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RECENT GULLY ACTIVITY IN MEEMAN–SHELBY STATE PARK, SOUTHWEST TENNESSEE

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ABSTRACT

Reconstructed sedimentation patterns for selected gullies in southwestern Tennessee indicate that historical sedimentation rates have increased 20–fold over presettlement values. Geomorphic evidence of current gully expansion includes incision into channel fill and fresh, nearly vertical headcuts ranging from one to three meters in height. This increase is in spite of extensive reclamation projects emplaced during 1935 to control gully development and soil erosion. Current factors influencing gully activity are improper water management from adjacent roadways and a fundamental instability in the geomorphic relationships within the gully system. It appears that in the near future, significant erosion will undermine several roads in the park, and continue to damage bottomland with sediment from eroding bluff hillslopes.

INTRODUCTION

Accelerated soil erosion in West Tennessee is widespread. Extensive gully development and lake sedimentation provide ample visual evidence of the erosional and depositional processes involved. Degradation of water quality, damage to bottomland forests, loss of crop productivity, and stream channel changes are consequences of soil erosion that are only now beginning to be fully understood (Shelton, Tyler, and Bernuth, 1984; Follett and Stewart, 1985). Agricultural cultivation often increases water and sediment yields from cropland. Seedbed preparation disrupts surface soil structure, influences and concentrates surface drainage down furrows, and decreases the surface cover of protective vegetation. The greater volume of water increases the stream power, which is a measure of energy available for work by the stream. Further, the increased sediment load is not transported through the fluvial system in one step. Schumm and his associates found that the sediment is moved through the channels in a series of episodic events during which sediment is stored temporarily, and then moved to another location where the process is repeated (Schumm and Hadley 1957; Schumm 1977; Schumm, Harvey, and Watson 1984; Schumm, Mosley, and Weaver 1987).

Along the course of any channel, erosional and depositional processes are intermixed, with one or the other dominating along specific reaches. Over time, the relative influence of each changes, creating a mosaic of depositional and erosional features in the channel. This is especially true for ephemeral channels because, by their very nature, they transfer water and sediment for only short periods of time. A knowledge of the geomorphic status of each channel is necessary in order to initiate and maintain gully erosion prevention programs (Schumm, Harvey, and Watson 1984). This study is part of a long–term project whose objective is to determine the nature of gully development in West

Tennessee by reconstructing the spatial and temporal sequences of erosion and deposition. This paper reports on recent gully activity as evidenced in the stratigraphic record, and exposed by gully incisions into historical (post–settlement) alluvium.

STUDY AREA

Meeman–Shelby State Park, located 40 km north of Memphis, Tennessee, covers about 5000 hectares of Mississippi River bottomland and loess bluffs. The bluffs were extensively cultivated from 1880 until 1935, when the federal government purchased the land to develop the Shelby Recreational Demonstration Project. In a massive program utilizing personnel from the Civilian Conservation Corps (CCC), the Department of Interior reclaimed farmland that was eroding severely due to poor land management and deforestation. Gullies were regraded and replanted with black locust, lespedeza, and honeysuckle. Over 600 log and debris dams were emplaced in gullies to retard sediment movement and stabilize channels.

Now, 50 years after the reclamation effort, the gullies are again active, extending their headcuts and incising their channel fills. What initially seemed to be a successful reclamation effort has become a serious problem for park management. Roads are being undercut and sediment deposition is filling channels on the bottoms. Without immediate and extensive action, several major roads in the park are likely to be lost in the near future.

MATERIALS AND METHODS

Aerial photos spanning the 1937–81 period were used to locate old fields, and to examine the spatial aspects of active gully development in the park. Channel longitudinal and cross–sectional profiles were surveyed. Data such as the depth of incision into channel fill, channel geometry, floodplain features, stratigraphy, and relative dominance of erosional and depositional processes were collected at one meter intervals in several tributary gullies, and at five meter intervals in major channels. The depth of sedimentation on floodplains was determined by examining stream channel exposures and using soil probes to locate identifiable stratigraphic units. Two such units were selected for their spatial distribution and unique characteristics, as seen in Figure 1.

The first is a buried soil (Ab horizon) found beneath 80–100 cm of strongly laminated silts and sands. Lying on its surface are modern cultural artifacts such as metal and glass fragments, wagon wheels, and fence posts and rails. This surface represents the ground surface around 1850, when the first settlers entered this area. The second unit (5C horizon) is a Tertiary sand and gravel layer that underlies the entire study area. Sediment deposited upon this unit is generally less than 5000 years old in the study area, as determined from radiocarbon–dated logs found at and above the top of the sand and gravel.

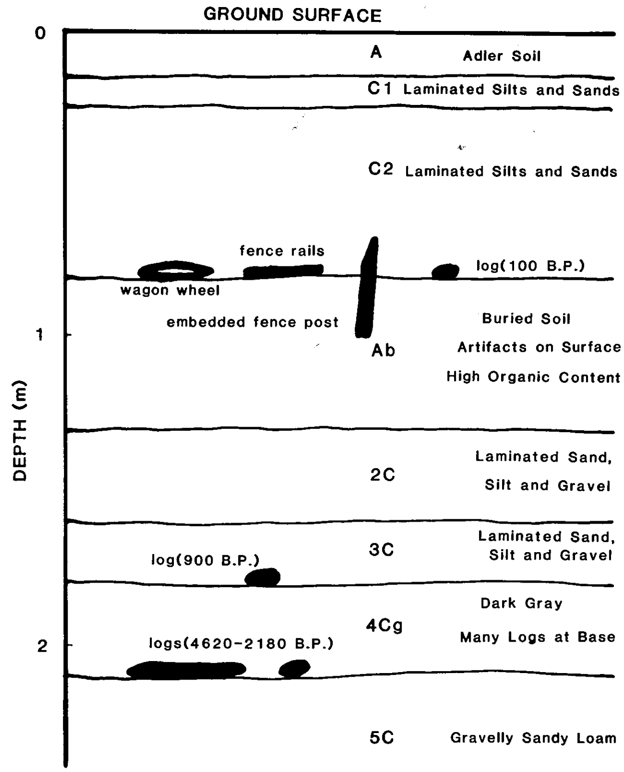

Figure 1. Stratigraphy of Wagon Wheels. Radiocarbon dated logs and modern artifacts establish reference surfaces from which estimates of sedimentation are made.

CALCULATING SEDIMENTATION RATES

Gully activity can be studied either by monitoring selected gully headcuts over a period of time, or by examining sedimentation patterns and volumes at specific locations to determine the rate of sedimentation. The latter is utilized in this study because a variety of dated surfaces are available for estimating rates over the last 5000 years. Figure 1 illustrates the stratigraphy at the Wagon Wheel Site, a two–meter deep incision into valley fill, along a major gully in the park. The stratigraphic relationship of the buried historical soil (Ab horizon) and the sand and gravel layer (5C horizon) is clearly established. Many logs from a former bottomland forest are exposed in stream incisions in the park, along the contact between the 4Cg and 5C units.

One log, from another locality, is dated at 4620 years B.P., while the log exposed at the Wagon Wheel site is dated at 2180 years B.P. (i.e., radiocarbon years Before Present, 1950 A.D.). An additional log found at the top of the 4Cg unit is dated at 900 B.P. This date provides a minimum age for the emplacement of the 4Cg unit at this site, and suggests that the 4Cg unit was deposited between 5000 and 900 years ago at an average rate of 0.02–0.05 cm/yr. Another log found lying on the surface of the Ab horizon is dated at 100 B.P. (ca. 1850 A.D.). This means that units Ab, 2C, and 3C were deposited at a rate of 0.1 cm/yr, a full magnitude greater than the previous 4000 years.

Historical artifacts confirm the radiocarbon date for the top of the Ab horizon. A bottle found at the top of the Ab horizon exhibits a design not found in this part of Tennessee until after 1892, suggesting that the Ab horizon was still the functioning surface around 1900. If the year 1900 is then used as a time reference, the 80–100 cm of sediment overlying the Ab horizon must have been deposited in just over 85 years. This yields a rate of over 1.0 cm/yr; one magnitude greater than during presettlement time, and two magnitudes greater than the oldest units at the Wagon Wheel site. These rates are similar to those calculated by Knox (1987) in his study of the Driftless Area of southwestern Wisconsin.

Discussion and Conclusions

The Wagon Wheel site appears to contain a complete record of sedimentation for the last 5000 years. Analyses of other exposures along the main channel incision confirm the stratigraphic sequence discussed above. Studying a stratigraphic column has a major advantage over monitoring gully sedimentation on a monthly or yearly basis. The stratigraphic column presents an average of the sedimentation rate. This eliminates the high variability related to seasonal and individual weather events. Also, if numerous dated surfaces are used, the averaging is over shorter time periods. This rate approaches the short–term average obtained from yearly monitoring, but without the high variability.

Several soil pits excavated into channel fill, in upper gully reaches, exhibit a buried soil at a depth as great as 110 cm. This soil is probably correlative with the Ab horizon of the Wagon Wheel site. Modern ceramic and glass artifacts lying on this surface suggest that it probably was active as late as 1935. If so, the rate of sedimentation may be as high as 2.0 cm/yr in some upper gully locations. The majority of gullies in Meeman–Shelby State Park are currently incising their channels. The sedimentation record supports the current geomorphic evidence of fresh headcuts and active incision into once stable stream channels.

The reclamation projects of 1935 seem to be failures. What happened to the stable channels created by the regrading and reclamation? Several factors appear to be interacting to create the gully instability. First, about 10–12 years after planting, most of the black locust trees were cut for fence posts. These trees played an important role in stabilizing the gully channel sediment. With their removal a part of the system was exposed to increased shear stress from running water. Second, even though the latest techniques were used to reclaim these gullies, the fundamental geomorphology of channel systems was not fully understood in the 1930's. It is entirely possible that the workers regraded the slopes and channels to an angle too steep to remain stable for long periods. In retrospect, the projects may have actually introduced an element of instability into the geomorphic system that initiated a series of interacting, intrinsic changes. Essentially, a threshold was exceeded, and the gully system is now progressing toward a more stable, adjusted configuration. Third, while this system is in a state of adjustment, still another element is being added. Many gullies have eroded headward so close to hardtop roadways that they are beginning to obtain a significant amount of their flow from roadside ditches. This is illustrated clearly where the uppermost part of the gully is extremely straight from headward erosion toward the ditch. The runoff creates a situation where, on a per storm basis, the gully transports a greater volume of water, carries a greater peak flow, and experiences a longer duration of flow than previously. This leads to an enlargement of the channel, primarily by incision into the channel fill.

Until these problems are addressed, it is unlikely that the gullies will stabilize. These gullies are reacting in a manner similar to natural channels that undergo artificial channelization. The increase in water volume and velocity increases the sediment transport capacity, resulting in channel modification through incision. The excavated sediment is then transported and stored in other parts of the channel further de-stabilizing the system. Schumm, Harvey, and Watson (1984) found that up to 15 years is needed to stabilize some sections of channelized streams in northern Mississippi. The gullies in Meeman–Shelby State Park seem farther from stabilization than 15 years because of the current water input from roadways. Also, the tremendous amount of incision that has already occurred in lower gully segments must be translated upstream. This amount appears to be nearly four meters, an amount sufficient to truncate most of the roads in the park.

Acknowledgments

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