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Gaps in studies and future perspective of research on the Lameta Formation and Bagh Group, central and western India

Ashok K. Srivastava, Neelam K. Kandwal
Department of Geology, SGB Amravati University, Amravati- 444602, India
ashokamt2000@hotmail.com

Abstract: Both Lameta Formation and Bagh Group of central and western India manifest many geological evidences which are helpful for reconstructions of paleoclimate, paleogeography and biotic community including dinosaur's inhabitation and survival. These stratigraphic units are under investigation from last 5-6 decades for their lithological settings and environments of deposition, dinosaurian remains, fossil biota, marine incursions etc. In the present work, an attempt has been made to synthesize the work done on various aspects of the Lameta and Bagh sediments. Based on the same, gaps in the studies have been identified which need the attention of researches to elucidate existing controversies about environment of deposition, palaeogeographic limits, marine incursion, dinosaur inhabitation for the Lametas and, to establish precise stratigraphic set up, time connotation of floral and faunal contents including their palaeoclimatic and palaeoecological implications for the Bagh Group of rocks.

Key words: Lameta Formation, Bagh Group, Dinosaur, Maastrichtian, Cenomanian-Coniacian, Palaeoecology.

Introduction

The Lameta Formation and the Bagh Group of rocks are significant stratigraphic units as they preserve multiple evidences to reconstruct palaeoecological, palaeobiological and palaeogeographical conditions during Upper Cretaceous period. Both these stratigraphic units are addressed for their sedimentological and palaeobiological aspects. The Lameta Formation of the Maastrichtian age, traditionally considered to be fluvial in nature, is now revealing the evidences of short lived marine incursion as manifested by mineralogical constituents of the rocks, occurrence of calcareous algae and trace fossils. Similarly, its geographical extent of deposition, dinosaur inhabitation including its nesting site is now modified due to addition of one more inland basin of sedimentation in Central India.

The Bagh Group of rocks ranging from Cenomanian to Coniacian is of immense significance because of having records of fluvial to marine environments with good preservations of related sedimentological attributes, sea level fluctuation, fauna and flora. This group is also explored extensively for its floral and faunal contents, lithological variations and temporal changes in conditions of depositional environments.

In the present paper, authors have attempted to present the changing scenario of work on these two stratigraphic units. New evidences are discussed to update the status of Lameta Formation and Bagh Group research.

The Lameta Formation

The Lameta sediments, restricted to central and western India, are exposed as scattered patches in widespread Deccan Trap area due to Satpura and other faults. These patches, resting disconformably over the Gondwanas or unconformably above the Precambrian rocks, are reported from Jabalpur, Sagar, Amarkantak and Betul districts of Madhya Pradesh; Nagpur, Chandrapur and Amravati districts of Maharashtra and Balasinor of Gujarat. Beside, good development of areno-argillaceous and characteristic calcareous lithounits, these exposures also preserve dinosaurian remains including eggs and coprolites, which aid in reconstruction of palaeoclimatic and palaeoecological conditions.

Mohabey (1996a),on the basis of surface exposures of these sediments has identified five inland basins of Lameta sedimentation namely, i) Nand-Dongargaon basin, ii) Jabalpur basin, iii) Sagar basin, iv) Ambikapur-Amarkantak basin and, v) Balasionor-Jhabua basin. Recently, a new inland basin viz., Salbardi-Belkher has been added which has a separate geographic identity, however, lithological architecture and dinosaurian remains are same as of other inland basins (Mankar and Srivastava, 2015) (Fig.1a). Similarly, scientific contributions have been added in last decade i.e., trace fossils of marine affinity (Saha et al., 2010), report of marine calcareous algae and possibility of sea incursion (Srivastava et al., 2018), dinosaur skeletal remains including eggs and nests (Srivastava and Mankar, 2013, 2015a; Aglawe and Bhadran, 2014; 2018; Bhadran and Aglawe, 2015; Fernández and Khosla, 2015), review of faunal elements from infra- and Intertrappean sequences (Kapur and Khosla, 2018); reappraisal of glauconite (Bansal et al., 2018) and revised palaeogeographic limits of Lameta sedimentation (Mankar and Srivastava, 2019). In the present attempt, these aspects are being discussed and synthesized for

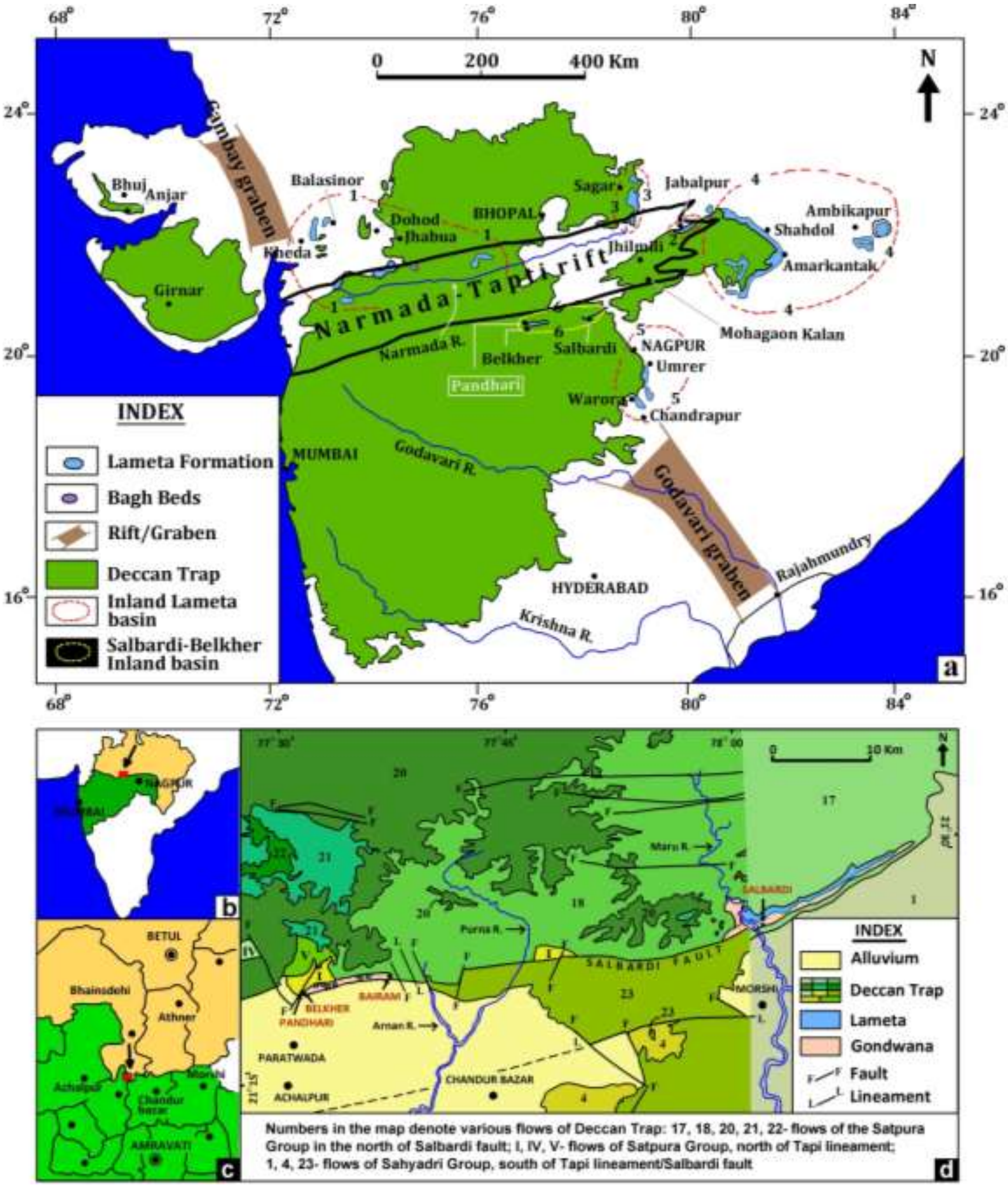

Fig. 1. Geological map proposed by Mankar and Srivastava (2019) showing: a) locations of various inland basins for Lameta sedimentation viz., 1) Nand-Dongargaon, 2) Jabalpur, 3) Sagar, 4) Ambikapur-Amarkantak, 5) Balasinor-Jhabua and 6) Salbardi-Belkher inland basin (Mohabey, 1996a; Bajpai, 2009; Keller et. al., 2009; Mankar and Srivastava, 2015); b,c) study area in regional and local set-up, d) locations of Pandhari, Bairam, Belkher and Salbardi areas in Salbardi-Belkher inland basin (GSI 2001, 2002).

comprehensive information on the Lameta sediments of India.

Recent studies in the Lameta Formation

Inception of Salbardi-Belkher inland basin

The Salbardi-Belkher inland basin in central India is a recent addition for Lameta sedimentation including dinosaur inhabitation (Mankar and Srivastava, 2015; 2019). It is located in the west of Nand-Dongargaon basin (Mohabey, 1996a) having almost same geographic extent as of the adjacent basin. The basin is established on the basis of four large and a few small Lameta exposures confined to its geographical area. The large exposures with good development of rocks ranging from 35 to 45m thickness are exposed at Bairam (21^{0}22'25" N: 77^{0}37'23" E), Belkher (21^{0}21'48" N: 77^{0}31'23" E), Pandhari (21^{0}22'02" N: 77^{0}32'54" E) and Salbardi (21^{0}25'15" N: 78^{0}00'00" E) (Fig. 1b).

In basinal set-up, the Lameta sediments along with disconformably overlying upper Gondwana rocks (~Jabalpur Group) are exposed in scattered manner in basaltic county of Deccan Trap. The basement rock is quartz-feldspathic gneiss of Archaean age, however, exposed at only Salbardi area. Alluvium and soil form the top of succession. The Lameta successions exposed at various areas have more or less similar lithological settings; however, lateral variations including thickness of various beds are frequent. The lithocolumn at Bairam locality (35m) is marked with brownish-yellowish-greenish clays with interbeddings of thin siliceous limestone at the base. It is overlain by medium to coarse grained arenaceous succession, followed by clay-marl with intercalations of siliceous limestone and further medium to coarse grained, bioturbated sandstone along with abundant arenaceous concretions. Overlying column is dominantly calcareous in nature i.e., nodular limestone having clasts of chert, jasper and, indurated, flat bedded chertified limestone. At Belkher area, the succession is comparatively thick and its lower arenaceous part is yellowish orange to grayish brown, medium to fine grained sandstone having preservations of parallel and cross beddings. Trace fossils namely, *Planolites, Planolites montanus, Thalassinoides* and stuff burrows are also reported showing polychaetes and crustaceans as benthonic community. The middle lithounit is calc-marl with abundant concretions and the upper part consists of nodular and chertified limestones. The Pandhari area succession can be considered as an eastward extension of the Belkher and lies barely at a distance of about one-kilometre in the east. Its lower part is dominantly represented by clays of greenish gray to yellowish brown shades having sandy concretions and interbeddings of siliceous and micritic limestones. The middle part is brownish-grayish-yellowish coloured, medium to fine grained, friable to hard sandstones with scattered occurrences of abundant irregular concretions. The upper calcareous column consists of brecciated, nodular and chertified limestones. The lower part of the succession at Salbardi area is dominantly arenaceous consisting of thinly bedded sandstones having intercalations of clayey beds. The middle part is calc-siliceous in nature with frequent lithological variations as recorded by preservations of by calcareous, calcretized beds, clayey horizons etc. The upper part is similar as the other localities and represented by nodular and chertified limestones. The top of succession is marked by intraformational brecciated limestone which is restricted to this locality only. Comparison of the lithological architecture of these successions with the Lameta successions of other basins shows almost similar set-up, however, variations in thickness of various lithounits are prominent (Fig. 2).

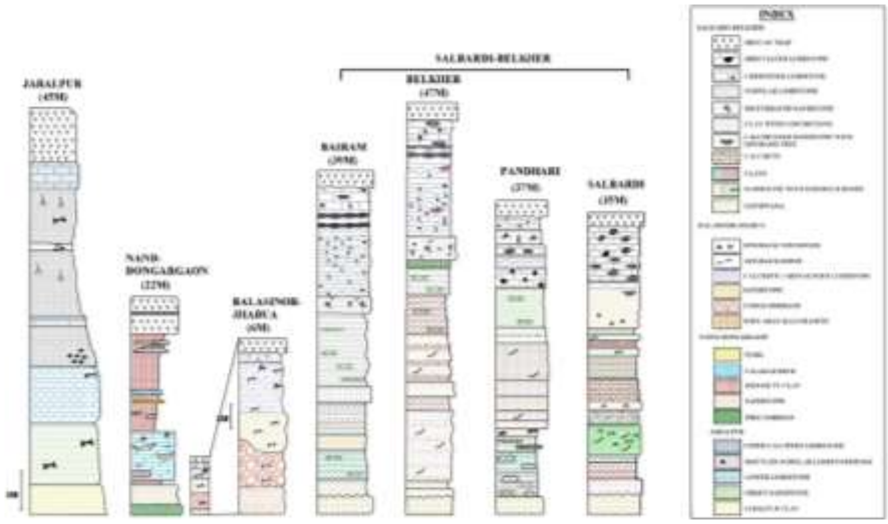

Fig. 2. Comparative lithologs of Lameta sediments in various inland basins of deposition (revised after Mankar and Srivastava, 2019).

Depositional environment and basin configuration

The newly added basin has also been investigated in detail for petrography, lithofacies and depositional environments (Srivastava and Mankar 2015b; Mankar and Srivastava, 2019). They have identified three different lithofacies associations i.e., a) arenaceous lithofacies, b) argillaceous lithofacies and, c) calcareous lithofacies. The arenaceous association includes, i) massive sandstone lithofacies, ii) green sandstone lithofacies, iii) thinly bedded, yellowish orange and grayish brown sandstone lithofacies, iv) coarse grained sandstone lithofacies, v) dark brown bioturbated sandstone lithofacies. The argillaceous association consists of, i) yellowish-brownish-greenish clay-siltstone lithofacies, ii) light gray silty clay with concretions lithofacies, whereas, the calcareous association includes, i) calcrete lithofacies, ii) nodular limestone lithofacies, iii) chertified limestone lithofacies and, iv) intraformational breccia lithofacies.

Based on lithofacies identified, their characteristic features and lithological architecture, the detailed depositional environments along with a model for temporal change in the environmental set-up have been proposed (Srivastava and Mankar, 2015b; Mankar and Srivastava, 2019). They interpreted fluvial-lacustrine set-up for the deposition of Lameta sediments in Salbardi-Belkher inland basin. Energy conditions of depositing medium and basin configuration have a control over the nature and pattern of sedimentation. The lower part of the succession at Salbardi area, associated disconformably with Gondwana succession, is represented together by medium to fine grained, thinly laminated sandstones having abundant rounded to subrounded pebbles of quartz and feldspar. It indicates low energy condition of deposition having common source of sediments as evident by the occurrence of pebbles of same nature in both the lithounits. However, the energy condition of the depositing medium was fluctuating, as represented by alternations of thin, fine grained argillaceous beds with cross to parallel bedded sandstones. Climate shows its influence during the deposition of the middle part of Salbardi succession as this lithounit is marked by pedogenic calcretes indicating prevalence of semiarid to arid climate (Wright, 1992; Wright and Tucker, 1991). During this period, the deposition has taken place in detached lakes and small water bodies having low water condition. This phase was followed by over flooding and high water condition of the river channel that favoured the deposition of medium to coarse, flat bedded sandstones. Preservation of about one-meter thick bioturbated sandstone at Belkher section suggests calm and quite water condition for a short duration indicating flourished but restricted diversity of benthonic fauna causing complete churning and intermixing of the sediments (Srivastava and Mankar, 2015b). They have also reported *Thalassinoides, Planolites, P. montanus* and stuffed burrows of crustaceans and polychaetes.

Nature of medium during the deposition of the upper calcareous columns shows a completely changed scenario from the previous. Dominance of various types of carbonate indicates an alkaline nature of depositing medium. A sheet flood environment of deposition as of type area succession (Tandon et al., 1995) has been interpreted for the contributing nodular and chertified limestones. Termination of the Lameta sedimentation took place due to changed climatic and geomorphic set-ups because of Deccan volcanic activity. The additional lithounit of intraformational breccia, forming the top of the Salbardi succession having clasts of pre-existing Lameta rocks in the micritic matrix exhibits a short phase of sediment transport by gravity flow mode.

The nature and configuration of the new basin is similar as of other inland basins identified by Mohabey (1996a) viz., Jabalpur, Nand-Dongargaon and Balasinor-Jhabua having fluvio-lacustrine set-up and also inhabitation of dinosaur. The size of the basin is almost equal to Nand-Dongargaon (Mohabey, 1996a), however, extended in east-west directions. The basin was comparatively shallow in the east as revealed by the calcrete horizons and calcretized sandstones in the lower part of Salbardi succession. In contrast, the Pandhari and Belkher exposures in extreme west are dominantly argillaceous in nature. These fine grained sediments are massive to laminated in nature showing suspension mode of deposition in low energy or, calm water condition depicting relatively deeper condition of the basin (Srivastava and Mankar, 2015b; Mankar and Srivastava, 2019).

Trace fossils

Singh (1981) reported vertical to inclined cylindrical burrows of *Thalassinoides* affinity from the Mottled Nodular Sandstone and the Upper Sandstone members of the type area succession at Jabalpur and interpreted coastal complex setting of the deposition. Recently, Shah et al. (2010) reported certain trace fossils from various members of Lameta Ghat and Chui Hill sections of Jabalpur area viz., *Arenicolites, Calycraterion, Fucusopsis, Laevicyclus, Macanopsis, Ophiomorpha, Paleomeandron, Rhizocorallium, Stipsellus, Thalassinoides* and *Zoophycos* together from Lower Limestone, Mottled Nodular Sandstone and Upper Sandstone. They interpreted that the trace fossil assemblage, including sedimentlogical attributes of lithounits, indicate coastal marine setting of deposition under sub aerial condition. Srivastava and Mankar (2012) reported *Thalassinoides, Planolites, P. montanus* and stuffed burrows from Belkher section of Salbardi-Belkher basin. They have not commented on the environment specifically as all the ichnofossils are facies crossing, however, placed them into fluvial-lacustrine environment on the basis of general agreement on same environment for most of the Lameta basins.

Dinosaurian remains including eggs

Dinosaur skeletal remains belonging to sauropod and theropod are reported mainly from Jabalpur, Balasinor-Jhabua, Nand-Dongargaon and Salbardi-Belkher inland basins. These remains from Jabalpur basin includes *Titanosaurus indicus* (Lydekker, 1877) and *Antarctosaurus septentrionalis* (Huene and

Matley, 1993) belonging to sauropod which were later validated to *Titanosaurus colberti* (*Isisaurus colberti*) (Wilson and Upchurch, 2003) and *Jainosaurus septentrionalis* (Hunt et al., 1994). The theropod includes *Indosuchus raptorius* (Huene and Matley, 1993), *I. matleyi* (Huene and Matley, 1993), *Lametasauru sindicus* (Matley, 1924), *Composuchus solus* (Huene and Matley, 1993), *Laevisuchus indicus* (Huene and Matley, 1993), *Jubbalppuria tenuis* (Huene and Matley, 1993), *Dryptosauroides (?)grandis* (Huene and Matley, 1993), *Ornithomimoides mobilis* (Huene and Matley, 1993), *O. barasimlensis* (Huene and Matley, 1993), *Ornithogoniosaurus matleyi* (Das-Gupta, 1930), *Coeluroides largus* (Huene and Matley, 1993) and *Brachypodosaurus gravis* (Huene and Matley, 1993). However, all these reported species were later validated to *Indosuchus raptorius* (Huene and Matley, 1993), *I. matleyi* (Huene and Matley, 1993) and *Laevishuchus indicus* (Huene and Matley, 1993). Similarly, Sauropod viz., *Antarctosaurus septentrionalis* (Mathur and Pant, 1986) and *Titanosaurus rahioliensis* (Mathur and Srivastava, 1987) reported earlier from Balasinor-Jhabuabasin were later redefined as *Jainosaurus septentrionalis*(Wilson et al., 2003). From Nand-Dongargaonbasin,sauropod remains belong to *Titanosaurus indicus* (Lydekker, 1877), *T. Blandfordi* (Lydekker,1879), *T.colberti* (Jain and Bandyopadhyay, 1997) and *Laplatasurus madagascariensis* (Huene and Matley, 1933) were later confined to *Titanosauru scolberti* (*Isisaurus colberti*) (Wilson and Upchurch, 2003). Matthew et al. (2010) discussed the history of collection of dinosaurian remains in central India during 1828-1947. They described early findings which are significant to understand the evolution, extinction and biogeography of dinosaurs. Recently, sauropod remains from Salbardi area belonging to *Titanosaurus colberti* (*Isisaurus colberti*) (Wilson and Upchurch, 2003) has been added by Srivastava and Mankar (2013). Fragmentary bones of turtle (Aglawe and Bhadran, 2014) and theropod (Bhadran and Aglawe, 2015) have also been reported from the same area. Apart from this, huge collection made from Salbardi and Pandhari area is under investigation by the authors group.

Similarly, the dinosaurian eggs and egg-nests are also reported from this basin for and were subjected for detailing and proper identification by subsequent researchers. The Jabalpur basin bears the report of *Megalolithus horidungriensi, M. cylindricus, M. jabalpurensis, M. Matleyi* (Junior synonym of *jabalpurensis*), *M. Phensaniensis* (Junior synonym of *matleyi*), *M. mohabeyi, M. baghensis, M.*

dholiyaensis, M. padiyalensis (Junior synonym of *Mohabeyi*) and *M. Dhoridungriensis* (Khosla and Sahni, 1995; Mohabey, 1996b; Vianey-Liaud et al., 2003) which have been later validated as *M. cylindricus, M. jabalpurensis, M. megadermus* and *Fusioolithus. baghensis* by Fernández and Khosla (2015). Shukla and Srivastava (2008) reported lizard eggs-nest of eleven eggs represented by nine partially preserved and two complete eggs from the Lower Limestone member of Jabalpur area and also commented that the deposition of host lithounit has taken place in alkaline lagoon that was connected to a marine embayment by channels. Later, on the basis of shape, pattern and ultra structure of the eggs, these were reassigned to be of crocodilian nest by Srivastava et al. (2015). They also suggested near shore, lagoonal and supratidal settings of deposition for this lithounit. The reported oospecies from Balasinor-Jhabua basin includes *M. rahioliensis (=cylindricus), M. phensaniesis, M. khempurensis (=megadermu), M. kachchhensis, M. dhoridungriensis, M. megadermusM. Balasinorensis* (junior synonym of *baghensis*), *Phensaniensis* (junior synonym of *mohabeyi*) and *Problematica* (?) (Mohabey, 1996b; Khosla and Sahni, 1995; Vianey-Liaud et al., 2003) were later redefined and restricted to only *M. cylindricus, M. jabalpurensis, M. megadermus, Fusioolithus baghensis* by Fernández and Khosla (2015). *M. matleyi* and *M. megadermus* (Mohabey, 1996b) from Nand-Dongargaon basin were later identified as *M. megadermus* and *M. jabalpurensis* by Fernández and Khosla (2015). Oogenus *Megaloolithus* is a recent addition from Salbardi area by Srivastava and Mankar (2015a) which is based on one complete and 3 incomplete eggs/ egg shell fragments. Recently, Aglawe and Lakra (2018) added *Megaloolithus cylindricus* from the Salbardi-Belkher inland basin.

Four types of coprolites from the Pisdura area of Nand-Dongargaon basin have already been reported by Matley (1939). Samant and Mohabey (2014) have studied palynomorphs from coprolites from the same basin and reported *Lecaniella* sp. *Oedogonium* sp. *Azolla* sp. *Araucariacites australis*, *Cycadopites* sp. *Classopollis* sp. *Podocarpidites* sp. *Cretacaeiporites* sp. *Compositoipollenites* sp. *Graminidites annulatus*, *Graminidites assamicus*, *Longapertites* sp. *Multiareolites* sp. *Palmaepollenites* sp. *Palmaepollenites* sp. *Periporopollenites* sp. *Retimonosulcites* sp. Alongwith *tetracolporate* pollens, *Tricolporate* pollen and fungal spores. Khosla et al. (2015) reported microbiota and plant remains from Type A coprolites of Nand-Dongargaon basin and interpreted that the faecal produces were intentional and inadvertent omnivorous that used to consume appreciable portion of animal tissues. Sonkusare et al. (2016) also reported assemblage of diverse spores and pollen, phytoliths, fungal remains etc. from sauropod coprolites of Nand-Dongargaon basin and interpreted that the sauropod ate soft tissues of angiosperms and gymnosperms.

Marine incursions and revised palaeogeography

Depositional environment for the Lameta succession is a matter of debate from last four decades that still continues. Traditionally, the formation is considered to be fluvio-lacustrine in nature, however, with restrictions for certain parts of the succession. Initially, the exposures of Jabalpur area have attracted the controversy about its fluvial-lacustrine or coastal complex setting of environment of deposition. The previous is advocated mainly on the basis of non marine floral and faunal remains along with dinosaurian skeletal remains, eggs, eggs-nest and coprolites (Mately, 1921; Pascoe, 1964; Mohabey, 1996b; Srivastava and Mankar, 2013, 2015a); characteristic lithological features including calcretization in alluvial plain environment, Jabalpur area (Brookfield and Sahni, 1987); pedogenic calcrete formation in sub-aerially exposed, semi arid, low gradient, pre-palustrine alkaline flat alluvial setting, Jabalpur area (Tandon et al. 1990, 1995, 1998; Tandon and Andrews, 2001); fluvial setting based on sedimentological studies of Bokara and Jaripatka area of Nagpur (Soman and Deshpande 1993); field details and petrography of Lameta sandstone of Jabalpur area interpreting Mahakoshal and Jabalpur groups as provenance for sediment supply (Ansari et al. 2008) studied. The other school of thought supporting coastal complex setting is based on the reports of algal structures and glauconite minerals in Green Sandstone lithounit (Chanda, 1963a,b, 1967; Chanda and Bhattacharya, 1966; Singh, 1981; Singh and Srivastava, 1981); facies architecture similar to coastal complex settings including beds having bioturbations and preservation of cylindrical burrows similar to *Thalassinoides* (Kumar and Tandon, 1977, 1978, 1979). Singh et al. (1983) discussed the stratigraphy and palaeoenvironmental set up based on the study of the Green Sandstone of the Jabalpur area and suggested estuarine channel deposit. Recently, Shukla and Srivastava (2008) and Saha et al. (2010) also supported coastal complex setting on the basis of records of lizard eggs and trace fossils of marine affinity. Prasad et al. (2011) reported fossil cuticles and associated phytoliths of the rice tribe in the Cretaceous period. The new fossil of grass suggests the changes in diversification and evolution in the varieties during Cretaceous time. Khosla (2014) described charophyta gyrogonite from the Lameta sediments of Jabalpur and concluded local lacustrine and palustrine depositing conditions. Murkute et al. (2016) made petrological studies including heavy and clay minerals of the Lameta exposures of Nagpur and surrounding areas and suggested lacustrine to fluvial environment of deposition.

In recent decade, many researchers have advocated for marine influence during the deposition of type area succession which is based on preservations of dinosaur/crocodile eggs, trace fossils, lithological architecture and traces of authigenic glauconite. Preservation of lizard egg-nest in the Lower Limestone and architectural setup of lithofacies suggest alkaline lagoon, connected to a marine embayment by channels (Shukla and Srivastava, 2008). However, the identification of eggs as of lizard was further redefined to crocodile affinity (Srivastava et al., 2015) but retained the depositional setup to coastal complex as suggested by Shukla and Srivastava (2008) i.e., near shore, lagoonal and supratidal setting. Trace fossils, specific to marine environment from Lameta Ghat and Chui Hill sections of Jabalpur area and bedding geometry of their host lithounits are suggest of marginal marine condition of deposition (Saha et al., 2010). Recently, Bansal et al. (2018) reported authigenic glauconite from the Green Sandstone lithounit of the Lameta Formation exposed at Phutlibaori area of Madhya Pradesh. They interpreted that the mineral is formed by the replacement of K-feldspar, primarily in the cleavages and fractures of feldspar, along peripheries of feldspar which later evolved as pellets in due course of time. The study is based on detailed geochemical and structure element studies i.e., EPMA, XRD, SEM, Mössbauer spectroscopy, field emission gun-scanning electron microscopy etc. They further interpreted that the glauconite with high concentrations of K, Si, Mg, Al and moderate Fe indicate its formation due to pseudomorphic replacement of K-feldspar in an estuarine environment.

Similar phenomena i.e., marine influence during the deposition of Lameta sediments is also reported from newly established Salbardi-Belkher inland basin. Srivastava et al. (2018) proposed short lived marine incursion on the basis of calcareous algae at Pandhari locality of the new basin. A thin discontinued bed of micritic limestone, preserved in lower argillaceous column having small, fragmentary bones of dinosaur, is marked with abundant calcareous algae. These algal remains are represented by chlorophyta viz. *Clypeina* sp., *Acroporella* sp., *Trinocladusradoicicae*, *Trinocladus* sp., *Dissocladellaundulata*, *Dissocladella* sp., (dasycladalean algae); *Halimedacylindracea*, *Halimeda* sp., (halimedacean); *Ovulites*sp. (ovulites); *Microchara* sp. (charophyta), *Lithoporella* sp., and *Sporolithon* sp. (rhodophyta).

The Bagh Group

The Bagh Group of rocks (Cenomanian-Coniacian) are exposed as small detached outcrops along the north bank of Narmada river in central and western India. Good exposures have been reported from Dhar, Jhabua and Vadodara (Baroda) districts of Madhya Pradesh and Gujarat, however, the type area locality of Bagh, have been explored extensively for sedimentological and palaeobiological details (Fig. 3a, b). These sediments are mostly unmetamorphosed, undeformed, flat bedded and rest unconformably over the Precambrian Bijawar Group. In most of the area, the Deccan Trap volcanics of Late Cretaceous period forms the capping. Stratigraphically, the succession was initially subdivided informally into four lithounits by Blandford (1869) which have been later subjected to refinement and formal classification by many researchers. The recent stratigraphic set-up proposed for the succession includes three formations viz., the Nimar Sandstone, the Nodular Limestone and the Coralline Limestone (Tripathi, 2006; Jatley and Ajane, 2013) which was further revised by Racey et al. (2016) (Table 1).

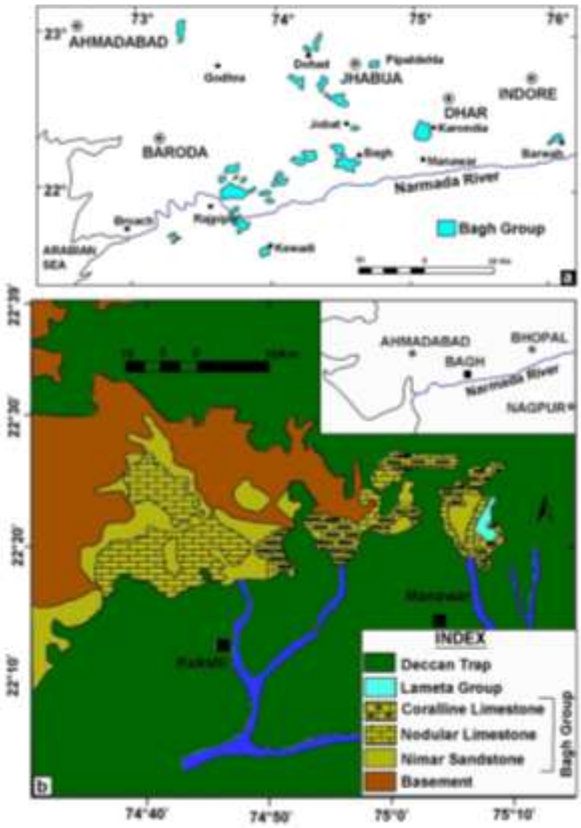

Fig. 3. Geological map showing, a) Bagh Group of rocks at various localities along Naramda river (Kundal and Sanganwar, 1998); b) stratigraphic set-up of Bagh Group of rock at type area (Kumar et al., 2018).

Lameta Group and Deccan Traps			
Group	Formation	Member	Age
Bagh	Coralline Limestone		Coniacia n
	Nodular Limestone	Chirakhan	Turonian
		Karondia	
Crystalline rocks			

Table 1. Stratigraphic set-up of Narmada basin (Tripathi, 2006; Jaitly and Ajane, 2013).

Background Information

The depositional environment, fossil content and biogenic structures were the significant aspects of work from decades back (Rode and Chiplonkar, 1935; Roy Chowdhary and Sastri, 1962; Murtyet al., 1963; Poddar, 1964; Sahni and Jain, 1966; Blandford, 1869; Pal, 1971; Dassarma and Sinha, 1975; Bose, 1884; Ramasamy and Madhavaraju, 1993; Taylor and Badve1995; Tripathi, 1995, 2000; Kennedy et al., 2003). Prasad et al. (1998) carried out paleomagnetic studies of Cretaceous Bagh Group from Narmada basin, which revealed reverse polarity for the entire succession with depositional age within the Cretaceous Normal Superchron. They concluded that Bagh Group has been remagnestized by igneous activity of Deccan basalt effusion and suggested counter clockwise rotation by 13±3°and latitudinal drift of Indian continent northwards by 3+3° during Deccan Volcanism. Vaidhynathan and Ramakrishnan (2008) compiled the available data on depositional environment and concluded that the sedimentation of Bagh Group of rocks started in fresh water fluviatile and estuarine conditions during the deposition of lower part of Nimar Sandstone which was further replaced by marine environment having many transgressive and regressive phases during the deposition of remaining successive lithounit.

Plenty of marine fossils belonging to ammonoids, bivalves, gastropods and echinoids are reported from this group. These fossils serve as a significant tool to redefine the biostratigraphy. Broadly, the age and stratigraphy of the Bagh Group were a matter of discussion. The age connotation of the succession is based on the fossil content i.e., ammonides (Chiplonkar and Ghare, 1976; Badve and Ghare, 1977; Chiplonkaret al., 1977; Bardhanet al., 2002; Kennedy et al., 2003; Jaitly and Ajane, 2013); bivalves (Kumar et al., 2018); echinoderms (Smith, 2010); nannofossils (Jafar, 1982); calcareous algae (Kundal and Sanganwar, 1998); and foraminifers (Raceyet al., 2016).

Trace fossil belonging to shallow marine environment are also reported (Chiplonkar and Badve, 1970, 1972). Fragmentary bones of dinosaurs e.g., humorous, femur, radius and ulna belonging to sauropod from the Nimar Sandstone of Dhar district are reported by Khosla et al. (2003).

Recent Studies in the Bagh Group of rocks

Racey et al. (2016) collected extensive field data from Cretaceous outcrops of North-East India including Narmada basin and provided revised chronostratigraphic framework based on litho-and biostratigraphic data base. They subdivided marine rocks of the Narmada basin into two i.e., the Lower Cretaceous Nimar Group and the Upper Cretaceous Bagh Group. The previous is further subdivided into, i) the Nimar Sandstone (Hauterivian-Albian) of fluvial nature and, ii) the 'Upper Nimars' of fluvial to shallow marine sediments of the (Albian-Cenomanian). Similarly, the Bagh Group of Turonian age has also been subdivided into, i) the Nodular Limestone Formation of deep to shallow shelf environment and, ii) Coralline Limestone Formation of temperate shallow marine condition. They have also provided the index fossil assemblages of various stratigraphic units in support of their stratigraphic divisions. Apart from using earlier reported fossils contents from various lithounits, the validation of the ages particularly for the Nodular Limestone and the Coralline Limestone formations are also supported with new records of foraminifers viz., *Praeglobotruncana stephani, Helvetoglobotruncana helvetica, Gavelinella tourainensis* for the previous, whereas *Rotalia* cf *algeriana* for later.

Bhattacharya and Jha (2014) studied tidalites from Nimar Sandstone which indicates sedimentation in upper subtidal to lower intertidal within fluvio-marine interactive system. The estimated parameter of earth-moon system in late Cretaceous time reveals no changes in last 100 Ma. Jha et al. (2016) reported seismites that are soft sediment deformational structures which were formed due to passing up of earthquake shocks from unconsolidated sediments. These structures, represented by convolute laminae, load and flame structures, pseudo nodules, contorted beddings, syn-sedimentary faults are preserved in middle part of the Nimar Sandstone. Based on the genetic aspects of the same, Jha et al. (2016) have interpreted a new phase of reactivation of Son-Narmada South Fault during the Cenomanian period. They have also made detailed study about various facies associations and interpreted that the lower part of lithounit shows predominantly fluvial setting of the deposition whereas, the middle and upper parts exhibit tide dominated estuarine to tide-wave influenced shoreface environment. Recently, Bansal et al. (2019) investigated glauconitic bed within the Limestone Formation of the Bagh Group in central India. They proposed that glauconites were formed within a shallow marine deposit across the Tethyan belt due to enhanced supply of K, Si, Al, Fe, Mg cations through continental weathering. The interpretation is based on petrography, geochemistry and mineralogy of the glauconite.

The report of dinosaurian remains from the succession was restricted to sauropod only (Khosla et al., 2003).So far, there was no record of theropoda from the Bagh Group. Recently, Prasad et al. (2016) discovered three isolated archosaur teeth from an oyster bearing Green Sandstone lying at the top of the Coralline Limestone at Phutibaori village of Dhar district. They identified two teeth of abelisaurid dinosaur (theropod), which is based on their similarities with premaxillary and maxillary tooth morphologies of *Majungasaurus* and *Indosuchus* and, remaining one is of indeterminate crocodile. These remains are considered it to be of Pre-Late to Late Maastrichtian age which is based on the stratigraphic position and age of host bed in the succession.

Patel et al. (2018) reported trace fossils viz., *Conichnusconicus*, *Conostichus broadheadi* and *C. stouti* from intercalated micritic sandstone and sandy allochemic limestone shale sequence of Bagh Group exposed in Man river basin at Uchad and Bhekhadiya villages. They have interpreted these ichnospecies as resting/dwelling structures of sea anemone which are preserved in association with Oyster fossils indicating shallow marine environment of deposition.

Ruidas et al. (2018) revisited the stratigraphic set-up including lithological details, fossil contents, trace fossils etc. The work is based on detailed field investigations of various localities including some of the unexplored sections. They proposed that the Nodular Limestone can be subdivided into three subunits equivalent to ‘member’ and also provided specific details of these subunits including their faunal assemblage and localities of ideal sections. Comments have also been made on their specific preservational attributes related with sea level fluctuations. Further, the nature and origin of modularity in the succession have also been explained. They suggested that the modularity is because of mechanical compaction due to the over burden of the Lameta Formation and Deccan Trap followed by the chemical compaction. Kumar et al. (2018) attempted to redefine the Nodular Limestone Formation of Bagh area on the basis of ammonoid and *Inoceramus* index taxa and assigned Turonian age for the formation. They further identified lower, middle and upper Turonian lithounits of the succession, of which, the age assigned to previous is based on *Spathites* and *Collignoniceras*. The middle is marked by *Collignoniceras* cf. *Carolinum* and *Inoceramus hobetsensis* whereas, the Upper Turonian stage is by an index species of *Inoceramus teshioensis,* preserved in association with *Placenticerasmintoi*.

Gaps in studies and perspective for future research

The literature survey reveals a good data bank on both Lameta Formation and Bagh Group of rocks covering mostly sedimentological and palaeobiological aspects including dinosaurs. However, there is a need for aspect based precise study. The Lameta sediments have been documented largely as fluvial, marginal marine or, of coastal complex, in addition to have marine incursions. This aspect needs a clear picture by reconstructing basin configuration in regional set up and establishment of event stratigraphy based on depositional environments, impacts of faunal and floral contents and determination of depositional ages. Secondly, there is a need to study depositional set up, flora, fauna including dinosaurs in context of revised palaeogeographic set up for Lameta sedimentation based on recent addition of the new Salbardi-Belkher inland basin to earlier identified five basins. Similarly, the Bagh Group still needs a precise stratigraphy that may be redefined by various micro and mega fossils. Here also, identifications of temporal changes in environmental and climatic conditions are requires for which, successions of the Bagh Group offer good scope for work.

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