UPPER CRETACEOUS OF HAZARA AND PALEOGENE BIOSTRATIGRAPHY OF AZAD KASHMIR, NORTH WEST HIMALAYAS, PAKISTAN

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Abstract: *The Hazara-Azad Kashmir area lies in the northwest Himalayas of Pakistan. The Upper Cretaceous to Paleogene rocks are exposed in the fossiliferous sedimentary cover sequence of the Indian plate. The Upper Cretaceous-Paleogene rock sequence of the Kawagarh Formation, Hangu Formation, Lockhart Limestone, Patala Formation, Margala Hill Limestone, Chorgali Formation and Kuldana Formation has been investigated for micropalaeontological studies. In Hazara area, the Cenomanian to Campanian marine transgressive cycle deposited the micritic limestones of Kawagarh Formation on the north subducting shelf of the Neotethys Ocean below the Kohistan Island arc. The presence of foraminiferal genera such as Globotruncana, Dicarinella, Rugoglobigerina, Heterohelix, Planularia, Lenticulina, Globorotalites, Buliminella and Vaginulina in Kawagarh Formation suggests that the formation deposited in shelf outer neritic conditions. This transgressive cycle ended before the Maastrichtian as a result the regressive to partially transgressive facies of Early Paleocene Hangu Formation deposited unconformably on the Kawagarh Formation. This regressive cycle occurred between the Maastrichtian to Lower Danian. This regressive gap is marked by the aerial, tropical and sub tropical brecciated quartzite, laterite and bauxite facies of the Lower Danian basal part of the Hangu Formation. However, the upper part of the Hangu Formation deposited partially transgressive restricted shallow marine to lagoonal facies as carbonaceous shale, coal seam, sandstone and siltstone in Upper Danian. The Cretaceous-Tertiary Boundary on the basis of fossils can not be marked in Hazara and Azad Kashmir, as there is no record of Maastrichtian and Danian fauna. However, the K-T Boundary can be placed at the basal residual part of the Hangu Formation. The second transgressive cycle deposited the Upper Paleocene-Early Eocene shallow marine limestone and shale sequence that includes the Lockhart Limestone, Patala Formation, Margala Hill Limestone and Chorgali Formation. The Middle Eocene Kuldana Formation records the transitional environments and marks the closing of the Neotethys Ocean and initiation of Middle Eocene to Miocene continental molasse of the Murree Formation.In these study 23 sections were measured from Hazara and Azad Kashmir. More than 1000 outcrop samples were analyzed for microfossils and microfacies of the Upper Cretaceous to Paleogene sequence. The Paleogene of Hazara and Kashmir includes the genera of larger and smaller benthic foraminifers such as Lockhartia, Operculina, Miscellanea, Ranikothalia, Assilina, Nummulites, Alveolina, Clavulina, Quinqueloculina, Spiroloculina and Thalmannita. The microfacies and faunal analyses represent warm shallow marine inner shelf or inner neritic environments during Paleogene transgression cycle. The Paleocene-Eocene Boundary is marked on the basis of disappearance of Lockhartia haimeis and Miscellanea miscella and the appearance of Nummulites atacicus and Nummulites mammillatus in the upper part of the Patala Formation and basal part of the Margala Hill Limestone.*

Introduction

The Upper Cretaceous Kawagarh Formation of Hazara and the Paleocene-Eocene succession of Azad Kashmir were studied for foraminiferal Biostratigraphy. The age assignment of the Kawagarh Formation (Coniacian-Campanian) ascertained on the basis of planktonic foraminifera. On the basis of faunal assemblage it was determined that the formation was deposited in outer neritic, open marine environments. The Paleocene-Eocene succession of the Azad Kashmir consists of the Paleocene Hangu Formation, Lockhart Limestone and the Patala Formation while the Eocene contributes Margalla Hill Limestone, Chorgali Formation and the Kuldana Formation. Age diagnostic benthic larger foraminifera belonging to the genera Operculina, Assilina, Nummulites, Lockhartia, Miscellanea, Ranikothalia, Discocyclina and Actinosiphon were encountered. The presence of the larger foraminifera was indicative of shallow shelf (inner neritic) marine environments.

The present work is partially sponsored by the Pakistan Science Foundation and Higher Education Commission and an attempt to study the Upper Cretaceous of Hazara and the Paleogene succession of Azad Kashmir with particular emphasis on the foraminiferal biostatigraphy for age evaluation and environmental interpretation. Twenty three (23) stratigraphic sections were measured at Dana Nuranlan, Lassan, Jabri, Sangjani, Sohaba, Mandiabani, Chanali, Hothla, Jhan, Kalsan, Jhansa, Khairagali, Changlagali, Chumbi, Kuzagali, Kundla, Mochidhara, Kalas, Reechmari, Yadgar, Tandabotha, Tattapani and Kamroti areas (Fig. 1). More than 1000 samples were collected at suitable interval covering lithological variations of all the rock units (Fig. 2). The samples were properly numbered. Thin sections of the carbonate sequence were prepared in the laboratory for micropalaeontological studies. Softer rocks like shale and marl having foraminiferal assemblages were processed for picking of micro fossils. This fauna was preserved in the micropalaeontological slides for study. The Paleogene rock sequence is rich in microfossil assemblages especially, foraminifera (Fig. 3). The regional species distribution and time boundaries of the Upper Cretaceous and Paleogene rock units tells more about the geological history and environments of deposition of the area. These also throw light on the timing of transgression and regression of the Neotethys Ocean .Closing of Neotethys Ocean and the Himalayan collision between the Indo-Pak Plate and the Eurasian Plate.

BIOSTRATIGRAPHY OF THE UPPER CREATACEOUS SEQUENCE OF HAZARA

Kawagarh Formation

The Kawagarh Formation comprises of light grey to grey limestone, sandy limestone and minor dolomitic layers (Fig. 2). The lower and upper parts of the formation are fine to medium grained limestone. The fine grained limestone alternates with fine to medium grained dolomite. The fine grained limestone shows conchoidal fractures. However, at places in the middle part of the formation sandy limestone is present. The sandy limestone is grey to dirty grey and medium to coarse grained. It has a number of colour shades like light to dark grey, light yellowish grey to creamish grey, brownish grey to rusty grey, whitish maroon to maroonish grey, red maroon to pale maroon and very pale maroon. The formation is generally medium to thick bedded and beds range in thickness from 0.4 to 2 meters Calcite veins is abundant and some of them are dolomitized. The fractures at places contain gypsum crystals. A joint set perpendicular to bedding, where closely spaced, imparts shattered appearance to the formation. It is tough to hammer and breaks with conchoidal fracture. Some horizons especially dolomitic break with irregular fractures. The yellowish horizons are dolomitic relatively coarse grained, show chopboard weathering, small solution depressions and micro ridges at places. The maroonish horizons are dolomitized limestones and contain holes due to solutioning. The palaeontologoical study shows that the Upper Cretaceous diagnostic species are as follows, which confirms the Coniacian- Campanian age of the formation.

Dicarinella carinata, Globotruncana linneiana, Globotruncana elevata-calcarata, Globotruncana fornicata, Globotruncana fornicate-caliciformis, Globotruncana concavata concavata, *Globotruncana* cf. *concavata carinata*, *Globotruncana* cf. *thalmanni, Rugoglobigerina rugosa ordinaria*, *Rugoglobigerina rugosa subrugosa, Heterohelix reussi, Heterohelix glubolosa*, *Heterohelix globulosa*, *Buliminella cushmani*, *Plannlaria liebusi*, *Lenticulina navarroensis extrauatus, Lenticulina muensteri*, *Globorotalites multisepta* and *Vaginulina subcomarginata (*Plate 2).

BIOSTRATIGRAPHY OF THE PALEOGENE SEQUENCE OF AZAD KASHMIR

Hangu Formation

The Hangu Formation in the study area is divided into the lower and upper parts. The lower part consists of brecciated sandstone/cherty quartzite, pebbly layers, laterite, bauxite and fire clay. However, the lithology generally varies at places in the lower part of the formation. The upper part includes siltstone, sandstone, carbonaceous shale and coal seams the basal part of the formation marks the disconformity.

In Hazara, the lower part is mostly marked by laterite, oolitic haematite and bauxite. However, at places the siltstone, sandstone, carbonaceous shale and local coal seams are present in the upper part of the formation .The thickness of the unit varies from 1 to 22 meters.

The Hangu Formation occurs in Reechmari, Balakot and Muzaffarabad area of Azad Kashmir. The lower and upper parts of the Hangu Formation are present in Balakot and Azad Kashmir areas. Near Reechmari, Balakot the formation consists of brecciated quartzite, ferruginous pisolitic bauxite, fire clay, carbonaceous shale and sandstone. The formation occurs between the Cambrian Abbottabad Formation and the Early Eocene Margala Hill Limestone. The thickness of the Hangu Formation is 9 meters. The Hangu Formation near Yadgar and Tandabotha includes brecciated quartzite, bauxite, limonite, fire clay, carbonaceous shale, ferruginous sandstone and coal seams. The basal brecciated zone is composed of aluminous to calcareous clays with abundant quartz and chert pebbles. The thickness of the unit at Yadgar and Tandabotha is 26 and 14 meters respectively. In Tattapani area the Hangu Formation consists of brecciated quartzite, bauxite, fire clay, carbonaceous shales and local coal seams. The thickness of the unit is 3 meters. The Hangu Formation near Kamroti includes aluminous to calcareous clays, quartz and chert pebbles, bauxite fire clay, carbonaceous shales and coal seams. The fire clay zone is grey to dark grey with cream to light grey clays. The bauxite is pisolitic and occasionally oolitic, compact and splintery in nature. Pisolitic bauxite is the top most zones, consisting of pisolits and oolites. It is reddish brown to cream coloured and partly lateritized. The laterite and bauxite consists mainly of the oxides of iron and alumina respectively. These are the ideal conditions for decomposition of the clay minerals to laterite. Similar environments must have prevailed in Hazara, Balakot and Azad Kashmir areas during the formation of laterites/bauxites. Formation of oolites in the laterite has taken place because of the transportation of iron content in colloidal form to shallower conditions where it transformed into oolitic/pisolitic form. Beyond the oolitic environment, the sandstone, sandy shale and shale were deposited under an oscillating shallow sea as characterized in the deposits of Hazara, Balakot and Azad Kashmir areas. Whereas, the carbonaceous shale with coal seams deposited under lagoonal conditions. The presence of pebbles and brecciated sandstone and quartzite in the basal part of the formation, shows the reworking of the underlying rocks during regression of the Neotethys Ocean before the formation of laterite, bauxite and fire clay in the lower part of the formation. The sandstone, siltstone, carbonaceous shale and coal seams of the upper part of the formation in Hazara, Balakot and Azad Kashmir, represent the shallow marine to lagoonal environments. In Hazara area, the Early Paleocene Hangu Formation overlies unconformably the upper Cretaceous Kawagarh Formation in Samana Suk Range it overlies unconformably the Kawagarh Formation. It is overlain by the Late Paleocene Lockhart Limestone in Hazara. The stratigraphic relationship in Hazara and Azad Kashmir suggests the Lower Paleocene age for the formation.

Lockhart Limestone

There is transgression of the sea during the deposition of the Lockhart limestone. It is mainly a calcareous, nodular limestone with subordinate shales in the lower and upper parts The limestone is grey, medium to thick bedded, medium grained and hard. The weathered surfaces indicate solution weathering, very prominent flazzer bedding and bluish to light grey in colour. On fresh surface generally dark grey and gives a foetid smell by hammering. There is a marked decrease of nodules towards the middle part of the unit. Nodularity increases towards its contact with the overlying shale of the Patala Formation. In the middle part of the unit calcite veins are common. Microfossils of foraminifer can be seen on the weathered surfaces in the form of tiny speaks less than one millimeter.

The nodular habit of the limestone appears to be of sedimentational origin. This origin is supported by the fact that the nodules are more frequent where shale and marls are interbedded with limestone. Topographically the formation forms ridges and cliffs. In Yadgar and Tandabotha areas of Muzaffarabad, the Lockhart Limestone is present between the Hangu Formation and the Patala Formation. The Lockhart Limestone is dominantly nodular and massive with subordinate shale intercalations. The massive portions of limestone show diffused nodularity. Nodules are generally 2 – 6 centimeters in length and 1-5 centimeter in width. The limestone is dirty grey to light grey on weathered surfaces and grey to dark grey on fresh surfaces. The limestone contains secondary calcite veins. It is highly fossiliferous and fossil size from 0.5-1.5 mm

The foraminifers like *Lockhartia, Assilina, Discocyclina* and *Ranikothalia* are present in the Lockhart Limestone (Plate 1, Fig. 3).

The larger foraminifera are known to characterize the shallow shelf carbonate environments. The Lockhart Limestone represents a shallow shelf carbonate platform as is evidenced by the occurrence of a number of larger foraminifera and dasycladacean algae in the formation. It is inferred that relatively constant water depth was maintained during accumulation of entire sequence. This is an indication of shallow shelf deposits.

In this study the following age diagnostic species of foraminifera are identified:

Operculina salsa, Operculina subsalsa, Lockhartia haimei, Lockhartia tipperi, Lockhartia conditii, Miscellanea miscella Daviesina langhami, Ranikothlia sindensis, Ranikothalia sp., *Kathina delseota, Sakesaria ornata, Quinqneloculina* sp., *Actiosiphon tibetica, Nodosaria* sp., *Textularia punjabensis, Textularia* sp., *Clavulina parisiensis, Pseudogloborotalia membranacea, Globorotalia* sp., *Bigenerina* sp. and *Triloculina* sp.

The other fossils identified in this study from various thin sections of Khaira Gali, Mandedabani, Jabri, Dana Nuranlan, Yadgar and Tandabotha areas include dasycladacean (green algae), red algae, pieces of corals, bryozoans, echinoderm spines and sponge spicules and forams.

Patala Formation

The formation at the type locality mainly consists of dark grey shale, which is sometimes carbonaceous and include workable coal seams. The shaly unit is intercalated with limestone and sandstone. The shale contains selenite and marcasite nodules at places in different levels. Slightly ferruginous beds also occur in higher part of the section. The shale contains foraminifers and Ostracods.

The formation is separated by underlying Lockhart Limestone and overlying Margala Hill Limestone by its significance nature in the area. Shale is the predominant component of the unit though thin limestone and marl band intercalations are frequent towards the base and the top of the formation. The shale represents a prominent olive green colour. The limestone is grayish yellow, mainly nodular with marl intercalation, medium to thick bedded and massive. In Hazara the Patala Formation is mainly a unit with intercalations of marl and limestone towards the base and the top of the formation. The shale varies in colour from khaki to pale grey and greenish grey to occasionally dark grey. It has a permeable nature in general so do not produce mud in the rainy season. These are much cleaved and have a tendency to splinter rather than split. The Hazara Formation on the other hand relatively arenaceous and slightly metamorphosed, with a habit of splitting into plates and devoid of fossils. The shale bands within Margala Hill Limestone of khaki colour differ from shale of Patala Formation by having forams of much larger size (4-8 mm). The khaki coloured shale of the Kuldana Formation is generally associated with purple and grey coloured gypceous shale. In the Changla Gali area, the intercalation of thin-bedded limestone is very common. Shale unit is observed in the Kuza Gali area.

Lithologically, the formation consists of alternating beds of limestone and shale, however, influence of little interbeds of marl and siltstone is also observed. The interbedded limestone is generally nodular.

The shale was deposited in quite water out of suspension while the thin intervening siltstone beds were deposited as distal deposits by occasional strong currents, which were possibly storm related. It is also possible that the shale in parts may have been deposited in the last phase of waning storm currents Swift, D. J. P., HAN, G. and C.E Vineent, (1986).the limestone beds suggest local fluctuation between clastic and non clastic environment of deposition. It is possible that the calcium carbonate was being deposited in the vicinity of the site of deposition of shale and siltstone, the currents during high energy conditions would have transported the calcareous material from its site of origin and deposited in its present position where predominant clastic material was being accumulated. This assumption is supported by the fact that some of the limestone beds are laterally lenticular uneven in the thickness and exhibits lower erosional bedding planes. The deposition of these limestone beds took place during wanning stage of the high-energy condition.

The Patala Formation display a remarkable succession of cyclic deposits in Hazara and Azad Kashmir as a result repetition of shale, limestone, coal and ironstone has been observed. Such cyclotherums are typically associated with unstable shelf or interior basin conditions in which alternate marine submergence and emergency occurred. During the emergent stages, local disconformities may be developed in the previously deposited sediments before the succeeding unit is deposited. Shale, clay and silt derived from rising elements in source areas were deposited over the low emergent plain mainly as alluvial detritus. As the source areas were lowered by erosion these were succeeded by marl and fresh water limestone deposits. The inflow of detrital material diminished and the broad plain was occupied by swamps or marshes. Such conditions were suitable for the accumulation of peat which was later transformed to coal. The accumulation of peat required fresh to brackish water conditions. These conditions were followed by a relative clearing of sea during which limestone was deposited. Restricted shallow marine conditions commonly developed after the initial limestone deposition to form the black laminated shale. As the cycle of sedimentation progressed, the environments lost its restrictions, developed open circulation and eventually the bio-sarite limestone was deposited in shallow current agitated water. The Patala Formation is highly fossiliferous and contains abundant foraminifers, mollusks and Ostracods. Latif [10], reported the macrofossils and microfossils from the formation at difference areas of Hazara.

In present study the detailed work on the foraminiferal assemblage of the formation is presented. The study indicates the occurrence of following species of foraminifera:

Lockhartia haimei, *Lockhartia conditi*, *Lockhartia tipperi*, *Lockhartia conica*, *Lockhartia prehaimei*, *Operculina salsa*, *Operculina patalensis*, *Operculina subsala*, *Ranikothalia nuttalli*, *Ranikothalia sindensis*, *Miscellanea miscella*, *Discocyclina ranikotensis*, *Nodosaria* sp., *Textularia punjabiensis*, *Textularia* sp., *Quinqueloculina* sp., *Pseudophragmina* sp., *Spiroloculina* sp., *Actinosiphon tibetica*, *Anomalina acuta*, *Anomalina bandyi*, *Globorotalia* sp., *Pseudogloborotalia membranacea*, *Cibicides* sp., *Clavulina parisiensis* and *Clavulina* sp. (Fig. 3).

On the basis of above mentioned microfaunal assemblage, the Upper Paleocene age has been assigned to the Patala Formation.

Margala Hill Limestone

The formation is essentially a nodular limestone with insignificant intercalations of marl and shale. It is dark grey on freshly broken surfaces and grey to pale grey on weathered surfaces. The weathered surfaces show concentration of larger foraminifera, which range in size from 2 to 6 mm. The limestone is typically nodular; the nodules range 12 cm to 26 cm in length and up to 32 cm in breadth. The nodules are surrounded by argillaceous material. Calcite veins are frequent, particularly where the limestone is massive. In the upper parts, pyrite specks have been noticed. There is a gradual change from the shale of the Patala Formation to the limestone of Margala Hill Limestone. The relatively resistant limestone forms as cliffs and occasionally dip slopes, as seen near Patala, Dunga Gali, Kuza Gali, Reechmari, Tattapani and Yadgar. The authors have measured the section in detail at Kuza Gali. The formation at this section primarily comprises of nodular limestone. The limestone is light grey to dark grey, weathers dull to brownish grey, fine to medium grained, thick bedded, massive nodular and nodules vary from 2 to 22 cm in diameter. The limestone gives foetid smell from the freshly broken surfaces. Prominent joints, fractures and slickenside surfaces occur in the lower part of the section. The lower limestone unit of the formation is highly fossiliferous, contains abundant foraminifers of larger size, which are visible with the naked eye. This is a distinguishing characteristic of the unit. Similar situation prevails elsewhere in the area.

The lithology of formation does not represent any marked deviation. The unit measures from 25 to 159 meters in the Hazara area. The formation forms high cliffs, ridges and escarpments, visible from the distance. The nodular aspects of the Margala Hill Limestone is a result of the differential compaction of the limestone and intervening argillaceous material which surrounds the nodules, pointing out the sedimentary origin as is the case with Upper Paleocene Lockhart Limestone. The digenetic fabrics of Margalla Hill Limestone are produced with effects of chemical compaction, pressure solution and mechanical compaction.

Abundant occurrence of larger foraminifera in the formation is the indication of shallow marine environment. The barrier like shoals more or less parallel to the coast created restricted shelf and open shelf environment. This is characterized by relatively high water energy, rich assemblage of heavy ornamented larger foraminifera, particularly species groups of *Alveolina*, *Orbitolites* and *Nummulites* Hottinger (1974). working on ecological condition of *Alveolinids* established that the carbonate environment form reef facies shoals in many places with similar environments. The formation consists primarily of limestones, which are mostly non-terrestrial origin depicted by the presence of foraminiferal and other fossils. The shallow sea is probably the place of the most expensive deposition of lime. The dark color of the limestone points to a higher organic contents. The fetid smell from the freshly broken surface of the limestone indicates the presence of bituminous matter and applies stagnation of water during the depositional process.

The Margala Hill Limestone is highly fossiliferous. The formation contains foraminifera, mollusks and echinoids. The other fossil remains from various sections of the area identified include pieces of corals, bryozoans, echinoderm spines and sponge spicules. The authors have carried out detailed work on the foraminiferal assemblage of the unit. For this purpose thin sections were studied from Kuza Gali, Khaira Gali, Tattapani, Kamroti and Yadgar areas. The cumulative study of the thin sections has indicated the occurrence of the following foraminifers:

Nummulites atacicus, *Nummulites mamillatus*, *Assilina granulosa*, *Assilina spinosa*, *Assilina laminosa*, *Assilina subspinosa*, *Ranikothalia sindensis*, *Operculina patalensis*, Lockhartia *tipperi*, *Lockhartia conditi*, *Alveolina* sp., *Pseudophragmina* sp., *Discocyclina dispansa*, *Discocyclina ranikotensis*, *Rotalia perovalis*, *Rotalia trochidiformis* and *Alveolina* sp.(Fig. 3).

On the basis of above mentioned microfossil assemblage the Lower Eocene age is assigned to the Margala Hill Limestone.

Chor Gali Formation

The Chor Gali Formation generally consists of limestones, marly limestone, argillaceous limestone, marl and subordinate shale. The limestone is rarely massive and generally shows a flaggy/platy habit, the flaggy habit is probably due to the increasing marly intercalations. The limestones weather into creamy light yellow and light grey colours and their freshly broken surfaces are light grey. The Margala Hill Limestone passes upwards with a gradual change of lithology into the Chor Gali Formation. However, the presence of larger foraminifera helps in its identification in the field. Occasionally these limestones of the formation weather to a chalky appearance. The marls of unit are generally in very light shades from khaki to grey. There is a significant increase in the argillaceous content towards the upper part of the formation which may range from argillaceous limestone to calcareous mudstone. The rock unit is generally thin bedded and less dense in nature and light to medium grey in colour, so visibly devoid of any fossils. The formation is occasionally found to be intensely folded, sheared and brecciated due to its less competent nature. It is fine grained at places, shows secondary calcite veins and gives bituminous smell from the freshly broken surfaces. Some of the beds are nodular and argillaceous. The shale is greenish grey and thin bedded. They are soft and calcareous and alternate with flaggy limestone.

The digenetic fabric of the rock unit is produced by the chemical compaction and pressure dissolution, which are very important burial processes. Apart from producing a range of dissolution textures, they also result in the dissolution of grains and sediments, and this may be a significant source of lime for burial cementation. Pressure dissolution arises from the increased solubility of material at grain contacts and long sediment interfaces as a result of applied stress.

The Chor Gali Formation consists of alternating beds of hard limestone and platy limestone within the shale sequence with abundant dissolution seams in wackstone / packstone. This is an example of fitted fabrics Tucker, M.E. and V.P. Wright, (1992). Bedding planes are developed in platy limestone. They are mostly destroyed by bioturbation. It appears that hard layers were selectively cemented earlier and eventually mechanical and chemical compaction affected the less cemented layers to produce platy limestone and bedding planes. This indicates that cementation of sediment was taking place periodically during shallow burial beneath the seafloor. Topographically, the formation generally forms slopes and low cliffs.

The Chor Gali Formation is fossiliferous particularly in the lower part. It contains foraminifers, Ostracods and mollusks. Vertebrate remains have also been reported from the formation in parts of Kohat and Kotli areas of Azad Kashmir Wells, N.A. and P.D. Gingerich,(1987).and Wells, N. A. and P.D. Gingerich, (1983).

The foraminifera have been studied in detail from the formation. Their preservation is poor in many parts of the relevant areas. The following foraminifers are reported from various lithobiosections of Hazara and Azad Kashmir:

Assilina granulosa, Assilina *spinosa, Assilina subspinosa, Assilina laminosa, Nummulites atacicus, Nummulites mamillatus, Lockhartia conditi, Lockhartia tipperi, Rotalia perovalis, Rotalia trochidiformis, Rotalia* sp., *Textularia punjabensis, Textularia* sp., *Nodosaria* sp., *Orbitolites complanatus, Globorotalia* sp., *Globorotalia aff. Prolata, Quinqnuloceline* sp., *Dictyoconus indicus, Spiroloculina* sp., *Globanamalina ovalis, Valvulineria* sp., *Bigenerina nodosa, Coskinolina* and *balsillei* (Fig. 3).

On the basis of these microfossils assemblage a Lower Eocene age is assigned to the Chor Gali Formation.

Kuldana Formation

The Kuldana Formation comprises dominantly of vary coloured shale, marl, limestone, gypsum and sandstone. The shale is purple, red, buff, crimson, pale grey to brownish grey, generally gypsiferous or arenaceous whitish or violet bentonitic. The clays are occasionally gypsiferous as observed in Bansra Gali. They have been excavated for sometimes in the area. They are plastic in nature, but have very limited extent. Marl is grey to greenish grey, compact, thin bedded and arenaceous. At places, these marls are leached and produced a vuggy structure. Impure gypsum is quite well developed near Mochidhara Cantonment.

The limestone is grey, marly, argillaceous, brecciated and fine grained. They are highly weathered and burrowed. The sandstone is embedded at different levels. These beds are composed almost entirely of distinctive, iron-stained and calcareous granules. These sandstones contain lithic grains of quartzite, chert, sandstone and limestone in coarser size. Most calcareous granules have matrix of small calcite rhombs. The granules are clearly recrystallized and degraded. Most granules have concentric rings of haematite. The features suggest that the granules are reworked soil nodules that grew under arid or semi arid conditions in calcareous soil. Calcareous soil nodules with radial fabrics and rims have been described by Asserto and Folk Frieindman, G.M. and J.E. Sanders, (1978).similar nodules are described by Wells Wells, N.A. and P.D. Gingerich, (1987).from lower Kuldana beds of Kohat area. Cracking and episodic haematite staining and coating of growing nodules could occur in an alternating wet and dry soil environment Siesser, W.G., (1973). Calcareous mud flats and minor erosion and winnowing of the clay during floods and stream channels incision could easily have produced significant lag concentrates, particularly in the absence of any other coarse material. Coarse interclastic limestone rudestone/ floatstone and dolomite occur at places.

Rendzina soil profiles are typical feature of the Kuldana Formation. These profiles have a very dark brown horizon that passes down into a zone of nodular calcite. In some cases nodules collapse to form a solid layer. Rendzina soil primarily indicates a calcareous substrate. They are common under grasslands on marl and limestone in humid to semi-arid climates. Similar conditions have been described by Wells Wells, N.A. and P.D. Gingerich, (1987).in Kohat area.

The red colouration of the clays of the formation is result of oxidation. Nacrite is relatively rare mineral occurring for the most part in association with metallic ores. The formation is generally calcareous at the base and arenaceous towards the top.

The Kuldana Formation with abundant clays indicates a condition of standing water in the immediate areas and high local environmental diversity with nearness to sea. The purple clays indicate a relatively high water table. The overlying marine beds with limestone and marl suggest that base level was rising. The presence of an aquatic fauna indicates that the rivers of the area were perennial rather than ephemeral.

Wells, N.A. and P.D. Gingerich, (1987).commented on the preservation of the Kotli, Azad Kashmir and Kala Chitta vertebrate fossils. The occurrence of mammals' bones suggests a greater rate of subsidence and sedimentation, which may have supported the burial and preservation. The sandstone did not appear to be the result of meandering streams. They are thin and appear to be deposited/ laid down by one or two floods. Most of the perennial streams may have entered the upper Kuldana coast and have removed most of the sediments during floods. The granulestone within the red beds apparently represents inland environments that were derived and scrub covered plains crossed by small and briefly active streams which apparently supported a sparse and limited fauna. They represent lags or low bars in large and mostly mud filled channel. It is also possible that streams wander area all over the landscape, thereby indicating its flatness.

Extreme flatness of the formation surely contributed to the immaturity of the early drainage system. Common over bank flooding and channel from sandstone occur at all levels. However, enormous clay deposits suggest additional input of clay by other processes like sheet wash and wind action. The impressed aggradations of red bands suggest that the draining of the sea by evaporation process left the basin floor below grade.

The Kuldana Formation represents a varied lithology consisting of marl, siltstone, limestone and oyster beds, which are interpreted to be deposited as white marls with commonly leached features are deposited as marsh, lake, or lagoon limestone. Some of the leached white marls have rough and irregular, solution pitted features, as a result of exposure and baking in the sun. Limestone/ bioclast, wackestone commonly gastropodal in thin sections are brackish water deposits.

Carbonates, particularly with purple and violet hue, show an extensive evidence of iron staining. They occur as nodules with unusual networks of curvilinear cracks. These are produced by soil forming processes, particularly those working in marshy conditions.

Oyster beds at the top of the Kuldana Formation are accompanied by one or more thin beds of broken shells. Because oysters are sessile and cannot tolerate rapid sedimentation in very muddy water, the sequence is believed to represent slow sedimentation under brackish water.

Coarse intraclastic limestone/ rudstone/ floatstone and dolomite in sandstone, siltstone and clays are caused by high energy conditions or by reworking of clasts formed by mud cracking or evaporate dissolution under lower energy conditions.

The flood plain clastic sediments having laminated gypsum beds /lenses represent extremely shallow water to emergent environments. The laminated gypsum resembles the quiet and shallow water deposits Schreiber,B.C., (1978).the reddish yellow gypsiferous shale with isolated selenite crystals, possibly represent a synsedimentary or very early diagenetic sabkha or subsankha muddy crystal mesh. The variegated red and green shale with long fan shaped gypsum crystals are similar to some of the crystals described from sabkha settings by Schreiber (1978) these shales may be the emergent feather-edge forms and the associated gypsum crystals may be formed under subaqueous conditions.

A brackish back-bar bay or lagoon that trapped mud and animal remains carried out to sea from the marshes along the shore.

On shore clays, completely pedogenized and apparently representing very slow sedimentation until the earliest Himalayan molasses was swept into the region.

The authors have identified foraminifera from the formation which include:

Assilina dandotica, Assilina granulosa, Assilina sp., Nummulites atacicus, Nummulites mammillatus, Nummulites sp., Quinqueloculina sp. and Milliolids (Fig.3).

On the basis of above mentioned faunal assemblage a Middle Eocene age is assigned to the Kuldana Formation.

Summary and Conclusion

The detailed field investigations, sample analysis, microfacies analysis and palaeontological study of Hazara, Balakot and Azad Kashmir areas lead to following conclusions.

The basinal evolution of the area started in the Mesozoic. The deposition of the Upper Cretaceous Kawagarh Formation in Hazara exhibits the deepening of narrow trough by containing planktonic foraminifera like *Globotruncana, Rugoglobigerina* and *Heterohelix*. However in Azad Kashmir, the area remained uplifted during the Upper Cretaceous and no Kawagarh Formation was deposited. The sequence from Ordovician to Cretaceous have been eroded or not deposited during pre-Paleocene tectonic uplift.

Having much time gap during Maastrichtian to Danian, the Kawagarh Formation was subjected to chemical weathering processes. It is inferred from overlying residual deposits and by missing fauna of Maastrichtian. The overlying pisolitic laterite, limonite, oolitic haematite and bauxite mark the first major stratigraphic break of the Cretaceous-Tertiary strata. This unconformity has a long time gap from Ordovician to Lower Paleocene in Azad Kashmir and Balakot regions by resting residual deposits of Hangu Formation on cherty dolomites of the Abbottabad Formation.

The Upper Cretaceous Kawagarh Formation records the shelf marine sedimentation which occurred during the subduction of the Indian plate below the Kohistan Island arc. The Kawagarh Formation deposited during major transgressive cycle from Coniacian to Campanian.

The start of initial collision of the Indian plate and Kohistan Island arc in the Maastrchtian- Early Paleocene, a major regressive cycle occurred in the Hazara area. The regressive cycle of Neotethys Ocean occurred due to pre-Paleocene tectonic uplift in the area. This regressive cycle deposited the basal part of the Early Paleocene Hangu Formation.

The laterite/ bauxite of the lower part of the Hangu Formation deposited during tropical to subtropical conditions where the sandstones, siltstones, carbonaceous shale and coal seams of the upper part of the Hangu Formation deposited under restricted shallow marine to lagoonal environments. The second transgressive cycle of Neotethys ocean deposited shallow marine shelf carbonate and shale sequence during Late Paleocene to Early Eocene .The formations which deposited during second transgressive cycle include Lockhart Limestone, Patala Formation, Margala Hill Limestone and Chorgali Formation.

The deposition of Lockhart Limestone with larger benthic foraminifer took place during the Upper Paleocene (Thanetian) after the transgression of the Neotethys Ocean in Hazara and Azad Kashmir. These carbonates (nodular limestone) microfacies are indicative of marine shallow shelf environments. Subsequently, shaly deposits of Patala Formation with interbeds of limestone seem to show a considerable regression of the sea with mostly quiet water deposition.

The shallow shelf carbonate deposition of the nodular Margala Hill Limestone continued in the Early Eocene time. The presence of dark shale and foetid fossiliferous limestone that accumulated in slight higher energy water has a basinal configuration across the Paleocene-Eocene boundary.

The pre-existing paleogeographic setting of the basin has been changed after the depositions of Margala Hill Limestone when a trend of younging of units towards the south has been observed during the Early Eocene. The flaggy limestone of the Chorgali Formation comprises near shore deposits and shows a single regression late in the Early Eocene marked southward shift in the basinal configuration that left the land dry during Middle Eocene fluctuations of the shoreline to the north and to the west.

In Middle Eocene the Kuldana Formation deposited under transitional environment. This indicates the closing of the Neotethys Ocean and strengthening the argument of the southward shift of the paleogeographic setting and the development of the Hazara- Kashmir foreland basin which marks the end of the Paleogene deposition in the area. The Middle Eocene is the time of main Himalayan collision in northern Pakistan and the formation of Hazara-Kashmir foreland basin. The Himalayan molasse initiated deposition as Murree Formation during Middle Eocene in Azad Kashmir and Miocene in the Hazara area. This indicates that the Himalayan molasse of the Murree Formation is time transgressive unit.

The occurrence of abundant foraminiferal fauna laterally and vertically in the succession from Upper Cretaceous to Paleogene made it possible to establish biozonation on the basis of several age diagnostic species. The zonal species belongs to three main groups of planktonic, larger benthic and smaller benthic foraminifera. The Upper Cretaceous Kawagarh Formation represents the planktonic genera *Globotruncana*, *Heterohelix, Rugoglobigerina, Planularia, Lenticulina, Globorotalites*, *Buliminella* and *Vaginulina* of foraminifera. The Paleogene strata consists mainly of larger and smaller benthic foraminiferal genera such as *Daviesina, Operculina, Miscellanea, Lockhartia, Ranikothalia, Rotalia, Globorotalia, Quinqueloculina, Textularia, Nodosaria, Clavulina, Thalaminita, Anomalina, Assilina* and *Nummulites.*

The Cretaceous-Tertiary Boundary on the basis of fossils can not be marked in Hazara as there is no record of Maastrchtian and Danian fauna. However, the K–T Boundary can be placed at the base of Lower Danian basal residual part of the Hangu Formation. The Upper Danian unfossiliferous upper part of the Hangu Formation at places shows very shallow marine lagoonal facies. The Paleocene-Eocene Boundary is placed by the disappearance of *Operculina salsa* and *Miscellanea miscella* and the appearance of *Nummulites atacicus* and *Nummulites mammillatus* in the upper part of Patala Formation and basal part of the Margala Hill Limestone respectively. In Hazara and Azad Kashmir, the whole succession from Upper Cretaceous to Middle Eocene was deposited by double cycle of transgression and regressions of Neotethys Ocean before the initiation of Himalayan molasse during the Middle Eocene to Miocene Himalayan collision.

Acknowledgments

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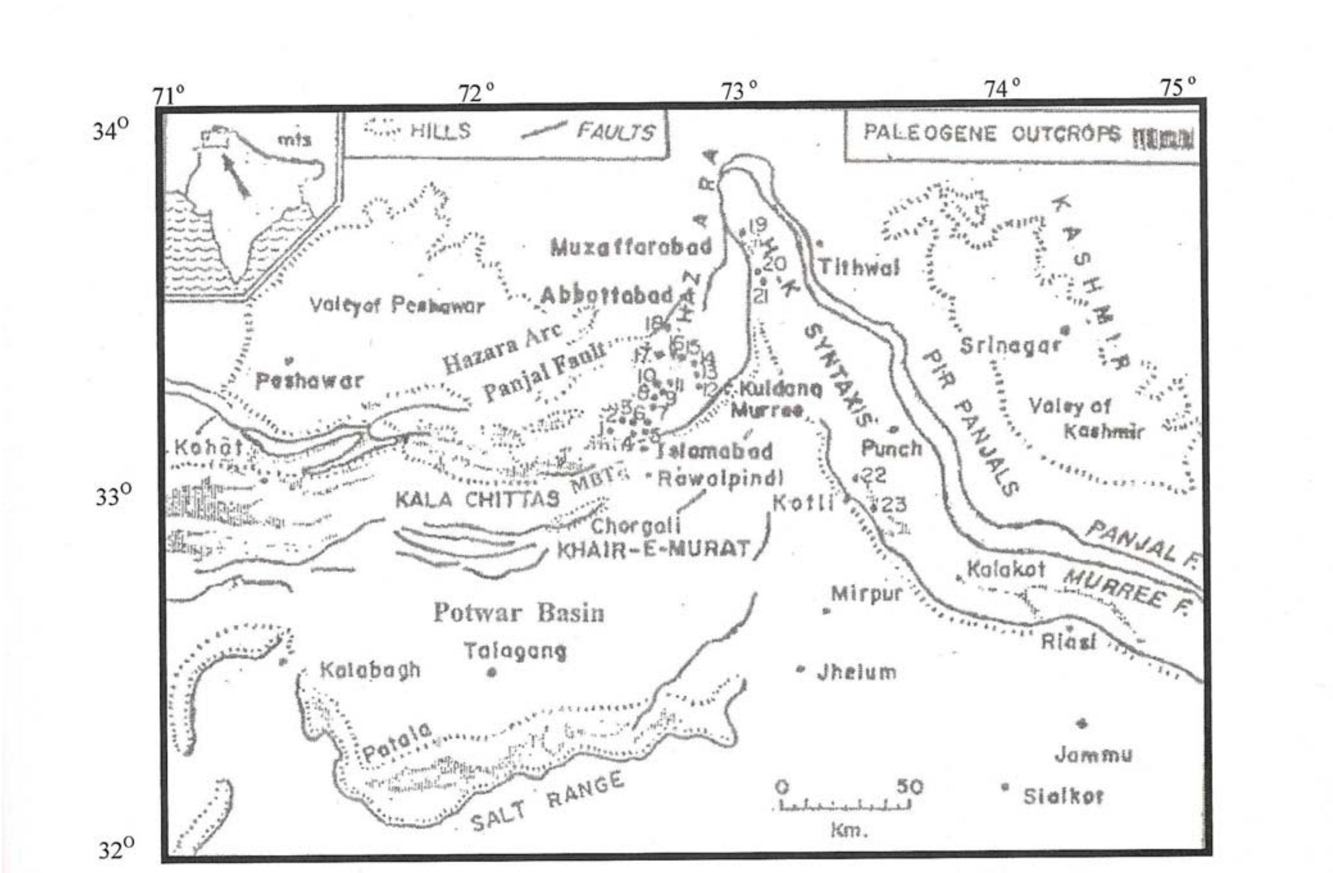

Fig. 1 Location map of Northwest Himalaya (Modified after Wells, N. A. and P.D. Gingerich, (1983).showing distribution of lithostratigraphic sections around the Hazara-Kashmir Syntaxis. Dananural (1), Lassan (2), Jabri (3), Sangjani (4), Sohaba (5), Mandibani (6), Chanali (7), Hothla (8), Jhan (9), Kalsan (10), Jhansa (11), Khaira Gali (12), Changla Gali (13), Chumbi (14), Kuza Gali (15), Kundla (16), Mochidhara (17), Kalas (18), Reechmari (19), Yadgar (20), Tandabotha (21), Tattapani (22) and Kamroti (23).

PLATE 1

Fig.1 Thin to medium bedded Upper Cretaceous Kawagarh Formation near Danna Nuranlan, Lora Maqsood Road, Hazara.

Fig.2 Overturned sequence showing the Paleocene Lockart Limestone at the base and the Upper Cretaceous Kawagarh Formation above intervened disconformably by oolitic haematite.

Fig.3 The contact between Cambrian Abbottabad Formation, Paleocene Hangu Formation and the Lockart Limestone at Yadgar, Muzaffarabad.

Fig.4 The Early Eocene Margala Hill Limestone, the Chor Gali Formation, and the Middle Eocene Kuldana Formation are exposed near Yadgar Neelum River, Muzaffarabad.

Fig.5 Thick bedded nodular Early Eocene Margala Hill Limestone near Kuza Gali, Hazara.

Fig.6 The variegated shales of the Middle Eocene Kuldana Formation (a) are in contact with the Early Eocene Chor Gali Formation (b) near Kamroti, Kotli.

PLATE 2

Fig.1 *Dicarinella carinata* (Brotzen), the Kawagarh Formation, Danna Nuranlan, Lora Maqsood Road (DN, 13) 80 X.

Fig.2 *Globoturncana linneiana* (d’ Orbigny), Sohaba, Hazara (SA, 12) 80 X.

Fig.3 *Dicarinella carinata* (Brotzen), Danna Nuranlan, Lora Maqsood Road (DN, 7) 80X.

Fig.4 *Globoturncana sp.* Kawagarh Formation, Sohaba Hazara (SA,16) 120 X.

Fig.5 *Heterohelix reussi* (Cushman), 120, Kawagarh Formation Sohaba Hazara (SA, 16)120 X.

Fig.6 *Heterohelix globulosa* (Ehrenburg), Kawagarh Formation, Danna Nuranlan, Lora Maqsood Road (DN, 7) 120 X.

PLATE 3

Fig.1 Vertical view of *Miscellanea miscella* (d’ Archiac & Haime), Lockart Limestone, Yadgar, Muzaffarabad (YR, 22) 40 X.

Fig.2 *Ranikothalia sindensis* (Davies), Lockart Limestone, Yadgar, Muzaffarabad. (YR, 22) 40 X.

Fig. 3 *Miscellanea miscella* (d’ Archiac & Haime), Lockart Limestone, Tandabotha, Muzaffarabad (TB, 12) 40 X.

Fig.4 *Orbitolites complanatus* Lockhart Limestone, Tandabotha Muzaffarabad (TB, 16) 40X.

Fig.5 *Dasycladacean* Packstone with *Spiroloculina* sp. in the center, the Lockhart Limestone, Yadgar Muzaffarabad (YR, 23) 40X.

Fig.6 *Miscellanea miscella* (d’ Archiac & Haime), Lockart Limestone, Khaira Gali, Hazara (KG, 29) 40 X.

PLATE 4

Fig.1 *Lockhartia diversa* (Smout), Lockhart Limestone, Tattapani, Kotli (TP, 8C) 40 X.

Fig.2 *Dictyoconus* (Davies), Lockhart Limestone Yadgar, Muzaffarabad (YR, 19) 40 X.

Fig.3 *Lockhartia conditi* (Nuttall), Lockhart Limestone, Yadgar, Muzaffarabad (YR, 23) 40 X.

Fig.4 *Ranikothalia sindensis* (Davies), Lockhart Limestone, Yadgar, Muzaffarabad (YR, 17) 40 X.

Fig.5 *Ranikothalia sindensis* (Davies), Lockhart Limestone, Yadgar, Muzaffarabad (YR, 15) 40 X.

Fig.6 *Ranikothalia sindensis* (Davies), Lockhart Limestone, Tandabotha, Muzaffarabad (TB, 9) 40 X.

Fig.7 Bioclastic packstone with laminated *pelecypod*, Margala Hill Limestone, Tattapani, Kotli, Azad Kashmir (TP, 18) 20 X.

PLATE 5

Fig.1 *Nummulites mamillatus* (Fichtel & Moll), Margala Hill Limestone, showing umbonal pillars and thick wall, Tattapani, Kotli (TP, 14) 20 X.

Fig.2 *Nummulites mamillatus* (Fichtel & Moll), Margala Hill Limestone, Kamroti, Kotli (KM, 18) 20 X.

Fig.3 *Nummulites atacicus* (Leymerie), Margala Hill Limestone, Kamroti, Kotli (KM, 16) 20 X.

Fig.4 *Nummulites atacicus* (Leymerie), Margala Hill Limestone, Kamroti, Kotli (KM, 16) 20 X.

Fig.5 Micropheric individual *Nummulites mamillatus* (Fichtel & Moll), Kuldana Formation, Yadgar/ Makra, Muzaffarabad (YR, 57) 20 X.

Fig.6 *Assilina granulose* (d' Archiac), Maragala Hill Limestone, Tattapani, Kotli, (TP, 12) 20 X.

PLATE 6

Fig.1 *Assilina subspinosa* Davies & Pinfold, Margala Hill Limestone, Tattapani, Kotli (TP, 14) 20 X.

Fig.2 *Assilina granulosa* (d' Archiac), Maragala Hill Limestone, Yadgar, Muzaffarabad Lockhart (YR, 12) 5 X.

Fig.3 *Assilina subspinosa* Davies & Pinfold, Chor Gali Formation, Yadgar area, Muzaffarabad (YR, 41).

Fig.4 *Assilina subspinosa* Davies & Pinfold, Margala Hill Limestone, Kamroti, Kotli (KM, 17) 10 X.

Fig.5 *Nummulites atacicus* (Leymerie), Margala Hill Limestone, Tattapani, Kotli (TP, 12) 10 X.

Fig.6 *Nummulites atacicus* (Leymerie), Chor Gali Formation, Kamroti, Kotli (KM, 16B) 10 X.

Fig.7 *Nummulites mamillatus* (Fichtel & Moll), Margala Hill Limestone, Kamroti, Kotli (KM, 16B) 10 X.

Fig.8 *Nummulites atacicus* (Leymerie) and *Alveolina* sp., Margala Hill Limestone, Kamroti, Kotli (KM, 25) 10 X.

Fig.9 *Assilina Laminosa* (Gill), Margala Hill Limestone, Tattapani, Kotli (TP, 12c) 5 X.

Fig.10 *Nummulites atacicus* (Leymerie), Margala Hill Limestone, Kamroti, Kotli (KM, 18)

PLATE 1

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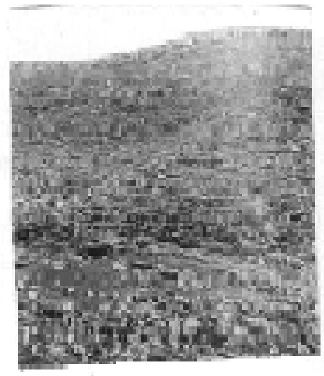

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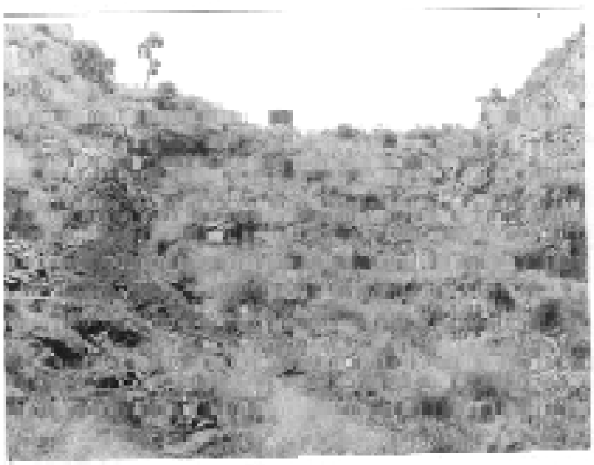

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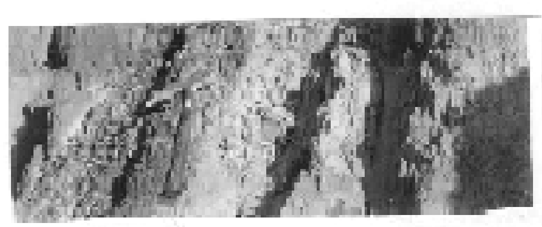

Fig. 6

PLATE 2

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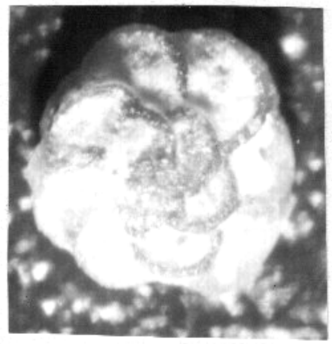

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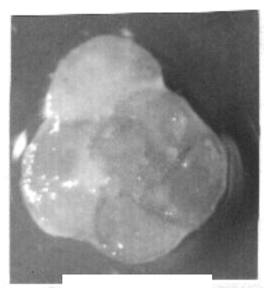

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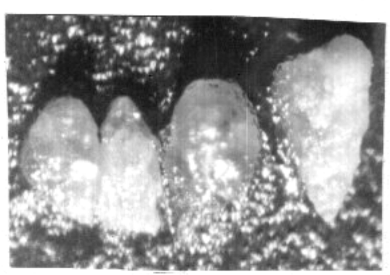

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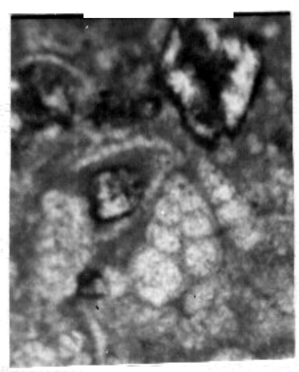

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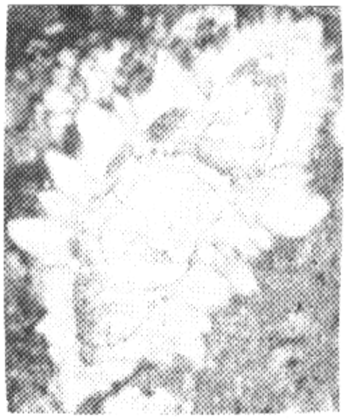

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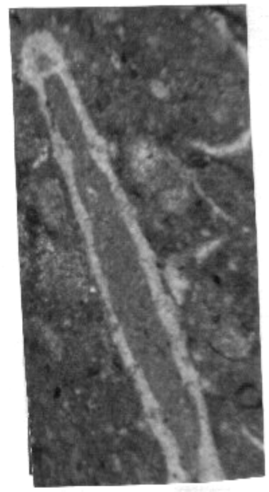

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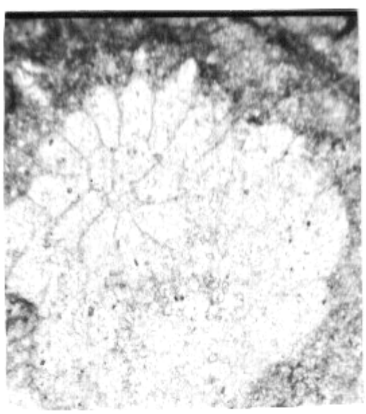

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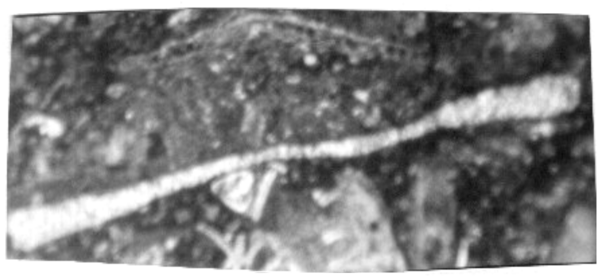

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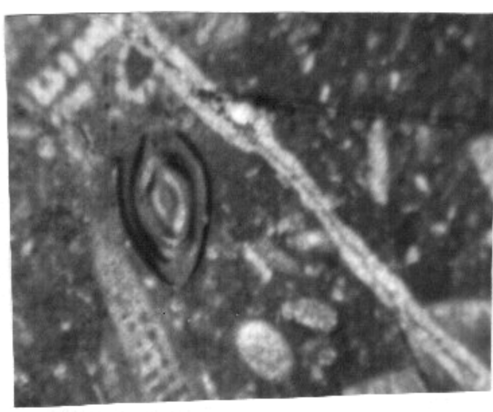

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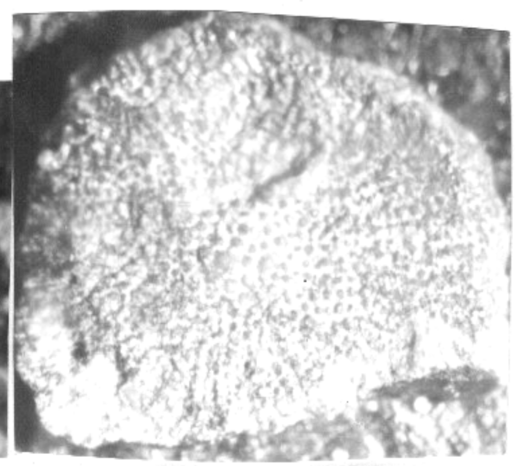

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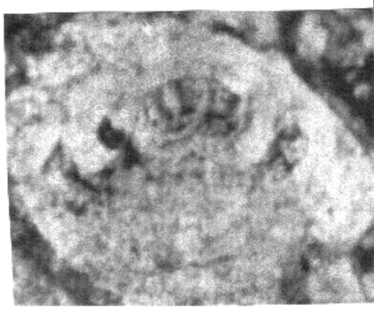

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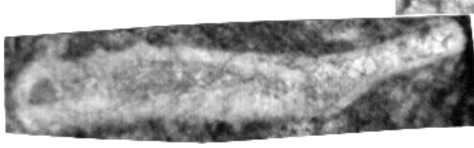

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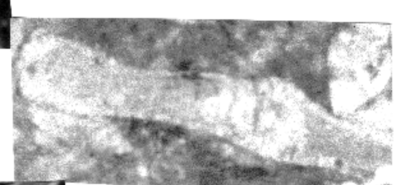

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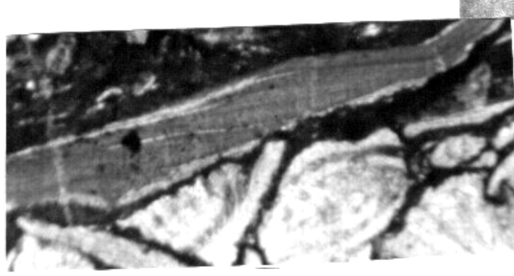

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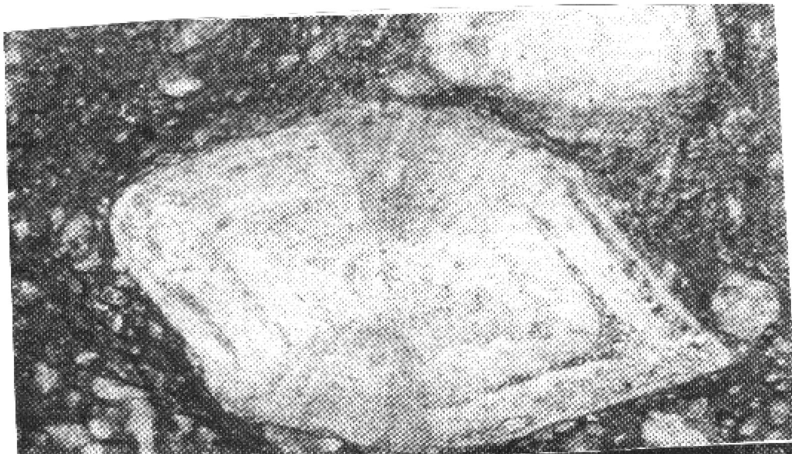

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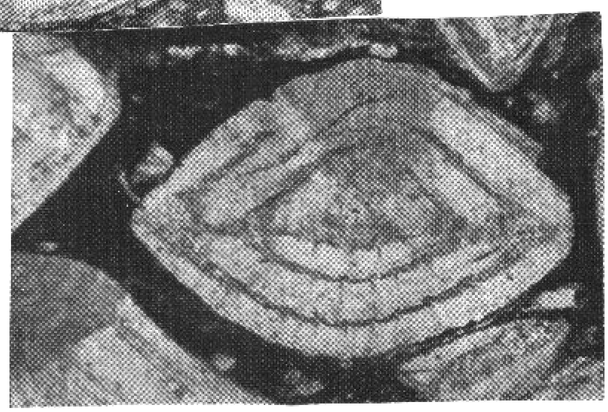

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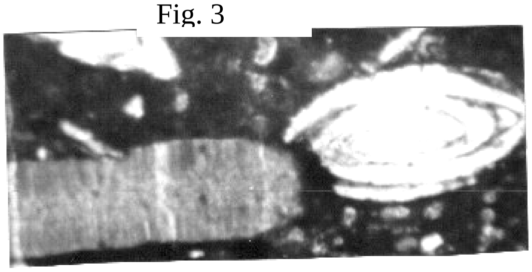

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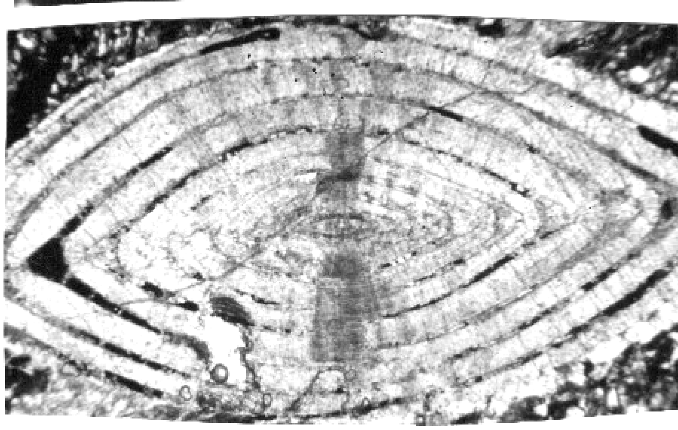

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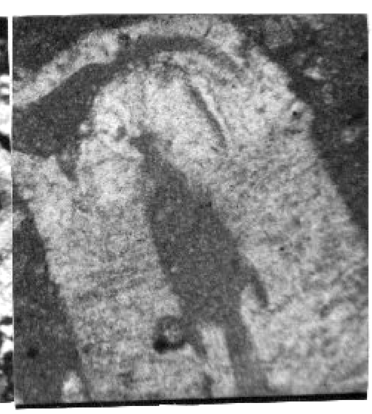

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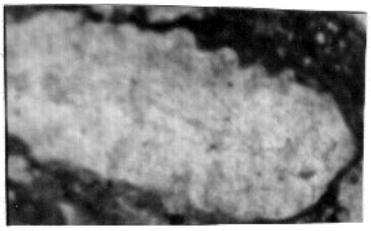

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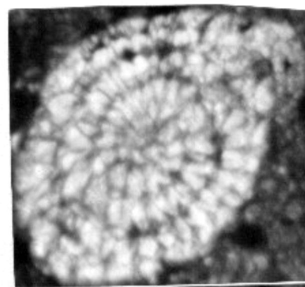

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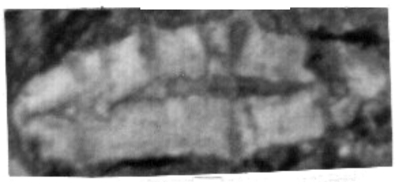

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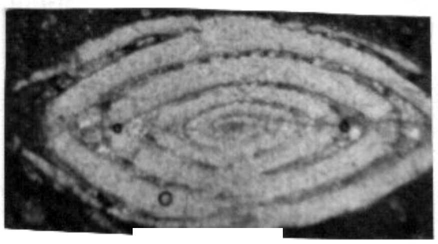

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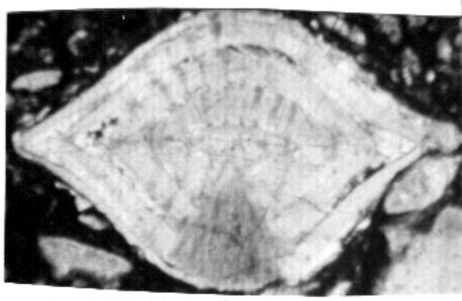

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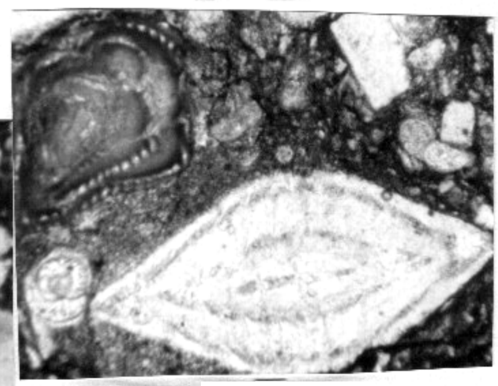

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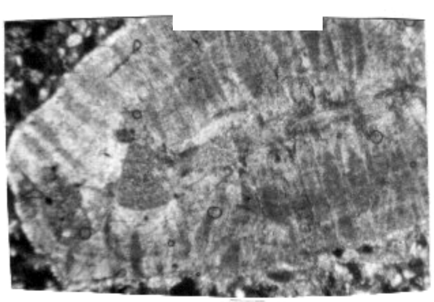

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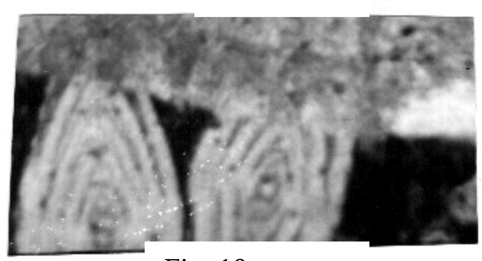

Fig. 10

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