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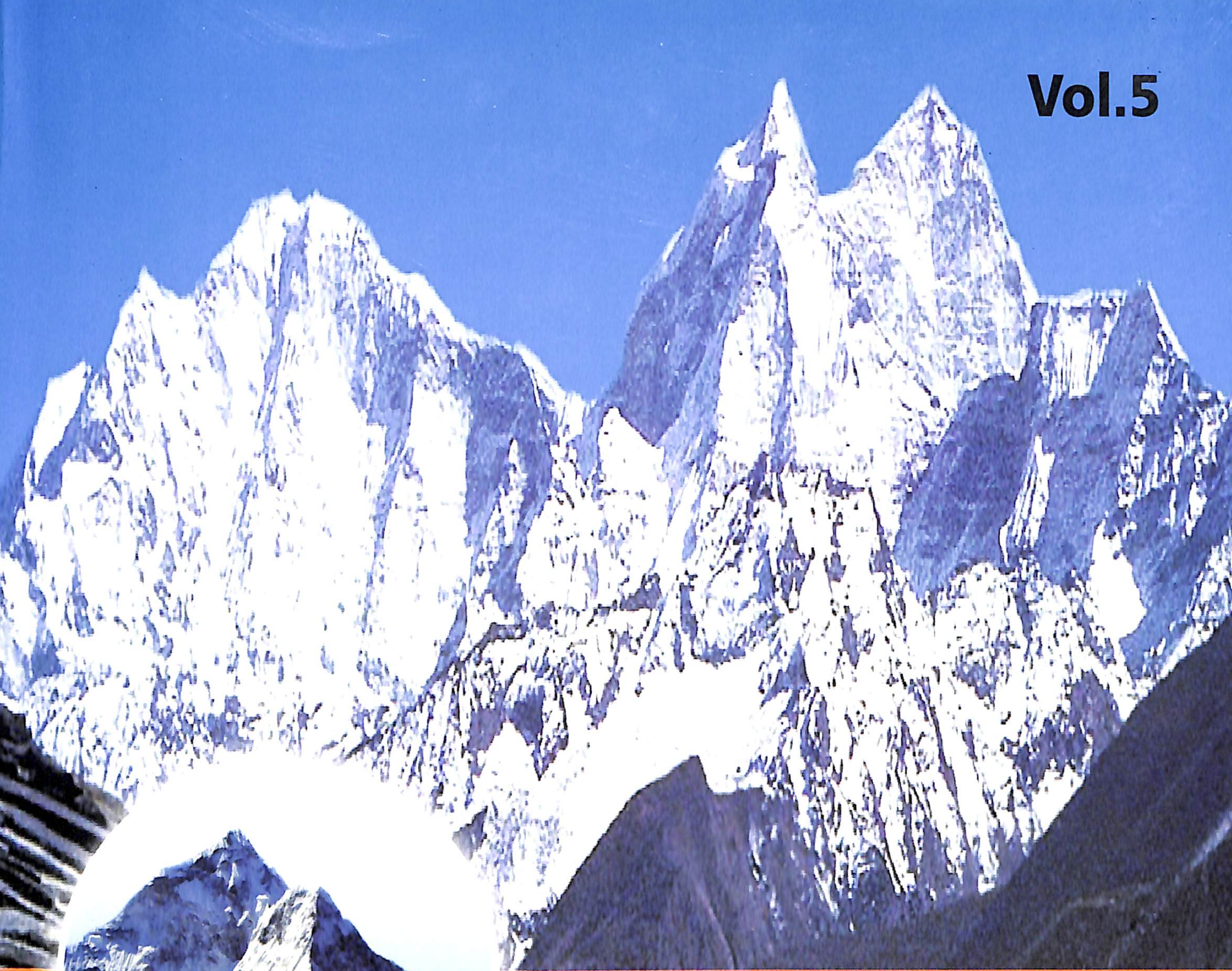

Edited by : Prof. P.S. Saklani

# HIMALAYA

## (Geological Aspects)

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# FOREWORD

A long time back I attended one function of Indian National Science Academy where (Late) Prof. D.S. Kothari was also present. I had a casual talk with him and he told me that in this function there are many FNAs, and non-FNAs. The irony is that many FNAs do not deserve to be FNAs and many non-FNAs should have been FNAs. His important remark pointed that evaluation of research contributions was possibly faulty and the same situation still exists in Earth Sciences. Many contributions are mainly based on analysis done in foreign laboratories. The workers who have done work in presently existing conditions are not seen to be encouraged. We must encourage and promote indigenous research and then only the the sciences would develop and progress properly in time to come.

I have mixed feelings about the research progress in Earth Sciences and the funding agencies. Some good projects have been turned down by DST, CSIR., U.G.C. etc. and huge grants are given but the outcome of the contribution is negligible. Having an excellent support from the contributors my venture for the 5th volume has materalised. Now I would write my comments about the contributions of the 5th volume.

K.P. Juyal and Manish Semwal remarked that the upper most marine sedimentary units in the lower Shyok area were deposited during early to late Cretaceous time (Aptian - Albian) in transgressive and regressive cycles. The final regression of sea from the area occurred at the end Albian owing to India - Asia collision.

B.S. Kotlia and Randheer Singh described the Krachipatra section of Dubjan Member (Hirpur Formation) in the Kashmir valley. Both lower vertebrate and invertebrate fauna are recovered. The vertebrates comprise three types of fish-teeth belonging to the family Cyprinidae, where as, invertebrates belong to nine species of gastropods. Abundance of freshwater gastropods and fishes indicate an entity of a river, stream or similar fresh water body in the Kashmir valley during the deposition of the Krachipatra fossiliferous horizon.

According to A.R. Chaudhri the Himalayan foot-hill zone between the Main Boudary Thrust and the Himalayan Frontal Thrust witnessed neotectonic activity in very recent past in Nadah, Dehra Dun and adjoining regions indicating that the foot-hill terrain is seismo-tectonically active.

O.P. Goel and S.S. Bhakuni have contributed about the Higher Himalayan Crystalline (HHC) in the Chamoli District, Garhwal Himalaya which consists of (1) the Munsiari Formation and (2) the Vaikrita Group; the two being separated by the Main Central Thrust (= Vaikrita, Valdiya, 1980) Geochemical investigations of bulk rocks indicate diverse source materials for the various formations of the Vaikrita Group, as testified by the presence of gneisses and granitoids, which have varied compositions similar to their protoliths: both typical sedimentary - pelites, psammites; and some igneous - granodiorite, granite and basalts. The principal control of compositional variations appears to be primary rock-forming process, and the prograde amphibolite-granulite facies led metamorphism in culmination of high grade gneisses and granites, as evident from the distribution of major, minor and trace elements.

B.C. Joshi is of the view that the rock units of Pokheri-Garhwal Himalaya consist of four tectonometamorphic episodes. Caledonian Orogeny is Episode I while Episode II and close tight folds of episode III are coaxial. Episode IV ended with Tertiary Orogeny.

Mallickarjun Joshi, A.N. Tiwari and Ph. Mitrabina Devi described the North Almora Shear Zone (NASZ) of Almora Nappe in Chaukhutia area, affected by two phases of metamorphism, viz. pre-Himalayan regional metamorphism ($M_1$) and Himalayan dynamic metamorphism ($M_2$). The metamorphic mineral assemblages and the thermobarometric results using TWEEQU program suggest that the pre-Himalayan regional metamorphism ($M_1$) reached up to upper amphibolite facies while the Himalayan dynamic metamorphism ($M_2$) reached only upto greenschist facies.

Abhishek Pandey and Santosh Kumar are of the view that extensive sequence of basalts and metabasalts belonging to the Bhimtal volcanics (BV) in Kumaun region of northwestern Himalaya is intimately associated with Nagthat Quartzite. Low acmite component and evolution of BV clinopyroxenes along enstatite-ferrosilite join strongly suggest tholeiitic nature of basaltic parent. High Ca/(Ca+Mg+Fe) and low alumina content of BV clinopyroxenes are, however, unrelated to subalkaline parent and appear slightly modified during metamorphism of tholeiitic basalt.

Karanpal S. Rawat and Girish Ch. Kothyari described the Ampadav locality lying in the Kumaun Siwalik region which witnessed a major mass movement disaster. The physical characteristics coupled with the hydrological parameters and temperature fluctuations over a longer period of time resulted in the slippage and triggering of the rockfall and associated debris flow.

According to S.C. Bhatt and P.S. Saklani the Pratapnagar (Chail 2) and Dharkot (Chail 3) thrust sheets are characterized by mylonitised Pratapnagar quartzite and slaty and schistose phyllites affected by four phases of deformation ($D_1$-$D_4$). The microstructural fabric configuration and asymmetrical orientation of C-axes fabrics indicate that the mylonitized Pratapnagar quartzite was evolved by non-coaxial deformation under ductile flow and low grade metamorphic conditions. The geometry of asymmetric pressure shadows, pressure fringes, rotated porphyroclasts, fluxion and shear bands imply that the pressure solution, and dynamic recrystallisation were important processes, which resulted into mylonitisation and nappe movement within these thrust sheets.

Kishor Kumar studied the area between Narendra Nagar, Rishikesh and Shivapuri in Garhwal Himalaya severely affected by debris flow, slides, slumps and falls followed by erosion.

Shashank Shekhar, P.S.Saklani and A.M. Bhola have contributed that the Srinagar area located in the lesser Himalaya zone is characterized by superimposed thrust sheets and demarcated by North Almora Thrust (NAT) in NE part and Sumari thrust in southern part. The rocks of the region experienced pronounced rotation by about 90°, which is exemplified by the presence of vertical folds, and this rotation is a late stress phenomenon.

Th. Devala Devi, R.A.S. Kushwaha and M. Okendro investigated About 200 km long zone of mélange along the western contact of Nagaland-Manipur Ophiolite Belt. In and around Ukhrul the mélange units occur along three linear zones consisting of sandstones, gritstones, conglomerates, limestones, cherts, silicified recrystallised rocks, shales and ophiolitic derivatives. The geochemical parameters like ($Fe_2O_3$ + MgO) % and $TiO_2$ %, $Al_2O_3$ / $SiO_2$, $K_2O$/ $Na_2O$ and $Al_2O_3$/ (CaO + $Na_2O$) suggest diversity in the tectonic setting of the basin i.e. Oceanic Island Arc, Continental Island Arc, Active Continental Margin and Passive Margin setting.

Vaibhava Srivastava and R.C. Lakhera have contributed about Kwanu - Shillai area in the Lesser Himalaya of the Uttaranchal and Himachal Pradesh which is characterised by the Krol Thrust, Tons Thrust and Deoban Fault besides numerous transverse faults, longitudinal faults and lineaments.

According to T. Talar, A.S. Rawat and R.C. Joshi the Landslide Hazards along National Highway 52 A in the area between Banderdewa to Itanagar which consist of four types of landslides i.e. transnational (Karsingsa locality), rotational (Barapani locality), wedge failure (Shivmandir locality) and some are just due to gravity and loose lithology (Midpu locality).

Soibam Ibotombi and R.K. Hemanta Singh have remarked that Transtensional Basin in Oblique Subduction Margin in Imphal Valley shows a relative motion between Indian and Myanmar plates associated with shear couple deformation. Palaeostress analysis reveals a constant stretching of the rocks of the Imphal Valley in the NNE-SSW (N-S) direction. Minor structures are three to four phases of stretching with a possible range of 25% to 77%.

Arun Kumar, Th. Dolendro and R.K. Chingkhei studied 2 km buffer along both sides of the NH 53 from Kotlen to Taobam approximately 62 km of the road length. Data consisting of 14 parameters including satellite derived information were used for the validation of severe, very high, high, moderate low and very low landslide zones.

A.K. Biyani is of the view that the Higher Himalaya is comprised of wide varieties of metamorphic rocks derived from sedimentary and igneous parentage. At least a dozen acidic magmatic spells as old as of Early Precambrian to less than 5 million year (Ma) and is a comparable case of basic magmatism. It has a polyphase deformational and metamorphic history possibly earliest one of late Precambrian age followed by episodes occurring in later periods of the Tertiary.

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# 1

# Faunal Events During Late Mesozoic North of Indus Tsangpo Suture and Shyok Suture Zone, Eastern Karakoram : Palaeobiogeographic Implications

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**ABSTRACT**

The lower and upper Shyok areas in Late Mesozoic were represented by the two different basins evolved during different times and were occupying areas to the south and to the north of Karakoram Batholith. The upper most marine sedimentary units in the lower Shyok area were deposited during early late Cretaceous time (Aptian – Albian) in a transgressive and regressive cycle. The final regression of sea from the area occurred at the end Albian owing to India - Asia collision. The lowermost Member-1 of Burtsa Formation was deposited in upper Triassic followed by Member-2 in Jurassic to lower Cretaceous. The upper most i.e. Member-1 of the Burtsa Formation was deposited in? Lower Cretaceous. The sea withdrew from the area in ? post early Cretaceous (? end of Berremian) time. The sea was closed earlier in the upper Shyok area than that of lower Shyok area, based on present biostratigraphic work. However, more comprehensive work on late Mesozoic fossil record needs attention of palaeontologist for further precise in biostratigraphic ages in the upper Shyok area (Karakoram block).

Biostratigraphic studies in the eastern Karakoram are in its infancy as a very few palaeontologists visited this area due to difficult accessibility. The reconnaissance palaeontological studies across S-N traverse were carried out from Hundiri (lower Shyok valley, at the foot of Karakoram Range) to Qazil Langer (near Karakoram Pass). The tectono-stratigraphic units exposed are: Ladakh Batholith, Khardung Volcanics, Shyok Volcanics, Hundiri and Saltoro Flysch formations (marine, early Cretaceous), Saltoro Molasse Formation (fresh water, post Albian), Ophiolitic Mélange (Cretaceous) and Metasediments (?Cambrian - Late Jurassic) [exposed between Ladakh Batholith and Karakoram Axial Batholith]; and in the north of the Karakoram Axial Batholith (KAB) the Karakoram Tethyan succession i.e. Pangong Tso (Precambrian–early Paleozoic), Saser Brangsa (Carboniferous), Aq Tash (early Permian), Chhongtash (late Permian), Morgo (early - mid. Triassic), Burtsa (late Triassic - ? early Cretaceous) and Qazil Langer (fresh water, ?post early Cretaceous) formations (Table 1). A perusal of these lithounits reveals that there are two tectonostratigraphic sequences exposed on either side of the KAB in the region- a) to the SW (presently occupied by the Ladakh range) and- b) to the NE (occupied by the Karakoram range). The present biostratigraphic studies are focused on the Hundiri and Saltoro Flysch formations (early Cretaceous) and the Burtsa Formation (late Triassic- ?early Cretaceous) developed to the southwest and northeast of the KAB. These lithounits are well exposed along north-south flowing Shyok river a major tributary of Indus. For the sake of brevity two geographical areas are recognised as lower Shyok and upper Shyok areas respectively. This study is focused on the faunal events occurred during the deposition of marine sedimentary units in the lower and upper Shyok areas. This is the first attempt to carry out comparative studies on fauna in these two areas. So far, a very few palaeontologists have visited this area and it is lacking comprehensive biostratigraphic studies. This study will help in understanding the deposition of environment in both areas and throw light on palaeobiogeographic reconstruction.

### Lower Shyok Area

Nubra - Shyok rock succession of lower Shyok area covers exposures encompassing Ladakh Range between northern margin of India and Karakoram microplate (Eurasian plate). Tectonically the area is bounded by two sutures, the Shyok Suture (SS) to the north and the Indus Tsangpo Suture (ITS) to the south (Fig. 1, Table 1). Geological investigations in the area from nineteenth century to present day are carried out by many pioneering geoscientist (Stoliczka 1874, Dainelli 1932, 1933, and Wyss 1940 among others) of British ruled India, and subsequently by other geoscientists, Gansser 1964, Frank et al. 1977, Desio 1979, Thakur 1981, Thakur et al. 1981, Srimal et al. 1982, Rai 1982, 1983, 1991, Thakur and Mishra 1984, Srimal 1986, Searle 1996, Rowley 1996, Sinha and Upadhyay 1997, Upadhyay 2001, and Burg 2006). The important contributions on palaeontology are made by (Fillipo De Fillipi 1912, Dainelli 1932, 1933, Wyss 1940, Norin 1946, Bhandari et al. 1979, Rai 1982, Juyal 1994, 1997-98, 2006, Juyal and Mathur 1998, 2000a,b, 2001, 2002, Upadhyay 1999). Except Juyal (2006) most of the workers focused their studies mainly on the traverses which were covered by them and sporadic samples collected along routes. In the present work comprehensive work on the fauna of the measured lithounits is focused to understand more precisely, age, environment of deposition and palaeobiogeography of the area. The present study deals with the biostratigraphy

**Table 1.** Showing tectonostratigraphic successions (south to north) of Lower and Upper Shyok areas in eastern Karakoram.

| NORTH | AGE | FORMATION | LITHOLOGY | FOSSILS |
|---|---|---|---|---|
| Karakoram-Tethyan succession (Karakoram Range), Upper Shyok area | ? post early Cretaceous | Qazil Langer Fm. (575 -750 m) | Conglomerate, khaki shale- sandstone intercalations | Rolled hydrozoans, mulluscan shell fragments and other rock boulders |
| | | | Unconformity | |
| | late Triassic - ?early Cretaceous | Burtsa Fm. (1000 m) | Pink, grey massive, platy, cherty limestone, shale, ferrugenous beds & gypsum, pink shale, sandstone | *Megalodon* ssp., *Heterastridium* sp., *Quinquelocolina juleana, Nazzazatanella* sp., *Gsollbergella spiroloculiformis, Charentia cuvillieri, Palaeomiliolina monstruosa, Saboudia* sp., *Cornuloculina* sp., *Nautiloculina oolithica, Lenticulina* sp., *Axipolina* sp., bryozoa, algae |
| | mid. - early Triassic | Morgo Fm. (920 m) | Grey limestone (often crystallised), phyllitic shale, | |
| | ? late Permian | Chhongtash Fm. (1000 m) | Black carbonaceous ferzile phyllitic shale, fossiliferous limestone intercalations, chert nodules and pillow lava | *Rugososchwagerina* sp., *Dunbarula* sp., *Oketaella* sp., *Palaeofusulina* sp., *Parafusulina sutschinica, Colaniella parva, Globivalvulina bulloides, Boltonia* sp., *Lunucammina permiana, Lunucammina* sp., *Cribrogenerina sumatrana, Endothyra* sp., corals, bryozoans and fragmentary brachipods. |
| | early Permian | Aq Tash Fm. (450 m) | Nodular shale (pink and varigated at base), limestone (fossiliferous), intrusion of volcanic rock i.e. rhyolites, basalt (intense faulting) | |
| | Carboniferous | Saser Brangsa Fm. (1000 m) | Grey crystallised limestone, phyllite, gneiss, schist | |
| | Precam. - early Palaeozoic | Pangong Tso Group | Gniess, schist, marble and metabasic | *Millerella* sp., ? *Pseudofusulina* sp., ?*Parafusulina, Schwagerina* sp. *Mizzia* sp. |
| | | | Sharp contact | |
| | ? Neogene | Karakoram Batholiths | Granite | |
| | | | Sharp contact | |
| Karakoram Foothills succession (Ladakh Range), Lower Shyok area | ? Cambrian - late Jurassic | Metasediments | Magmetic gneiss, biotite quartz schist, phyllite, schist, limestone, mylonite gneiss | |
| | Cretaceous | Ophiolitic Mélange | Red carbonaceous shale, phyllite, serpentinite, chromite, basic volcanic | |
| | | | Thrust | |
| | post Albian | Saltoro Molasse Fm. (fresh water) | Conglomerate (clasts of conglomerate contains fossiliferous limestone, pebbles, shales and sandstone, volcanic rock), sandstone, shale | Derived *Orbitolina* limestone and atker pebble |
| | | | Unconformity | |
| | late Albian | Saltoro Flysch Fm. (marine) (300 m) | Phyllite, slate, carbonaceous shale, calcareous - siliceous sandstone, quartzite | *Praeorbitolina cornyi, Cribratina* sp., *Praeorbitolina* sp., *Mesorbitolina ? drasensis, M. parva- texana, M. gergaria, M. subconcava, Palorbitolina* sp., *Orbitolina discoidea, Mesorbitolina* sp., *Spiroplecta* sp., and *Paracoskinolina* sp., rudist, algae |
| | Aptian-Mid. early Albian | Hundiri Fm. (marine) (150 m) | Massive to platy, grey limestone (often fossiliferous), carbonaceous shale at base | |
| | | | Intrusive | |
| | Cretaceous | Shyok Volcanic | Volcanic rocks | |
| | | | Intrusive | |
| | Oligocene | Khardung Volcanic | Volcanic rocks | |
| | | | Intrusive | |
| SOUTH | Cretaceous- Lr. Eocene | Ladakh Batholiths | Granite | |

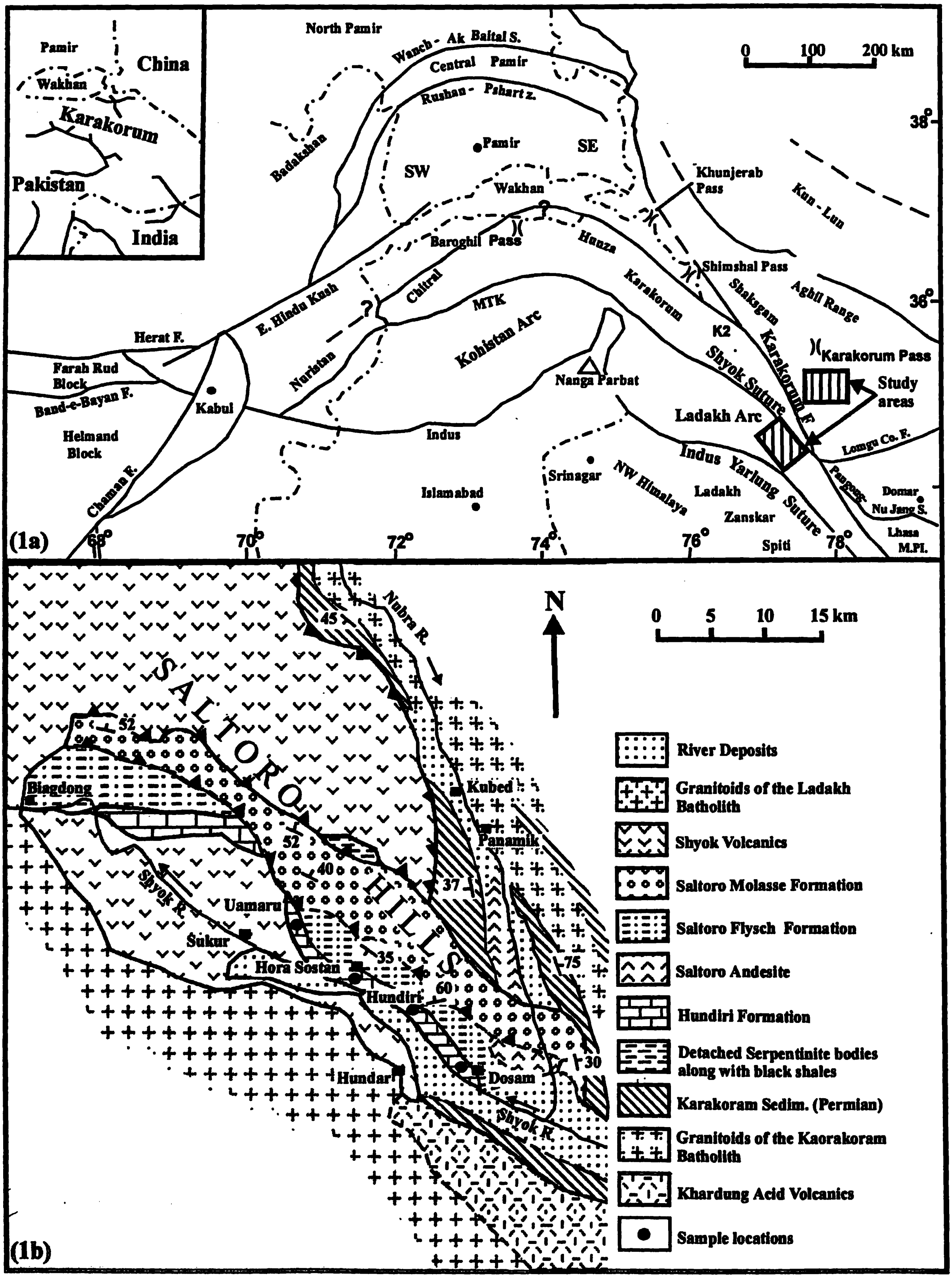


**Fig. (1a)**: Major tectonostratigraphic blocks and sutures with index map (inset) of the Pamir- Karakoram knot (adapted from Gaetani 1997). The boxes indicate the study area. **(1b)**: Geological map of lower Shyok area (modified after Rai 1991).

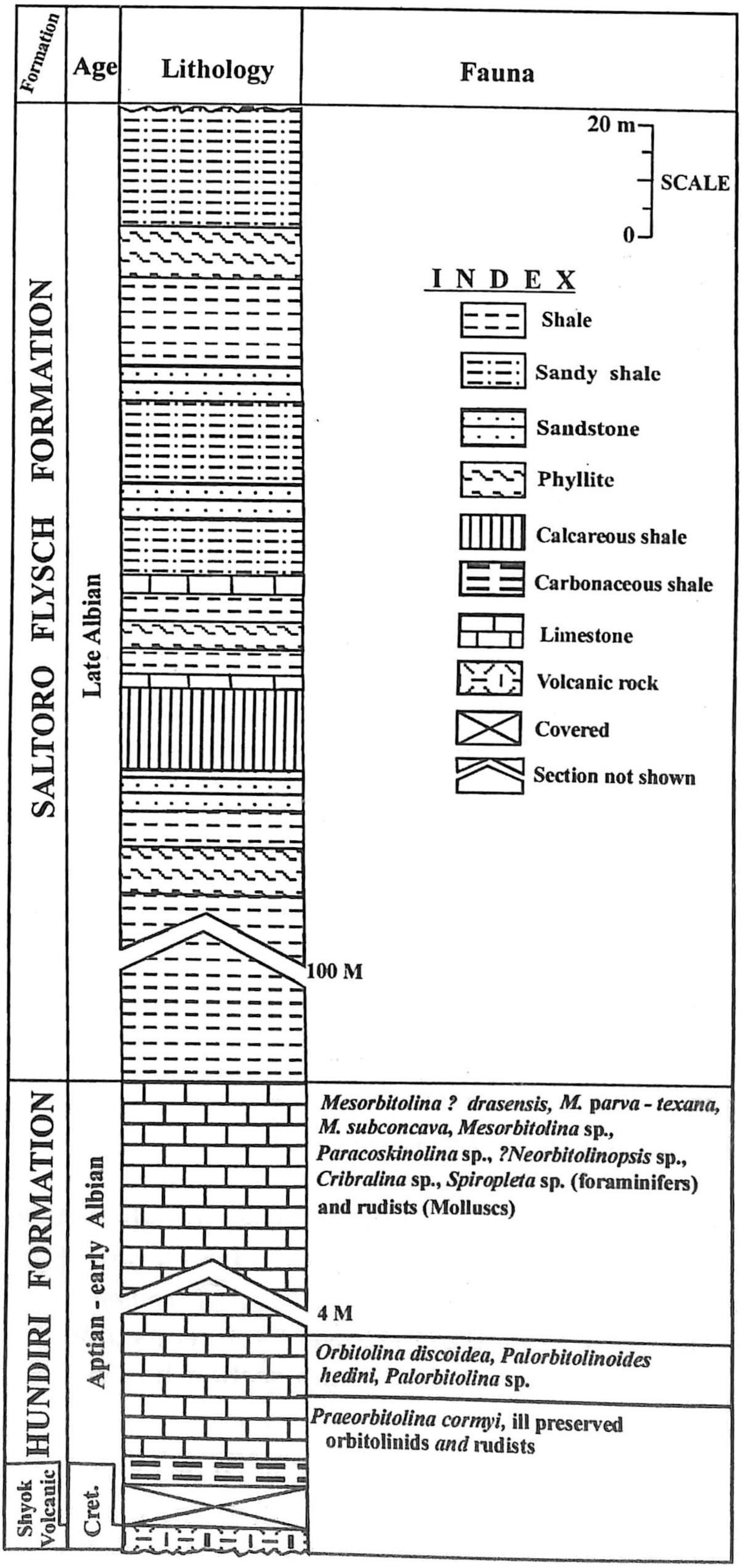


Fig. 2. Biostratigraphic section of the Hundiri and Saltoro Flysch formations (after Juyal, 2006).

of the marine Hundiri and Saltoro Flysch formations (Aptian – Albian) in order to understand faunal events which took place in the lower Shyok area and adjoining regions.

## Biostratigraphy

The biostratigraphic studies in the present work are carried out on the marine sequences exposed along three sections represented by the Hora Sostan, Sukur *Nala* and Dosam sections. The well preserved orbitolinid fauna is recovered from Hora Sostan section (a generalized biostratigraphic section is given in Fig. 2). The fauna from this section show high species richness from top to bottom. Other two sections, the Sukur *Nala* and the Dosam have not yet yielded orbitolinid fauna. However, these sections are characterized by age diagnostic rich fossil assemblage consists of algal taxa.

The additional orbitolinid and other age diagnostic fauna in the present work from the platformal limestone at Hora Sostan section includes, namely *Praeorbitolina cormyi* Schroeder, *Palorbitolinoides hedini* Cherchi and Schroeder, *Mesorbitolina ? drasensis* (Mamgain and Jagannatha Rao), *M. parva* (Douglass) – *texana* (Reomer), *M. subconcava* Leymerie, *Mesorbitolina* sp., *Orbitolina discoidea* Gras, *Palorbitolina* sp., ?*Neorbitolinopsis* sp. and *Paracoskinolina* sp. (orbitolinids) and other benthic foraminifers i.e. *Cribralina* sp. and *Spiroplecta* sp. (Plate 1). The orbitolinid fauna indicates deposition in a transgressive and regressive cycle.

Juyal (2006) has carried out systematic biostratigraphic studies in the Hundiri Formation of lower Shyok area. These studies have been substantiated by the present biostratigraphic investigations. The faunal assemblages recovered from Hora Sostan section are as follows:

1. *Praeorbitolina cormyi* - rudist assemblage (early Aptian age).
2. *Palorbitolinoides hedini* - *Orbitolina discoidea* assemblage (late Aptian age).
3. *Mesorbitolina ?drasensis* – *M. parva* - *texana* assemblage (early Albian age).

In addition to foraminiferal species, rudist (bivalve), bryozoans, corals, echinoid spine and algae were also recovered. In the Hundiri Formation at Sukur *Nala* section we have recorded *Salpingoporella* sp., ?*Salenopora* sp., and *Cayeuxia piae* (algae). These taxa are found in the lower Cretaceous though their age ranges vary. The Hundiri Formation at the Dosam section has yielded unidentifiable algae.

The Hundiri Formation is overlain by the Saltoro Flysch Formation with a normal contact. The later lithounit has not yielded any fauna so far. The authors presume that these sediments were deposited in the deeper water and their environment of deposition was unfavaurable for development of marine life. The

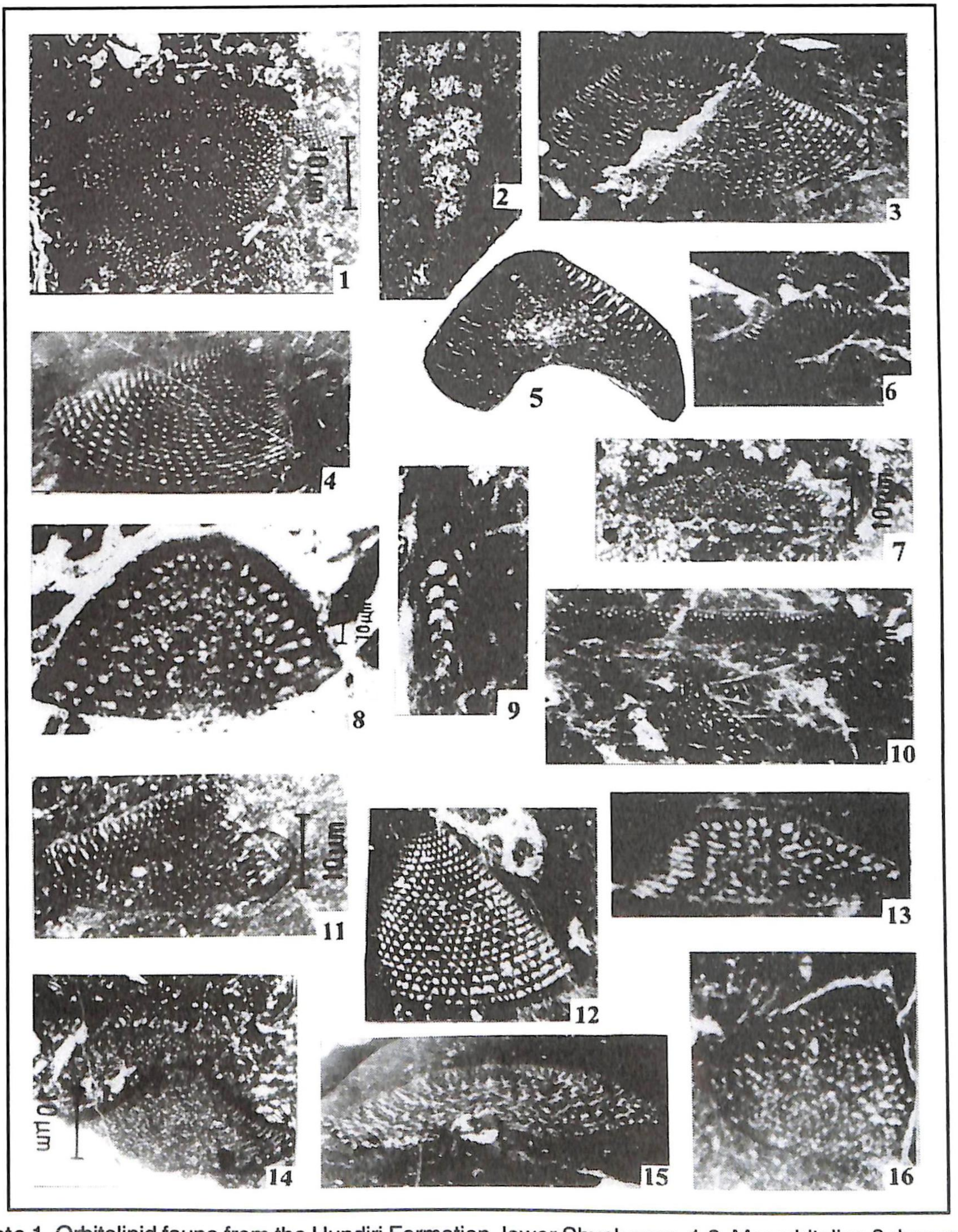


Plate 1. Orbitolinid fauna from the Hundiri Formation, lower Shyok area. 1,3. Mesorbitolina ? drasensis (Mamgain and Jagannath Rao) (WIMF/A 581, 583). 2. Cribratina sp. (WIMF/A 582) 4. Praeorbitolina sp. (WIMF/A584). 5. Mesorbitolina gergaria Zhang Binggo (WIMF/A585). 6,7,13. Mesorbitolina sp. oblique section (WIMF/A586, 587, 553). 8,11,12. Praeorbitolina cormyi Schroeder, tangential section passing through Procoulus (WIMF/A588, 552, 591). 9. Spiroplecta sp. (WIMF/A589). 10Palorbitolina sp. (WIMF/A590). 15. Orbitolina discoidea Gras, subaxialsection of discoid form (WIMF/A558). 16. Paracoskolina sp. (WIMF/A593).

above marine succession is unconformably overlain by Saltoro Molasse Formation, i.e. mainly conglomerate containing reworked fossiliferous fragments of sedimentary rocks along with other rock boulders.

## Environment of Deposition in the Lower Shyok Area

Ecological studies of the orbitolinid fauna are carried out by number of workers in the past in order to understand environment of deposition. These taxa are found in warm, clear waters with normal salinity in reef shoal sediments (Lozo 1944, Bergquist and Cobban 1957, Douglass 1960, Jones 1969). Recent studies on ecology and deposition of environment by Arnoud Vanneau and Premoli Silva (1995) points that *Orbitolina* is found either with wave resistant species in course sand or during rise of sea level in lagoons and their diversity in sediments is poor except in periods of rising sea. Orbitolinids associated with rudists and algal taxa are found in the Hundiri Formation indicates environment of deposition that persisted in the lower Shyok area. It shows that deposition took place in a platform during transgressive and regressive phases.

## Correlation

The orbitolinids from the Shyok tectonic belt are comparable with the taxa similar to those taxa which are known to occur in Ladakh, Chitral, Burzil Pass (Indo - Pak regions), Afghanistan, south Tibet and Myanmar. The fossil data suggest existence of transgressive Neo - Tethys sea during early Cretaceous occupied by these regions and named as the Lhasa - Shyok - Kohistan block (Srimal 1986, Juyal 2006, Juyal and Semwal 2006, communicated).

## Upper Shyok Area

Geological studies in the Karakoram Tethyan sediments of upper Shyok area are carried out by De Fillipi (1912), De Terra (1932), Dainelli (1932 -33), Wyss (1940), Norin (1946), Desio et al. (1991), Gergan and Pant (1983), Pant and Gergan (1983), Juyal (1994), Juyal and Mathur (1996, 1997), Upadhyay (2001, 2002) and Upadhyay et al. (1999a,b, 2005) and others. The upper Shyok area encompases area around Karakoram Pass. The Stratigraphic units exposed in the area are given in Table 1.

The Burtsa Formation (1000m thick) is well exposed in a core of a syncline between Yunam and Qazil Langer and overlies the Morgo Formation with a normal contact. This formation commences with basal conglomerate overlain by carbonate, chert shale sandstone, conglomerate, gypsum and ferruginous shale.

Three Member 1-3 (in ascending order), have been recognised in this formation. Member-1 contains basal conglomerate (thin bed) at the base and massive limestone intercalated; and sandstone, conglomerate, gypsum and ferrugeous shale intercalation, in the middle part; by the calcareous shale in the


Fig. 3. Biostratigraphic section of the Burtsa Formation.

upper part. Member-2 consists of cherty limestone and pink shale intercalation. Lastly the Member-3 contains intercalated, massive, oolitic limestone beds (Fig.3). These three lithounits contains age diagnostic fossils.

## Biostratigraphy

Although palaeontological work in the Karakoram is carried out in the past by several workers. However work by Dainelli (1932, 1933) and Norin (1946) (in eastern Karakoram) and Gaetani in Desio et al. (1991) (western Karakoram) is known in their monographs. Major work carried out by all of them is from western Karakoram as well as northern Tibet. In the eastern Karakoram the palaeontological work is still in its infancy.

Recently the biostratigraphic investigation in the upper Shyok area, eastern Karakoram have been carried out by Pant and Gergan (1983), Juyal (1994), Juyal and Mathur (1993, 1994 a,b, 1996), Juyal in Bagati et al. (1994), Upadhyay et al. (1999) and others. These studies are lacking in bringing out the comprehensive biostratigraphic picture as they are based on the sketchy work on fossil find. In the present study authors have recorded number of age diagnostic taxa for the first time from the measured stratigraphic section giving precise age and deposition of environment of the Burtsa Formation.

In all the three members (1-3 in ascending order) of Burtsa Formation biostratigraphic investigations is carried out. The Member-1 of this formation has yielded, *Megalodon* ssp. (mollusc) *Hetrastridium pachystylum, H. conglobatum* and *Heterastridum* sp. (hydrozoan). This unit has also yielded foraminiferal species, namely, *Trocholina crassa, T. granosa, Agathammina multispira, Aulotortus chialingchialingensisis, O. oscillens, Glomospira regularis, Earlaindinita ladinimca,* and *Ammodiscus* (Foraminifera), molluscs, echinoid spines and sponge tylots. These fossil assemblages are restricted to Carnian – Rhaetian time.

Member-2 of Burtsa Formation has yielded? *Gsollbergella* sp., *Palaeomiliolina monstruosa* (E.V. Bykova), *Lenticulina* sp., *Cornuloculina* sp., *Quinqueloculina juleana* (d'Orbigny)? *Textularia* sp., *Nautiloculina oolithica* Mohler, *Nodosaria*, sp., *Charentia cuvillieri* Neumann, *Saboudia* sp., *Axipolina granufestucae* Neagu . On the basis of this fossil assemblage the middle part of this formation has been assigned Jurassic – lower Cretaceous age.

The upper most part (Member-3) of the Burtsa Formation has yielded foraminiferal species, namely *Dentalina* sp., *Conorbinella* sp., *Balirinopsis* sp., *Trocholina valdensis* (Reichal), (foraminifera) and *cylindroporella* sp. (algae), bryozoans and algae. These fossils occur in ?early Cretaceous age. The biostratigraphic age calibration in the upper part of Burtsa Formation still needs more comprehensive work on fauna from upper part. The Burtsa Formation, thus, range in age from upper Triassic to ?early Cretaceous (Berrimian).

## Environment of Deposition in the Upper Shyok Area

The megalodontids in the basal part of Burtsa Formation show deposition in shallow waters resulting dispersal of fauna in wider areas as shown by the occurrence of megalodonids. In the upward sequence *Heterastridium* (hydrozoans) a planktonic organism is found in slightly deeper water environment. It has wide occurrence else where, mostly in the Karakoram region as well as its east-west adjoining regions. The benthic foraminiferal taxa found in the Burtsa Formation represent shallow water depth. However, they are also restricted in Karakoram and in the adjoining areas to the east-west direction. The alternating gypsiferous (andhydrite) and ferruginous sequence from upper part of Member-1 of this formation were deposited in low energy of 'Sabkha' like environmental conditions. Further upwards the area was submerged by shallow marine water during deposition of the Member-2,3 of the Burtsa Formation. The fauna from this part has yielded foraminifers, bryozoan and algae.

## Comparison of Fauna from Upper Shyok Area

Member-1 of the Burtsa Formation has yielded *Megalodon* ssp., hydrozoans, fragmentary molluscan fauna alongwith several species of benthic foraminifera. Megalodontids, are recorded from several lithounits in the north-south transact of Tethyan Himalayan and Karakoram sediments, namely *Megalodon* beds of Spiti, Zanskar (Tethyan Himalaya) and Aghil Formation in Shaksgam region, western Karakoram. It implies thereby, that during deposition of Burtsa formation in the upper Triassic time there were shallow marine conditions persisted in eastern Karakoram region. The shallow water conditions permitted dispersal of megalodontid fauna to disperse in a larger geographical area.

The intercalating *Megalodon* limestone and shale units in the lower part of Burtsa Formation have several other beds of limestone and calcareous shale which contain species of *Heterastridium*. This is a true planktic organism and found in Tethyan belt and also in Cordilleran, North America (Stanley 1994). It occurs in a wide geographical area during the Carnian - Rhaetian time (Stanley et al. 1994). In the eastern Karakoram these taxa found in Chikchi-ri-Shales (Parona 1928), Shaksgam valley and Karakoram pass (Stoliczka 1874, De Terra 1932, Dainelli 1932, 1933). During the deposition of limestone containing *Heterastredium*, possibly there were slightly deeper water conditions restricting this taxa in the Karakoram microplate and other adjoining region. Possibly the presence of geographical barrier is tenable to restricted dispersal of hydrozoan taxa in the northern margin of Karakoram Tethyan domain.

The presence of foraminiferal taxa from member-2 in the further upward succession of Burtsa Formation has affinity of similar taxa known from Carpathians, Italy, Switzerland and other parts of Turkey and Europe during Jurassic – Cretaceous time. The fauna from middle part of Burtsa Formation is also comparable with that of Marpo Formation of Shaksgam region of the western

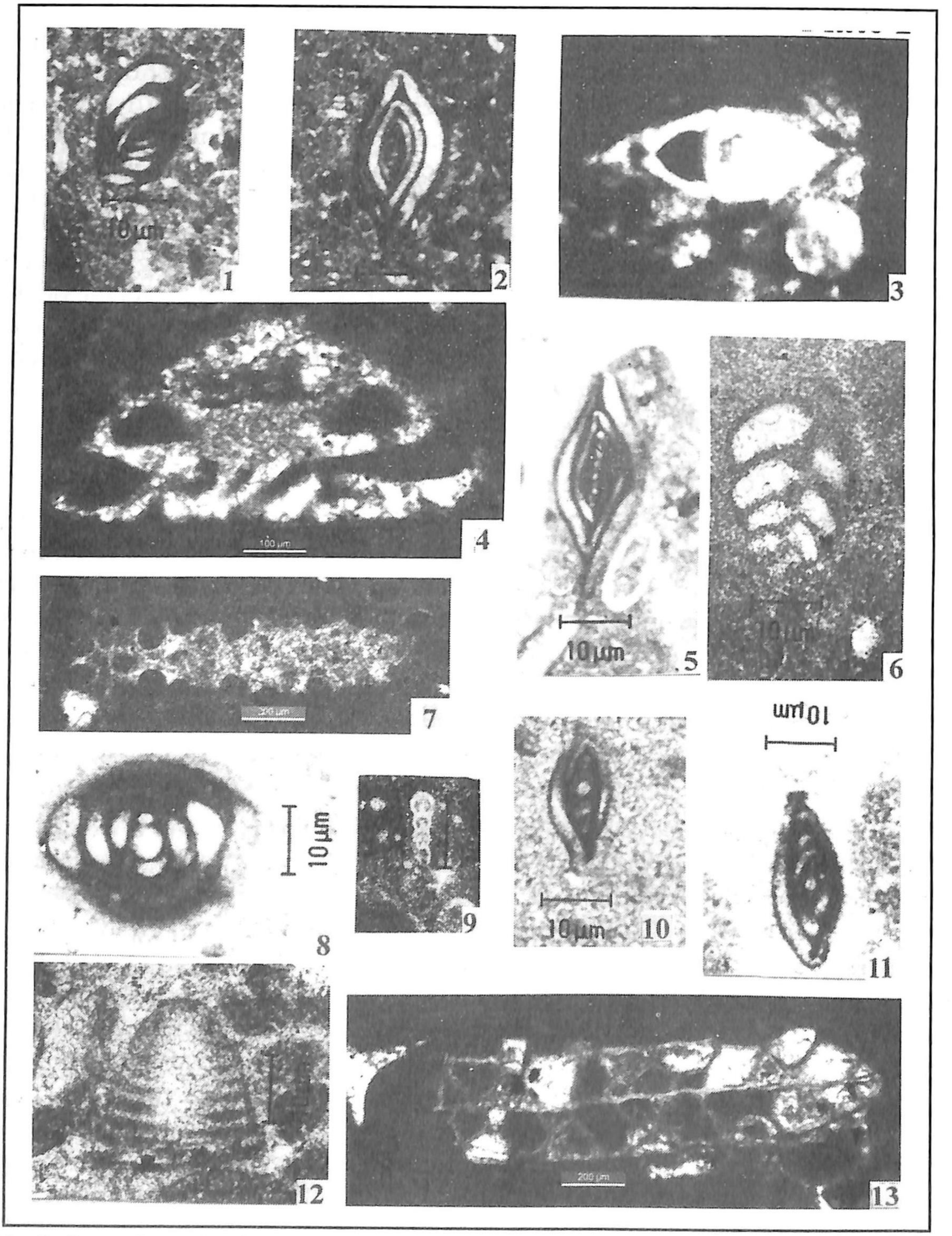


Plate 2. Fauna from the Burtsa Formation, upper Shyok area. 1. Gsollbergella spiroloculiformis (Oraveczne Scheffer), (WIMF/A594). 2,5. Palaeomiliolina monstruosa (E.V. Bykova), (WIMF/A595, 598). 3. Lenticulina sp., (WIMF/A596). 4. Trocolina valdensis (Reichel) (WIMF/A597). 6. Textularia sp. (WIMF/A599). 7. Salpingoporella sp. (WIMF/A600). 8. Nautiloculina oolithica Mohler (WIMF/A601). 9. Nodosaria, sp., (WIMF/A602). 10,11. Axipolina granufestucae Neagu (WIMF/A603, 604). 12. Saboudia sp., (WIMF/A605). 13. Bryozoa (WIMF/A606).

Karakoram. The uppermost member of the Burtsa Formation has yielded foraminifera, bryozoan and algal taxa indicating ?lower Cretaceous age. Samples from this part of the Burtsa Formation are still under progress for further studies.

The Burtsa Formation unconformably overlain by the Qazil Langer Formation which was deposited in a fresh water environment. The latter unit is consisted of a thick sequence of conglomerate with minor shale and sandstones. The conglomerates of the Qazil Langer Formation are constituted by oolitic and fossiliferous limestone pebbles, rolled hydrozoans and other rolled pebbles of the sediments transported from the Burtsa Formation.

The age of Qazil Langer Formation is controversial. Earlier workers considered the age of this formation as Triassic (De Terra 1932, Dainelli 1933 and Norin 1946). This formation was considered to have been deposited during Cretaceous time (Gergan and Pant 1983) and post Maastrichtian (Juyal and Mathur 1996). In the present biostratigraphic investigations carried out in the Burtsa Formation revealed that this formation was deposited during upper Triassic - ?lower Cretaceous as indicated by fossils entombed in different rock units of this formation. These fossils are contained by the conglomerates of the derived boulders of the Qazil Langer Formation. Our faunal data indicate ?post lower Cretaceous age to the Qazil Langer Formation. However more comprehensive work is envisaged on palaeontology.

## Interpretation

1. As discussed above, the faunal data from the lower Shyok area, marine sedimentary succession containing orbitolinid was laid down from east to west between two north - south sutures (i.e. SS and ITZ) encompassing Lhasa - Ladakh - Kohistan block during Aptian - Albian (lower Cretaceous). It suggests that marine connection were in east to west between these two sutures. Environment of deposition of orbitolinid fauna indicates high energy conditions as a result of transgressive and regressive phase possibly due to the early initiation of India - Asia collision along Shyok Suture zone, lower Shyok area which took place at the end of Albian time.

In the lower Shyok area marine sequence is unconformably overlain by the fresh water Saltoro Molasse Formation. Conglomerates boulders of the Saltoro Molasse Formation containing derived fossils of marine Burtsa Formation indicates upliftment of the latter unit after Albian time in the lower Shyok area. The transgressive and regressive cycle during the deposition of Burtsa Formation as indicated by Orbitolinid fauna came to an end in the post Albian during which the fresh water Saltoro Molasse Formation was deposited. The Tethyan sea regressed to southwards from the Shyok Suture zone (SSZ) at end Albian in the Indus Tsangpo Suture zone (ITSZ) and continued in this zone till late Ypresian time. The faunal evidence in support of presence of sea in ITSZ is known through the work by Mathur and Juyal (1996).

In upper Shyok area, Burtsa Formation containing the megalodontids, hydrozoans, foraminifers, ostracods, bryozoa and algae are representing upper Triassic -? lower Cretaceous age. The marine sediments in the Karakoram - Tethyan zone north of SSZ is the part of basin that in which continuous sedimentation occurred from ?Carboniferous period or earlier time. Occurrence of megalodontids in the wide geographical area indicates that the shallow sea persisted in the area resulting wider distribution of this fauna. It indicates shallow water that was connecting wide geographical area. Other fauna found is *Heterastridium* which occur in the slightly deeper water condition and mostly found in northern margin of Eurasian continent indicates physical barriers between northern and southern margins of Tethys that was existed between Karakoram and Indian plates. Alternating ferruginous and gypsum beds of Burtsa Formation indicate very shallow to brackish water environment in upper late Triassic (Rhaetian). During the deposition of sediments in upper part of Burtsa Formation shallow marine conditions returned in the area during which Member-2, 3 of the Burtsa Formation were deposited in Jurassic - lower Cretaceous time. The upper part has yielded shallow marine benthic foraminefers and other fossils. It indicates palaeobiogeographic history in the area during deposition of upper part in Karakoram - Shyok zones. The biotic assemblages from late Triassic to early Cretaceous indicated variation in environment of deposition as well as changes in fauna record in different geographical areas. The Tethyan sea depicted changes in marine connections between various blocks i.e. eastern Karakoram, northern margin of India, western Karakoram, northern Tibet, Iran, Iraq Carpathian Mountain, Italy, Afghanistan and other regions in European continents. Possibly these changes were resulted due to tectonic activities in the area.

Further upwards in the upper Shyok area the marine sedimentation of Burtsa Formation came to end at ? lower Cretaceous (?end of Barrimian). This formation is unconformably overlain by fresh water Qazil Langer Formation which contains conglomerates. Pebbles of conglomerate comprise rolled hydrozoans and pebbles of other fossiliferous limestone derived from the Burtsa Formation indicates that the area was uplifted in lower Cretaseous and influxed freshwater sediments for the development of the Qazil Langer Formation in ?post lower Cretaceous time.

2. Comparison of fauna with adjacent regions from lower Shyok area suggests that in the lower Shyok area the sea was extended east - west between SS and ITS during Aptian - Albian time indicating that Lhasa - Shyok - Kohistan block was represented by a separate palaebiogeographic province during lower Cretaceous (Aptian - Albian).

On the other hand fauna (upper Triassic - ?lower Cretaceous) from the Burtsa Formation, upper Shyok area, eastern Karakoram, shows biotic affinities during different times with different blocks. Work on fauna is still in progress from Burtsa Formation, upper Shyok area for further precise time constrains. Our present work shows that marine units of lower and upper Shyok areas were deposited in two separate basins during different times.

Extensive palaeontological and other geological studies will throw light on the geological evolution of both basins (lower and upper Shyok areas) more precisely in the late Mesozoic. However based on the present faunal data and their interpretations, following conclusion are drawn.

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