

## A report of a 157.8 m.y.-old dinosaur bone from the Jurassic marine Chari Formation, Kutch, Gujarat and its taphonomic significance

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**Record of the Middle Jurassic dinosaurs is rare in India. The present paper describes the proximal part of hindlimb bone of a sauropod from the Middle Callovian horizon of Kutch, Gujarat. It was found in shallow marine shelf facies, associated with stenohaline faunas, e.g. brachiopods and ammonites. Co-occurrence of dinosaurs and ammonites is a rare phenomenon and specific identification of time-diagnostic ammonite species thus provides a precise 157.8 million years, when the present dinosaur lived. The bone is supposed to have been derived from a floating carcass and its marine association has taphonomic implications.**

THERE are reports of dinosaurs in marine deposits from different parts of the world. For example, the good preservation of a stegosaur skeleton comes from the British marine Lias<sup>1</sup>. Several caudal vertebrae of a sauropod have been found in the Portlandian limestone sequence of Haute-Marne, eastern France<sup>2</sup>. Similar finds of dinosaur vertebrae have also been reported from the Cretaceous of France<sup>3,4</sup>. Recently dinosaur bones have been reported from several Jurassic horizons of Kutch<sup>5,6</sup> and Rajasthan<sup>7</sup>, India. Here we provide a detailed description of the proximal part of tibia which belonged to a sauropod dinosaur. The bone is found to be associated with ammonites on the top of a shallow marine sandstone. Although marine occurrences of dinosaurs are known, they are rarely associated with ammonites. This provides a unique opportunity to determine the precise age of the dinosaur with the help of associated time-diagnostic ammonites and their co-occurrence implies taphonomic significance.

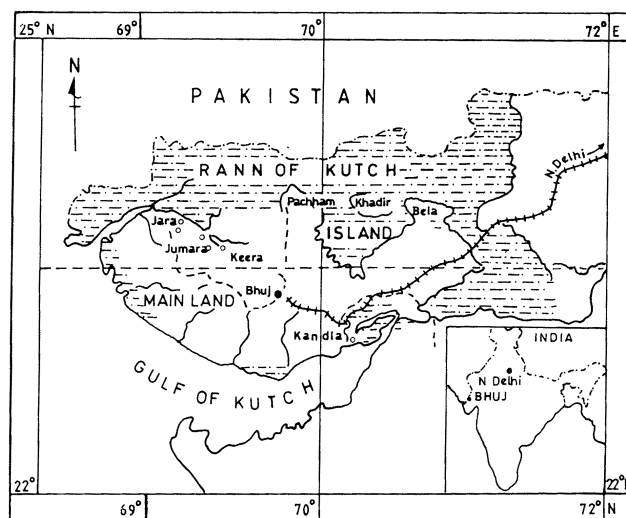
Mesozoic rocks of Kutch are the products of repeated marine transgressions within a peri-continental sea occupying a rifted graben. Kutch is famous for its rich ammonites and other invertebrate faunas. The Mesozoic succession of Kutch includes four major subdivisions, the Patcham, Chari, Katrol and Bhuj Formations in ascending order, ranging in age from the Bathonian to Aptian<sup>8-11</sup>. The Chari Formation which spans the Late Bathonian to entire Callovian and Oxfordian crops out in several structural domes along the fold axis of the central anti-

cline running NW-SE. Jumara (Figure 1) is the type area of Chari Formation, where the older Patcham Formation is partially exposed at the core. The Chari Formation is about 200 m thick and regionally persistent. The lithologies are mainly shale, sandstone and limestone which were deposited in a warm, shallow marine environment<sup>12-14</sup>.

The sauropod bone under discussion here has been found from the top of a sandstone<sup>12,13</sup> within the Chari Formation at Jumara (Figure 2). The bed is yellowish-grey and resistant forming a ridge across the mainland of Kutch. It is 16 m thick in Jumara, but the thickness increases towards the eastern basin margin. It is commonly multi-storied and contains large scale cross-stratification<sup>12</sup>.

Evidence of bioturbation is completely lacking in this bed. These sandy facies occur more than once in the stratigraphic sequence and form a cyclicity. It represents a shoaling upward phase<sup>14</sup> and has been formed during storm surges<sup>12</sup>. Absence of any bioturbation perhaps indicates rapid deposition.

The bed is very rich in perisphinctid ammonites like *Reineckeia anceps* (Reinecke), *Indosphinctes indica* (Seimiradzki), *Choffatia cobra* (Waagen), *C. perdagatus* (Waagen) and *Phlycticeras* spp, indicating a Middle Callovian age<sup>15,16</sup>. *R. anceps* is an excellent marker in Submediterranean France and a chronostratigraphic zone marking the base of Middle Callovian has been named after it<sup>16</sup>. Spath<sup>15</sup> introduced Rehmanni Zone for the lower part of the Middle Callovian of Kutch. However, the European *Rehmannia rehmanni* (Oppel) is very poorly known<sup>12</sup> or absent altogether<sup>17</sup> in India. Indeed the abundant reineckeii species which graced this level, including the present bone-bearing horizon (bed 10, Figure 2) and previously identified as *Reineckeia indosabuda* Parona and Banarelli has now been synonymized with the Euro-



**Figure 1.** Geographic location of Kutch with Jumara from where the present dinosaur bone is described. The patterned area is the Rann of Kutch.

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pean index species *R. anceps*<sup>17</sup>. Spath<sup>15</sup> however, erroneously named the superjacent fossil bearing horizon (bed 11, Figure 2) as Anceps Zone on the basis of other reineckeii species, especially Waagen's<sup>8</sup> *Perisphinctes anceps* (Reinecke) Waagen, which he himself redesignated later as *Reineckeia reissi* Steinmann, an endemic Indo-Madagascan form. Our vertebrate specimen occurs immediately below this *R. reissi*-bearing horizon which also includes well time-diagnosed ammonite species such as *Collotia gigantea* (Bourquin) and *Erymnoceras coronatum* (Bruguière). These two species together are found only in the lowest horizon of Subtethyan Coronatum Zone (immediately overlying the Anceps Zone)<sup>17,18</sup>, of which *E. coronatum* is the zonal index species. Besides, another marker species, i.e. *Reineckeia tyranniformis* Spath is found from bed 9 (Figure 2) that lies immediately below the dinosaur-bearing horizon (Kayal, pers. commun.). It is also found in the lower faunal horizon, i.e. Blyensis horizon of the upper Subzone, Tyranniformis of the Mediterranean Anceps Zone<sup>16</sup>. Thus the precise age of the

sandstone yielding the present bone can be safely placed at the top of the Anceps Zone of the Middle Callovian.

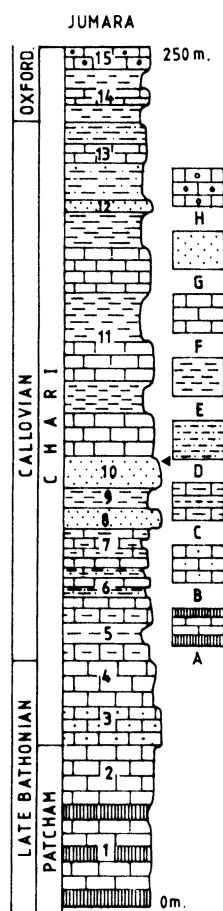
It would be interesting to estimate the age of the top of the Anceps Zone in absolute terms. In Europe, the Jurassic chronostratigraphy is well standardized and the Callovian Stage has been divided into six zones, with average duration for each zone being about 720,000 years<sup>19</sup>. If the absolute age of the base of the Callovian stage is 160 m.y.<sup>20,21</sup>, the top of Anceps Zone marks 157.8 m.y. – a time when the present dinosaur lived and died.

A single but well-preserved bone fragment (sp. no. JUM/V/1) was collected from the top of the bed 10, Jumara and repositated at the Museum of Department of Geological Sciences, Jadavpur University, Kolkata.

The bone represents the proximal part of left tibia (Figure 3). It is massive, stout and straight till the broken end. Shaft is relatively thick, but considerably tapering with respect to the proximal end. The transverse diameter (26 cm) is greater than the antero-posterior diameter. The ratio is 1.73. Cnemial crest is indistinct. The broad proximal end is well preserved, still retaining the two broad surfaces which articulate condyles of femur.

On the basis of the proximal part of a tibia, it is difficult to assign a dinosaur even at the family level. In view of the paucity of reports of Jurassic dinosaurs from India, it may be useful to attempt a brief review of such dinosaur occurrences from India. The oldest fossils come from the Kota Formation, a member of the Gondwana Supergroup of the Pranhita–Godavari Valley, Andhra Pradesh, belonging to genera *Barapasaurus*<sup>1,22</sup> and *Kotasaurus*<sup>23</sup>. The sediments of Kota Formation are believed to be lacustrine deposits<sup>1</sup>. The associated fossil fishes (e.g. *Tetragonolepis*, *Paradapedium*, *Lepidotes* and *Indocoelacanthus*) indicate a Liassic age for *Barapasaurus* and *Kotasaurus*. The tibia of the *B. tagorei*<sup>24</sup> although slightly larger than the present one, corresponds closely in overall shape (Figure 4). The ratio between transverse width and antero-posterior width of the former is about 1.87. Close comparison can also be made with the tibia of *Camarasaurus supremus*<sup>25</sup> reported from Morrison Formation of Late Jurassic age.

It is interesting to mention that Ghevariya and Srikarni<sup>5</sup> reported sauropod caudal vertebrae and pelvic girdle from



**Figure 2.** Stratigraphic section at Jumara. Arrow (top of bed, 10) indicates the horizon from where the present bone is recorded. Key: A, Coral biostrome–limestone alternation; B, Green oolitic limestone; C, Shale–marl alternation; D, Shale–fossiliferous limestone alternation; E, Shale and fine sandstone; F, Limestone; G, Coarse sandstone; H, Oolitic, conglomeratic limestone (modified after Datta<sup>12</sup>).



**Figure 3 a–c.** (a) Anterior, (b) posterior and (c) proximal views of left tibia (sp. no. JUM/V/1). Scale bar equals 26 cm.

the 'coralline limestone' (? Mainland) and teeth, bone and eggshell fragments from Goradongarh, Patcham Island of Kutch. The fossils belong to the Patcham Formation (Bathonian). A recent report<sup>6</sup> from Kuar bet, Patcham island includes dinosaur vertebrae and other fragments along with large petrified woods from the relatively older conglomeratic horizon (? Aallenian–Early Bajocian). The Patcham island constitutes northern fringe of Kutch basin<sup>26</sup> and dinosaur bone-yielding horizons represent near-shore deposits<sup>27</sup>. Along the eastern shoreward margin, dinosaurian footprints and rib bones have been recorded from the Katrol (Tithonian) and younger Bhuj Formations<sup>5</sup>. Ghevariya and Srikarni interpreted that these dinosaurs inhabited adjacent lake margins and preferred strandline as nesting sites. However, they did not record any tibia, only ilium and pubis have been mentioned. Some dinosaur-bone fragments from the Middle Jurassic rocks of Jaisalmer, Rajasthan<sup>7</sup> have been discovered, but no details are available.

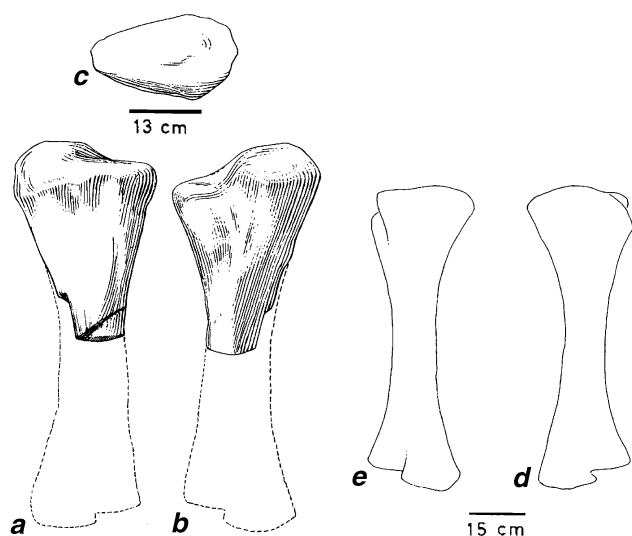
The occurrence of a sauropod in marine sequence deserves special discussion. Generally, occurrence of isolated bones or skeletons of sauropods in marine sediments is interpreted as the remains of floating carcass washed into the sea<sup>2–4</sup> where water currents and wave actions are two main physical processes of bone transport<sup>28</sup>. Carcass or even disarticulated bones with remains of organic matter are buoyant and may remain afloat for days<sup>29</sup>, and thus are readily transportable by moving water<sup>28</sup>. Disarticulation of bones from the floating carcass follows a sequence<sup>29–32</sup>. In marine mammals<sup>33</sup> as well as in terrestrial forms<sup>31</sup> drifted into sea, the order of disarticulation of bones from the floating carcass involves

release of lower jaw first, followed by cranium; phalanges of the fore limb are lost next. Decay in the foot region where there is not much flesh or internal fluid, slows down resulting in the delay of disintegration and they may remain afloat many more days. Dodson<sup>33</sup> suggested that the amount of tendon in different joints has a fundamental control over disarticulation. He showed that the last part of the bones that still remained articulated in the drifting carcass was pelvis–hindlimb unit and parts of the tail. The knee joints in which tendon is greatly involved were last to disarticulate.

Jumara, where the present tibia was found is far away from the palaeo-shoreline<sup>26</sup>. Like the above-mentioned disarticulation sequence of mammals, the present tibia of the sauropod dinosaur perhaps had a similar hydrodynamic behaviour. It perhaps remained afloat for a considerable time and drifted by oceanic currents to quite a great distance, and dropped off late from the carcass as a single bone. Recent marine mammals, e.g. drifting seals, remain afloat for 48–57 days<sup>31</sup> and may be subjected to transport for a considerable distance. Empty shells of *Nautilus* in modern oceans although having greater buoyancy than dinosaur carcass, may travel a distance of a few hundred kilometres for a period of 32 days<sup>34</sup>. It is pertinent to mention that northern and eastern palaeo-strand lines of Kutch sea are about 100 and 300 km, respectively from Jumara<sup>26</sup>. Sauropodian and other dinosaurs inhabited these coastal swampy forest areas during the Middle Jurassic to the Upper Cretaceous<sup>5,6,35</sup>. The Jurassic dinosaur remains come from the '? Aalenian–Early Bajocian', Kuar belt of Patcham Island, the Upper Bathonian in the Mainland and the Tithonian in the eastern Kutch<sup>6</sup>. The present find adds another dinosaur remnant from the Middle Callovian. The carcass of the present dinosaur is believed to have been swept away from one of these areas.

Ghevariya and Srikarni<sup>5</sup> did not mention the locality of coralline limestone of Patcham Formation which yielded the Bathonian sauropod bones. But, the bed is famous and is found only in Jumara. Interestingly, they also recorded only the pelvic and tail bones, which were last to separate and fall from the 'drifting sack' of a dead body<sup>31</sup> and thus support our taphonomic model. On the other hand, teeth, rib bones, vertebrae and broken eggshells have been believed to have suffered little posthumous drift<sup>31</sup> and in fact, have been recorded from strandline or near-shore deposits along the basin margins<sup>5,27</sup>.

The present bone represents the proximal part, but still retains its surface details. The broken edge is still sharp, uneven and jagged. These imply little transport after settling. This is also supported from the size of the sedimentary particles which are finer from its 'quartz-equivalent'; thus minimal transport is inferred (also see Shipman<sup>32</sup>). Moreover, the associated ammonites which are highly assorted death assemblage include specimens with aptychi (jaw apparatus) preserved in body chamber and excellently preserved microconchs still retaining their



**Figure 4 a–c.** Left tibia (sp. no. JUM/V/1) in (a) anterior, (b) posterior and (c) proximal views. Reconstructed part in broken line. Scale bar equals 13 cm. **d–e.** Left tibia of *Barapasaurus tagorei* in (d) anterior and (e) posterior views. Scale bar equals 15 cm. Reproduced from figure 2, Jain *et al.*<sup>24</sup> with permission. Note close correspondence between these two forms.

delicate lappets. This indicates little post-mortem drift and almost no hydraulic movement after settling (Bardhan, pers. commun.). However, the possible cause of tibia breakage is hard to resolve. Without any appreciable weathering effect and bed-load transportation, bones may be cracked due to many factors like physical impact (the bed yielding the present bone is a product of high-energy storm event), sand blasting and bone crushing scavengers<sup>28,36</sup>.

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## Modern pollen–spore rain in Schirmacher oasis, East Antarctica

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**Pollen analysis of five moss cushions and three dry algal mat samples collected from the vicinity of Lake Priyadarshini in Antarctica has been carried out to elucidate the interplay of pollen and spores deposited in the sediments. The encounter of different pollen and spore types reflects their long-distance transport ranging from tropical to temperate floristic regions around Antarctica mainland which is devoid of any higher plant taxa, except for members of Poaceae and Caryophyllaceae. Lower plants such as mosses, lichens and algae do inhabit the region, often forming gregarious patches or colonies.**

POLLEN analytical studies of a region are based on the premise of subfossil pollen contained in the analysed sediments which reflect changes in the vegetation of the region through time. The studies thus involve on one hand, a detailed understanding of the ecology of the present vegetation in relation to climatic, microclimatic, edaphic and biotic factors, and on the other, the reconstruction of the existing pollen rain pattern in a region.

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