Vol. XVI, No. 1 SCIENTIA SINICA February, 1973

STRATIGRAPHY OF THE MOUNT JOLMO LUNGMA REGION IN SOUTHERN TIBET, CHINA

Mu An-tze (穆恩之), Wen Shih-hsuan (文世宣),
Wang Yi-kang (王义刚), Chang Ping-kao (章炳高)
(*Nanking Institute of Geology and Palaeontology, Academia Sinica*)
and Yin Chi-hsiang (尹集祥)
(*Institute of Geology, Academia Sinica*)

Received Nov. 25, 1972.

Abstract

This paper, based on the material of the scientific expeditions to the Mount Jolmo Lungma region made during the years 1966—1968, deals briefly with the Ordovician, Silurian and Devonian marine strata discovered for the first time there, as well as their classifications and correlations. The marine strata, about 10,000 m in thickness and ranging from Ordovician to old Tertiary, were deposited almost continually. The fossils were abundant, being more than twenty kinds in all, and some were discovered for the first time in the Mount Jolmo Lungma region, or even in the Himalayas. The stratigraphical development of the southern part of the Mount Jolmo Lungma region is quite different from that of the northern: in the former, strata ranging from the Ordovician to the old Tertiary were exposed more completely, and the sediments seem to be of the so-called platform type; while in the latter, only the Permo-carboniferous and Mesozoic were seen, and the sediments there resemble those of the so-called geosycline type.

The Mount Jolmo Lungma region here mentioned denotes the vast area between China's southern frontier to the south and the Yalu Tsangpo River to the north, Chilung to the west and Yatung to the east. After the peaceful liberation of Tibet, the geological surveys, the multi-purpose investigations and the mountain-climbing scientific investigation, all done here in succession, provided valuable information for further study on the stratigraphy of this region. During the years 1966—1968 in the period of the Great Proletarian Cultural Revolution, an extensive scientific investigation to this region was carried out by a large-scaled team under the auspices of Academia Sinica. A mass of materials and data on stratigraphy and palaeontology have been obtained. The fossiliferous Ordovician, Silurian and Devonian rocks were discovered for the first time in this region. The Mesozoic and Cenozoic were classified in detail. A more complete stratigraphical system is thus established. The marine strata, about 10,000 m in thickness ranging from Lower Ordovician to Eocene, are nearly continuous in sedimentation. They are very rich in fossils, including plants, algae, spores, foraminifers, radiolarians, corals, conularians, stromatoporoids, hydroids, bryozoans, brachiopods, lamellibranchia, gastropods, nautiloids, ammonites, belemnites, tentaculites, trilobites, ostracods, crinoids, echinoids, graptolites, ichthyosauria, etc. Among them several were

discovered for the first time in this region, or even in the Himalayas. Of great significance to the stratigraphy and palaeontology is the discovery of the Ordovician nautiloids and trilobites, the Silurian and Devonian graptolites, especially a Devonian monograptid faunule, the Devonian tentaculites, the Lower Carboniferous ammonites, the Upper Triassic flora, belemnites and radiolarians, the Lower Jurassic ammonites and foraminifers and the Upper Cretaceous and early Tertiary ostracods. In accordance with the stratigraphical development and geographical distribution, the region here referred to may be divided into two parts by the Kangma-Sakya-Sutso line directed from east to west. In the southern part, the strata ranging from early Palaeozoic to Tertiary are exposed more completely (shown in Table 1); whereas in the northern part, only the Permo-Carboniferous and Mesozoic are seen.

Cambro-Ordovician

A series of low-grade metamorphic rocks, exposed about 3 km to the northwest Rouqiecun in Nyalam, is named the Rouqiecun Group (Fig. 1). This group is succeeded continually by the Chiatsun Group, but is in fault contact with the underlying pre-Cambrian Jolmo Lungma Group. Owing to the presence of a thicker-bedded mylonite below the fault zone, its basal part is absent and its exposed thickness varied from 40 to 160 m.

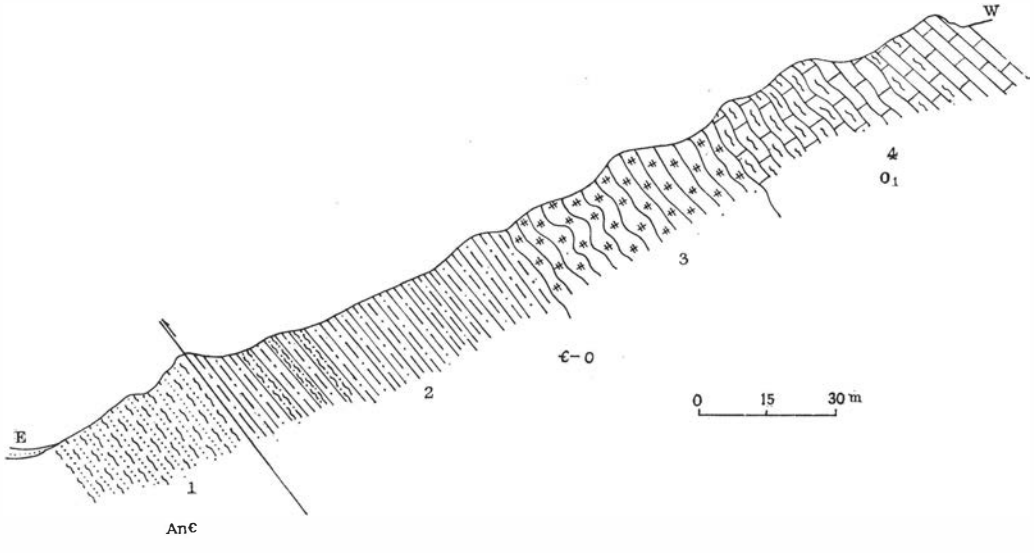


Fig. 1. Diagrammatic section of the Rouqiecun Group, NW of Rouqiecun in Nyalam district.

1 — Jolmo Lungma Group, 2 — Lower Formation of Rouqiecun Group, 3 — Upper Formation of Rouqiecun Group, 4 — Lower Formation of Chiatsun Group.

According to the different degree of metamorphism, the Rouqiecun Group may be divided into two Formations. The Lower Formation consists of diopside-quartz-schist intercalated with muscovite-biotite-schist, occasionally with migmatite and mylonite. The Upper Formation consists of crystalline limestone with various mineral constituents, such as calcite, quartz, plagioclase, biotite, apatite, epidote, diopside, sericite, etc. The crystalline calcite and quartz grains are elongated and orientated in

arrangement. The quartz grains appear to be in distinctly undulatory extinction. It is probable that the detrital quartz, plagioclase and biotite in the limestone are derived from the underlying metamorphic and granitic rocks.

The Rouqiecun Group, being influenced to a varied degree by the dynamothermal metamorphism which reduces rapidly upward, shows no regional metamorphical characteristics. As mentioned above, the Rouqiecun Group is overlain conformably by the Chiatsun Group of Middle and late Lower Ordovician. The Upper Formation of this group may represent the early Lower Ordovician. As the basal part of the group is missing by a fault, the existence of Cambrian could not be ruled out. Accordingly, the Rouqiecun Group may represent the strata ranging from the Cambrian to the early Lower Ordovician.

The crystalline limestones obtained from the summit of Mount Jolmo Lungma show a strong similarity in structural character, metamorphism and mineral constituents to those from the Upper Formation of the Rouqiecun Group. The limestone samples obtained from the summit and from the locality, 8,500 m in height, are determined by the U–Pb methods of dating to be 410—515 million years. It is justifiable to regard these limestones as belonging to the Lower Ordovician, approximately corresponding to the Upper Formation of the Rouqiecun Group.

Ordovician

In this region, the Ordovician rocks crop out approximately in a east-west direction from Tuota of Yatung, through Chiapula and Chaya of Tingri and to Chiatsun of Nyalam. Based on the Chiatsun section, the Ordovician rocks may be divided into two units: the Chiatsun Group below and the Hongshantou Formation above (Fig. 2). Judging from rock characters and fossil contents, the Chiatsun Group can be subdivided into the Lower and the Upper Formations.

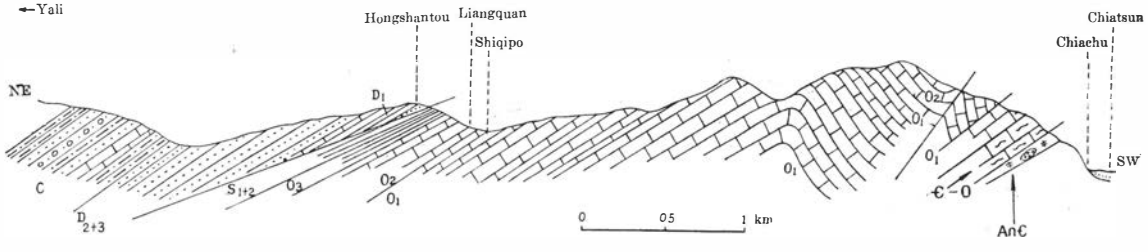


Fig. 2. Section of the Ordovician to Devonian from Chiatsun to Yali, north of Nyalam district.

$An\epsilon$ — Jolmo Lungma Group, ϵ-O — Rouqiecun Group, O_1 — Lower Formation of Chiatsun Group, O_2 — Upper Formation of Chiatsun Group, O_3 — Hongshantou Formation, S_{1+2} — Shiqipo Group, D_1 — Liangquan Formation, D_{2+3} — Pochu Group.

The Lower Formation is composed of grey limestones attaining 726 m in thickness. It contains in the lower part the following fossils: *Ordosoceras, Manchuroceras, Wutinoceras, Aporthophyla, Orthambonites, Leptellina, Xizangostrophia* (gen. nov.), *Eucalymene,* Asaphidae gen. indet. and *Maclurites,* etc. *Ordosoceras* was originally known from the middle of the "Zhuozishan Limestone" in Inner Mongolia, lying between the *Polydesmia*-bearing bed below and the *Amplexograptus confertus* zone above, and also found from the Lower Ordovician in Shantung. *Manchuroceras* and *Wutinoceras* are

recorded from the Lower Ordovician Liangchiashan Formation in North China; the former, common in the Hunghuayuan Formation of South China, is regarded as an important member of the *Coreanoceras* zone (i.e. "*Cameroceras*" zone); whereas the latter has been reported from the "Zhuozishan Limestone" in Inner Mongolia and from the Lower Ordovician in Chilianshan. *Eucalymene* has been known to exist in the Dawan Formation of Lower Ordovician in the Upper Yangtze. In the upper part of the Lower Formation, there occur *Dideroceras* sp. and *Paradonatoceras* sp. nov., which are the representatives of the Kuniutang Formation (Upper Llanvirnian). Therefore, the Lower Formation of the Chiatsun Group may represent the Lower Ordovician, corresponding approximately to the strata from the Hunghuayuan to Kuniutan Formation in South China (Arenigian-Llanvirnian).

The Upper Formation of the Chiatsun Group is composed of pinkish limestone, amounting to a thickness of 97 m. It contains *Sinoceras chinense, S. densum, Michelinoceras yüi, M. xuanxianense, M. paraelongatum, M.* spp. nov., *Dideroceras, Paromoceras, Beloitoceras, Curtoceras* and *Actinomorpha,* together with *Ellipsoellipticus himalayensis* (sp. nov.) and *Maclurites* sp. 2. *Sinoceras chinense* is a characteristic member of the Middle Ordovician Pagoda Formation and the Meijiang Formation (i.e. the lower part of the formerly Linxiang Formation) of the Yangtze region. *Beloitoceras, Curtoceras* and *Actinomorpha* are first made known in China. *Beloitoceras* frequently occurs in the Middle and Upper Ordovician of North America and Europe, and is akin to *Richardsonoceras* from the Middle Ordovician Pagoda and Meijiang Formations in South China. *Curtoceras* is common in the Lower and Middle Ordovician in North America and Europe, and has an affinity with *Discoceras* from the Middle Ordovician Pagoda Formation in South China. *Actinomorpha* was originally reported from Middle Ordovician(?) in North America, but its definite horizon is still uncertain. The fauna, as a whole, shows affinities with the Middle Ordovician ones and, therefore, the Upper Formation of the Chiatsun Group may be referable to the Middle Ordovician (Llandeilian-Middle Caradocian).

The unfossiliferous Hongshantou Formation is composed of brown shales, measuring 70 m in thickness. It is conformably underlain by the Chiatsun Group and is overlain by the Silurian Shiqipo Group. Its age belongs presumably to the late Ordovician.

Silurian

The Silurian rocks in this region, exposed 2 km to the north of Chiatsun, are named the Shiqipo Group. This group is underlain conformably by the Upper Ordovician Hongshantou Formation, but is in fault contact with the overlying Lower Devonian Liangquan Formation. It amounts to about 136 m in thickness, and may be divided into the Lower and the Upper Formations (shown in Fig. 2).

The Lower Formation comprises sandstones at the base, graptolite-bearing black shales in the middle and limestones in the upper. The black shales contain *Climacograptus normalis, C. medius, Streptograptus lobiferus, Monograptus priodon,* etc. The limestones yield *Geisonoceras robustum* (sp. nov.), *Geisonoceras?* sp., *Columenoceras* sp. nov., *Michelinoceras capax, M.* spp. nov., *Favosites* sp., *Triplophyllum* sp. nov., etc. The graptolite-bearing beds may belong to the Middle and late Lower Silurian, corresponding approximately to the Dark Band Formation in Nepal.

The Upper Formation of the Shiqipo Group, 46 m thick, is composed of dark-grey, sandy limestones interbedded with dark-grey shales, yielding *Monoclimacis vomerina subgracilis, Pristiograptus dubius, Michelinoceras jucundum,* etc. In the light of the graptolite assemblage, this formation may be considered to be the Middle Silurian in age. Because the top part of this formation is cut off by a fault, it remains unknown whether the late Middle and Upper Silurian are present or not; but judging from the finding of graptolites in the overlying Lower Devonian, the whole Silurian system might exist elsewhere in this region.

Devonian

The Devonian of this region is distributed in the Nyalam, Tingri and Tingkye districts. Near Liangquan, about 2 km to the north of Chiatsun, the Devonian rocks are well exposed and may be divided into two stratigraphic units: the Liangquan Formation in the lower and the Pochu Group in the upper (Fig. 2).

The Liangquan Formation, about 40 m thick, is succeeded conformably by the Pochu Group, but is in fault contact with the underlying Shiqipo Group. It comprises in the lower part the grey graptolithic shales, containing *Neomonograptus himalayensis* (gen. et sp. nov.), *N. atopus* (Bouček) *rigidus* (var nov.), *Monograptus thomasi, M.* cf. *yukonensis, M. yaliensis* (sp. nov.), *M. nyalamensis* (sp. nov.), *M. immaturus* (sp. nov.) and *Nowakia acuaria.* The upper part of this formation is alternating beds of grey shales and thin-bedded limestones, carrying *Nowakia acuaria, Guerichina xizangensis* (sp. nov.), *Metastyliolina, Styliolina, Viriatellina, Crassilina,* together with *Leiopteria* sp., *Michelinoceras* sp., etc. Of special significance is the occurrence of monograptid faunule which is first known in China. Of this faunule, *Monograptus thomasi,* originally found from the Wilson's Creek Shale in Victoria of Australia, has recently been reported from the Pragian stage in Yukon of Canada, in Nevada of the United States, in Пай-Хое of the Soviet Union and in Malaya. *Monograptus yukonensis,* the widespread species, first recorded in the Road River Formation in Yukon of Canada, has of late been made known from the Pragian stage in Alaska and Nevada of the United States, in Bohemia of Czechoslovakia, in Thailand, in Malaya and in the Soviet Union. Concurrently with *Monograptus* cf. *yukonensis, Neomonograptus atopus* (=*Pristiograptus atopus* Bouček) has been seen only in the Dvorce-Drokop limestone of the Pragian stage in Czechoslovakia. Besides, this faunule contains some endemic new forms, all identified to be of the *M. yukonensis* type. As regards the tentaculite faunule, *Nowakia acuaria,* the characteristic species of the Pragian stage in the world, is often found associated with *M. yukonensis. Guerichina xizangensis* (sp. nov.) bears a similarity with *G. strangulata* of the *G. strangulata* zone of the Pragian stage in Bohemia of Czechoslovakia. Judging from the faunal assemblages, the Liangquan Formation should be referred to the Pragian stage of Lower Devonian (late Sigenian to early Emsian) and may be correlated with all the above-mentioned corresponding horizons outside this country. As far as our present knowledge goes, they represent the youngest *Monograptus*-bearing horizon all over the world.

The Pochu Group, 256 m thick, is composed of grey median- to thick-bedded quartzose sandstones, containing only plant fragments at the top. It lies conformably on the Lower Devonian Liangquan Formation and is overlain by the Lower Carboni-

ferous Yali Formation. Taking into consideration the lithological character and the stratigraphical position, it may be regarded as the Middle and Upper Devonian, corresponding approximately to the "Muth Quartzite" in western Himalayas.

Carboniferous

Here the Carboniferous is distributed in the Nyalam and Tingri districts. At Yali and Naxing, north of Nyalam, the Carboniferous rocks may be differentiated into two divisions: the Yali Formation below and the Naxing Group above (Fig. 3).

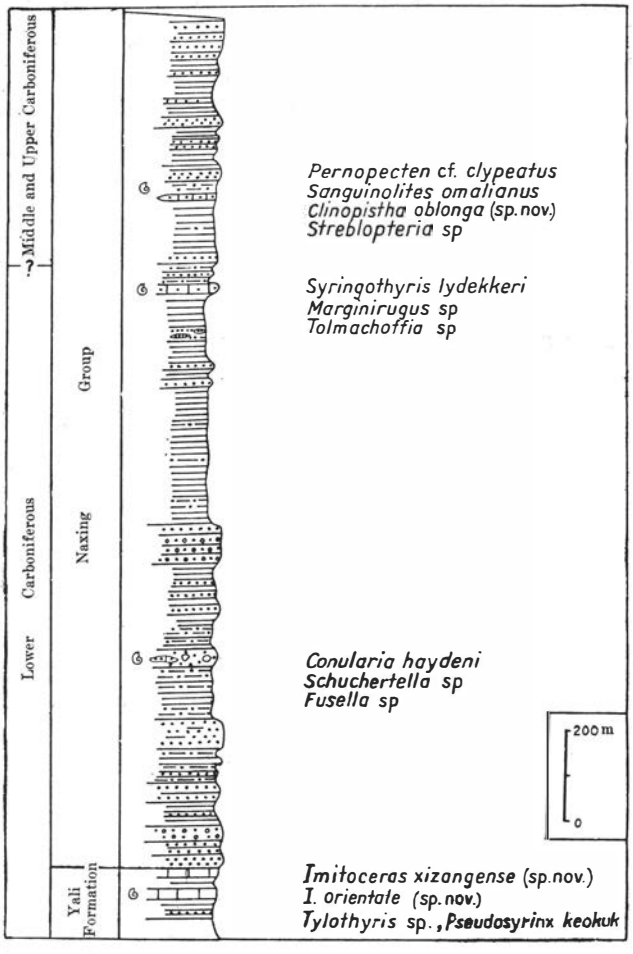


Fig. 3. Columnar section of the Carboniferous from Yali to Naxing, north of Nyalam district.

The Yali Formation 126 m thick consists chiefly of greyish-black shales intercalated with argillaceous limestone at the upper part. It yields *Imitoceras orientale* (sp. nov.), *I. xizangense* (sp. nov.), *I. yaliense* (sp. nov.), *Tylothyris* sp., *Pseudosyrinx keokuk*, *Girtyella* sp., etc. *I. orientale* (sp. nov.) bears a similarity to *I. compressum* from the basal part of the Kinderhookian Series in North America. *Tylothyris* is known from the Lower and Middle Carboniferous, but *Pseudosyrinx keokuk* is an early Lower Carboniferous species in North America. So far as the faunal assemblage is concerned,

the Yali Formation may be assigned to the early Lower Carboniferous (early Tournacian).

The Naxing Group is composed chiefly of greyish-black shales intercalated with conglomerates, sandstones and marls, measuring 1,888 m in thickness. In accordance with the lithological characters and fossil contents, it may be subdivided into three parts. The lower part carries, together with *Conularia, Fusella, Eochoristites, Schuchertella* and *Composita.* The middle part is characterized by primitive dictyoclostids, including *Syringothyris, Marginirugus* and *Tolmatchoffia.* In the vicinity of Selung, there is a series of shales, most probably deposited synchronously with the middle part of this group, where occur the Visean *Gigantoproductus, Striatifera, Syringothyris,* etc. The upper part of this group yields, among other fossils, *Pernopecten, Streblopteria, Aviculopecten, Sanguinolites,* etc., which are in common with or, at least, akin to those from the Middle and Upper Carboniferous in Europe. Judging from the fossil aspects, the lower and middle parts of this group may belong to the Tournacian and the Visean of Lower Carboniferous respectively, and the upper part is assigned provisionally to the Middle and Upper Carboniferous.

Permian

In the southern part of this region, the Permian is named as the Selung Group by the Shisha Pangma Scientific Research Party in 1964.

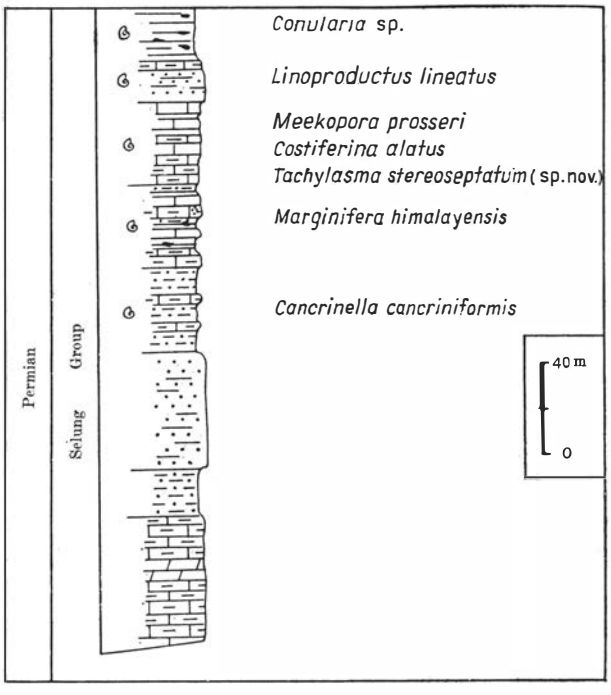


Fig. 4. Columnar section of the Permian from Naxing to Tulung, north of Nyalam district.

The Selung Group is widely distributed in Nyalam, Tingri, Chilung and Tingkye districts. At Tulung and Naxing, it is composed of limestones, sandstones and sandy shales with the lower part faulted, and the exposed thickness is about 281 m (Fig. 4).

This group contains among other fossils the following: *Neospirifer, Spriferella, Dictyoclostus, Linoproductus, Waagenoconcha, Costiferina, Stenoscisma, Meekopora, Fistulotrypa, Stenopora, Polypora, Fenestella, Streblotrypa, Lophophylloidium, Wannerophyllum, Tachylasma, Lytvolasma, Ufimia, Plerophyllum,* etc. However, no fusulinids have yet been found. It seems that the fossil assemblages here resemble those from the "Zewan Beds" and the "*Productus* Shales" in western Himalayas, and those from the Wargal Formation in Salt Range. Thus the Selung Group may be considered to be the late Lower Permian. Since no definite forms of the Loping Series of South China have yet been found from here, it is probable that in this region there is a paraconformity between Permian and Triassic.

In the northern part of this region, the Permo-Carboniferous rocks are, up to now, known as the oldest strata, which crop out in Kangma and Ngamring districts. In the vicinity of Kangma, the Permian is composed of a series of slightly metamorphic rocks, namely, conglomerate, quartzite, slate and crystalline limestone with simple sedimentary rhythm, attaining a thickness of about 350 m. The crystalline limestone yields *Chonetella nasuta, Stenoscisma gigantea, Athyris xetra,* etc., which are similar to those from the Selung Group in the southern part of this region.

Triassic

The Triassic rocks are well developed in this region, especially in the southern part, and may be divided in ascending order into the Tulung Group, the Qulonggongba Formation and the Derirong Formation, including 14 ammonite zones, 3 lamellibranch zones and one zone of *Ichthyosauria* (shown in Table 2).

The Tulung Group, typically developed in the vicinity of Tulung of Nyalam, comprises the interbedding of limestones, bioclastic limestones and sandy shales, with a thin bed of dolomite at the base. Its total thickness amounts to 640 m. This group containing 11 ammonite zones (Table 2, Zones (1)—(11)) may be subdivided into three units: the lower part is composed of the Zones (1)—(5) (Lower Triassic), the middle part is equal to the Zones (6)—(7) (Middle Triassic) and the upper part to the Zones (8)—(11) (Carnic to Lower Noric).

The Qulonggongba Formation, 465 m in thickness, consists chiefly of the interbedding of siltstones and sandy shales, intercalated with thinly-bedded bioclastic limestones. It contains three ammonite zones (Table 2, Zones (12)—(14)) (Middle and early Upper Noric) and is famous for yielding *Himalayasaurus tibetensis* (gen. et sp. nov.). In the northern hill of Chutsung in Tingri, this formation yields among other fossils the hydroid *Spongiomorpha* (*Heptostylopsis*) cf. *ramosa. S.* (*H.*) *ramosa* is known to occur in the Upper Noric in Alps and Alaska. In the northern hill of Posong in Tingri, a limestone corresponding to those of this formation contains the belemnite *Asteroconites* aff. *savuticus* concurrently with ichthyosauria, ammonite, etc.

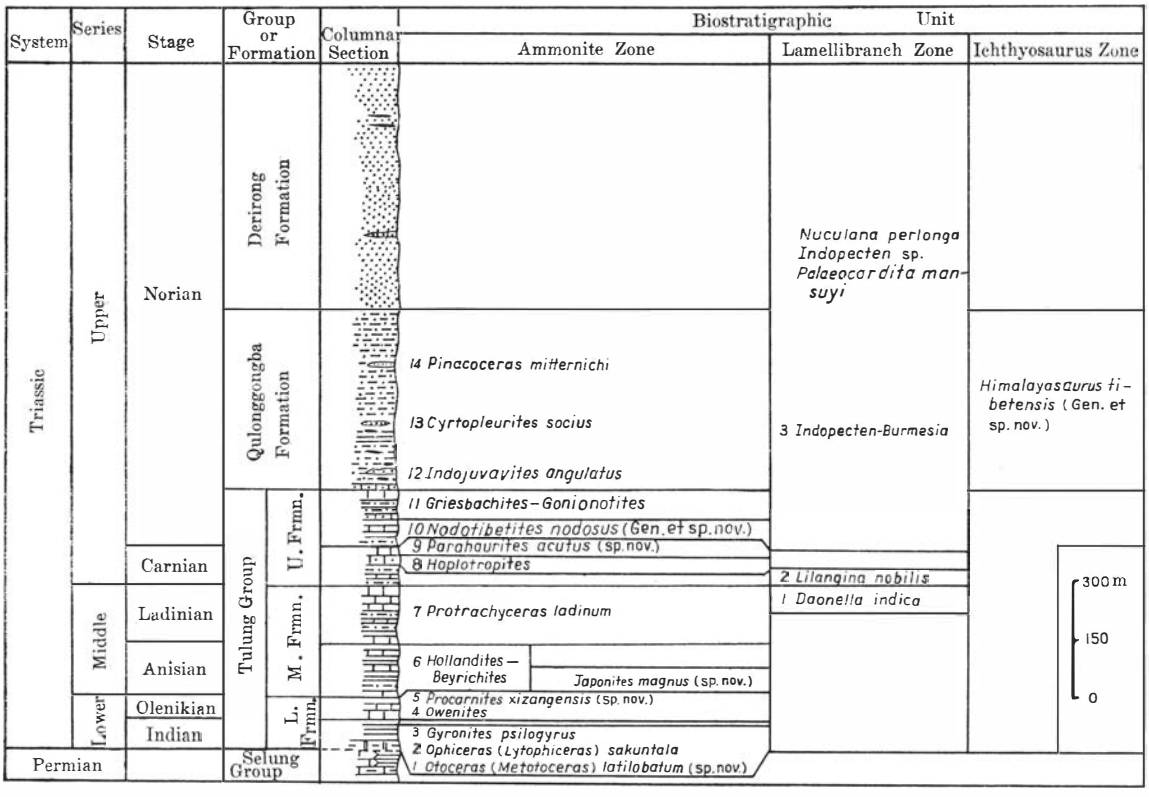
The Derirong Formation (at the type locality) near the Derirong bridge, to the east of Tulung, is composed chiefly of quartzose sandstones intercalated with sandy limestones and carbonaceous sandstones, attaining a thickness of 591 m. It yields the Upper Triassic *Palaeocardita mansuyi, Nuculana perlonga, Indopecten* sp.

In the following is given a brief account of the Triassic ammonite zones:

1. The *Otoceras* (*Metotoceras*) *latilobatum* Zone is of the lowest in Triassic, where

Table 2

The Triassic Sequence in the Southern Part of the Jolmo Lungma Region



occur *Glyptophiceras* cf. *liassrense* and *O.* (*Metotoceras*) *latilobatum* (sp. nov.), but no *Ophiceras* is present.

2. The *Ophiceras* (*Lytophiceras*) *sakuntala* Zone contains the following four species: *O.* (*Lytophiceras*) *sakuntala, O. serpentinum, O. demissum* and *Anotoceras intermedium. O. serpentinum* is not so widely distributed in this region as *O.* (*Lytophiceras*) *sakuntala.* For this reason, the present zone is named after the latter species.

3. The *Gyronites psilogyrus* Zone yields *Gyronites, Prionolobus, Kymatites, Koninckites, Glypeoceras* and *Flemingites.* With the exception of *Flemingites,* all of them are commonly met with in the "*Meekoceras* Bed" of western Himalayas or in the Mittiwali Member of the Mianwali Formation of Salt Range.

4. In Tulung, there exists between the *Gyronites* Zone and the *Owenites* Zone an unfossiliferous bed, which probably corresponds to the Flemingitan of the Upper Indian Stage in western Himalayas.

5. The *Owenites* Zone contains only one fragmentary specimen identified as *Owenites.* However, it was found for the first time in this region, thus making possible the correlation of this ammonite zone with its equivalents in Asia as well as in America.

6. In the *Procarnites* Zone, the following genera may be recognized: *Procarnites, Proptychitoides, Eukashmirites, Anakashmirites, Hemiprionites, Gurleyites, Keyserlingites, Nordophiceras, Svalbardiceras, Xenodiscoides, Xenoceltites*?, *Pseudospidites, Iscu-*

litoides, Leiophyllites, Eophyllites, Anasibirites, etc. It should be pointed out that *Procarnites* was first discovered in the Himalayan region.

7. The *Hollandites-Beyrichites* Zone is characterized by *Hollandites* and *Beyrichites* and may represent the Anisic stage. It contains *Japonites, Gymnites, Anagymnites* and *Buddhaites* in the lower part. Special importance should be attached to the species *Japonites magnus* (sp. nov.), which is not only greater in number, but widely distributed in this region. Therefore, the *Japonites magnus* Subzone is suggested for the lower part of this zone.

8. The *Protrachyceras ladinum* Zone yields, with some endemic forms, abundant Ladinian members, including *Epigymnites, Apolococeras, Parapinacoceras, Paratrachyceras, Maclearnoceras,* which make their first appearance in this region. Except the last one, recorded from Canada (Tozer 1963), the others are originally known from the Alps. Thus the present ammonite zone may represent the Ladinic stage. This zone also carries a few Anisician forms *Beyrichites, Aristoptychites, Malletoptychites* and the Carnian ones *Joannites* and *Rimkites.*

9. It is yet uncertain whether the Lower Carnic exists or not in this region. The Upper Carnic may be separated into two ammonite zones: the *Hoplotropites* Zone below and the *Parahaurites acutus* Zone above. The *Hoplotropites* Zone contains Tropitidae in plenty, including *Hoplotropites, Tropites, Paratropites* and *Anatropites.* The *Parahaurites acutus* Zone is rich in Carnitidae, but lacking in Tropitidae. Thus, it may be correlated to the *Klamathites macrolobatus* Zone in Canada and in Nevada of the United States.

10. Directly resting on the *Parahaurites acutus* Zone is the *Nodotibetites nodosus* Zone, which may represent the Lower Noric. It affords *Nodotibetites* (gen. nov.), *Neotibetites, Anatibetites* and *Paratibetites,* of which the former two belong to the primitive type of Tibetitidae.

11. The *Griesbashites-Gonionotites* Zone contains *Griesbashites, Gonionotites, Guembelites,* etc., and may represent the upper part of the Lower Noric.

12. The *Indojuvavites angulatus* Zone may be correlated with the "*Juvavites* Horizon" in western Himalayas. Diener (1912) referred the "*Juvavites* Horizon" to the Lower Noric. Considering the occurrence in this zone of *Acanthinites* and *Cyrtopleurites,* which are usually present on higher beds, we are in favour of assigning this zone to the Middle Noric.

13. The *Cyrtopleurites socius* Zone carries *C. socius, C. bicrinatus,* etc., together with *?Helicitites, Parathisbites, Megaphyllites, Pinacoceras, Didymites, Indoclionites, Tibetites, Anatibetites,* etc., and may be correlated with the *C. bicrenatus* Zone in Europe.

14. The *Pinacoceras mitternichi* Zone is known, up to the present, to be of the uppermost in the Triassic, where occurs *P. mittarnichi,* together with *Distichites, Dittmarites* and *Ectolites.*

In the northern part of this region, i.e. from Ngamring to Chiachia, the Triassic rocks are less developed but greater in thickness. They are composed chiefly of variegated sandstones, shales, intercalated with basic volcanic rocks and radiolarian siliceous rocks. The variegated shales contain *Monotis salinaria,* while the siliceous rocks yield *Hexalonche* and *Cenosphaera,* etc. The fossil-bearing beds may represent the Noric stage with certainty.

Jurassic

The Jurassic rocks show their different characteristics in the southern and northern parts of this region.

Along Chilung, Tingri and Kangpa districts in the southern part of this region, the Upper Jurassic is named the Menkatun Formation, and the Middle and Lower Jurassic form a unit termed as the Niehnieh Hsiungla Group (Fig. 5).

The Niehnieh Hsiungla Group consists chiefly of limestones and quartzose sandstones with shale intercalations, amounting to 2,060 m in thickness. The lower part of this group carries the ammonites *Schlothemia, Sulciferites, Gleviceras* and the foraminifers *Orbitopsella, Rhapydionina,* etc., obviously belonging to the Lower Jurassic. The middle part of this group flourishes with lamellibranchia, including *Camptonectes lens, Goniomya* cf. *trapezicostata,* etc. At the higher bed of this part, there occur the ammonites *Dorsetensia* and *Witchella.* Accordingly, it is preferable to assign this part to the early Middle Jurassic (Bajocian), corresponding to the "Lungma Limestone" exposed in the south of Kangpa. The upper part of this group, yielding only some species of Macrocephalitidae, may represent the late Middle Jurassic (Callovian).

The Menkatun Formation is composed chiefly of silty shales and siltstones with thinly-bedded quartzose sandstones and clay nodules, exceeding 360 m in thickness. It contains, together with *Belemnopsis uhligi, Haplophylloceras strigile, Pterolytoceras exoticum, Virgatosphinctes densiplicatus,* all known as the characteristic forms of the "Middle Spiti Shales" and the lower part of the "Upper Spiti Shales" in the Spiti region of western Himalayas. Therefore, the Menkatun Formation belongs probably to the Upper Jurassic. At Menkatun, overlying on this formation are unfossiliferous greyish limestones, which seem to be of Cretaceous(?) in age. In Kangpa, this formation passes through its shales with *Himalayites* sp. and *Astarte spitiensis* into the succeeding Cretaceous Kangpa Group, which shows almost the same lithological characters as the former.

In the western hill of Hsimuti village, to the northeast of Tingri, the Jurassic limestones contain *Actinostromina grossa, Actinostromaria taenia* (sp. nov.), *A. tibetensis* (sp. nov.), *Bouneia irregularis* (sp. nov.), *Ptychochaetes* cf. *globosus,* identified to be of late Jurassic in age.

In the northern part of this region, the Jurassic rocks, exposed in Gyantse, are a series of thickly-bedded calcareous shales intercalated with sandstones. Higher up is a bed of sandy shales with belemnites and ammonites, which is of early Cretaceous in age (Valanginian).

Cretaceous

In this region the Cretaceous in the southern part is quite different in development from that in the northern part.

In the southern part, the Cretaceous rocks are well exposed in Tingri, especially in Kangpa, where the exposures were studied by H. Hayden (1907) and the fossils described by H. Douvillé (1916). After our careful investigation, the following divisions are preferably recommended, namely, the Kangpa Group in the lower, the Zongshan Formation in the middle, and the Jidula Formation in the upper.

The Kangpa Group comprises the formerly-called units: the "Giri Limestone", the

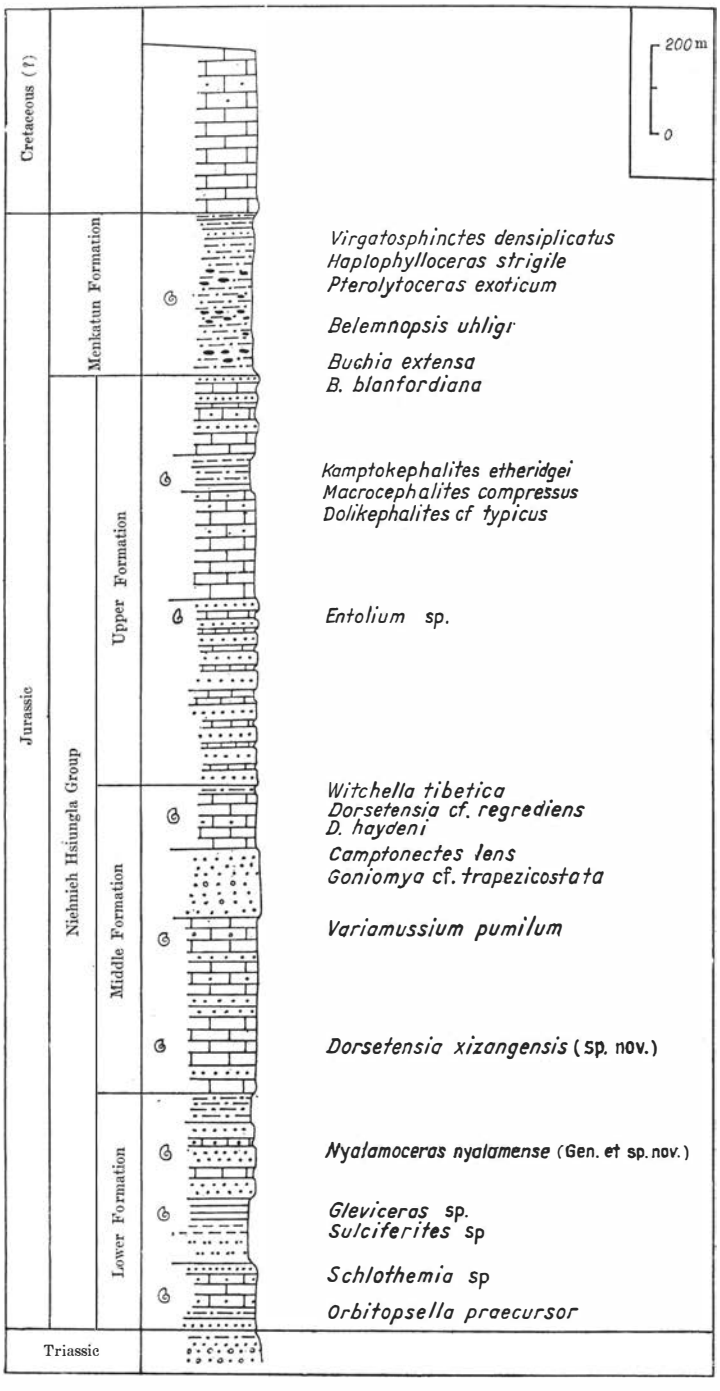


Fig. 5. Columnar section of the Jurassic in southern part of the Jolmo Lungma Region.

"Kampa Shales" and the "*Hemiaster* Shales" (by Hayden). In this group, the basal part contains the early Lower Cretaceous *Neohoploceras* etc.; the middle part affords *Mortoniceras, Dipoloceras, Oxytropidoceras* of late Lower Cretaceous (the latter two genera seen in the vicinity of Tingri); the upper part yields *Rotalipora, Calycoceras,*

Hemiaster front-acutus and *Camptonectes curvatus* of early Upper Cretaceous age. Thus the Kangpa Group may represent the early Lower Cretaceous to the early Upper Cretaceous (Valanginian to Turonian or Coniacian).

The Zongshan Formation consists of the three formerly-called "Scarp Limestones" and the "Tüna Limestone" (by Hayden). The lower part of this formation carries *Globotruncana linneiana, G. carinata, G. ventricosa,* etc., corresponding approximately to the Campanian stage. The upper part of this formation contains, together with other fossils, *Orbitoides media, Omphalocyclus macroporus, Hemipneustes compressus* and *Bournonia tibetica,* belonging probably to the Maestrichtian stage.

Directly overlying upon the Zongshan Formation is a series of quartzose sandstone, designated as the Jidula Formation, known previously as "Ferruginous Sandstone" (by Hayden). In the limestone intercalation of this formation, the following fossils were for the first time obtained: *Trochactaeon, Cymopolia tibetica* and *Uroleberis.* The former two are confined to the Cretaceous, but the latter one has been known to appear as early as in the Palaeocene. Above this formation, there exists a bed of limestone, which corresponds roughly to the *Cardita beaumonti* Bed of the Danian stage in Pakistan. According to the fossil aspects, it may be referred for the time being to the top part of the Cretaceous.

The Cretaceous in the northern part of this region is represented by the Shigatze Group, widely distributed in Jenpu, Shigatze, Lhatze and Ngamring, south of the Yalu Tsangpo River. Resting unconformably on the granites of the Yenshan stage, this group begins with basal conglomerates, which are succeeded immediately by the rhythmic interbedding of sandstones and shales intercalated with minor continental beds containing freshwater molluscans and plant fossils. The total thickness is estimated at 6,000—7,000 m. The name Shigatze Group was erected by the Tibet Geological Party of Academia Sinica (1951—1953) and believed to belong to the Tertiary. During the recent years, several kinds of fossils were collected from the limestone beds of this group, they are: from the lower part *Orbitolina concava, O. concava gatarica* and *Daxia cenomana* of early Upper Cretaceous (Cenomanian); from the middle and upper parts *Mammites* and *Plesioptygmatis* of Upper Cretaceous age. Thus the Shigatze Group is most probably confined to the Upper Cretaceous.

In the district of Gyantze, lying conformably upon the Upper Jurassic rocks is a series of sandstone and shale with the early Cretaceous *Calliptychoceras walkeri* and *Belemnopsis, Hibolithes,* etc. Above the fossil-bearing beds comes a series of thicker-bedded variegated sandstones and shales intercalated with cherts and siliceous limestones, containing *Globotruncana linneiana, G. ventricosa, G. fornicata,* etc. These foraminifers seem to be similar to those from the lower part of Zongshan Formation in the southern part of this region, belonging probably to the Campanian stage.

Tertiary

The Tertiary marine strata are distributed in Kangpa and Tingri districts in the southern part of this region. Near Kangpa, the Tertiary is well exposed and is named as the Zongpu Group. It comprises the strata from Hayden's "Gastropod Limestone" to "Dzongbuk Shales", attaining a thickness of 345 m. From the basal limestone come the early Palaeocene (Danian) *Bernaya expansa, Campanile ganesha, Heligmotenia* cf.

molli, Confsiscala indica, etc., which are usually met with in the *Cardita beaumonti* Bed of Pakistan. The lower part of this group is composed of limestones, bearing *Miscellanea miscella, M. stampi, M. meandrina, Daviesina langhami, Rhinoclavis pissarroi, Crommium pervicina* and *Spondylus rouaulti* of the Palaeocene age, which are the common forms in the Ranikot Series of Pakistan. The upper part of this group consists of shales with limestone intercalations, where prevail *Orbitolites complanatus, O. cotentinensis, Nummulites beaumonti, N. laevigatus, Fasciolites* (*Fasciolites*) *elliptica nuttalli,* etc. (the latter three seen in the vicinity of Tingri), which resemble those from the Laki Series and Khirthar Series of the Eocene in Pakistan. The uppermost bed of this group may be referable to the Middle Eocene (Lutetian).

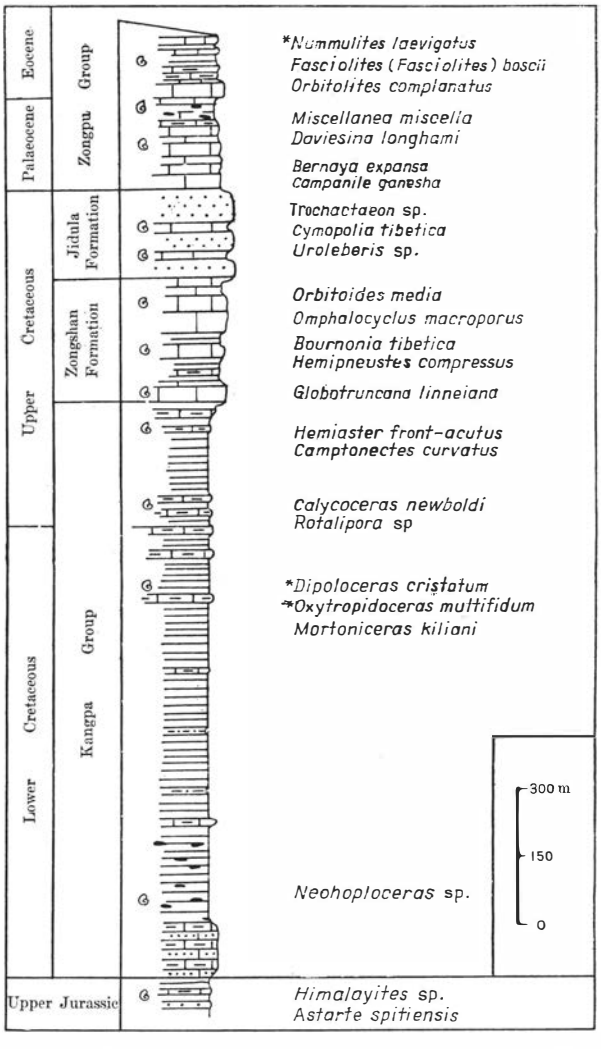


Fig. 6. Columnar section of the Cretaceous and Lower Tertiary in Kangpa district.
(* seen in Tingri)

So far as our investigation goes, all the Tertiary rocks exposed in Kangpa and Tingri districts are cut off by faults at the top parts. The youngest bed here is, up

to the present, known to be the Middle Eocene (Lutetian). It seems that in this region the history of marine sedimentation has been closed post Eocene.

Concluding Remarks

From the foregoing statement on the stratigraphy of the Jolmo Lungma Region, some points may be remarked as follows:

1. In view of the stratigraphical development, the marine succession from the Lower Ordovician (possibly from Cambrian) to Eocene (possibly even younger) is rather complete in the southern part of this region. The strata were deposited in an almost continually depressed shallow sea. The Upper Devonian rocks afford some plant fragments indicating an uplifting of the earth crust. There is probably a sedimentary hiatus between the Permian and Triassic. The occurrence of the Upper Triassic flora reveals that the earth crust might have uplifted once again. The top part of the Eocene formation has been faulted, with the result that the exact position of the youngest marine strata in this region is undeterminable. However, generally speaking, the history of the marine sedimentation in this region has been closed post Eocene.

In the northern part of this region, only Permo-Carboniferous and Mesozoic are observed, the older strata seem not exposed. The Upper Cretaceous Shigatze Group is deposited on the granite of the Yenshan Stage (79×10^6 years). It is most probable that there is a sedimentary discontinuity between the Lower and Upper Cretaceous series, while in the southern part of this region, the Upper Cretaceous rests conformably on the Lower Cretaceous.

2. From the sedimentary point of view, the strata in the two parts of this region are deposited in different conditions. Those in the southern part are greater in thickness but simpler in the lithological association and rich in fossils. They were deposited in a shallow sea. These sediments seem to be of the so-called platform type. In the northern part, the Permian rocks, especially the Mesozoic ones, are different from those in the southern part. They are very great in thickness, simple in fossils, complex in lithological components. They are deposited in a flysch type with radiolaria-bearing siliceous rocks, intercalated with continental sediments and basic volcanic rocks. These sediments resemble strongly those of the so-called geosyncline type.

3. In the faunal aspect, most of the Palaeozoic faunas in this region are in common with those of North China, Central China and the marginal area of Northwest China. Most Ordovician nautiloids are known to occur in North China, and some in Central China. The Ordovician trilobites are in common with those from Central China. It is evident that all the sea bodies of the regions mentioned above were connected during the Ordovician period. But the faunal difference between North, Central and South China is due to the different environment of the sea basins. The Silurian graptolite shales and the cephalopod and coral limestones are similar to those in Central China. The discovery of the Devonian monograptid faunule is very remarkable. It is the youngest graptolithic horizon in China. This faunule associated with Tentaculites contains some forms known to occur in Europe, Australia and North America. It reveals that these regions just mentioned were all related to the Jolmo Lungma region in the Pragian time. The Carboniferous and Permian corals, bryozoans and brachiopods and the Carboniferous ammonites resemble closely those in Sinkiang and Inner

Mongolia. However, no fusulinids are found in this region. The Mesozoic and Cenozoic faunas strongly resemble those of the Tethys and other parts of the Himalayas, but also contain many endemic forms.

References

中国科学院西藏工作队地质组 1955 科学通报，(7) 62.
李 璞等 1965 科学通报，(10) 925.
施雅风、刘东生 1964 一九六四年北京科学讨论会文集.
顾庆阁 1965 地质论评，**23** (4)，256.
Douvillé, H., 1916 *Paleont. Indica, N. S.*, **V**, Mem. 3.
Egeler, C. G. *et al.* 1964 *22nd Intern. Geol. Congr.*, pt. 11.
Fuchs, G. R. 1964 *Verhandl der Geologischen Bundesanstalt*, Heft 1.
Gansser, A. 1964 *Geology of the Himalayas*, Interscience Publishers.
Gysin, M. & Lombard, A. 1960 *Ecl. Geol. Helv.*, **53** (1).
Hagen, T. 1959 *Ecl. Geol. Helv.*, **52**.
Hayden, H. 1907 *Mem. Geol. Surv. India*, **36**, pt. 2.
Heron, A. M. 1922 *Rec. Geol. Surv. India*, **54**, pt. 2.
Strachan, I. *et al.* 1964 *Geol. en. Mijub.*, **43**.
Vredenburg, E. W. 1909 *Pal. Indica, N. S.* **3** (1).
Wager, L. R. 1939 *Rec. Geol. Surv. India*, **74**, pt. 2.

Table 1

The Stratigraphy in the Southern Part of the Mount Jolmo Lungma Region

System	Series	Group or Formation		Thickness (m)	Lithologic Characters	Main Fossils
					Fault	
Tertiary	E_2	Zongpu Group	Upper	147	Shale intercalated with limestone	*Nummulites beaumonti*, *N. laevigatus*, *Fasciolites (F.) boscii*, *Orbitolites cotentinensis*, *O. complanatus*, *Assilina subpinosa*
	E_1		Middle	120	Massive limestone intercalated with shale at the upper part	*Miscellanea miscella*, *M. stampi*, *M. meandrina*, *Daviesina langhami*, *Spondylus rouaulti*, *Rhinoclavis pissarroi*
	Danian		Lower	78	Nodular limestone and massive limestone	*Bernaya expansa*, *Campanile ganesha*, *Confsiscala indica*, *Diconomorpha* cf. *elegans*, *Heligmotenia* sp.
Cretaceous	K_2	Jidula Formation		188	Quartzose sandstone intercalated with sandy limestone at the middle and upper parts	*Uroleberis* sp., *Xestoleberis* sp., *Trochactaeon* sp., *Cymopolia tibetica*, *Acicularia americana*
		Zongshan Formation		278	Limestone intercalated with calcareous shale	*Orbitoides media*, *Omphalocyclus macroporus*, *Bournonia tibetica*, *Hemipneustes compressus*, *Globotruncana linneiana*, *G. ventricosa*
	K_1	Kangpa Group		1187	Dark grey shale intercalated with marl and sandstone	*Hemiaster front-acutus*, *Calycoceras newboldi*, *Dipoloceras cristatum*, *Oxytropidoceras multifidum*, *Mortoniceras kiliani*, *Neohoploceras* sp.
Jurassic	J_3	Menkatun Formation		360	Dark grey shale intercalated with sandy shale	*Haplophylloceras strigile*, *Virgatosphinctes densiplicatus*, *Pterolytoceras exoticum*, *Belemnopsis uhligi*, *Buchia extensa*, *Buchia spitiensis*
	J_{1+2}	Niehnieh Hsiungla Group		2060	Limestone intercalated with quartzose sandstone, and with deep grey shale at the lower part	*Camptonectes lens*, *Goniomya* cf. *trapezicostata*, *Witchella tibetica*, *Dorsetensia* cf. *regrediens*, *Schlothemia* sp., *Orbitopsella praecursor*
Triassic	T_3	Derirong Formation		591	Light grey quartzose sandstone intercalated with carbonaceous shale and coal-lines.	*Palaeocardita mansuyi*, *Nuculana perlonga*, *Indopecten* sp., *Myophoria* sp.
		Qulonggongba Formation		465	Deep grey shale interbedded with sandy shale, and intercalated with thin-bedded marl	*Pinacoceras mitternichi*, *Cyrtopleurites socius*, *Indojuvavites angulatus*, *Asteroconites* aff. *savuticus*, *Indopecten serraticosta*, *Himalayasaurus tibetensis* (gen. et sp. nov.)
		Tulung Group	Upper Formation	278	Grey limestone intercalated with deep grey sandy shale, shale, and with dolomite at the basal part	*Burmesia lirata*, *Paratibetites* cf. *wheeleri*, *Nodotibetites noclosus* (gen. et sp. nov.), *Parahaurites acutus* (sp. nov.), *Hoplotropites jokelyi*, *Lilangina nobilis*
	T_2		Middle Formation	259		*Daonella indica*, *Protrachyceras ladinum*, *Protrachyceras* cf. *longobardicum*, *Hollandites voiti*, *Beyrichites srikanta*, *Japonites magnus* (sp. nov.)
	T_1		Lower Formation	103		*Procarnites xizangensis* (sp. nov.), *Owenites* sp., *Gyronites psilogyrus*, *Ophiceras serpentinum*, *Otoceras (Metotoceras) latilobatum* (sp. nov.), *Claraia pinkandana*
					Paraconformity	
Permian	P	Selung Group		281	Sandstone, sandy shale and limestone	*Waagenoconcha purdoni*, "*Dictyoclostus*" *gratiosus*, *Costiferina alatus*, *Wannerophyllum* cf. *rothopletzi*, *Tachylasma stereoseptatum* (sp. nov.)
					Fault	
Carboniferous	C_{2+3}	Naxing Formation		1888	Dark grey shale intercalated with light grey quartzose sandstone and minor marl	*Pernopecten* cf. *clypeatus*, *Sanguinolites omalianus*, *Syringothyris lydekkeri*, *Tolmatchoffia* sp., *Fusella holdhausi*, *Conularia haydeni*
	C_1	Yali Formation		126	Dark grey shale intercalated with thin-bedded marl at the upper part	*Imitoceras orientale* (sp. nov.), *I. xizangense* (sp. nov.) *I. yaliense* (sp. nov.), *Tylothyris* sp., *Pseudosyrinx keokuk*
Devonian	D_{2+3}	Pochu Group		256	Light grey quartzose sandstone	
	D_1	Liangquan Formation		40	Deep grey shale intercalated with thin-bedded limestone at the upper part	*Guerichina xizangensis* (sp. nov.), *Nowakia acuaria*, *Neomonograptus atopus rigidus* (gen. et var. nov.), *N. himalayensis* (gen. et sp. nov.), *Monograptus thomasi*, *M.* cf. *yukonensis*
					Fault	
Silurian	S_2	Shiqipo Group	Upper Formation	46	Limestone intercalated with deep grey shale and quartzose sandstone at the upper part; dark grey shale at the lower part, with quartzose sandstone at the basal part	*Michelinoceras jucundum*, *Monoclimacis vomerina subgracilis*, *Pristiograptus dubius*
	S_1		Lower Formation	90		*Climacograptus medius*, *C. normalis*, *Monograptus priodon*, *Streptograptus lobiferus*, *Geisonoceras* sp. nov., *Favosites* sp.
Ordovician	O_3	Hongshantou Formation		70	Brown shale intercalated with fine-grained sandstone	
	O_2	Chiatsun Group	Upper Formation	97	Light-purple, light grey limestone at the upper part; grey limestone intercalated with siltstone at the lower part	*Sinoceras chinense*, *Curtoceras* sp., *Michelinoceras xuanxianense*, *Beloitoceras* sp. nov., *Michelinoceras* spp. nov., *Ellipsoellipticus himalayensis* (sp. nov.)
	O_1		Lower Formation	726		*Aporthophyla* sp. nov., *Eucalymene tuberculata* sp. nov., *Dideroceras* sp., *Ordosoceras* spp. nov., *Manchuroceras* sp., *Maclurites* spp. nov.
Cambro-Ordovician	ϵ–O	Rouqiecun Group		40—160	Crystalline limestone at the upper part, changing downwards into diopside-quartz-schist	
					Fault	
Pre-Cambrian	Anϵ	Jolmo Lungma Group				