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MICRO AND MEGA-VERTEBRATE FOSSILS FROM THE LATE TRIASSIC TIKI FORMATION, SOUTH REWA GONDWANA BASIN, INDIA: PALAEOENVIRONMENTAL AND PALAEOBIOGEOGRAPHIC IMPLICATIONS

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ABSTRACT

The predominantly red bed sequence of Tiki Formation, representing a significant lithostratigraphic unit of the South Rewa Gondwana Basin of India, is well known for its vertebrate fossil assemblage of Late Triassic age. The present study reports the teeth remains of anuran, *Eodiscoglossus* sp. and primitive fish Coelacanthidae, for the first time from the Late Triassic deposits of India. Fossils of Sphenodontidae (Rhynchocephalia) and *Cladodus* sp. (fish) are also reported here for the first time from Tiki Formation. The present work also records certain micro and mega vertebrate remains from Tiki Formation comprising of disarticulated fragments of phytosaurid (*Parasuchus hislopi*); isolated tooth of ornithischian dinosaur; dromatherid cynodont and mammalian teeth; teeth, scales and clavicles of piscean remains including those of actinopterigian fish, hybodont shark teeth including *Lissodus duffini, Parvodus tikiensis,* several broken and complete isolated teeth of *Ceratodus* sp.*,* semionid fish, etc. The vertebrate faunal assemblage of Tiki Formation is correlated with coeval Maleri Formation of the Prahnita-Godavari basin and also with other equivalent deposits from certain parts of the globe. The present study gives the global palaeobiogeographic scenario of Late Triassic time which is well supported by closely correlatable Late Triassic taxa in different continents which might have served a relatively rapid intercontinent passage of the vertebrate community extending across the ancient supercontinent, Pangea.

Keywords: Mammal, cynodont, elasmobranches, Tiki Formation, Late Triassic.

INTRODUCTION

The Triassic period in the Earth's geological history is one the most significant time owing to its palaeogeographic set up in the form of the supercontinent Pangea, its fossil contents comprising of the terrestrial ecosystems in the past which underwent significant reorganizations of its fauna, especially in the composition of tetrapod communities (Behrensmeyer *et al.,* 1992; Sues *et al.,* 1994; Bandyopadhyay, 1999; Chatterjee and Scotese, 1999; Heckart and Lucas, 2000). This period is also well known for the evolutionary event marked by a dramatic transition from a more primitive fauna dominated by "mammal-like reptiles" (synapsids-dicynodonts and cynodonts), rhynchosaurs, temnospondyl amphibians, and primitive archosauromorphs to a more advanced fauna dominated by derived archosaurs (including dinosaurs and crocodiles), mammals, lissamphibians (frogs and salamanders) and lepidosaurs (lizards, sphenodonts and snakes) (Hackert, 2004). Taking into consideration of its global significance, a research project under the title 'Study of Cynodont, mammal and other vertebrate fossil in the Tiki Formation, South Rewa Gondwana Basin, M.P. and study the faunal correlation with other parts of world' was taken up at Tiki Formation exposed in parts of Shahdol district (Survey of India Toposheet nos.64E/5 and 63H/8) of Madhya Pradesh during the G.S.I. field seasons 2013-15 (Jitendra and Milankumar**,** 2015a).

The Tiki Formation represents an important lithostratigraphic cum biostratigraphic unit. In view of this, a systematic palaeontological exploration of the Late Triassic continental sedimentary rocks exposed in the South Rewa Gondwana basin of Madhya Pradesh was taken up during the early nineties by the Geological Survey of India. The Tiki Formation is well known for its vertebrate fossils assemblages of Late Triassic age (Chatterjee, 1978; Chatterjee and Majumdar, 1987; Datta and Das, 1996; Datta *et al.* 2004; Jitendra and Milankumar**,** 2015a, b). The earlier records of certain well known mega tetrapod index fossil remains from this Formation represent parasuchids like *Parasuchus* (Chatterjee, 1978), rhynchosaurids like *Hyperodapedon* (Benton, 1983), rauisuchuid such as *Tikisuchus romeri* (Chatterjee and Majumdar, 1987) and metoposaurid amphibians *Buettneria* (Sengupta, 2002) and dipnoan lung fish *Ceratodus* (Datta and Das, 1996). However, micro-tetrapod assemblage comprise of an advanced cynodont *Rewaconodon* (Datta *et al.*, 2004), a morganucododontid mammal *Gondwanadon* (Datta and Das, 1996) and *Tikitherium* (Datta, 2005). Acrodont Iguanian lizard *Tikiguania* (Datta and Roy, 2006) is also known from this formation. Isolated dental remains of ornithischian dinosaurs like *Galtonia* sp.*, Pikinosaurus* sp. and the *Revoeltosaurus* sp. (Das and Datta, 1997, 1999; Datta, 2003) were also noted. The Piscean remains of the Tiki Formation comprise of elasmobranch selachian fauna *Xenacanthus* sp., *Hybodus* sp. and dipnonian fish *Ceratodus* sp. (Das and Datta, 1997, 1999; Datta and Das, 2001; Datta, 2003; Gupta, 2013).

The present work involved the field work as well as the laboratory investigations during 2013-14 and 2014-15. Nearly 30 sq. kms area around Tiki village (N 23°55.345'; E 81°21.439'), Jora village (N 23°53.884'; E 81°21.019'), Simaudh village (N 23°54.707; E 81°19.802'), Tenduar village (N 23°59.009'; E 81°23.95') in Shahdol district were scanned for mega vertebrate fossils. The said area was also sampled for microvertebrate analysis. The present study reports the additional record of certain micro and mega vertebrates from the study area and discuss their palaeoenvironmental and palaeobiogeographical significance.

The field work included geological investigation and exploration for megavertebrate and maceration of paleosol samples for the microvertebrate from the selected sections. For the purpose of micro-vertebrate study, about 1.5 tons of bulk samples from paleosol horizons were collected and disintegrated in water. The disintegrated samples were macerated by wet washing method using 40 to 100 mesh size sieves. The residues collected at the sieves were made air dried and screened under the stereozoom microscope for picking and study of micro-vertebrate remains. The collected fossils were cleaned and studied using stereozoom binocular microscope and Scanning Electron Microscope, Zeiss EVO 40, housed at the Palaeontological Lab. GSI, CHQ, Kolkata for taxonomic identification. The collected samples were properly catalogued and stored at the GSI Repository, Kolkata.

Geology of the study area

The study of Gondwana deposits of the Rewa basin dates back to first geological investigation of Hughes (1881) and later on followed by certain workers (Cotter and De, 1917; Fox, 1931, 1934) in which the Upper Gondwana succession of this area was classified into three distinct lithostratigraphic horizons, namely the Pali, Parsora and Tiki formations in succeeding order. Rao and Sukla (1954) re-examined the stratigraphic status of Pali and Tiki sediments and grouped these under a single lithostratigraphic unit, the 'Pali-Tiki' Group which is unconformably overlain by Parsora sediments. Dutta and Ghosh (1993) considered that the Parsora Formation is younger than the Tiki Formation and is exposed on hills and hummocks which is in contradiction to Shah (2000, 2001) who considered the Parsora Formation to be underlying the Tiki Formation and suggested that the Parsora Formation is equivalent or slightly younger than the Early Triassic Panchet Formation of the Damodar basin.

In the studied area, four major lithostratigraphic units could be recognized viz. Pali, Karki, Tiki and Parsora formations in ascending order (Fig. 1) (Mukherjee *et al.,* 2012). The Tiki Formation occupies a distinct space for both the lithostratigraphic and biostratigraphic study as a separable entity from the older unit of Karki Formation and younger deposits of Parsora Formation. On the basis of lithology and faunal assemblages, the Tiki Formation is divisible into two units namely the Lower and the Upper Tiki. The Lower Tiki Formation, about 28-30m thick, is characterized by presence of predominantly reddish mudstone/claystone with thin calcareous intercalations, laminated siltstone, calcarenite (Fig. 2), limestone and feldspathic quartzarenite (Datta and Das, 2001). The non-laminated mudstone beds usually contain calcareous globules, calcified rootlets, calcareous nodules (Fig. 2), and small to large concretions. The Upper Tiki Formation overlying the conglomerate bed containing lime-pellet (Fig. 3A) comprises mainly of sandstone and reddish mudstone which are deposited as an alternate sequence. Fossils are mainly recorded from the lower Tiki Formation. The unionid bivalve consisting beds (Fig. 2D) act as marker for the fossiliferous horizons of Lower Tiki Formation. Tiki is considered to be the Late Triassic (Carnian-Norian) based on vertebrate fauna and palynological assemblage (Chatterjee and Roychoudhury, 1974; Maheshwari and Kumaran, 1979; Datta and Das, 1996, 2001 and references therein). The Tiki Formation is present in the central and north-eastern parts of the Shahdol district. There is no record of vertebrate fossil from Pali and Parsora formations.

Near the Karki village, a distinct change in the lithological characters marks the base of an essentially arenaceous horizon overlying the Pali Formation. The Karki Formation is characterised by thick (1-5 m) multistoried, multilateral sandstone bodies (Fig. 3: C) comprising of quartz arenite, coarse to very coarse grained sandstone with sporadic pebble of quartz, cherts; grey to light pinkish sandstone (Fig. 5: B). The underlying Pali Formation consists of coarse grained, micaceous, pebbly, medium to fine grained sandstone, siltstone and mudstone, carbonaceous mudstone; mudstone having variegated colour of brown, olive, yellowish to reddish showing incipient development of paleosol profile (Mukherjee *et al.,* 2012). Certain sedimentary structures such as trough planner cross bedding, graded bedding, convolute bedding are associated with the sedimentary rocks of the Pali Formation.

Lithostratigraphically, the lithounits of Tiki Formation are unconformably overlain by the Parsora Formation. The Parsora Formation comprises a basal siltstone-mudstone succession followed by essentially arenaceous succession (Mukherjee *et al.,* 2012). The lithologies of Parsora Formation mainly consists of greyish to reddish colour, coarse grain, feldspathic, laminated to cross-bedded sandstone with minor amount of siltstone and grey mudstone intercalations. This Formation predominantly consists of the multistoried sandstone with the minor amount of siltstone and mudstone and is considered to be devoid of vertebrate fossils as there in no significant report of vertebrate fossil finding from the Parsora Formation. Likewise, till date, no vertebrate fossils have been reported from the Pali Formation. The basal part of the Parsora Formation is marked by the presence of 5-6 m thick palaeosol horizon thereby development of haematite/limonite concretion, calcretes and goethite are well observed (Datta and Das, 2001).

SYSTEMATIC PALAEONTOLOGY

Class **Cynodontia** Owen, 1861
Order **Therapsida** Broom, 1905
Family **Dromatheriidae** Gill, 1872
Genus ***Rewaconodon*** Datta *et al*., 2004

Rewaconodon tikiensis Datta *et al.,* 2004
(Pl. I, figs. 1-4)

Locality and horizon: Red mudstone bed above the *Unio* bed exposed near Jora village.

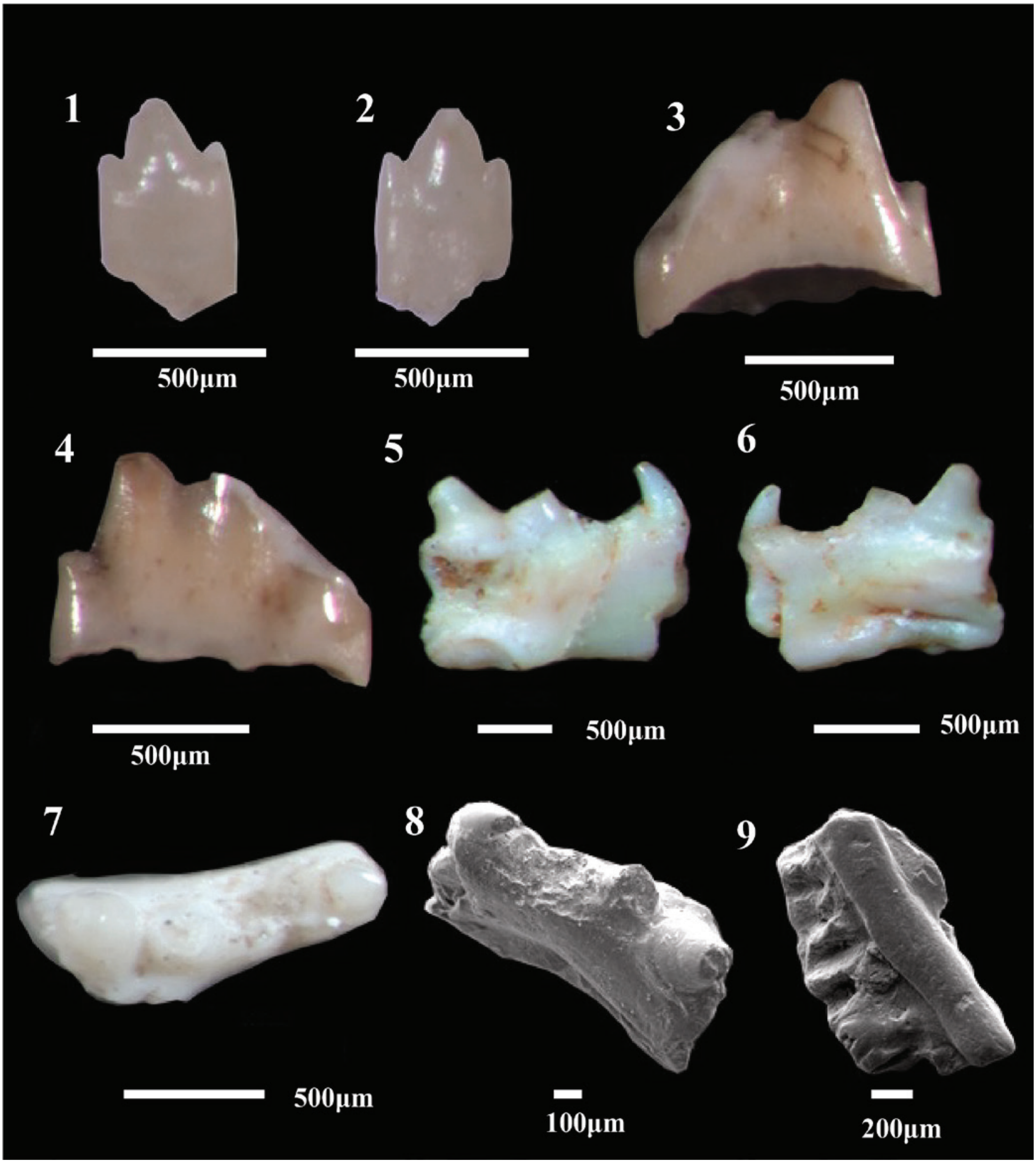
Material: Teeth of a cynodont (C02-04/ Pal/CHQ/Tiki/15).

Remarks: Specimens numbers C02 & 03/ Pal/CHQ/Tiki/15 (Pl. I, figs. 1, 2) are tricuspid teeth of post canines which closely resemble to the micro teeth of small mammal like reptiles. Two

EXPLANATION OF PLATE I

Figs. 1-3. ***Rewaconodon tikiensis*** Dromatherid cynodont (C02-C04/ Pal/CHQ/Tiki/15); Figs. 1 and 2. Labile/Lingual views of with tricuspid; Fig. 3. Lingual-lateral view of ***Rewaconodon tikiensis*** Dromatherid cynodont with tetracuspid; Fig. 4. Lingual view of ***Rewaconodon tikiensis*** Dromatherid cynodont with tetracuspid; Figs. 5-8. **Sphenodontidae** incertia sedis, (R01-C04/ Pal/CHQ/Tiki/15); Fig. 5 in external/labial view, Fig. 6 in internal/lingual view, Fig. 7 in occlusal view, Fig. 8 in lingou-occlusa view; Fig. 9. ***Eodiscoglossus*** sp. indet. (R02/ Pal/CHQ/Tiki/15) in medial view.

Plate I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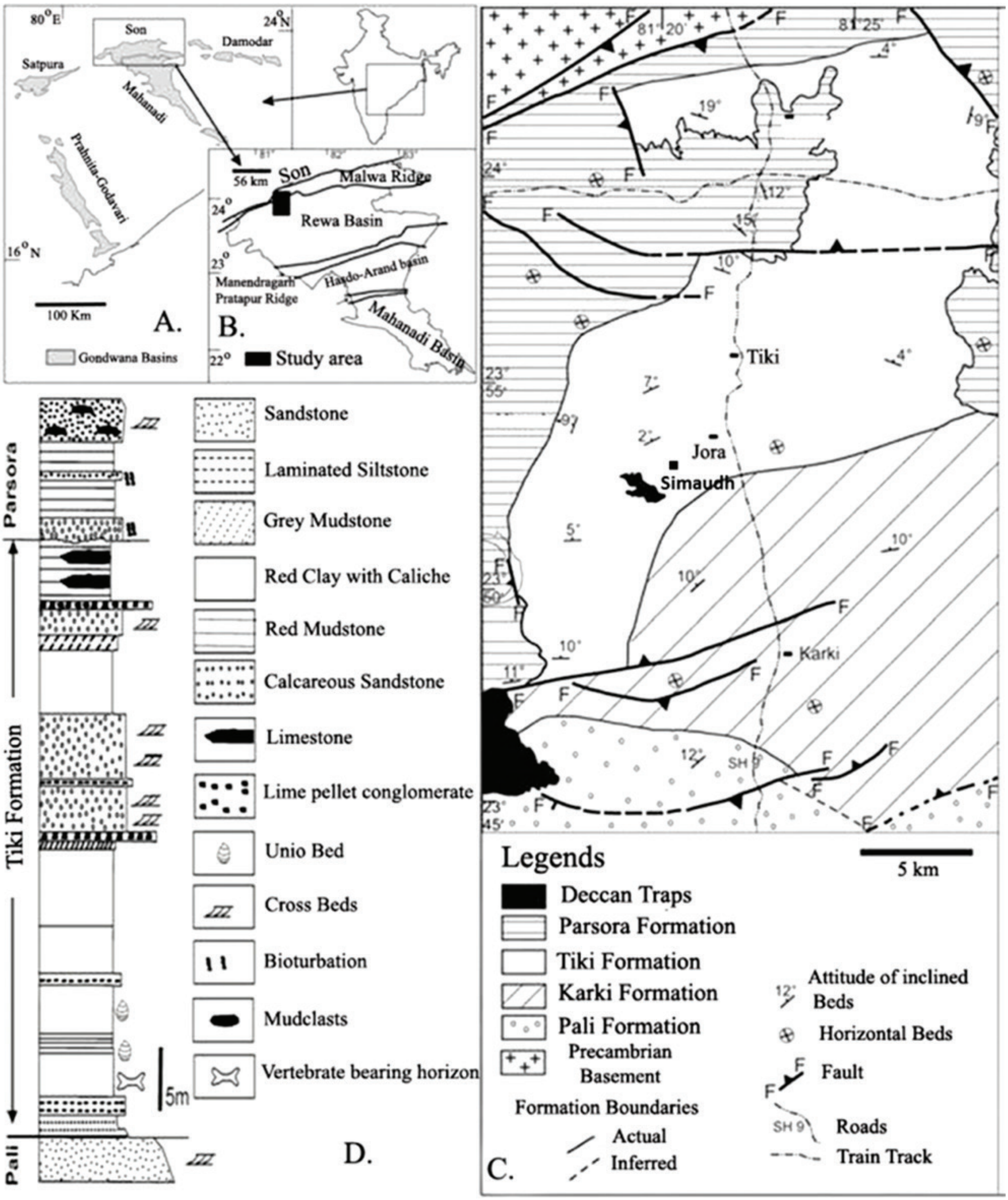
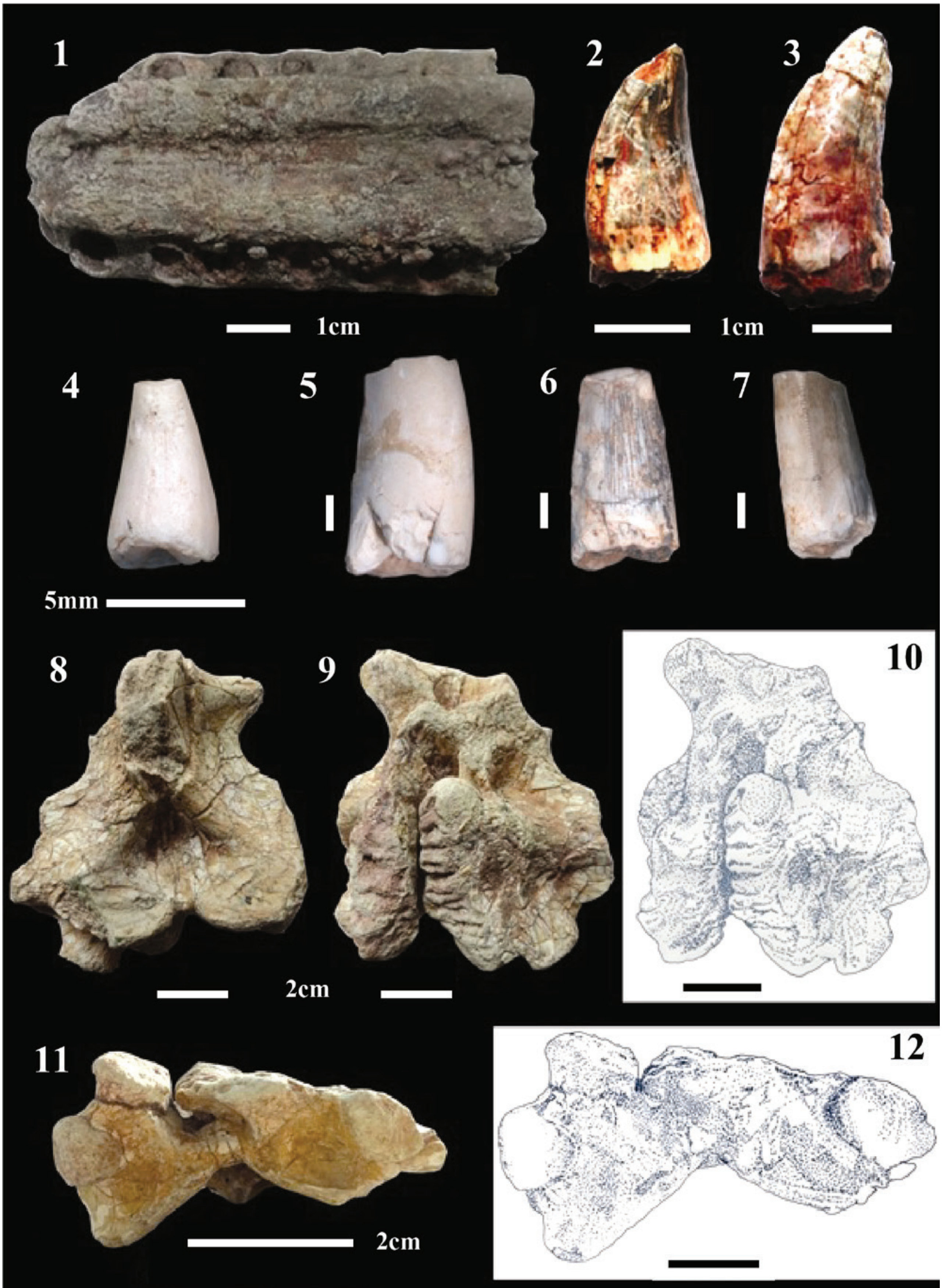


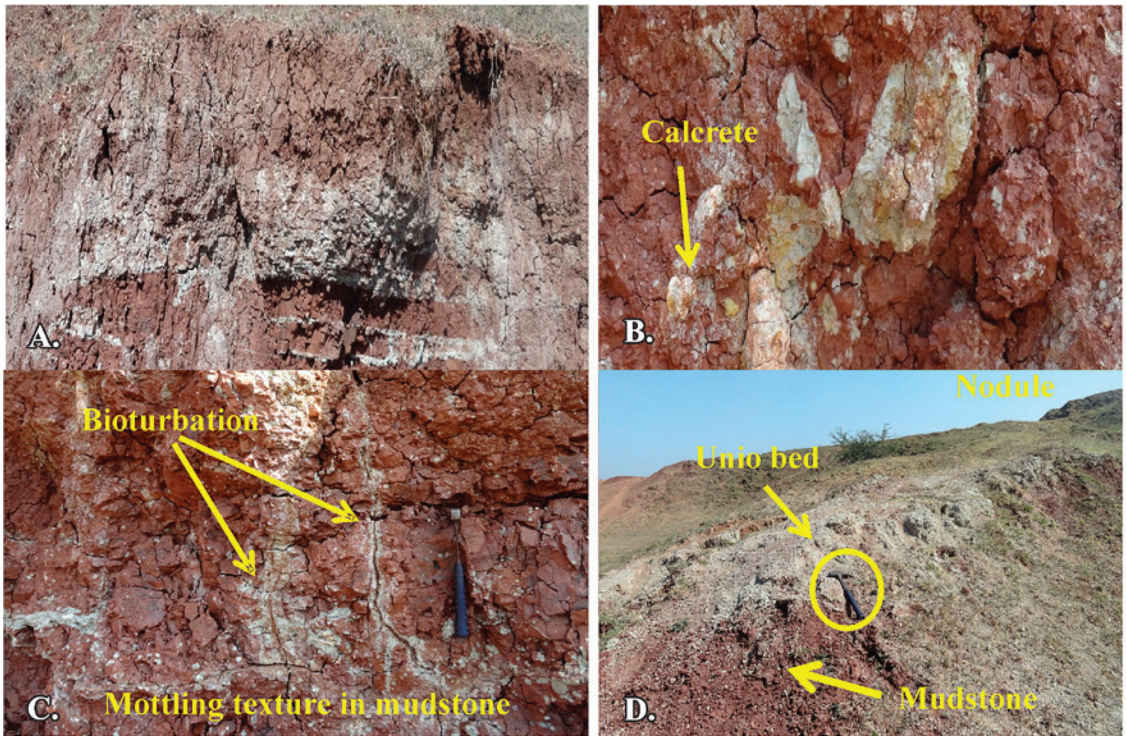
Fig. 1. Geological map showing (A) major Gondwana basins of the peninsular India; (B) Position of the study area within the Rewa basin (Source: Mukherjee *et al.,* 2012); (C) Geological Map of the study area, Tiki area in parts of Shahdol district of Madhya Pradesh, India (Source: Datta and Das, 2001; Datta *et al.,* 2004; Mukherjee, *et al*., 2012); D. Lithostratigraphical sequence in Tiki area, south Rewa Gondwana basin, Sahdol, M.P. India, (Source: Datta and Das, 2001; Datta *et al.,* 2004).

EXPLANATION OF PLATE II

Fig. 1. Maxillary Jaw fragment of ***Parasuchus hislopi*** (PH01/Pal/CHQ/Tiki/15); Figs. 2-7. Isolated tooth of Phytosaur ***Parasuchus hislopi*** (PH02-PH06/Pal/CHQ/Tiki/15); Figs. 8-12. (PH07/Pal/CHQ/Tiki/15) Neural arch of Phytosaur of side, top and front views respectively. Figs. 10, 12 are Schematic representation of Figs. 9, 11 respectively.

Plate II





Figs. 2: (A) Reddish colour mudstone of Lower Tiki near Jora village; (B) Development of calcretes/ nodules at Lower Tiki mudstone, Ghosa village; (C) Palaeosol development at Lower Tiki reddish mudstone of near Ghosa village; (D) The exposure of fossiliferous mudstone/clay just below the marker horizon of Unio bed at the Lower Tiki near Jora village.

specimens (Pl. I, figs. 1, 2) have both root and cusp and are characterized by tricuspid pattern. In these specimens the height of root is more than cusp's height. In one specimen (Pl. I, figs. 3, 4) there are four cusps (tetracuspid) and has no root. All the cusps are pointed in both tricuspid and tetracuspid. In tricuspid the medial cusps are tall as compared to lateral cusps. The above characters indicate that these are an advanced non-mammalian cynodont, possibly from the Dromotheriidae family and these are identical with the *Rewaconodon tikiensis* teeth described by Datta *et al.* (2004).

Class **Reptilia** Laurenti, 1768
Order **Rhynchocephalia** Gunther, 1876
Family **Sphenodontida**e Cope, 1870

Sphenodontidae *incertae sedis*
(Pl. I, figs. 5-8)

Locality and horizon: Red mudstone bed above the *Unio* bed exposed near Jora village.

Material: An incomplete jaw fragment of sphenodontid reptile (R01-C04/ Pal/CHQ/Tiki/15).

Remarks: The specimen preserves the fragment of upper jaw right premaxilla with visible three teeth of acrodont type dentition (Pl. I, figs. 5-8); cheek teeth are simple and conical in shape, the pointing apex of the crown of the teeth are worn out, slightly concave anteriorly with minor posterior edge, succession dentitions consist of larger and anterio-posteriorly compressed teeth, the tooth bearing portion of the premaxilla bone is wide. In external or labial view the teeth bearing bone is more flattened while in the internal or lingual view it bears minor lateral constriction. The present specimen is comparable with the sphedontian of *Diphydontosaurus* teeth and jaw fragmental remains decribed from the Late Triassic Dhurdham Down Cliff of United Kingdom (Foffa *et al.,* 2014) in pluerodont anteriorly and acrodont in posterior on the maxilla. The present specimen is also comparable with the teeth of Late Triassic sphenodontid *Clavatosaurus* in having the nearly rounded and stout morphology but it differs from *Clavatosaurus* teeth in having comparatively small posterior cusp. The previous records of sphenodontid from India come from the Early Jurassic Kota Formation of Gondwana deposits which are represented by teeth and jaw remains of *Rebbanasaurus jaini* and *Godavarisaurus* (Evans *et al*., 2001). The present specimens differ from *Rebbanasaurus* which are having pyramidal and faceted anteriorly like the dentary with coarse striae and from the *Godavarisauru* which are having premaxillary teeth are antero-posteriorly flattened and unstriated, with blunt crowns. The incomplete preservation of the present jaw fragment makes it difficult for proper taxonomic identification.

Class **Reptilia** Laurenti, 1768
Order **Anura** Rafinesque, 1815
Family **Discoglossidae** Günther, 1859

Eodiscoglossus sp.
(Pl. I, fig. 9)

Locality and Horizon: Red mudstone bed above the *Unio* bed exposed near Jora village.

Material: An incomplete jaw of *Eodiscoglossus* sp. indet. (R02/ Pal/CHQ/Tiki/15).

Remarks: The present specimen represents an incomplete fragmented right maxilla in medial view (Pl. I, fig. 9). The dental parapets highly worn out, pars palatinum is elevated forming a ridge shape structure. The maxilla bears the shallow longitudinal grooves extending upto the base of the tooth. The present specimen is comparable in shape and morphology with

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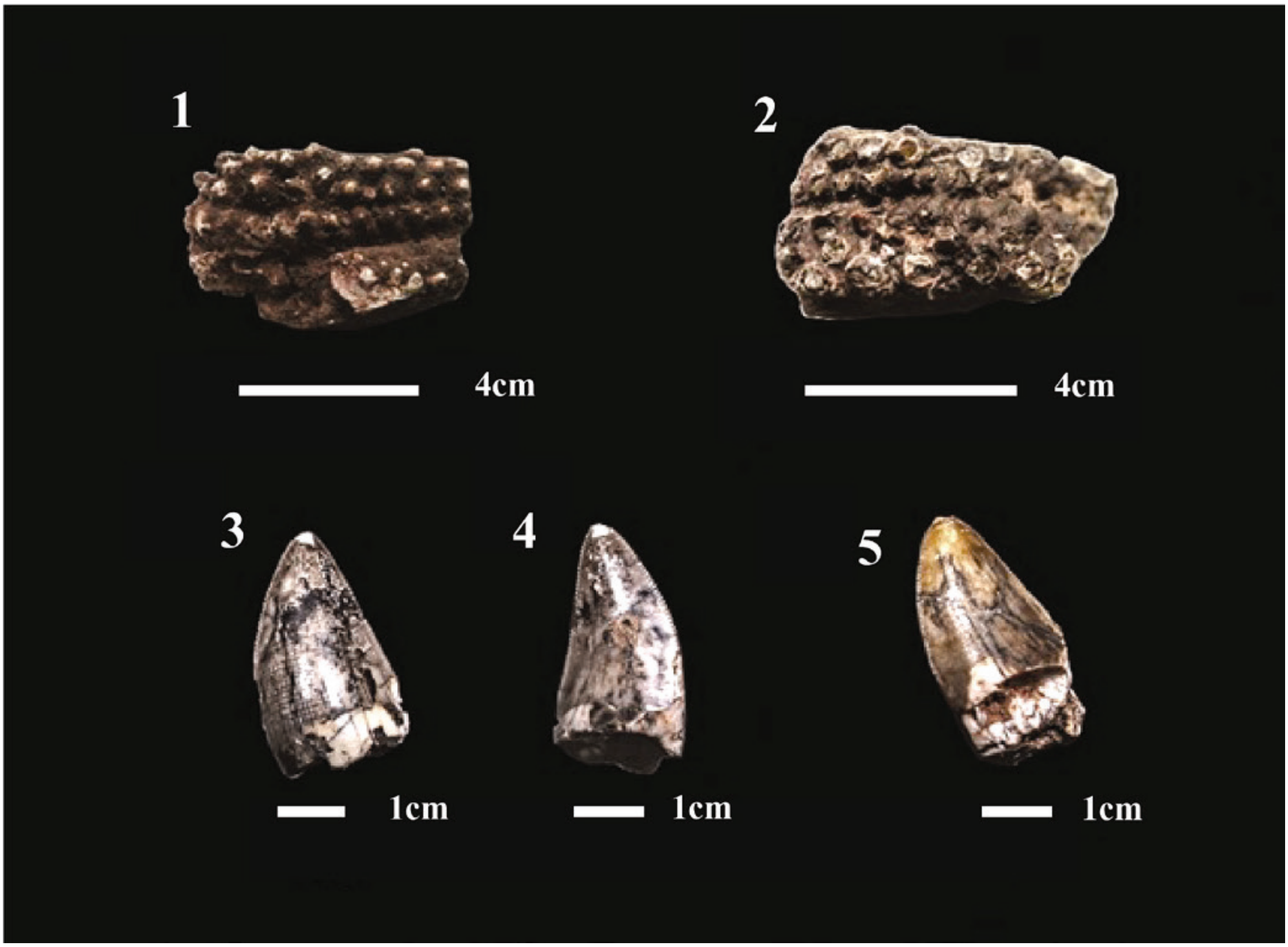


EXPLANATION OF PLATE III

Figs. 1, 2. ***Paradapedon huxleyi*** (RH01 & RH02/Pal/CHQ/Tiki/15) in ventral views; Figs. 3-5. Teeth of **Orthinischian** Dinosaur (OD01-OD03 /Pal/CHQ/Tiki/15) in buccal views.

the *Eodiscoglossus* sp. of Grigorescu *et al.* (1999) described from the Cretaceous deposits of the Hateg Basin of Romania. However, this specimen from the Tiki Formation is smaller in size. *Eodiscoglossus oxoniensis* of Evans *et al.* (1990) from the Middle Jurassic of England is comparable in size. However, the incompleteness of the specimen makes it difficult to assign the specimen to a particular species. The present finding is the first record of Anura remains from the Late Triassic Tiki Formation.

Class **Reptilia** Laurenti, 1768
Order **Phytosauria** von Meyer, 1861
Family **Phytosauridae** Jaeger, 1828
Genus ***Parasuchus*** Lydekker, 1885

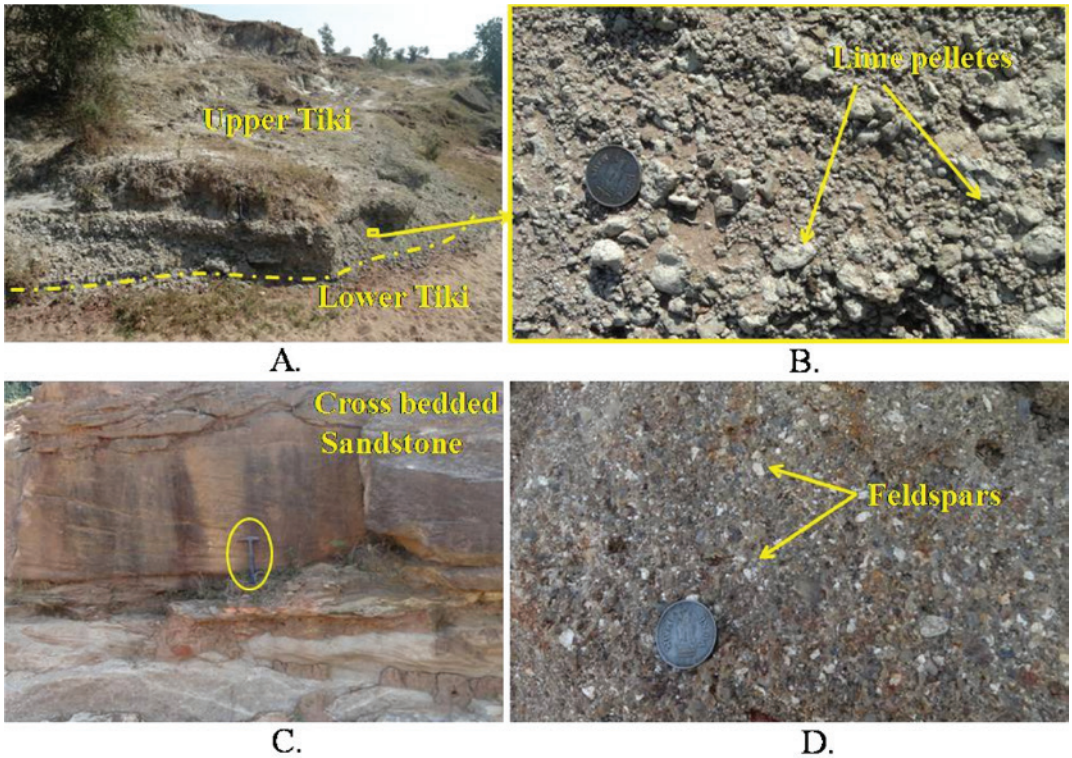
Parasuchus hislopi Lydekker, 1885
(Pl. II, figs. 1-7)

Locality and horizon: Reddish mudstone bed below the *Unio* bed near Jora village.

Materials: One incomplete maxilla (PH01 /Pal/CHQ/Tiki/15), six isolated teeth-two complete (PH02 and PH03/Pal/CHQ/Tiki/15) and four fragmentary (PH04- PH07/Pal/CHQ/Tiki/15) and (PH08/Pal/CHQ/Tiki/15) neural arches.

Measurement The length of the jaw fragment is 7.5 cm, width of the jaw fragment is 3.5cm; thickness of the jaw fragment is 2.5 cm. Height of well-preserved sockets is ~1.4 cm.

Remarks: It (PH01/Pal/CHQ/Tiki/15) is incomplete maxilla fragment of phytosaur characterized by two rows with homodont teeth sockets (Pl. II, fig. 1). Teeth sockets are more or less circular in shape and are placed more or less at an equal distance except on the anterior portion, where they are more closely spaced. The anterior portion of the jaw is narrow while posterior is wide. The specimen is also characterized by distinct lateral and medial areas which are separated by a well-developed longitudinal groove, extended along the entire length of the maxilla. There are two parallel longitudinal lateral ridges on both sides of this medial groove, extended along the entire length of the maxilla. The groove is symmetrical in shape. There are seven sockets preserved in the right lateral while five in the left lateral side. Morphologically the specimen is well comparable with *Parasuchus hislopi* described from the Maleri Formation (Chatterjee, 1974). Of the six phytosaurian teeth, two (Pl. II, figs. 2, 3) are almost complete and the remaining four are incomplete (Pl. II, figs. 4-7) with broken apex. Teeth are conical and broadly curved posteriorly. They bear fine longitudinal



Figs. 3: (A) Boundary between the Lower and Upper Tiki Formation; (B) Lime-Pebble conglomerate demarcates the Lower and Upper Tiki Formation; (C) Showing cross bedded multistoried sandstone of the Karki Formation from Karki area; (D) Coarse grained greyish to reddish feldspathic sandstone of the Parsora Formation.

striations. An incomplete neural arch (PH08/Pal/CHQ/Tiki/15) of a phytosaur has also been collected. Because of the proximity of all the above collection comprising teeth, maxilla and neural arches and their similarity with those of phytosaur, it is presumed that they belong to a single species *Parasuchus hislopi.*

Earlier, Milankumar and Jitendra (2015) described appendicular osteoderms of phytosaur for the first time from Late Triassic Tiki Formation of India. Their collection comprises of three morphotypes of ellipsoidal, sub-circular to circular shape and irregular shape. It is considered that osteoderms are commonly found in many groups of extant and extinct reptiles and amphibians including phytosaurs, crocodylomorphs, various groups of dinosaurs, aetosaurs, etc. (Rogers *et al.,* 2011) and are widespread amongst the phytosaur and aetosaur (Romer, 1956; Scheyer *et al.,* 2013). Earlier, Chatterjee (1978) reported osteoderms, certain bones and a well preserved skull of a basal phytosaur, *Parasuchus hislopi* from the coeval deposits of Late Triassic deposits of Maleri Formation.

Class **Reptilia** Laurenti, 1768
Order **Rhyncosauria** (Gervais) Osborn, 1903
Family **Rhyncosauridae** Huxley, 1887.
Genus ***Paradapedon*** Huxley, 1859

Paradapedon huxleyi Lydekker, 1881
(Pl. III, figs. 1, 2)

Locality and horizon: Reddish mudstone bed from Simaudh and Jora villages.

Material: Maxillary dental plate of rhyncosaurian reptile (RH01 and RH02/Pal/CHQ/Tiki/15).

Remarks: These two specimens (Nos. RH01 and RH02/Pal/CHQ/Tiki/15) are characterized by distinct lateral and medial areas which are separated by multiple rows of teeth in both sides of the medial (Pl. III, figs. 1, 2). There is a well developed longitudinal groove, extending to entire length of the maxilla. In both specimens groove is wider in the middle of the maxilla. On either side of the longitudinal groove, several longitudinal rows of teeth tend to lie parallel to the median groove and to one another. The maxillary teeth of both the specimens are pyramidal or conical in shapes, pointed and straight in their tips, but broad at the base. The tooth arrangement is regular in patterns in both specimens. The teeth are arranged in two alternative patterns, oriented in rows, either a longitudinal or a diagonal pattern of rows. In both specimens there are three rows parallel to the longitudinal groove. These specimens are identical with the rhyncosaurian reptile of Maleri Formation (Chatterjee, 1974).

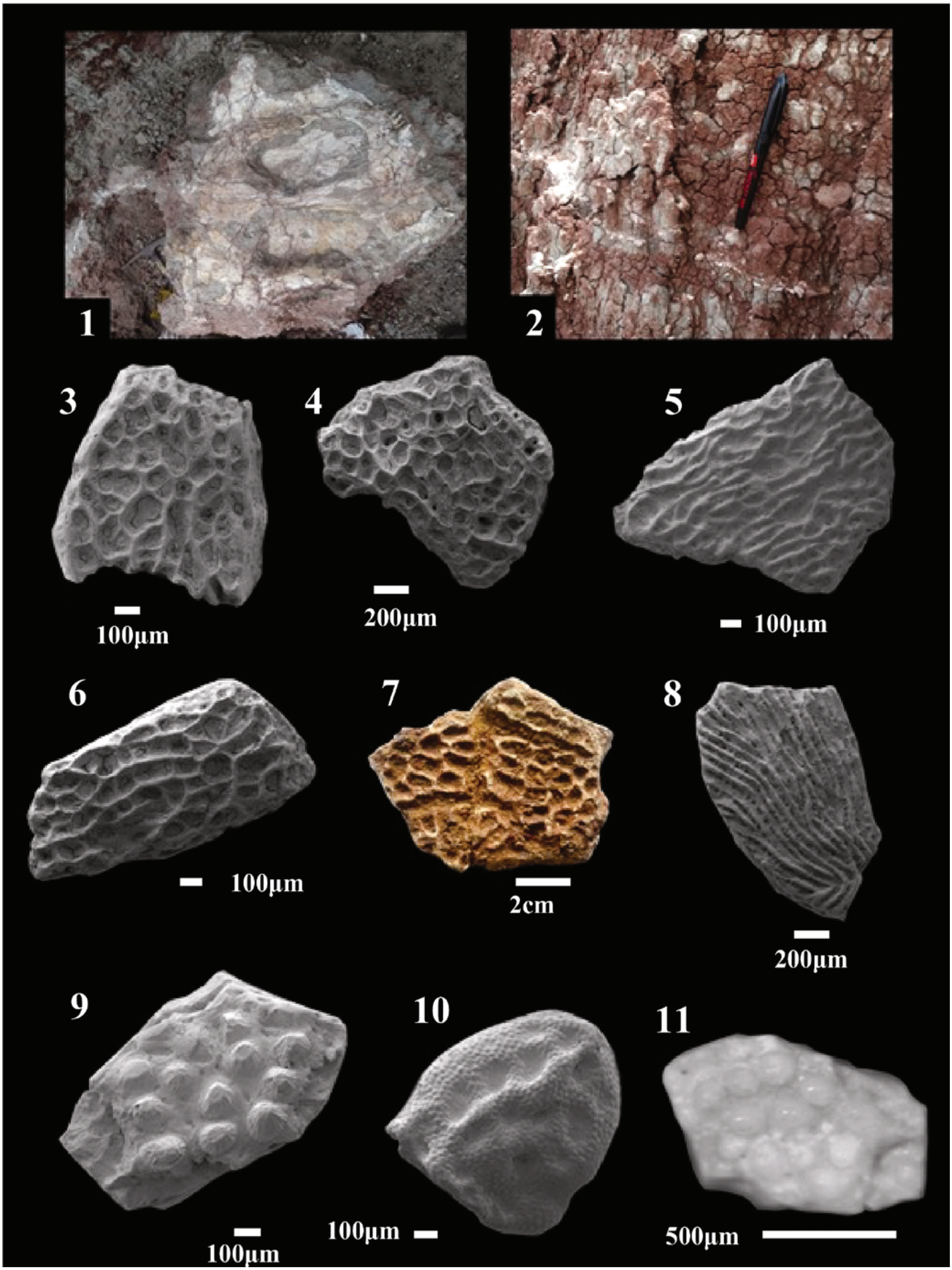
Class **Reptilia** Laurenti, 1768
Order **Ornithischia** Seeley, 1888

Gen. et sp. indet.
(Pl. III, figs. 3, 4, 5)

EXPLANATION OF PLATE IV

Fig. 1. Poorly preserved ***Metaposaur*** skull (RH01/Pal/CHQ/Tiki/15) in Dorsal view; Fig. 2. Cross-section of calcareous mudstone with ***Metaposaur***; Figs. 3-8. Clavicles of ***Metaposaur*** sp. indet. (MPG01, MPG02, MPG03, MPG04, MPG05 & MPG6/Pal/CHQ/Tiki/15 respectively) in ventral view; Figs. 9, 11. Teeth plate of **Coelacanthidae** indet. (F07-F08/Pal/CHQ/Tiki/15 respectively); Fig. 10. Unidentified specimen (F03/Pal/CHQ/Tiki/15).

Plate IV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2
3
4
5
100µm
200µm
100µm
6
7
8
100µm
2cm
200µm
9
10
11
100µm
100µm
500µm

Locality and horizon: Reddish mudstone below the *Unio* bed exposed at Jora and Tiki villages.

Material: Teeth of an ornithischian dinosaur (OD01-OD03 /Pal/CHQ/Tiki/15).

Remarks: Specimens OD01, OD02 and OD03/Pal/CHQ/ Tiki/15 (Pl. III, figs. 3, 4, 5) have been recovered from the lower part of Tiki formation. These are characterized by low, triangular tooth crown in lateral view, recurvature are absent and well developed neck separating crown from roots (Pl. III, figs. 3, 4, 5). The tooth is more or less trenchant triangular in shape with two margins serrated and surface rugose. The presence of serration indicates carnivorous nature of the reptile. These specimens are somewhat comparable with the ornithischian teeth reported by Chatterjee (1978) from the Late Triassic of Texas, as well as from the Tiki (Datta and Das, 2001).

Class **Amphibia** Linnaeus, 1758
Order **Temnospondyli** Zittel, 1895
Family **Metoposauridae** Watson, 1919
Genus ***Metoposaur*** Lydekker, 1890

Metoposaur sp. indet
(Pl. IV, figs. 1-8)

Locality and horizon: Skull fragment from the calcareous mudstone bed exposed at Tanduar village and clavicles are from the red mudstone/clay bed below the *Unio* bed from Jora village.

Material: Skull fragment of a Metoposaurid; Incomplete fragments of a Metoposaurid clavicle (specimen nos. MPG01, MPG02, MPG03, MPG 04 & MPG05/Pal/CHQ/Tiki/15) and certain unnumbered specimens.

Remarks: RH01/Pal/CHQ/Tiki/15 (Pl. IV, figs.1, 2) is a skull fragment characterized by slightly broader posterior than the anterior. The teeth of the specimen are conical in shape and are mainly present in anterior side. The specimen is too friable to be collected. The present specimen was compared with the metoposaurid fossils collected by Das and Dutta (1997, 1999) and the characters were found to be matching. The specimens (MPG01-6/Pal/CHQ/Tiki/15) are incomplete clavicles of *metaposaurian* origin (Pl. IV, figs. 3-8). As the specimens are very small fragments identification of the specimen and its position in the pectoral girdle as a part of clavicle and interclavicles portions is quite difficult. The specimens are highly sculptured, ornamented with very small area of rounded or horizontal depression. Earlier reports of metoposaurids from India are known from the Late Triassic Maleri Formation of the Pranhita–Godavari basin and the coeval Tiki Formation of the Rewa basin (Roy Chowdhury, 1965; Sengupta 1992, 2002).

Class **Sarcopterygii** Romer, 1955
Order **Coelacanthiformes** Berg, 1937
Family **Coelacanthidae** Agassiz, 1843

Coelacanthidae indet.
(Pl. IV, figs. 9, 11)

Locality and horizon: Red mudstone/clay bed just below and above the *Unio* bed.

Material: Incomplete fragments of tooth plates of coelacanthid fish (F07-F08/Pal/CHQ/Tiki/15)**.**

Remarks: Several tooth plates oriented in a regular fashion along the plate (Pl. IV, figs. 9, 11). The teeth are blunt, faint striations are present at the crown winnowing into a point at the tip of the tooth (Pl. IV, figs. 9). These small size teeth sometimes form a tooth row, several teeth appearing as an elongated block. Wear facets can be seen on some tooth surfaces as the striations have worn down. The present tooth plate is having similar looks with those of Coelacanthidae tooth plates from Triassic Snyder Quarry North-Centran New Mexico (Heckert and Jenkin, 2005) and also Chinle Group have previously been referred to as Colobodontidae or Perleididae, extinct groups of actinopterygians similar to the palaeoniscids (Murry, 1982; Huber *et al.,* 1993; Heckert, 2001, 2004). The first fossil coelacanth, *Indocoelacanthus robustus* from India comes from fluviatile sediments of the Lower Jurassic (Kota formation) in the Pranhita-Godavari valley of Central India (Jain, 1974). His collection comprises of skull bone, palate and other dissociated bones, appendicular skeleton and fin pelvic plate, etc. with no visible dentition jaw. However, the dentition is prominent in the present specimen. This report is first of this kind from the Late Triassic deposit of India.

Class **Chondrichthyes** Huxley, 1880
Order **Ctenacanthiformes** Zangerl, 1981
Family **Ctenacanthidae** Dean, 1909
Genus ***Cladodus*** Egerton, 1841

Cladodus sp.
(Pl. V, figs. 1-6; Pl. VI, figs. 1-7)

Locality and horizon: Red mudstone bed above the *Unio* bed from Tiki, Simaudh and Jora villages.

Material: Teeth of *Cladodus* sp. (F12- F15/Pal/CHQ/ Tiki/15; F16-F23/Pal/CHQ/Tiki/15, respectively) and certain unnumbered specimens.

Remarks: The present specimens (Pl. V, figs. 1-6; Pl. VI, figs. 1-7) are characterized by conical in shape with striations; lingually concave (Pl. V, figs. 2, 3). In most of the specimens striations are present only in upper part of the cusp while in few, these continue throughout the cusps (Pl. VI, figs. 2). Maximum specimens have only one cusp but in few specimens both median and lateral cusps are present but lateral cusps are broken. Roots are partially preserved only in the few specimens; present depression in the basal part of the cusps (Pl. V, figs. 2, 3). The above characters are similar with *Cladodus* shark teeth. These have been reported earlier by Ginter *et al.* (2005) and Duffin and Ginter (2006). The present specimens are fragmented so there is problem in the classification up to the species level.

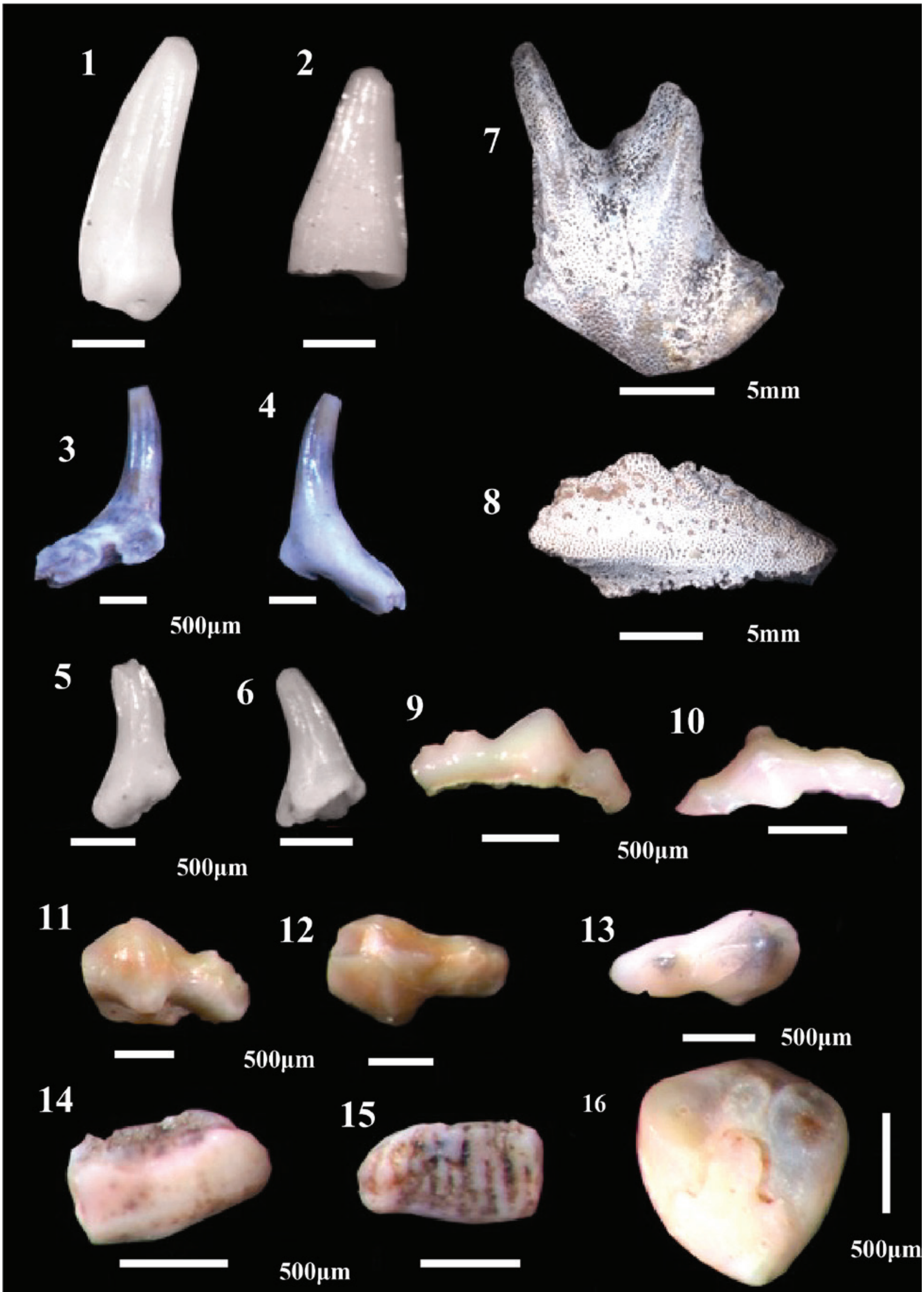
Class **Sarcopterygii** Romer, 1955
Order **Ceratodontiformes** Berg, 1940
Family **Ptychoceratodontidae** Martin, 1982
Genus ***Ceratodus*** Agassiz, 1837

Ceratodus sp.
(Pl. V, figs. 7, 8)

EXPLANATION OF PLATE V

Figs. 1-6. Isolated tooth of ***Cladodus*** sp. (F12- F15/Pal/CHQ/Tiki/15, respectively); Figs. 7, 8. ***Ceratodus*** sp. (F01/Pal/CHQ/Tiki/15, F02/Pal/CHQ/Tiki/15), both in labio-occlusal view; Figs. 9-10. ***Parvodus tikiensis*** (F03/Pal/CHQ/Tiki/15, F04/Pal/CHQ/Tiki/15), Fig. 9. in lingual view and Fig. 9 in labio-occlusal; Figs. 11-13. ***Lissodus duffini***, (F05/Pal/CHQ/Tiki/15, F06/Pal/CHQ/Tiki/15), Figs. 11. Labial view, Figs. 12, 13 are in occlusal view; Figs. 14, 15, 16. Unidentified fish teeth (F10, F11/Pal/CHQ/Tiki/15, respectively).

Plate V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500μm

Locality and horizon: Red clay bed from the upper part of Tiki Formation near Tenduar village.

Material: Teeth plate of *Ceratodus* sp. (Specimen No. F01-F02/Pal/CHQ/Tiki/15).

Remarks: - Small incomplete, vomerine dental plates of *Ceratodus* sp. (Pl. V, figs. 7, 8). Crowns of the tooth plate is high, possessing pulp cavity and ridge (Pl. V, figs. 7, 8), occlusal view is ornamented with the presence of multiple tubercles and pitted structures; three high ridges are preserved in one of the specimen (Pl. V, figs. 8). The ridge and furrows structure in the tooth are arranged in a radiating fashion in which each of the ridges bears single row of unworn denticles in lingual view. Two successive ridges form an acute angle. Earlier *Ceratodus* sp. has been reported from Tiki Formation by Gupta (2013) and Shastri *et al*. (1977).

Class **Chondrichthyes** Huxley, 1880
Order **Euselachia** Hay, 1902
Family **Lonchidiidae** Herman, 1977
Genus ***Parvodus*** Rees and Wonderwood, 2002

Parvodus tikiensis Prasad *et al.,* 2004
(Pl. V, figs. 9-10)

Locality and horizon: Red mudstone bed below the *Unio* bed near Jora village section.

Material: Teeth of a fresh water shark (F03/Pal/CHQ/Tiki/15, F04/Pal/CHQ/Tiki/15).

Remarks: The specimens are signified by the presence of labio-lingually compressed tooth bearing two pairs of lateral cusplet on either side of the main cusp (Pl. V, figs. 9-10). The main cusp is the highest of all which is followed by the first lateral cusp with nearly half of the height of the principal cusp. The principal cusp is high, diamond shaped. Vertical striations are absent on both the labial and lingual surfaces of the tooth. The occlusal crest is sharp, crenulated, developed strongly and linguo-laterally curved. Earlier the first report of *Parvodus tikiensis* has been made by Prasad *et al.* (2004). The present specimens are similar with the *Parvodus tikiensis* morpho-type 2 of Prasad *et al.* (2014).

Lissodus duffini Prasad *et al*. 2004
(Pl. V, figs. 11-13)

Locality and horizon: Red mudstone bed below the Unio bed exposed near Jora village.

Material: Teeth of a fresh water shark (F05/Pal/CHQ/Tiki/15, F06/Pal/CHQ/Tiki/15) and certain unnumbered specimens.

Remarks: The present specimen are robust, incomplete, triangular in shape in occlusal view (Pl. V, figs.12, 13); crest prominent, principal cusp is diamond shape with lateral cusplet, one of each lateral cusplet in the present specimens are broken away; longitudinal ridge prominent; roots are not well preserved; apex of the principal crow are pointed, very high and more than half of the height of first lateral cusp. The base of the main cusp is much larger than those of the first lateral teeth; lateral end of the crown acutely tapering. Prasad *et al.* (2004) described *Lissodus duffini* as a new species from the Tiki Formation.

Class **Actinopterygii** Klein, 1885
Actinopterygian indet.
(Pl. VI, figs. 8-16)

Locality and horizon: Red Mudstone bed above the *Unio* bed from *nala* sections near Tiki, Jora and Sirmaur villages.

Material: Teeth (F24-F27/Pal/CHQ/Tiki/15) and scale of actinopterygian fish (F28-32/Pal/CHQ/Tiki/15) and certain unnumbered specimens.

Description: Complete or near-complete teeth as pertaining to actinopterygian (bony); can be distinguished into three distinct morphotypes and the remaining teeth are miscellaneous and probably may represent into genera. Some of these fish teeth are well preserved as evidenced by the presence of well preserve crystal tips, however the root portion are not preserved well which are broken.

Fish morphotype 1: This type of tooth is conical, bent/curved at the middle of crown, with thicker base and apex is tapering (Pl. VI, fig. 8). The tip is not directly above the centre of the base, but more to one side. This group comprises certain teeth which are mostly conical, a broader base and significantly smaller towards the tip, thickness, length and degree of curvature each specimen may vary. It is difficult to identify the specimen to generic /specific level.

Fish morphotype 2: Like the tooth of morphotype 1, this type of tooth is also conical, slightly curved to straight, the crown with pointed apex; it differs from the first one in having an abruptly tapering crystal tip at the upper portion of the crown (Pl. VI, figs. 9-11). The base of the teeth are broader, roots are not well preserved.

Actinopterygiian Scale: The majorities of the collected fish scales are rhomboid in shape, smooth external surface, and have a slightly concave external surface at the middle with convex leading edge that articulates with a shallow concavity in the next most anterior scale (Pl. VI, figs. 12-16). Some of the present specimens show well-preserved scale (Pl. 6: figs. 12-14) with their original iridescence of the enameloid are still present. The specimens represent an array of morphotypes ranging from simply smooth rhombohedral shape (Pl. VI, fig. 13) to nearly robust external ornamentation (Pl. VI, fig. 15). The majority of the osteichthyan scales, teeth and bone fragments from Tiki Formation, even though they seem quite diverse, are difficult to identify up to genus and species levels.

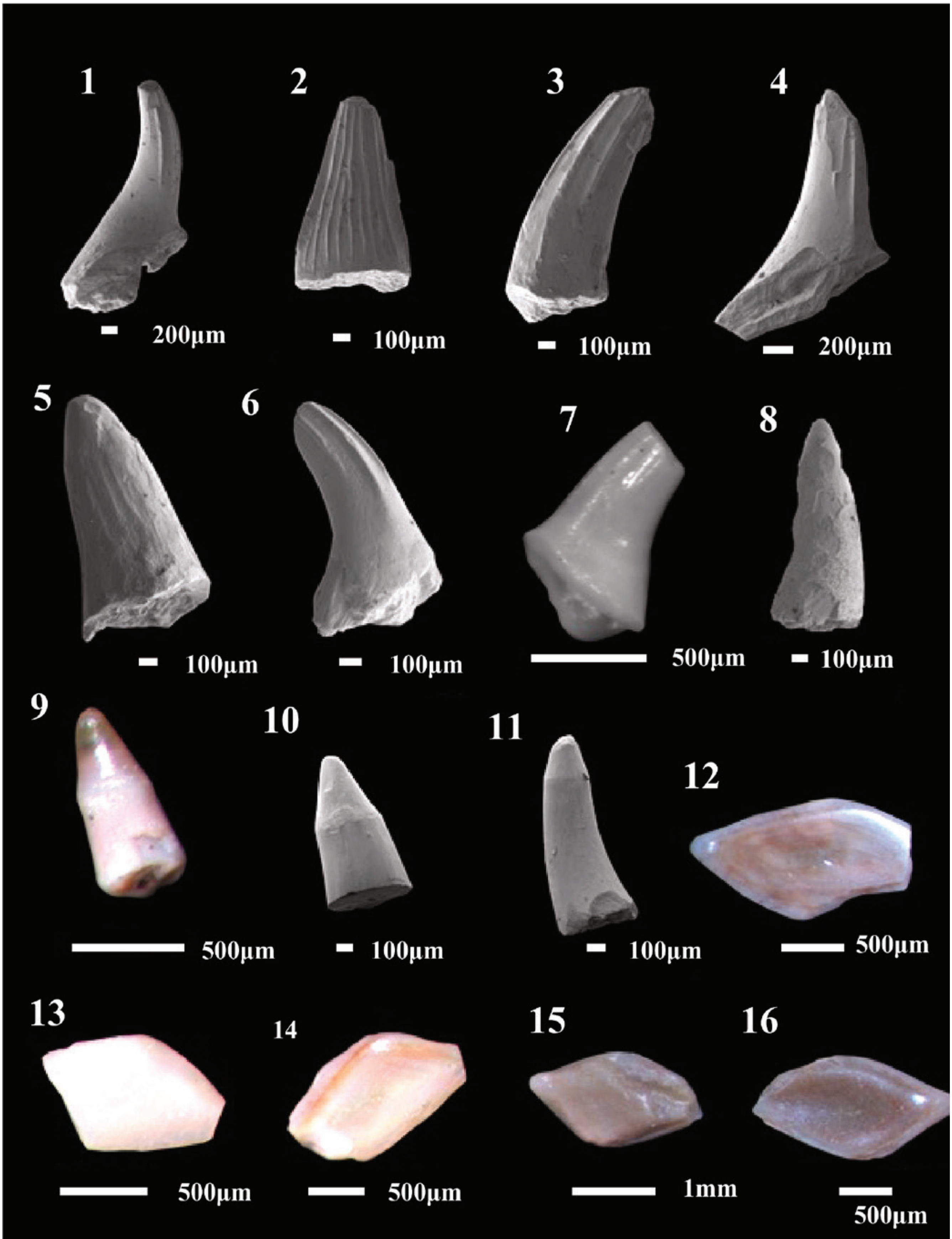
DISCUSSION

The Triassic vertebrate remains found throughout the globe show a major change in evolutionary trend from the Late Palaeozoic (therapsid) to the Mesozoic (archosaur) stage of tetrapod faunal evolution (Ochev and Shiskenin, 1989) which are well preserved at certain geological formations of the erstwhile supercontinent called the Pangaea. The facts that the continents during the Late Triassic period were grouped together as a supercontinent Pangaea and its certain continental processes were probably very active and hence the terrestrial (non-marine) Triassic deposits are extensively found in India, South Africa, South America, western and eastern North America, Antarctica,

EXPLANATION OF PLATE VI

Figs. 1-7. Isolated tooth of ***Cladodus*** sp. (F16-F23 /Pal/CHQ/Tiki/15 respectively); Figs. 8-11. Lateral view of **Actinopterigiian** teeth (F24-F27/Pal/CHQ/Tiki/15 respectively); Figs. 12-16. Scales of **Actinopterigiian** fish in external view (F28-F32/Pal/CHQ/Tiki/15, respectively).

Plate VI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Australia, USSR, western Europe, etc. The presence of closely related Late Triassic taxa in different continents may be one of the major attribute of a relatively rapid intercontinent passage which in turn is the result of manifestation of the integral part of the vertebrate community extending across the ancient supercontinent Pangea (Bandhopadhyay, 1999).

In Indian Gondwana deposits, the faunal remains of Tiki Formation are closely comparable with it equivalent deposits of Maleri Formation in Pranhita-Godavari basin. The predominant fauna of Tiki Formation comprise of the temnospondyl *Metoposaurus maleriensis* (Sengupta, 2002), the rhynchosaur *Hyperodapedon tikiensis* (Mukherjee and Ray, 2014) and the phytosaur *Parasuchus hislopi* (Chatterjee, 1978). The vertebrate fauna of the Maleri Formation comprise of phytosaur: *Parasuchus hislopi* (Chatterji, 1978); rhynchosaur: *Paradapedon huxleyi* (Chatterjee, 1974); amphibian: *Metaposaur maleriensis* (Roy Chowdhury, 1965), *Compsocerops cosgriffi* and *Kuttycephalus triangularis* (Sengupta, 1995); Eosuchian: *Malerisaurus robinsonae* (Chatterjee, 1980); coelurosaur: Alwalkeria malerensis (Chatterjee, 1987); Aetosaurus: *Typothorax* sp. (Chatterjee, 1980); cynodont: *Exaeretodon statisticae* (Chatterjee, 1982); fishes: *Ceratodus hislopianus*, *C. hunterianus*, *C. virapa* (Oldham 1859; Miall 1878), *C. nageswari* (Shah and Satsangi, 1969), *Xenacanthus indicus* (Jain, 1980), subholostian fish (Jain *et al*. 1964); *Polyacrodus contraries* (Prasad *et al.,* 2004), etc. The vertebrate fossils from Tiki Formation have also been correlated with those of Santa Maria Formation of Brazil, Ischiguelasto Formation of Argentina, Chinli Formation of USA, Dockum fauna of North America with the possibly migration route during Late Triassic through northern Africa. The presence of a raisuchid, *Tikiuchus romeri* and other associated vertebrates mention above regarded the Tiki fauna to be a typical Late Triassic continental assemblage of German Keuper and equivalent to Carnian stage of the standard marine sequence (Chatterjee, 1978; Chatterjee, 1987). The microvertebrate piscean remains of *Xenacanthus* sp., *Hybodus* sp. and dipnonian fish *Ceratodus* sp. show closed affinities with those of Santa Maria Formation of Brazil, Ischiguelasto Formation of Argentina, Keuper deposits of German, Late Triassic of Morocco, Late Triassic of Madagascar, etc.

Evan *et al.* (2001) discussed the palaeobiogeographic significance of the sphenodontian records from the Kota Formation of India and their presence in India at Jurassic time had been predicted prior to the breakup of Pangaea. Present record from the Late Triassic of Tiki Formation reconfirmed that the Indian-Madagascan-Seychellian plate was connected to Africa to the west and to Antarctica and Australia to the south till Late Triassic and their might be possible migration and passage certain fauna across the Pangea even though the earlier records of Gondwanan sphenodontian remains are meager and recorded from the Upper Triassic of Madagascar (Flynn *et al.,* 1997, 1999) and Brazil (Ferigolo, 1999), and in the Lower Jurassic of Zimbabwe (Gow and Raath, 1977) and South Africa (Sues and Reisz, 1995), Late Triassic of United Kingdom (Foffa *et al.,* 2014), Late Triassic of Argentina (Martinez *et al.,* 2013), etc.

The records of Late Triassic dromatherid cynodont, *Rewaconodon tikeinsis* (Datta *et al.,* 2004) broaden the perspective in the study of paleobiogeography, evolutionary aspects of cynodont reptile and their palaeobiogeographic correlations with the similar faunas of the rest of the Late Triassic Gondwana deposits of Pangaea. Datta *et al.* (2004) described the extent of palaeobiogeographic distribution of dromatherids described earlier from the Carnian sediments of the Newark Supergroup and Dockum Group of North America (Sues *et al.,* 1994; Lucas and Oakes, 1988), Norian- Rhaetian sediments of Europe (Hahn *et al.,* 1994; Godeifroit and Battail 1997) and closely correlatable therioherpetid from the Carnian stage of Santa Maria formation of Brazil (Hahn *et al.,* 1987; Battail, 1991; Bornaparte and Barberena, 1975; Abdala and Ribeiro, 2000).

In India, records of fossil osteoderms are very poor. Earlier, *Parasuchus hislopi,* a phytosaurian reptile associated with dermal armour was recorded from the Late Triassic Maleri Formation of Pranhita-Godavari Valley (Chatterjee, 1978). Milankumar and Jitendra Kumar (2015) reported osteoderms of phytosaurian remains from Tiki Formation. The other authentic reports and description come from the Late Cretaceous Lameta Formation, from where D'Emic *et al.* (2009) described fossil remains of *Titanosaur* osteoderms. However, osteoderms of archosaurian reptile are known from certain upper Triassic strata of all the continents except Antarctica and Australia (Heckart and Lucas, 2000). The occurrence of phytosaurian remains from the Late Triassic Gondwana deposits have been reported from western United State (Lower Dockum Group, Camp Spring member of the Trecovas Formation, Lower Chinle Formation, Popo Agie Formation), Germany (Blasensandstein), Morocco (Argana Formation), Austria (Opponitzer Beds), Scotland (Lossiemouth Sandstone Formation), South America (Santa Maria Formation and Ischigualasto Formation) (Hunt and Lucas, 1991 and references therein).

Late Triassic temnospondyl metoposaurid amphibians are known from many localities in North America, Africa, Europe and India (Fraas, 1913; Chowdhury, 1965; Hunt, 1993; Dutuit, 1978; Sengupta, 1992; Jalil, 1996), Central European Krasiejów in the Opole Silesia, Poland (Dzik *et al.,* 2000) of which the earliest species is known from the Late Carnian (Schilf sandstein) of Germany, and the latest one from the Early Norian of Arizona, New Mexico and Texas (Hunt, 1989). The presence of traversodontid cynodont *Exaeseretodon statisticae* in Tiki Formation (Gupta, 2013) which was earlier reported from the Late Triassic Maleri Formation by Chatterjee (1982) has biochronological and palaeobiogeographic significance. Again, the presence of isolated tooth of an ornithischian dinosaurs and similar teeth reported earlier (Datta and Das, 2001) from the Late Triassic Tiki Formation, South Rewa Gondwana Basin, M.P. and from Texas (Chatterjee, 1982). This faunal asssemblage of the Tiki Formation also shows a striking resemblance to the lower fauna of the Late Triassic Maleri Formation, India, and to the oldest "North America Land Vertebrate Fauna chron "A" of the Camp Springs Member of the Dockum Formation, Texas, North America and these three units exhibit strong correlation (Chatterjee, 1986; Kutty and Sengupta, 1989; Hunt and Lucas, 1991; Hunt, 1993; Datta, 2004; Gupta, 2013).

Triassic hybodont sharks have been reported earlier from North America, South America and Europe. The late Triassic hybodont sharks from the Gondwana of India (Tiki and Maleri formations) comprise of five species viz. *Lonchidion estesi, L. incumbens, Lissodus duffini, Parvodus tikeinsis* and *Polyacrodus contarious* (Prasad *et al.,* 2008). Earlier records of Lonchidiid hybodonts from the former Gondwanaland includes *Lissodus africanus* (Broom, 1909) from the Lower Triassic Beaufort Beds of South Africa, *L. cassangensis* (Teixeira, 1956) from the Lower Triassic of Angola, *Lonchidion marensis* (Duffin and Sigogneau-Russell, 1993) from the Cretaceous for

Morocco and Lissodus sp. as well as Diabodus tetaouinensis from the Lower Cretaceous of Tunisia (Cuny *et al.,* 2004). The microvertebrate remains of the Late Triassic of India also show close biogeographic affinities with those of Laurasia.

Based on the sedimentological characteristics, Tiki Formation predominantly comprises of mud dominating lithology intercalated with subordinate siltstone and sandstone beds and it is considered to be deposited in the channel and overbank facies where the river channel was confined within the extensive floodplain (Mukherjee *et al.,* 2012). Majority of the fossil fauna reported here were collected from the reddish mudstone beds which are exposed just above and below the *Unionid bivalve* beds which is considered as marker for the fossiliferous horizons of Lower Tiki Formation indicating the presence of either swamps in this extensive floodplain deposits or lacustrine type of environment (Milankumar and Jitendra, 2015). The palaeontological and sedimentological data from the study area suggest the prevailing of semiarid climate with the seasonal rainfall of monsoon type (Chatterjee, 1978; Mukherjee *et al.,* 2012).

CONCLUSION

The present palaeontological investigation reports teeth remains of Anura, *Eodiscoglossus* sp. indet. and Coelacanthidae indet. first of this kind from the Late Triassic deposit of India and Sphenodontidae, *Cladodus* sp. from Tiki Formation of India. The faunal records of the Tiki Formation comprising of phytosaur osteoderms, teeth, vertebrate, jaw associated with other fossil remains of mollusc, fresh water selachian, rhynchosaur, metoposaurid, rauisuchid, cynodonts, mammals and other microvertebrate assemblages of microvertebrates assemblages fossil fishes remains including *Xenacanthid, Hybodonts*, *Ceratodus,* semionid fish, actinopterigiians, etc. Both the sedimentological and fauna data from the Tiki Formation especially the Lower parts suggest an extensive floodplain to lacustrine environment of deposits. The current faunal remains from the Late Triassic Tiki Formation conforms to the earlier evidences witnessing a more biologically diverse series of origin and diversification events in the Triassic period including very early or first appearances of mammals, dinosaurs, lepidosaurs, pterosaurs, turtles, crocodiles, and lissamphibians, etc. The mega and microvertebrate remains of the Late Triassic of India also show close biogeographic affinities with those of similar deposits of Gondwanaland and Laurasia comprising of Santa Maria Formation of Brazil, Ischiguelasto Formation of Argentina, Chinli Formation of USA, Dockum fauna of North America; Late Triassic continental assemblage of German Keuper; Late Triassic of Morocco, Late Triassic of Madagascar; Carnian sediments of the Newark Supergroup; Camp Spring member of the Trecovas Formation, Lower Chinle Formation, Popo Agie Formation of United State; Norian-Rhaetian sediments of Europe; Morocco (Argana Formation), Austria (Opponitzer Beds), Scotland (Lossiemouth Sandstone Formation), etc. Thus, the global palaeobiogeographic scenario of Late Triassic time which is well supported by closely correlatable Late Triassic taxa in different continents which might have served a relatively rapid intercontinent passage of the vertebrate community extending across the ancient supercontinent, Pangea. The presence of closely related Late Triassic taxa in different continents as may be one of the major attribute of a relatively rapid intercontinent passage which in turn is the result of manifestation of the integral part of the vertebrate community extending across the ancient supercontinent, Pangea.

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