TOPOGRAPHIC, MICROCLIMATIC AND ANTHROPIC INFLUENCES UPON "A" HORIZON DEVELOPMENT IN SOILS FORMED IN GLACIAL OUTWASH: MARINETTE COUNTY, WISCONSIN

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Introduction

The major factors which affect soil formation are climate, organisms, relief, parent material and time (Jenny, 1941). These factors combine to influence what soil order forms at a particular locale. Climate is the driving force behind soil formation and more importantly, microclimate exerts a great influence upon localized soil development. Microclimate is the climate structure that exists close to the Earth’s surface which can be affected by the character of the surface materials, local relief and slope orientation.

Organisms (ie. microorganisms, termites, worms, trees, etc.) also affect soil development because they are: 1) sources of organic matter, 2) active in the breakdown of organic material and 3) agents for soil mixing. But the organism which possibly exerts the greatest impact upon contemporary soil development, especially surface soil horizons, is man. Man strips and plows the land which alters drainage patterns causing accelerated erosion, and intensive cropping degrades the soil resource. As a result of man’s influence upon soils, the soil classification Anthrosol was developed. Anthrosols are soils that have been materially affected in their physical or chemical properties by human activities (Bates and Jackson, 1987).

The type of parent material in which a soil forms also greatly influences the soil formation process. The mineral makeup and physical structure of the parent material influences the rate at which organic matter and chemicals within the surface organic horizons are leached into the soil profile thus forming soil horizons. As time passes and the soils are subjected to chemical weathering, the influence of parent material becomes less evident and soil properties become better developed.

The purpose of this paper is to assess the relationships between topographic position, microclimate, land use and development of the "A" soil horizon. Donahue and others (1977) define the "A" horizon as the uppermost soil horizon which is characterized by an accumulation of organic matter (A1), or accumulations of resistant minerals due to leaching of clay and/or sesquioxides (A2 - now called the "E" horizon), or a transitional horizon to the underlying "B" horizon (A3). In the context of this manuscript, "A" horizon refers to the A1 horizon as defined by Donahue and others. The term topsoil is a partial synonym for "A" horizon (Bates and Jackson, 1987) which perhaps better illustrates for the layman the importance of the "A" horizon in terms of soil fertility and ability to support plant growth.

Land use practices greatly affect the physical and chemical nature of the upper soil horizons and can cause accelerated erosion, decreased "A" horizon fertility and overall degradation of the soil resource. Land clearance for eventual farming removes the natural vegetation which is the source of organic materials. Crop residues provide lesser inputs of these materials and plowing mixes the upper twenty centimeters of soil making this zone more susceptible to erosion, especially on steep slopes. Intensive agriculture decreases soil fertility prompting the use of chemical fertilizers to replenish the minerals necessary for successful crop production. If unchecked, the soil resource can become so severely degraded that it is no longer economically viable to farm in these areas.

The Study Area

The study area is a 45 hectare tract in central Marinette County in the Mount Tom topographic quadrangle located at Township 33 N, Range 20 E, Section 17 (USGS, 1972) (Figure 1). The mean relief in the study area is nine meters and the topography is gently rolling with low areas occupied by a sphagnum bog, a black spruce swamp and a cedar swamp. Contemporary land use consists of tree farming, wildlife habitat proliferation through forest management and limited logging. Approximately 35 hectares of the study area are northern mixed forest, five hectares are former pasture and farm...
Figure 1 - Location of the Study Area - Mount Tom Wisconsin Quadrangle, Township 33 North, Range 20 East, Section 17, 1/4 Section Southeast.
fields, four hectares have been planted with white pine (Pinus strobus) and less than one hectare has been logged.

The study area soils have formed primarily in sandy glacial outwash, and are classified in the soil orders Spodosol and Entisol (Soil Survey Staff, 1975) (Reeder, 1990). The orders Entisol and Histosol (derived from organic parent material) were noted to form in the topographically low areas occupied by the bog and two swamps, and soils classified as Spodosols formed on hilltops and slopes.

The catena discussed in this manuscript was comprised of nine soil pits excavated along a north-south transect which extended nearly the entire length of the study area. Land use in the vicinity of pits one to five was formerly pasture and crop agriculture, and is currently tree farming at pits four and five. These soils were classified as Anthropic Spodosols because they exhibited both man induced "A" horizon alterations and reddish-brown sandy "B" horizons indicative of Spodosols. Pits six to nine were located amongst northern hardwood forest and were classified as Spodosols.

**Research Procedures**

The following data were collected at the nine soil profiles excavated along the north-south transect (Figure 2 and Table 1).

**Elevation** - The surface elevation of each pit was surveyed based on a 100 meter datum.

**Vegetation** - The types of vegetation found in the vicinity of each pit were grouped into the general categories (1) grasses, (2) planted conifers, (3) conifers, and (4) mixed conifers and deciduous.

**Land Use** - Land use was noted in the vicinity of each pit, which during subsequent data analysis proved to be an important factor affecting "A" horizon development.

**"A" Horizon Thickness** - The thickness of the "A" horizon was measured from the land surface to the center of the transition boundary with the underlying horizon.

**Soil pH** - Samples were collected from the center of each "A" horizon and were subsequently analyzed using the 2:1 soil solution pH method as described by Liegel and others (1980).

**Soil Color** - Color was also noted for each soil horizon (Munsell, 1975).

The ensuing discussion will focus upon land use in the vicinity of each pit, the parameters depicted in the cross section and how these parameters combine to affect the development of the "A" soil horizon.

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Table 1 - Summary of data for soil pits one to nine which were excavated along a north-south transect

<table>
<thead>
<tr>
<th>Pit #</th>
<th>&quot;A&quot; Horizon Thickness (CM)</th>
<th>Land Surface Elevation Based on a 100 M Datum</th>
<th>Type Vegetation Present</th>
<th>Diagnostic Horizon(s) Present</th>
<th>Soil Solution pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ap(20) A1(7)</td>
<td>108.0</td>
<td>Grass</td>
<td>Spodic</td>
<td>5.8</td>
</tr>
<tr>
<td>2</td>
<td>AP(9)</td>
<td>106.2</td>
<td>Grass, Conifers</td>
<td>Spodic</td>
<td>5.9</td>
</tr>
<tr>
<td>3</td>
<td>AP(20) A1(4)</td>
<td>104.1</td>
<td>Mixed</td>
<td>Spodic</td>
<td>5.9</td>
</tr>
<tr>
<td>4</td>
<td>AP(20) A1(2)</td>
<td>105.8</td>
<td>Planted Conifers</td>
<td>Spodic</td>
<td>5.9</td>
</tr>
<tr>
<td>5</td>
<td>AP(6)</td>
<td>105.1</td>
<td>Planted Conifers</td>
<td>Spodic</td>
<td>5.3</td>
</tr>
<tr>
<td>6</td>
<td>A1(8)</td>
<td>103.9</td>
<td>Mixed</td>
<td>Albic, Spodic</td>
<td>4.7</td>
</tr>
<tr>
<td>7</td>
<td>A1(7)</td>
<td>101.2</td>
<td>Conifers</td>
<td>Albic, Spodic</td>
<td>4.2</td>
</tr>
<tr>
<td>8</td>
<td>A1(21)</td>
<td>100.0</td>
<td>Mixed</td>
<td>Albic, Spodic</td>
<td>4.6</td>
</tr>
<tr>
<td>9</td>
<td>A1(11)</td>
<td>98.9</td>
<td>Conifers</td>
<td>Albic, Spodic</td>
<td>3.9</td>
</tr>
</tbody>
</table>
Figure 2 - A cross section depicting data collected from nine soil profiles.

Legend

- G - Grass
- PC - Planted Conifers
- C - Conifers
- M - Mixed Conifers and Deciduous

PH AND VEGETATION TYPE INDICATED

CROSS SECTION OF NORTH - SOUTH TRANSECT WITH A HORIZON THICKNESS.
The Spodosols in pits six to nine were noted to have strongly acid sandy "B" horizons where pH values ranged from 4.7 to 3.9 and ashy white "E" (A2) horizons over strong brown (7.5 YR 5/6), red (2.5 YR 4/6) or yellowish red (5 YR 4/6) spodic "B" horizons. The soils in pits one to five were classified as Anthropic Spodosols because evidence of human disturbance in the upper horizons was present and the subsols exhibited spodic characteristics similar to the soils in pits six to nine.

In pits one to five the upper portion of the "A" horizon was plowed and was classified as an "Ap" horizon. The "Ap" horizon was noted to extend to a depth of 20 centimeters in pits one, three, and four which corresponds to the depth of a furrow slice. Below this depth the "A" horizons were classified as A1 and exhibited no direct anthropic influence. In pits two and five the furrow slice also extend 20 centimeters below the surface, but because the "A" horizons were only nine and six centimeters thick respectively, the "plowed" horizon extended into the spodic subsols.

All nine pits have Spodic "B" horizons which formed as the result of iron, aluminum and organic matter being leached out of the surface horizon, carried downward, and deposited in the subsoil (Huddleston and Kling, 1984). Pits six through nine have dark brownish gray (10 YR 4/2) or pinkish gray (7.5 YR 6/2) albic "E" horizons located just below the "A" horizon. These albic horizons are soil horizons from which clay and sesquioxides have been removed by intense leaching so that their color is determined by the sand particles and not their coatings. Albic horizons occurred only in soils which were not plowed. It can therefore be postulated that human intervention destroyed or inhibited the formation of albic horizons in the Anthropic Spodosols in pits one to five.

In pits two and five, slope wash possibly enhanced by erosion after plowing, sufficiently decreased "A" horizon thicknesses and the "E" horizon was possibly mixed into the "A" horizon. Also, higher soil solution pH values were noted to occur in the vicinity of pits one to five. Former land uses in these areas were pasture (grasses) and crop agriculture, hence the natural mixed deciduous and coniferous forest was cleared. The natural forest produced more acidic litter which lowered soil solution pH and increased leaching which caused the formation of an albic "E" horizon. Once the forest was cleared, the sources of the acidic organic materials were removed, soil solution pH values increased, leaching decreased and the gray "E" horizons' soil particles were eventually coated with organic matter and incorporated into the "A" horizon.

Approximately ten years ago, about four hectares, where soil pits three and four are located, were planted with white pine trees. Eventually this coniferous vegetation will lower soil solution pH values and an albic horizon will begin to develop.

Soil pits six through nine were located in areas of natural forest which was composed of mixed deciduous and coniferous or exclusively coniferous forest growth. Soil solution pH values were 4.2 and 3.9 in the vicinity of coniferous growth and 4.7 and 4.6 in areas of mixed deciduous and coniferous growth. Pits six through nine were all noted to have well developed albic horizons with pit nine's "E" horizon 15 centimeters thick. The thickness of the albic horizon in pit nine is a result of mature coniferous growth, which is approximately 80 years old and has a maximum diameter of one meter, which lowered soil solution pH and enhanced leaching, which led to the development of the thick "E" horizon. This increased leaching in the albic horizon inhibits "A" horizon development because at lower pH values organic matter is quickly removed from the surface horizons thus enhancing "E" horizon development and inhibiting formation of the "A" horizon.

The thickness of the "A" horizons in pits six, seven and eight reflect interactions between topographic position, slope orientation, microclimate, the type of forest cover and soil solution pH. Pit six was located at the top of a north facing slope in an area of mixed deciduous and coniferous growth. Soil solution pH values in areas of mixed forest cover were previously noted to be intermediate between the higher values found in the Anthropic Spodosols at pits one to five and the lower values in the areas of exclusively coniferous growth at pits seven and nine. North facing slopes generally exhibit more microclimatic differences than south facing slopes. North facing slopes receive less sunlight which influences air and soil temperatures, the type of vegetation that will grow, the way water moves over and through the soil zone and the organic matter content of the soil. The cooler temperatures and the more intense slope wash on north facing slopes inhibits the development of organic matter. The microclimatic effect on "A" horizon thicknesses on north facing slopes and lower soil solution pH values in the vicinity of coniferous forest cover led to the formation of rather thin, eight and seven centimeters respectively, "A" horizons in pits six and seven.

The "A" horizon in pit eight was 21
centimeters thick, which is markedly thicker than the “A” horizons in pits six and seven. Pit eight is located in a nearly flat area below the north facing hillslope where pits six and seven were located. Slope wash effectively transported organic material from the hillslope to the flatter area in the vicinity of pit eight and the microclimatic conditions and slightly higher soil solution pH values caused the organic material to decay more slowly forming a thicker “A” horizon. The “A” horizon thinned toward pit nine because, as previously mentioned, lower soil solution pH values due to mature coniferous forest growth inhibited formation of the “A” horizon and proliferated formation of the “E” horizon.

Summary and Conclusions

Anthropic disturbances brought about by land use changes altered the “A” horizon in the vicinity of pits one to five. Geomorphic processes, enhanced by plowing, in some instances accelerated slope wash therefore decreasing the thickness of the “A” horizon. Plowing also mixed the upper 20 cm of soil prompting these zones to be classified as “Ap”. The “E” (A2) horizon, which probably existed beneath the natural mixed deciduous and coniferous forest cover, was mixed with overlying soils after forest clearance during plowing in pits three and five where the “A” horizon was less than 20 cm thick. Forest clearance removed the sources of acidic organic matter, increased soil solution pH values, decreased rates of leaching, and eventually organic matter coated the soil particles in the “E” horizon incorporating them into the “A” horizon.

Topographic position and orientation were noted to affect microclimate which in turn affected “A” horizon formation. These microclimatic variations affected the hydrologic regime developed on and within some of the study area soils and in some instances influenced the rate at which organic materials were transported and decayed, thus affecting the formation of the “A” horizon.

The type of vegetation adjacent to the soil pits was also noted to affect “A” horizon formation. Vegetation types were grouped into the general categories of grasses and planted conifers, which were located where the soils were classified as Anthropic Spodosols, and mixed deciduous and coniferous growth or exclusively coniferous growth, which were located in naturally forested areas. The type of vegetation found in a particular locale was noted to directly affect soil solution pH values which determined to what degree an albic horizon formed beneath the “A” horizon. The lower the soil solution pH, the more intensely leached the “A” horizon. This intense leaching led to a better developed albic “E” horizon, which in turn inhibited “A” horizon formation.

The thickness of the “A” horizon in the nine soil pits excavated along the north-south transect were noted to be controlled by complex interactions between various parameters, including Anthropic influences, related to forces which act upon or are related to the land surface. The combination of parameters have melded into a coherent progression of processes which over time sculpted the areas landscape, formed soils in the glacial outwash parent material and in this location, formed “A” horizons of various thicknesses.

Acknowledgements

I am particularly grateful to Mr. John Brinkmann, the landowner, for allowing me to conduct this research on his property. Appreciation is also expressed to Mike Kolb, Lab Manager at the Soils and Physical Geography Lab at UW-Milwaukee, for reviewing this manuscript and Donna Schenstrom, director of the UW-Milwaukee Cartographic Services Laboratory and cartographer Linda Estowski who prepared Figure One.

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