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GEOLOGY OF WESTERN NEPAL AND A COMPARISON WITH KUMAUN, INDIA*

by

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(with 6 text-figures, 1 table and 1 plate)

Abstract

Geologic structure of western Nepal has two tectonic systems, one being the Himalayan gneiss zone and its klippes of allochthonous nature and the other being the Midland meta-sediment zone of autochthonous or parautochthonous nature; the former is thrust over the latter along a salient tectonic zone called the Main Central Thrust zone.

The Himalayan geneisses composed of high grade metamorphic rocks of the Barrovian type have a monotonous structure dipping gently northward. Meanwhile, the Chakhure-Mabu crystallines, which make up a klippe on the Midland meta-sediments, have been derived from the root of the Himalayan gneisses in the north. It is considered that the Jajarkot crystallines also form another klippe derived from the Main Central thrust zone in the north.

The Midland meta-sediments show an anticlinorium structure composed of a thick sequence of platform-type sediments and are divided into five formations. The lower part of them is composed of the calcareous Ila Formation with stromatolite and the quartzite-rich Dali Formation, both of which are respectively correlative with the upper calcareous Subgroup and the middle siliceous Subgroup of the Midland meta-sediment Group of central Nepal. The Midland meta-sediments of western Nepal is considered to range in age from Riphean to Eocambrian despite of a possibility that the upper part would be of Palaeozoic in age.

The Main Central Thrust zone is a profound tectonic zone characterized by intensely mylonitized rocks accompanied with characteristically blastomylonitic "augen" gneiss and garnet-mica-chlorite phyllitic schist.

Geology and tectonics of western Nepal are correlated very well with those of eastern Kumaun of India immediately adjacent to the west.

Introduction

The Nepal Himalayas have been subjected to geological investigations intermittently but systematically by many geologists of Hokkaido University since Professor S. Hashimoto started geological work along the route from Kathmandu to Mt. Manaslu in 1955, and the results were published in "Geology of the Nepal Himalayas" in 1973, in which Ando and Ohta described a result of route survey from Surkhet to the Chinese border via Jumla in western Nepal. According to them, two major geological units are distinguished in the Midland (Lesser Himalayas), namely, autochthonous Midland meta-sediments with Jumla meta-sediments and allochthonous Chakhure-Mabu gneisses which rest over the former.

The allochthonous nature of the Midland meta-sediments was, however, insisted by Hagen (1969), who investigated in the whole Nepal, and Fuchs and Frank (1970), who

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made an excellent geological map of the area between the rivers Kali Gandaki and Thulo Bheri. In addition, a different idea was offered by them in respect to the age of the Midland meta-sediments. Meanwhile, the geology of Kumaun of India has recently been investigated by a large number of geologists including Valdiya and Gupta (1972), Power (1972), Mehdi et al. (1972), Rupke (1974), Bhattacharya (1974), Agawal (1974), Kumar and Agawal (1975) and Valdiya (1977).

In spite of the studies mentioned above, the geology of western Nepal has remained unsolved in many respects as compared with that of Kumaun adjacent to the present area.

This paper gives a brief description of geology and structure surveyed in 1977 of western Nepal among Dailekh, Jajarkot, Jumla and Rara Lake as well as discussing a geological correlation between this region and Kumaun.

Lithostratigraphy

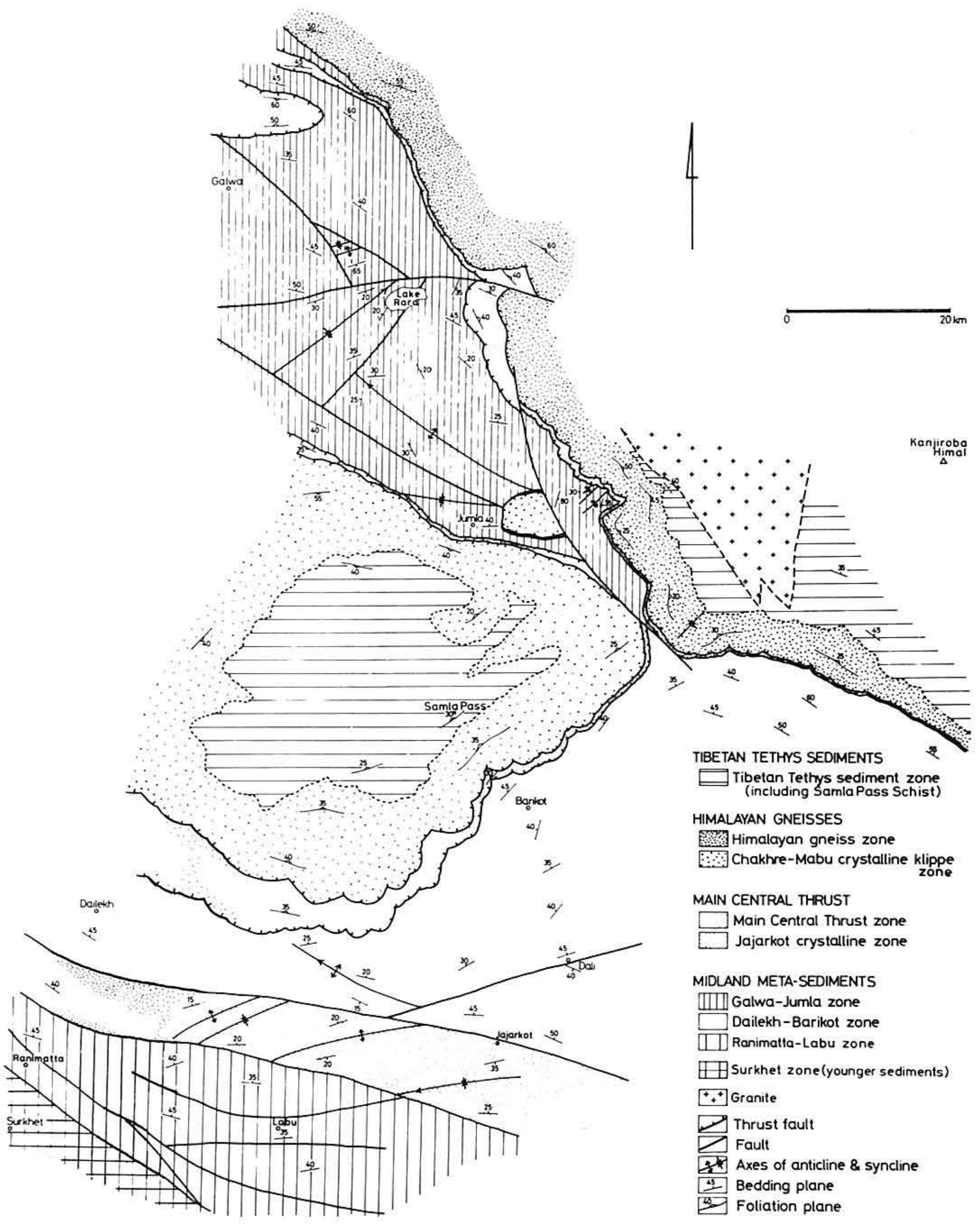
Geologic structure of western Nepal is divided into seven units by faults and thrusts from north to south as follows (Text-fig. 1):

1) Tibetan Tethys sediment zone: Composed of fossiliferous Tethys sediments of Palaeozoic to Mesozoic age.
2) Himalayan gneiss zone: Composed of highly metamorphosed rocks such as garnet-kyanite gneiss, sillimanite gneiss and migmatites.
3) Main Central Thrust zone: A distinct tectonic zone between the Himalayan gneisses and the Midland meta-sediments with various widths in places.
4) Midland meta-sediments zone: Occupying a vast area of the Midlands, it is composed of various sediments, a large portion of which is slightly metamorphosed. This zone is subdivided into three subzones.
   a) Galwa-Jumla zone.
   b) Dailekh-Barikot zone.
   c) Ranimatta-Labu zone.
5) Chakhure-Mabu crystalline klippe zone: This crystalline allochthon has been dislocated southward from the Himalayan gneiss zone to the north.
6) Jajarkot crystalline zone: Appearing to be a kind of klippe derived from the Main Central Thrust zone to the north.
7) Surkhet zone: Appearing to correspond to the Piuthan zone whose sediments are of Mesozoic to Tertiary in age (Hagen, 1969); not covered in this paper because of a lack of data about the zone.

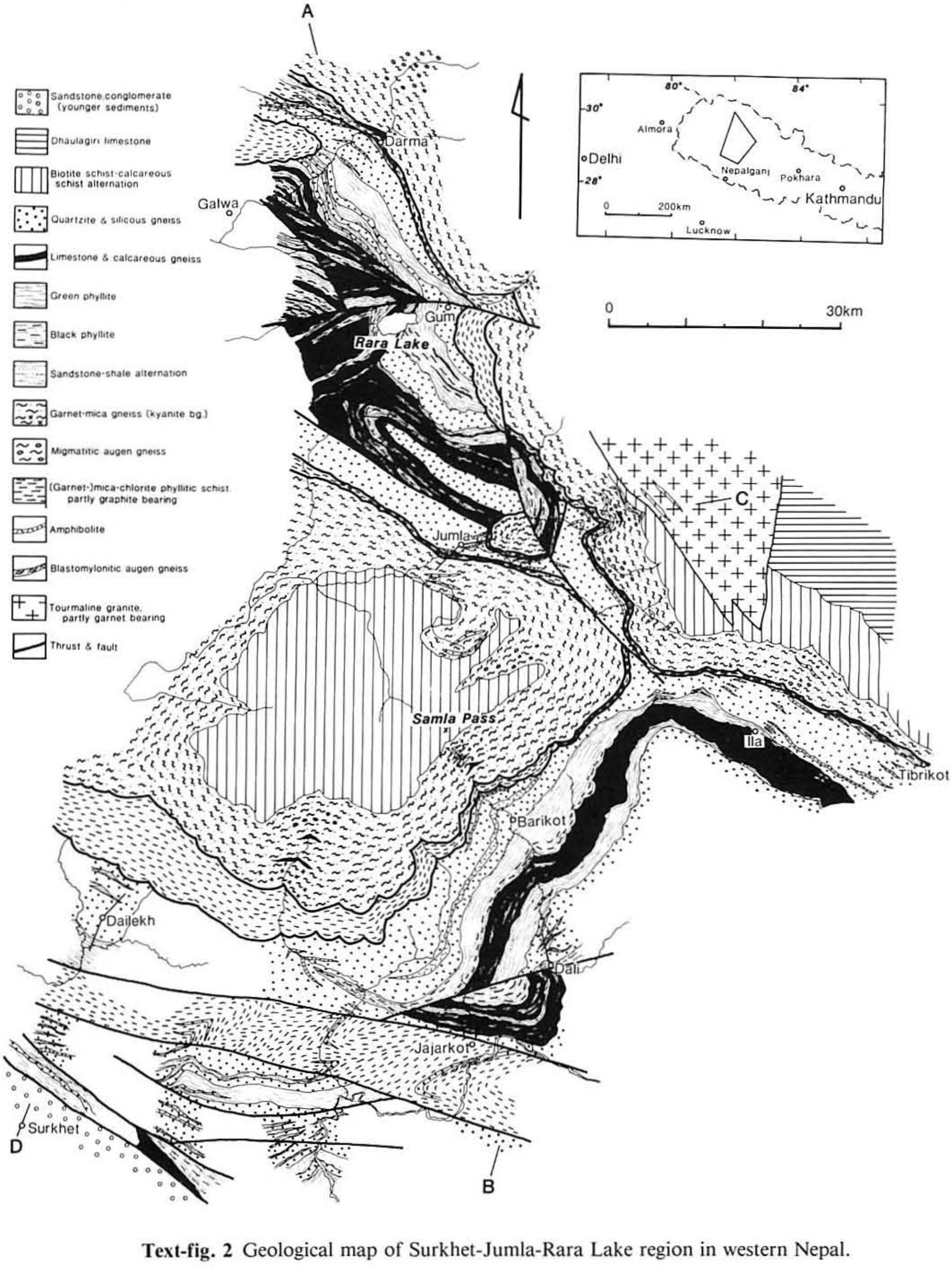
Text-figs. 2, 3-a and 3-b are a geological map and lithostratigraphical columnar sections, respectively.

Tibetan Tethys sediment zone

Only a small area of the Tibetan Tethys sediment zone was surveyed by us. According to Fuchs and Frank (1970), however, 2,000 to 4,000 *m* thick Dhaulagiri Limestone consisting of argillo-arenaceous limestone occurs in the Kanjiroba Himal* area north-



Text-fig. 1 Structural division and tectonic map of Surkhet-Jumla-Rara Lake region in western Nepal.



Text-fig. 2 Geological map of Surkhet-Jumla-Rara Lake region in western Nepal.

east of the present area. Erratic boulders in the Garpung Khola* in the northeastern margin of the present area, which show an alternation of calcareous sandstone and cross-laminated sandstone, seem to be derived from the Dhaulagiri Limestone.

A thick sequence (over 2,000 *m*) of calc-argillaceous crystalline schist crops out in the Samla Pass area; this schist will be described later as Samla Pass schist.

Himalayan gneiss and Chakhure-Mabu crystalline klippe zones

Himalayan gneisses occupy the northern and central regions separately in the surveyed area. The gneisses in the northern region show a homoclinal structure dipping northeast, while those in the central region occur as a klippe with a synform structure which is named the Chakhure-Mabu crystalline klippe.

The Himalayan gneisses consist mainly of banded pelitic and psammitic gneiss, siliceous gneiss and calcareous gneiss. Migmatites with schlieren and augen structures also occur in parts. The total thickness exceeds 7,000 *m* (Text-fig. 3-a). Fuchs and Frank (1970) designated them as the Upper Crystalline Nappe.

While quartz and plagioclase are the common constituents, the main mineral assemblages of these gneisses are as follows:

sillimanite-biotite-(muscovite)
kyanite-garnet-biotite-muscovite
garnet-biotite-muscovite
calcite-biotite-muscovite-microcline-(scapolite)
calcite-diopside-hornblend-garnet-biotite-microcline-(scapolite)
diopside-biotite-microcline

Kyanite often reaches up to 3 *cm* in length (Plate 1-E). Sillimanite occurs as acicular aggregates along quartz grain boudaries. Coarse-grained migmatitic gneiss with augen-shaped microcline of several centimeters in size sporadically occurs (Plate 1-F). Metamorphic grade in the Himalayan gneiss zone appears to decrease slightly upward.

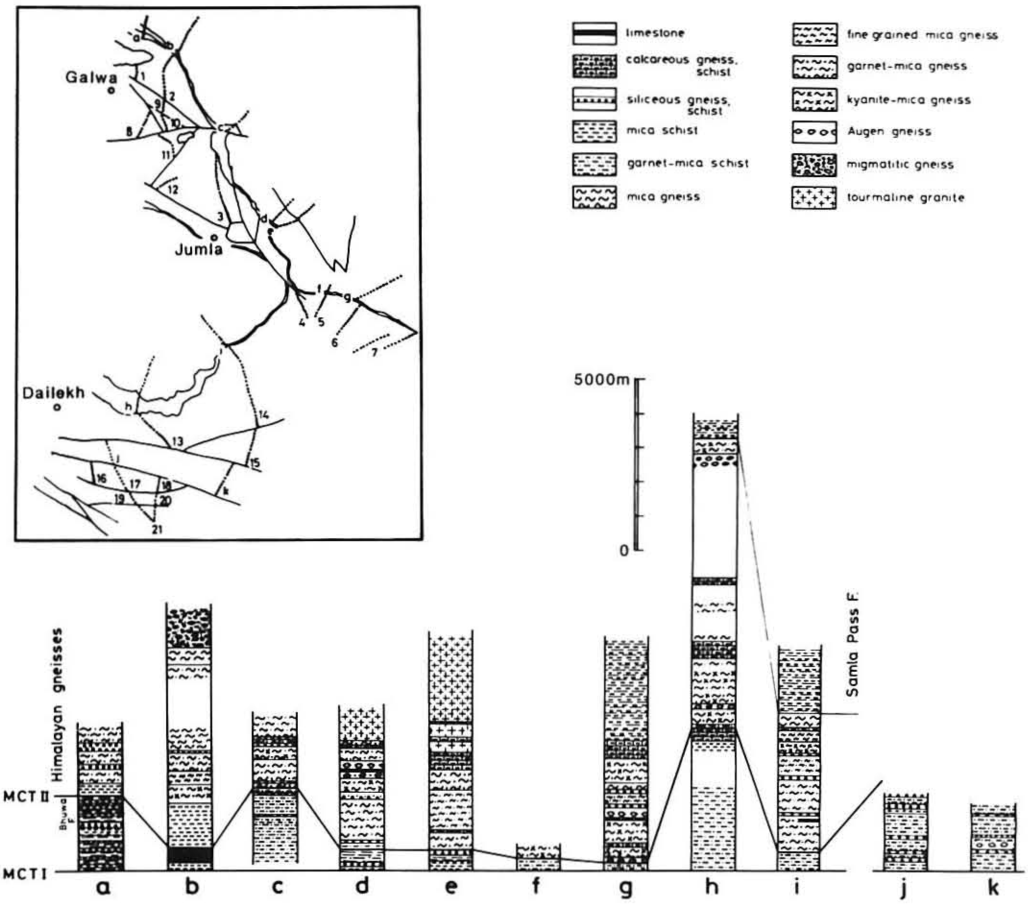
In this zone the Himalayan gneisses are conformably overlain by the Samla Pass schist. However, the passage between them is sharp in both lithology and metamorphic grade.

The Samla Pass schist occupies a vast higher plateau over 4,000 *m* to the south of Jumla and constitutes the Chakhure-Mabu crystalline klippe zone together with the underlying Himalayan gneisses. The Samla Pass schist consists of fine alternating beds, of fine-grained biotite-muscovite schist and biotite spotted calcareous schist, in a thickness of a few to ten centimeters; the former being relatively predominant in the upper part and the latter in the lower part. The rugged weathered surface is characteristic of this schist (Plate 1-A). Calcareous layer has a more competency for folding than psammitic layer and its axial plane dips gently northward along which dykes and veins of tourmaline granite are intruded.

Main Central Thrust and Jajarkot crystalline zones

Main Central Thrust zone, which has been designated as the Lower Crystalline

* Himal and Khola mean a mountain range and a river in Nepalese, respectively.



Text-fig. 3-a Lithostratigraphical columnar sections along mapped routes in the Himalayan gneiss and the Main Central Thrust zones. Dotted lines represent mapped routes. Alphabets under columns correspond to those of routes. MCT I and II represent the Main Central Thrust I and II, respectively. Figures of routes refer to Text-fig. 3-b.

Nappe (Fuchs and Frank, 1970), occurs beneath the Himalayan gneisses of the Himalayan gneiss zone and the Chakhure-Mabu crystalline klippe zone. The thickness of this zone varies from hundreds to several thousand meters from place to place (Text-fig. 3-a). This zone is made up of a pile of mica-chlorite phyllitic schist with or without rotated garnet porphyroblasts, green schist, green and black phyllites, quartzite and amphibolite. Graphite phyllite also occurs characteristically. The rocks are all intensely sheared. Blastomylonitic augen gneiss, which occurs widely in the Main Central Thrust zone of central and eastern Nepal (Hashimoto *et al.,* 1973), is observed just south of Jajarkot in the Jajarkot crystalline zone and found as erratic boulders on the east side of Rara Lake. The augen of this blastomylonite is cataclastic microcline perthite of 0.5-1 *cm* in diameter.

The same rock association of the sheared phyllites, schists and blastomylonitic augen gneiss also occurs in the Jajarkot crystalline zone, which is, therefore, considered to be a klippe derived from the Main Central Thrust zone to the north, although it is now bounded by steep faults on both the north and the south sides (Text-figs. 3-a and 4).

Midland meta-sediments zone

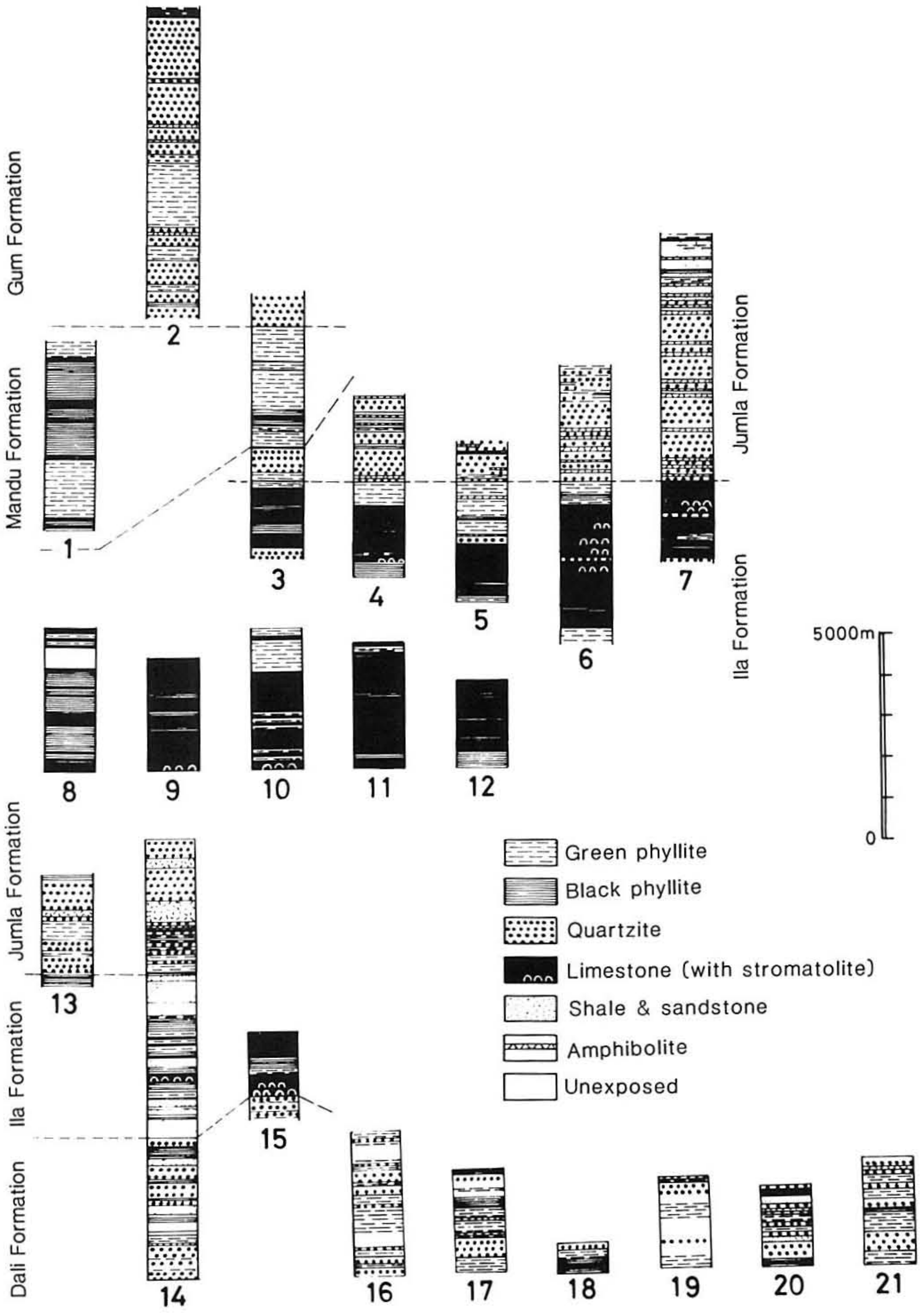
Midland meta-sediments are distributed in three zones as previously mentioned (Text-fig. 1) and lithologically divided into the Dali, Ila, Jumla, Mandu and Gum Formations in ascending order (Text-fig. 3-b). The relationship among these formations is inferred to be a conformity and their total thickness exceeds 23,000 *m*, providing that the supposed repetition of the formation owing to faults and foldings is disregarded.

Dali Formation

This Formation crops out in the core of an anticline to the north of Jumla village and along the Kalayagu Gad (river) near Dali village, and is mainly composed of white to grey colored quartzite with intercalations of thin layers of slate and black phyllite. Alternating beds of shale and fine-grained sandstone are predominant in the upper part. The fine-grained sandstone is characterized by fine lamination of 2 to 4 *mm* thick. Intercalations of reddish purple tuffaceous sandstone are sometimes found. The quartzitic succession, to the north of Jajarkot village, intercalates a sheet of meta-basite consisting of altered plagioclase (albite), recrystallized hornblende and quartz and subordinate chlorite. The total thickness of the Formation is estimated to be over 3,200 *m*. Meta-sediments of the Ranimatta-Labu zone may be correlated tentatively with this Formation, although no direct continuation exists between both due to the existence of the Jajarkot crystalline zone.

Ila Formation

This Formation consists mainly of grey, white and brown colored dolomitic limestones with thin layers of green phyllite, black phyllite and/or shale. The limestones often alternate with layers of chert and contain stromatolite colonies. The lithology of the Formation changes laterally and in the Dailekh-Barikot zone the Formation is made up chiefly of a phyllite- and shale-rich sequence (Text-fig. 3-b, Column 14), which is rich in alternation of slate and calcareous shale in the lower part and grades into alternating beds of slate and laminated sandstone to the top. Fuchs and Frank (1970) reported an occurrence, to the south of Barikot village, of Tertiary rocks containing Nummulite fossils which overlies the Tal beds of Jurassic age. This occurrence may indicate the existence of a depression belt. The Ila Formation is correlative with a part of the Krol and Shali Formations of Fuchs and Frank (1970) and probably corresponds to the upper calcareous Subgroup of the Midland meta-sediment Group in central Nepal (Hashimoto *et al.*, 1973). The total thickness of the Formation attains about 4,000 *m*.



Text-fig. 3-b Lithostratigraphical columnar sections along mapped routes in the Midland meta-sediments zone. Figures under columns correspond to route numbers in Text-fig. 3-a.

Jumla Formation

It is mostly composed of white, grey and brown colored quartzite with subordinate green phyllite. Amphibolites often occur in this Formation as thick sheets generally in parallel and/or subparallel to bedding of quartzite (Plate 1-B). Marginal parts of amphibolites are often converted into green phyllite or schist. Quartzose rocks of this Formation have various facies such as colloidal chert, completely recrystallized banded sericite-quartz schist and quartzose sandstone with ripple marks and cross-laminations which show a normal stratigraphic polarity.

Like the Ila Formation the Jumla Formation is most widely distributed in the Midland meta-sediments zone and the lithic facies of this Formation is similar to the middle argillo-siliceous Subgroup of the Midland meta-sediment Group in central Nepal. Nevertheless, the Formation should be deduced to occupy an upper horizon than the foregoing middle Subgroup (Table 1), because it is observed in many places that the Jumla Formation rests without any sign of tectonic disturbance on the Ila Formation, which is equivalent to the upper calcareous Subgroup as already mentioned. The total thickness reaches to 6,000 *m*. This is correlative with the Chail Formation of Fuchs and Frank (1970).

Mandu Formation

This Formation is exposed in the vicinity of Galwa and on the east side of Rara Lake (Text-fig. 3-b, Columns 1 and 3) and consists of alternating beds of limestone and green and black phyllites. The green phyllite is especially abundant at the top and bottom. Recrystallized muscovite and biotite are often present in the limestone. The Mandu Formation as well as the Gum Formation is distributed only in the Galwa-Jumla zone. The total thickness exceeds 4,500 *m*.

Gum Formation

The Gum Formation, the uppermost sequence of the Midland meta-sediments in the present region, consists of quartzite and subordinate green phyllite (Text-fig. 3-b, Columns 2 and 3). A thick pile of quartzite-rich formation, which appears to be equivalent to the Gum Formation, occurs widely to the west of Darma village. Although there is another possibility that this quartzite-rich formation might be correlated with the Jumla Formation because of an occurrence of meta-basites like the Jumla Formation, it is tentatively treated as the Gum Formation.

Granites

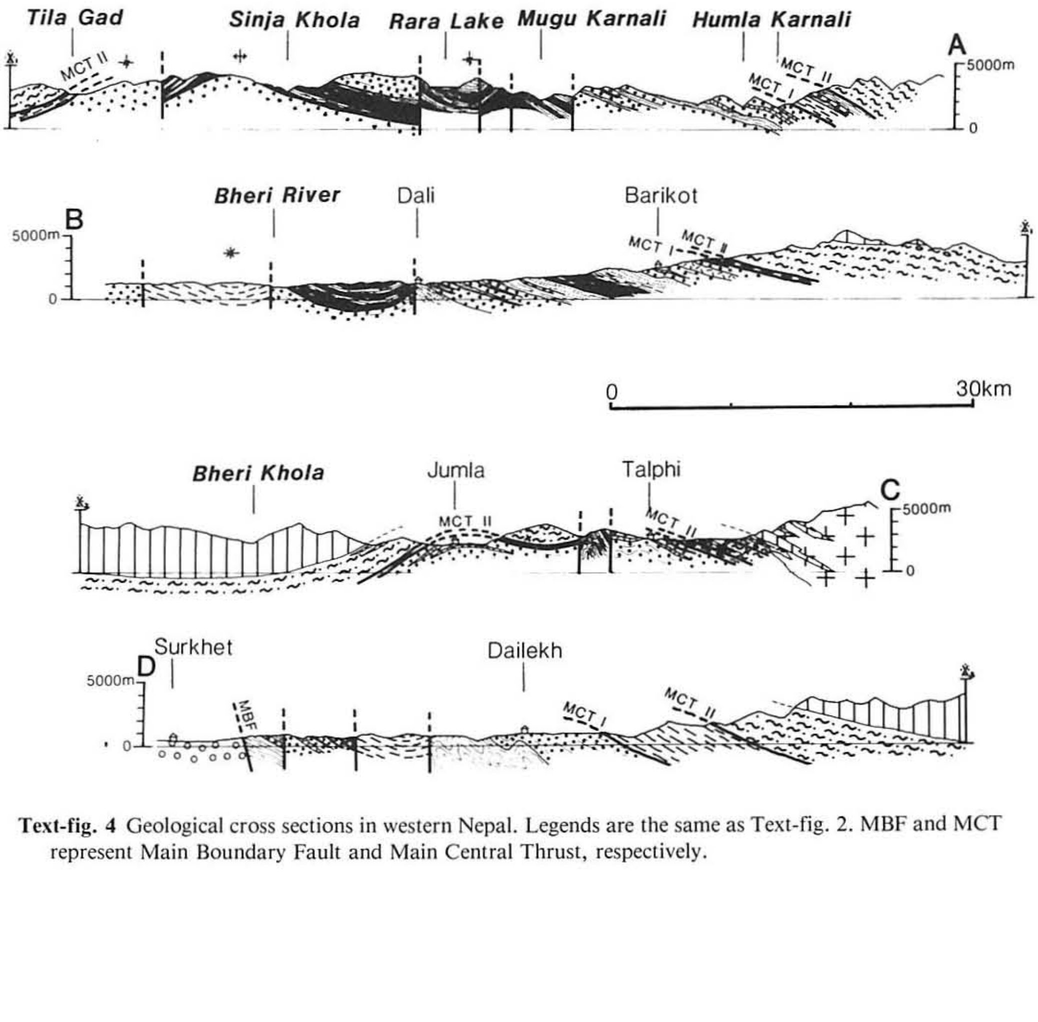
Large granite body is emplaced into the Samla Pass schist and the Dhaulagiri limestone in the northeastern area. The intrusion of this granite is discordant on the geological map scale, but is seemingly concordant on the scale of outcrops. This granite contains various rock facies from place to place: tourmaline granite with or without garnet, biotite granite and muscovite granite (Plate 1-D). The hornblende-diopside-calcite gneiss, which may originally be an equivalent of the Samla Pass schist, often occurs as xenoliths of a few to several hundred meters in length which preserve their original folded structure. This fact suggests that this granite was intruded gently into the calcareous rocks along their bedding planes without any structural disturbance. Tourmaline granitic dykes are fairly common around the granitic body and in the Samla Pass schist of the Chakhure-Mabu crystalline klippe zone.

Structural features

Geologic structure of the present area is principally divided into two major components, namely, a huge sequence of the Midland meta-sediments of autochthonous to parautochthonous nature and the Himalayan gneisses and their southern klippes of allochthonous nature (Text-fig. 1). The latter is thrust over the former by the Main Central Thrust zone (Text-fig. 4).

Himalayan gneiss and Chakhure-Mabu crystalline klippe zones

The Himalayan gneisses together with rocks of the Main Central Thrust zone of the present area are thrust over intensely and glide southward in the same way as those in eastern Nepal (Hashimoto *et al.*, 1973). The southern detachment of the Himalayan



Text-fig. 4 Geological cross sections in western Nepal. Legends are the same as Text-fig. 2. MBF and MCT represent Main Boundary Fault and Main Central Thrust, respectively.

gneisses comprises the Chakhure-Mabu crystalline klippe and the Jumla crystalline klippe of several kilometers in diameter to the east of Jumla village. The Jajarkot crystalline zone is also considered to be a klippe of the Main Central Thrust zone to the north, although there is no cover of the Himalayan gneisses owing to erosion in the latter stage.

The Himalayan gneisses have a homoclinal structure which dips 25°NE in the southeast to 50°NE in the northwest. Two different linear structures exist in the Himalayan gneisses: a mineral lineation accompanied by a microfolding of the NE-SW direction and a microfolding axis with a small-scale undulation of the WNW-ESE direction (Text-fig. 5, Plate 1-C). Hand specimens clearly tell that the former predates the latter.

The Chakhure-Mabu crystalline klippe zone constitutes an eastern margin of a gentle synform with the axis of the WNW-ESE direction (Text-fig. 6). The rock of the klippe has two trends of linear structure similar to those of the Himalayan gneisses in the north. Meanwhile, the Jajarkot crystalline zone has a predominant mineral lineation and microfolding axis in the NNE-SSW direction, whereas the mineral lineation of the E-W direction is rare, although some axes of synform and antiform are in the ENE-WSW direction. This zone is separated from the Midland meta-sediments by steep faults on both the north and south sides, although this zone seems to be thrust over the latter originally.

Midland meta-sediments zone

The Midland meta-sediments in the Dailekh-Barikot zone are folded gently to form an anticlinorium with axes of the WNW-ESE direction and plung to WNW, while those in the Galwa-Jumla zone occur as blocks separated one another by steep faults (Text-fig. 1). The Midland meta-sediments have two trends of lineation, namely, NE-SW and WNW-ESE as well as the Himalayan gneisses (Text-fig. 5). The former trend predated the latter as already mentioned. The latter is accompanied only by weak mineralization. Despite that Fuchs and Frank (1970) have mentioned the existence of allochthonous Chail Nappe and Rukum Nappe, no distinct structural difference and clear shear zone between them are observable. The writers regard the Midland meta-sediments as of autochthonous origin in the same manner as those in central Nepal (Hashimoto *et al.*, 1973).

Discussion

Age of the Midland meta-sediments

The Midland meta-sediments have been designated variously by many researchers and the age of them has remained unsettled for a long time.

No fossil has been found in the Midland region in western Nepal except for stromatolites in the Ila Formation and Nummulites in the vicinity of Barikot village. As mentioned already, two linear structures, the axis of folding accompanied by a mineral arrangement (NE-SW direction) and the axis of microfolding (WNW-ESE direction), are

Text-fig. 5 Fabric diagrams showing bedding and foliation planes, mineral lineation and axis of micro-folding. Three diagrams in a row represent bedding or foliation planes, mineral lineation and axis of microfolding from left to right. In single diagram contours, open circles and solid circles represent bedding or foliation planes, mineral lineation and axis of microfolding, respectively. The fingures at bottom left and right of each diagram are the number of element measured and the percentage number of the contours, respectively. Projected on lower hemisphere.

observed fairly widely in the Midland meta-sediments and the Himalayan gneisses. The former lineation was formed prior to the latter. Such a relation between the two lineations is also observed in the Midland meta-sediment Group of central Nepal, where the NE-SW mineral lineation is considered to have predated the sedimentation of the Kathmandu Group, which is believed to be of early to middle Palaeozoic age (Hashimoto *et al.*, 1973). The lower part of the Midland meta-sediments in the surveyed area is correlative with the upper and middle Midland meta-sediment Subgroups and is assumed to be of Eocambrian age or older (Table 1). The pile of the Midland meta-sediments in western Nepal, however, has an upper stratigraphic sequence than that of central and eastern Nepal. No corresponding formations to the Jumla, Mandu and Gum Formations may exist in central Nepal. Accordingly, it is impossible to deny a possibility that the upper part of the Midland meta-sediments in western Nepal belongs to Palaeozoic age. If this is the case, a serious question arises as to whether or not the upper part can be correlative with the Dhaulagiri Limestone or the Garbyan Series to the north. This problem counts for much in considering a relationship between the sedimentary basins of the Lower Himalayas in the south and of the Higher and Tethys Himalayas in the north.

Agarwal (1974) reported Bryozoan fossils indicating Ordovician to Silurian age from phyllitic slates in dolomitic limestone of the Lameri Formation of the Garhwal Group near Rudraprayag in Kumaun. While this Group is distributed between the Main Central Thrust and the North Almora Thrust, its eastern extension may continue to the Galwa-Jumla zone, although not clear yet in detail.

Significance of the Main Central Thrust zone

The term, Main Central Thrust, has been so far used as a boundary thrust between the Higher Himalayas (Himalayan gneisses) and the Lower Himalayas (Midland meta-sediments and Main Central Thrust zone) by many researchers since early work of Heim and Gansser (1939). But the writers look on it as a wide *tectonic zone*, not as a single thrust fault. The Main Central Thrust zone comes to contact with the underlying Midland meta-sediments and the overlying Himalayan gneisses by the Main Central Thrust I and II, respectively. The Main Central Thrust II is recognized easily in the field, but it is often difficult to recognize the Main Central Thrust I. Furthermore, the rock association of the Main Central Thrust zone resembles that of the underlying Midland meta-sediments. Accordingly, the Midland meta-sediments appear often to grade upward into the rocks of the Main Central Trust zone. The zone is traceable along the base of the Himalayan gneisses all over the Himalayas although its thickness varies considerably with the location. Therefore, the Main Central Thrust zone has played an important role as a sliding plane along which the Himalayan gneisses have been thrust southward.

The rocks of the Main Central Thrust zone are of intensely mylonitic nature, whereas the grade of their metamorphism is perceptibly higher than that of the underlying Midland meta-sediments. A large number of quartz lenses and veinlets occur parallel to and often cutting obliquely the schistosity cleavage of phyllites and schists.

Table 1 Correlation of lithostratigraphy among central Nepal, western Nepal and Kumaun. MCT I = Main Central Thrust I; MCT II = Main Central Thrust II.

	Kumaun (India)	Western Nepal	Central Nepal		Age
Tibetan Himalaya	Tethys sediments Changru Series Garbyang Series	Tethys sediments Dhaulagiri Limestone	Tethys sediments Dhaulagiri Limestone		Palaeogne ~ Ordovician Cambrian (?)
	Budhi schist	Samla Pass schist			Precambrian (?)
	(?)	(?)	(Disconformity ?)		(?)
Great Himalaya	Rungling crystalline (high grade)	Himalayan gneisses	Himalayan gneisses		Precambrian
	(Vaikrita Thrust = MCT)	(MCT II)	(MCT IV)		(Thrust)
Lesser Himalaya	Sirdang sedimentary Group	Bhuwa quartzite Formation			Precambrian (?)
	(Thrust)	(Thrust)			
	Chhiplakot crystalline (low grade)	Main Central Thrust zone			
	(Dharchula Thrust)	(MCT I)	(MCT I)		(Thrust)
	Sandra Group (orthoquartzite, amphibolite band)	Gum quartzite Formation		Midland meta-sediments	Palaeozoic (?)
	upper Deoban Group (limestone with stromatolite, slate, quartzite)				
	middle Deoban Group (slate, quartzite, black shale	Jumla quartzite-phyllite Formation (amphibolite band)			
	lower Deoban Group (stromatolitic limestone, black shale)	Ila limestone Formation (stromatolite)	Upper Subgroup (limestone with stromatolite, phyllite)		Precambrian
	Sauri Gad Group (greywache, basics)	Dali quartzite-sandstone Formation (with ripple mark)	Middle Subgroup (quartzite with ripple mark, amphibolite band)		
	Damta Group (turbidites, greywache, slumped beds)		lower Subgroup (greywacke, green phyllite lowermost Subgroup (argillite)		
	Valdiya and Gupta (1972), Powar (1972) and Rupke (1974)	Present study	Hashimoto *et al.*, (1973)		

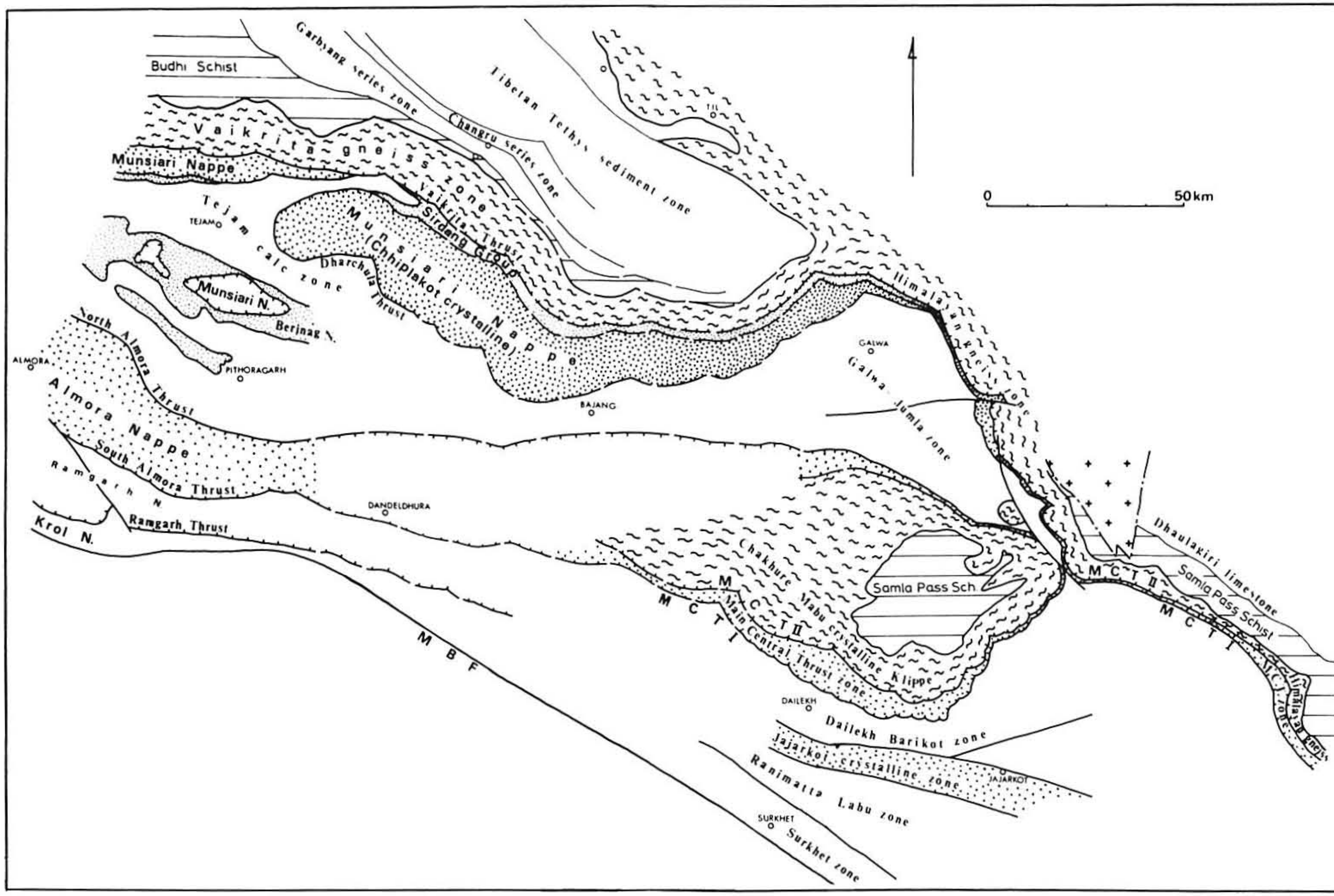
In addition, the metamorphism of the Midland meta-sediments increases in grade northward (stratigraphically upward) as approaching to the Main Central Thrust zone. A possibility that such a "reverse metamorphism" took place in the Lower Himalayas has been discussed for a long time (Gansser, 1964). In this connection, it may merit emphasis to say that the "reverse metamorphism" is due to a thermodynamic metamorphism as the result of shear heating on the thrust movement of the Main Central Thrust zone and should be distinguished from the older regional metamorphism. The thrust movement resulting in the "reverse metamorphism" seems to be related to reactivation of the basement gneiss in the Alpine orogeny. The isotopic ages of mylonitic augen gneiss, encountered widely in eastern Nepal, are 20 to 30 m.y. (Kai, personal communication, 1977).

Geological correlation between western Nepal and eastern Kumaun

A compiled tectonic sketch-map of western Nepal and eastern Kumaun of India is shown in Text-fig. 6. The crystalline rocks of the Higher Himalayas have a variety of names: Darjeeling gneiss (Auden, 1935) in Darjeeling; Kathmandu Nappe (Hagen, 1969), Tibetan slab (Bordet *et al.*, 1972) and Upper Crystalline Nappe (Fuchs and Frank, 1970) in Nepal; Central crystalline (Heim and Gansser, 1939), Rungling crystalline (Powar, 1972) and Vaikrita gneiss (Valdiya, 1977) in Kumaun; Vaikrita Group (Hayden, 1904) in Himachal Pradesh. Thus, they are distributed along the central zone of the Himalayas. As they show almost the same lithology and metamorphic grade up to the upper amphibolite facies of the Barrovian type, Hashimoto *et al.*, (1973) designated them as the Himalayan gneisses. According to Valdiya and Gupta (1972), in northeastern Kumaun the Vaikrita Group (Himalayan gneiss) is overlain by a basal Tethys succession (Garbyang Series) with a transitional passage between them (Text-fig. 6). From the high grade metamorphics to the passage bed known as the Budhi Schist, gradations in lithology and metamorphic grade are appreciable. The Budhi Schist and the overlying Garbyang Series are the same in structure. Consequently, judging from such a relationship among the Vaikrita Group, the Budhi Schist and the Garbyang Series, it may be safely concluded that the second and the third are correlative with the Samla Pass Schist and the Dhaulagiri Limestone in the present area, respectively. Heim and Gansser (1939) assigned the Garbyang Series to the Cambrian on the basis of a flat gastropod, while the lower part of the Dhaulagiri Limestone was also considered to be of the Cambrian because the middle part of it yielded Ordovician fossils (Fuchs and Frank, 1970)

The foregoing passage, which is gradual in tectonics but abrupt in metamorphic grade, from the upper part of the Himalayan gneisses to the basal part of the Tethys sediments, is observed in some places in the Himalayas. Such a relationship between the basement crystallines and the Tethys sediments is debatable, although Hashimoto *et al.* (1973) inferred that it was originally in disconformable contact, the trace of which was intensely obscured by later tectonic and igneous activities in the Alpine stage.

The Main Central Thrust zone extends westward and is considered to continue to



Text-fig. 6 Tectonic sketch-map of western Nepal and eastern Kumaun. M.B.F. = Main Boundary Fault; MCT = Main Central Thrust; Sources: Valdiya and Gupta (1972), Power (1972), Hashimoto *et al.* (1973) and authors' observations.

the Chhiplakot crystalline (Powar, 1972). According to him, the Chhiplakot crystalline is also characterized by cataclastic and diaphthoritic rock series, which are the same as those of the Main Central Thrust zone. Valdiya (1977) has considered that this intensively mylonitized zone forms a nappe structure and designated it as the Munsiari Nappe (Text-fig. 6). In Nepal, however, the nappe structure is not recognized in this zone; only the imbricate structure is observable.

The Sirdang sedimentary Group (Powar, 1972), which may correspond to the rocks of the Berinag Nappe (Valdiya, 1977), is composed of quartzite and meta-basite and occurs between the Vaikrita gneisses and the Munsiari Nappe. However, the possible easternmost extension of the quartzite-phyllite formation is thinned out to the northeast of Galwa village in western Nepal (Text-fig. 6). The Main Central Thrust I and II may correspond to the Dharchula Thrust (Powar, 1972) and Vaikrita Thrust (Valdiya, 1977) which has been called the Main Central Thrust in general (Table 1).

The Galwa-Jumla zone of the Midland meta-sediments may probably correspond to the Tejam calc zone in eastern Kumaun, which consists of the Deoban Group including stromatolite limestone of middle Riphean in age (Valdiya, 1977). It follows that the geological sequences of the Lower Himalayas in the area investigated may be correlative with those in eastern Kumaun which were compiled by Rupke (1974) as shown in Table 1. In his opinion, however, these formations in the Lower Himalayas are largely of Palaeozoic age.

On these autochthonous sediments, the Chakhure-Mabu crystalline klippe overlies and it seems to continue westward to the famous Almora Nappe in Kumaun. The Almora Nappe is thrust over the Ramgarh Nappe (Valdiya, 1977). The eastern extension of the Ramgarh Nappe is not clear in western Nepal, although there is a possibility that the Ramgarh Nappe corresponds to the Jajarkot crystalline zone or the Main Central Thrust zone in the Chakhure-Mabu crystalline klippe. Further south, the Krol Nappe, which consists of Palaeozoic and Mesozoic sediments, shows a narrow distribution along the Main Boundary Fault. On the other hand in western Nepal, younger sediments occur in the Surkhet zone along the Main Boundary Fault. This zone may correspond to the Piuthan zone in central Nepal (Hagen, 1969), which is composed of sediments of Mesozoic to Tertiary age.

Concluding remarks

1) Geology of western Nepal is well correlative with that of the eastern Kumaun west of it. The Himalayan gneisses, the Main Central Thrust zone and the Chakhure-Mabu crystalline klippe may be correlative with the Vaikrita gneisses (Rungling crystalline), the Chhiplakot crystalline (Munsiari Nappe) and Almora Nappe, respectively.

2) The Vaikrita Thrust (Main Central Thrust) and the Dharchula Thrust in Kumaun correspond to the Main Central Thrust II and I in western Nepal, respectively.

3) The Midland meta-sediments are of autochthonous origin and consist of platform-type sediments such as quartzite with ripple marks, stromatolite bearing limestone, phyllite and slate ranging in age from Riphean to Eocambrian, and possibly even

Palaeozoic. It is suggested, as shown in Table 1, that the lithostratigraphical succession of the Midland meta-sediments in western Nepal is well correlative with that in Kumaun. Total thickness of them is estimated to be more than 23,000 *m* provided that the supposed repetition of the formations is disregarded.

4) Main recrystallization stage of the area which resulted in the mineral lineation of the NE-SW direction in the Himalayan gneisses and the Midland meta-sediments seems to be at the end of Precambrian age, although the lineation was promoted by southward thrust movement of the Main Central Thrust zone in the Alpine stage.

5) The Main Central Thrust zone is situated in between the Himalayan gneisses of allochthonous nature and the Midland meta-sediments of autochthonous nature as a profound *tectonic zone*, the width of which varies with the location. This tectonic zone was formed in association with the reactivation of the basement gneisses in the Alpine stage, whereby this movement resulted in the "reverse metamorphism" of the underlying Midland meta-sediments. The Main Central Thrust zone played an important role as a gliding surface of the overlying Himalayan gneisses.

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Explanation of Plate 1

A: Samla Pass schist shows a characteristic rugged weathering surface, which represents alternation of calcareous schist (projected part) and pelitic schist. At Samla Pass.

B: Quartzite of the Jumla Formation intruded concordantly by thick meta-basite (dark layers). Quartzite can be seem also at upper left-hand and lower right-hand corners. 8 *km* east of Jumla.

C: Two intersecting lineations on a foliation plane of banded garnet-mica gneiss. Pencil and clinometer show axes of wavy folding of the WNW-ESE direction and a microfolidng with mineral lineation of the NE-SW direction, respectively. In the Himalayan gneiss zone ENE of Jumla.

D: Garnet bearing tourmaline granite, which intrudes discordantly into Samla Pass schist. ENE of Jumla.

E: Kyanite-garnet gneiss of the Himalayan gneiss zone. Kyanite is abundant in a flaky micaceous layer.

F: Augen gneiss in the Himalayan gneiss zone. Augen is microcline and occasionally reaches the size of several *cm*. 20 *km* E of Jumla.


A
B
C
D
E
ASAHI PENTAX
F
ASAHI PENTAX

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