First Late Triassic nannofossil record from the Neo-Tethyan sediments of the Indus–Tsangpo Suture Zone, Ladakh Himalaya, India

In northern India, the Ladakh block lies along a critical geological juncture and is characterized by two suture zones – the Indus and Shyok (Figure 1) – that mark the closing of different branches of the Tethys Ocean and finally the collision of India with Asia, 60–50 Ma. The Indus–Tsangpo Suture Zone has been recognized as one among the best examples of suture zones. It lies between the Palaeozoic–Palaeogene Zanskar platform sediments of the Indian passive margin in the south and the Karakoram block in the north[1–3]. All along its length, the suture is represented by obducted materials of the Neo-Tethyan oceanic crust, together with marine Triassic to Eocene sediments. The complex thus includes turbidites, ophiolitic melanges with seamounts, calc-alkaline volcanics, granitic batholith and post-orogenic molasse sedimentary deposits[4–10]. The detailed geological structure of the Indus–Tsangpo Suture Zone has been discussed elsewhere.

Apart from other rock formations, the syn-post-rift Triassic–Eocene, slope to deep marine Neo-Tethyan sediments of the Lamayuru Complex have been deposited on the leading passive edge of the Indian subcontinent[11–14]. The NW–SE trending sediments are tectonically caught between the overridden or backthrusted Mesozoic Zanskar platform sediments in the south and the Jurassic–Cretaceous Ophiolitic Melange Zone of the active margin of the Indus Suture in the north (Figure 2 *a* and *b*). The Lamayuru Complex comprises calcareous turbiditic sandstones, siltstones, carbonaceous and calcareous shales, slates and limestones; sandstones and thin intercalations of grey pelagic limestones predominate at some levels. Shelf, fore-reef and basin margin (slope) olistoliths (exotic blocks of limestone) of Permian–Jurassic age are also tectonically juxtaposed within the Lamayuru Complex[11,14] (Figures 2 *a* and 3).

The Late Triassic calcareous nannofossil record from the Lamayuru Complex, exposed along the Indus–Tsangpo Suture Zone in Ladakh, is being reported in the present study. This Late Triassic nannofossil-bearing horizon is exposed along the Srinagar–Leh National Highway and located around ~500 m northwest of the Lamayuru Monastery (Figures 2 *a* and 4). The thinly-bedded, fine-grained, grey and buff to dirty yellow-coloured calcareous shale has also yielded abundant Triassic bivalve *Daonella indica*[13,14]. Similar *Daonella*-bearing outcrops from the Lamayuru Complex have earlier been reported by Fuchs[4] and Shah[6]. The presently recorded *Daonella*-bearing calcareous shale samples were processed and studied for nannofossil assemblage by one of the authors (J.R.) and field work, interpretation and presentation of results by another (R.U.). Detailed examination revealed the presence of a number of calcareous nannofossils.

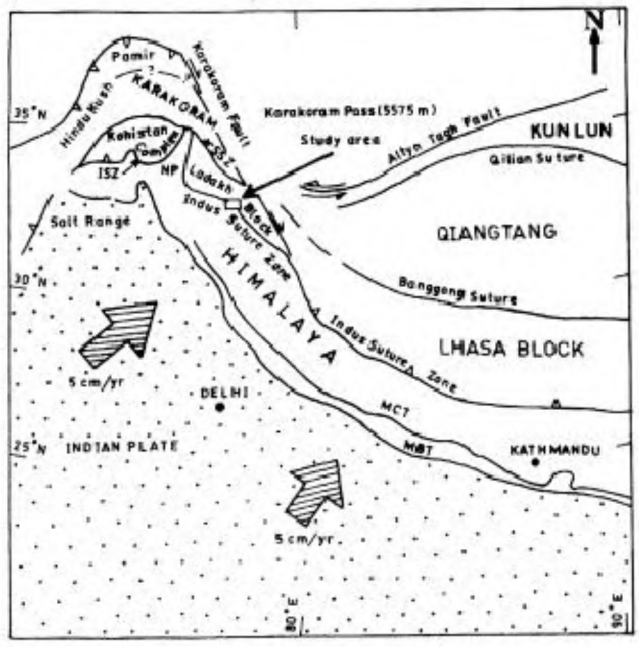

Figure 1. Simplified tectonic sketch map of Himalaya and Central Asia (modified after Searle[7] and Upadhyay[26]). ISZ, Indus Suture Zone; MBT, Main Boundary Thrust; MCT, Main Central Thrust; NP, Nanga Parbat–Haramosh syntaxis; SSZ, Shyok Suture Zone. Not to scale.

The presently recorded calcareous nannofossil assemblage is fairly well-preserved, diverse and represented by the occurrence of *Archaeozygodiscus kossensis*, *Crucirhabdus minutus*, *Hayococcus floralis*, *Obliquipithonella* sp., *Orthopithonella geometrica*, *O. misurinae*, *Prinsiosphaera triassica*, *Tetralithus cassianus*, Gen *et* sp. indet. 1, Gen *et* sp. indet. 2 (Figure 5) and a variety of calcispheres, broken tests of calcareous dinoflagellates and few unidentified forms. The assemblage is indicative of Norian–Rhaetian age (~220–203 Ma), which is equivalent to NT2 *P. triassica* zone recorded by Bralower *et al.*[15] from the Wombat Plateau, NW Australia (ODP Leg 122).

More than three decades of intensive deep-sea drilling activity through the Deep Sea Drilling Project, now the Ocean Drilling Programme, brought the stratigraphic value of calcareous nannofossils to the attention of industry as well as the scientific community[16]. First recorded occurrences of calcareous nannofossils are from the Late Triassic[15–20]. However, all over the world the Triassic nannofossil records are limited. These are typically of low diversity and seem to be restricted in Late Triassic low palaeolatitudinal areas[15,16]. One consequence of the first occurrence of calcareous nannofossils in the Late Triassic lies in the fact that this was the first time open ocean

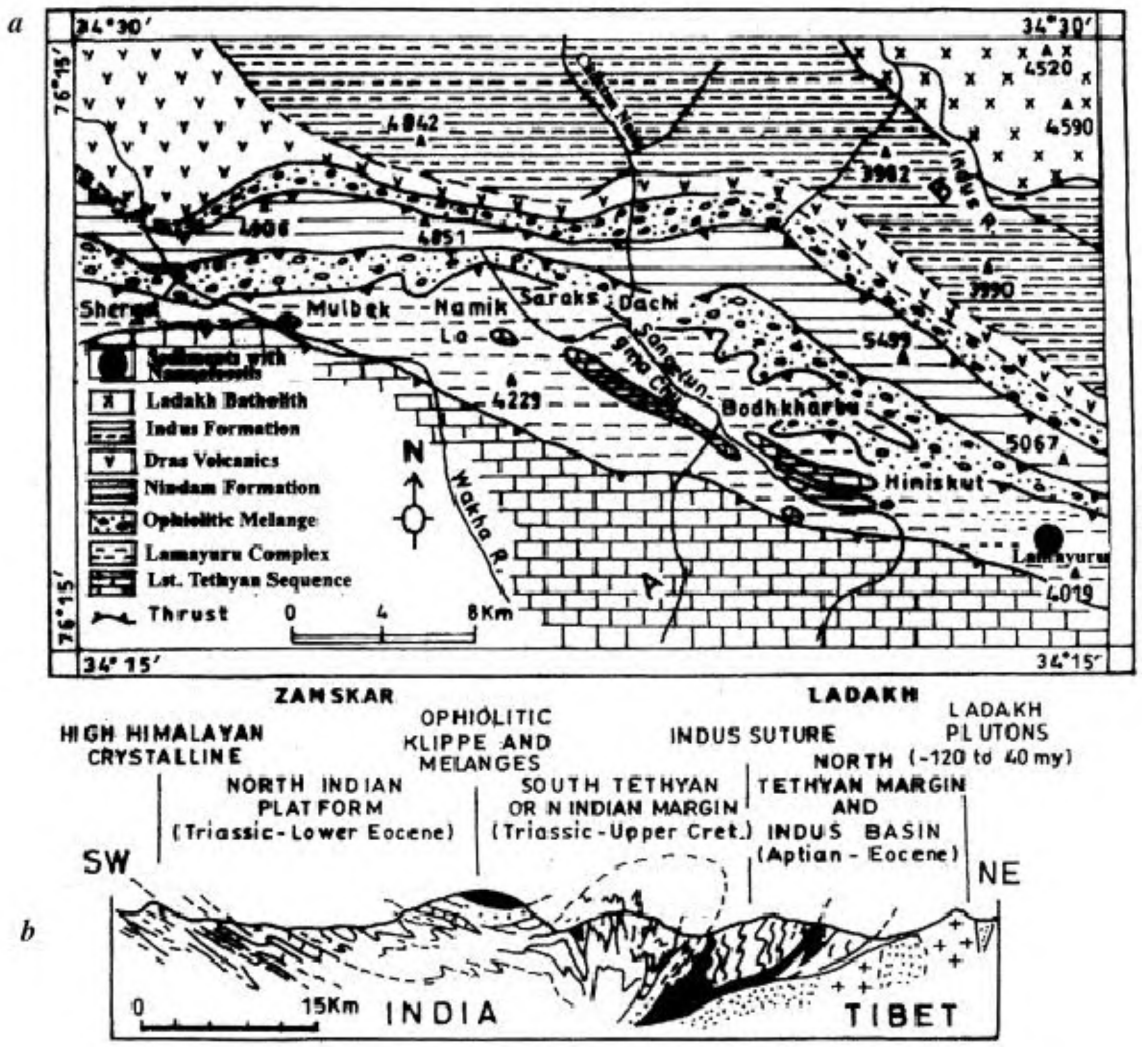

Figure 2 *a*. Geological map of the area between Shergol and Lamayuru, western Ladakh Himalaya, India (modified after Sinha and Upadhyay[13]) showing the location of the *Daonella indica*-bearing calcareous shale which has yielded Late Triassic nannofossils. Locality: ~500 m NW of the Lamayuru Monastery on the Srinagar–Leh National Highway. ***b***, Cross-section showing tectonic relation of the Zanskar platform sediments to those of the Indus Suture Zone (modified after Colchen[27]).

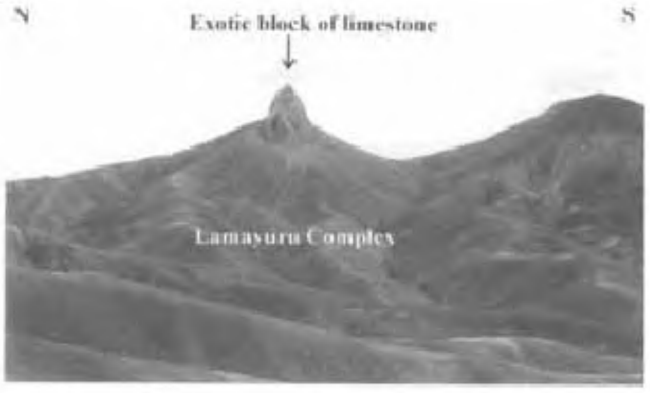

Figure 3. Field photograph showing the presence of exotic block of limestone (olistolith) within the Lamayuru Complex as seen near the Namik La (Photo by R.U.).

Figure 4. Field photograph showing the village of Lamayuru, the Lamayuru Monastery and the rocks of the Lamayuru Complex (Photo by R.U.).

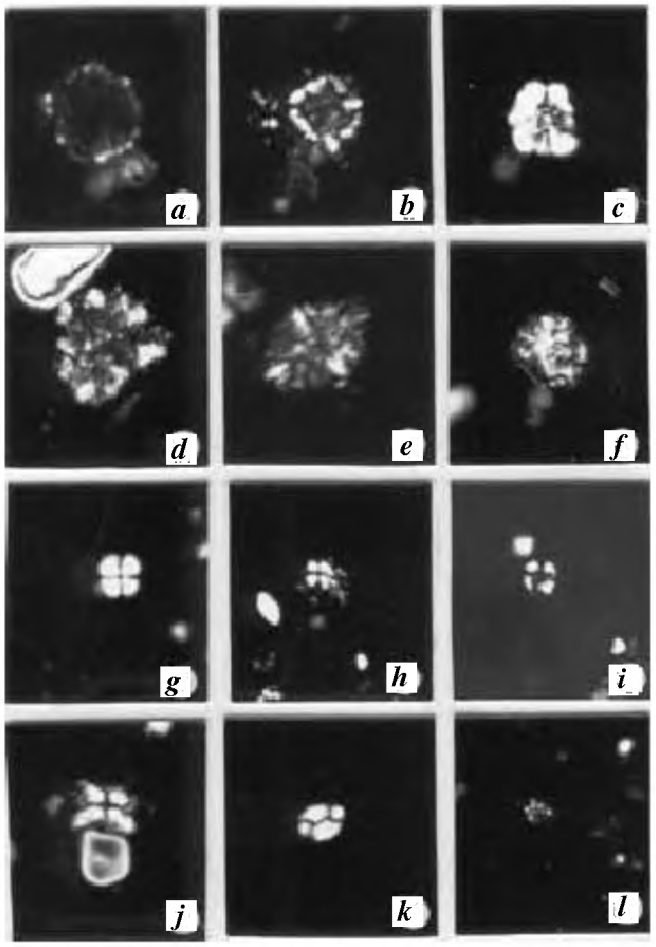

Figure 5. Late Triassic (Norian–Rhaetian, ~220–203 Ma) nannofossils (all photographs are enlarged × 2000). ***a***, ***b***, *Orthopithonella misurinae*; ***c***,. *Obliquipithonella* sp.; ***d***, *Prinsiosphaera triassica*; ***e***, Gen *et* sp. indet 1; ***f***, *Prinsiosphaera triassica*; ***g***, *Hayococcus floralis*; ***h***, *Tetralithus cassianus*; ***i***, ***j***, *Hayococcus floralis*; ***k***, Gen *et* sp. indet 2; and ***l***, *Crucirhabdus minutus.*

planktonic organisms utilized calcareous skeletons and exported calcium carbonate into the deep oceans[16].

Prior to our find, the record of Late Triassic nannofossil assemblages has so far been exclusively reported from Calcareous Alps of Austria and Germany[17–21], the Mediterranean region[22], NW Australian continental shelf of Wombat Plateau[15,16]. This indicates that Late Triassic nannofossils had a wide distribution throughout early Neo-Tethys[15]. The Late Triassic nannofossil assemblage of the Lamayuru Complex is also similar to that observed in the Wombat Plateau. It is worth mentioning here that the Indian plate was part of Pangea and also connected with the East Gondwana continent till it drifted from Africa–Madagascar during the Jurassic[8,23–25]. Therefore, it is quite likely that the Late Triassic nannofossil-bearing sediments of the Lamayuru Complex, deposited on the northern margin of the Indian plate during Triassic, were situated in the vicinity of Wombat Plateau (NW Australia) depositional area, and are the remnants of those recorded from the Neo-Tethyan sediments elsewhere. The presently acquired data may assist future discoveries and be able to improve geological information and their correlations on a large scale to further unravel and refine ideas related to palaeogeography, palaeoclimatology and palaeooceanography of the Tethyan realm *vis-à-vis* processes of rifting and drifting during the Triassic–Jurassic Period.

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MEETINGS/SYMPOSIA/SEMINARS

International Workshop on the Indian Monsoon and Climate Variability during Holocene

Date: 17–18 May 2004
Place: Bangalore

Themes include: How and why did the Holocene climate vary on different time scales? How well do properly dated marine and continental records match? Are there new instrumental and historical data for the Indian monsoon? Are there new paleoclimate proxies? etc.

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International Conference on Health, Occupation and Environment

Date: 1–3 November 2004
Place: Lucknow

Objectives include: Current status/scenario of occupational health in India particularly in unorganized sector; Assessment of occupational health risks in unorganized sector; Targeting of work places and assessment of occupational health risks in workers and children; Creating a better, brighter, safer and healthier environment for industries.

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