# Geology and Tectonics of the part of Higher Central Himalayan Tethyan Zone

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*Abstract*: The area incorporated in the paper covers the part of earlier known Painkhanda and Malla Johar regions of Higher Central Himalaya of Garhwal and Kumaun, lying north of Central Crystalline zone of Greater Himalaya. The Tethyan sedimentary sequence presents a thick pile of sediments with well preserved fossils from Cambrian to early Tertiary. The Hercynian orogeny is well marked. The flysch horizon in this section has yielded dinoflagellates and coccoliths reported first time, pointing towards Tertiary elements in flysch which was previously considered only Upper Cretaceous. The radiometric dates of ophiolitic complex have indicated Upper Cretaceous volcanism associated with "Exotic Blocks" of dolomitic limestone which has moved over flysch sediments. Besides the NW-SE trending axis of folds and faults the N-S trend is also developed. This zone exhibits thrust nappe structures having movement from North to South. The contact between Tethyan and Crystalline zones is clearly tectonic with profuse magmatic activities.

## INTRODUCTION

Geologic work north of Central Crystalline zone of Central Greater Himayala has remained difficult even in the present time due to inaccessibility in the terrain and inclemency of weather in high altitude. The investigated area of research falls in the terrain of rugged topography with average height of 3000-4000 m. Since the area is situated in the "shadow-zone" of monsoon rainfall, having lofty Nanda Devi (7820m) group of peaks south of it, there is scanty vegetation patches on the northern slope. Notable amongst them are the berches, and white and violet variety of rhododendron. The general picture of this Tethyan zone is extremely rugged and barren with precipitous scarps, glaciated and deep cut valleys and ravines. The only season to work in this zone of Himalaya is during June-July-August months of the year. The explorer is always beaten by the strong Tibetan plateau wind blowing after 10 O'clock in the morning, and strong burning radiation of ultra-violet rays.

The investigation in this area has been taken up since 1973 in a series of expeditions organised by Wadia Institute of Himalayan Geology as a part of long-term project. The massive pile of sedimentary sequence exceeding over tens of kilometers of thickness offers the researcher a challenge to trace back their geologic history of deposition since Precambrian time to the Early Tertiary.

Tracing back the history of geologic investigation the collection of Tibetan fossils by Strachey (1857) and their identification by Salter and Blandford (1865) is to be referred. Amongst the poineers, the best of all geologic investigations and monumental work of Griesbach (1891, 1893) would outcast perhaps all and would remain as classic with the years to come. He was the first investigator to draw the attention to unusual disposition of rocks which later on was investigated by von Kraft (1902) and became the enigma in world geologic literatures as "Exotic Blocks" of Malla Johar. On further elaboration Diener (1895a, 1895b, 1895c, 1897a, 1897b, 1898, 1903, 1906, 1912) established many new facts. Reed (1912) described fossils from Ordovician and Silurian. The monograph by Heim and Gansser (1939) brought forth a new dimension of thinking in the investigation. The research in post independent period of India is enriched by Kumar *et al.* (1971), Valdiya and Gupta in Kali valley (1972), Shah and Sinha (1974c), S. Kumar *et al.* (1977), Sinha (1977), Valdiya (1979), Sinha (in Press) and others.

In the present paper first time the geologic map of the area in 1: 63,360 (1 inch = 1 mile) scale has been incorporated along with the recent biostratigraphic data bearing column (Fig. 2) and eight other figures and photographs to bring an illucidating geologic picture of one of the most fascinating part of Himalaya.

## GEOLOGIC SETTING WITH BIOSTRATIGRAPHY

In conformity with the terminology proposed by the celebrated Austrian geologist Edward Suess the name of "Tethyan zone" in Himalaya was introduced

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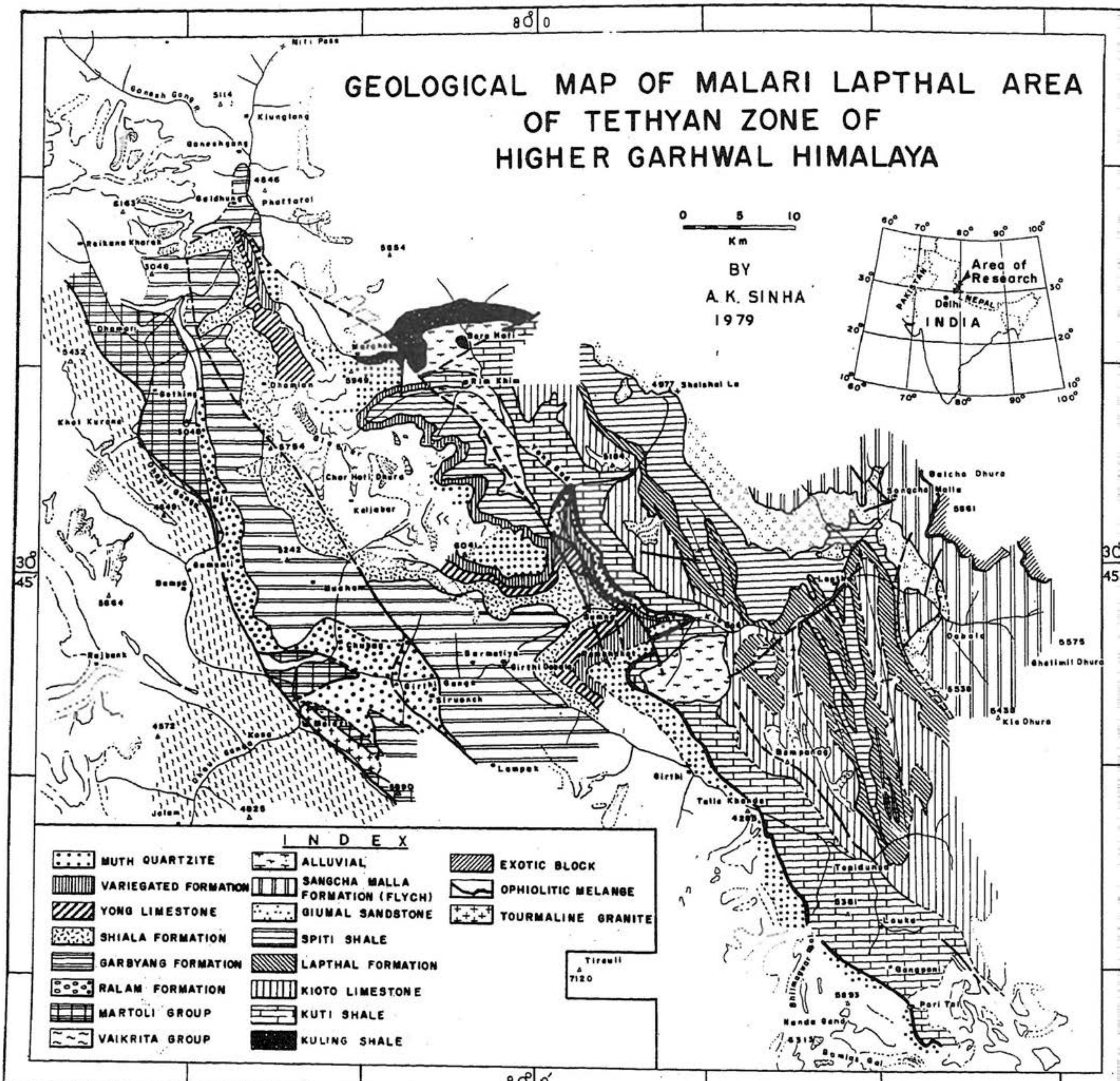
GEOLOGICAL MAP OF MALARI LAPTHAL AREA
OF TETHYAN ZONE OF
HIGHER GARHWAL HIMALAYA
BY
A. K. SINHA
1979
Km
Area of Research
PAKISTAN
NEPAL
Delhi
INDIA
INDEX
MUTH QUARTZITE
VARIEGATED FORMATION
YONG LIMESTONE
SHIALA FORMATION
GARBYANG FORMATION
RALAM FORMATION
MARTOLI GROUP
VAIKRITA GROUP
ALLUVIAL
SANGCHA MALLA FORMATION (FLYCH)
GIUMAL SANDSTONE
SPITI SHALE
LAPTHAL FORMATION
KIOTO LIMESTONE
KUTI SHALE
KULING SHALE
EXOTIC BLOCK
OPHIOLITIC MELANGE
TOURMALINE GRANITE
Niti Pass
Kiunglang
Ganeshgang
Phaffarai
Reikana Kharak
Bara Hoti
Rim Khim
Shalshal La
Dhamjan
Char Hoti Dhura
Kaljabar
Belcha Dhura
Sangcha Malla
Dobala
Shalimil Dhura
Kio Dhura
Bampa
Malari
Lampak
Girthi
Talla Khanda
Topidunga
Lauka
Gangpani
Pari Tal
Nanda Gand
Tirsuli
Jolam
Dhampa
Sething
Khel Kurane
Rajbank
Sirsanch
Girthi Ganga
Barmatiya
80°0'
30°45'

Fig. 1

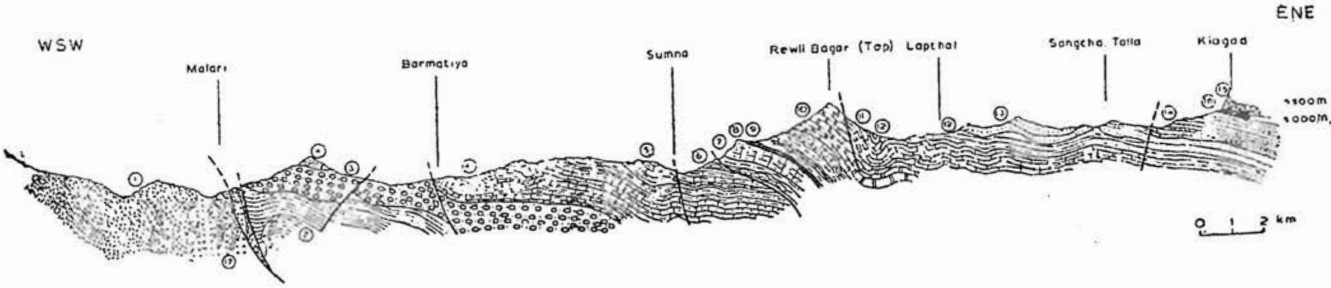


**Fig. 2.** Geologic Cross-Section along SW-NE Section across "Exotic-Blocks" (after Shah and Sinha, 1974).

1. Vaikrita Group; 2. Martoli Fmn; 3. Ralam Fmn: 4. Garbyang Fmn; 5. Shiala Fmn; 6. Yong Lst; 7. Variegated Fmn; 8. Muth Qzt; 9. Kuling Shale; 10. Trias and Kioto Lst; 11. Lapthal Fmn; 12. Spiti Shale; 13. Giumal Sst; 14. Flysch; 15. Exotics; 16. Ophiolite; 17. Granitic intrusive

by Auden (1937) to identify the widespread sedimentary basin the north of Central Crystalline rocks (Fig. 1). It is to be borne in mind before analysing the palaeogeologic setup that "Garhwal-Kumaun Tethyan-Basin" has remained separate from such sedimentary basins of Spiti in the NW and Nepal-Tibet area in the NE. Visibly it is due to the striking axially uplifted crystalline complex on the either sides.

A geologic cross section (Fig. 2) is presented here to elucidate the geologic setting.

The detail biostratigraphy of this zone has been worked out in recent expeditions with Dr. Shah (Shah and Sinha, 1974c) and Drs. S.P. Jain and A.C. Nanda in successive expeditions of 1975 and 1976. The biostratigraphic column (Fig. 3) has been prepared with careful measurement of the section and preparation of litholog. The authors have been benefited by Dr. Shah of Jammu University, India, and Prof. Mme G. Termier of Paris University with their valuable consultations in identifying the different forms.

Although the biostratigraphic column prepared by author with Dr. Nanda (Fig. 3) is self explanatory of the litho-and bio-units with the lucid description of lithology and fossil zonation, however, a concise description is also incorporated herewith for the benefit of the readers.

*Vaikrita Group* (Central Crystalline): Metamorphic rocks of this group show their grading from low to high grade kata-zone sillimanite-kyanite schist with appreciable thickness of hundreds of metres of quartzite sometimes occurring with garnets and gneissose part of argillaceous sediments. The other components of crystalline complex are various grades of gneisses and schists including granite-gneisses of different phases. The earlier phase is sillimanite-kyanite bearing, whereas the last phase is of aplitic-pegmatitic type. This younger phase of granites are mostly confined along the tectonized zone with the Tethyan sediments. Along certain zones there is intense development of migmatites. Annapurna Gneiss complex (Bodenhausen *et al.*, 1964) is the continuation of the zone in Nepal. Tectonically, the crystalline complex show one very prominent earlier phase of recumbent isoclinal folding which is conspicuous in the quartzite horizon as well. It is to be noted that such phase is completely absent in the Tethyan zone sediments.

*Martoli Group:* This group has attained its immense thickness (appro. 6,000m) along the Martoli-Goriganga valley section, whereas in the Malari-Dhauliganga section an appreciable thickness is truncated by the fault. In both the sections the contact zone with the crystalline complex is intruded by the younger granites. Lithologically in ascending order the base of Martoli is rather more metamorphosed known as Rilkot or Budhi schist with characteristic porphyroblasts of biotite. This horizon tectonically overly the kata-zone metamorphics of sillimanite-kyanite schists and persistently intruded by younger phase of granite. In ascending order over the biotite-porphyroblast schist the lithological units are quartzite and sericite schist in intercalation followed by phyllite, serpentine schist, quartzitic sandstone and siltstone, quartzite with well developed cubes of pyrites and calc-silty argillites in the uppermost part. The top of this enormously thick low grade or almost unmetamorphosed sequence is overlain by marked angular unconformity in the Gonkha Gad valley near Milam Glacier region. The overlying Ralam Conglomerate horizon dips at low angle 35°-40° due NE parallel with the unconformity plane whereas the Martoli Group rocks stand erect with high angle of dip and showing irregular deformation pattern.

*Ralam Formation:* This formation has previously been named as Ralam conglomerates only. But in total of the thickness (400-500 m) more than half is merely the quartzites. The brick red conglomerate with quartzitic unsorted clasts and hard siliceous cement imperceptly grades into massive greyish white quartzite of the upper horizon. In this paper the author would

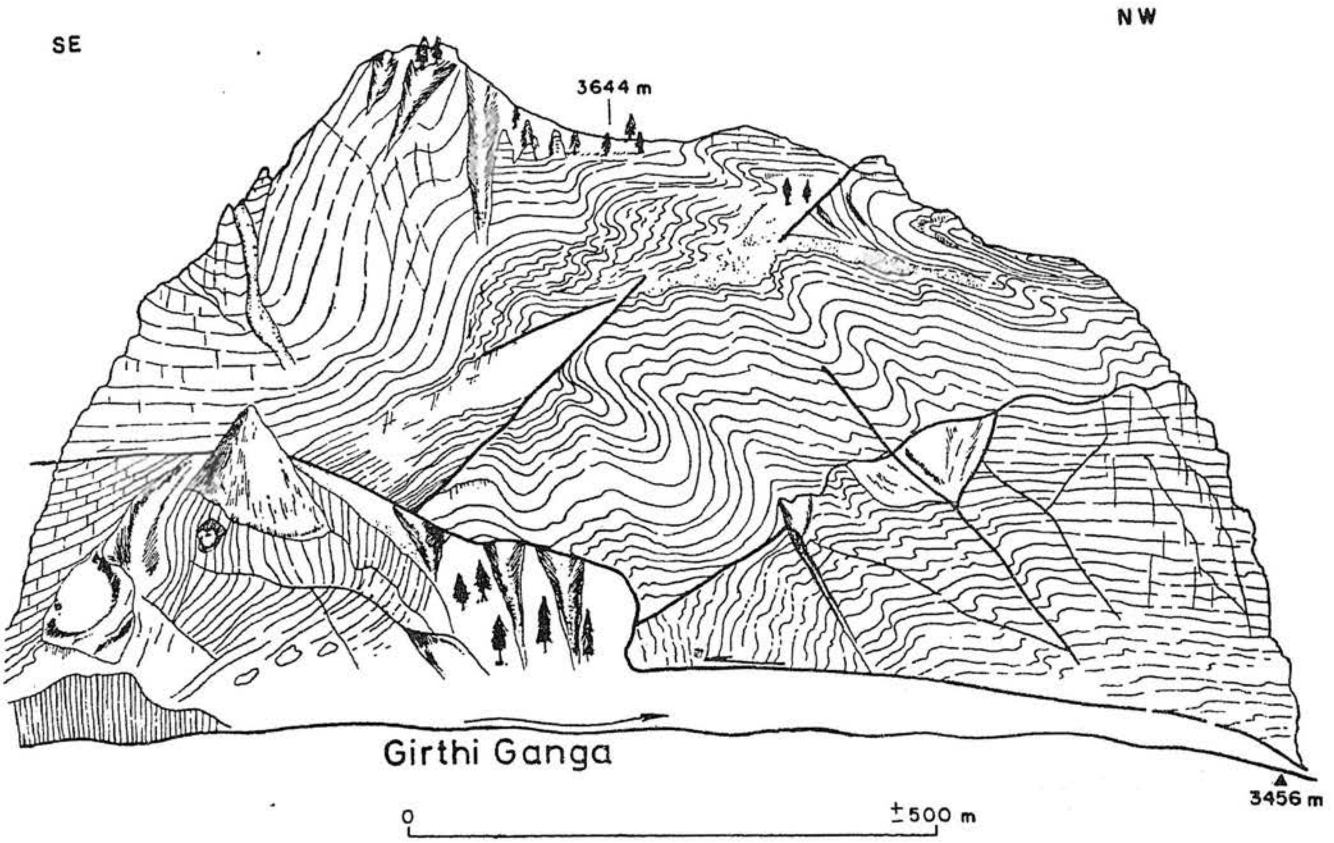


**Fig. 4.** Gravitational back-foldings in the Garbyang Fmn. of Girthi Gorge near Barmatiya.

like to make special remark about the angular unconformity over Martoli Group, because, although it was pointed out by Heim and Gansser (1939) not much attention was paid towards its tectonic implication. This aspects would be taken up in the following tectonic sub-heading.

*Garbyang Formation:* This huge pile of sediments (appr. 1000 m) conformably overly the Ralam formation in the Girthi, Dhuli and Goriganga valleys. This series of rocks consists of alternating bands of calcilulite, calcsiltstone and brown dolomitic limestone in the lower part and crinoidal and oolitic limestone in the middle, whereas the upper part consists of cross-bedded calcareous sandstone and predominating shaly member at the top which imperceptibly trangresses into Shiala horizon. The lower and middle part is clearly demarcated by persistant yellowish marl bands. In the upper shaly horizon fragments of unidentifiable trilobites have been observed. But within the sandstone shale-unit, in upper part, over the ripple surface, well preserved *Eccliopteris kushanensis* Grabau have been collected, pointing towards Middle Ordovician age.

In the lower part of Garbyang a rich barite deposit associated with polymetallic mineralization has been discovered (Shah and Sinha, 1974b, Sinha, 1977). The rocks in general dip with monoclinal nature due N-NE but closer to the tectonic lineament dividing the Central Crystalline with Tethyan sequence in Girthi valley a lucid picture of gravity sliding causing back folding could be seen (Fig. 4) near Barmatiya.

*Shiala Formation:* The Garbyang transitionally passes over to the Shiala Formation with greenish shales, intercalated bands of arenite and gradually becoming total quartzitic in the upper part. This formation is rich in fauna and has been divided into four zones in Girthi valley, viz., *Orthis (Dalmanella) testidunaria* zone; *Rafinesquina aranea* zone; *Monotyrpa* zone, and *Rafinesquina alternata* zone. A Middle to Upper Ordovician age is assigned to this zone.

*Young Limestone Formation:* This unit was first identified as independent formation during our 1973 expedition (Shah and Sinha, 1974a), since then it was logged in all the sections in Garhwal-Kumaun Tethyan zone. This is the horizon with useful character with biostromal debris. The biota consists of calcareous branching algal, stromatoporids, arinoids, corals and bryozoans etc. In the Yong Gad ravine (Fig. 1) it presents a rather domal character with imperceptible bedding features. This horizon's thickness varies in fiftees of meters.

*Variegated Formation:* It comprises of limestone and shale with bands of quartzite showing a typical chocolate brown colour, easily spotable from distance with the marked eye, and holds good as marker horizon for mapping in the snow capped and savagely glaciated region. The typical brown colour of weathered rocks from this series help to differentiate the Bamlas Glacier (Fig. 1) in Unta Dhura Pass (5450 m) area. Besides *Strophonella, Pasceolus mellificus* has been identified from this horizon.

*Muth Formation:* The lower part of this persistent marker mapping horizon (400 m) in this area is dolomitic with profuse shells of fossils *(Pentamerus)* but the upper horizon is extremely white sugary crystalline quartzite, without discernible fossils. The competent character of the rock is marked by the cliffs and resistant walls of amphitheatre glacial geomorphologic features. Some of the notable fossils of this horizon are: *Schellwienella williami, Leptaena rhomboidalis, Atrypa reticularis* etc. It is accepted to be Devonian horizon.

*Kuling Shale:* The name has been derived from originally described locality in Spiti basin north-west of the area being described in the paper. This persistent horizon of euxinic facies of black friable, silty micaceous shale with fossils (appro. 20-100 m) gives a contrasting setup of geology (Fig. 1, 2, 3) over white sugary competent quartzite of Muth. No carboniferous horizon with *Fenestella* could be recovered from this area. The fossil identified are: *Paramarginifera himalayensis, Cyclolobus oldhami* and *Waagensconcha purdoni.*

*Kalapani Limestone and Kuti Formation:* In this part there is no overlapping horizon of chocolate series (Heim and Gansser, 1939), but we come across Kalapani Limestone with Kuti shale of Trias. The Kalapani limestone ( ≈ 50 m ) is rich in faunal assemblage as well as algal structures. But they are not well developed forms to be identified as stromatolites. Other fossil assemblages are typical *Crinoidal* stems (5-10 cm), *Gymnites, Arcestes, Ptychites, Griesbachites, Halobia* etc.

Kuli shale ( ≈ 500 m ) is a typical alternation of intercalating shale and limestone bands with beautifully disharmonically (Fig. 5) folded structures. Sometimes there are local faulting and thrusting of much academic interest (in the Girthi valley). Besides the earlier reported faunal assemblage (Jeannet, 1959; Heim and Gansser, 1939) with Dr. Nanda we have identified *Juvavites* (?) *Angulatus, Lilanqina* cf. *nobites* (Fig. 3).

*Kioto Formation:* This massive limestone formation is exposed in the area forming high cliffs and escarpment SE of Dhauli valley to Kiogad and Girthi valley over Topidunga campsite (Fig. 1). From the bottom in ascending order formation shows arenaceous compo-

**Fig. 5.** Disharmonic fold pattern in the Kuti-shale of left bank of Kiogad near Rewalibagar. Camera facing NE.

nent in lithology with synsedimentational structures, while the upper part is more calcareous with oolitic and coquina in character. In the lower part pelecypod *Megalodon* appears in all the sections as persistent horizon and it has been popularly called as *"Megalodon Limestone"*. Beside that there are other fossils viz. *Pecten, Spiriferina, Protocardium, Lima* etc. In figure 6 the escarpment of Khingru Dhura pass (5244 m) area exhibits the type of folding these rocks have undergone being complicated by box type folding along axial zone (NNE-SSW). Furthermore the western limb is complicated by inverted anticlines and synclines with plunge towards north. Some detail work on stratigraphy and correlation of Kioto has been described in the publication of Gupta (1977).

**Fig. 6.** Style of folding in the Mesozoics of Girthi valley in Khingru Dhura Pass area. Camera facing North.

*Lapthal Formation:* The name of this formation was given by Heim and Gansser (1939) from the locality of the mapped area (Fig. 1). The exact thickness in the exposed gorge of Kiogad has been logged to be

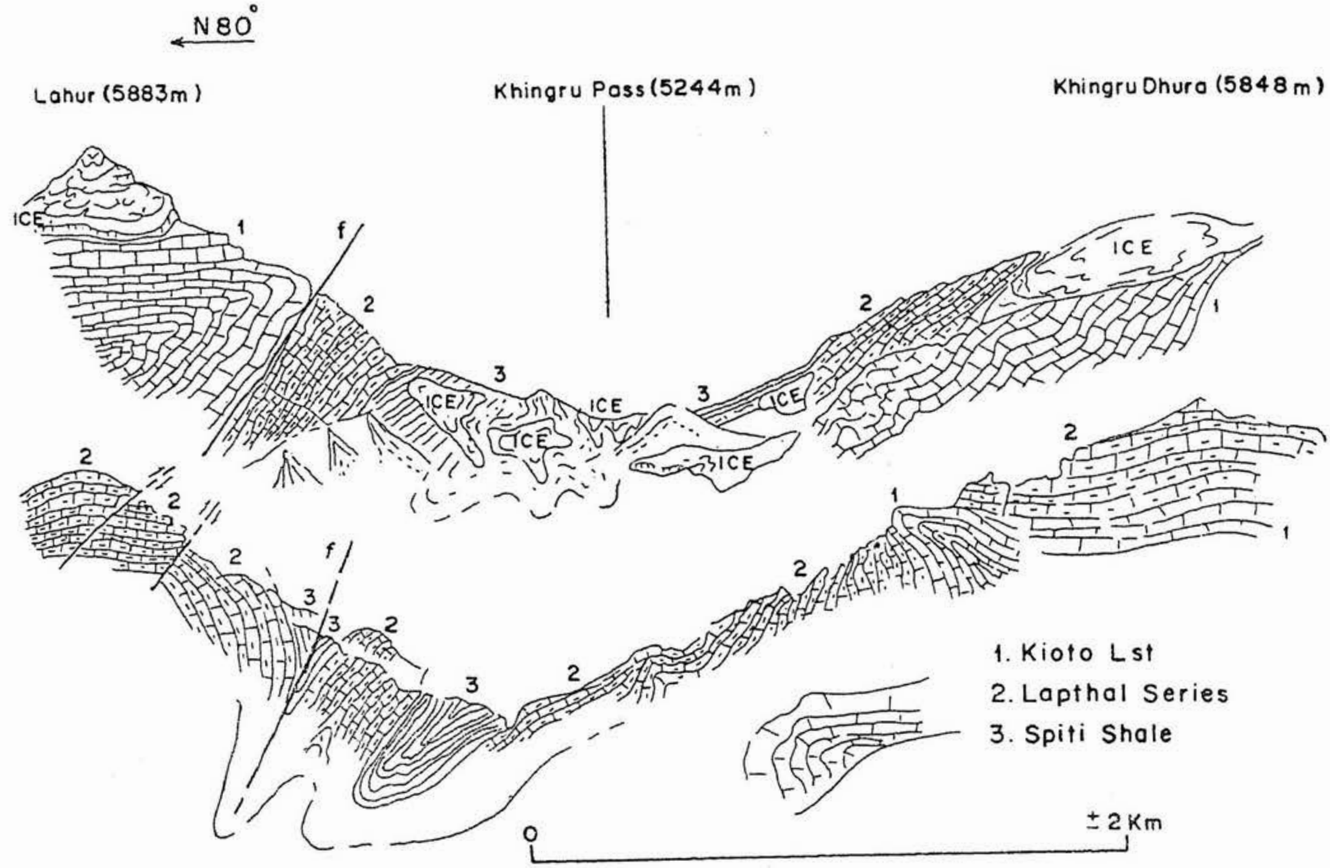


**Fig. 7.** Inverted fold structures in the complicated limbs of Chidamu-Lapthal Syncline.

90 m. On detailed documentation it has been that the main lithologic component is calcareous in mixture with arenaceous. This horizon is profusely dotted with fossils. Besides a large number of interlayered horizons of *lumachelle* in them, the characteristic feature to spot this formation in the field. On this basis it has been also called *"Lumachelle Formation"* in Nepal. Some of the typical fossils identified from this horizon are: *Rhynchonella, Astarte, Nucula, Ostrea, Lima (Radula)* cf. *Hettangiensis, Isognomon* sp. Immediately overlying this formation a thin ferrugenous oolitic capping (1-2m) of a new horizon was recorded by earlier workers and it has been mapped by author throughout the area. The typical fossils is the *Sulcacutus* of Calovian age. The structure involving these rocks in the Chidamu-Khingru Dhura pass (Fig. 7) is well illustrative to imagine the complication of limbs of northerly plunging syncline with Spiti-Shale in the core.

On the basis of fossils the age of Lapthal goes down to upper Rhaetic (Fuchs, 1977) in the adjacent basin of Nepal.

*Spiti Shale:* This persistent horizon of crumpled black shale provides a picture of rather flat topography caught between competent calcareous Kioto-Lapthal horizon and sandstones of Giumal. The entire formation is full of ammonites and belemnites but none of them are to be extracted in situ. The ammonites are mostly enclosed within concretions. An excellent account of fossil described from this horizon is given by Jeannet (in Heim and Gansser, 1939).

*Giumal Sandstone* (appr. 400 m): The resistent cliffs of Glauconitic sandy shale, sandstone and chert in the upper part are very prominent in the Sangchatalla-Shalshal belt of the mapped area. These Lower Cretaceous horizon have yielded *Pseudomontis, Inoceramus Gryphea* (Sinha and Nanda, in press).

*Flysch:* Overlying the Giumal sandstone horizon without any unconformity radiolarian bearing cherty horizon marks the base horizon of flysch (Fig. 1, 2 and 3). Radiolarian bearing cherty horizon is followed by shaly and felspathic sandstones, chocolate reddish shale with calcareous and cherty lenses, greyish black silty shale, greywacks and greenish shale. The radiolarian have shown a phenomenon of replacement by glauconite indicating a sharp fluctuation of deepening and shallowing (Sinha and Srivastava, in press).

The discovery of dinoflagellates (Mehrotra and Sinha, in press) indicate younging of flysch to lower Tertiary. The coccolith studied under scanning-electron microscope and being reported first time (Sinha and Dmitrenko, MS) confirms the Cretaceous affinity of the horizon. However, the detailed reports on these findings are yet to be finalised.

The Sangcha Malla palynological assemblage mainly comprises fossil dinoflagellates. Besides a few other microplanktonic forms have also been recorded. The dominant dinoflagellate genera of the Sangcha Malla Formation are: *Odontochitina* Deflandre 1935; *Oligosphaeridium* Davey and Williams 1966; *Diphyes* Cockson 1965; *Cordosphaeridium* Eisenack 1963; *Aerospheridium* Eaton 1976; *Hystrichokolpoma* Klumpp 1953; *Hystrichosphaeridium* (Deflandre) Davey and Williams 1966; *Cleistosphaeridium* Davey, Downie, Sar jeant and Williams 1966; and *Gonyaulacysta* Deflandre 1964. The characteristic Upper Cretaceous dinoflagellate species *Odontochitina cribropoda* Deflandre and Cockson 1955, is very abundant in the lower levels of the Sangcha Malla Formation. This is suggestive of an Upper Cretaceous lower limit. *Oligosphaeridium* complex Davey and Williams 1966, *O. pulcherrium* Davey and Williams 1966, *Systematophora Schindewolfi* Neale and Sarjeant 1966, and *Diphyes* colligerum Davey and Williams 1966, are the stratigraphically significant species which have been frequently recorded from the Upper Cretaceous and Eocene sediments of India, England and Australia. *Oligosphaeridium* complex is very common in the Eocene of Lesser Himalaya. This indicates the possibility that the Sangcha Malla Formation may range upto Eocene in age.

*Ophiolites and "Exotic-Blocks" :* The reknown occurrence of "Exotic-Blocks" associated with the unknown ophiolite term has been described in classic work of von Kraft (1904). The pioneer could not survive longer afterwards to complete his own works and died on 22nd Sept., 1901, in Calcutta. These "Exotic-Blocks" of Permian to Triassic age are composed of completely deformed and shattered dolomitic limestone lying over ophiolitic melange. In them some microfossils have also been reported (personal communication Dr. N.C. Mehrotra). Detail investigation is in progress.

Below these pell-mell blocks there is a horizon of ophicalcite and ophiolitic melange. The age of this ophiolitic suit has been dated to be Campanian-Meestrichtian (75,73 m. y.) and 107.5 m. y. (Sinha et al, 1977). Gansser (1974, 1977, 1979) and Shah (1977) have attempted to throw new lights on these suit in recent work. Fig. 8 is the sketch drawn at field season during 1976 Expedition to give a picture of disposition of geologic set up of the area.

## TECTONICS

The map area described covers only a northwestern fringe of southern part of whole Tethyan basin

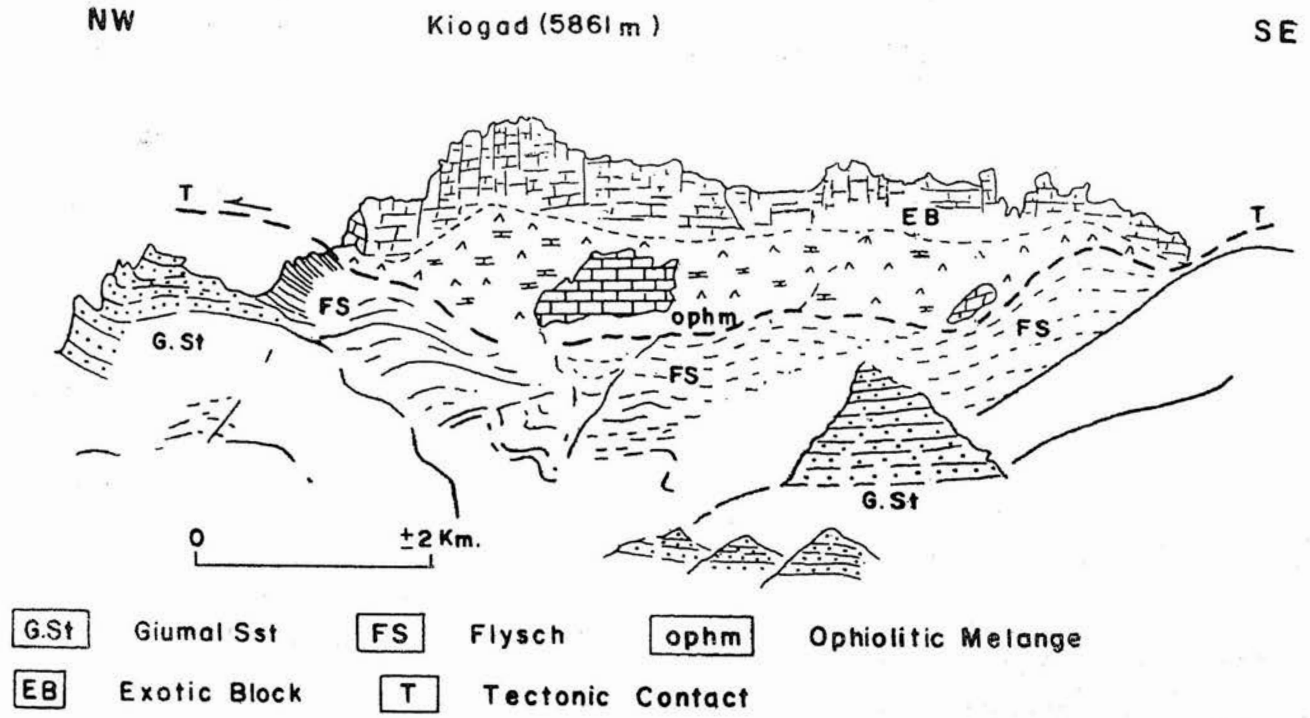


**Fig. 8.** "Exotic-Blocks" of Malla Johar Kiogad I peak, sketched from south.

occupying the territory of Indian Garhwal and Kumaun and Tibet in the north. The most prominent tectonic feature of this region is the MALARI-NITI DEEP SEATED LINEAMENT which divides the Central Crystalline zone from the thick sedimentary sequence. This tectonic line presently assumes the nature of the steep angle thrust along which the sedimentary pile of Tethys has ridden over the crystalline complex. The deep seated and long living nature of this basement fault line is supported by intense igneous activities observed. There are two clear phases of granitic intrusions characterized by granite with kyanite and sillimanite and the later aplitic-pegmatitic type confined in this zone right from Malari area in the NW to Goriganga, Darma and Kali valleys upto Budhi in the Kali valley in the border of Nepal. However, the detail about this lineament and its proper nomenclature would be taken up in the forthcoming monograph (Sinha, MS). The other major thrust of the area is the KIOGAD NAPPE (von Kraft, 1904; Gansser, 1979) carrying the ophiolitic melange with flysch and "exotic blocks" of Permian to Triassic age of Tibetan facies (Fig. 8). These facies are no where found to be *in situ* now, and hence it is presumed that this part of basin after squeezing has been subducted along the Gilgit-Dras-Darchen Deep seated lineament in Darchen area (Sinha and Jhingran, 1977).

Besides these two major tectonic feature the area is dissected by the sets of faults having Himalayan strike directions of NW-SE. The other set of faults are perpendicular to the previous direction, i.e., NE-SW observed in the Kiogad gorge in Lapthal area. The NW-SE trending fault at Siruanch at Girthi gorge on further tracing SE perhaps merges with the "Samgaon-Thrust observed by author in Gonkha Gad near Milam. Here the Ralam overrides the Gorbyang and sequence repeats. The general fold pattern holds the regional strike in NW-SE direction but the Mesozoics in Khingru Pass-Chidamu-Lapthal gorge is peculiarly folded with N-S axis. The two parallel anticlines plunging due north named as "Lahur-Anticline" in the east and "Bampanag-Antcline" in the west are having synclinorial features along Chidamu-Lapthal axis plunging to north (Figs. 6 & 7). The eastern and western limbs of this syncline is tightly folded and faulted with Spiti-shale in the core. Cureously enough the Garbyangs near Barmatiya in the left bank of Girthi gorge have undergone gravity structure of back fold type with low angle displacement (Fig. 4). The Kuti-shale being incompetent between two competents of Kioto limestone and Muth quartzite have suffered fold pattern in disharmonic manner (Fig. 5) observed in the right bank of Kiogad in Rewalibagar camping site. A thin-skin tectonics has been observed under which Lapthal rocks below Spiti shale and above Kioto limestone have undergone Jura type folding (Fig. 2). This phenomenon is observed in the northern slope of Rewalibagar cliff.

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