Orphans in soil classification: Musing on Palaeosols in the World Reference Base system

Karen Vancampenhout[A,B] and Jozef Deckers[A]

[A]Department of Earth and Environmental Sciences, K.U.Leuven, Celestijnenlaan 200E, 3001 Leuven, Belgium. Email karen.vancampenhout@ees.kuleuven.be and seppe.deckers@ees.kuleuven.
[B]Department of Biosciences and Technology, KHKempen University college, Kleinhoefstraat 4, 2440 Geel, Belgium

Abstract
Despite the ongoing discussion, there is a strong need for a well-defined, widely usable classification for buried palaeosols that can accurately represent the main palaeosol characteristics. Rather than developing a separate system, the authors evaluate the use of WRB 2007 without major alterations. For palaeosols buried deeper than 2m, they propose to consider the upper boundary of the palaeosol as the 'soil surface' and add the word 'Buried'. RSGs and qualifiers can then be used unaltered to represent an array of major palaeosol characteristics, making this approach particularly suitable to classify welded or polygenetic palaeosol-complexes. Not all definitions used in WRB 2007 can be indisputably applied to palaeosols, but small adaptations in future versions could easily solve this problem. The use of WRB 2007 is assessed for five benchmark palaeosols or pedo-stratigraphic markers from Belgium and this case study illustrates that the concept of WRB could easily be extended to include palaeosol classifications.

Key Words
Palaeosols, soil classification, WRB, Tertiary palaeosols, Rocourt, Usselo.

Introduction
Classifying buried palaeosols still is an issue of debate. Although most soil classification systems are not primarily indented to classify palaeosols, there is a strong need for an interdisciplinary reference: the vast array of ill-defined terms, concepts and adaptations today is confusing. Moreover, a well-designed classification system would enable a rapid understanding of the main properties of a certain palaeosol. This paper aims at establishing a proof of concept for the applicability of World Reference Base 2007 (IUSS Working Group WRB 2006/07) in classifying palaeosols, by evaluating its performance in describing the properties of five Belgian Tertiary and Quaternary palaeosols (both deep seated as more superficial).

State of the art
Mack *et al.* (1993) and James *et al.* (1998) proposed a system based on Soil Taxonomy (Soil Survey Staff 1992), further elaborated upon by Nettleton *et al.* (1998) for buried soils. Krasilnikov and Garcia Calderon (2004) state that WRB is more suitable and propose to use the prefix Thapto- followed by the (modified) name of (modified) Reference Soil Group (RSG). These types of adapted system emphasize on only one diagnostic horizon, while palaeosols are often polygenetic. Moreover, adaptations of existing systems may cause confusion. Proposing a completely new system for buried palaeosols is not advantageous either, as the main goal of any classification system, i.e. to provide a reference to a large a number of soil scientists, is not attained.

Therefore, the option of using a basically unaltered well-known classification system merits more attention. A system based on strictly defined profile characteristics such as WRB eliminates the need for speculation and can be used without major adaptations: only the traditional constraint for material within 2 m of the Earth's surface needs to be adapted to make the system applicable to deep-seated soils. The authors propose to substitute the palaeosol top for the surface (if >2m) and to add the word 'Buried'. The qualifier system used in WRB moreover allows to focus on multiple properties. Hereby it should be noted that in WRB qualifier lists in the Reference Soil Groups are not restrictive.

Classification of five benchmark palaeosols

The 'chocolate sands' near Pellenberg

A deep seated (>10m), up to 4m thick, chocolate brown colored palaeosol occurs in the Early Oligocene Tongerian Kerkom sands near Pellenberg (Figure 1). These sands are chemically poor, coarse and cross-bedded, illustrating a fluvio-marine environment. The 'chocolate' dull brown to very dark brown horizon contains C_{org} up to 0.6%, cementation and cracked coatings on sand grains. Slightly darker lamellae of variable thickness occur with carbon contents up to 1.27%. It is interpreted as the B horizon of a giant coastal Podzol with lateral groundwater flow and fulfils the requirements of a spodic horizon (Buurman *et al.* 1998; Van Herreweghe *et al.* 2003). Hence this soil should be termed a "Buried Carbic Podzol", totally in line with the available data on this soil (Buurman *et al.* 1998; Van Herreweghe *et al.* 2003). Arenic and Dystric also apply to this soil, but can be considered redundant and not considered in the qualifier's list of the Podzols. Other qualifiers such as Fluvic or Tidalic or Gleyic would capture more properties of this soil, but their current definition is not indisputably applicable on palaeosols. Hence, the introduction of Palaeofluvic, Palaeotidalic or Palaeogleyic should be considered. Furthermore, it would be useful to extend the definition of Lamellic (currently only for clay lamellae) and Profondic (currently only for argic horizons) to account for the hyper-dimensions (4-10m) of the spodic horizon. Its genesis by lateral intrusion of DOC is not accounted for in the classification.

Figure 1. The 'chocolate sands' near Pellenberg.

Figure 2. The Boom Clay near Pellenberg.

The Boom clay near Pellenberg

The Tertiary Boom Clay is a deep seated (>7m) tropical marine formation (Rupelian) of black, acid clays. A soil has formed in its top including 2-4% organic material, jarosite infillings, concretions of gypsum and silicified septaria (Vandenberghe *et al.* 1997). The boom clay can be accurately defined as a thionic horizon. Given its clear marine origin, this soil logically should be termed a "Buried Fluvisol (Thionic, Gypsiric, Clayic)". However, the current definition of fluvic material is problematic for palaeosols, as it requires "sediments that receive fresh material at regular intervals or have received it in the recent past". An exception for palaeosols could be a solution. If not, a "Buried Umbrisol (Thionic, Gypsiric, Clayic)" should be the correct classification. Again, a Palaeotidalic or Palaeofluvic qualifier would be useful as would one that accounts for the septaria, e.g. Septaric.

The Rocourt Pedocomplex (Veldwezelt-Hezerwater)

The Rocourt Pedosequence is a pedo-stratigraphic marker for the last interglacial and early glacial period in Upper Pleistocene loess deposits. Most typically it is described as a complex of one or more reddish B horizons showing clay coatings and a polygonal network of bleached desiccation cracks. They are overlain by a banded light-gray bleached layer caused by stagnating, laterally moving melt water and at the top a complex of A horizons with slightly more organic matter. The pedocomplex is intensely welded and highly influenced by frost action. At Veldwezelt-Hezerwater, the B horizons in the profile described by Vancampenhout *et al.* (2008) do not fulfil the requirements for an agric horizon and part of the clay coatings originate from soil welding, i.e. they were formed when these horizons were no longer near the surface. The organic matter content of the A horizons is 0.5% or less. Requalification at the top of the profile resulted in very high base saturation of the upper horizons.

This soil may therefore be named a “Buried Fragic Endostagnic Protoluvic Cambisol (Hypereutric, Siltic, Chromic)”. The qualifiers Turbic, Glossalbic and Cutanic would be useful to express the observed, cryoturbation, albeluvic properties and clay cutans in this profile. However, the cryoturbation is -at present- not at the palaeosol surface or above a cryic horizon and the albeluvic properties and clay coatings do not occur in a natric or argic horizon. The qualifier Ochric would be very appropriate to represent the organic horizons, yet is no longer used in WRB 2007. If these additional qualifiers can be used, the WRB classification successfully captures all main properties of this complex, intensively welded, polygenetic palaeosol.

Figure 3. The Rocourt Pedocomples at Veldwezelt-Hezerwater

Figure 4. The Usselo Soil (dry variant)

Figure 5. The Usselo Soil (wet variant)

The Usselo soil near Lommel

The ‘Usselo-palaeosol’ represents the soil formed during the Allerød interstadial in Quaternary coversands. It is found <2 m below present-day surface and is overlain by Podzols. It consists of a bleached layer containing charcoal particles and beetle bioturbations and some cryoturbation (white veins originating from ice lenses) in the dry variants, while peaty accumulations of organic material characterize the wet variants. Some variants of the Usselo soil have a subdued rubified expression (Kaiser *et al*. 2009). As the palaeosol is not buried deeper than 2m, the regular WRB classification applies. The present-day soil profile and included palaeosol classify as a “Haplic Podzol (Thaptoalbic)” for the dry variant and a “Carbic Podzol (Thaptohistic)” for wet variant. The rubified expressions could not be accounted for in WRB 2007. Indications for the palaeo-cryoturbations (at present not linked with a cryic horizon) and beetle bioturbations would likewise be useful.

The buried Albeluvisols near Bertem

The forest near Bertem is featured by an unaltered topography, characterized by a Holocene flat-bottomed valley catena of undisturbed Albeluvisols (plateau), Atlantic Luvisols or Alisols (slopes) and buried palaeosols (valley bottom). This valley topography originates from the Dryas stadials, when the slopes eroded by solifluction and the valley bottom was covered by the eroded material The profile in the valley bottom shows prominent albeluvic tonging at a depth of ca. 70 cm. This palaeosol is overlain by a Haplic Alisol rich in manganese and iron accumulations (Brahy *et al.* 2000). As the palaeosol occurs at shallow depth, the profile classifies as a ‘Haplic Alisol (Manganiferric, Dystric) over Albeluvisol’, which perfectly describes its main characteristics.

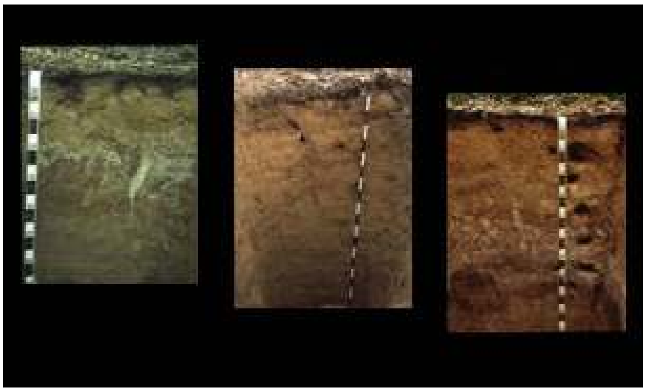

Figure 3. The Bertembos-valley catena: plateau soil (left), slope soil (center) and valley bottom soil (right)

Conclusion

If the upper boundary of a palaeosol is regarded as the 'soil surface', the definitions of WRB can very successfully be used for palaeosols. Qualifiers are well suited to comprehensively indicate the main properties of palaeosols, even the complex nature of polygenetic palaeosols on loess is well represented. In order to use WRB more effectively for palaeosols, a revision of the boundary conditions for the use of certain qualifiers would be advantageous. New qualifiers may also be proposed and the use of applicable qualifiers that are not enlisted in the reference groups is to be encouraged.

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