INCIPIENT SOIL DEVELOPMENT ON BASAL TILL, NASHVILLE CEMETERY SITE, DARKE COUNTY, OHIO

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INTRODUCTION

Basins in glacial environments begin to fill with sediment soon after their formation. They are good traps for windblown silt, and rainwater washes fine material from the walls of the basin to the bottom. Nevertheless, there is usually a recognizable contact between the basal till and the overlying postglacial sediments in our cores. If the basal till was exposed long enough, high-resolution chemical analyses of the upper portion of the till should show trends indicating the selective removal of mobile elements. This paper attempts to provide a first approximation of the basin exposure time through study of chemical trends in the upper portion of the till at the bottom of one basin.

Chemical studies of soils on glacial materials in Ohio have typically been restricted to post-Wisconsinan soils exposed at the surface (such as Smeck and Wilding, 1980). However, the surfaces on which these modern soils are developed have been exposed for at least 10,000 years. They are not, therefore, good analogues to the weathering profile, if any, at the bottom of our sediment core, which formed over a few hundred years at most. Soils developed on late Holocene deposits are closer in age to that in our coring basin, but chemical studies of these soils (such as Burt and Alexander, 1996; Lichter, 1998; and Birkeland, 1994) preferentially include well-drained profiles, especially those on moraines. This paper is, therefore, unusual, in that it uses chemical trends to study a briefly exposed and poorly drained surface.

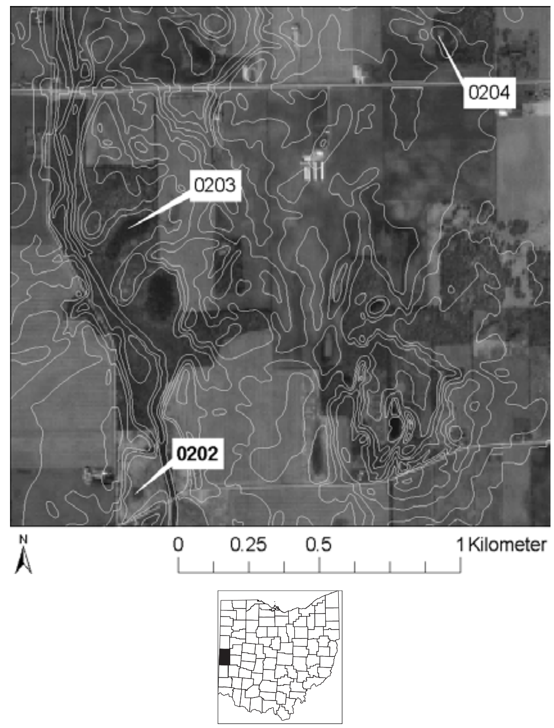

Figure 1. Location of Darke County (in black) and context of study site (0202; in boldface), including relationship of study site to two other coring basins (0203 and 0204). Contour interval 5 feet. County outlines from Wells (2000).

SITE DESCRIPTION

Site 0202 is located just northeast of the intersection of Palestine-Union City and Nashville Roads on the Greenville West, OH 7.5-minute quadrangle map. See Figure 1 for the location and context of the site. Its latitude and longitude are 40.093317° N and 84.74343° W. The site is well within the southern limit of Wisconsinan drift, but still south of the Union City moraine. The local drainage flows northward, emptying into a former ice-marginal stream (Greenville Creek) that runs parallel to the Union City

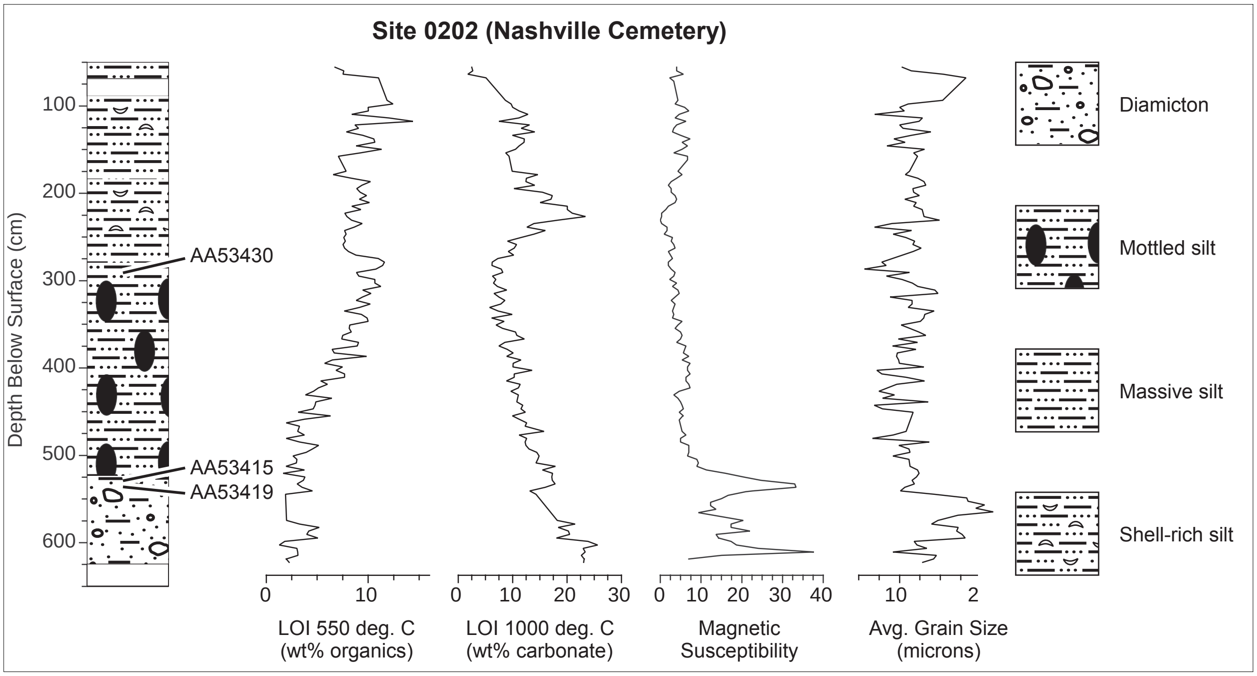

Figure 2. Graphic log with loss-on-ignition (LOI), magnetic susceptibility, and average grain size data. Character strings next to graphic log (e.g., AA53419) refer to radiocarbon samples whose dates are listed in Table 1.

moraine. There is a large hill, which may be a kame, about a kilometer to the east of the site.

The basin itself is ovoid, and appears as a dark spot on aerial photographs. It is about 60 meters long from north to south. There is a shallow channel at either end of the basin. Probe rods driven into these channels encountered rocks and loose stones within about a meter of the surface. The basin may originally have drained water from the glacier margin.

METHODS

We extracted our sediment core using a modified Livingstone piston corer (Wright, 1967). The Livingstone corer extracts a core from a borehole in 1-meter segments ("thrusts"). Recovery in any given borehole is rarely total, and there is usually some loss between thrusts. To compensate, two closely spaced cores were taken. The second core was offset vertically by half a meter from the first one, so that the gaps between thrusts in the first core were covered by material recovered in the second core. Once extracted, the thrusts were extruded, described, and enclosed in split PVC pipes for transport.

After the thrusts were delivered to the workshop, they were cut lengthwise to expose their internal stratigraphy. They were described individually, and correlated based on field notes and sedimentary structures. They were also analyzed at four-centimeter intervals for magnetic susceptibility, average grain size of the fine fraction, and loss of organic carbon and carbonate on ignition.

Organic matter was extracted from different depths within the core (see Figure 2) for accelerator mass spectrometry (AMS) radiocarbon dating. The samples were sent to the Limnological Research Center at the University of Minnesota for preparation, and the mass spectrometry was done at the University of Arizona’s AMS laboratory.

Chemical data for the upper part of the till was obtained using X-ray fluorescence (XRF). The ten centimeters of core immediately below the till/fill contact were cut into slices, each one centimeter thick. Each slice was dried, crushed in a mortar, and passed dry through a #18 sieve, which has openings 1 millimeter wide. The sieving process removed the coarse sand and pebble fraction of the till, which probably does not participate in the earliest stages of weathering. The fines from each slice were then ground to a fine powder in a SPEX ball mill with a tungsten carbide cylinder. The powder was poured into a cylindrical die and pressed into discs under a force of about twenty tons. These ten discs were run through

Table 1. AMS radiocarbon dates.

Lab code	Depth (cm)	Material	Uncalibrated age (^{14}C years)	Calibrated age (calendar years) 1σ: maximum (intercept) minimum
AA53430	298-299	Leaf fragments	14,588 ± 79	15,789 (15,517) 15,258
AA53415	529	Twig and leaves	15,934 ± 95	17,387 (17,066) 16,759
AA53419	534	Twig and pieces of bark	15,869 ± 91	17,309 (16,991) 16,688

a Rigaku 3070 X-ray spectrometer. The intensity data from the XRF machine was reduced to concentrations of various elements using a multiple regression technique. The multiple regression technique is designed to eliminate interference from multiple elements with peaks in the same range.

RESULTS

Results of the magnetic susceptibility, loss-on-ignition (LOI), and average grain size analyses are given in Figure 2. Note that the magnetic susceptibility and grain size of the till is both greater and more variable than that of the overlying silt. Also note that the shelly zone between 200 and 250 cm stratigraphic depth produces a peak in the LOI 1000 degrees plot.

Figure 2 shows the stratigraphic positions of the radiocarbon samples. Table 1 gives the uncalibrated and calibrated dates, in radiocarbon and calendar years, respectively, derived from these samples. Calibration was done using CALIB software (HTML version 4.2; Stuiver et al., 2000). The lower two dates are remarkably similar, and with the uppermost date, they bracket the mottled silt package. Deposition must have been relatively rapid over that interval, since those 2.3 meters of sediment accumulated in about 1,500 calendar years.

Plots of selected major elements, plus Zr, as a function of depth are given in Figure 3. The error bar on each data point has a width equal to one standard deviation of the results from nine analyses for that element on a single standard of known composition. For some of the selected elements (Ca, Mg, Zr), the error bar is so narrow that it cannot be seen on these plots.

DISCUSSION

If there is a soil developed on the upper surface of the till, mobile elements should increase in concentration with depth, while the trends of immobile elements should decrease with depth. The bedrock north of the site is Silurian dolomite and shale. Since calcite and dolomite are somewhat soluble in the weathering environment, Ca and Mg should be mobile. Zr and Ti have been used as immobile elements in soil studies on glacial materials elsewhere in Ohio (Smeck and Wilding, 1980). Si and Al may be proxies for the amounts of silicates and clay minerals, respectively, in each sample.

There is some provisional evidence for soil development in these graphs. If we accept Si and Al as proxies for silicates and clay minerals, their graphs indicate that these components of the parent material are being selectively enriched as the more soluble carbonates are removed. This interpretation is reinforced by the graphs of Zr and Ti, which decrease with depth, and Ca and Mg, which generally increase with depth. Following this interpretation, the soil is developed from 0 to 7 centimeters depth below the till/fill contact.

There is a zone about three centimeters thick at the till/fill contact that contains pieces of wood disseminated through a silty matrix. These pieces are oriented sub-horizontally. If they had been washed to the bottom of the basin with their matrix, they would have a random arrangement, rather than lying flat. Instead, they probably grew in place on the till. This zone may represent several cycles of plant growth followed by low-energy burial events, possibly from standing water trapped in the basin. This organic-rich zone corresponds approximately to the top three centimeters of the chemical graphs, and may

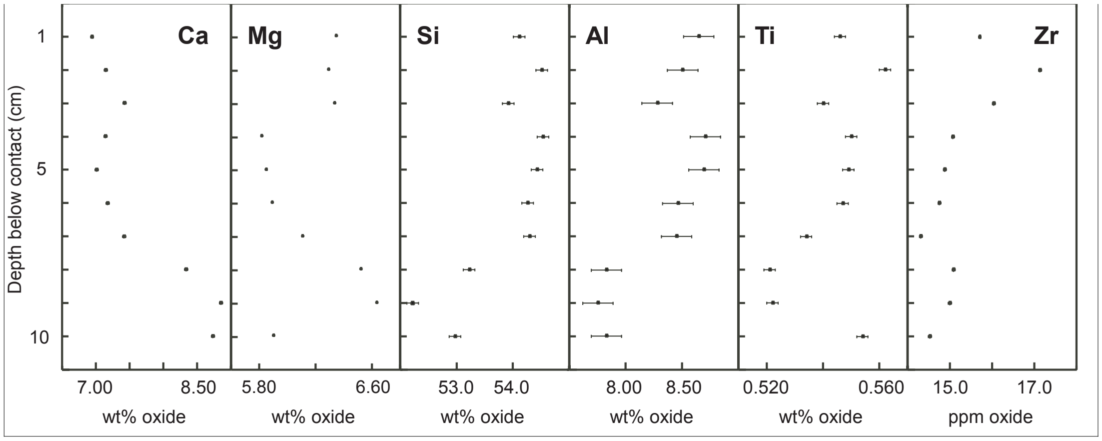

Figure 3. Chemical trends in top ten centimeters of core below the till/fill contact. Error bars have a width equal to one standard deviation of results from nine analyses for that element on a single standard of known composition. For Ca, Mg and Zr, error bars are too narrow to see in this figure.

explain the unusually high values of Mg in that range.

Accepting that the chemical data does indicate soil development, we return to the question of how long the bottom of the basin sat exposed. The time of exposure cannot be determined through comparisons with similar profiles described in the literature, because there have been few (if any) other studies of incipient soil development on poorly drained surfaces. The most that can be said is that burial did not occur immediately. If the organic horizon represents several generations of plants separated by burial events, the exposure time must have been at least several years. Any further study of this question will need to include an assessment of the colonization time of small plants in modern glacial basins, as well as incipient soil development in that setting.

ACKNOWLEDGEMENTS

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