Aeolian Research 19 (2015) 137–149

Contents lists available at ScienceDirect

Aeolian Research

journal homepage: www.elsevier.com/locate/aeolia

The origin of collapse features appearing in a migrating parabolic dune along the southern coast of Lake Michigan

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ARTICLE INFO

Article history:
Received 15 July 2015
Revised 15 September 2015
Accepted 15 September 2015

Keywords:
Coastal dune
Collapse feature
Dune migration
Dune decomposition chimney
Fungi
Biomineralization

ABSTRACT

Dune decomposition chimneys are collapse features formed when migrating dunes encroach on a forest and buried trees subsequently decay, leaving a temporarily stable open hole. The recent appearance of holes on the stoss slope of Mount Baldy at the Indiana Dunes National Lakeshore provided an opportunity for study of such features. Mount Baldy is a large parabolic dune that is rapidly migrating onshore over a late Holocene landscape with stabilized relict parabolic dunes that supported oak (*Quercus* spp.) trees visible on the 1939 aerial photo. Individual holes were mapped to locations on the dune surface that would directly overlie the arm of a buried relict parabolic dune. Analyses of buried trees and surrounding sediment indicated that saprotrophic wood decay fungi continue to actively decompose trees after burial and biomineralization of a calcium-carbonate-rich cement occurs at the contact between organic material and sands. Scanning electron microscopy of the cement showed neoformed authigenic minerals and organic structures consistent in morphology with fungal hyphae. We propose that, within the dune, portions of the decayed trees progressively collapse and infill, and open holes are temporarily stabilized by the calcium-carbonate-rich cement. Further, holes can exist undetected at the surface, covered by a thin veneer of sand. Migrating dune systems are observed in many coastal and inland areas. Ongoing work must address the relative contributions of individual environmental factors on the formation of dune decomposition chimneys, including the biomineralization of cement, sand mineralogy, rate of dune movement, tree species, climate, and the composition of fungal communities.

1. Introduction

Narrow and temporarily stable holes (<30 cm in diameter) are forming on the stoss slope of a large coastal parabolic dune that has migrated inland over a forested late Holocene landscape along the southern coast of Lake Michigan (Fig. 1). The discovery of the holes at Mount Baldy in the Indiana Dunes National Lakeshore made world news when a six-year old boy was rescued safely after being buried under approximately 3.3 m of sand for more than 3 h in July, 2013 (Sabar, 2014). Upon arriving at the site there were no obvious signs of disturbance at the surface to suggest a collapse of sediment. But the boy's friend who was present at the time reported that they had seen an open hole, went to investigate its depth, and the boy slid out of sight into the hole which immediately infilled with sand. With the focus on search and rescue, no photographs or measurements were collected at the accident site to aid in the investigation of the hole's origin, and the excavation area was immediately backfilled for safety. Emergency responders reported finding other holes radiating toward the main vertical hole from which the boy was rescued. They described a pattern of void development similar to limbs branching from a tree trunk but no organic material was recovered or clearly observed at that time. Physicians hypothesized that there must have been an "air pocket" inside the dune that sustained the boy during the time of burial. At the time this study was completed, nine additional holes had been identified on Mount Baldy. The incident and detection of additional holes raised important questions about our understanding of the internal processes of migrating dunes. How could narrow holes form at various orientations and maintain an open structure to a depth of several meters in unconsolidated sediment? What happens to organic material, specifically, trees, that are buried by encroaching dunes? Was this an isolated incident, or have similar holes been observed in other dune systems? The purpose of this contribution is to present a mechanistic model for the formation of voids in actively migrating dunes; features

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http://dx.doi.org/10.1016/j.aeolia.2015.09.008
1875-9637/

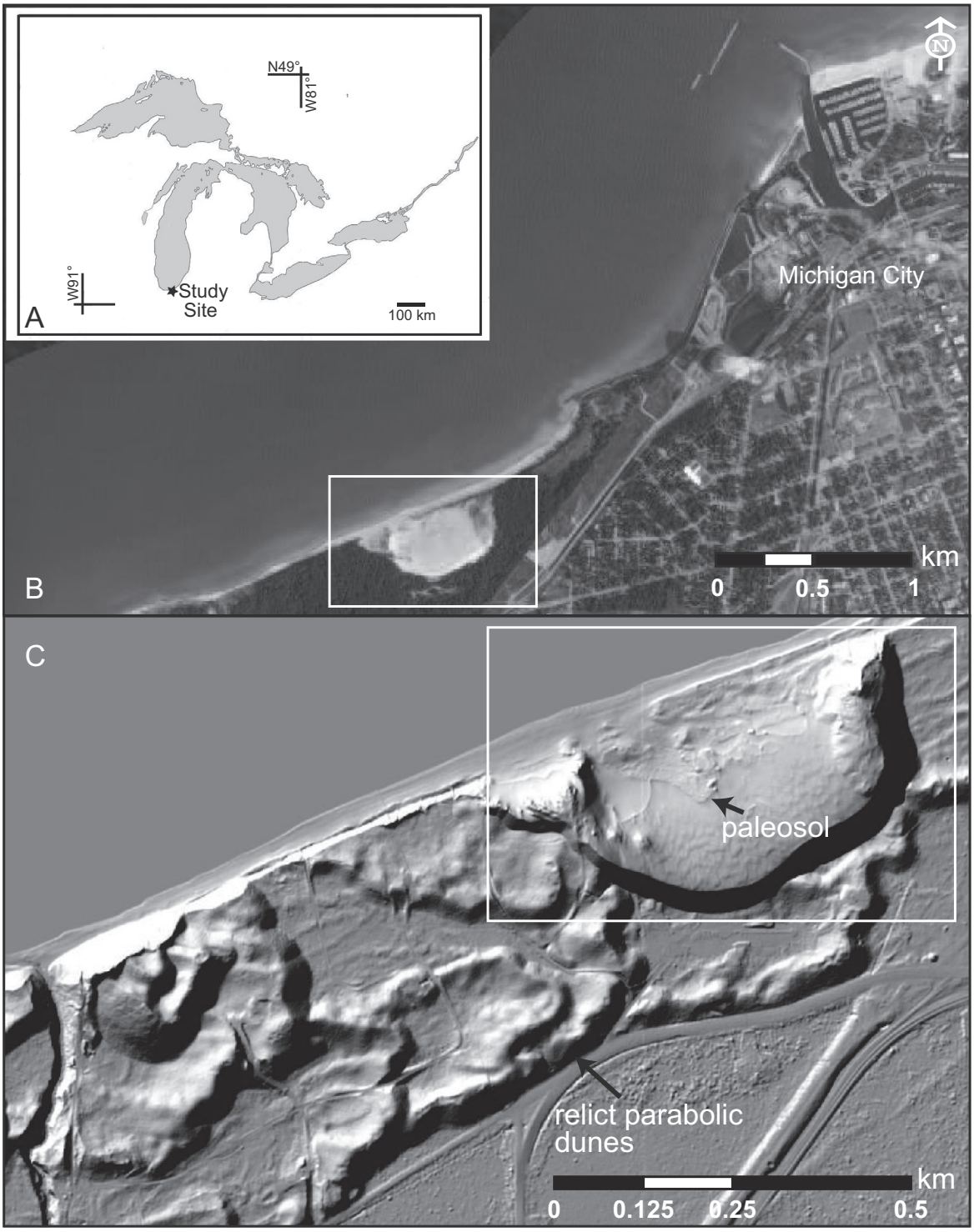

Fig. 1. Location of the study area; (A) within the Great Lakes region; (B) on aerial photo showing the Mount Baldy dune (white box) and Michigan City harbor structures; (C) close up 2013 LIDAR view of the Mount Baldy dune.

that we will subsequently refer to as dune decomposition chimneys.

The encroachment of mobilized dunes on forested landscapes is not an uncommon phenomenon and is observed in both coastal and inland dune systems around the world. In fact, Cowles (1899) described and photographed the encroachment of dunes on forests dominated by jack pine (*Pinus banksiana*) and black oak (*Quercus coccinea tinctori*) at the Indiana Dunes State Park; he concluded that the fate of the trees is an "inevitable" death dependent only the rate of the dune's advance. But migrating dune systems are well researched in coastal areas such as the Walking Dunes of Napeague, New York (Girardi and Davis, 2010), Jockey's Ridge, North Carolina (Mitasova et al., 2005), Atalaia Beach in equatorial Brazil (Buynevich et al., 2011), and along the Oregon coast