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Loess Derived Karst Soils and Sediments in Southwestern Wisconsin

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I. Introduction

In the southwestern Wisconsin Driftless Area there is significant surface and subsurface karst development in the Paleozoic carbonates of the Upper Mississippi Valley. The southwestern Wisconsin karst is part of a larger karst region in the Upper Mississippi Valley (Day, Reeder, and Oh, 1989). The karst contains over 200 caves, more than 10,000 springs, at least 250 sinkholes, thousands of dry valleys, overburden, and wind-blown silt (loess) (Day and Reeder, 1989).

II. Karst soil characteristics

The soil development in loess of southwestern Wisconsin is mainly controlled by bedrock, relief, and eolian additions. The soil horizons are particularly affected by contributions of sandstone outcrops. Although the parent material is typically classified as Peorian loess, the texture of the entire soil profile is not silt but it is loam instead since the silt content is only 51.1 % in the solum. Soil profiles contain a substantial amount of sand (34.3 %) in the loessial parent materials due to colluvial and hydrologic processes. Weathered St. Peter sandstone outcrops and their residuals provide sand. Each horizon developed as a result of geomorphic and pedologic processes.

The texture, structure, and thickness of the Ap horizon is widely affected by anthropogenic activities. The AB horizon contains substantial amount of clay (20 %), and has piping which represents colluvial pedo-hydrologic process. The argillic horizons have less clay composition (17.3

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%) than that of the AB horizon, however, they show abundant iron oxide coatings, and have angular strong blocky structure with clay loam texture. Though the Cr horizon has very thin layer (20 cm) with bedding, it gives a great physical implication of colluvial processes including hydrologic, sedimentary, and erosional processes.

Karst in southwestern Wisconsin displays significant surface and subsurface developments in the Upper Mississippi Valley. Investigating the sinkhole sediments of the aeolian silt mantled karst system in southwestern Wisconsin is an important undertaking, for such sinkhole sediments could potentially contain various paleo-materials. Chronological sequences of sinkhole sediments can be established by an interpretation of stratigraphy. Analysis of the properties of the stratified sediments can further differentiate the source(s) of the sediment.

1. Problems and methods

According to the tentative excavation of the Seneca closed sinkhole in the Driftless Area of southwestern Wisconsin, sinkhole sediments contain reworked organic loess with local sandstone particles and a primary paleosol with two different organic horizons above the bedrock (Oh and Day, 1989). This investigation is proposed to answer two questions raised from the previous study:

(1) Could sinkhole sediments contain entire potential source materials from weathered materials (Silurian to Ordovician-aged bedrocks) and exotic materials (aeolian silt and gravels of Windrow formation) or others?

(2) Could a stratigraphy with chronosequence of sinkhole sediment reveal the Pleistocene erosional history of the Driftless Area, or to the pre-Quaternary physical environments?

To solve these problems, field and laboratory research should be undertaken. Sediment samples of twenty sinkhole sites in southwestern Wisconsin would be collected in order to perform stratigraphic analysis and sediment analysis which will delineate karst landform evolution. Laboratory work will consist of analysis of texture, organic matter, $CaCO_3$, heavy minerals. Relative and absolute dating from stratigraphic units will be done. The study will attempt to provide evidence of karst landform development in the southwestern Wisconsin Driftless Area during the Quaternary and significantly, the Late Tertiary.

2. Results

This paper presents some preliminary results of an investigation of sediments in caves, voids, shafts, and sinkholes of the loess-covered southwestern Wisconsin karst. The sediments differ due to the wide variety of depositional environments and differing origins of materials even though loess affects all the sediment properties. Karst sediments have different physical and chemical characteristics. In the Atkinson rock shafts, fallen pile sediments have high silt (64.8 %), and low clay (18.2 %) and sand contents (17 %) with abundant rock fragments from the surface. There is an inverse chemical relationship between pH (which increases with depth) and organic matter (which decreases with depth). Sediments from two small vertical voids contain high OM (9.9 %) and sand (66 %) but have very low clay contents (5 %).

Sediments from a small cave (10 m long) connected to the rock shafts have high sand (85 %) and low silt (11 %) and clay contents (4 %) with few rock fragments. In Pop's Cave, sediments from horizontal voids near the collapsed sinkhole entrance have similar contents of sand (27.3 %) and clay (28 %), and high pH (7.9) and OM (2.9 %) with weathered bedrock fragments. In Star Valley Cave, piled soils of the collapsed sinkhole entrance have a high pH (8.1) with much sand (58.3 %) but low silt (14.3 %) and low OM (0.1 %) contents. Sediments from the end of the cave show high clay (58 %) and low silt (13 %). Sediments from the ceiling of the cave have high pH (8.2) and low OM (<0.1 %), and similar amounts of silt (21 %) and clay (23 %).

The sinkhole sediments and cave sediments have different physical and chemical properties. Deep sinkhole sediments (>5.7 meters) in Seneca are very sandy (41.8 %) and have little clay (9.6 %). There are bedding sequences containing 79-99 % sand particles. Organic matter and pH decrease with depth. A paleosol from the bottom of the sinkhole has a low pH (5.3) and low OM (0.1 %), but a similar texture to upper sinkhole sediments. In a Muscoda sinkhole, sediments have higher silt (61.7 %), and lower sand (23 %) contents than at Seneca.

Organic matter and pH increase with

depth. Sediments in Bogus Bluff Cave have high clay content (64.5 %) and pH (8.0) but low OM (<2.7 %) and silt (6 %). Overall, sediments properties in sinkholes and cave entrances are controlled by local bedrock character. Sediments derived from dolostone contain high clay content derived from weathered residuum: John Gray Cave entrance (30 %), Star Valley Cave entrance (22.7 %), and Pop's Cave entrance (21.5 %), whereas Seneca sinkhole sediments have a high sand content (41.8 %) because of St. Peter sandstone bedrock. Values of pH and OM of sediments in Seneca sinkhole, John Gray Cave entrance, and Star Valley Cave entrance decrease with depth, but that of sediments in the Pop's Cave entrance and Muscoda sinkhole increase with depth.

Ⅲ. Karst sediment characteristics

Karstic depressions (dolines) are developed particularly in the Ordovician limestones and dolostones of the Driftless Area uplands, where they occur in interfluvial ridge tops and on the upper side slopes of dry valleys. To date over 250 dolines have been recorded and inspected. Investigating the doline sediments of the mantled karst system in southwestern Wisconsin is important because the sediments potentially contain paleo-materials. There are several potential sources of doline sediments in southwestern Wisconsin including exposed bedrock sources, overburden sources, and exotic sources. In particular, it appears that heterogeneous sequences of dolostone, shale, and sandstone produce heterogeneous doline sediments. Excavation of two closed dolines (at Seneca and Muscoda, Wisconsin), reveals significant amounts of sand (ca. 32 %) and paleosols which include abundant tree stumps of historical provenance.

1. Provenance of materials

The object of this study is to identify the potential sources of the sinkhole sediments in southwestern Wisconsin. To achieve this goal, this project proposes to investigate exposed bedrocks, overburden, and exotic materials with their chemical and mineral compositions providing indications as to potential sources from bedrock units, overburden materials, aeolian silts, and remnants of the Windrow formation. The potential sources of sinkhole sediments in southwestern Wisconsin are of particular importance because they could provide a record of the complex Quaternary physiographic history of the Upper Midwest region, and a history of pre-Quaternary karst landscape evolution.

There are several potential sources of sinkhole sediments in southwestern Wisconsin. These can be divided into three categories: exposed bedrock sources, overburden sources, and exotic sources. Exposed bedrock sources are currently exposed bedrocks. Bedrock sources, Silurian and Ordovician sedimentary rocks which include dolostones, shale, and sandstone, could produce heterogeneous sinkhole sediments since they have different petrological characteristics and properties. Overburden sources are weathered materials (residuum) from different types of previously exposed bedrocks. Exotic sources could be alluvial sediments (Windrow formation) from paleo- fluvial processes, clastic sediments from glacial and peri- glacial processes, and Pleistocene aeolian silt (loess) additions.

IV. Conclusions

Soils and sediments in sinkholes of the southwestern Wisconsin Driftless Area exhibit significant variations in depositional characteristics due to variable toposeqences, colluvial processes, parent materials, and anthropogenic activity. In this study we compare the soils and sediment sequences around the edge of one sinkhole with those at the center of the same sinkhole. The sediment sequences in these two locations might be expected to be different as the edge of the sinkhole is translational but the center of the sinkhole is depositional. Although much of the surface of the Wisconsin karst is mantled by wind blown silt (loess), sediment in the Seneca sinkhole contains considerable sand (39.9 %) which is derived from upslope sandstone outcrops. At the edge of the sinkhole sediment has a loamy texture and strong blocky structure, however, the center of the sinkhole has silt loams with very weak granular structure. In addition, chemical properties (pH and organic matter content) and color are also different. The edge of the sinkhole reflects a variety of slope processes and continuous soil development, whereas the center of the sinkhole shows the effects of long-term sediment deposition with at least one paleosol.

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