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UPPER CRETACEOUS (MAASTRICHTIAN) DINOSAUR EGGS *MEGALOOLITHUS CYLINDRICUS* FROM SALBARDI-GHORPEND AREA, BETUL DISTRICT, MADHYA PRADESH

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ABSTRACT

Recently, Salbardi-Belkher Inland basin has been recognized as a new dinosaur palaeo-habitat site in Central India after the discoveries of dinosaurian remains including dinosaur nests near Salbardi-Ghorpend area. These Upper Cretaceous (Maastrichtian) dinosaur fossil eggs are naturally preserved in off-white to yellowish calcareous sandstones of Lameta Formation along Maru River section, south to Ghorpend village. Previous work on Salbardi dinosaur eggs were restricted only up to oogenous level i.e oogenus- *Megaloolithus*. Based on the examination of the macroscopic, microscopic and ultramicroscopic (SEM) characters of the five Sauropod fossil eggs and eggshell fragments, reveals that these eggs belongs to oospecies *Megaloolithus cylindricus* of Oofamily: *Megaloolithidae.*

Keywords: Upper Cretaceous, Dinosaur eggs, Lameta, Salbardi-Ghorpend, *M. cylindricus.*

INTRODUCTION

At present, the well established localities for dinosaur eggs in India are Kheda and Dohad in Gujarat, Jabalpur, Dhar, Jhabua and Salbardi in Madhya Pradesh, Chandrapur in Maharashtra and Ariyalur in Tamilnadu. The nearest dinosaur palaeo-habitat sites are Bara Simla-Patbaba ridge in Jabalpur district (Madhya Pradesh) and Pavna in Chandrapur district (Maharashtra) which is approximately 390km NE and 241km SW respectively from Salbadri. From Salbardi-Ghorpend area, Sauropod ulna of *Titanosaurus colberti* , dinosaur eggs by Srivastava and Mankar (2013a, 2015a) and chelonian bones by Aglawe and Bhadran (2014) and also Theropod bone (abelisaurids) by Bhadran and Aglawe (2015) has been successfully documented. However, the previous discovery of Salbardi-Ghorpend dinosaur eggs were studied only upto oogenus level i.e oogenus - *Megaloolithus* (Srivastava and Mankar, 2015). In 2015-16, GSI has reported an occurrence of dinosaur nests in Lameta strata at left bank of Maru River near Ghorpend, Betul district, Madhya Pradesh (Aglawe and Lakra, 2016). In the present paper, based on macroscopic, microscopic and ultramicroscopic characters (SEM) of dinosaur eggs, the authors have unraveled the oospecies for the dinosaur eggs reported in Salbardi- Ghorpend area, Betul district, Madhya Pradesh.

GEOLOGICAL SETTING

In India, the Maastrichtian Lameta deposits have been widely distributed over 10,000km (Sahni and Khosla,1994) and deposited over six inland basins, namely; (1) Nand-Dongargaon, (2) Jabalpur, (3) Balasinor-Jhabua, (4) Ambikapur-Amarkantak, (5) Sagar and (6) Salbardi-Belkher (Srivastava and Mankar, 2015b). The Salbardi-Belkher inland basin has small, detached and roughly NE trending Lameta outcrops, well exposed near Ghorpend along Maru River (Fig.1A). Sratigraphically, the oldest lithounit is represented by deformed pink qurartzo-feldpathic gneiss of Archaean age as a basement which is further intruded by numerous basic dykes. The gneissic rock extends ENE-WSW across Maru River over a strike of 3.6km with width of 150-200meters as a thin wedge in between the Deccan Trap in the south and Gondwana sediments in the north. Rocks of Gondwana Supergroup are represented by sandstone and shale, unconformably overlie the basement rock with low dips between 5^o and 22^o due north or northwest. Rocks of Lameta Formation unconformably overlie the rocks of Gondwana with distinct pebbly marker bed at the base. Lametas are in turn overlain by basaltic flows of Deccan Trap. In Salbardi-Ghorpend area, the Lameta strata have been further classified as i) green sandstone, ii) intercalations of purple and green sandstones with clay, iii) off-white to yellowish calcareous sandstone, iv) massive limestone, v) cherty limestone, and vi) brecciated and nodular limestone. The 0.60-5.40m thick, lowermost lithounit (green sandstone) is hard and compact, medium to coarse grained with planar sedimentary structures comprises pebbles and clasts of jasper and chalcedony and has yielded numerous broken bone fragments of dinosaur and chelonian. The 0.40-2.5m thick purple-green sandstone intercalations are medium to coarse grained, weakly compacted and non-fossiliferous in nature. The fossiliferous off-white to yellowish calcareous sandstone is hard and compact, medium to coarse grained with irregular chert bands ranging in thickness from <1cm to more than 3cm. The top surface of the sandstone show poly-directional fissures and cracks with prominent sub-vertical dipping two set of joints. It also comprises circular to elliptical ferruginous siliceous nodules ranging in size from <1cm to 3cm across. The maximum thickness of off-white to yellowish sandstone is 3.80m. Under microscopic, the fossiliferous off-white to yellowish calcareous sandstone shows poor sorting of grains and contains sub-angular to sub-rounded grains of quartz in siliceous cementing material (Fig.10). The secondary silica and calcite filling in veins and voids are common. The uppermost strata of the Lameta are represented by massive and cherty limestone. The thickness of the massive limestone and cherty limestone varies from <1-2.50m and 0.35-2.10m respectively. The cherty limestone show distinct certification in the form of lenses, discrete pockets and irregular veins of various thicknesses. In general, Lameta beds are low dipping (3° to 8°) due north with an approximate thickness of about 25m. Thickness of Lameta strata varies from <0.5m-25m, in the Salbardi-Ghorpend area (Fig.1B). Deccan Trap belongs to Satpura Formation and has more than 11 basaltic flows in the Salbardi-Ghorpend area of pahoeo and "aa" type and are associated with 0.30-1.5m thick fossiliferous intertrappean (IT) beds. Lameta rocks are conventionally considered as non-marine fluvial-lacustrine deposits comprising overbank, channel and back swamp environments under semi-arid conditions (Medlicot, 1872; Brook field and Sahni,1987; Mohabey *et al*, 1993, Sahni and Khosla, 1994; Khosla and Sahni 2000, 2003; Srivastava and Mankar, 2010, 2013b).Tectonically, the rocks including Lameta Formation exposed in Salbardi-Ghorpend area are affected by NE-SW trending Salbardi fault. Joints trending N-S, NE-SW to NW-SE with sub-vertical to high dips in Lameta Formation and Deccan Trap are common.

MATERIALS AND METHODS

We have carried out macroscopic and microscopic study of dinosaur eggs collected from Salbardi-Ghorpend area. At site, the eggs are studied in cross section view, as it is embedded in siliceous matrix. The measurements were taken by using vernier calipers at site. For microscopic study standard 30 micron meter thick thin sections were prepared. Microscopic studies were carried out under compound microscope Leica DMRX attached with RICOH XR-X3000 camera between 2.5X-10X at RPL, Nagpur. Microscopic measurements were recorded using Leica Qwinplus software. For SEM study, gold coated samples were studied under Carl Zeiss Scanning Electron Microscope EVO-40. Prior to analysis, the eggshells were submitted to a process of ultrasonic bath with 10%-20% hydrogen peroxide.

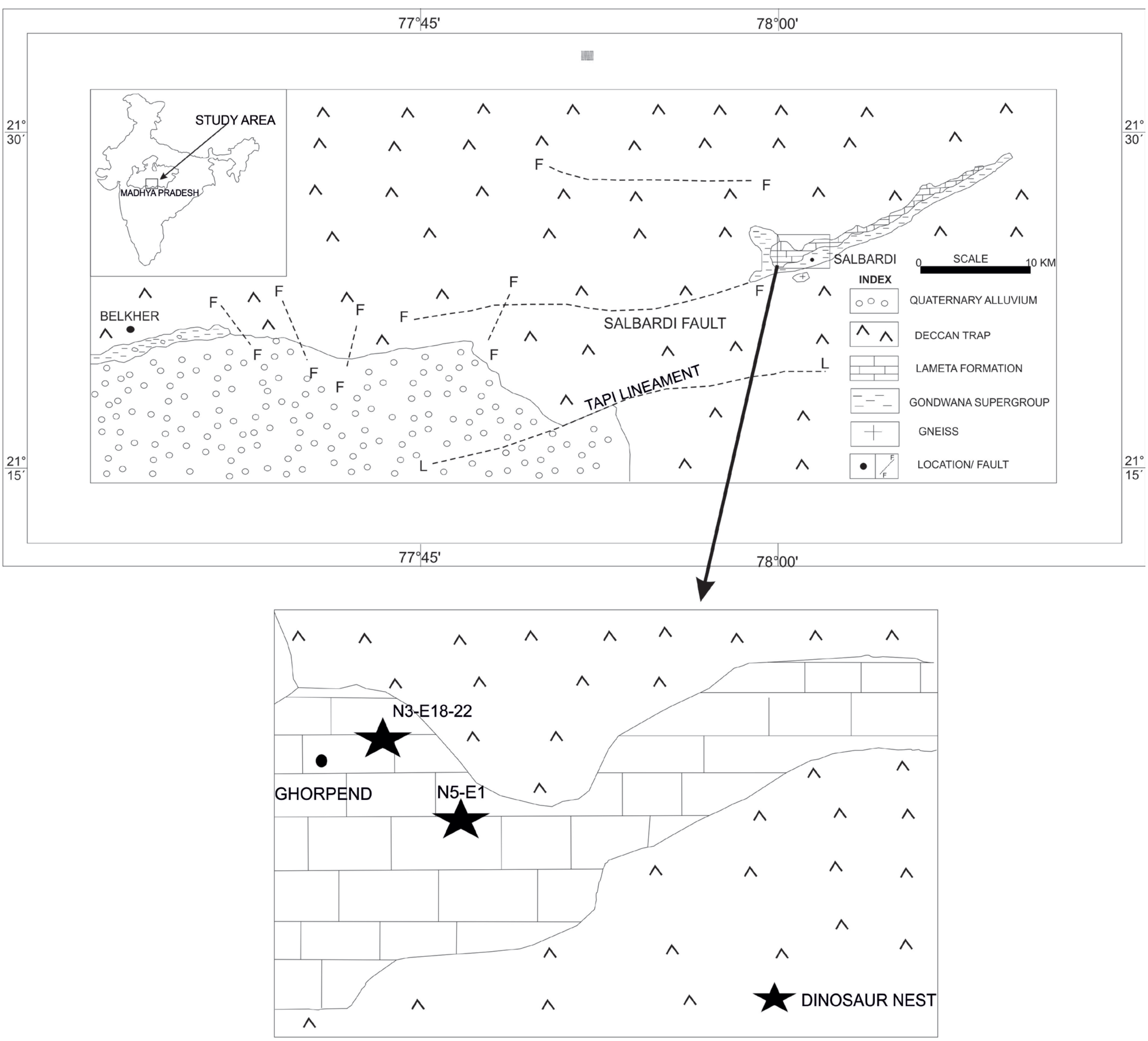

Fig. 1 (A). Geological map of Salbardi-Belkher area showing dinosaur nests.

All the registered samples (Egg no. N5-E1 (Reg. No. 335/GSI/PAL/CR/2016/N5-E1), thin section of egg no. N3-E19 (Reg. No. 333/GSI/PAL/CR/2015/N3-E19), N3-E28 (Reg. No. 333/GSI/PAL/CR/2015/N3-E28) are housed at GSI, Palaeontology Division, CR, Nagpur. Egg no. N3-E19, N3-E20, N3-E21 and N3-E24 are embedded in sandstone (at field).

SYSTEMATICS AND CLASSIFICATION

Basic Organizational group: Dinosauroid spherulitic, Mikhailov, 1991

Structural morphotype-Tubospherulitic type, Mikhailov, 1991

Oofamily **Megaloolithidae** Zhao,1979

Oogenus ***Megaloolithus*** Vianey-Liaud *et al*., 1994

Diagnosis: Dinosauroid-Spherulithic basic type; tubospherulithic morphotype; tubocanaliculate pore system; compactituberculate ornamentation (Mikhailov,1991). Spherical to sub-spherical eggs 12-20cm; egg shell 1.5-3.0 mm thick.

Megaloolithus cylindricus, Khosla and Sahni, 1995

Locality and Horizon: Northwest of *Ghorpend* village which is located about 9 Km from Morshi, Amravati district and 1.5 Km NW of Salbardi village, Betul district, Madhya Pradesh, India (Survey of India, Toposheet No.55K/03). The nesting site is located on the left bank of Maru River near small waterfall and embedded in off-white to yellowish calcareous sandstone.

Stratigraphic occurrence: Embedded in off -white to yellowish calcareous sandstone of Lameta Formation at 388 RL.

Studied material: Nest comprising one complete egg and three partially preserved eggs (Sample No. N3-E19, N3-E20, N3-E21, N3-E 22) and one isolated egg (Sample No. N5-E1; Fig.2).

Diagnosis: Spherical eggs 12-15.3cm in diameter, eggshell thickness (1.80-2.60mm); mostly discrete nodes, tall spheroliths, cylindrical shape, Height to Width ratio 4:1; pores sub-circular, basal caps medium sized (0.2-0.5mm in diameter), pore canals: narrow and straight.

Description: The nest comprises four spherical eggs along with other broken eggshell fragments embedded in off-white to yellowish, medium to coarse grained calcareous sandstone of Lameta Formation. Spherical eggs varies from 12.1-15.3cm in diameter. Thickness of the eggshell varies from 1.80-2.60mm and eggshell colour appears to be dark to light brown.

Under microscope, the shell unit thickness varies from 1.37-1.42mm and width varies between 0.29mm and 0.37mm in sample No. N3-E19. In sample No. N5-E1, thickness of

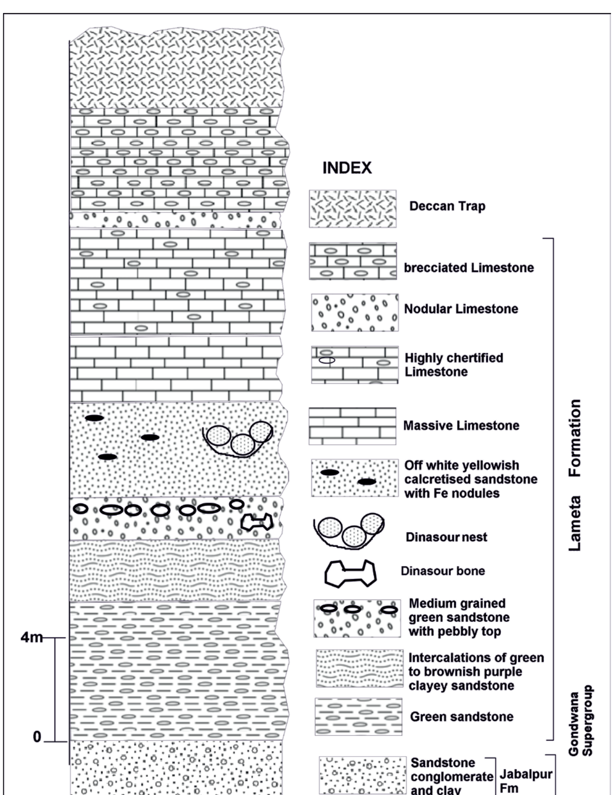

Fig. 1(B). Litho-section of rocks exposed in Salbardi-Ghorpend area.

Fig. 2. Spherical egg (N5-E1) embedded in calcareous sandstone near Maru River, Ghorpend, Madhya Pradesh.

Fig. 3. Closer view of egg no. N3-E24 showing well developed outer surface (External surface) of dinosaur egg.

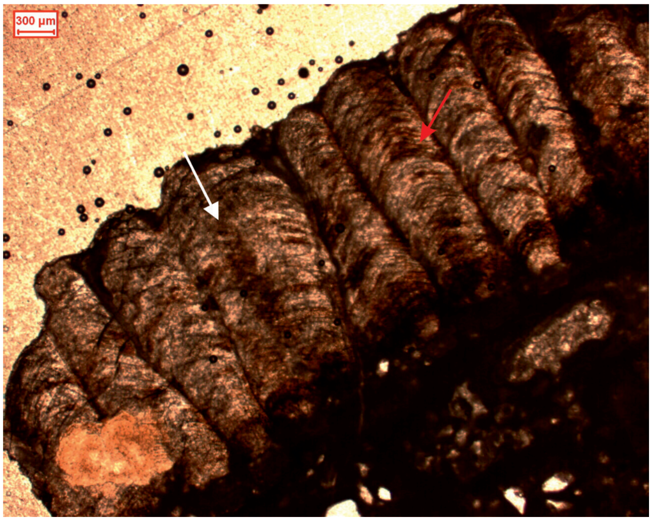

Fig. 4. Photomicrographs showing well developed nearly cylindrical shape shell units showing arch shape growth lines in sample no. N5-E1 under plane light. *Red arrow:* Cylindrical shape spherolith, *white arrow*-fusion in spheroliths.

shell unit ranges from 2.22-2.47mm and width varies from 0.51- 0.85mm (Fig.8). The height to width ratio comes to be about 4:1. The shell units are tall and cylindrical in shape. In radial section, spheroliths show moderately arch shape growth lines following the contours of the external profile. However, all the spheroliths are not exactly same in size and shape and hence it provides nodular appearance in the external surface of the egg. Preservation of basal caps is rare they are sub-circular ranging in diameter from 0.10-0.20mm. In few spheroliths, partial fusion has been noticed with the adjacent one. The outer surface exhibits nodose ornamentation with closely spaced circular to sub-circular nodes (Fig. 3 and 7). The diameter (short axes X long axes) of nodes varies from 378.7X433.3 µm to 651.6X776.2 µm. The inter-nodal spaces varies from 88.14-198.2µm. In radial section, well preserved narrow and straight pore canals are clearly visible (Fig. 4 and 5).

Fig. 5. Microstructural features of nearly slendrical to cylindrical shape spheroliths in N3-E28.

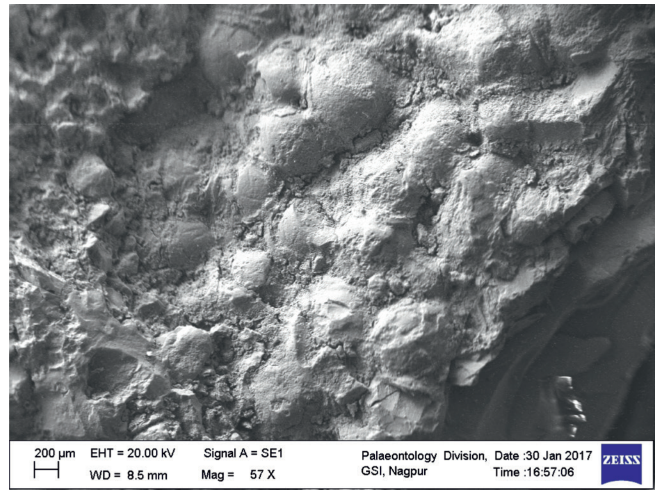

Fig. 6. SEM image showing nodal structure on outer surface of the eggshell. Circular to sub-circular pores are visible between adjacent nodes.

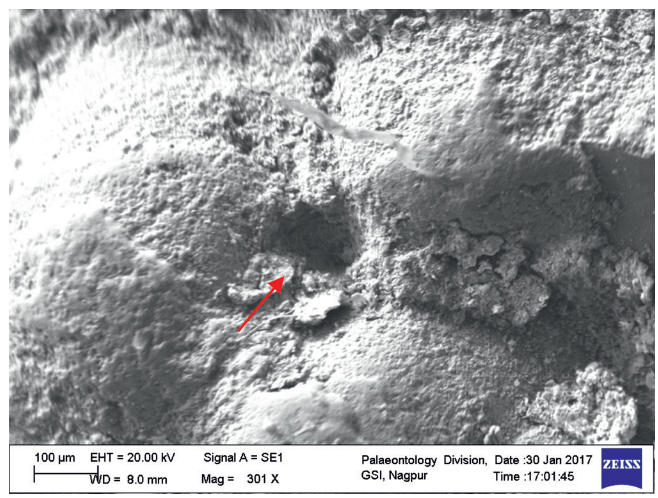

Fig. 7. SEM image showing sub-circular pore canal on the outer surface of the eggshell in closer view.

Eggshells are affected by severe burial diagentic alteration. Silicification and calcification are most common alteration features observed so far. Due to presence of calcite (having three set of perfect cleavage) herringbone pattern (Fig.4) are developed within spherolilths, overlapping the original growth lines. Spheroliths are sometimes filled with sparry calcite and chert. However, in most the samples marginal parts of the spheroliths are covered with silica. Sometimes pore canals are modified after filling with secondary silica (Fig.10).

DISCUSSION AND CONCLUSION

The parataxonomic classification of Indian dinosaur eggshells was documented by Khosla and Sahni (1995) and Mohabey (1996). Khosla ad Sahni (1995), established 7 new Megaloolithus oospecies for fossil eggs collected from Bara Simla, Chhota Simla, Patbaba ridge, Lameta ghat area, Jabalpur and Jhabua and one oospecies *Subtiliolithus kachhchensis* from Anjar inter-trappean. Later, 8 oospecies of Megaloolithus was established, which includes *Megallolithus rahioliensis,*

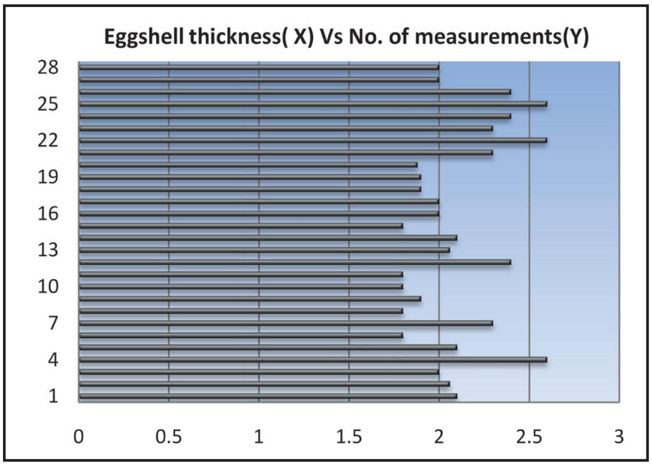

Fig. 8. Histogram showing eggshell thickness of dinosaur egg measured in Salbardi-Ghorpend.

M. phensaniensis, *M. khempurensis, M. dhoridungriensis, M. megadermus, M. balsinorensis, M.problematica , M. matleyi and Increta sedis* (Mohabey, 1998) based on histostructural and morphological features of the dinosaur eggs. However, out of 15 Indian oospecies attributed to Megaloolithidae Oofamily, 9 have got the global acceptance (Vianey-Liaud *et al*., 2003; Selles *et al*., 2013). However, in general (genus level), all the diagnosis features of the eggs collected from Ghorpend resemble and well fit with the diagnostics characters proposed as by Vianey-Liaud *et al*., 1994 and there is no doubt to categorise it within oogenus: *Megaloolithus.* The macroscopic and microscopic characters of the two Indian oospecies namely *M. cylindricus* and *M.rahioliensis* seems to be closer to the eggshells descried in this paper. Also, the comparison made amongst *M. cylindricus, M. rahioliensis, M. siruguei*, and *M. microtuberculata* had provided significant clue to establish the oospecies for the eggs and eggshell fragments reported from the Salbardi-Ghorpend.

Field observations (Macroscopic study) of eggs reveals spherical to sub-spherical shape which resemble with *M.* cylindricus, *M. siruguei*, *M. rahioliensis* and *M. microtuberculata*. Size of the all eggs falls within the range of 12-20cm (120-200mm). Eggshell thickness of the Ghorpend eggs varies from 1.80-2.60 mm and which has similarities with M. *cylindricus* (1.7-3.5 mm), *M. siruguei* (1.70-3.20mm*), M. rahioliensis* (2.80-3.50 mm), *M. microtuberculata* (1.84-2.52 mm), *M. mohabeyi* (1.88-1.90 mm) and *M. khempurensis* (2.36-2.50 mm). Under Microscope, the spheroliths of *M.cylindricus* are long, slender, elongated, compressed and cylindrical in shape. *M. rahioliensis* have tall and slender spheroliths. The shape of the spheroliths described in the present paper is also slender to cylindrical. However, shell unit's height to width ratio of the eggs studied here is differing from *M.mohabeyi* and *M.khempurensis* and it resembles with *M.cylindricus*, *M. siruguei, M.microtuberculata* and *M. rahioliensis.* (Table-1 and Fig. 9)

The external sculpturing (outer surface) of the eggs reported form Salbardi-Ghorpend has compactituberculate ornamentation (Fig. 3, 6 & 7) and it closely similar with *M. cylindricus*. *M.cylindricus* is also closely similar in external sculpturing of the egg shells, spherolith shape, pore pattern to Type-4 of Williams's *et al*., (1984), *M.siruguei* (Vianey-Liaud *et al*., 1994), type-B of Srivastava *et al*., (1986) and *M.khempurensis* (Mohabey,1998). In radial section, all the oospecies studied here have straight and narrow pore canals. However, the reticulate pattern of the pore canals has been observed in *M. microtuberculata* which is absent in *M.cylindricus*

Based on the macroscopic and microscopic examination of 1 complete and 3 incomplete eggs/egg shell fragments the eggs were described upto oogenus level by previous workers (Srivastava and Mankar, 2015). The authors of the present paper have undergone macroscopic and microscopic (including SEM) examination of 5 eggs (2 complete and 3 partially preserved). Finally it may be concluded that the fossil eggs and eggshell fragments reported so far from the Salbardi-Ghorpend area have close affinity with Indian oospecies: *M. cylindricus* and hence, the authors of the present paper advocates to categorise the eggs

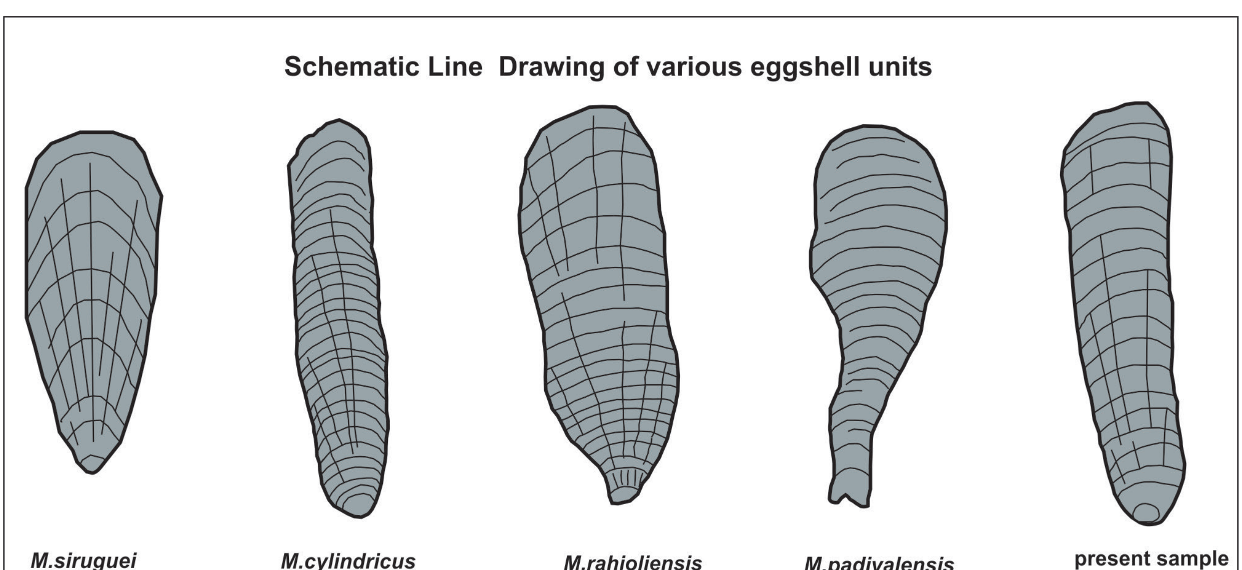

Fig. 9. Schematic line drawing of spheroliths of various oospecies**:** From Left to right*, M.sirguei, M.cylindricus, M.rahioliensis, M.padiyalensis and spheroliths from Salbardi-Ghorpend.*

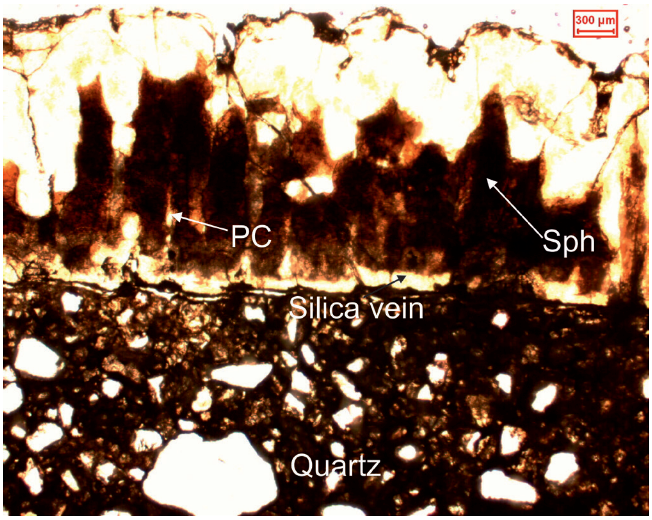

Fig. 10. Microphotographs of poorly preserved eggshell embedded in off-white to yellowish sandstone showing silicification along veins and outer parts of spheroliths. **PC**-pore canals, **Sph**-Spheroliths.

and eggshell fragments of the Salbardi-Ghorpend area under oospecies: *M. cylindricus* under Oofamily : *Megaloolithidae*.

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