Published in Geoderma 120 (2004)

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Revisiting the definitions of gypsic and petrogypsic horizons in Soil Taxonomy and World Reference Base for Soil Resources

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Abstract

Gypsic and petrogypsic horizons occur in large areas of arid and semi-arid regions of the world. The occurrence of gypsum in soils is considered a key feature by most soil classification and mapping systems, that have coined specific names for these soils and horizons. However, the current methodology for description and definition of gypsic and petrogypsic horizons in the two most popular soil taxonomic systems “Soil Taxonomy” and “World Reference Base for Soil Resources” (WRB) doesn’t address sufficiently the advances in knowledge of the constitution, genesis and behavior of gypseous horizons. Some of their basic statements, like the presence of secondary gypsum or the degree of cementation are often ambiguous in the field. Further, the definitions of gypsic and petrogypsic horizons should not be interlocked, each definition should be based on field characteristics linked with microscopic and hydric properties that control the durability and the life-supporting capability of gypseous soils. The avoiding of confusion between gypsum-rich and calcium carbonate-rich horizons when grouping soil taxa or diagnostic horizons by means of soil-forming processes is stressed.

Keywords: soil classification, gypsum, diagnostic horizons, aridity.

1. Introduction

Soil Taxonomy (Soil Survey Staff, 1999) has become a world reference for soil classification and survey, at least at the most detailed scales. Although the system is not easily applied by non-professional soil scientists, some recent adaptations have made it more accessible utilizing already existing knowledge, as pointed out by Swanson (1999). This perspective depicted by Swanson, together with the accelerated convergence among national or international soil classification systems, and the global access to information based on the new technologies, make clear the need for a sound representation of all the soils of the world in Soil Taxonomy. The World Reference Base for Soil Resources, or WRB, (F.A.O., 1998) has been developed from previous F.A.O. documents with a world wide scope and has achieved a high degree of convergence with Soil Taxonomy. A process-related emphasis in soil classification has been claimed (Bockheim and Gennadiyev, 2000) as a way to illustrate the global soils and for a better understanding of both Soil Taxonomy and WRB.

In Europe and the United States gypsum-rich soils occur mainly in arid or semiarid areas, often in lands marginal for production, whereas in other countries with arid regions these soils are common in agricultural, grazing, or urban areas (Herrero and Boixadera, 2002). This paper aims to give some elements for reflection about gypsic and petrogypsic horizons, in order to improve their definitions and position within the modern classification systems in the framework of soil forming processes.

2. Horizons with gypsum in Soil Taxonomy and WRB

The introduction of a so called “sulfate rich horizon” in Soil Taxonomy can be traced in Cline (1979) from 1956 until the definition of the gypsic horizon (Soil Survey Staff, 1960). The concept has undergone some changes until the definition of gypsic and petrogypsic horizon by the Soil Survey Staff (1999), as discussed in the following paragraphs.

The removal of the condition of having a gypsum content higher than that of an underlying horizon (Soil Survey Staff, 1994), allows a horizon on gyprock or other gypseous material to qualify as gypsic.

The definition of gypsic by Soil Survey Staff (1975) as a “horizon of enrichment with secondary sulfates”, was changed in the second edition of Soil Taxonomy (Soil

Survey Staff, 1999) to “illuvial horizon in which secondary gypsum has accumulated...”. Both sentences are not well suited for soils in areas with ubiquitous gyprock or other gypsum sources because in these cases the pedogenic or lithogenic origin of gypsum in soils can not be distinguished, and therefore lacks functional interest. The quoted sentence of the second edition is not in the “Required Characteristics” section, thus can be deleted in both gypsic and petrogypsic definitions without perturbating of the system.

Both editions of Soil Taxonomy (Soil Survey Staff, 1975 and 1999) define gypsic and petrogypsic in an interdependent way. In the first edition, petrogypsic must be a gypsic, with some supplementary properties, whereas in the second edition, the gypsic is subjected to the lacking of one property of petrogypsic, as discussed later.

In the early stages of Soil Taxonomy, the definitions and treatments of gypsic and petrogypsic horizons mimicked those of the calcic and petrocalcic horizon, and the same happened with the soils containing these horizons. The treatment of the horizons of gypsum accumulation became more independent during the evolution of Soil Taxonomy, as stressed by Herrero and Porta (1991). The same authors noted the splitting of soils with gypsic or petrogypsic horizon in several Orders, a splitting that has to be accepted because of the criteria for the highest levels of Soil Taxonomy. Notwithstanding, the suggestions of Tavernier et al. (1981) and the International Committee on Aridisols (Eswaran and Zi-Tong, 1991; Ahrens and Eswaran, 2000) could have been adopted with only a slight perturbation of Soil Taxonomy. These suggestions are compatible with the present knowledge about the gypsum translocation processes and their effects on soil appearance and behavior, and should help to address the unfeasibility of distinguishing between gypsum of geologic or of pedogenic origin in some soils (Herrero et al., 1992; Stoops and Poch, 1994; Artieda, 1996; Artieda and Herrero, 2003). This unfeasibility and the differences in genesis and properties between gypsum-rich and calcium carbonate-rich horizons fade in a recent proposal of Bockheim and Gennadiyev (2000), that combine under a “Calcification Process” several taxa of Soil Taxonomy having either gypsum or calcium carbonate accumulation.

The sixth edition of Keys to Soil Taxonomy (Soil Survey Staff, 1994) reorganized the Aridisols into new suborders, following recommendations of the International Committee on Aridisols (Eswaran and Zi-Tong, 1991; Ahrens and Eswaran, 2000). The introduction of these suborders was an outstanding improvement, and is now official (Soil Survey Staff, 1999). In contrast with the changes introduced in the Aridisols, the present definitions of gypsic and petrogypsic do not reflect the actual field and microscopic knowledge of these horizons. The references given by Herrero and Porta (2000) and by Herrero and Boixadera (2002) together with other articles (Reheis, 1987; Carter and Inskeep, 1988; Buck and Van Hoesen, 2002) display a panorama of this knowledge.

The definitions of gypsic and petrogypsic diagnostic horizons in WRB (F.A.O., 1998) include a reference to secondary accumulation of gypsum in the general description, but not in the diagnostic criteria, although ISSS Working Group RB (1998, page 85) states “Primary gypsum such as gypsum rock and mobile gypsum sand are excluded from the definition of gypsic horizons”. The distinction probably lacks behavioral interest, and is not practical in the field and in cases like sand sized and smaller fragments of gyprock, or gypsum lenticular crystals (Laya et al., 1993; Artieda and Herrero, 1997) transported over a short distance. The notion of gypsiric (F.A.O., 1998) is explicitly out of genetic considerations and could help to address the definitions of gypsic and petrogypsic horizon if completed with some granulometric or micromorphological criteria.

2.1. The gypsic horizon

In lands where gypsum is ubiquitous in parent materials, many horizons fit the requirement of “5 percent or more gypsum”. As this statement of the Soil Survey Staff (1999) is not genetic, the percentage can be established, if needed, by chemical analysis. However, in these kinds of horizons, the requirement of having “... 1 percent or more (by volume) of secondary visible gypsum” (page 42) is often difficult, or impossible, to determine.

The characteristic “cemented or indurated” appeared in negative form in the definition of gypsic and in affirmative form in the definition of petrogypsic both in Soil Survey Staff (1994) and in Soil Survey Staff (1999); i.e., gypsic horizon must be ”... not cemented or indurated to such a degree that it meets the requirements of a petrogypsic horizon”, and petrogypsic must be “cemented or indurated by gypsum,...”.

Two practical problems arise from these wordings: (i) the definition of the gypsic horizon is subjected to the definition of petrogypsic. Being that gypsic is more common than petrogypsic, many soil surveyors dealing with gypsic may not be acquainted with petrogypsic; and (ii) as discussed in the next section, the definition of petrogypsic has a weak point in the required degree of cementation.

The 15% gypsum content required for the gypsic horizon by WRB (FAO, 1998) is convenient in the field, but some ambiguity remains because of the genetic requirement in the introduction, as discussed in the above section. The same document uses hypergypsic for gypsic horizons with ≥ 60% gypsum even though the word hypergypsic was previously proposed for horizons by ICOMID (Eswaran and Zi-Tong, 1991) and for soils by Herrero et al. (1992), in both cases without genetic assumptions.

2.2. The petrogypsic horizon

The definition of petrogypsic by Soil Survey Staff (1975) comprise the following characteristic: “is strongly enough cemented with gypsum that dry fragments do not slake in water”. This characteristic did not appear in the sixth edition of the Keys to Soil Taxonomy (Soil Survey Staff 1994), that require the petrogypsic horizon to be “cemented or indurated by gypsum”, as does Soil Survey Staff (1999). This wording is not clear in reference to the rupture resistance classes established by Soil Survey Division Staff (1993, pages 174 and 175), because a cemented class is not provided by this document. Moreover, the mention “dry fragments do not slake in water” re-appears in Soil Survey Staff (1999) but the characteristic of “slaking in water” does not meet even the less cemented class, or “extremely weakly cemented” established by the Soil Survey Division Staff (1993, page 174). One more time the sentence is not in the “Required Characteristics” section of the definition of petrogypsic horizon.

In WRB (F.A.O., 1998), the definition of petrogypsic is independent of gypsic, but the mention to secondary gypsum is maintained; the required degree of cementation is described with field criteria, even though the cementing agent is not indicated.

Finally, the field criteria given in the definition of petrogypsic should mention the changes in consistence of some gypseous materials when exposed to the sun (Herrero and Porta, 2000), and include instructions for diagnostic field-test application. Such a mention should be also needed in the definition of gypsic, if the present subjection to the definition of petrogypsic is conserved in STS.

3. Some specific features of gypseous horizons

The main effect of gypsum on soil is often described as associated only with the saturation of the soil solution with calcium sulfate, and the resultant effect of Ca^{2+} on the clay fraction. Saturation in Ca^{2+} can be reached even at gypsum content lower than that required for gypsic horizon.

Significant parts of gypseous horizons are composed of gypsum crystals that are in direct contact with each other. The mechanical behavior of these horizons is specific and quite unknown because the binding forces are not well identified and because the gypsum crystals are occasionally interlocked. A “clay-centric” line of reasoning can cause these facts to be overlooked.

When gypsum is the major component of a horizon, the following features should be considered: (i) the mechanical properties like those studied by Poch and Verplancke (1997) that can be related to the root limiting layers seen in the field; (ii) the changes in consistence due to water content or to sun heating (Herrero and Porta, 2000); (iii) the wide differences in morphologies of gypseous soils, as in the examples presented by Pankova and Yamnova (1987) and by Buck and Van Hoesen (2002), or by the references given by Herrero and Porta (2000); and (iv) the strong differences in the water transmissivity of the horizon and in the soil-moisture characteristic curve that can be inferred from field and microscope observation.

All of these properties control the capacity of gypseous soils to support life, and their dynamics in relation to time, weathering and land use. Thus, the definitions of the diagnostic horizons would have to evolve to reflect these properties.

4. Completing the distinction gypsic/calcic horizon

A close parallelism between calcic/gypsic and petrocalcic/petrogypsic definitions is unsatisfactory. Calcium sulfate and calcium carbonate behave distinctly in terms of solubility and precipitation. The different properties of gypseous versus calcareous horizons are due, in part, to the pushing action of the gypsum crystals growth on the surrounding materials (Macfadyen, 1950; Reheis, 1987). This pushing action was shown experimentally in sandy (Plet-Lajoux et al., 1971) and in clayey (Delmas et al., 1985) materials, and observed in the field with weathering and pedogenic effects by

Artieda (1996, 1999) and by Artieda and Herrero (2003). The Romans had the word *calx* (*calcis* in genitive case) for lime, and a different word *gypsum* for this distinct material. Soil Taxonomy (Soil Survey Staff, 1975, 1999) states that the formative element calc- is derived from Latin *calcis*, lime. Both quoted editions of Soil Taxonomy give calcic horizon as a connotation of the formative element calc-, and the calcic horizon was defined as calcium carbonate or other carbonates accumulation and never as calcium or as calcite accumulation. Thus, calcic refers to lime, and not to the Ca element by itself, even that in the first edition of Soil Taxonomy (Soil Survey Staff, 1975) calcium appeared as a mnemonicon, for the users not familiar with Latin-derived languages. In the same way, gypsic refers to gypsum, and not to the Ca element. Neither the fact that in early stages of Soil Taxonomy the soils with gypsum accumulation were not well recognized nor the existence of Ca in both lime and gypsum allow to mix gypsic with calcic horizons from the genetic point of view.

Even though gypsic and calcic horizons are now well distinguished in Soil Taxonomy, definitions still hold that weaken that distinction. This is the case of the two Great Groups Calciaquolls and Calcixerolls that are allowed to have a gypsic or a calcic horizon, resulting in misleading names for soils having gypsic as the only diagnostic subsurface horizon.

5. Final considerations

Different types of gypseous horizons should be characterized by field studies in benchmark soils including physical and hydrological tests and criteria. The linking of these studies with micromorphology will help to distinguish these varieties and to understand their field properties, to check the soundness of the distinction between gypsic and petrogypsic horizon, and to improve their definitions.

No proposals are made here about changes in the definition of the concerned diagnostic horizons, nor about the differential characteristics –micromorphological or others– between gypsic and petrogypsic. One reason is the limited area of expertise of the author, and other is that such possible changes must be undertaken in relation with the definitions of the other diagnostic horizons in Soil Taxonomy or in W.R.B. and having in mind the effects on the whole considered system.

Acknowledgements

The discussion with O. Artieda on an early draft is greatly appreciated.

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