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QUATERNARY RODENT FAUNA OF THE KASHMIR VALLEY, NORTHWESTERN INDIA; SYSTEMATICS, BIOCHRONOLOGY AND PALAEOECOLOGY

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ABSTRACT

Extensive screening operations of Karewa sediments have resulted in the large collection of microtine rodents which present the most useful biostratigraphic tool for the correlation of continental sediments and have proved to be useful indicators of the local environment. Present discovery of a new microtine rodent, *Kilarcola*, showing morphological similarities with *Ophiomys* and *Mimomys*, is the first and only occurrence of microtines in Indian subcontinent. The most distinctive features of the find are, small sized rodent lacking cement in re-entrant valleys, its rooted teeth, primitive enamel pattern on M^1, higher dentine tracts on M^1, and confluence of dentine fields. The vertebrate yielding horizons exposed along the rivers Rembiara and Birnai, constituting the Lower Karewa Formation are about 1.8 Myr to 1.6 Myr in age whereas the Upper Karewa Sombur bone bed falls within the Brunhes magnetic epoch, hence is younger than 0.73 Myr

INTRODUCTION

Set like a jewel in the tangled mass of gigantic Himalayas, the Vale of Kashmir (33°25'00"-34°39'30"N and 73°55'05"-75°36'30"E), an intermontane basin, is surrounded in the northeast, southwest, northwest and southeast by Great Himalayan, Pir Panjal, Kaznag and Saribal mountain ranges respectively. The basin (Fig. 1) which was developed during Pliocene due to the ponding of southwardly flowing drainage lines by uplift of the Pir Panjal Range, is filled with the Plio-Pleistocene sediments comprising of mudstone-sandstone-conglomerate succession. Both the Lower and the Upper Karewa Formations of the Karewa

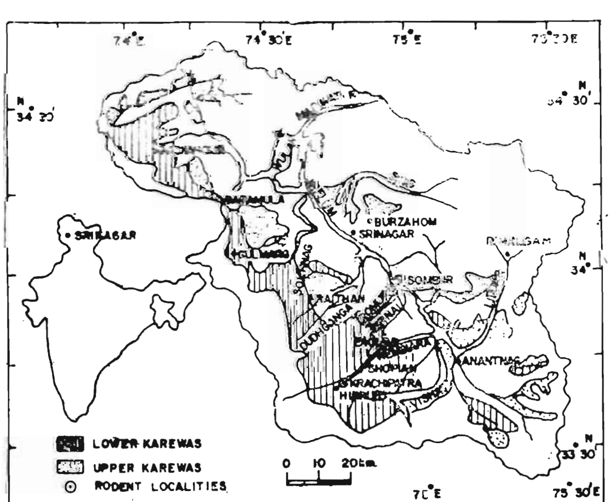

Figure 1. Map of Kashmir intermontane basin showing distribution of Lower and Upper Karewas and rodents yielding sites.

Group rocks have been examined many times by the palaeontologists, because they constitute more than a kilometre thick sedimentary sequence which has preserved well diverse mammalian fauna.

Though the vertebrate palaeontological studies in the Karewas of the Kashmir Valley were started with collection of fossil fish remains by Godwin-Austen (1864) and Hora (1937), the first reference of the occurrence of mammalian fossils was given by De Terra and Paterson (1939). Since then, the biostratigraphy of Karewas has been been widely discussed by Wadia (1951), Badam (1968, 1972), Tewari and Kachroo (1977), Sahni (1981, 1982) and, Kotlia, Sahni, Agrawal and Pant (1982). Based on the discovery of *Equus*, *Elephas*, *Cervus*, *Sus*, *Felis*, *Sivatherium* etc. made by these workers, Karewas have previously been interpreted as being solely Pleistocene (De Terra and Paterson, 1939; Badam, 1973, 1984; Tewari and Kachroo, 1977) and as spanning the late Pliocene and much of the Pleistocene (Lydekker, 1883; Sahni, 1936; Wadia, 1951; Bhatt, 1975; Bhatt and Chatterji, 1976, 1979).

Geochronological studies in the Karewas were initiated by Kusumgar (1980), Kusumgar, Agrawal, Korisettar and Pant (1982), and Agrawal, Bhatt, Kusumgar and Pant (1981) and followed by Burbank (1982, 1983, 1985), Burbank and Johnson (1982, 1983), Agrawal (1985), and Kusumgar, Agrawal and Kotlia (1985a). Kusumgar (1980) and Agrawal *et al.* (1981) indicated that the Lower Karewas span the late Gilbert to early Matuyama magnetic polarity chrons (~3.5 to ~2.0 Myr ago). Burbank (1982) and Burbank and Johnson (1982, 1983) developed a new chronology for the Karewas through the use of magnetostratigraphies with fission track dating of volcanic ashes and suggested that the Karewa sedimentation had commenced by about 4.0 Myr ago where the Hirpur sequence extends from about 3.0 Myr to 2.1 Myr and the Romushi section, from about 2.4 Myr to the Brunhes magnetic epoch. Agrawal (1985) and Kusumgar *et al.* (1985a) carried out more detailed geochronological investigations and suggested that the Lower Karewas span the Gilbert to late Matuyama polarity chrons ($\sim$4.0 Myr to $\sim$0.73 Myr) and the Upper Karewas encompass the Brunhes magnetic chron.

Through the combined use of vertebrate paleontology and magnetic polarity stratigraphy, Kotlia (1984) and Kusumgar, Kotlia and Agrawal (1985b) worked out the stratigraphic occurrence of the various Karewa fossils and their placement in the magnetic polarity scale and postulated that the Karewa localities, yielding characteristic faunal element (*Equus*, *Elephas*, *Cervus*, *Canis*) are younger than 2.48 Myr (Gauss/Matuyama boundary).

The technique of microvertebrate washing and screening in the Karewa sediments, for the first time, was applied by Kotlia (1984, 1985) and Sahni and Kotlia (1985) to recover the smaller vertebrates. The rodent fauna, described herein, was recovered applying underwater screening technique to the Lower Karewas, exposed along the rivers Rembiara and Birnai at Krachipatra and Kilar localities respectively, and to the Upper Karewas exposed at Sombur (Fig. 1). Palaeomagnetic measurements carried out by Kotlia (1984), Agrawal (1985) and Kusumgar *et al.* (1985a, b) have shown that the Krachipatra bone bed falls within the Olduvai event (1.8 Myr to 1.6 Myr) whereas the Sombur bone bed encompasses the Brunhes magnetic chron (Fig. 2). The conglomerate bed exposed at Kilar has been traced to the Romushi section whose magnetostratigraphy is better known and is used here to date the Kilar bone bed (Olduvai event).

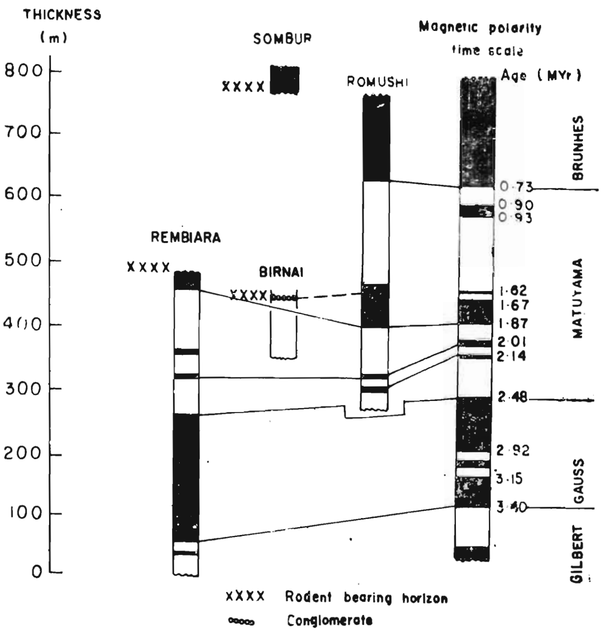

Figure 2. Rodent chronology of the Karewas. Krachipatra (Rembiara section) and Kilar (Birnai section) bone beds are 1.8 Myr to 1.6 Myr (Olduvai event) in age. Sombur ossiferous horizon is younger than 0.73 Myr (Brunhes/Matuyama boundary). Romushi and Birnai sections are correlated on the basis of a conglomerate bed, thus the Romushi magnetostratigraphy is used to date Kilar bone bed. (Magnetostratigraphy after Agrawal (1985) and Kusumgar *et al.* (1985a).

SYSTEMATIC PALAEONTOLOGY

The present study is the first and only report of microtine rodents in the Plio-Pleistocene stratigraphy of Indian subcontinent. Possible comparisons with North American microtines are given here to highlight the common forms found in North America and other places, similar to which may in future be found besides the Karewas, in other Quaternary basins of Indian subcontinent.

The systematic position of the microtine rodents, is, however, in some controversy. Hibbard (1950, 1964, 1967), Paulson (1961), Hibbard and Dalquest (1966) have placed the microtines under the family Cricetidae. Olsen (1958) proposed a subfamily Microtinae under the family Cricetidae. Zakrzewski (1969, 1972) divided the Cricetidae into subfamilies, Cricetinae and Microtinae. Hibbard (1970) suggested that the subfamily Microtinae could be placed under the family Muridae. Skinner and Hibbard (1972) discussed the microtines under subfamily Arvicolinae and family Muridae. Further modification was made by Martin (1975), who described voles under the subfamily Microtinae and family Microtidae. Recently, Hibbard, Zakrzewski, Eshelman, Edmud, Griggs and Griggs (1978) and Koenigs wald (1980, 1981, 1982) have placed the microtine rodents under a separate family, Arvicolidae. The dental nomenclature (Figs. 3, 4) and classification of Karewa microtine rodents, employed here, are that of Hinton (1926), and Hibbard *et al.* (1978) and Koenigswald (1980, 1981, 1982) respectively.

Class	Mammalia
Subclass	Theria
Order	Rodentia
Family	Arvicolidae
Subfamily	Microtinae
Genus	*Kilarcola* KOTLIA, 1984

Diagnosis : A small microtine rodent with rooted teeth that lack cement in the re-entrant valleys; M_1 having a posterior loop, five alternating triangles and a

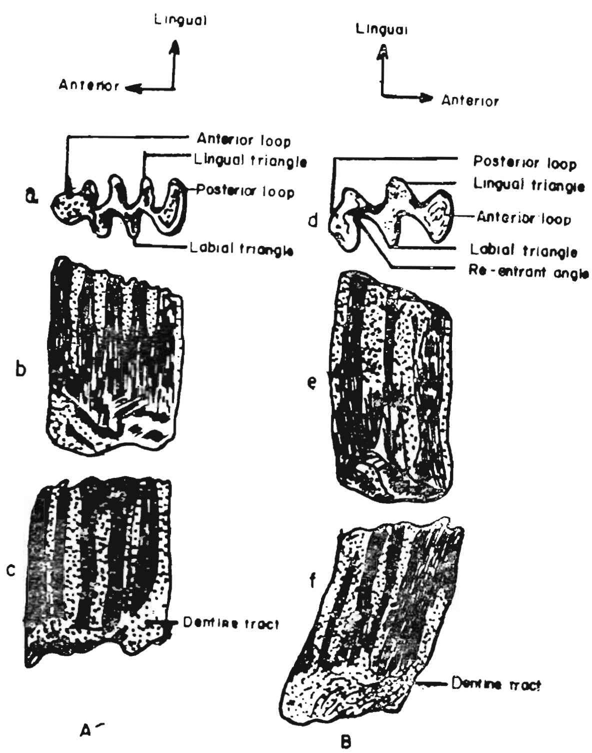

Figure 3. Dental terminology of left lower and upper cheek teeth of *Kilarcola kashmiriensis*, Kotlia, 1984. (a, d = occlusal views; b, e = lingual views; c, f = labial views)
A. Left lower molar
B. Left upper molar

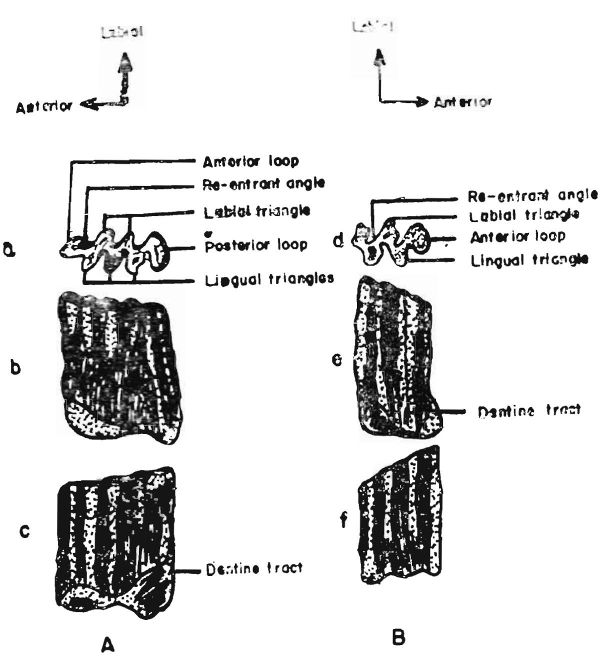

Figure 4. Dental terminology of right lower and upper cheek teeth of *Kilarcola kashmiriensis*, Kotlia, 1984. (a, d = occlusal views; b, e = lingual views; c, f = labial views).
A. Right lower molar (holotype)
B. Right upper molar

simple anterior loop ; the first and second alternating triangles of M_1-M_3 open and nearly confluent ; M_2 with a posterior loop and four alternating triangles; reduced and folded nature of labial cusps on RM_2 ; M_3 having three alternating triangles ; dentine tracts variable in the height ; M^1 having an anterior loop and four open alternating triangles ; M^2 and M^3 with a simple anterior loop and three alternating triangles : single and deep lingual re-entrant fold on M^2; enamel pit on M^3; anterior loop always simple ; labial salient to angles sharper than lingual salient angles ; similar to *Ophiomys* in LM_3 and to *Nebraskomys* in RM_2 ; more advanced rodent as shown by the higher dentine tracts on the labial side of RM_1.

Kilarcola kashmiriensis KOTLIA, 1984

(Plate I—1-7; Plate II—1-4; Plate III—1-5; Plate IV—1-5; Figs. 3, 4)

Holotype : VPL/B 2007, an isolated right lower first molar (RM_1).

Paratypes : VPL/B 2001, RM_1 and VPL/B 2014, LM_1.

Referred material : VPL/B 2002, RM^1 ; VPL/B 2003, RM^2 ; VPL/B 2004, LM_3 ; VPL/B 2005, RM^3 ; VPL/B 2006, LM^3 ; VPL/B 2008, LM^1 ; VPL/B 2013, LM_2 and VPL/B 2015, RM_2 ; VPL/B 2023 to VPL/B 2025 unidentifiable; VPL/B 2016 to VPL/B 2022, incisors.

Horizon and locality : Sandstone lenses in mollusc bearing Lower Karewa mudstone exposed along the Birnai Nala at Kilar, 60 km NW of Srinagar. Two specimens, VPL/B 2013 and 2016 were collected from greyish sandy mudstone exposed along the Rembiara River at Krachipatra, 67 Km NW of Srinagar. VPL/B 2018-2019 came from the Upper Karewas exposed at Sombur, 12 km NE of Srinagar.

Age : The vertebrate rich level of the Rembiara section is stratigraphically 52.3 m above the base of the Olduvai event. The Birnai and Romushi sections are correlated on the basis of a conglomerate bed. It can be explained that the ossiferous level yielding microtines in the Birnai section falls within the Olduvai event and is located near its top. Sombur bone bed is younger than 0.73 Myr (Fig. 2).

Description :

Incisors. VPL/B 2016 to VPL/B 2022 (Plate I—1-7)

In the same beds as the teeth described below here occur many isolated incisors. These cannot be definitely classified or correlated with cheek teeth as yet but they are of some importance morphologically and seem to warrant brief description.

VPL/B 2016 and VPL/B 2017 are well preserved incisors whereas VPL/B 2018 to VPL/B 2022 are incomplete and broken anteriorly and posteriorly. Natural facet of wear is preserved. VPL/B 2016 has a completely enameled, pointed upward and curved crown with a flat inner surface, convex outer surface and concave upper working face. It is elliptical in the cross section. VPL/B 2017 has an excavated posterior surface It is more slender and less strongly curved. VPL/B 2018 is stouter and more strongly curved gliriform type. The incisor is broken anteriorly and posteriorly. VPL/B 2019 to VPL/2022 are gliriform and arcuate with limited enamel band. The natural facet of the wear is not seen in the specimens.

Lower dentition :

LM_1. VPL/B 2014 (Plate IV—2)

The tooth consists of a posterior loop, five alternating triangles and a simple anterior loop. The fifth alternating triangle opens broadly into the anterior loop. Cement has not been deposited on the molar but the dentine tracts are best developed on lingual and labial sides and extend well up both the sides of the anterior loop. The posterior wall of the posterior loop is flat. The re-entrants are broad and angular. The third lingual and second labial re-entrant angles form almost a right angle to the longitudinal occlusal plane of the tooth. The molar is two rooted. The broad anterior root supports the anterior loop, fourth and fifth alternating triangles and part of the second and third triangles. The posterior root supports the posterior loop and part of the second and third alternating triangles. The anterior loop is simple and there is no evidence of either a prism fold or an enamel pit.

Comparison : LM_1 of *Kilarcola kashmiriensis* resembles *Pedomys*, *Pliopotamys*, *Mimomys* and *Synaptomys* in having a posterior loop, five alternating triangles and a broad anterior loop, but there is an indication of prism fold and enamel pit on the anterior loop of *Mimomys* (Hibbard, 1970) and *Pliopotamys* (Hibbard, 1949). The fourth and fifth alternating triangles are confluent in *Pedomys* (Hibbard, 1955) while they form part of anterior loop in *Synaptomys*. *Pliolemmus*, *Ondatra*, *Microtus* and *Pitymys* (Hibbard, 1955) are distinct from *Kilarcola* in having seven alternating triangles, exclusive of the posterior and anterior loops. The alternating triangles in *Microtus* are almost closed and they are nearly opposite in *Pliolemmus* and *Pitymys*. *Ophiomys* is distinct from *Kilarcola* in having a large anterior loop which is formed by the fourth and fifth alternating triangles. *Cosomys* (Zakrzewski, 1969) has 3-4 alternating triangles and a complex anterior loop with a prism fold on it. *Pliophenacomys* (Hibbard, 1949) is distinct from *Kilarcola* in having closed first and second alternating triangles and a complicated anterior loop having the prism fold. *Kilarcola* is similar to *Ogmodontomys* in having five alternating triangles but differs in the greater simplicity of the loop.

LM_2. VPL/B 2013 (Plate IV—1)

The two rooted molar consists of a posterior loop and four alternating triangles. The third and fourth alternating triangles are broadly confluent. The posterior wall of the posterior loop is flat. There is absence of cement in the re-entrant valleys and of the dentine tracts on both the sides of the molar. The anterolabial area of the fourth alternating triangle is slightly lower. The first labial re-entrant fold is better developed and the lingual re-entrants are deep. The apices of the lingual re-entrant folds are angular. The fourth alternating triangle is simple without an enamel pit.

Comparison : *Kilarcola* is similar to *Ogmodontomys* in the morphology of LM_2 but is distinct in not having the excessively deep lingual re-entrants. The anterior wall of the third and fourth alternating triangles is a semicircle in *Ondatra* (Semkin, 1966). The anterolingual area of the third triangle is slightly curved in *Microtus* (Hibbard, 1955) whereas it is pointed in *Ophiomys* (Hibbard and Zakrzewski, 1967). *Kilarcola* is distinct from *Ondatra* and *Microtus* in having the open first and second alternating triangles. The first and second alternating triangles and the third and fourth alternating triangles are oppoosite and broadly confluent on LM_2 of *Microtoscoptes* (Schaub, 1924). *Kilarcola* is distinguished from *Cosomys* in having the broad opening of the posterior loop into the first alternating triangle. *Pliophenacomys* (Hibbard, 1949) is distinct from *Kilarcola* in having the closed first and second alternating triangles that are separated from the third alternating triangle by a thin enamel connection.

LM_3. VPL/B 2004 (Plate II—4)

The tooth consists of a posterior loop, two alternating triangles and a wide anterior loop. The second and third alternating triangles broadly open into the anterior loop. The posterior loop is narrowly separated from the first and second alternating triangles. A thick enamel is present on the anterolabial area of the anterior loop. The dentine tracts on the lingual side are absent and are incipient on the labial side. There is no cement in the re-entrants of the molar. The poorly developed second lingual re-entrant fold is much higher in position than the first lingual re-entrant fold and broadly opens into the anterior loop. The molar has two developed roots with the posterior root being larger.

Comparison : The character of having a posterior loop, two alternating trinangles and a wide anterior loop on LM_3 in *Kilarcola* is shared with *Ophiomys*, *Microtus* and *Ogmodontomys* (Hibbard, 1964). *Kilarocla* is distinct from *Ophiomys* in having a weakly developed second labial re-entrant fold. The second labial trangle is greatly reduced in *Synaptomys* (Olsen, 1958). *Microtus* has a complicated anterior loop with a groove on the antero-labial surface. In *Microtus*, the first lingual triangle narrowly opens into the anterior loop whereas it forms a part of the anterior loop in *Kilarcola*. *Microtoscoptes* and *Paramicrotoscoptes* (Martin, 1975) are similar in having the confluent and opposite lingual and labial triangles and so differ with *Kilarcola*. It can also be differentiated from *Pliophenacomys* in having a wide anterior loop which is rounded on the anterolingual area. *Ondatra* (Semkin, 1966) has a posterior loop, three alternating triangles and an anterior loop, in which the third triangle broadly opens into the anterior loop.

RM_1. VPL/B 2001 : VPL/B 2007 (Plate II—1; Plate III—3)

The RM_1 has a posterior loop, five alternating triangles and an anterior loop. The fifth triangle broadly opens into the anterior loop. The lingual triangles are oriented normal to the anterior axis. The dentine tract on the anterolabial side of the anterior loop extends well above the base of anterolabial re-entrant angle. The apices of the lingual alternating triangles are broad and generally directed forward. The labial re-entrants are oblique and crescent shaped. The molar has three roots, the middle being the largest. The posterior root supports the posterior loop and the second alternating triangle. The middle root supports the first. third and fourth alternating triangles. The anterior loop and part of the fifth alternating triangle are supported by the anterior root.

Comparison : There are no dentine tracts developed on M_1 of *Ophiomys*. In some species of *Ophiomys*, the M_1 consists of an enamel pit on the anterior loop. *Kilarcola* is also distinct from *Ophiomys* in having a simple anterior loop. *Cosomys* is distinguished from *Kilarcola* in having only 3 or 4 alternating triangles and a trilobed anterior loop. The first and second alternating triangles are confluent and nearly opposite in *Nebraskomys* (Hibbard, 1957) and so differs from *Kilarcola*. It is further distinct from *Pliopotamys* in having the simple anterior loop. RM_1 in *Mimomys* lacks cement but has a deep enamel pit on the anterior loop. *Pliophenacomys* differs from *Kilarcola* in possessing a small sixth alternating triangle that becomes a part of the anterior loop (Skinner and Hibbard, 1972). The character of having five alternating triangles on M_1 of *Microtus pennsylvanicus* (Semkin, 1966), is shared with *Kilarcola* but *Microtus pennsylvanicus* consists of a trilobed anterior loop. The fifth alternating triangle in *Microtus paroperarius* is open and confluent with the anterior loop. The apices of the re-entrant angles in *Nebraskomys* are not directed as sharply anteriorly as in *Mimomys* and *Kilarcola*. *Mimomys* possesses only three alternating triangles. *Kilarcola* shows morphological similarity with *Pliomys* but differs in greater simplicity of the anterior loop.

RM_2. VPL/B 2015 (Plate IV—3)

The two rooted tooth consists of a posterior loop and four alternating triangles, the third and fourth triangles forming the anterior loop. The first and second alternating triangles and the third and fourth alternating triangles are separated from the posterior loop and the third and fourth alternating triangles by a thin enamel connection. There is an enamel pit on the anterior loop. Dentine tracts on the labial side of the molar are incipient.

The apices of the second lingual and second labial re-entrants are opposite. The labial re-entrant valleys are perpendicular to the anteroposterior axis of the molar. The molar resembles M_2 of *Nebraskomys rexroadensis* and M_3 of *Ogmodontomys poaphagus*. *Cosomys* is distinguished from *Kilarcola* in having the angular apices of the lingual triangles. The first and second alternating triangles and the third and fourth alternating triangles are not confluent in *Ondatra*. *Synaptomys* has a rootless M_2 with greatly reduced fourth alternating triangle. *Microtus* is distinct from *Kilarcola* in having the narrow openings of the alternating triangles. The character of having four alternating triangles in *Paramicrotoscoptes* is shared with *Kilarcola* but it differs from *Kilarcola* in having the opposite arrangement of the first and second, and the third and fourth alternating triangles.

Upper dentition.

LM^1. VPL/B 2008 (Plate III—4)

The left upper first molar consists of an anterior loop, three alternating triangles and a posterior loop. The third triangle broadly opens into the posterior loop. The anterior loop is triangular in shape. The lingual dentine tracts reach higher up the posterolingual side. The lingual re-entrants form almost a right angle to the longitudinal occlusal plane of the tooth. The labial re-entrants are sharper and directed posteriorly. The labial salient angles are sharper than the lingual salient angles. The molar is three rooted. The anterior root supports the anterior loop. The middle root is on the lingual side of the tooth and supports the first and second alternating triangles. The posterior root supports the third triangle and the posterior loop.

Comparison : LM^1 of *Kilarcola* is similar to *Pliomys* in having three alternating triangles and equal anterior loop but differs in the posterolingual area of the posterior loop. The posterior loop is complicated in *Pliolemmus* (Hibbard, 1955). *Pliophenacomys* is distinct from *Kilarcola* in having the narrow openings of the alternating triangles. The character of having four alternating triangles in *Paramicrotoscoptes* is shared with *Kilarcola* but it differs in having the opposite arrangement of the first and second, and the third and fourth alternating triangles.

LM^3. VPL/B 2006 (Plate III—2)

The molar has a large anterior loop which is joined by the greatly reduced first alternating triangle. The first lingual alternating triangle is followed by the posterior loop. There is no cement in the re-entrant folds. The posterior root possesses an enamel pit. The short dentine tracts are on the lingual side of the anterior loop and the posterior face of the posterior loop.

Comparison : *Pliolemmus*, *Nebraskomys* and *Pliopotamys* are distinct from *Kilarcola* in having the two alternating triangles. *Ophiomys* has a simple anterior loop on M^3. Three rooted condition of M^3 in *Ogmodontomys* distinguishes it from *Kilarcola* and *Mimomys*. The posterior loop in *Ogmodontomys* (Skinner and Hibbard, 1972) is lingually compressed. The character of incipient angle in the posterior loop of *Ondatra* is shared with *Kilarcola* but it differs in having three alternating triangles.

RM^1. VPL/B 2002 (Plate II—2)

Three rooted molar comprises an anterior loop and four alternating triangles, a typical microtine occlusal pattern. The third alternating triangle widely opens into the posterior loop. The anterior loop is simple and closed. The dentine tract on the labial side is absent while it extends upward from the base of the tooth on lingual side. The tooth has two outer re-entrant angles, the first is better developed along the outer side of the anterior loop. Apices of the re-entrants on the labial side are turned posteriorly and form a right angle to the longitudinal axis of the molar. The anterior root supports the anterior loop. The middle root supports the first alternating triangle and part of the third alternating triangle. The posterior root supports fourth alternating triangle and part of the third alternating triangle. The posterior root supports fourth alternating triangle and part of the third alternating triangle. The molar has a small depression near the base of crown on the posterior internal surface.

Comparison : The three rooted molar of *Kilarcola* resembles *Nebraskomys*. *Synaptomys* and *Ondatra* are distinct from *Kilarcola* in having a slightly complicated anterior loop. *Pliophenacomys* has a well developed lingual re-entrant pit at the junction of the third and fourth alternating triangles. The presence of single alternating triangle between the anterior and posterior loops distinguishes *Pliophenacomys* from *Kilarcola* and *Ogmodontomys*. *Paramicrotoscoptes* is distinct from *Kilarcola* in having the large lingual re-entrant angle and two confluent posterior triangles which form the posterior loop. *Ogmodontomys* comprises low crowned M^1 which lacks cement.

RM^2. VPL/B 2003 (Plate II—3)

M^2 consists of an anterior loop, two alternating closed triangles and a posterior loop. The first lingual alternating triangle broadly opens into the posterior loop. The anterior loop is wider on the inner side and the posterior loop is slightly curved on the posterolabial side of the tooth. Lingual dentine tracts are incipient. They are approximately of the same height on the anterior loop and the base of apex of the second alternating triangle. Tooth lacks re-entrant pits on the lingual side. Apex of the single and deep lingual re-entrant fold is directed posteriorly. The second labial re-entrant fold is better developed and both the labial re-entrant valleys are deep. There is an indication of enamel pit. The molar is two rooted. The anterior root supports the anterior loop and the labial triangle. The posterior root supports the lingual triangle and the posterior loop.

Comparison : *Pliophenacomys* is chiefly three rooted. The posterior loop is distinctive in that the posterolabial side is flat giving a triangular appearance to this loop. *Paramicrotoscoptes* is distinct from *Kilarcola* in having a large anterior loop, a broad lingual re-entrant angle and two confluent posterior triangles. The lingual re-entrant valley on M^2 in *Ophiomys* reaches higher up the base of labial re-entrant fold. *Microtoscoptes* is distinctive from *Kilarcola* in having the posterior enamel pit. The character of the strong development of the lingual and labial re-entrants in *Cosomys* is shared with *Pliopotamys* but the re-entrants are shallow in *Kilarcola* compared to *Cosomys* and *Pliopotamys*. The lingual and labial re-entrants are excessively deep in *Ogmodontomys*.

RM^3. VPL/B 2005 (Plate III—1)

M^3 has an anterior loop, two alternating triangles and a posterior loop. The first alternating triangle is joined to the anterior loop and the second alternating triangle is broadly confluent with the posterior loop. The posterolabial area of the posterior loop is slightly curved, giving the appearance of a third alternating triangle. The anterior loop is wide and bilobed. The anterior loop and the first alternating triangle are separated from the second alternating triangle and the posterior loop by an enamel connection. The molar has two outer re-entrants, the first is poorly developed along the outer side of the anterior loop. There is a slight appearance of the third labial re-entrant on the outer side of the posterior loop. Between the two labial re-entrant angles, the first is better developed and reaches close to the second labial re-entrant angle. The tooth is two rooted. The first root supports the anterior loop and the first alternating triangle. The posterior loop and the second alternating triangle are supported by the second root.

Comparison : The behaviour of the re-entrant folds is the distinction between *Kilarcola* and *Pliopotamys*. M^3 of *Pliopotamys* has the first labial re-entrant valley better developed than the second (Hibbard, 1949), while in *Kilarcola* the first re-entrant valley is less developed. The second lingual re-entrant is better developed in M^3 of *Pliopotamys* whereas this re-entrant is less developed in *Kilarcola*. The posterior loop is slightly complicated in *Pliophenacomys* (Hibbard and Zakrzewski 1972) with minor folds on the posterolabial and posterolingual areas of the loop. The character of having an anterior loop, two alternating triangles and a posterior loop in *Kilarcola* is shared with *Paramicrotoscoptes*, *Ogmodontomys* and *Ophiomys* but M^3 of *Kilarcola* differs in having weak development of the second labial triangle.

Measurements in mm :

Incisors.

VPL/B number	2016	2017	2018	2019	2020	2021	2022
Antero-posterior diameter (L)	9.6	5.5	6.8	6.6	7.2	3.5	3.9
Transverse diameter (W)	1.2	1.1	1.3	1.2	1.1	0.9	1.1

Lower dentition.

Position of tooth	LM_1	LM_2	LM_3	RM_1	RM_1	RM_2
VPL/B number	2014	2013	2004	2001	2007	2015
Anteroposterior diameter (L)	1.6	1.5	1.6	3.0	2.8	1.5
Transverse diameter (W)	1.0	0.9	0.9	1.4	1.4	0.9
W/L	.625	.600	.563	.467	.500	.600

Upper dentition.

Position of tooth	LM^1	LM^3	RM^1	RM^2	RM^3
VPL/B number	2008	2006	2002	2003	2005
Antero-posterior diameter (L)	1.6	1.5	2.2	1.9	1.7
Transverse diameter (W)	1.2	0.9	1.2	1.3	0.9
W/L	.750	.600	.545	.684	.530

DISCUSSION

Kilarcola kashmiriensis is similar to *Ophiomys* in having the same dental characteristics, i.e., rooted molars that lack cement, M_1 con isting of a posterior loop, five alternating triangles (except in some species of *Ophiomys*) and an anterior loop; usually three rooted M_1 and M^1; two rooted M_2 and M^2 and two rooted M_3 and M^3. *Kilarcola kashmiriensis* is more advanced rodent as shown by the higher dentine tracts on the labial side of M_1. The fourth and fifth alternating triangles in *Kilarcola kashmiriensis* are not exactly opposite to each other. There is no enamel pit on M_1 of *Kilarcola* whereas *Ophiomys* may or may not have the enamel pit on M_1. The prism fold and enamel pits are present on M_2 in some species of *Ophiomys* (Hibbard and Zakrzewski, 1967). The anterior loop in *Kilarcola kashmiriensis* shows greater simplicity.

The second oldest microtine, *Ogmodontomys* (Hibbard, 1964) which is to be considered as ancestral to *Ophiomys* (Hibbard and Zakrzewski, 1967), was recovered from Saw Rock Canyon fauna of Kansas. *Kilarcola* also resembles *Ogmodontomys*. The apices of the second and third lingual and the second labial re-entrant angles constricted more sharply anteriorly in *Kilarcola*. This character distinguishes it from *Ogmodontomys*. The enamel pit reported on the M^3 of *Ogmodontomys* by Zakrzewski (1967) from Rexroad Formation is found only on immature specimens and disappears immediately with wear (Hibbard and Zakrzewski, 1967). Exactly half of the M^3s of *Kilarcola* have an enamel pit.

On the basis of the present study, it can be suggested that *Ophiomys* and *Kilarcola* could have been evolved from the genus, like *Ogmodontomys*.

Among rapidly evolving mammals, the rodents are outstanding. The microtine group of rodents has been sufficiently examined in North America and Europe in the correlation of global critieria to produce a functional biochronology for the Quaternary. The microtines are temperate to arctic rodents and their biochronologic use is thus restricted (Repenning, pers. comm.). Few have penetrated Central America, northern India and northeastern Asia. The microtines are extensively used in North America to differentiate between the Plio-Pleistocene faunal assemblages (Skinner and Hibbard, 1972 ; Jacobs and Flynn, 1981). It may be noted that at the Olduvai event, a number of small mammals have been reported from northern Pakistan (Opdyke, *et al.*, 1979). Lindsay *et al.* (1980) have pointed out a dispersal event at approximately 1.9 Myr which corresponds with a good approximation of the transition from middle to late Villafranchian. The Potwar locality of Pakistan, yielding the early Pleistocene rodents is younger than 1.9 Myr and probably correlates with Villafranchian (Jacobs, 1978).

Below the Olduvai event and between the Olduvai and the Jaramillo magnetic events, the biochronology of microtine rodents in the Karewas, is so far not available. Microtines are again discovered from Sombur bone bed which is younger than 730,000 years (Brunhes/Matuyama boundary). So far Sombur bone bed has yielded only incisors similar to Kilar specimens. The Sombur fauna with additional discovery of jaws and teeth can, in future, be assigned to a different microtine genus.

PALAEOECOLOGY

The present rodent collection consists of a number of isolated incisors and upper and lower molars of microtine rodents. The Kilar bone bed is also characterised by numerous fish teeth, gastropod shells, remains of *Equus sivalensis* and soricid insectivores. Simiarly, Krachipatra ossiferous horizon has yielded fresh water ostracodes, cyprinid fishes and fragmentary mammalian bones. Sombur bone bed is characterised by abundant fish remains, bird egg shell fragments, lizards and remains of *Elephas hysudricus*. The changes in sandstone body geometry at Kilar and Krachipatra suggest a change in fluvial regime. It may be assumed that the vertebrates were living in abundance around the periphery of a land-locked water areas. The bar finger sands must have been produced by the rivers and channels (Singh, 1982). At Sombur, the sand bodies embedded in mudstones represent lake delta sequences (Singh, 1982). It may therefore be suggested that these sandstones represent subaqueous parts of the delta distributaries.

Based on the faunal assemblages of the Karewa beds, Kotlia (1984) reconstructed the Karawa palaeocommunities, i.e. upland community, megaterrestrial community and lacustrine community. The author opines that the microtine rodents and Schizothoracinae fishes form a part of Karewa upland community. The presence of microtines indicates cold mountainous regions, corresponding to the present day distribution of the Himalayan voles. In India, voles are found only in the higher levels of the Himalayas, Kashmir, Ladakh and Tibet. Himalayan vole (*Alticola roylei*) is known to occur at high altitudes of 3000 m (Prater, 1971). The Murree vole (*Hyperacrius wynnei*) and the Sikkim vole (*Pitymys sikimensis*) are found at elevations ranging from 2100m-3700m. Microtines also live in highlands to the north of Potwar Plateau (Roberts, 1977). The voles are certainly derived from the upland streams and probably washed down from hill streams to be deposited in the more low-lying Karewa basin as all the microtine rodents were recovered from the sediments resembling channel facies. At present, schizothoracine fishes have been recovered from altitudes as high as 3600 m (Mukherji, 1936 ; Kotlia, 1984). This indicates that the mountains surrounding the Karewa basin were at least of this altitude during the time of deposition of the above ossiferous horizons while the basin itself was at about 1500 m m.s.l.

The Karewa micromammalian fauna, described herein, is characterised largely by the microtine rodents together with murids and insectivores. So far, microtines have as yet not been found in the nearby Upper Siwalik molasse, Pinjor Formation of which resembles the Karewas. Among the Upper Siwalik aged rodents, rhizomyids, ctenodactylids and thryonomyids from the Neogene Siwalik deposits of India and Pakistan were worked out by Black (1972) and subsequently by Jacobs (1978). Flynn (1982) carried out comparative biochronology of India and Pakistan and suggested that the rhizomyid record which shows strong affinity between India and Pakistan at Miocene, differs by the Pliocene. The reason for this differentiation according to Flynn (1982) might reflect the late Neogene biostratigraphic division of the Indian subcontinent caused by ecological partitioning. In fact, the rhizomyids are one of the most common and important elements to provide chronology and palaeoecology in the Upper Siwaliks. In the Karewas of Kashmir, on the other hand, the dominant rodents are the microtines which constitute nearly 95% of the micromammal component. The distributional disparity is probably a result of palaeoecological differences because even after allowing for Pleistocene uplifts in the Kashmir area, the Karewa deposits appear to have been deposited at a higher elevation than those in the Pinjor basin. This hypothesis gets further support from the nearly continuous vertical distribution of Schizothoracine fishes which presently are found at higher altitude. These fishes are still unknown in the Pinjor Formation as the Pinjors were deposited by the meandering rivers in a flood plain and the water which laid down the Siwaliks came from the adjacent mountains which were at a considerable altitude. Therefore the reason for the disparity in type of rodents and fishes found both in Karewas and Upper Siwaliks is also a result of ecological and palaeoecological differences.

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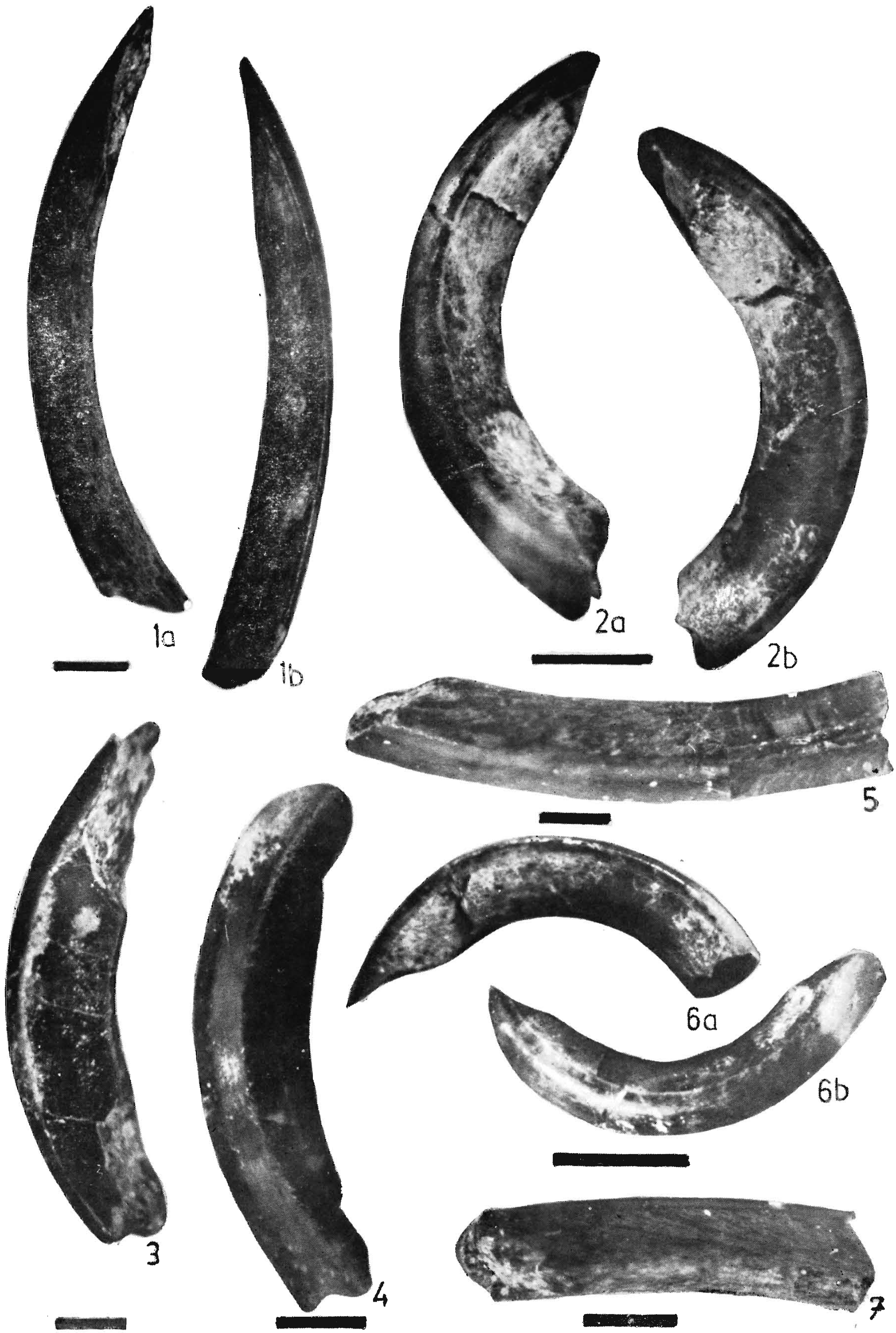
EXPLANATIONS OF PLATES

PLATE I

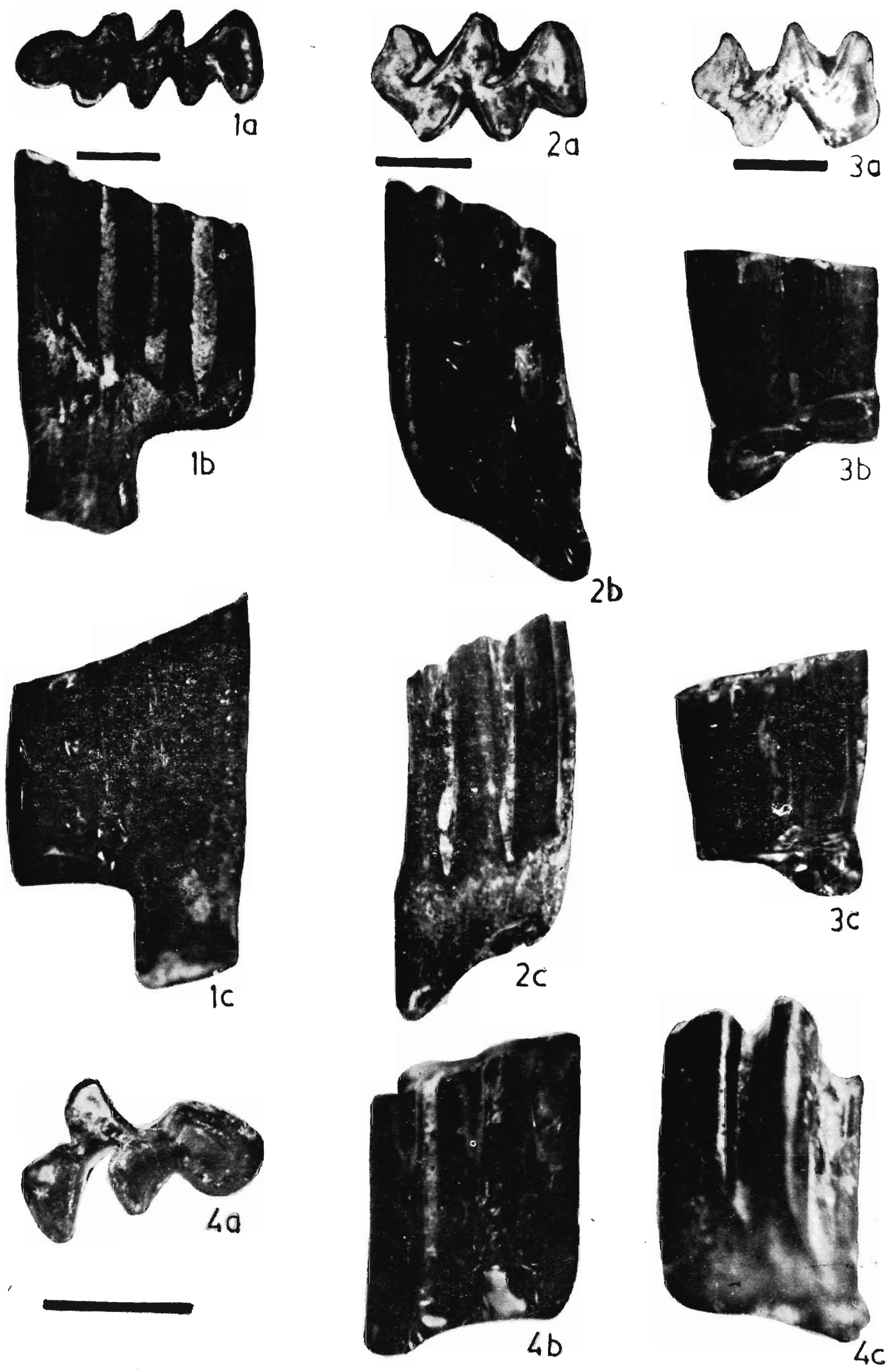
(Bar represents 1 mm. All are lateral views)

Kilarcola kashmiriensis, Kotlia

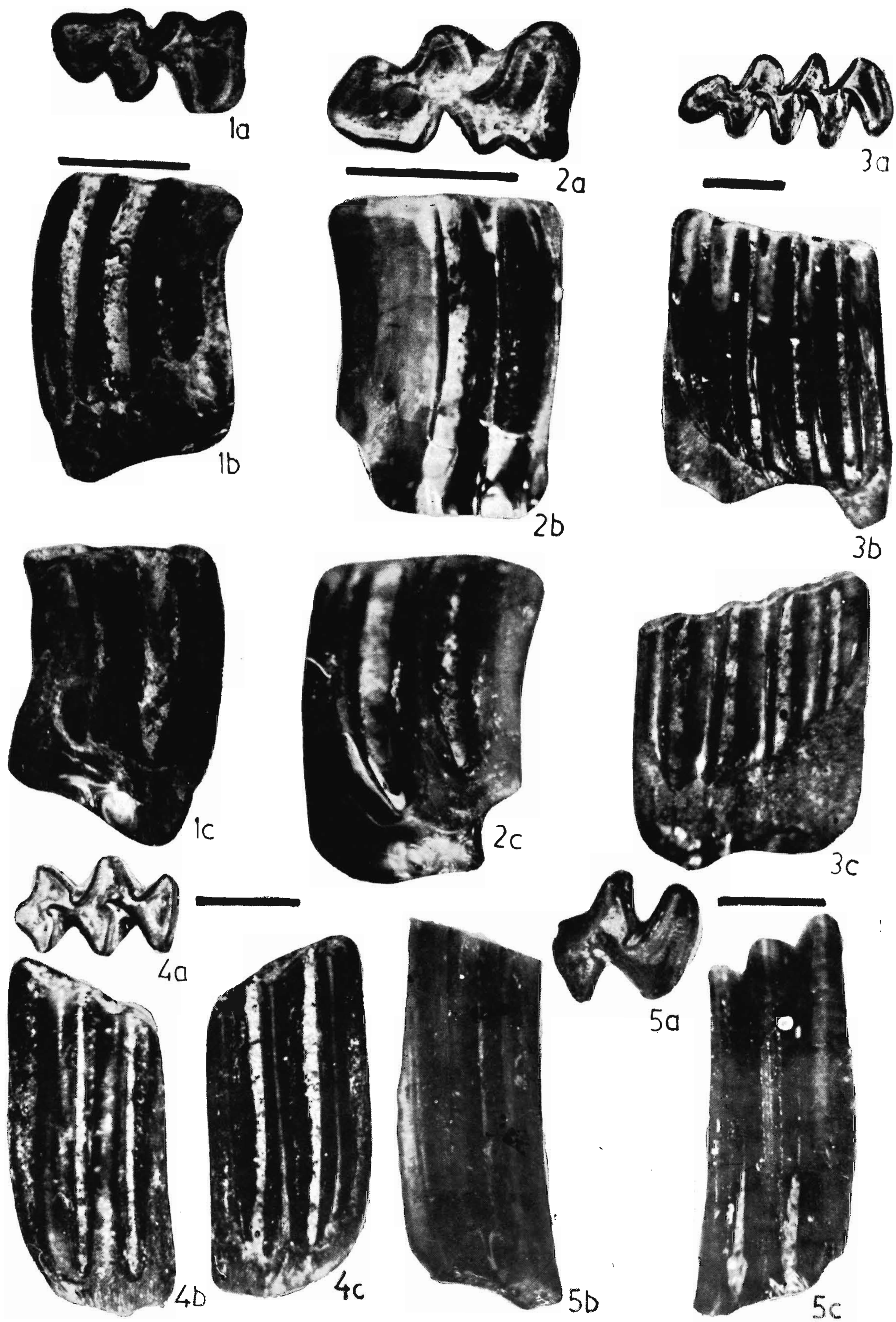
1.	VPL/B 2016,	isolated incisors
2.	VPL/B 2017,	-do-
3.	VPL/B 2018,	-do-
4.	VPL/B 2019,	-do-
5.	VPL/B 2020,	-do-
6.	VPL/B 2021,	-do-
7.	VPL/B 2022,	-do-

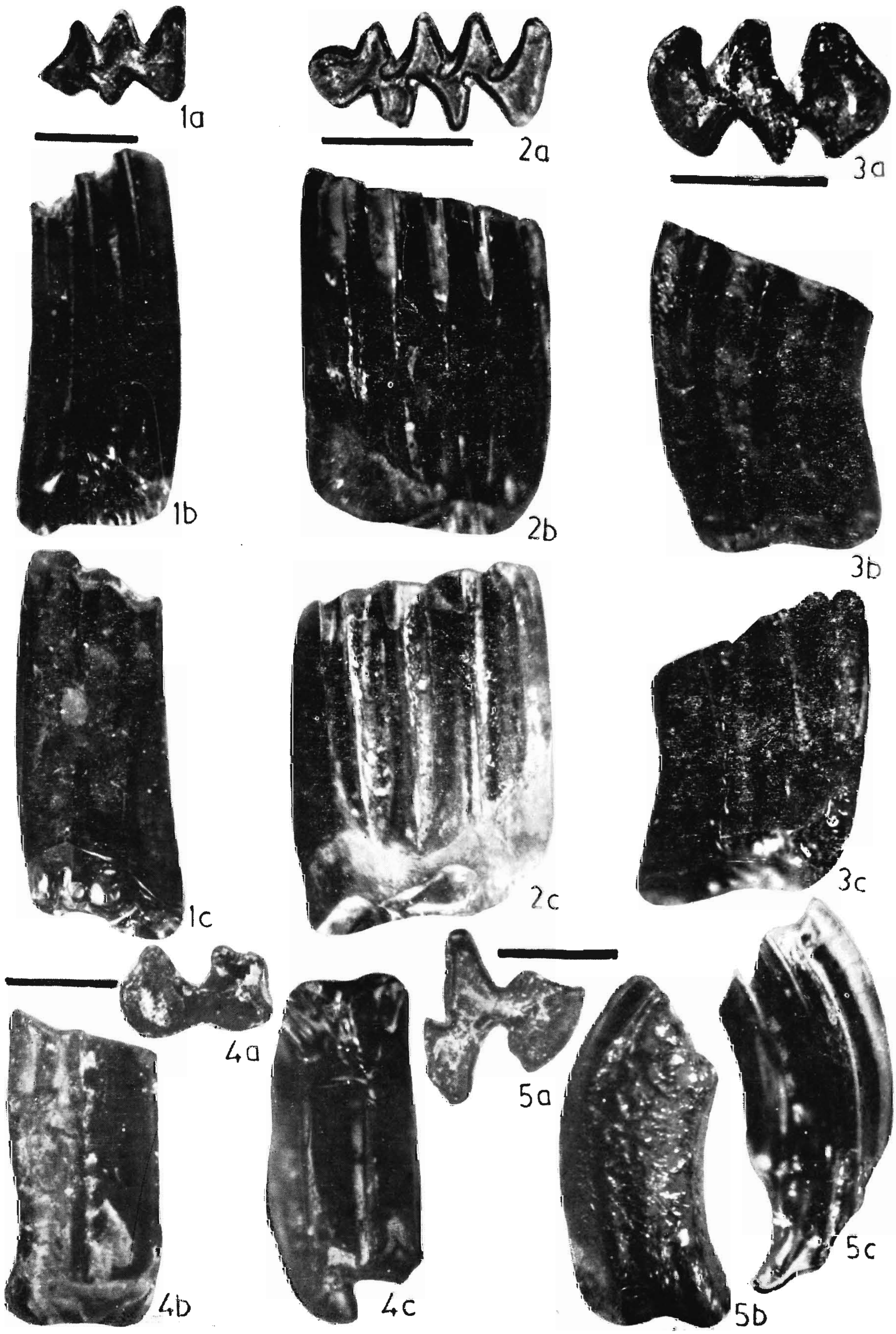


KOTLIA



KOTLIA


1a
2a
3a
1b
2b
3b
1c
2c
3c
4a
5a
4b
4c
5b
5c



KOTLIA

PLATE II

(Bar represents 1 mm. a, b, c are occlusal, lingual and labial views respectively)

Kilarcola kashmiriensis Kotlia

1. VPL/B 2001, isolated RM_1 (paratype)
2. VPL/B 2002, isolated RM^1
3. VPL/B 2003, isolated RM^2
4. VPL/B 2004, isolated LM_3

PLATE III

(Bar represents 1 mm. a, b, c are occlusal, lingual and labial views respectively)

Kilarcola kashmiriensis Kotlia

1. VPL/B 2005, isolated RM^3
2. VPL/B 2006, isolated LM^3
3. VPL/B 2007, isolated RM_1 (holotype)
4. VPL/B 2008, isolated LM^1
5. VPL/B 2009, isolated molar

PLATE IV

(Bar represents 1 mm. a, b, c are occlusal, lingual and labial views respectively)

Kilarcola kashmiriensis Kotlia

1. VPL/B 2013, isolated LM_2
2. VPL/B 2014, isolated LM_1
3. VPL/B 2015, isolated RM_2
4. VPL/B 2023, isolated molar
5. VPL/B 2024, isolated molar