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MICROFAUNAL REMAINS FROM THE UPPER DHARMSALA FORMATION, DHARMSALA, KANGRA VALLEY, H.P.

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ABSTRACT

Microbiota comprising fish remains, ostracods and charophytes has been recovered along with fragmentary mammalian and reptilian remains from the Upper Dharmsala Formation. The fossil-bearing horizon is exposed in a high gradient stream below Traffic Check Post (TCP) on Dharmsala - Mcleod Ganj road. The fossiliferous horizon is a 1.5 m thick bright grey mudstone unit which is approximately in the middle part of the Upper Dharmsala Formation. The assemblage, barring charophytes, is described along with palaeohistological aspect of vertebrate fossil tissues. Cyprinid fishes in the assemblage being terrestrial type indicate fresh water depositional environment for the sediments. Fluvial depositional environment, characterised by low energy conditions, prevailed during the deposition of the Upper Dharmsala sediments as is evident from the occurrence of fragile faunal elements along with other field evidences.

INTRODUCTION

Tertiary stratigraphy of Himachal Pradesh, particularly of Kangra Valley with Subathu, Dharmsala and Siwalik horizons, is broadly established. However in Kangra Valley it requires details concerning lower and upper contacts and fauna of Dharmsala beds. Paucity of palaeontological data from Dharmsala sediments in the backdrop of well documented faunas from Subathu and Siwalik is a major handicap in understanding the precise account of the Tertiary geology of the region. ONGC workers looking for hydrocarbon reserves have contributed significantly towards the sedimentological and palynological aspects of the Dharmsala sediments (Raiverman, 1986; Mathur, 1984).

Lack of unanimity regarding stratigraphy of the pre-Siwalik non-marine Tertiary sediments of northwestern Himalaya as has been discussed by Chaudhari (1986) is continuing till today. These horizons named as Murree (Pakistan; Jammu, India), Dharmsala (Kangra Valley, HP) and Dagshai/Kasauli (Simla Hills, HP) are presumably homotaxial ones because tectonically active basins to the south of the Central Himalaya are devoid of identifiable isochronous horizons. Additionally, rather continuous recycling of the sediments in the Subathu-Dharmsala-Siwalik basin and subsequent intensification of tectonics, faithfully recorded in the basinal sediments, further complicated the stratigraphy. All these complexities are manifested in the widely differing views of ONGC and GSI workers (Raiverman, 1986; Datta, 1970; Ranga Rao, 1986, Raina *et al.* 987; Shanker *et al.* 1989).

Obviously, faunal succession will be of immense help in ascertaining stratigraphy for pre-Siwalik non-marine Tertiary horizons of northwestern Himalaya inculcating resolution enough to know the geological history of the region during that period. Amongst the three pre-Siwalik non-marine Indian Tertiary horizons, named above, attention was focussed on Dharmsala Group for vertebrate palaeontological investigations through WIHG Project No. BS -1A by the end of 1987 taking lead from a brief report (Verma and Verma, 1979) and from an unpublished dissertation (Kumar, 1985).

The present paper is a preliminary account of the palaeobiological investigations in the Upper Dharmsala sediments (Oligocene-Lower Miocene) recording the occurrence of typical freshwater

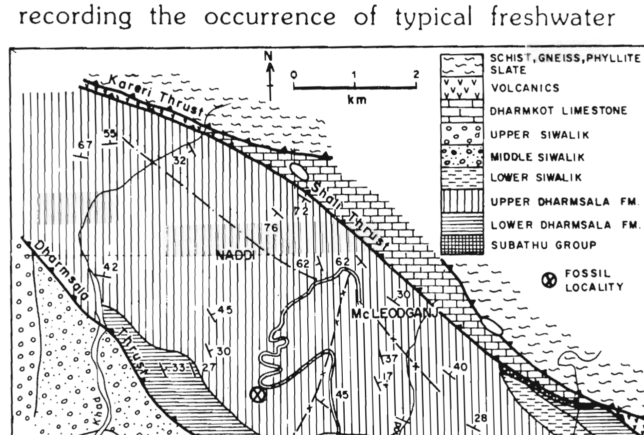

Fig. 1. Geological Map of the area showing fossil locality.

cyprinid fishes along with ostracods and charophytes. All the specimens are from a locality in a high gradient stream below Traffic Check Post ($32^{0}13'52''$: 76^{0} $18'28''$), henceforth TCP, around 5 km from Dharmsala towards Mcleod Ganj on State Road No. 23 (Fig.1). Approximately, the assemblage-yielding horizon falls in the middle part of the Upper Dharmsala Formation and is a bright grey mudstone unit measuring 150 cm. (Fig.2).

All the material for this study was collected, during two field seasons in 1987-88 and 1988-89 and was processed in the Vertebrate Palaeontology Laboratory of the Institute. However a few test-samples were processed and scanned under microscope in the Geology Department of P.G. College, Dharmsala. Bulk samples from the fossil bearing mudstone unit were macerated by boiling with Quart-O repeatedly. Most of the specimens were picked under microscope from residue in 25 and 40 no. ASTME sieves. The specimens described here are catalogued with the Wadia Institute of Himalayan Geology repository and bear WIMF/A numbers.

GEOLOGICAL BACKGROUND

The rock formations at Dharmsala are in strike continuity of those found in Simla region and show tectonic and structural complexity. Lahiri (in Heron, 1939), while mapping parts of Kangra Valley, named the pre-Siwalik mica-devoid, fine to medium grained sandstone and intercalated mudstone sequence in the valley as "Dharmsala beds". Talukdar *et al.* (1959), while concentrating in Dharmsala-Mandi region for ONGC, subdivided Dharmsala horizons on the basis of lithology into two — Lower Dharmsala and Upper Dharmsala.

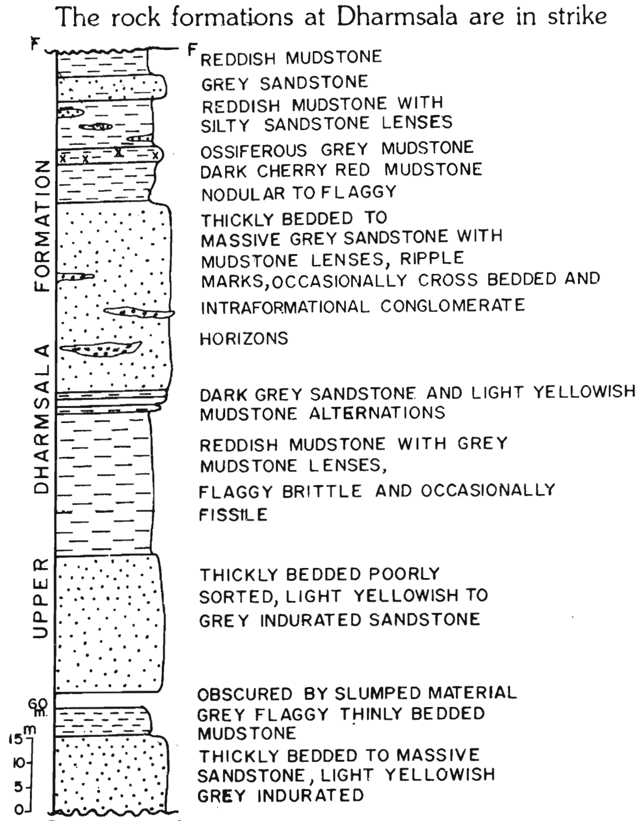

Fig. 2. Distribution of lithounits at the fossil-locality.

Palaeobiological records exclusively from Dharmsala beds are confined to a few published references (Verma and Verma. 1979; Dogra *et al.*, 1985; Jolly *et al.*, 1986).

GEOLOGY AND TECTONICS OF THE AREA

Lithologically distinguishable Lower and Upper Dharmsala are more than 3500 m thick with increasing thickness towards north, i.e. towards their provenance. In Dharmsala area, Upper Dharmsala exposures predominate over the Lower Dharmsala Formation (Fig.1). Dharmsala Group sediments consist of medium to fine-grained, dirty, buff and greenish non-micaceous sandstones interbedded with dark grey, khaki and reddish mudstone units. Silt dominated mudstone units are micaceous. Dharmsala syncline having northwest-southeast trend (Fig. 1) manifests the north-south compressive forces operative during the most vigorous second phase of Himalayan Orogeny culminating in the Middle Miocene (Raina *et al.* 1987). Shali Thrust towards north and Dharmsala Thrust towards south delimit Dharmsala sediments in the area. Gaj Khad and other streams in the area run across the synclinal axis. Lower Dharmsala horizons are exposed in the southern limb of the syncline. Road side sections on SR No. 23 joining Dharmsala and Mcleod Ganj reveal the distribution and variety of lithounits of the Upper Dharmsala Formation exhibiting current ripples and large scale cross bedding at a few places. Following is the geological settings in the area close to Dharmsala town:

Dharmkot Formation	North
– – – – – –Shali Thrust– – – – – –	
Upper Dharmsala Formation	
Lower Dharmsala Formation	
– – –Dharmsala Thrust/MBF– – –	
Middle Siwalik Subgroup	
– – – – – – – – – – – – – – – – – –	
Moraines and Alluvium	South

Closer examination of the section at the locality (Fig. 2) revealed the presence of abundant dark grey mud clasts at the base of a medium grained sandstone unit, minute horizontal branching burrows and a few vertical escape burrows filled with sand grade sediments in claystone units. The uppermost Upper Dharmsala sediments exposed in the vicinity of Naddi village belong to red facies in contrast to the older Upper Dharmsala sediments which are predominantly grey coloured. Dip amounts vary from 30^0 to 50^0 in northeasterly direction in southern limb. However, in the northern limb of the syncline near Shali Thrust more steeper dips as high as 76^0 have been noticed.

SYSTEMATIC PALAEONTOLOGY

All the faunal material described herein is from dark grey mudstone horizon of the Dharmsala Formation exposed in TCP locality (Fig. 1). Description of charophyte gyrogonites is presently deferred for want of their identification.

A. MICROVERTEBRATES

Class Osteichthyes
Infraclass Teleostei
Order Cypriniformes
Family Cyprinidae

Pharyngeal tooth morphology may constitute a distinquishing character (Annandale and Hora, 1925) but solely it is insufficient to lead us to the generic level identification. Scales have certainly that much of potential but they have been tentatively referred here to Cyprinidae because of small sample size and incomplete scales, occurring with following five varieties of cyprinid pharyngeal teeth informally designated as Type A to E.

Cyprinid Pharyngeal Teeth Type A
(Plate I — 1-6)

Material : WIMF/A 601 to 605, five catalogued isolated pharyngeal teeth; more than 20 unnumbered specimens in the collection.

Description : Occlusal outline varies from subrounded rectangular to triangular with a plane to curved surface. Margin is mostly striated or crenulated and in a few specimens slightly elevated above the worn out dentine on the occlusal surface. Lateral view is characteristically trapezoidal. Generally roots are broken; when intact, roots are hollow and filled with matrix.

	Length	Width	Height in mm.
WIMF/A 601	.62	.28	.3
WIMF/A 602	.56	.3	.26
WIMF/A 603	.64	.28	.32
WIMF/A 604	.6	.3	.42
WIMF/A 605	.66	.26	.45

Cyprinind Pharyngeal Teeth Type B
(Plate I — 7-8)

Material : WIMF/A 612 and 613, two catalogued isolated pharyngeal teeth; 3 more specimens in the collection.

Description : Characteristically the occlusal plane is strongly oblique with enameloid folding seen in lateral view. Occlusal surface is bordered by slightly elevated enameloid envelope covering the lateral sides of the teeth. Roots broken and/or filled with matrix.

	Length	Width	Height in mm.
WIMF/A 612	. 64	.22	.7
WIMF/A 613	.7	.4	1.26

Cyprinid Pharyngeal Teeth Type C
(Plate I — 9-13)

Material : WIMF/A 614 to 620, seven catalogued isolated pharyngeal teeth; more than 50 unnumbered specimens in the collection.

Description : These are mostly unworn teeth with hook-shaped and pointed projections varying in number from 7 to 3. Projections are characteristically enveloped in thick enameloid covering, thickest being on the top. Barring the main single hook-shaped projection, remaining projections are in pairs equally spaced on sloping crown surface. Roots hollow, filled with matrix and are mostly broken. Overall appearance of the tooth is cylindrical with lateral compression noticed in some specimens.

Remarks : Sahni *et al.* (1984) reported type C teeth from the homotaxial Kuksho Formation of the Indus Group, Ladakh. A Ladakh specimen (LDA 2) is, however, 10-15 times bigger than the type C specimens of the Upper Dharmsala Formation. Five representative specimens are illustrated (Plate I — 9-13) showing variations in type C teeth.

	Length	Width	Height in mm.
WIMF/A 614	.42	.2	1.44
WIMF/A 615	.9	.6	1.72
WIMF/A 616	.74	.42	1.72
WIMF/A 617	.34	.3	.7
WIMF/A 618	.8	.3	1.34
WIMF/A 619	.32	.3	.9
WIMF/A 620	.64	.38	.8

Cyprinid Pharyngeal Teeth Type D
(Plate I — 14-18)

Material : WIMF/A 606 to 611, six catalogued isolated teeth with more than hundred in collection.

Description : Occlusal surface if oval with a medial ridge-like feature without any relief in most of the specimens. Lateral view is deep, saucer shaped with root at the base. Roots are generally not present.

	Length	Width	Height in mm.
WIMF/A 606	.82	.32	.74
WIMF/A 607	.76	.32	.72
WIMF/A 608	.72	.44	1.04
WIMF/A 609	1.2	.54	.74
WIMF/A 610	.48	.22	.8
WIMF/A 611	.88	.42	.62

Cyprinid Pharyngeal Teeth Type E
(Plate I — 19-20)

Material : WIMF/A 621 to 623, three catalogued specimen with 5 more in collection.

Description : Fan-shaped concavo-convex teeth with circular outline. Margin regular and slender with a notch very close to root. Concentric growth lines are seen in a few specimens. Convex side of the tooth bears the root attachment scar.

	Length	Height in mm.
WIMF/A 621	.82	.72
WIMF/A 622	.7	.64
WIMF/A 623	.7	.5

Other types of fish teeth (Plate I — 21,22) are also there in the assemblage but are poorly represented.

Scanning electron microscopy of fractured surfaces on the cyprinid teeth reveals interesting palaeohistological characters of fish dentine (Plate I — 23, 24). Dentinal tubules are sparsely distributed at enamel/dentine junction (EDJ) – a character akin to mammalian dentines. Further, bifurcating nature of the fish dentinal tubules is evident from the tubuli-pairs seen at EDJ which happens to be a characteristic feature of reptilian dentine (Tiwari, 1982). Diameter of the tubules is approximately 1.5 micrometer.

Fish Scales and Vertebrae: Fish scales and vertebrae, found associated with cyprinid pharyngeal teeth, are mostly incomplete and very few in our collection. A few scales (Plate II—1-5) described below certainly merit attention as they add to our knowledge regarding Upper Dharmsala fish species. WIMF/A 652 is longer than broad: circuli closely packed in partially preserved apical region; basal region has circuli exhibiting dicassating character: nucleus not preserved. Another fish scale (WIMF/A 653) is broader than long with basal region having closely packed circuli, nucleus present, basal radii not present. Its apical region has sparse circuli which are more or less straight. A few incomplete scales bear tubercles in apical region (Plate II — 4,5).

Numerous microscopic, amphicoelous vertebrae and other appendicular remains have also been recovered (Plate II — 6-9). Amphicoelous vertebrae are mostly found isolated excepting a few specimens where two vertebrae are fused (Plate II — 6,7). A few appendicular skeletal elements from the same horizon are tentatively being referred to fishes. A few of them have one articulating end (Plate II — 9).

Class Reptilia
Order Crocodilia
Genus *Crocodylus*

(Plate II — 10-13)

Material : WIMF/A 655 and 656, two isolated teeth.

Description : Small-sized crocodilian teeth have fluting and antero-posterior ridges. LS of the crocodilian dentine is devoid of concentric growth rings which can be explained as an indicative of even climatic conditions throughout the year. LS of crocodilian dentine from younger Siwalik horizons exhibit growth rings marking the climatic variations during that period (Tiwari, 1982).

Class Mammalia

Mammalian Bones : Transverse sections of a few Upper Dharmsala bone fragments exhibit typical mammalian bone characteristics i.e. osteons, lacunae, etc. similar to the ones described from younger and older horizons. In Dharmsala mammalian bones, harvesian canals are wide open and filled with crystallized carbonate material. Secondary harvesian units are also seen in the sections (Plate II — 14,16). A few sections exhibit close packing of osteons. Wide canals noticed in Dharmsala mammalian bones indicate the post-mortem bacterial activity on the bones before their final burial.

B. OSTRACODS

Class Crustacea
Order Ostracoda
Suborder Podocopa

Family Cyprididae
Subfamily Cypridinae

Cypridopsis BRADY 1867
(Plate III — 1-4)
Material : WIMF/A 657 to 660, 4 specimens.

Description : Carapace thin shelled, subcircular; elongate, ovate or rentiform, both end rounded, maximum height in the middle; surface smooth, internal features not seen, hinge as per genus, central muscle scars not seen; eye spot absent; right valve slightly larger than the left valve.

	Length	Height	Width in mm.
WIMF/A 657	1.2	.8	.6
WIMF/A 658	1.3	.7	–
WIMF/A 659	.9	.5	.2
WIMF/A 660	1.2	.7	–

Erpetocypris BRADY AND NORMAN 1889
(Plate III — 5-9)
Material : WIMF/A 661 to 664, 4 specimens.

Description : Carapace elongate, thin shelled and slightly compressed, the height almost half of the length, anterior and posterior margins broadly rounded, dorsal margin slightly convex, while ventral margin straight or faintly concave, surface smooth, inner structures not visible as only closed shells are seen; eye spot absent. Left valve larger than the right.

	Length	Height	Width in mm.
WIMF/A 661	1.4	.7	.5
WIMF/A 662	1.4	.7	.4
WIMF/A 663	1.4	.6	.3
WIMF/A 664	1.3	.8	–

Candonapsis VAVRA, 1891
(Plate III — 10, 11)
Material : WIMF/A 665 to 666, 2 specimens.

Description : Carapace thin shelled, bean shaped, more or less similar to *Candona;* maximum height in the middle, approximately half of the length; both ends broadly rounded; surface smooth; inner structures not seen. Eye spot absent. Left valve is larger than right, Dorsal margin convex upward, ventral margins slightly concave.

	Length	Height	Width in mm.
WIMF/A 665	1.5	.7	.5
WIMF/A 666	1.0	.4	.4

Metacypris ? BRADY AND ROBERTSON, 1870
(Plate III — 12)
Material : WIMF/A 667, one carapace.

Description : Carapace oblong oval in lateral view. Eye spot absent, surface smooth.

	Length	Height	Width in mm.
WIMF/A 667	1.2	.6	.45

Ostracod genera described above together constitute a freshwater assemblage with rather similar ecological requirements. For want of more material Dharmsala ostracod studies are confined at this stage up to tentative generic identifications only.

DISCUSSION

With the termination of marine deposition represented by Subathu and older horizons in the NW Frontal Himalayan Zone during Cenozoic, a new dominantly fluvial depositional cycle set in During transitional period Dharmsala sediments were deposited in the Kangra depression (Raiverman *et al.* 1983) and were followed by definite fluvial and younger Siwalik horizons in the region. Subathu and Siwalik sediments and their biota are known to be distinct from each other. The faunal remains described above are from the intervening period which is of the order of 25 Ma between Subathu and Siwalik and is least known faunistically.

Since Eocene transgression, the NW Himalaya has a continuous history of sedimentation barring a few inferred hiatuses in the succession (Ranga Rao 1986; Pandey, 1986). Sedimentological and palynological studies reveal continuity of sedimentation in the region from Middle Eocene to early Middle Miocene (Chaudhri, 1968; Singh, 1978; Mathur, 1984). "Missing Oligocene" concept on regional scale of a few workers is perhaps based on the non-recovery of Oligocene terrestrial fauna from the Cenozoic sediments of the NW Himalayan Zone (Ranga Rao 1986; Sharma, 1984). Record of *Leptomeryx*, an Oligocene artiodactyl from Murree, Jammu region indicates the possibility of finding Oligocene faunal assemblage which in turn will mark the faunal continuity as well (Mehta and Jolly, 1989). However, scarcity of the Upper Eocene-Oligocene fauna in the region may be interpreted in terms of the collison tectonics known to have adverse effect on life (McKenna, 1972).

Fishes comprising long ranging taxa are incapabale of providing age constraints in the present context. Mammalian remains, including *Dinotherium* recorded by Kumar (1985) from the section, are too fragmentary to be of much use for relative dating. Palynological studies by Dogra *et al.* (1985) in the same section yielded a characteristic Oligocene form viz. *Meyeripollis*, though they preferred to propose Lower Miocene age for the sediments. Mathur (1984) on the basis of similar palynological assemblage from the Upper Dharmsala sediments from different sections advocated Oligocene-Lower Miocene age for the horizons. We support Mathur's (1984) age interpretation and propose an Oligocene-Lower Miocene age for the biota described above.

Recovery of peculiar freshwater cyprinid fishes (M'Clelland, 1980) from a palynologically dated Upper Dharmsala section provides us a definite proof of freshwater depositional environment in Dharmsala basin during Oligocene-Lower Miocene. The associated ostracods and charophytes lend support to our contention and further restrict the freshwater depositional environment to be characterised by low-energy conditions. Preservation of delicate fish scales also indicates sluggishly flowing water channels. Invoking the depositional environment models we find fluvio-deltaic depositional environment suggested by Srivastava and Casshyap (1983) or alluvial plain with swiftly shifting shallow braided streams by Singh (1978) most suitable for the deposition of the Upper Dharmsala sediments containing bright grey mudstone unit having fish and ostracod remains described above along with charophyte gyrogonites.

Interestingly, the heterogenous assemblage from the TCP locality is a rather complete food-cycle of fluvial ecosystem. In the food cycle, crocodiles feeding on fishes and smaller mammals were the terminal members. Fishes, in turn, survived on submerged vegetation represented by charophytes, decaying vegetational elements, and ostracods. A few piscivorus cyprinids might have also consumed smaller harbivorus cyprinids, as it happens in their present day assemblage (M'Clelland, 1980). Smaller body-size of food-cycle members, particularly of crocodiles, from the Upper Dharmsala indicates towards the impoverished, small and shallow fluvial habitat supporting them.

As has been enumerated above, the recovered Upper Dharmsala biocoenosis (assemblage living together) comprising charophytes, cyprinids, and ostracods was, by analogy, adapted to tolerate only very slight variations in salinity (Gall, 1983). Such stenohaline (salinity sensitive) organisms have been further subdivided into two groups. viz. fossilizable i) freshwater and ii) brackish water stenohalines with charophytes and ostracods as their index elements respectively (*sensu* Boggs, 1987). Abundance of charophytes in comparison of the poor representation of ostracods in the TCP locality indicates predominance of former type of stenohalines in the Upper Dharmsala depositional environment.

Lastly, common faunal elements from the homotaxial sequences of the Indian Himalaya, known through present work and by Sahni *et al.* (1984), Kumar (1985), and Dutta and Singh (1975), provide the basis to presume that Oligocene-Lower Miocene faunal province prevalent in Dharmsala-Jammu region included Ladakh basin too. Record of cyprinids continuing till today, begins with these horizons in the northwestern Himalaya, though cyprinids were already present in the Indian subcontinent as per their record from the Palaeocene intertrappeans (see Sahni *et al.*, 1984).

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REFERENCES

ANNANDALE N. & HORA, S.L. 1925. Freshwater fish from the Oil Measures of the Dawna Hills *Rec. Geol. Surv. India,* : **56**: 204.

BOGGS, S. JR. 1987. *Principles of Sedimentology and Stratigraphy* : Merrill Publishing Company, Ohio.

CHAUDHRI, R.S. 1988. Stratigraphy of the Lower Tertiary Formations of Punjab Himalayas. *Geol. Mag.* **105** : 401-430.

DATTA, A.K. 1970. Some observations on the sedimentological and palaeontological aspects of the Subathu and Lower Dharmsala sediments in the Simla Hills area and their bearing on the tectonic evolution of the foot-hill belt. *Pub. Cent. Adv. Study. Geol. Panjab Univ.* **7**: 23-30.

DATTA, A.K. & SINGH. P. 1975. Microfossils from the Murree Formation of the Surrin Mastgarh area. *Him. Geo.* **5** : 236-244.

DOGRA, N.N., SINGH, R.Y. & MISRA, P.S. 1985. Playnology of Dharmsala Beds, Himachal Pradesh. Jour. *Pal. Soc. India.* **30**: 63-77.

GALL, J.C. 1983 *Ancient sedimentary environments and the habitats of living organisms.* Springer-Verlag, Berlin.

JOLLY, A., CHAUDHARY, M. & SURI, P.S. 1986. Angiosperm leaf impressions from the Upper Dharmsala Formation, Palampur, Himachal Pradesh, *Res. Bull. (Science) Panjab Univ.,* **37** (I-II) : 103-112.

KUMAR, M. 1985. Contribution to the Biostratigraphy of the Type Dharmsala Section, Dharmsala, H.P. *Unpublished M. Phil. Dissertation, Panjab University*, Chandigarh : 1-134.

LAHIRI, H.M. (in Heron, 1939). General Report. *Rec. Geo. Surv. India* **74** (i) : 70.

MATHUR, Y.K. 1984. Cenozoic palynofossils, vegatation, ecology and climate of the North and Northwestern Sub-Himalayan Region, India. In : *The Evolution of East Asian Environment,* Eds. R.O. Whyte. et. al. Centre of Asian Studies, Hong Kong, **II** : 504-55.

Mc KENNA, M.C. 1972. Possible biological consequences of Plate Tectonics. *Bioscience,* **22** (9) : 519-525.

M'CLELLAND J. (reprint of the original) 1980. *Indian Cyprinidae, Freshwater fishes of India.* Cosmo Publications, New Delhi.

MEHTA, S.K. & JOLLY, A. 1989. *Leptomeryx,* an Oligocene artiodactyl from the Lower Murree of Sial Sui (Kalakot Tehsil), District Rajauri, J & K. *Curr. Sci.* **58** (11) : 625-627.

PANDEY, J. 1986. Some recent palaeontological studies and their implications on the Cenozoic stratigraphy of Indian subcontinent. *Bull ONGC,* **23** (2) : 1-44.

RAINA, B. N., PATI, U.C. & SRIMAL, N. 1987. Himalayan Orogeny. In *Global Correlation of Tectonic Movements,* Eds. Yu. G. Leonov and V.E. Khain : 199-225

RAIVERMAN, V. 1986. Sedimentation pattern and its controlling factors in the Cenozoic Basins of the Indian subcontinent. *Bull. ONGC,* **23** (1) : 1-13.

RAIVERMAN, V., KUNTE, S.V. & MUKHERJEE, A. 1983. Basin Geometry, Cenozoic sedimentation and Hydrocarbon prospects in Northwestern Himalaya and Indo-Gangetic Plains. *Petroleum Asia Jour.* : 67-92.

RANGA RAO, A. 1986. Northwest Himalayan Foothills. Its stratigraphical record and Tectonic Phases. Bull. ONGC, **23** (2) 109-128.

SAHNI, A., SRIKANTIA, S.V., GANESAN, T.M. & WANGDUS, C. 1984. Tertiary fishes and molluscs from the Kuksho Formation of the Indus Group, Near Nyoma, Ladakh. *Jour. Geol. Soc. India,* **25** (11) : 244-247.

SHANKER, R., KUMAR, G, & SAXENA, S.P. 1989. Stratigraphy and Sedimentation in Himalaya : A Reappraisal. In : *Geology and Tectonics of the Himalaya, Special Publication* **26**, *Geol. Surv. India* : 1-60.

SHARMA, K. 1984. The sequence of phased uplift of the Himalaya. In : *The Evolution of the East Asian Environment,* Eds RO Whyte *et al,* Centre of Asian Studies, Hong Kong, **I** : 56-70

SINGH, I.B. 1978. On some sedimentological and palaeontological aspects of Subathu-Dagshai-Kasauli succession in Simla Hills. *Jour. Pal. Soc. India,* **21** & **22** : 19-28.

SRIVASTAVA, V.K. & CASSHYAP, S.M. 1983. Evolution of Pre-Siwalik Tertiary Basin of Himachal, Himalaya, *Jour. Geol. Soc. India,* **24** : 134-147.

TALUKDAR, S.N., RAIVERMAN, V. & KRISHNAN, P.V. 1959. Geology of the parts of Joginder nagar, Sadar and Sarkaghat Tehsils, Mandi District, H.P. *Prog. Report ONGC,* (Unpublished).

TIWARI, B.N. 1982. Geology and Vertebrate Palaeontology of the Siwalik Group of Kalagarh-Koti Rao Section, District Pauri Garhwal (U.P.), with special reference to palaeohistological studies *Unpublished Ph. D. Thesis, Lucknow University* : 1-304.

VERMA, B.C. & VERMA, N.K.R. 1979. Occurrence of Vertebrate fossils in Upper Dharmsala Formation and their palaeoecological significance. *Abstracts, N/Q Boundary Seminar, Chandigarh*: 44.

EXPLANATION OF PLATES

PLATE I

1-22 Pharyngeal teeth

1-6 Type A 1-3 Occlusal views of WIMF/A604 (X60), WIMF/A602 (X64), WIMF/A601 (X34); 4 closeup of occlusal surface of WIMF/A601; 5 & 6 lateral views of WIMF/A 601 (x51) and WIMF/A603 (x66).

7 & 8. Type B Lateral views of WIMF/A612 (x70) and WIMF/A613 (X48).

9-13. Type C Lateral views of WIMF/A617 (x56), WIMF/A619 (x46), WIMF/A616 (x12), WIMF/A618 (x42) and WIMF/A614 (x35).

14-18. Type D 14-17 Lateral views of WIMF/A610 (46), WIMF/A607 (X45), WIMF/A608 (34) and WIMF/A609 (x50); 18 occlusal view of WIMF/A611 (x58).

19 & 20. Type E Occlusal views of WIMF/A621 (x44) and WIMF/A668 (x60).

21. WIMF/A626 isolated fish tooth (x28).

22. WIMF/A625 pharyngeal tooth patch (x27).

23 & 24. Surface views of the cyprinid fish dentine showing tubules at EDJ. Bars equal 10 mm.

PLATE II

1. WIMF/A652 Cyprinid fish scale showing radii, nucleus with thick circuli towards posterior margin x36.

2. WIMF/A653 Cyprinid fish scale lacking nucleus x37.

3. WIMF/A654 Cyprinid fish scale devoid of circuli in the nucleus region x30.

4 & 5. WIMF/A669 4. Partially preserved. fish scale showing tubercles x37: 5. closeup of framed part of figure 4.

6. WIMF/A631 Fused fish vertebrae x16.

7. WIMF/A670 Fused fish vertebrae x44.

8. WIMF/A632 Incomplete centrum of fish vertebra x31.

9. WIMF/A627 Dorsal spine with articulating end x27.

10. WIMF/A655, Crocodile tooth, side view x7.5.

11-13. WIMF/A656, Crocodile tooth, 11. top view x31; 12. side view x17; 13. enlarged view of crocodile dentine (x44) with closeup of framed part towards right.

14 & 15. WIMF/A671 14. Mammalian bone TS with widened canals filled with carbonate (x7); 15. closeup of the framed part in figure 14.

16. Mammalian bone TS showing distribution of osteons of various size depicting remodelling of bone x50.

PLATE III

1. WIMF/A658, Cypridopsis right valve view x48.

2. WIMF/A659, Cypridopsis Carapace right valve view x48.

3. WIMF/A657, Cypridopsis carapace right valve view x37.

4. WIMF/A660, Cypridopsis carapace left valve view x49.

5-6 WIMF/A661, Erpetocypris carapace 5. left valve view x54; 6. dorsal view x38.

7. WIMF/A663, Erpetocypris carapace left valve view x55.

8. WIMF/A662, Erpetocypris carapace left valve view x50.

9. WIMF/A664, Erpetocypris broken carapace x37.

10. WIMF/A665, Candonapsis carapace left valve view x36.

11. WIMF/A666, Candonapsis carapace left valve view x47.

12. WIMF/A667, Metacypris ? carapace left valve view x50.


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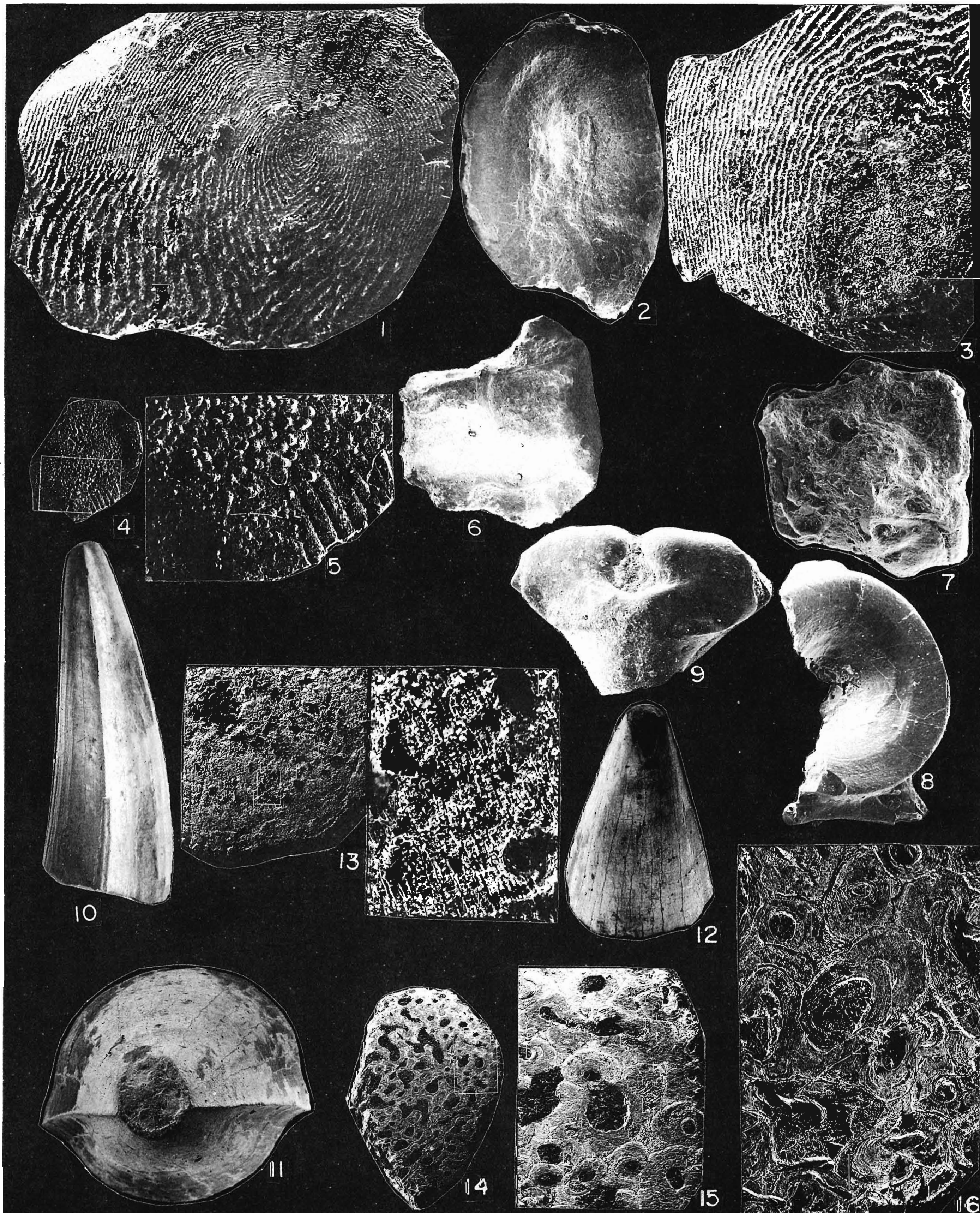
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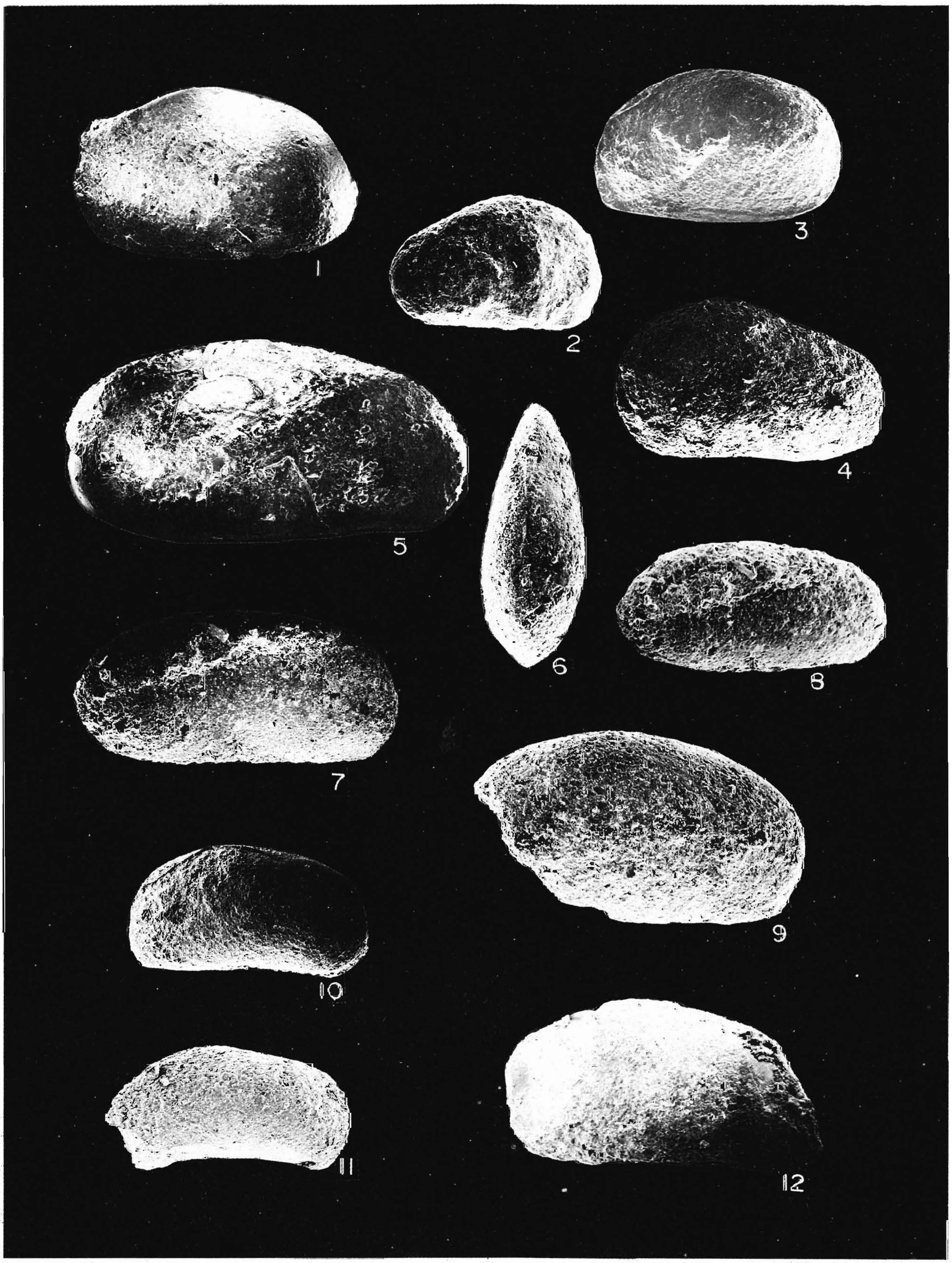

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