Regional climatic effects of a large ash fall on the microfossils of the Miocene Latah Formation

Stefanie A. Pipis
Geological Sciences, University of Idaho, Moscow, ID 83844, stef.pipis@gmail.com
William C. Rember
Tertiary Research Institute, University of Idaho, Moscow, ID 83844, rember@uidaho.edu

ABSTRACT

The Latah Formation has been known for its plant megafossils since 1897, when clay and siltstone near Spokane, Washington were found to contain fossil leaves. The sediments in the study area were deposited around and behind the basaltic flows of the Priest Rapids member of the Wanapum formation of the Columbia River Flood Basalt. Over a period of ~2 Ma the CRBs added significant amounts of CO_2 to the atmosphere, probably causing in part a climb in global temperature known as the Mid-Miocene Climatic Optimum. Approximately 15 Ma a one meter thick ash fall not related to the Columbia River volcanism was deposited in Miocene Lake Clarkia. Sediments were sampled from below, within, and above the ash and analyzed for their pollen content. Samples were taken every 20 centimeters below and above the ash and every 10 centimeters within the ash. The results of this palynology study indicate that the climate of the Miocene Lake Clarkia was warm temperate to subtropical. This conclusion was reached using the pollen spectrum coupled with the macrofossil assemblage to identify the most likely climate. The effects of ash fall RA-3 did not indicate any long term impact on the regional vegetation of the Clarkia Basin. This study in conjunction with continuing ash chemistry/dating studies helps to tentatively date the Clarkia Floras to ~15 to 15.5 Ma, occurring directly on the apex of the Mid-Miocene Climatic Optimum.

QUESTIONS TO BE ADDRESSED:

- Establish a pollen spectrum for defined intervals above and below ashfall unit RA-3 in the Clarkia fossils
- Examine the effects (if any) of ash bed RA-3
- Determine any significant short term effects of the ash bed to the regional vegetation in and around Miocene Lake Clarkia

DISCUSSION

The Clarkia flora is unique for its preservation and abundance, which is useful in reconstructing its depositional climate. The best modern analogue for this flora assemblage is the Metasequoia Valley in China. Of the taxa found within the Clarkia florules, 94 % are represented in the extant genera from this area in Eastern China. This indicates that the annual precipitation is evenly distributed throughout the year and the annual mean temperature ranged from 13 - 20°C with cold month average temperature not falling below 1°C (Smiley and Rember, 1985).

Since the Miocene, there has been a lack of tectonic influence on the topography of the modern day inland northwest. Due to this, the paleotopography of the Clarkia basin would have represented a higher relief than what exists today. Because of this, there are many different biomes represented within the Clarkia Florules. This accounts for the wide spectrum of climates represented by the pollen analyzed for this project (Figures 5 and 6).

While there are many different taxa represented in the Clarkia Florules, not all are useful in helping to reconstruct the climate of the region, because they are prevalent in a wide spectrum of climate settings (warm temperate to cold). The presence (or absence) of *Taxodium* (TCT) and *Picea* is key to reconstructing changes in the regional climate (Groot, 1991).

The results of the pollen counts indicated that the TCT population in conjuncture with the *Castanea/Lithocarpus, Castanea* populations strongly indicate site P-37 was located in a warm temperate to subtropical climate during the Mid-Miocene. The macrofossils of the TCT group, including *taxodium, cunninghamia, glyptostroboides, and metasequoia* are several examples of flora that exists in warm climates.

Upon analysis of the taxa in Zones 1 – 3 it is clear that there is not much change in the population of the taxa from Zone 1 to 3. While there is not much pollen found within Zone 2 (with the exception of the number of *Castanea/ Lithocarpus* found on whole-slide counts of Zone 2), the pollen counts rebound in Zone 3, with the exception of the dinoflagellates.

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Figure 1

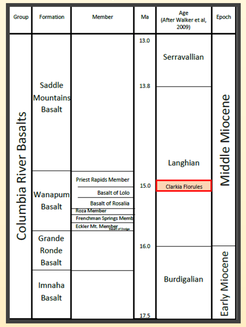
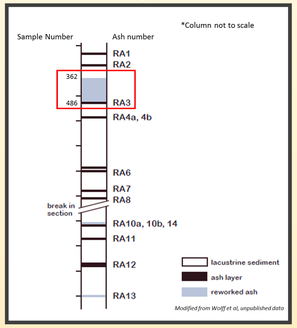


Figure 2

Figure 3



INTRODUCTION

The aims of this study are to establish a pollen spectrum for a defined interval adjacent to an ash unit in the Clarkia fossil beds (Figure 1), examine the effects (if any) of ash bed RA-3 (Figure 3), and conclude if there were any significant effects of the ash bed to the regional vegetation in and around Miocene Lake Clarkia.

The physical site of this study is located at UIMM P-37: Sec. 33, T43N, R1E, Benewah Co., Idaho (Figure 2). This work focuses on a palynology study of ash bed RA-3 (Figure 3), which is significant for its thickness (1 meter), located in the P-37 Emerald Creek area outside of Clarkia, ID. This ash bed was chosen due to the volume of leaf macrofossils located in the 50 cm above the ash. These leaf macrofossils are very sparse above this 50 cm interval.

This study was also performed in order to examine the climatic effects of the ash on the regional vegetation surrounding Miocene Lake Clarkia. Sediments were sampled from below, within, and above the ash. In order to sample the pollen and spores available, the microfossils were separated from the sediment and washed using a modified version of the Fægri-Iversen method (Fægri and Iversen, 1989). During the fall of 2011, samples were collected from the Clarkia fossil beds, washed, and counted.

This palynological review of the Latah Formation is significant due to the timing of these sediments. They occur during the apex of the Micoene Climatic Optimum, during which vegetation is found perfectly preserved within these sediments (Figure 2). They lived during a gradually climbing atmospheric temperature.

This study is based on the first synthesis international group, NECLIME, Neogene Climate Evolution in Eurasia (Bruch et al., 2007). This group is centered in Eurasia and was formed in 2000. Their first project focused on a climate study of the Miocene of Europe. Through analysis of 300 Miocene fossil floras NECLIME was able to identify several climatic parameters (Bruch et al., 2007). This the first studies to target the North American Miocene Climatic Optimum through a palynology study.

Figure 5

Climate	Taxa
Non-Specific	*Chenopodiacae* Monolete Spores ***Taxodiaceae/Cupressaceae/Taxaceae (TCT)*** Trilete Spores
Algae, Fungus, Cysts	Dinoflagellate Fungal Spores and Hypha Segments
Warm temperate to subtropical	***Castanea/Lithocarpus*** *Nyssa*
Temperate to sub-tropical	*Carya* ***Castanea (L)*** *Ilex* *Pterocarya* *Quercus* *Tilia*
Warm temperate to temperate	*Cornus* *Juglans* *Platanus*
Temperate	*Acer* *Aesculus* *Ephedra* *Isoëtes* *Ostrya* *Rhamanus*
Warm temperate to cool temperate	*Alnus* *Betula* *Claytonia* *Fagus* *Liquidambar* *Ulmus*
Warm temperate to cold	*Caltha* *Pinus* *Salix* *Vaccinium*
Cool temperate	*Dodocatheon* *Pseudotsuga/Larix* *Tsuga*
Cold	*Abies* ***Picea***
Cold arid	*Lewisia*

The figure above illustrates the taxa identified and the climate for which they represent. The taxa in bold on the right identify those of which are most significant in reconstructing the Miocene climate.

CONCLUSIONS

There is significant oxygen isotope data to support the warming in the Middle Miocene (Kürschner et al., 2007). Additionally, this study has illustrated through the high quantity of warm temperate to subtropical taxa that there is biological evidence to support the climatic apex. The total biological evidence, including both micro and macrofossils, found in the Clarkia Basin lacustrine sediments indicate the Latah Formation is located on or near the apex of the Mid-Miocene Climatic Optimum (MMCO).

The MMCO was likely driven by the large scale volcanism occurring in the Columbia River Plateau. The ashflow unit, RA-3, while not directly associated with the Columbia River Flood Basalts was thought to have some effect on the regional vegetation of the Clarkia Basin due to its relative thickness. According to the graphical representation of the pollen counts, the regional vegetation was not affected by the ash. However, the high number of fungal spores found within the ash layer itself indicates there was an effect on the local vegetation.

Immediately following the mass extinction after the Permian-Triassic boundary, there was a fungal spike following the widespread die off of living flora and fauna (Eshet et al, 1995; Steiner et al, 2003). In this study, the fungal spike indicates a local effect of the ash layer RA-3 on the vegetation. The sudden die off of vegetation caused massive amount of rotting organic material to suddenly be introduced to the local area surrounding P-37. A leaf or plant which experienced a period of decomposition could be expected to retain a number of different fungi (Sherwood-Pike and Gray, 1988). While this die off did not last permanently or long-term, there was an intermittent period of time when the pollination of the existing flora was suppressed.

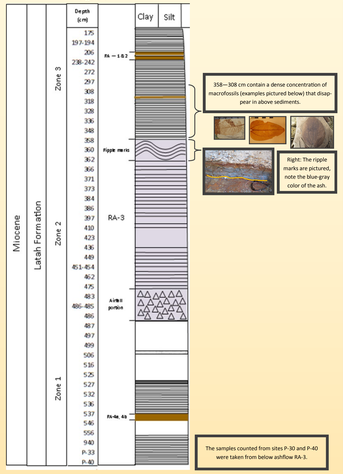
ASH RA – 3

Although the exact origin of this rhyolitic ash bed (Figure 3) is still unknown, the chemical information collected to date most closely matches the Swisher Rhyolite Unit erupted from a volcanic province in the Juniper Mountains located in the three-corner area of Idaho, Oregon, and Nevada.

As for the exact age of the ash, what is definitely known is that RA-3 is younger than the 15.3-15.9 Ma Dinner Creek Tuff and the Spring Creek Tuff that erupted from the Castle Rock caldera in the Lake Owhyee volcanic field (Idaho/Oregon graben) (Nash et al, 2006). These tuffs sit stratigraphically lower than RA-3 (Figure 3). The ashes lower in section than RA-3 in the Latah formation match these tuffs more closely on a chemical level and have been correlated to site P-33 through drill core (Yang et al, 1995).

Attempts to date the ash using Ar^{40}/Ar^{39} radiometric dating have been made, however, the feldspar crystals separated from the detrital sediment in order to measure the Ar^{40}/Ar^{39} ratio have been too small to effectively determine a date. This small size is due to the distance this ash traveled from the source area.

Figure 4



PHYSICAL STRATIGRAPHY

The section of the strata below ash RA-3 has been named Zone 1. The ash itself is Zone 2, and the portion of the unit that sits above the ash is referred to as Zone 3 (Figure 4).

Beginning in Zone 1 at sample 556, the sediment is massive up to the bottom of a 2.5 cm thick ash (RA-4) at 540 cm. About 15 cm above RA-4 until a 1 cm thick dark gray clay layer appears. Between RA-4 and the 1 cm clay layer the sediments are rhythmic. The 15 cm above the 1 cm clay layer is a massive layer that terminates at a 1 cm thick white clay layer. The sediments from this 1 cm thick white ash layer are massive up to sample site 486, which is the bottom of ash RA-3.

The bottom 10 cm of RA-3 is the airfall portion of the ash. Above the airfall portion, starting at about 476 cm, the ash appears to be thinly bedded rhythmic up to 435 cm. From 435 cm to 415 cm the sediments are massive. The ash is then laminated for 3 cm and then again massive to 405 cm. Above 405 cm the ash is thinly bedded to 390 cm where there are ripple marks (Figure 6).

The top of ash RA-3 is located at a depth of 362 cm. The sediments above the ash are very thinly laminated. There is a very fine clay layer within the laminations from 312 – 308 cm. Above this clay layer, the sediments are finely laminated up to the top of the section.

Figure 6

Right: All specimen photos are relative to scale in μm.

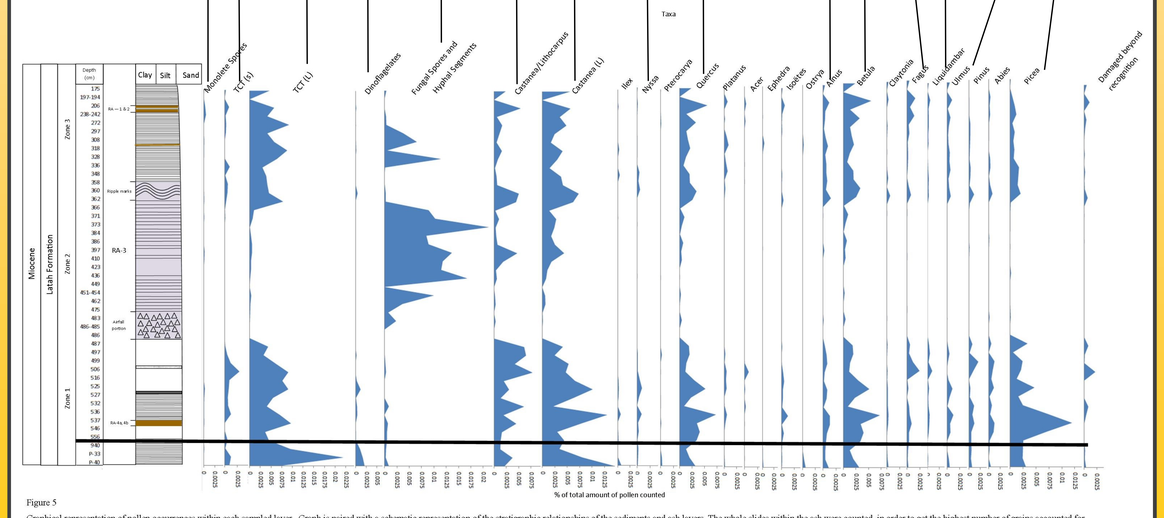


Figure 5

Graphical representation of pollen occurrences within each sampled layer. Graph is paired with a schematic representation of the stratigraphic relationships of the sediments and ash layers. The whole slides within the ash were counted in order to get the highest number of grains accounted for.