Giant fossil Prototaxites: Unraveling a 400-million-year-old mystery

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Contradictions and puzzles surround the giant fossil *Prototaxites*. The fossils resemble tree trunks, and yet they are from a time before trees existed. The stable carbon isotope values are similar to those of fungi, but the fossils do not display structures usually found in fungi. Plant-like polymers have been found in the fossils, but nutritional evidence supports heterotrophy, which is not commonly found in plants. These are a few of the confounding factors surrounding the identification of *Prototaxites* fossils.

Since the first fossil of *Prototaxites* was described in 1859, researchers have hypothesized that these organisms were giant algae, fungi, or lichens. A recent study by Dr. Linda Graham and her colleagues published evidence in the February issue of the American Journal of Botany that they believe resolves this long-standing mystery.

Prototaxites existed during the Late Silurian to Late Devonian periods--approximately 420-370 million years ago (ma). *Prototaxites* fossils have a consistent tubular anatomy, composed of primarily unbranched, non-septate tubes, arranged in concentric or eccentric rings, giving the fossils an appearance similar to that of a cross-section of a tree trunk. The fossil "trunks" vary in size and may be up to 8.8 m long and 1.37 m in diameter, making *Prototaxites* the largest organism on land during the Late Siluarian and Devonian periods.

Graham and her colleagues hypothesized that *Prototaxites* fossils may be composed of partially degraded wind-, gravity-, or water-rolled mats of mixotrophic (capable of deriving energy from multiple sources) liverworts that are associated with fungi and cyanobacteria. This situation resembles the mats produced by the modern liverwort genus *Marchantia*. The authors tested their hypothesis by treating *Marchantia polymorpha* in a manner to reflect the volcanically-influenced, warm environments typical of the Devonian period and compared the resulting remains to *Prototaxites* fossils. Graham and her colleagues investigated the mixotrophic ability of *M. polymorpha* by assessing whether *M. polymorpha* grown in a glucose-based medium is capable of acquiring carbon from its substrate.

"For our structural comparative work," Graham said, "we were extremely fortunate to have an amazing thin slice of the rocky fossil, made in 1954 by the eminent paleobotanist Chester A. Arnold."

Their structural and physiological studies showed that the fossil *Prototaxites* and the modern liverwort *Marchantia* have many similarities in their external structure, internal anatomy, and nutrition. Despite being subjected to conditions that would promote decomposition and desiccation, the rhizoids of *M. polymorpha* survived degradation, and with the mat rolled, created the appearance of concentric circles. The fungal hyphae associated with living liverworts also survived treatment, suggesting that the branched tubes in fossils may be fungal hyphae. The very narrow tubes in the fossils resemble filamentous cyanobacteria that the researchers found wrapped around the rhizoids of the decaying *M. polymorpha*.

"We were really excited when we saw how similar the ultrastructure of our liverwort rhizoid walls was to images of *Prototaxites* tubes published in 1976 by Rudy Schmid," Graham said.

In their investigations into the nutritional requirements of *M. polymorpha*, Graham and her colleagues found that the growth of *M.*

polymorpha in a glucose-based medium was approximately 13 times that seen when the liverwort was grown in a medium without glucose. Stable carbon isotope analyses indicated that less than 20% of the carbon in the glucose-grown liverwort came from the atmosphere. The stable carbon isotope values obtained from *M. polymorpha* grown with varying amounts of cyanobacteria present span the range of values reported for *Prototaxites* fossils. Taken together, these results demonstrate that the liverworts have a capacity for mixotrophic nutrition when glucose is present and that mixotrophy and/or the presence of cyanobacteria could be responsible for the stable carbon isotope values obtained from *Prototaxites*.

Graham and her colleagues' results demonstrate that liverworts were important components of Devonian ecosystems. Their results support previous hypotheses that microbial associations and mixotrophy are ancient plant traits, rather than ones that have evolved recently.

More information: The full article in the link mentioned is available for no charge for 30 days at www.amjbot.org/cgi/content/full/97/2/268

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