



Short Communication

Discussion: Oil seepage or fossil podzol? An Early Oligocene oil seepage at the southern rim of the North Sea Basin, near Leuven (Belgium) by E.D. van Riessen & N. Vandenberghe, *Geologie en Mijnbouw* 74: 301–312 (1996)

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Introduction

When Van Riessen and Vandenberghe changed the museum-quality fossil podzol in the Roelants sand pit at Pellenberg into an oil seepage, we have seriously reconsidered our earlier interpretations. This reconsideration has not changed our opinion that it is indeed a fossil podzol and not an oil seepage, which opinion we will defend in the following.

At first sight it is strange that scientists propose a new interpretation for a well-known feature without giving serious thought to the old interpretation. In the case of the paper discussed here, we have to suppose that the authors are unacquainted with soils, podzols, and soil organic matter and have not consulted the literature on these topics. Nevertheless, a good understanding of podzols in general and of their specific forms and properties is necessary to understand the merit of the interpretation of the organic-rich horizons at the top of the Kerkom Sands as a fossil podzol.

A fossil podzol of approximately the same age as the 'oil impregnation' described by Van Riessen and Vandenberghe, can be found in the Francart clay pit near Henis, just north of Tongeren (Buurman & Jongmans 1975). Henis is about 47 km east of Pellenberg. We found various indications of soil formation, in addition to podzolization in the top of the Neerrepn Sands, i.e.:

- an eluvial and an illuvial humus layer (podzolization),
- a fragipan (a layer that is brittle and hard when dry and slakes in water when wet; it is due to rearrangement of particles (e.g. clay coatings around

grains and in pores) and is related to terrestrial environments),

- an increase in smectite content in the eluvial layer (typical in podzols, through weathering of e.g. micas),
- pyrite accumulation in root channels, linked to the subsequent transgression,
- weathering of pyrite and formation of gypsum in an undefined later stage.

The soil profile was formed in more or less horizontally stratified sands of up to 2 m thickness, overlying a tidal-flat system witnessed by small cliffs of fine sediments with steep narrow creeks filled up with the same fine sand in which the soil profile was developed.

At the time of study (1974), the Francart clay pit was dug out in the top of the Neerrepn Sands till about 2 m below the directly overlying Henis Clay. The podzol development of the profile was weak, but clearly indicated by coatings of organic matter on sand grains and on the oriented clay coatings of the fragipan.

We observed the same paleosol in similar stratigraphic setting at Membrugge (8 km NE of Tongeren) and Valkenburg (28 km NE of Tongeren). At Valkenburg, the soil occurs in laminated deposits that overlie tidal deposits, which in their turn overlie and cut into the Neerrepn Sands. The paleosol is overlain by Henis Clay, as at Henis (Buurman & Jongmans 1975).

At Vissenaeken, 9 km SE of Pellenberg, the tidal sediments at the top of the Neerrepn Sands still carry the same paleosolic features; here the sands are called Kerkom Sands and have formed in an estuarine environment followed by a beach facies. Although the stratigraphic level of the podzols in the Neerrepn

Sands and that in the Kerkom Sands may be different, the environment is similar. In both cases deposition of sands in a shallow-marine environment is followed by emergence and soil formation.

After publication of the paper by Van Riessen & Vandenberghe, we revisited the Francart pit, which has been dug out till at least 5 m below the base of the Henis Clay. We found two superposed, darkly stained horizons, of which the bottom one is very similar to that of the Roelants sand pit at Pellenberg. We also visited and sampled the Roelants sand pit for comparison.

We want to base our defense of the podzol-nature of the dark-coloured, organic-matter-impregnated horizons at Pellenberg on two aspects: 1) the nature of podzols in (sub)tropical landscapes, and a comparison of the structural features that they may exhibit with the features encountered at Pellenberg, and 2) a comparison of the chemical composition of the organic matter of the Pellenberg and Henis locations with that of podzol illuvial horizons from recent landscapes.

Podzols in (sub)tropical coastal landscapes

Literature on podzols, including those of tropical landscapes, is abundant. A compilation can be found in Buurman (1984). Later publications have added detail but not changed the general scope. Various bibliographies and summaries on tropical podzols are available (Anonymous 1962, 1965, 1978; Klinge 1965a).

In the (sub)tropics, podzols are common in up-lifted coastal areas consisting of sandy deposits. Podzolization starts in the litter layer, where unsaturated organic acids are produced. Such acids leach carbonates from sandy parent materials in a relatively short period. After carbonate removal, well-sorted coastal sandy deposits have very little buffer capacity for acids left. Acids that are not neutralized, and other fine-particulate organic substances, start moving down the soil profile, either in solution or in suspension. Part of the organic matter is precipitated at a certain depth by, for example, complexation with Al and Fe that is set free by weathering of primary minerals. The organic matter that is not precipitated chemically and not oxidized by microbes, precipitates where the vertical water transport stops. In low-rainfall areas, this vertical transport may be restricted to 0.5 to 1 m, but in the perhumid tropics it may not be limited because water percolation occurs throughout the year.



Figure 1. Poorly-drained Holocene podzol in Younger Dryas cover sand under peat of Atlantic age. The irregular, fuzzy contact between eluvial and illuvial horizon, and the banded organic-matter accumulation at the bottom are clearly visible. Ossendrecht, the Netherlands. Length of ruler is 1.5 m.

The transported organic matter precipitates in the so-called illuvial horizon. Because production of organic acids in the litter layer continues, the illuvial layer usually dissolves at its top, while it grows at its lower boundary. This results in a gradual downward movement of the illuvial horizon. Because dissolution is influenced by selective water penetration, the contact between the eluvial and the illuvial layer may be very irregular, as in the Roelants pit. The eluvial horizon thus grows vertically and may reach a thickness of metres and, in extreme cases, more than 10 m. In the eluvial horizon of strongly podzolized sands, only quartz and minor amounts of other resistant minerals remain, resulting in extremely white quartz sands.

In sandy soils with shallow groundwater, vertically moving dissolved or suspended organic matter will eventually reach this ground water. Lateral groundwater movement may transport this organic matter in large quantities over large distances. When



Figure 2. Irregular contact (dissolution patterns) between eluvial and illuvial horizon of a Holocene tropical podzol from the east coast of Malaysia. Profile height shown is 1.8 m.

organic-matter-laden groundwaters reach rivers, so-called black-water rivers come into being (e.g. Reeve & Fergus 1983). Not all organic matter reaches open drainage systems. Much remains behind in the subsoil, where its accumulation is regulated by small changes in porosity. Zones of lateral organic-matter accumulation tend to show darker and lighter bands. Dark bands may be widely spaced (up to metres), depending on texture or groundwater flow characteristics. They accentuate every barrier in their path: ripples, ghosts of shells, minor joints. They can be strongly cemented. Chunks of cemented material do not slake in water. Bands of lateral organic-matter accumulation are common in all poorly-drained podzols in sands. They are not restricted to the tropics, but are also found in temperate areas. Very good examples occur in Holocene podzols in the Belgian Kempen and in Dutch cover-sand areas (Figure 1). They form rapidly, perhaps in a matter of one or two thousand years.

The podzols of Pellenberg and Henis show all essential characteristics of typical lowland podzols with a lateral groundwater flow. Some of these can be recognized in Figures 5b and c of Van Riessen & Vandenberghe:

- Although the original soil surfaces have been eroded, remnants of an eluvial horizon are encountered in both locations. The white-coloured ‘Heide Sands’ between the gray Berg Sands and the black illuvial material in the Kerkom Sands belong to the eluvial horizon. The irregular contact that Van Riessen & Vandenberghe interpret as an ero-

sion surface in cemented, oil-impregnated Kerkom Sands (their Figure 5c), is the dissolution pattern at the contact between eluvial and illuvial layer. Careful observation shows that there is no lithological discontinuity between the overlying white and the underlying organic-matter-impregnated layer in Figure 5b. Sedimentary structures continue from one layer into the other and there is no sign of a lag deposit at the contact. The irregular and sharp transitions that are shown in Figure 5c and at the base of Figure 5d, are common in Holocene podzols (cf. our Figure 2 and Figure 4 of Klinge 1965b).

- Some parts of the Pellenberg location and the whole of the Henis location show a vertical gradation from more diffuse organic-matter accumulation near the tops to more banded structures in the lower parts of the profiles. This is a normal transition from the top part that has some biological homogenization by roots and/or animals to the lower, permanently wet part, where the sedimentary stratification is undisturbed (cf. our Figure 1).
- In addition to evidence of lateral transport and vertical dissolution, both the Pellenberg and the Henis locations show organic-matter accumulation that is related to vertical transport: accentuation of the tops of ripples and of ghosts of shells in zones that do not have massive organic-matter accumulation.

The aforementioned clearly indicates that morphologically there is a perfect corroboration between the features that are found in modern podzols and those of the

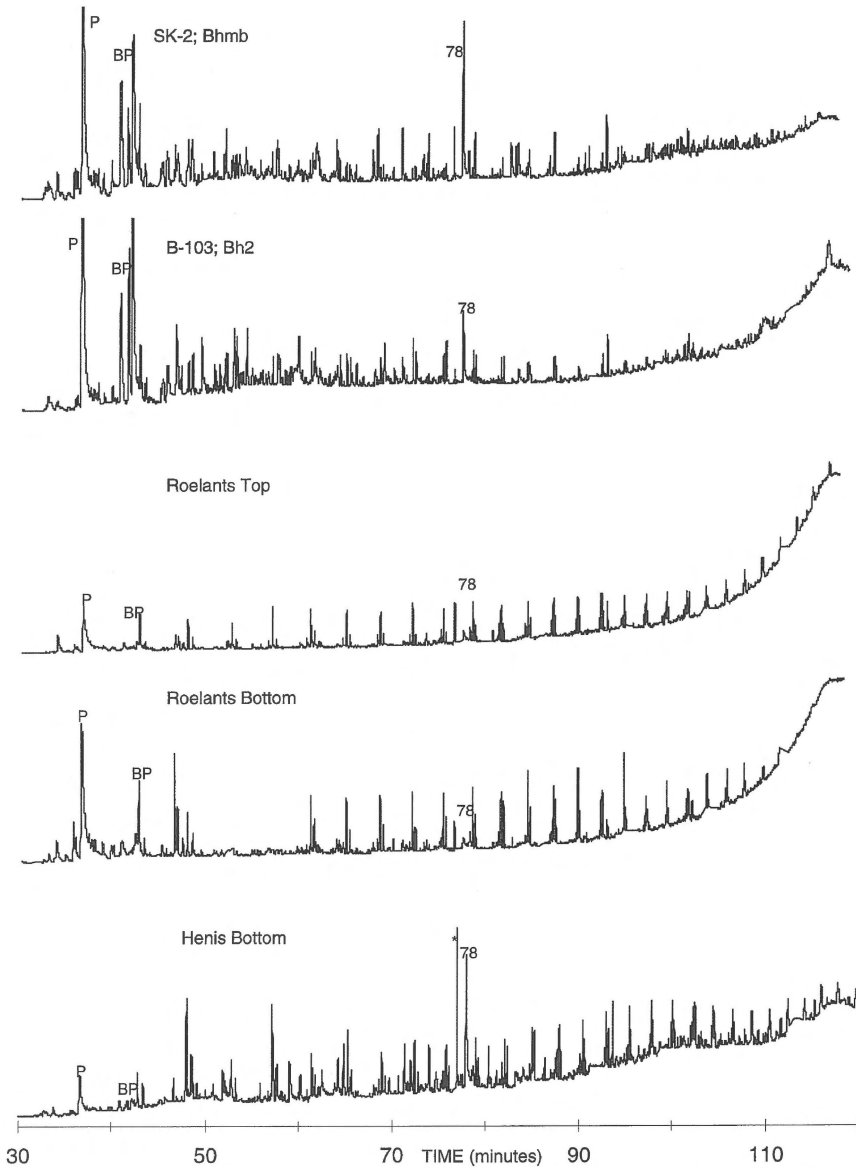


Figure 3. Chromatograms of pyrolysed samples of Holocene podzol-B horizons (SK-2 and B-103) and organic matter from the Roelants and Henis sand pits. The peak marked with * in the Henis Bottom chromatogram is a pollution. P = polyphenols, BP = methyl phenols and methoxy phenols. Bhmb and Bh2 are soil horizon indications.

Pellenberg and Henis organic-matter accumulations. Parts of cemented bands are sufficiently coherent to stand some transport in tidal channels that erode the E and Bh horizons of the soil.

Organic-matter chemistry

Van Riessen & Vandenberghe have used organic matter of a Chinese soil for comparison. Because organic-matter chemistry in soils is quite variable, and differ-

ences between podzols and other soils are major, this does not make much sense. In addition, the authors' own interpretations indicate their doubts: the absence of hydrocarbon smell (p. 307) and the mismatch (p. 311) between the chemical characteristics of the black layer from Pellenberg and those of the oil from the proposed source area in the western Netherlands.

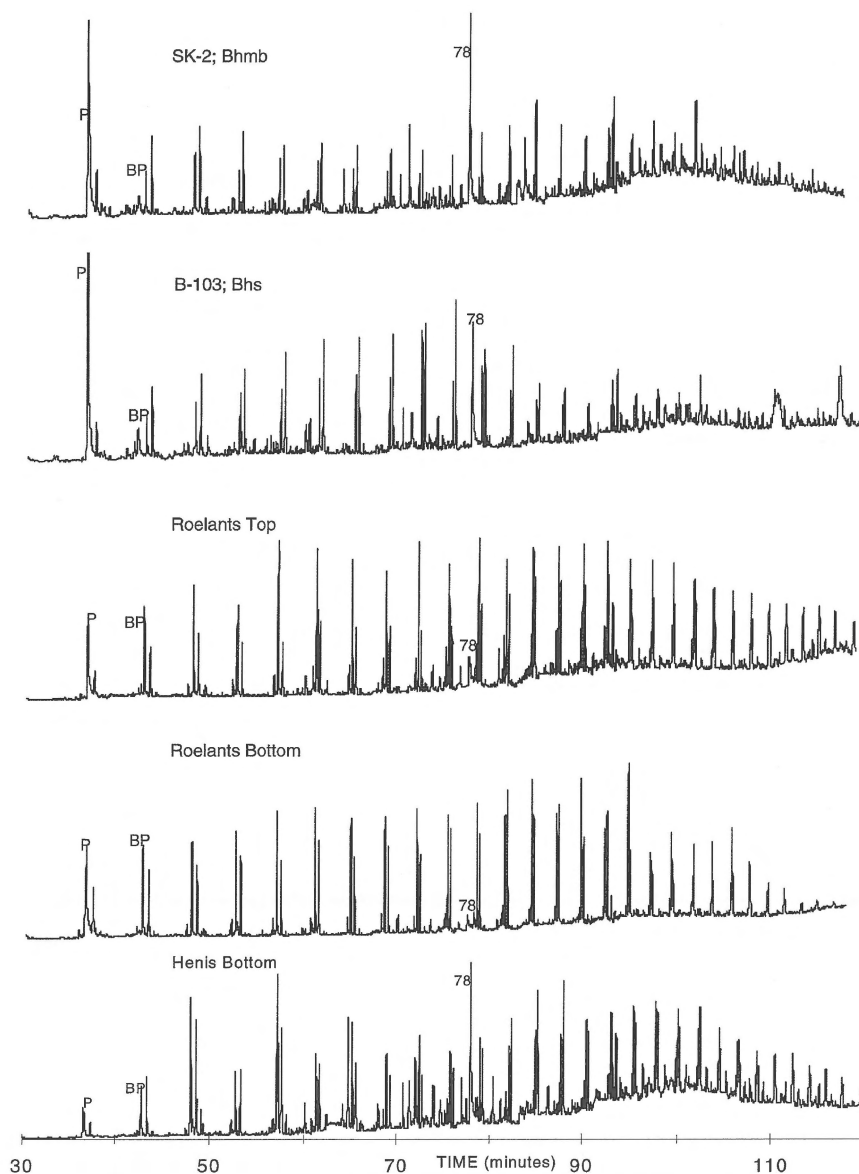


Figure 4. Chromatograms of Figure 3 filtered for aliphatic masses 55 and 57.

Methods

We have taken two samples of each of the Pellenberg and the Henis organic matter accumulations. In addition, we have analysed two accumulation horizons of organic matter from poorly-drained Holocene podzols: a Bh2 horizon from profile B-103 from the Belgian Kempen, and a Bhmb horizon from profile SK-2 from Sarawak. The Sarawak soil was studied in detail by Andriess (1969). Both profiles have been described by Mokma & Buurman (1982) and are available for study at the International Soil Reference and Information Centre (ISRIC) in Wageningen. Profile B-103 has

a very clearly banded subsoil, and one of the bands was taken for analysis.

Organic matter was extracted from the samples by 23 hours end-over-end shaking of 10 g sample in 100 ml 0.5M NaOH. This extracts more than 99% of the organic matter. The extract was decanted and centrifuged at 4000 rpm to remove particulate material. The extract was then acidified to pH 1 with HCl. Remaining silica was removed in 0.3M HF (1 hr shaking), after which the organic material was dialysed to neutral pH. The extract was freeze-dried and analysed by pyrolysis-GC-MS.

Pyrolysis was performed with a Horizon Instruments LTD Curie-Point pyrolyser on an Interscience GC8000 gaschromatograph with a MD800 mass spectrometer. The GC column was a Chrompack CP-Sil5 Low Bleeding column (dimensions: 25 × 0.25 × 0.40 cm). Mass spectra were recorded scanning the masses in the range from 45 to 650 Atomic Mass Units.

Results

The chromatograms of the two Holocene podzol-B horizons and of three of the four samples from the Oligocene deposits are given in Figure 3. The Holocene podzols (SK-2 and B-103) are dominated by phenolic compounds. The main peak in the chromatograms is the phenol (P) peak at 37 min. The cluster of peaks (BP) around 42 min. are methyl- and methoxy-phenols and phenols with larger subgroups. In the Oligocene deposits, the phenolic compounds are also present, but the peaks are less intense. The Roelants Bottom sample has the highest phenol peak of the three fossil samples. The fourth sample (Henis Top; not shown) is completely dominated by aliphatic signals.

At 78 minutes all samples have a peak of a fatty acid, presumably the C₁₆ fatty acid. In the Roelants sample this peak is very low, but in the other samples it is clearly marked.

If the specific masses for aliphatics (masses 55 and 57) are filtered from the total ion current, the chromatograms of the fossil samples give a nice homologue series of aliphatics (Figure 4). The doublets are the alkene and alkane peaks. If triplets appear instead of doublets, the first two peaks are alkenes and dienes. The development of the homologue series is strongest in the Henis Top sample (not shown), which is almost completely aliphatic. The Roelants Bottom and Roelants Top samples are intermediate, while the development is weakest, but still clear in the Henis Bottom sample. In the modern podzols, the development of the homologue series is less expressed, and better developed in the profile from Sarawak than in that from Belgium. When the homologue series is more strongly developed, it shifts to higher molecular weights, suggesting stronger polymerization.

The spectra of the Holocene samples have a large number of minor peaks which are not visible in the reproduced figures of the fossil samples. At larger magnification, however, they are also found in the fossil samples.

Conclusions

The clear relation to a land surface of the Pellenberg humus-accumulation layer, and its similarity to the proven podzols in the Neerrepn Sands, strongly suggest that it is due to soil formation. The morphology of the humus-accumulation layer and of its upper and lower boundaries are fully similar to those found in modern hydromorphic podzols, both of tropical and of temperate climates.

Pyrolysis-GC-MS of the whole organic-matter fractions indicates a gradation between the various fossil samples. If the fossil organic matter is compared with that of Holocene podzols, a pattern arises that shows loss of polyphenols and an increase in long-chain aliphatics in the fossil samples. Although the chromatograms of the Holocene samples are not identical with those of the fossil ones, there appears to be a genetic development sequence between the two groups rather than a systematic difference.

All the evidence taken together strongly suggests that the organic-matter accumulations in the top part of the Oligocene Kerkom Sands at Pellenberg are the remains of a fossil podzol-B horizon, and not of an oil seepage.

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