



A review on process of Fossilisation with reference to Ecological, Evolutionary and Environmental relationship.

Ramashray Singh¹, Anil Kumar Dwivedi²

¹Research Scholar, Department of Botany, Deen Dayal Upadhyay Gorakhpur University, Gorakhpur, Uttar Pradesh, India.

²Professor, Department of Botany, Deen Dayal Upadhyay Gorakhpur University, Gorakhpur, Uttar Pradesh, India.

Abstract

The process of fossilization is poorly understood. However, it is central to our understanding of the evolution of life. It is unclear how plant tissues become fossilized, whether fossilization is selective to specific biopolymers, or whether original organic constituents survive. We have replicated the fossilization process in the laboratory by using both microbial and chemical approaches to pyritize plant debris. These results demonstrate that initial pyritization can be an extremely rapid process (within 80 days) and is driven by anaerobic bacterial-mediated decay. Initially, pyrite precipitates on and within plant cell walls and in the spaces between them. Further decay and infilling at all scales preserve broad cellular anatomy. The results have implications for fossilization in general and the fidelity of the taxonomic and biomolecular information preserved in fossils.

Keywords: Cryptospore, Paleoenvironment, Paleovegetation, Paleogeography.

FOSSILISATION

The process of fossilization is poorly understood. However, it is central to our understanding of the evolution of life. It is unclear how plant tissues become fossilized, whether fossilization is selective to specific biopolymers, or whether original organic constituents survive. We have replicated the fossilization process in the laboratory by using both microbial and chemical approaches to pyritize plant debris. These results demonstrate that initial pyritization can be an extremely rapid process (within 80 days) and is driven by anaerobic bacterial-mediated decay. Initially, pyrite precipitates on and within plant cell walls and in the spaces

between them. Further decay and infilling at all scales preserve broad cellular anatomy. The results have implications for fossilization in general and the fidelity of the taxonomic and biomolecular information preserved in fossils.

ECOLOGY AND EVOLUTION

Parasitism is one of the most successful modes of life, as evidenced by its convergent appearance in numerous lineages and its sheer absolute and relative abundance among extant biodiversity. Antagonistic interactions, in the form of arms races between parasites and their hosts, have been considered important drivers of evolution and might also have contributed to the origin of sexual reproduction. Because parasitism also has an obvious societal importance with many parasitic taxa being of significant biomedical, veterinary or economic importance, it is here that most of the research effort is focused. This focus is narrow and fails to provide the wider evolutionary picture or an appreciation of the influence of parasitism on, and as part of, biodiversity. Indeed, despite their importance and ubiquity, the evolutionary history of parasites is still poorly known, a phenomenon not helped by their inadequate, or rather inadequately explored, fossil record. Establishing time-calibrated evolutionary frameworks to test the origins and radiations of parasites in parallel with studies on environmental parameters, or the degree of coevolution between parasites and hosts, is a difficult but as yet a largely unexplored means by which ancient associations may be revealed.

The evolution of oxygenic photosynthesis had a profound impact on the Earth's surface chemistry, leading to a sharp rise in atmospheric oxygen between 2.45 and 2.32 billion years ago and the onset of extreme ice ages^{N3}. The oldest widely accepted evidence for oxygenic photosynthesis has come from hydrocarbons extracted from 2.7-Gyr-old shales in the Pilbara Craton, Australia, which contain traces of biomarkers (molecular fossils) indicative of eukaryotes and suggestive of oxygen-producing cyanobacteria. The soluble hydrocarbons were interpreted to be indigenous and syngenetic despite metamorphic alteration and extreme enrichment of ¹³C relative to bulk sedimentary organic matter. Results show that both kerogen and pyrobitumen are strongly depleted in ¹³C, indicating that indigenous petroleum is 10–20% lighter than the extracted hydrocarbons. These results are inconsistent with an indigenous origin for the biomarkers. Whatever their origin, the biomarkers must have entered the rock after peak metamorphism and thus do not provide evidence for the existence of eukaryotes and cyanobacteria in the Archaean eon. The oldest fossil evidence for eukaryotes and cyanobacteria therefore reverts to billion years ago. Results eliminate the evidence for oxygenic photosynthesis billion year ago and exclude previous biomarker evidence for a long delay (300 million years) between the appearance of oxygen-producing cyanobacteria and the rise in atmospheric oxygen.

The cryptospore record now ranges from Middle Cambrian to Lower Devonian, establishing the existence of some degree of subaerial terrestrial plant cover throughout this time. Although mesofossil plants are not recovered prior to the Wenlock (Silurian), cryptospore tetrads and cryptospore dyads reflect possible hepatic and rhyniophytoid affinity, respectively. Although it is certainly possible that some cryptospores are the diasporas of chlorophytes, or even charophytes, the bulk of ultrastructural, morphological, and evidence from Lower Devonian in situ studies of mesofossil sporangia all favor an embryophytic origin of the cryptospores. It

is difficult not to conclude in the light of the fossil record that there was an extensive subaerial flora on Earth by Middle Cambrian time. However, the extent to which this bryophyte-grade flora established coverage over dry land is not known. At the very least, marginal fluvial and lacustrine habitats would have been inhabited by the cryptospore-producing plants. The existence of such a transitional flora, in bridging the gap between a microbial and tracheophytic world should, have had some impact on terrestrial ecology and Earth systems. The cryptospore record indicates that the colonization of terrestrial habitats occurred in three stages: a microbial phase, followed by a bryophyte- grade phase, and ending in the establishment of the tracheophytes that persist today. This does not contradict the neontological view of embryophytes having evolved from charophyte ancestors. But it certainly affects the timing and nature of evolutionary processes that brought about the evolution of the plant kingdom and the terrestrial hierarchy that is dependent upon it.

PALEOENVIRONMENT

The present study aims to provide the paleoenvironmental reconstruction of freshwater sequences in the Lingala-Koyagudem Coal belt of the Godavari Graben, using palynofacies. The palynofacies analysis was conducted on some samples from borehole from the Lower Gondwana successions of the Godavari Graben. Palynofacies/Sedimentary Organic Matter were analyzed quantitatively, and cluster analysis was performed on different percentages of Sedimentary Organic Matter to obtain zones for the depositional pattern in the lake deposit. The work is based on the hypothesis that huge coal bearing lacustrine deposits developed during the Gondwana time-span and these coal formations need to be fully understood in terms of the palynofacies to provide insight into the physical and biological processes. Based on the dominance and sub-dominance of the existing Sedimentary Organic Matter, four distinct palynofacies units were identified, representing the differential environmental setting in the lake. The palynofacies components are dominated by terrestrial palynomorphs, structured terrestrial particles, black oxidized particles.

PALEOVEGETATION

The last thousands of years are of particular interest to the understanding of the Earth System because the boundary conditions of the climate system did not change dramatically, and because abundant, detailed regional paleoclimatic proxy records cover this period. Here, we present fossil pollen data and examine their climatic interpretation based on a 200-cm-deep trenched sedimentary profile from Mahanadi River side, located near the Barpahar hillock of Bargarh District, Odisha, which is influenced by the South-west and North-east monsoon. The chronology of the sediment core is based on three ^{14}C dates on soil samples. During dense tropical mixed deciduous forest consisting of *Madhuca*, and *Acacia* flourished in the region along with *Rhizophora* under a warm and humid climate governed by high monsoonal activity. This phase of climate is associated with the Holocene Climatic Optimum which falls within the temporal range. Subsequently, an increase in humidity was discerned between as evident by increase in forest elements, under warm and relatively humid climate in response to an increased monsoon. The climate was mild and in general less humid than today. This climate event was inevitably influenced by a notable global cold event 4200 years ago, which is synchronous with the collapse of the world's first human empire in Mesopotamia. After this event, there was a return of more humid climate, marked by high values of plants, and fungal and trilete fern spores. This is further

supported by the presence of Rhizophora and Sonneratia indicating high precipitation under the influence of coastal habitation. A striking signal of the Little Ice age was observed since past when the climate became relatively dry, as recognized in a sudden decline in major arboreals, along with high frequency of occurrence of dry herbs. This changing pattern of humidity was also reflected in the proportions of marshy/aquatic taxa, as well as ruderal taxa which is a result of human impact. The study will be helpful to display the palaeovegetation and climate in the region between Bengal and the Ganga plains.

PALAEOGEOGRAPHY

Period of the Paleozoic were a time of marked climatic and geographical change and significance diversification in terrestrial vegetation. These factors together have resulted in a significance provincialism in plant fossil distribution giving them a considerable value for paleogeographic work. Describing the distribution and main palaeobotanical characteristics of the various phytochorion that have been organized. It deals almost exclusively with the adperson record as only very few petrifications from this stratigraphical interval known outside of palaeogeographical region.

BIODIVERSITY

In recent years, the Indian subcontinent has received focused attention from the geoscientific community across the world because of the hypothesized link between Deccan flood basalt volcanism and mass extinctions at the Cretaceous Palaeogene boundary and the proposal that some extant Asian biotic elements had actually originated in the former Gondwanaland and later dispersed out of India, which served as a Noah's Ark during its northward flight. Thus, India was suggested as a centre of origin for early evolution for certain major groups of organisms during its northward journey as is evident from recent works from the Late Cretaceous and Early Eocene of India. Considerable work was also done on Triassic and Jurassic ammonoid biostratigraphy of Kachchh and Himalayan regions which helped us in refining the chronostratigraphy and sequence stratigraphy of these Mesozoic sequences. Isotope systematics have also been used in understanding the Phanerozoic bioevents of India and their relationship to climate and major tectonic events.

CLIMATIC CONDITION

Early Mesoproterozoic (~1600 Ma old) stromatolitic cherts of the Salkhan Limestone of the Semri Group, Vindhyan Supergroup exposed in Rohtas district, Bihar contain well-preserved, distinctive population of nostocalean akinetes belonging to different species of Archaeoellipsoides. These are smaller in size in comparison to other known assemblages of Archaeo ellipsoids and are comparable to the akinetes of modern bloom forming Anabaena. Small-sized akinetes of heterocystous cyanobacteria display rod-shaped, ellipsoidal to spindle-shaped morphologies, with prominent intracellular mass in two species out of three. Their distribution indicates allochthonous, presumably planktic and possibly dormant resting nature. Their presence also helps in understanding the evolution of marked cell differentiation in cyanobacteria. The recognition and record of akinetes are important to trace the antiquity of Nostocales and understanding the concentration of oxygen in the

atmosphere in the geological past, corroborating the geochemical evidence of atmospheric oxygen level about 15% PAL for Late Palaeoproterozoic to Early Mesoproterozoic (48).

Isolated elongate spore-like cells present in the >1600 Ma-old Salkhan Limestone of the Semri Group, Vindhyan Supergroup, India are considered akinetes of the heterocystous cyanobacteria. Small to large size, and young (single walled) to mature (double walled) akinetes – namely, *Archaeoellipsoides bactroformis*, *A. conjunctivus*, *A. dolichos*, *A. elongatus*, *A. grandis*, *A. major* and *A. minor* – found in the stromatolitic and bedded cherts have been reported in the present paper. Their role in understanding extreme environmental conditions is a subject matter of this paper. Additionally, the occurrence of doubly-terminated quartz crystals and fan-fabrics in the Salkhan Limestone indicates adverse conditions for the survival of life forms. The depositional environment of the Salkhan Limestone, Vindhyan Supergroup is suggested to be shallow marine intertidal with pulses of the intermittent hypersaline regime during which akinetes, closely resembling those of extant Nostocaceans, were formed by cyanobacteria for survival in the extreme conditions (49).

Mesoproterozoic (~1600 Ma old) Salkhan Limestone (Semri Group) of the Vindhyan Supergroup, exposed in Rohtas district of Bihar, India, preserves an abundant and varied ancient microbial assemblage. These microfossils are recorded in three distinctly occurring cherts viz., bedded chert, stromatolitic chert and cherty stromatolites. 27 morphoforms belonging to 14 genera and 21 species have been recognized. Six unnamed forms are also described. The microbial assemblage, almost exclusively composed of the remnants of cyanobacteria, is dominated by entophysalidacean members and short trichomes and can be termed as ‘typical Meso-proterozoic microbiotas. The assemblage includes characteristic mat-forming scytonematacean and entophysalidacean cyanobacteria. *Eoentophysalis* is the dominant organism in the assemblage. Ellipsoidal akinetes of nostocalean cyanobacteria (*Archaeoellipsoides*) and spherical unicells also occur; both are distinct from mat forming assemblage, allochthonous and possibly planktic. Co-occurrence of the microbiotas and precipitates is related to the depositional environment of the Mesoproterozoic tidal flats with high carbonate saturation (50).

Objective:

1. Collection of fossil sample and their photograph from study site.
2. The present study focusses on fossil flora with special reference to phytogeographic and paleoclimatic implication and exploration of nearest living relative.
3. Study of environmental condition of the selected site.
4. Linking the Paleoclimatic condition of floristic diversity.
5. Reconstruction of Paleoclimatic and evolutionary evidences using Co-existence approach.

Materials and Methods:

1. Collection of necessary fossil sample.
2. Use standard method of grinding and polish of the sample where ever necessary.
3. Preparation of slides.
4. Identification of slides.
5. Carbon dating of selected fossil.
6. Application of CA (Coexistence approach) and NLR (Nearest Living Relatives).

Conclusion:

On the basis of physical appearance of fossil and molecular analysis, we conclude that the zoological time period that fossil had form. Those plant groups which are found in fossil form which is related with the living genera. All fossil plant has a relationship between any plant group.

References:

1. Thomas, B. A. (1976). An introduction to fossil plants. *Journal of Biological Education*, 10(4), 173-180.
2. Srivastava, G., Su, T., Mehrotra, R. C., Kumari, P., & Shankar, U. (2019). Bamboo fossils from Oligo–Pliocene sediments of northeast India with implications on their evolutionary ecology and biogeography in Asia. *Review of palaeobotany and palynology*, 262, 17-27.
3. Srivastava, G., Mehrotra, R. C., & Srikarni, C. (2018). Fossil wood flora from the Siwalik Group of Arunachal Pradesh, India and its climatic and phytogeographic significance. *Journal of Earth System Science*, 127(1), 2.
4. Mehrotra, R. C., & Srivastava, G. (2017). In situ Lecythidaceae wood from the Oligocene of Makum Coalfield, Northeast India. *IAWA Journal*, 38(2), 162-169.
5. Srivastava, G., Mishra, S. R., Barman, P., Mehrotra, R. C., & Tripathi, S. C. (2018). Lagerstroemia L. fossil wood from the Indus molasse sediments (possibly late Miocene) of Trans-Himalayan region and its phytogeographic and climatic significance. *Review of Palaeobotany and Palynology*, 255, 14-21.
6. Mehrotra, R. C., Mehrotra, N., Srivastava, G., & Shah, S. K. (2017). Occurrence of fossil woods in the unakoti district, Tripura and their palaeoclimatic significance. *Journal of the Palaeontological Society of India*, 62(1), 17-30.
7. Brocks, J. J., Logan, G. A., Buick, R., & Summons, R. E. (1999). Archean molecular fossils and the early rise of eukaryotes. *science*, 285(5430), 1033-1036.
8. Arnold, C. A. (2013). *An introduction to paleobotany*. Read Books Ltd.
9. Rolfe, W. D. I., & Brett, D. W. (1969). Fossilization processes. In *Organic geochemistry* (pp. 213-244). Springer, Berlin, Heidelberg.
10. Grimes, S. T., Brock, F., Rickard, D., Davies, K. L., Edwards, D., Briggs, D. E., & Parkes, R. J. (2001). Understanding fossilization: experimental pyritization of plants. *Geology*, 29(2), 123-126.

11. Zaborac-Reed, S. J., & Leopold, E. B. (2016). Determining the paleoclimate and elevation of the late Eocene Florissant flora: support from the coexistence approach. *Canadian Journal of Earth Sciences*, 53(6), 565-573.
12. Murthy, S., Sarate, O. S., & Aggarwal, N. (2019). Palynofloral and Palynofacies Evidences and its Implication on the Depositional Environment from Wardha Valley Coalfield, Maharashtra. *Journal of the Geological Society of India*, 93(1), 85-94.
13. Cleal, C. J. (1991). *Plant fossils in geological investigation: the Palaeozoic*. Ellis Horwood Ltd.
14. Sumathi, M 1 , Kumarasamy, K , Thiyagarajan, M, and Punithavathi, J (2011). A study on the temperature and rainfall conditions of pudukkottai district, Tamil Nadu, India. *International Journal of Development Research* Vol. 1, Issue, 3, pp.022-026, June.
15. Srivastava, G., Paudyal, K. N., Utescher, T., & Mehrotra, R. C. (2018). Miocene vegetation shift and climate change: evidence from the Siwalik of Nepal. *Global and Planetary Change*, 161, 108-120.
16. Tripathi, S., Basumatary, S. K., Singh, V. K., Bera, S. K., Nautiyal, C. M., & Thakur, B. (2014). Palaeovegetation and Climate oscillation of western Odisha, India: a pollen data-based synthesis for the Mid-Late Holocene. *Quaternary International*, 325, 83-92.
17. Singh, V. K., & Sharma, M. (2014). Morphologically complex organic-walled microfossils (OWM) from the late Palaeoproterozoic-early Mesoproterozoic Chitrakut Formation, Vindhyan Supergroup, central India and their implications on the antiquity of eukaryotes. *Journal of the Palaeontological Society of India*, 59(1), 89-102.
18. Adams, K. R., & Gasser, R. E. (1980). Plant microfossils from archaeological sites: research considerations, and sampling techniques and approaches. *Kiva*, 45(4), 293-300.
19. Prasad, B., Uniyal, S. N., & Asher, R. (2005). Organic-walled microfossils from the Proterozoic Vindhyan Supergroup of Son Valley, Madhya Pradesh, India.
20. Sharma, M., & Pandey, S. K. (2012). Stromatolites of the Kaladgi Basin, Karnataka, India: Systematics, biostratigraphy and age implications. *The Palaeobotanist*, 61(1), 103-121.
21. Sharma, M., & Shukla, M. (2003). Studies in Palaeo-Mesoproterozoic stromatolites from the Vempalle and Tadpatri formations of Cuddapah Supergroup, India. *Vistas in Palaeobotany and Plant Morphology: Evolutionary and Environmental Perspectives*.
22. De Baets, K., & Littlewood, D. T. J. (2015). The importance of fossils in understanding the evolution of parasites and their vectors. In *Advances in Parasitology* (Vol. 90, pp. 1-51). Academic Press.
23. Strother, P. K. (2000). Cryptospores: the origin and early evolution of the terrestrial flora. *The Paleontological Society Papers*, 6, 3-20.
24. Friedman, W. E., & Cook, M. E. (2000). The origin and early evolution of tracheids in vascular plants: integration of palaeobotanical and neobotanical data. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 355(1398), 857-868.
25. Javaux, E. J., Knoll, A. H., & Walter, M. R. (2001). Morphological and ecological complexity in early eukaryotic ecosystems. *Nature*, 412(6842), 66-69.

26. Nath, K. S. Microfossils based Palaeoecology and Palaeocommunity Structure of Upper Siwalik Deposits of Jammu, JandK, India.
27. Aggarwal, N., Thakur, B., & Jha, N. (2019). Palaeoenvironmental changes in the Lower Gondwana succession of the Godavari Graben (South India) inferred from palynofacies. *Journal of paleolimnology*, 61(3), 329-343.
28. Drobner, E., Huber, H., Wächtershäuser, G., Rose, D., & Stetter, K. O. (1990). Pyrite formation linked with hydrogen evolution under anaerobic conditions. *Nature*, 346(6286), 742-744.
29. Krishnan, S., Samson, N. P., Ravichandran, P., Narasimhan, D., & Dayanandan, P. (2000). Phytoliths of Indian grasses and their potential use in identification. *Botanical Journal of the Linnean society*, 132(3), 241-252.
30. Holt, K. A., & Bennett, K. D. (2014). Principles and methods for automated palynology. *New Phytologist*, 203(3), 735-742.
31. Bercovici, A., & Vellekoop, J. (2017). Methods in paleopalynology and palynostratigraphy: an application to the K-Pg boundary. In *Terrestrial Depositional Systems* (pp. 127-164).
32. Burnham, R. J. (1993). Reconstructing richness in the plant fossil record. *Palaios*, 376-384.
33. Sunil, B., Prasad, G. V. R., Vandana, P., Jai, K., & Anindya, S. (2012). Recent advances on phanerozoic biodiversity, bioevents and climate in India. *Proceedings of the Indian National Science Academy*, 78(3), 445-455.
34. Ray, J. S. (2006). Age of the Vindhyan Supergroup: a review of recent findings. *Journal of Earth System Science*, 115(1), 149-160.
35. Ramasamy, S., Ramachandran, A., Velmurugan, K., David Lalhmingliana Chawngthu, B. S., & Suresh Gandhi, M. (2012). Sedimentological studies of Kallamedu Formation in Ariyalur area, Tamil Nadu, India. *Int. J. Geol. Earth Environ. Sci*, 2, 218-234.
36. Javaux, E. J., Knoll, A. H., & Walter, M. R. (2004). TEM evidence for eukaryotic diversity in mid-Proterozoic oceans. *Geobiology*, 2(3), 121-132.
37. Tu, T. T. N., Bocherens, H., Mariotti, A., Baudin, F., Pons, D., Broutin, J., ... & Largeau, C. (1999). Ecological distribution of Cenomanian terrestrial plants based on $^{13}\text{C}/^{12}\text{C}$ ratios. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 145(1-3), 79-93.
38. Ray, J. S., Veizer, J., & Davis, W. J. (2003). C, O, Sr and Pb isotope systematics of carbonate sequences of the Vindhyan Supergroup, India: age, diagenesis, correlations and implications for global events. *Precambrian Research*, 121(1-2), 103-140.
39. Hatté, C., & Jull, A. J. T. (2007). Radiocarbon Dating| Plant Macrofossils.
40. Corbett, S. L., & Manchester, S. R. (2004). Phytogeography and fossil history of *Ailanthus* (Simaroubaceae). *International Journal of Plant Sciences*, 165(4), 671-690.
41. Hatté, C., & Jull, A. J. T. (2006). Radiocarbon dating| Plant macrofossils. *Encyclopedia of Quaternary Science*, 2958-2965.
42. Sumathi, M., Kumarasamy, K., Thiyaagarajan, M., & Punithanvathi, J. (2011). A study on the temperature and rainfall conditions of pudukkottai district, tamil nadu, india. *Int. J. Dev. Res*, 1(3), 022-026.

43. Sharma, M. U. K. U. N. D. (2006). Small-sized akinetes from the mesoproterozoic salkhan limestone, Semri Group, Bihar, India. *J. Palaeontol. Soc. India*, 51, 109-118.
44. Sharma, M., & Shukla, B. (2019). Akinetes From Late Paleoproterozoic Salkhan Limestone (> 1600 Ma) of India: A Proxy for Understanding Life in Extreme Conditions. *Frontiers in microbiology*, 10, 397.
45. Sharma, M. (2006). Palaeobiology of Mesoproterozoic Salkhan Limestone, Semri Group, Rohtas, Bihar, India: systematics and significance. *Journal of earth system science*, 115(1), 67-98.
46. Shukla, B., & Sharma, M. (2016). A NEW ASSEMBLAGE OF LARGE-SIZED MICROFOSSILS FROM THE SALKHAN LIMESTONE (> 1600 MA), SEMRI GROUP, VINDHYAN SUPERGROUP, INDIA. *Journal of the Palaeontological Society of India*, 61(2), 287-299.
47. Locatelli, E. R. (2014). The exceptional preservation of plant fossils: a review of taphonomic pathways and biases in the fossil record. *The Paleontological Society Papers*, 20, 237-258.

