BIOGEOCHEMICAL ACTIVITY OF CRITICAL ZONE CLAYS ON LONG ISLAND'S NORTH SHORE

Vanessa M. Alfonso[1], Peter M. Groffman[1], Zhongqi Cheng[1], David E. Seidemann[1]

[1]Department of Earth and Environmental Sciences, Brooklyn College of the City University of New York

2900 Bedford Ave, Brooklyn, NY 11210

Abstract

Late Cretaceous clays exposed at three sites located on the north shore of Long Island, New York were sampled to explore questions about how contemporary factors and processes interact with ancient geological materials. Chemically and biologically catalyzed weathering processes have produced multi-colored clays belonging to the kaolin group with inclusions of hematite, limonite, and pyrite nodules. We sampled exposed clays at three sites to address three questions: 1) Do these exposed clays support significant amounts of microbial biomass and activity, i.e, are they alive? 2) Do these clays support significant amounts of nitrogen (N) cycle activity? 3) Are these clays a potential source of N pollution in the contemporary landscape? Samples were analyzed for total C and N content, microbial biomass C and N content, microbial respiration, potential net N mineralization and nitrification, soil nitrate (NO_3^-) and ammonium (NH_4^+) content, and denitrification potential.

It is generally assumed that geologic materials are not an important source of N for contemporary ecosystem processes (Schlesinger, 2013). Most of the primary rocks that make up the Earth's core and mantle contain very little N, and the dominant global pool of N is in the atmosphere. The focus of much N cycle research is on the energetically expensive movement of atmospheric N into biological pools (Galloway et al., 2004). The largest pools of N in ecosystems are in particulate and dissolved organic matter (OM) pools in soils, sediments, and the ocean (Groffman et al., 2021). More recently recognition of the fact that much of this organic N becomes incorporated into geological materials has stimulated interest in the role of these materials in contemporary ecosystem processes. Recent analyses show that 10^{21} of global fixed N was incorporated into sedimentary rocks by the burial of OM in marine and freshwater sediments (Morford et al., 2011). These analyses have led to studies of the movement of deeply buried organic N into actively cycling pools of N in soils and vegetation (Houlton et al., 2018) and interest in the exposure of ancient materials at the soil surface, such as the clays collected for this study.

At our study sites, burial of OM likely occurred in a shallow delta or estuary where the Late Cretaceous deposits of the western north shore of Long Island were formed (Fuller, 1914; Swarzenski, 1983). The N content of these samples is within the range of previous reports of sedimentary and metasedimentary rock N content of 200 – 1200 mg N kg^{-1} (Holloway and Dahlgren, 1998). Organic-rich marine sediments commonly exceed 1000 mg N kg^{-1} and some of our samples fit these criteria (Li, 1991). As these bedrock materials weather, N is released in plant available forms that stimulate ecosystem productivity and C storage (Dahlgren, 1994). Bedrock is also a source of N to aquifers, which is a concern with our samples which have a hydrogeologic origin from exposures of aquifer margins in a region with great concern about groundwater N pollution (Karamouz et al., 2020).

The surface exposure of the clays in our study allowed us to directly measure microbial biomass and activities that are central to biogeochemical cycling of C and N. These measurements shed light on the role that these weathered secondary minerals may be playing in the contemporary N cycle on Long Island and in the Critical Zone elsewhere on Earth. These measurements also allowed for comparison of these geological materials with surface and subsurface soils in the region that have been assayed with the same methods (Downey et al., 2021; Mejía et al., 2022; Morse et al., 2014). Our analysis showed significant microbial biomass and activity in many samples, with much of the variation in activity driven by the total C and N content of the samples. The results strongly support the idea that ancient geologic materials play a role in contemporary N and C cycling in the Critical Zone.

Figure 1a

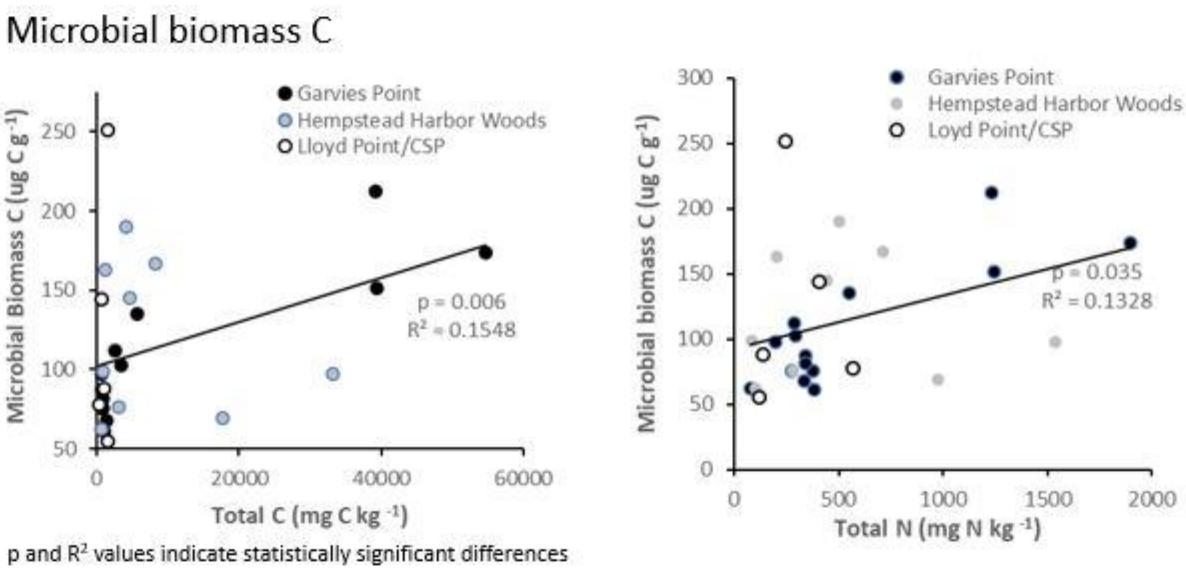

Figure 1b

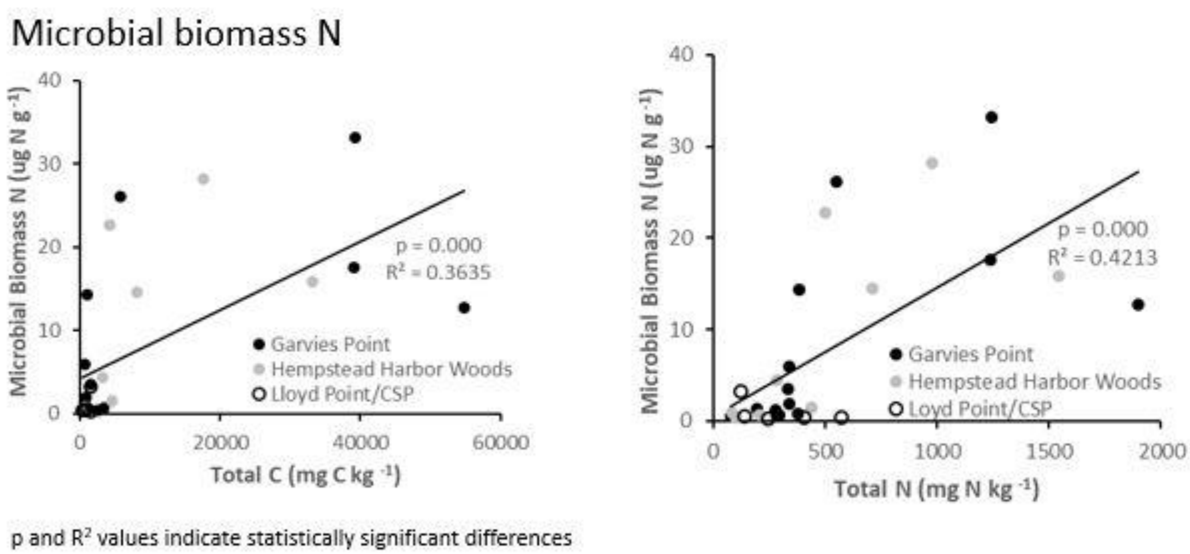

Figure 1 (a-b): Relationships between microbial biomass C and N, and total C and N content.

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