The age of the Nodular Limestone Formation (Late Cretaceous), Narmada Basin, central India

SUSHEEL KUMAR, DEO BRAT PATHAK*, BINDHYACHAL PANDEY,
ANAND KUMAR JAITLEY, and JAI PRAKASH GAUTAM

Department of Geology, Stratigraphy and Invertebrate Palaeontology Laboratory, Center of Advanced Study,
Banaras Hindu University, Varanasi 221 005, India.

*Corresponding author. e-mail: dbpathak@yahoo.com

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The age of the marine Nodular Limestone Formation of the Bagh Group is refined at Substage level through ammonoid and inoceramid index taxa. The study is based on the fresh collections from three well-defined successive intervals (Lower Karondia, Upper Karondia and Chirakhan members) of this formation having excellent exposures in different localities of the Narmada Basin, central India. The first record of the widely distributed Turonian ammonoid genera *Spathites* Kummel and Decker and *Collignonicerias* Breistroffer from the Nodular Limestone Formation constrained its age exclusively to Turonian. The Early Turonian species *Spathites* (*Jeanrogericerias*) aff. *revelieranus* (Courtillet) and *Mytiloides labiatus* (Sclotheim) occur in the lower part, while the Middle Turonian marker *Collignonicerias* cf. *carolinum* (d'Obrigny) and *Inoceramus hobetsensis* (Nagao and Matsumoto) occurs in the upper part of the Karondia Member. The record of the index species *Inoceramus teshioensis* (Nagao and Matsumoto) in association with *Placenticerias minto* Vredenburg from Chirakhan Member allows a definite Late Turonian age. The present contribution is an attempt to resolve the controversies in the age of the Nodular Limestone Formation and also demarcation of the three divisions (Early, Middle and Late) of the Turonian Stage in the Narmada Basin, central India.

Keywords. Nodular Limestone Formation; ammonoids; inoceramid bivalves; Turonian; Narmada Basin.

1. Introduction

Narmada Basin is an intracratonic rift basin confined to a narrow ENE–WSW trending graben (Biswas 1987; Acharya and Lahiri 1991; Tripathi 2006). It is bounded by a series of sub-parallel strike-slip faults forming the Narmada–Son lineament and originated due to the reactivation of fault during the Early Cretaceous along the Narmada–Son lineament with regional uplift to the north and south forming an intervening graben (Kumar *et al.* 1999; Racey *et al.* 2016). The termination of

Cretaceous sedimentation in the Narmada Basin is most probably due to the uplift of the Saurashtra Arch (horst) to the NW (Biswas 1987).

The Cretaceous sedimentary successions in the Narmada Basin occur as isolated outcrops over Precambrian crystalline (granites/metamorphic) basement and overlain by Deccan basalts in the central and western peninsular regions of India (Tripathi 2006; Racey *et al.* 2016). These sedimentary records were initially designated as ‘Bagh Beds’ by Blanford (1869) with four lithounits, later formally named by Bose (1884) as Nimar

Table 1. *Lithostratigraphic framework of marine sedimentary succession in the Narmada Basin, central India (after Jaitly and Ajane 2013).*

Lameta Group and Deccan Traps			
Group	Formation	Member	Age
Bagh	Coralline Limestone		Coniacian
	Nodular Limestone	Chirakhan	Late Turonian
		Karondia	Middle Turonian
			Early Turonian
	Nimar Sandstone		Cenomanian
Crystallin rocks			

Sandstone, Nodular Limestone, Deola-Chirakhan Marl and Coralline Limestone in the ascending order. The lithostratigraphic scheme of Bose (1884) is considered as the basic classification which has been consistently subjected to various modifications by subsequent workers. Further, ‘Bagh Beds’ was renamed as Bagh Group by Akhtar and Khan (1997) along with its further subdivisions into four formations (Nimar Sandstone, Nodular limestone, Deola-Chirakhan and Coralline Limestone formations in the ascending order). The recent lithostratigraphic scheme of Jaitly and Ajane (2013) appears to be more persuasive and is followed in the present work (table 1).

Several stratigraphic sections of the Bagh Group are investigated in different localities (Sitapuri, Rampura, Bagh Cave, Kosdana, Chakrur, Zeerabad, Karondia and Khanwara) of Bagh area (figure 1). However, all the three Nimar Sandstone, Nodular Limestone and Coralline Limestone formations are exposed on the left bank of the Mann River in the west of Sitapuri and near Rampur village. These have yielded all the ammonoids and inoceramids used here for the biostratigraphic purpose.

The age of the Bagh Group, in general, and the Nodular Limestone Formation, in particular, has always been a matter of discussion among the investigators working on the different fossil groups. The present annotations are noteworthy to reach on a definite conclusion and strengthening the assignment of Turonian age to the Nodular Limestone Formation. Also, the elaborated evidences permit us to exactly differentiate the Early, Middle and Late Turonian substages within the Nodular Limestone Formation in the Narmada Basin, central India.

2. Age of the Nodular Limestone Formation

Chiplonkar and Ghare (1976), Badve and Ghare (1977) and Chiplonkar *et al.* (1977) assigned Turonian–Coniacian age to the Nodular Limestone and Coralline Limestone formations on the basis of the presence of various placenticeratid ammonoids. The immediately underlying uppermost part of the Nimar Sandstone Formation has been dated as Late Turonian–Early Coniacian by Jafar (1982) based on nannofossils, while the record of the bryozoans *Chiplonkarina dimorphopora* Chiplonkar from the same unit suggests an age not older than Upper Cenomanian (Racey *et al.* 2016) as evident through its known stratigraphic range (Taylor and Badve 1995). Kundal and Sangnwar (1998) identified the diverse calcareous algae assemblages from the uppermost part of the Nimar Sandstone and suggested a Cenomanian–Turonian age. Bardhan *et al.* (2002) recorded ammonite *Placenticerus kaffrarium* Etheridge and inoceramid *Voliceramus involutus* (Sowerby), respectively from the middle and uppermost parts of the Nodular Limestone Formation and concluded that the Nodular Limestone Formation is of Early to Middle Coniacian age. Khosla *et al.* (2003), while recording dinosaur bones from the Nimar Sandstone Formation, reviewed earlier classifications of the Bagh Group and suggested Cenomanian–Turonian age. Later on, Kennedy *et al.* (2003) recorded the Late Turonian marker ammonite *Prionocyclus germari* Reuss in the upper Nodular Limestone (?Chirakhan Member) in the Hatani River near Kukshi, and concluded that the previous ammonites and inoceramids records were compatible with a Late Turonian age. He also recorded ammonite fauna *P. kaffrarium* (synonym

Figure 1. Geological map of the Bagh area, Dhar district, Madhya Pradesh (modified after Jaitly and Ajane 2013).

of *Placenticerias mintoi* (Vredenburg)) and *Parastantonoceras* Collignon from the same unit in other part of the basin supporting Turonian age. Further, Kennedy *et al.* (2003) mentioned a late Middle–early Late Turonian age for an inoceramid fauna from the lower part of the Nodular Limestone Formation (without listing the

fauna). An Upper Turonian age to the uppermost part of the Nodular Limestone has been also suggested by Smith (2010) on the basis of the echinoderms. He identified *Euporophyma lefebvrei* Gauthier (a taxon restricted to the Turonian in Egypt), *Micraster mutabilis* Lambert, *Leptosalenia keatingei* Fourtau and *Hemiaster integer* Lambert

Figure 2. Differentiation of the Turonian subages within the Nodular Limestone Formation on the basis of ammonoid and inoceramid species.

Figure 3. (a and b) *Spathites* (*Jeanrogericeras*) aff. *revelieranus* (Courtiller 1860), (BHU 2014/Sn1/1), (a) lateral view, (b) ventral view, lower part of the Karondia Member, Nodular Limestone Formation, Sitapuri, Narmada Basin, central India, Early Turonian. (c and d) *Collignoniceras* cf. *carolinum* (d'obrbigny 1841), (BHU2014/Sn 3/10), (c) lateral view, (d) ventral view, upper part of the Karondia Member, Nodular Limestone Formation, Sitapuri, Narmada Basin, central India, Middle Turonian. (e and f) *I. hobetsensis* (Nagao and Matsumoto 1939), (BHU 2014/ Sm 12), (e) external view of left valve, (f) anterior view of both valves, upper part of the Karondia Member, Nodular Limestone Formation, Sitapuri, Narmada Basin, central India, Middle Turonian. (g and h) *P. mintoi* (Vredenburg 1906), (BHU2014/Sn 3/1), (g) lateral view, (h) apertural view, Chirakhan Member, Nodular Limestone Formation, Sitapuri, Narmada Basin, central India, Late Turonian. (i and j) *M. labiatus* (Sclotheim 1813), (BHU2014/Rn1/18), (i) external view of left valve, (j) (BHU2014/Rn1/49), external view of left valve, lower part of the Karondia Member, Nodular Limestone Formation, Rampura, Narmada Basin, central India, Early Turonian. (k) *I. teshioensis* (Nagao and Matsumoto 1939), (BHU2014/Rn1/7), external view of left valve, Chirakhan Member, Nodular Limestone Formation, Rampura, Narmada Basin, central India, Late Turonian.

(known from the Upper Turonian of Madagascar) suggesting that the Nodular Limestone Formation is of Turonian age. Similarly, on the basis of morphologically highly variable ammonite *P. mintoi* (Vredenberg), Jaitly and Ajane (2013) concluded that the Nodular Limestone Formation is of Turonian age. Recently, Racey *et al.* (2016) have also assigned a Turonian age to the Nodular Limestone Formation based on the record of the planktonic foraminifera species *Praeglobotruncana stephani* Gandolfi, *?Helvetoglobotruncana helvetica* Bolli and *Gavelinella tourainensis* Butt.

Globally, ammonoids are widely used for age assignment of the Mesozoic marine sedimentary successions; however, inoceramids and planktonic foraminifers are equally good chronometer especially in the Late Cretaceous. Several ammonoid and inoceramid bivalve specimens have been collected from the three successive intervals within the Nodular Limestone Formation (figure 2). The systematic study of these fauna resulted into the identification of ammonoid genera *Spathites* Kummel and Decker and *Collignonicerases* Breistroffer along with the inoceramid species *Mytiloides labiatus* Sclotheim, *Inoceramus hobetsensis* Nagao and Matsumoto, *Inoceramus teshioensis* Nagao and Matsumoto, etc., known to be restricted within the Turonian (Nagao and Matsumoto 1939; Wright *et al.* 1996; Zonova and Yazykova 1998).

The detailed review of the earlier works elaborated above and study of the freshly collected ammonoids and inoceramids, the age of the Nodular Limestone Formation can be safely assigned to Turonian. In the present work, the substage level differentiation of the Turonian has been made for the first time in the Narmada Basin (figure 2).

2.1 Early Turonian

The ammonoid species *Spathites* (*Jeanrogericeras*) aff. *revelieranus* (Courtyiller) (figure 3a and b) has been collected from Bed No. 8a at Sitapuri of the lower part of Karondia Member (figure 2). The subgenus *Jeanrogericeras* itself is known to be restricted within the Early Turonian (Wright *et al.* 1996), while its species *Spathites* (*Jeanrogericeras*) *revelieranus* (Courtyiller) has been recorded from Early Turonian (*Mammites nodosoides* Zone) of southern Europe (Wilmsen and Nagm 2013). *M. labiatus* (Sclotheim) (figure 3i and j) collected from the same lithounit at Rampura (Bed No. 7a, figure 2) also represents the Early Turonian interval (Zonova and Yazykova 1998). However, the authors

failed to find any evidence of the earliest Turonian *Watinoceras coloradoense* Zone in the basal most part of the Karondia Member.

2.2 Middle Turonian

The *Collignonicerases* cf. *carolinum* (d'Obrbigny) (figure 3c and d) and *I. hobetsensis* (Nagao and Matsumoto) (figure 3e and f) have been collected from Bed No. 9 at Sitapuri (figure 2). *Collignonicerases carolinum* (d'Obrbigny) is so far known only from the Middle Turonian of the Mediterranean region (Ion *et al.* 2004; Kennedy and Gale 2016), while *I. hobetsensis* appears first and dominates in the Middle Turonian, although it continues up to Late Turonian (Zonova and Yazykova 1998). The presence of these ammonoid and inoceramid index fauna suggest a Middle Turonian age for the upper part of the Karondia Member.

2.3 Late Turonian

The Chirakhan Member (also known as 'Deola Marl' or 'Deola-Chirakhan Marl') of the Nodular Limestone Formation has been assigned Late Turonian convincingly by earlier workers (Kennedy *et al.* 2003; Smith 2010) mainly based on ammonoid and inoceramid index species. The present record of the Late Turonian index species *I. teshioensis* (Nagao and Matsumoto) (figure 3k) from the Bed No. 9 at Rampura (figure 2) in association with the ammonoid species *P. mintoi* (Vredenburg) (figure 3g and h) from the Bed No. 10 at Sitapuri (figure 2) further authenticate its Late Turonian age.

3. Conclusions

- The detailed investigation of nearly complete sequence of the Bagh Group has been made particularly near Sitapuri and Rampura localities of the Dhar district, central India which allowed us to differentiate all the three successive lithounits – Nimar Sandstone, Nodular Limestone and Coralline Limestone formations.
- The lower Karondia Member and upper Chirakhan Member are also lithostratigraphically differentiated within Nodular Limestone Formation.
- The taxonomic determination of freshly collected ammonoid and inoceramid fauna (figure 3) from the lower and upper parts of the Karondia Member, as also from the Chirakhan Member, strengthens the Turonian age to the Nodular Limestone Formation.

- The Turonian Stage has been further differentiated into Lower, Middle and Upper Turonian within the Nodular Limestone Formation based on the index Lower, Middle and Upper Turonian ammonoid and inoceramid genera/species.

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