Fungi in a Warmer World – Fungal Diversity in the Tropical Miocene Climate Optimum of the Clarkia Region of Idaho, USA

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Introduction

A knowledge gap associated with how fungal communities change in response to climate was identified in the 2018 State of the World Fungi report (Willis, 2018). While it is virtually impossible to test in the present, fungal assemblage changes can be studied in sediments from a warmer-than-present period such as the Miocene Climate Optimum (MCO) (Romero et al. 2021; O'Keefe 2017). The Fungi in a Warmer World project aims to generate and analyze a global-scale data set of fungal biodiversity, ecology, and associated flora from MCO sediments. This dataset will be used to model past fungal assemblage changes across the MCO and forecast future changes in line with IPCC RCP 4.5-8.5 warming.

The MCO is the warmest interval of the last 23 MY. It is among the best analogs for near-future climate change scenarios, as calculated atmospheric CO2 concentrations across the MCO range from approximately current levels to levels forecast for the end of this century, or ~450-550 ppm (IPCC RCP 2021; Steinthorsdottir et al., 2021a,b).

The Clarkia lagerstätten (upper Latah Formation), located near Clarkia, Idaho (Figure 1), is well known for its exceptionally preserved fossil leaves, insects, and palynomorphs preserved in finely laminated silt and clay (Steinthorsdottir et al., 2021b; Caldede et al., 2018; Pipis, 2012; Phipps, 2007; Phipps and Rember, 2004; Otto et al., 2003; Smiley & Rember, 1985a,b, 1981; Smiley et al., 1985). Fossil fungi have been previously reported, but never in great detail, except for leaf moulds (Sherwood-Pike, 1985, Sherwood-Pike and Gray, 1988; Phipps and Rember, 2004, Phipps, 2007). The lake deposits are well-dated because many ashes were deposited with them. The sediments range from 15.9-15.5 Ma in age, coincident with peak MCO warming (Steinthorsdottir et al., 2021). At this time, the region was a humid warm-temperate mixed forest, with similarities to modern forests in the southeastern United States and southern China (Steinthorsdottir et al., 2001).

Here we present preliminary results from our examination of fossil fungi from FiaWW's northernmost site in the USA, the Clarkia lagerstätten (Figures 2-11).

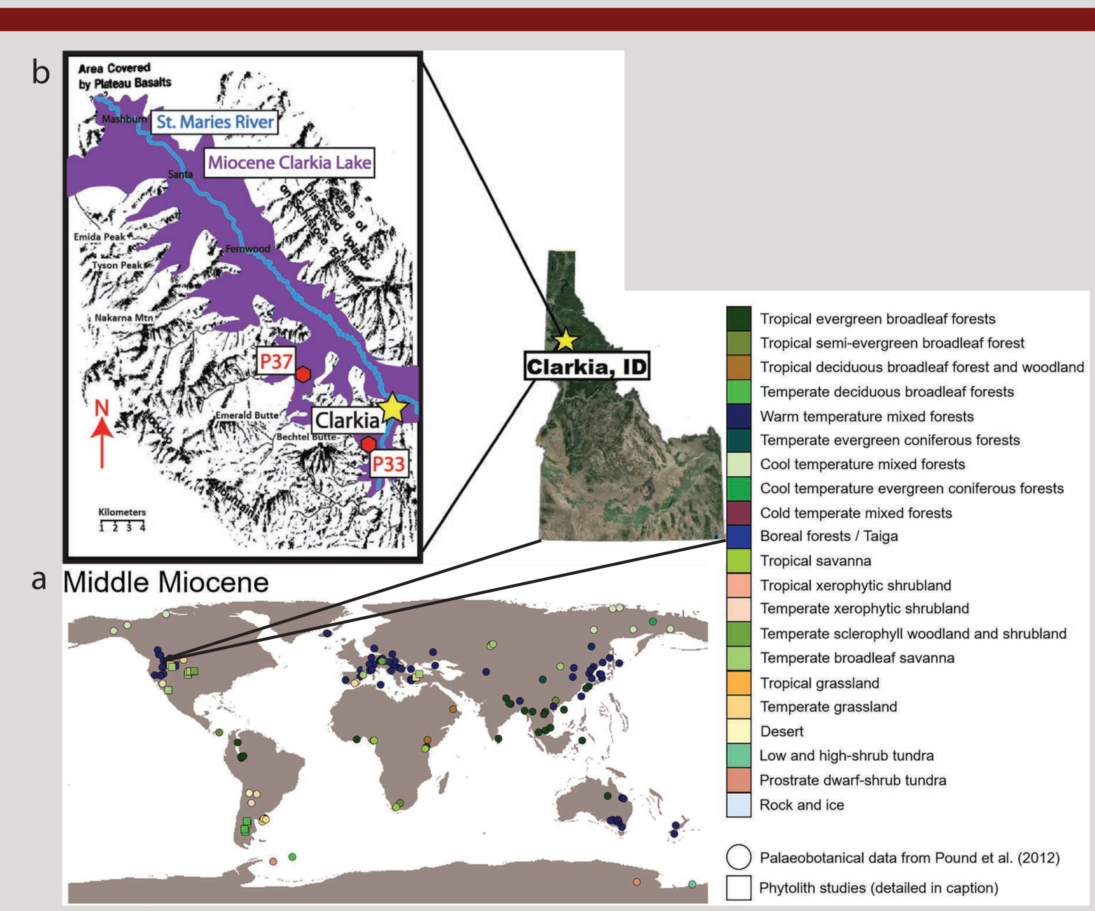

Figure 1 - Study Area.
(a) Palynology and Paleobotany has indicated that Miocene Clarkia Lake was in the northern Hemisphere warm-temperate mixed forest belt (Steinthorsdottir et al., 2021a). (b) Sites P33 and P37 (red dots), near Clarkia (yellow star) and Evergreen, Idaho, respectively, were studied to generate a composite section through the entire lake.

Methods

Samples were extracted from sites P33 and P37 on 10 cm-spacing by driving 2.5-cm diameter PVC pipes into the deposit after excavating through the weathering rind. Samples were processed via acid-free methods to extract palynomorphs (O'Keefe & Eble 2012; Pound et al 2021). Once extracted, samples were mounted on slides and analyzed under 1000x magnification using Leica DM750P microscopes with integral ICC50W cameras and Leica Application Suite® software. Z-stacked specimen images were classified by septation and morphology.

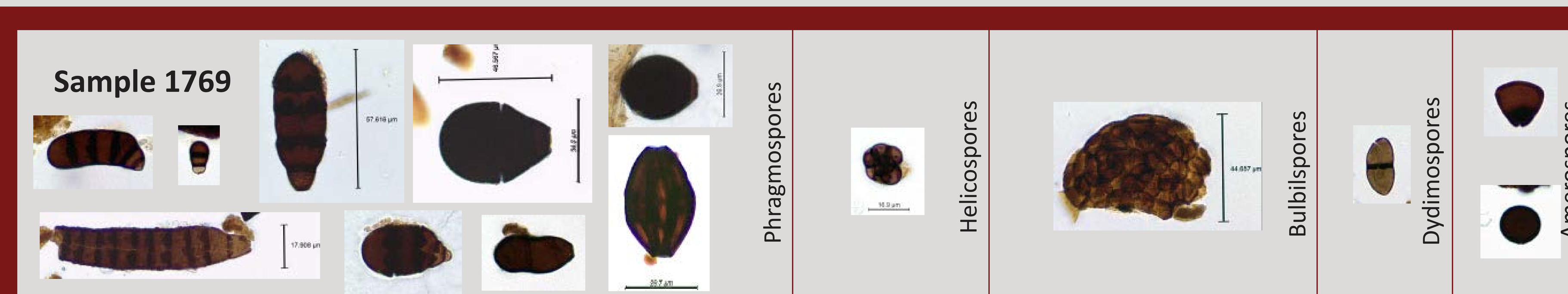

Figure 11. Uppermost Sample

- Elongate phragmoconidia indicative of wood decay under water occur.
- *Diporotheca gorda* (*) occurs; indicates tropical conditions.

Figure 10

- A mixture of simple amerospores and phragmoconidia.

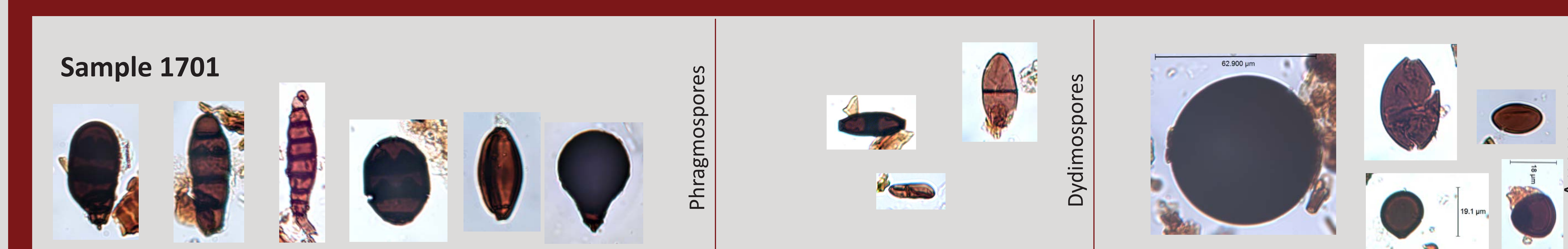

Figure 9

- Larger and longer phragmoconidia become more common.

Figure 8

- *Brachysporium*-like small phragmoconidia indicate plant pathogens were present
- Large *Delitschia*-like dung fungal didymospores occur

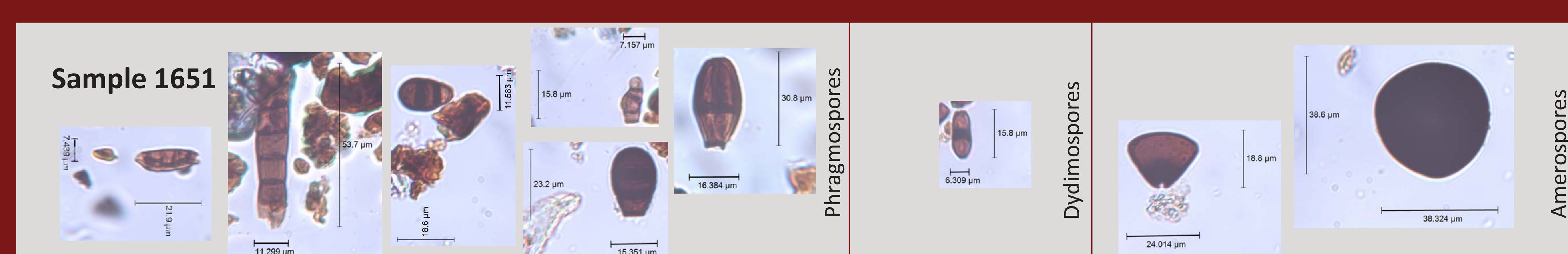

Figure 7

- Majority are three-celled phragmos
- Larger ameros reappear

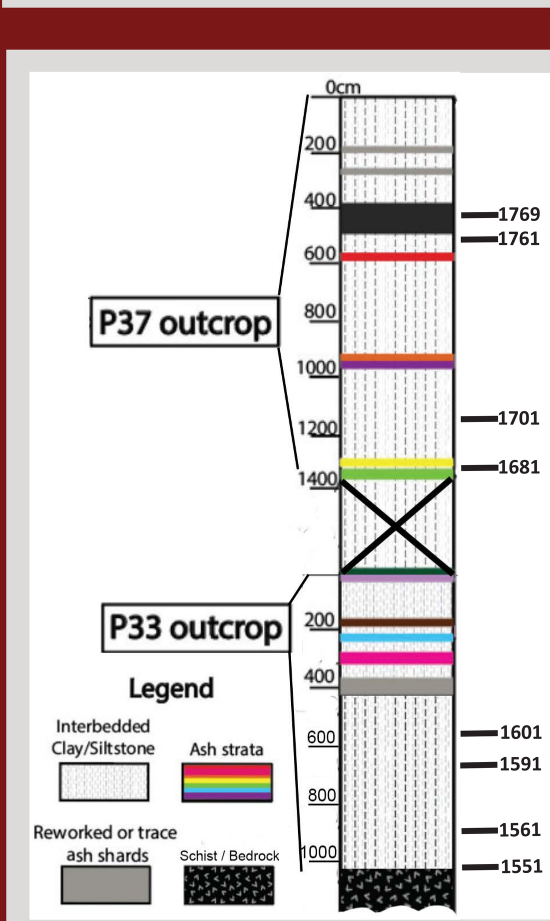

Figure 2. Stratigraphy.
Approximately 1023 cm of section were sampled at P33, and 1400 cm of section at P37. Approximately 8 m of section are inaccessable between the two exposures. The combined DRAFT stratigraphic column is edited from Steinthorsdottir et al. (2021) using field notes. Approximate locations of samples examined for this preliminary study are shown to the left of the column.

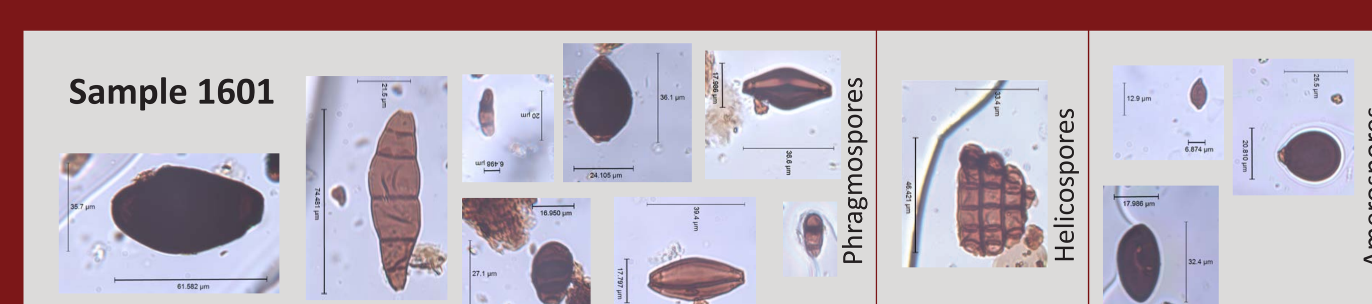

Figure 6

- First occurrence of *Striadiporites* sp. and *Diporotheca* sp. (known today from Illinois)
- Only occurrence of *Helicoönites*.

Figure 5

- Large round to rounded triangular spores suggestive of mycorrhizal spores
- Medium black amerospores with a single porus suggestive of *Acrogenospora* sp., a known freshwater fungus

Figure 4

- Simple ameroconidia and ascospores are most common.

Figure 3. Basal Sample

- Simple ameroconidia & ascospores, a few didymospores and phragmospores.
- Of interest, the third from the left is known to occur in Florida (Alum Bluff) and Colombia during the MCO.

Conclusions

The samples from the Clarkia lagerstätten contained diverse fungal palynological assemblages, dominated by small round ameroconidia with one attachment scar and small ovoid ascospores with a germ slit.

The lower section of the Clarkia site contains mostly amerospores, didymospores, and 2-septate phragmospores, while the upper part of the section contains more complex spores, such as longer phragmospores and bulbilspores, indicating wetter conditions.

To date, the conidia of the waterlily parasite & saphrotroph *Helicoönites* only occurs in Sample 1601. This spore suggests that the lake was seasonally dry.

The rare fossil taxon *Striadiporites* sp. appears in sample 1601; after sample 1701 it is replaced by *Diporotheca gorda*, which suggests a change to tropical or near-tropical conditions during peak warming.

Future work will include analysis of all samples collected from Clarkia and continued fungal identification; we expect to see significantly more fungal diversity as the project progresses.

The results of this study will be included in a global database containing ecological and climatological information useful to model fungal responses to modern climate change.

Acknowledgements

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