unoxidized residual organic carbon (non-metabolizable fraction). Studies on Late Devonian Ohio Shale[15] show a pronounced decrease of ~77% in organic carbon near soil profile accompanied by a pronounced decrease in Re (~99%) and to a lesser extent Os (~39%). The Ganga river at Farakka (Gan10S) where the sediments are derived from up-, mid- and downstream parts of the Ganga as well as all the major tributaries, show high Os (51.7 pg g^{-1}), Re (0.63 ng g^{-1}) and $^{187}Os/^{188}Os$ ratio (2.4) indicating the presence and transport of radiogenic sediments from all sources.

Table 2 presents Re and Os load in the Ganga at various locations based on discharge data of Rao[16] and Sarin *et al.*[12] (as recent discharge data are difficult to obtain), and suspended sediment concentration in the present samples. The Os flux by sediments in the upper reaches is around 0.3 kg yr^{-1}, which increases to 12 kg yr^{-1} at Farakka (Gan10S), the farthest downstream location. This is an increase of about 40 times, which probably gets transported to the Bay of Bengal if there is no burial and other estuarine processes acting in the removal of Re and Os from the sediments.

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Middle Eocene prosimian primate from the Subathu Group of Kalakot, northwestern Himalaya, India

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An upper molar tooth of a possibly new but unnamed prosimian primate (Mammalia, Primates) is described from the Middle Eocene, in the uppermost part of the Subathu Group exposed east of Babbian Gala near Kalakot (northwestern Outer Himalaya) in the Rajauri District, Jammu and Kashmir, India. To the best of our knowledge, this is the first pre-Siwalik primate from India and the only primate tooth identified thus far in a remarkably rich and varied land mammal fauna known from the red beds of the Subathu Group. Its occurrence is significant, as the Eocene primates of the Indian subcontinent are important for understanding the early primate radiation in Asia.

IN the last three decades, dental and skeletal remains of a number of small-to-medium-sized terrestrial mammals representing Creodonta, Condylarthra, Rodentia, Artiodactyla, Perissodactyla, Proboscidea, and basal Cetacea have been documented from the Middle Eocene horizons of the Subathu Group, northwestern Outer Himalaya, India[1–11]. In such varied and rich fauna, the absence of primates was intriguing, especially in view of the fact that largely similar fauna from the coeval beds of the Kuldana Formation in Pakistan includes at least five primate species, though based mostly on isolated teeth.

Here we report a possibly new but unnamed Eocene primate species from the red beds of the uppermost Subathu Group of Kalakot, Rajauri District, Jammu and Kashmir (India). The Kalakot primate is represented by a single molar tooth and its documentation is important because (i) to the best of our knowledge it is the first pre-Siwalik and Eocene primate from India (ii) it is based on an upper molar tooth, whereas the previously recorded Eocene primates from the coeval beds of Pakistan are known by lower teeth; (iii) it is metrically and morphologically distinct from the known Eocene primates, and (iv) it increases the known diversity, size range and geographic range of Indo-Pakistan Eocene primates. The report of an Eocene primate from India is also significant because early primates from Asia are less known in comparison to Europe and North America. Prior to this

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report, the Eocene primate remains from Asia were recorded from Pakistan[12–15], China[16–21], Mongolia[22], Myanmar[23–27] and Thailand[28–29].

The molar tooth from Kalakot attributed here to a prosimian primate, was earlier mistakenly referred to *Diacodexis pakistanensis* by Kumar and Jolly[30], who had reported this primitive dichobunid artiodactyle based on fragmentary LM1/ and RM3/, and complete LP/3 and RM2/. A subsequent study of these teeth by the present authors suggests that the RM2/ (VPL/K 555, new no. WIMF/A 1611) referred in the work of Kumar and Jolly[30] to *Diacodexis*, belongs to a primate. We can say this on the basis of the transverse nature of the tooth with an extended and triangular lingual part, poorly developed metaconule, and presence of a distinct parastyle. In *D. pakistanensis*, the M2/ is triangular but its length and width are subequal, both paraconule (=protoconule) and metaconule are equally well developed, a parastyle is lacking and teeth are somewhat bunodont. The taxonomic status of rest of the material (VPL/J 101 and 102, isolated fragmentary LM1/ and RM3/: VPL/J 103, an isolated LP/3) that was referred to *D. pakistanensis* by Kumar and Jolly[30], remains unchanged.

The primate tooth reported here was collected from red beds of the upper part of the Subathu Group, East of Babbian Gala (EBGL) locality that is best known for the Middle Eocene rodents[6,10–11,31], but has also yielded other mammals[7–9], pristichampsine crocodiles[31,32], and pycnodont, osteoglossid and silurid fish remains[33,34]. The red beds of the Late Paleocene–Middle Eocene Subathu Group yield rich land vertebrate remains at several localities in Himachal Pradesh and Jammu and Kashmir, and depict a faunal and sedimentary transition from a marine set-up to brackish and fluvial conditions[35,36]. At EBGL, the main fossiliferous bed is a 10 to 15 cm thick band of purple 'pisolitic' granulestone, which occurs sandwiched within the purple shale in a road section near Culvert number 69/3, 15 km east of Kalakot on Metka-Mohgala Road, Rajauri District (Figure 1). A taphonomic study of the EBGL bone assemblage has indicated that the rodent remains concentrated here were initially accumulated in the mammalian predator scats and later deposited as lag concentrate under fluvio-deltaic conditions[37].

The Kalakot primate tooth shows a number of primitive features that clearly distinguish it from the teeth of primitive anthropoids, which are characterized by quadrangular outline, tetracuspate crown and complete lingual cingulum. Among the prosimians, it has similarities with the teeth of adapids as well as omomyids. However, it looks more akin to the former in features like lingually bent buccal cusps, labially slanted protocone and reduced metaconule.

The specimen referred and illustrated in this work was previously in the personal collection of K.K. (number VPL/K 555). It is now registered as WIMF/A 1611 with the Museum of the Wadia Institute of Himalayan Geology, Dehradun.

Order Primates Linnaeus, 1758
Suborder Prosimii Illiger, 1811
Infraorder ?Adapiformes Hoffstetter, 1977
Genus & species indeterminate
(Figures 2, 3)

WIMF/A 1611, an isolated right upper second molar (M2/) is triangular and very transverse (length = 3.5 mm, width = 5.3 mm); protocone, paracone and metacone well developed; hypocone absent; paracone and metacone slightly lingually bent; protocone robust and labially slanted with an extensive (2.5 mm) lingual slope; para cone larger and slightly more labially extended than

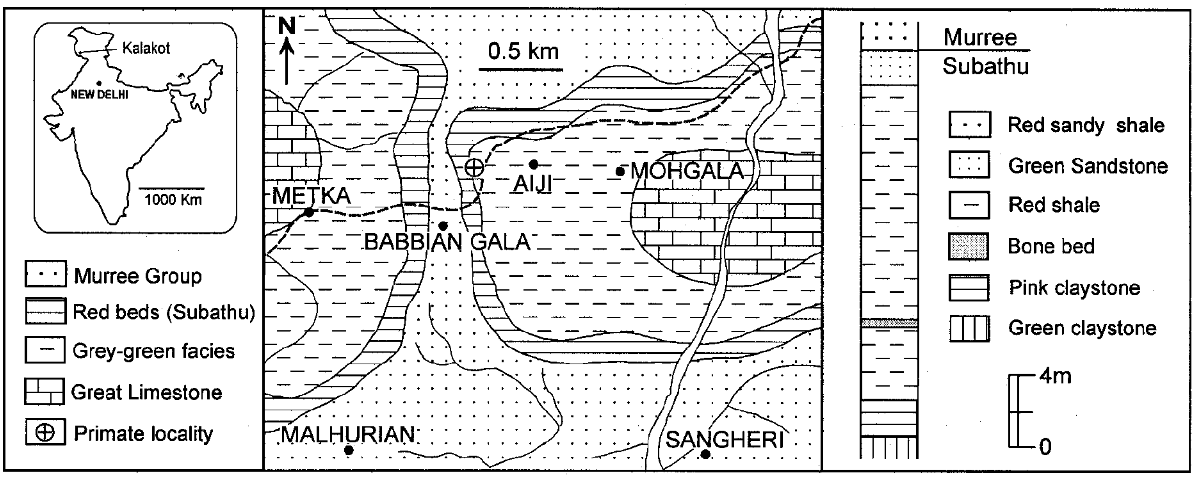

Figure 1. Location and geological map of Babbian Gala near Kalakot (northwest Outer Himalaya), Rajauri District, Jammu and Kashmir showing the fossil locality, and a stratigraphic column of the primate tooth-yielding section (EBGL) showing position of the fossiliferous bed with respect to the Subathu–Murree boundary.

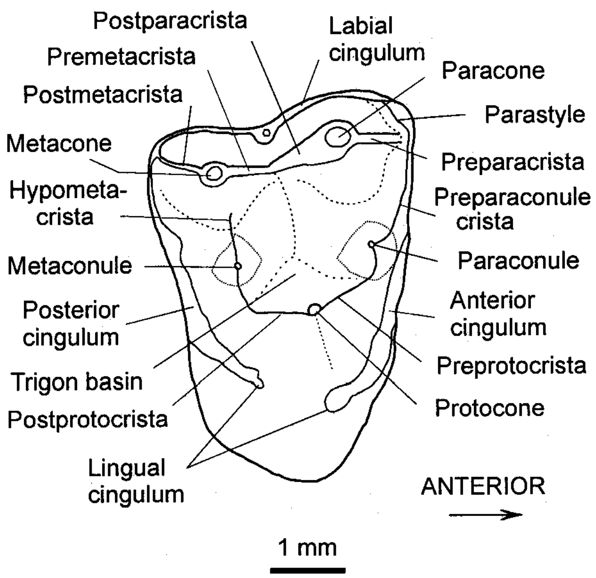

Figure 2. WIMF/A 1611, line drawing of RM2/ in occlusal view showing terminology used in text.

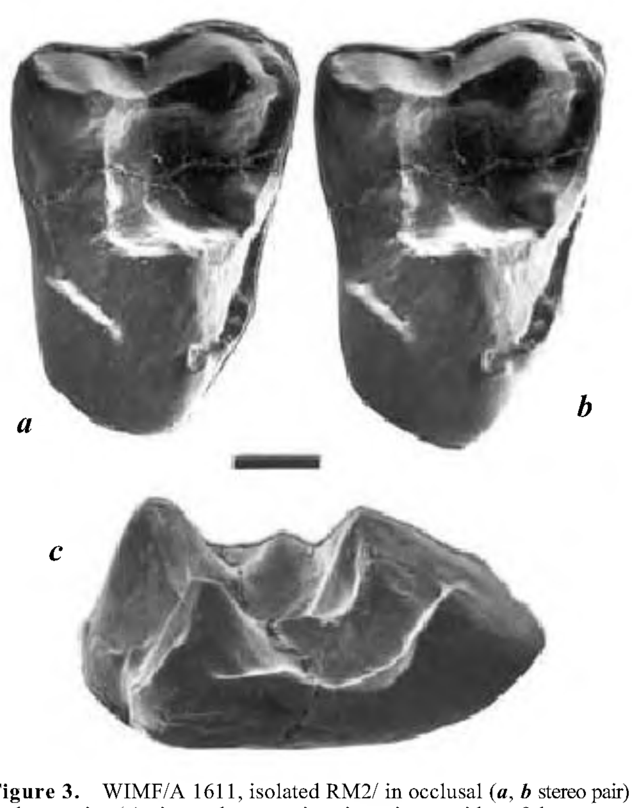

Figure 3. WIMF/A 1611, isolated RM2/ in occlusal (*a*, *b* stereo pair) and posterior (*c*) views; the posterior view gives an idea of the crown-height. Scale bar equals 1 mm.

metacone; paraconule and parastyle small but distinct; metaconule reduced; postparacrista and premetacrista sharp and form a V-shaped shearing edge; preparacrista blends with the parastyle, whereas postmetacrista joins the posterolabial cingulum; hypoparacrista absent; hypometacrista short and restricted near the base of metacone; paraconule separated from the paracone by a longitudinal valley and joined to the parastyle by the preparaconule crista; it is slightly anteriorly shifted from the line of protocone and paracone; preprotocrista runs from the apex of protocone to the base of paraconule, where a shallow valley separates it from the latter; metaconule joined to the protocone by an arcuate postprotocrista; postmetaconule crista absent. The protoloph comprising preprotocrista and preparaconule crista and metaloph consisting of postprotocrista and hypometacrista encompass a deeply excavated U-shaped trigon. The anterior cingulum originates below the paraconule, runs lingually and terminates at the lingual base of protocone. The posterior cingulum starts a little short of metacone and extends slightly on the lingual side. The lingual ends of the anterior and posterior cingula do not meet. So the lingual cingulum is discontinuous. The labial cingulum is weak.

The primate M2/ from Kalakot resembles corresponding teeth of European and North American adapiforms *Europolemur*, *Mahgarita*, *Pronycticebus* and *Anchomomys* in lacking a postprotocone fold (= *Nannopithex* fold) and in reduced metaconule, but differs from them in lacking a hypocone. *Europolemur* and *Mahgarita* also differ from it in possessing a continuous lingual cingulum. With respect to lingual cingulum, Kalakot M2/ is similar to *Anchomomys* M2/, but size-wise it is larger. WIMF/A 1611 differs from the teeth of *Periconodon*, *Microadapis*, *Leptadapis*, *Adapis*, *Afromonius* and *Djebelemur*, in lacking a hypocone. *Cantius torresi*, the oldest primate of modern aspect from North America is metrically similar to WIMF/A 1611, but it differs from the latter in tooth shape (squarish as opposed to triangular), and in possessing a *Nannopithex* fold and larger metaconule. *Adapoides*, a middle Eocene adapid from Shanghuang (China)[21] is over 20% smaller than Kalakot primate and has less transverse upper molars. Its M1-2/ (IVPP V11021) also differs from WIMF/A 1611 in being less triangular and in possessing continuous lingual cingulum and a small hypocone. Two anterior upper molars (IVPP V11019 and 11020) also from Shanghuang[21] referred to *Europolemur*-like adapiform are quite similar to Kalakot M2/, but differ from the latter in being considerably smaller, less transverse (L/W = 0.77), and in possessing less (labially) slanted protocone. *Hoanghonius*[16] and *Rencunius*[17] from China differ from WIMF/A 1611 in possessing pericone and hypocone and larger metaconule. *Petrolemur*, a Late Paleocene adapid from China[38] is smaller and also differs from Kalakot primate in possessing a rectangular and less transverse M2/ with complete lingual cingulum. *Wailekia*, a sivaladapid from Thailand[29] is much larger.

Five Eocene primate species, viz. *Kohatius coppensi*, *Kohatius* sp. ‘A’, cf. *Kohatius* sp. (omomyids), *Panobius* *afridi* and cf. *Agerinia* sp. (adapids) from Pakistan, are all based on lower teeth[12–15]. Metrically, the Kalakot M2/ is substantially larger to be conspecific with any of these. *A. roselli*, the European species of *Agerinia*, is more or less of the same size as Kalakot species, but its upper molars[39] possess a *Nannopithex*-fold, which is lacking in the latter.

Among omomyids, the Kalakot primate shows considerable similarity with *Teilhardina* and *Donrussellia*. It resembles the former in tooth shape, especially its length/width proportion, extended lingual slope of protocone, and in lacking a hypocone; but *Teilhardina* is smaller and also differs in possessing a well-developed metaconule and an incipient postprotocone fold. Upper molars of *Donrussellia* are strikingly similar to WIMF/A 1611, but differ in being smaller and somewhat squared. Other omomyids, viz. *Anaptomorphus*, *Tetonius*, *Absarokius* and *Anemorhysis*, differ from Kalakot M2/ in possessing a postprotocone fold. *Omomys* lacks a postprotocone fold, but it possesses distinct hypocone and pericone. *Altanius* from Mongolia[22] is tiny in comparison to Kalakot primate, whereas *Macrotarsius*[19] and *Asiomomys*[21] from China are larger. *Lushius* also from China[18] has M2/ with characteristically continuous ectoloph and a small hypocone.

The Kalakot primate differs from similar-sized Eocene anthropoid primates in tooth shape as well as crown morphology. *Bahinia* and *Pondaungia* from Myanmar have tetracuspate molars with distinct hypocones. Lower molars of *Amphipithecus*, another anthropoid from Myanmar, and of *Eosimias*, a basal simian from China[19] are considerably larger compared to WIMF/A 1611. *Myanmarpithecus*, a latest Middle Eocene anthropoid from the Pondaung Formation of Myanmar[27] is in the size range of Kalakot primate, but it has a rectangular to pentagonal M2/ with low inflated cusps and a hypocone that is separated from the postprotocrista by a groove. M2/ of *Siamopithecus*, a Late Eocene anthropoid from the Krabi Formation of Thailand[28] also possesses a large and widely separated hypocone, which is lacking in WIMF/A 1611.

Thus the Kalakot primate molar most closely resembles the European adapiforms like *Europolemur* and *Donrussellia*, and a *Europolemur*-like unnamed species from China. Such relationship is in consonance with the published faunal records - a European genus *Agerinia* is among the Eocene primates already known from the coeval deposits in Pakistan. Besides this, several other European elements, viz. dichobunid artiodactyls and helaletid perissodactyls are also represented in the Indo-Pakistan Eocene land mammal faunas. So the Kalakot primate may well be an European immigrant. It may have come to the Indo-Pakistan region from Europe via Asia sometime in early Eocene, as also suggested by the presence of a *Europolemur*-like form in China and several Eurasiatic elements in the Indo-Pakistan Eocene faunas[40].

The cusp and crest morphology and moderate crown height of M2/ point towards an omnivorous (insectivorous and frugivorous) dietary regime for the Kalakot primate. The body weight of Kalakot primate, based on extrapolation[41] from tooth dimensions of contemporary adapids, is estimated to be around 1000 g. This is the largest among the known Eocene primates from the Indo-Pakistan region. With the report of this prosimian from Kalakot, the Indo-Pakistan Eocene primates now comprise at least six species, all of which are non-anthropoids.

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Implications of novel results about Moho from magnetotelluric studies

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Moho boundary is well established on the basis of seismological studies. Magnetotelluric (MT) studies have not been able to establish this boundary due to the presence of highly conducting continental lower crust (CLC). MT studies over the Eastern Indian (3.3 Gyr) and Slave (4.03 Gyr) cratons resolve the crust–mantle boundary due to the absence of highly conducting CLC. The upper mantle beneath these two cratons cannot be of pure olivine as resistivity of the uppermost mantle is much less than the laboratory studies on pure olivine. From these two studies it can be speculated that a dynamics other than the plate tectonics possibly existed up to the mid-Archaean.

THE electrical conductivity of rocks is more closely related to geochemical changes than other bulk physical properties such as acoustics impedance, density and seismic velocity. The magnetotelluric (MT) method used for the investigations of deeper structures, therefore, provides complementary, sometimes supportive but other times alternative interpretations of geochemical characters in geological units. It has been suggested on the basis of laboratory studies that for dry rock assemblages there may be an observable difference in conductivity between deep crustal mafic and upper mantle ultramafic rocks[1].

Ionic conduction is a dominant type of conduction in the crust and upper mantle. It is responsible for conduction in fluids and also for olivines at high temperatures. Dry silicate rocks are highly resistive. The electronic conduction in most solids is a thermally activated process governed by the appropriate activation energy for the material, Boltzmann constant and the absolute temperature. A region of enhanced electrical conductivity therefore represents interconnected network of fluid and/or mineral conducting phase. The enhanced conductivity of the continental lower crust (CLC) remains one of the puzzles regarding the earth about which comparatively little is known. This characteristic of the deep crust has been observed globally, using MT method, but explanations for its existence remain controversial. The enhanced conductivity of CLC can be explained either by interconnected brine below the brittle–ductile transition[2–6] or by interconnected, thin, grain-boundary carbon film[7,8]. The MT method becomes unsuitable in determining the depth of Moho due to the presence of highly conducting CLC. The presence of enhanced conductivity in CLC limits the ability to resolve the uppermost mantle conductivity structure and only a maximum limit can be placed on its value[9]. Therefore, in such cases, upper mantle resistivity and the nature of olivine as upper mantle constituent cannot be determined. Thus, when the enhanced conductivity of CLC is absent, only then can one resolve the conductivity structure of the uppermost mantle. Here we report the definite identification of crust–mantle boundary due to the lack of a conducting lower crust over Eastern Indian Craton (EIC)[10–12] and Slave province, Canada[13] using MT data and discuss its implication in delineating the crust–mantle boundary.

The eastern part of the Indian Precambrian shield is characterized by Archaean nucleus of Singhbhum Granite (SG) batholithic complex and ancient supracrustals surrounded by several elongate and arcuate Proterozoic belts. The major units of the EIC are shown in Figure 1[14]. This Archaean nucleus is bounded by the arcuate Copper Belt thrust zone (or Singhbhum shear zone) in the east, north and northwest and Sukhinda thrust in the south (not shown in Figure 1). Geochronologically, the Archaean nucleus is at least ~ 3.3 Gyr old[15], represented by tonalite–trondhjemite–gneiss (TTG) and amphibolites of older metamorphic group (OMG). The OMG rocks are intruded by SG of ~ 3 Gyr age which occupies most of the craton. Both OMG and SG are unconformably overlain by supracrustals of Iron Ore Group (IOG) rocks con-

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