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The environmental significance of ventifacts: A critical review

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Abstract

Ventifacts (wind-abraded clasts or rock surfaces) are common features of many terrestrial hot and cold deserts, coastal, periglacial and mountain environments, as well as on Mars, and have a long history of investigation. This review paper discusses some of the main themes in terrestrial ventifact research including their formation and geomorphic controls. The varied morphological forms of ventifacts in terrestrial environments, and their environmental significance as indicators of past and present wind direction and sediment mobility, are critically evaluated. Future research directions are identified.

Keywords: wind abrasion; periglacial; coasts; mountains; deserts; sediment dynamics

1. Introduction

Erosional landforms developed as a result of abrasion by wind-carried particles (including, sand, dust, snow/ice crystals) are known from a range of terrestrial environments and geomorphic settings including hot and cold deserts, mountains, and coasts (e.g. Greely and Iversen, 1985; Pye and Tsoar, 1990; Seppälä, 2004). Erosional landforms can be developed on both soft and hard substrates. Those on such soft, unconsolidated substrates as beach/dune sand and soil can be considered as transient phenomena whose morphology is capable of responding dynamically to small changes in wind conditions. Such landforms, therefore, may reflect variable local winds over relatively short time scales, and have limited preservation potential in the geological record. Wind-eroded scarps found around the edges of sand dunes are a typical example (e.g. Jackson and Cooper, 1999). By contrast, the wind-eroded forms developed on hard, consolidated land surfaces such as bedrock or stable surficial clasts are often geomorphically delicate, showing intricate surface details, with very clear and sharp edges. These landforms, including yardangs and ventifacts (Grolier et al., 1980; Halimov and Fezer, 1989; Pye and Tsoar, 1990; Laity, 1992, 1995), reflect what might be considered mean wind conditions over relatively long time periods (often decadal or longer scales), and have a much higher preservation potential in the geological record. Ventifacts and similar 'hard' erosional features therefore represent only part of a spectrum of forms recording the relationship between wind activity, the presence of wind-carried abraders, and the land surface.

Ventifacts, developed on these hard land surfaces, are useful because they can indicate both present and past wind conditions including wind direction and, often, wind strength. Their usefulness arises because of their high preservation potential and because they often remain as relict (residual) surface forms in hot/cold deserts, mountains and coastal environments, and are often not concealed by later sediment, soil or vegetation cover. In addition, because ventifacts (as geomorphic features)

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record the effects of wind-blown abraders in transit, they are the 'missing link' between wind blow activity (as evidenced by wind climate records) and wind-deposited sediment (such as sand dunes, coversand and loess) (Fig. 1).

1.1. Problems with terminology and the identification of ventifacts

Ventifacts are defined on a morphological basis as subaerially-exposed clasts or bedrock surfaces that have been abraded by the action of wind-carried particles (Greely and Iversen, 1985). Abrasion of the faces of these clasts and rock surfaces gives rise to distinctive and smooth plano-concave to plano-convex faces (Fig. 2). The number and disposition of these abraded faces (which are termed *facets*) was used during the early Twentieth Century as important criteria to identify and distinguish different ventifact types. Ventifacts with one significantly abraded facet and one unabraded face were termed *einkanter* (forming a Brazil-nut shape in plan view), and those with three opposing edges, which together give rise to a pyramidal ventifact shape in plan view, were termed *dreikanter* (e.g. Wade, 1910; Kuenen, 1928). The term *ventifact* was coined as a replacement for these morphological terms by Evans (1911, p.335), to mean 'a general expression… for any wind-shaped stone'. Although genetic, the term ventifact makes no assumptions of the detailed morphology or alignment of the ventifact with respect to wind direction, and the term therefore remains a useful one. This terminology, however, considers only the basal outline of the ventifact, and does not consider the different types of detailed surface forms present on the wind-abraded facets themselves (discussed later).

A central problem in the study of ventifacts is that they are identified on a subjective, visual basis, and that little work has been done to standardise methodologies for their identification, particularly in field settings. Kuenen (1960, p.447) argued that quartzite ventifacts can be developed and identified visually in hand-specimen where there is an erosive loss of about 6% from wind-abraded surfaces compared to those surfaces that have not been abraded. The calculated time-period over which this ventifaction takes place depends nonlinearly on wind strength and abrader size (Kuenen, 1960). This figure of 6% (based on weight loss) also assumes that abrasion is consistent across the surface, which in practice it is not. It is likely that substantial wind-abrasion effects can be observed on rocks with surface losses below this 6% threshold value, when these surfaces are examined in detail. Equally, even on rock surfaces with high abrasion loss, ventifacts might not be identified if this abrasion is consistent across all surfaces. Although, therefore, the term ventifact refers to the external shape of a wind-abraded rock as a whole (when observed in hand specimen), wind-abrasion effects can be observed at different scales. Therefore the term ventifact refers to only one part of a continuum of abrasion scales, and should be considered within a wider geomorphic context. Better resolving these issues of scale and degree of abrasive loss, through linked field and laboratory studies, will enable a better understanding of the relationships between ventifaction and other processes associated with rock surface abrasion. In addition, determining threshold values of abrasion loss is likely a critical issue in identifying what is, and what is not, a ventifact. It also means that ventifacts have been likely under-recorded in the field. A bibliography of aeolian research for the period 1647–present, which includes works on ventifacts, is maintained by Gill et al. (2007).

2. Aims of this paper

This paper is structured into five main parts that critically address the past, present and future directions of ventifact research. In detail the paper aims to (1) review the history of ventifact research from the English-language literature and to identify the key themes of these studies and their wider geomorphological significance; (2) outline the geographical and environmental controls on the presence and formation of ventifacts; (3) describe the macroscale and detailed

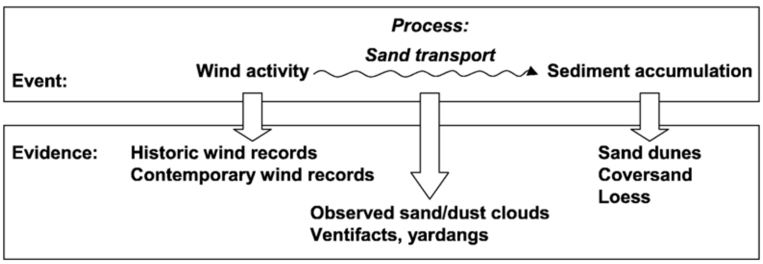

Fig. 1. Illustration of the role of ventifacts as the 'missing link' between wind activity and sediment accumulation.