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Morphology and composition of submarine barchan dunes on the Scotian Shelf, Canadian Atlantic margin

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Abstract

Submarine barchan dunes have been mapped on Browns Bank, Scotian Shelf, using multibeam sonar bathymetry and backscatter strength. The morphology of subaerial barchans has been studied for almost a century but the advent of multibeam sonar technology now enables a quantitative investigation of their submarine counterparts. The Browns Bank submarine barchans occur at a depth of 60–70 m and are crescentic in planform, reaching almost 700 m in horn width and 5 m in height. The barchans are convex to the SE with steep lee faces to the NW, indicating a dominant NW-flowing current. The barchans overlie a widespread gravel lag covered elsewhere with little or no sand. Obstacle marks emanate from the lee faces of the barchans and represent a lack of sand deposition and exposure of gravel lag on the sea floor. The Browns Bank submarine barchan sediment texture is gravelly sand or sandy gravel and is primarily composed of subrounded to well-rounded quartz grains. The allometric relationship between submarine barchan slip face height and distance between horns is markedly different from that of subaerial barchans. For the same dune height, barchan horn width is about ten times greater in the marine environment. The superimposition of megaripples on the stoss slopes of the submarine barchans suggests that the barchans are active and therefore represent an engineering risk to sea floor infrastructure. Current observations and models indicate that seasonal mean current strength is less than the critical velocity required for barchan migration. However, the barchans may be active under higher-velocity, storm-induced currents. Repetitive multibeam sonar mapping is required to detect if barchan migration is occurring over longer time scales.

Keywords: Barchan; Dune; Submarine; Multibeam; Backscatter; Scotian Shelf

1. Introduction

Sedimentary bed forms on Canada's Atlantic continental shelf historically have been identified and mapped through the use of acoustic methods and seabed photographs (Drapeau, 1970; King, 1970;

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MacLean and King, 1971; Drapeau and King, 1972; King and MacLean, 1976; Fader et al., 1977; MacLean et al., 1977). Amos and King (1984) compiled this bed form mapping, clarified differing terminologies used to define them, and assessed the significance of bed form distribution. A new generation of three-dimensional sedimentary bed form mapping has arrived with the advent of multibeam sonar over the last decade. This new technology has revolutionized sea floor mapping, providing 100% coverage with unparalleled resolution, and reveals previously unrecognized bed form morphologies and sediment attributes (Courtney and Shaw, 2000). This paper describes the morphology and composition of submarine barchan dunes discovered on the Scotian Shelf on the Canadian Atlantic continental margin. The submarine barchans are compared to subaerial barchans which have been studied for almost a century (Beadnell, 1910).

The offshore geomorphological research described in this paper is a key component of the systematic sea floor mapping of the Canadian continental shelves to support integrated resource management (Pickrill and Todd, 2003). Coastal and ocean environments worldwide are coming under increasing pressure from resource development. With the collapse of offshore fisheries and competition among industries for use of the seabed, many maritime countries now recognize that high-resolution sea floor data are needed for sustainable management of offshore resources (Pew Oceans Commission, 2003). Developments in multibeam sonar mapping technology, in concert with traditional marine geoscience survey techniques, now provide the capability to discriminate objects on the sea floor 0.5–10 m in size, depending on water depth. The maps generated using these technologies provide the fundamental underpinning for the practice of sustainable management and offer unprecedented opportunities to examine submarine geomorphology.

In the world's deserts, the suite of aeolian dune shapes has been classified mainly on the amount of available sand and on the wind direction over the year (Bagnold, 1941; Pye and Tsoar, 1990; Besler, 1992; Cooke et al., 1993; Lancaster, 1995). Perhaps the most recognizable type of dune is the crescent-shaped barchan dune. The formation and stability of these dunes require a narrow range of wind directions, about 15° or less about a mean value (Tsoar, 1986). Isolated barchans occur where the available sand is limited. With an increasing sand supply, individual barchans can coalesce to form a series of connected crescents in planview. Barchans occur on the margins of sand seas and in sand transport corridors linking sand source zones with depositional areas. Regions of barchan occurrence are characterized by a gravel-covered substrate and an irregular spacing of dunes (Lancaster, 1995).

Submarine barchan dunes occur in the world's oceans over a range of water depths in areas having a unidirectional current, a hard substrate, and a limited but continuous supply of well-sorted sand (Belderson et al., 1982; Allen, 1984). These bed forms have been recognized for half a century. Illing (1954) described submarine barchan dunes composed of oolites on Great Bahama Bank in <10 m of water. Barchan dunes of foraminiferal sand occur at a depth of 2650 m in the eastern equatorial Pacific Ocean (Lonsdale and Malfait, 1974) and at 3200 m in the Gulf of Mexico (Kenyon et al., 2002). Individual barchans and dune fields have been observed at depths of 600–1000 m in the NE Atlantic Ocean (Dorn and Werner, 1993; Wynn et al., 2002). The submarine barchan dunes described in this paper occur on the Canadian Atlantic continental shelf at a depth of 60–70 m. The significance of mapping of these bed forms using multibeam sonar is that this approach enables measurement of underwater barchan dune height, width, and length to a higher degree of horizontal and vertical resolution than previously possible. Hence, comparisons of their detailed morphology can be made with their terrestrial counterparts.

2. Barchan shape

In planview, aeolian barchans are ellipsoidal in shape with a convex stoss slope, a concave slip face (lee), and horns extending downwind. This morphological model is extended to submarine barchans in which the wind direction is replaced by current direction (Fig. 1). The shape of an idealized aeolian barchan is symmetrical about the axis of wind direction (Howard et al., 1978) but asymmetrical shapes are commonly introduced by variation in wind direction, changes in sand supply, and inclined substrates (Lancaster, 1982). Early