

important role in the degradation of organic matter, thus making the Lonar ecosystem a live one. Isolation of aerobic bacteria from Lonar lake sediment has already been reported by Kanekar *et al.*²⁰. This signifies the biodiversity of Lonar lake with respect to microbial life.

In conclusion, strain LN 1 isolated from the sediment of Lonar crater is an alkalophilic, halotolerant methanogenic archaeon that can grow at pH 9.0, which differs from the known species of the *Methanosarcina*.

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Microfauna and age of the Sangcha Malla Formation of Garhwal Tethys Himalaya, India

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Biostratigraphic investigations of the Sangcha Malla Formation in the type area of the Garhwal Tethys Himalaya were carried out during an expedition. Systematic investigations of samples from this unit led to the recovery of several well-preserved species of *Archaeoglobigerina*, *Rosita*, *Globotruncana*, *Globotruncanita*, *Heterohelix* and *Pseudotextularia*. The faunal assemblage is indicative of deposition under a deep marine condition. The foraminiferal taxa are recorded from the upper part of the Sangcha Malla Formation, which is the youngest marine litho-unit deposited in the Garhwal Tethys Himalaya. Stratigraphic distribution of the taxa indicates that this part of the Sangcha Malla Formation was deposited during the Campanian times. The fauna recovered herein from the Garhwal Tethys Himalaya shows a close affinity with that of the Zaskar region of Ladakh Himalaya and the Spiti region of Himachal Pradesh, suggesting thereby that during the Late Cretaceous times there were marine connections in these regions and the Upper Cretaceous sediments were deposited under similar (deep marine) palaeoenvironment.

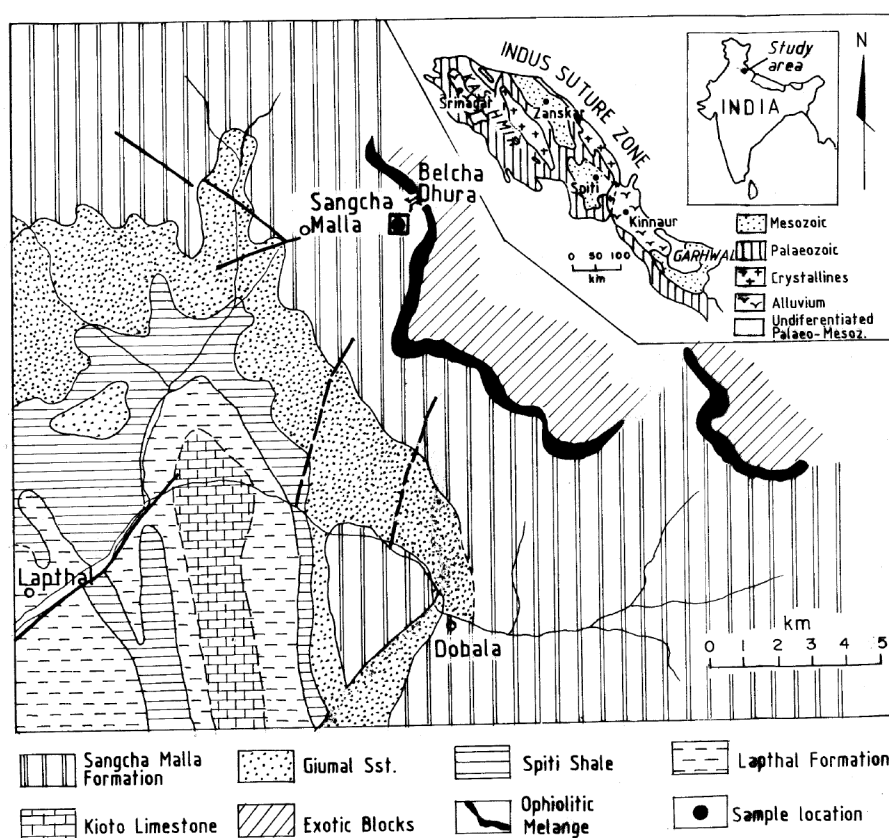
THE fossiliferous sedimentary succession of the remote Malla Johar area in the Kiogad sector of the Garhwal Tethys Himalaya has been studied since early times. Heim and Gansser¹ gave a detailed geological account of the area and differentiated various litho-units. Several other geologists contributed to the geology of the area^{2–6}. The present contribution is based on the field-work carried out by two of the authors (K.P.J. and S.K.P.) in an expedition in the Garhwal Tethys Himalaya organized by the Wadia Institute of Himalayan Geology, Dehra Dun in 1998.

A perusal of the literature reveals that age of the Sangcha Malla Formation of the Garhwal Tethys Himalaya was established mainly on the basis of planktonic foraminifera^{3–5} studied in thin sections of rocks. Planktonic foraminiferal studies based on thin sections without their morphotypes have been questioned by several workers⁷, as the latter provide additional characters such as peripheral keels, ventral and dorsal suture lines, etc. for specific determination. For precise identifica-

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Table 1. Lithostratigraphic framework of the Malla Johar area

Litho-unit	Lithology
Sangcha Malla Formation (>1000 m) (Turonian–Campanian)	Grey shale often gritty Variegated shale Marl with sandstone and red shale Variegated shale Green shale with greywacke
Giumal Sandstone (Late Neocomian–Cenomanian)	Greenish-grey sandstone and sandy shale with thick bands of massive radiolarian chert. Thick-bedded glauconitic sandy shale and sandstone
Spiti Shale (Late Jurassic – Early Neocomian)	Black shale with phosphatic, ferruginous and calcareous concretions (fossiliferous)
Lapthal Formation (Lias)	Dark blue to grey limestone with bands of coquina
Kioto Limestone (Late Triassic)	Grey limestone with <i>Megalodon</i>

**Figure 1.** Location and geological map of the Sangcha Malla area, Garhwal Tethys Himalaya (modified after Sinha⁶).

tion up to the species level, several workers have favoured study of both thin sections of rocks as well as of morphotype specimens⁸ of planktonic foraminifera.

The Sangcha Malla area, lying in the northern part of Chamoli District of Garhwal region, falls in the Tethyan Himalayan zone. The lithostratigraphy of the area is shown in Table 1. Several workers in the past had investigated fauna of the various litho-units exposed in the area. The present paper deals with biostratigraphy of

the Sangcha Malla Formation, which is exposed between Sangcha Malla and Belcha Dhura localities (Figures 1 and 2).

The Sangcha Malla Formation is the youngest litho-unit exposed in the Kiogad segment of the Garhwal Tethys Himalaya. This unit lies conformably over the Giumal Sandstone and the contact between the two units is marked by a variegated red shale horizon. Lithologically, the Sangcha Malla Formation comprises

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sandstone and chocolate reddish shale with intercalated chert bands, greenish-grey shale, marl, greywacke and black silty shale. This unit was named as 'Upper Flysch' by Heim and Gansser¹ and was subsequently named as 'Sangcha Malla Formation' by Shah and Sinha³.

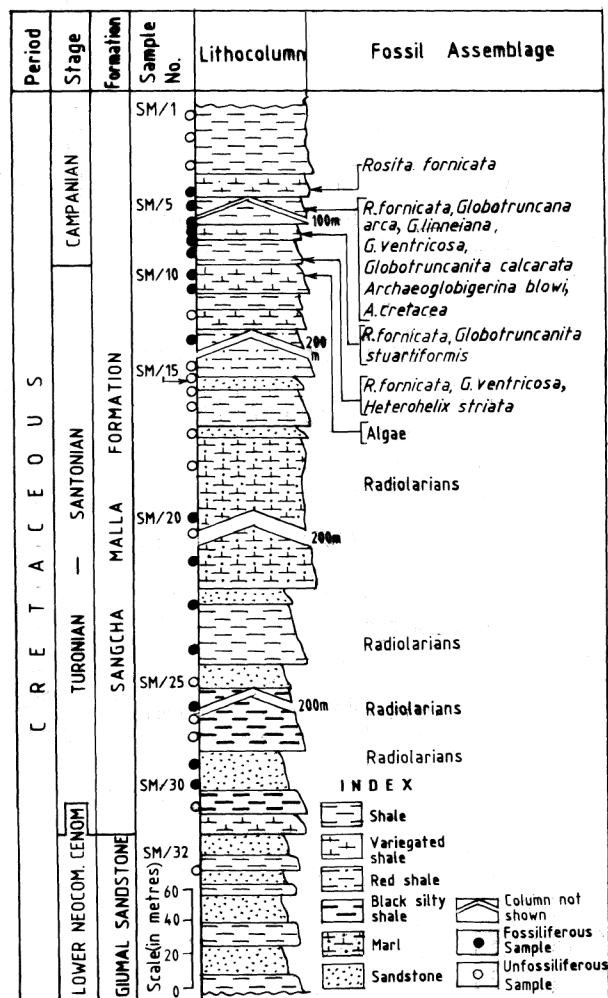


Figure 2. Biostratigraphic column of the Sangcha Malla Formation.

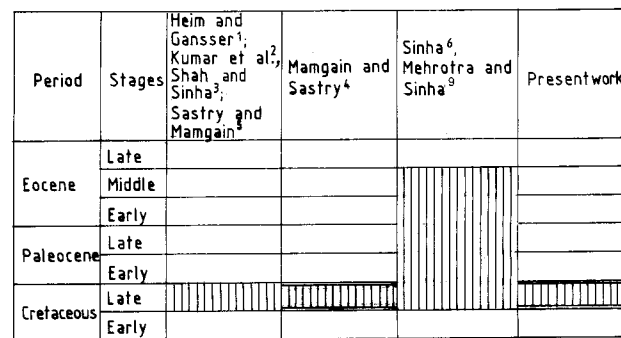


Figure 3. Age of the Sangcha Malla Formation and the earlier age assignments by different workers.

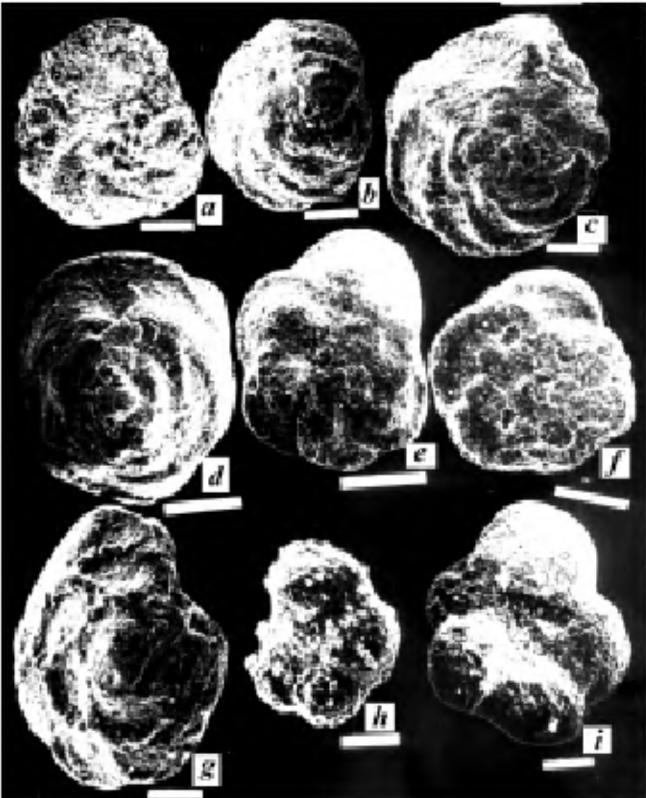


Figure 4. *Globotruncana arca*. a, Ventral view; b, c, Dorsal view; d-f, *Globotruncana linneiana*, dorsal view; g, *Rosita fornicata*, dorsal view; h, *Archaeoglobigerina blowi*, ventral view; and i, *A. cretacea*, ventral view (bar size = 0.1 mm).

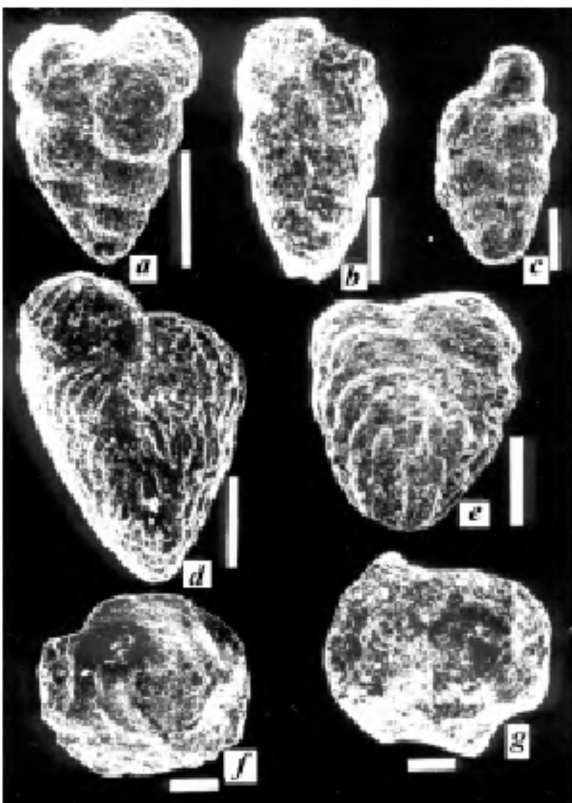


Figure 5. a, *Heterohelix* sp. I. front view; b, c, *H. striata*, front view; d, e, *Pseudotextularia elegans*, front view; f, g, *Globotruncanita calcarata*, dorsal view (f), ventral view (g) (bar size = 0.1 mm).

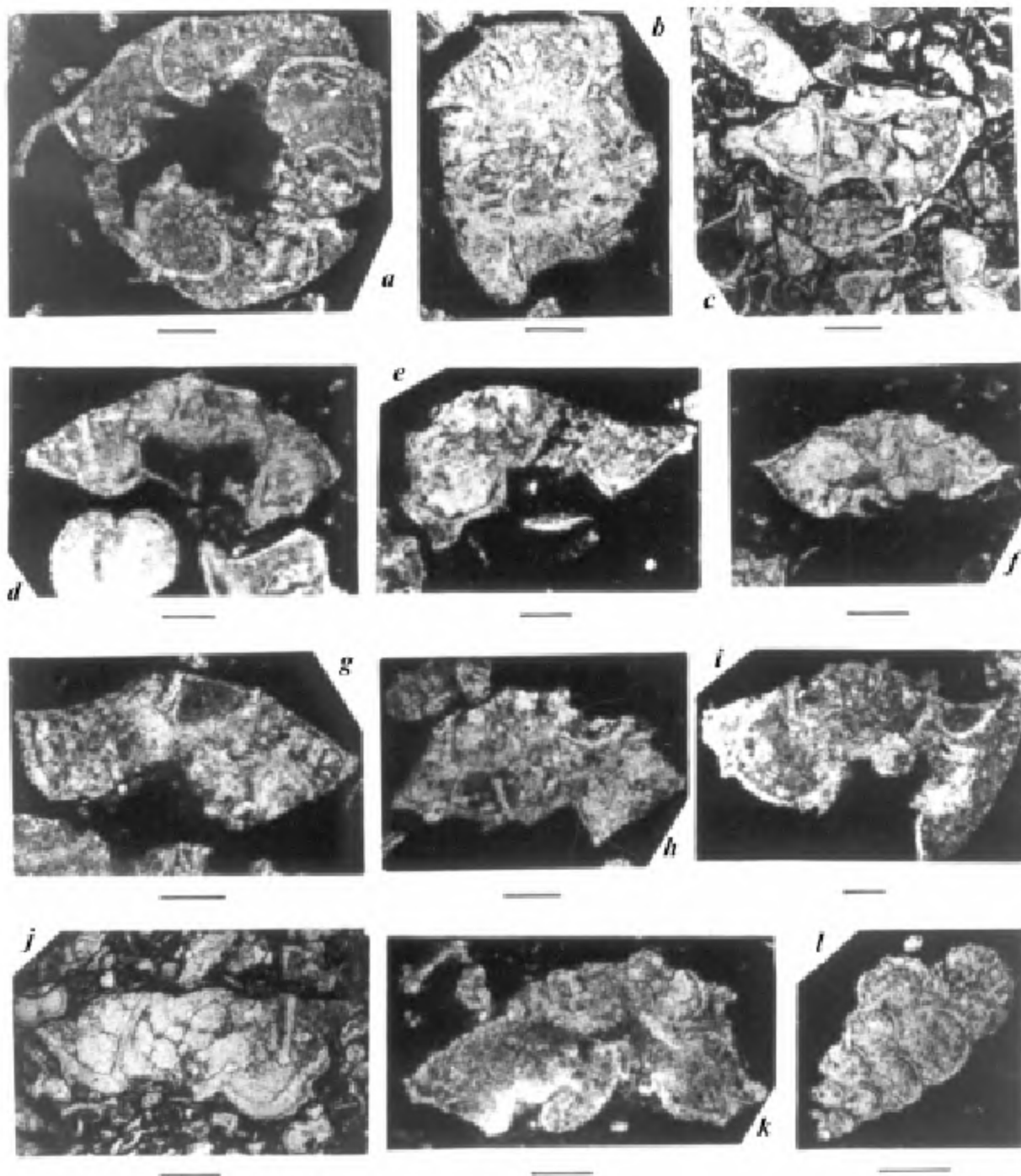


Figure 6. *a–d*, *Globotruncanita calcarata*; *e, k*, *Rosita fornicata*; *f*, *Praeglobotruncana* sp.; *g, h*, *Globotruncanita stuartiformis*; *i*, *G. elevata*; *j*, *Globotruncana ventricosa*; *l*, *Heterohelix* sp. II (bar size = 0.1 mm).

Heim and Gansser¹ recorded small globular radiolarians and Nasellarians and assigned a Late Cretaceous age to this formation. This age assignment was supported by Kalia (fide Shah and Sinha³, p. 19) who recorded *Globotruncana*, *Heterohelix*, *Plummerita*, *Shackoina* and *Eouvigerina* from purple shale occurring in the upper part of this unit. Mamgain and Sastry⁴ carried out palaeontological studies in the Jhangu Gad (a

tributary of Kiogad) section of the Sangcha Malla area, and reported twenty-one taxa of planktonic foraminifera from the upper part of the unit and assigned it an early Maastrichtian age. They also reported five taxa from this section, one metre above the base of their 'Upper Flysch' unit and assigned a Late Cenomanian age to the lower part of the unit. During biostratigraphic studies in this area, Sastry and Mamgain⁵ assigned a Late Creta-

ceous age to this unit based on the occurrence of *Globotruncana* spp. and *Heterohelix* spp. Later on, Mehrotra and Sinha⁹ and Sinha⁶ recorded several taxa of palynomorphs from the Sangcha Malla Formation and assigned it a Late Cretaceous to Middle Eocene age. However, Jain and Garg¹⁰ questioned their identifications. The age assigned by different workers is shown in Figure 3. Recently, Juyal and Parcha¹¹ illustrated the morphotypes of foraminifera from this unit.

In this communication, we place on record the presence of several morphotype planktonic foraminiferal taxa from the Sangcha Malla Formation of the Garhwal Tethys Himalaya. The present identifications are based on well-preserved complete specimens from this unit, which give additional features for their comparison and detailed studies for a precise age assignment.

Thin sections of rocks from lower and middle parts of the Sangcha Malla Formation have revealed the presence of radiolarians. Due to their poor preservation, no precise age could be assigned to these parts of the unit. However, lower age limit of this unit may be assigned on stratigraphic grounds, as it overlies the Giumal Sandstone without any apparent sedimentological gap. The Giumal Sandstone has been assigned a late Neocomian–Cenomanian age. Therefore lower and middle parts of the Sangcha Malla Formation are considered to have been deposited during Turonian–Santonian interval. Samples from the upper part (Figure 2) yielded prolific foraminiferal fauna, indicative of Late Cretaceous age. Well-preserved material enabled us to identify eleven foraminiferal species, namely *Archaeoglobigerina blowi* Pessagno, *A. cretacea* (d'Orbigny), *Rosita fornicata* (Plummer), *Globotruncana arca* (Cushman), *G. linneiana* (d'Orbigny), *G. ventricosa* White, *Globotruncana calcarata* (Cushman), *G. elevata* (Brotzen), *G. stuartiformis* (Delbeiz), *Heterohelix striata* (Ehrenberg), and *Pseudotextularia elegans* (Rzehak) (Figures 4–6).

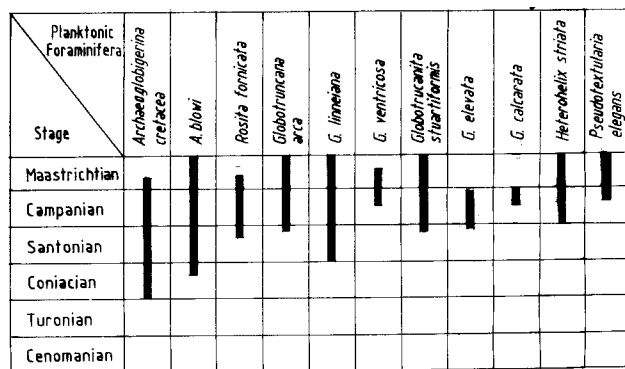


Figure 7. Stratigraphic ranges of planktonic foraminifera occurring in the Sangcha Malla Formation of Garhwal Tethys Himalaya, Malla Johar area (ranges of taxa are after Caron¹²).

Stratigraphic distribution of the planktonic foraminifera occurring in the Sangcha Malla area is arranged according to their stratigraphic ranges based on the work of Caron¹² (Figure 7). As seen in Figure 7, most of the taxa in the upper part of the Sangcha Malla Formation range in age from Campanian to Maastrichtian. However, *G. calcarata* is a zonal planktonic foraminiferal species, which is restricted to upper Campanian sediments elsewhere. It is, therefore, interpreted that the sediments in the upper part of this unit were deposited during the Campanian times supporting thereby the age assigned to this unit by Mamgain and Sastry⁴.

The planktonic foraminiferal taxa recovered during the present biostratigraphic investigations from the Garhwal region are also recorded by earlier workers from the Zaskar and Spiti regions. Nine taxa recorded from the Zaskar region^{13,14} have also been recovered herein from the Garhwal region, which include *A. cretacea*, *R. fornicata*, *G. arca*, *G. linneiana*, *G. ventricosa*, *G. calcarata*, *G. stuartiformis*, *H. striata*, and *P. elegans*. Four species, namely *G. linneiana*, *G. calcarata*, *G. stuartiformis* and *P. elegans*, recorded from the Chikkim Formation of the Spiti region by Mamgain and Sastry⁴, are also common to the Sangcha Malla Formation of the Garhwal Tethys Himalaya. Thus the fauna shows close similarity in these regions.

Palaeontological data from the Sangcha Malla Formation of Garhwal Tethys Himalaya are of great importance, as this region lies at the northern margin of the Indian plate. Foraminiferal taxa recorded herein from the Sangcha Malla area and those recorded by earlier workers from Spiti and Zaskar, which lie adjacent to the Sangcha Malla area, are comparable. Most of these taxa are common to these regions. This shows that during the Late Cretaceous times, all these regions were well connected under sea waters of at least 80–120 m paleobathymetry or more.

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