Geoheritage values of the
Hoge Kempen Rural-Industrial Transitional Landscape

The Hoge Kempen Rural-Industrial Transitional Landscape (HKRIL) bears unique geological and geomorphological witnesses of rather extreme global changes that once affected this area, grading from warm and humid tropical swamps to cold and dry permafrost conditions. Moreover, the effects of dramatic climatological changes that once affected (and still affect) our living planet, can clearly be demonstrated in natural or artificial outcrops that occur witin the geographical boundaries of the HKRIL. More especially, abandoned sand and gravel pits represent interesting geological windows for educational purposes: they offer unique opportunities to display the layer-cake structure of the subsurface and to unravel the contrasting climatological conditions and depositional settings in which the exposed unconsolidated sediments and sedimentary rocks have been formed.

The backbone of the HKRIL is a huge sandy-gravelly alluvial fan from the ice age (Middle Pleistocene) covering a succession of underlying Tertiary (Miocene) shallow marine to coastal marine sands and coastal marsh deposits. These alluvial sands and gravels in turn are overlain by more recent windblown (eolian) sands (Latest Pleistocene and Holocene cover sands), now colonized by heather and forests. Finally, huge coal spoil heaps, mostly overtaken by nature, are the only relics of a once booming deep coal mining industry: these tips now stand as huge beacons at the surface of the Campine Plateau and refer to the existence of a hidden “Carboniferous Park” in the deeper subsurface of the HKRIL.

The Carboniferous rain forest

The spoil heaps (“terrils” or “coal tips”) represent the sterile, mineral remains of deep coal mining. The waste material originates from both the drilling of shafts, blinds shafts, stone drifts and coal faces and from coal washing. The coal-bearing strata originated as extensive tropical swamps and deltaic plains during the Upper Carboniferous (the Westphalian, ca. 300 million years ago) that covered large parts of Western Europe, from England to Poland. Through subsidence, burial and coalification and over a very long timespan (millions of years) the swamp vegetation litter (leaves, twigs, branches, roots, etc.) gradually turned into peat, brown coal and finally into bituminous coal. This Carboniferous rain forest (“Carboniferous Park”) was colonized by real giant organisms such as tall lycopod trees and horse-tails, giant dragonflies and huge millepeds. Fossil remains of lycopod trees (e.g. scale trees), horse-tails and fossil ferns can still be found in the waste material of the spoil heaps. The latter heaps consists predominantly of clay-rich sediments (mainly bituminous shales, shales and siltstones) with minor sandstone, conglomerate and carbonate (siderite): all these sedimentary rocks originated either as mud, silt or sand at the bottom of fresh-water swamp lakes or as the infilling of meandering / anastomosing fluvial channels and crevasse splays, crosscutting the Carboniferous swamp and delta plain.

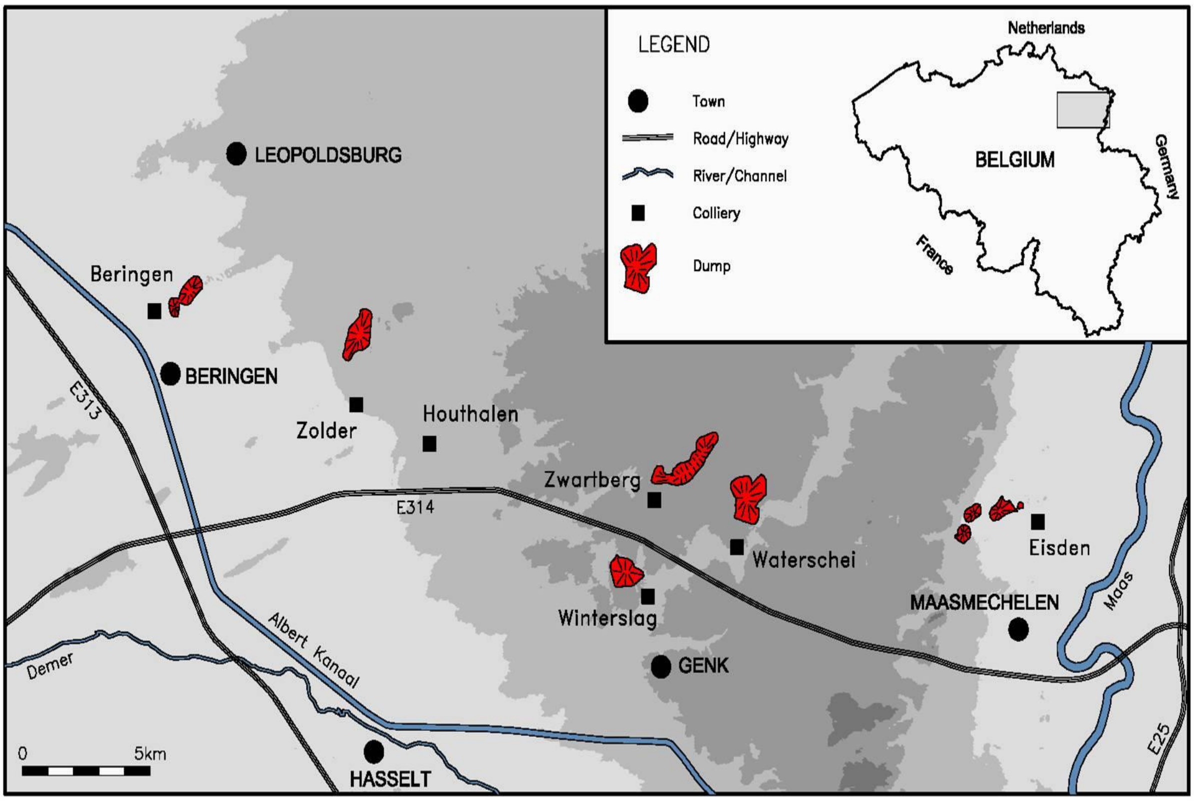

Fig. 1. Actual location and outline of the remaining coal waste dumps (red) in the Campine area, after reclamation (Credit: J. Matthijs, VITO)

The first hard coal seam was discovered by borehole in As on August 2, 1901 by the geologist André Dumont, at a depth of 541m. This was the start of a real coal rush in the province of Limburg and of almost 100 years of deep coal mining in the Campine area. Because of the great depths (up to 1000m) the coal seams could only reached by long shafts, the steel headframes of which are still preserved in the HKRIL as important industrial archeological heritage sites. Most of the spoil heaps of the former collieries of Waterschei, Winterslag, Zwartberg and Eisden are incorporated within the boundaries of the HKRIL. The total volume of waste rock in these heaps originally amounted to more than 140 million tons. Their heigths originally reached up to 100m. Most of them have now been reclaimed through remodelling, compacting and plant colonisation (hydro-seeding) so that the slopes are stabilized and acid water run-off is prevented. Moreover, the heaps of Waterschei and Eisden have become natural reserves in the meantime, hosting characteristic thermophilic and halophytic flora and fauna. Some heaps are red colored, such as the oldest coal spoil heap of Eisden, due to spontaneous combustion of coal relics as a result of the exothermic oxidation of pyrite present in the waste rock. The high amount of relict coal in the latter heap results from less-efficient coal washing techniques that were used in the earlier days of coal mining.

Fig. 2. The coal spoil heaps of Eisden, most of which have been taken over now by nature. In the background the red spoil heap (Credit: Het Belang van Limburg)

Cover sands and climatic oscillations

The Pleistocene (2,6 million years to 12.000 years ago) was a period characterized by alternating glacial periods (ice ages) and interglacial periods (interstadials). During this period a cold climate ruled over our study area, with a permament frozen underground (permafrost) and a tundra vegetation (mosses and dwarf shrubs). The sea level was also considerably lower then because of the enormous quantities of water captured in the land ice (ice caps and glaciers). This resulted, amongst other phenomena, in an important increase of the erosion capacity of the rivers. Rainwater runoff was capable of transporting large volumes of loose sand. During the interstadials the climate was warmer and more humid with a luxurious vegetation: deciduous forests protected the soils against runoff and the erosion capacity declined. Moreover, the sealevel rose again so that the erosion base of the rivers rose as well, resulting in a decreasing erosion capacity as well. This alternation (increase and decrease of erosion capacity) as well as the effects of tectonic activity (subsidence along graben faults) in the study area, lead to the formation of several river terraces (e.g. those of the Meuse river). During the last glacial a permanent anticyclone ruled above the northern ice cap, generating icy northerly winds over the Campine area. These strong winds transported sand and loess, blown out of the end moraines of the glaciers and the dry sea bottom and river beds. In this way, the whole area from the Northern Netherlands, Northern Germany through Middle Belgium became covered with a 2 m thick sand blanket (the so-called cover sands). During the gradual warming at the end of the last glacial period (latest Pleistocene- Holocene), westerly winds replaced the permanent northerly winds: the cover sands became locally reworked into sand ridges, parabolic dunes and hollows.

Fig.3. Historical sand dunes near Opglabbeek - Gruitrode (photograph: D. Van Uytven)

At Opgrimbie, a Late Glacial dune complex is thought to enclose a complete record of the Late Pleniglacial (Weichselian) to the present interglacial (Holocene). Only a few places in the NW European coversand belt exist where both the Bölling and Alleröd soil horizons can be identified. The latter soil horizons (also called the “Opgrimbie Soil” and “Usselo Soil”) are bleached sands with an average age of about 13.000 years: they represent short-term relatively warm interstadials. Locally, charcoal is present in the fosillized soils pointing to widespread forest fires. Some authors refer to the existence of a worldwide charcoal-rich layer of Alleröd age (Usselo), even suggesting the possibility of an extraterrestrial cometal impact. This could possibly account for the megafaunal extinction event at the end of the Pleistocene. Due to the presence of two superposed bleached horizons, laterally grading into peat (see Fig. 4), the dune complex at Opgrimbie is considered as a key reference section for the stratigraphy of the Late Glacial sandy eolian deposits in the southernmost part of the NW European coversand belt. Radiocarbon and optical datings as well as palynological analysis have been performed, the results of which have been published (Paulissen & Munaut, 1969; Derese et al, 2009).

Fig.4. One of the bleached horizons ("Usselo Soil") laterally grading into peat in a temporary section of the Late Glacial dune complex in Opgrimbie (Kikbeek sand pit) (Photographs: R. Dreesen)

The Hoge Kempen alluvial fan

The Campine Plateau originated during the Pleistocene as well. During the Early Pleistocene the Meuse river did not turned off to the north near Liège (as it is now), but it continued its way to the East as a affluent of the Moselle-Rhine. During the Middle Pleistocene (Cromerian-Elster), the Meuse had to transport an enormous amount of debris (floods from glacier bursts in the Vosges?) and its lower course got obstructed. Simultaneously, a tectonic subsidence along the westernmost graben fault of the Rhine graben system created a depression and the Meuse breached its northern interfluvium (between the Meuse valley and the northern Lowlands) (see Fig. 5). The Meuse then throwed its self in this low-lying area with little heighth gradient, so that the river coud no longer transport its enormous load and a huge alluvial fan was created. The low-lying area north of the Rauw Fault became filled with Meuse debris in the South, in the North by Rhine sediments. The Campine Plateau thus consists of a huge alluvial fan, deposited by the Meuse during the Cromerian-Elster period. Since then, the Meuse has eroded his own alluvial fan during succeeding phases, creating numerous river terraces. This process was the result of a combination of changing climatic conditions, sea level fluctuations and erosional capacities, within an area that was gradually uplifted. Differential erosion finally created an inversion of the landscape: the Meuse river deposits that originally filled a depression have now become a plateau: the Campine Plateau, the most conspicuous topographic structure in Northern Belgium (see Fig.6). The cemented gravel and sands (through iron(hydrox)ides) that composed the alluvial fan were indeed more resistant to erosion than the surrounding loose Tertiary sands (e.g. The Mol Sands). The latter have been eroded during the Saale and Weichsel ice ages, leading to the relief inversion.

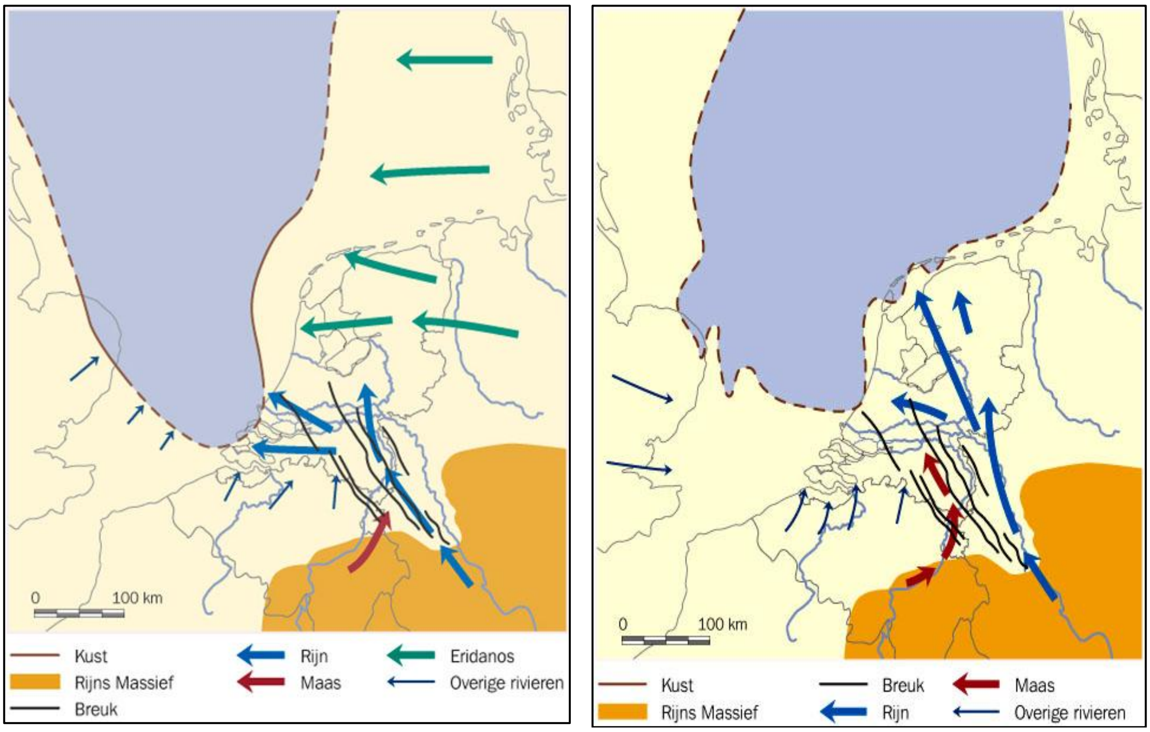

Fig. 5. Changes in the flow directions of the Rhine (blue arrows) and Meuse (red arrows): Early Pleistocene (left) and Middle Pleistocene (right). Black lines represent Roerdal graben faults. Credits: NITG-TNO

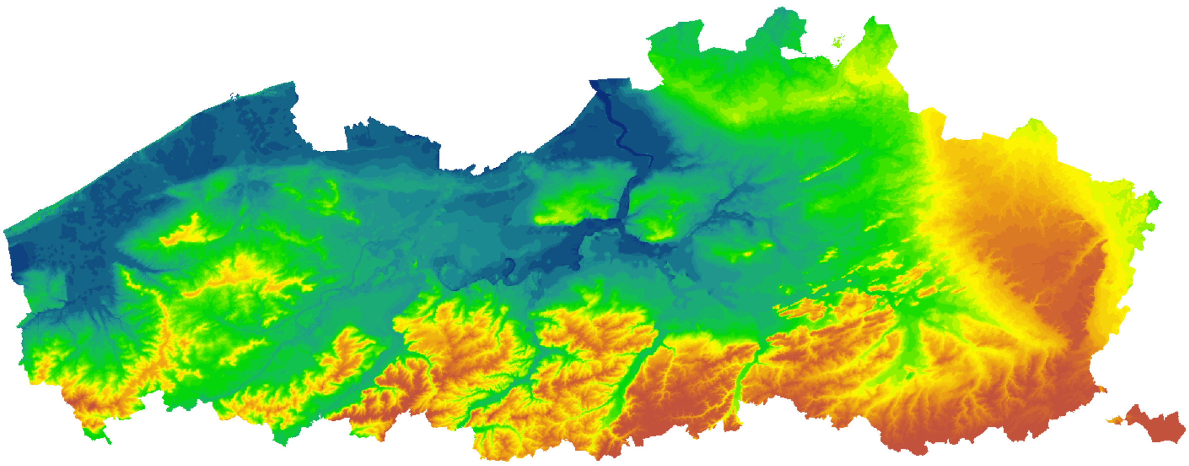

Fig.6. Digital Terrain Model of Flanders, showing the conspicuous lozenge-shaped Campine Plateau (extreme right) corresponding to the topographically inversed Meuse river alluvial fan (Courtesy of ALBON & VITO, 2010)

The Campine Plateau is a topographic unit with a lozenge to triangular shape that raises well above its surroundings. Its eastern edge is rather sharp (the escarpment or so-called "steilrand") and corresponds to the western Meuse valley border (see Fig. 7). It is very conspicuous because of its steepness: up to 40 m high. It runs almost straight to the North for almost 20 km. This particular scarp outline is probably controlled by the presence of a deep-seated fault (Feldbiss fault bundle) that belongs to the western boundary faults of the Roer Graben. The SW and NE-boundaries are less conspicuous. The Campine plateau slopes down from over 100 m (near Lanaken) to 40 m (near Leopoldsburg).

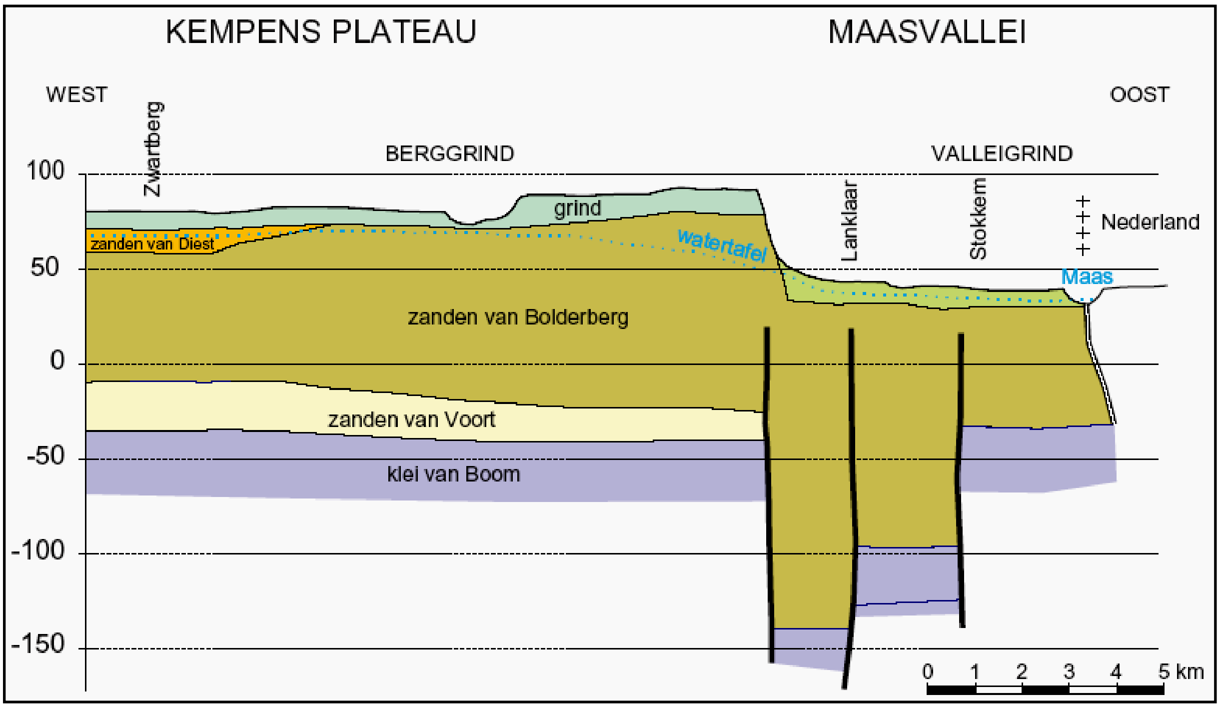

Fig.7. Geological WE-cross section from Zwartberg (Genk) to the Belgian-Dutch border, showing the topmost gravel layer, the layer-cake structure of the subsurface of the Campine Plateau and the fault-controlled steep eastern slope or escarpment ("steilrand")(Courtesy of ANRE, 1996)

The HKRIL covers the SE-part of the Campine plateau. It encloses also the Nationaal Park Hoge Kempen. The thickness of the Quaternary (sand & gravel) varies here between 4m and 22m, with a gravel thickness of 8m-16m. The alluvial fan deposits correspond to a volume of more than 7,5 cubic km or ca. 15 billion Tons. The gravelly part of the alluvial fan has been called the Zutendaal Grind (gravel) and represents the oldest Meuse river terrace in Limburg (Middle Pleistocene, about 600.000 years ago).

Braided rivers, ice rafts and boulders

Abandoned (and reclaimed) gravel and sand pits within the HKRIL, such as the Kikbeek sand pit and the former "Hermans gravel pit" in As (which was the first geological monument in Flanders; Bats et al, 1997), offer excellent opportunities to observe the internal structure and lithological composition of the Zutendaal Gravel and to unravel its depositional history. Moreover, in its topmost part this particular deposit has been affected by spectacular (handbook-type) cryoturbations (see further).
The Zutendaal Gravel lithologic unit is a matrix- (sand, silt and mud) supported fluvial deposit, displaying characteristic features of both meandering and braided river systems. Several superposed fluvial cycles can be observed, starting with coarse gravel units grading into finer sediments (sand, silt and clay). Numerous small channels cut into the underlying sediment (see Fig. 8). Fluvial fining upward sequences, through cross stratification and imbrication phenomena can easily be observed. Braided streams occur in rivers with high slope and/or large sediment load. Braided channels are also typical of environments that dramatically decrease channel depth, and consequently channel velocity, such as river deltas, alluvial fans and peneplains. The channels and braid bars are usually highly mobile,

with the river layout often changing significantly during flood events, such as melt water floods. Most conspicuous is the very bad sorting of the deposit, including clay, loam (silt), gravel (with diameters between 2m and 8 cm), and boulder sized debris (the latter with diameters exceeding 1-2 m and weights over 1 Ton). The pebbles are subangular to well-rounded wheras the matrix is colored reddish brown (see further). The presence of such huge boulders within the gravel is puzzling and it is still a matter of speculation amongst scientists, as no really matching recent analogues exist. However, it has been generally accepted now that the boulders could have been incorporated in and transported by ice rafts on peak discharges of melt waters from glacier burst during the summer of the glacial period.

Fig.8. Detail of a gravel pit wall in the HKRIL: cross-stratified sands, eroded by a gravel-filled channel, containing boulders of Cambrian quartzite.

Lithological and petrographical analysis of the pebbles and boulders unraveled their geological provenance: these have all been derived from hard-rock geological formations that were once exposed in the upper catchment area of the Meuse river, including also the former catchment area of the Moselle (as it once was a confluent of the Meuse). They all come from Paleozoic, Mesozoic and Cenozoic hard rock formations exposed in de Meuse river valley and its confluents in Northern France (Vosges area), South and Belgium (Ardenne, Condroz, Herve) (see Fig.9). Moreover, the well-rounded flint pebbles represent in fact reworked pebbles occurring at the respective bases of eroded Tertiairy sand formations ("basisgrind"). The following rock types have been identified in the gravel (pebbles and boulders): Devonian granites (very rare), Devonian microgranitic dyke material (rare), Precambrian-Cambrian quartzites and vein-quartz (predominant), Lower-Middle Devonian sandstones and conglomerates (frequent), Lower Carboniferous silicified limestones (rare), silicified calcarenites and flints from the Upper Cretaceous (frequent), and Tertairy quartzarenitic sandstones or silcretes (rare). Interestingly, no material has been derived from the weathering-sensitive Jurassic marlstones and claystones, Upper Devonian and Lower Carboniferous limestones and shales and Upper Carboniferous sandstones and shales. Thus, only the physically and/or chemically most resistant materials have reached the Campine area after a supposed relative long journey of several tens or several hundreds of km. However, some large phyllites and microgranite blocks that are normally easily weathered during transport, do occur as well, supporting the above suggested idea of transport by ice rafts.

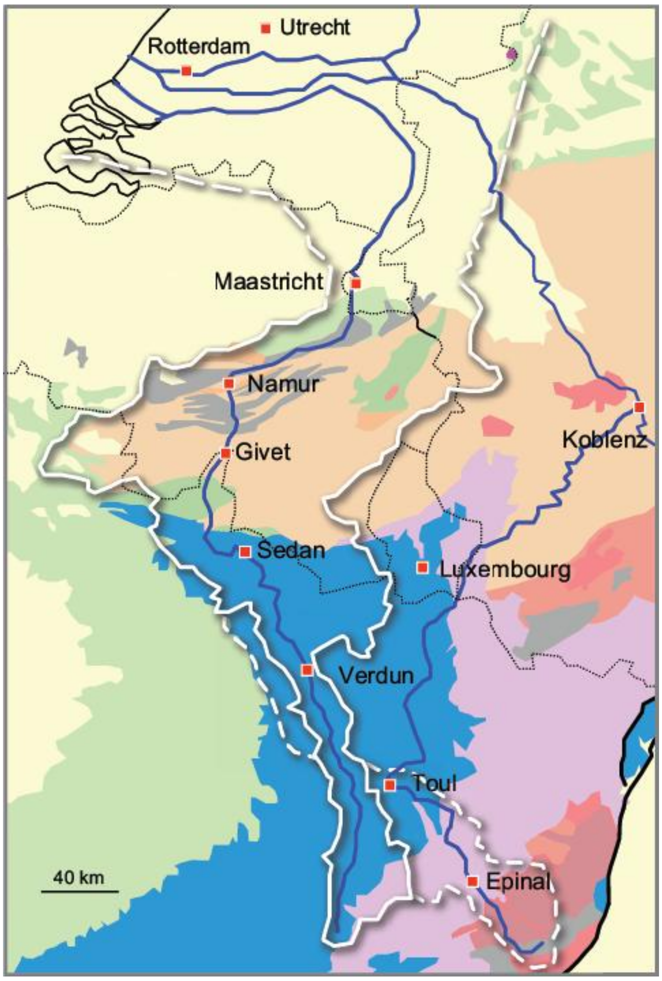

Fig.9. Left: Geological map of the Meuse river basin displaying the heterogenous geological provenance areas for the Middle Pleistocene Zutendaal Gravel, including the Vosges area (near Epinal) when the Moselle river was still a tributary of the Meuse (Credit: Jagt et al, 2010 after Bosch, 1992). The colors represent different geological formations. Right: example of a red-stained Devonian conglomerate (right) displayed in the geological rock garden of the Kikbeek sand pit (photograph: R. Dreesen)

The matrix of the gravel is reddish brown due to staining and cementing by iron(hydr)oxides (goethite). The intensity of the staining increases towards the top: it has been attributed to weathering processes after deposition of the gravel, during succeeding warmer interstadials with a more Meditteranean-type vegetation: this phenomenon corresponds to the so-called As paleosoil.

Fig.10. Visitors at the geological garden in the Kikbeek sand pit: each boulder tells its own fascinating geological history…

A representative set of the lithological varieties of boulders that have been found in-situ during gravel extraction, have been organized as a true geological rock garden: a large circle of stones in the abandoned Kikbeek sand pit displays geological time in a stratigraphic way (clockwise from the Precambrian through the Holocene) and allows to comment on the geological history of the provenance areas (see Fig. 10). For instance, pyrite-bearing Precambrian-Cambrian quartzites display numerous milky-white quartz veins that cross each other, witnessing of succeeding orogenic phases (mountain building periods) that affected the Ardenne area (Caledonian and Variscan orogenies). Further, nice examples of red-stained cross-bedded Devonian conglomerates represent erosion products of the Old Red Continent, the red colour of which points to the then prevailing arid climatologic conditions on this continent (desert-type environment with evaporites and wadi’s).

Besides a geological garden, a colourful brochure (“Keienzoekkaart”) has been published by the Regionaal Landschap Kempen & Maasland and the geological working group of LIKONA, to help teachers and their pupils, walkers, hikers and bikers, to accurately identify the numerous and often intriguing pebbles found along the different nature trails in the National Park area (see Fig.11). In this brochure a short determination key is presented together with a simplified classification scheme of the present rock types.

Fig.11. Extract of the guide for pebbles, published by the Regionaal Landschap Kempen & Maasland and the Geologische Werkgroep van LIKONA (Limburgse Koepel voor Natuurstudie) in 2007.

Permafrost

In the uppermost part of the gravel deposit, just below the Late Pleistocene-Holocene eolian sands, spectacular examples occur of a particular type of cryoturbation. In section the items look like vertical tongues or flames (“involutions”) up to 2-3 m in length whereby the pebble axes are vertically oriented (see Fig.12). In plane section (at the surface), these tongues form a characteristic network of large polygonals with diameters of less than 1m up to several m. This type of ground deformation is called “patterned ground” and it is most typical of periglacial areas, more particularly of areas affected by permafrost conditions. In periglacial areas repeated freezing and thawing of groundwater forces larger stones toward the surface as smaller soils flow and settle underneath larger stones. At the surface, areas that are rich in larger stones contain much less water than highly porous areas of finer grained sediments. These water-saturated areas of finer sediments have a much greater ability to expand and contract as freezing and thawing occur, leading to lateral forces which ultimately pile larger stones into clusters and stripes. Through time, repeated freeze-thaw cycles smooth out irregularities and odd-shaped piles to form the common polygons of patterned ground. These form mostly within the active layer of permafrost. Water percolating through the soil builds up underneath pebbles or larges stones. When it freezes, pebbles are pushed up towards the surface. When the soil thaws, the pebbles do not return to their original location because finer particles fill in voids. The process continues until the pebbles or stones reach the surface.
These spectacular polygons represent silent witnesses of the harsh (cold and dry) climatic conditions that prevailed in the study area during the last ice ages, particularly during the Weichselian (about 20.000 years ago). They are characteristic of arctic regions or areas with tundra, like those located around the actual pole circle (Canada, Spitsbergen, Greenland).

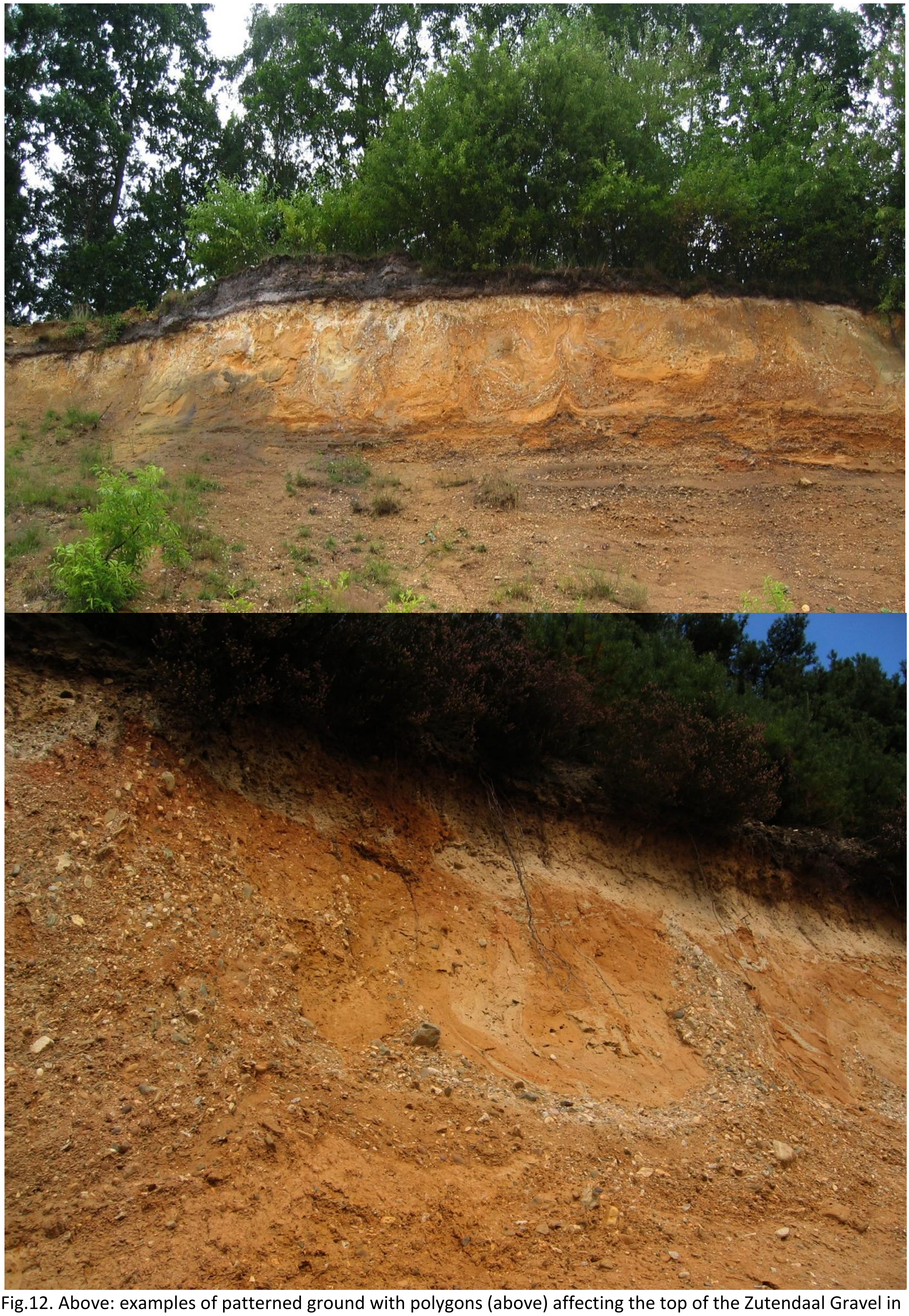

Fig.12. Above: examples of patterned ground with polygons (above) affecting the top of the Zutendaal Gravel in the HKRIL. Below: Detail of a vertical section of a polygon showing the “flames” or vertical stackings of pebbles. The internal space has been filled with cover sand; the topmost layer corresponds to the bleached horizon of a spodosol (podzol) developed within the Holocene cover sands (Photographs R. Dreesen).

Another indication of permafrost conditions that once ruled over the Campine Plateau is the frequent occurrence of dry valleys. These particular geomorphological features originated during the “summers” of the glacial episodes through runoff of melt waters: the partially thawed sandy underground became eroded, because the water could not infiltrate or penetrate into the permanent frozen underground (permafrost). These dry valleys are crosscutting the Campine Plateau (see Fig.13), including also its steep eastern escarpment.

Fig.13. Nice example of a dry valley in the Campine Plateau (Photograph: Courtesy of D. Van Uytven)

Coastal marches and silver sands

Most sand pits in the area of the Nationaal Park Hoge Kempen resulted from the excavation of extremely pure quartz sands or bright white “silver sands”. These pure sands (they consist almost exclusively of quartz) are quite rare on a global scale, but they do occur in the subsurface of the Campine Plateau, underlying the alluvial fan gravels, as the result of particular tectonic and sedimentary processes. Their occurrence in the HKRIL is geologically controlled: they are part of a NWN-ESE trending zone that is, at least partly bounded by faults that are related to the Rhine Graben tectonics. They probably result from long-lasting in situ leaching by humic acids percolating from overlying peat layers (now brown coal or lignite beds) that developed during a continental episode in the Early Miocene (Late Burdigalian, about 16 milion years ago). The Burdigalian represents the first and longest warm period in the Miocene. In the shallow subsurface of the Campine Plateau, near Opgrimbie, important reserves of silver sands occur: they are known as the Maasmechelen Sands and belong to the Bolderberg Formation. A brown coal layer (2- 7m thick) subdivides the Bolderberg sands, into 2 lithological units (see Fig.14, right). This threefold subdivision results from a the above mentioned short continental episode interrupting the deposition of shallow-marine, estuarine and tidal sands (the Bolderberg sands) in the Early Miocene. The latter normally consist of clean, clay-free sands, well-sorted by wave and current activity in a shallow marine bay of the paleo-North Sea, located in the North of Limburg. Due to subsidence along the western shoulder of the Roerdal Graben, about 40 m of yellow glauconite-bearing marine sands were deposited. Upwards, the yellow sands grade into bright white sands, the famous silver sands. These pure white sands only occurs where they are overlain by lignite or brown coal. As the sea briefly pulled back (regression) extensive coastal marshes developed in the study area, leading to the formation of peat, and subsequently lignite (brown coal). The brown coal is mainly composed of driftwood although swamp trees grew in place, as evidenced by numerous roots that penetrate the underlying sands. Palaeobotanical data revealed the dominance of swamp cypress trees (Taxodium), pointing to a depositional setting anlogue to the recent Everglades (Florida, US). Geological, depositional and paleocological data show good affinities with the better known and time-equivalent Lower-Middle Miocene brown coals of the Lower Rhine Embayment in the NW of the Rhenish Massif. Here, the brown coal seams reach a total thicknesss of 100 m due to continuous subsidence in the rift basin. The coastal marshes were subsequently invaded by the sea and covered again by yellow marine sand, the Opgrimbie sands, about 10m thick.

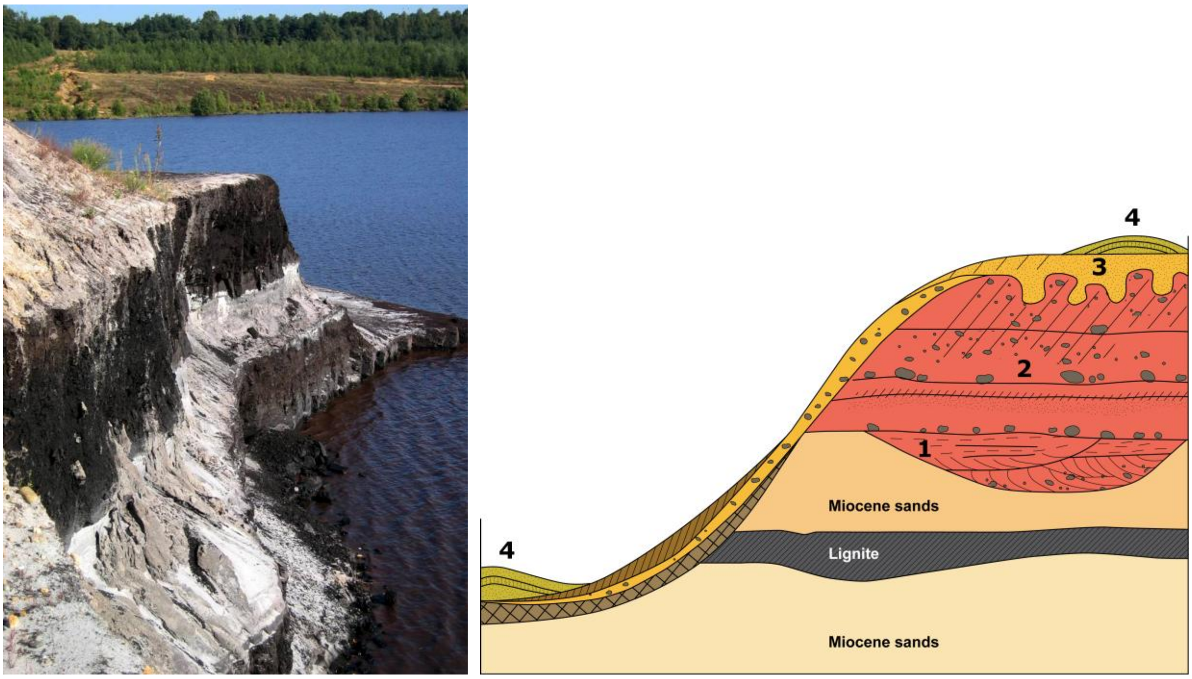

Fig.14. Left: Reclaimed Sibelco silver sand pit (Kikbeek pit in Opgrimbie) showing a browncoal doublet (the Kikbeek Lignite beds) and underlying white silver sands. Right: geological NS section of the Kikbeek sand pit showing the most important geologcal units: 1. Fluvial deposits (Zutendaal gravel), 2. Red-staining (As paleosoil), 3. Patterned ground (polygons) and cover sands, 4. Sand dunes with interstratified paleosoils (a.o. the Usselo soil) and subrecent spodosols (figure not to scale; taken from Dreesen et al, 2006; after Gullentops & Bastin, 1967)

About 1,5 m below the base of the brown coal, hard quartzarenitic sandstones occur (the Bolderian Sandstones) in the silver sand, forming thick plates or lenticular beds, displaying nice organic forms. These particular sandstones are pedogenic features, called silcretes, formed through silicification of the sand. Their origin is related either to post-depositional groundwater circulation or to evaporation processes in arid climates. They are analogous to the so-called “Sarsen stones” of the UK and the “Braunkohlequartzite” of the German Lower-Rhine area. They have been used as a vernacular building stone, e.g. for the restoration of the Sint-Quintinus cathedral in Hasselt. Moreover, when some of these huge, massive stones became unearthed through erosion of the enveloping sand by rainwater runoff, the prehistoric men dicovered them at the surface and used them for polishing his flint tools, e.g. the so-called Holsteen in Zonhoven (see Fig.15)

Fig.15. Quartzarenitic sandstones (Bolderian sandstones) outcropping at the surface and probably used by prehistoric men as a polishing tool (photograph: R. Dreesen)

Summary – intrinsic geoheritage values

The landforms and the subsurface of the National Park contain all elements to explain global climate change. The Campine Plateau is a unique geomorphological object and the best-kept example in Europe of an enormous and intact, alluvial fan formed during the recent Ice Ages (Mid-Pleistocene). Its actual form is the result of interfering erosional and tectonic processes. A conspicuous 20 km long eastern escarpment is related to fault activity along the western shoulder of the Roerdal rift basin. Spectacular patterned grounds with polygons affecting the top of the alluvial fan point to harsh, permafrost conditions during the youngest Pleistocene (Weichselian). A particular dune complex represents a key reference section for the Late Glacial sandy eolian deposits in the southernmost part of the NW European coversand belt, because of excellent preservation of fossilized soils, rarely seen elsewhere. The gravelly braided river deposits contain huge boulders that have been transported in and on ice rafts. Moreover, those boulders display a broad lithologic spectrum, representative of the geology of the upstream area of the Meuse river basin. Below the Pleistocene gravel blanket, pure white quartz sands occur the origin of which is related to the presence of lignite formed during the Miocene in coastal marshes analogue to the recent Everglades. Finally, huge spoil heaps at the surface represent enormous beacons referring to the luxurious tropical rain forests during the Upper Carboniferous that formed numerous coal layers, present in the deep subsurface of the Hoge Kempen: their discovery in 1901 meant the beginning of a real coal rush in the Province of Limburg.

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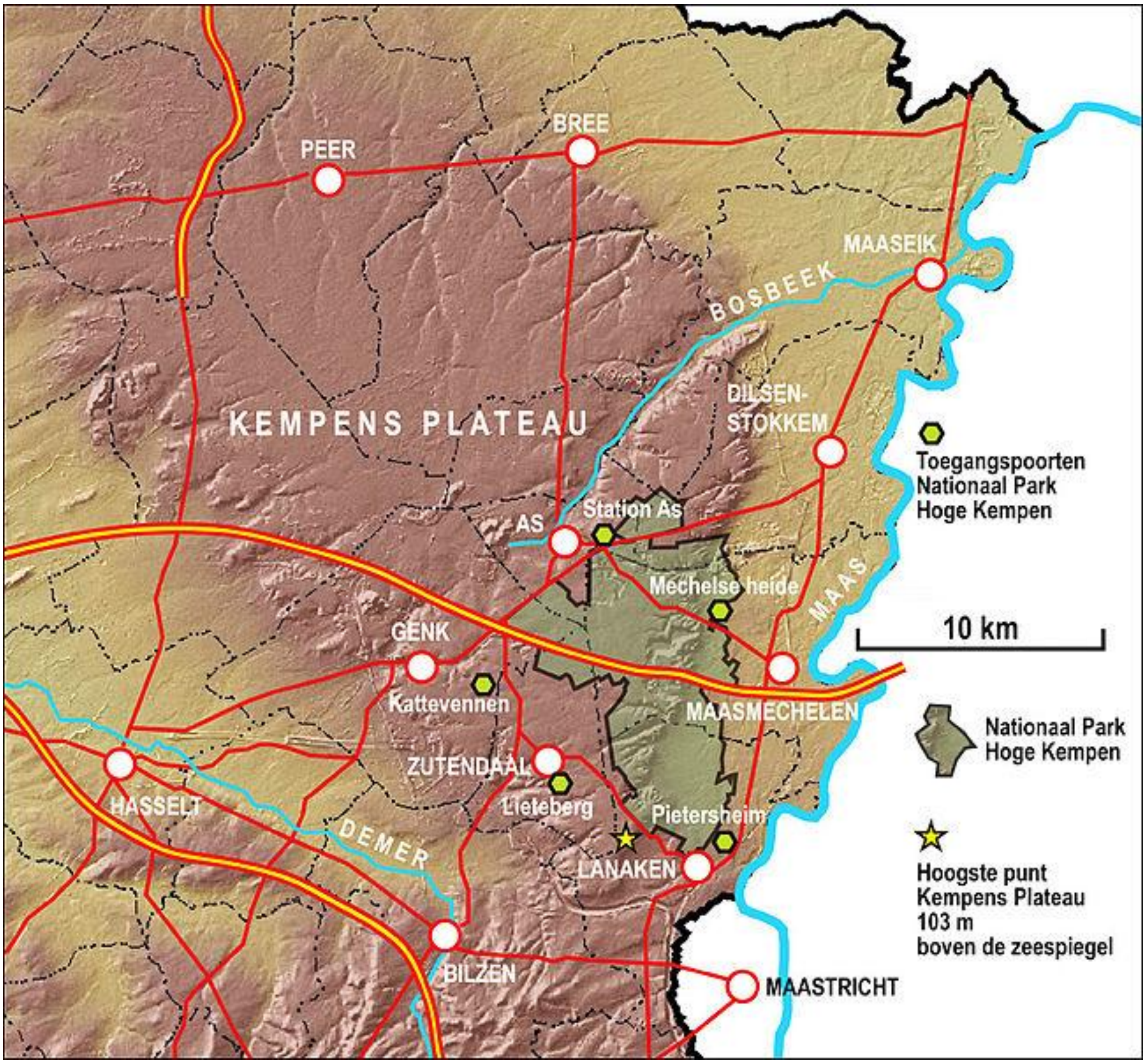

The Campine plateau with the location of the Nationaal Park Hoge Kempen and its different gates (http://nl.wikipedia.org/wiki/Nationaal_Park_Hoge_Kempen)

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