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FIRST DINOSAUR REMAINS FROM THE CENOMANIAN-TURONIAN NIMAR SANDSTONE (BAGH BEDS), DISTRICT DHAR, MADHYA PRADESH, INDIA

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ABSTRACT

Sauropod remains are recorded for the first time from the lower and upper parts of the Late Cretaceous (Cenomanian-Turonian) Nimar Sandstone representing fresh water and intertidal environments of deposition respectively. The Nimar sandstone is the lowermost member of the Bagh beds of district Dhar, Madhya Pradesh. The material includes limb elements and numerous fragmentary bones belonging at least to two individuals. The specimens are referred here to Sauropoda, but lower-level comparisons are not yet possible. The Bagh dinosaurs are the earliest Cretaceous dinosaurs known from India.

The sauropod bones are found in two different settings within the Nimar Sandstone: a fluvial and an intertidal palaeoenvironments.

Key words: Bagh beds, Cenomanian-Turonian, dinosaur, Dhar, Madhya Pradesh, Nimar Sandstone, sauropod.

INTRODUCTION

In 1996, one of us (Ashu Khosla) discovered sauropod dinosaur remains in the Cenomanian-Turonian deposits of Nimar Sandstone (Bagh beds). The localities are situated about 3-4 km away from Bagh caves in a westerly direction along the road leading to Jobat and Kukshi (fig. 1). The other dinosaur bone-bearing locality is situated about 40 km NE of Bagh town at Ratitalai in district Dhar, Madhya Pradesh (figs. 2, 5). In January-February, 2001, more complete sauropod elements were recovered, i.e. two femora, a broken humerus and fragmentary bones at Borki and Rampura (figs. 1, 3, 4). Together, these discoveries constitute the first record of dinosaur remains from the Nimar sandstone, District Dhar, Madhya Pradesh. Dinosaur specimens recovered from the upper and the lower parts of the Nimar Sandstone, are here interpreted as representing different palaeoenvironments : the lower part representing coarse conglomeratic fluviatile deposits while the upper part comprising the oyster bands associated with gritty, sometimes conglomeratic marine sandstone intercalated with red sandy shale material, referred to Cenomanian-Turonian age. This is the oldest Cretaceous sauropod from the Indian subcontinent. In addition, a few fragmentary pieces of dinosaur bones have also been recovered from the freshwater Maastrichtian Lameta Formation at Borkui and Rampura sections, District Dhar, Madhya Pradesh (figs. 3, 4).

Late Cretaceous (Maastrichtian) sauropod dinosaurs are well known from the Lameta Formation of Jabalpur (Madhya Pradesh, Matley, 1921; Von Huene and Matley, 1933; Buffetaut, 1987), Pisdura (Von Huene and Matley, 1933), Umrer in Nagpur District, (Prasad and Verma, 1967) and Dongargaon (Maharashtra, Berman and Jain, 1982; Jain and Bandyopadhyay, 1997). Cretaceous Indian sauropod skeletal remains are restricted to Titanosauria. Despite their fragmentary nature, they have been assigned to numerous species (*Titanosaurus indicus, T. blanfordi, Isisaurus colberti* Wilson and

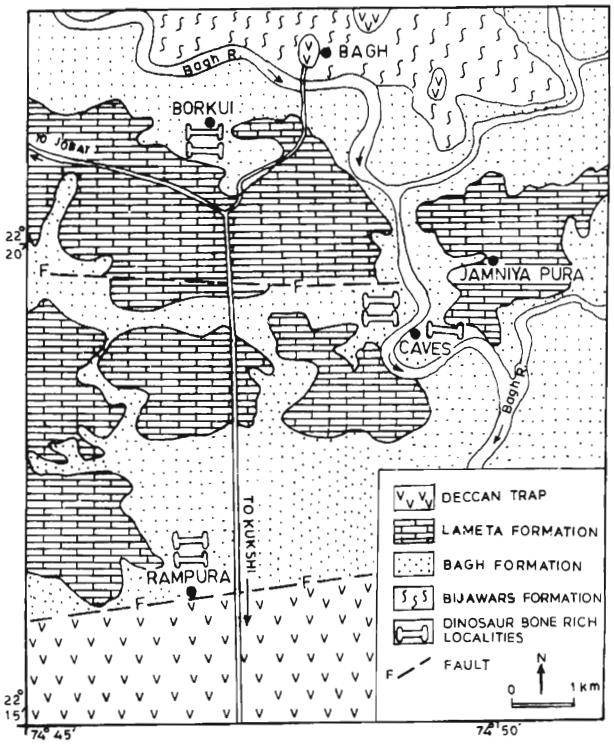


Fig. 1. Geological map of the Bagh area (District Dhar, Madhya Pradesh) showing dinosaur bone-bearing localities (modified after Joshi, 1995).

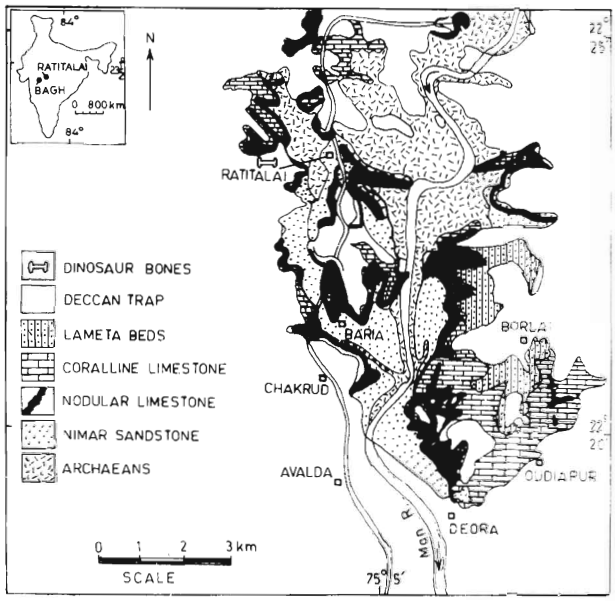


Fig. 2. Geological map of the Ratitalai area (District Dhar, Madhya Pradesh) showing dinosaur bone bearing locality (Map modified after Roychowdhury and Sastri, 1962).

Upchurch, 2003, *T. rahioliensis* and *Jainosaurus septentrionalis*, Hunt *et al.*, 1994; Wilson and Upchurch, 2003).

The present record of dinosaurs from district Dhar is significant because Indian Cretaceous dinosaurs were previously restricted to the freshwater Lameta Formation. This discovery verifies the occurrence of Cenomanian-Turonian sauropod dinosaurs in India and will shed light on the evolution of India's dinosaur fauna.

GEOLOGY AND STRATIGRAPHY

The dinosaur bone-bearing sections are exposed near the Bagh River in a westerly direction along the road leading to villages Jobat and Kukshi (fig. 1) and at village Ratitalai in district Dhar, Madhya Pradesh (fig. 2). In these sections, the Bagh beds attain a maximum thickness of about 33 m. The dinosaur bone-bearing Nimar Sandstone overlies the basement rocks (Archaeans and Bijawars), which attain a thickness of about 27 m at Jamniya Pura and Borkui, 22 m at Bagh Caves (fig. 3) and 2 m at Rampura (fig. 4).

In between the upper part of grey ferruginous Nimar Sandstone, there are alternating sequence of red sandy shale material, which are mostly intercalated in patches containing well-preserved but broken dinosaur bones, i.e. humerus, radius, ulna and other unidentifiable fragmentary parts of bones from Jamniya Pura section (Pl. I. figs. C-E; Pl. II, fig. A). Two big femora (Pl. I. figs. A, B) and humeri bones have been recovered from the upper gritty Nimar

EXPLANATION OF PLATE I

Sauropod indet

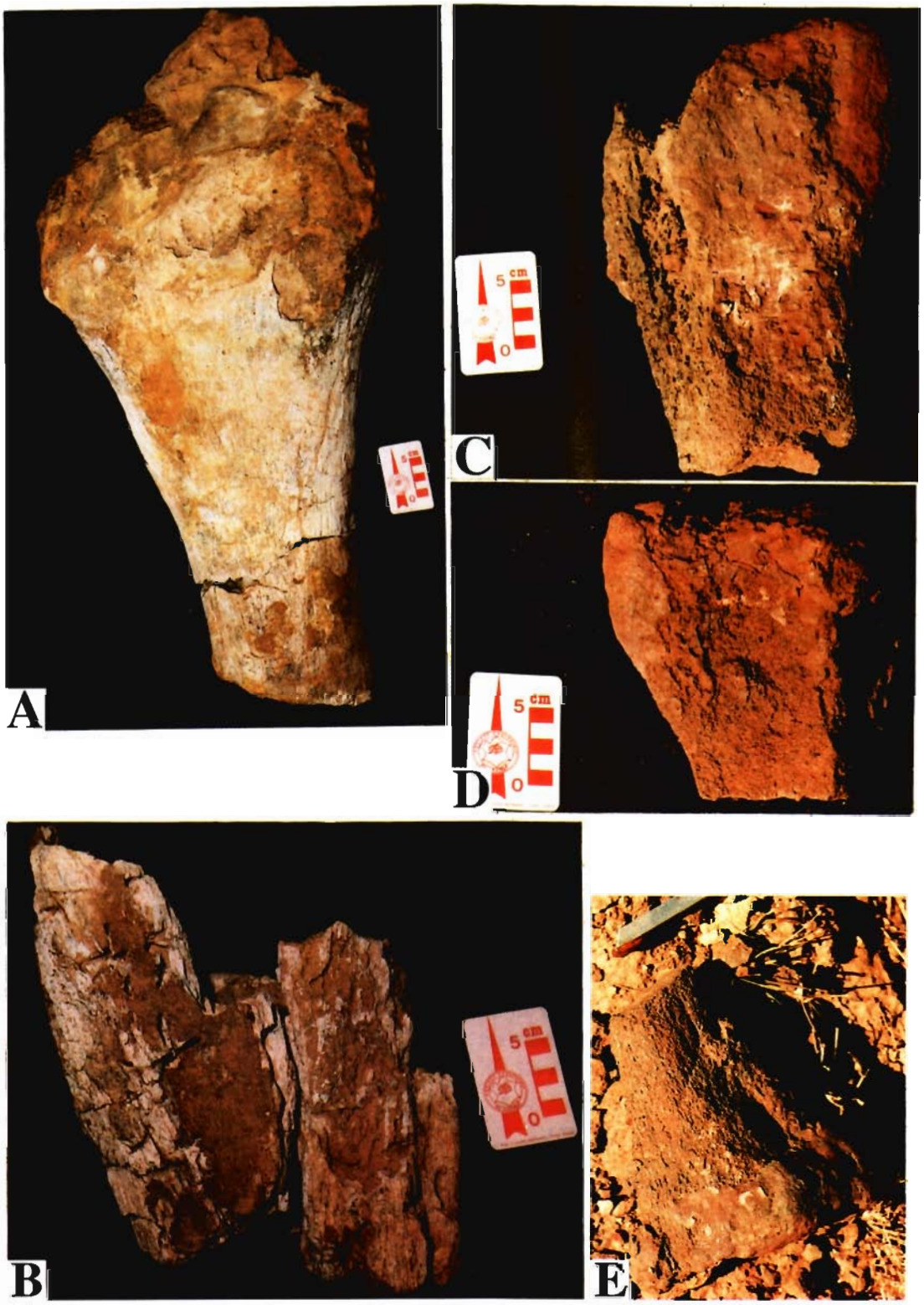
A. Incomplete distal end of right femur (VPL/KH/3500) in posterior view.

B. Broken part of a weathered femur (VPL/KH/3501) in posterior view.

C. Proximal end of an incomplete right humerus (VPL/KH/3503) in medial view.

D. Broken left ulna (VPL/KH/3504) in posterior view.

E. Incomplete left radius (VPL/KH/3505) in posterior view. Scale for figures A-D = 5 cm; Scale (stapler) for figure E = 9 cm.


A
B
C
D
E
5 cm
0

Sandstone and a few fragmentary pieces of dinosaur bones from the red sandy shale bands at the Borkui section. The marine sandstones are red-greyish in colour and generally horizontal. In addition to these, more recently, two broken femora (Pl. II, fig. C) have also been recovered from the red sandy horizon within the Nimar Sandstone at Ratitalai section (Pl. II, fig. B, Khosla, work in progress). Small, scattered pieces of dinosaur bones are found in the lower part of coarse conglomeratic fluvial Nimar Sandstone at Borkui, Jamniya Pura, Bagh Caves, Rampura sections (District Dhar, Madhya Pradesh, figs. 1, 3, 4) and Jamni (District Jhabua, Madhya Pradesh, Khosla, work in progress).

Thick (2-8 m) Nodular Limestone overlies the Nimar Sandstone. In the Bagh Caves and Rampura sections, the Coralline Limestone of about 3.5-5 m overlies the Nodular Limestone. Overlying the marine sequence is the well indurated, sandy, nodular, and cherty 3-5 m thick Lameta Limestone. This layer, which is well exposed at the western extremity of the Bagh area and forms peneplained surfaces locally in the region, is rich in dinosaur eggs and eggshell fragments (Khosla, 2001; Khosla and Sahni, 1995). In the Jamniya Pura and Borkui sections, the Lameta Limestone is further overlain by a 1 m thick smooth Red Sandstone. Deccan traps overlie the Lameta Formation in all of the Bagh area sections (Table 1).

MATERIALS AND REPOSITORY

Five broken femora, two incomplete humeri, two incomplete radii and ulna and numerous other fragmentary parts of bone. All the material is housed at Vertebrate Palaeontology Laboratory, Panjab University, and Chandigarh (VPL/KH= Vertrebrate Palaeontology Laboratory/Khosla), India with Dr. Ashu Khosla.

SYSTEMATIC PALEONTOLOGY

Sauropoda Marsh, 1878
Incertae sedis

(Pl. I, figs. A-E; Pl. II, figs. A, C; figs. 6 A-D; figs. 7 A-D)

Material: Five broken femora, two incomplete humeri, two incomplete radii and ulna and numerous other fragmentary parts of bone.

Referred specimen: Isolated distal half of a humerus (No. VPL/KH/3503).

Description: Although many partial elements referable to Sauropoda were discovered in the Bagh beds, the humerus is preserved in sufficient detail to warrant description for future comparisons.

Humerus (VPL/KH/3503, Pl. I, fig. C; figs. 6 A, B; Maximum length = 30 cm; Maximum width = 21 cm): The humeral fragment (Pl. I, fig. C) is well preserved and represents approximately half of the original element. It likely represents the proximal side, but this cannot be determined with confidence in the absence of the proximal half of the element. As seen in cross section, the shaft of the humerus is anteroposteriorly compressed, its transverse diameter is more than twice than of its anteroposterior diameter. The axis of the humerus is straight in both lateral and anterior views. The shaft of the humerus broadens towards the distal condyle.

Femur (VPL/KH/3500, Pl. I, fig. A, Maximum length = 77 cm; Maximum width = 43 cm; Pl. I, fig. B, broken femur (VPL/KH/3501): The femur is documented by the distal end of the right bone and is figured in posterior view (Pl. I, fig. A). The diameter of the femoral shaft increases toward the distal articular end. Additionally, the diameter of the shaft is slightly more at the proximal end of the preserved fragment, than half the width across the distal end. Due to increase in width the medial portion of the distal end is more prominent than the lateral one. Distal condyles (i.e. lateral and medial) occupy subterminal positions on the posterior (i.e. ventral) aspect of the femur. The femur bone (VPL/KH/3502, Pl. II, fig. C, Maximum length= 108 cm) recovered from Ratitalai section is very fragmentary and thinner than the femur bones described from Borkui section. In near future, additional material is needed to comment on this new type of bones from Ratitali (Khosla, work in progress).

Radius and Ulna (Pl. I, figs. D, E; figs. 6 C, D; figs. 7 A-D): The radius (VPL/KH/ 3505, Maximum length= 20 cm; Maximum width= 17 cm) and ulna (VPL/KH/3504, Maximum length= 19 cm; Maximum width = 18 cm) are incomplete and is

Table 1: Generalized stratigraphic succession at Bagh Region (Districts Dhar and Jhabua, Madhya Pradesh).

Formation	Age	Lithology
Deccan Traps	Late Cretaceous	Basaltic flows
Lameta Formation	Late Cretaceous	Red Sandstone
	(Maastrichtian)	Lameta Limestone
----------Disconformity----------		
Bagh Beds	Cenomanian	Coralline Limestone
	to	Nodular Limestone
	Turonian	Nimar Sandstone
----------Unconformity----------		
Archaeans and	Precambrian	Phyllites, Quartzites
Bijawars		and Gneisses

preserved humeral articular surface of the ulna shows a distinct rounded olecranon (ol). In proximal articular end of the ulna a subtriangular shallow concavity is observed, i.e. radial fossa.

Phylogenetic Affinities: The partial humerus from Bagh can be referred to Sauropoda on the basis of several shared derived characters of the group (Wilson and Sereno, 1998; Wilson, 2002). These include subterminal distal condyles, anteroposteriorly compressed humeral midshaft, articular surfaces covered by roughened, rugose bone, and a straight limb axis. A more specific determination of the

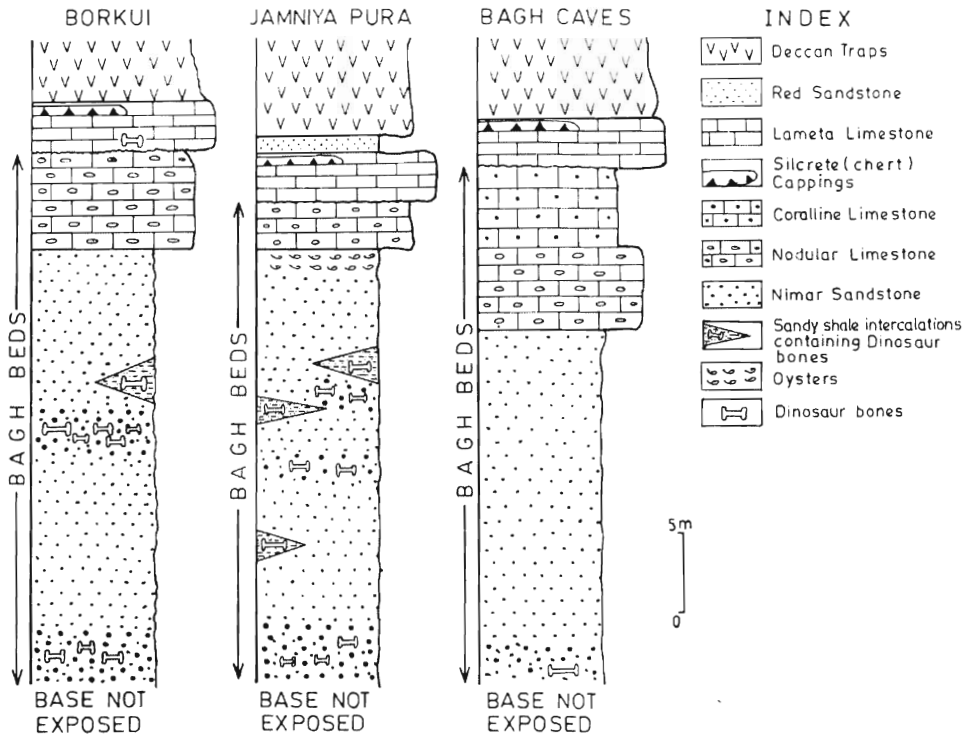


Fig. 3. Stratigraphic succession at Borkui, Jamniya Pura and Bagh Caves (District Dhar, Madhya Pradesh) showing dinosaur bone-bearing Nimar Sandstone horizon.

phylogenetic affinities of the Bagh sauropod is not possible at this time. Continued sampling of these important sediments are required to discover new and better-preserved elements.

Horizon and Age: Nimar Sandstone, Late Cretaceous: Cenomanian-Turonian.

Distribution: Near Bagh village (Borkui, Jamaniya Pura, Bagh caves, Rampura and Ratitalai), District Dhar and Jamni (District Jhabua, Madhya Pradesh).

DISCUSSION

Taphonomic Considerations

Excavation of the dinosaur-bearing Nimar Sandstone has yielded many sauropod bones, i.e. five well-preserved but broken femora, two radii, two humeri an ulna and numerous other fragmentary bones strewn in lower and upper part of Nimar

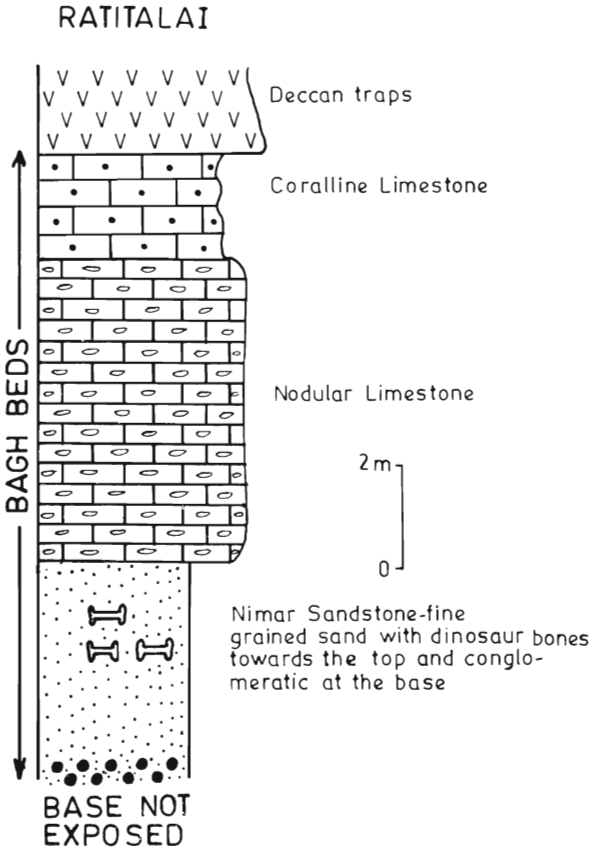


Fig. 5. Stratigraphic succession at Ratitalai (District Dhar, Madhya Pradesh) showing dinosaur bone-bearing Nimar Sandstone horizon.

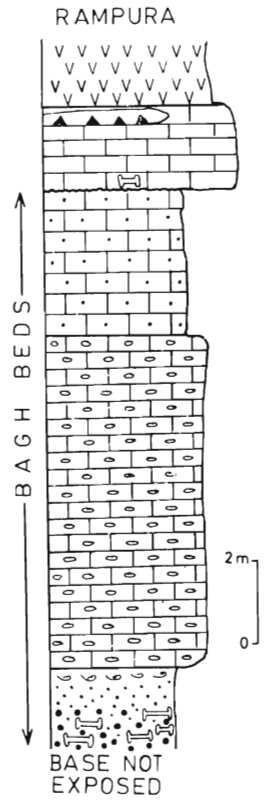


Fig. 4. Stratigraphic succession at Rampura (District Dhar, Madhya Pradesh) showing dinosaur bone-bearing Nimar Sandstone horizon. Index for figure 4 is same as for figure 3.

Sandstone with red sandy shale bands intercalated within Sandstone at many levels (fig. 3; Pl. II, figs. A, C). Preliminary results from taphonomic and sedimentological analysis reveal that skeletal material represents autochthonous remains dominated by disarticulated remains of these sauropod dinosaurs. More than one species dominance of the assemblage found in different localities shows sudden death of these Cenomanian-Turonian sauropods by unknown causes. The possible cause of very little transportation of the skeletal material within the coarse conglomeratic Nimar Sandstone and red sandy shale bands is by fluvial activity. It seems that with subsequent decomposition skeletal material was badly disarticulated and the easily transported elements were removed from the site by water action. Weathering among individual bones (Pl. I, figs. B, C; Pl. II, fig. C) and all bones indicates relatively limited subaerial exposure prior to burial. Two different depositional environments are recorded within the bone horizon. The lower half of the coarse

conglomeratic Nimar Sandstone bearing bone horizon represents absence of any marine fauna and flora indicating a freshwater, fluvial environment. Small pieces of bones and petrified wood fragments are scattered in the lower part and seems to be trapped in conglomeratic Nimar Sandstone (Pl. III, figs. A, B, i.e. channel deposits), while the upper half of the dinosaur bone-bearing Nimar Sandstone horizon consists of typical marine deposits containing abundant scattered remains of oysters and fossil logs of wood (cf. *Rhizophora*) at Rampura (Pl. III, figs. C-F), Jamniya Pura and Borkui sections (District Dhar, Madhya Pradesh).

Palaeoenvironments And Palaeoecological Implications

Two distinct and different palaeoenvironments have been recorded within the Nimar Sandstone, suggesting that it is a heterogenous unit. The uppermost part of the unit contains a fauna indicative of marine influence (Badve and Ghare, 1978; Singh and Srivastava, 1981) and its environment have been interpreted by sundry workers as shallow water to near shore conditions with shifting sandy substrate and turbulant waters (Phelegar, 1960; Badve and Ghare, 1978; Nayak, 2000), shallow sub-littoral (Chiplonkar *et al.*,1977a; Kundal and Sanganwar, 2000), intertidal to inner subtidal (Singh and Srivastava, 1981), shallow shelf deposits (Bose and Das, 1986) and macrotidal estuarine complex environment comprising tidal channels (Ahmad and Akhtar, 1990).

The lower portion of conglomeratic Nimar Sandstone was deposited under fluviatile conditions, which is indicated by this first record of dinosaur skeletal remains, coarse grained sedimentation, channel deposits, current bedded sedimentary features and the absence of marine organisms. The basal part of the Nimar Sandstone is certainly of freshwater origin as evidenced by the presence of firstly recorded logs of fossil wood (Pl. III, fig. B) belonging to Angiospermae cf. *Rhizophora* (Aggarwal and Ambwani, pers. comm.; Khosla, work in progress) in Rampura and Ratitalai sections (District Dhar, Madhya Pradesh) and palynoflora assemblage (Upper Gondwana age) recorded from the carbonaceous clay in the Nimar Sandstone exposed at Umrali (District Jhabua) Madhya Pradesh (Murty *et al.*, 1963; Kumar, 1994). The logs of fossil wood (cf. *Rhizophora*) with well-preserved oysters has also been recorded from the upper part of fine grained Nimar Sandstone (Pl. III, figs. C-F). Towards the top, this section of the Nimar Sandstone becomes ferruginous (and on weathering imparts a reddish colour to the soil), hard, compact and gritty. It is calcareous, containing red shaly intercalations and has yielded *Ostrea* sp., *Turritella* sp., and a few shark teeth in a number of localities, i.e. south of Bagh town on Bagh-Kukshi road, Amlipura and Ajantar (Dassarma and Sinha, 1975). The uppermost part contains a thin oyster bed that indicates a high energy environment in a near shore area (Kulshreshtha, 1995). The occurrence of the Trace fossil horizon, two oyster beds and *Astarte-Turritella* bed within the upper part of the Nimar Sandstone near the Bagh Caves area (Chiplonkar and Badve, 1972, 1973; Badve and Ghare, 1978) further indicates an episode of marine transgression along the Narmada valley and the rapid transition

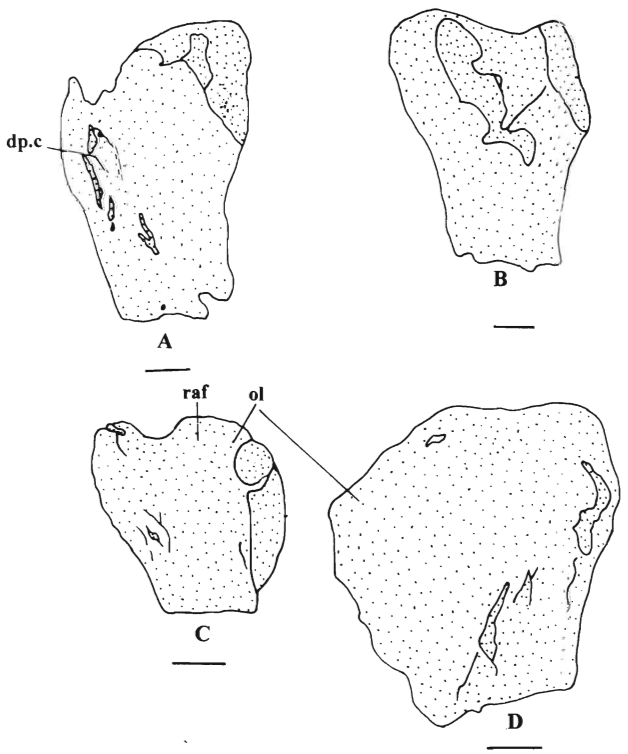


Fig. 6. Sauropod indet. Incomplete proximal end of right humerus (VPL/KH/3503) in A, B, medial views. dp.c. = delto-pectoral crest; C, D, broken left ulna (VPL/KH/3504) in posterior views. ol. = olecranon, raf = radial fossa. Scale for all figures = 5 cm.

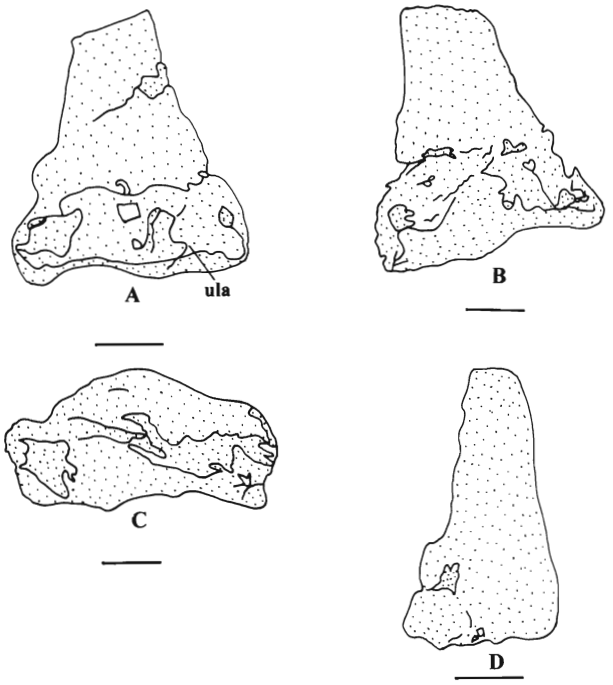


Fig. 7. Sauropod indet. Incomplete left radius (VPL/KH/3505) in medial (A), posterior (B), distal (C) and lateral views (D). ula. = ulnar articular surface. Scale for all figures = 5 cm.

from continental to marine conditions of deposition (Dassarma and Sinha, 1975). This episode was followed by short regressive and transgressive pulses resulting in oyster and *Astarte-Turritella* communities. Thus, the occurrence of oyster beds at different levels within the Nimar Sandstone seem to be intraformational units indicating various regressive pulses of the sea in a shifting shoreline (Kulshreshtha, 1995).

Singh and Srivastava (1981) recorded *Thalassinoides* and crab burrows in the Nimar Sandstone at Man River and Hatni River sections (District Dhar Madhya Pradesh), which suggest deposition of this horizon in a tidal flat area during slow marine transgression. The marine nature of the upper part of the Nimar Sandstone is further corroborated by the presence of algae (Badve and Nayak, 1983, 1984 a,b) belonging to four families (viz. Codiaceae, Dasycladaceae, Corrallinaceae and Cyanophyceae) along with other thick shelled bivalve genera (*Protocardium*, *Jhabotrigonia* and *Granocardium*) in the uppermost part of Nimar Sandstone in Jhabua District (Nayak, 2000). The algae assemblage indicates that the top portion of Nimar Sandstone must have been deposited in shallow marine water conditions of tropical region with normal salinity (Nayak, 2000), whereas the bivalve assemblage indicates near shore conditions with moderate to high energy levels of deposition (Badve and Ghare, 1978; Nayak, 2000).

The recent record of rich and diverse ichno-assemblage assigned to *Cruziana* facies (Frey, 1975) by Kundal and Sanganwar (2000) from the uppermost part of Nimar Sandstone at Baria and Karondia (Manawar area, district Dhar, Madhya Pradesh) clearly points to a shallow sublittoral to nearshore environment of deposition with moderate to high energy levels. In summary, the palaeontological data indicate that the deposition of the dinosaur bone rich basal portion of coarse conglomeratic sandstone starts under fluviatile conditions. As the sequence fined upward, the entire calcareous topmost portion was deposited under marine transgressive phase/estuarine conditions.

Age of the Dinosaur Bone-bearing Nimar Sandstone

Nayak (1987) assigned an Upper Cretaceous (Albian-Cenomanian) age to the Nimar Sandstone, based on the presence of planktonic and benthic foraminifera. Rajshekhar (1995) examined Nayak's foraminifera collection and found important taxa, which include: *Miliammina manitobensis* (Wickenden) and *Gavelinella plummerae* (Tappan), which are characteristic forms of the Albian/

EXPLANATION OF PLATE II

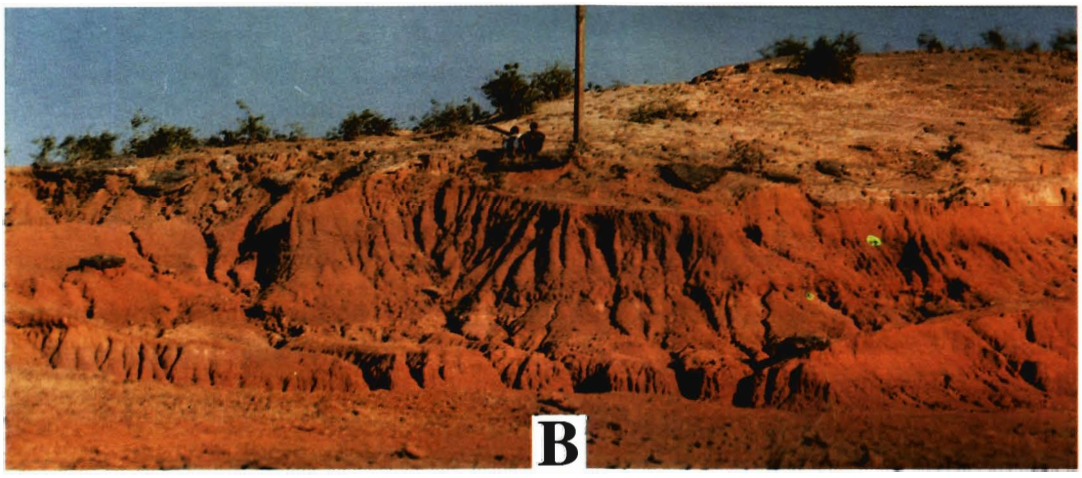
A. Fragmentary sauropod bones scattered in the Nimar Sandstone horizon at Jamniya Pura section.

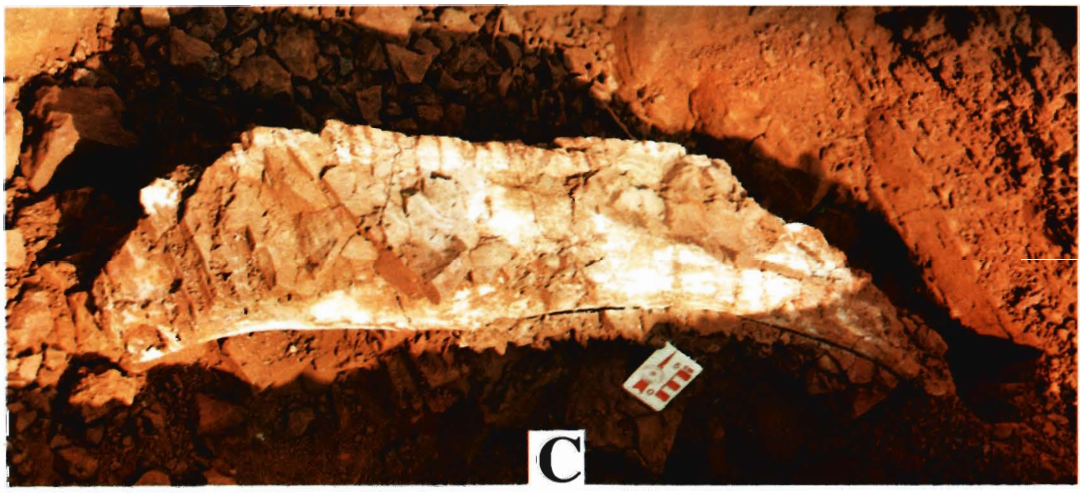
B. Panoramic view of dinosaur bone bearing red sandy soil within the Nimar Sandstone horizon at Ratitalai section.

C. Fragmentary femur (VPL/KH/3502) recovered from the red sandy soil within the Nimar Sandstone horizon at Ratitalai section (District Dhar, Madhya Pradesh).

Scale for Fig. A (hammer) represents = 29. 5 cm; Scale for Fig. C represents = 5 cm.


A


B


C

Cenomanian (Stelck and Wall, 1954). The presence of *Astarte sinuicostata*, *A. hexicostata*, *Cardium phataensis* and *Protocardia pondicherriense* indicates a pre-Cenomanian age (Chiplonkar and Badve, 1973). The presence of shark teeth *Ostrea* and *Turritella* in the uppermost gritty portion of the Nimar Sandstone (Dassarma and Sinha, 1975) indicates an age not earlier than Cenomanian for the Nimar Sandstone. Additionally, marine fossils such as echinoids, ammonites and bivalves in the upper part of the Nimar Sandstone indicate a Cenomanian-Turonian age (Dassarma and Sinha, 1975; Chiplonkar *et al.*, 1977 b). Based on calcareous nannoplankton, a Turonian age has been assigned to the upper calcareous part of Nimar Sandstone exposed near Chikli and Sitapuri sections, District Dhar, Madhya Pradesh (Jafar, 1982). The recovered assemblage comprises 31 species assigned to *Eiffellithus eximius* zone of Manivit *et al.*, (1977).

More recently, Nayak (2000) reported 15 bivalve species belonging to ten genera from the uppermost part of the Nimar Sandstone exposed in the Pipaldehla, Rajla, Ranapur, Udaygarh, Kanakakra and Akholi sections (District Jhabua, Madhya Pradesh). Based on the bivalve assemblage, Nayak (2000) assigned a Cenomanian-Turonian age to the Nimar Sandstone. In summary, multiple lines of evidence clearly point to a Cenomanian-Turonian age for the Bagh Group, on the basis of planktonic foramanifera (Late Cenomanian-Early Turonian), echinoids (Cenomanian), bivalves (Cenomanian-Turonian), ammonites (Turonian) and bryozoans (Cenomanian-Turonian, Sharma, 1976; Chiplonkar 1980; Chiplonkar *et al.*, 1977 a; Jafar, 1982; Taylor and Badve, 1995; Nayak, 2000; Bardhan *et al.*, 2002).

CONCLUSIONS

The presence of dinosaur bones in the Nimar Sandstone is very important because Cenomanian-Turonian dinosaurs are unknown from India and this constitutes their first record. The fragmentary nature of dinosaur bones recovered from the lower part of coarse conglomeratic Nimar Sandstone suggests that these are lag, trapped in the channel deposits conglomeratic Nimar Sandstone. The dinosaur-bearing level in districts Dhar and Jhabua, Madhya Pradesh has great potential in understanding the early evolutionary history of Indian Cretaceous sauropods. One of the well-preserved femur bone (VPL/KH/3500) is about 43 cm in diameter and its estimated length would probably have exceeded well over approximately 1.5 meters. The bone suggests the presence of gigantic early Cretaceous dinosaurs. The Nimar Sandstone in the sections studied has numerous interclations of red sandy lenses, which contain bones in various states of preservation.

Sauropod dinosaurs represent two distinct palaeoenvironmental settings within the Nimar Sandstone comprising a basal fluvial and an upper largely intertidal environment. The basal productive horizon contains large pieces of petrified wood parallel to sub parallel or the cross bedding of the coarse channel sandstone; in contrast the upper horizon contains fossil logs of wood showing more brackish water to marine conditions with close

EXPLANATION OF PLATE III

A. Fragmentary piece of dinosaur bone (VPL/KH/3515) trapped in lower part of conglomeratic Nimar Sandstone at Rampura (District Dhar, Madhya Pradesh). Scale = 2.3 cm.

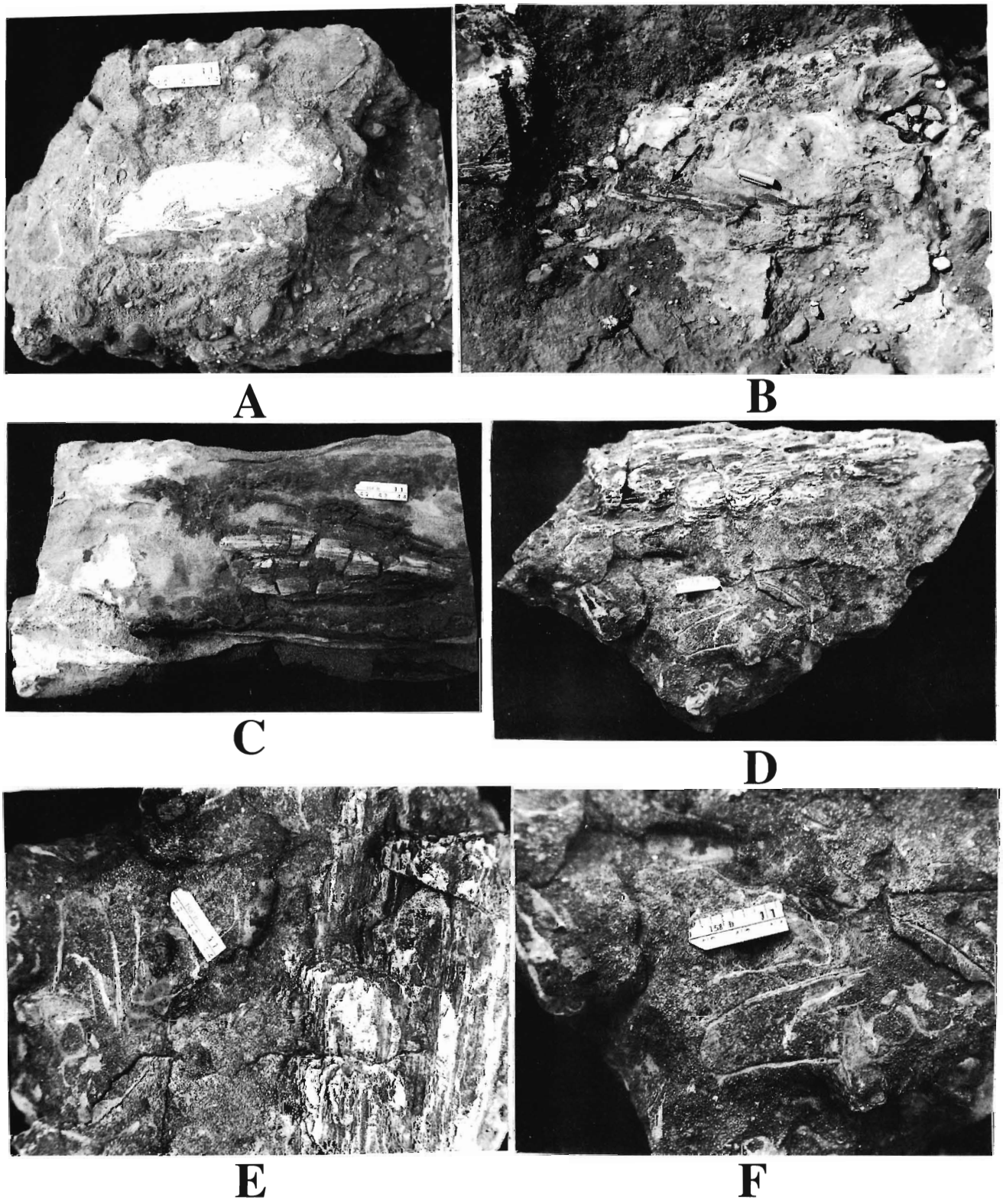
B. Field photograph showing logs of fossil wood (cf. *Rhizophora*) marked by arrows embedded in lower part of conglomeratic Nimar Sandstone at Rampura (District Dhar, Madhya Pradesh). Scale (pen cap) = 5.5 cm.

C. Log of fossil wood (cf. *Rhizophora*) (VPL/KH/3540) embedded in upper part of fine grained Nimar Sandstone at Rampura (District Dhar, Madhya Pradesh). Scale =2.3 cm.

D. Log of fossil wood (cf. *Rhizophora*) with oysters (VPL/KH/3541) embedded in upper part of fine-grained Nimar Sandstone at Rampura (District Dhar, Madhya Pradesh). Scale =2.3 cm.

E. Enlarged view of part of fig. D showing well-preserved oysters. Scale = 2.3 cm.

F. Enlarged view of part of fig. D showing well-preserved oysters. Scale = 2.3 cm.


A
B
C
D
E
F

association of numerous well-preserved oysters and fragmentary bone material suggesting close proximity to land.

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