The first record of chigutisaurid amphibian from the Late Triassic Tiki Formation and the probable Carnian pluvial episode in central India

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A new, partially preserved skull of chigutisaurid amphibian (Temnospondyli) has been reported for the first time from the Late Triassic Tiki Formation of India. The specimen belongs to the genus *Compsocerops* prevalent in the Late Triassic Maleri Formation occurring 700 km south. However, the chigutisaurid specimen recovered from the Tiki Formation is a new species when compared to that of the Maleri Formation. Biostratigraphically, it proves that the Tiki Formation, is not only coeval with the Lower Maleri Formation but also a part of Upper Maleri too. Chigutisaurids are now known to occur in the Early and Late Triassic of Australia, Late Triassic in India, Argentina and Brazil, in Jurassic of South Africa and Australia and Cretaceous of Australia. In India the first appearance of chigutisauids marks the Carnian – Norian Boundary. This work also attempts to correlate, again for the first time, the advent of chigutisaurids and the occurrence of Carnian Pluvial Events in Late Triassic Maleri and Tiki Formation of Central India.

1 # The first record of chigutisaurid amphibian from the Late Triassic Tiki

2 # Formation and the probable Carnian pluvial episode in Central India.

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Abstract

13 A new, partially preserved skull of chigutisaurid amphibian (Temnospondyli) has been reported

14 for the first time from the Late Triassic Tiki Formation of India. The specimen belongs to the

15 genus *Compsocerops* prevalent in the Late Triassic Maleri Formation occurring 700 km south.

16 However, the chigutisaurid specimen recovered from the Tiki Formation is a new species when

17 compared to that of the Maleri Formation. Biostratigraphically, it proves that the Tiki Formation

18 is coeval with the Lower Maleri Formation and a part of Upper Maleri. Chigutisaurids are now

19 known to occur in Australia's Early and Late Triassic, the Late Triassic in India, Argentina, and

20 Brazil, the Jurassic of South Africa and Australia, and the Cretaceous of Australia. In India, the

21 first appearance of chigutisaurids marks the Carnian – middle Carnian / Norian Boundary. This

22 work also attempts to correlate, again for the first time, the advent of chigutisaurids and the

23 occurrence of Carnian Pluvial Episodes in the Late Triassic Maleri and Tiki Formation of Central

24 India.

Introduction

Temnospondyls are a very diverse and widespread group of extinct amphibians that thrived from Carboniferous to Cretaceous reaching their peak in the Triassic. Capable of flourishing in both land and water in a variety of ecological niches, the fossils of these extinct amphibians are found in almost all places from Antarctica in the South to Greenland in the North, India being no exception. The temnospondyl fossils in India are found in various Gondwana deposits throughout the country. Chigutisaurids are by far one of the most important temnospondyl amphibians, the majority of which originated in the Upper Carnian to Lower Norian of the Late Triassic Period and continued till the Cretaceous. The family Chigutisauridae is much less diversified than the other temnospondyl families. Falling within the superfamily Brachiopoidea which comprises parabolic, brevirostrine skulled temnospondyls, Chigutisauridae forms a single monophyletic family in the phylogenetic position. The spatial and temporal distribution of the chigutisauridae (Cabrera 1944; Rusconi 1949; Rusconi 1951; Bonaparte 1975; Warren 1981; Warren & Hutchinson 1983; Warren & Hutchinson 1983; Sengupta 1995; Marsicano 1999; Warren & Marsicano 2000; Bandyopadhyay & Ray 2020a; Dias-da-Silva et al. 2012; Pledge 2013) is schematically represented in Table -1 along with their general habitat. The earliest origin is in the Early Triassic of Australia with the latest being in the Cretaceous of Australia as well. So far, the origin and diversification of chigutisaurids remain restricted only to the Gondwana countries.

The Gondwana Successions of India are exposed in four discrete basins coinciding with some of the major river valleys throughout the Indian Subcontinent (Robinson 1970; Pascoe 1973; Veevers & Tewari 1995). Of these, the Late Triassic Maleri and the Tiki Formations of the Pranhita-Godavari Valley Basin and the Son Valley Basin respectively are long known to be coeval (Robinson 1970; Chatterjee & Roy-Chowdhury 1974; Kutty & Sengupta 1989; Mukherjee & Ray 2014).

48 Both Formations are known for the metoposaurid *Panthasaurus maleriensis* (Sengupta 2002;

49 Chakravorti & Sengupta 2019) In the Late Triassic Maleri Formation *P. maleriensis* is thought to

50 be restricted within the Carnian and the chigutisaurids appear in the mid-Carnian to early Norian

51 (Sengupta 1995; Chakravorti & Sengupta 2019). Though a considerable amount of work has been

52 done on the microvertebrates (Ray et al. 2016a; Bhat 2017; Hussain 2018) rhynchosaurs (Mukherjee

53 & Ray 2012; Mukherjee & Ray 2014) and phytosaurs (Datta et al. 2019; Datta et al. 2021a; Datta et al.

54 2021b) of the Tiki Formation; no comprehensive work has been done in the last decade on its

55 temnospondyl faunal contents. (Chakravorti & Sengupta 2019) in their taxonomic revision of the

56 Indian metoposaurids, included the metoposaurids of the Tiki Formation and grouped them into a

57 new genus *Panthasaurus maleriensis* based on morphometric and phylogenetic approaches.

58 However, the biostratigraphic implications of the Tiki Formation based on its temnospondyl

59 contents have not been attempted so far. Taphonomic aspects of *Panthasaurus* have recently

60 been studied by (Rakshit & Ray 2020). Also, to date, no chigutisaurid remains were reported from

61 the Late Triassic Tiki Formation though the same is widely prevalent in the Late Triassic Maleri

62 Formation (Sengupta 1995). Therefore, the finding of a chigutisaurid amphibian from the Late

63 Triassic Tiki Formation is very important in the context of correlating the Late Triassic Maleri

64 and Tiki Formation, India, and their position concerning global biostratigraphic correlation. This

65 paper will subsequently highlight a brief geological setting of the Tiki Formation followed by the

66 taxonomic status of chigutisaurids from the Tiki Formation and subsequently its role in

67 demarcating the Carnian Pluvial Episode in India.

68 Geological setting of the Tiki Formation

69 The Tiki Formation named after a small village of Tiki in the district of Shahdol, Madhya

70 Pradesh has been an interest to scientists for decades. Reports on the geology and palaeontology

71   of the Tiki Formation date back to as early as 1877 when (Hughes 1877) noticed reptilian fossils

72   near this village. (Cotter 1917) noticed several other such fossils and finally (Fox 1931) formally

73   designated the area as the "Tiki stage". (Aiyengar 1937) first divided the "Tiki stage" into

74   lithostratigraphic units viz. the lower unit being fossiliferous and composed dominantly of red

75   and green mudstones, proportionately lesser number of sandstones and mud-galls while the

76   upper unit is composed of ferruginous sandstones and shales. (Robinson 1970) in her memoir kept

77   the Tiki Formation to be coeval with the Late Triassic Maleri Formation. However, (Dutta &

78   Ghosh 1993) did not recognize the separate entity of the Tiki Formation and placed Tiki rocks in

79   the upper part of the Pali Formation forming the "Pali-Tiki Formation". (Roychowdhury et al.

80   1975) based on the megaflora assemblage noted the age of the Nidhipur beds is Anisian and

81   separated the upper part of the Tiki Formation to be Carnian – Rhaetian in age. (Maheshwari et al.

82   1976) separated the Tiki Formation to be a separate entity (including the Nidhipur beds) and

83   based on the mega flora and faunal assemblages suggested the age of the Tiki (including

84   Nidhipur beds) Formation to be ranging from Anisian to Norian with a possible extension to

85   Rhaetian. (Mukherjee et al. 2012) revised the stratigraphy of the Rewa Basin and put the Tiki

86   Formation with the coeval Carnian Lower Maleri Formation. (Ray et al. 2016b) the study of

87   vertebrate faunal assemblage of the Tiki formation also suggested Tiki Formation be of Carnian

88   in age but they narrowed the range to Otischalkian to early Adamanian. The common

89   conclusions of all this literature are that the Late Triassic Tiki Formation is dominantly Carnian

90   and its fauna can be correlated with the Lower Maleri fauna. So far, no evidence of a Norian age

91   was assigned to any part of the Tiki Formation. As stated earlier, based on the faunal pieces of

92   evidence and correlating it with the Late Triassic Maleri Formation of the Pranhita – Godavari

93   valley a Carnian age was assigned to the Tiki Formation (Kutty et al. 1987; Sengupta 1992; Dutta &

94   Ghosh 1993). Henceforth, through Decades, the Tiki formation was considered to be coeval with

95   the Carnian Maleri Formation (Veevers & Tewari 1995; Sengupta 1992; Mukhopadhyay et al. 2010).

96   Only recently, (Datta et al. 2021b) while describing a new phytosaur from the Tiki Formation,

97   commented that the age of the Tiki Formation may range from Carnian to early/Middle Norian.

98   To date, the faunal assemblage of the Tiki Formation includes fishes belonging to the family

99   Ceratodontidae, Hybodontidae and new undescribed forms of Xenacanthidae (Ray et al. 2016b),

100   temnospondyl amphibians belonging to Metoposauridae; reptilian belonging to families

101   Rhyncosauridae, Rauisuchidae, Rhyncocephalia, Acrodanta, basal Saurischia, Dromatheridae,

102   and Traversodontidae. Mammaliaformes are also reported from the Tiki Formation (Ray et al.

103   2016b; Bandyopadhyay & Ray 2020b). An updated list of the faunal list of the vertebrate fossils so

104   far excavated and reported from the Tiki Formation is provided in Table 2a and Table 2b.

105   The appearance of chigutisaurids in India is noted with the demise of the metoposaurs,

106   rhynchosaurs, and primitive phytosaurs. Large prosauropods also appeared during that time

107   (Novas et al. 2010). Those events were thought to demarcate India's Carnian – Norian boundary

108   (Datta et al. 2021). However, recent signatures of the pluvial event and its role in extinction might

109   shift this boundary to Carnian – mid-Carnian/Norian. The Maleri Formation starts with a 250-

110   meter-thick mudstone (Kutty & Sengupta 1989; Dasgupta et al. 2017). At the top of the mudstone, a

111   sandy zone initiates the sand–mud alternations of Upper Maleri (Kutty & Sengupta 1989). This

112   sandy zone contains a maximum number of rhynchosaur fossils, abundant metoposaurids, and

113   unionids. The chigutisaurids in Maleri appear just above this sandy zone (Sengupta 1995) and no

114   rhynchosaurs or metoposaurids are known from that level (or above that). The occurrence of

115   chigutisaurids in Tiki is also restricted within a sandy zone which do not contain metoposaurids

116   or rhynchosaurs. Unionids are also present there but in lesser abundance than Maleri. Phytosaur

117   teeth are also present. This sandy horizon noticed in Maleri and Tiki has been stratigraphically

118   placed below the Carnian – mid-Carnian/ Norian boundary and may indicate the Carnian Pluvial

119   Episodes (CPE) in India.

120   Materials used and overview of their preservation

121   Preservation of specimen RH01/Pal/CHQ/Tiki/15-

122   Only the picture of the palate published in the paper (Kumar & Sharma 2019) (Fig:1a, b) could be

123   studied. as mentioned in the paper (Kumar & Sharma 2019) the material could not be excavated

124   from the field. The photograph of the said publication was reproduced with permission of the

125   journal editor and a higher resolution image was reproduced for better clarity and study. The

126   palate is dorsoventrally elongated and slightly sheared. The edges of the palate are not well

127   preserved.

128   The new specimens with ISI numbers, ISI A 202 and the published specimen of (Kumar & Sharma

129   2019) RH01/Pal/CHQ/Tiki/15 were recovered from mudrocks at a distance of about 100 meters

130   from each other from the village of Tenduadh in the Late Triassic Tiki Formation. Thus, ISI A

131   202 and RH01/Pal/CHQ/Tiki/15 are now the two chigutisaurid individuals that are being

132   reported from the Tiki Formation for the first time.

133   Preservation of specimen ISI A 202 - The skull along with a fragmentary clavicle, ISI A 202, is

134   poorly preserved (Fig: 2a,2b,3a,3b,4,5). Only the left half of the skull is preserved and the

135   specimen is heavily eroded. Thus, the ornaments are not well observed in all the areas. The upper

136   part of the parietal and postfrontal have coarse ridges and grooves preserved in them. The palate

137   ISI A 202/1, ISI A 202/3-5 (Fig: 3a,3b). The skull, its fragments and the clavicle, all have been

138   excavated from the same point in the location and were present together with the same individual

139   as the skull.

140 The electronic version of this article in Portable Document Format (PDF) will represent a

141 published work according to the International Commission on Zoological Nomenclature (ICZN),

142 and hence the new names contained in the electronic version are effectively published under that

143 Code from the electronic edition alone. This published work and the nomenclatural acts it

144 contains have been registered in ZooBank, the online registration system for the ICZN. The

145 ZooBank LSIDs (Life Science Identifiers) can be resolved and the associated information viewed

146 through any standard web browser by appending the LSID to the prefix http://zoobank.org/. The

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148 4174334A7EF4. The online version of this work is archived and available from the following

149 digital repositories: PeerJ, PubMed Central SCIE, and CLOCKSS.

150 ## Chigutisauridae from the Tiki Formation

151 ### Systematic Palaeontology

152 Temnospondyli Zittel 1888

153 Stereospondyli Zittel 1888

154 Chigutisauridae Rusconi 1951

155 *Compsocerops* Sengupta 1995

156 *Compsocerops tikiensis* sp. *nov*. (ISI A 202/1, ISI A 202/2, ISI A 202/3, ISI A 202/4, and ISI A

157 202/5, RH01/Pal/CHQ/Tiki/15) (Fig: 2.a, 2b)

158 Type material: ISI A 202/1 which comprises the left half of a skull roof, ISI A 202/2 – a

159 nearly complete clavicle and ISI A 202/3, ISI A 202/4, and ISI A 202/5 – broken parts of the

160 skull are the holotype. The holotype materials are housed in Geological Studies Unit, Indian

161 Statistical Institute, Kolkata, India (Fig: 2a, b).

162   **Paratypes:** ISI A 202/2, ISI A 202/3, ISI A 202/4 and ISI A 202/5,

163   RH01/Pal/CHQ/Tiki/15.

164   **Referred material:** A palate (RH01/Pal/CHQ/Tiki/15) previously assigned to a

165   metoposaurid by (Kumar & Sharma 2019) has been referred (Fig: 1a,b). The parabolic skull

166   outline, vaulted pterygoid, shape and proportion of the interpterygoid vacuities, wide and folded

167   palatine ramus of the pterygoid, and comparatively narrow cultriform process of the

168   parasphenoid in RH01/Pal/CHQ/Tiki/15 indicate that it is not a metoposaurid. The cultriform

169   process is wider than *Compsocerops cosgriffi* but narrower than any of the metoposaurids. This

170   palate is comparatively well preserved and bears definite characteristics of a chigutisaur as it

171   appears from the field photograph (Fig: 1a, b). Only the photograph of the palate is available for

172   study.

173   **Locality:** Southwest of the Village of Tenduadh (23°59'41" N; 81°25'02" E), just next to

174   the Barakachh - Beohari Road in the district of Shahdol, Madhya Pradesh, Central India.

175   **Etymology:** The new species of chigutisaur is named after the Late Triassic Tiki

176   Formation from where the specimen has been excavated and studied.

177   **Diagnosis of genus:** A chigutisaur temnospondyl identified as *Compsocerops* by the

178   presence of the following combination of characters: skull outline parabolic in shape, orbits

179   anteriorly placed, raised rim of the naris, presence of a well preserved conspicuous quadratojugal

180   projection, presence of squamosal horn (which though broken and eroded is recognizable), and

181   ill preserved postparietal horn (though ill preserved the presence of horns can be clearly

182   identified), well preserved vaulted pterygoid, long and narrow cultriform process of the

183   parasphenoid, dentigerous area restricted to the anterior portion of the palate, short and restricted

184   palatine dentition not reaching to the middle of the choana, wide ramus of the pterygoid with a

185   gentle fold, walls like quadrate ramus of the pterygoid, presence of postpterygoid process, typical

186   shape of the ramus of the pterygoid and that of the subtemporal vacuities, long dorsal process of

187   the clavicle with a distinct groove and bean-shaped cross section.

188   **Diagnosis of species:** The new species of *Compsocerops* is identified by the presence of

189   an inward curved process of the quadratojugal as opposed to the straight downward trending

190   process of the quadratojugal in *Compsocerops cosgriffi*, presence of vomerine foramen, shorter

191   and wider interpterygoid vacuities, wider subtemporal vacuities, the base of the interpterygoid

192   vacuities at the same level with the base of the subtemporal vacuity as opposed to *Compsocerops*

193   *cosgriffi* (where the base of the interpterygoid vacuity is lower than the base of the subtemporal

194   vacuity making the interpterygoid vacuities longer and slenderer in *Compsocerops cosgriffi*) and

195   wider cultriform process of the parasphenoid.

196   ## Description and comparative anatomy

197   *The skull roof* (Fig: 2a, b)

198   The dorsal part of the skull roof can only be studied in ISI A 202.

199   The skull roof is parabolic in shape with a broad and concave posterior part of the skull table.

200   Even though the anterior part of the skull roof is mostly broken, a major portion of the left orbit

201   is preserved. The orbit is subcircular in shape and bordered by the prefrontal, jugal, postfrontal

202   and postorbital. The orbit is located in the anterior half of the skull and is laterally placed. The

203   posterior and posterolateral part of the left external nares is also preserved. It can be understood

204   from the posterior outline of the external nares that they are oval. The external nares are located

205   very close to the anterior border of the skull roof. The posterior part of the external nares is thick

206 and raised. This character is noted in chigutisaurids and is found in *Pelorocephalus tenax*

207 (Marsicano 1999) and *Compsocerops cosgriffi* (Sengupta 1995). The supraorbital sensory canal in

208 the region of the naris is unusually deep around the posterolateral border of the naris which is

209 responsible for the thick and raised posterior part of the naris in the ISI A 202. This characteristic

210 feature has also been noted in *Compsocerops cosgriffi* (Sengupta 1995) where anteriorly the naris

211 is flushed with the skull roof. The entire disposition of the sensory sulci is not well preserved in

212 the specimen. Apart from the supraorbital sulcus, the presence of postorbital dermal sensory

213 sulcus through the postfrontal can be recognized by the deep continuous canal like structure in

214 these two bones. The infraorbital sulcus is visible in the maxilla but gradually becomes less

215 prominent as it enters the jugal to form the jugal lateral dermal sensory sulcus. Just like other

216 comparable chigutisaurids like *Keratobrachyops australis* (Warren 1981), *Siderops kehli* (Warren

217 & Hutchinson 1983), *Pelorocephalus tenax* (Rusconi 1949; Marsicano 1999), *Compsocerops cosgriffi*

218 (Sengupta 1995) the lacrimal is absent in ISI A 202 and the maxilla enters the border of the

219 external nares. However, the anterior part of the skull is fragmentary and heavily eroded. The

220 better-preserved left side of the dorsal part of the skull roof consists of partially preserved

221 prefrontal, postfrontal, postorbital and supratemporal. The squamosal is broken at the posterior

222 part, and parietal, postparietal, tabular, jugal and quadratojugals are also partially preserved. The

223 surfaces of the bones are eroded in most places and ornamentations are poorly preserved. The

224 parietal is comparatively large, rectangular and broken along the midline. Coarse ridges and

225 grooves can be recognized from the anterior part of the parietal. Just as in *Compsocerops* the

226 postparietal of ISI A 202 (Fig: 2a, b) is much shorter in length than the parietal. The pineal

227 foramen is not preserved in the parietal. The suture of the postparietal with the tabular is

228 obliterated. The postparietal is broken and eroded along the midline and at its posterior part in

229   the region of the postparietal horn. The postparietal horn is broken in ISI A 202 (Fig: 2a, b).

230   However, there is clear evidence that the horns exist. Postparietal horns are the most

231   unambiguous synapomorphy of *Compsocerops*. It is preserved in *C. cosgriffi* (Sengupta 1995), *C.*

232   *sp.* (Dias-da-Silva et al. 2012) and *C. tikiensis*. These horns are not preserved in any other

233   chigutisaur (the relevant area is not preserved in *Siderops* though (Warren & Hutchinson 1983) and

234   *Koolasuchus* (Warren et al. 1997). The tabular is most likely to be in contact with the parietal

235   though that part is not very well preserved. The broad tabular–parietal contact is considered to be

236   a diagnostic character of *Compsocerops* (Sengupta 1995). The tabular horn is broken. This post-

237   quadratojugal process is robust and despite the very poor preservation of the skull in general, the

238   posterior quadratojugal process is well preserved. The shapes and sutural patterns of the posterior

239   left side of the skull are very similar to *Compsocerops cosgriffi*.

240   *The Palate* (Fig: 3a, b)

241   Kumar and Sharma 2019, (Fig: 1a, b) described the palate (RH01/Pal/CHQ/Tiki/15) as a

242   metoposaurid palate (Fig:1a, b). However, no detailed osteological description or identifying

243   characters were described by the authors as to why the specimen was identified to be a

244   metoposaurid. The authors only described the palate to be the 'dorsal' part of a metoposaurid as

245   it has conical teeth present on the anterior part. However, this description is vague and of no

246   taxonomical significance whatsoever as all temnospondyls have conical teeth and both

247   chigutisaurids and metoposaurids have teeth and tusks in the anterior part of the skulls. Again,

248   dentition restricted to the anterior margin of the skull is a characteristic of all temnospondyls

249   with parabolic skulls. Additionally, (Kumar & Sharma 2019) grouped the palate collected from the

250   village of Tenduadh with the specimens of metoposaurid clavicle collected from the village of

251   Jora. This grouping is not viable as the two villages are approximately 12 kilometres apart from

252 each other and there is a probability that these two villages might be parts of the Upper and

253 Lower parts of the Tiki Formation and may even be of different ages as discussed later. The

254 specimen, as said in Kumar and Sharma (2019), was too friable and could not be excavated by

255 them. Thus, there is no option to study the specimen first-hand. Henceforth, the image of Kumar

256 and Sharma (2019), has been replicated into a high-resolution photograph with the required

257 permission from the editor of the Journal of the Palaeontological Society of India to study the

258 detail of the described specimen (RH01/Pal/CHQ/Tiki/15) (Fig: 1a, b).

259 The studied specimen is the palate of a temnospondyl and not the dorsal view of the skull as

260 erroneously stated by Kumar and Sharma (2019). The palate showed in the picture

261 (RH01/Pal/CHQ/Tiki/15) (Fig: 1a, b) has a distinct vaulted pterygoid, parabolic skull outline,

262 and comparatively narrow cultriform process than metoposaurids. The specimen

263 (RH01/Pal/CHQ/Tiki/15), (Kumar and Sharma 2019) (Fig: 1a, b) has a parabolic skull, thickening

264 of the pterygoid, presence of vaulted pterygoid, presence of post-pterygoid process and concave

265 vertical wall of pterygoid that are characteristic of chigutisaurids as written repeatedly above.

266 The specimen is indeed friable with dense networks of fractures that obscured the clear

267 identification of the sutures. The specimen (RH01/Pal/CHQ/Tiki/15) is partly eroded along the

268 lateral margins as well as anteriorly and posteriorly. The right half of the palate is slightly

269 compressed, deformed and curved (Fig: 1).

270 The anterior portion of the palate is considerably broken both anteriorly and anterolaterally.

271 Though the sutures cannot be delineated, the presence of vomer is very apparent. The vomer is

272 broken anteriorly and the anterior palatal vacuity is not preserved (RH01/Pal/CHQ/Tiki/15) (Fig:

273 1). The posterior part of the preserved vomer includes the anterior tongue of the cultriform

274 process of the parasphenoid. The left half of a possible vomerine cavity is preserved. The

275   vomerine cavity is present only in Jurassic chigutisaur *Siderops kehli* (Warren and Hutchison

276   1983) and it is absent in *Compsocerops* (Sengupta 1995) or *Pelorocephalus* (Marsicano 1999).

277   The left lateral margin of the right choana is aligned to the left lateral margin of the right

278   interpterygoid vacuity. The ectopterygoids are exposed on the anterolateral margins of the

279   interpterygoid vacuities and are preserved on both sides. The ectopterygoid borders the anterior

280   portion of the subtemporal vacuity inwards. The subtemporal vacuity is wide and broad bordered

281   by the ectopterygoid and the parasphenoid on the inward margin and the quadratojugal, the alar

282   process of the jugal on the outward lateral margin. The dentigerous area is restricted to the

283   anterior region of the palate. The anterior and the anterolateral margins of the palate are broken,

284   and all teeth are not preserved. However, two broken ectopterygoid teeth can be seen preserved

285   at the anterolateral corner of the ectopterygoid in contact with the palatine in the left part of the

286   palate. The palatine teeth row in the left half of the skull is also preserved partially. Like other

287   chigutisaurids, the dentigerous area of the palate is remarkably short. The palatine row of teeth is

288   not continuous up to the middle of the choana. This character has been considered to be a

289   synapomorphy of *Compsocerops cosgriffi* (Sengupta 1995). Conical, inward curved four complete

290   palatine teeth are preserved in the margin of the left palatine bone of the palate. Since, the

291   dentigerous area is restricted to the anterior part of the skull the posterior part is longer in

292   proportion and covered by large and wide subtemporal vacuity (Fig: 3a, b).

293   In (RH01/Pal/CHQ/Tiki/15) (Fig: 1a, b) (Kumar and Sharma 2019) both the interpterygoid

294   vacuities are well preserved. The interpterygoid vacuities are quadrangular in shape, shorter and

295   wider compared to *Compsocerops cosgriffi* (Sengupta 1995). The borders of the interpterygoid

296   vacuities are approximately parallel sided. The interpterygoid vacuities are bordered dominantly

297   by the cultriform process along the inward margin as well as the vomer. Anteriorly, it is

298   bordered by the vomer and the palatine. The pterygoid forms the dominant margin of the

299   interpterygoid vacuities laterally with a small area being occupied by the ectopterygoid.

300   Posteriorly, these are formed by the parasphenoid. In ISI A 202/1, the interpterygoid vacuities

301   are not completely preserved. In both, the specimens ISI A 202 and (RH01/Pal/CHQ/Tiki/15)

302   (Kumar and Sharma 2019), the interpterygoid vacuities are shorter and broader than *Compsocerops*

303   *cosgriffi* where the base levels of the interpterygoid vacuities are lower than that of the

304   subtemporal vacuities. The subtemporal vacuity extends anteriorly to the level higher than the

305   centre of the interpterygoid vacuities.

306   In (RH01/Pal/CHQ/Tiki/15) (Kumar and Sharma 2019) (Fig:1a, b) both the pterygoids are

307   preserved. They are deep and vaulted. The vertical lateral wall of the pterygoid projects

308   posteriorly possibly up to the posterior level of the occipital condyles which are broken. The

309   palatal ramus of the pterygoid is visible on both sides in (RH01/Pal/CHQ/Tiki/15). The palatal

310   ramus of the pterygoid is longitudinally concave with a gentle fold which is again a character of

311   some chigutisaurids specially *Compsocerops*. The quadrate ramus of the pterygoid is better

312   preserved on the right side of the palate (RH01/Pal/CHQ/Tiki/15). The quadrate ramus of the

313   pterygoid looks like a wall as they are deeply vaulted. The ascending ramus of the pterygoid is

314   not visible in (RH01/Pal/CHQ/Tiki/15). A broken post pterygoid process that is a projection

315   from the posterior border of the pterygoid corpus is visible on the right side of the palate

316   (RH01/Pal/CHQ/Tiki/15). This area on the left side of the palate of (RH01/Pal/CHQ/Tiki/15) is

317   broken. The postpterygoid process is considered to be an apomorphic character for

318   *Compsocerops cosgriffi* (Marsicano 1999). The suture of the quadrate and pterygoid is present on

319   the outer side of the downturned part of the quadrate ramus of the pterygoid. In ISI A 202, (Fig:

320   3a, b) only the right pterygoid is ill-preserved but the bone surface is crushed. However, a

321 distinct post pterygoid process characteristic of *Compsocerops* is present. Though the bone is

322 crushed and compressed, the vaulted nature of the pterygoid can be made out because of the

323 concavity of the vertical wall of the pterygoid. In both, the specimens (RH01/Pal/CHQ/Tiki/15)

324 (Kumar and Sharma 2019) and ISI A 202, the palatine ramus of the pterygoid is much broader and

325 wider than that in *Compsocerops cosgriffi.*

326 Just like other chigutisaurids, the base of the parasphenoid is almost hexagonal with a long

327 extension in the form of the cultriform process placed between two interpterygoid vacuities in

328 (RH01/Pal/CHQ/Tiki/15) (Kumar and Sharma 2019). The parasphenoid has a long suture with the

329 pterygoid laterally and the exoccipitals posteriorly. A distinct raised longitudinal keel is present

330 on the ventral surface of the cultriform process in this specimen. The presence of this keel in the

331 cultriform process has been noted by Marsicano (1999) as a distinguishing character present only

332 in *Pelorocephalus mendozensis.* However, first-hand studies reveal that this longitudinal keel of

333 the cultriform process is also present in *Compsocerops cosgriffi* from the Maleri Formation of

334 Pranhita - Godavari Valley Basin. The cultriform process of parasphenoid of this specimen is

335 comparatively narrower than all other specimens of *Compsocerops cosgriffi.* The cultriform

336 process of the *Compsocerops* species from Tiki is wider than *C. cosgriffi,* the cultriform process

337 is also comparatively broader than *Siderops kehli,* more comparable to the width of the

338 cultriform process in the specimen previously denoted as *Kuttycephalus triangularis* (Sengupta

339 1995). The cultriform process preserved in (RH01/Pal/CHQ/Tiki/15) (Kumar and Sharma 2019) is

340 thin and constricted in the middle part of the interpterygoid vacuities and gets broader as it

341 progresses to the anterior part of the process. This type of cultriform process is unique among the

342 chigutisaurids. In the specimen photographed by Kumar and Sharma (2019), the anterior tongue of

343 the cultriform process is in contact with the vomer and lies posterior to the level of the anterior

344   margin of the interpterygoid vacuities. The cultriform process is not preserved in ISI A 202. The

345   occipital condyles are broken as well. In the earliest known chigutisaur *Keratobrachyops*, the

346   cultriform process of the parasphenoid is also narrower than ISI A 202.

347   *The Occiput* (Fig: 4)

348   The occiput is very ill preserved only in ISI A 202 (Fig: 4). The occiput could not be prepared

349   due to the extremely fragile nature of the skull. Removing the matrix load from the occiput

350   would result in the sagging of the entire specimen. However, from the little that could be studied,

351   it can be said that in occipital view, the quadrate ramus of the pterygoid is deeply downturned.

352   The vagus nerve foramen is preserved on the left exoccipital lateral to the broken occipital

353   condyle. The ascending process of the exoccipital is wide and inclined and meets the descending

354   process of the postparietal. A sub-circular, matrix filled, paraquadrate foramen is present in the

355   quadratojugal. The quadrate is partially preserved in the occipital view. It is bounded by the

356   squamosal, quadratojugal and the downturned pterygoid. The absence of occiput makes the

357   comparison of ISI A 202 difficult with the different species of *Pelorocephalus* as different

358   species of the genus are differentiated, to a great extent, by their occipital characters (Marsicano

359   1999).

360   *Clavicle* (Fig: 5)

361   An almost complete left clavicle (ISI A 202/2) (Fig: 5) was found associated with the skull (ISI

362   A 202/1) during excavation. The clavicle has a flat eye-drop shaped blade and a long straight

363   dorsal process that ascends almost straight, nearly at ninety degrees with the plate. The cross-

364   section of the process at the dorsal end is bean shaped as a feeble furrow runs along the process.

365   This is very similar to the clavicle of *Compsocerops cosgriffi* (Sengupta 1995), *Siderops kehli*

366   (Warren and Hutchinson 1983) and *Koolasuchus cleelandi* (Warren et al. 1997).

The Carnian Pluvial Episode – A Global Climatic Consequence

368   The Carnian Pluvial Episode (CPE) can be defined as a geologically short-lived (234-232

369   Million years ago) monsoonal period of extreme rainfall that brought about significant changes

370   in several depositional environments (Schlager & Schöllnberger 1974; Simms & Ruffell 1990; Furin et

371   al. 2006; Arche & Lopez-Gomez 2014; Dal Corso et al. 2015). The Carnian Pluvial Episode was a

372   global phenomenon. Geochemical data suggest that global warming involved environmental and

373   biotic changes. Radioisotopic ages coupled with biostratigraphic correlation suggest a possible

374   link to the eruption of the Wrangellia Large Igneous Province (LIP) (Dal Corso et al. 2020). CPE

375   was a significant (but previously neglected) time of extinction linked to the Carnian explosive

376   diversification of many key modern groups of plants and animals (Dal Corso et al. 2020). The CPE

377   marks a distinct change in the hydrological cycle during which the climate shifted from arid to

378   humid conditions and back again to arid conditions (Bernardi et al. 2018). It is represented by

379   remarkable enhancement of the hydrological cycle demarcated by four episodes of increased

380   rainfall indicated by diverse sedimentary and paleontological data, repeated Carbon Cycle

381   perturbations, evidenced by sharp negative C-isotope excursions, coincided with global

382   environmental changes and climate warming all of which suggest a cause and effect relationship

383   (Dal Corso et al. 2015, Dal Corso et al. 2020).

384   The Carnian is the earliest part of the Late Triassic and its base or lower boundary is dated at

385   approximately 237 million years based on U-Pb radiometric dating of a single crystal zircon

386   from a tuff layer within a section having strong biostratigraphic constraints (Corso et al. 2012; Dal

387   Corso et al. 2015; Dal; Maron et al. 2019). The upper boundary of the Carnian is constrained at

388   approximately 227 million years based on magnetostratigraphic correlations between the marine

389   successions of Tethys and the astrochronological time scale of the continental Newark Basin

390   (Kent et al. 2017). The Carnian is subdivided into Julian (Early Carnian) and Tuvalian (Late

391   Carnian) substages. The Julian – Tuvalian boundary occurs at approximately 233 million years

392   (Dal Corso et al. 2015; Kent et al. 2017; Dal Corso et al. 2020). The beginning of the onset of CPE is

393   well defined from ammonoid, conodont, and sporomorph biostratigraphic dating and

394   synchronous in several geological settings. It coincides with the first appearance of the

395   ammonoid genus *Austrotrachyceras* in the Julian (Simms & Ruffell 1990; Roghi et al. 2010; Dal Corso

396   et al. 2020; Dal Corso et al. 2012; Dal Corso et al. 2015; Sun et al. 2016). However, the upper

397   boundary or the end of CPE is poorly defined in most locations. It is usually placed at the base or

398   within the Tuvalian 2 based on sedimentological (e.g., end of terrigenous sediment supply) and

399   chemostratigraphic (last C-isotope excursion) evidence (Dal Corso et al. 2015; Dal Corso et al. 2018;

400   Dal Corso et al. 2020). The total duration of this pluvial episode is variable. Cyclostratigraphy of

401   marine successions of the South China Block and continental successions of the Wessex Basin

402   (United Kingdom) gives a duration of the CPE of approximately 1.2 ma but this is variable and

403   longer to 1.6-1.7 million years as indicated by integrated stratigraphy (biostratigraphy and

404   magnetostratigraphy).

405 Significance of temnospondyl amphibians in the Carnian Pluvial Episode

406   The CPE facilitated the Dinosaur Diversification Event (DDE) (Bernardi et al. 2018). But the role

407   of CPE on the temnospondyls has not much been discussed barring a few papers (Buffa et al.

408   2019; Fortuny et al. 2019; Lucas 2020; Gee & Jasinski 2021b). The amphibious temnospondyls living

409   both on land and water were the most sensitive to the changes in climate. Two dominant groups

410   of temnospondyls, in this context, were the metoposaurids and the chigutisaurids. According to

411 (Fortuny et al. 2019) the gigantism of the metoposaurids might have been linked to the Carnian

412 Pluvial Episode. (Buffa et al. 2019) also stated that the diversification of the metoposaurids might

413 have been linked to the CPE and the post CPE aridification led to the extinction of the

414 metoposaurids during the Rhaetian. (Gee & Jasinski 2021a) have also commented on the fact that

415 the physiological variation of the metoposauridae and their palaeoclimatic range also

416 corroborates a palaeo-environmental barrier. Finally, (Lucas 2020) concluded that climate change

417 that occurred during CPE played an important part in the metoposaurid evolution. According to

418 Lucas (2020), Metoposaurids appeared during the CPE, attained their highest diversity and

419 cosmopolitan distribution during this time and had reduced diversity and showed endemism in

420 the post CPE climate.

421 Significance of *Compsocerops tikiensis* in demarcating the Carnian Pluvial
422 Episode (CPE) in India.

423 The presence of *Compsocerops* in both Maleri and Tiki Formation enhances the scope to discuss

424 the palaeoenvironment of these two Late Triassic basins in India and to compare the possible

425 reason for faunal turnover from Carnian to Norian (Sengupta 1995) concerning the amphibious

426 temnospondyls.

427 In the light of the newly excavated chigutisaurid *C. tikiensis*, the faunal changeover in the Tiki

428 Formation is now more apparent and as follows:

429 Tiki Formation

430 No detailed sedimentological or geochemical studies have been carried out in the Late Triassic

431 Tiki Formation in India to analyse the associated changes from Carnian to Norian through the

432 humid phase of the Carnian Pluvial Episode. Though, (Ahmed & Ray 2010) presented a

433 geochemical analysis of 42 nodular carbonates confirming their pedogenic origin, no details of

434   the localities of collection in terms of lower and upper Tiki have been provided. The map of the

435   temnospondyl bearing localities of the Tiki Formation has been modified here with faunal

436   boundaries (hypothetical faunal boundary demarcated in red dotted line) after Mukherjee et al.

437   (2012) (Fig: 6). Till date, no temnospondyl fauna has been recorded from the upper part Tiki

438   Formation. Excavation taken up in 2018 revealed the first chigutisaurid from the Tiki Formation

439   in the Tenduadh locality (Fig: 7) in the upper part of the Tiki Formation. Several vertebrae and

440   postcranial bones of metoposaurid have been excavated from the Jora and Tiki Nala sections

441   which have been assigned to the lower Tiki Formation

442   Based on the changes in the faunal assemblage in the lower and the upper Tiki Formation and

443   considering the lithostratigraphy, a boundary between the basal and upper Tiki Formation has

444   been assigned and the zone demarcating the Carnian to Norian faunal turnover in the Tiki

445   Formation has been approximated and marked in red dotted line in the map (Fig: 6).

446   The lithological logs modified after Kumar and Sharma (2019) and Mukherjee et al. (2012) reveal

447   that just like the Maleri Formation, the basal Tiki Formation is dominated by a large band of red

448   mudrock intercalated with peloidal calcirudite-calcarenite (Sarkar 1988) (Fig: 8). The Jora Nala

449   section in the Carnian basal Tiki has been logged in detail in this work (Fig:8a). This shows the

450   dominance of greenish to reddish siltstones and mudstones in the Jora Nala section with sparse

451   deposition of trough cross-bedded sandstones in between. The terrestrial influx of sediments is

452   significantly low at that period as denoted by the sparse occurrence of sandstones in the basal

453   Tiki Formation (Fig: 8a, b,c). The presence of Unio beds in between the basal thick layers of

454   mud (Fig: 9) reflects a stagnant quiet and well-watered environment. This basal mud

455   encompasses areas like the Jora and Tiki River sections. Abundant postcranial fragments of

456   metoposaurids and rhynchosaurs have been collected from these sections. Moving upwards in

457   the direction of the dip of the beds, there is a sudden influx of siliciclastic sediments marked by

458   thick sandstone units with little intermittent mudstone. This could be a demarcation of the rapid

459   influx of siliciclastic sediments that took place during CPE in the Tiki Formation. Only two

460   dominant sand bodies are observed in Tiki before the recurrence of a thick horizon of mud and

461   subsequently sand-mud alternations indicating the onset of seasonality and aridity in the Norian

462   (Fig: 9). The Norian of Tiki Formation is demarcated by red mudstones, whitish sandstones and

463   sparse calcirudites. The Norian Upper Tiki Formation is exposed in sections near Tenduadh as

464   shown in the map (Fig: 6) and an estimated approximate faunal boundary between the Carnian

465   and the Norian in the Tiki Formation is also furnished as in Fig: 6.

466   Tiki has a long history of yielding fossil vertebrates (Chatterjee & Roy-Chowdhury 1974;

467   Bandyopadhyay & Ray 2020b) (Table 1). It has a rich Late Triassic faunal association marked by

468   different taxa of Chondrichthyes and Osteichthyes fishes, a metoposaur *Panthasaurus*, a

469   phytosaur *Volcanosuchus* belonging to the subfamily Mystriosuchinae and leptosuchomorphs, a

470   rhynchosaur *Hyperodapedon tikiensis*, a rauisuchid named *Tikisuchus*, cynodonts and

471   mammaliaformes taxa among others (Chatterjee & Majumdar 1987; Bandyopadhyay & Ray 2020b;

472   Mukherjee & Ray 2014). The Tiki faunal assemblage was thought to be coeval to the Lower Maleri

473   faunal assemblage (Kutty & Sengupta 1989; Datta 2005). However, Datta et al. (2019) stated that the

474   Tiki fauna ranges from Middle Carnian to Early Norian and is younger than Lower Maleri

475   Fauna. The mid Carnian / Norian Upper Maleri fauna has chigutisaurids. The Discovery of a

476   chigutisaurid from the upper part of the Tiki Formation confirms Datta et al. (2019) regarding the

477   presence of Middle Carnian / Norian fauna in the Tiki Formation. The presence of

478   *Compsocerops* in Tiki, for the first time, confirms the presence of the Upper Maleri faunal

479   element in Tiki. (Lucas 2020) thought that the demise of metoposaurids in most parts of the world

480   was at the end of Carnian and that tallies with the last appearance datum of the metoposaurids of

481   Maleri. The chigutisaurids, both in Maleri and Tiki have their first appearance datum at the onset

482   of the Middle Carnian or Early Norian.

483   ## Maleri Formation

484   The overall palaeoenvironment and sedimentology of the Maleri formation have been worked

485   upon by several workers (Sarkar 1988; Dasgupta & Ghosh 2018). Most of these studies were done

486   on the Maleri Formation as a whole without distinguishing its basal and upper parts. However,

487   no detailed analyses about the changes in sedimentology or geology or geochemistry have been

488   done to study the changes in the pattern of sedimentation from the Carnian basal Maleri to the

489   Norian Upper Maleri.

490   The temnospondyl bearing (metoposaurid and chigutisaurid) localities of the Maleri Formation

491   have been extensively mapped and modified after (Kutty & Sengupta 1989; Dasgupta et al. 2017)

492   (Fig: 10) and a boundary between the Carnian basal Maleri and Middle Carnian / Norian Upper

493   Maleri has been established from both lithological and faunal contents (Fig: 10 – faunal

494   boundary indicated by a green broken line). From the field studies and maps it is evident that

495   though sandstone - mudstone alternation is present throughout the Maleri Formation, the Carnian

496   basal Maleri is abundant in red mudrocks and calcirudites (Fig: 10,11) and moving towards

497   Upper Maleri there is a sudden increase in the deposition on siliciclastic sediments leading to the

498   more frequent occurrence of sandstone bands alternating with red mudstone (Fig: 11). The

499   abundance of red mudstone in basal Maleri Formation (Fig: 12) with a sudden increase in the

500   frequency of sandstone bands in the upper part can be correlated with the advent of the Carnian

501   Pluvial Episode (CPE) in India. The CPE had a significant impact on the terrestrial environment

502   and ecosystem globally. The evidence of CPE has never been worked upon or mentioned in India

503   because of the lack of proper age constraints present in the Late Triassic Formations in India,

504   both in the Maleri and Tiki Formations. However, evidence from detailed geological mapping,

505   logs and associated faunal turnover in the Late Triassic Maleri Formation all point toward the

506   distinctive effect of CPE in India. The overall thickness of the Maleri Formation is about 350-

507   600 m which is variable in different places. From the map of the Maleri Formation and log of the

508   same near Achlapur and Nalapur (Fig: 11), it is evident that the basal part of the Maleri

509   Formation has a large stretch or band of red mudrock dominated unit. This unit of red mudrock

510   stretches from about 100m- 200m in thickness in basal Maleri and is the thickest band of red

511   mudrock encountered in the entire Maleri Formation. It encompasses villages namely

512   Aigerrapalli (19°15'22.4" N; 79°27'23.4" E), Achlapur (19°09'34" N; 79°31'51" E) and

513   Nambala (19°13'47" N; 79°26'07" E), areas slightly north of village Gampalpalli (19°10'11" N;

514   79°30'53" E) and is rich in vertebrate fossils, the most significant among them being

515   rhynchosaurs and metoposaurids. This significantly thick basal Maleri mudstone has sporadic

516   carbonate grainstones (*sensu* Dunham 1962); calcarenites–calcirudites of Sarkar 1988) and the

517   presence of palaeosols with no significant siliciclastic deposition of sandstone present within this

518   mud. The upper part of the Formation is approximately 200–350 m thick and has three to four

519   multi-storeyed sheet sandstone bodies (each 10–35 m thick) vertically separated by mudrock

520   dominated intervals (15–55 m thick). The mudrock intervals in the upper part are lithologically

521   similar to those occurring in the lower part of the Formation. The mudrock units comprise both

522   stratified and massive mudstones (Dasgupta et al. 2017) with sporadic carbonate grainstones

523   (calcirudite of Sarkar 1988). Moving upwards from the thick stretch of mudrock, the influx of

524   siliciclastic sedimentation increases as evident from the increase in the deposition of frequent

525   sandstone units. The beginning of these sandstone units is marked by the presence of

526   metoposaurids and rhynchosaurs and unionid fossils in a sandy zone. In the upper part, apart

527   from the chigutisaurids, there are basal sauropods like *Jaklapallisaurus*, and sauropodomorphs

528   like *Nambalia*, probable Guaibasaurids and *Herrerasaurus* like forms (Novas et al. 2010). The

529   authors in the same work, also mentioned that early theropods are known from the Norian-

530   Rhaetian time from North and South America, India, South Africa, and Europe and the demise of

531   members of Lower Maleri fauna like rhynchosaurs together with the global extinction of

532   *Chiniquodon* (cynodont) and Proterocampsidae (archosauriform) mark the Carnian – Norian

533   boundary and also the North Tethyan Pluvial Event of end Carnian (CPE). Benton et al. (2018)

534   have argued that CPE triggered the diversification of early dinosaurs. It has been discussed

535   earlier those indications of CPE are present in Maleri and Tiki Formations of India. The sudden

536   appearance of several basal dinosaurs like *Jaklapallisaurus*, *Nambalia*, probable Guaibasauridae

537   and *Herrerasaurus* (Novas et al. 2010) in the Norian Upper Maleri fauna also corresponds to that.

538   Thus, the palaeoenvironment of the Maleri Formation shifted from a comparatively arid and dry

539   climate in the Julian at the basal substage of Carnian to a high competence fluvial-lacustrine

540   environment with the presence of small, ephemeral and vegetated swamps or ponds along the flow

541   path of the channels at the time of Carnian Pluvial Episode from the end of Julian to Tuvalian and

542   back again to fluvial deposition in the Norian (Dasgupta et al. 2017). The episodes of increased

543   rainfall during the Carnian Pluvial Episode demarcated by increased frequency of sandstone

544   deposition are intervened by seasonality as evident from the red mudrock alternations between

545   sandstones. Similar climatic shifts are seen from the coeval Santa Maria to Caturrita formations

546   of Brazil (Dal Corso et al. 2015). These shifts indicating a major variation of the hydrological regime

547   in terrestrial depositional settings suggest an enhancement of the hydrological cycle during the

548   CPE. Recently, Lucas (2010) stated that the demise of metoposaurids in most parts of the world

549   during the Carnian is related to the end of the enhanced hydrological cycle at the dying phase of

550   CPE. The disappearance of key herbivorous groups such as dicynodonts and rhynchosaurs of

551   Carnian and their places taken up by giant sauropodomorphs seems to be linked to CPE which is

552   not documented in India so far.

553   Also, the *Hyperodepadon* Assemblage Zone (HAZ) is characterized by the presence of

554   rhynchosaur *Hyperodepadon* and is present in the lower part of the Ischigualasto Formation of

555   Argentina, the Lossiemouth Sandstone Formation of Scotland, and the Lower Maleri Formation

556   of India (Langer et al. 2010). The HAZ is dated as late Carnian to early Norian, approx. 228–224

557   Ma by some authors (Brusatte et al. 2010; Ezcurra et al. 2017; Benton et al. 2018). Most metoposaurids

558   in the Gondwana deposits are considered to be Carnian in age (Chakravorti & Sengupta 2019; Gee &

559   Jasinski 2021b; Sengupta 2002). The demise of the metoposaurids *Panthasaurus maleriensis*

560   (Chakravorti & Sengupta 2019) in India along with the demise of *Hyperodepadon* in both Late

561   Triassic Maleri and Tiki Formation also points to the presence and effect of CPE in India. The

562   demise of the metoposaurids left a vacant niche to be occupied by the chigutisaurids in the Norian

563   suggesting short lived aridity in post Carnian stage.

564   ## The Effect of CPE on the terrestrial ecosystem of Maleri and Tiki
565   ## Formations

566   The Carnian of Argentina has its age radiometrically constrained between 231.4 ± 0.3 and 225.9

567   ± 0.9 Ma (Martínez et al. 2016) and similar reports are present from Santa Maria and Caturrita

568   Formations of Brazil (233.2 ± 0.7 and 225.4 ± 0.4 Ma) (Langer et al. 2018). The onset of CPE is

569   well constrained in stratigraphic sections like the Southern Alps of Italy, Northern Calcareous Alps

570   of Austria, Transdanubian Range of Hungary, and the Nanpanjiang Basin of the South China block

571 and is placed at the substages Julian 1 – Julian 2 boundary of the Carnian (Gallet et al. 1994, Dal

572 Corso et al. 2016). Due to the lack of any radiometric dating, Late Triassic Maleri and Tiki

573 Formations are poorly constrained and pose difficulty in global correlation, their correlation is

574 based only on available fauna. The CPE has always been dated as mid-Carnian (Ruffell et al. 2016)

575 but this is not a unanimous viewpoint. The Italian Dolomites occur between the

576 Aonoides/Austriacum interval (about Julian) and the base of the Subbullatus Zone (Tuvalian),

577 dated at 234–232 Ma (Roghi et al. 2010; Dal Corso et al. 2015). The further constraint has been

578 documented in borehole successions in the southwest UK, which indicates a maximum duration

579 of 1.09 MYA (Miller et al. 2017). The precise radiometric dating to constrain the Maleri and Tiki

580 Formations and to denote the beginning of CPE in India will shed further light on the pattern of

581 faunal diversification post CPE event in the subcontinent and help in the global stratigraphic

582 correlation. A continental carbon isotope record in southwest England shows multiple carbon cycle

583 perturbations during CPE (Miller et al. 2017). The CPE is not only the time interval of increased

584 humidity but also a major carbon perturbation (Dal Corso et al. 2016). Unfortunately, no carbon

585 isotope data is noted from the Maleri and the Tiki Formations of India.

586 ## Conclusion

587   1. In the current work a new species of chigutisarid amphibian, *Compsocerops tikiensis*

588   from the Late Triassic Tiki Formation of the Rewa Gondwana Basin has been described

589   in detail. The presence of chigutisaurid *Compsocerops tikiensis* in the Upper part of the

590   Tiki Formation is the first evidence of the Norian chigutisaurid amphibian from the said

591   Formation and is important for correlation of the Late Triassic basins worldwide.

592   2. Along with the extinction of the rhyncosaurs and *Parasuchus* (primitive phytosaur),

593   chiniquodontids (cynodonts), the Carnian – Norian Extinction Event (CNEE) also caused

594   the extinction of the metoposaurids in India. Chigutisaurids appeared in Middle Carnian /

595   Norian and India is the only place which accommodates definite metoposaurids and

596   chigutisaurids within the same formations (the Late Triassic Maleri and Tiki Formations)

597   the former being replaced by the latter. Incidentally, among the phytosaurs, the

598   *Parasuchus* of Lower Maleri fauna is replaced by the *Leptosuchus* like forms of Upper

599   Maleri and *Volcanosuchus statisticae* in the upper part of the Tiki Formation.

600   3. The post-CNEE empty niche left by the metoposaurids in the Late Triassic Gondwana

601   deposits of India (controversially Brazil as well, see (Dias-da-Silva et al. 2011) was

602   occupied by the chigutisaurids in the Norian. The availability of phytosaur teeth along

603   with *C. tikiensis* only indicated their co-existence in the same aquatic niche but does not

604   necessarily point towards any prey-predatory relationship between the phytosaurids and

605   the chigutisaurids. However, detailed studies on histology and growth pattern of the

606   chigutisaurids might shed light on the gigantism of these amphibious animals in the post-

607   CNEE and recovery of the temnospondyls.

608   4. The presence of both metoposaurids and chigutisaurids and the faunal turnover from the

609   Carnian to the Norian along with the extinction of the rhynchosaurs (*Hyperodapedon*)

610   and *Parasuchus* in the Carnian of both the Late Triassic Maleri and Tiki Formation and

611   the presence of prosauropods in the Upper Maleri Formation and undescribed

612   dinosauriformes including theropod-like forms (Bandyopadhyay & Ray 2020b) sheds light

613   and documents for the first time the existence and effect of the Carnian Pluvial Episode

614   in India.

615   5. The finding of *Compsocerops tikiensis* from the Tiki Formation and assessing its

616   importance in global palaeoclimatic and palaeoclimatic correlation paves the way for

617   future scope of works in finding the effect of CPE in India and comparing its faunal

618   diversification at a global scale. Also, finding any new and better-preserved specimen of

619   *Compsocerops tikiensis* from the Tiki Formation would help to establish the phylogenetic

620   relationship of the other chigutisaurids around the world with that of the Indian

621   counterparts. As the specimens are deformed broken and have poor preservation

622   potential, phylogenetic analysis is beyond the scope of this paper as it will add more

623   missing and misinterpreted data.

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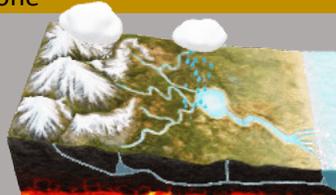
834

Spatial and temporal range of the family Chigutisauridae along with their paleoecology and paleoenvironment.

Abbreviations Max ma = Maximum age million years ago, Min ma = Minimum age million years ago, Fm. = Geological Formations from which the specimen had been excavated. The table has been modified after data was acquired from the Paleobiology Database on 10th May 2022, using the family name "Chigutisauridae". Data for the table was modified after Bonaparte 1957; Marsicano 1999; Dias – da- Silva and Sengupta 2012; Warren 2006; Pledge 2013; Cabrera 1944; Rusconi 1949; Rusconi 1951; Sengupta 1995; Warren and Hutchinson 1983; Warren 1981; Warren and Marsicano 2000)

1 ## Table 1

Name	Early_interval	Late_interval	Max_ma	Min_ma	Country	Fm.	Lithology	Palaeoenvironm
Koolasuchus cleelandi	Late Aptian	_	122.46	112.03	Australia	Eumeralla Fm.	Sandstone	
Koolasuchus cleelandi	Late Aptian	_	122.46	112.03	Australia	Eumeralla Fm.	Sandstone	
Koolasuchus cleelandi	Late Aptian	_	122.46	112.03	Australia	Eumeralla Fm.	Sandstone	
Koolasuchus cleelandi	Late Aptian	_	122.46	112.03	Australia	Eumeralla Fm.	Sandstone	
Koolasuchus cleelandi	Aptian	_	125	113	Australia	Eumeralla Fm.	Sandstone	
Siderops kehli	Pliensbachian	Toarcian	190.8	174.1	Australia	Evergreen Fm.	Ironstone/Sandstone	
Chigutisauridae indet	Mid Carnian	_	228	_	Australia	Leigh Creek Fm.	Siltstone	
Compsocerops	Mid Carnian	Norian	228	208.5	Brazil	Santa Maria Fm.	Mudstone	
Compsocerops cosgriffi	Mid Carnian	Norian	228	208.5	India	Upper Maleri Fm.	Mudstone	
Kuttycephalus triangularis	Mid Carnian	Norian	228	208.5	India	Upper Maleri Fm.	Mudstone	
Compsocerops tikiensis	Mid Carnian	Norian	228	208.5	India	Upper Tiki Fm	Mudstone	
Pelorocephalus mendozensis	Carnian	Norian	237	208.5	Argentina	Cacheuta Fm.	"Siliciclastic"	The overall palaeoenvironm
Pelorocephalus tenax	Carnian	Norian	237	208.5	Argentina	Cacheuta Fm.	"Siliciclastic"	is fluviolacustri
Pelorocephalus cacheutensis	Carnian	Norian	237	208.5	Argentina	Cacheuta Fm.	"Siliciclastic"	
Pelorocephalus ischigualastensis	Carnian	Norian	237	208.5	Argentina	Ischigualasto Fm.	Siliciclastic	
Keratobrachyops australis	Induan	_	252.17	251.2	Australia	Arcadia Fm.	Mudstone	

2 Table -1: The table shows the spatial and temporal range of the family Chigutisauridae along with their paleoecology and paleoenvironment.

3 Abbreviations Max ma = Maximum age million years ago, Min ma = Minimum age million years ago, Fm. = Geological Formations from which the

4 specimen had been excavated. The table has been modified after data was acquired from the Paleobiology Database on 10th May 2022, using

5 the family name "Chigutisauridae". Data for the table was modified after Bonaparte 1957; Marsicano 1999; Dias – da- Silva and Sengupta 2012;

6 Warren 2006; Pledge 2013; Cabrera 1944; Rusconi 1949; Rusconi 1951; Sengupta 1995; Warren and Hutchinson 1983; Warren 1981; Warren and

7 Marsicano 2000)

Fossils excavated from the Late Triassic Tiki Formation modified after Bandopadhyay and Ray 2020

2a. Fish fossils excavated from the Late Triassic Tiki Formation (modified after Bandopadhyay and Ray 2020).

2b. Vertebrate fossil assemblage (tetrapod content) of the Late Triassic Tiki Formation of the Rewa Basin, India (modified after Bandopadhyay and Ray 2020).

1   Table 2a

Order/Family	Genus and Species	OSTEICHTHYES	
CHONDRICHTHYES		Ptychocerato-dontidae	*Ceratodus sp.*
Lonchididae	*Lonchidion estesi*		*Ptychoceratodus oldhami*
	Lonchiodon incumbens	Gnathorhizidae	*Gnathorhiza sp.*
	Pristrisodus tikiensis	Actinopterygii	Undescribed
Xenacanthidae	*Mooreodontus indicus*		
	Mooreodontus jaini		
	Tikiodontus asymmetricus		

4   Table- 2a: Fish fossils excavated from the Late Triassic Tiki Formation (modified after Bandopadhyay and Ray 2020).

7   Table 2b

Order/Family	Genus and Species	Order/Family	Genus and Species

AMPHIBIA		**DIAPSIDA**	
Metoposauridae	*Panthasaurus maleriensis*	Archosauriformes	*Galtonia sp., Protecovasaurus sp.,* and other intermediate forms
Chigutisauridae	*Compsocerops tikiensis*	Dinosauriformes	Undescribed Theropod-like (?) forms
DIAPSIDA		Aetosauria	Undescribed
Phytosauria	*Volcanosuchus statisticae(?) leptosuchomorph*	**SYNAPSIDA**	
Rhynchosauria	*Hyperodapedon tikiensis*	Cynodontia	*Ruberodon roychowdhurii*
Rauisuchidae	*Tikisuchus romeri*	Mammaliaformes	*Tikitherium copei*
Rhynchocephalia	*Undescribed*		*Gondwanadon tapani*

8   Table- 2b: Vertebrate fossil assemblage (tetrapod content) of the Late Triassic Tiki Formation of the Rewa Basin, India (modified
9   after Bandopadhyay and Ray 2020).

Figure 1

Palatal surface of the skull photograph (RH01/Pal/CHQ/Tiki/15) Kumar and Sharma 2019, recreated with permission from the editor of the Palaeontological Society of India.

a. Shows the field photograph published in Kumar and Sharma (2019). b. is the line drawing showing the disposition of the bones in the palatal surface of the skull published in Kumar and Sharma (2019). The abbreviation stated in the figure are as follows: cf = cultriform process, ect= ectopterygoid, itv = interpterygoid vacuity, pal= palatine, ps = parasphenoid, q = quadrate, stf = subtemporal foramen, v = vomer.

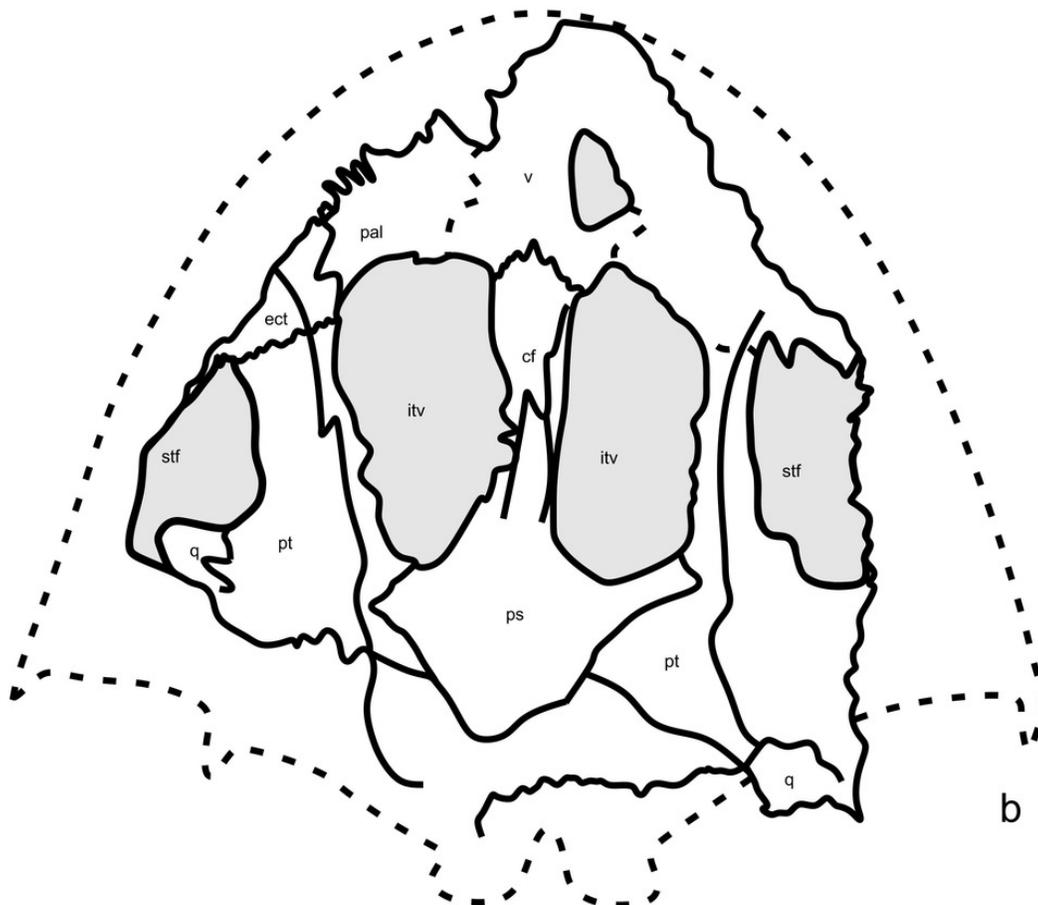
a

b

Figure 2

Dorsal surface of the skull roof of ISI A 202 *Compsocerops tikiensis*.

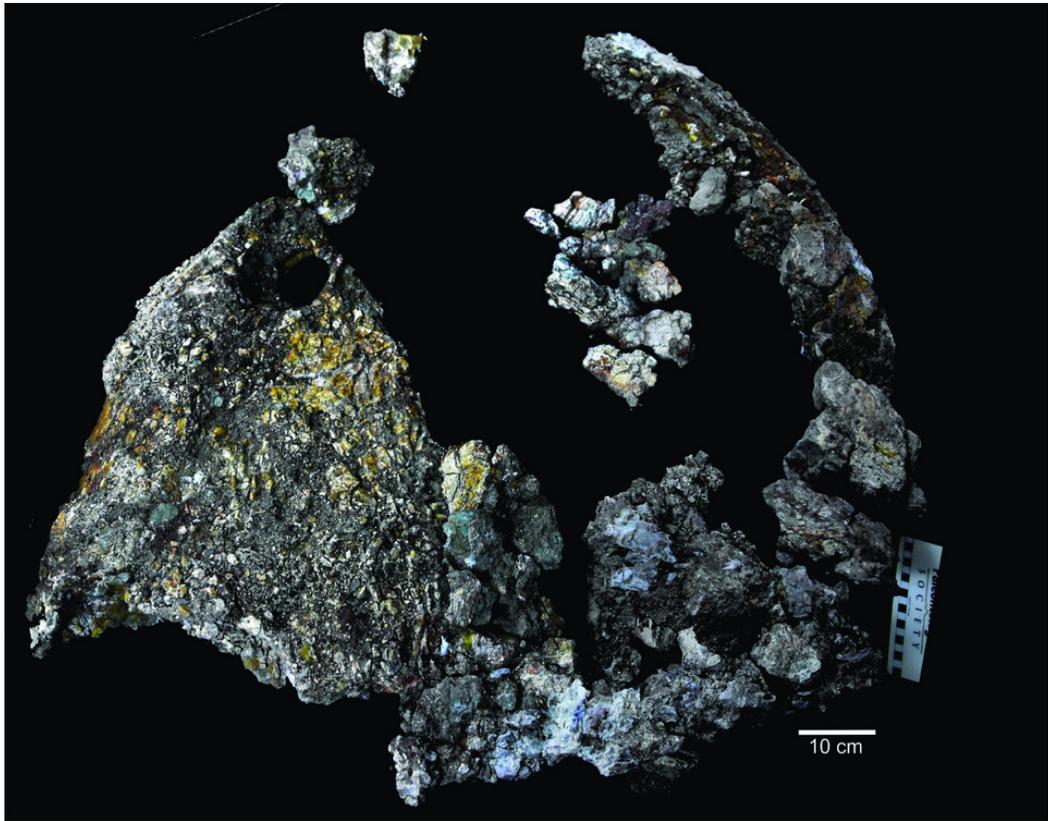
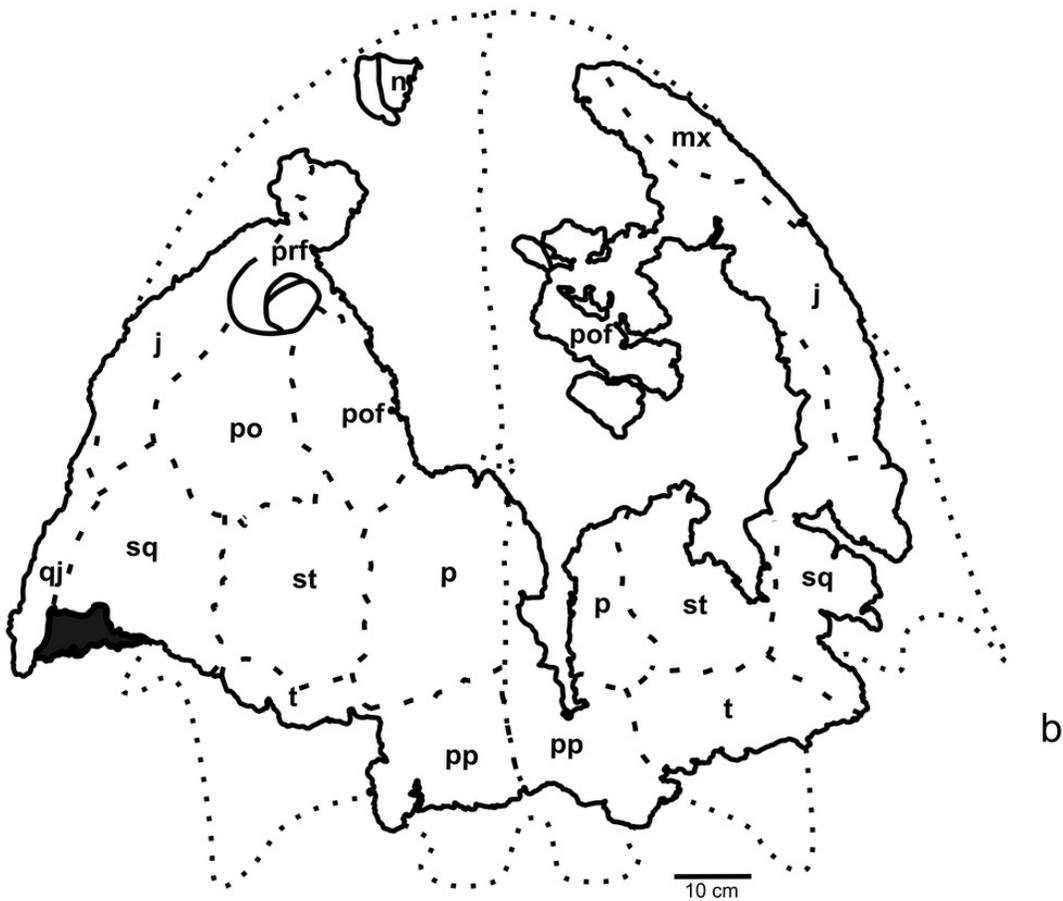
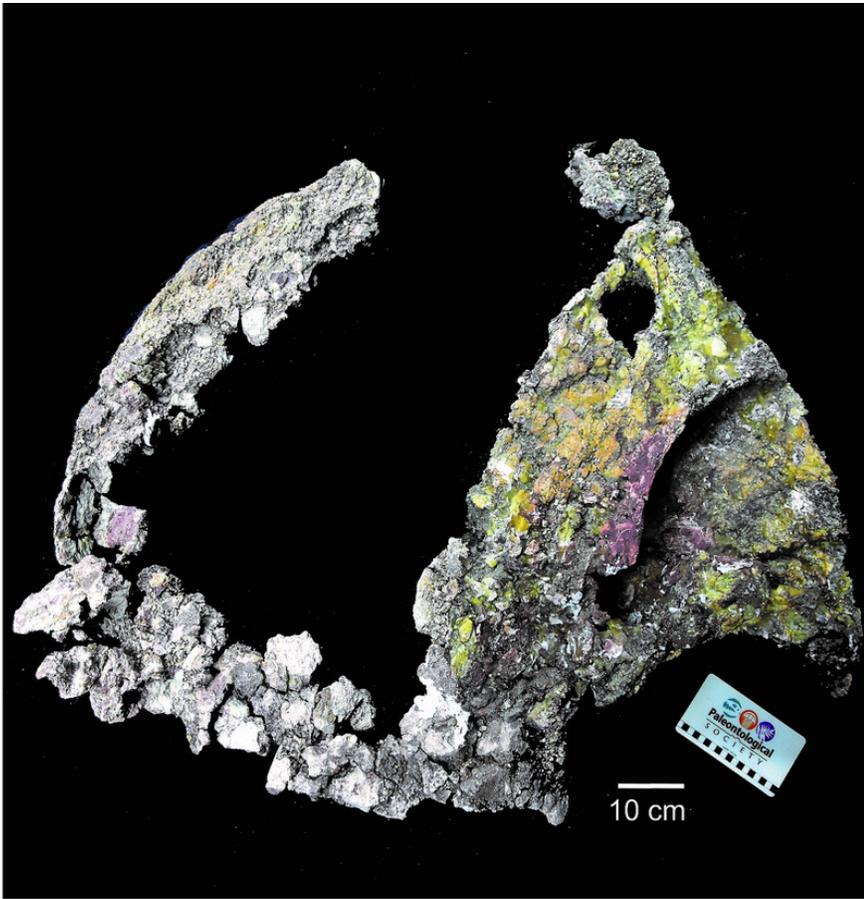
a. Reconstructed photograph of the dorsal surface of the skull roof of ISI A 202. Scale bar = 5 cm. b.Line drawing showing the disposition of the preserved bones in the dorsal part of the skull roof in ISI A 202. The abbreviation stated in the figure are as follows: j=jugal, mx=maxilla, n=nasal, p = parietal, po = postorbital, pof = postfrontal, pp = postparietal, prf = prefrontal, qj = quadratojugal, sq = squamosal, st = supratemporal, t = tabular. Scale bar = 5 cm.

a

b

Figure 3

Palatal surface of the skull of ISI A 202 *Compsocerops tikiensis*.

a. Reconstructed photograph of the palatal surface of the skull of ISI A 202. Scale bar = 10 cm. b.Line drawing showing the disposition of the preserved bones in the dorsal part of the skull roof in ISI A 202. The abbreviation stated in the figure are as follows: ect = ectopterygoid, eo = eoccipital, pal = palatine, ps= parasphenoid, pt= pterygoid, pv= palatine vacuity, q= quadrate, stf = subtemporal foramen.

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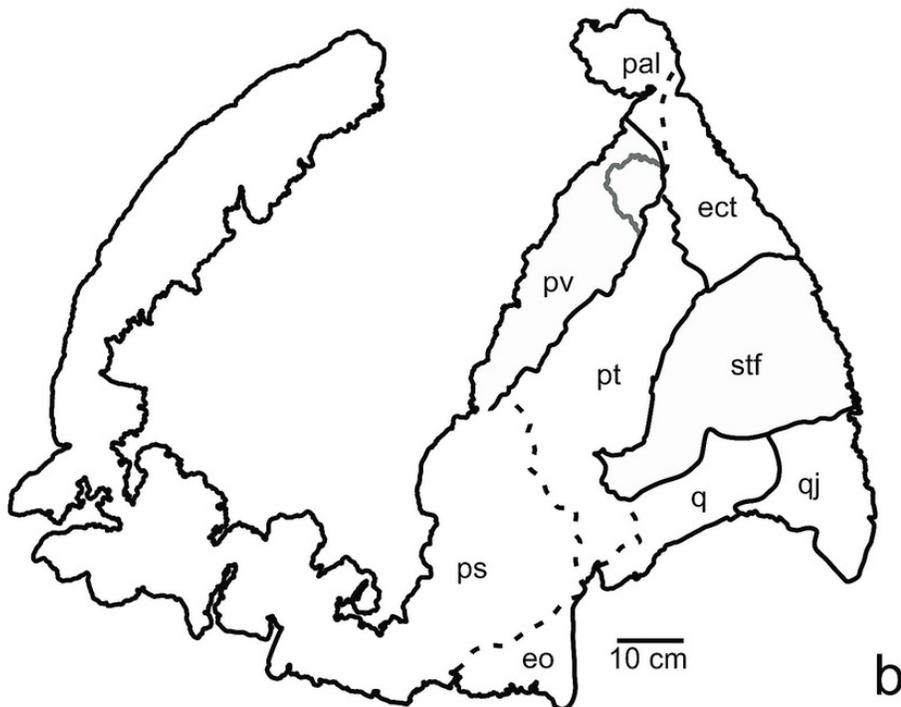
b

Figure 4

The poorly preserved occiput of ISI A 202 *Compsocerops tikiensis.*
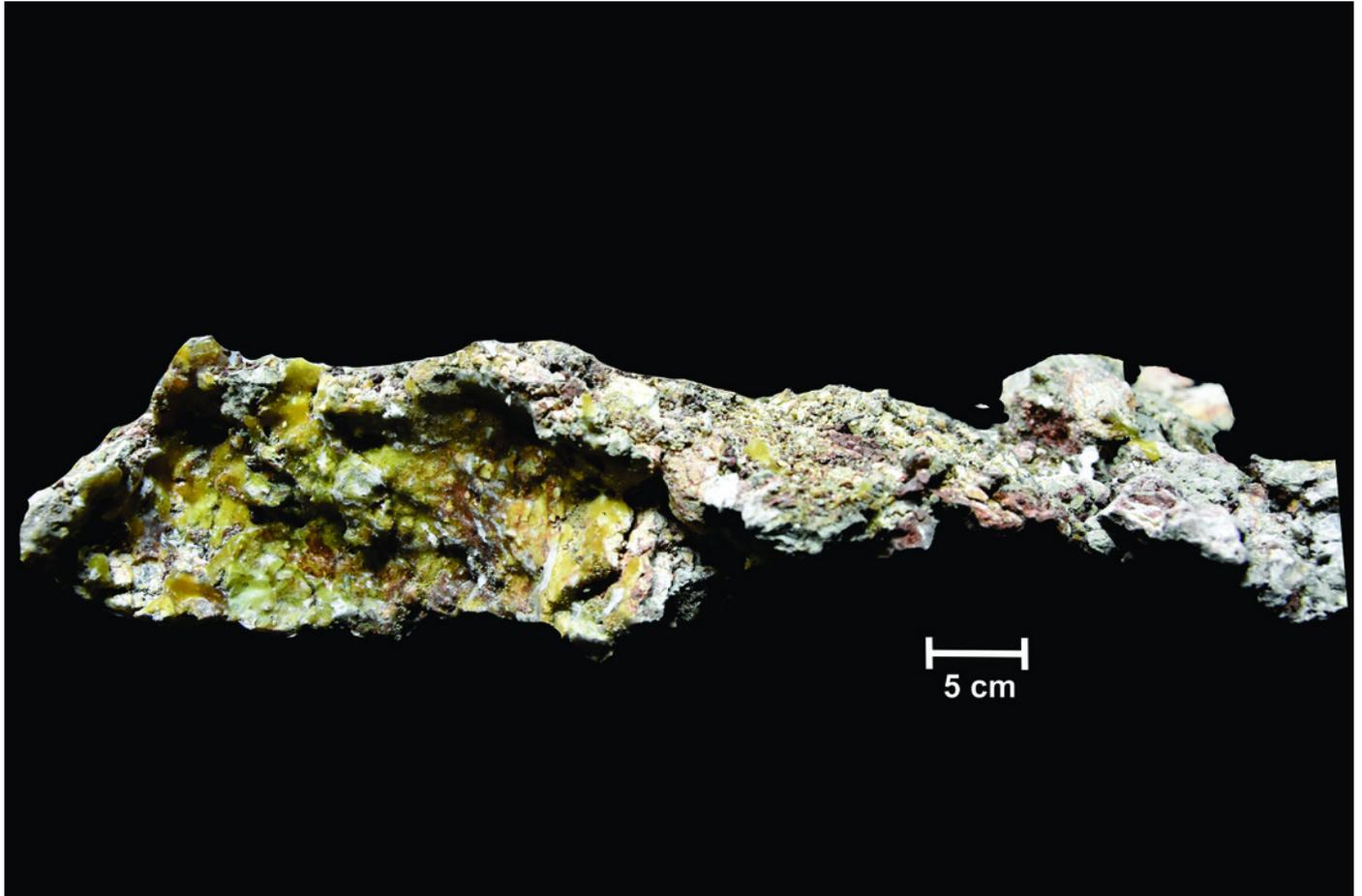
Figure 5

Dorsal view of poorly preserved left clavicle of ISI A 202 *Compsocerops tikiensis*.

Figure 6

Geological Map showing the Tiki Formation, Rewa Basin, India.

Geological map of the Tiki Formation, Rewa Basin, India, modified after Mukherjee et al. (2012). The red dotted line shows the hypothetical faunal boundary.

N

81° 15'   81° 20'   81° 25'   81° 30'

24° 05'

23° 55'

23° 40'

F
F
F
F
F
F
F
19°
Beohari
4°
9
Tenduadh
F
10°
F
Tiki
4°
7°
Hirwah 9°
2°
Jora
5°
Balaundi
10°
Hartala
11
F
F
F
F
F
F
F
F
F
F
F

LEGEND

	PRECAMBRIAN BASEMENT
	PALI FORMATION
	KARKI FORMATION
	TIKI FORMATION
	PARSORA FORMATION
	DECCAN TRAP
▪▪▪▪	FAUNAL BOUNDARY

F
F   FAULT LINE

ATTITUDE OF BEDS

5 KM
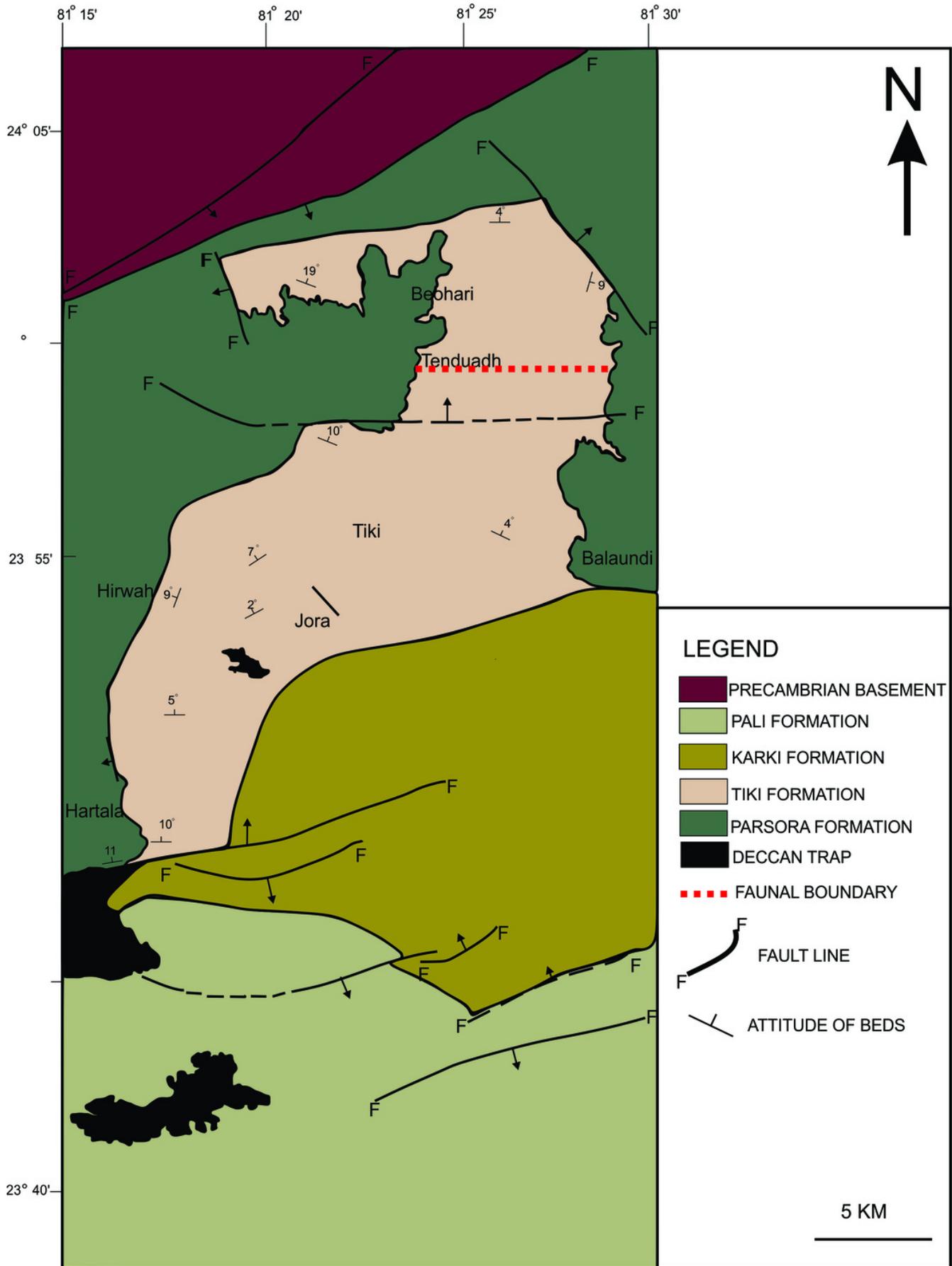
Figure 7

Field photograph showing the exposure of *Compsocerops tikiensis* embedded in mudstone in the Upper part of the Tiki Formation.

Figure 8

Lithologs of the Tiki Formation.

a. Litholog in the Jora Nala Section in the Lower Tiki Formation. b. Litholog in the Lower part of Tiki Formation modified after Mukherjee et al. (2012). c. Litholog of the Tiki Formation modified after Kumar and Sharma (2019).
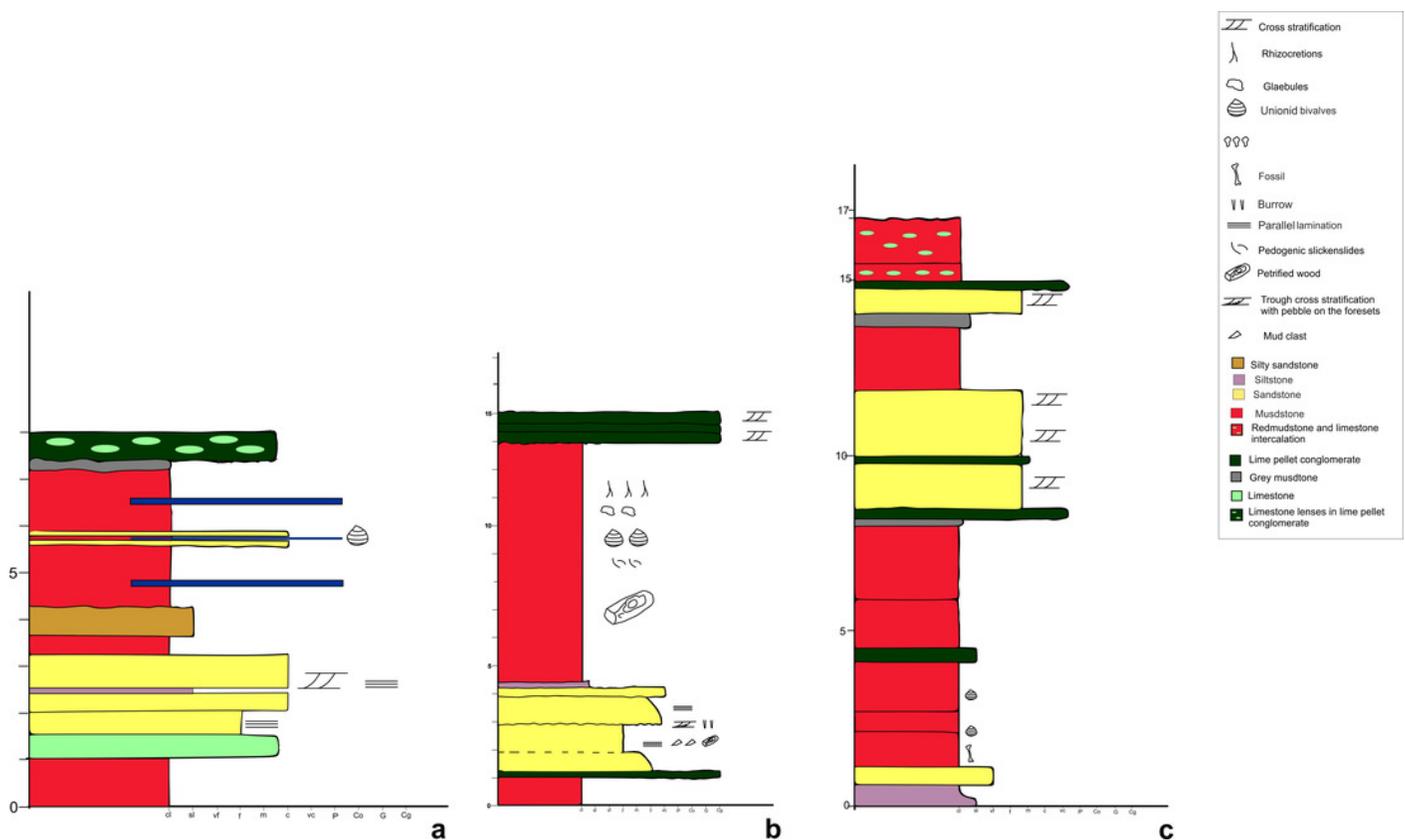
Figure 9

Field photograph of the sand-mud alternation in the Tiki Formation near Tenduadh.

a. Trough cross- bedded sandstone in the Tiki Formation b. Extensive mudstone in the Tiki Formation.

Figure 10

Geological map of the Maleri Formation, Pranhita-Godavari Valley Basin, India

Geological map modified after Kutty and Sengupta (1989), Dasgupta et al. (2017) showing the sand- mud alternations in the Maleri Formation, Pranhita- Godavari Valley Basin, India. The green line represents the faunal boundary that occurred due to the faunal turnover from the Carnian Lower Maleri to the Norian Upper Maleri Formation.
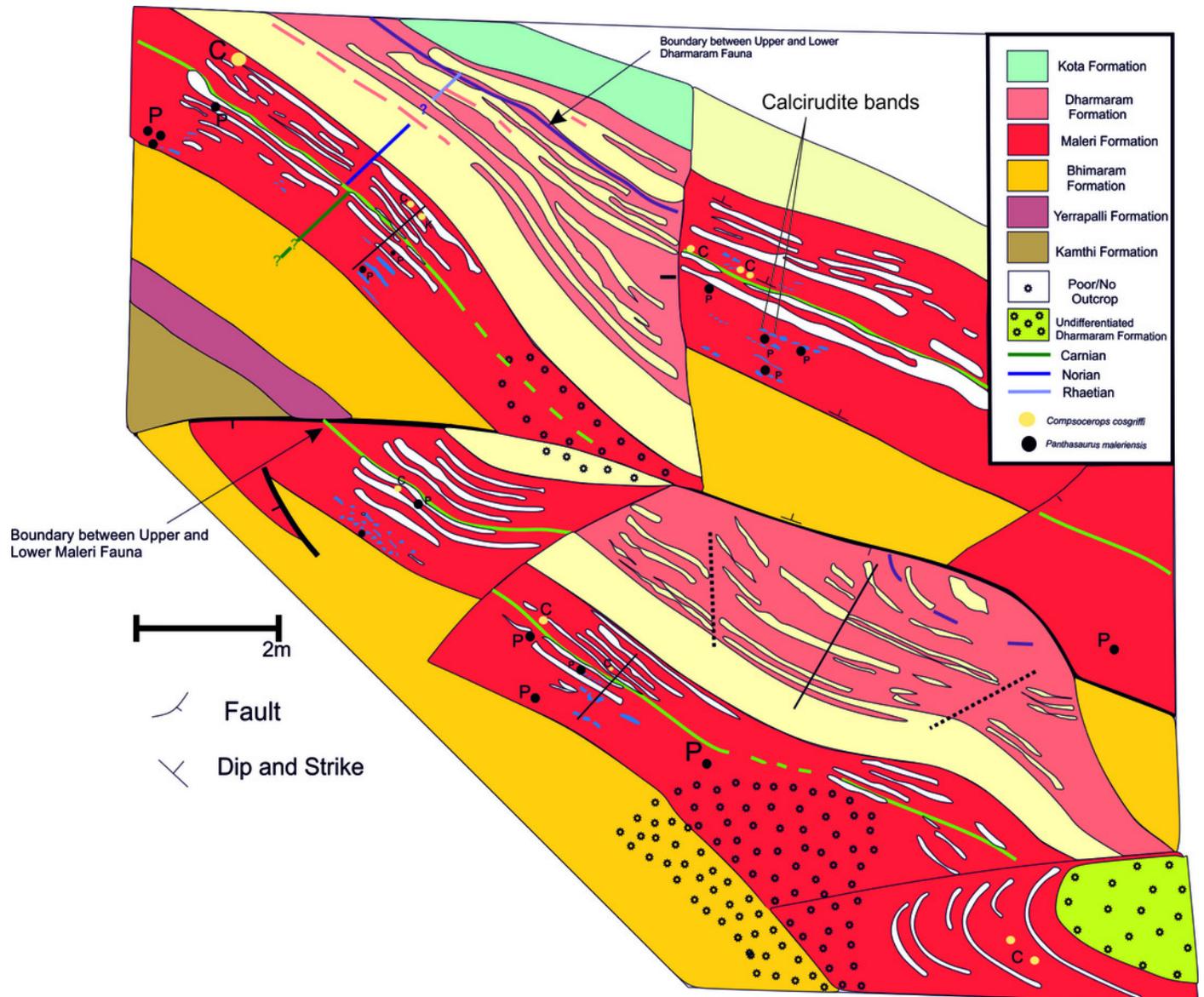
Figure 11

Litholog of the Maleri Formation modified after Kutty and Sengupta (1989).
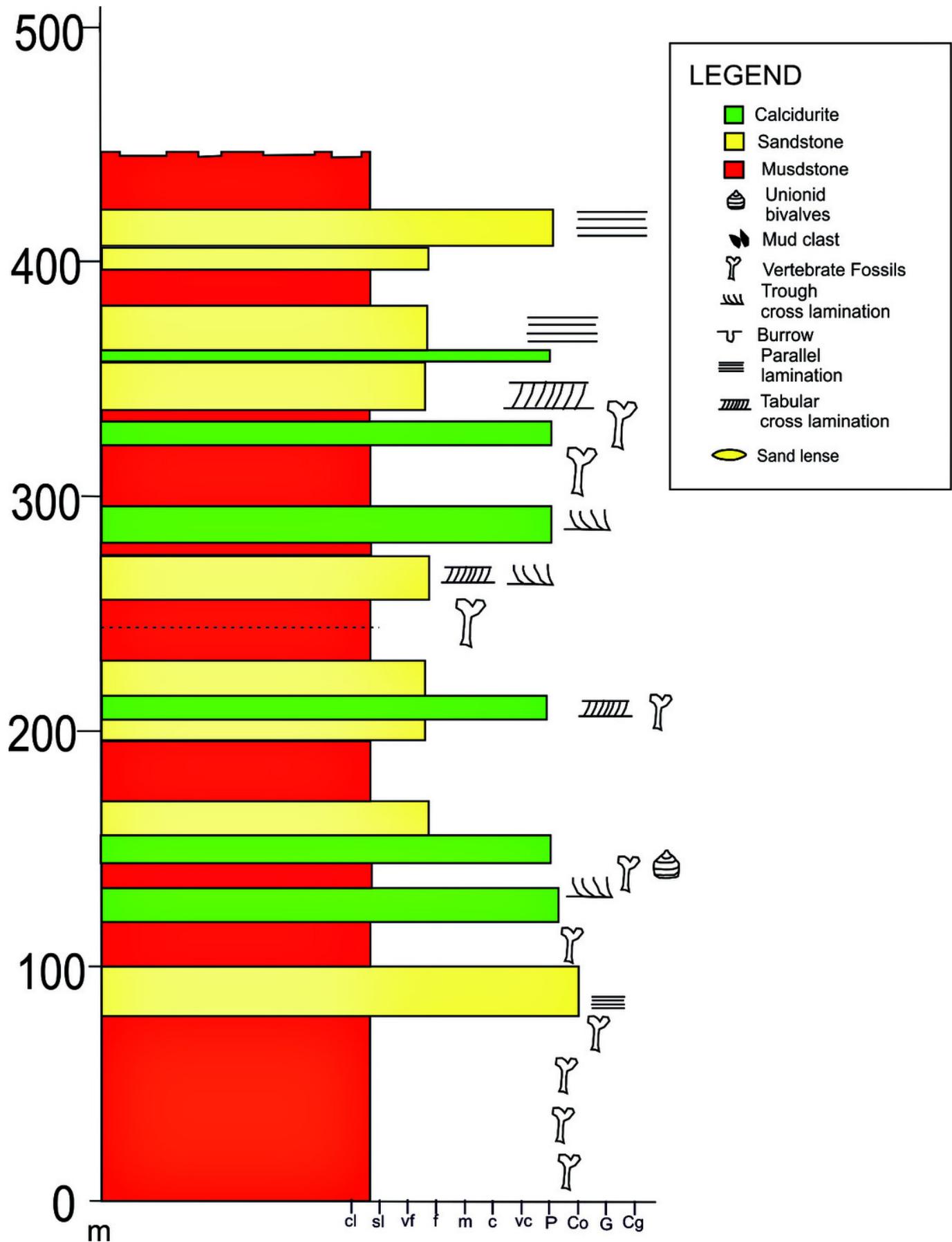
Figure 12

Field photograph showing the abundance of red mudstone in the basal part of the Maleri Formation.