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A REVIEW OF STRATIGRAPHY OF PARTS OF UTTAR PRADESH TETHYS HIMALAYA

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ABSTRACT—A sequence of marine sedimentry rocks lying north of the Central Crystalline Gneiss (Heim and Gansser, 1939), ranging in age from Algonkian to Cretaceous (except Carboniferous), has been reviewed by the authors on the basis of their traverses in 1963 and 1964 in parts of Darma valley, Malla Johar and Niti valley, Uttar Pradesh. The Area constitutes the part of the Northern Central Himalaya[1] (i. e., Tethys Himalaya) bounded by north latitudes 30°14′ and 30°55′, and east longitudes 79°50′ and 80°40′.

INTRODUCTION

Strachey (1851) was the pioneer to prepare geological map of the Malla Johar area of Uttar Pradesh. He distinguished several formations which were later modified and reviewed by Griesbach (1891) who differentiated Vaikratas and Haimantas on the basis of their relationship with the rocks of Spiti. Further in 1893, Griesbach along with Diener discovered the 'Exotic Blocks' of Malla Johar which were again studied in more detail by von Krafft (1902).

Heim and Gansser (1939) examined the eastern part of the Northern Central Himalaya[1] from Malla Johar to the Kali river, and further classified the Haimantas into four series, viz., the Martoli (Algonkian), Ralam (Basal Cambrian), Garbyang (Cambrian) and the Shiala (Ordovician).

Besides the above mentioned workers, there have been a number of publications on the area dealt in the paper and also in the adjoining areas, but are of little significance for the present work.

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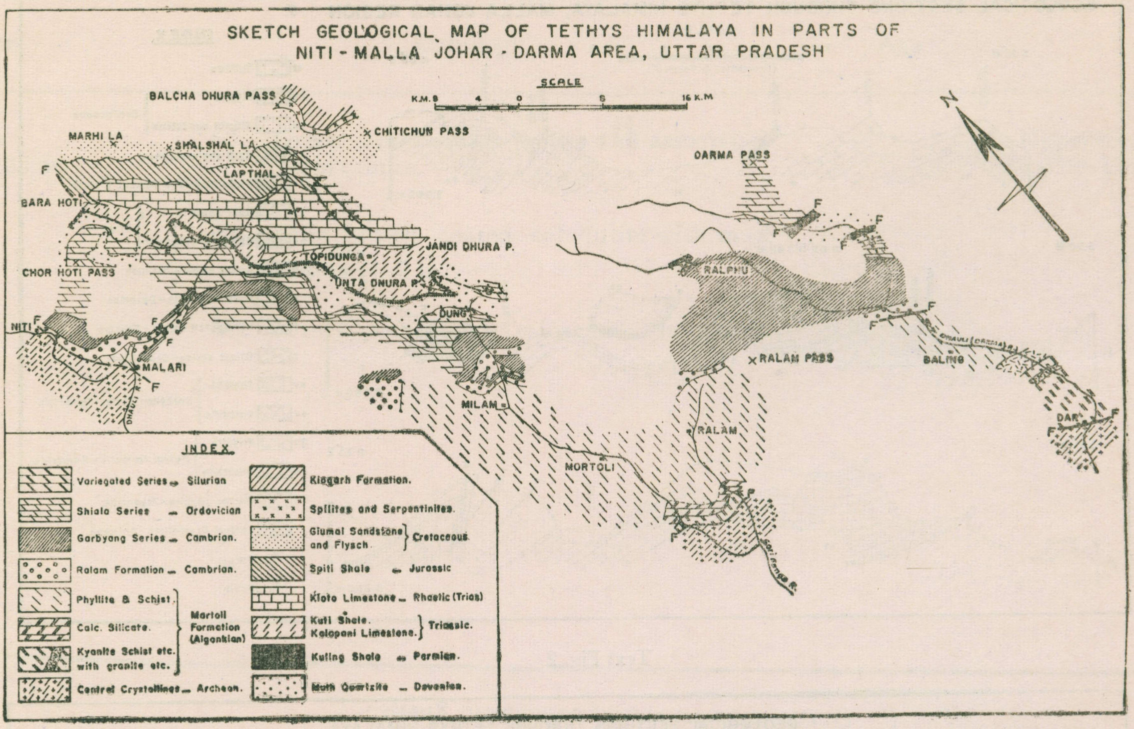
1. In modification to Heim and Gansser (1939), the Central Himalaya has been subdivided by the authors into Southern Central Himalaya which is composed of Central Crystalline Gneiss, and the Northern Central Himalaya corresponding to the Tethys Himalaya composed of Palaeczoic to Mesozoic sediments.



Text Fig. 1

The authors almost followed the Heim and Gansser's classification of Haimantas and other younger formations, and traversed parts of area of Darma valley and Malla Johar and extended Heim and Gansser's observations to the west towards Niti valley in the area bounded by north latitudes 30°14′ and 30°55′ and east longitude 79°50′ and 80°40′.

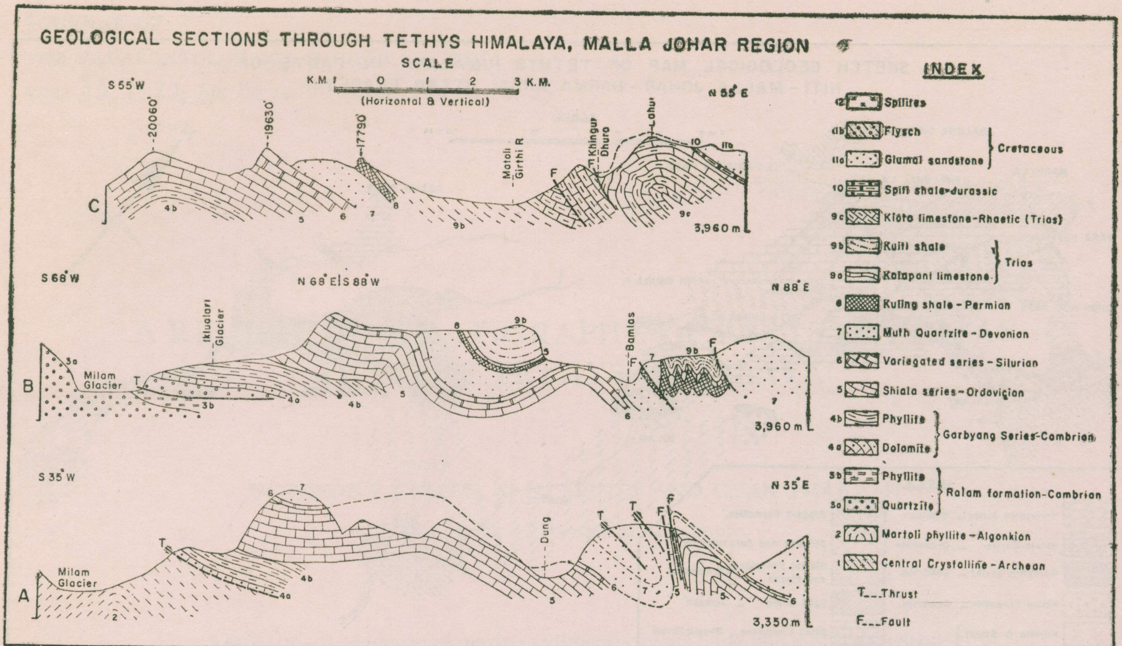
GEOLOGY

The geology of the Tethyan sediments of part of Darma valley—Malla Johar—Niti valley area (Text fig. 1) is given below in Table 1 (age assigned to the formations is purely on the lithological correlation as described by Heim and Gansser and not on the faunal distribution which could not be studied; as such ages are subjected to revision).

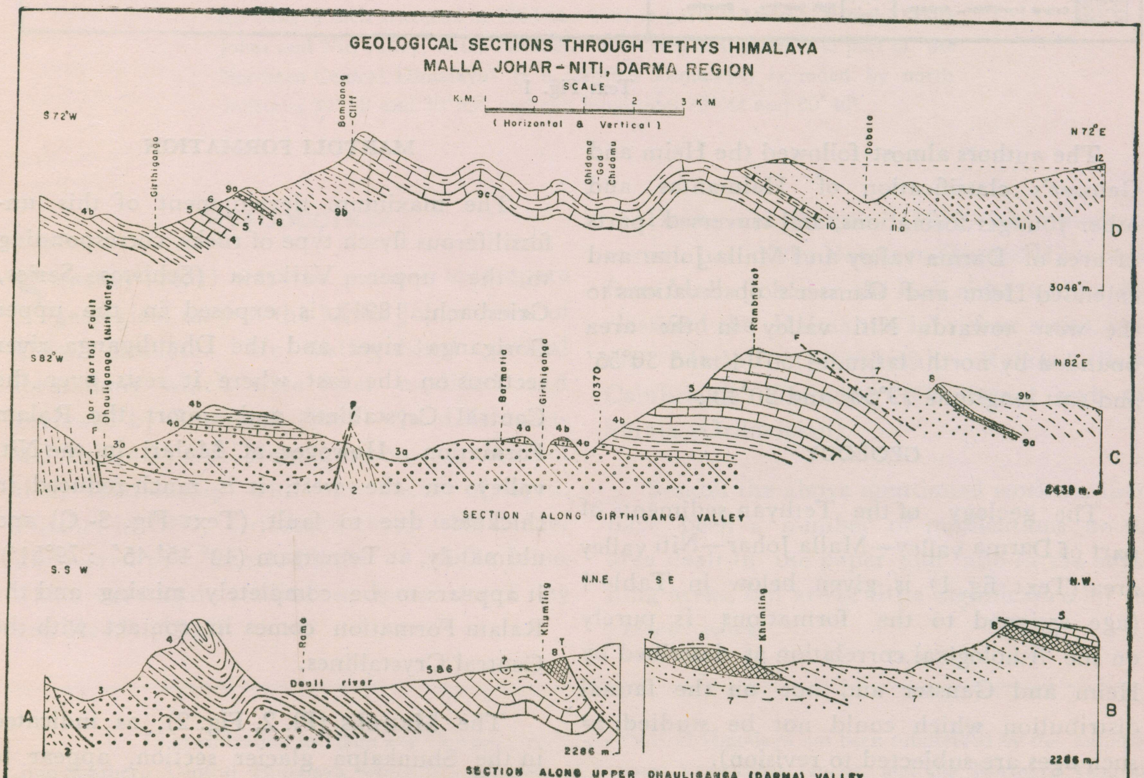
MARTOLI FORMATION

The maximum development of this unfossiliferous flysch type of rocks, corresponding to the upper Vaikrata (Schistose Series, Griesbach, 1891), is exposed in the upper Goriganga river and the Dhauliganga river sections on the east where it rests over the Central Crystallines and suport the Ralam Formation. However, at Malari in the Niti valley on the west, it is much reduced in thickness due to fault (Text Fig. 3- C) and ultimately, at Temarsam (40° 45′ 45″ : 79°51′), it appears to be completely missing and the Ralam Formation comes in contact with the Central Crystallines.

The Matrolis (Pl. 2, Fig. 2), as indicated in the Shunkalpa glacier section, appear to



Text Fig. 2



Text Fig. 3

TABLE—1

Formation	Lithology	Age	Period
Balcha Dhura Volcanics (225 m)	63. Green and reddish spilite and associated serpentinite.		Uppermost Cretaceous to Post-Cretaceous.
Flysch Series (570 m)	62. Thin brown coated calcilutite with mud cracks (1–2 m).		Upper Cretaceous
	61. Brown weathered micaceous felspathic sandstone (greywacke) with thin beds of greenish phyllite and purple rock. (30 m).		
	60. Yellow sandstone (2 m).		
	59. Interbedded greenish crumbling phyllite passing below to dark grey phyllite (178 m).		
	58. Red and grey shale with foraminiferal limestone (360 m).		
	57. Light grey felspathic sandstone.		
Giumal Sandstone (600—700 m)	56. Green phyllite.		Lower Cretaceous
	55. Glauconitic micaceous sandstone.		
Spiti Shale (100–300 m).	54. Grey sandy and marly limestone.	Portlandian	Jurassic
	53. Micaceous hard shale with thin layers and lenses of sandstone.		
	52. Black to grey shale with limestone partings and sporadic shaly nodules.		
	51. Black ferruginous shale with shaly and calcareous nodules. Nodules contain sometime ammonite.		
	50. Grey soft, friable shale containing *Belemnites* sp.		
Ferruginous Oolite (3—5 m)	49. Ferruginous oolite with ammonite, *Belemnites* sp.	Collvian	
	— — — (Disconformity) — — —		
Series 0 m)	48. Grey shell limestone with *Belemnites* sp. (5 m).	Lias	
	47. Thinly bedded grey limestone with thin layers of shale and thin (10 cm) shell layers (20–30 m).		
	46. Brown weathered shell limestone with *Trigonia* sp. at base (3–5 m).		
	45. Thinly bedded grey limestone (12–15m).		

	46. Brown weathered shell limestone with *Trigonia* sp. at base (3-5 m).		
	45. Thinly bedded grey limestone (12–15m).		
	44. Brown weathered shell limestone (4–6m).		
Kioto Limestone (500—700 m)	43. Dark grey, massive, thickly bedded limestone.	Rhaetic	Upper Triassic
	42. Grey oolitic limestone.		
	41. Dark grey, massive limestone.		
Passage Zone (50—70 m)	40. Purple, white and green glauconitic quartzite (6–10 m).	Noric	
	39. Grey limestone (3 m)		
	38. Grey shale and quartzite (12–15 m).		
	37. White quartzite (6–8 m).		
	36. Dark grey siliceous limestone (15 m).		
	35. Brown weathering limestone with black shale in lower part (30 m).		
Kuti Shale (800—900 m)	34. Limestone with shale.		
	33. Dark grey micaceous shale with limestone partings.		

(*Contd.*)

TABLE—1 (*Contd.*)

Formation	Lithology	Age	Period
Kalapani Limestone (12 m)	32. Fossiliferous dark grey limestone with minor grey shale.	Anisic to Carnic	Middle to Upper Triassic
Chocolate Series (2—4 m)	31. Greenish grey shale with corals, pelecypods, brachiopods and cephalopods (1-2 m).	Scythic	Lower Triassic
	30. Sandy limestone and shale with cephalopods (1-2 m).		
Kuling Shale (12—15 m)	29. Black friable shale with *Productus* sp.		Upper Permian
	— — — ? Disconformity. — — —		
Muth Series (1000 m)	28. Intercalated quartzite and dolomite.		Devonian
	27. White, fine-grained, massive quartzite; gritty towards top. Occasionally ripple marked.		
	26. Brown dolomitic quartzite.		
Variegated Series (70 m)	25. Grey limestone/dolomite (30 m).		Silurian
	24. Purple quartzite (4 m).		
	23. Greenish shale (6 m).		
	22. Red crinoidal shale (30 m).		
Shiala Series (+ 100 m)	21. Greenish phyllite and limestone with a thin (15 cm) band of ferruginous oolite.		Ordovician
	20. Greenish grey phyllite with bands of grey nodulous limestone, sandy phyllite and dolomite. Brachiopods (*Rafinesquina* sp.) abundant towards top.		
	19. Grey limestone and greenish phyllite with fragmentary corals, pelecypod shells.		
	18. Red siltstone and siliceous limestone.		
Garbyang Series	17. Greenish phyllite.		Cambrian
	16. Dolomite and green to light grey phyllite.		
	15. Brown coated massive dolomite with thin intercalations of green phyllite.		
Ralam Formation	14. Green phyllite with bands of purple quartzite.		
	13. Purple, gritty to fine-grained quartzite, microbreccia and associated intraformational conglomerate.		

Ralam Formation	13.	Purple, gritty to fine-grained quartzite, microbreccia and associated intraformational conglomerate.	
Martoli Formation	12.	Thinly laminated quartzite-phyllite.	Algonkian
	11.	Spotted quartzite-phyllite.	
	10.	Carbonaceous phyllite.	
	9;	Chloritic phyllite.	
	8.	Porphyroblastic carbonaceous phyllite.	
	7.	Garnet phyllite.	
	6.	Porphyroblastic biotite phyllite.	
	5.	Banded Calc-silicate hornfels. } with dykes and sills of granite, aplite and pegmatite.	
	4.	Kyanite-, sillimanite-, staurolites-, biotites schist. } with dykes and sills of granite, aplite and pegmatite.	
		— — — Dar-Martoli Fault — — —	
Central Crystallines	3.	Banded para-gneiss and associetad calc-silicate.	Archean
	2.	Banded psammite gneiss with para-amphibolite, ortho-gneiss.	
	1.	Garnet chlorite schist, cataclastic gneiss.	

grade in the Ralam Formation where a band of quartzite having resemblance with the Ralam quartzite appears in the schist. In other sections however, the contact between the two is a fault (Text Fig. 3-A). The contact with the Central Crystallines is more complicated and in the authors opinion appears to be a major fault—the Dar-Martoli Fault. A large number of acid intrusives—granite, aplite and pegmatite—are confined to the basal part of the Martolis and are not traceable in the Central Crystallines.

Heim and Gansser (1939) grouped the high grade basal Martolis in the Upper Crystallines putting a conformable boundary between their zones 'f' (biotite-psammite gneiss and calc-silicate) and 'g' (Budhi Schist—porphyroblastic phyllite) on the basis of "dying out of pegmatites and lesser metamorphism". The porphyroblastic phyllite, comparable to the Budhi Schist, is present in all the sections excepting in the Darma valley where maximum intrusion of granite and other allied rocks has taken place at this level. The authors are of the opinion that the absence, in general, of intrusives in the Central Crystallines and upward gradual decrease in grade of metamorphism would tend to suggest a complete dissociation of these two formations from stratigraphic and tectonic point of view. The high grade rocks are possibly the earliest Martolis which reached the depth of migmatisation during geosynclinal subsidence. Similar observations were made by Auden (1949, p. 76) in adjoining Harsil area, Uttarkashi district, Uttar Pradesh, where he differed with Griesbach and mentions "in reality, the Vaikratas, which consists of meso-grade garnet biotite granulites, garnet biotite schist, staurolite schist and kyanite schist,are partly if not wholly the metamorphosed equivalents of epigrade Haimantas". Auden also recorded intrnsions of granodiorites in these rocks.

RALAM FORMATION

The quartzite forms the base and develops through purple, greenish or white current bedded (Plate 2–3) quartzite to greenish phyllite with dolomitic partings towards top, ultimately grading to dolomite and phyllite of the Garbyang Series. Such gradational contact is exposed in the Milam glacier valley at Iklualari (30°32′ 30″ : 80°04′). The basal quartzite has locally developed into so called "basal Ralam conglomerate" (Heim and Gansser, 1939). This conglomerate is intraformtional consisting of subangular to angular quartzite pebbles and boulders of varying sizes, the biggest measuring 35 cm × 15 cm. Heim and Gansser (1939, p. 202) considered it to be basal conglomerate and suggested "a great interruption of normal marine sedimentation at the end of the Algonkian time". This does not appears to be so; for this conglomerate is only locally developed due to redeposition at a close distance under shallow sinking basin.

Recent studies by authors of the heavy minerals like magnetite, rutile, leucoxene, tourmaline, zircon and apatite in different thin sections of the rocks suggest their genesis from the granites and gneisses possibly from the Central Crystallines.

GARBYANG SERIES

The quartzite of the Ralam Formation passes gradationally to the Garbyang Series characterised by rocks of the calc-facies. The brown coated massive dolomite with a few intercalations of green chloritic phyllite of the Ralam Formation of Heim and Gansser has been grouped by the authors in the Garbyang Series on the basis of difference in facies, i.e , predominently arenaceous (Ralams) and calcareous (Garbyangs).

SHIALA SERIES

The Garbyang Series is followed conformably by the rocks of the Shiala Series corresponding to the Lower Silurian of Griesbach. Heim and Gansser (p. 204) thought that the coral limestone which underlies the red Crinoidal limestone (Silurian) at Spiti, is absent in the Kumaon Himalaya, but infact the nodular limestone of Dung (30° 31′ 30″ : 80° 11′ 45″). which they included in the Variegated Silurians, is actually interbedded with grineesh grey phyllite and dolomite containing abundant Ordovician brachiopods. It is conformably underlain by coral limestone.

Amongst a large collection of fossils made from the area, the authors found two interesting Nautiloids—*Lambeoceras* sp. and *Ormoceras* sp. (Plate 1–1, 2) from Talla Khanda (30°39′ : 80° 06′ 30″) and northeast of the Chor Hoti Pass (30° 48′ : 79° 54′ 30″) respectively. The later has been reported for the first time from India. *Lambeoceras* sp. (Kobayashi, 1934)[1] is the only cephalopod so far known from Ordovicians of the Himalaya. The other fossils in the recent collection include *Rafinesquina* cf. *arena* (Salter) brachiopod, and corals. The fauna as a whole support the age of the series as Ordovician.

The authors consider the series to be a warm shallow water marine facies deposited under agitating conditions as evidenced by the fragmentary nature of the fossils and ferruginous oolite.

VARIEGATED SERIES

The Variegated Silurians conformably overlie the Shialas. It varies in thickness from a few metres to about 200 metres. Mud cracks conspicously developed in the red crinoidal shale, are seen in the Lebong glacier area. In the Nui glacier area it is repeated several times due to folding and could not be mapped separately from the Shialas.

According to Heim and Gansser, the Variegated Silurians were deposited under deep sea conditions, but present work views that the crinoids generally live under warm shallow water conditions much similar to those of the coral reefs, and also the red colouration indicating widespread oxidation is generally attributed to shallow water conditions.

MUTH SERIES

The Variegated Series is succeeded conformably by the Muth Series consisting mainly of white quartzite. The maximum development of the series at Dung (30°31′30″ : 80°11′45″) is more than 1000 metres. The sequence near Lebong glacier and in — Goankhha *Gad* between Dung and Lassar (30°32′15″ : 80°14′) is highly disturbed and the Muth quartzite appears to be folded in a tight syncline (Text Fig. 2–B). At the latter place it is also folded into an anticline (Text Fig. 2–A) plunging to wards northwest. In the Dhauliganga near Khumling (30°20′ : 80°27′30″) it is thrust over the Kuling Shale (Text Fig. 3–B). Such tectonic contact could also be seen on the face of the

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1. *Lambeoceras* sp. was described by Reed (1912) as *Gonioceras* cf. *anceps* (Hall) and was latter revised by Kobayashi (1934).

Bankphu cliff in the Lissar valley from Ralphu (30° 25′ : 80° 24′). In the Kio *Gad*, east of Sumna (30° 44′ : 80° 01′ 45″), it rests over the Ordovicians due to a thrust.

The quartzite of the series is fine-to medium-grained, thickly bedded and highly jointed. It is partly gritty towards top in the Dhauliganga section. Here, it gradationally passes to an intercalated strata of quartzite and light brown dolomitic quartzite. Just north of Pungrung (30°23′ : 80°31′), it is injected with miniature sandstone dykes probably connected with slumping. Some elliptical pebbles are also caught up along the bedding near the deformed laminae. Ripple marks are also preserved at some places indicating normal sequence.

Under microscope, the quartzite shows fine–to medium-grained, well sorted, closely packed, subrounded to rounded quartz grains with slight authegenic border growth. Cement is very subordinate, and in contrast to the Ralam Quartzite, it is purely argillaceous. Heavy minerals are rounded tourmaline, zircon, rutile, leucoxene and ilmenite. In the quartzite with dolomitic intercalations, the matrix is calcareous which has also developed as authegenic individual carbonate grains. Sorting is relatively poor. This change within the series is probably connected with the change in environmental conditions during deposition. The preponderence of rounded heavy minerals as well as quartz in the rocks of the series favours the reworking of sediments from pre-Muth quartzites, i. e., Ralam and older formations, which appear to have been eposited in an unstable fore-deep

KULING SHALE

The Muth Series is overlain by the rocks of the Upper Permian, i. e., the Kuling Shale, characterised by black friable shale containing brachiopod fauna. The hiatus (Carboniferous to Middle Permian), though not visual, can be differentiated on the basis of absence of sediments from Carboniferous to Middle Permian.

The Kuling Shale, about 20—30 metres thick, is uniformly black and occassionally yield phosphatic nodules. Some of the nodules on breaking show ammonites and bivalves. The shale appears to have been deposited under marine conditions.

CHOCOLATE SERIES

In the region of Malla Johar, the Kuling Shale is succeeded by Mesozoic rocks. The authors adopting the lithological classification of Heim and Gansser (1939), traversed the rocks of the Chocolate Series at the confluence of the Shalshal *Gad* with the Yong *Gad* (i. e., the Paikhanda section) only. Further south-eastwards, in the Unta Dhura Pass (30° 34′ 30″ : 80° 10′30″) the rocks of the series appear to be absent and the Kalapani Limestone rests over the Kuling Shale.

KALAPANI LIMESTONE

In the Paikhanda section, the Chocolate Series is conformably overlain by nodular limestone and shale cosntituting the Kalapani Limestone. It continues south-eastwards to south of Unta Dhura where it is repeated a number of times due to above mentioned syncline (Pl.—2-1). It contains abundant fossil ammonites at Matoli (30° 38′ : 80°08′).

KUTI SHALE

The Kalapani Limestone is succeeded conformably by about 800—900 metres thick zone of the Kuti Shale with calcareous intercalations, quite regular in upper part. It is well developed in the Unta Dhura—Jandi Dhura Pass (30°36′ : 80° 11′30″) area occurring in the trough of above mentioned syncline. Further westwards, it has been traced continously beyond Rim Khim (30°50′ : 79°58′). Fossils in the Kuti Shale are not as abundant as in the underlying Kalapani Limestone. However, a bed rich in ammonites, brachiopods and pelecypods has been noticed at Lauka (30°36′ : 80°10′).

The Kuti Shale, in general, appears to be of deep-sea facies.

PASSAGE ZONE

The rocks of this zone conformably overlie the Kuti Shale and were studied by the authors on the precipitous slopes northeast of Matoli in the Girthiganga and about 5 km east of Sumna in the Kio *Gad*. The lower beds of this zone contain a few pelecypod shells.

The quartzite, under microscope, shows subrounded quartz grains, tightly packed in glauconitic and argillaceous matrix. There is abundant iron-ore filling the interstices.

The predominance of quartzite, which is occasionally glauconitic, indicates a shallowing of the basin during this period.

KIOTO LIMESTONE

The dark grey oolitic and massive Kioto Limestone conformably overlie the rocks of the Passage Zone. It extends from Jandi Dhura on the southeast to Bara Hoti 30°51′ : 79°58′) on the northwest. North of Jandi Dhura, it has been folded into an overturned anticline and a syncline (Text fig. 1-C) forming the Lahur peak (30°39′ : 80°10′30″) and Khingur Dhura Pass (30°39′ : 80°09′40″) respectvely. Both the folds, plunging to north with axial plane dipping towards east, gradually become symmetrical (Text Fig. 3-D) northwards. Just to the north of Chidamu (30°41′ 45″ : 80°09′20″) a minor doubly plunging anticline (Pl. 1-3) could also be seen.

The main body of the limestone is thickly bedded, massive which encloses the "problemitica" (Heim and Gansser, 1939). This problemitica, in the authors opinion, is nothing but an oolitic limestone containing cavities ("problemitica") filled with secondary calcite of coarser granularity.

A thick band of oolitic limestone appears within the massive limestone in the Kio *Gad* section, but south-eastwards in the Girthiganga, the lower massive limestone has not been developed and the oolitic limestone rests over the Passage Zone rocks. The oolities are irregular, oval, circular and disc-shaped; some of these are formed around the nuclii of microfossils.

The Kioto Limestone indicates return of shallow agitating conditions of water as evidenced by thick beds of oolite.

LAPTHAL SERIES

In the area around Lapthal (30°44′15″ : 80° 09′) the Kioto Limetsone conformably passes

EXPLANATION OF PLATE 1

1. *Lambeoceras sp.* x$\frac{2}{3}$. 2. *Ormoceras sp.* x 1.5 3. View of the folded Kioto Limestone (KL) and Spiti Shale (SS) at Chidamu, looking north. Note the doubly plunging anticline in the centre.

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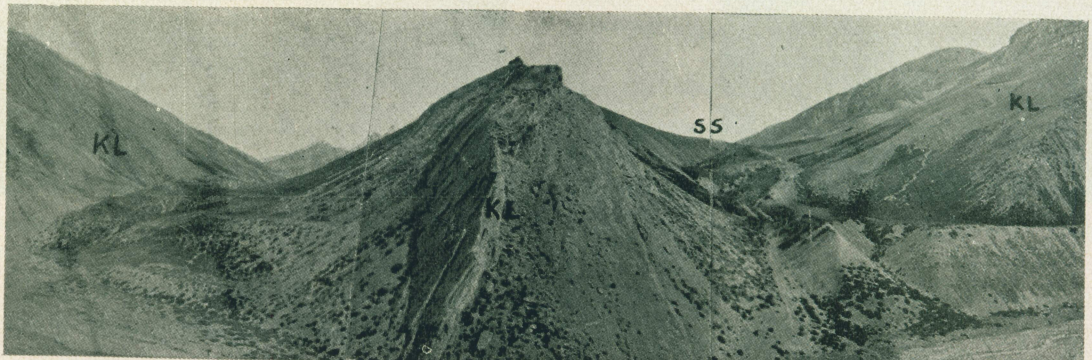

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GOPENDRA KUMAR, S. H. MEHDI AND GYAN PRAKSH : STRATIGRAPHY OF U. P. TETHYS HIMALAYA


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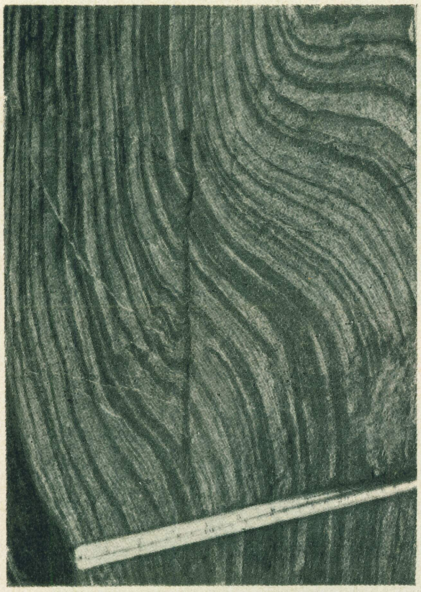

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into thinly bedded grey limestone with repeated layers of fossils agglomerate–the Lumachelle (Heim and Gansser, 1939). The fossils collected recently are mainly pelecypods and cephalopods, a few easily recongnisable are *Arca* sp., *Trigonia* sp., *Belemnites* sp. etc.

FERRUGINOUS OOLITE

The Lapthal Series with a sharp disconformable contact is overlain by Ferruginous Oolite. It contains well preserved ammonites and *Belemnites* sp. Northwestwards, at Chojjan La (30°47′30″ : 80°40′45″), and eastwards, it is not developed and the Spiti Shale rests over the Lapthal Series.

SPITI SHALE

The Spiti Shale overlying the Ferruginous Oolite at Lapthal and the Lapthal Series at other places, is well developed in Chojjan La-Sangcha Talla (30°46′ : 80°19′45″) area. It also occurs as a narrow tongue and as an outlier in the trough of the Khingur Dhura syncline (Text Figs. 1 and 3 C) between Lapthal and Chidamu, and at Khingur Dhura Pass respectively. An outlier of the Spiti Shale also occurs about 7.5 km west of Chidamu due to folding. The lower part of the series is made up of soft shale with abundant fragments of *Belemnites* sp. It passes on through much friable black to dark grey splintery shale to middle black ferruginous shale with abundant nodules which are generally pyritous and occasionally formed around ammonite. Some of the nodules are phosphatic. The shale, towards top, contains less nodules and is intercalated with limestone partings as well seen at Chojjan La ; and finally with the appearance of hard concretions and sandstone partings, it gradationally passes on to the Giumal Sandstone of Lower Cretaceous.

GIUMAL SANDSTONE

The Spiti Shale is succeeded conformably by green micaceous partly glauconitic sandstone and shale gradually developing from the Spiti Shale. It constitutes the Giumal Sandstone, and is best developed between Sangcha Talla and Sangcha Malla (30° 46′ 45″ : 80° 10′ 30″) and west of Dobala (30° 44′ : 80° 11′). It is overlain by Flysch sequence with a sharp contact.

The glauconitic sandstone is made up of fine to medium-grained, rounded, well sorted quartz and a few felspar grains in glauconitic argillaceous matrix. A few quartz grains show strain effects. Some calcite is also present in the matrix. Heavy minerals are rounded zircon and tourmaline.

FLYSCH SERIES

The light grey felspathic sandstone (? greywacke) of the Flysch sequence, outcroping about 1.5 km north of Kio Dhura Pass (30° 44′ : 80° 14′ 45″) and overlying the Giumal

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EXPLANATION OF PLATE 2

1. View of the "Bamlas Synclinorium" (Heim and Gansser, 1939) from Unta Dhura Pass, looking south. S—Shiala Series ; M—Muth Quartzite ; KS—Kuling Shale ; KL—Kalapani Limestone ; KU—Kuti Shale ; F—Fault.

2. Interbedded phyllite (dark)—quartzite (light grey) of Martoli Formation at Shunkalpa, Ralam *Gad.*

3. Current bedding in Ralam Quartzite near Go, Darma Valley.

sandstone, suggests a marked change in the depositional environment. It is succeeded by a succession of shale with intercalations of foraminiferal limestone, micaceous felspathic sandstone (greywacke) capped by calcilutite with mud cracks, best developed in Sangcha Malla-Balcha Dhura Pass (30° 47′ : 80° 13′) area. It is overlain by spilitic flow and associated serpentinite. Associated with the shale are seen "Exotic Blocks".

The felspathic sandstone (? greywacke), in contrast to the Giumal Sandstone, is made up of poorly sorted, angular to subangular fragment of felspar and quartz in siliceous to partly argillaceous matrix. The felspars, both potassic and sodic, percentage upto fifty. In contrast to the angular to subangular felsper and quartz grains, the detrital zircon is rounded, suggesting that the material constituting the greywacke has not travelled long, and possibly derived from metamorphosed sediments. There are a few flakes of detrital biotite.

The micaceous felspathic sandstone (greywacke) consists predominently of subangular to subrounded quartz and a few felspars grains in argilloceous, partly glauconitic, matrix. Thc felspar grains are mainly of perthite, microcline and orthoclase with few plagioclase. Heavy minerals are rounded zircon and tourmaline.

Heim and Gansser regarded the whole sequence as 'Upper Flysch similar to those of the Ultrahelvetic of Alps. They differed with von Krafft's divisions 'c–f' (corresponding to their division 'd') and mentioned that the upper most units forming, the crest of the Balcha Dhura is not a tuff, but are alternation of red and green sandstone and shale rich in radiolarian cherts. The present observations are some what similar to those of von Krafft. The top most bed of von Krafft ('f') is actually spilite flow with serpentinite. The radiolarian cherts, however, are not met by the authors.

BALCHA DHURA VOLCANICS

In the region of Balcha Dhura Pass are seen basic rocks—spilite and associated serpentinite, overlying the Fiysch Series. These extend westards to Blacha Dhura (30°47′:80° 10′) and southwards to Ghatmila Dhura (30° 44′30″:80° 15′) where these are overlain by the Kiogarh Formation (Heim and Gansser, 1939).

The so called red and green sandstone wcre considered by Heim and Gansser (1939) to be thrust over the Flysch sediments. It might be recalled that von Krafft considered these rocks to be tuffs resulted from volcanic explosions. The present observations also suggest that the "red and green sandstone and shale," as already mentioned, sre apilites, no tectonic distrubance has been noticed along the contact of these rocks with the underlying Flysch sequence. Therefore, the "Exotic Thrust" (Heim and Gansser, 1939) is of doubtful proposition.

It is interesting to note that associated with the Flysch Formations are seen amygdaloidal volcanic rocks made up entirely of palagonite. The cavities are fileed up with calcite.

OBSERVATIONS ON "EXOTIC BLOCKS"

The authors examined one occurrence of the "Exotic Blocks" about 1. 6 km north of Kio Dhura (30°41′20″:80°13′15″). It is of two different rocks, one reddish limestone with abundant fragments of fossil foraminfera (may be similar to those found in the red foraminiferal limestone associated with red and grey shale of the Flysch Series) and the other is the felspathic sandstone (greywacke) similar to the greywacke forming the basal part of the Flysch squence. These are embedded in the grey shale. Another "Exotic" is also seen about 3 km northwest of Kio Dhura caught up along a fault plane in between the Giumal Sandstone.

Griesbach and Diener (Griesbach, 1893) discovered the "Bxotic Elocks" of Malla Johar and latter von Krafft (1902) considered that the "Exotic Blocks" of Tibet and the adjoining frontier districts are intimately connected with volcanic action. Heim and Gansser (1939) discarded von Krafft's view and connected some of these blocks with thrusting. Authors work on the "Exotic Blocks" is very little but the one examined by them is quite intimately enclosed within the shale, and it might be connected with the depositional conditions and the prevailing tectonism within the basin.

STRUCTURE

Faults. The Dar—Mrtoli Fault, between the Central Crystallines and the Martoli Formation, is the only major tectonic dislocation mapped in different sections. It extends from Dar (30°04′15″:80°30′15″) in the Dhauliganga (Darma Valley) to Ralam *Gad* and the Goriganga river trending in W. N. W.—E. S. E. direction, and further westwards, it appears to take northerly swing around Nanda Devi[1] (30°17′30″ : 75°59′) and the same has been mapped from Malari to beyond Niti (30°46′:76°51′) in the Dhauli river. The keta-zonal basal Martolis are gradually cut-off due to this fault as one proceeds from east to west, until at Temarsam it completely disappears.

The other faults are seen in the Northern Central Himalaya which appear to be younger to the Dar-Martoli Fault. Except for the repeated faulting along the Kuling Shale, there is lack of evidence of any tectonic dislocation on a regional scale. Faults (or thrusts) of second order, mainly imbricate in nature, and specially along the Kuling Shale, are numerous. The Kuling Shale, as mentioned above, seems to have hosted a number of reverse faults which have successively brought older strata over the younger rocks in the Darma and Unta Dhura areas.

There is another fault of lesser magnitude, trending in north-south direction, affecting the Martolis and the Ralam Quartzite in the Girthiganga river, west of Barmatia (30°42′ 30″ : 79°58′). Here, a small inlier of the Martolis is exposed due to this fault.

Folds. The major folds are noticed in the Malla Johar area only. The axes of the folds trend in N. W.—S. E. to N. S. direction. As mentioned earlier, in the Unta Dhura Pass area, the formations are folded into a north-westerly plunging overturned syncline (Plate 2-1) and complimentary anticline (Text-Fig. 2-A) trending in N. W.—S. E. direction. Another folding is seen in the Khingur Dhura Pass—Lapthal area where the Mesozoic strata have been folded into an overturned Khingur syncline and Lahur anticline. (Text Fig. 2, C), both plunging towards north. These folds, as traced northwards, gradually become upright and flatten out. Minor folding is also

1. The Nanda Devi area was not mapped by the authors but they think the position of the fault as referred above.

present at Chidamu where a doubly plunging upright anticline (Pl. 1-3), trending in north-south direction, develops in the synclinal trough of the Khingur Syncline.

There also appears to be another, but northeasterly plunging broad syncline in Nanda Devi—Malla Johar area which has affected all the earlier structures. The northerly swing in the trend of the formations and the Dar-Martoli Fault around Nanda Devi appears to be due to this folding.

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