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(For figures and references se the German text)

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The Origin of Landscape

(TRANSLATION: KARI HIEPKO-ODERMANN)

In Philips Koninckx' painting "*An extensive Dutch Landscape*" (Fig. 22) the scene originates from an elevated view looking over the Dutch low lands. A large river with several branches meanders through the landscape and the only elevation is a sandy hill on which the viewer seems to be standing. A cart with a horseman on a wide sandy path visually draws the observer into the scene. Small woods, long stretches of hedge, fields and meadows indicate that this is a *Kulturlandschaft*, a cultivated landscape that is influenced by man as much as by nature.

Dutch paintings of the 17th century show different characteristics of landscape in the Netherlands with an almost photographic precision, with watercourses, meadows, fields, dunes and coasts. This "realism" in most cases, however, is not based on a linear reproduction of an existing topography but is a painted composition in which the single landscape elements are portrayed in a natural state. This leads not only to the question if a real part of the Dutch topography is painted, but also if the elements, which characterise the Dutch landscape, are reproduced properly.
These questions, as we will see, are closely connected to the geological history of this part of Europe. How have the landscapes been formed that are put into scene so perfectly by the masters of the Golden Age?

From the geoscience point of view these landscapes, as every landscape, are a segment in time and space in a giant cycle of rocks. Earth's face is in continuous change. Landscape, or the surface of our planet, is a result of processes that are driven by forces that act in the interior and on the surface of our planet.

Water, Wind and Sun

To begin our analysis we will examine the forces that shape the surface of Earth. A mountain range, like the Alps, will be carried away in the course of millions of years by sun, wind, water and ice. Heating by solar radiation and subsequent cooling causes cracks in the rocks. Water enters these small rock fractures and freezes, breaking the rocks into pieces. Rockslides, rain, avalanches and glaciers transport these weathered rocks into the valleys (Fig. 9). Streams and rivers then move the rocks and boulders further on.

Dutch landscape painters brought the impressions of these geological processes with them from their journeys to Norway or from crossing the Alps on their way to Italy. They included this in their pictures or passed the knowledge on to their colleagues in the painters guilds. The waterfalls created by Jacob van Ruisdael (Fig. 24) or the mountain landscapes of Allart van Everdingen with their massive boulders (Fig. 25) depict the starting points of the course of rocks from the mountains to the sea, while the above mentioned painting of Koninckx marks the endpoint. In the transportation process the rocks continue to be broken down and are also deposited along the way depending on the velocity of the flow: the higher the flow speed the larger the rocks that can be transported. When landslides occur these geological processes become evident. Such catastrophic processes – seen geoscientifically – represent only extreme events: in form of scree and the greenish-blue glacier milk (Fig. 10, 11) in effect giant masses are transported continuously over millions of years into the valleys and finally into the sea.

Plate Tectonics and Sedimentary Basins

Over geological time scales mountains and even continents are eroded and washed into the sea. If this was a one sided fact, the oceans should be filled with the eroded material of the past 340 million years (Negendank 1981). The oldest continental rocks that have been found, however, display an age of about 4 billion years. This shows that besides the erosion process there must be some other process at hand that continuously provides new material. Today we know that new

mountains are formed by the collision of the plates of the lithosphere. The peaks of the Alps, for example, are made up of the floor of a long gone ocean (Fig. 12). Furthermore we know that in the mid-Atlantic the sea floor splits open in a rift and new, hot, molten rock material comes up out of the Earth's mantle resulting in a spreading of the Atlantic. The driving force for these processes is found in the heat energy of the Earth's interior. One part of this is remnant from the origin of our planet and the other one results from radioactive decay. Within the Earth's mantle, giant convective rolls are set into motion by this energy which manifests itself in the horizontal movement of lithosheric plates on the Earth's surface.

For our analysis of the rock cycle in Central Europe it is important to know that due to the collision of Africa with Eurasia the Alps have been folded up for 80 million years. These mountains are the source of a large part of rock material that is transported by the Rhine River up to the North Sea. At the mouths of the Rhine (which were not always situated like today) this rock material was and is being deposited; in the erosion processes it was grinded into clay and silt: making up the extensive sediment deposition that we know as the Dutch low lands (Hantke 1993).

320 million years ago a huge mountain range stretched across present day Europe. Some remnants today form the hilly landscape of the Upper Palatine (Oberpfalz) and the Rheinish Slate Mountains (Rheinische Schiefergebirge). These so-called **Variscides** were washed into the foothills and the North German Basin, a sedimentary basin into which the eroded material was transported and deposited. Sedimentary basins such as this are found on many locations on Earth. In a time scale of millions to 100 millions of years huge sedimentary masses are accumulated. According to their genesis, they consist of a mixture of different minerals and organic substances, which were deposited, in an interaction of atmosphere, hydrosphere and biosphere. Examples of the contents are sands, clay, salts and calcareous muds. By continuous accumulation of new sediments, in a depth of hundreds of meters to some kilometres sedimentary rocks are formed like sandstone, claystone and limestone. Sediment basins are small in comparison to the complete surface of Earth, yet contain the most important resources for man such as oil and natural gas, coal, lignite and peat. Moreover, ground water is extracted from sedimentary rocks for the largest part of drinking-water supply. Besides this, sedimentary basins are sources for metallic and non-metallic raw materials, construction materials, cement and fertilisers.

Of course the Dutch masters of the Golden Age did not recognise these geological correlations. Their depiction of the landscape of Holland however reproduces in exact detail the single characteristics of a landscape that was formed by the processes explained above.

The Characteristics of Holland's Landscape

The geological existence of Holland started about 10,000 years ago at the end of the last ice age. Melting water from the giant glaciers poured into the oceans until the enormous ice sheets that covered North America and Europe were melted away. During the last ice age the mean sea level was more than a hundred meters below its level today. It rose in 5000 years with a speed of about 2 meters per century. The rising sea flooded large coastal and shelf areas, which had lain dry before. The coast of the North Sea stretching before roughly at a line near the Dogger bank then moved south. Great Britain was separated from the European continent and the land bridge between Siberia and Alaska where the first humans immigrated into America was flooded.

The end of the last ice age still has an impact on the continents today: since the huge masses of ice on the continents melted away the underlying subsoil was relieved of the weight and since then rises slowly. The north of Scandinavia has moved upwards more than 300 meters since the last glacial period. At the same time, northern Germany and Holland are continuously subsiding.

This process is reflected in the change of the coast line: large parts of the coast of the North Sea were torn into the sea by storm tides, the most famous flood of 1362 (*Groote Mandränke* or the Big Drowning) brought death to more than 200,000 people. Other major storm floods, as in 1634, shaped the coastline of the North Sea forming it as we know it today (Fig. 13). The subsidence of the coastal areas due to lifting and sinking of the continent as a consequence of the melting of the ice masses was an important precondition for these catastrophic floods. Additionally the sea level was rising by about 20 centimetres per century at this point.

Land from the Sea: Man conquers Land

The rise of the sea level did not take place gradually but in a sequence of several accelerated phases. First, erosion of the coast to the south, then the withdrawal to the north and the subsequent re-advancement to the south mark these phases. In the course of this land was eroded by the sea and bays were washed out. The inhabitants of the coast tried to cope with this by building dykes and warfts. A speciality of Dutch landscape is the polders, land that was wrested away from the sea by the construction of dykes. The most famous of these anthropogenic land areas are the polders of the Ijssel Sea, which were won by the construction of the Ijssel barrage

dam (Fig. 14). The conquest of such land from the sea has been taking place in these coastal areas since the 11th century; by the 17th century this could be called almost an industrialised process.

It was part of the daily tasks to secure this land from the sea, as is shown in the painting "Dutch Landscape with the reconstruction of the Muider dyke 1651" by Jan Asselijn (Fig. 27). A closed winter dyke construction existed along the Friesian coast since the 13th century. It, in turn, increased the build-up of water, and thus the level of storm tides resulting in huge floodings and the changing of coastal shore (Behre 1999). Almost all the catastrophic storm floods were generated from extreme north-westerly gales in connection with spring tides (Glaser 2001) - a combination that is a heavy threat also to the modern dykes of today and can cause them to break.

But even if the coast can be fortified in a human-timeframe by the construction of dykes: all these stretches of land that have been wrested away from the water will fall back to the sea by erosion in geological times. This also is an inevitable result of the processes in the natural cycle of rocks.

Islands and Dunes, Ooze and Clay

From the geological perspective, an intimate interaction of tectonic processes and deposition of sediments created Holland. Today, the lowlands of Holland, which are one part of a major sedimentary basin reaching from Poland to Belgium, were above all shaped by the Rhine river, which today still transports Alpine material down to the North Sea. This area shows a considerable variety of landscapes: in the west the Netherlands are marked by dunes up to 60 meters high, this band of dunes dissolves to the north-east into the chain of the Westfriesian Island.

Between the islands and the mainland mud flats are found (Fig. 15), followed by the marsh that was generated by deposits of the sea and rivers. Here we find the polders that reach down 6 meters below sea level. This section of the coast is characterised by dunes almost along its entire length (Fig. 4).

In the east of the country we find ground- and frontal-moraines from the last glacial which in some locations have formed heath landscapes (Fig. 17).

The southern Netherlands consists of alluvial deposits that were accumulated by the melt water currents and which is formed by gravel and rubble covered with a thin layer of eolian sands and loess.

Where does this multitude of landscapes come from?

Once more, we have to start with the geological modelling power of water. Water erodes rocks, transports it and deposits it again. The size of the transported rock material depends on the velocity of flow: the stronger the current, the coarser the material that can be dragged along. Geoscientists determine the size of the crunched and crushed rocks with a grain size scale. Depending on the force of the flow rocks, gravel, sand or silty ooze are deposited (Fig. 16). In the millions of years this process took place, the creeks and rivers constantly change their course from the mountains to the sea. In a complex interaction of coastal currents, flow of rivers, sedimentation and vegetation, influenced by wind and weather, the grinded material finally is deposited in flat river mouth areas, thus generating landscape.

The low velocity of the Rhine and other water courses in the Dutch low lands leads to the early deposition of coarser rock material, and so in the river mouth zone mainly fine-grained material is suspended in the water. Silt and clay were accumulated in the course of time and today form the major part of land close to the coast inland.

This precious and fertile soil in Holland was very soon used for cattle breeding (Fig. 28); corn cultivation played a less important role and mainly took place in the coastal sandy moorlands (Fig. 29). Holland's corn was mainly imported from the countries on the Baltics (North, 1992). A view over the Dutch low lands (Fig. 18, 23) gives an impression of this shaping of the landscape by man and nature.

Each tourist on holidays praises the dunes at the edge of the sea and on the offshore islands. The Westfriesian Islands resulted from the sea level rise after the last ice age and are relicts of former mainland. The coastline of today was formed, more or less, some 3000 years ago. From a broad wall of dunes and beach a chain of islands developed which was changed permanently by the sea and the weather. Between islands and mainland the mud flats evolved. The transport-, erosion- and sedimentation-forces of wind and waves carried away the finer mineral and organic parts of the soil in the course of time (Fig.19).

What remains is sand with a certain grain size that is transported and accumulated by currents and wind: dunes and beach. Philips Wouwerman's painting (Fig. 30) shows a path through the dunes which explains the characteristics of this geological process: grass and even a little tree is growing

on the dunes, but on the slope of the dune a is bush of grass slipping down, indicating the erosion and displacement of the dune by wind and rain. As a means of coastal protection, dunes can only serve for a limited amount of time.

The same process also takes place with the islands. Here, with the tides, the erosive force of water is augmented. The prevailing westerly winds and coastal currents the Friesian Islands move from west to east, a process in which some islands can even disappear or also evolve over a longer time span. These continuously working forcing of air and water are very effective. They are supported by meteorological extreme events. An example is the St. Lucia storm tide of 1287 that swept away large parts of the once inhabited island of Griend; today we can see only a small bank of sand off the coast of Harlingen where the island once was. It is as true now as then that protection measures for dykes and islands with plants cannot stop this process completely but only slow it down (Fig. 20, 21).

Landscape – the ever changing face of earth

This short overview of the processes that shape and change landscapes shows Earth as a constantly changing planet. Its face, which for our human time scale seems almost invariable, varies steadily and profoundly. "Landscape" is just another word for the land surface of our Earth, which is continuously sculptured and changed by processes that exert their forces from the interior and from exterior. Landscape presents itself in a miraculous multitude, which is reproduced in particular by the Dutch painters of the "Golden Age" with a meticulous precision. Geoscientifically, all the important landscape characteristics of Holland are represented in the paintings. Perhaps this does not always reveal the inner meaning of the paintings. But the quotidian surroundings of man in Holland's 17th century, the environment, and the processes shaping it, are portrayed so accurately that geoscientists can recognise them.

(Translation from the catalogue: " Die ‚Kleine Eiszeit': holländische Landschaftsmalerei im 17. Jahrhundert", Berlin, ed.: Gemäldegalerie, Staatl. Museen zu Berlin Preußischer Kulturbesitz, 2001. 92 pp. , ISBN 3-88609-195-3 ("The 'Little Ice Age': Dutch Landscape Painting in the 17th Century", out of print)

When in Berlin, please visit the original paintings in the Painting Gallery.