# Microenvironments in a Danish Dune Area Råbjerg Mile

by

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Abstract

Elements of forms which may be observed on an excursion to a dune area near the Skaw, Denmark, are described: naked transverse ridges with slip-faces, erosion sheets, great ripples, and spots of "black sand". Grain sizes of materials from these environments are analysed. Correlations between sand and environments are explained by transport type and mobility of the grains.

## 1. Introduction

Råbjerg Mile is a drifting transverse dune without vegetation, and poor in humus. The word "mile" in Danish means a high, naked drifting dune. Råbjerg Mile is situated in a dune area, well-known to many Danes, at a distance of about 15 km. southwest of the Skaw (Skagen), in the neighbourhood of the seaside resort Kandestederne. In fig. 1 is seen the posi-

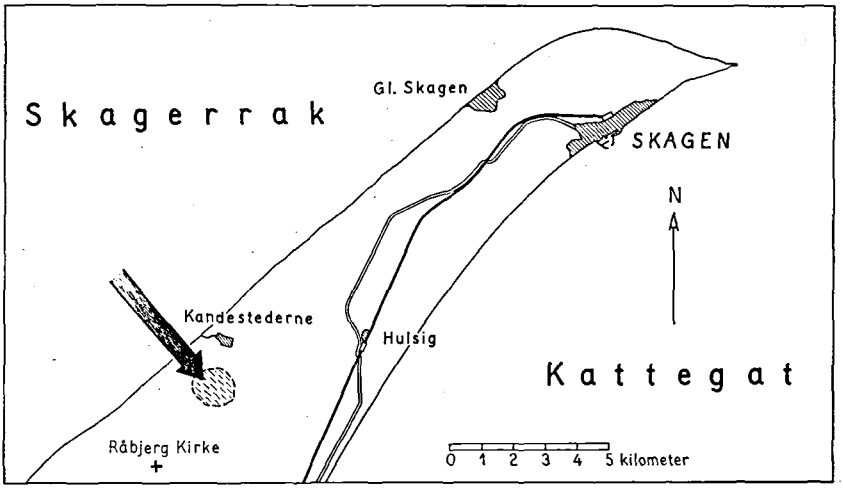


Fig. 1. Sketch-map showing the position (the arrow) of the drifting dune Råbjerg (Studeli) Mile in relation to the northern point of Jutland.

tion of the Mile in relation to the northern point of Jutland; it is without any direct connection with the existing coast. This dune, being one of the last naked drifting dunes in Denmark, is under preservation regulations. All previous dunes of the same type have been rendered immobile by planting.

The purpose of this article is to describe the observations which may be made, during an ordinary excursion to the Råbjerg Mile, of the macro dune-morphology and the micro dune-morphology and, further, to give an interpretation of the observed phenomena on the basis of the local grain sizes and the dynamics of the sand transport.

Classical descriptions of this locality (also called the "Studeli Mile") are found in papers by A. JESSEN, 1899, p. 333–335 and by E. WARMING, 1907–09, p. 9 and 27–31. The short exposés of these two authors do not seem to indicate, that at the beginning of this century the aspect of this area was considerably different from its present appearance. The whole of the area shown in my sketch-map consists of sediments which have been deposited and redeposited in the Holocene.

## 2. Description

The Mile is a sand mount about 20 m. high, 800 m. broad, which rises from the west with a gradient of 8°–10°, and which descends towards the east with a medium inclination of 20°–25° in the part which does not collide with residual dunes covered with vegetation. In front of the Mile, towards the west, is found a sand sheet, wetted from the ground-water, which acts partly as a transit plane, partly as a deflation plane. This sand sheet is often seen covered with water between the scattered, low return-sand dunes. To the north and to the south Råbjerg Mile is flanked by high, longitudinal dunes with grasses which stabilize the dune ridges.

The Mile and the longitudinal dunes are oriented almost west-east, a fact which is conditioned both by the "predominant wind" (west) and by the coastal development in former times. The shape of the up-wind side of the Mile is due to aerodynamic conditions; its profile tends to a stream-lined shape. The inclination towards the east is determined by the shelter

Table 1

| sample \ $d_{mm}$ | 1.00 | 0.75 | 0.50 | 0.40 | 0.30 | 0.25 | 0.20 | 0.15 | 0.12 | 0.10 | 0.06 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | % > | | | | | |
| I | | | 0.0 | 0.1 | 1.4 | 20.3 | 75.5 | 98.2 | 99.5 | 99.8 | 99.9 |
| II | | | | 0.0 | 0.4 | 9.9 | 64.8 | 96.3 | 99.0 | 99.7 | 99.9 |
| III | | | 0.0 | 0.3 | 3.7 | 18.1 | 77.0 | 97.1 | 99.1 | 99.7 | 99.9 |
| IV | | 0.0 | 0.1 | 1.4 | 14.0 | 40.3 | 82.2 | 99.4 | 99.9 | 100.0 | |
| V | | | | | 0.0 | 0.2 | 10.3 | 68.2 | 88.3 | 96.1 | 99.7 |
| VI | 0.1 | 2.4 | 75.7 | 82.9 | 89.2 | 93.4 | 97.8 | 99.9 | | | |
| VII | | 0.0 | 0.2 | 0.9 | 19.9 | 45.9 | 81.9 | 98.9 | 99.7 | 99.8 | 99.9 |

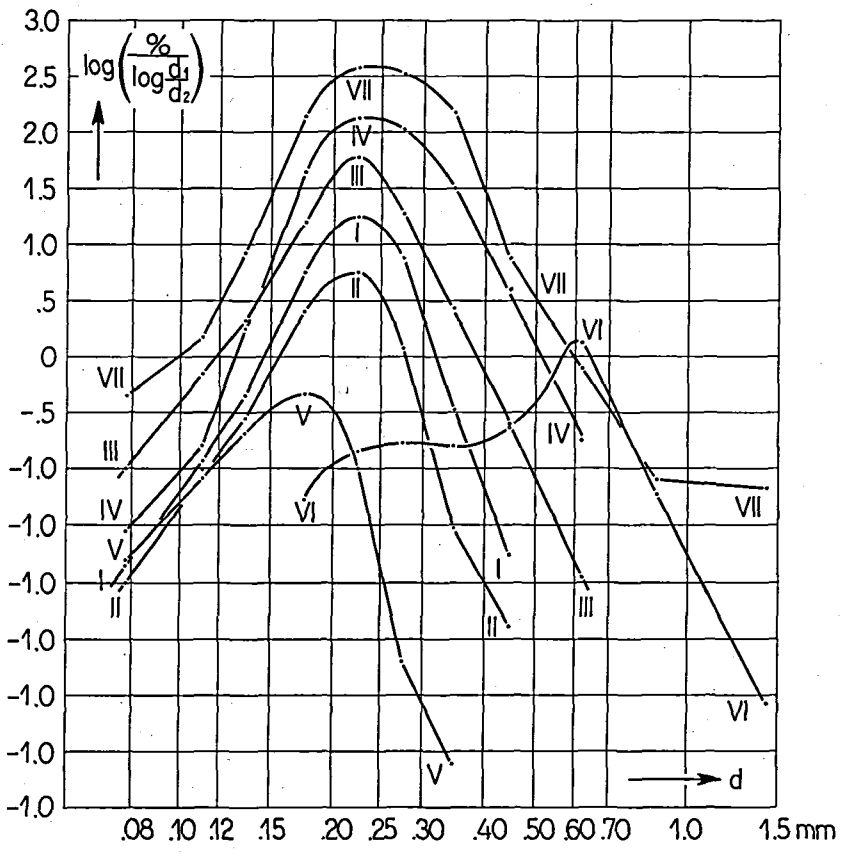


Fig. 2. Distribution of the grain sizes of sand from the Råbjerg Mile, graphically presented according to R. A. BAGNOLD's method. The abscissa shows the log. grain diameter; the ordinate, which, for each curve, is displaced in relation to the numbers indicated, expresses the logarithm to the weight-% of sand per unit on the abscissa scale (log. the proportion between the mesh-sizes of two successive sieves).

created by the dune itself and by the angle of repose of the sand. The macro-form of the Mile is composed of homologous small forms (a feebly ascending up-wind side and a slip-face 30°, 1–3 m. high), disposed in a stepped pattern across the macro-shape. The small forms reflect the changing transport conditions. Across the wind-exposed surfaces of the small and the big sand masses stretches a skin of ripples. At a walk in the dune it is apparent that the packing and the moisture of the sand have an extremely complex variation. Firmly packed sand (at up-wind), the volume of which is 80–90% incoherent sands, retains the humidity, whereas loose-packed sand (at slip-face) often is thoroughly dry and partly hygrophobic. In our humid climate the existence of the incoherent, semi-hygrophobic sand is of fundamental importance; it has the effect that rain and humidity do not always hamper the sand-drifting.

In the high-lying parts of the Mile the grain-size distribution of the normal surface-sand is as shown in fig. 2 and table 1: I and II (by sieving). In sand-layers situated somewhat deeper is found, for instance, grain-distribution III. The greater part of the top-most sand has grain-sizes between 0.15 and 0.30 mm. A sand sample from the deflation-surface is shown in: IV; the sample is significantly coarser than I–III; however, an analogous grain-distribution may be observed in the slip-face sand of the dune: sample VII. If it is intended to prove the influence of the transport route on the grain sizes, only samples from uniform micro-environments should be compared.

During a walk in Råbjerg Mile even a fleeting glance will reveal some surface-sand which is radically deviating from the normal; it is a question partly of dark-coloured fine-sand, "black sand", partly of some reddish coarse-sand. These anomalies are introduced by means of V and VI in the table. The dark fine-grained sand (almost totally $< 0.25$ mm.) is seen at moderate wind in the valleys of the wind ripples and on the top of the slip-face; it has a remarkably superficial position and is relatively sheltered (containing some magnetite). The coarse-sand, of which the predominant grain-size often is 0.6 mm., appears as big, atypical wind ripples in the lower part of the Mile, where there is a local wind concentration. At the slidings and the rollings of the sand along steep slip-faces an out-separation of coarse-sand will often be observed too.

## 3. Interpretation

In order to "explain" and "understand" the above-mentioned observations it is necessary to study the transport types in such an eolian environment. A distinction can be made between the following transport types: suspension, saltation, saltation-conditioned creeping and gravity-conditioned slidings. With the exception of suspension, the transport is intimately related to the surfaces. The superficial transport of the saltation creates the formation of wind ripples, the wave length of which reflects the average saltation-length (BAGNOLD). In figure 3 are indicated the different limit "wind forces" for the various transport modes in relation to grain diameters in uniform, spherical quartz-grain population. This diagram has been worked out on the basis of informations given by BAGNOLD, ZINGG and DAPPLES and is absolutely open to discussion. Its lack of clearness is due to the fact that the "wind-force", in order to be a unique and comparable measure, must be indicated both by the velocity in standard height and by the friction velocity $V_*$ (about $^1/_6$ of the velocity gradient, when the height is expressed in log.). The frequency of appearance of the different wind-forces in Råbjerg Mile is unknown, and the climatic tables only give a rough estimate, for inst.: 0.20 mm. grain may as an optimum be in saltation in 60% of the year; 0.30 mm. in 40%; 0.50 mm. in 15% and 1.00 mm. in 1%; however, as the diagram shows, grains in saltation may, as a maximum, push grains having 6 times their own diameter. Suspensive "wind-forces" as an optimum appear in 50% of

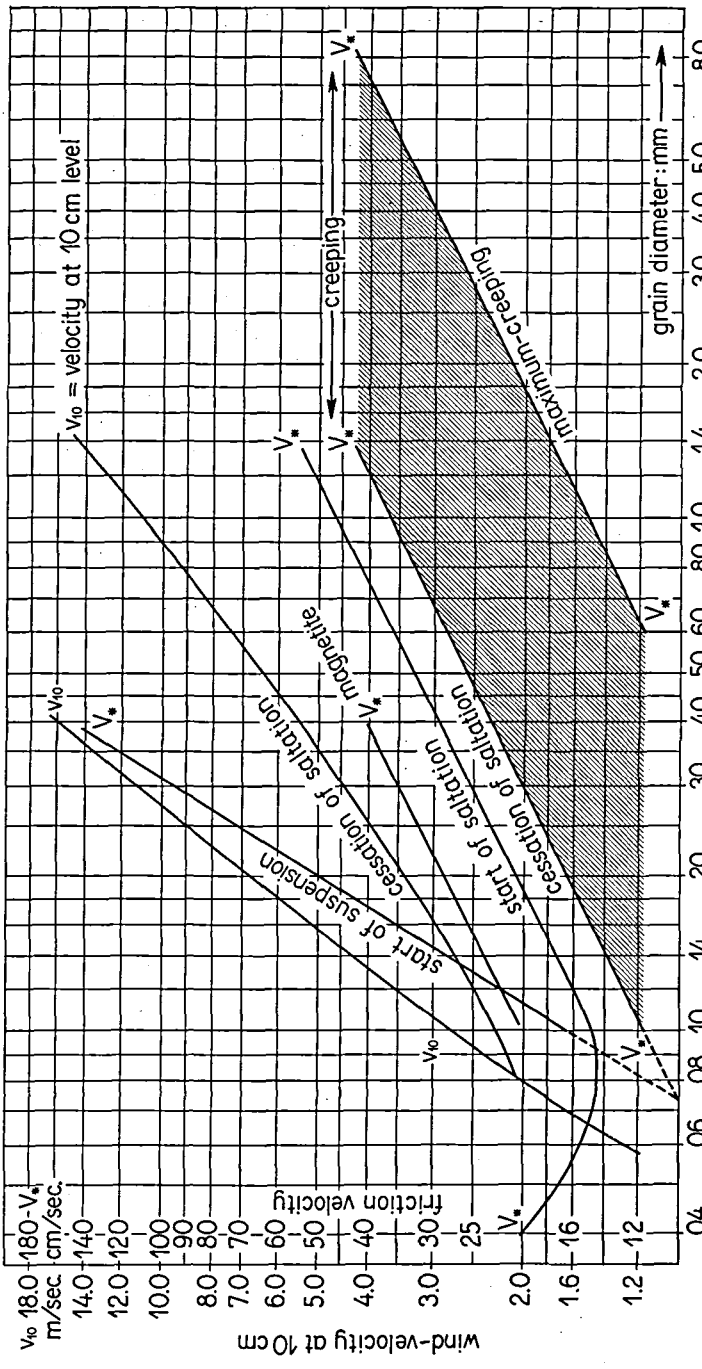


Fig. 3. Threshold "wind-forces" for the various aeolian transport modes in relation to the grain-size for homogeneous groups of ball-shaped quartz-grains. The "wind-force" is expressed both by the velocity at a height of 10 cm. and by the friction velocity $V_*$ (according to Bagnold, Zingg, and others).

the time for grains of 0.10 mm.; in 20 % of the time for 0.15 mm. and 1 % for 0.25 mm.; bigger grains will hardly ever be suspended at this place.

The normal surface-sand observed has almost the grain distribution which must be considered as a theoretical-statistical limit for saltation-sand. The slip-face sand may form grain patterns which are independent of "what is probable from an eolian point of view". At moderate wind the "black sand" becomes a sheltered residual on account of its great density; at the spots are not found any quartz grains, which are its "dynamic equivalent"; the black sand would almost demand wind-forces able to move directly the coarse-sand, which in the atypical wind ripples must be considered as an out-sorted, exclusive, creeping material.

The genesis of dunes is a consequence of a local reduction or cessation of the superficial transport; the saltation-transport is biggest on firm surfaces (which may be moist); it is least on vegetation-covered surfaces. As Råbjerg Mile is surrounded by vegetation-covered areas, which, in general, may regenerate at a deposition of sand, if any, and as the sources of this drifting dune are very small it will develop, in the course of time, into another species: immobile and vegetation-covered.

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