

Earliest record of slime moulds (Myxomycetes) from the Deccan Intertrappean beds (Maastrichtian), Padwar, India

Myxomycetaceous fossil spores are reported from the Deccan Intertrappeans beds near the village Padwar in Jabalpur District, Madhya Pradesh, India. These remains are found in association with index spore-pollen taxa of Maastrichtian age (~70 to 65 million years) and are the oldest records of fossil Myxomycetes.

The Myxomycetes, though formerly placed under the fungi (Myxomycota), are no longer considered part of this group. These are now placed under Mycetozoa group of the Amoebozoa, which include the following three groups: Myxomycetes (plasmodial slime moulds), Dictyosteliida (cellular slime moulds) and Protostelids. However, their classification is still debatable and workers are trying to resolve the relationships among these three groups. Nonetheless, credit goes to mycologists who studied these inconspicuous entities to reveal their bizarre life cycles comprising three types of uninucleate cells, a multinucleate somatic phase, a resting stage and finally a reproductive phase^{1–6}. They occur in a wide variety of colours; have a phagotrophic mode of nutrition and feed on bacteria and fungi that live upon dead plant material; and have a motile habit with flagella in at least some stages of their life cycles^{7–11}. Slime mould (or mold) is a general term which refers to part of some of these organisms life cycles where they appear as gelatinous slime. This is most commonly observed with the Myxomycetes, which are the only macroscopic slime moulds.

The Myxomycetes are ubiquitous in distribution and can grow in any possible habitats – the temperate and the tropical forests, the Arctic and Antarctic regions and the desolate deserts. Most slime moulds are smaller than a few centimetres, but some species may reach sizes of up to several square metres. The extant Myxomycetes were reported from India around 1830 by Wight¹² and thereafter, studied by a number of workers^{13–21}. However, being soft and gelatinous they are rarely preserved as fossils. The fossil records of Myxomycetes are extremely rare and include fruiting bodies, sporocarp, few spores and swarm cells in sexual conjugation^{22–26}. So far the oldest unambiguous record of fossil Myxomy-

cetes is from Eocene Baltic amber (35–40 million years ago) from where species of *Stemonites*²³ and *Arcyria* have been described²⁴. Other older records include fossil of a Myxomycete plasmodium in amber from the Eocene–Oligocene (25–35 Ma) deposits in the Dominican Republic²⁷ and fossil spores from the Oligocene (23–33 Ma) and Pleistocene (2.6–0.01 Ma)²⁵. Earlier, swarm cells of slime moulds were reported from the Deccan Intertrappean beds of Padwar, India²⁶. Now the recovery of Myxomycetes spores from the same beds is indeed unique, as these are the oldest records of Myxomycetes hitherto known and has pushed the antiquity of Myxomycetes by 25–30 million years.

The Deccan Traps, one of the largest continental basalt provinces in the world, cover an area of ~500,000 sq. km, occupying western, central and southern parts of the Indian peninsula. In the recent past, extensive radiometric dating of the traps has provided an age constraint of 67–64 million years (Ma) for the duration of trap activity, with a broad consensus that the major volcanic episode was for a short duration (~1 Ma) centered around 65 Ma. Rapid eruption (~2 sq. km/yr) and wide distribution (~2 km thick pile covering an area of ~500,000 sq. km) of lava flows reflect the magnitude of the catastrophic event. This volcanic eruption gets an additional importance as it occurred at the juncture of the Cretaceous–Tertiary transition^{28–33}. The Deccan volcanism has also been linked with the mass extinction at the Cretaceous–Palaeogene boundary³⁴.

Thin sedimentary beds (=intertrappeans) sandwiched between the volcanic flows were deposited during the quiescence phases of volcanic activity, in the shallow lakes and water bodies formed due to the obstruction of drainage system by the lava flows. The water bodies were ephemeral in nature and the deposits were subsequently covered by the traps to eventually preserve them as intertrappean sediments. The intertrappean beds are exposed in isolated patches mostly on the peripheral areas of the Deccan volcanic province and preserve the signatures of the then biotic communities. The flora and fauna of the intertrappean deposits

have evoked considerable interest since long. Angiosperms, gymnosperms, pteridophytes, charophytes, blue–green algae, aquatic ferns, ostracodes, molluscs, fishes, dinosaurs and other vertebrates thrived during the volcanic episode³⁵ and provide an opportunity to study the organisms in terms of extinction, survival and evolution, manifested in response to the stressful environment. Since the last two decades, considerable new palynological data have been generated from these volcano-sedimentary deposits^{36–43}.

The fossil spores of the Myxomycetes were recovered from the highly carbonaceous lignitic shales of a dry dug out well near the village Padwar, Jabalpur district, Madhya Pradesh, India. The well is ~9 m deep and the basal and top parts comprise of the traps. In between there is a 3 m thick volcanic ash bed; the lignite, clay and shale beds are interspersed with the traps (Figure 1). The thickness and lateral extent of the sediments indicate that they were deposited in a relatively large water body. On the basis of palynological studies, a Maastrichtian age has been assigned to the deposits due to the occurrence of marker taxa such as *Mulleripollis bolpurensis*, *Azolla cretacea*, *Ariadnaesporites intermedius*, *Gabonisporites vigourouxii* and *Aquilapollenites bengalensis*. The section has further been divided into a lower *Aquilapollenites bengalensis* zone and the upper algal-dominated zone^{44–46}; the spores of Myxomycetes occur in the *Aquilapollenites bengalensis* zone.

For the release of palynomorphs from the sediments, the samples were treated with commercial nitric acid (40%) followed by a wash with potassium hydroxide solution (5%). The macerates were sieved by a 400-mesh sieve, the residue was placed on slides, mixed with polyvinyl alcohol solution and when dried was mounted in Canada Balsam. The samples are rich in fungal and pteridophytic spores and angiosperm pollen. However, only the myxomycetaceous spores are described here.

The spores are dark brown, subcircular, 31–57 × 27–55 µm in size, broadly reticulate on both sides, sculptural patterns often obscure due to dark brown colour. Outline undulated for projection

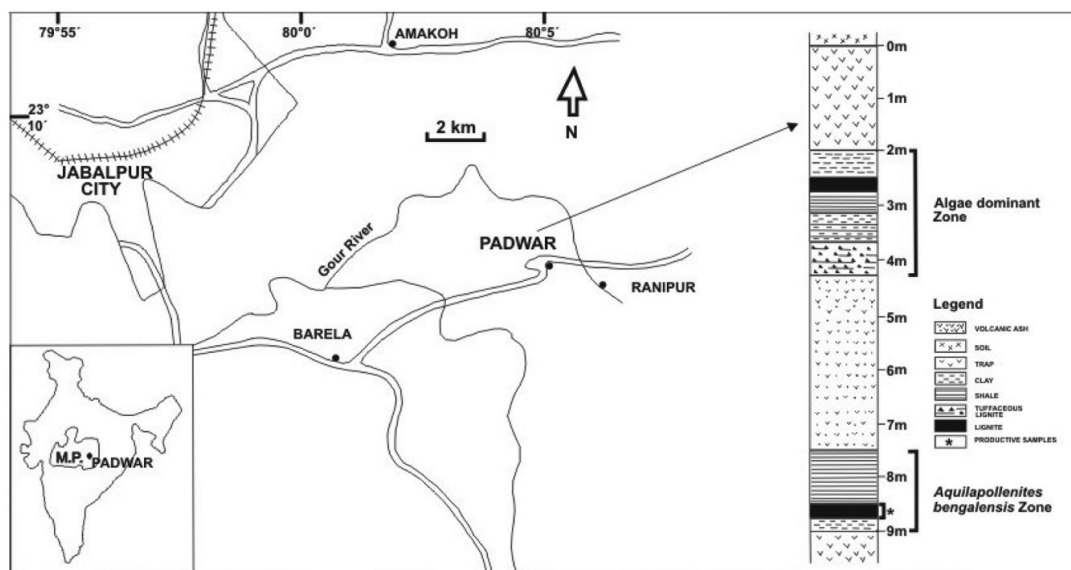


Figure 1. Locality and litholog of the well section showing the position of samples (after Sahni *et al.*⁴⁵).

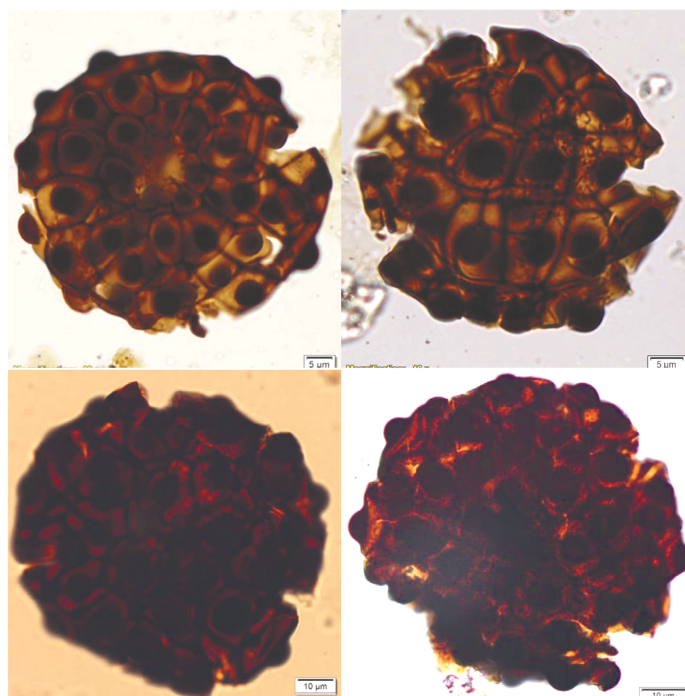


Figure 2. Spores of Myxomycetes.

of verrucae; reticulation perfect, hexagonal-rhomboidal in shape, muri raised up to 1 μm , verrucae 5–11 μm , sparsely placed (Figure 2). The Myxomycetes in general have five types of spores: spiny or warty, rugose, columnar, banded, reticulate and smooth. The ornamentation pattern is of taxonomic value and they are further subdivided to delineate the various species. The reticulate type comes close to the present forms due to the presence of the same type of reticula-

tion, but is distinguished by its verrucae¹¹. The myxomycetaceous spores apparently resemble some pteridophytic spores in having subcircular shape and broad reticulation. However, the absence of trilete or monolete marks and its dark brown colour due to the presence of melanin easily differentiates them from the others⁴⁷.

The spores of the present study are distinguished from all other comparable genera by their alele nature, subcircular

shape and presence of broad reticulation on both the sides. Some species of Myxomycetes such as *Craterium*, *Lycogola*, *Reticularia*, *Tubifera*, *Hemitrichia*, *Trichia*, *Diachea*, *Didymium*, *Lamproderma* and *Stemonites* have reticulate, subcircular spores. However, the combination of reticulum and verrucae is not found in any species of these genera except in *Stemonites fusca*. But the spores in this species are less than 8 μm , whereas in the fossil specimens the size varies from 31 to 57 μm . So it seems that the fossil spores reported here are closely related to *Stemonites*. The habitat of *S. fusca* is on dead and decaying woods, and the fossil forms reported here are also associated with the highly carbonaceous/lignitic shales.

The Myxomycetes are cosmopolitan in distribution and occur in all possible habitats. The occurrence of Myxomycetes is generally governed by the climate and the nature of vegetation of a particular place. Their favourable place happens to be dead and rotten leaves and stems, under suitable moisture and temperature⁴⁸. It has been observed that the optimum temperature for the germination of spores varies from 20°C to 30°C and the ideal pH for the same is 4.0 to 8.0 (ref. 49). They grow in abundance in India generally at the commencement of the rainy season, are shade loving and grow luxuriantly under dead wood, leaf litter and crevices¹².

The Myxomycetes studied here were recovered mostly on the highly carbonaceous and lignitic shales indicating their

preference to the decomposed debris. The lake and its surroundings were highly productive as is evident by the presence of lignitic layers. The sediments were deposited under lacustrine environment, which ensured abundant water supply to the organisms. The presence of swarm cells and absence of myxamoebae in the assemblage also corroborate this supposition, because it has been observed that the abundance of water patronizes the formation of swarm cells⁵⁰. The temperature in the quiescent period of volcanism was suitable for their rapid growth and multiplications as manifested in the different phases of their life cycles. The food for them might have been plenty from the microorganisms thriving on the decaying organic matter.

The Myxomycetes have some characters common to both plants and animals and they are generally placed at the basal rugs of the ladder of evolution. The history of these organisms is quite old; but their delicate, slimy structures and the fragile nature of the fruiting bodies could have stood on their way for the process of fossilization⁵¹. So far the oldest records were from Eocene amber^{23,24}, which probably provided a conducive medium for the preservation of these fragile forms. Perhaps during the lull period of Deccan volcanic eruptions, the climatic and environmental conditions at the site of deposition were congenial for these microorganisms to get fossilized in the intertrappean sediments.

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ACKNOWLEDGEMENTS. We thank Prof. Ashok Sahni for his constant encouragement to work on the Deccan Intertrappeans and to Prof. Sunil Bajpai, Director, Birbal Sahni Institute of Palaeobotany for permission to publish this paper.

Received 9 April 2014; revised accepted 23 September 2014

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