Remarkable Pleistocene periglacial slope deposits in Luxembourg (Oesling): pedological implication and geosite potential

Jérôme Juilleret, Jean François Iffly, Laurent Pfister & Christophe Hissler

Centre de recherche public – Gabriel-Lippmann, Département environnement et agro-biotechnologies (EVA), 41 rue du Brill, L-4422 Belvaux, Luxembourg (juillere@lippmann.lu)

Juilleret, J., J. F. Iffly, L. Pfister & C. Hissler, 2011. Remarkable Pleistocene periglacial slope deposits in Luxembourg (Oesling): pedological implication and geosite potential. *Bulletin de la Société des naturalistes luxembourgeois* 112: 125-130.

Abstract. This article describes a remarkable geologic and pedologic outcrop located in the Luxembourg Ardennes (Oesling). The observed superficial formation is recognized as Pleistocene periglacial slope deposit (PPSD). Soil horizons are strongly influenced by the different layers of PPSD. The biologically active topsoil, made of an Ah and Bw horizon developed from the silty loamy UL, is influenced by the loess deposit. The BL represents a lithologic discontinuity in the soil profile according to an abrupt rise of the amount of coarse elements. PPSD, which are witnesses of past climates and landscapes play an important role in the ecosystem functioning of the Oesling, especially for water residence time and flowpaths. The easily accessible site should be valorized as an example of a geosite in Luxembourg.

Key words. Cover beds, Rhenish Massif, WRB soil classification, valorization.

1. Introduction

Soils of the Rhenish Massif in Western Europe have not developed from *in situ* weathered rocks, but from Pleistocene periglacial slope deposits cover beds (PPSD) (Kleber 1997, Semmel & Therhorst 2010). These PPSDs were formed during the Quaternary glaciations under periglacial climatic conditions and are composed of a mixture of eolian loess atmospheric deposits and of fragmented bedrock (Semmel 1993, Pissart 1995). The occurrence of periglacial slope deposits has been well reported from studies in the German and Belgium parts of the Rhenish Massif (Sauer & Felix-Henningsen 2006, Therhorst 2007, Rhixon & Juvigné 2010). They where also recognized in Luxembourg (Hermanns 1955, Kwad and Mücher 1977). The cover beds consist of laterally down-slope transported material during cold climate periods, mostly by periglacial processes such as solifluction or cryoturbation.

According to the lithological discontinuities and their stratigraphical position, the PPSDs are differentiated in the German soil classification system (AG Boden 2005): into "Hauptlage" (upper layer, UL), "Mittellage" (intermediate layer, IL), and "Basislage" (basal layer, BL). The "basal layer" (BL) lies immediately on top of the bedrock in almost every relief position. It consists of debris of the phyllite saprolite of the underlying bedrock and is free of loess. Its thickness varies from 20 to 100 cm. The "intermediate layer" (IL) is rich in loess and only occurs in positions, which favour loess accumulation and preservation. Its thickness varies from 0 to 50 cm. Its position is usually on top of the BL. The "upper layer" (UL) contains rock debris and loess. Where it has not been eroded, it covers the land surface with a thickness of about 50 ± 20 cm in all relief positions. The rock fragments are usually oriented parallel to the slope.

In soil surveys carried out in natural areas, the soil properties are generally attributed to the characteristics of the underlying bedrock. However, studies have shown that in many cases the influence of the fresh underlying bedrock is limited and that lithological discontinuities of the regolith play a crucial role on the pedogenetic evolution (Lorz &

Phillips 2006, Juilleret et al. 2012). According to the prior concept, the mapping and the characterization of the PPSD layers are crucial for the study of the soil/subsoil functions (water storage capacity, organic matter stability and nutrient cycling). In such a system, the soil characteristics (stone content, texture, field capacity, soil depth and rootability) are rather driven by the lithological properties of the PPSD than by some pedogenetic processes.

Based on a remarkable outcrop, the main purpose of this article is to illustrate the concept of PPSD in Luxembourg and its impact on the soil horizonation and properties. The secondary purpose is to show the great interest of the studied outcrop as an example of geosite in Luxembourg.

2. Study site and geological setting

Observations were made at a large outcrop located in the north of the "Petit-Nobressard" village in the Oesling (Fig. 1). The



Fig 1. Location of the "Petit-Nobressart" outcrop (yellow star) in Luxembourg. Oesling: Luxembourg part of the schistose Rhenish Massif, Gutland: Luxembourg part of the sedimentary Paris Basin.

Oesling represents the Luxembourg part of the Rhenish Massif and consists of a plateau that has an average altitude of 450 meters. The Devonian rocks, which compose this region, mainly consist of schists, phyllites, sandstones and quartzites. The plateau, which supports cropland and forests, is incised by a dense network of rivers and streams, which created deep V-shaped and forested valleys, mainly as a consequence of uplifting processes that occurred in this region (Demoulin et al. 2009).

The outcrop is located along the road CR 310 (X: 53754 m, Y: 95168 m according to Luxembourg Reference Frame) (Fig. 2). The removal of rocks, probably consecutively to road maintenance or quarry activities, allows the observation of the bedrock, its saprolite and the overlying PPSD along more than 15 meters. According to the geological map of Rédange (Colbach & Maquil, 2003), the bedrock consists of Devonian phyllites of the "Formation de Grumelange (d2G)" (Fig. 2). Measures of the cleavage made in the fresh bedrock indicate that the striking is 75 N degrees and the dipping is 70 degrees to the South-West. Those values are in accordance with Bintz (2006).

3. Material and methods

Field investigations were started by a lithostratigraphical recognition of the different PPSD layers observed above the bedrock. In a second step, we differentiated the soil horizons using the texture, the colour, the hydromorphy features, the volume of coarse elements (size >2mm), and the soil pH (using the *in situ* Hellige pH-indicator).

4. Results and discussion

4.1. Identification of the PPSD layers

The outcrop shows a succession of 2 PPSD layers from the soil surface to the bedrock (Fig. 3).

At the top, the "upper layer" (UL) presents a mixture of para-auchtonous rock clasts and a loamy silty matrix. In this layer, the orientation of the clasts is subhorizontal and

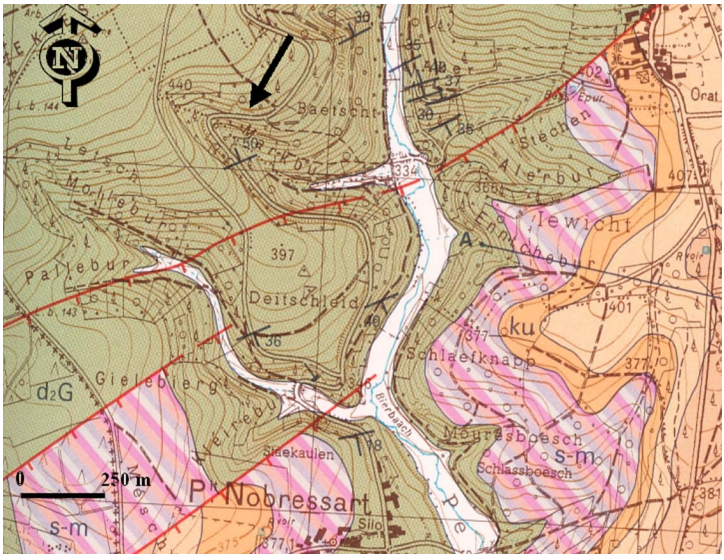


Fig 2. Location of the "Petit-Nobressart" outcrop (black arrow) on an extract of the geological map of Rédange (Colbach & Maquil 2003) - d2G: Formation de Grumelange, s.m: Muschelkalk and undifferentiated Buntsandstein, ku: Lettenkeuper.

parallel to the actual soil surface. The silty-loamy matrix is explained by the presence of loess deposits in the UL.

The "basal layer" (BL) is located immediately above the bedrock. It exclusively consists of para-autochthonous rock debris, which are oriented across and parallel to the soil surface depending on the observed zone of the outcrop. Some clasts are still fixed in the bedrock, suggesting that their downslope displacement is modest. According to the literature, the BL is composed of clasts directed parallel to the actual soil surface, which is not always the case herein. However, we can note that the fixation of the clasts is often visible but not always along the outcrop, where clasts tend to be increasingly inclined. In some places of the outcrop, distinction of the weathered phyllites and a "pure" BL is fuzzy and the observed layer is an intergrade between a BL as described in the literature. The parallel to slope orientation of the debris in the UL and BL is explained by a slow downslope displacement of the clasts by solifluction or soil creeping processes. Solifluction

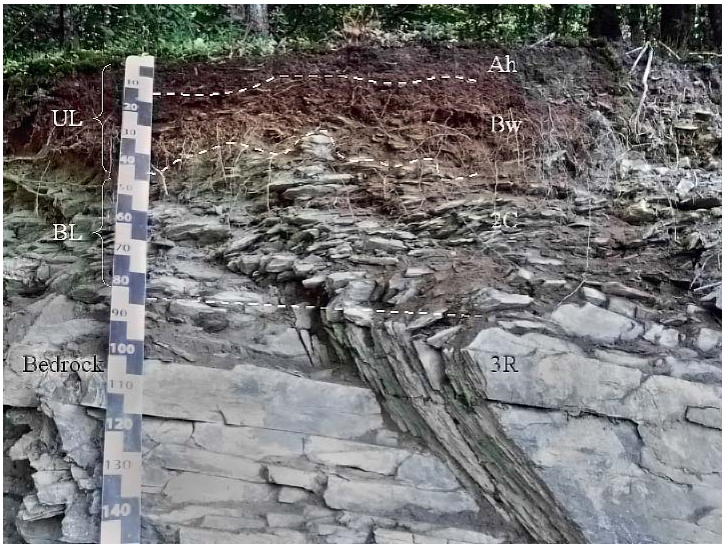


Fig 3. Lithological and pedological typology of the observed outcrop. Lithological units are UL (Upper Layer) and BL (Basal Layer). Pedological units are Ah (organo-mineral horizon), Bw (Cambic horizon), 2C (mineral horizon of alteration) and 3R (bedrock).

is a typical type of earth flow found in periglacial environments underlain by permafrost. During summer the surface layer of permafrost melts, creating a water-saturated layer that becomes mobile. The underlying frozen ground acts as a sliding plane along which the soil mass can slowly move downslope. According to Sauer & Felix-Henningsen (2006), the climate during formation of the BL, which is free of loess, must have been cold and humid. Their development must have taken place before the periods of intensive loess accumulation during the Pleniglacial.

4.2. Pedological implication

4.2.1. Soil description

From a pedological point of view, the soil developed from the observed PPSD is not intensively differentiated. Limits of the topsoil and the subsoil are essentially herited from the lithostratigraphical limits induced by the PPSD layers (see annexes for the complete soil description).

The UL constitutes the parent material of the topsoil. Resulting from its loam and silt amount herited from loess deposits, and its friable consistence, the UL represents the biologically active part of the soil where the root system is well developed. Nevertheless, we didn't note an intense earthworm channel network due to the low pH, which reduces the activity of the macrofauna. Hence, the topsoil supports a moder humus type. This UL permits the development of an Ah horizon and of a cambic Bw horizon. Both are not calcareous, with a moderately blocky angular structure and a silty loamy texture. The amount of coarse elements is quite high in both horizons and estimated at 15 to 40% of the horizon volume. No reductimorphic properties were observed and the field pH test indicates values between 3 and 5. These chemical properties characterize an acidic soil with a low base saturation.

The BL implies a lithological discontinuity in the pedological sequence due to a sharp increase of the volume of coarse elements. Accordingly, the BL corresponds entirely to the 2C horizon of the pedological sequence. This horizon is very compact, non-calcareous and essentially composed of coarse elements made of angular, platy and slightly weathered rock fragments. The volume of the silty loamy matrix is less than 10%. No reductimorphic properties were observed.

4.2.2. Soil classification

The Cambic horizon Bw described in this profile is the diagnostic horizon used to classify this soil through the World Reference Base for soil resources (FAO-ISRICI-USS, 2006). The WRB is a comprehensive classification system consisting of a combination of a set of prefix and suffix qualifiers that are uniquely defined and added to the soil name allowing a precise characterization (and information about the soil functions) and classification of the soil profiles:

- as the soil profile has a continuous bedrock within the 100cm of the soil surface the prefix "Leptic" has to be added,

- the lithological discontinuity and the increasing volume of coarse elements between the UL and the BL mark the deeper part of the soil profile. This lithological discontinuity is noted with the suffix qualifier "Ruptic" and by the suffix "2" in the horizon sequence,

- as the soil supports an Ah horizon, the organic carbon contents in the fine earth fraction exceed 1 percent to a depth of 50 cm, the suffix "Humic" has to be added,

- the acidic properties of the soil indicate a very low base saturation and allow adding the suffix qualifier "Dystric",

- the large amount of gravels, exceeding 40% in volume over a depth between 50 and 100 cm from the soil surface is noted with the suffix qualifier "Endoskeletic",

- the silty loamy texture in the Bw horizon, allow to add the suffix "Siltic".

Consequently and according to the WRB classification (FAO-ISRICI-USS, 2006), the soil developped from the observed PPSD is a Leptic Cambisol (Humic, Ruptic, Dystric, Endosketelic, Siltic).

4.3. The "Petit-Nobressart" outcrop as a geosite example

According to Strasser et al. (1995), geotopes (geosites) are portions of the geosphere

delimited in space with a particular importance from a geological point of view. They provide an overview of the changing landscape and climate. They make the geosites "unique" due to their specific physical, morphological, climatic and structural factors. Identifying, cataloguing and evaluating geosites is a preparatory activity for their protection, conservation and valorization as recommended by the committee of ministers from the Council of Europe in the "Recommendation Rec(2004)3" on conservation of the geological heritage and areas of special geological interest" (Council of Europe, 2004). The latter recommend that governments of member states identify in their territory areas of special geological interest and support information and education programmes to promote action in the field of geological heritage conservation. Considering the scientific and pedagogic interest of the PPSD observed in the "Petit-Nobressart" outcrop as a witness of past climate conditions, considering the easy access to the site we would like to promote the valorization and conservation of this place as a geosite.

5. Conclusions

The PPSDs have been well reported in the German and Belgium parts of the Rhenish Massif. They are usually composed of 3 lithostratigraphic layers. In this paper, we recognize and describe the Upper Layer and the Basal Layer, which constitute the most widespread layers found in the literature. Observations were made on an exceptional outcrop site located in the southern part of the Oesling. The length of this outcrop offers a window to the Luxembourg geodiversity. This site, which is easily accessible, represents a pedagogic example of the PPSD and allows to look backward at past climate conditions. It should be classified as a geosite in Luxembourg. Mapping and characterizing the different PPSD layers in Luxembourg is of great relevance for the understanding of soil evolution and on its impact on hydrological processes in relation with climate change. Furthermore, these pedo-geological formations open the understanding to the past and present ecosystem functioning.

Acknowledgments

The authors would like to acknowledge Alexandre Fernandes for his help during the preparation and the photography of the soil profile and the reviewers for their comments, which helped improving this manuscript.

Appendix

Ah horizon (0-15 cm): 10YR22, silty loamy, moderately blocky subangular structure. Clear and wavy horizon boundary. Soft and non-calcareous. Many fine and medium gravels made of angular and slightly weathered Phyllites rock fragments. Common fine roots. Absence of mottles. Field pH test indicates a value of 4.

Bw horizon (15-45 cm): 10YR43, silty loamy, moderately blocky subangular structure. Abrupt and wavy horizon boundary. Soft and non-calcareous. Many fine, medium and coarse gravels made of angular and slightly weathered Phyllites rock fragments. Few fine roots. Absence of mottles. Field pH test indicates a value of 5.

2C horizon (45-85 cm): stratified rock structure essentially composed of coarse elements made of angular, platy and slightly weathered phyllites rock fragments essentially oriented parallel to the actual slope. Clear and abrupt horizon boundary. Extremely hard and non-calcareous. Very few fine roots. Absence of mottles.

3R horizon (85-200 cm): stratified rock structure essentially composed of stones made of angular, platy and slightly weathered Phyllites rock fragments oriented vertically according to the cleavage.

References

AG Boden (Ad-hoc-Arbeitsgruppe Boden), 2005. Bodenkundliche Kartieranleitung. 5th edn., ed.: Bundesanstalt für Geowissenschaften und Rohstoffe in Zusammenarbeit mit den Staatlichen Geologischen Diensten, Hannover, 438 pp.

Bintz, J., 2006. Schistosité et allure tectonique dans l'Ardenne luxembourgeoise. *Bulletin de la Société des naturalistes luxembourgeois* 106: 181-192.

Colbach, R. & R. Maquil, 2003. Carte géologique du Luxembourg 1/25000-Feuille n° 7 Rédange. Edition du Service Géologique du Luxembourg.

Council of Europe, 2004. Recommendation Rec(2004)3 on conservation of the geological heritage and areas of special geological interest. Council of Europe, Committee of

Ministers. https://wcd.coe.int/ViewDoc.jsp?id=740629&Lang=en

Demoulin, A. & E. Hallot, 2009. Slope and amount of the Quaternary uplift of the western Rhenish shield and the Ardennes (western Europe). *Tectonophysics* 474: 696-708.

FAO-ISRIC-IUSS, 2006. World reference base for soil resources 2006. *World Soil Resources Reports* 103. Food and Agriculture Organisation, Rome, 128 pp.

Juilleret, J., J.F. Iffly, L. Hoffmann & C. Hissler, 2012. The potential of soil survey as a tool for surface geological mapping : a case study in a hydrological experimental catchment (Huewelerbach, Grand-Duchy of Luxembourg). *Geologica Belgica* 15: 36-41.

Kleber, A., 1997. Cover-beds as soil-parent materials in midlatitude regions. *Catena* 30: 197-213.

Lorz, C. & J. D. Phillips, 2006. Pedo-ecological consequences of lithological discontinuities in soils – examples from Central Europe. *Journal of Plant Nutrition and Soil Science* 169: 573-581.

Pissart, A., 1995. L'Ardenne sous le joug du froid. Le modelé périglaciaire du massif ardennais. *In*: L'Ardenne, essai de Géographie physique (A. Demoulin, éd.), Département de Géographie physique, Université de Liège, pp. 136-154.

Rixhon, G. & E. Juvigne, 2010. Periglacial deposits and correlated processes in the Ninglinspo Valley (Ardenne massif, Belgium). *Geologica Belgica* 13: 49-60.

Sauer, D. & P. Felix-Henningsen, 2006. Saprolite, soils and sediments in the Rhenish Massif as records of climate and landscape history. *Quaternary International* 156-157: 4-12.

Semmel, A., 1993. Grundzüge der Bodengeographie. Teubner, Stuttgart, 133 pp.

Semmel, A. & B. Terhorst, 2010. The concept of the Pleistocene periglacial cover beds in central Europe: A review. *Quaternary International* 222: 120-128.

Strasser, A., Heitzmann P., Jordan P., Stapfer A., Stürm B., Vogel A., & Weidmann M, 1995. Géotopes et la protection des objets géologiques en Suisse: un rapport stratégique. Groupe de travail pour la protection des géotopes en Suisse, Fribourg, 27 pp.

Therhorts, B. 2007. Periglacial cover beds and soils in landslide areas of SW-Germany. *Catena* 71: 467-476.