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Dunes and scattered light

Jacob van Ruisdael's painting "Dünenlandschaft mit Eselstreiber" ["Dune landscape with donkey driver"], MdbK Leipzig

Dutch landscape painting is characterised by representations of nature that are rich in detail and rendered with precise powers of observation.Nevertheless, these paintings are generally not linear renderings of the landscape, but compositions in which individual, realistically portrayed elements - clouds, flora, fauna, soils, buildings – are assembled to create a harmonious representation.

An undisputed master of such "invented realities" is Jacob van Ruisdael. Regarding his painting "Dune landscape with donkey driver" (Fig. 1), then, the following comment is spot on: it is "*not a 'realistic' illustration of a dune, but a picture of a section of landscape that wavers between the two poles of idealisation and undomesticated wilderness*" (Nicolaisen 2002). Based on the representation of the geological conditions and the sky, the following will show how keenly Ruisdael observed nature and how precisely he constructed his renderings of it.

Fig. 1: *Jacob van Ruisdael, "Dünenlandschaft mit Eselstreiber" ["Dune landscape with donkey driver"], (1647), oil on canvas, 71.7 x 95.3 cm, Museum der bildenden Künste [Museum of Fine Arts], Leipzig, Inv. No. 1055 (click to enlarge)*

In the painting, a narrow path leads up the side of a dune. A donkey driver with two donkeys is coming down this path, while above, on top the dune, set off against the bright sunlight, two men with dogs look into the distance. In the blue summer sky, a few cumulus clouds are dissipating; at the horizon and toward the sun, the blue sky is tinged with white and yellow.

At the front edge of the picture heather and yarrow can be seen; at left in the foreground is a pond with reeds and other plants.

Which dune? The landscape in the painting

In the context of Dutch landscape painting, dunes are usually connected with the coast and the sea. For this reason, it is easy to overlook that even in Holland, especially near the Dutch-German border, there are inland dunes that are completely different than coastal dunes in terms of geology.

On one hand, the Dutch landscape is characterised by the interplay of sea and land, of atmosphere and geology.On the other hand, the entire northern German lowlands, to which Holland belongs, geologically speaking, resulted from the changes to the earth's surface brought about during the ice ages (Ossing et al. 2001, Ossing/Brauer 2006). The so-called Saale Ice Age (in approx. 350,000 to 140,000 BCE) and the Drenthe glaciation (approx. 350,000 to 250,000 BCE), named after the Dutch province, shaped the northwest German and Dutch bay with glacial thrusts and subsequent retreats,

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meltwater rivers and dry phases. The influence of the wind shaped, and is still shaping, the structure of the dunes and sand drifts over the hilly ground moraines and terraced landscape left behind.In the 17th century, large parts of the Northern German Basin were still difficult to access, "*undomesticated wilderness*" (Nicolaisen, see also Blackburn 2007).

The scenery depicted by Jacob van Ruisdael shows a section of such an inland dune.

Next to the large sand body of the dune at the left edge of the picture is a small pond, which indicates a ground moraine area an impervious till bed.The tall reeds and grass at the pond alludes to the highly nutritious marly soil of the ground moraine. Here in this narrow area, wet depressions alternate with dry successions of dunes. This sheds light on Ruisdael's correct rendering of vegetation that varies within a small space:reeds at the pond, yarrow and heath at the edge of the picture in the foreground, and small growing trees on the dune.

Fig. 2: *Path in the heathland with bleach-white soil, Nijverdal/Almelo, the Netherlands (Photo: F. Ossing, click to enlarge)*

A path or livestock trail with bleach-white sand is emphasized at the centre of the painting. In large areas of this landscape, with its sand from varying origins (carried in by glaciers, transported by water, blown in on the wind), the type of soil is known as podsol. Under the covering of humus, this soil is often bleached. This results from the action of organic acids formed by the scattered needles of pinewoods and heathers (Fig. 2). In Ruisdael's painting, we see this bleach-white, nutrient-poor soil on the path that leads up the dune.

Blue sky and white colouration

Our eyes perceive light and colour represented by the visible section of the electromagnetic radiation spectrum.Visible sunlight consists of radiation made up of a range of wavelengths from about 0.4 to 0.7 micrometers (µm). This yields a colour spectrum that extends from violet and blue to green and on to yellow, orange and red. White light is created by a combination of these wavelengths and colours.

We see all objects other than direct sources of radiation such as the sun by the light that they reflect or scatter. As light passes through the atmosphere, it may be scattered, reflected, or absorbed. All of these processes depend both on the particles in the atmosphere including the air molecules, aerosol particles, cloud droplets, ice crystals, raindrops, snowflakes, etc., and also on the light's wavelength, or its "colour".

All skylight is sunlight that has been scattered by particles in the atmosphere. Surprisingly, the most important factor that determines the nature of the scattered light is the ratio of the size of the object that scatters the light to the wavelength of the light. Thus, light is scattered differently by tiny air molecules than by the much larger aerosol particles (colloquially called dust) and cloud droplets, etc.

Rayleigh Scattering

In 1871, the English physicist Lord Rayleigh proved that particles that are much smaller than the wavelength of light (such as air molecules) scatter light more or less equally in all directions and scatter shorter waves with much higher efficiency than longer waves. For example, air molecules

scatter the shortest visible violet waves with an efficiency 10 times greater than they scatter the longest red waves. When the sun is high in the sky and we look at the sky well above the horizon, the sum total of all scattered light we see is blue. That explains why our sky is normally blue.

But Rayleigh scattering also explains why the sky near the horizon turns yellow, orange and red at sunrise, sunset and twilight. The atmosphere is like a thin veneer, much thinner in proportion to earth than the skin of an apple. When the sun is near the horizon its light must travel obliquely through this thin layer. So much of the short waves, the violet, blue, and green light are scattered that only the longer waves reach an observer. Thus the sun or moon appear red when at the horizon. But even the scattered light, which in the distance near the sun is at first mostly violet and blue, loses most of its violet and blue to scattering as it passes horizontally through the atmosphere and eventually turns yellow, orange, and red by the time it reaches an observer at the ground.

Mie scattering

Aerosol particles and all water drops or ice and snow crystals are much larger and therefore scatter light differently from air molecules. Mie scattering generally refers to scattering on particles with diameters that are the same size as or larger than the wavelength of the radiation. In 1908, the physicist Gustav Mie proved that larger particles scatter light of all wavelengths much more efficiently than smaller particles. Mie scattering, in contrast to the Rayleigh scattering mentioned above, is only weakly dependent on wavelength, and this dependency decreases as particle size increases. In this way, the light is scattered across a broad spectrum of wavelengths and colour, and hence it is "whiter".Mie scattering also explains why clouds are white.

But most of the light scattered by these larger particles is only deflected by small angles. This is why the sky is both whiter and brighter near the sun, especially on hazy days. It is also why it is so blinding and difficult to look through a windshield of a car when driving into the sun and when the windshield is dirty.

Fig. 3: *Sky blue and washed-out white are the result of Rayleigh and Mie scattering of sunlight.The sun is at the left, just outside of the picture. (Photo: F. Ossing, click to enlarge)*

From this, we can conclude that the more washed-out the blue of the sky, the greater the number and/or size of the suspended particles in the air.

In the atmosphere, Rayleigh and Mie scattering always occur together because there are always air molecules and always at least some aerosol particles.

Let's apply these principles to Ruisdael's painting. The sun is low in the sky at the right edge of the picture behind the trees. We see a blue, late afternoon sky and can conclude that the air is reasonably clean. But the sky grows both brighter and whiter (even yellow) as we scan from left to right and approach the direction of the sun. Thus there are some aerosol particles in the air which have made it slightly hazy, and in the late afternoon setting, when the air near the ground has begun to cool and the relative humidity to rise, the water soluble aerosols can grow, scatter light more efficiently, and make the sky near the horizon appear hazier.

The clouds in the painting correspond with this observation. We see disintegrating cumulus clouds which are typical for a late summer afternoon with an air mass that is slightly unstable. High pressure characterizes the weather. High pressure areas are connected with slowly sinking air over a region of hundreds of kilometers that warms and dries the atmosphere aloft. This means that the soluble particles dry out and shrink, which leads to a clear, deep blue sky. But when the sun heats the ground during the day, bubbles or thermals of heated air near the

ground become buoyand and rise to form cumulus clouds. Then as the sun descends, this convective activity dies off and the remaining cumulus clouds slowly evaporate and lose their distinct edges. Ruisdael, with his keen observations of nature, has precisely captured all these effects that are typical for a continental european air mass in summer.

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