Current Trends in Geology Vol. 10 (Gluconite : Form & Function) 1986 : 93-116
Today & Tomorrow's Printers and Publishers, New Delhi-110005.

THE NATURE OF GLAUCONITE IN THE UPPER TAL FORMATION OF THE LESSER HIMALAYAN BELT AND ITS ROLE IN RESOLVING THE PROBLEM OF UNCONFORMITY BETWEEN UPPER TAL QUARTZITE AND SHELL LIMESTONE

R.A.K. Srivastava and Vinod C. Tewari
Wadia Institute of Himalayan Geology,
Dehra Dun - 248001

ABSTRACT :

This paper records for the first time the presence of two major varieties of glauconite from the Shell Limestone, and the underlying Quartzite member of the Tal Formation exposed in the Garhwal and Mussoorie synclines of the outer Lesser Himalayan belt. The gluconite in the Quartzite member is essentially authigenic, pale green in colour, crystallographically disordered and immature with low potassium and iron contents. It occurs mainly as matrix/cement and has replaced the oolitic textures in the early diagenetic stages. It is originated by the glauconitization of clayey material in normal marine environment. Contrary to it, the glauconite in the Shell Limestone is green with spheroidal, ovoidal or lobate morphology, crystallographically disordered with more potassium, iron, magnesium, calcium and strontium indicating its high maturity. It occurs as nucleus of the oolitic textures, compressed between quartz grains and also as pellets having secondary coatings indicating their allogenic nature.

This marked difference in the nature and origin of glauconite within these two stratigraphic units of the Tal Formation has been used in this paper to establish the presence of unconformity in between these two lithounits. This finding is also supported by other field evidences and an erosional unconformity has been postulated in between these two lithounits. It is also interpreted that Shell Limestone is not the integral part of the Tal Quartzite and represents a marine transgression in Cretaceous times.

INTRODUCTION:

The Tal Formation is represented by the youngest lithounits of the Krol belt sequence of the Lesser Himalayan formations. This formation has been subdivided into Lower and Upper by Auden (1934) and into Lower, Middle and Upper by Bhargava (1975). Valdiya (1975) has also classified the Tal Formation into Jogira, Masket and Bansi members. Singh (1977) separated the Upper Tal Formation (Limestone Member) from Quartzite Member based on sedimentological break and designated it as Nilkanth Formation. Bhargava (1979), Bhatia (1980) and Singh (1981) have reviewed the geological problems related with Tal Formation. However, the lithological details of the various litho-units constituting the Tal Formation is presented in Table-1 (based on Shanker, 1971).

Table 1: Lithological details of various units of Tal Formation (based on Shankar, 1971)

Subathu Formation		Olive Shale, Shell, Marl and Limestone	
		Unconformity	
Upper Tal Formation	(ii)	Limestone member (Shelly calcareous) (Grits)	15-20 m
	(i)	Quartzite member (Asequence of quartzite, arkoses, grits to pebbly quartzite and thin grey, to green shales, red siltstone, often mud cracked	
Lower Tal Formation	(iv)	Calcareous member ferrugineous, siliceous or sandy limestone	5m
	(iii)	Arenaceous member Massive and banded Silstone/Subgraywakes	300-500 m
	(ii)	Argillaceous member (c) Silty Shale and Siltstone (b) Calcareous splintery, banded Shales; buff coloured on weathering (a) Black micaceous shale, with pyrite, often carbonaceous	150 m
	(i)	Chert member (b) Phosphate unit Phosphate rock with thin intercalations of shales and chert (a) Chert unit Bedded black with subordinate layers of black shale and thin streaks of Phosphate rock.	150 m

Krol Formation

Very recently Tewari (1984 e) has revised the Lesser Himalayan stratigraphy based on the new fossil finds of conodonts, hyolithids etc. (Azmi *et al.*, 1981; Azmi, 1983; Azmi and Pancholi, 1983; Azmi and Joshi, 1983; Bhatt *et al.*, 1983), trace fossils of trilobites, trilobite impressions, calcareous algae, archaeocyatha (Singh & Rai, 1983 & 1984 Rai & Singh, 1983), brachiopods and microgastropod body fossils (Kumar *et al.,* 1983) and discovery of new stromatolite forms and oncolites (Tewari, 1984 b, c, e). These fossils are being reproduced from different parts of Mussoorie and Garhwal synclines and show biotic changes from Late PreCambrian to early Palaeozoic. The PreCambrian-Cambrian boundary lies between the uppermost Krol and the lowermost Tal Formation (Tewari, 1984 b, c, e). The younger fossils recorded from the Krol and Tal Formations are either not being reproduced or their palaeontological validity is questioned. Therefore, a Cambrian age for the Tal Formation (excluding Shell Limestone) is suggested. The chert member of the Lower Tal Formation has yielded Tommotian Shelly microfauna andstromatolites *Collumnaefacta vulgaris* and *Aldania mussoorica.* The record of Lower Cambrian algae (A.D. Ahluwalia personal communication) further supports this age which was earlier described as moravamminids by Patwardan (1978).

The Arenacous Member shows rich development of trace fossils made by trilobites and possibly ranges upto Atdabanian age. The calcareous member has yielded definite Atdabanian to Botomian? brachiopod fossils (Kumar *et al.,* 1983), and Kumar, G. personnel communication) from Garhwal and Mussoorie syncline. The Tal Quartzite on the basis of existing fossil records cannot be assigned any age younger than Late Cambrian. However, from the Shell Limestone, constituting the topmost unit of the Upper Tal Formation (Shanker, 1971) definite body fossils of Maestrichtian–Danian age (Mathur, 1977, Saklani *et al.,* 1977; Bhatia, 1980) have been recovered. The revised stratigraphic setup of the Tal Formation is presented in Table 2 (after Tewari, 1984 e).

The contact between the Late Cambrian Upper Tal Quartzite and the overlying Maestrichtian–Danian Shell Limestone has become an enigma in the stratigraphic ladder of the Lesser Himalayan formations. This contact is still a matter of dispute amongst the geoscientists. The Shell Limestone was earlier taken as an integral part of the Tal Quartzite and the contact between them as conformable. It is very difficult, in fact, to visualise a regional unconformity in between these two topmost units of the Tal Formation. However, there is a sharp change in lithology and the contact seems to be gradational. The Shell Limestone is a high energy carbonate sand bar-shoal complex with reworked oolites, shell fragments and glauconite pellets. Whereas the underlying Tal Quartzite is a mature, medium to coarse grained orthoquartzite with large scale cross laminations and basically unfossiliferous. Auden (1937) proposed an unconformity between these two units. Shanker (1971) suggested the presence of disconformity between the quartzite member and the calcareous member within the Tal Formation. Singh (1977, 1979) has also suggested a major unconformity/sedimentological break between the Shell Limestone (his Nilkanth Formation) and the Tal Quartzite member. On the basis of palaeontological and tectono-stratigraphic dispositions Acharyya (1979, 1981) and Valdiya (1980) have further suggested the presence of unconformity and have stressed the need of separating the Shell Limestone (his Singtali Formation/ Bansi Member) unit from rest of the underlying Tal units. On the contrary, Bhatia (1980) does not agree with the view on the presence of unconformity between these two units and suggests a conformable contact.

TABLE 2. LITHOSTRATIGRAPHIC SET UP OF THE TAL FORMATION IN THE MUSSOORIE AND GARHWAL HIMALAYA
(based on the recent works of Azmi and Pancholi, 1983; Azmi, 1983; Singh & Rai, 1983; Rai & Singh 1983; Tewari, 1984 b,c,e; Tewari and Qureshy, 1985
G. Kumar *et al.,* 1983).

Amri/Bijni Crystallines			
	Tectonic contact (Thrust)		
Subathu Formation	(Nummulites)		Eocene Transgression
	Unconformity		
Shell Limestone			Cretaceous Transgression
	Unconformity/Hiatus		
TAL FORMATION	Quartzite member	CAMBRIAN	Regression
	Calcareous member		
	Arenaceous member		Atdabanian
	Argillaceous member		
	Chert member		Tommotian
	Krol E		
Upper Krol Formation	Krol		PreCambrian (Vendian/Yudomian)

This stratigraphic problem of the contact relationship between Shell Limestone and the underlying Upper Tal Quartzite initiated the authors to search for the direct and indirect evidences to resolve this problem. During the course of the geological investigations on this problem the authors realised the importance of potential mineral glauconite which has already been reported by Kumar & Singh (1978) from the Shell Limestone unit exposed near Singtali. The authors were fortunate to record for the first time the presence of glauconite from the Tal Quartzite unit also from the Tal valley. Thus, the presence of glauconite in both these units served as convincing tool to add more reliable data on this problem. The glauconite has already been used to resolve the problem of diastem or unconformity in a number of such problematic horizons in other parts of the world (Goldman, 1921; Triplehorn, 1966).

Since the first report of glauconite from the Shell Limestone by Kumar & Singh (1978) no systematic efforts were made to study this mineral in detail and to use it to interpret the bathymetric conditions, environmental fluctuations, stratigraphic breaks etc. The authors started systematic efforts in this direction and detailed sampling of the Shell Limestone and the underlying Quartzite member exposed in Mussoorie and Garhwal synclines of the outer Lesser Himalayan Krol belt was done. Special attention was paid to study the nature of contact in the field and to collect samples near the contact zone of these units.

THE NATURE OF CONTACT IN THE FIELD:

The Tal Quartzite attains a huge thickness in Mussoorie and Garhwal synclines. This mature, medium to coarse grained white and grey coloured orthoquartzite shows very good preservation of primary sedimentary structures (Fig. 1 a) like large scale cross-bedding (formed by the migration of mega ripples), parallel bedding, ripple bedding, lenticular and flaser bedding, herringbone cross bedding, climbing ripple laminations, ripple marks, channels and planes of discordances suggest a medium to high energy subtidal sand bar, sandy intertidal flat and beach-shoal complex as the depositional environment. The migrating sand bars in shallow sea produced long shore bars and mega ripples which made the large scale cross beddings. These structures show a complete prograding sequence of a regressive sea. The bands of tuffaceous rocks varying in thickness from 25 cm to half a meter occur within the Tal Quartzite (Fig. 1c). The overlying Shell Limestone is grey, oolitic, sandy containing fragmentary bivalves, gastropods, bryozoans along with glauconite. This has been referred as Shell/ Limestone/Sandy oolitic limestone/oosparite/calcarenite/bioclastic grainstone/Singtali Formation/Bansi Formation/Nilkanth Formation etc. in the earlier geological literature (Singh, 1977; Valdiya, 1980; Bhatia, 1980).

The contact between Tal Quartzite and overlying Shell Limestone looks like gradational in the Tal valley, Singtali and Gopi Chand Ka Mahal sections but the transitional passage from Quartzite to limestone is in fact the mixing of the thin regressive terrigeneous clastics with transgressive sandy carbonate sea (the thin sections of quartzite show calcareous cement). The Quartzite in contact with Shell Limestone does not show development of any sedimentary structure in Gopi Chand Ka Mahal sections. In fact the contact shows irregular surface with pinching of beds towards the upper part (Fig. 1 b). A very thin zone of weathering

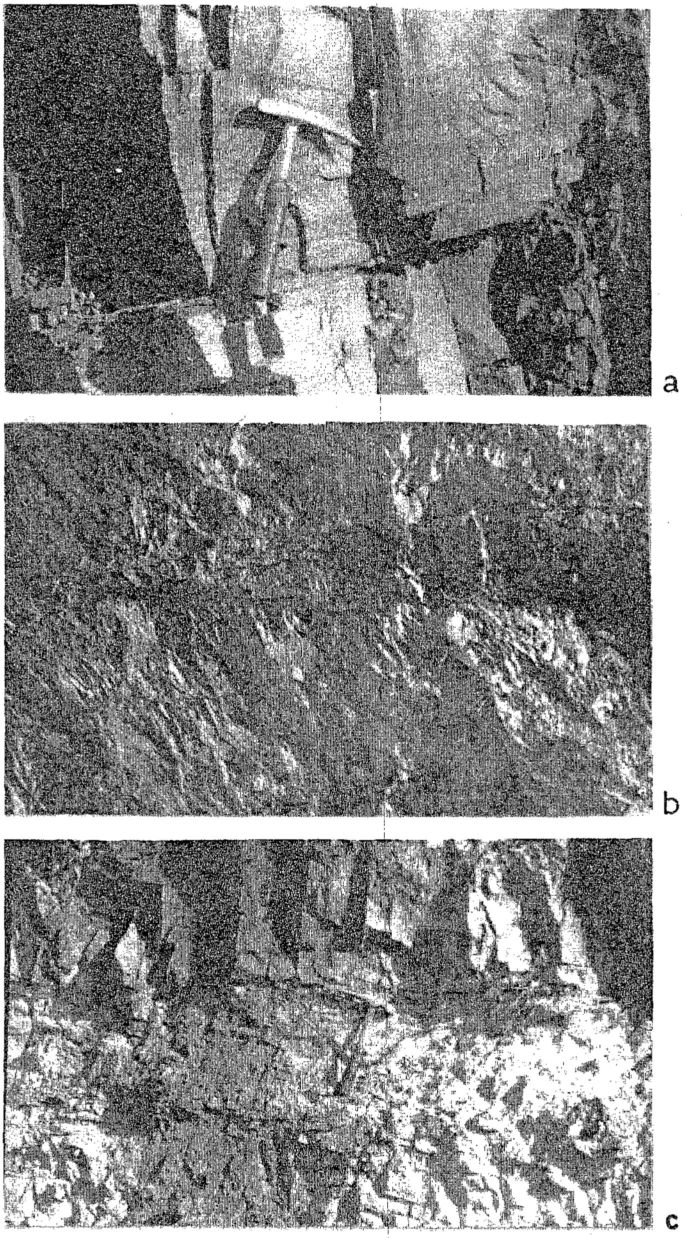

Fig. 1.

(a) Field photograph showing cross-bedding in Upper Tal Quartzite unit in Dhaulagiri Section.
(b) Field photograph showing pinching of beds of Shell Limestone in Gopi Chand Ka Mahal Section.
(c) Field photograph showing bands of tuffaceous rocks in Upper Tal Quartzite unit in Dhaulagiri Section.

(palaeosol)? and minor undulations on the surface of the contact is also seen in this area. These evidences directly indicate towards the presence of an erosional unconformity. Further the marine transgressions, which have produced the Shell Limestone (see discussion), are generally of erosional character. Thus, it is visualised that the transgressive carbonate sea (Shell Limestone) removed the then exposed surfaces of the regressive deposits (Tal Quartzite) and deposited over the erosional surfaces. Such events are marked as unconformity in the geological literature. Therefore, the authors visualise an erosional unconformity on the basis of the field evidences. The occurrence of arkosic quartzite at the base of the Shell Limestone, as reported by Shankar (1971), is also suggestive of an unconformity. However, no regional unconformity is visualised in Tal Valley but the hiatus is inferred based on detailed study of mineral glauconite in the Tal Quartzite and Shell Limestone.

THE TWO VARIETIES OF GLAUCONITE:

Besides the direct field evidences on the nature of the contact between Shell Limestone and Tal Quartzite the authors studied the mineral glauconite in detail from both these units. The petro-mineralogical characters of the two major varieties of glauconite found in these two litho-units is presented in the following paragraphs:-

ANALYSIS OF GLAUCONITE:

A large number of thin sections were prepared from the samples of both the units for petrographic studies. The individual glauconite grains were separated from the Shell Limestone unit by dissolving smaller chips of the samples in dilute acitic acid. The insoluble residue thus obtained was further processed and the glauconite grains were manually picked up under a zoom binocular microscope. The separation of glauconite grains from the Quartzite unit was fairly difficult. It was done by careful breakings of the samples in smaller pieces treatment with acitic acid, washing and seiving and finally using isodynamic seperator and manual picking.

Besides the petrographical studies, the seperated glauconite material from both the litho-units were subjected for geochemical analysis, infrared studies, differential thermal analysis and X-ray studies to distinguish the petro-mineralogical differences of the glauconite found in Shell Limestone and the Quartzite unit.

(a) MICROSCOPIC INVESTIGATIONS:

The loose glauconite grains, separated from the Shell Limestone and

Quartzite unit, were studied under the binocular microscope. Not much difference was found in the morphological characters of these glauconite grains. (Fig. 2) The palegreen glauconite occuring in Quartzite unit is mostly irregular in shape and has tendency towards rounding (Fig. 2 a, b, c, d & e). In case of the green glauconite grains from Shell Limestone larger pellets having rounded, spheroidal, ovoidal and lobats morphology has been found (Fig. 2 f, g, h, i, j, k, l, m). In thin section, both the varieties of glauconite have random microcrystalline internal structure.

The glauconite in the Quartzite unit occurs essentially as matrix/ cement within the framework of associated detrital mineral grains (Fig. 3 b). It is also found authigenically replacing the pre-existing oolitic radial textures as well (Fig. 4 a, b, c). Partial replacement of clay pellets by glauconite is also observed in the thin sections (Fig. 3 a, c). Glauconite is also found as unbroken and irregular pellets (Fig. 3 b). The nature of occurrence of glauconite in the Quartzite unit is indicative of their secondary nature which has been generated in the marine environment of the basin itself.

In contrast, the glauconite in the Shell Limestone appears to the allogenic in nature. It is observed as nucleus of the oolitic textures, with expansion or dessication cracks and infilled with minute crystals which may be of diagenetic origin and difficult to identify (Fig. 5 a). The glauconite is found replacing the radial textures of the oolites in case of Quartzite unit whereas in case of Shell Limestone it has served as nucleus. Thus the glauconite is of secondary origin in Quartzite and is of primary origin in the Shell Limestone.

Further more, the glauconite in Shell Limestone is also observed as broken pellets (Fig. 5 b), squeezed and deformed between adjacent quartz grains (Fig. 6 c). This deformed and squeezed glauconite was probably a spheroidal pellet which was squeezed during compaction processes. Many of the glauconite grains in Shell Limestone have shiny dark coatings of pyritic or phosphatic materials (Fig. 6 a) and also have secondary growths on their outlines probably of calcareous minerals (Fig. 5c, 6b). The glauconite in Shell Limestone never occurs as cement or overgrowths. The grains are either fragmental or with some degree of rounding. The high percentage of such features observed in the glauconite grains found in Shell Limestone indicate that they are recycled in their genetic history and are representative of allogenic glauconites.

It is also an interesting observation that the percentage of glauconite is less in Quartzite unit as compared with the percentage of glauconite in the Shell Limestone. From rest of the lithounits of Tal Formation there is no report on the presence or absence of glauconite so far.

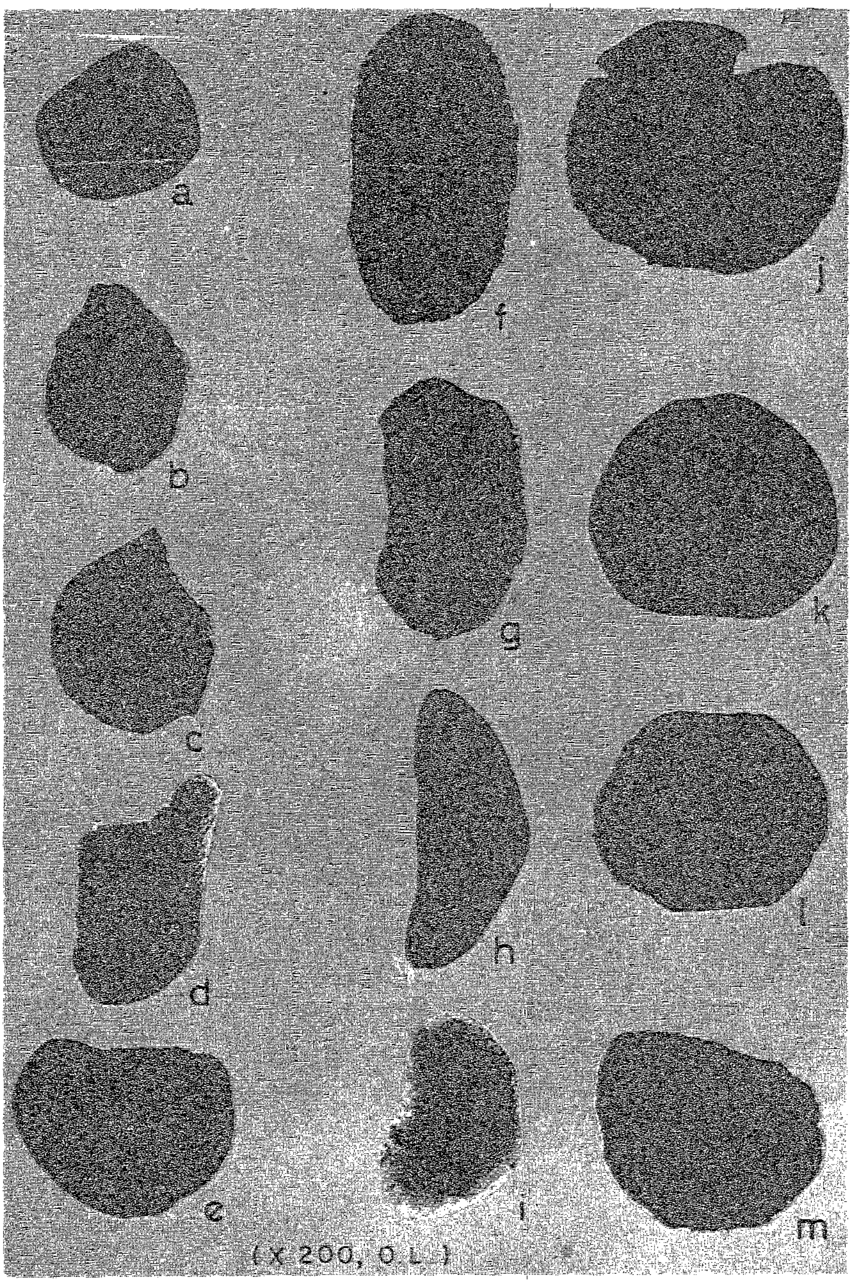

Fig. 2.

a,b,c,d and e shows the morphological varieties of glauconite in Upper Tal Quartzite.

f,g,h,i,j,k,l and m shows rounded, spheroidal, ovoidal and lobate morphology of the glauconite found in Shell Limestone unit.

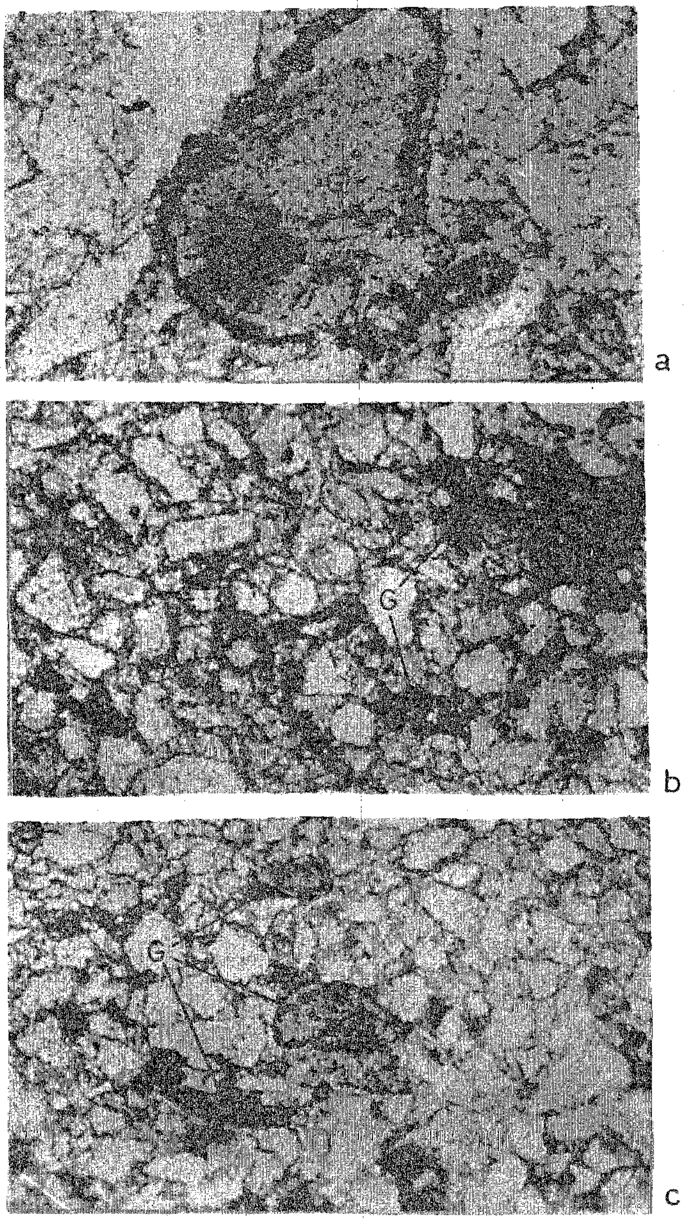

Fig. 3.

(a) Photomicrograph showing partial replacement of clay pellets by glauconite in Upper Tal Quartzite unit.

(b) Photomicrograph showing glauconite as cement/matrix in the Upper Tal Quartzite unit.

(c) Photomicrograph showing glauconitization of clayey material in Upper Tal Quartzite unit.

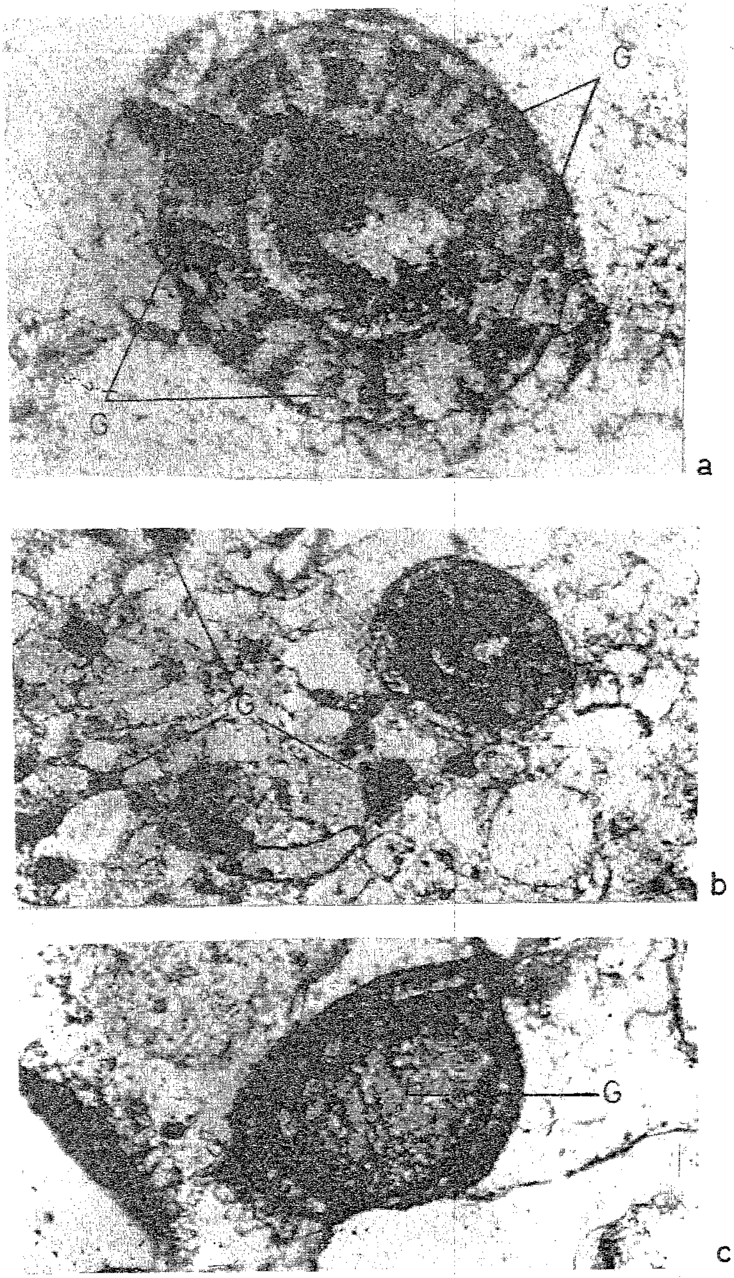

Fig. 4.

(a) and (b) Photomicrograph showing the authigenic replacement of the radial textures of oolites by glauconite in the Upper Tal Quartzite unit.

(c) Photomicrograph showing the replacement of the internal texture of a oolitic body by glauconite in Upper Tal Quartzite unit.

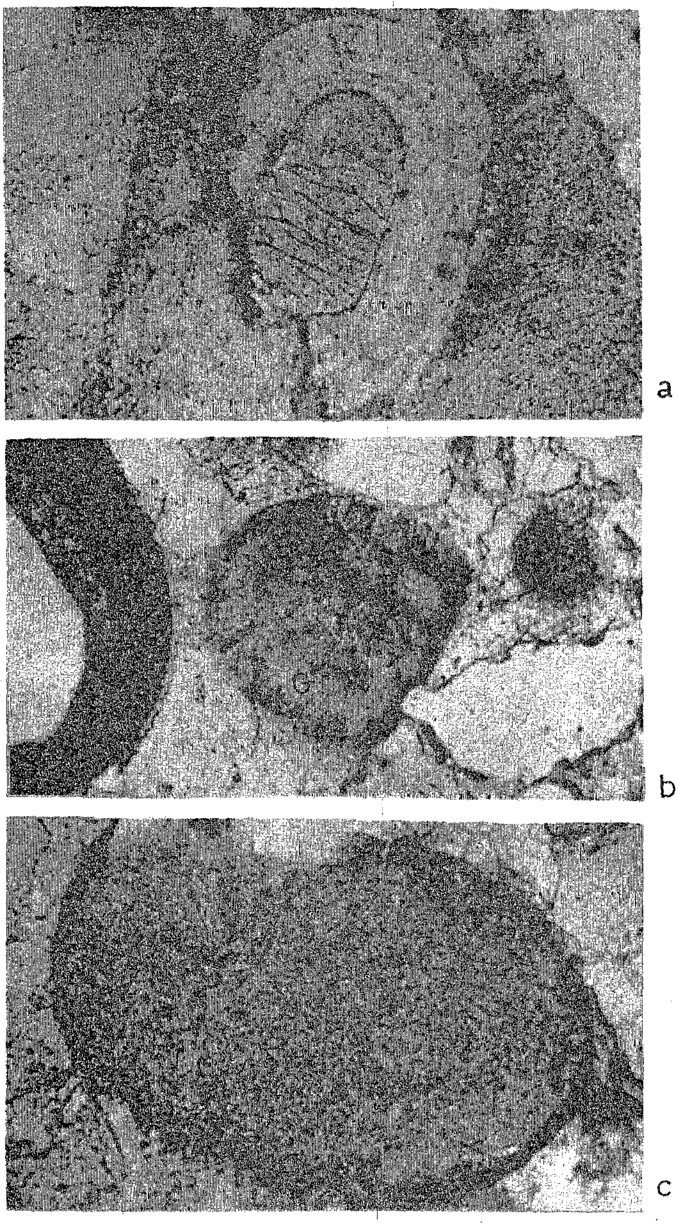

Fig. 5.

(a) Photomicrograph showing presence of glauconite as nucleus of the oolitic texture in Shell Limestone Unit.

(b) Photomicrograph showing broken pellet of glauconite in Shell Limestone unit.

(c) Photomicrograph showing secondary overgrowths of calcareous material over the glauconite pellet in Shell Limestone unit.

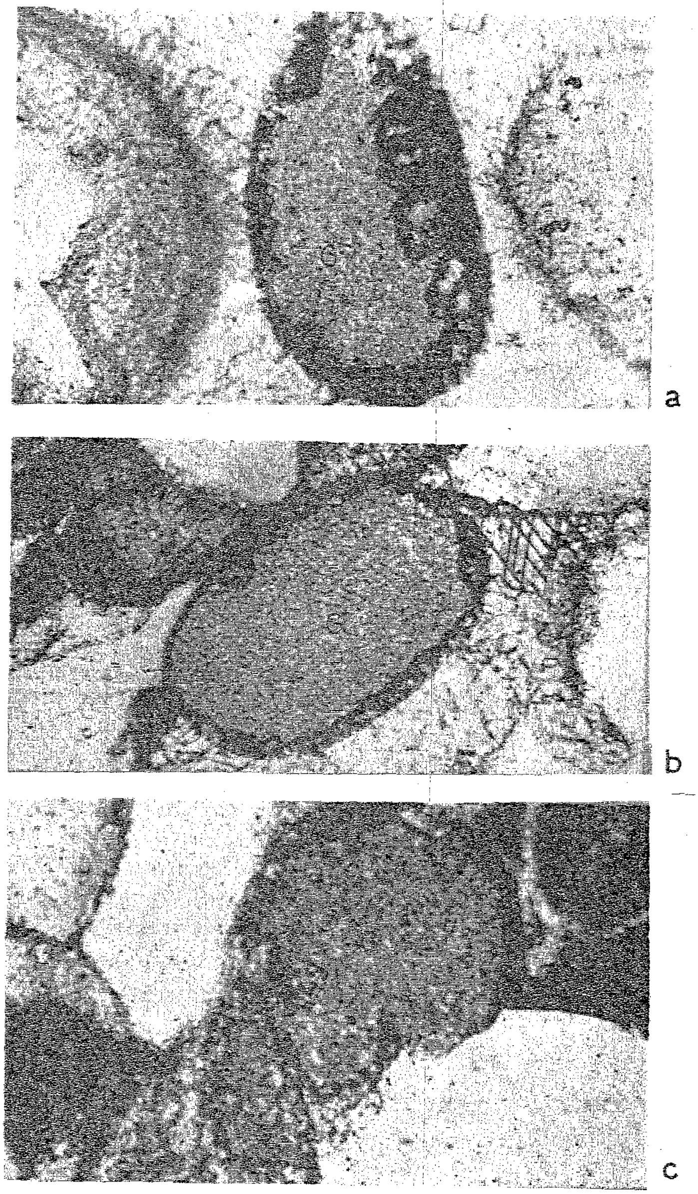

Fig. 6.

(a) Photomicrograph showing secondary coatings of pyritic/phosphatic material over the glauconite pellet in Shell Limestone unit.

(b) Photomicrograph showing secondary overgrowths of well crystallized calcareous material over the glauconite pellet in Shell Limestone unit.

(c) Photomicrograph showing squeezed and deformed glauconite pellet between adjacent quartz grains in Shell Limestone unit.

(b) X-RAY DIFFRACTION STUDIES:

The X-ray differactogrames for the representative glauconites from Quartzite and Shell Limestone are presented in Fig. 7. The presence of glauconite is confirmed with the main peaks at 10.05 Å, 4.51 Å, 3.35 Å, 2.58 Å and 2.40 Å. One significant difference is the presence of large peak of quartz in case of quartzite sample which may be due to the unseparated quartz grains.

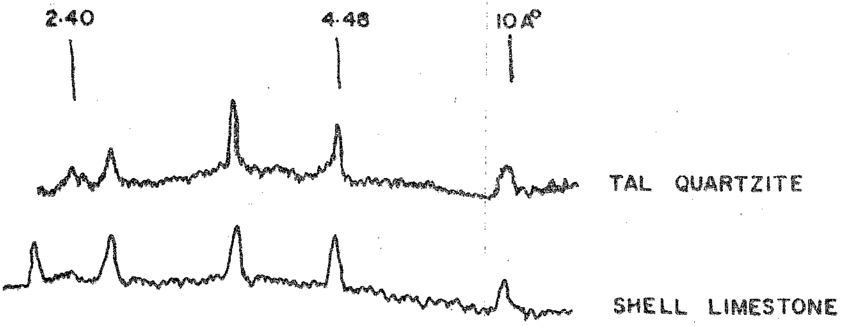

Fig. 7.

X-ray diffractogram of glauconite mineral from Upper Tal Quartzite and Shell Limestone units.

(c) INFRARED STUDIES:

The infrared spectrum of both the types of glauconite is presented in Fig. 8. The peaks present in the 1300-4000 cm^{-1} range are due to the absorbed OH molecules. The chain structure of SiO_4 vibrations are present in the 760 – 1050 cm^{-1} range and other peaks in lower ranges may be due to the various expandable layers present in the glauconite.

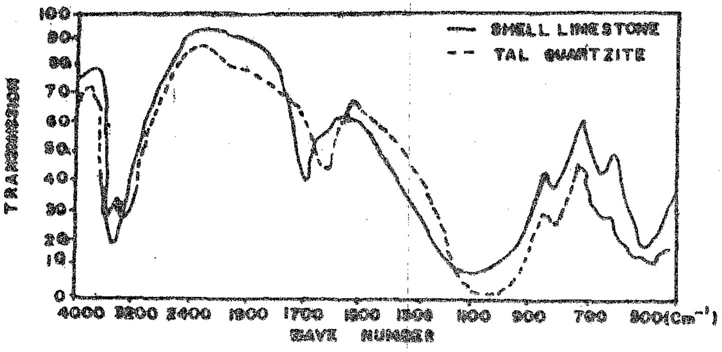

Fig. 8.

Infrared spectrum of glauconite mineral from Upper Tal Quartzite and Shell Limestone units.

(d) DIFFERENTIAL THERMAL ANALYSIS:

The D.T.A. curves for the glauconites from Quartzite and Shell Limestone are presented in Fig. 9. These D.T.A. patterns are also compared with the representative curves given by Grim *et al.* (1951). The endothermic peaks at 180°C is due to the losses of absorbed water. The exothermic peak of smaller magnitude at 380°C may be due to the oxidation of the structural Fe^{2+} and the associated loss of water. A complete dehydroxylation is reflected at 580°C. The peaks at 980°C are due to recrystallization of the different minerals produced on heating. The major difference is noted only at 980°C in these two samples which may be related to the percentage of Fe^{3+} in the glauconite lattice and the nature of the end product.

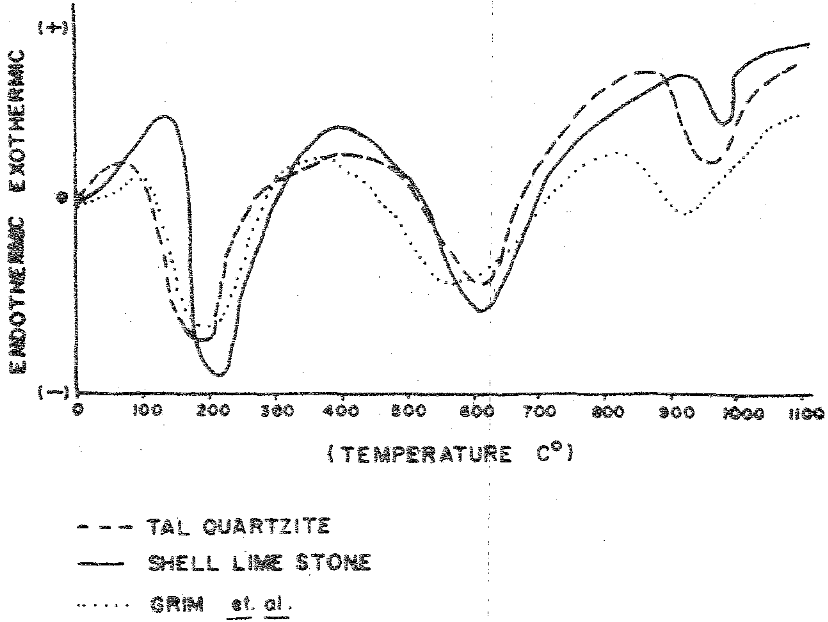

Fig. 9.

D.T.A. curves of mineral glauconite from Upper Tal Quartzite and Shell Limestone units.

(e) GEOCHEMICAL STUDIES:

The results of quantitative and semi-quantitative analysis for the alkali and metal elements in both the types of glauconite are presented in table 3.

TABLE 3. ABUNDANCE OF SELECTED ELEMENTS IN THE GLAUCONITES OF UPPER TAL QUARTZITE AND SHELL LIMESTONE

(a) Quantitative Analysis

Elements	Wt % Oxide Quartzite	Shell Limestone
Fe_2O_3	6.25	14.32
CaO	0.5	1.28
MgO	–	1.75
Na_2O	5.24	6.44
K_2O	3.65	7.62

(b) Semi-Quantitative Analysis (by X-ray Flurorescene)

Element	in ppm	in ppm
Cr	4	<2
Ni	105	<2
Cu	21	8
Zn	18	6
Pb	64	13
Th	3	<2
U	19	7
Rb	30	27
Sr	12	156
Y	37	28
Zr	219	107

The low iron content in case of glauconite from Quartzite unit probably accounts for the paler colour. The higher percentage of sodium oxide in both the varieties of glauconite is unexpected with their genetic or diagenetic implications. The higher percentage of potassium in case of glauconite from the Shell Limestone is indicative of its mature nature. The distribution of trace elements in both the varieties of glauconite is not consistent.

GENESIS OF GLAUCONITE:

The glauconite, a mineral of complex structure and chemistry, is formed at a low temperature and pressure within a limited range of Eh, pH, salinity and other environmental conditions. Authigenic glauconite essentially forms under exclusively marine conditions (Cloud, 1955, McRae, 1972) and can be used with confidence as a significant sedimentary environmental indicator. It provides valuable information to the conditions prevailing at the site of its formation.

In the recent past extensive studies have been made on the physical chemical properties of glauconite, its origin and conditions of formation. It has an extremely wide spectrum of possible source or parent materials from which it may originate (Mc Rae, 1972). Glauconite has also been considered as an original precipitate (Pratt, 1962, Bailey and Atherton, 1969). Most commonly it is formed by progressive absorption of potassium and iron into a degraded silicate lattice (Brust, 1958a; 1958b; Hower, 1961).

The glauconite in the Quartzite unit of the upper Tal Formation is generally found as cement and matrix indicating their post-deposition origin, but whether early or late is uncertain. Their irregular outlines, tendency towards rounding and the obvious difference from the partly glauconitized clay pellets indicate that they are formed in the depositional environment prior to burial. The partly glauconitized clay pellets, replacement of the radial fabrics of the oolitic textures probably reflect post-depositional and diagenetic glauconitization. Carozzi (1960) and Dapples (1967) have pointed out that in most cases the matrix/cement glauconite is after a primary clay matrix.

The pale green colour and low potassium content of the glauconite found in the Quartzite unit suggests that this glauconite is immature (Mc Rae, 1972). Further the low magnesium, calcium and strontium content of this glauconite is suggestive of their genesis under condition of salinity less than normal marine (Degens *et al.*, 1957). It seems that in moderate to high energy conditions the bottom sediments were undergoing significant bottom transport to disperse widely the detrital clay which were deposited very quickly as clay pellets but in small amount. At the slopes of the sediment water interface, both the energy and the sedimentation rates reduced greatly and repeated micro-fluctuations generated at the oxidation-reduction boundary to produce microreducing environment to give rise conditions for the glauconitization of the primary clay matrix and pellets in various forms at different stages of diagenesis (Wermund, 1964). All these evidences indicate an early diagenetic transformation that did not proceeded to completion before burial in many cases. Further the textural homogeneity of the authigenically developed glauconite in the radial textures of oolites and in portions of clay pellets with the glauconite as matrix/cement, suggest that either similar chemical conditions existed during the diagenetic stages as prevailed during the development of clay pellets or resonably enough the diagnesis accelerated the glauconitization during authigenesis. It is hard to believe that similar depositional and diagenetic conditions do existed in sediments where existence of organic matter is not found at all to generate chemically active solutions after deposition as is the case with Quartzite unit.

On the basis of the above facts and the nature of glauconite occurring in the Quartzite unit of the Upper Tal Formation it can be safely concluded that they are essentially authigenic formed by the alteration of clayey material in early stages of diagenesis. The criteria to recognize such authigenic varieties of glauconite have been suggested by Light (1952) and Carozzi (1960).

However, the glauconite found in the overlying Shell Limestone unit of the Upper Tal Formation differ notably from the glauconite found in the underlying Quartzite unit. The glauconite is much abundant in the Shell Limestone in comparison to the Quartzite unit. Thus, the abundance of glauconite in the Upper Tal Formation increases upwards in the stratigraphic succession. This indicates that either genetic conditions progressively became more favourable, or progressively more glauconite was supplied from older sedimentary sequences. It is interesting to note that no report of occurrence of glauconite is found in the lower units of Tal Formation (Chert-Phosphorite, Argillaceous, Arenaceous, and Calcareous units) or even in the Blaini-Infrakrol-Krol formations of Krol belt sediments. The occurrence of glauconite in these upper most litho-units of Tal Formation is of marked significance as it indicates drastically different tectono-sedimentation realm of deposition in comparison to other lithounits.

However, it has already been pointed out that the glauconite in the Quartzite unit is authigenic and is found essentially as matrix/cement. But in case of Shell Limestone unit the glauconite is never observed as matrix/cement. Notably it shows all evidences of transportation and recycling. It occurs as nucleus of the secondary oolitic textures, squeezed between quartz grains, broken fragments and having secondary overgrowths of calcareous/phosphatic and pyritic material. These evidences are enough to suggest that the glauconite found in Shell Limestone is not authigenic at all. A small amount of local transport may not have broken up the lobate grains. Carozzi (1960) and Cullen (1967) clearly recognised the tendency for lobate grains to breakup with transportation. The spheroidal and ovoidal grains present in the Shell Limestone also indicate their recycling prior to deposition.

These evidence left only two alternatives now for the origin of glauconite in the Shell Limestone. It is either perigenic, derived from some unrepresented facies of this unit, or is allogenic, derived by erosion from the underlying Quartzite unit. The characteristics of the glauconite found in Shell Limestone, which has already been described, proves that they are not perigenic but are certainly allogenic which has been supplied to the site of deposition along with other such recycled components. If we go into the detailed petrography of the Shell Limestone, abundance of recycled fossil fragments and quartz (angular to subangular in shape) grains having secondary overgrowths are found.

Thus, the presence of these two major varieties of glauconite within the topmost lithounits of Tal Formation in the Lesser Himalaya adds significant data to the geological history of the basin. These observations has been used in this paper as a strong evidence to suggest the presence of hiatus/unconformity between the Shell Limestone and the underlying upper Tal Quartzite unit. It can safely be concluded that the glauconite of the Tal Quartzite and Shell Limestone belong to two different cycles of sedimentation and a hiatus exists between them.

DISCUSSION :

The present study proves the presence of authigenic glauconite in the Upper Tal Quartzite and allogenic glauconite in the overlying Shell Limestone. It seems that the source for this allogenic glauconite is the pre-existing Upper Tal Quartzite because glauconite is not found so far in any other horizon in this part of the Krol Belt except the Upper Tal Quartzite.The supply of glauconite to the depositional site of the Shell Limestone must have resulted due to the uplift and subsequent erosion of the Upper Tal Quartzite unit. It is postulated that such conditions developed due to the uplift of the Upper Tal Quartzite during the Cretaceous-Tertiary Himalayan orogeny. It is believed that the transgression of the Tethys started southwards during the collision of the Indian and Eurasian plates in late Cretaceous-Palaeocene times. The marine conditions started regressing from the Tethyn zone of the Himalaya during this marked tectonism and widespread transgression of the calcium rich marine waters took place along some narrow weak zones into the Lesser Himalayan platform affecting the then exposed older rocks in many parts of this belt. The occurrence of Shell Limestone and Subathu (Nummulitics) over different lithounits of the Lesser Himalaya confirm the transgressive nature of the sea.

This sandy oolitic carbonate sea (marine transgression) is finally responsible for the erosion of the Upper Tal Quartzite as it is an established fact that marine transgressions are generally of erosional character. This eroded material was recycled and deposited over the erosional surface and was brought towards the depositional site of the Shell Limestone. Further, the glauconite found in Shell Limestone units also suggest the mode and nature of erosion and recycling of glauconite from the Upper Tal Quartzite. It is supposed that constant reworking in a submarine environment will produce relict type of glauconite (Bell and Goodell, 1967). Relict type of glauconite is also produced in case of submarine erosion from older sediments (Cullen, 1967; Ballance and Nelson, 1969). But the glauconite found in Shell Limestone does not represent the relict type of glauconites. Therefore, it is inferred that the glauconite supply to the calcium rich marine waters available at the site of deposition of Shell Limestone was done during subaerial recycling. The other detritus were also supplied along with glauconite from the Upper Tal Quartzite by the subaerial erosion and subsequent recycling. This subaerial condition was developed in this part of the Lesser Himalaya during *Oregonian/Austrian hiatus* (= 100 m.y.). On the basis of detailed studies on glauconite from Malla Johar area (Sinha and Srivastava & Virdi, in this volume) the presence of *Oregonian/Austrian hiatus* has already been established in the Tethyan zone of Himalaya. .This hiatus may be represented in the form of Unconformity/Sedimentological break between Upper Tal Quartzite and Shell Limestone in this part of the Lesser Himalayan belt. Thus an erosional surface can safely be visualised at the contact of Upper Tal Quartzite and Shell Limestone in this part of the Lesser Himalayan belt. This erosional surface can be observed between Dhaulagiri and Gopi Chand Ka Mahal section in the Mussoorie syncline. Tewari (1985 IGA Workshop) has discussed this point in detail.

Furthermore, the mature type of glauconite in Shell Limestone (having more than 7% K_2O) is suggestive of a period of slow deposition associated with the marine transgression. But Singh (1977, 1981) has suggested a high energy carbonate sand bar-Shoal complex as the depositional environment of the Shell Limestone. These high energy conditions were fluctuating and a period of calm and quite conditions does also prevail (Rupke, 1974; Srivastava, 1984) during the deposition of the Shell Limestone. However, the Upper Tal Quartzite is a product of coastal beach-tidal flat environment and represents a prograding sequence of a regressive sea. This inference is drawn on the basis of detailed studies based on sedimentary structures. These facts reveal that the environment of deposition of both these units are more or less similar. This similarity of environment of deposition is taken by some workers (Bhatia, 1980) as a valid ground to show the absence of unconformity or sedimentological break but the basic difference of their being representatives of regression (Upper Tal Quartzite) and transgression (Shell Limestone) is emphasized here to mark the hiatus in between these two litho-units.

CONCLUSIONS:

On the basis of the sedimentological studies and the mode of occurrence and origin of glauconite in the Upper Tal Quartzite and overlying Shell Limestone following conclusions are drawn:

a) The Upper Tal Quartzite is a regressive deposit the basin which was existing in Lesser Himalaya since Riphean times, was uplifted and the sea finally withdrawn after the deposition of this unit in Late Cambrian times (around 500 m.y.).

b) The Upper Tal Quartzite unit was again uplifted during Mid-Cretaceous times (Oregonian/Austrian phase) and was subarerially eroded by the transgressing sandy carbonate sea to supply detritus along with glauconite to the depositional sites of the Shell Limestone.

c) The glauconite found in Shell Limestone is allogenic and mature (more than 7% K_2O) representing their recycling from the underlying Tal Quartzite.

d) The contact between Upper Tal Quartzite and Shell Limestone is represented by an erosional surface.

e) The erosional surface present in between Upper Tal Quartzite and Shell Limestone represents an erosional unconformity.

f) The glauconite found in Upper Tal Quartzite and Shell Limestone belong to the different cycles of sedimentation and a *hiatus* do exists between them.

SUGGESTIONS:

On the basis of the above studies the authors wish to suggest the following:

a) On the basis of our present study it seems to us that Shell Limestone is neither a integral part of the Subathu nor the Tal Quartzite. It belongs to a separate marine transgression during Cretaceous times. Moreover, the Shell Limestone is uncomformably overlain by Subathu Formation in the Central part of the Krol Basin and is unconformably underlain by Tal Quartzite. Therefore, it is suggested that the Shell Limestone should be excluded from the Tal Formation and be redefined according to the Indian code of stratigraphic nomenclature. The name Nilkanth Formation (Singh, 1977) or Singtali Formation (Valdiya, 1980) may be retained as alternative stratigraphic code for Shell Limestone.

b) From the present study it is clear that the glauconite found in Upper Tal Quartzite is authigenic in origin whereas the glauconite found in Shell Limestone is allogenic. Therefore, it is suggested to use the glauconite found in Upper Tal Quartzite for K/Ar isotopic dates or for fission track dating. The allogenic glauconite found in Shell Limestone will not give age for the Shell Limestone.

ACKNOWLEDGEMENT:

The authors are greatful to the Director, Wadia Institute of Himalayan Geology, Dehra Dun, for providing necessary field and laboratory facilities. Thanks are due to Prof. A.T. Cross, Michigan University, U.S.A. and to Dr. B.J. Bluck, Glasgow University Scotland, for fruitful discussions in the field. The authors are also thankful to Dr. N.S. Mathur, W.I.H.G. Dehradun for his critical suggestions during preparation of this paper.

REFERENCES:

Acharyya, S.K., 1979, Environment and age of the Tal Formation of Mussoorie and Nilkanth areas of Garhwal Himalaya-Comment. *Jour. Geol. Soc. India,* 20: 619-620.

Acharyya, S.K., 1983, Biostratigraphic evidence in the Lesser Himalayan Tectonism. *Him. Geol.,* 11: 323-342.

Auden, J.B., 1934, The Geology of the Krol belt. *Rec. Geol. Surv. India,* 67: 357-454.

Auden, J.B., 1937, The structure of Himalayan in Garhwal, *Rec. Geol. Surv. India.* 71: 407-433.

Azmi, R.J., Joshi, M.N. and Juyal, K.P., 1981, Discovery of the Cambro - Ordovician conodonts from the Mussoorie Tal Phosphorite. Its significance in correlation of the Lesser Himalaya in : *Contemporary Geoscientific Research in Himalaya,* Sinha, A.K. (Ed.) 1, 245-250. Bishen Singh Mahendra Pal Singh, Dehradun.

Azmi, R.J., 1983, Microfauna and age of the Lower Tal Phosphorite of Mussoorie Syncline, Garhwal Lesser Himalaya, India. *Him. Geol.,* 11: 373-409.

Azmi, R.J. and Joshi, M.N., 1983, Conodont and other biostratigraphic evidences on the age and evolution of the Krol belt. *Him. Geol.,* 11: 198-2B23.

Azmi, R.J. and Pancholi, V.P., 1983, Lower Cambrian (Tommotian) Conodonts and other shelly microfauna from the Upper Krol of Mussoorie Syncline, Garhwal Lesser Himalaya with remarks on the Pre Cambrian-Cambrian boundary. *Him. Geol.,* 11: 360-372.

Bailey, R.J. and Atherton, M.P., 1969, The petrology of a glauconite sandy chalk. *Jour. Sediment. Petrol.,* 39: 1420-1431.

Ballance, P.F. and Nelson, C.S., 1969, Differential Cementation in the Waikawan Limestone (Waitemata Group), West Auckland. *N.Z. Journal of Geology & Geophysics,* 12: 67-86.

Bell, D.L. and Goodell, H.G., 1967, A comparative study of glauconite and the associated clay fraction in modern marine sediments. *Sedimentology,* 9: 169-202.

Bhargava, O.N., 1975, The lithostratigraphy and sedimentation of the Tal Formation, Nigali Dhar Syncline, Himachal Pradesh, *Geol. Surv. India, Misc. Publ.,* 24: 27-33.

Bhatia, S.B., 1980, The Tal Tangle, *Stratigraphy and Correlation of Lesser HImalayan Formation,* K.S. Valdiya and S.B. Bhatia (Eds.), 79-96.

Bhatt, D.K.; Mamgain, V.D.; Misra, R.S. and Srivastava, J.P., 1983, Shelly microfossils of Tommotian age (Lower Cambrian) from Chert-phosphorite member of Lower Tal Formation, Maldeota, Dehra Dun District, Uttar Pradesh. *Geophytology,* 116-123.

Brust, J.F., 1958a, "Glauconite" pellets: their mineral nature and applications to stratigraphic interpretations. *Am. Assoc. Petrol. Geologists Bull.*, 42: 310-327.

Brust, J.B., 1958b, Mineral heterogeneity in "glauconite" pellets. *Am. Mineralogists,* 43: 481-497.

Carozzi, A.V., 1960, *Microscopic Sedimentary Petrology,* John Wiley, New York, 485p.

Cloud, P.E., 1955, Physical limits of glauconite formation, *Am. Assoc. Petrol. Greologists Bull.,* 39: 484-492.

Cullen, D.J., 1967, The age of glauconite from the Chatham Rise, east of New Zealnd, *N.Z. Journal of Marine and Freshwater Research,* 1: 399-406.

Dapples, E.C., 1967, Diagenesis of sandstones, pp. 91-125. in *Diagenesis of sediments,* Larsen, G. and Chillinger G.V. (Eds.), Elsevier, Amesterdam.

Degens, E.J.; Williams, E.G. and Keith, M.L., 1957, Environmental studies of Carboniferous sediments. Part I: Geochemical criteria for differentiating marine from fresh water shales. *Am. Associ. Petrol. Geologists Bull.,* 41: 2427-2455.

Goldman, M.I., 1921b, Association of glauconite with unconformities. *Geol. Soc. Am. Bull.,* 32: 25.

Grim, R.E.; Breadly, W.F. and Brown, G., 1951, The mica clay minerals pp. 138-172 in Brindley, G.W. (Ed.) "*X-Ray Identifcation and crystal structure of clay minerals*". Mineralogical Society London.

Hower, J., 1961, some factors concerning the nature and origin of glauconite. *Am. Mineralogists,* 46: 313-334.

Kumar, G.; Raina, B.K.; Bhatt, D.K. & Jangpangi, B.S., 1983, Lower Cambrian body and trace fossils from the Tal Formation, Garhwal synform, Uttar Pradesh, India. *Jour. Palaeont. Soc. India,* 28: 106-111.

Kumar, S. and Singh, S.N., 1978, Occurrence of glauconite in the Tal formation, Singtali area, Dehra Dun District, U.P., *Curr. Sci.,* 47: 860.

Light, M.A., 1952, Evidence of authigenic and detrital glauconite. *Science,* 115: 73-75.

Mathur, N.S., 1977, Age of the Tal and Subathu formations in the Garhwal region, Uttar Pradesh, India. *Bull. Ind. Geol. Assoc.,* 10: 21-27.

McRae, S.G., 1972, Glauconite. *Earth-Science Reviews,* 8: 397-440.

Patwardhan, A.M., 1978, First Moravamminids from the Himalaya. *Nat. Acad. Sci. Letters,* 1: 7-8.

Pratt, W.L., 1962, Origin and distribution of glauconites and related clay aggregates on sea floor off Southern California. *Amer. Assoc. Petrol. Geologists Bull.* 46: 275.

Rai, V. and Singh, I.B., 1983, Discovery of Trilobite impression in the Arenaceous member of Tal Formation, Mussoorie area, India. *Jour. Palaeont. Soc. India,* 28: 114-117.

Rupke, J., 1974, Stratigraphic and structural evolution of the Kumaun Lesser Himalaya. *Sed. Geol.,* 11: 81-265.

Saklani, P.S.; Khanduri, H.C. and Singh, S., 1977, A reappraisal of geology of a part of Mussoorie syncline around Satengal, Garhwal Himalaya. *Chayanica Geologica,* 3: 95-103.

Shankar, R., 1971, Stratigraphy and sedimentation of Tal Formation, Mussoorie syncline, U.P., *Jour. Palaeont. Soc. India,* 16: 1-15.

Singh, I.B., 1976, Evolution of Himalayas in the light of marine transgressions in the Peninsular and Extra-Peninsular India. *Proc. 125th Ann. Celebr. Geol. Surv. India Symposium,* Lucknow (preprint)

Singh, I.B. and Rai, V., 1977, On the occurrence of stromatolites in the Krol Formation of Nainital area and its implications on the age of Krol Formation. *Curr. Sci.,* 46: 736-738.

Singh, I.B., 1979, Recognition of a sedimentological break between Quartzite and Limestone Members of the Tal Formation, Lesser Himalaya, India. *Curr. Sci.*, 48: 206-208.

Singh, I.B. and Rai, V., 1983, Fauna and biogenic structures in Krol-Tal succession (Vendian-Early Cambrian), Lesser Himalaya: Their biostratigraphic and palaeoecological significance.. *Jour. Palaeont. Soc. India,* 28: 67-90.

Singh, I.B. and Rai, V., 1984, Discovery of Archaeocyatha in the Upper Krol Carbonates, Mussoorie hills, Uttar Pradesh, India. *Curr. Sci.*, 53: 243-246.

Sinha, A.K. and Srivastava, R.A.K., 1978, On the occurrence of glauconite with radiolarites in the flysch sediments of Malla Johar area in Higher Himalaya and its significance in Tectonics and Sedimentation. *Him. Geol.,* 8: 1042-1048.

Srivastava, R.A.K., 1984, Quiet water oolites from the Upper Tal Limestone, Garhwal Himalaya, India. In *Sedimentary Geology of the Himalaya,* R.A.K. Srivastava (ed.): 55-60. Today and Tommorrow's publishers, New Delhi.

Srivastava, R.A.K. and Virdi, N.S. (in this volume). The first record of glauconite-radiolarite association from the Nidar ophiolite suite of eastern Ladakh and its significance in the recognition of Oregonian phase in the Himalaya.

Tewari, Vinod, C., 1984b, Discovery of Lower Cambrian stromatolites from Mussoorie Tal Phosphorite, India. *Curr. Sci.*, 53: 319–321.

Tewari, Vinod, C., 1984c, First record of *Conophyton* Maslov Mussoorie syncline and its significance on the age of the Krol Formation. In *Sedimentary Geology of the Himalaya* (R.A.K. Srivastava, ed.), 203–207. Today and Tomorrows Publishers, New Delhi.

Tewari, Vinod C., 1984 e, Stromatolites and PreCambrian–Lower Cambrian biostratigraphy of the Lesser Himalaya. *Proc. 5th Indian Geophytological Conference.* Special Publication of Palaeontological Soceity of India. 71–79.

Tewari, Vinod. C and Qureshy, M.f., 1985a, Algal structure from the Upper Krol-Lower Tal Formations of Garhwal and Mussoorie synclines and their Palaeoenvironmental significance. *Jour. Geol. Soc. India,* 26: 111–117.

Triplehorn, D.M., 1966a, Morphology, internal structure and origin of glauconite pellets. *Sedimentology,* 6: 247–266.

Triplehorn, D.M., 1966b, Glauconite provides good oil search data, *World Oil,* 162: 94–97.

Valdiya, K.S., 1975, Lithology and age of the Tal Formation in Garhwal and implication on stratigraphic scheme of Krol Belt in Kumaun Himalaya, *Jour. Geol. Soc. India,* 16: 119–134.

Valdiya, K.S., 1980, Stratigraphic scheme of the sedimentary units of the Kumaun Lesser Himalaya. In *Stratigraphy and Correlations of Lesser Himalayan Formation,* K.S. Valdiya and S.B. Bhatia (eds.), Hindustan Publ. Corp. (India), Delhi, 283–289.

Wermund, E.G., 1964, Geological significance of fluviodetrial glauconite. *Jour. Geol.*, 72: 470–476.