Trace Element Trends In Sediment Cores From Crab Meadow Marsh, Northport, NY: Evidence for the Great Acceleration and the start of the Anthropocene in the recent sedimentary record

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Abstract

Crab Meadow marsh is a tidal wetland on the north shore of Long Island, New York near the town of Northport (Figure 1). To investigate the environmental history of the marsh we collected 1-2 meter sediment cores by driving hollow aluminum pipe into the subsurface using a vibracoring apparatus. Four cores were extracted from different locations in the marsh (Figure 2), split, photographed, and sampled in centimeter increments using non-metallic instruments to decrease the possibility of metal contamination. Following preparation, selected samples throughout the cores were sent to a commercial lab and analyzed to determine their trace element composition. We also performed grain size analysis on selected samples using wet and dry sieving through a standard sieve series and Rotap process. Plotting trace metal concentrations against depth within the cores revealed trends in trace element concentration (Figures 3-6). The most significant trend that can be observed is the substantial upsection increase in parts per million of the elements Copper (Cu), Lead (Pb), and Zinc (Zn) in all four of the cores. Between a depth of twenty to thirty centimeters, the concentrations of each three of these metals reach their maximum values near the top of the cores. The overall trends up through the cores resemble the famous "hockey stick" shape of exponential increase (Figure 7). The cores vary in sediment type throughout different depths, and minor trends seen in these elements do correlate to the percentage of fine sediment at different levels. However, the significant increase in trace metal concentrations seen near the tops of the cores cannot be attributed to sediment effects. The increasing levels of the metals Cu, Pb, and Zn found in all four of the Crab Meadow cores is consistent with the pattern of exponential increase associated with the "Great Acceleration" in human impact on the global environment that began after World War II. The anthropogenic input of metals into the atmosphere by industrial activities in the Long Island region is recorded in the marsh environment, leaving a marker for the beginning the Anthropocene, also known as the geological Age of Man.

The Great Acceleration and the Anthropocene

The "Great Acceleration" is the term used to describe the exponential increase in human impact on Earth systems associated with the corresponding exponential growth in human population and global human activity that began in the 1950s following the end of the Second World War (Steffen et al. 2004) . The most familiar manifestation of the Great Acceleration is the exponential increase in anthropogenic carbon dioxide produced by the burning of fossil fuels, which when graphed produces a curve resembling an upturned hockey stick. Impacts associated with the Great Acceleration on the function of geological processes that are preserved in the sedimentary record could provide the basis for formal recognition of the Anthropocene - a new geological epoch defined as the age of human domination of Earth systems.

<u>Location</u>

Sediment cores were collected from 4 locations in the high marsh at Crab Meadow in Northport, NY (Figure 1).

Core	Longitude W	Latitude N
CM1	73.323340	40.926156
CM2	73.323982	40.926507
CM3	73.324628	40.925850
CM4	73.325115	40.924929

Figure 1. Coring localities within the Crab Meadow Marsh, Northport, NY.

Vibracoring Method

A concrete vibrator is attached to a length of 3" diameter aluminum pipe and used to drive the pipe into the marsh substrate. After capping the pipe, a truck jack is used to pull the pipe out. The core pipe is cut lengthwise in the lab and split to reveal the stratigraphy of the marsh. Each core was sampled at 1 cm intervals for trace element and grain size analysis.

Figure 2. Photomontage illustrating the vibracoring process. From top left: positioning the hollow core tube, starting the motor to vibrate the core tube, driving the vibrating core tube into the marsh subsurface (middle row images), extracting the core, and splitting, photographing, and sampling the core.

Results and Data

Stratigraphic diagrams of the cores are presented below with plots of the percent fine sediment (silt and clay particles less than 63 um in diameter) and trace metal concentrations (ppm) for sampled levels in the cores.

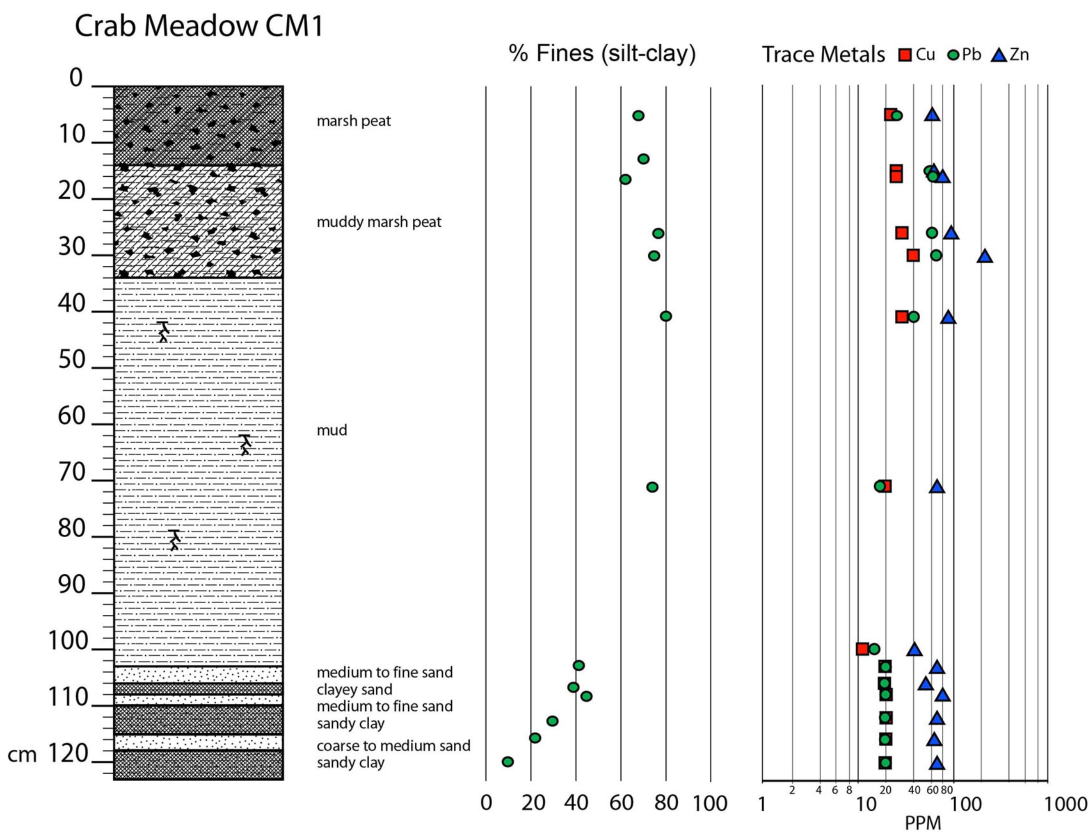

Figure 3. Stratigraphic diagram and associated data for core CM1.

Core CM1 penetrated approximately one meter of predominantly fine-grained sediments consisting of peat and organic-rich silt and clay muds, overlying 20 cm of sand and muddy sand. Trace metal concentrations in the lower part of the core are similar for the sandy and muddy layers, indicating background (pre-industrial) levels of 20 ppm for Cu and Pb and 60 ppm for Zn. Trace metal concentrations begin to rise between 70 cm and 40 cm and Pb concentration peaks between 30 cm and 15 cm below core top.

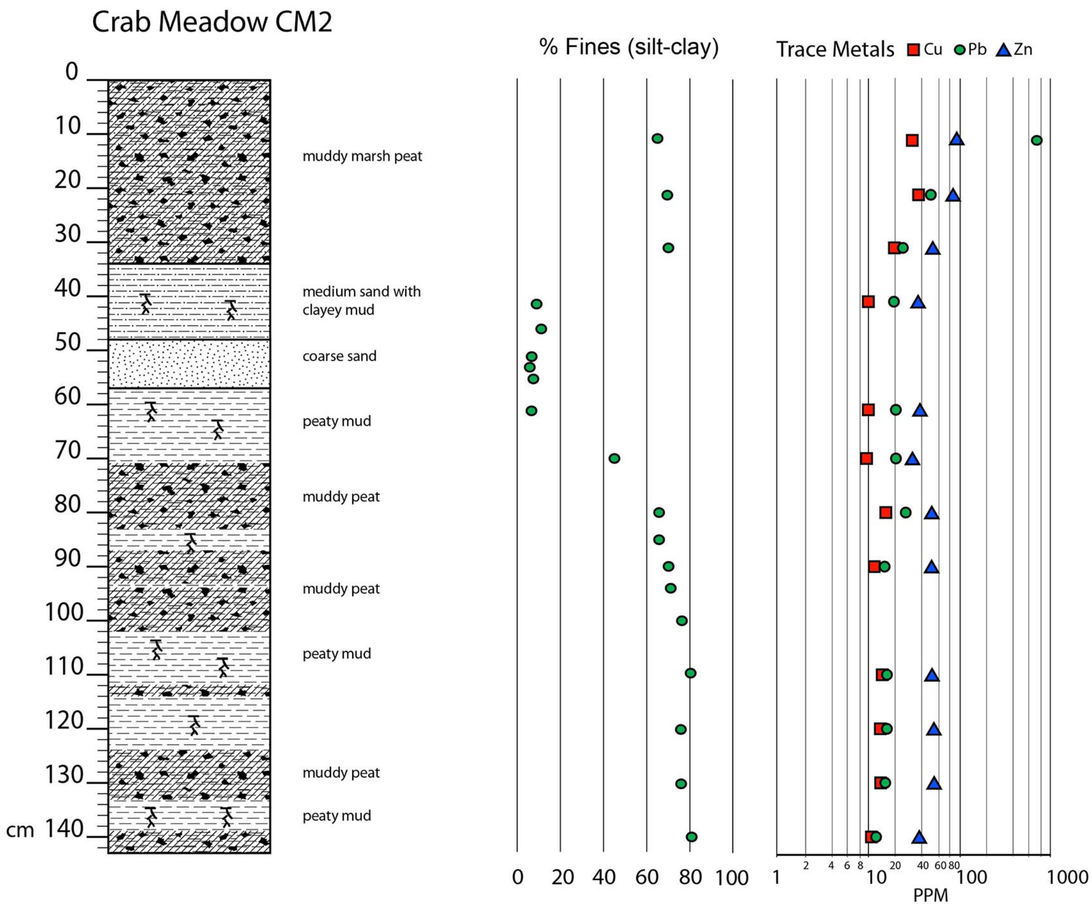

Figure 4. Stratigraphic diagram and associated data for core CM2.

Core CM2 penetrated approximately 1.4 meters of predominantly fine-grained sediments consisting of peat and organic-rich silt and clay muds interrupted by a 10 cm interval of coarse sand between 48 cm and 58 cm. Trace metal concentrations in the lower part of the core indicate background (pre-industrial) levels of 10-20 ppm for Cu and Pb and 40-60 ppm for Zn. Trace metal concentrations begin to rise between 90 cm and 80 cm and Pb concentration peaks between 20 cm and the core top. The anomalously elevated lead measurement at 12 cm is likely erroneous.

The sandy interval between 48 cm and 58 cm appears to be a tempestite. Of the four cores collected CM2 is most proximal to the shoreline and thus more likely to have penetrated a lobe of storm overwash sand extending into the marsh from the beach.

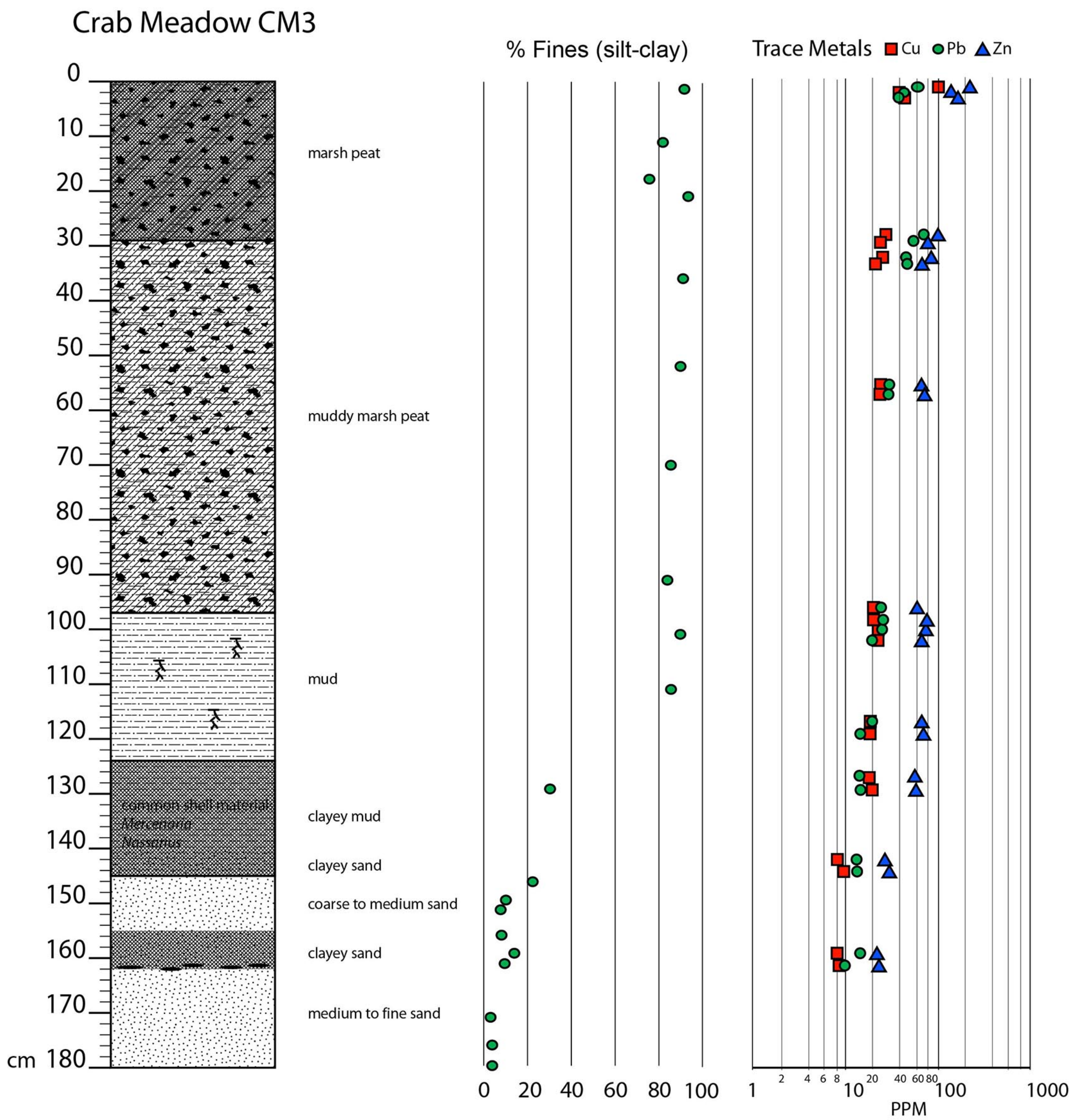

Figure 5. Stratigraphic diagram and associated data for core CM3.

Core CM3 penetrated approximately 1.4 meters of predominantly fine-grained sediments consisting of peat and organic-rich silt and clay muds, overlying 40 cm of sand and muddy sand. Trace metal concentrations in the lower sand-dominated interval of the core are lower than in the overlying mud-dominated deposits (10-15 ppm vs 20-25 ppm for Pb) but this difference is likely due to the lack of fine material in the lower sandy intervals. In the mud-rich sediments background (pre-industrial) levels are 15-20 ppm for Cu and Pb and 60-80 ppm for Zn. Trace metal concentrations begin to rise between 55 cm and 30 cm and Pb concentration peaks between 30 cm and the core top.

Subfossil remains of juvenile marine mollusks and calcareous foraminifera were observed in the muddy sands at the bottom of the core, indicating that a more open-marine environment such as a sheltered bay existed at this time. Alternatively, this interval could preserve the remains of a tidal channel.

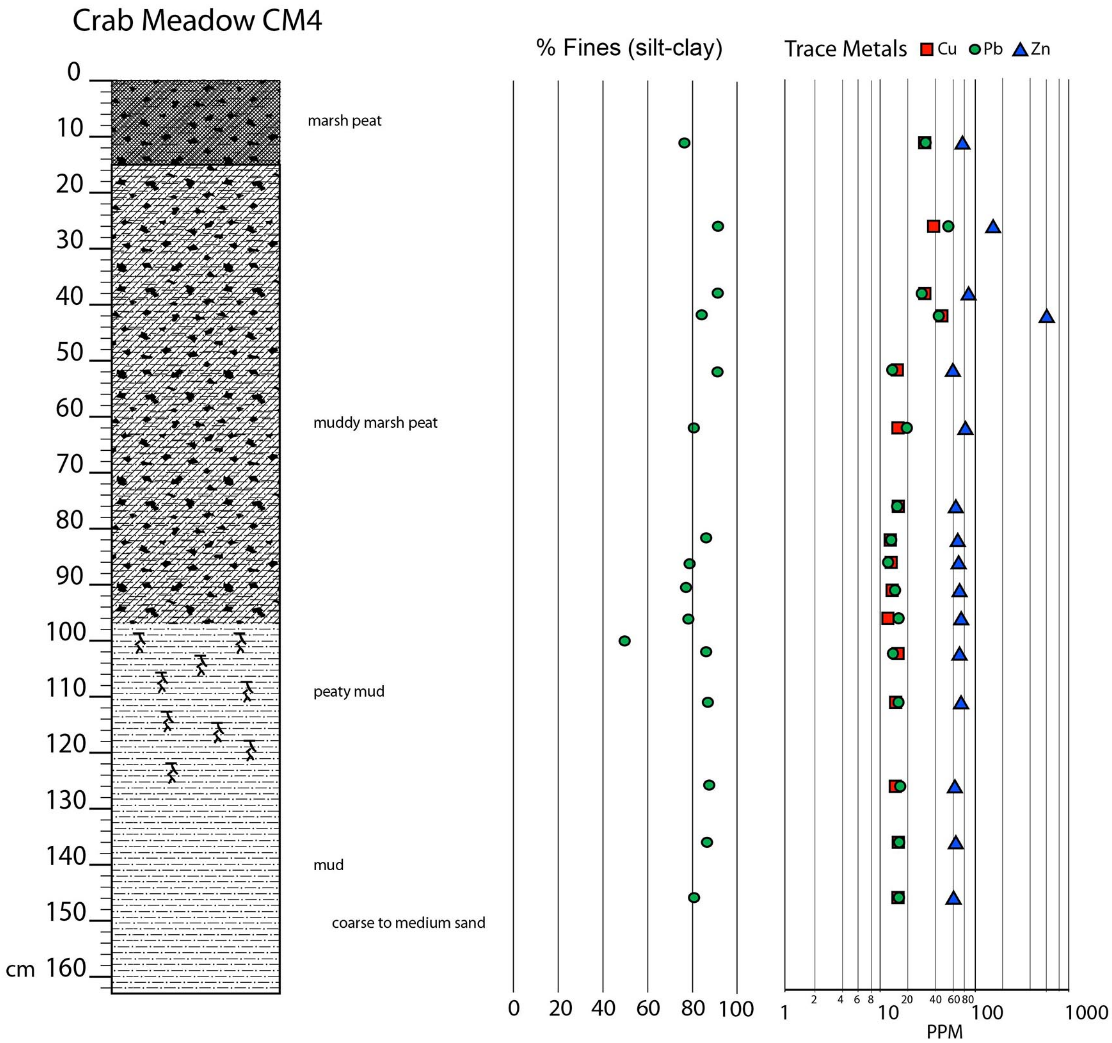

Figure 6. Stratigraphic diagram and associated data for core CM4.

Core CM4 penetrated approximately 1.6 meters of predominantly fine-grained sediments consisting of peat and organic-rich silt and clay. Trace metal concentrations in the lower part of the core indicate background (pre-industrial) levels of 15-20 ppm for Cu and Pb and 60-65 ppm for Zn. Trace metal concentrations begin to rise between 50 cm and 40 cm and Pb concentration peaks aroung 25 cm.

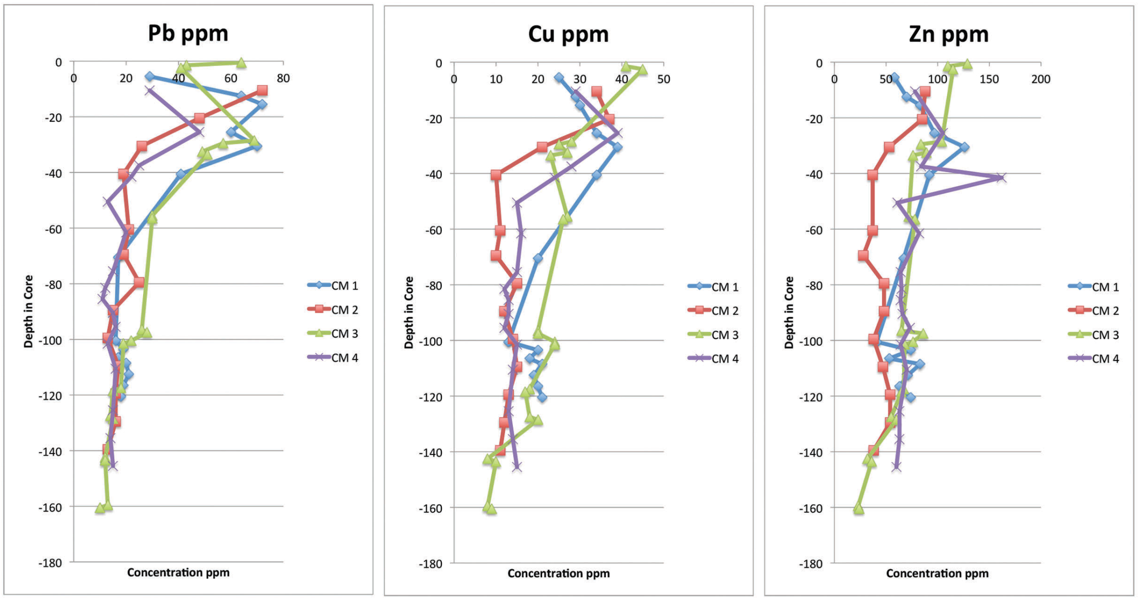

Figure 7. Plots of trace metal concentration (ppm) in all cores for lead, copper, and zinc.

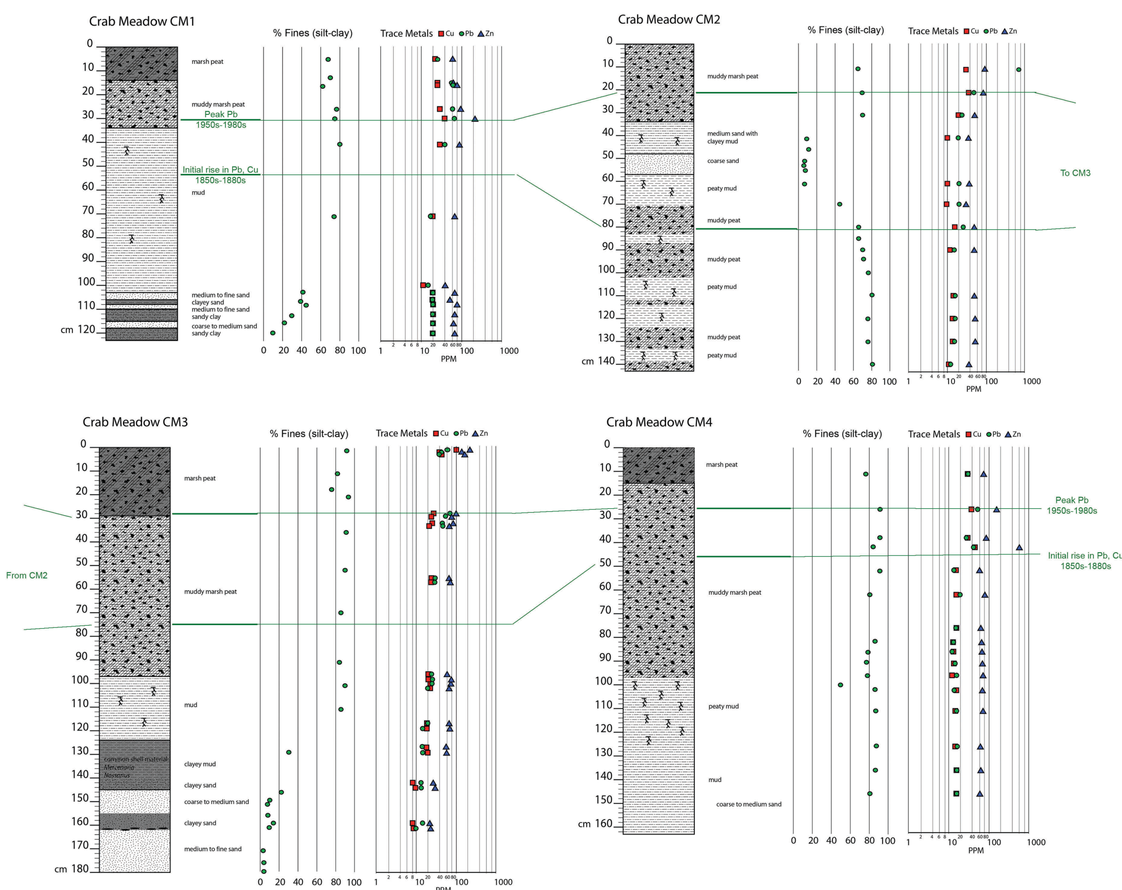

Figure 8. Chronostratigraphic correlation of all four cores based on initial rise in lead concentration above background levels and peak lead concentration.

Discussion:

Trace metals are deposited in marsh sediments via runoff, tidal flow, and atmospheric deposition from local, regional, and global sources. The anoxic chemistry of marsh sediments causes the industrial metals copper (Cu), lead (Pb) and zinc (Zn) to complex with sulfate and remain immobilized in the sediments (Cochran et al. 1998). Trace metal levels have been shown to correlate with the silt and clay content of the sediment (Moffett, Poppe, and Lewis 1994), therefore trace metal trends must be interpreted against trends in sediment composition in the cores. For Pb, pre-industrial (prior to the 1850s) concentrations of 20 ppm and post-industrial concentrations up to 60 ppm have been previously reported in estuary sediments in western Long Island Sound (Balbas et al. 2009). Scileppi and Donnelly (2007) use the initial rise in Pb and Cu levels above background levels in sediment cores from Long Island marshes as indicative of the mid-late 1800s (1865-1885). Peak Pb levels in sediment cores have been reported to correspond to the peak in consumption of leaded gasoline in the United States from the 1950s to the 1980s (Cochran et al. 1998). The post-industrial increase in metal pollutants associated with the mid-1800s industrialization of the United States and the steep increase associated with the late 20th Century and the "Great Acceleration" are shown in the Crab Meadow sediment cores (Figures 3-6) and can be used to establish a rough chronostratigraphy for the upper section of the cores (Figure 8). We suggest that the decrease in metal concentrations seen approaching the tops of the cores (Figure 7) likely result from the phasing out of leaded gasoline in the 1980s and the overall change in the post WWII regional economy away from manufacturing, as well as the increasing regulation and control of industrial emissions in the United States.

References:

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