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Pedogenesis and landscape relationships of a Holocene age barrier island

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ABSTRACT

Soil characteristics and pedogenic processes are relatively unstudied on Holocene age barrier islands in the Mid-Atlantic region of the United States. The objective of this study was to assess how landform stability and hydrologic conditions (water availability) influenced pedogenesis in barrier island soils. Ten topographic transects were established on different barrier island landforms (i.e., washover fan, back-barrier flat, barrier flat, and dune field) which ranged in age from 1 to 228 years. The topographic transects spanned drainage conditions, ranging from very poorly to excessively drained. The primary evidence for pedogenesis across the chronosequence was in the accumulation of organic matter, expressed in the formation of A and O horizons. Pedogenic development was restricted by the young age and weathering resistant nature of the soil parent material. The close proximity of the water table to the soil surface was associated with greater organic matter inputs from vegetation and slower decomposition under anaerobic conditions, which together led to increased accumulation of organic carbon in lower, wetter landscape positions. Frequency and duration of saturation also impacted subsoil development, producing subtle, but noticeable color differences between oxidized and reduced horizons.

1. Introduction

Barrier islands are an important geomorphic component of coastal zone ecosystems. They make up about 15% of the world's coastlines and are particularly extensive along the east coast of North America (Glaeser, 1978; Ritter et al., 2002). Barrier islands are generally elongate, up to several kilometers long, less than 1–2 km wide, and composed of unconsolidated marine sediments (Davis, 1994). They are aligned roughly parallel to the mainland shore and are separated from the mainland by bays, lagoons, or marshes. The islands provide physical protection for the mainland and adjacent bays and marshes by absorbing the impact of storm surges and the direct wave action of the ocean (Stone and McBride, 1998). Existing at the interface between marine and terrestrial ecosystems, barrier islands provide a unique habitat essential to aquatic and terrestrial species that rely on both ecosystems for portions of their life cycle, nesting, reproduction, or food sources. In addition to providing an important ecological role, barrier islands are also valuable to humans for recreational, residential, commercial, and industrial purposes, and thus can face serious developmental pressures.

Barrier islands are young, dynamic environments and the relative roles of wave, tidal, and storm processes affect their size, shape, formation, and development (Beets and van der Spek, 2000; Davis, 1994). Barrier island systems can be divided into a number of different geomorphic units, including the beach, foredunes, barrier core, inlets, tidal marshes, and coastal lagoon. Differences in the marine and subaerial deposition and erosional processes across the island affect the landforms that develop. The relative stability of these landforms affects the establishment of vegetation and the duration of pedogenic processes. More extensive reviews of the formation, geomorphology, and landforms of barrier islands are provided by Beets and van der Spek (2000), Davis (1994), Leatherman (1979), and Oertel (1985).

Prior to the 1980s, soil mapping efforts on barrier islands in the United States were limited, and soils were typically lumped into miscellaneous land types, such as Coastal Beaches, Dune Sands, or Coastal Beach and Dune Land (e.g., Hall, 1973; Ireland and Matthews, 1974; Markley, 1977; Stevens, 1920). In more recent soil survey updates along the Mid-Atlantic coast, soil series have been developed and applied to barrier island landscapes (e.g., Barnhill, 1990, 1992; Demas and Burns, 2004; Gagnon, 2001; Hatch et al., 1985; Peacock and Edmonds, 1994; Soil Survey Staff, 2014b; Tant, 1992; Vasilas and Hole, 2002). However, understanding of the pedogenic processes and detailed characterizations of these soils have been limited (e.g., National Cooperative Soil Survey, 2014). While there has been extensive research on plant communities (e.g., Hill, 1986; Shao et al., 1996), ecological succession (e.g., Ehrenfeld, 1990; Tackett and Craft, 2010), and geomorphology and landform dynamics (Havholm et al., 2004; Kochel and Wampfler, 1989; Morton et al., 2007; Morton and Sallenger, 2003) on barrier islands in this region, studies of pedogenic processes in these systems has been limited. There have been more extensive studies of

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soil development in barrier island and coastal dune landscapes in other parts of the world, including northern Europe (e.g., Grootjans et al., 1998; Jones et al., 2008; Jungerius, 2008; Nielsen et al., 2010; Rohani et al., 2014), Canada (e.g., Protz et al., 1984; VandenBygaart and Protz, 1995), and Australia and New Zealand (e.g., Eger et al., 2011; Pye, 1981). Many of these studies have focused on early soil formation processes, particularly organic carbon accumulation.

The objective of this study was to better understand the processes and factors contributing to soil development on Mid-Atlantic barrier island landscapes. We focused on two factors, time (related to landform stability) and soil hydrology (reflected in topography). Since barrier islands are relatively small in area, the soil forming factors of climate and parent material are relatively constant across the island. The biotic factor influences soil development, but is itself influenced by the other soil forming factors. We hypothesized that age and landform stability will have a significant influence on observable soil properties. Additionally, within a given landform, soil characteristics will vary as a function of topography (which is closely related to hydrology).

2. Materials and methods

2.1. Study site

Assateague Island National Seashore, located along the eastern coast of Maryland and Virginia (Fig. 1), is approximately 60 km long, and ranges from 0.5 to 4.5 km wide. The island is separated from the mainland coast by Chincoteague and Sinepuxent Bays. Average annual air temperature on Assateague Island is 13.9 °C (Western Regional Climate Center, 2013). Average annual precipitation is 1100 mm (mostly as rainfall) and is fairly evenly distributed over the year (Natural Resources Conservation Service—Water and Climate Center, 2013).

Ten sites were selected to encompass the range of landforms and vegetation communities across the barrier island landscape (Table 1). Sites were located on dune fields, washover fans, barrier flats, and back-barrier flats. Landforms were identified using the terminology of the Natural Resources Conservation Service (NRCS) Geomorphic Description System (Schoeneberger and Wysocki, 2012). Vegetation ranged from relatively sparse herbaceous and dwarf-shrub species on

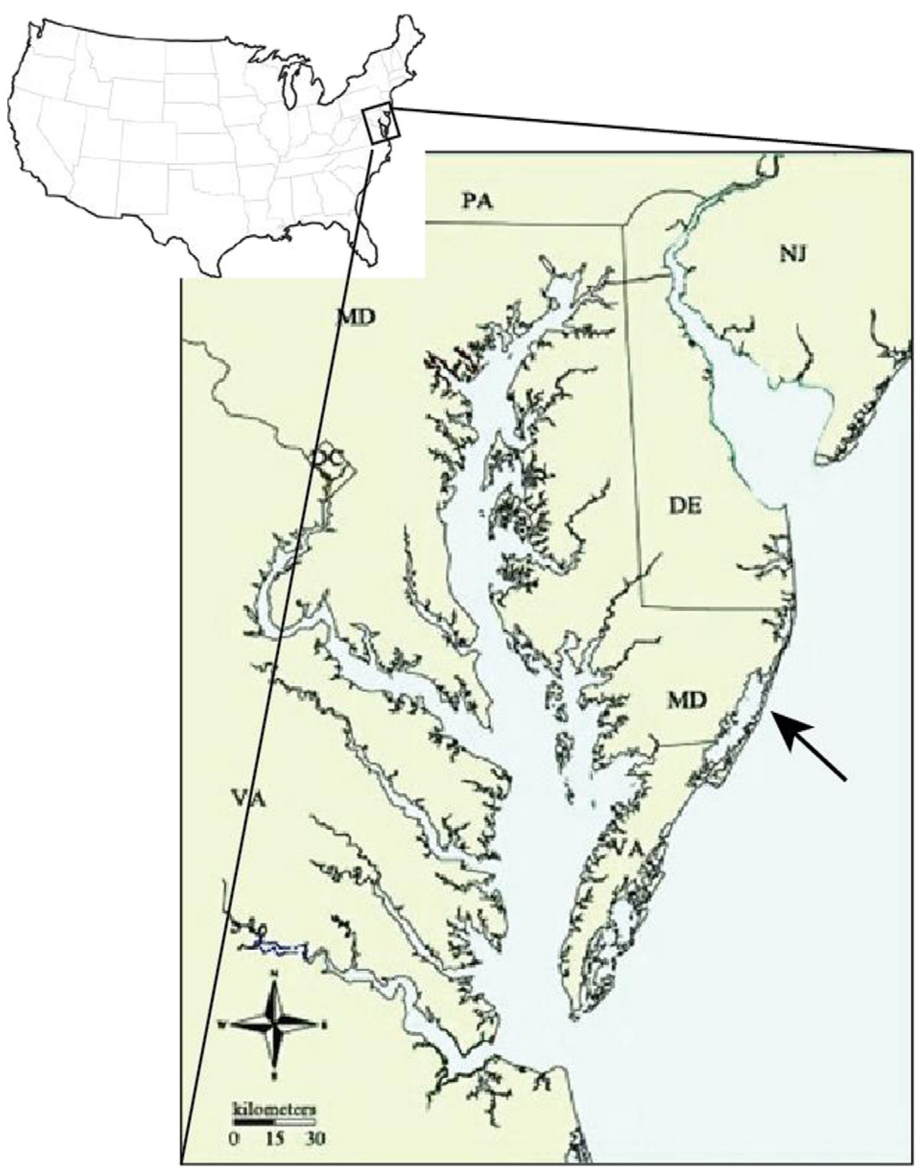

Fig. 1. Location of study sites at Assateague Island National Seashore, MD, USA. Regional map of Maryland and surrounding states showing location of Assateague Island (indicated by arrow).