

Faunal evidence for the withdrawal of the Tethys in the Lesser Himalaya, Northwestern India

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ABSTRACT — *The Subathu Formation of the Lesser Himalaya represents the last phase of the Tethys in northwestern India. The Subathu sediments show a progressive continentality in sedimentation from the basal beds to the topmost red bed sequence. This regressive phase is documented both on lithological criteria and facies variation as well as on palaeontological evidences. Faunal assemblages represented by vertebrates (fishes, turtles, crocodiles and mammals) and the invertebrates (foraminifera, ostracods, molluscs and bryozoans) record the shallowing of the remnant tethyan basin.*

RIASSUNTO — [Prove faunistiche del ritiro della Tetide dall'Himalaya Minore, India nord-occidentale] — *La Formazione di Subathu nell'Himalaya Minore rappresenta l'ultima fase della Tetide nell'India nord-occidentale. I sedimenti di Subathu mostrano un carattere progressivamente più continentale dalla parte basale alla successione sommitale di arenarie rosse. Questa fase regressiva è documentata sia dai caratteri litologici e dalle variazioni di facies, sia dalle prove paleontologiche. Le associazioni faunistiche di vertebrati (pesci, tartarughe, coccodrilli e mammiferi) e di invertebrati (foraminiferi, ostracodi, molluschi e briozoi) testimoniano l'assottigliarsi del bacino tetisiano residuo.*

INTRODUCTION

The generally accepted concepts of the geological evolution of the Tethys in the Indian Subcontinent envisage a long and nearly continuous sedimentation history from the uppermost Precambrian to the latest Cretaceous times, leading to a terminal phase marked by an ophiolite melange, exotic blocks and radiolarian cherts in the Indus Suture Zone (Pascoe, 1962; Jain *et al.*, 1978). Though this history may well mark the extinction of the main branch of the Tethys, other narrow marine seaways, parallel to the Himalayan axis existed in the Tertiary. The existence of one of these is corroborated by the occurrence of *Nummulites*-bearing beds in the Tsangpo Valley in Tibet (Hayden, 1907; An-tze *et al.*, 1973) and is beyond the purview of this paper. The other seaway was a narrow and fairly continuous feature confined to the Lesser Himalaya, south of the Great Himalayan Divide, spanning a period ranging from the Uppermost Palaeocene to the Middle Eocene. It is to this remnant branch of Tethys

and its epicontinental seaways across the Sind-Baluchistan flank in the west that attention will be paid to in the present paper. Taken in a broad sense, the gradual and progressive regression of marine deposits southwards, both in the Sind-Baluchistan and Burmese arcs in the Palaeogene and the Neogene, is in itself a record of the last phase of the remnant portion of the Indian Tethys.

The youngest marine deposits in the northwestern part of the subcontinent (Salt Range of Pakistan; Jammu and Kashmir and Himachal Pradesh in India) are of upper Lower Eocene or lower Middle Eocene age (Sahni, 1981). Thereafter, fluvio-deltaic sedimentation progressed continually southwards (Graham *et al.*, 1975.) This clastic influx is still continuing in the Indus Cone (Siebold, 1972) and the Bengal submarine fan (Curry and Moore, 1974).

The importance of the increasing continentality of Palaeogene Himalayan sediments in relation to geotectonic processes was generally recognized, but interpretation as to the causes of such episodes differed

depending on static, geosynclinal hypotheses and more recently on plate tectonic models. In the Nondrift framework, the extinction of the Tethys in the northern part of the subcontinent was related to upheavals in the Himalayan geosyncline leading to the early impulses for Himalayan uplift (Pande and Saxena, 1968). The reinterpretation of the palaeontological and sedimentological history of Early Palaeogene sediments in terms of plate tectonic models has led some workers (Keast 1972; Sahni and Kumar, 1974; West, 1980; Sahni, 1981) in recent years to a growing awareness that the dominantly fresh water molasse deposits in the northern Himalaya and the influx of Middle Eocene mammals of Central Asiatic affinity, indicate impingement of the Indian Plate on the Sino-Siberian (Tibetan) Plate. The sediments of the lesser Himalayan Tethys represented by the Subathu Group/Formation of Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh document the shallowing of the basin and the final withdrawal of the Tethys from the region.

LIMITS AND EXTENSIONS OF SUBATHUS

The Subathu sediments and their equivalents extend from Pakistan southeastwards through the Lesser Himalayan ranges to their limit at about 84°E longitude in Nepal (Bhandari and Aggarwal, 1967). In the Jammu region, exposures are limited to three inliers – Kalakot, Metka and Moghla – and to some discontinuous patches north of Jammu. In the Bilaspur-Simla Hill region, fairly thick sequences are found, thinning eastwards to Uttar Pradesh. The thickness varies from about 150 m in Kashmir, 1500-1800 m in Himachal Pradesh to about 170 m in Uttar Pradesh.

The Subathus rest on various rock types and suggest a marine transgression over predominantly Precambrian basement except in the Dogadda area of the Garhwal Lesser Himalaya where the Subathus overlies the Upper Tals (of probable Cretaceous-Palaeocene age, Ganesan, 1972; Bhatia, 1980). The Precambrian basement rocks include stromatolitic dolomitized limestone (Great Limestone of Jammu and Kashmir, Sharma and Krishnaswami, 1969; Gupta and Dixit, 1970, 1971; Raha, 1972; Singh and Vimal, 1972; Raha and Sastry, 1973), Tundapathar Limestone and Simla Slates of Himachal Pradesh.

The occurrence of Palaeogene transgressive tethyan sediments over a Precambrian basement led Singh (1981) to postulate the development of a rift valley-like zone termed Subathu-Dogadda Weak Zone which developed in the initial stages of the break up of Pangaea. Singh (1981) believes that the Subathu-Dogadda Zone of the Lesser Himalaya is similar to the Narbada-Sone Valley Weak Zone of Peninsular India.

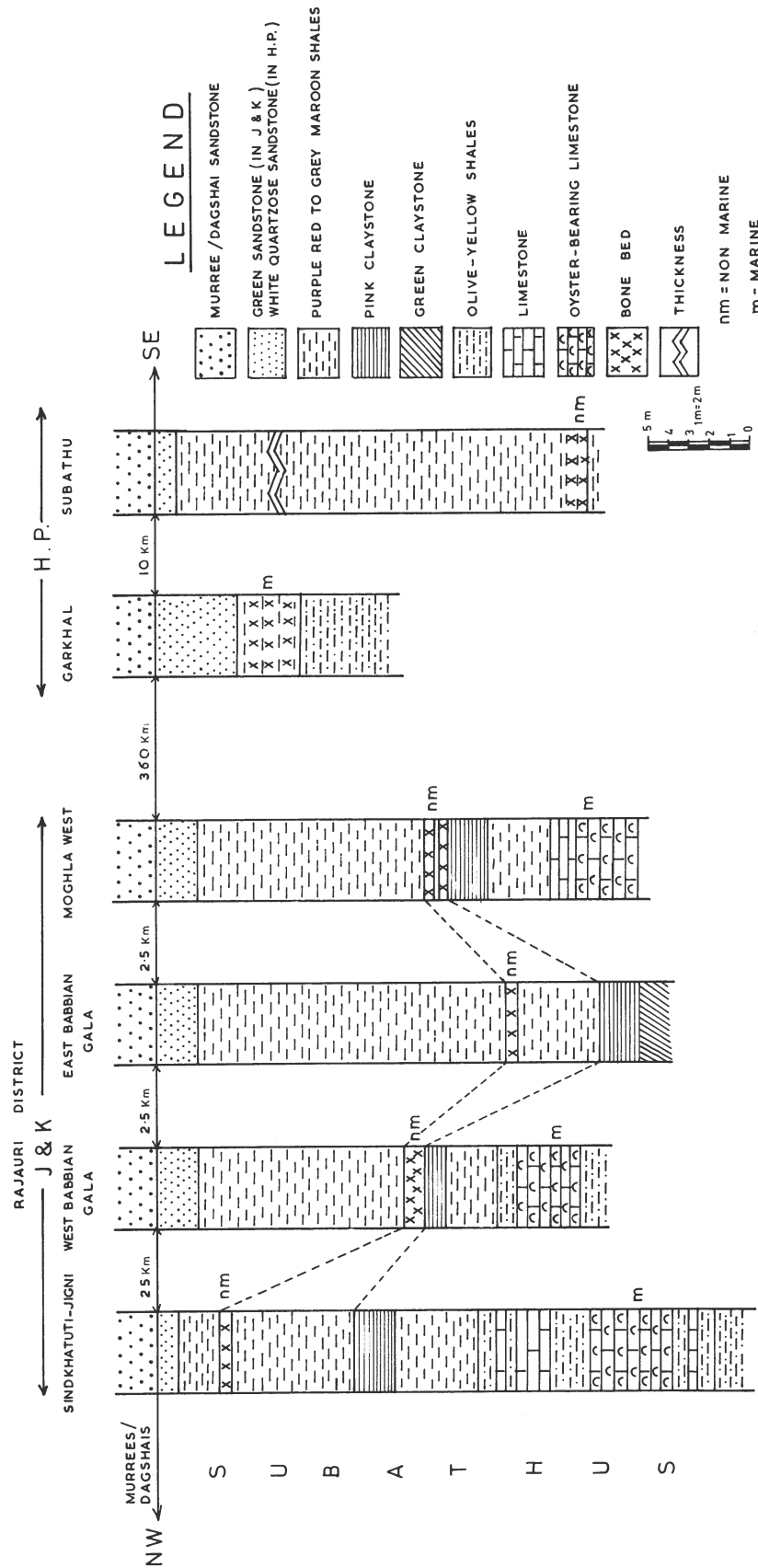
SEDIMENTOLOGICAL HISTORY AND FACIES INTERRELATIONSHIP

The Subathu sediments provide a record of basinal shallowing leading to the complete withdrawal of the sea. The Subathus are characterized by three main lithologies:

- (i) a basal black-grey shallow water unit.
- (ii) a middle dominantly green shale-thin bedded limestone unit.
- (iii) a topmost red bed facies.

BASAL SUBATHUS (Black-grey facies) — The basal Subathus are equivalent to Singh's (1980) Beragoa Formation in Rajauri and Rishikesh, Mathur's (1979) Zone I - III and Raiverman and Raman's (1971) Green facies. They are characterized by a black shale carbonaceous facies which, in the Jammu area, contains commercially exploitable coal deposits. These beds are traceable for over 260 km eastwards to the Type Section at Subathu, Himachal Pradesh. In the Type Area, the deposits are shallow water in nature and are intercalated with green sandstones containing fragmentary vegetal remains and vertebrates. The vertebrates include a large marine mammal *Isbatherium subathuensis*, probably related to the Sirenia. Associated are coquinooid oyster bands and shark and ray teeth. Of interest are the teeth of tetraodont fish *Stephanodus* and diodontid *Diodon*. The foraminiferal assemblage in the beds immediately below the vertebrate-bearing horizon contains an impersistent foraminiferal assemblage, but dominated by *Assilina dandotica* which, in Pakistan, is known only from the Palaeocene horizons. In India, however, Tewari (1961) has recorded it from the Lower Eocene, but the record cannot be confirmed as no description or illustration is given.

GREEN SHALE FACIES — The middle part of the Subathus is equivalent to Singh's (1980) Kalakot and Arnas Limestone formations in Jammu and Kashmir, Raiverman and Raman's (1971) Green Shale facies in Bilaspur, Himachal Pradesh and Mathur's (1978) Zones IV to VIII in the Type Area, Subathu. It consists of olive green and grey splintery and calcareous shales interbedded with thin dark grey coloured limestone bands. Towards the top of the Middle Subathus, occur massive limestone bands which are either unfossiliferous or highly fossiliferous oyster-bearing coquinities. Coquinities are indicative of brackish water conditions which gradually grade into fresh water conditions during the Upper Subathu times. The middle portion of the Subathus is fairly rich in invertebrate fossils. The representative groups are Gastropoda, Pelecypoda, Echinoidea, Ostracoda and Bryozoa.



Text-fig. 1 - Measured sections of the Subathu showing the transition from a near-shore environment (coquinoid oyster beds) to a red-bed non-marine Ossiferous horizon towards the top.

The vertebrates include dental elements of fishes and crocodiles, and some fragmentary chelonian and mammalian bones.

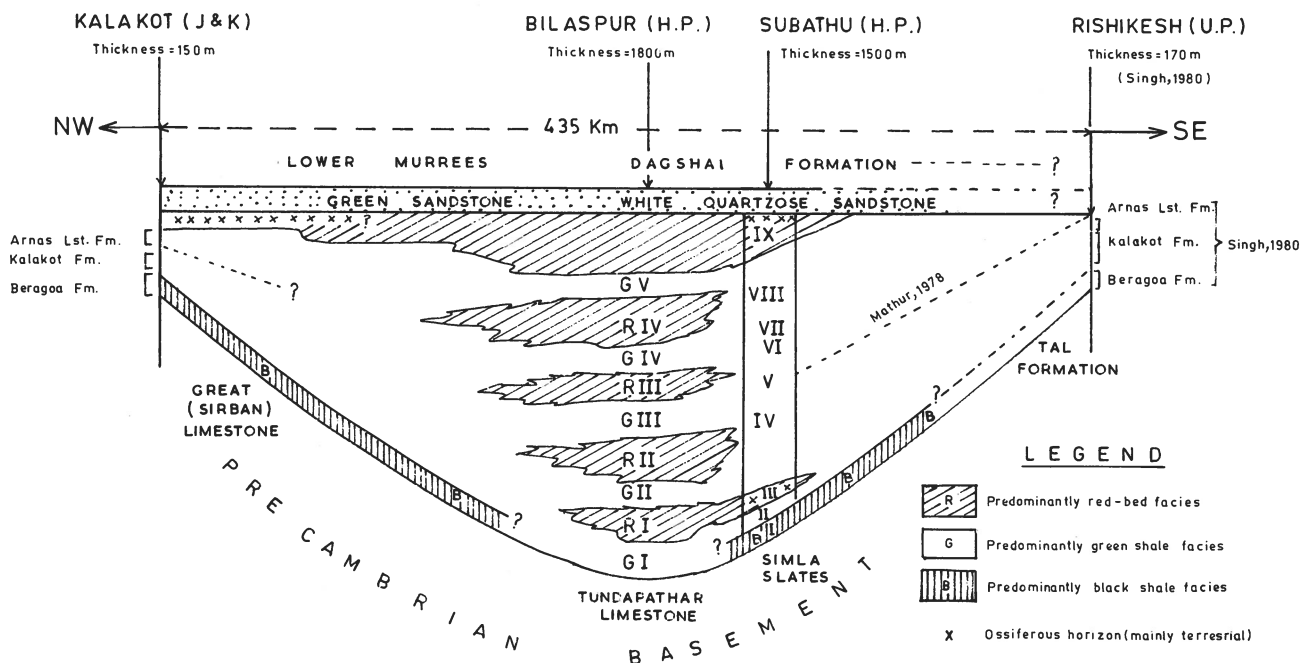
RED BED FACIES — The topmost Subathu are equivalent to Raiverman and Raman's (1971) Red facies, Mathur's (1978) Zone IX and Singh's (1980) Basal Murrees. They are characteristically red in colour and are overlain by a green or white orthoquartzitic sandstone which has been considered as the boundary between the Subathu and the overlying Murree or Dagshai formations of Oligocene age.

The topmost sequence shows both a faunal and sedimentological transition from marine conditions to brackish water and fluvial conditions (Text-fig. 1). Nummulitic limestones are overlain by extensive oyster deposits. These in turn are succeeded by variegated shales with fragmentary vertebrates and pulmonate gastropods (Bhatia and Mathur, 1965). Pisolitic vertebrate-bearing conglomerates underlie the pure quartzitic sandstone.

These vertebrate-bearing beds are of great significance as they occupy the same stratigraphic position in relationship to the marine succession below and the brackish-fluvial sequence above. The bone bed marker has been traced in Pakistan (Gingerich, 1977; Gingerich *et al.*, 1979; Gingerich *et al.*, 1979; Hussain *et al.*, 1978; West, 1980). In India, it is known from

Poonch area (Ranga Rao, 1980), Kalakot, Metka and Moghla inliers (Ranga Rao, 1971a, 1971b, 1972, 1973; Ranga Rao and Obergfell, 1973; Sahni and Khare, 1972, 1973; Sahni and Srivastava, 1976; Sahni and Srivastava, 1977; Sahni *et al.*, 1978; Sahni and Kumar, 1981; Kumar, 1982) and Himachal Pradesh (Sahni, 1979; Sahni *et al.*, 1981).

The bone bed with its dominantly terrestrial mammalian faunas (some archaeocetes are also known from Pakistan, Gingerich, 1977; West, 1980 and the Jammu and Kashmir area, Kumar and Sahni, in preparation) effectively marks the end of tethyan sedimentation in the Himalayan region of India. The Subathu sediments have undergone great structural deformation so that it is at times impossible to determine a good measured section for biostratigraphical purposes. This problem has created a serious controversy among geologists working on the Subathu and has led to two opposing and divergent opinions. Although the basal black shale facies can be recognized as a distinct unit at the cores of eroded anticlinal axis, the relationship between the green and red facies is uncertain. One school of thought (Datta *et al.*, 1965; Datta and Banerjee, 1972; Chaudhary and Pande, 1976; Mathur, 1978) considers the red and green facies as an alternating sequence, while the other feels that red and green facies are lateral facies variants (Raiverman and Raman, 1971; Raiverman, 1979).



Text-fig. 2 - Diagrammatic cross-section of Subathu sediments of the Lesser Himalaya showing facies relationship (not to scale). Correlation of various sections as follows: Kalakot (Singh, 1980; Sahni and Khare, 1973); Bilaspur (Raiverman and Raman, 1971); Subathu (Mathur, 1978) and Rishikesh (Mathur, 1978; Singh, 1980).

Text-figure 2 diagrammatically illustrates the facies relationship of the Subathu extending over a distance of approximately 435 Km. The figure illustrates the predominance of red beds in the Bilaspur region fairly low down in the Subathu succession. The Bilaspur red bed sequence probably represents deltaic conditions.

STRATIGRAPHIC POSITION OF THE TOPMOST SUBATHU OSSIFEROUS HORIZON

While the entire Subathu Formation of the Type Section has been found to yield fragmentary vertebrates in various lithologies (for further details see Sahni *et al.*, 1981; Bhatia, 1982) the main ossiferous horizons are in the black shale facies at the base (Uppermost Palaeocene - Lowermost Eocene) and in the topmost transitional red bed facies (Middle Eocene).

The stratigraphic position of the bone bed throughout the 450 Km stretch along which it has been traced, is essentially the same. The ossiferous horizon lies between the youngest oyster beds of the marine Subathu and a hard orthoquartzite of white or green colour (Text-fig. 1). The principal lithologies of the bone bed are (i) a maroon argillaceous sandstone as in the Kalakot area (Sahni and Khare, 1973). This has yielded the greatest number of large mammals and fishes. Rodents and crocodiles are rare in this horizon. (ii) red pisolitic conglomerate both in the Metka inlier (Jammu and Kashmir) and in the Type Section at Subathu. This bed has yielded mainly rodents and crocodiles and fishes.

The location of the bone bed with a diversified fauna only a few meters above the oyster bands indicates a fairly rapid alternation of shallow water marine and fresh water conditions along the entire length of the Lesser Himalayan Tethys. Oyster bands are good indicators of strandline conditions. Associated fossils include thalassinoid-type crab burrows, bioturbated deposits and local development of coquina limestones. These features indicate inter-tidal conditions (Singh, 1978).

The topmost Subathu bone bed marks the initiation of dominantly non-marine sedimentation which has persisted in the Lesser and sub-Himalayan regions during most of the Neogene and Quaternary times. Although, the southern flank of the Himalaya was tectonically much disturbed in subsequent orogenic impulses, a definite pattern can be observed in the distributional pattern of Palaeogene and Neogene clastic sediments derived from a northerly Central Himalayan source.

The topmost Subathu and later Palaeogene sequences (Lower Murrees, Dagshais) crop out in the higher reaches of the Lesser Himalaya, southwards and at succeeding lower elevation are located the lower,

middle and upper Neogene Siwalik subdivisions of the Sub-Himalayas. Subrecent and Recent alluvial fill occupies the Indo-gangetic plain.

NORTHERN TERTIARY STRANDLINES OF THE TETHYS AND ITS EPICONTINENTAL SEAWAYS IN THE NORTHWESTERN PART OF THE SUBCONTINENT

Strandlines for various successive epochs of the Tertiary have been demarcated on the basis of the northernmost occurrence of marine deposits (Text-fig. 3). The oldest and northernmost strandlines are those of the Sindhu Sea during the deposition of the Subathu (Sahni and Kumar, 1974). In contrast to the situation in India, in the Salt Range area of Pakistan, the sea underwent a greater number of oscillatory phases leading to the intercalation of fresh water and marine beds. By the Oligocene, the sea had regressed to about latitude 31°N. Pliocene and Pleistocene marine deposits are confined mainly to coastal areas.

FAUNAL AFFINITIES

VERTEBRATES

Mammals — Of the vertebrates, the affinities of the sharks, rays and crocodiles are cosmopolitan in nature. However, the mammal *Ishatherium* cannot be directly related to any known mammal (though it does bear some resemblance to large raoellids such as *Pilgri-mella*, *Lammidhanja* etc.). Additional collections comprising of two fragmentary teeth, a vertebra, the distal part of a left femur and the major portion of the pelvic girdle indicate sirenian affinities. The relationships of *Ishatherium* have been discussed elsewhere (Sahni and Kumar, 1980). The girdle element exhibits a cylindrical distally tapering ilium as in *Protosiren*, a massive acetabular cavity about 7 cm in diameter and a flattened pubis and ischium. The pelvic girdle elements indicate an amphibious mode of existence. Similarly in Kutch, sacral elements referred to *Moeritherium* may belong to archaeocetes. The early Palaeogene Tethyan mammals clearly indicate extremely primitive forms not previously known from other parts of the world. The distinctness of Tethyan Palaeogene mammals led McKenna to coin the term 'tethytherian' which has since been used by several workers including West (1980). The term is apt for describing primitive Tethyan mammal assemblages.

A separate family, the Raoellidae was proposed by Sahni *et al.* (1981) to accommodate several genera, endemic to the Indian Subcontinent. These genera are characterized by possessing fairly long snout, bunolophodont teeth, upper molars with weak protoconules and reduced posterolobe and sectorial premolars.

Representatives of the family Raoellidae (occupied niches of small artiodactyles) were previously classified in various families of the Artiodactyla. In only one instance (*Gobiobius* by West, 1980) was a generic assignment made related to a form known outside the Tethyan realm. The raoellids appear to be a homogeneous group of small to large size individuals indigenous to the Indian Tethys. The primitive nature of both the marine mammal orders in the Subcontinent suggests that the transition of terrestrial mammals to marine habitats took place in the Indo-Tethys region. The presence of these mammals is all the more surprising as the associated mammalian assemblage can be related to forms known in Central and East Asia.

The most significant group for establishing the affinities of the Indian Tethyan mammals are the perissodactyls represented by the tapiroids, rhinocerotoids and brontotheres. The tapiroids are generically identical or related to Mongolian forms (Sahni and Khare, 1973). The hyracodont rhinocerotoid *Forstercooperia jigniensis* from Kalakot, J&K is also similar to Mongolian, Chinese and North American forms. The Indian species has recently been removed from *Forstercooperia* by Lucas *et al.* (1981) on the basis of large and distinct parastyle on upper teeth, incomplete lingual cingulum on P₄, upper molars wider than long and lower molars with molariform P₄ and posteriorly convex hypolophids on the M₂ and M₃. Notwithstanding this, a close relationship exists with Palaeoartctic forms. Similar, is the case with the brontotheres. In India, only one fairly large genus, close to *Eotitanops*, is known (Kumar and Sahni, in preparation). The perissodactyls clearly represent the first wave of mammalian immigrants into the Indian subcontinent.

Another group with Central Asiatic affinities, are the ctenodactylid rodents of both India and Pakistan previously described under various familial names (Sahni and Khare, 1973; Sahni and Srivastava, 1976; Hartenberger, 1980). Rodents are one of the most common components of the Subathu throughout the Lesser Himalayan region. They have been reported from the Poonch District near the Pakistan border (Ranga Rao, 1980), in the Kalakot and Metka inliers, Rajuari District, J&K (Sahni and Khare, 1973; Sahni & Srivastava, 1976) and more recently in the Type Section of Subathu by a team of scientists from the University of Montpellier, University of Paris and the Centre of Advanced Study in Geology, Panjab University. Although the rodent fauna from the Type Section is admittedly meagre (eight complete teeth and some fragmentary ones), their relationships are clearly with those described from the more westerly localities of Jammu and Kashmir. A single specimen has been found associated in a shallow water marine sequence

associated with turritellids, *Venericardia* etc. and other benthonic invertebrates.

Although several mammalian orders have now been described from northwestern part of the subcontinent, mesonychid-archaeocete specimens constitute an interesting element. The work of Gingerich, (1977), Gingerich *et al.* (1979) and West (1980) has documented the diversity of the Pakistani archaeocetes in the Himalayan region. These archaeocetes are basically different to those from Kutch (Sahni and Mishra, 1972). In India, only the genus *Ichtyolestes* has been reported so far and this is associated with rodents and pristichampsine crocodiles in the Metka locality (Sahni *et al.*, 1978). Other mammals include an omomyid primate (Russell and Gingerich, 1980) and indeterminate insectivore taxa. Crocodiles in the red bed sequences of Lesser Himalaya are dominantly pristichampsine (Sahni *et al.*, 1978). They are found closely associated with the rodents in Jammu and Kashmir as well as in Himachal Pradesh. In the black shale facies of Lower Subathu, crocodilian teeth are non-serrated while in the topmost intercalated red and green facies, the crocodiles have serrated teeth. Pristichampsine crocodiles are believed to have spread from the Mongolian-Chinese area and were probably active predators.

The affinities of the fishes are also of interest. Some forms (the tetraodont *Stephanodus*, osteoglossid *Musperia*, *Dasyatis*, and *Eotorpedo*) can be directly related to Uppermost Cretaceous-Palaeocene fish faunas of Central peninsular India (Jain and Sahni, 1982). The affinities of the sharks are in general cosmopolitan and lie with the Medito-Tethyan region and its epicontinental spread in Nigeria. Genera include *Caracharodon*, *Hemipristis*, *Galeorhinus*, *Galeocerdo*, *Paragaleus*, *Alopias*, *Oxyrhina* etc. A notidanid genus, probably new, is a common element.

Pycnodont fishes are associated with the sharks, rays and teleosts in the basal black shale facies. Pycnodonts decrease progressively upwards in the red bed sequence where *Chrysophrys* - like teeth belonging to the Labrodontidae become exceedingly common (Singh, 1982). The main fish assemblage of the red bed sequence at J&K was described by Khare (1976). The fish elements include members of the families, Polycanthidae, Nandidae, Ariidae and Ophiocephalidae.

INVERTEBRATES

Foraminifera — As is well known, the earliest Tertiary marine transgression in the Himalaya took place in the Upper Palaeocene times. The larger foraminifera of Palaeocene age were first recorded by Datta and Banerjee (1966) from Nahan-Dadahu areas.

The fauna comprised *Lokhartia haimei*, *L. tipperi*, *Dictyoconoides flemingi* and *Dictyokathina dadabuen-sis*. Rocks of Palaeocene age in the Gambhar River Section were formally designated as the Kakra Series by Srikantia and Bhargava (1967). These have yielded *Lokhartia conditi*, *Ranikothalia* sp. (a Palaeocene genus), *Rotalia trochidiformis*, *Operculina* sp. and some rotalids. Rocks of this age in the Jammu area and in the Rishikesh area have been called as Beragoa Formation by Singh (1973, 1980a, 1980b). In the Simla Hills, Mathur (1978) recorded an Upper Palaeocene succession comprising Laterite and carbonaceous shales in the lower part and containing *Lokhartia conditi* which occurs in the Palaeocene of Qatar and Palaeocene and Lower Eocene of Pakistan.

More recently, Ahuja (1980) has recorded a typical Palaeocene assemblage from Paroi, near Halog, Simla Hills. The assemblage comprises *Subbotina triloculinoidea*, *Rotalia hensoni*, *Lokhartia conditi*, *Daviesina danieli* and two other indeterminate species belonging to this genus. *D. danieli* and *R. hensoni* are diagnostic species of the Palaeocene of Qatar.

The major thickness of the Subathus, which is of Ypresian age, has yielded characteristic Lower Eocene assemblage (Singh, 1970a, 1970b, 1973, 1980a; Mathur, 1977) comprising *Nummulites atacicus*, *N. mamilla*, *Assilina granulosa*, *A. granulosa* var. *chhumbiensis*, *A. daviesi* and *A. laminosa*. There are a few long ranging taxa like *Assilina mamillata* which is known to range from Ypresian to Lutetian and *A. spira* which is restricted to Middle and Upper Eocene of Europe, Pakistan, Assam and Simla Hills. Beds containing these two taxa along with beds containing fresh water molluscs, oysters and vertebrate remains have been designated as zones VI to IX by Mathur (1978) and assigned a Middle Eocene (Lutetian) age.

Ostracoda — The ostracod fauna of the Subathu Formation in India and equivalent formations in Pakistan are inadequately known. The main works being those of Latham (1938), Sohn (1959) and Siddiqui (1971) from Pakistan and by Tewari and Singh (1967), Mathur (1971) and Singh (1982) from India. In so far as the distribution of marine ostracoda of the Tethys are concerned, it is interesting to note (McKenzie, 1967) that the Tethys has played a significant role in the distribution of marine ostracod faunules in the Caribbean, Mediterranean, Indo-Pacific and Australian provinces by allowing a relatively rapid dispersion of genera during the Palaeogene. The tethyan corridor which helped in this dispersion gradually disrupted and from Neogene onwards the ostracod faunules became more provincialized.

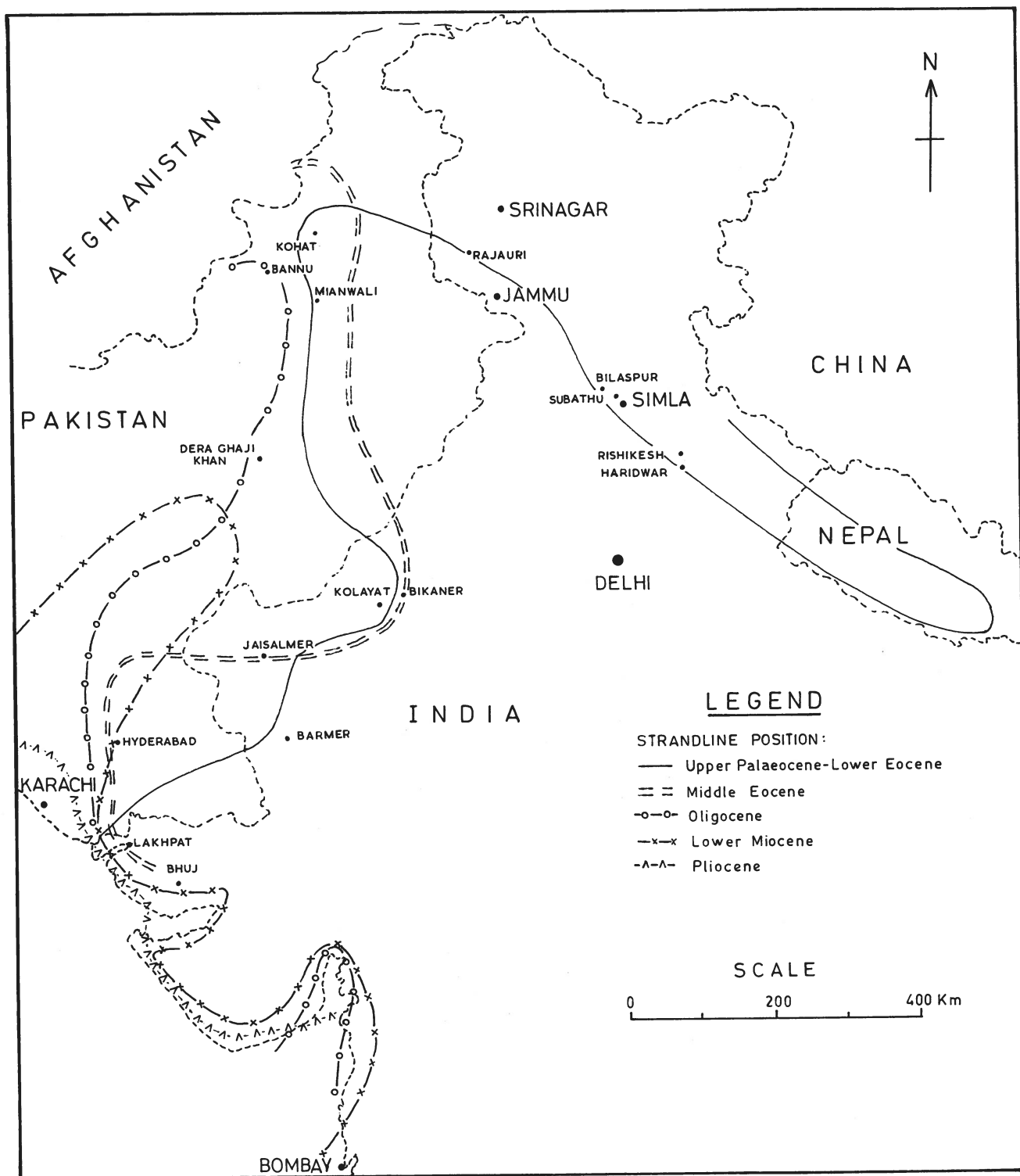
As regards the ostracod fauna of the Subathu Formation the bad preservation has so far precluded a

detailed and more systematic study based on modern taxonomy. However, works cited above show that the fauna is dominated by several species of *Krithe* (now transferred to the genus *Dentokrithe*), *Paracypris*, *Neocyprideis*, *Leguminocythereis*, *Semicytherura*, *Xestoleberis*, *Cytherella* and *Alocopocythere*. At the generic level, most of these taxa have world-wide distribution, but at the specific level, many are endemic to the Indian Subcontinent. The genus *Alocopocythere* Siddiqui, which was first described from the Lower Eocene of Pakistan (Siddiqui, 1971) and represented there by several species, is now widely recorded from the Tertiary strata of Burma (several species) and Neogene and Pleistocene of Ethiopia (Gramman, 1975) and also from the Lower Miocene of Kutch in Western India where it is represented by *A. fossularis* (Lubimova and Guha). Singh (1982) has recorded *A. abstracta* Siddiqui from the Subathu Formation. Bhatia (Ms) has shown that the genus has had a long geological history and had its origin in the tethyan corridor where it attained wide distribution and rapid evolution in the Palaeogene times. Several ostracod taxa which occur in the Subathu Formation and also in the Eocene beds of Rajasthan (Khosla, 1972) have been recorded from the marine Palaeogene of Garo Hills, Meghalaya (Mathur *et al.*, 1977).

Mollusca — Perhaps the most comprehensive work to date on the molluscan fauna of the Subathu Formation is the one by Mathur (1975) who records 52 taxa. The fauna, which has undoubted affinity with the Ypresian and Lutetian faunas of the tethyan range, contains several taxa which appear to be endemic to the Indian Subcontinent. These include *Tellina pakistanica*, *Trachycardium halaense*, *Venericardia (Glyptoactis) sindensis*, *Pinna punjabiensis*, *Anomia pakistanica*, *Turritella soriensis*, *T. rakhiensis*, *Discors simlaensis*, *Pelecypora (Cordiopsis) subathooensis*, *Venus subgumberensis* and *Aplexa kohatica* among others. More recently, Singh (1982) has recorded an interesting assemblage of diminutive mollusca like *Roxania* sp., *Spiratella* cf. *S. pseudopygmaea* and *Planorbis* cf. *P. alienatus*, from the subathus of Bilaspur region. All these taxa were hitherto known only from the Lower Eocene of Pakistan.

SUMMARY

The closure of the Tethys in the Lesser Himalayan region has been documented by the fossil record of a number of invertebrate and vertebrate fossil groups. Among these, the mammals, the fishes, ostracods, foraminifers and molluscs are the most important. Although, the Subathus are tectonically disturbed throughout their wide lateral extent, it has been pos-



Text-fig. 3 - Tethys strandline positions during Palaeogene and Neogene.

sible to work out major facies relationships. The extensive red beds at Bilaspur, H.P. yielding fresh water to estuarine forms and intercalated with marine shales and limestones indicate the position of a proto-delta. Successive strandline positions through the Palaeogene-Neogene document a southwestward withdrawal of the Tethys.

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