Palynology of Cretaceous Sediments near Marmarth, ND: Using Pollen Analysis to Locate the Stratigraphic Location of the Cretaceous-Paleogene Boundary

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Abstract:

The Hell Creek Formation is a group of laterally extensive sedimentary beds exposed throughout North Dakota and Montana. It is one of the best exposures of Late Cretaceous sediments in the world and is known for its iconic dinosaur fossil assemblages. To obtain more detailed information about the timing and impact of the Cretaceous - Paleogene (K-Pg) mass extinction it is important to precisely determine the stratigraphic location of the K-Pg boundary, which is found near the top of the Hell Creek Formation. Palynology can be used to determine this boundary by observing the relative abundances of fossilized pollen. Previous palynological analysis has described relative abundances of pollen samples throughout the region of exposed Hell Creek strata across the contact between the Hell Creek and overlying Fort Union Formations. A significant decrease in pollen abundance corresponds to the mass extinction event that marks the end of the Cretaceous period. Locally, the K-Pg boundary must first be identified using palynological analysis. The stratigraphy of the boundary can then be determined more precisely in this region. Sediment samples from the Hell Creek Formation near Marmarth, North Dakota were collected from the top of a butte estimated to be close to the stratigraphic K-Pg boundary. These samples were prepared for analysis at the University of Minnesota's LacCore pollen processing lab. Microscopic analysis to determine relative abundances of pollen species was performed at Winona State University. Knowing the stratigraphic location of the boundary near Marmarth will allow for more extensive studies of the K-Pg extinction and help to temporally locate excavations in the area. Better stratigraphic understanding of the boundary throughout the Hell Creek Formation will increase our understanding of the timing of the extinction and the environmental conditions before, during, and after the event.

Introduction:

66 million years ago a global extinction event killed off more than 75% of the species on Earth. This included not only the iconic non-avian dinosaurs, but also a number of terrestrial plant species. Pollen and spores from plants are commonly preserved in the terrestrial Cretaceous sediments of North and South Dakota and Montana. At the Cretaceous – Paleogene (K-Pg) boundary, the diversity and abundance of these pollen species decreases dramatically in conjunction with the end-Cretaceous extinction event[1]. Analyses of pollen and spore species at or near the K-Pg boundary have been performed at various locations throughout the Hell Creek Formation[1,2,3], and changes in pollen diversity and abundance across the K-Pg boundary have been documented[4].

Erosion is the dominant geological process in the southwestern North Dakota landscape where the K-Pg boundary is preserved. Determining the stratigraphic location of the boundary before erosion removes any evidence of it is extremely important in understanding the stratigraphy of the region. This understanding will improve stratigraphic and temporal accuracy of excavation sites in the area. This study is the first in a multi-stage palynological analysis of sediments collected near Marmarth, North Dakota that aims to accurately determine the stratigraphic location of the K-Pg boundary in the area. Because most sediments in the area are Cretaceous in age and lie below the boundary, samples for this study were collected at the highest elevation on a privately-owned ranch east of the town, the most likely location of exposed K-Pg boundary sediments. Microscopic analysis of six sediment samples was conducted to determine if abundances of pollen and spore species displayed patterns similar to those observed at known K-Pg boundary sites.

Methods:

Sediment samples were collected near Marmarth, ND on August 2nd, 2014 from the top 1/3 of the tallest butte in the area east of the town. Stratigraphic sections were dug into the hillside to a depth of at least 12 inches to avoid slumped sediment and ensure that undisturbed horizontal sediments were being sampled. Distinct strata were identified using standard texture and color sediment analysis. Samples from each identified stratum were collected in plastic Ziploc™ bags. Samples ET1 and ET2 were collected at the same stratigraphic level on opposite sides of the butte. Samples were returned to Winona State University, where six of them were pulverized and homogenized. Approximately 1 cc of sediment from each of these was sent to the National Lacustrine Core Facility (LacCore) at the University of Minnesota in Minneapolis and St. Paul where the samples were prepared for palynological analysis. Processed samples were returned to Winona State University in silicone oil. Samples were transferred onto glass slides with a Teflon™ microspatula. Three slides of each processed sample were prepared and pollen grains were identified by genus[3,5]. The abundances of each genus were tallied for each slide.

Results:

Four of the identified genera were deemed the most recognizable and abundant throughout the section. When these were tallied and related to the stratigraphic location of each sediment sample, both a prominent decrease in abundance and a prominent decrease in diversity were observed (Figure 2).

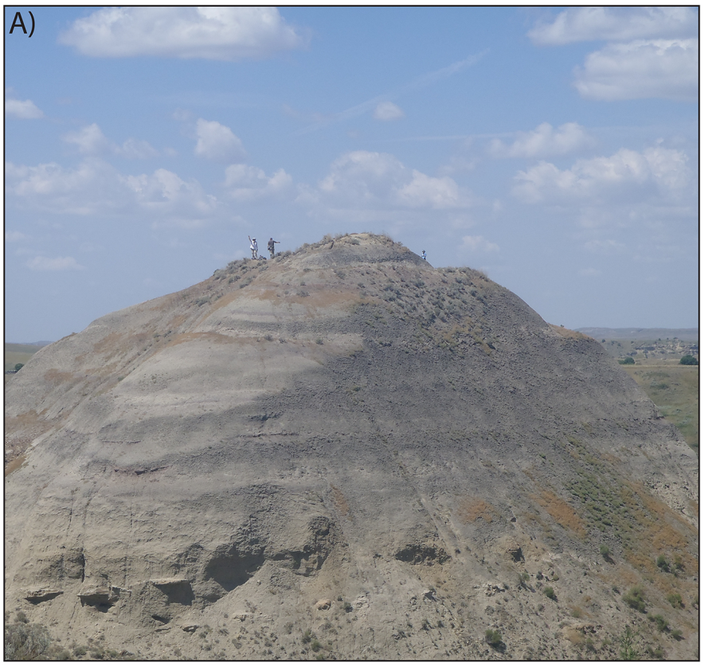


Figure 1.
A) Butte east of Marmarth, ND. Sediment samples were collected from the upper 1/3 of the butte.
B) Partial image of the stratigraphic section dug into the south side of the butte. Digging a section in this manner ensures that horizontal strata, rather than slumped sediment, is sampled. Pink markers in the section indicate changes in strata.

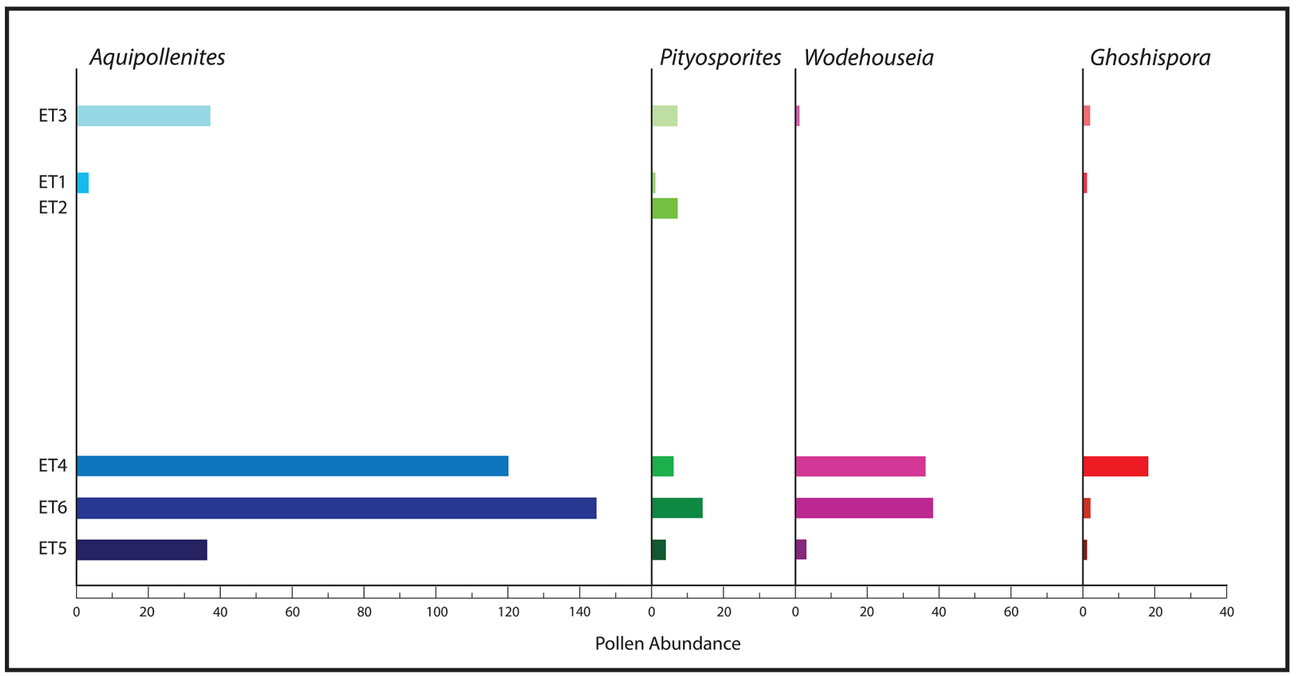
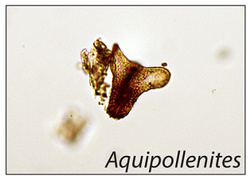
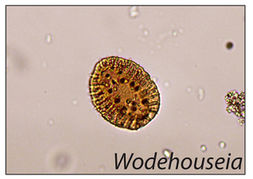
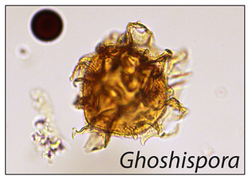


Figure 2.
Abundances of the most recognizable pollen forms collected from the stratigraphic section in Figure 1. The vertical axis is scaled to position in the stratigraphic section. The significant decreases in abundance of all genera between stratigraphic locations ET4 and ET2 may indicate the presence of the K-Pg boundary.







80 µm

Discussion:

The evidence for a significant decrease in species diversity and abundance between samples ET4 and ET2/ET1 could potentially indicate the presence of the K-Pg boundary in the stratigraphically uppermost sediments east of Marmarth. A more definitive determination of the location of the boundary in this area will require further and more detailed analysis of pollen species and sediment composition.

The order-of-magnitude increase in the number of *Aquipollenites* in sample ET3 does not follow the pattern observed for other genera. There are a number of possible explanations, the first being that the butte where the samples were collected lies entirely below the K-Pg boundary. It is possible that a sampling error or slump may have influenced the pollen count within sample ET3, although the likelihood of slump moving up-section is low. Sample ET3 was collected just below the entrance to an ant hill situated on the very top of the butte. Ants in the area are well-known for redistributing and concentrating microfossils[6], and it is possible that ants excavated sediment with higher pollen abundances and deposited that sediment on the top of the butte. Sample ET3 not only has a recurrence of *Aquipollenites*, but also an increase in total pollen abundance in relation to samples ET1 and ET2. With this line of thinking, however, it is questionable that the abundances of *Wodehouseia* and *Ghoshispora* did not increase as significantly in ET3. The lack of increase in those genera may simply be due to their lower relative abundances compared to *Aquipollenites* in lower stratigraphic samples. Finally, the recurrence of *Aquipollenites* may be the result of limiting the identification analysis to the genus level. There are many species of *Aquipollenites* in Cretaceous sediments, including species that survive the K-Pg extinction. The increase in abundance could be caused by hardier species replacing those that died out. Without further identification to the species level, this possibility cannot be eliminated.

References and Acknowledgments:

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