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Parabolic dune reactivation and migration at Napeague, NY, USA: Insights from aerial and GPR imagery

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ABSTRACT

Observations from mapping since the 19th century and aerial imagery since 1930 have been used to study changes in the aeolian geomorphology of coastal parabolic dunes over the last ~170 years in the Walking Dune Field, Napeague, NY. The five large parabolic dunes of the Walking Dune Field have all migrated across, or are presently interacting with, a variably forested area that has affected their migration, stabilization and morphology. This study has concentrated on a dune with a particularly complex history of stabilization, reactivation and migration. We have correlated that dune's surface evolution, as revealed by aerial imagery, with its internal structures imaged using 200 MHz and 500 MHz Ground Penetrating Radar (GPR) surveys. Both 2D (transect) and high-resolution 3D GPR imagery image downwind dipping bedding planes which can be grouped by apparent dip angle into several discrete packages of beds that reflect distinct decadal-scale episodes of dune reactivation and growth.

From aerial and high resolution GPR imagery, we document a unique mode of reactivation and migration linked to upwind dune formation and parabolic dune interactions with forest trees. This study documents how dune–dune and dune–vegetation interactions have influenced a unique mode of blowout deposition that has alternated on a decadal scale between opposite sides of a parabolic dune during reactivation and migration. The pattern of recent parabolic dune reactivation and migration in the Walking Dune Field appears to be somewhat more complex, and perhaps more sensitive to subtle environmental pressures, than an idealized growth model with uniform deposition and purely on-axis migration. This pattern, believed to be prevalent among other parabolic dunes in the Walking Dune Field, may occur also in many other places where similar observational constraints are unavailable.

1. Introduction

The development and migration of aeolian dunes is a complex process that is strongly affected by factors such as wind strength and direction, sediment supply, and barriers to migration such as vegetation (McKee, 1979; Schenk, 1990; Lancaster, 1992; de Castro, 1995; Baas, 2007). Each type of dune morphology records a unique pattern of growth as it migrates downwind and deposits sands over the crest (McKee, 1979). Due to the sensitivity of aeolian dunes to environmental pressures, however, there are commonly anomalies or irregularities in the record of their growth, and it is important to understand what controls those anomalies and the corresponding changes in internal dune structures.

Traditionally, studies of dune dynamics and structure have relied heavily on deep trenches to expose stratigraphy hidden deep within the dune (e.g., Bagnold, 1941; McKee, 1966, 1979; Bigarella, 1979; Fryberger, 1990). Because of the destructive nature of trench digging, only a limited number of cross-sections could be obtained before the dune was, at best, partially destroyed. With the advent of GPR, it has become possible to study internal dune structures in an entirely new way (Schenk et al., 1993; Harari, 1996; Bristow et al., 1996, 2000; Pedersen and Clemmensen, 2005; Buynevich et al., 2007; Buyevich et al., 2007).

The aim of this paper is to use GPR-imaged internal dune structures and georeferenced maps and aerial images to document the development of parabolic dunes in space and time, focusing on the most active dunes in the Walking Dune Field of Napeague, NY. We find a distinctive mode of parabolic dune reactivation and migration characterized by changing positions of the blowout on the dune. These changes in blowout position appear to be influenced by the dune's response to the formation of younger upwind dunes (which alter the near surface wind flow) as well as by the dune's interactions with a forested area that has provided barriers (trees) to its reactivation and subsequent migration.

2. Regional setting

The Walking Dune Field (WDF) of Hither Hills State Park (Black, 1993, 1996; Dubecky and Maher, 1994) is a coastal parabolic dune

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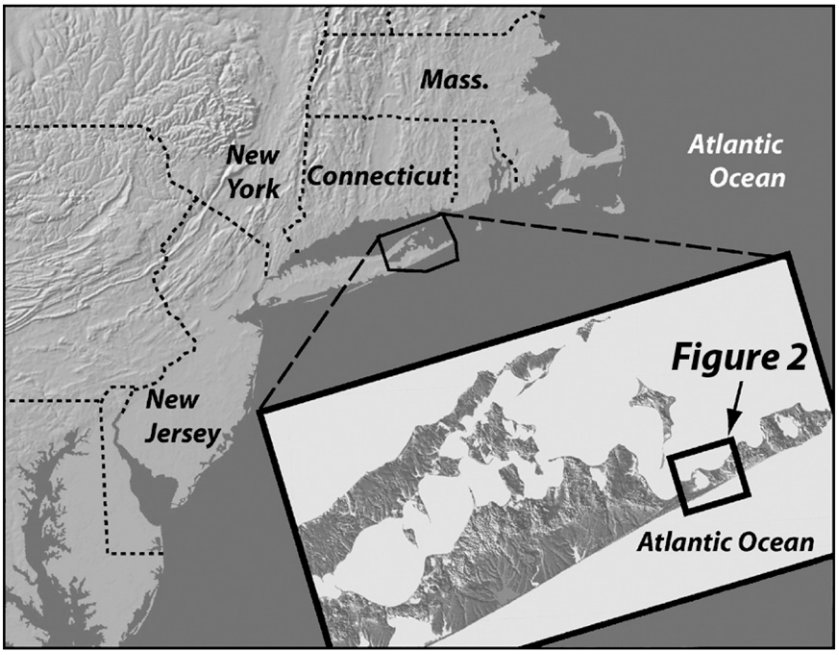

Fig. 1. The Walking Dunes of Napeague, NY are located atop the glacial sediments of the south fork of eastern Long Island.

field located along the south fork of eastern Long Island in Napeague, NY (Fig. 1). This modern 2 km^2 dune field is bounded by Napeague Bay to the west, Gardiners Bay to the north, and the Atlantic Ocean to the south (Fig. 2). The main aeolian features of the WDF are five parabolic dunes ranging from 8.5 to 13 m in height above the underlying Pleistocene glacial deposits. These parabolic dunes are shown in Fig. 2 and include the downwind Dunes 1 and 2, which are older, larger, and stabilized, and the smaller and actively migrating upwind Dunes 3, 4, and 5. Dunes 1 and 2 appear to be 'simple' dune forms (not in contact with other dunes), however field studies confirm that these are in fact parabolic ridge dunes in compound morphology according to the classification of McKee (1979). The actively migrating Dune 4 (Fig. 2) is the focus of this study, and has a complex morphological relationship with the older Dune 3, to which it is laterally linked, and the younger Dune 5 which is superimposed on its western limb (Fig. 2, inset). From aerial imagery we have documented that these dunes formed in succession, with Dune 4 and Dune 5 nucleating as blowouts on the western limb of the preceding dune. In the simplest sense Dunes 3, 4 and 5 exist in compound morphology (McKee, 1979), but a more accurate description is that

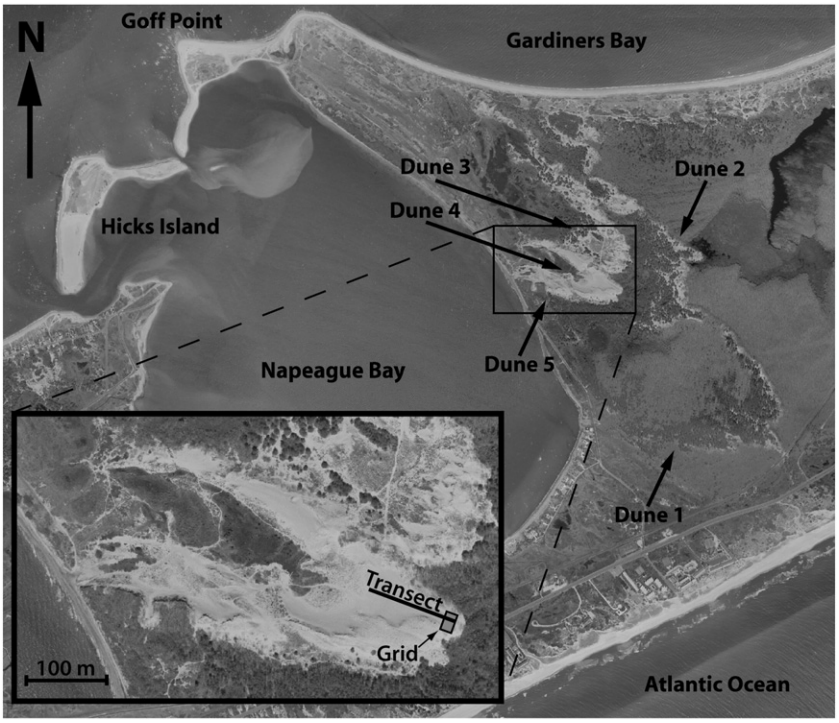

Fig. 2. Five major parabolic dunes are identified within the Walking Dunes dune field. The dunes are fed by sediment that has been transported into Napeague Bay (to the west), and they migrate in a southeasterly direction, toward the Atlantic Ocean. Inset: Compound morphology of Dunes 3–5. The black line and the rectangle indicate the locations of the 2D transects (Figs. 3 and 4) and the 3D grid survey (Figs. 5–8), respectively.