the part of the Patkai–Manipur–Lushai hills, one of the 25 microcentres of endemism2. The Lushai hills rise to a mean elevation of 1200 m in the west and 1600 m in the east, and in places even up to 2400 m (Mt. Phawngpu or Blue Mountains). The flora of this region mainly constitutes the Indo-Myanmar elements.

The genus Rhynchanthus occurs in these phytogeographical provinces and extends up to South China. Another closely allied monotypic genus, Stadiochilus R.M. S. also occurs in the Indo-Myanmar mountain systems. These two genera are remarkably alike in general facies3. The unique microhabitat specificity of R. longiflorus may be one of the reasons for restriction of this taxon to the Lushai hills.

Proper and adequate information regarding the taxon is essential for the conservation and preservation of the species. This may be the main reason why this species is not listed in the IUCN red list category, Red Data Book of Indian flowering plants and the scheduled category of plants in the Indian Wild Life Protection Act 1972. The major threat to R. longiflorus is habitat loss due to anthropogenic intervention. In Mizoram, people practice a primitive method of shifting cultivation called ‘humming’ cultivation, where all the virgin forests are cut down, burnt and the land is used for rice cultivation for two or three years. Thus a major portion of the evergreen forest of Mizoram has vanished and has been transformed into a secondary forest, especially bamboo brakes of Melocanna baccifera Kurz. and grasslands of Saccharum arundinaceum Hook. f. This poses a major threat to the existence of the taxon. Deforestation in this area also brings in a natural catastrophe; the landslides that wipe out the remnants of the fragmented patches of evergreen forest. This species survives in some of the islands of fragmented forests of Saireiplang and Kolasib. The population of this taxon in these areas is not viable, because the population size is insufficient for the successful existence of a species according to the conservation rules. The narrow distributional range, microhabitat specificity, nonviable population, etc. are bringing this species closer to extinction. Our efforts to introduce this species into the Calicut University Botanical Garden were not successful due to the drastic difference in bio-climatic conditions. Both in situ and ex situ conservation strategy should be adopted to save this remarkable species from the verge of extinction. Any natural disaster like landslides, diseases, pest attack, etc. may eventually wipe out the remaining populations of this species.


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First record of Middle–Late Jurassic polyomorphs from the Lamayuru Complex, Indus Suture Zone, Ladakh, India

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We report here Middle–Late Jurassic polyomorphs bearing sediments from the Lamayuru Complex, exposed along the Indus-Tsangpo Suture Zone in Ladakh. Apart from addition of new data towards understanding the geodynamics of the India-Asia collision zone, this will be helpful in understanding the formation of the slope-deep marine passive margin turbidites basin along the Indus Suture Zone, its palaeogeography and the processes of sedimentation and tectonics during subduction of the Indian plate beneath the Asian plate. The presently recorded Middle–Late Jurassic polyomorphs from the Lamayuru Complex also help to further strengthen our viewpoint that the Permian and Mesozoic polyomorphs bearing sediments were reworked from the Zanskar–Lamayuru Complex Tethyan realm and transported through the Lamayuru Complex to the Nindam basin during ongoing geodynamic processes operative within the India-Asia trench-forearc subduction complex between Cretaceous–Palaeocene time span.

In northern India, the Ladakh block lies between the Indian plate in the south and the Asian plate in the north. To the west, the Ladakh block is largely separated from the Kohistan Complex by the Nanga Parbat–Haramosh syntaxes and to the east it is cut off from the Lhasa block by the Kar—

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koram Fault (Figure 1). Most workers interpreted the Ladakh block and Kohistan Complex as a single accreted island arc terrane. The Ladakh block is delineated by two suture zones – the Indus Suture in the south and the Shyok Suture to the north. These sutures mark the closing of different branches of the Tethys Ocean and finally the collision of India with Asia at 60–50 Ma. The more northerly Shyok Suture (Figure 1) separates Ladakh from Asian continental rocks of the Karakoram mountains to the north and contains ophiolitic mélanges, rifted back-arc basin detritus and thrusting components of the southern Asian margin that were juxtaposed as Kohistan/Ladakh collided with Asia at 102–85 Ma. To the south, the Indus Suture is tectonically juxtaposed against slope-to-deep marine sedimentary rocks of the Lamayuru–Karamba Complex, interpreted to be the deep-marine passive margin of the Indian plate (Figures 1–3). Farther south, the Lamayuru Complex is separated by a south-dipping post-emplacement regional backthrust from the platform carbonates of the Zanskar region (Figures 1b and 2). All along its length, the Indus Suture is represented by obducted remnants of the Neo-Tethyan oceanic crust. The complex sequence of rocks that occur along the Indus Suture includes turbidites, ophiolitic mélanges with basalts interpreted as accreted seamounts, calc-alkaline volcanics, a granite batholith and post-orogenic molasse sedimentary deposits (Figures 1b, 2). Some representative rock formations along the Indus Suture in Ladakh are named as the Lamayuru Complex, Ophiolitic Melange, Nindam Formation, Dras Volcanics, Indus Formation and Ladakh Batholith.

Apart from other rock formations, the syn-post-rift Triassic–Eocene sediments, slope-to-deep marine ocean basin and fine-grained turbidites of the Lamayuru Complex (Figures 1b, 2–4) were deposited on the leading passive edge of the Indian subcontinent (R. Upadhyay, unpublished). The NW–SE trending rocks are tectonically intercalated between
the back-thrusting 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 (Figures 1b and 4). Shelf, fore-reef and basin margin (slope) olistoliths (exotic blocks of limestone) of Permian–Jurassic age are tectonically juxtaposed within the Lamayuru Complex. The long time span is shown by in situ Middle Triassic bivalve Donella indica, Late Triassic nannofossils, Jurassic (Hettangian) Psiloceras ammonoid and Late Cretaceous to Early Eocene foraminiferal remains.

Here we report the first record of Middle–Late Jurassic palynomorph-bearing sediments from the Lamayuru Complex, exposed along the Indus–Tsangpo Suture Zone in Ladakh. Apart from addition of new data towards understanding the geodynamics of the India–Asia collision zone, this discovery will also be helpful in understanding the formation of the slope–deep marine passive margin turbidites basin along the Indus Suture Zone, its palaeogeography and the processes of sedimentation and tectonics during subduction of the Indian plate beneath the Asian plate. This Middle–Late Jurassic palynomorph-bearing sedimentary succession is exposed ~300–400 m NW of the Kharang village, i.e. on a ridge situated on the left side of the Kharang–Chiktan road section (Figures 1b, c and 3). The thinly-bedded, fine-grained, grey and buff to dirty yellowish-coloured calcareous shale has also yielded Hettangian (Early Jurassic) ammonoid Psiloceras. The presently recorded samples of thinly-medium-bedded, fine-grained silticlastics of the Lamayuru Complex are lying a few meters (~5–10 m) above the Hettangian horizon (Figure 4). The collected samples were processed and studied to attempt and examine the presence of palynological assemblage. Interestingly, a detailed examination revealed the presence of a number of palynomorphs (Figure 5).

The samples were macerated in hydrofluoric acid 40%, followed by commercial HNO₃ and washed in 2–5% KOH solution. The macerates were passed through 150 and 400-mesh sieves to get the final residues. Finally the residues were mixed with polyvinyl alcohol solution, spread on slides and mounted in Canada balsam. The samples and slides are deposited at the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Eight samples were macerated out of which four have yielded palynomorphs. The samples are poor in spores and pollen grains. The assemblage comprises 13 genera and 12 identifiable species (Figure 5). These are Aquitriniradiates sp., Araucariaeites australis, Alispites grandis, Callialaspis trilobata, C. dampieri, C. turbata, Coptospora sp., Cyathidites australis, Dictyophylldites sp., Impardesipora apiverrucata, Murospora florida, Microcachryiditesantarcticus, Perinopollenites elatoides, Podocarpidites grandis, Podosporites tripakshi and Podosporites sp. and few phytoplanktons.

Some reworked Permian palynomorphs were also recorded in the assemblage. These are Crescentipollenites, Striattites, Striatopodocarpites, Scheuringipollenites Vercipollenites and Virkhipollenites.

The triletes are represented by 5 genera and 3 identifiable species, hilaletes by 1 genus, monosaccates by 3 genera and 5 species, bisaccates by 2 genera and 2 species and trisaccates by 2 genera and 2 species. The assemblage is dominated by monosaccates (61%) and followed by nonstriate bisaccates (28%). Trisaccates contribute 5%, triletes 3%, phytoplanktons 2% and hilaletes 1% to the assemblage. C. dampieri is the most common species (61%), followed by P. grandis (21%). Other counted species are A. grandis (7%), M. antarcticus (3%), M. florida (3%), P. tripakshi (2%), Coptospora (1%) and phytoplanktons (2%).

Jurassic palynomorph-bearing sediments are not well exposed in India except in Kutch, Kumaon, Rajasthani, Vemavaram, Durgapur and Rajmahal. In Kutch, Gu-
Figure 3. Panoramic view and tectonic juxtaposition of the Lamayuru Complex across a S–N cross-section of the Indus Suture, as seen from a ridge situated near the Khangral village in Ladakh. Note location of the Middle–Late Jurassic palynomorph-bearing Lamayuru Complex near the Khangral village.

Figure 4. Schematic tectonostratigraphic column of Lamayuru Complex (modified after Upadhyay, unpublished).

The Jurassic sediments have a considerable thickness. In Australia, on the other hand, the Jurassic sediments are extensive and have wide geographical distribution. Different palynostratigraphic zones were established in Australia, which range from Hettangian to Albian besides some younger horizons. Helby et al. divided Hettangian to Albian sediments into two palynostratigraphic superzones: the lower Calhialasporites dampieri Superzone (Hettan-
gian–Kimmeridgian) and upper *Microcachrydites* Superzone (Tithonian–Albian). The former is again subdivided into *Corollina torosa* Zone, *Callialasporites turbatus* Zone, *Dictyosporites* complex Zone, *Contignisporites cooksoniae* Zone and *Murospora florida* Zone.

The *Murospora florida* Zone of Middle Callovian to Kimmeridgian age has a close similarity with the presently recorded palynomorphs in our samples, belonging to the Lamayuru Complex. Our palynomorph assemblage is dominated by *C. dampieri* along with the presence of *A. australis, M. antarcticus, M. florida* and *P. grandis*. On that basis, a Middle Callovian to Kimmeridgian (Middle–Late Jurassic) age is assigned to the presently recorded palynomorph assemblage of the Lamayuru Complex. This age assignment is logical in the sense that the Hettangian (Early Jurassic) ammonoid-bearing horizon has already es-
tablished a few metres below the presently recorded Middle–Late Jurassic polynomorph-bearing, fine-grained siliciclastic sediments of the Lamayuru Complex. Although it is known that the Neotethyan sediments of the Lamayuru Complex span between Triassic and Eocene, it is for the first time that the Middle to Late Jurassic polynomorph-bearing sedimentary sequences are encountered within the Lamayuru Complex.

Interestingly, Upadhyay and co-workers recently also recorded Permian, Mesozoic and Palaeozoic polynomorphs from the Nindam forearc basin, exposed along the Indus Suture Zone in Ladakh. According to them, the Palaeozoic polynomorphs and sediments were transported to the Nindam trough from nearby elevated landward regions (islands). These Palaeozoic provenance areas were characterized by an estuarine, near-shore, tropical, warm-humid environment and were situated at equatorial palaeolatitudes. However, the occurrence of Permian and Mesozoic polynomorphs in the assemblage indicates that the Late Palaeozoic and Mesozoic Tethyan sedimentary rocks exposed along the northern margin of the Indian plate were redeposited onto the tectonically active Cretaceous–Palaeocene trench–subduction complex that existed between the Indian and the Asian plates until the collision took place at ~50–60 Ma.

Logically, apart from diverse implications towards understanding the palaeogeography, litho-tectonostratigraphy of the Lamayuru Complex and the India–Asia subduction and subsequent collision processes, the presently recorded Middle–Late Jurassic polynomorphs from the Lamayuru Complex also help to further strengthen our viewpoint that the Permian and Mesozoic polynomorph-bearing sediments were reworked from the Zanskar–Lamayuru Complex Tethyan realm and transported through the Lamayuru Complex to the Nindam basin during ongoing geodynamic processes operative within the India–Asia trench–forearc subduction complex between the Cretaceous–Palaeocene time span. The presently acquired data may assist future discoveries and be able to further modify the present state of knowledge and evolution of the Indus Suture Zone vis-à-vis India–Asia collision in Ladakh.

Natural analogue study of Resubelpara Group of thermal springs at Garo Hills, Meghalaya for demonstration of safe geological disposal of nuclear waste

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A group of thermal springs (with temperatures up to 50°C) occurring around Resubelpara locality near Sarangkhol, East Garo Hills district, Meghalaya has been studied to elucidate the geological analogy of various geochemical, thermal and geological features around them with those expected around disposed nuclear waste over packs in granitic rocks in the depth range of 400–500 m in a geological repository. Discrete uraninite occurring in granites and high radon content have been considered to be analogous with a part of radioactive waste. High mobility of uranium is noticed under combinations of favourable groundwater chemistry (high concentration of carbonates and phosphates) and potential geological pathways. It is found that hot groundwater in granites is capable of transporting uranium into the biosphere when provided with suitable structural conduits like deep-seated faults. While in the areas of granites devoid of potential pathways, no significant transport of uranium is observed, the study demonstrates the capability of good host rock coupled with suitable geological set-up in providing long-term safe disposal of nuclear wastes. This is also an attempt to use natural analogue in India to demonstrate safety of nuclear waste disposal.

The feasibility of permanent disposal of nuclear waste in repositories located in deep geological formations is being studied worldwide. The most credible release pathway for radionuclides is interaction between nuclear waste forms and groundwater followed by hydrologic or vapour transport to the accessible environment. Active geothermal systems and low-grade metamorphic rocks have provided insights into how physico-chemical parameters control rates of processes operating at nuclear waste–water–rock interfaces. The relative effects of temperature, pressure, water chemistry, material composition and duration can be systematically established from natural analogues. These also provide a test bed to assess long-term effects, which are otherwise impossible to generate in a laboratory-based simulation. Extrapolation of results of short-term laboratory experiments on nuclear waste disposal to long-term environmental conditions within the repository is not possible, because no direct validation of these extrapolations is accessible. However, thermal springs with suitable geological set-up form a natural analogue, constituting an indirect mean to build a model useful for such extrapolations. Uraninite mineral (UO₂) is considered as a good analogue of spent fuel. The major differences between uraninite and nuclear waste are intense radiation effects in the former and the presence of high amount of fission products in the latter. Uranium mineralization in Francrboville sandstones at Oklo, Republic of Gabon as well as Cigar Lake, Canada has been extensively used to demonstrate safety of geological disposal.

Geologically, the Meghalaya plateau is an extension of the main peninsular shield separated by NS trending Jamuna fault. The western part of the plateau constitutes the Garo Hills, and is chiefly made up of Proterozoic metasediments, older gneisses and migmatites intruded by granites. The study area is located on the easternmost fringe of the East Garo Hills and exposes mainly grey medium-grained biotite granites and augen gneisses of the Archaean Gneissic Complex (Figure 1). Late stage, coarse-grained grey granites and pegmatites intrude these (A. N. Basu and T. P. S. Rawat, unpublished report). The granites around Sarangkhol are known to contain anomalous uranium (up to 0.02% U₃O₈), mainly due to the presence of the