Dinosaur bones from Meghalaya

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Abundant fossil bone fragments of dinosaurs have been found at Dirang village near Ranikor, West Khasi Hills district, Meghalaya. These bone fossils occur within a four to five metre thick coarse-grained purple-coloured sandstone horizon of Mahadek Formation of late Cretaceous (Maestrichtian) period. The bones are poorly preserved and fragmentary in nature, as a result of the prevailing high energy condition in the depositional basin. The size, shape and nature of the bones; palaeohistological studies under microscope as well as continental type of environment for the animals thriving, confirmed dinosaurian origin for these bones.

DINOSAURS, the giant reptiles dominated the earth's biosphere from about 225 million years up to 65 million years before present during Triassic, Jurassic and Cretaceous periods of Mesozoic era in the geological time scale. Fossil records in the form of skeletal materials and eggs from various localities all over the world have been recovered by the palaeontologists from time to time and gradually an idea about the size, shape and habitat of different species of this extinct animal has been developed. In India, fossil remains of dinosaurs have been reported from western, central and southern parts of the country within rocks ranging from Jurassic to Cretaceous periods. Some of the areas have yielded reasonably complete skeletal structure and eggs of the animal, where preserving media were suitable and depositional environment was calm. At the same time in some localities, only fragmentary dinosaurian bones could be recovered. Palaeohistological studies of the materials, in some of those areas, along with other evidences have shown that they are actually remains of dinosaurs. The present study has been carried out in an area around Dirang, a small village near Ranikor, West Khasi Hills district, Meghalaya from where abundant fragmentary fossil bones have been collected. The largest size of the recovered bones is about 80 cm in length; many 30 to 40 cm long and innumerable smaller bones have also been found. Obviously, the size of the animal was quite large. Associated sediments were deposited under a continental environment (alluvial fan, river and lake) which indicates that the animal was land-dwelling. Such large, land-dwelling animal in Cretaceous time can only be the dinosaur. Palaeohistological studies of the bones in thin section under microscope show development of dense secondary haversian system throughout the compacta. This also confirms dinosaurian origin of the bone fossils of Dirang area.

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The southern fringe of Meghalaya plateau is covered by a sedimentary rock package of Cretaceous–Tertiary period, popularly known as the shelf sediments of Shillong plateau. The basement for this package is made up of one or a combination of the earlier rocks right up to Precambrian time, e.g. Gneissic Complex (Archaean); sedimentaries of Shillong Group and associated intrusives (Proterozoic) and Sylhet Trap (Jurassic–Cretaceous). A large number of geologists[1–8] worked in this area, mostly to map this less-accessible terrain. Gradually, the existing lithostratigraphic classification of the rocks present in the area has been evolved. For the present work, the classification of Murthy *et al.*[8] has been followed, with some modifications as shown in Table 1.

Fossil bone fragments of dinosaurs have been found to occur at Dirang (topo sheet no. 78 O/4), a small village near Ranikor along Ranikor–Nongnah road section in the south-eastern corner of West Khasi Hills district, just to the north of India–Bangladesh international border. The area is 132 km away from Shillong by road through Mawsynram (Figure 1).

The potential fossil-bearing zone is restricted to a four to five metre thick sandstone horizon spreading over about one sq km area around Dirang village. Different sandstones in the area are generally massive and reddish to purple in colour. A few pebble-rich beds occasionally occur within the sandstones. The framework of the rock – mainly quartz, feldspars and rock fragments – are coarse, gritty, poorly sorted and mineralogically immature. The matrix is quartzo-feldspathic in composition and the cementing materials are siliceous/ferruginous. Coarse feldspar grains in which crystalline faces are well preserved, occasionally float in the matrix. The sandstones can be classified as subarkose after Pettijohn[9]. The lithostratigraphy of this area has been studied carefully and is shown in Figure 2. The sequence has been correlated with the Late

Table 1. Lithostratigraphic classification of Cretaceous rocks in Meghalaya

Tertiaries			
Late Cretaceous (Maestrichtian)	Khasi Group	Mahadek Formation	Coarse gritty sandstones
		Jadukata Formation	Alternations of sandstones and conglomerates
		Bottom Conglomerate Formation	Impersistent conglomerates
Unconformity			
Jurassic–Cretaceous		Sylhet Trap	Basalts
Unconformity			
Precambrians			

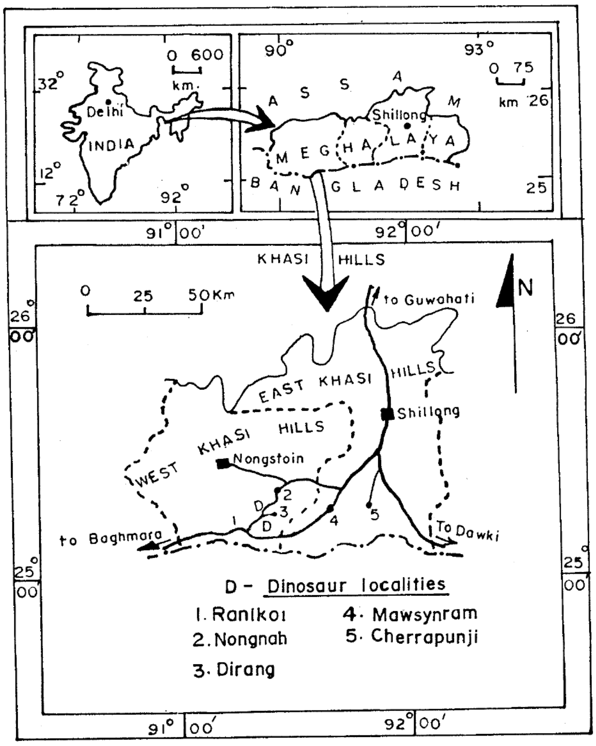

Figure 1. Location and accessibility map of the dinosaur bone fossil bearing area at Ranikor–Dirang section, West Khasi Hills district, Meghalaya.

Cretaceous (Maestrichtian) Khasi Group of rocks where the dinosaur-bearing zone occurs at the upper part of the sequence. As revealed from the sedimentary package and the associated fossil biota here, the entire Khasi Group of rocks, excepting the topmost member of the sequence belonging to Mahadek Formation, was deposited under continental environment.

Presence of glauconite at the topmost member (Figure 2) is suggestive of marine condition. Marine invertebrate fossils, e.g. ammonoids, echinoids, molluscs, etc. are present in the topmost member only, indicating a marine transgression at the culminating phase of Mahadek time. All other lower members of the sequence contain fossilized twigs, woods and/or ichnofossils (burrows). General coarse size of the clasts, presence of reddish to purple colour, occurrence of carbonaceous materials and plant fossils all point towards a continental depositional condition for these members of the sequence of rocks. From these it can be made out that the fossil bones must be of such an animal that lived in a land environment during that time.

In the study area, only fragmentary bones are present. This is because of the prevailing high energy condition during sedimentation. The characteristics of the clasts present in the sandstones of the bone bearing horizon, e.g. almost intact feldspar crystals, coarse size, gritty and poorly sorted nature of the grains suggest that the sediments are river-borne and suffered very limited transportation prior to deposition. High gradient rivers from the rapidly uplifted landmass carried tremendous sediment load into a low-lying shallow lacustrine basin at a very rapid rate, in cycles, resulting in alternations of gritty, massive and laminated layers with occasional pebble-rich beds. Intermittent calm periods favoured growth of vegetation, responsible for carbonaceous materials and woods. Under this high energy condition, the bones of the dead animals dropped at high lands were also transported into the basin and in the process got fragmented. The fragmented bones preserved within coarse-grained sediments were subjected to more groundwater action during diagenesis in later periods, causing considerable solution and replacement effects on the bones.

Innumerable heavy broken bones, mostly of the limbs, are preserved here. During transportation, fragmentation and alteration most of the bones lost their original size and shape. However, many of the recovered bones are individually more than 30 to 40 cm in length – the largest being about 80 cm long – all in fragmented state. Obviously, the concerned animal must have been very large in size. Such a large land-dwelling animal living in Cretaceous period can only be the dinosaur. The loss of original shape of the fragmented bones was a problem for the comparative diagnostic study of the bones with the standard dinosaurian skeletal materials, e.g. skull, vertebrae, digits, teeth, etc. However, in a few of the recovered bones, the shape of the articulating surfaces is somewhat preserved. Figure 3 *a* and *b* shows photographs of a vertebrae and a massive bone, respectively. The vertebrae is analogous to that of dinosaurs. Similar large and wide bone fragments of other skeletal parts resembling those of dinosaurs are also present in Dirang area, but poor preservation limits their specific identification.

Due to the above constraints, palaeohistological studies of the bone materials have been undertaken. Palaeohistology is the study of fossil bone tissue structure under a microscope. The available literature[10–16] on this subject is very scanty. In India, dinosaur fragmentary bones from Jaisalmer (Rajasthan) and Kachchh (Gujarat) have been identified[17–20] based on palaeohistological studies.

In palaeohistological studies, development of secondary haversian system in the fossil bone tissue is the most important feature to be looked into for identifying bones of dinosaurian origin. Haversian system is best studied under microscope in thin transverse sections of bones containing both the inner spongy layer (spongasia) and the outer compact layer (compacta). Haversian system is an irregularly branching anastomizing thick-walled cylindrical structure with a narrow canal at the centre. Transverse sections of such a system show solid concentric rings with central hollows. The system can either be primary or secondary. In secondary ones, haversian systems of several generations develop one after another, overlapping the earlier systems. This, in transverse sections, is manifested as unit primary/

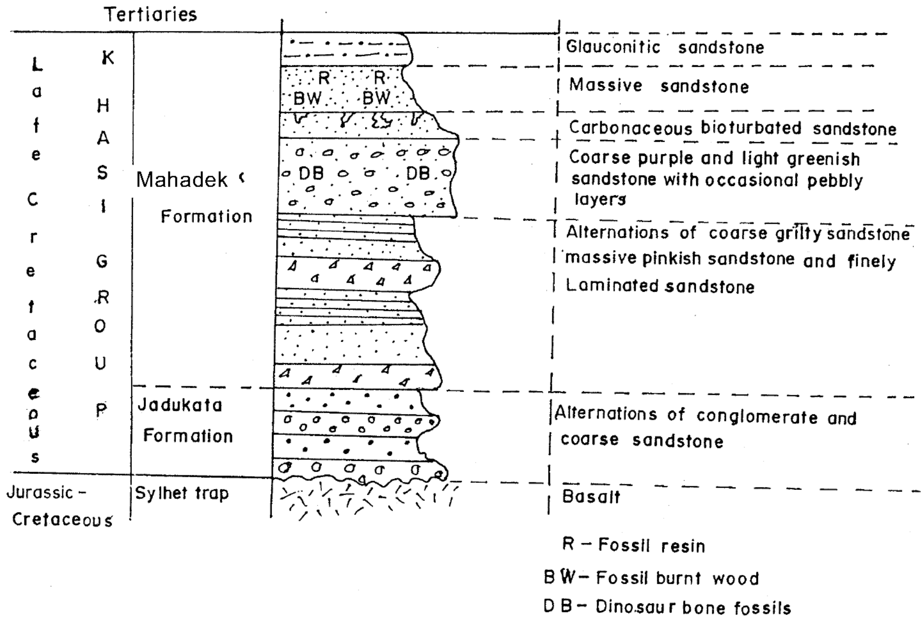

Figure 2. Lithostratigraphy of the rocks exposed in the area.

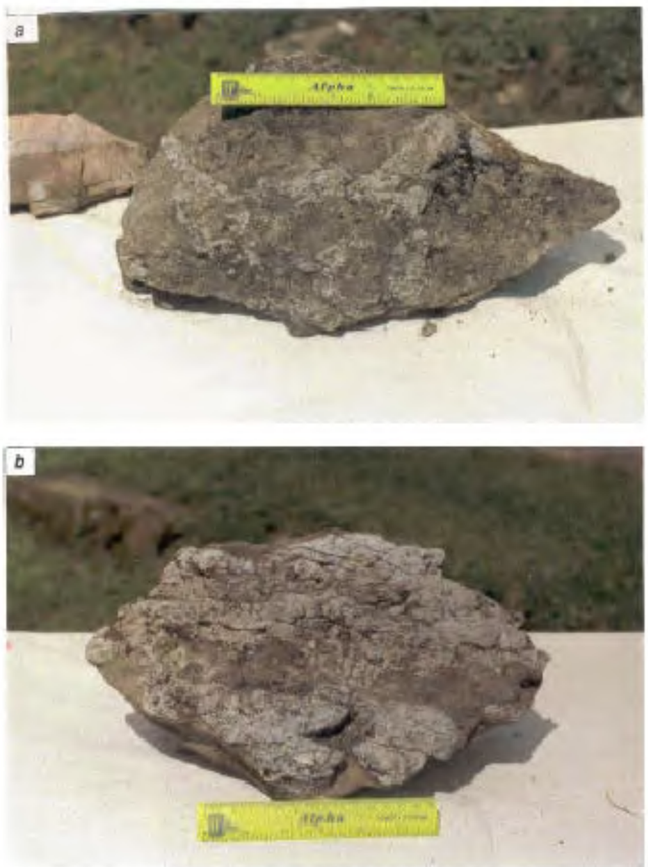

Figure 3. ***a***, Fossil bone of a single vertebra; ***b***, Preservation of a large, massive and fragmented fossil bone of a dinosaur at Dirang.

secondary rings overlapped by later developed secondary rings. The skeleton of huge creatures thereby grows and is strengthened time and again by the process, throughout the ontogeny of the animal.

For the palaeohistological studies of the recovered fragmented bone fossils in the Dirang area, only bones in which all the layers were preserved have been chosen. Transverse thin sections of these bones have been prepared. Studies of such selected bones in thin sections under a microscope show development of dense secondary haversian system of several generations throughout the compacta. In transverse section, haversian systems of later generations are found to overlap similar systems of earlier generations. All examined sections reflect similar overlapping throughout the compacta. This has been illustrated in Figures 4 and 5. Such all-round development of secondary haversian system is possible within the bones of dinosaurs only.

It is to be mentioned here that in the bones of crocodiles and turtles of the Mesozoic era, secondary haversian system developed in some restricted parts of compacta (and not throughout). Even in the bones of some marine reptiles of that time, such systems, also developed. The size and shape of the bones found at Dirang are suggestive of dinosaurs, rather than turtles or crocodiles. In palaeohistological studies also, unlike turtles and crocodiles, secondary haversian systems have been found to be developed throughout the compacta. Thus, turtilian or crocodilian stock for these bones can be ruled out. At the same time, as the associated sedimentary package and biota proved that the animal was land-dwelling, the bones cannot be those of marine reptiles.

Considering all the factors, it is concluded that the fragmentary fossil bones found at Dirang are actually remains of dinosaurs. However, the search for locating

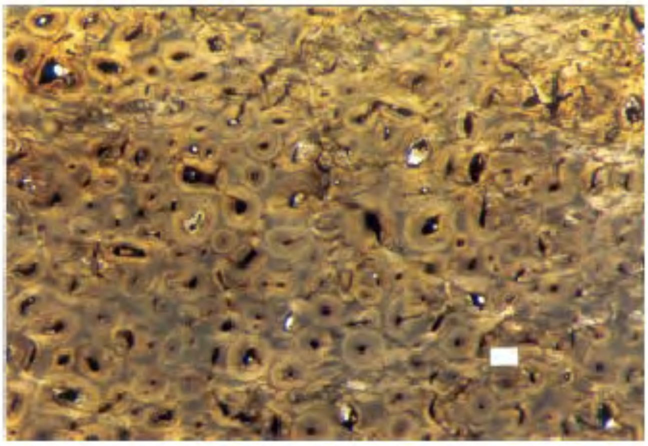

Figure 4. Photomicrograph of transverse section of a dinosaur bone at Dirang showing development of dense secondary haversian system throughout the compacta. Bar scale = 0.3 mm.

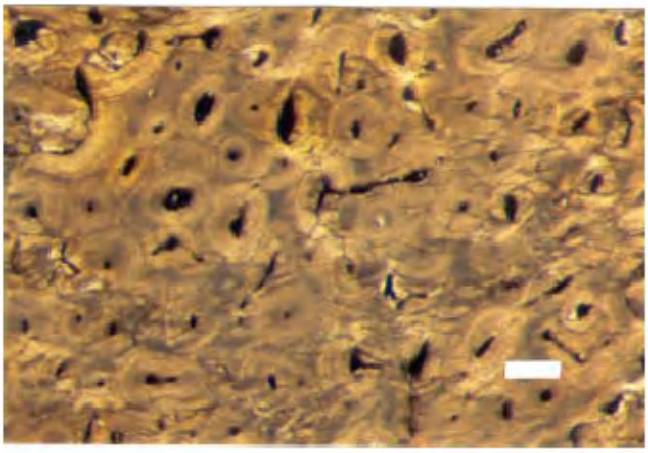

Figure 5. Photomicrograph (closer view) of secondary haversian system of a dinosaur bone at Dirang. Transverse section of cylindrical secondary haversian canals are seen as irregular rings, where concentric growth rings (lamellae) grow towards inner spaces; rings of later generations overlap those of earlier ones. Bar scale = 0.3 mm.

more complete skeletal remains of the animal, is being continued in and around Dirang for getting a more complete picture about the creature and identification of the genera and species.

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Disturbance time variation of geomagnetic vertical field in the Indian equatorial electrojet

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The disturbance time variations of the vertical component (*Z*) of the geomagnetic field at stations in the Indian chain, following a sudden commencement storm show a spectacularly large decrease at only the electrojet stations, Thiruvananthapuram, Etaiyapuram, Kodaikanal and Annamalainagar. This decrease is not synchronous in time with the decrease of the horizontal (*H*) field. The peak depression of the *Z* field occurs about three hours before the time of peak decrease of *H*, i.e. during the middle of the main phase of the storm, when the ring current is developing at the fastest rate. This first clear description of Dst(*Z*) at Indian electrojet stations is further confirmation of the sub-surface conducting channel in Palk Strait, where currents are induced by the ionospheric source current, producing large decrease of *Z* field at ground level. Similar analysis of Dst(*Z*) at different equatorial stations around the world is recommended to understand the abnormal features of Indian equatorial electrojet.

Moos[1] was the first to make an extensive study of the magnetic disturbance effects on the horizontal geomagnetic field (*H*) using the data from Colaba, India. After

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