300-Million-Year-Old Soils and Their Implications on Predicting Ancient Climate Conditions

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1. Introduction

During the Virgilian Stage of the Pennsylvanian Period, approximately 300 million years ago, the area that is now Kansas was located 5-7 degrees north of the equator. The climate was expected to be generally warm, moist, and tropical (Heckel, 1979, 1995; Joeckel, 1994). After completing a summer of measuring sections in southeastern Kansas and northeastern Oklahoma, we identified ancient soils associated with seasonal precipitation and arid conditions (Mack, 1993, 1994; Retallack, 2001). The initial field interpretations do not warrant the classification of wet equatorial soils like the Appalachian coal measures. A closer study of the soil profiles was required to find if the variation was due to local controls or if the accepted paleoreconstruction was incorrect.

2. Results

The paleosol (i.e. ancient soil) profile of this study is exposed on a 200-m wide road cut about 15 miles east of Eureka along Highway 54 in Greenwood County, Kansas. The ancient soils formed on sandstones and mudstones of the Oread Cyclothem. Lateral variability is indicated by changes of type, thickness, and number of stacked paleosols from levee to floodplain areas of an ancient river system. Siltstone-rich levee deposits dominate at the western and eastern parts of the outcrop, and floodplain mudstone in the middle. Protosol, Calcisol, and Vertisol were interpreted (Retallack, 1997, 2001; Mack, 2001). Protosols have poorly developed soil horizons, relict laminations, and limited bioturbation. Calcisols contain a well-developed Bk horizon rich in discrete and amalgamated, equant to elongate calcitic nodules. Vertisols have m to cm-scale oblique slickensides, some of which are lined with nodular to tabular pedogenic calcite. Commonly, three to four paleosols stack upward from thin (50 cm) immature Protosol to thick (80-200 cm) mature Calcisol or Vertisol, suggesting increasing exposure time following episodic floodplain deposition. A Gleysol containing iron oxide nodules and pyrite overlies the Calcisol or Vertisol. The formation of Gleysol suggests a raised water table, which may be caused by a climatic change from semi-arid to subhumid conditions, or shoreline approaching the locality due to a rising sea level. In either case, the upper boundary of the uppermost mature Calcisol or Vertisol represents a stratigraphic turning point of climatic change and/or shoreline transgression (Yang, 1996). Variations in paleosol type, thickness, and stacking indicate alternate periods of fast and slow sedimentation controlled partially by topography and climate.

3. Significance

Sedimentary rocks commonly exhibit repetitive patterns in the geologic record, suggesting that sedimentation has been cyclic and the controlling factors, such as climatic, sedimentary, and tectonic processes, have also been cyclic. Thus, an understanding of these controlling factors provides insights into the mechanisms of cyclic sedimentation. Soils are abundant in the geologic record and they document important climatic information because the conditions of their formation are ultimately affected by climate. Therefore, the type and thickness of a soil horizon can give some insight into the duration and climate conditions that occurred while the soil was forming.

4. Conclusions

At this location, there is high variability in paleosol profiles on a meter to centimeter scale. Variances in bedrock lithology, regional and local climate, duration of exposure, local topography, water table fluctuations, rates of sedimentation, unit cohesion, climate, and intensity of bioturbation can effect soil formation (Retallack, 1997, 2001; Mack, 2001). Protosols thicken toward both ends of the outcrop and thin toward the middle while Calcisols and Vertisols are thicker in the middle and thin to the ends. This is likely due to local topography and location of stream channels. The number of stacked paleosols increases toward the center, where the duration of exposure was longer, further away from the channel(s). The occurrence of gleyed or waterlogged soils increase up section as a result of transgression within the Oread Cyclothem.

Further research on the lateral variations of the soil horizons will show climatic changes across southeast Kansas and northeast Oklahoma. The change of climatic conditions through time will be used to better understand the processes and mechanisms of cycle formation, and can be used as analogs to predict future climatic changes. However, the high variability within a soil profile as demonstrated in this study can complicate climate interpretation. The question of regional climate requires further study to clarify paleoreconstruction or paleosol classifications of soils formed in southeastern Kansas and northeastern Oklahoma 300 million years ago.

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6. References

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