Sedimentologic and Petrologic Analysis of the Chinle Formation in Colorado

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I. Abstract

The Permian-Triassic boundary denotes the largest mass extinction event on record, as well as a time with concurrent rises in temperatures and CO_2 levels. This is similar to what the Earth is experiencing today. Outcrops located at South Canyon Creek near Glenwood Springs, Colorado, are part of the Eagle Basin, and are currently being researched with the intent of discovering conclusive information that can be utilized to infer about past environmental conditions during the Permian-Triassic extinction event. This area is home to a variety of rock formations, including the State Bridge and Chinle Formations. The State Bridge and Chinle Formations were likely deposited during and after the extinction event, respectively. Therefore, they offer an opportunity to study how climate changed during and after the largest mass extinction on record. Particular areas of these formations are home to fossilized soils, or paleosols, which serve as a proxy for past climate data. Field observations include vertic features such as wedge-shaped peds and slickensides, as well as carbonate and iron/manganese nodules, root traces, and burrow structures. Micromorphological investigation indicates differences in the style of root traces and burrow structures. The calcic and vertic features along with the nodules are interpreted for form as a result of seasonality. The occurrence of root traces and burrows likely indicates the presence of an abundance in early soil colonizers after the extinction evident. Further analysis of this information will lend to a greater understanding of modern-day climatic processes and events in analogous conditions.

II. Goals

1) Identify and describe paleosols noted in previous published research.
2) Delineate field relationships of rock types and paleosols, to assess paleoclimate during Chinle Formation deposition.
3) Analyze and evaluate whether diagenesis affected paleosol profile clay mineralogy.
4) Gain a better understanding of drainage processes, and what fauna may have been living in the paleosol.

III. Background

The State Bridge and Chinle formations are located near Glenwood Springs in western Colorado. A neighboring formation in the Front Range known as the Lykins Formation is thought to be deposited before and during the Permian-Triassic extinction event and is likely equivalent to the State Bridge Formation (Hagadorn et. al. 2016) that occurred approximately 252 million years ago (Ma; Burgess et al., 2014). The Permian-Triassic boundary marks a major mass extinction event, and the State Bridge Formation is thought to have been deposited during this time as well. Furthermore, overlying the State Bridge Formation is the Chinle Formation, which has been dated ~209-218 Ma (Upper Triassic; e.g. Irmis et al., 2011). These formations are of great interest because the State Bridge Formation may be used to reconstruct the paleoclimate that was occurring during a mass extinction event, and the Chinle Formation may be used to reconstruct the paleoclimate during the recovery post extinction.

(Scotese, 2016)

Figure 1: Paleogeographic reconstruction of the Permian-Triassic boundary. The yellow star marks denotes the location of the outcrop. Features on the map are designated by color: dark blue represents deep marine, light blue depicts shallow marine, green areas represent vegetation, and brown areas represent regions of uplift.

IV. Methods

A Brunton Compass was used to measure the strike and dip of the strata in the field, and a Jacob's Staff and open-reel tape measure was used to measure the stratum thickness. Paleosol layers were identified through observation of evidence of soil-forming features i.e. horizon thickness, texture and the occurrence of any notable features such as slickensides and mottling, and degree of carbonate accumulation (Retallack, 1988). Samples were classified based on grain size, ped shape, and color using a Munsell Chart (Retallack, 1988). The clay mineralogy was assessed using X-ray diffraction (XRD) analyses of the clay-sized fraction of the paleosols through creation of oriented aggregates using methods outlined in Moore and Reynolds (1997). Micromorphology of thin sections was performed using a Meiji plane polarized microscope and images were compared to those in Stoops et al., (2010).

Figure 2: Paleosol #1 located at the Derby Junction Outcrop in Colorado.

Figure 3: Measuring Stratigraphy at the South Canyon Creek Outcrop in Colorado.

V. Results

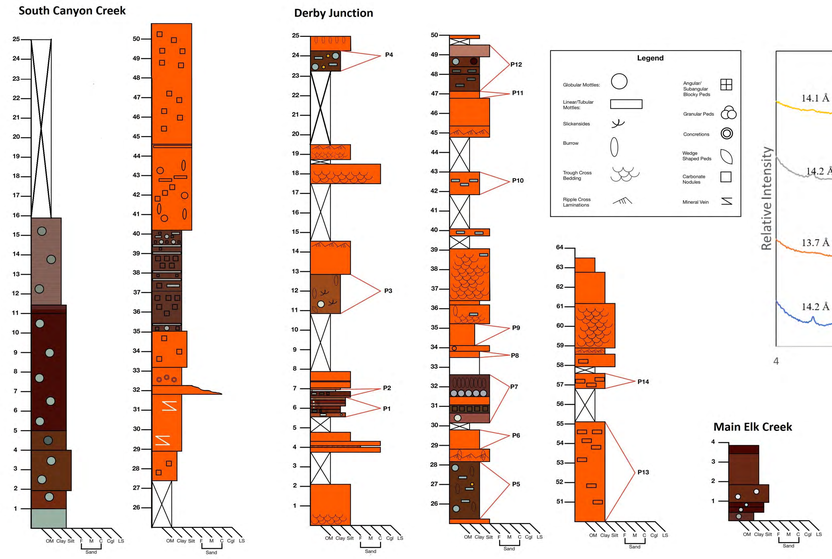

Figure 4: Stratigraphic section with outcrops visited in the Chinle Formation. Colors correspond to colors determined on a Munsell Soil Color Chart. Orange denotes where a Munsell color was not taken. Browns denote colors ranging from 2.5 YR – 10R or browns that suggest iron in an oxidized state. Pale greens/blues/grays denote Munsell colors ranging from G1-G2, or gleied colors, which suggest iron oxides in a reduced state.

Figure 5: X-Ray Diffraction analysis shows the mineralogy of the clay-size fraction (<2 μm) is dominated by Chlorite or Vermiculite (~14 Å), Illite (~10Å, ~5 Å, & ~3.3Å), and Kaolinite (~7Å).

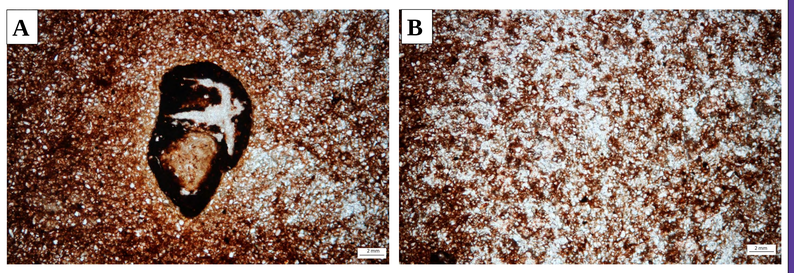

Figure 6: A photomicrograph of a nodule with a septarian crack under plane polarized light (PPL) at 50x magnification **(A)**.
A photomicrograph of a structure similar to a termite termitarium under plane polarized light (PPL) at 50x magnification. **Note:** Current evidence suggests that termites were not present during this point in the rock record however the structures present are akin to termite termitarium **(B)**.

Note: Outcrops for the State Bridge Formation were originally planned to be visited; however, due to time constraints, this was not possible. Consequently, no samples, data, or inferences were derived from the State Bridge Formation.

VI. Conclusions

Based on the work performed in the field and in the lab, the region where the Chinle Formation was deposited most likely experienced rates of evaporation that were higher than the rates of precipitation which is indicated by the abundance of carbonate present in hand samples and in thin section. Additionally, examination of samples in thin section reveals the occurrence of pedogenic carbonate which indicates the soil was well-drained; however, the general accumulation of iron and manganese oxides and nodules also indicates there were periods when the soil was poorly drained and waterlogged. This suggests that the region experienced complex hydrologic processes. Analysis of the clay mineralogy indicates the presence of illite. Modern soils that possess slickensides are dominated by the 2:1 expansible clay mineral, smectite, which undergoes transformation to illite during heating. The presence of illite instead of the predicted smectite suggest these paleosols have undergone some diagenesis and bulk elemental geochemistry data are suspect. Additionally, the presence of burrows and root traces found in the field and in thin section indicate the presence of early soil colonizers after the end Permian mass extinction event.

VII. Acknowledgements

We would like to thank the Tennessee Tech Department of Earth Sciences for allowing us to utilize their assets and the CISE Grant for funding the project. We also like to thank Ms. Peggy Medlin for all her help, Rochelle Brannon and Israel Rowland for housing us, Dr. James Hagadorn for his insights into the field site and logistical support, and Dr. Wayne H. Leimer for providing his insight and help with XRD and petrography. We would also like to thank Donald and Jaqui Preston for their love and support.

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