Unearthing eolian deposits in southwestern Montana

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Abstract

Loess deposits are key archives of past wind activity, exemplified by the extensive Chinese Loess Plateau. Isolated latest Eocene–Oligocene (~37–31 million years ago) loess outcrops. suggest a past more extensive loess plateau in the western U.S. In southwestern Montana, deposits from the Renova Formation were largely fluvial but may partially be deposited by wind. This study tests the hypothesis that wind played a role in their transport and deposition. Grain size analysis was conducted on 64 sandstone and siltstone samples from low-energy floodplain environments, which revealed multimodal distributions with a common peak at ~10 µm. End-member analysis identified three modes: 10 µm (EM1), 100 µm (EM2), and 500 µm (EM3). Comparisons with Wyoming loess suggest EM1 and EM2 represent long- and short-term aerial suspension, while EM3 indicated fluvial deposition. Eolian sediments are best preserved in sheetflood and floodplain fines deposits, supporting wind deposition in the Sage Creek Basin during the mid-Eocene to early Oligocene. This likely resulted from aridification due to global cooling and uplift in the southern Cordillera. Future work will use SEM imaging of quartz grains to confirm micro-scale eolian features. These findings will enhance understanding of paleowind dynamics and climate shifts during the Eocene-Oligocene transition.

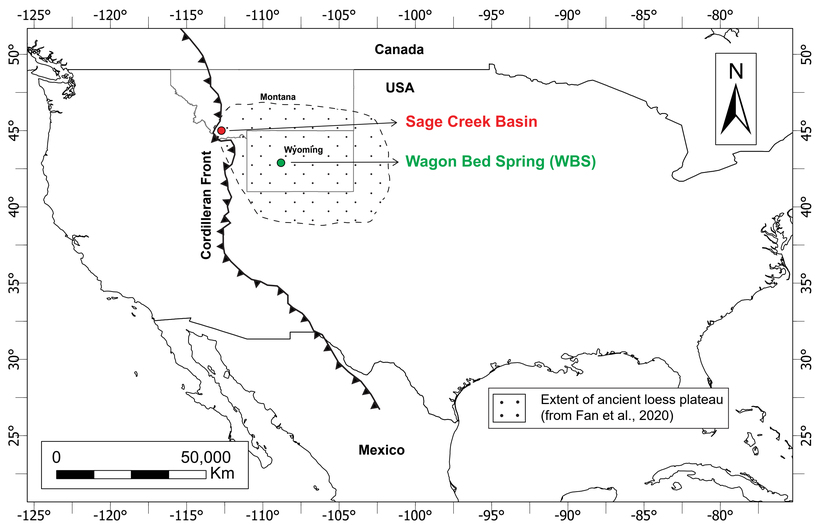
Objective

Assess the presence of ancient (~44-25 million years old) eolian deposits within the Sage Creek Basin in Southwestern Montana from lithofacies and grain size analysis

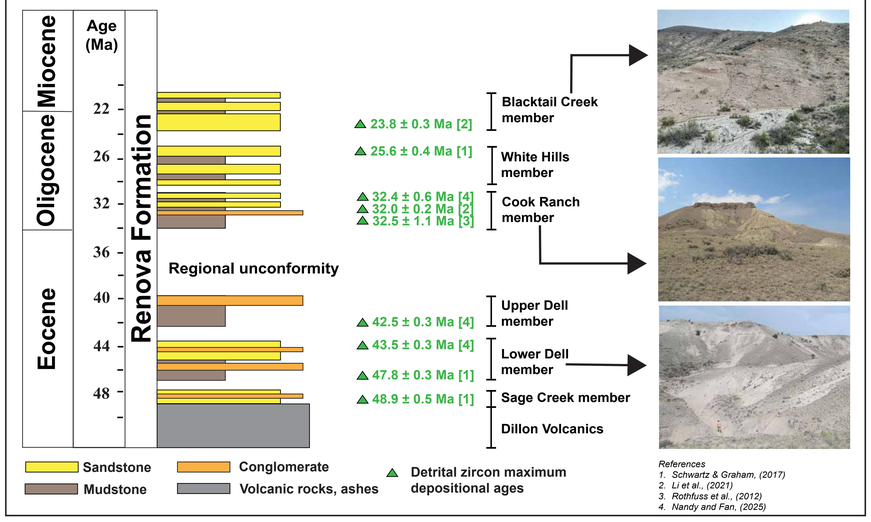
Methodology

- Collection of 64 Eocene-Oligocene sandstone and mudstone samples in the Renova Formation
- Lithofacies analysis using field data, for separating low and high energy deposits
- Standard procedures of sample preparation and grain size analysis using the MasterSizer 3000 at Baylor University
- General Weibull End-Member Analysis using the AnalySize package in MATLAB (Paterson and Heslop, 2015)
- Comparison of the end members with nearby loess outcrops to determine loess signatures

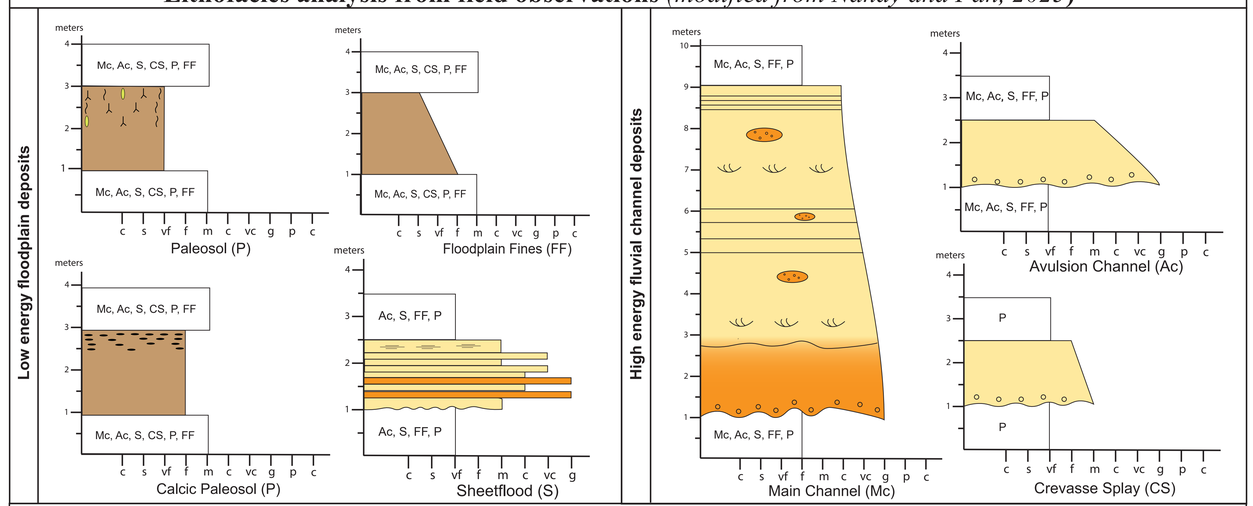
Location of the Sage Creek Basin and the inferred NA loess plateau



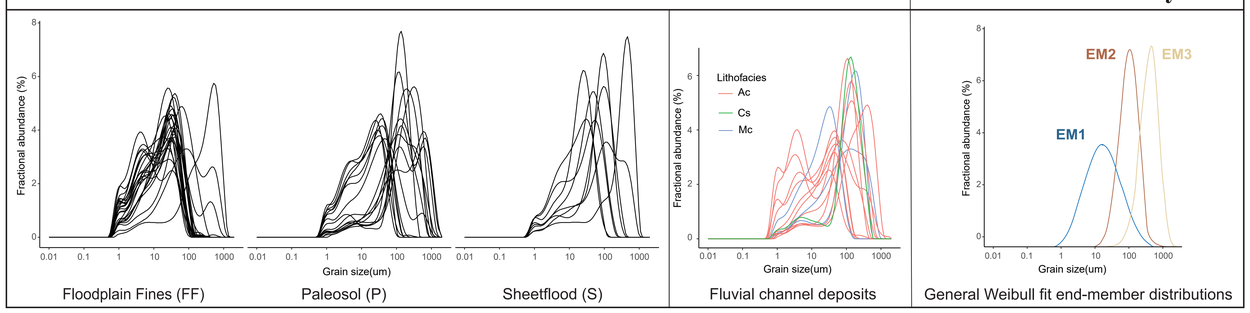
Eocene-Oligocene deposits of the Sage Creek Basin



Lithofacies analysis from field observations *(modified from Nandy and Fan, 2025)*

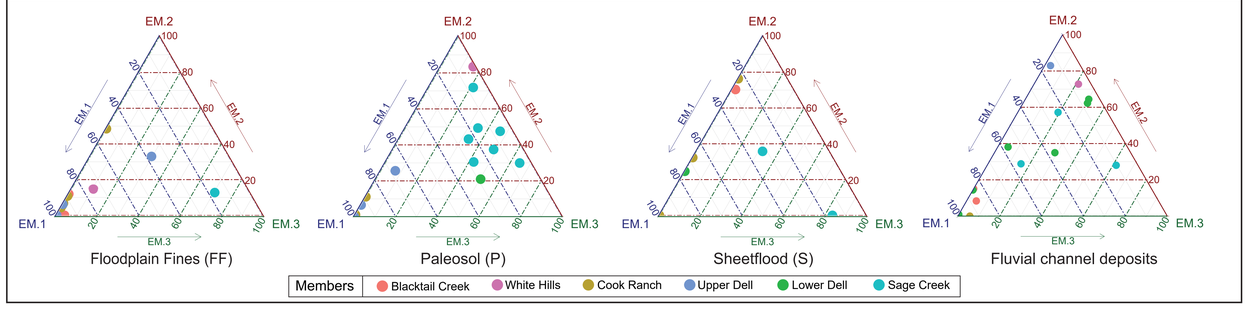


Grain size distribution

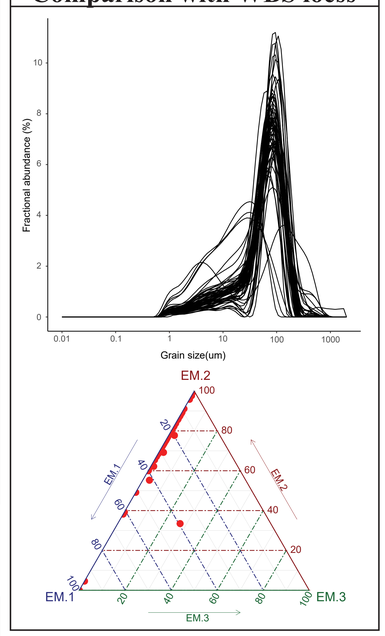


End Member Analysis

End Member contributions grouped by lithofacies



Comparison with WBS loess



Results

Grain size spectra from the Sage Creek Basin reveal a wide range of grain sizes in both low-energy floodplain and high-energy fluvial channel deposits, ranging from ~0.5 µm to 1000 µm. The coarsest samples are found in the middle Eocene fluvial Sage Creek Member. The samples are multimodal, with the floodplain fine deposits displaying a prominent large peak at approximately 10 µm. The grain size spectra from the WBS loess has two prominent peaks at approximately 25 µm and 90 µm. Similar spectra are also found in all the members of the Sage Creek Basin.

The grain size distributions for both locations can be explained by weighted contributions of three end-members, with modes at 10 µm (EM1), 100 µm (EM2), and 400 µm (EM3). The end-members accurately reproduce a majority of the grain size distributions with strong correlations (R^2 ~ 0.86–0.88) between the actual and modelled spectra.

Discussions

Breaking down the WBS loess grain size spectra into the three end-members indicates that eolian, or wind-driven, deposition is characterized by a combination of EM1 and EM2. This represents dust grains generated from long-term suspension by high-altitude winds and short-term, near-surface transport by strong surface winds, respectively.

The samples of similar spectra as WBS loess, with EM1 and EM2, in the Sage Creek Basin suggests the presence of reworked loess across all depositional environments. This hypothesis will be further investigated by conducting detailed examinations of quartz surface textures in future studies.

The EM3 end-member are mostly in paleosols in the Sage Creek member, and fluvial channel deposits, likely reflects near-source fluvial deposition. Persistent winds are unlikely to transport larger grains (~500 µm) except during brief dust storms (Nickling et al., 1983). The decrease in thecontribution of the EM3 end-member as we move from the middle Eocene members (Sage Creek and Lower Dell) to the late Eocene-early Oligocene (Upper Dell and others) members suggest a decrease in fluvial activity.

References

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