



*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). Reply by the Authors**

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In their discussion Buurman et al. (this issue) suggest that we did not seriously consider the well-known soil hypothesis for the chocolate-coloured horizon in the top of the Kerkom Sands of the Early Oligocene Tongeren Group in the Leuven area (Belgium). On the contrary, both of us have discussed the genesis of the organic-rich horizon during numerous field trips with many professional geologists, including soil scientists, some of them favouring a soil origin as well as some favouring an oil-impregnation origin. A careful consideration of all arguments raised, led us to the conclusion that field characteristics alone could not decide between both hypotheses. Therefore we submitted the organic matter for an organic geochemical analysis, of which the results were published in the paper now under discussion. The Francart clay pit podzolic soil described earlier by Buurman & Jongmans (1975), which is indeed of undisputed origin, is stratigraphically distinctly different from the chocolate-coloured horizon under discussion and both horizons have a very different physical appearance. These distinct differences prompted us to further investigate the horizon at Pellenberg. The Francart type podzolic soil can be observed in the Pellenberg area a couple of hundred meters to the south in a pit near the academic hospital. It underlies the Hoogbutsel Complex, still another soil and lagoonal complex, and the Kerkom Sands in the top of which the chocolate-coloured horizon occurs. Therefore arguments from the Francart podzolic soil should not be used in discussing the chocolate-brown horizon.

Another element brought into discussion by Buurman et al. is the nature of the white sands overlying the chocolate horizon. These white sands are known in the literature as the Heide Sands and occur only

locally. Buurman et al. claim that these sands are the eluvial part of the soil and the chocolate sands the illuvial part. They argue that our interpretation of the boundary between both sands as being erosional is wrong.

The possibility that the white sands are the reworked eluvial part of the former soil profile was considered by us; however, the erosional nature of the boundary is beyond question. Indeed, contrary to the claim of Buurman et al., the base of the Heide Sands does contain numerous flint pebbles and in fact the small flat and black flint pebbles, well known at the base of the overlying Berg Sands, first appear with the flooding bringing the white sands over the area. The sands are structured in thin alternating units with current cross bedding and with a wealth of specific bioturbations, quite distinct from the underlying Kerkom Sands. The chocolate-sand pebbles of very different sizes were taken up in the streaming water, rounded and mixed with the sand and the flint pebbles. In addition one can observe occasionally small chocolate-sand pebbles, or purple sand streaks derived from a decomposing chocolate-sand pebble, at the base of the Berg Sands. In some places the top of the chocolate horizon is colonized by worms burrowing into the sands. Contrary to the claim by Buurman et al. no sedimentary structures continue across the contact between the brown horizon and the overlying white sands. All these observations show that there is a clear break between the chocolate sands and the later Heide Sands. Gullentops, a notorious pro-soil colleague, has described the boundary features as an erosive cliff (Gullentops et al. 1988).

In order to test the hypothesis that the white sands might be reworked eluvial sands we made grain-size

analyses of a vertical profile consisting of four samples of white sands and of two chocolate-coloured sands. The two types of sands are distinct with respect to sorting and to the size of the finest and the coarsest fractions. Based on these data, the hypothesis of reworked eluvial sands was not retained in our paper.

The last element brought into discussion by Buurman et al. is the organic geochemistry. Buurman and his collaborators use the approach of extracting the humic-acid-type organic matter with an inorganic base. They then compare the extracts of fossil soils with recent analogues. They consider the presence of phenols and the nature of the long-chain aliphatics in the humic fraction of the chocolate sands as good indicators for a soil origin. Although their extraction procedure has the advantage of analysing a large amount of the organic fraction, the humic-type acids are also among the most difficult to characterize with respect to their origin. The term humic acids refers to a fraction extracted by a particular extraction procedure frequently used in soil analyses. Humic-type acids however are not solely restricted to the soil environment. Humification takes place in all kinds of sedimentary and early-diagenetic environments and hence humic acids will be an important component of the organic matter of all such immature sediments. There is no reason to believe that hydrocarbons spilled at an oil seepage would not be humified and converted into protokerogen. However, the processes involved in the formation of protokerogen and kerogen are badly known. Biodegradation, polymerization, condensation, selective preservation and natural vulcanization are believed to be involved but the role of each of them is still under debate. The composition of the humic acids will depend on the initially available organic matter as well as on the poorly understood transformation reactions. Due to the complex interaction between organic matter, bacteria and environmental conditions, an accurate study of the origin of the humic fraction should involve the examination of potentially source-specific compounds liberated from the protokerogen by pyrolysis. Such a genetic characterization of the humified fractions is a tedious procedure, involving more than just a visual comparison procedure as proposed by Buurman et al.

In our approach we therefore preferred the procedure of extracting in an apolar organic solvent (dichloromethane) the relatively unaltered bitumen fraction, generally a small proportion of the total organic matter. Total organic matter in the horizon varies but can reach more than one percent as determined

by weight loss. Bitumen originates not only from crude oil but also from biodegradation and alteration of biomolecules, but in contrast to protokerogen it does not form complex polymers. Therefore it can be easily studied with conventional chromatographic procedures and mass-spectrometry. Moreover, as bitumen compounds are important geochemical tools for the characterization of oils, their origin and diagenetic fate have been well studied. This led to the definition of a large number of well-tested geochemical parameters to unravel depositional environments, maturity and (bio)degradation. This small fraction of so-called organic fossils hence is very useful to rapidly study the organic matter of a deposit. As presented in our paper, the GC-MS analysis of this extract shows a mature bitumen generated from a marine, marly and probably slightly hypersaline source rock. Especially the maturity does not agree with the immature Kerkom Sands, deposited in probably brackish water, leading to our interpretation of the chocolate horizon as an oil seepage. Unfortunately, our organic geochemical interpretation of the data is not discussed by Buurman et al. and the soil hypothesis defended by Buurman et al. does not answer the question where this inconsistent fraction of organic matter comes from. In addition, it could be argued that if the contribution of continental organic matter should be as large as proposed by Buurman et al. one would expect to find traces of it in the bitumen fraction which is not the case in our interpretation.

In conclusion, we continue to believe that the chocolate horizon has not yet delivered all its secrets and would welcome further more refined analysis of the organic matter.

## References

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