no. 5. The glaciation of the southern slope of Nyainqentanglha mountain*

On the basis of differences in contact relations, weathering degree and the distribution of the moraine, 3 glacial ages can be classified in the Quaternary glaciation at the southern slope of Nyainqentanglha as it is shown in Fig. II-2.

Furthermore, at the southern slope of Nyainqentanglha mountain, Early Pleistocene sedimentary gravel bed outcrops widely. The composition of the gravels which are mainly sandstone, slate and volcanics shows marked difference from those of later periods. Little gneiss which constitutes the core of the Nyainqentanglha mountain has been found here, showing that in Early Pleistocene the extent of surface dissection was not so great and the drainage system was quite different from that of today.

*Visiting spot no. 6. Holocene peat at Qilongduo*

In addition to slope wash-pluvial and glacial deposits widely distributed at the piedmont, Holocene sediments of lacustrine-marsh facies are developed, which include a large amount of saline, diatonite deposits and peat accumulations. Climate of this period underwent various stages of development: from the post-glacial age to 7,000 years B. P., it was cold and wet; from 7,000—3,000 years B.P., it was warm and the annual average temperature was 3°C higher than that of today. At 2,980 years B. P. and from 1,900—1,700 years B. P., the temperature dropped and the glaciers advanced, the area of the frozen ground expanded and in Holocene sediments of some districts, cryopedologic geomorphology-congelfold was formed. At that time, the annual average temperature was 2—4°C lower than that of today. Since then, climate has turned to be more arid. The Qilongduo section of Yangbajain basically reflects the gerneral trend of changes of Holocene climate in this district.

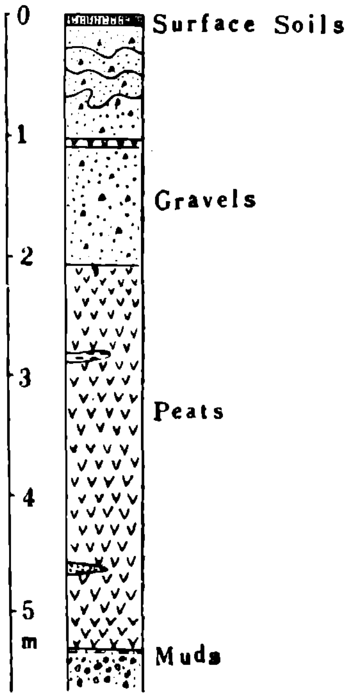



Fig. II-3 Holocene section of Qilongduo at Yangbajain

## III. Kangdese magmatic rock belt

The Kangdese magmatic rock belt lies across the middle part of Xizang, situated at the southern margin of Kangdese-Nyainqentanglha tectonic belt. On the south, it borders with the famous Yarlung Zangbo-Ganges geosuture belt and on the north, with the magmatic belt of northern Xizang. On the east, the belt detours Yarlung Zangbo great turn and connects with the Zayu-Bome granitoids belt and on the west, it extends along Ayi La mountain to Ladakh in Kashmir. The belt extends roughly in an arc shape along the Kangdese mountain and Guogalariju mountain with a length of 1,000 km and more from east to west and a width of 100 km and more from north to south (Fig. III-1). The belt is mainly formed by a series of gigantic granitoid batholiths and a wide area of intermediate, intermedite-acid to acid calc-alkali volcanic rocks.

## *Granitoids*

Kangdese granitoid belt is a complex rock body. Most of the rock bodies intrude into Mesozoic beds. The youngest bed that some individual rock bodies intrude into is Late Cretaceous volcanics. In Rinbung, Xzitongmoin, the margins of the large batholiths are covered by Late Cretaceous and Tertiary conglomerate deposits.

Kangdese granitoid belt may be divided into 3 intrusive periods and 6 major intrusive stages (Table III-1). The quartz-diorite of early period distributes mainly along both sides of the Yarlung Zangbo river, sporadically outcropping at the southern margin of the belt. Granitoids of the main period distributes slightly to the north, outcropping at the

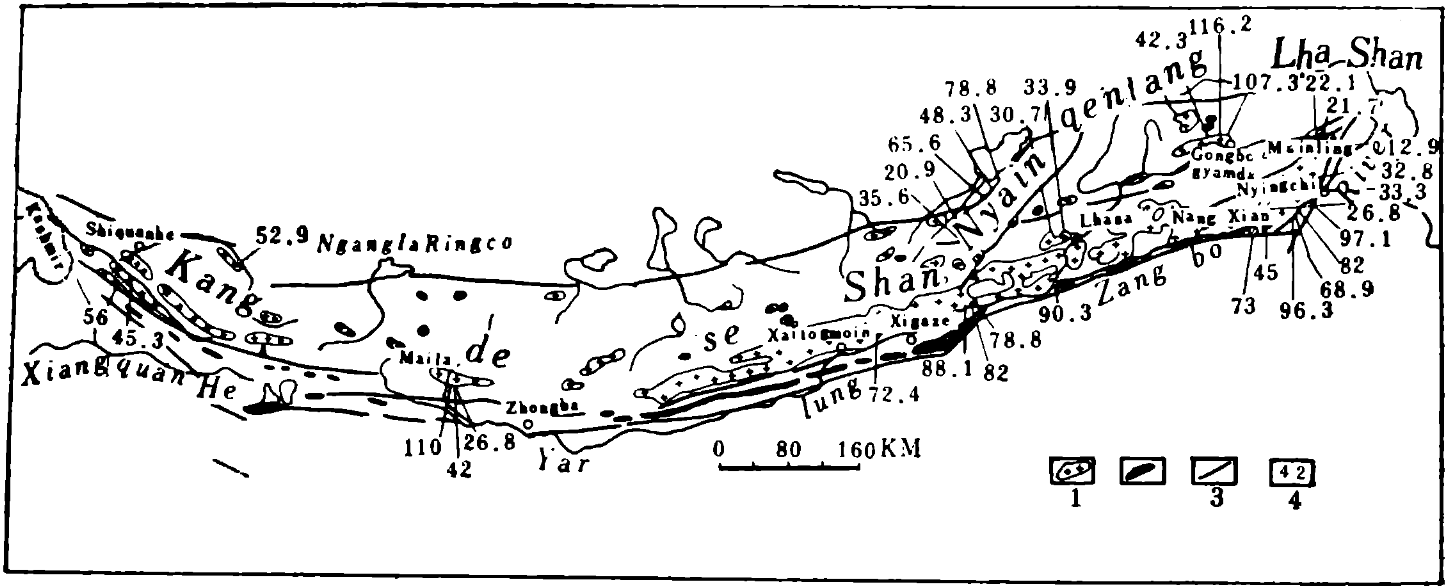



Fig. III-1 The distribution of the rock bodies in Kangdese granitic belt and their K-Ar ages

1. granite body; 2. ultramafic rock; 3. major fault; 4. K-Ar ages (m.y.)

**Table III-1 Classification of intrusive periods and stages of Kangdese granitoids**

| Intrusive period | Time | Stage | Major rocks | K/Ar Ages (m.y.) |
|---|---|---|---|---|
| late | Eocene-Miocene | 6 | granites (including various granites and pegmatite and other acid rock veins) | 40—20 |
| | | 5 | muscovite-biotite monzonitic granite | |
| main | Late Cretaceous-Eocene | 4 | biotite granite | 70—40 |
| | | 3 | granitic diorite (including some quartz-biotite-diorite) | |
| | | 2 | quartz-monzonite | |
| early | Early Middle Cretaceous (?)-Late Cretaceous | 1 | quartz-diorite (including quartz-monzonite, a small amount of two pyroxene gabbro, pyroxene diorite, some granitic diorite and monzonitic granite). | 110—70 |

The average chemical composition of the main kinds of rock in the rock belt is shown in Table III—2. Obviously, ($FeO + Fe_2O_3$) and CaO trend to decrease from south to north, while $SiO_2$, ($K_2O + Na_2O$), $K_2O$, $K_2O/Na_2O$ and $K_2O/SiO_2$ increase.

**Table III-2 The average chemical composition of the major rock kinds in the Kangdese granite belt**

| | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | FeO | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ | Total | Analytic values | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| granite | 74.24 | 0.19 | 12.69 | 1.12 | 1.12 | 0.01 | 0.76 | 1.01 | 3.17 | 4.79 | 0.08 | 99.41 | 8 | North ↑ |
| biotite monzonitic granite | 73.05 | 0.22 | 13.28 | 1.68 | 1.04 | 0.02 | 0.74 | 2.73 | 3.67 | 3.71 | 0.10 | 100.24 | 25 | |
| granitic diorite | 68.22 | 0.67 | 14.44 | 2.91 | 1.77 | 0.06 | 1.63 | 3.09 | 3.62 | 2.98 | 0.14 | 99.55 | 18 | |
| quartz-monzonite | 63.97 | 0.15 | 16.14 | 3.72 | 2.05 | 0.07 | 1.95 | 3.63 | 3.65 | 3.58 | 0.17 | 99.58 | 12 | |
| quartz-diorite | 58.31 | 0.65 | 16.73 | 5.00 | 3.08 | 0.21 | 3.21 | 6.17 | 3.78 | 1.89 | 0.28 | 99.30 | 10 | South |

southern slope of the backbone of Kangdese mountain, forming the main bodies of large batholiths. The rock types in the east show marked difference from those in west direction: in the west and middle sections granitic diorite and quartz-monzonite predominate, while in the east section, mainly biotite-monozonitic granites. A part of the granitoids or the late period forms the intrusive facies of late period of the batholith and others form independent small rock bodies in the northern and eastern sections of the batholith. Their distributed area apparently shifts to the north. Therefore granitoids of the Kangdese belt shows clearly a belt-like feature from south to north, the granitoids vary from intermediate—intermediate-acid—acid and their ages from old to young. From west to east, the granitoid types trend to be more acid and younger in age.

### *Volcanics*

At the northern side of Kangdese batholith, Late Cretaceous to Early Tertiary volcanics of a grand scale occur and extend nearly 1,000 km in east—west direction. The maximum width of this section may reach 100 km and more. The petrography is mainly characterized by intermediate, intermediate-acid lavas and volcanic clastic rocks intercalated with a little basalt. The rock series trends to increase in acidity from west to east, namely in Ngari district, it is mainly intermediate—intermediate-basic rocks, while reaching the middle east section, it is mainly intermediate—intermediate-acid rocks; in the west section, lava is met more

**Table III-3 The chemical composition of some rocks in the Kangdese magmatic rock belt**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 72.39 | 73.15 | 73.39 | 57.26 | 56.45 | 52.64 | 60.90 | 64.39 | 57.04 | 73.51 | 72.51 | 52.88 | 51.45 |
| $TiO_2$ | 0.29 | 0.44 | 0.34 | 0.71 | 0.60 | 0.94 | 0.58 | 0.80 | 0.81 | 0.35 | 0.31 | 1.00 | 1.41 |
| $Al_2O_3$ | 14.70 | 12.58 | 14.19 | 19.79 | 17.67 | 17.80 | 17.31 | 16.70 | 16.92 | 12.91 | 13.81 | 19.14 | 18.28 |
| $Fe_2O_3$ | 1.08 | 3.49 | 1.42 | 4.06 | 4.38 | 9.37 | 2.81 | 3.05 | 4.47 | 1.80 | 3.45 | 7.15 | 12.44 |
| FeO | 1.34 | 0.40 | 1.23 | 3.25 | 4.19 | 0.01 | 3.02 | 1.72 | 4.70 | 0.43 | 0.37 | 1.29 | — |
| MnO | 0.10 | 0.08 | 0.12 | — | 0.12 | 0.16 | 0.14 | 0.08 | 0.10 | 0.08 | 0.10 | 0.12 | 0.47 |
| MgO | 0.57 | 0.95 | 1.18 | 4.22 | 3.59 | 3.82 | 2.34 | 1.67 | 3.91 | 0.49 | 0.61 | 2.20 | 3.37 |
| CaO | 2.20 | 2.05 | 2.40 | 5.09 | 6.80 | 8.60 | 4.48 | 3.58 | 6.82 | 1.02 | 0.88 | 7.49 | 3.69 |
| $Na_2O$ | 3.97 | 3.55 | 3.76 | 4.18 | 3.70 | 4.40 | 4.13 | 4.00 | 3.03 | 3.30 | 3.17 | 3.90 | 5.00 |
| $K_2O$ | 3.30 | 3.05 | 2.52 | 1.65 | 1.30 | 1.00 | 3.24 | 3.80 | 1.92 | 4.60 | 4.62 | 2.00 | 2.93 |
| $P_2O_5$ | 0.09 | 0.12 | 0.68 | 0.23 | 0.30 | 0.28 | 0.09 | 0.34 | 0.28 | 0.07 | 0.10 | 0.39 | 0.40 |
| $H_2O^+$ | | | | | | | | | | 1.20 | | 1.74 | |
| $H_2O^-$ | | | | | | | | | | | | | |
| Burnt loss | 0.48 | | | | | | 0.71 | | | 0.21 | | 0.21 | |
| Total | 100.51 | 99.86 | 100.22 | 100.44 | 99.10 | 99.02 | 99.81 | 100.13 | 100.0 | 99.97 | 99.93 | 99.51 | 99.71 |

1, 2, 3—medium granular biotite granite (Lhasa rock body, visiting spot No. 2). 4, 5—pyroxene diorite (visiting spot No. 4). 6—pyroxene diorite (xenolite 1 km north of visiting spot No. 3) 7—granitic diorite (Quxu river district, south of visiting spot No. 3). 8—magnophyric granitic diorite (north of visiting spot No. 3). 9—andesite (north of Doilungdeqen District). 10, 11—rhyolite (Margyang). 12, 13—andesitic basalt (Margyang). (1, 4, 7 were analysed by Guiyang Institute of Geochemistry, the rest by the 9th Lab. of Institute of Geology, Academia Sinica. The same below.)

often, while in the middle east section the clastics increase. In the lower part of the Kangdese volcanic rock series, it is andesite, upwards gradually varies to rhyolite. In the petrochemistry, overwhelming majority of the samples are potash rock and rocks of calc-alkali of transitional type. Up to the present, rocks of alkali series are merely found at the north of Margyang and the piedmont of Nyainqentanglha mountain which is sharply different from the volcanic series in the Yarlung Zangbo ophiolite belt. Geographically, the volcanics trend to increase in $K_2O/SiO_2$ from south to north. Along the line of Lunggar-Damxung-Pondo, potasium-rich rock of potasium-rich trachyadensite and leuitebasalt outcrop. The whole rock isotopic ages of the volcanics of calc-alkali series in Kangdese district are between 40—70 m.y., which corresponds to the time from Late Cretaceous-Eogene.


**Fig. III-2 The unconformity between Lingzinzong Formation (upper) and Takena formation (lower)**

*Visiting spot no.* 1. *The unconformity between Lingzizong formation* ($K_2$) *and Takena formation* ($K_1$)

It is situated at the vicinity from Saixim to Maqu (Fig. III-2). The rock lying above the unconformity is Lingzizong formation of Late Cretaceous. It is mainly consisted of grayish blue and greenish gray andesite porphyry intercalated black shale in the lower part, upwards, it varies to thin-bedded red sandy conglomerate, total thickness 1,560 m. Below the unconformity, it is Takena formation of Late Early Cretaceous mainly consisting of a series of mottled shale, sandstone and argillaceous limestone, folded strongly and the total thickness is 1,000 m.

*Visiting spot no.* 2. *Lhasa granite body*

The rock body is situated at the North Mountain of Lhasa in a length of 50 km or more from east to west and a width of 20 km or more from south to north. The rock body is mainly composed of medium-coarse granular porphyritoid biotite granite partially rich in hornblende. The intrusion of this rock body occurred in relatively late period of the Kangdese belt. In the rock body, porphyritic and massive xenoliths of dark diorite are seen and a few aplitic veins inject. Up to the present isotopic ages of 39.0, 36.0 m.y. have been obtained, which indicates the main rock body intruded 30—40 m.y. ago.

At the back of the site of Highway Surveying Team and the mouth of Zhaibung Si ravine, granitic rock body intruding into Jurassic limestone is seen and garnet skarns of limited width develop.

*Visiting spot no.* 3. *Quxu intermediate-acid complex*

The Quxu rock body is situated at the middle segment of Kangdese batholith. The petrography is comparatively complex mainly consisting of coarse porphyritic granitic diorites. Up to the present, only 1 isotopic age of 34 m.y. (granitic diorite) has been obtained. Some of the rocks show gneissose structure with evident recrystallization of minerals, indicating that it underwent some kind of metamorphism. In the rock body, also many xenoliths of pyroxene diorite are found and at the cleaved section, they distribute in groups.

At the side of the highway, 2km northeast of Chabalang village, dark gray tonalite intruded by grayish white granite can be seen. At the contact, granitic veins inject into the diorite. In the granite and in the tonalite as well, schistosity is slightly seen and minerals are recrystallyzed indicating some degree of metamorphism.

*Visiting spot no.* 4. *Diorite south of the Quxu bridge*

It represents one of the diorite rock bodies at the southern margin of Kangdese rock belt. These rock bodies which sporadically remain in the rocks of later intrusive periods are the products of the earliest period of intrusion in the rock belt. On the basis of data correlated with the D'ag Chuka rock body, the isotopic ages are 79—82 m.y.

The diorite is fresh, with medium-coarse granular texture. Hornblende and intermediate-basic plagioclase are interwoven together, constituting the major part of the rock. One of its characteristics is the content of hypersthene and pyroxene, but both are replaced by hornblende. Thus, petrographically it should be referred to hypersthene pyroxene diorite.

## IV. Yarlung Zangbo ophiolite belt

The Yarlung Zangbo ophiolite belt, the total length of which may reach 2,000 km and more, roughly extends along the south of Yarluug Zangbo river valley. It connects with the Indus ophiolite belt to the west, and to the east it detours the Yarlung Zangbo great bending and connects with the ophiolite belt at the Indian-Burmese border. To the north, the rock belt presents in fault contacts with Late Cretaceous

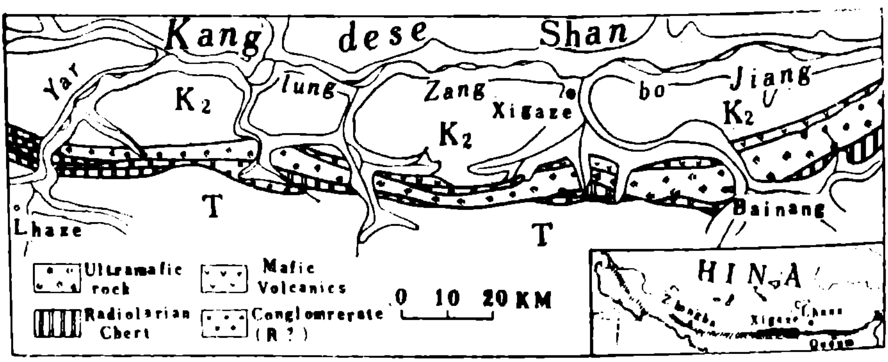



Fig. IV-1 A sketch map of the central section of Yarlung Zangbo ophiolite belt

flysch and to the south, it also borders with Mesozoic slightly metamorphic rock series in faults with a width from north to south several to 10 km and more. In Xigaze district, the spacial relations of various categories of rock in the belt are shown in Fig. IV-1.

No unanimity of knowledge to the original stratigraphic sequence of Yarlung Zangbo ophiolite has yet been reached up to the present, which is remained to be studied henceforth. On the basis of studies of some colleagues, the following sequence possibly occurs (from bottom up);

1) the ultramafic rock; 2) gabbro-diabase; 3) mafic massive lava; 4) mafic pillow lava (intercalated with several ore beds of sulfides); 5) eruptive sheets interbedded in the radiolarian siliceous rocks.

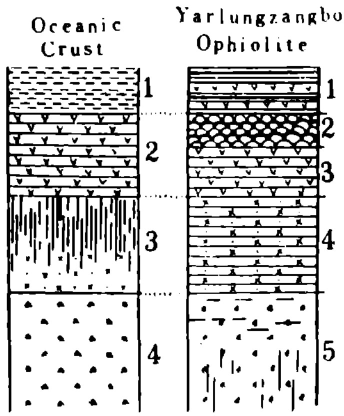



Fig. IV-2 The correlation between the original stratigraphic sequence of the Yarlung Zangbo ophiolites and present ocean crust (sketch thickness)

Present ocean crust

1. present oceanic sediments 2. tholeiite (many with pillow structure) 3. dike swarms (the upper part) and gabbro (the lower part) 4. serpentinite

Yarlung Zangbo ophiolite

1. siliceous rock intercalated with sheeted lava 2. the upper pillow lava 3. the lower massive lava 4. gabbro-diabase 5. serpentinized harzburgite

The sequence basically corresponds with that of the structure of present ocean crust (Fig. IV-2). In many districts, owing to possible disorder during the tectonic emplacement or the absence of some beds and sections, the ultramafic rock at the bottom generally intermittently occurs as lenticles, characterized mainly by harzburgite in petrography with dunite and lherzolite coming next. Generally, the rocks are intensively serpentinized with marked foliation and brecciated structure, and often inclusive fragments of other rocks are found. The rock bodies contact with the wall rocks in faults and high-temperature metamorphism of the wall rock is not evident. The average composition of harzburgite is shown in Table IV-1. Mg/(FeO) is generally greater than 8. The above mentioned features agree with those of typical rock bodies of Alpine type.

Fig. IV-3 Pillow lava (Congdu, Xigaze)

**Table IV-1 The average chemical composition of various igneous rocks in Yarlung Zangbo ophiolites**

SI: Solidification Index

| Rocks | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | FeO | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $Cr_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| top sheeted lava | 48.33 | 3.13 | 13.63 | 8.33 | 6.32 | 0.32 | 4.43 | 5.77 | 3.90 | 0.23 | — |
| upper pillow lava | 49.08 | 1.38 | 16.86 | 6.07 | 3.69 | 0.15 | 5.68 | 6.72 | 4.49 | 1.32 | — |
| lower massive lava | 51.36 | 1.04 | 14.98 | 4.98 | 3.94 | 0.77 | 6.43 | 6.88 | 4.44 | 0.26 | — |
| gabbro-diabase | 48.36 | 1.07 | 15.18 | 4.35 | 5.32 | 0.20 | 7.74 | 9.54 | 3.33 | 0.25 | |
| harzburgite | 41.28 | 0.08 | 1.10 | 3.04 | 5.98 | 0.22 | 41.79 | 1.18 | 0.17 | 0.03 | 0.38 |

| Rocks | NiO | $H_2O^+$ | $H_2O^-$ | $CO_2$ | $P_2O_5$ | Total | MgO/[FeO] | [FeO]/MgO | SI |
|---|---|---|---|---|---|---|---|---|---|
| top sheeted lava | — | 4.43 | 0.48 | 0.39 | 0.45 | 100.14 | | 2.9 | 19.0 |
| upper pillow lava | — | 3.72 | 0.58 | 0.14 | 0.14 | 100.0 | | 1.6 | 26.7 |
| lower massive lava | — | 4.20 | 0.57 | 0.13 | 0.16 | 100.0 | | 1.3 | 32.2 |
| gabbro-diabase | | 3.53 | 0.51 | | 0.19 | 99.57 | | 1.2 | 36.5 |
| harzburgite | 0.28 | 4.08 | 0.31 | 0.41 | — | 100.19 | 8.6 | | |

The gabbro occurs as veins in the rock body at Bainang. At Congdu, above the ultramafic rock, comparatively thick bedded gabbro-diabase occurs, the chemistry of which agree with that of the abyssal tholeiite and are not frequently seen in other places.

The massive lava generally contains ophitic and trachybasaltic textures and the pillow lava is present above the massive lava. The pillow structure develops well (Fig. IV-3) and the rocks contain trachybasaltic, spilitic or inter-crypto-crystal textures. The sheets contain a great amount of palagonite and much of titanaugite. Volcanic rocks are commonly choritized, epidotized, carbonized and spilitized and the regional metamorphism does not exceed green schist facies.

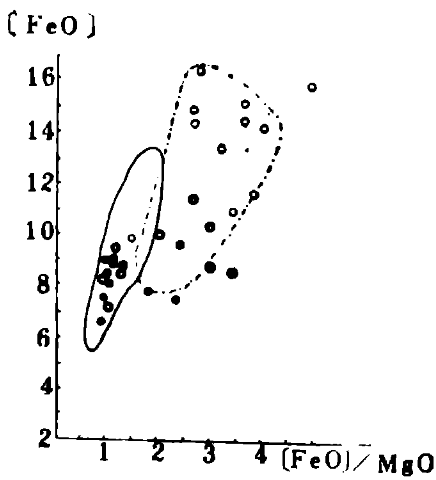



Fig. IV-4 The diagramatic relation of (FeO)-(FeO)/MgO in volcanics.

The full lines represent ocean tholeiite area and the dotted lines represent island-arc tholeiite area, the dots—massive lava, double-circles—pillow lava, single-circle—sheeted lava.

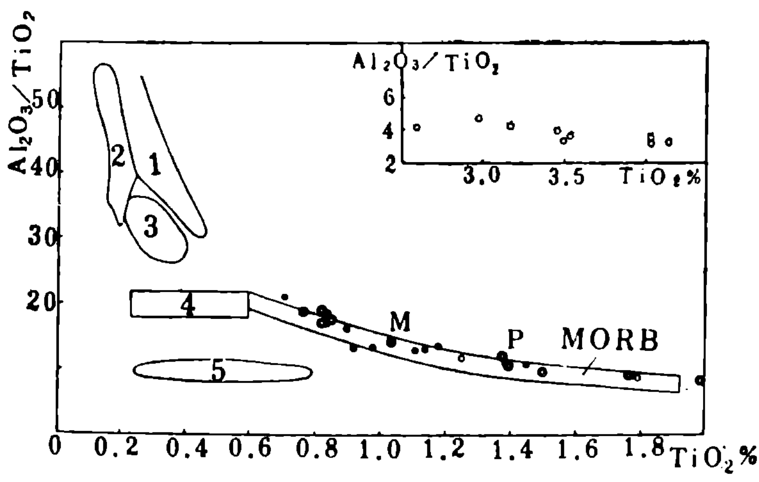



Fig. IV-5 $Al_2O_3/TiO_2$-$TiO_2$% Diagram of volcanic rocks
M-average values of massive lava, P-average values of pillow lava (symbols identical with Fig. IV-3)

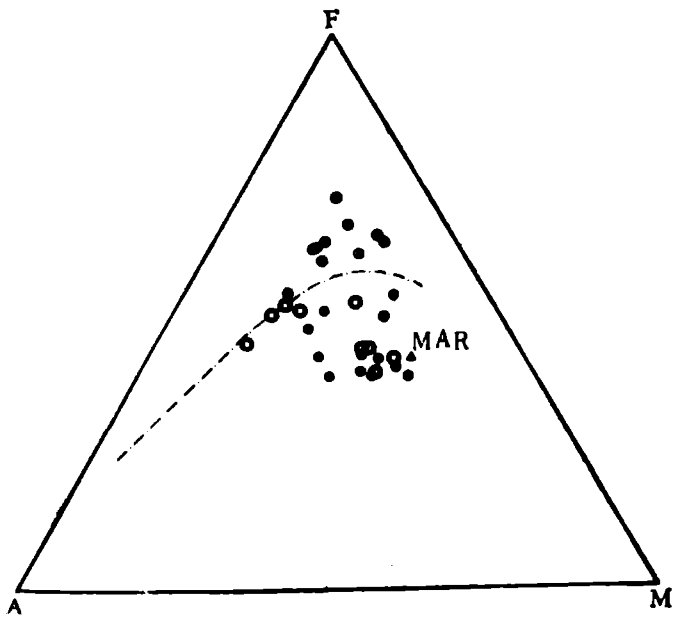



Fig. IV-6 AFM diagram of volcanic rocks
MAR—average of mid-Atlantic ridge basalts

The above mentioned average composition of igneous rocks is shown in Table IV-1. The petrochemical studies of the volcanics (IV-4, 5, 6, 7) prove that the massive and pillow lavas are similar to the abyssal tholeiite, while the sheets are mainly tholeiites of island arcs or marginal seas.

During the transition from Eocene to Oligocene, the continental crust of the Indian plate collided with that of Eurasian plate and the Tethys closed. The ophiolites as a part of fragments of oceanic crust were extruded to the upper crust. In the molasse of Oligocene-Miocene (Liuqu conglomerate), gravels of ultramafic rock and volcanic rocks are found. Thus, the emplacement of the ophiolites occurred between Eocene-Miocene. Associating with the above mentioned event, melange, exotic blocks and intensive foldings and reversions of flysch of quite large scales occurred. Therefore, ophiolites and the associated composite linear tectonic belt of a series of tectonic elements

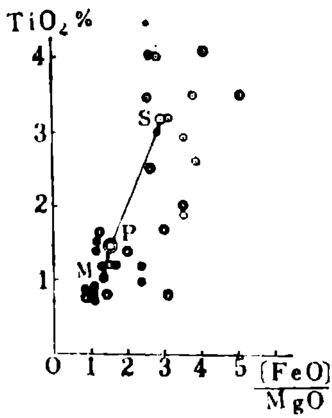



Fig. IV-7 $TiO_2$%-(FeO)/MgO of volcanic rocks

**Table IV-2 The chemical composition of gabbro and volcanics in ophiolite section at Bainang***

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $SiO_2$ | 45.75 | 47.87 | 51.98 | 51.89 | 48.39 |
| $TiO_2$ | 1.04 | 0.90 | 0.71 | 0.84 | 0.84 |
| $Al_2O_3$ | 14.23 | 15.15 | 15.26 | 14.74 | 16.49 |
| $Fe_2O_3$ | 3.85 | 3.09 | 3.74 | 5.43 | 7.02 |
| FeO | 6.93 | 6.71 | 4.75 | 3.72 | 2.16 |
| MnO | 0.15 | 0.16 | 0.14 | 0.19 | 0.12 |
| MgO | 7.73 | 7.52 | 7.42 | 6.39 | 6.29 |
| CaO | 13.55 | 12.82 | 6.70 | 7.89 | 9.47 |
| $Na_2O$ | 2.30 | 2.80 | 5.15 | 5.00 | 4.30 |
| $K_2O$ | 0.14 | 0.30 | 0.16 | 0.16 | 0.14 |
| $P_2O_5$ | 0.19 | 0.16 | 0.16 | 0.16 | 0.16 |
| $CO_2$ | 0.43 | 0.43 | — | 0.25 | 0.09 |
| $H_2O^+$ | 3.03 | 2.27 | 3.13 | 3.32 | 3.91 |
| $H_2O^-$ | 0.98 | 0.49 | 0.33 | 0.65 | 0.49 |
| Total | 100.30 | 100.69 | 99.55 | 100.61 | 99.87 |

* 1, 2—gabbro vein IV-1-(4) 3, 4—massive lava-IV-1-(2)
5—pillow lava-IV-1-(2)

are precisely the Yarlung Zangbo geosuture belt.

*Visiting spot no.* 1. *Bainang ophiolites*

The section is situated from the South Hill of Luobujiangzi to the county town of Bainang. The direction of the section is northeast and the total length is 8 km.

Program for visiting

IV-1-(1) the unconformity between Liuqu conglomerate and ultramafic rocks or volcanic rock;

IV-1-(2) the major features in petrography and contact of the two lavas;

IV-1-(3) the contact between siliceous rock and pillow lava;

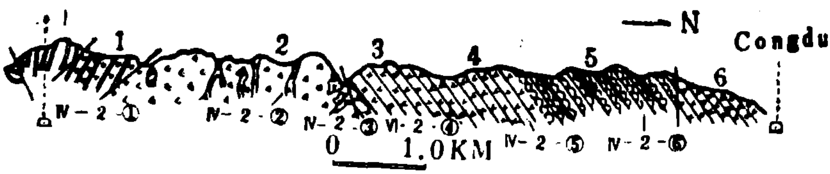



Fig. IV-8 The section of ophiolites at Qema-Congdu

1. Purple-red siliceous rock and siliceous shale containing a great amount of radiolaria which are unfortunately obscure owing to recrystallization;
2. Ultramafic rock, characterized mainly by serpentinized harzburgite, in the rock body, dikes of metamorphosed basic rock interpenetrate;
3. Gabbro-diabase;
4. Massive lava;
5. Pillow lava, intercalated with many ore beds of sulphide;
6. Basic volcanic rocks with brecciated structure.

IV-1-(4) the intrusion, occurrence and petrography of gabbro dyke swarm;

IV-1-(5) the ophiolitic melange (blocks of volcanic rocks, basic rocks and siliceous rocks accumulated mixedly and disorderly in the ultramafic rock).

*Visiting spot no.* 2. *Ophiolites at Qema-Congdu*

The section is situated at the western slope of Xialu village 18 km southeast of Xigaze. The total length of the section is nearly 10 km.

Program for visiting

IV-2-(1) The radiolarian siliceous rock at the outer contact zone, brecciated structure develops; the ultramafic rock body is in a tectonic emplacement of low angles;

IV-2-(2) Blocks of metamorphosed basic rock (rodingite) in the ultramafic rock body, some occur as dikes, some as chambers; the rock containing a great amount of grossular and hornblende. Meanwhile, observe the petrographic features of harzburgite;

IV-2-(3) The northern contact zone of the ultramafic rock body; in the rock body, lumps of basic rock and also ore copperization are found;

IV-2-(4) Gabbro-diabase, fresh, with medium—fine granular gabbro-diabase texture; diopside occupies 38—42% in volume and plagioclase An 45—60. Uralitization, chloritization and epidotization are found in the rocks, and its petrochemistry is similar to that of abyssal tholeiite;

IV-2-(5) Massive lava;

IV-2-(6) The occurrence and petrography of pillow lava and the sulfide ore beds (with malachite);

IV-2-(7) The pillow lava (the upper part) and the massive

**Table IV-3 The chemical composition of various rocks in the ophiolite section at Congdu**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 48.49 | 49.29 | 50.54 | 47.93 | 53.41 | 51.91 | 47.13 | 49.32 | 46.84 | 50.23 | 15.87 |
| $TiO_2$ | 0.06 | 0.74 | 1.04 | 0.90 | 0.84 | 0.92 | 1.58 | 0.84 | 0.77 | 0.70 | — |
| $Al_2O_3$ | 0.29 | 15.58 | 16.94 | 15.05 | 16.18 | 12.79 | 15.48 | 15.26 | 14.86 | 13.51 | 3.54 |
| $Fe_2O_3$ | 7.14 | 5.25 | 3.48 | 3.03 | 3.68 | 5.78 | 6.97 | 3.92 | 5.14 | 7.62 | 67.18 |
| FeO | 0.85 | 3.15 | 5.37 | 4.81 | 5.75 | 1.45 | 3.25 | 4.61 | 2.65 | 12.92 | 0.48 |
| MnO | 0.12 | 0.23 | 0.20 | 0.16 | 0.12 | 0.20 | 0.16 | 0.15 | 0.22 | 0.23 | 0.11 |
| MgO | 35.20 | 8.24 | 7.53 | 6.60 | 8.76 | 7.20 | 7.11 | 7.94 | 6.64 | 6.39 | 0.51 |
| CaO | 0.63 | 7.40 | 7.73 | 5.68 | 1.60 | 5.78 | 5.68 | 6.99 | 8.80 | 0.58 | 0.43 |
| $Na_2O$ | 0.60 | 3.60 | 3.67 | 5.00 | 4.30 | 3.30 | 5.13 | 5.13 | 3.45 | 0.10 | 0.20 |
| $K_2O$ | — | 0.45 | 0.37 | 5.10 | 0.10 | 0.10 | 0.16 | 0.23 | 0.10 | 0.10 | 0.07 |
| $H_2O^+$ | 12.94 | 4.05 | 3.61 | 5.74 | 5.61 | 6.60 | 4.80 | 3.77 | 5.16 | 7.44 | 10.23 |
| $H_2O^-$ | 2.47 | 0.20 | 0.43 | 1.22 | 0.46 | 0.93 | 1.26 | 0.69 | 1.03 | 0.67 | 0.80 |
| $CO_2$ | 1.88 | 0.40 | — | 3.55 | 0.20 | 3.73 | 0.95 | 0.96 | 4.20 | — | 0.40 |
| $P_2O_5$ | — | 0.12 | 0.07 | 0.19 | 0.18 | 0.16 | 0.19 | 0.16 | 0.06 | 0.16 | 0.12 |
| Total | 100.51 | 99.88 | 101.1 | 99.91 | 100.35 | 100.31 | 99.85 | 99.97 | 99.92 | 100.65 | 99.94 |

1—harzburgite, including $Cr_2O_3$ 0.20, NiO 0.30 (IV-2-[2]); 2—gabbro (IV-2-[4]); 3—gabbro-diabase (IV-2-[4]); 4,5—massive lava (IV-2-[5]); 6—massive lava (IV-2-[7]); 7,8—pillow lava (IV-2-[6]); 9—pillow lava (IV-2-[7]); 10—ferruginous intercalated beds in pillow lava (IV-2-[7]); 11—massive sulfides (IV-2-[7]); (reference data).

lava (the lower part) to the southwest of Congdu village. Observe pillow structure, boundary of the two lavas and the massive ore beds of sulfide.

*Visiting spot no.* 3. *Exotic blocks at Quxar*

From Quxar to Cuola (mountain pass), the Permian limestones scatter irregularly upon the peaks and slopes composed of Triassic sandstones, shales intercalated with limestones, presenting as isolated blocks of different size (Fig. IV-9). Among them, the biggest one is found at the southwest of Quxar village — the Jiezhangshan exotic block with an area of 4.4 $km^2$, and the diameter of the smaller ones is under 10 m.

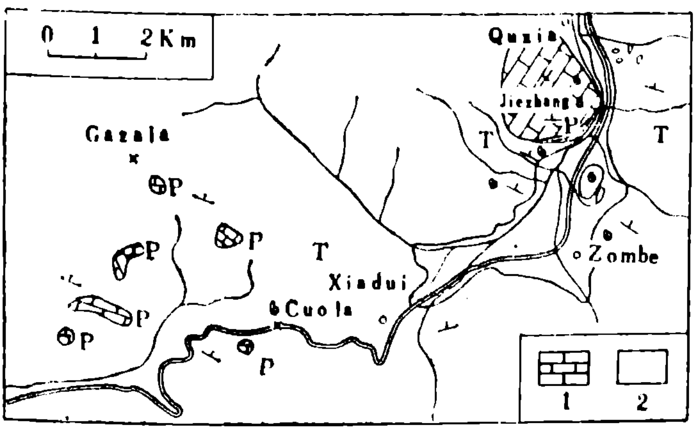



**Fig. IV-9 Distribution of the exotic blocks in Quxar-Cuola district**

1. Permian limestone; 2. Triassic sandstone and shale

The exotic block at Jiezhangshan is mainly composed of white gray tinged with pink bioclastic limestone, intercalated with a little argillaceous rock, shale and siltstone, containing abundant fossils. Among them, brachiopods are *Stenoscisma giganten* (Diener), *S.* cf. *purdoni* (Davidson)? *Marginifer* sp., *Spiriferella* ragah (Salter), *S. sinica* Chang, *Neospirifer* sp., corals are: *Amplexocarinia* sp. and others. The features of fossil fauna are similar to those in Quburika formation of Permian at the northern slope of Mt. Qomolangma. In the Triassic sandstone and shale below the exotic blocks, ammonites, pelecypods (*Halobia* sp.) and belemnites

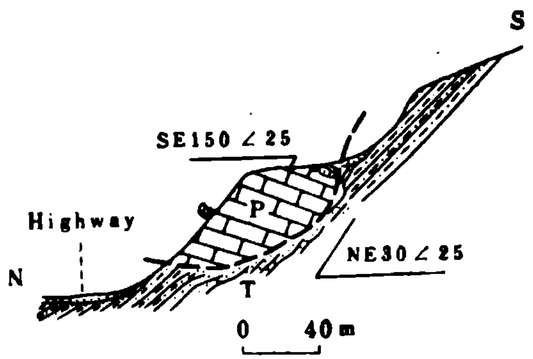



Fig. IV-10 The sketch map of the tectonic contact between the exotic Permian limestone and Triassic sandstone and shale at the southern foot of the Jiezhanshan

Permian (6) white gray massive limestone (2—4m)

——— thrust ———

Triassic (5) purple red calcareous conglomerate intercalated with medium to thin bedded limestones, (1—2m)

(4) gray, red gray calcareous argillaceous rock (3m)

——— fracture zone ———

(3) alternation of beds of gray, grayish green, yellow gray shale and limestones of medium to thick beds (10m)

(2) gray shale intercalated with thin bedded limestone and sandy argillaceous rock (15m)

(1) alternation of beds of gray black shale and gray medium bedded limestone changing into yellow gray after weathering (6—8m visible)

(*Asteroconites* sp.) are found.

Between the exotic limestone block of Jiezhanshan and the underlying sandstone and shale, a thrust fractured zone is clearly seen. The sandstone and shale are relatively soft showing many contortions and small foldings and its axis surface reverses toward the south, while the limestone is hard and brittle and is mostly fractured and filled by calcite veins (Fig. IV-10).

*Visiting spot no.* 4. *Cuola exotic block*

The Cuola exotic block at the slope to the northern side of the highway is situated 500 m west of Cuola mountain pass. The exotic limestone block is 50—60 m in east-west direction and 60 m from south to north (Fig. IV-11). At the northern side of the block, there is a cliff and at the foot of the cliff, debris from the weathering block body are accumulated, in which tectonic brecciated limestone is occassionally seen. The limestone contains crinoid stems and the lithology and the fossil contents are similar to those of the Quxar exotic block which is also of Permian. The southern part of the limestone block embeds into the Triassic sandstone and shale and purple red argillaceous rock. Sandstone and shale as well as thin-bedded limestone underwent strong tectonic compression and deformation and many of the thin bedded limestone are sheared and dislocated. In the sandstone and shale at Cuola, Late Late Triassic pelecypods (*Monotes salinaria* Bronn, *Halobia* cf. *superbescene* Kittl) are found.

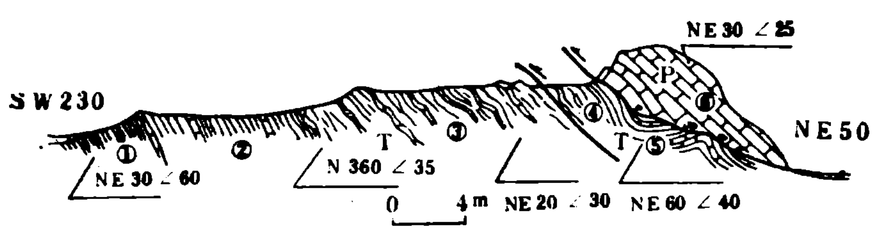



Fig. IV-11 The sketch map of the section of Cuola exotic block

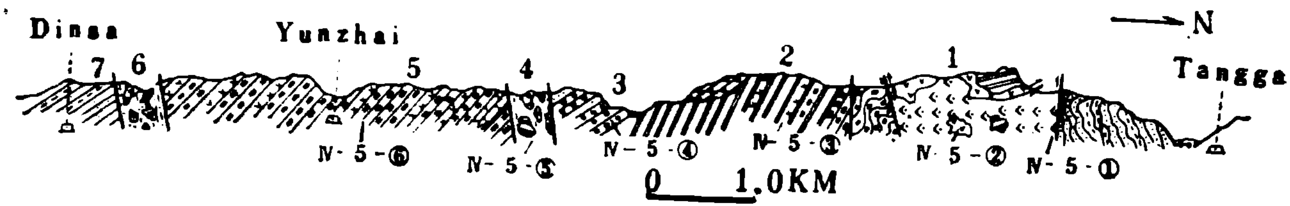



Fig. IV-12 The ophiolite section from Tanggar to West of Dingsa in Lhaze county

1. Ultramafic rock; mainly harzburgite, occassionally, a few scattered impregnated chromite veins are found. In the rock body, a great amount of slabs of mafic volcanic and siliceous rocks are discovered;
2. Radiolarian siliceous rock, siliceous shale intercalated with volcanic rock beds, partially containing a little sandstone. The volcanics are sheet-like and conformable with the siliceous rock and its lithology is characterized by spilite and basalt;
3. Liuqu conglomerate ($E_3$-$N_1$?); mainly are purple, mottled siliceous conglomerate, unconformably deposited on the siliceous rock;
4. Ophiolite mèlange;
5. Siliceous shale intercalated with volcanic sheets, particularly containing limestone lens and sandstone beds;
6. Ophiolite mèlange (similar to 4);
7. Sandstone and shale (T).

*Visiting spot no. 5.* ***Ophiolite section from Tanggar—West of Dingsa***

The section is situated at the locality from Tanggar commune to the west of Dingsa of Lhaze county, the direction of the section is nearly south-north, the total length 10 km.

Program for visiting

IV-5-(1) At the northern border, the ultramafic rock body has a tectonic contact with the flysch of Xigaze group. At the marginal part of the rock body, strong foliation, striations and fragmental breccia can be seen; the high-temperature metamorphism is not evident;

IV-5-(2) Slabs of volcanic and siliceous rocks in the ultramafic rock body characterized by no resorption;

IV-5-(3) Siliceous rock and intercalated beds of volcanic rock. Volcanic rock of this section is characterized by basalt with abundant titanaugite. The thickness of the volcanic rock is generally 10 m and more;

IV-5-(4) The unconformity between purple red thick-bedded siliceous rock and the overlying Liuqu conglomerate. The two all dip southward, but the dip angle of the conglomerate is lower. Meanwhile, observe features in lithology;

IV-5-(5) Visiting ophiolite mélange, which is a fault zone of northwest strike with a width of 100 m and more, in which ultramafic rock, mafic volcanic rock, siliceous rock, and limestone mixedly distribute in blocks and slabs of different size and irregular form;

**Table IV-4 The chemical composition of various rocks at Tanggar ophiolite section**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 39.07 | 46.53 | 48.03 | 45.00 | 44.67 | 44.85 | 47.95 | 49.03 | 49.71 | 48.98 | 44.88 | 50.33 |
| $TiO_2$ | 0.05 | 2.24 | 1.98 | 4.04 | 4.04 | 3.46 | 4.14 | 3.52 | 3.49 | 2.97 | 1.24 | 1.78 |
| $Al_2O_3$ | 1.28 | 15.53 | 14.94 | 13.84 | 14.68 | 13.71 | 13.62 | 12.53 | 11.95 | 14.15 | 15.61 | 15.77 |
| $Fe_2O_3$ | 6.15 | 3.89 | 4.10 | 8.70 | 5.66 | 5.92 | 7.34 | 7.12 | 13.47 | 7.49 | 4.30 | 6.55 |
| FeO | 1.32 | 6.72 | 5.50 | 8.53 | 10.05 | 9.07 | 7.52 | 7.95 | 4.00 | 8.49 | 6.13 | 5.16 |
| MnO | 0.16 | 0.20 | 0.20 | 0.55 | 0.50 | 0.32 | 0.29 | 0.32 | 0.38 | 0.36 | 0.19 | 0.18 |
| MgO | 33.78 | 6.17 | 5.26 | 5.91 | 5.68 | 5.48 | 3.46 | 3.81 | 3.19 | 4.12 | 6.73 | 3.18 |
| CaO | 1.11 | 9.58 | 9.92 | 3.18 | 4.79 | 9.09 | 7.27 | 8.03 | 3.68 | 3.77 | 10.87 | 4.92 |
| $Na_2O$ | 0.03 | 3.29 | 3.78 | 2.83 | 2.67 | 3.60 | 4.87 | 4.40 | 3.10 | 3.20 | 3.26 | 5.83 |
| $K_2O$ | 0.15 | 0.92 | 0.13 | 0.16 | — | 0.17 | 0.25 | 0.16 | 0.16 | 0.32 | 0.48 | 0.26 |
| $H_2O^+$ | 14.02 | 3.48 | 3.70 | 5.74 | 6.09 | 3.74 | 3.05 | 2.30 | 5.26 | 5.28 | 5.03 | 4.03 |
| $H_2O^-$ | 2.24 | 0.41 | 0.62 | 0.66 | 0.52 | 0.69 | 0.33 | 0.31 | 0.86 | 0.38 | 0.17 | 0.24 |
| $P_2O_5$ | — | 0.36 | 0.37 | 0.35 | 0.45 | 0.29 | 0.32 | 0.32 | 0.46 | 0.48 | 0.17 | 1.26 |
| $CO_2$ | 0.06 | 0.29 | 0.87 | — | 0.29 | 0.18 | — | 0.24 | 0.27 | 0.28 | 1.16 | 0.70 |
| Total | 99.80 | 99.61 | 99.40 | 99.49 | 100.09 | 100.57 | 100.41 | 100.05 | 99.98 | 100.27 | 100.21 | 100.19 |

1—harzburgite, average of 6, including $Cr_2O_3$ 0.20, NiO 0.2 (IV-5-[1][2]); 2,3—spilite (IV-5-[2]); 4-8—five layers of volcanics of island arc tholeiite (IV-5-[3]); 9—island arc tholeiite (IV-5-[6] the 1st layer of volcanics); 10—spilite (average of 3, the 1st, 2nd, 3rd layers of volcanics south of IV-5-[6]); 11—spilite (average of 4th, 5th, 6th layers of the volcanics south of IV-5-[6]); 12—alkali-basalt (average of 7th, 8th, 9th layers of the volcanics south of IV-5-[6]).

IV-5-(6) Limestone lens and sheet lava in siliceous shale. The limestone generally has a length about 10 m and more with a thickness of several meters. At some occassions colitic texture and bioclastic fragments are seen. In this section, 9 and more intercalated beds of volcanic rock are found and the siliceous rock shows purple, grayish white and other variegated colors and the argillaceous component obviously increases.

## V. The Pliocene and the Quaternary in Nyalam district

Many Late Cenozoic basins at the northern slope of Himalaya mountain occur and commonly deposit clay rock, siltstone and fine sandstone mainly of lacustrine and alluvial facies with thickness from 200—800 m, in which *Hipparion* sp. and other fossils are found. In Pliocene, the natural environment at the northern slope was still very similar to that of the southern slope in Himalaya. In the stratigraphic section of the southern slope at Yagru Kongla (formerly called Niehnieh Hsiungla) coarse conglomeratic sediments overlying on Pliocene sediments can be seen and the age of the former is Early Quaternary. Since Quaternary, at least 3 glaciations have developed, which were mainly valley and piedmont glaciers. The scale of the glaciation reduced one after another and the Quaternary glaciation in Fuqu valley at Nyalam county reflects this characteristic. In Yarleb (formerly called Yali), fossil plants in travertine and the advance and regression of the existing glaciers indicate many changes of cold and warm climate occurred in Holocene.

*Visiting spot no.* 1. *Pliocene and Pleistocene sections in Yagru Xongla*

Yargru Xongla (5,122 m) is situated 45 km north of Nyalam county (or 30 km northeast of Mt. Xixabangma). The section is situated at both sides of the 63rd highway maintenance squad (Date) of the highway from China to Nepal at the southern slope of the Yagru Xongla including Pliocene, Lower and Middle Pleistocene beds. (Fig. V-1, Table V-1). Following is the succession from bottom up:

8) Middle Pleistocene ($Q_2$)

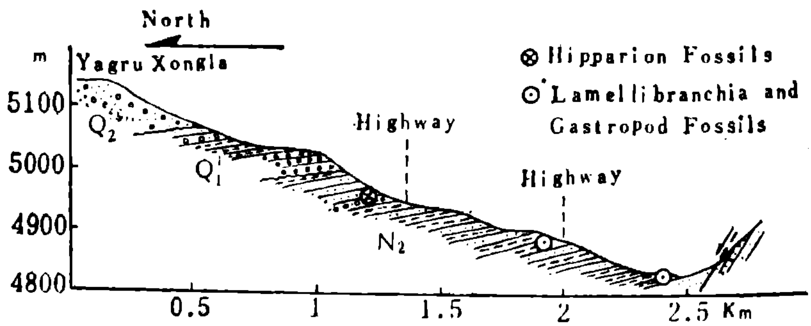



**Fig. V-1 The section of the Pliocene and Pleistocene of the southern side of Yagru Xongla**

Gray and light grayish yellow glacial gravel beds widely distribute on the Yagru Xongla table. The thickness of the gravel beds, the composition and roundness of gravels vary at different parts of the table. At the margin of the table, the thickness of the gravel bed is about 80 m and the average diameter of gravels is 4.8 cm, the largest one may reach 1 m. The main components are granite, gneiss and schist (71%), coming next are quartz sandstone, quartzite (21%) and other rocks occupy 8%. Most of the gravels are subspherical and spherical and show the characteristic of some degree of sorting. In the past, it was held that this gravel bed was moraine ("Niehnieh Hsiungla moraine");

7) Lower Pleistocene ($Q_1$)

The upper part: light blue gray, grayish white and light brown silts, fine sands intercalated with sand and gravel beds and partially containing ferruginous stripes and lumps. In sand beds, fossil ostracods: *Candona* sp., *Candoniella* sp., *Leucocythere* sp. and *Leucocytherella* sp. are found. Thickness is about 90 m.

The lower part: Gray gravel bed cemented by calcium as "rock" outcropping on the surface as cliffs. The component of the gravels are mainly limestone, quartzite and sandstone (above 75%), the roundness and sorting are good and the sorting coefficient is 1.3, while the asymmetric coefficient is 1.2 and the average diameter of gravels is 4.2 cm. Most of the gravels are flat, showing certain degree of orientation, generally dipping to N 50°E with a dip angle of 20. The strata dip to N 25°E, with a dip angle of 10° and a thickness of 20—30 m.

~~~~~~ unconformity ~~~~~~

Pliocene ($N_2$)

6) Grayish white, grayish yellow and purple medium and fine sandstone intercalated coarse sandstone bearing gravels. Oblique bedding, cross bedding develop and multi-
~~~~~~

layer purple red ferruginous sandstone containing *Hipparion* fossils is intercalated. The thickness is 90 m and 6 layers can be subdivided:

(f) Indigo gray fine sandstone intercalated with thin bedded siltstone clay rock, 25 m;

(e) Indigo gray and purple gray coarse sandstone intercalated with ferruginous sandstone, 45 m;

(d) Purple gray thick bedded medium-coarse granular sandstone, cross beddings develop; the upper part is gray sandstone intercalated with purple red ferruginous sandstone, 12 m;

(c) Gray sandstone with gravels, containing *Hipparion* sp., spores and pollens which are mainly herb-like *Artemisia* and a small amount of *Quercus* and *Betula*;

(b) Purple gray sandstone with gravels. Oblique beddings develop intercalated with 7 layers of purple red ferruginous sandstone (each layer 5—20 cm thick), 8 m;

(a) Purple gray sandstone intercalated with fine conglomerate 2 m;

5) Indigo gray siltstone and brown sandstone, occassionally intercalated with ferruginous thin-bedded sandstone; *Quercus* predominates overwhelmingly in spores and pollens; 120 m;

4) Light purple gray thick-bedded massive argillaceous rock and brown yellow siltstone, fine sandstone with gravels intercalated with many layers of ferruginous sandstone con-

taining abundant fossil pelecypods: *Unio* cf. *douglasia* Grif et Pidg, *Unio tschiliensis* Stuarang, *Pisidium* sp., *Sphasrium* sp., 80 m;

3) Alternation of beds of brown yellow fine sandstone and blue gray siltstone. Spores and pollens are mainly *Quercus* and *Cedrus*, others such as *Podocarpus* and *Pinus*, are also found, 60 m;

2) Gray yellow and purple gray fine sandstone in which 9 layers of red ferruginous sandstone lens are found and each layer is 15—40 cm thick, weathering as spheroidal lumps, containing legume fossils (*Thermopsis prebarbata* Li), 80 m;

1) Gray yellow and gray green siltstone intercalated with gray yellow fine sandstone, containing 4 fossil beds of gastropod and ostracod, each bed 2—5 cm. Among them, gastropods are: *Adelinella regularis* Yu, *Staja xizangensis* Yu; ostracods are: *Ilyocypris gibba* (Komdohr), *Limnucythere dobiosa* Li, *L.* sp., spores and pollens are mainly arbor, among them *Cedrus* occupies 70.9%, coming next are *Quercus, Pinus, Abies, Picea, Yew podocarpus, Ketelleria, Carya, Tsuga* 70 m.

*Visiting spot no.* 2. *Holocene sinter deposits at Yarleb*

Sinter at Yarleb mainly distributes at the left bank of Boqu river, 4,300 m above sea level. The frontal margin of the sinter is 2 m higher than the water level of the river and gradually rising towards the foot of the mountain. The dip angle of the surface is about 3°. From the section of the riverside of the sinter frontal margin, carbonate deposits of compact bedded, colitic and gas-pore texture can be seen and the spring water comes from the Ordovician limestone at the east side. In the bedded and porous sinter in the middle and upper parts beds of plant leaves and stem imprints are found, which are *Lonicera* cf. *hispida,* Pall., *Viburnum* cf. *erubescens* Wall., *Rhododendron* cf. *hypenanthum, Rosa* sp., *Spiraea* sp., *Rhamnus* sp., *Lonicea tomentella* HK et Thomas *Salid* spp. Furthermore, on the surface, stone nucleus, flakes, leaves, round scraper and other microliths of Late Mesolithic age have been collected, which correspond basically with those often found in the "microlith culture" in North China. Therefore, the possible age of the formation of the sinter may be Early—Middle Holocene.

The plant fossils in the sinter are similar to the bushes growing at the height of 3,400—3,800 m above sea level now, some 500 m lower than the level of the present Boqu river valley. Here, the annual average temperature is 3.5°C—5°C, the annual precipitation is greater than 614 mm, which indicates the climate during the formation of the sinter at the vicinity of Yarleb was milder and warmer and more humid than that of today. Today, in Yarleb the climate is comparatively cold and arid with an annual average temperature of 1.5°C and precipitation less than 500 mm.

*Visiting spot no. 3. Quaternary glaciation of the lower reaches of the Fuqu river at the vicinity of Nyalam*

The Fuqu river rises from the existing glacier at the southern slope of Mt. Xixabangma and converges into Boqu river at Nyalam. The existing mountain glaciers developing in Mt. Xixabangma area and the snowy Qeaung Peak are mainly valley glaciers of smaller type, but the scope of Quaternary glaciation was very large and it filled the Fuqu river valley for several times and inletted into the Boqu river. On the ground of the difference of the structure of moraine morphology, weathering degree of the moraine deposits and characteristics of the ancient soil on different parts of the moraines, Quaternary glaciation of the Fuqu valley can be

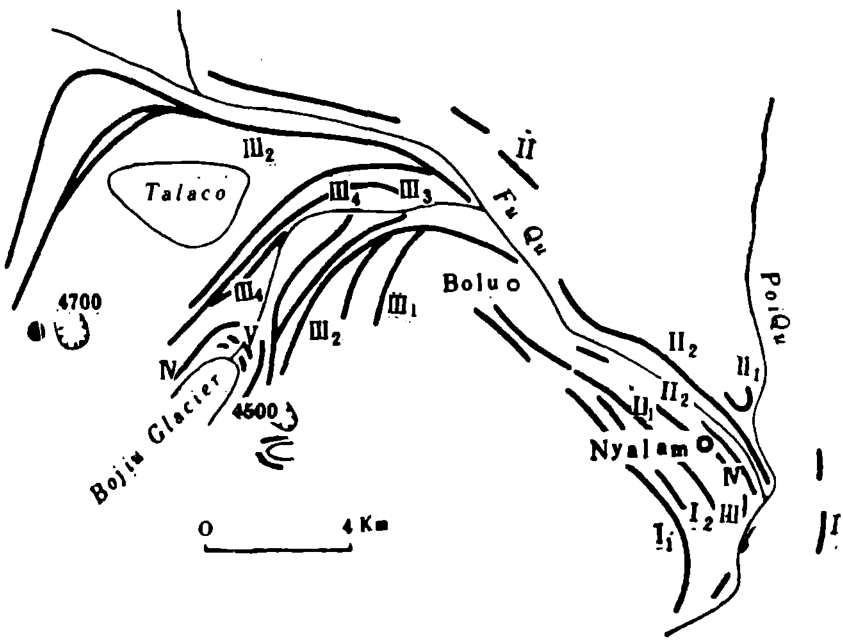



Fig. V-2 The sketch map of the Quaternary glaciation of the lower reaches of the Fuqu river at the vicinity of Nyalam county

I. Nyalam glacial age (Nieniexiongla glacial age); II. Jilongsi glacial age; III. Rongbusi glacial age; IV. New glacial age; V. Minor glacial age.

classified into 3 glacial ages and 2 stages of Holocene

**Table V—1 Pliocene and Pleistocene Stratigraphic Scale in Yagru Xongla**

| Time | Strata | Columnar section | Thickness m. | Lithology | Fossils | Spores and pollens |
|---|---|---|---|---|---|---|
| $Q_2$ | Niehnieh Hsiungla gravel bed | | 80 | gray and grayish yellow loosened gravel bed | | |
| $Q_1$ | Goinba conglomerate | | 110 | light blue gray and gray yellow silt, fine sands intercalated with gravel beds, partially bearing ferruginous bands; gray coarse gravel bed, calcareously cemented into "rock" | ostracods: *Candona* sp., *Candoniella* sp., *Leucocythere* sp., *Leucocytherella* sp. | |
| | | | 90 | grayish white, grayish yellow and purple medium to fine grained sandstone, sandstone bearing gravels, intercalated with beds of ferruginous sandstone | *Pipparion* sp. | *Artemisia*, *Cyperaceae* *Gramineae*, *Quercus*, *Pinus*, *Betula* |
| | | | 120 | indigo gray siltstone, brown sandstone, occasionally intercalated with ferruginous thin-bedded sandstone | | *Quercus*, *Pinus*, *Salix*, *Cedrus*, *Artemisia*, *Polypodiaceae* |

| | | | | | | |
|---|---|---|---|---|---|---|
| $N_2$ | Date formation | | 80 | light purple gray thick-bedded argillaceous rock and brown yellow siltstone, fine sandstone bearing gravels intercalated with thin-bedded ferruginous sandstone | pelecypods: *Unio* cf. *douglasia* Grif et Pidg, *U. tschiliensis* Stuarang, *Pisidium* sp., *Sphasrium* sp. | *Quercus*, *Cedrus*, *Podocarpus*, *Pinus*, *Picea*, *Abies*, *Carpinus*, *Magnolia*, *Polygonaceae*, *Polypodiaceae* |
| | | | 60 | alternation of beds of brown yellow fine sandstone and blue gray siltstone, intercalated with a little thin-bedded ferruginous sandstone | | |
| | | | 80 | gray yellow and purple gray fine sandstone intercalated with beds of ferruginous sandstone | legume: *Thermopsis prebarbata* Li | |
| | | | 70 | grayish yellow and grayish green siltstone intercalated with grayish yellow fine sandstone | gastropods: *Adelinella regularis* Yu, *Staja Xizangensis* Yu<br>ostracods: *Ilyocypris gibba* (Komdohb) Li, *Limnocythere dobiosa* Li, *L.* sp. | *Cedrus*, *Quercus*, *Pinus*, *Podocarus*, *Ketalleria*, *Carya*, *Tsuga* |
| J | | | | quartz sandstone and limestone | | |

glaciation (Fig. V-2).

*New glacial age* (IV)

The high and large terminal and lateral moraines of this glacial age are next to the two terminal moraines of the ice tongue of the existing glacier, some 500 m away from the end of the existing glacier. On the terminal moraine dense azalea bushes grow.

The advancing time of the existing glacier probably corresponds to that in southeastern region of Xizang, i.e. 1,700—1,900 B.P. and 3,000 B.P.

*Rongbusi glacial age* (III)

Several stages may be found in this glaciation. On the moraines of earlier stage, yellow ancient soil bed was formed. At that time, the Fuqu valley from Bulu upward was filled and damaged by ice flow, forming gigantic dentritic valley glaciers, the end of which was on a level of 3,900 m above the sea.

*Interglacial age*

The moraines of Jilongsi glacial age were damaged by weathering and brown yellow ancient soil bed, 30 cm thick was formed on the surface;

*Jilongsi glacial age* (II)

It is a gigantic composite glacier which flew out from the Fuqu into the Boqu valley forming the moraine belt of great boulders at the southern part of Nyalam county (the height of the top surface of the moraine is 3,830—3,837 m);

*Interglacial age*

In this age, the bed of the Boqu river undercut con-


Fig. VI-1a A Sketch of the Paleozoic outcrops from Chiatsun-Yarleb

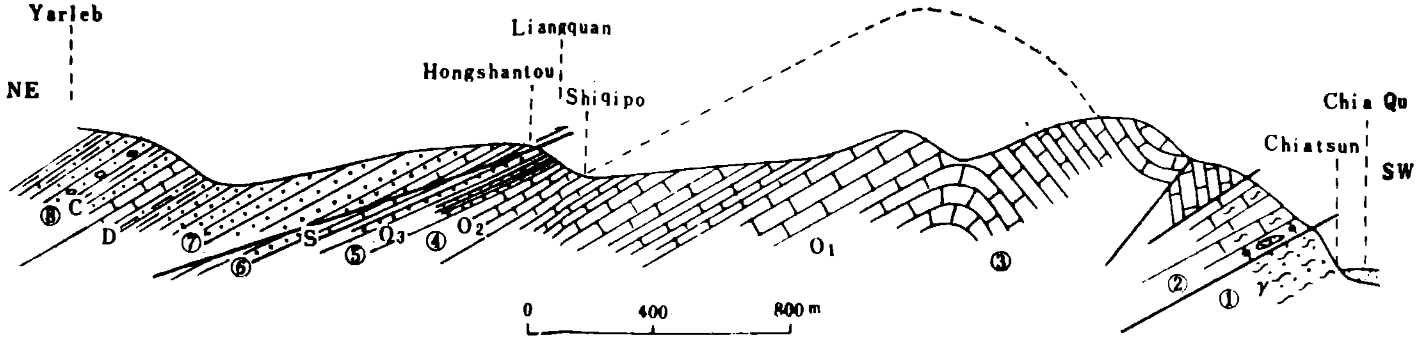



Fig. VI-1b The Section of Ordovician-Devonian from Chiatsun-Yarleb

(1) fractured muscovite granitic gneiss ($\gamma$)
(2) Rouqi-cun formation ($O_1^1$)
(3) Lower formation of Chiatsun group ($O_1$)
(4) Upper formation of Chiatsun group ($O_2$)
(5) Hongshantou formation ($O_3$)
(6) The Silurian [Shiqipo formation ($S_1$); Pulu group ($S_{2+3}$)]
(7) The Devonian [Liangquan formation ($D_1$); Pochu group ($D_{2+3}$)]
(8) The Carboniferous [Yali formation ($C_1^1$); Naxing formation ($C_{2+3}$)]

tinually forming siliceous ferruginous alumina-rich residuum of 30—50 cm in thickness.

*Nyalam glacial age (Niehnieh Hsiungla glacial age)* (I)

The yellow moraine platform 3,930 m in height in the southern part of Nyalam is referred to the products of this glacial age and the weathering of the moraines is strong. At that time, the glacier entered into Boqu and extended southwards along the Boqu to the south of Puluoke village, which is the largest glaciation in scale found in this region. On the ground of the difference of the moraine morphology, 2 stages can be subdivided in this glaciation.

According to regional stratigraphic correlation, the above mentioned I glaciation was formed in Middle Pleistocene and II, III glaciations were formed in Late Pleistocene, while the IV was formed in Late Holocene.

## VI. The Paleozoic and Mesozoic Stratigraphy in Nyalam District

Nyalam is situated at the south sub-zone of the Tethys-Himalaya of the Xigaze district. Well-outcropping beds from Sinian-Cambrian to Eocene are almost completely marine sediments (see the first chapter, Table I-3). Except that the Sinian-Cambrian is a comparatively great thickness of argillaceous series with flysch structure from the middle and upper parts of Lower Ordovician to Eocene, the rocks are all unmetamorphic, in simple lithologic assemblages and abundant in fossils, totally 10 thousand m. and more in thickness, and are mostly neritic deposits which are close to the generally so-called platform-type sediments or stable epicontinental sediments. Biota from Ordovician to Devonian can be referred to the bio-type of North, Central and Southwest China. Sediments and biota of Gondwana facies are found in the Carboniferous and Permian and sediments and biota of typical Tethyan type are found in the Mesozoic and Eogene.

*Visiting spot no.* 1. *Lower formation of Chiatsun group* ($O_1$)

It is bed 3 on the section from Ordovician-Devonian at Chiatsun-Yarleb (Fig. VI-1).

The lithology is characterized mainly by gray, dark gray limestone, occasionally intercalated dolomitic limestone, calcareous siltstone and fine sandstone, 726 m thick. The lower formation of Chiatsun group contains fossil cephalopods, brachiapods, trilobites and gastrapods.

2 zones can be subdivided by the horizons of cephalopod fossils and the features of genera and species. The lower part is *Ordosoceras-Manchuroceras* zone, in addition to zone fossils, *Wutinoceras, Ormoceras* are found. The features of the cephalopod fauna in this zone is closest to those of Zhuozishan formation of Neimenggu (Inner Mongolia), but species bear local characteristics of this region. The age ranges from Middle to Late Arenigian of Early Ordovician to Early Llanvinian. The upper part is *Dideroceras-Paradnatoceras* zone of Llanvinian.

Brachiopods contain *Leptellina, Aporthophyla, Ortham-*

*bonites* and *Xizangostrophia*, which are similar to the features of brachiopod fauna of *Tablehcadian* in North America and the age is referred to Middle to Late Early Ordovician.

Trilobites such as *Pseudoeucalymene tuberculata* (Chien) are seen in the horizons in the middle part, and gastrapods are mainly characterized by genus *Maclurites*.

Fauna of the lower formation of the Chiatsun group is very similar to those of the correspondent rock series in the central and northern parts of Nepal (Nilgiri formation), but is hard to correlate with those in Kashmir, Kumaon and Spiti of India. The cephalopod fauna is similar to those of North China and North America which possibly may be the same fauna.

*Visiting spot no. 2. The upper formation of Chiatsun group* ($O_2$)

This formation shown as the 4th bed in Fig. VI-1 is mainly purple red argillaceous limestone, with abundant cephalopods, such as ***Sinoceras, Miohelinoceras, Parormoceras, Beolitoceras, Curtoceras, Actinomorpha*** and ***Dideroceras*** as well as crinoid stems (*Pentagonopentagonalis, Enipsoelliptidus, Cyclocylicus*) and brachiopods (*Orthambomites?* sp.) The upper formation of Chiatsun group may correspond to the entire Middle Ordovician.

The cephalopod fauna in the upper formation of Chiatsun group is close to that of Yangzi region of China. From all the faunas contained in the upper formation, just as the faunas in the lower formation, they are similar to those of the correspondent rock series in the central and northern parts of Nepal, but different from those in Kashmir, Kumaon, Spiti of India.

*Visiting spot no 3. Hongshantou formation* ($O_3$)

This formation placed as the 5th bed in Fig. VI-1, 70 m thick, is characterized by brown gray, brown red calcareous, silty shale intercalated with several fine sandstone beds with rare fossils. On the ground of the conformities with both of the underlying upper formation of Chiatsun group and the overlying Shiqipo formation of Early Silurian, it is postulated as Late Ordovician in age.

In Himalaya region, the Late Ordovician is mainly composed of clastic rock and mottled rock with rare fossils, which is quite similar to that in the northern part of Africa, where at the end of Ordovician it was influenced by glaciation causing the rarity of fossils. However, to the west of Lhasa or Xainza district, some 360 km straight away northeast to this section, the Upper Ordovician is a large suite of limestone containing trilobite *Dalmanella* which is similar to that in the Yangzi region of China.

*Visiting spot no. 4. The Silurian section*

The Silurian shown as the 6th bed in Fig. VI-1 overlies conformably on the Hongshantou formation of the Upper Ordovician, upwards contacts in faults with the Lower Devonian, and the outcropping thickness is 136 m. On the basis of fossil content and lithology, the Silurian can be subdivided into 2 stratigraphic units, namely, Shiqipo formation ($S_1$) and Pulu group ($S_{2+3}$).

Shiqipo formation (formerly called "the lower formation of Shiqipo group") is 90 m thick. The lower part is sandstone; the middle is shale with graptolites and the upper is limestone with cephalopods and a small amount of corals. The graptolitic shale in the middle part contains *Climacograptus normalis* Lapworth, *Cl. rectangulatus* (M'Coy), *Streptograptus lobiferus* (M'Coy), *Oktavites circularis* (Elles et Wood), *Monograptus priodon* (Bronn), the horizons equal to the middle and upper parts of the Lower Silurian, corresponding to *Orthograptus vesiculosus* zone *to Streptograptus crispus* zone. The graptolite fauna of this formation is similar to that in Dark Band formation in the central and northern parts of Nepal, to which the horizons here can roughly correspond or slightly higher.

Pulu group (formerly called "the upper formation of Shiqipo group") is 46 m thick. In the middle and lower parts, they are mainly grayish white quartzose sandstone, intercalated with calcareous shale containing graptolites and the upper part is gray limestone with abundant cephalopods. Graptolites are *Monograptus vomerina subgracilis* Pribyl, *Pristiograptus dubius* (Suess), *P. dubius tatus* (Boacek), and cephalopods *Michelinoceras* (*Kopaninoceras*) *jucundum* (Barrande). On the ground of the fossil content, horizons of this formation can be referred to Middle and

Upper Silurian. The Silurian in Spiti of India is mainly shelly facies, yielding abundant trilobites, brachiopods and corals, which is quite different from those of this region.

*Visiting spot no. 5. The Devonian section*

The Devonian shown in Fig. VI-1 as 7th bed can be subdivided into Liangquan formation ($D_1$) and Pochu group ($D_{2+3}$).

Liangquan formation, about 40 m thick; its lower part is shale containing graptolites and tentaculites and the upper part is an alternation of beds of black thin bedded limestone and shale containing abundant tentaculites and a few pelecypods, cephalopods and brachiapods. This formation includes 1 *Monograptus* zone and 2 tentaculite zones.

*Neomonograptus himalayensis* zone chiefly includes *Neomonograptus himalayensis* Mu et Ni, *N. atopus* (Boucek) *rigidus* Mu et Ni, *Monograptus thomasi* Jaeger, *M.* cf. *yukonensis* Jackson et Lenz, *M. nyalamensis* Mu et Ni. The graptolithic fauna of this zone is the most abundant graptolithic fauna among those which are yielded from the Praguian or the correspondent beds throughout the world.

*Nowakia acuaria* zone associates with the above mentioned graptolithic zone representing horizons of the lower part of Liangquan formation, with abundant tentaculites, but the genera and species are monotonous, mainly *Nowakia acuaria* (Rickter) and *Styliolina?* sp.

*Guerichina xizangensis* zone overlies on the preceding zone, representing the horizons of the upper part of the


Fig. VI-2a A sketch of the Triassic outcrop at Tulung, Nyalam County

⊕ spots where *Himalayasaurus tibetensis* Dong were collected

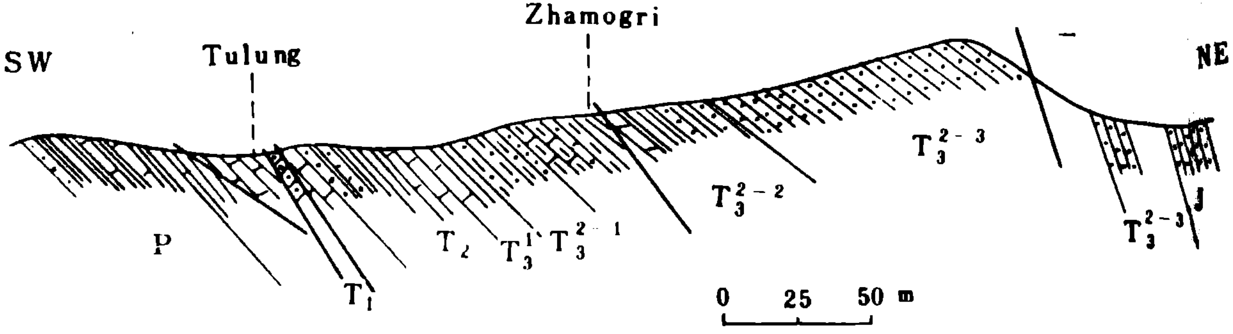



Fig. VI-2b The Triassic section at Tulung, Nyalam county

$T_1$ Kangshare formation

$T_2$ Laibuxi formation

$T_3^1$ Zamuro formation

$T_3^{2-1}$ Dashalong formation

$T_3^{2-2}$ Qulonggongba formation

$T_3^{2-3}$ Derirong formation

Liangquan formation, characterized by *Guerichina xizangensis* Mu, others, such as *Nowakia lepida* Mu, *Grassilina praevia* Mu and *Styliolina* cf. *minuta* Boucek, are present.

The ages of the above two tentaculites zones are referred to Praguian of Early Devonian.

Pochu group, 2 formations can be subdivided, namely, the upper and the lower:

The lower formation, 256 m thick, is mainly composed of grayish white quartzose sandstone, the upper of the sandstone contains plant fragments. The lithology and horizon of this formation can be roughly correlated with the "Muth quartzite" in Kashmir and Kumoan districts of India. The upper formation (formerly called the lower part of "Yali formation"), 66m thick, mainly gray shale intercalated with fine sandstone containing pelecypod *Paracyclos* cf. *dubia* Beushansen and coral *Metriophyllum* sp. This formation transits continually upwards to the Yali formation of the lower part of the Lower Carboniferous.

From Yarleb northward to Laixi, the Lower Carboniferous outcrops (Yali formation and Naxin formation). The Carboniferous-Permian beds containing glacial marine sediments and *Glossopteris* flora are well preserved in Rongpu Si district of Dingri county or along Jilonggongba-Qubu at the northern slope of Mt. Qomolangma.

*Visiting spot no.* 6. *The Triassic in Tulung*

The section is situated at the vicinity of Tulung, the thickness of the Triassic is 1,696 m (Fig. VI-2b The Triassic section at Tulung, Nyalam county). From bottom up it is Tulung group ($T_1$ — the lower part of $T_3^2$), Qulonggongba formation (the middle part of $T_3^2$) and Derirong formation (the upper part of $T_3^2$). The Tulung group is 640 m thick and can be subdivided into Kangshare formation ($T_1$), Laibuxi formation ($T_2$), Zamure formation ($T_3^1$) and Dashalong formation (the lower part of $T_3^2$).

Kangshare formation ($T_1$), 103 m thick; at the bottom, it is dolomite of 20—30 cm, and in the middle and upper parts, alternations of limestone and shale. From bottom up, there are 3 ammonite zones: (1) *Gyronites psilogyrus* zone; (2) *Owenites* zone; (3) *Procarnites* bed. They belong to the middle and upper parts of the Indusian stage and the Olenikian stage.

Laibuxi formation ($T_2$), 259 m; the lower part is an alternation of sandstone and shale and the upper part is limestone intercalated with shale. From bottom up there are 3 ammonites zones or beds: (1) *Japonites magnus* zone; (2) *Anacrochordiceras nodosum* zone; (3) *Protrachyceras-Joannites* bed, associated with which is *Daonella indica* zone. This formation corresponds to Anisic and Ladinic stages.

Zamure formation ($T_3^1$), 99 m thick. The lithology is an alternation of bio-clastic limestone and sandy shale, from bottom up comprising 3 ammonites zones or beds: (1) *Indonesites diereri* bed; (2) *Hoplotropites* zone; (3) *Parahauerites acutus* zone. This formation corresponds to Carnic stage.

Dashalong formation (the lower part of $T_3^2$), 179 m thick, mainly are alternations of limestones and sandstone-shale. From bottom up, 2 ammonite zones are comprised: (1) *Nodotibetites* nodosus zone; (2) *Griesbachites-Gonionobites* zone. This formation corresponds to the lower part of Noric stage.

Qulonggongba formation (the middle part of $T_3^2$), 465 m thick, mainly are sandy shale alternated with siltstone and intercalated with fine sandstone and bio-clastic and sandy limestones. From bottom up, 2 ammonite zones are established: (1) *Indojuvavites angulatus* zone; (2) *Pinacoceras metternichii* zone, with the accosiation of *Himalayasaurus tibetensis* Dong. This formation corresponds to the middle part of Noric stage.

Derirong formation (the upper part of $T_3^2$), 591 m thick, mainly are quartzose sandstone and also feldspathic quartzose sandstone and a little of quartzite-like sandstone. In the middle part, a layer of dolomite and sandy limestone containing pelecypod fossils, such as *Palaeocardita mansuyi* Reed, *Indopecten margariti* (Dienere). In the upper part, carbonaceous shale containing carbonized plant fragments is intercalated. This formation represents the upper part of Noric.

*Visiting spot no. 7. The Middle and Lower Jurassic from Derirong bridge to Yagru Xongla*

From Derirong bridge to Yagru Xongla in Nyalam county, the middle and lower parts of the Jurassic outcrop (Fig. VI-3 the Jurassic section from Derirong bridge to

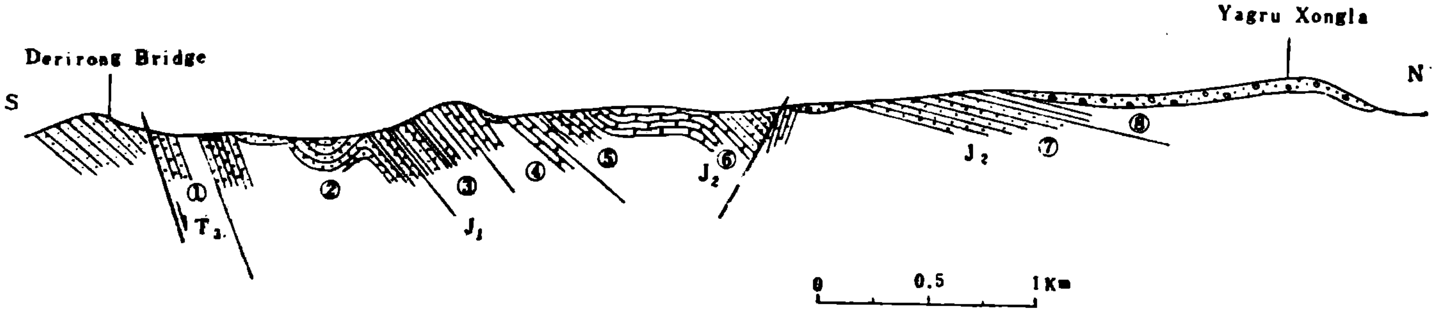



Fig. VI-3 The Jurassic section from Derirong bridge to Yagru Xongla, Nyalam County

①—③ Pupuga formation ($J_1$)

④—⑧ Niehnieh Hsiungla formation ($J_2$)

Yagru Xongla, Nyalam county).

The Lower Jurassic here is named Pupuka formation, the Middle Jurassic, Niehnieh Hsiungla formation. The Pupuka formation, formerly called "Niehnieh Hsiungla lower formation" is placed at the 1st—3rd beds in Fig. VI-3, 495 m thick. The lithology is mainly characterized by gray yellow green sandstone and shale, and in the middle and lower parts, many layers of limestone, sandy limestone (or calcareous sandstone) are intercalated, yielding ammonites *Schlothemia* sp., *Sulciferites* sp. and *Gleviceras* sp.; foraminifera *Orbitopsella praccursor* (Gumbel), *Rhapydiomina urensis* Henson; pelecypod *Astarte* cf. *voltzii* Goldfuss.

Niehnieh Hsiungla formation (formerly called the middle and upper formations of Niehnieh Hsiungla group) is placed in the 4—10th beds in Fig. VI-3, with a thickness of 1,565 m. In the lower part, it is mainly gray black limestone intercalated or alternated with sandstone and argillaceous limestone, while in the upper part, it is an alternation of gray limestone and quartzose sandstone.

Beds of the lower part of this formation yield ammonites *Dorstensia haydeni* Arkell, *Witchellia tibetica* Arkell, pelecypods *Camptonectes* (*Camptonectes*) *lens* (Sowerby), *C.* (*Camtonectes*) *laminatus* (Sowerby), *Grammatoden* (*Indogrammatodon*) *egertonicanus* (Stoliczka), *Trigonia* (*Trigonia*) *brevicostata* Kitchin. The age of the fossil beds of the lower part is Bajocian.

In the upper part, pelecypods *Entolium demissum* (Phillips), *Camptonectes* (*Camptonetes*) cf. *rigidus* (Sowerby) and ammonite *Macrocephalites* sp. are found. The age of the fossil beds of this formation is from Bathonian to Callovian.

## VII. High Himalaya Metamorphic Rock Series in Nyalam District

Metamorphic rocks in this region widely distribute. Take Jangling tourmaline granite as a demarcation line, the southern part is gneiss and migmatite metamorphosed in medium degree and the northern part is slightly metamorphosed schist. In slightly metamorphic rocks many granitic and pegmatitic veins interpenetrate.

In the southern part, from the Friendship bridge to Jangling, medium metamorphic rocks are named Nyalam group (formerly called the middle and lower parts of "Qomolangma group"). Its age is inferred as Pre-Sinian (?). From Quxam to Friendship bridge, gneiss predominates (Fig. VII-1), including sillimanite gneiss, almandine biotite schist (gneiss), biotite quartz schist, quartzite. In the southern part, kyanite schist, staurolite-kyanite-sillimanite gneiss, kyanite-sillimanite gneiss and thin-bedded marble occur. The migmatization is comparatively weak, mainly veins, ptygmatic veins and lens of halleflint, pegmatite and aplite. Some banded migmatites are restricted in the northern part. This suite of metamorphic rock is named Dingringbo Qiao formation (corresponding to the formerly called "Dalaimaqiao formation" and "Dingringbo Qiao formation"), the thickness outcropping is 13,000 m.

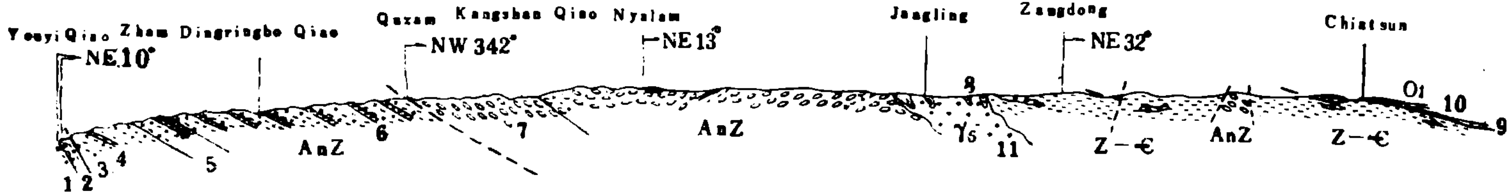



Fig. VII-1 The sketch map of geologic section from Chiatsun—Friendship bridge, Nyalam county

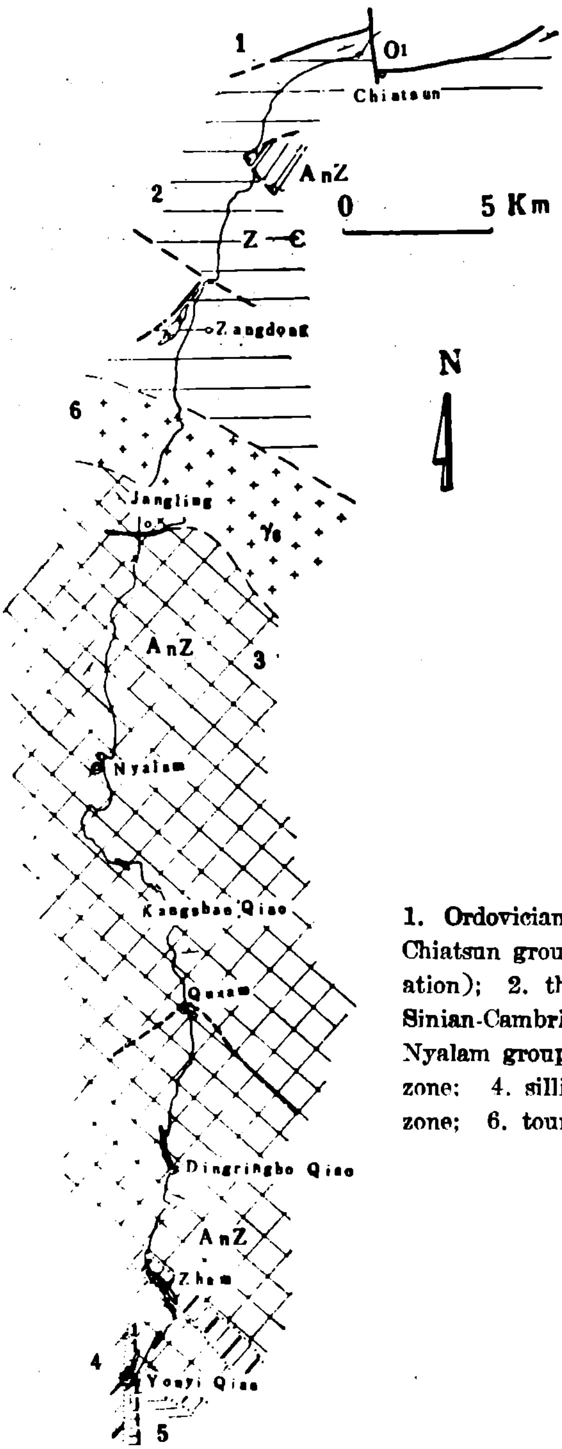
Nyalam group(1—7): 1. kyanite-sillimanite gneiss; 2. kyanite-almandine schist; 3. sillimanite gneiss; 4. marble; 5. quartzite, biotite-quartz schist; 6. almandine-biotite schist; 7. ocular and banded migmatite;

North Col formation: 8. biotite-albite-quartz schist, biotite-quartz schist; 9. cataclastic muscovite granitic gneiss;

Rouqi-cun formation: 10. crystalline limestone; 11. tourmaline granite.

From Quxam to Jangling, it is characterized by a wide distribution of migmatite, among which is mainly ocular migmatite. In the south, some banded magmatite is present. Potash feldspathic or quartzose, potash feldspatic and plagioclase eye balls can reach a size of 10 × 14 cm. To the north of Kangshan bridge, in the ocular migmatite, sillimanite gneiss, biotite schist, quartzite and several layers of marble are intercalated with a thickness of 9,000 m, which is called Kangshanqiao formation (corresponding to the formerly called "Kangshanqiao formation" and the middle and lower parts of "Jiaquqiao formation").

The regional progressive metamorphic belt of Nyalam group can be classified into kyanite zone, sillimanite I zone and sillimanite II zone. The kyanite zone is marked by the occurrence of kyanite in metapelites. The sillimanite I zone is characterized by the assemblage of staurolite-kyanite-sillimanite or kyanite-sillimanite, and roughly corresponds with the upper limit of the staurolite stable area and the vicinity of the transformation boundary of kyanite $\rightleftharpoons$ sillimanite facies, which is estimated between 7—9 kb and 620—680°C. The sillimanite II zone is marked by the stable occurrence of sillimanite + muscovite and the disappearance of kyanite and staurolite. Therefore, the metamorphic rock of Nyalam group is referred to amphibolite facies and the metamorphic degree of the south is slightly lighter than that of the north (Fig. VII-2), showing a reversed progressive metamorphic order, which suggests some possible tectonics of reversed characteristics.




1. Ordovician (the lower formation of Chiatsun group and Rouqi-cun formation); 2. the North Col formation of Sinian-Cambrian, greenschist facies, Nyalam group (3 – 5); 3. sillimanite II zone; 4. sillimanite I zone; 5. kyanite zone; 6. tourmaline granite ($\gamma_6$)

Fig. VII-2 The metamorphic map from Chiatsun to Friendship bridge in Nyalam county

On the basis of the characteristics of metamorphic rocks, mineral assemblages and the petrochemical analyses, taking Xigaze district as a whole, the Nyalam group is a suite of parametamorphic rock series, the original rocks of which are mainly composed of argillaceous sandstone, feldspar sandstone and shale intercalated with thin-bedded limestone and volcanics and the cyclothemes are evident and the thickness is great, which suggests flysch sediments of miogeosynclinal type. Index minerals of Nyalam group are kyanite, staurolite, sillimanite, which should be referred to the medium pressure facies series of Barrovian type.

Northwards from Jangling to Chiatsun, mainly composed of biotite-albite-quartz schist, hornblende granulite, biotite-quartz schist, calcite granulite intercalated with marble and the common minerals are biotite, quartz, albite, plagioclase, calcite and hornblende. Muscovite, chlorite and epidote are rare. The regional metamorphism can be referred to greenschist facies and locally some can reach the low-grade amphibolite facies. Owing to the grequent interpenetration of granitic and pegmatitic veins, contact metamorphism is comparatively developed, forming diopsite hornstone, hornblende hornstone and some skarns, the veins locally develop and even diktyonite or magmatite are found.

Metamorphic rocks in this region originally are considered as basement metamorphic rock series, the age of which is still in dispute. In fact, the metamorphic degree of this suite is comparatively light and its lithology and metamorphic degree are quite similar to those of the North Col formation in Rongpusi district but different from the Kangshanqiao formation of Nyalam group at its southern side. Therefore, temporarily we can correlate it with the North Col formation and its age may correspond to Sinian-Cambrian.

The granitoids outcropping in this region are referred to Himalayan granitoids belt, which is mainly composed of tourmaline-muscovite granite, coming second are muscovite-biotite granite and gneissoid muscovite-biotite granite and pegmatite with a comparatively small scale and occurrence of veins, mainly restricted to the north of Jangling and the south of Chiatsun thrust. The Jangling tourmaline granite is the only larger one in scale and the outcropping width is about 3 km, with a NWW strike, which can be inferred to be a sill, intruding into the space between the migmatite-gneiss of Kangshanqiao formation of the Nyalam group and the biotite-albite-quartz schist of North Col formation. Many residual bodies of biotite-quartz schist are found in the granite. K-Ar ages of the granites and pegmatites in Nyalam district is 10—20 m.y.

The southern part of Nyalam group is characterized by fold tectonics, while the northern part is faults and the folds are in a gentle-wave form.

The boundary between the Dingringboqiao formation and the Kangshanqiao formation is covered by regolith. On the basis of the evident difference between rocks of the upper and lower walls, compressive crushes and closed folds of smaller size, a possible fault of comparatively large scale (named Quxiang thrust) is inferred in the vicinity of Quxiang.

In the northern part of the present region, the famous Chiatsun thrust occurs, separating the Rouqi-cun formation (formerly called the lower formation of Roqui-cun group) from the North Col formation of the Ordovician. The thrust is characterized by cataclastic muscovite granitic gneiss of tens to hundreds meters wide, which may be the product of dynamic metamorphism plus migmatization.

Furthermore, on the basis of the evident difference of the metamorphic degree of the rock beds south and north of the Jangling granites, the development in a large scale of ocular migmatite in the southern part and the frequent interpenetration of granitic and pegmatitic veins in the northern part, it is inferred that the rock body may possibly intruded along the preexisting breaks, and according to its tectonic position, the fault corresponds to the main north thrust.

*Visiting spot no.* 1. *The Chiatsun thrust*

In the vicinity of Chiatsun, the metamorphic rocks of the lower wall of the thrust are biotite-quartz schist and marble, and its age is temporarily referred to Sinian-Cambrian. Granitic and pegmatitic veins penetrating into and intersecting obliquely the beddings are well developed. The upper wall is composed of quartz schist, thin-bedded and crystalline limestone with argillaceous bands, upwards transiting into fossiliferous Early Ordovician limestone.

The thrust dips to the north gently (Fig. VII-3).

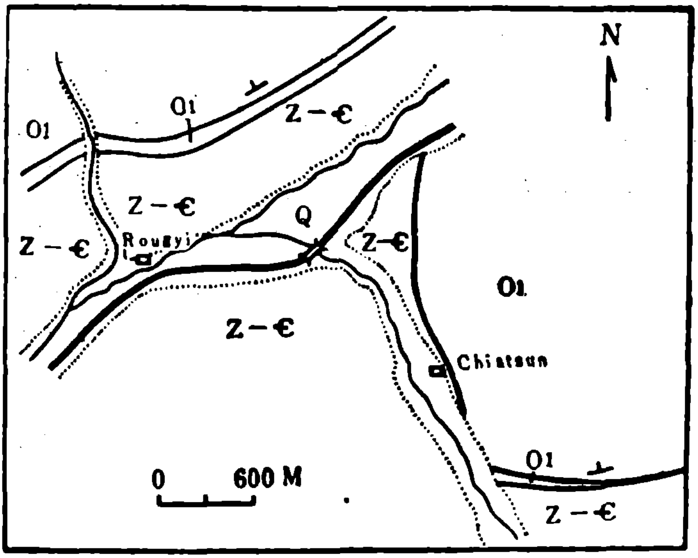



Fig. VII-3 The sketch map of geologic tectonics in the vicinty of Chiatsun, Nyalam county in Xizang

Z-€ Sinian-Cambrian slightly metamorphic rock series;
$O_1$-Early Ordovician limestone;
Thick full line—the Chiatsun thrust;

The significant mark of the thrust is the occurrence of the muscovite granitic gneiss undergoing intensive tectonic faulting in the thrust belt and the rock contains evident scratchs and crushes and the size of the muscovite obviously augments. In some sections intensively polished mylonite is formed and the upper wall of the thrust has also developed a series of drag folds. All the signs show that the upper wall came through a movement from north to south (as a reversed fault belt, it is composed of a series of faults).

*Visiting spot no. 2. The light-grade metamorphic rock series on the highway west of Zangdong village*

The Chiatsun thrust passes through the northwest of Zangdong village and its strike is NE. Below the fault, biotite albite-quartz schist, biotite granulite, hornblende granulite intercalated with quartz marble and metamorphic calcareous sandstone, which is temporarily referred to North Col formation. Many veins of gneissoid biotite-muscovite granite, tourmaline granite and pegmatite are intercalated and the breadth of the veins is 1—10 m. At the margins, diopside hornstone of contact metamorphism is seen. Several mylonite belts parallel with the orientations of schistosity are developed and the breadth of the belt is from tens cm to 2 m.

*Visiting spot no. 3. Ocular migmatite and gneiss at the highway sides south of Jangling*

To the south of Jangling tourmaline-muscovite granite (not outcropping at the highway), migmatite-gneiss, ocular migmatite, sillimanite gneiss, biotite gneiss and biotite schist of Kangshanqiao formation in Nyalam group are found and

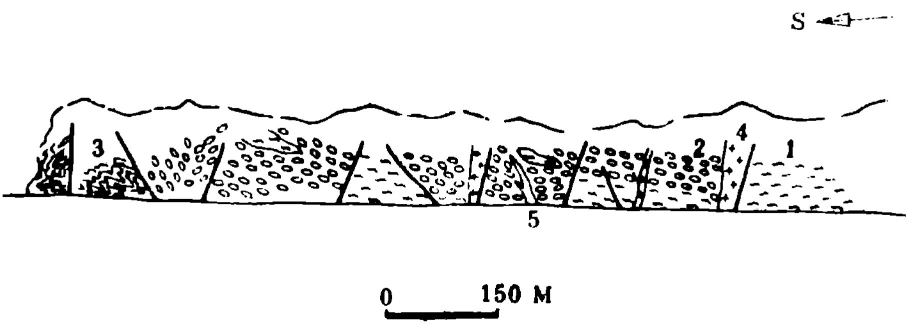



**Fig. VII-4 The geologic sketch map south of Jangling**

**1. gneiss; 2. ocular migmatite; 3. schist; 4. granite ($\gamma_4$); 5. pegmatite.**

the occurrence is gentle. In the southern part of the section, closed and reversed folds of smaller size and faults develop, but the fault displacement is not so large. Veins of biotite-muscovite granite, tourmaline granite and pegmatite occur along the faults and the widest one is 30 and more meters, intersecting gneiss and migmatite and the contact metamorphism is not so evident (Fig. VII-4).

*Visiting spot no. 4. Striped migmatite, gneiss and schistose quartzite*

The northern part is composed of striped migmatite of Kangshanqiao formation in Nyalam group intercalated locally with ocular migmatite and the size of the eye ball is 2—4 cm; the southern part is composed of biotite schist, biotite-quartz schist, quartzite and sillimanite gneiss of Dingringboqiao formation in Nyalam group. Contact between the gneiss of Dingringboqiao formation and the migmatite of Kangshanqiao formation is covered by regolith and is obscure. In the migmatite of the northern side, faults and closed folds of smaller size develop and the crushed texture of the migmatite in the vicinity is obvious. Mylonite and mylonitized migmatite are found. In the schist of the southern side, small closed folds and hot spring sites are seen. On the ground of the marked difference of the lithologies of the two sides and the phenomena of fragmentation and compression, it is deduced that between the Kangshanqiao formation and the Dingringboqiao formation, there may be a thrust, i.e. the "Quxiang thrust".

*Visiting spot no. 5. Kyanite schist at the east of Friendship bridge*

Here, kyanite-almandine schist, kyanite schist, quartzite and almandine-biotite schist of Dingringboqiao formation in Nyalam group are found. In the thin-bedded kyanite-almandine schist between comparatively hard quartzites, small closed flexible folds are yielded, indicating the occurrence of reversed folds in the vicinity.

## References

Xizang Scientific Investigation Team, Academia Sinica; The natural features and the geological development of the Mt. Qomolangma district in the southern part of Xizang, China: Kexue Tongbao, 1973, Vol. 18(1), 11—21.

Xizang Scientific Investigation Team, Academia Sinica; Report on the scientific investigations (1966—1968) in Mt. Qomolangma district—geology: 1974 Science Press, 1—299.

Xizang Scientific Investigation Team, Academia Sinica; Report on the scientific investigations (1966—1968) in Mt. Qomolangma district—palaeobiology: Part I (1975), 1—423; Part II(1976), 1—457; Part III(1976), 1—545; Science Press.

Xizang Scientific Investigation Team, Academia Sinica; Report on the scientific investigations (1966—1968) in Mt. Qomolangma district—Quaternary geology: Science Press, 1—112.

The K-Ar Isotopic Age Group, Institute of Geology, Academia Sinica; Determination of isotopic geological age in South Xizang and the periods of Himalayan movement: Scientia Geologica Sinica, 1979, 1, 13—21.

Wang Yigang, Wang Yujing, Wu Haoruo; Discussion on the problem of Gyarag formation in the South Xizang and the discovery of the Lower Jurassic in Lhunze District: Scientia Geologica Sinica, 1976, 2, 149—156.

Yin Jixiang, Guo Shizeng; Discovery of beds of Gondwana facies at the northern slope of Mt. Qomolangma: Scientia Geologica Sinica, 1976, 4, 291—322.

Yin Jixiang, Guo Shizeng; Mt. Qomolangma and the beds at its northern slope: Scientia Sinica, 1978, 1, 90—102.

Wu Haoruo, Wang Dongan, Wang Liancheng; The Cretaceous along Lhasa-Gyangze in South Xizang: Scientia Geologica Sinica, 1977, 3, 250—262.

Li Jijun, Wen Shixuan, Zhang Qingsong, Wang Fubao, Zheng Benxing, Li Bingyuan; Discussion on the rise period, rise range and type of Qinghai-Xizang Plateau: Scientia Sinica, 22(1979), 6, 608—616.

Tong Wei et al; The Himalayan geothermal belt: Acta Beijing University (Natural Science Version). 1978, 1, 76—86.

Jin Chengwei, Zhou Yunsheng; The magmatic rock belt in the Himalayan and Kangdese arc mountain ranges and their modes of genesis: Scientia Geologica Sinica, 1978, 4, 287—312.

Jin Yugan, Liang Xilo, Wen Shixuan; New data on Permian fossil fauna at the northern slope of Mt. Qomolangma: Scientia Geologica Sinica, 1977, 3, 236—249.

Xu Ren; Discovery of *Glossopteris* flora in South Xizang and its significance in geology and palaeogeography: Scientia Geologica Sinica, 1976, 4, 223—339.

Huang Wanpo, Ji Hongxiang; The first discovery of Xizang *Hipparion* fauna and its significance to the plateau rise: Kexue Tongbao, 1979, 19. 885—888.

Zhang Binggao, Mu Xinan; Discovery of marine Tertiary to the north of Yarlung Zangbo River, Xizang: Journal of Stratigraphy, 3 (1979), 1, 65—66.

Yang Lihua, Liu Tungsheng; Neotectonic movement of Mt. Qomolangma District: Scientia Geologica Sinica, 1974, 3, 209—220.

Shi Yafeng, Liu Tungsheng; Report on the scientific investigation of Mt. Xixabangma District: Kexue Tongbao, 1964, 10, 928—938.

Wu Haoruo and Deng Wanming, Basic geological features of the Yarutsangpo ophiolite belt, Tibet, China—In Abstracts of paper submitted, 1979, p. 36. International Ophiolite Symposium, Nicosia, Cyprus.