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Some new observations on the Krol-Tal problem of the Lesser Himalaya, India.

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Field workshop

The Tal Formation, which is the youngest unit of the Krol belt sequence was studied during the I.G.A. field meeting in Tal Valley and Mussoorie syncline. Following three sections were studied in detail for the nature of contacts between different lithological units of the Tal Formation vis-a-vis Shell Limestone and Subathu (Nummulitics).

1. Tal Valley section (Bidasini-Tal confluence)
2. Mussoorie-Tehri road section
3. Maldeota section.

1. Tal valley section

The Tal Formation was first named and studied by Medlicott (1864) in Tal valley and subsequently mapped by Middlemiss (1885) and Auden (1934). The contact between the Tal Quartzite and the Shell Limestone is still a matter of dispute in Tal Valley. The Shell Limestone was taken as an integral part of the Quartzite Member by many earlier workers and the contact between them as conformable. Auden (1937) mentioned about the unconformity between the Upper Tal Quartzite and the overlying Upper Tal Limestone and Calc-grit (Shell-Limestone), since then no unconformity, disconformity/hiatus or sedimentological break was proposed till Singh (1976, 79) suggested a major unconformity and a sedimentological break between the Shell Limestone Member (his Nilkanth Formation) and Quartzite Member in Nilkanth section. Shankar (1971) has suggested disconformity between the Quartzite Member and Calcareous Member within Tal Formation. The contact between the Tal Quartzite and Shell Limestone is also taken as unconformable by Acharyya (1979) and Valdiya (1980) based on palaeontological finds but Bhatia (1980) suggested a conformable contact between Tal Quartzite, Shell Limestone and overlying Subathu (nummulitics), contradicting the unconformity proposed by earlier workers.

The present author has visualized an erosional uncoformity/hiatus between the Tal Quartzite and overlying Shell Limestone in Tal velley and Gopi-Chand-Ka-Mahal section based on the field evidences and study of glauconite in them. In field, no regional unconformity is observed, however there is sharp change in lithology of Shell Limestone and Tal Quartzite. The Shell Limestone is a high energy carbonate sand bar-shoal complex with reworked oolites, rounded shell fragments, glauconite pellets and fossils of definite Maastrichtian-Danian age. The underlying Tal is a mature medium to coarse - grained orthoquartzite with large scale cross-laminations and basically unfossiliferous. The glauconite is reported for the first time from Tal Quartzite by the present author. The authigenic glauconite occurs in quartz grains and along the fibrous fabric of oolites (Plate II, Fig. 3) in Tal Quartzite. The glauconitization has taken place in early diagenetic stages. It is interpreted that the glauconite of Shell Limestone and Tal Quartzite belongs to two different ages and hiatus/erosional unconformity is inferred between them. (Tewari and Srivastava, under preparation). The contact between Shell Limestone overlying Subathu (olive-green shales with limestone containing larger foraminifera is marked by a thin zone of ferruginous shales, chamositic ooids and limonite (palaeosol ?) which represents an unconformity. The chamositic ooids show complete replacement of original carbonate texture, however some relicts of carbonates have been observed. The chamositic ooids are being studied in detail.

2. Mussoorie-Tehri road section

The present author is of the view that the Upper Krol (Krol E) grades into the black shale, chert-phosphorite (based Tal Chert Member) at Masrana and Mussoorie-Tehri by-pass road. The contacts between the Argillaceous Member, Arenaceous Member (bioturbated facies containing trilobite impressions) and overlying Quartzite Member exposed between Kaplani and Jabarkhet toll barrier is gradational. The Calcareous Member is not very well developed here and occurs at places as lenses. The Shell Limestone is not seen anywhere in this section and the sedimentation seems to be ceased after the deposition of Tal Quartzite which shows near shore (coastal sand bar-tidal flat) environment.

3. Maldeota Section

The Krol-Tal cotact is exposed at surface outcrops near Maldeota Phosphorite mine. There is a swing in the strike in this section. The contact is gradational where Upper Krol algalmat carbonates (algal oncolites, pisolites fenestral laminites, calcareous algae, stromatolites, microstromatolites (Plate II, Fig. 2) and archaeocyathids) gradually change into the overlying black phosphatic shales and chert bands with thin layers of intraclasts. This is a facies change from warm water algal-archaeocyathid facies of Uppermost Krol to facies of restricted circulation (shallow lagoon) of Lower Tal Chert Phosphorite.

No sedimentological break has been observed in this section. The other members of the Tal Formation are exposed along the road from Maldeota to Dhaulagiri and Gopi-Chand-Ka-Mahal which is discussed separately. The algal oncolites from Krol D unit of Maldeota area were studied in detail. The oncolites are circular to elliptical in shape with alternating dark (algal) and light (carbonate) concentric laminae.

They vary in size from 0.5 cm to 2 cm. (Plate II, Figs. 1 & 2). The composite oncolites are also found in which more than two microoncolites are enveloped by a single rim (Plate II, Fig. 1). The oncolites show radial fibrous fabric due to recystallization of calcite. It is quite interesting to note that the oncolites have developed in a fenestral fabric (Plate II, Figs. 1 & 2). These oncolites are oomparable with *Osaggia*, *Volvatella* and *Vesicularites* forms of the IV Yumdoma complex of U.S.S.R. (Tewari, 1984c). The *microstromatolites* are also found associated with these *fenestral laminite oncolite microfacies* (Plate II, Fig. 1). These *microstromatolites* (*Epiphyton* and *Renalcis*) are now considered af diagenetic microfossils formed by ealcification of Coccoid blue green algae. The laterally linked small *Conophyton* have also been recorded from Krol D Member ranging in diameter from 1 mm to 7 mm and

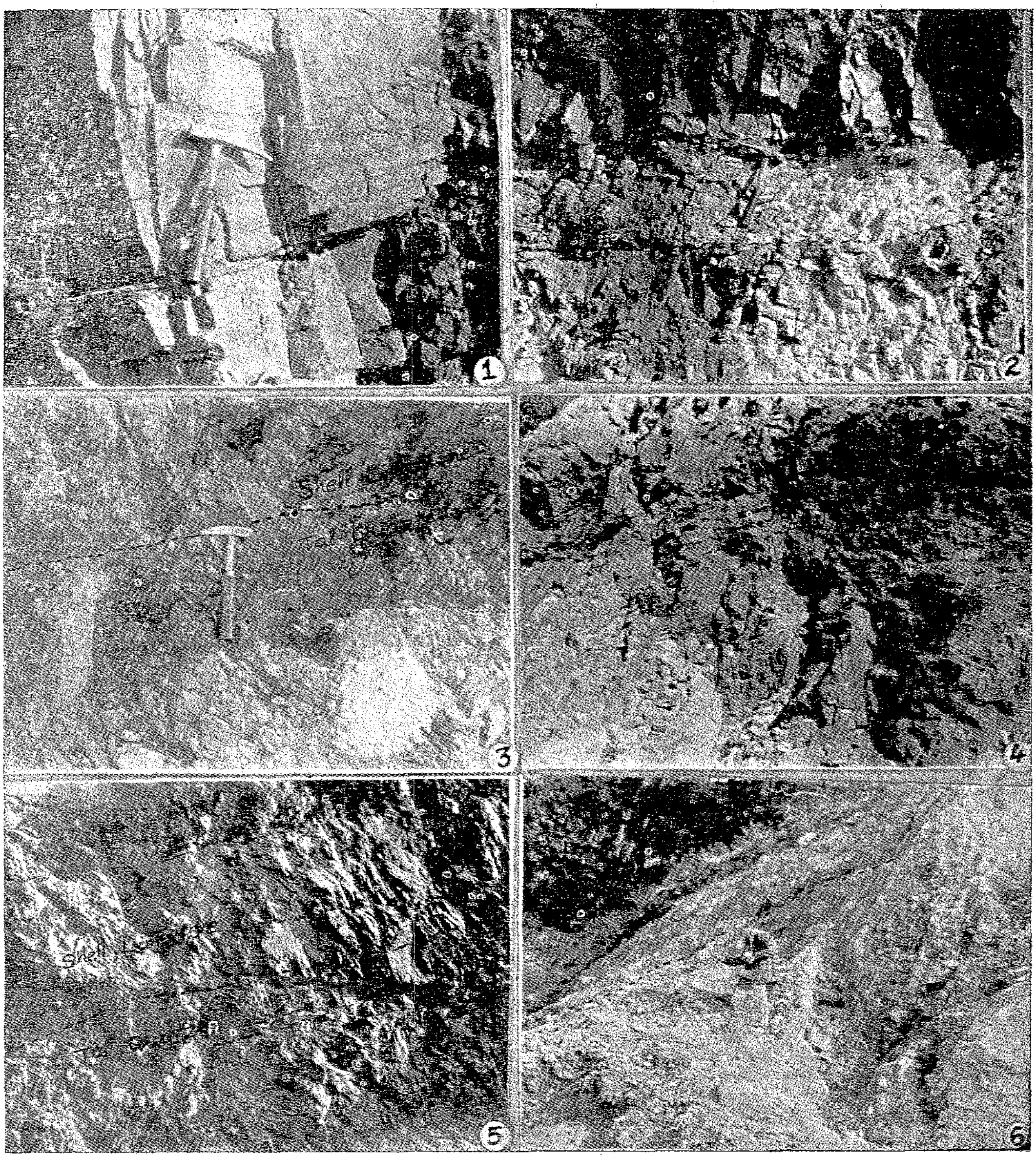

Plate 1. Figs. 1. Thick large scale cross bedded unit of Tal Quartzite, Gopi-Chand-Ka-Mahal. 2. Band of tuffaceous rock between Tal Quartzite, on the way to Dhaulagiri. 3. Contact betweeh Shell Limestone and Tal Quartzite (marked by pen dotted lines) inferred as erosional unconformity, Gopi-Chand-Ka-Mahal. 4. The mixing of regressional deposit (Tal Quartzite) and transgressiue carbonate sea (Shell Limestone) near the contact, Gopi-Chand-Ka-Mahal. 5. The pinching nature of beds at the contact of Tal Quartzite and Shell Limestone, Gopi-Chand-Ka-Mahal. 6. The thin ferruginous (limonitic) bed below the Subathu (nummulitics) marks the unconformity between the Shell Limetone and Subathu, Gopi-Chand-Ka-Mahal.

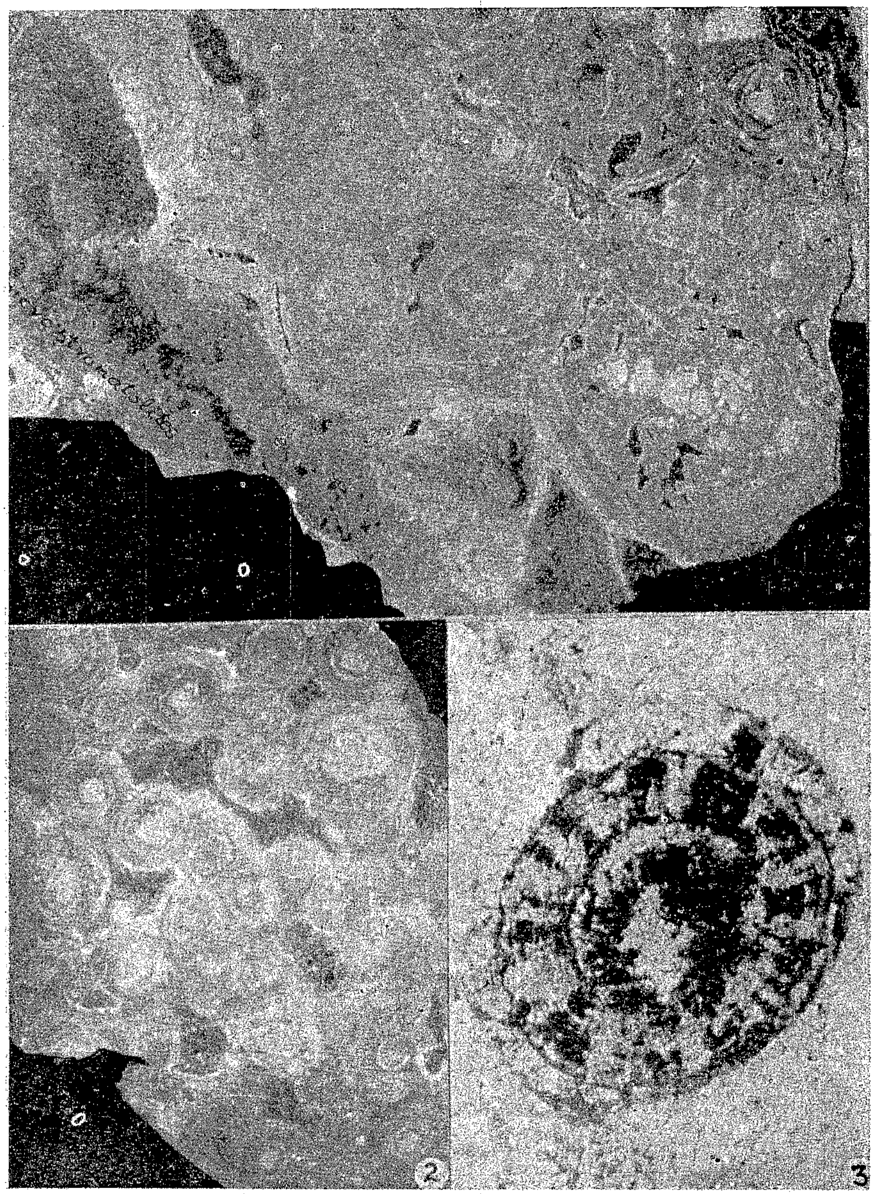

Plate II. **Figs. 1.** *Oncolites* and *microstromatolites* in Krol D showing fenestral fabric, Maldeota area, **2.** Development of *oncolites* in fenestral fabric. Radial fibres showing recrystallization of calcite. Maldeota area. **3.** Glauconitization along fiberous fabric in a oolite within Tal Quartzite, Tal Valley.

height upto 2 cm. The detailed studies are in progress.

Section studied other than the field workshop

Gopi-Chand-Ka-Mahal section

A complete sequence of Krol belt sediments is exposed along the motor road from Maldeota village to Dhaulagiri village and no major break in sedimentation is observed in the entire sequence. The contact between the Tal Quartzite. Shell Limestone and Subathu can be seen between Dhaulagiri and Gopi-Chand-Ka-Mahal which is an excellent section to study the contact relationship. The Subathus (dark greenish grey shales, highly folded though nummulitics not recovered from these rocks so far) are covered by the Bijni/Amri nappe along a tectonic contact (thrust). The contact between Tal Quartzite, Shell Limestone and Subathu as inferred in this section is discussed below.

A huge thickness of mature medium to coarse-grained quartzite is exposed between the Dhaulagiri and Gopi-Chand-Ka-Mahal. The Tal Quartzite shows very good preservation of primary sedimentary structures. The author has studied these structures in detail and a complete prograding sequence of a regressive sea has been observed. The quartzite show large scale cross bedding formed by the migration of mega ripple (Plate I, Fig 1), parallel bedding, ripple bedding, lenticular and flaser bedding, herring bone cross bedding, climbing ripple lamination, ripple marks, channels and and planes of discordances. These structures suggest a medium to high energy subtidal sand bar, sandy intertidal flat and beach-shoal complex depositional environment for Tal Quartzite in this area. The development of shoals and migrating sandbars in shallow sea produced longshore bars and mega ripples which made large scale cross bedding.

The bands of tuffaceous rock varying in thickness from 25 cm to half a meter occur within the Tal Quartzite (Plate I; Fig. 2). A thick cross bedded qnartzite unit with rich concentration of iron around some nucleii varying in size from 0.5 mm to 1 cm in diameter have been recorded (Plate I; Fig, 1).

The contact between the Shell Limestone and Tal Quartzite is exposed in road section north of the Gopi-Chand-Ka-Mahal. The contact between the Shell Limestone and Tal Quartzite is inferred as erosional unconformity by the author. There is sharp change in the lithology of the two formations and the minor undulations in the surface of contact represents a diastem/erosional unconformity (Plate I; Figs. 3 & 6). A very thin zone of weathering (palaeosol ?) also occurs at the contact of Shell Limestone and Quartzite. It is suggested that the high energy carbonate sea (sandy oolitic Shell Limestone) transgressed over the Tal Quartzite in Late Cretaceous times. The marine transgressions are generally of erosional character The transgressive carbonate sea (Shell Limestone) removed the thin regressive deposit (Tal Quartzite, which was a mature stable land mass being eroded by some agency) and deposited over the erosional surface. Such events are marked in geological history as unconformities. Prof. A. T. Cross of Michigan University, U.S.A. also visited this section along with the author and confirmed the same. An erosional surface was visualized at the contact The contact show irregular surface with pinching of beds towards the upper part (Plate I,

Crystallines of Amri/Bijni Nappe				
		—Thurst—		
Subathu Formation (Nummulitics)				Eocene Transgression
		—Unconformity—		
Shell Limestone/Nilkanth Formation (Singh, 1979) Singhali Formation/ Bansi Member (Valdiya, 1980)			Sandy Oolitic Shell Limestone	Cretaceous Transgression
		—Unconformity/hiatus—		Regression
Tal Formation	CAMBRIAN	Quartzite Member		Botomian ?
		Calcareous Member		Atdabanian
		Arenaceous Member		
		Argillaceous Member		
		Chert Member		Tommotian

Table 1. Proposed lithostratigraphy of Tal Formation in Mussoorie and Garhwal area (Based on various workers and author's our observations).

Fig. 5). Shankar (1971) has also mentioned about the occurrence of arkosic quartzite (with microcline grains) in Upper Tal Quartzite below Limestone Member (Shell Limestone) and suggests a granitic terrain being exposed to the erosional agencies This arkosic quartzite at the base of Shell Limestone also represents an unconformity. This contact looks gradational to some of the workers but the transitional passage from Tal Quartzite to Shell Limestone is in fact the mixing of the thin regressive terrigenous clastic deposit with transgressive sandy carbonate sea. (The thin sections of the quartzites show calcarous cement). The quartzite in contact with Shell Limestone does not show development of any sedimentary structures.

The contact between the Shell Limestone and Subathu (nummulitics) is marked by a thin zone of ferrugious shales (limonite) in this section which also represents unconformity. The Amri/Bijni rocks are thrusted over Subathu (nummulitics) in this section.

Author's view on the problem supported by new data

The author has already published some of his new recent findings about the age of Krol Tal Formations (Tewari, 1984 a, b, c; Tewari and Qureshy, 1985). The author has also proposed a revised Lesser Himalayan stratigrapny based on new fossil finds of conodonts, hyolithids etc. (Azmi *et. al.* 1981; Azmi, 1983; Azmi and Joshi, 1983; Azmi and Pancholi, 1983; Bhatt *et. al.* 1983), trace fossils of trilobite and trilobite impressions, calcareous algae archaeocyatha (Singh and Rai 1983, Rai and Singh, 1983), brachiopod and microgastropod body fossils (Kumar *et al.* 1983) and discovery of new stromatolite form genus/species and oncolites (Tewari, 1984 a, b, c.) The above mentioned fossils are being reproduced from different parts of Mussoorie syncline and show biotic changes from Late Precambrian to early Lower Palaeozoic. The archaeocyatha and stromatolites cannot be reworked as they are carbonate rock builders. The Precambrian-Cambrian boundary has also been tentatively defined which lies between uppermost Krol and lowermost Tal formations (Tewari, 1984 a, b, c).

The younger fossils recorded from Krol-Tal formations are either not being reproduced or their palaeontological validity is questioned. A Cambrian age for Tal Formation (excluding Shell Limestone) is suggested by the author. The Chert Member has yielded Tommotian (Trilobite free) shelly microfauna and stromatolites *Collumnaefacta vulgaris* and *Aldania mussoorica* (Tewari, 1984 a,b,c). The record of Lower Cambrian algae (A.D. Ahluwalia in IGA workshop, Dehra Dun) further supports this age which was earlier described as moravamminids by Patwardhan (1978). The Aranaceous Member show 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 (G. Kumar, personel communication) from Garhwal area. The Tal Quartzite on the basis of existing fossil record cannot be assigned any age, younger than Late Cambrian. The Tal Quartzite was a stable and mature land mass till Createceous time. The Shell Limestone (Sandy oolitic limestone) unconformably/disconformably rests over the Tal Quartzite and represents a transgressive phase in Late Cretaceous times. The contact between the Tal Quartzite and Shell Limestone is visualized as an erosional unconformity/diastem (in Gopi-Chand-Ka-Mahal section) and hiatus (in Tal Valley) as already explained by the presence of glauconite in them. The Subathu Formation (Nummulitics) of Eocene age unconformably (represented by palaeosol lateritic deposits) overlies the Shell Limestone and also represents a wide spread marine transgression. The above mentioned marine transgressions are also interpreted in the light of Upper Cretaceous-Tertiary Himalayan orogeny and plate tectonics. The Tethys sea was closed along the Indus-Tsang Po Suture Zone in Late Cretaceous-Palaeocene time after the collision of Indian plate and Eurasian plate. The carbonate sea from Tethys transgressed southward into the Lesser Himalayan platform along some narrow weak zone and deposited over the eroded stable landmass of Tal Quartzite. The occurrence of Subathu (Nummulitics) over the different formations of Lesser Himalaya also confirms the transgressive nature of the sea from the Tethyan Zone of the NW Himalaya. To conclude, it is proposed that the Shell Limestone unconformably underlain by Tal Quartzite and in turn unconformably overlain by Subathu Formation. The Shell Limestone is neither integral part of Subathu nor Tal Quartzite. It belongs to a separate marine transgression during Cretaceous time. Shell Limestone only occurs in the central part of the Krol basin (Mussoorie-Garhwal region) which extends from Solan to Nainital. It is suggested that the Shell Limestone should be excluded from the Tal Formation and redefined according to the 'Indian Code of Startigraphic Nomenclature.' The name 'Nilkanth' (Singh, 1979) or Singtali Formation (Valdiya, 1980) may be retained as alternative for Shell Limestone.

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