= Bharattherium =

Bharattherium is a mammal that lived in India during the Maastrichtian (latest Cretaceous) . The genus has a single species , Bharattherium bonapartei . It is part of the gondwanathere family Sudamericidae , which is also found in Madagascar and South America during the latest Cretaceous . The first fossil of Bharattherium was discovered in 1989 and published in 1997 , but the animal was not named until 2007 , when two teams independently named the animal Bharattherium bonapartei and Dakshina jederi . The latter name is now a synonym . Bharattherium is known from a total of eight isolated fossil teeth , including one incisor and seven molariforms (molar @-@ like teeth , either premolars or true molars) .

Bharattherium molariforms are high , curved teeth , with a height of 6 to 8 @.@ 5 millimetres (0 @.@ 24 to 0 @.@ 33 in) . In a number of teeth tentatively identified as fourth lower molariforms (mf4) , there is a large furrow on one side and a deep cavity (infundibulum) in the middle of the tooth . Another tooth , perhaps a third lower molariform , has two furrows on one side and three infundibula on the other . The tooth enamel has traits that have been interpreted as protecting against cracks in the teeth . The hypsodont (high @-@ crowned) teeth of sudamericids like Bharattherium are reminiscent of later grazing mammals , and the discovery of grass in Indian fossil sites contemporaneous with those yielding Bharattherium suggest that sudamericids were indeed grazers .

= = Taxonomy = =

A gondwanathere tooth , catalogued as VPL / JU / NKIM / 25 , was first discovered in the Maastrichtian (latest Cretaceous , about 70 ? 66 million years ago) Intertrappean Beds of Naskal , India , in 1989 , but it was not identified as such until another gondwanathere , Lavanify , was found on Madagascar in the middle 1990s . The discoveries of Lavanify and VPL / JU / NKIM / 25 were announced in Nature in 1997 . Gondwanatheres were previously known only from Argentina ; these discoveries extended the range of the gondwanathere family Sudamericidae across the continents of the ancient supercontinent of Gondwana .

In 2007 , two teams of scientists independently named the Indian gondwanathere on the basis of new material ; both teams included VPL / JU / NKIM / 25 in their newly named species . Guntupalli Prasad and colleagues named the animal Bharattherium bonapartei on the basis of an additional tooth , VPL / JU / IM / 33 , from another Intertrappean locality , Kisalpuri . The generic name , Bharattherium , combines Bharat , Sanskrit for " India " , with the Ancient Greek therion , meaning " beast " , and the specific name , bonapartei , honors Argentine paleontologist José Bonaparte , who was the first to describe a gondwanathere fossil . G.P. Wilson and colleagues named Dakshina jederi on the basis of six teeth (in addition to VPL / JU / NKIM 25) , and identified some additional material as indeterminate gondwanatheres . Of these teeth , three (GSI / SR / PAL @-@ G059 , G070 , and G074) are from a third Intertrappean site at Gokak and three (GSI / SR / PAL @-@ N071 , N210 , and N212) are from Naskal . Dakshina , the generic name , derives from Sanskrit daakshinaatya " of the south " , and refers both to the animal 's occurrence in southern India and to the distribution of gondwanatheres in the southern continents . The specific name , jederi , honors University of Michigan paleontologist Jeffrey A. Wilson , nicknamed " Jeder " , who played an important role in the project that led to the discovery of Dakshina . Wilson and colleagues also described three other gondwanathere teeth from Gokak (GSI / SR / PAL @-@ G111 , G112 , and G211) , which they tentatively identified as a different species of gondwanathere on their small size . In 2008 , Prasad commented that Bharattherium bonapartei and Dakshina jederi represented the same species and that Bharattherium , which was published first , was the correct name .

= = Description = =

Bharattherium bonapartei is known from a total of eight isolated teeth . Among the seven teeth in their sample , Wilson and colleagues tentatively identified five as fourth lower molariforms (mf4) ?

because gondwanathere premolars and molars cannot be distinguished , they are collectively known as " molariforms " ? one as a third lower molariform (mf3) and one as a lower incisor (i1) . These determinations were made on the basis of comparisons with a sample of the South American gondwanathere Sudamerica ameghinoi , in which all eight molariform positions are known . However , the large number of mf4s led Wilson and colleagues to suspect that the criteria used for distinguishing Sudamerica tooth positions may not apply directly to Bharattherium . Prasad and colleagues did not assign their two Bharattherium teeth to any tooth position , but suggested that they may represent different tooth positions and that one may come from the upper and the other from the lower side of the jaw . As is characteristic of sudamericids , Bharattherium molariforms are hypsodont (high @-@ crowned) and have a flat occlusal (chewing) surface atop a high tooth , with furrows that extend down the height of the tooth . Bharattherium molariforms are the smallest of any sudamericid ; those of Lavanify , for example , are about 35 % larger . Unlike Sudamerica molariforms , those of Bharattherium taper towards the top .

= = = Molariforms = = =

GSI / SR / PAL @-@ G074 , a well @-@ preserved right mf4 that Wilson and colleagues selected as the holotype of Dakshina jederi , is 7 @.@ 57 mm high and has a crown of 3 @.@ 66 × 2 @.@ 99 mm . It is curved , with the base more distal (towards the back) than the top . The occlusal surface is rectangular . On the lingual side (towards the tongue) , there is a deep furrow (filled in part with cementum) that extends from the top to near the base of the tooth . There is also a much smaller indentation on the buccal side (towards the cheeks) . The occlusal surface is mostly covered with enamel surrounding a dentine lake , but there is a V @-@ shaped islet in the middle , with the tip of the V towards the lingual side , that forms the remnant of an infundibulum ? a deep cavity in the tooth . Perikymata ? wave @-@ like bands and grooves ? are visible in the enamel .

The right mf4 GSI / SR / PAL @-@ G070 , which is damaged on the buccal , distal , and lingual sides , is 8 @.@ 40 mm high , but has an occlusal surface of only 2 @.@ 49 × 1 @.@ 75 mm . Unlike in GSI / SR / PAL @-@ G074 , the dentine on the occlusal surface is not exposed , and the occlusal surface is oval in shape . Furthermore , the V @-@ shaped islet is larger and the lingual furrow is less prominent at the occlusal surface , because it tapers near the tip of the tooth . In the heavily damaged left mf4 GSI / SR / PAL @-@ N071 (height 7 @.@ 16 mm) , only the distal side is well preserved . The infundibulum is exposed internally ; it extends 4 @.@ 01 mm down the crown . The occlusal surface is poorly preserved , but its dimensions are at least 2 @.@ 14 × 2 @.@ 42 mm . GSI / SR / PAL @-@ N212 , a right mf4 , is damaged on the mesial side and has a height of 5 @.@ 86 mm and an occlusal surface of at least 2 @.@ 66 x 2 @.@ 04 mm . Cementum fills the V @-@ shaped islet .

VPL / JU / NKIM / 25 was the first Indian gondwanathere fossil to be described ; it is damaged on one side . Wilson and colleagues identified it as a left mf4 (implying that the damaged side is buccal) with strong similarities to GSI / SR / PAL @-@ G070 , including a curved crown and a V @-@ shaped enamel islet atop a deep infundibulum . The occlusal surface is oval . The tooth is 6 mm high and Wilson and colleagues estimate that the occlusal surface is 2 @.@ 5 × 1 @.@ 8 mm , close to the dimensions of GSI / SR / PAL @-@ G070 . They suggest the tooth probably had enamel on all sides of the crown , but Prasad and colleagues point to a possible enamel @-@ dentine junction on the damaged side as evidence that enamel may be absent there .

GSI / SR / PAL @-@ G059 , identified as a left mf3 , has a height of 5 @.@ 97 mm at the mesial side , but only 2 @.@ 02 mm at the distal side because of curvature . On the lingual side , two long furrows are visible , and on the buccal side breakage exposes three long infundibula , of which the most mesial one is the longest and the most distal one the shortest . In the occlusal surface , these three infundibula merge into a single islet . In addition , three dentine lakes are visible in the occlusal surface , which has dimensions of 4 @.@ 58 × at least 2 @.@ 52 mm . Although in Sudamerica , mf2 , mf3 , and the upper molariforms MF3 and MF4 all have three lophs , like GSI / SR / PAL @-@ G059 , its curvature matches the mf3 of Sudamerica best .

VPL / JU / IM / 33 , the holotype of Bharattherium bonapartei , is 7 @.@ 33 mm high , 2 @.@ 66

mm long , and 2 @.@ 0 mm wide . The occlusal surface is about rectangular and is mostly covered by a V @-@ shaped dentine lake , which encloses a small heart @-@ shaped enamel islet at the top of an cementum @-@ filled infundibulum . A vertical furrow is also present . Near the top of the tooth , enamel covers the entire crown , but further down there is no enamel on the concave face of the tooth .

= = = Incisor = = =

The left i1 GSI / SR / PAL @-@ N210 is flat on the medial side (towards the middle of the head) but convex on the lateral side (towards the side of the head) and bears a shallow groove on the lateral side . At the base , the tooth is broadest on the lower end . The tooth is slightly curved upward towards the tip . Measured on the lower side , the tooth is 11 @.@ 76 mm long , but breakage means the true length is probably larger . The depth of the tooth is about 3 @.@ 39 mm . Wilson and colleagues identified this incisor as Dakshina on the basis of its size ; the upper and lower incisor that they assigned to an indeterminate gondwanathere are smaller .

= = = Enamel microstructure = = =

The microstructure of the enamel of VPL / JU / NKIM / 25 has been studied . Unlike other gondwanatheres , it has enamel consisting of three layers ? radial enamel , tangential enamel , and PLEX . The rows of small , round enamel prisms are separated by interprismatic matrix that forms crystals oriented at right angles relative to the prisms . Prisms arise at the enamel @-@ dentine junction , run through the enamel , and meet the outer enamel at a high angle . These features of the enamel are apparently adaptations that protect the tooth from cracks .

= = Relationships = =

Bharattherium is identifiable as a sudamericid because it has hypsodont molariforms with cementum @-@ filled furrows . Among the four known sudamericid genera ? Gondwanatherium and Sudamerica from Argentina ; Lavanify from Madagascar ; and Bharattherium ? it shares with Sudamerica and Lavanify the presence of furrows that extend down to the base of the tooth . In addition , it shares several features with Lavanify , suggesting the two are closely related . Wilson and colleagues list three features shared by the two : the presence of an infundibulum (seen in only one of two specimens of Lavanify) , interprismatic matrix , and perikymata . Prasad and colleagues also interpreted the interprismatic matrix as a shared character , but added the absence of enamel on one side of the tooth crown . Wilson and colleagues identified the presence of a V @-@ shaped enamel lake on mf4 and of three layers in the enamel as autapmorphies (uniquely derived characters) of the Indian sudamericid .

= = Range and ecology = =

Remains of Bharattherium have been found at three widely separated Late Cretaceous sites in peninsular India ? Naskal , Andhra Pradesh ; Gokak , Karnataka ; and Kisalpuri , Madhya Pradesh . All sites are in the Intertrappean Beds (part of the Deccan Traps) and are Maastrichtian (latest Cretaceous) in age . The Intertrappean Beds have yielded a variety of fossil animals , including eutherian mammals such as Deccanolestes , Sahnitherium , and Kharmerungulatum . In the perhaps slightly older Infratrappean Beds , a possible member of the ancient and enigmatic mammalian group Haramiyida has been found , Avashishta . Members of the family Sudamericidae , in which Bharattherium is classified , are also known from the Cretaceous of Argentina , Madagascar , and possibly Tanzania and from the Paleogene of Argentina and Antarctica , and the second gondwanathere family , Ferugliotheriidae , is known with certainty only from the Cretaceous of Argentina . Thus , Bharattherium is an example of a Gondwanan faunal element in India and indicates biogeographic affinities with other Gondwanan landmasses such as Madagascar and

South America .

In modern mammals , hypsodont teeth are often associated with diets that include abrasive vegetation such as grasses . Hypsodonty in sudamericids has been interpreted as indicating semiaquatic , terrestrial habits and a diet with items like roots or bark , because it was thought that grasses had not yet appeared when sudamericids lived . However , grass remains have been found at Intertrappean sites contemporary with those where Bharattherium was found , suggesting that sudamericids like Bharattherium were indeed the first grazing mammals .