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IDENTIFICATION AND USE OF SUBTYPES OF THE ARGILLIC HORIZON

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IDENTIFICATION AND USE OF SUBTYPES OF THE ARGILLIC HORIZON

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ABSTRACT

The definition of the argillic horizon, on the basis of clay increase and the presence of coatings of oriented clay, and its use at the highest level of soil classification, has given rise to much debate. Many strongly weathered soils of tropical regions turn out to have such a horizon, but the accessory agro-ecological properties, originally associated with the argillic horizon, are often absent or very weakly expressed in these soils.

It is advocated to identify several subtypes of the argillic horizon, each with its own set of accessory properties. Suggestions are given for criteria that may be used at the definition of lixo-argillic, nito-argillic, ortho-argillic, abrupto-argillic and plano-argillic horizons.

INTRODUCTION

Many red and yellow soils of the lower latitudes show signs of clay illuviation, their B horizon qualifying as an argillic horizon.

The formal definition of this horizon, both in the FAO/Unesco Legend (FAO/Unesco, 1974) and in the USDA "Soil Taxonomy" (Soil Survey Staff, 1975), is on the basis of a measurable vertical increase in the percentage of clay or fine clay in comparison to the overlying A horizon, and the presence of coatings of oriented clay on ped and pore surfaces, the so-called argillans or clay skins. It was recognized that these features by themselves are of little importance to quantitative soil classification. They were however thought to be marks of a number of associated features that were considered important for the soil as a medium for plant growth, like structure, consistency and porosity. It would appear that the two features were easily observable in the field, and accurately measurable in the laboratory, especially for the loamy soils with a mixed clay mineralogy on the stable landscapes of higher latitutes. The argillic horizon was therefore selected as a criterion for separation at high categoric level.

THE PROBLEM

Soon after the argillic horizon was selected as an important classification criterion, it became evident that an increase in clay content is a common feature in many sandy soils and low-activity-clay soils, while so-called clay skins as identified in the field, more often than not appeared to consist mainly of non-oriented material at microscopic scrutiny. For this reason and a number of others, the limits of the two diagnostic criteria - clay increase and argillans - were gradually shifted to ever lower values, and their relationship with an assumed set of accessory properties of agro-ecological nature became ever weaker (cf. Eswaran & Sys, 1979; Isbell, 1980; Arnold, 1979; McKeague, 1983). As a consequence, there can now be a wide variation in the degree of development of an argillic horizon. The increase in clay content may be more than 20% within a vertical distance of 7.5 cm, or only 3% over a distance of 30 cm. Coatings of oriented clay may comprise well over 5% in cross section, appearing as nearly continuous linings; as only 1% broken-up parts within structural elements, or even as scattered tiny bridges between sand grains; in some conditions they are even allowed to be absent.

The above variation is accompanied, but not systematically, by large differences in the over-all texture; in clay mineralogy and associated physico-chemical activity of the clay fraction (CEC-clay; specific surface); in base saturation and cation composition; in macro-structural development; in porosity and bulk density; in aggregate stability, and in drainage condition. These large differences in agro-ecological properties make the use of the argillic horizon at the highest level of classification *irrelevant*.

Many red and yellow soils of the lower latitudes, originally supposed to be Latosols or Lateritic soils (Ferralsols, Oxisols), now turn out to have an argillic horizon as finally defined, and therefore key out as Acrisols and Nitosols (Ultisols) or Luvisols (Alfisols). The sheer expanse of soils belonging to these units make the use of the argillic horizon at the highest level of classification *unwieldy*.

Moreover, the handling of the two criteria proves to be less accurate than hoped for. Many "obvious" clay skins by field examination turn out to be pressure faces or else (e.g. "flood cutans", "agricutans", "flocculation cutans") with micromorphological analysis. Many "obvious" cambic horizons, on the other hand, prove to have more than 1% oriented clay coatings in one form or another (cf. the review by Isbell, 1980). Micromorphological analysis would therefore be necessary for all profiles examined and sampled during soil surveys. This is expensive, cumbersome, time-consuming and specialistic, and thereby defeats the aim of working with easily identifiable and measurable features. It may be added that reliable quantification of argillans with micromorphological techniques has not yet been reached, even among specialists (cf. Murphy, 1983).

The determination of the increase in clay content has several uncertainties, too. The "feel" of the texture in the field varies strongly with the type of clay mineral. This may be partly overcome if a range of test samples is available to the soil surveyor. More disturbing, however, is the substantial variation in textural analyses in the laboratory, as exemplified by recent cross-checking programmes. Reference be made to the variation in data obtained by different laboratories analysing exactly the same samples, e.g. Cronce's data (1980) for seven laboratories in North-eastern USA, and the ISM-Labex programme data (Van Reeuwijk, 1982) for twenty major laboratories dealing with tropical soils. In both cases the precision in clay content determination was about 6% (relative). Since at the calculation of the increase of clay content from A to B horizons at least two separate laboratory figures are used, the variability in the values for clay increase would be at least 12%. For low-activity-clay soils in general, the laboratory figures on increases in clay content from A to B horizons tend to be inflated. This is due to the difficulty of reaching complete dispersion in topsoil samples. A substantial amount of organic matter binds the low-activity clay particles so strongly that a part of the clay fraction may be measured as silt or sand. Special dispersion techniques are needed in such cases, which some laboratories, especially smaller ones, are not willing or able to apply. Clay increase data of laboratories in different tropical countries can therefore often not be compared in an absolute sense.

In summary, the establishment of the presence of oriented clay skins and the determination of the increase in clay content are proving to be also rather *unreliable*.

SUGGESTIONS FOR CHANGE

One way out of the problem is to use the presence of an argillic horizon, in its present definition, at a lower level of classification, as is done in the new soil classification system proposed by an ORSTOM working group (Fauck et al., 1979).

Another possibility is to identify *subtypes* of the argillic horizon, in which not only the increase in clay content and the presence of argillans is diagnostic, but in which also a set of associated accessory properties is taken into account, according to their degree of expression - to be defined per subtype. This has in fact already been tried, halfheartedly, through the identification of a "natric" horizon, of "abrupt textural change" (in both Soil Taxonomy and the FAO/Unesco Legend), of "fragipan", and of elements in the definition of some "pale" great groups in Soil Taxonomy. Further efforts have been made in recent years by the USDA-sponsored International Committee on the classification of Low-Activity-Clay soils (ICOMLAC), through a series of workshops in key field areas and a number of circular letters. A host of alternatives, variants and subdivisions has been voiced in the bosom of this committee, but formally only the definition of a "kandic" horizon has emerged for testing (Moormann and Buol, 1982). The latter, unfortunately, is based solely on a precisely quantified increase in clay content within a certain vertical distance, with low-activity of the clay fraction as the only other requirement*.

In view of the demonstrated variability in textural analysis, the increase in clay content should anyhow be handled with a degree of flexibility. A range of at least 12%, if not 15% (both relative), on both sides of the formal limit should be allowed. This brings the criterion in fact in the same category of less-than-absolute quantification as the set of accessory properties, hitherto largely disregarded, like structure (grade, class, and type), and consistency.

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*The need for defining the kandic horizon for Soil Taxonomy may have partly arisen from the fact that a significant increase in clay content is a common feature in the reddish yellow to pale yellow soils that structurally and mineralogically fit the Oxisol concept, be it with low iron content. This increase occurs especially in such soils if they have been cleared from forest a considerable time ago; they are sometimes denoted as "degraded Oxisols" (Bennema, 1982).
In the FAO/Unesco Legend, which uses colour as one of the criteria for subdivision of its Ferralsols (~ Oxisols), such soils are accommodated as Xanthic Ferralsols. At any updating of this Legend, the need for identification of a kandic horizon, placing the soil concerned outside the Ferralsols, may therefore not exist - at least as long as kandic horizon is defined on an increase in clay content only.

It is true that structure and consistency, as defined in the 1951 Soil Survey Manual of the USDA (and in the FAO guidelines for soil profile description), are not easily quantifiable - as proven by the often equivocal field description of these characteristics by different soil surveyors. But then, there has been, in the past 40 years or so, precious little effort to refine the criteria; everybody is still referring to the same old drawings and photographs on structure types. Nor has there been much research on the basic processes that determine the different forms and grades of structure and consistency. Refinement of the definitions, use of additional terms like "polyhedric", "floury", "degree of pedality", etc., and updated drawings and photographs are called for. Through international training or refresher courses - working with new standardized examples - field descriptions on structure and consistency can be much improved. They may then become useful as diagnostic criteria (cf. structure and consistency elements in topsoil definitions like the mollic epipedon). One can also promote the use of laboratory analyses indicative for structure and consistency, like "water-dispersable clay/total clay ratio", silt/clay ratios, coefficients of linear extension, bulk densities, Atterberg values and the like (cf. El-Swaify, 1980); some tests used in soil engineering may also come in handy.

One will still need one or two leading criteria, which may well be the clay increase and the CEC-clay (the latter as indicative for the physicochemical behaviour of the mineral constituents), but then in a less-than-absolute manner, i.e. allowing a flexibility range (see also Arnold, 1979). The data on the co-varying accessory properties like structure, consistency and/or their replacing laboratory indicative tests, may then sway the decision either way of the flexibility range. In other words, the limits of the horizon definition should be rigid as to the sum, product or other combination of a number of criteria, but may be flexible as regards a single criterion. The co-varying properties are then in fact not anymore accessory, but part of the definition of the horizons, in the same way as the presence of argillans in different forms and grades of expression.

At the same time, one may define the clay increase requirements in a more logical way. The gradation of the required increase in relation to the texture of the A horizon is at present inconsistent, and requires calculations. A smooth line on a graph - including a zone of flexibility - can be divised, which makes it easier to check whether the clay increase requirement is met.

SOME POSSIBLE SUBTYPES OF THE ARGILLIC HORIZON

With the above approach, several subtypes of the argillic horizon can be identified. One of them, the natric, was already formally established; one or two exist informally, and some others have already been suggested at ICOMLAC meetings by this author (cf. Sombroek and Muchena, 1979).

Proposed are the following:

- *ortho*-argillic*, or *luvo*-argillic (the "original" argillic as conceived for soils on loamy materials of Pleistocene-early Holocene age in temperate climates);
- *natro*-argillic (the existing "natric" of Soil Taxonomy);
- *plano*-argillic, or *stagno*-argillic (the B-horizon of Planosols and Stagnogley soils);

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*The "argillic" postfixes may be deleted eventually, leaving only "luvic", "natric", "planic", etc.

- *abrupto*-argillic (with the "abrupt textural change" of Soil Taxonomy and the FAO/Unesco Legend, but without signs of water stagnation above it);
- *nito*-argillic (the B-horizon of the original concept for FAO/Unesco's Nitosols; cf. Sombroek and Siderius, 1982 and the "bulgique/brillant" of Fauck et al., 1979);
- *lixo*-argillic (comparable to the "kandic" as proposed by Moormann and Buol, 1982, but with further specification; see also the "weathered ferrallitic soils" of Young, 1983).

The detailed proposals for limits of their set of characteristics, as given in table 1, are compiled from a number of publications on soils of the tropics and subtropics. The listing is nevertheless tentative and incomplete. Further quantification is needed, to make the subtypes mutually exclusive (with at least 95% reliability?). This can only be fruitfully pursued after extensive testing of the validity of the over-all approach, on a great number of well-described and fully analyzed key soil profiles/pedons from all over the globe.

A *key* can be developed once agreement in principle is reached on the feasibility of using the sets of characteristics as suggested in the table. In anticipation of such keying-out, also the set of characteristics of an "Akric" and an "Oxic" horizon are given in table 1.

Conceptually, still other subtypes can be identified (some of them already suggested elsewhere, explicitly or implicitly) as follows:
- *neo*-argillic (for the argillic horizon on the cambic side, i.e. relatively young soils with a substantial reserve of weatherable material); cf. MacVicar et al., 1977);
- *retro*-argillic (for the compacted horizons of some yellowish Oxisols after arable cropping; showing a significant increase in clay content and relatively high bulk density, but with low CEC, low silt/clay ratio and low percentage of weatherable minerals; cf. Bennema 1982, and the "thin-argillic-over-oxic" of Eswaran and Sys, 1979);
- *fibero*-argillic (for the argillic horizon in the lamellae form);
- *fragio*-argillic (for the fragipan soils; all fragipans would seem to contain oriented clay bodies - cf. Soil Survey Staff, 1975);
- *ferro*-argillic (for the horizons with ferric mottles or nodules, cf. FAO/Unesco, 1974; possibly identical to the "paleo-argillic" of the soil classification of England and Wales - Avery, 1980);
- *plintho*-argillic (for the B-horzion of the Groundwater Laterite soils" of Baldwin, Kellogg and Thorp, 1938; cf. the "veson" of FitzPatrick, 1980, and the "horizonte plintico" of the Brazilian Soil Survey - Anon, 1981);
- *grano*-argillic (or paleo-argillic; for the reddish B-horizons of old landscapes in aridic environment; showing oriented clay on sand grains only, without predominant masking by carbonate accumulation; cf. Gile and Grossman, 1979).

CONSEQUENCES

Defined as such and amply tested, the above subtypes of the argillic horizon may indeed be useful at high categoric level of classification, in replacement of the broad, single-type as used at present. Such a drastic change may not be any more feasible in existing and widely used classification systems. They may however well serve for defining main (sub)units in the current ISSS/FAO/Unesco/UNEP efforts to arrive at an International Reference Base for soil classification (IRB).

Table 1. Characteristics that may be used for the definitions of subtypes of the argillic horizon

		Akric (~oxydon)	Oxic (~ferraliton)	Argillic (sensu-latu): Nito- (brillant-bulgique)	Lixo- (~kandic)	Luvo- (ortho)	Abrupto- (~pale pp)	Plano- (~epiaquic/ stagno)	Natro- (~natric)
	depth of profile (A+B)	(>>100 cm)	(>>100 cm)	(>150 cm)	(>100 cm)	(<100 cm)	(<100 cm)	(<100 cm)	(<100 cm)
mineralogy	SiO_2/Al_2O_3 ratios clay-mineralogy free-iron (dithionite) specific surface (EGME)/clay CEC-clay (NH_4OAc; pH 7)[2] ECEC-clay	(<1.0) oxidic (gibbsitic) <<8% (<1?) <<150m²/g (<50?) <1.5 $pH_{KCl} > pH_{H_2O}$	(1.0–2.2) oxidic-kaolinitic <8% <150m²/g <16 <12	(2.0–2.5) kaolinitic + halloysite >8% >150m²/g (<24) (<16)	(>2.2) kaolinitic <8% <150m²/g <24 <16	(>2.5) mixed-illitic — (>100m²/g) (>24) (>16)	(>2) varying — (>100m²) (>24) (>16)	(>3.0) (illitic) — (>100m²) (>24) (>16)	(>3.0) (smectitic) — >100m² (>24) (>16) >15% Na/>50% Na+Mg
weathering	weatherable minerals in fine sand fraction silt/clay ratio	<3% <0.25	<3% <0.25	(<10%) <0.40	<10% >0.25 (<0.6?)	(>10%) >>0.25 (>0.6?)	(>10?) (>0.6)	(>10%) (>0.6)	(>10%) (>0.6)
illuviation textural differentiation	textural increase[3] horizon boundary A-B[4] argillans (micromorphological), percentage and position	(<1.2) (diffuse) <1 ——	<1.2, over >12 cm diffuse-gradual <1 (in the fabric)	<1.2, over >12 cm diffuse-gradual variable (in the fabric)	>1.2 (>1.4?), within 12 cm gradual-clear <5 (in fabric and on peds)	>1.4, within 30 cm clear-gradual >5 (on peds and in pores)	>2.0, within 2.5 cm abrupt >5 (on peds and in pores)	>2.0, within 7.5 cm clear to abrupt (1–5) (on peds)	>2.0, within 7.5 cm clear to abrupt (1–5) (on peds)
org. matter differentiation	bleaching in A org. matter decrease A to B	none gradual	none gradual	none gradual	bleached sand grains clear (blotchy)	bleached sand grains clear	bleaching even or absent clear	mottled bleaching (E) abrupt (or inverse E-B)	(often bleached) abrupt
structure	macro structure, strength macro structure, shape[5] micro structure (plasmic fabric) bulk density structure index[6]	 (pm) isotic/asepic <1.4 (<90)	 wc pm (floury) asepic <1.4 >90	moderate to strong abk-sp (lower part) asepic/insepic <1.4 >90	weak to moderate sbk-sc pm insepic >1.4 <90	moderate abk-pr masepic >1.6 <80	moderate to strong abk-pr masepic >1.6 (>60?)	moderate to strong pr masepic >1.6 (<60)	(moderate) cpr masepic/omnisepic >1.6 (<50)
physical management properties	consistency moist consistency dry root penetration water penetration	very friable slightly hard (raw) (everywhere) very easy	very friable soft (everywhere) very easy	(very) friable hard (within peds) very easy	friable hard-very hard (within peds) rather easy	firm hard-very hard around peds mainly restricted	firm hard within peds? somewhat restricted?	very firm extremely hard around peds very restricted	very firm extremely hard around peds very restricted

[1] underlined: leading criteria; non-underlined: complementary criteria ("sway" criteria within flexibility range of leading criteria; between parentheses: non-systematically co-varying accessory properties.

[2] CEC-clay: meq/100 g; organic matter-corrected, by Brazilian graphical method.

[3] textural increase: ratios for the intermediate textures, with absolute percentages as defined in Soil Taxonomy and elsewhere.

[4] horizon boundary diffuse if change over > 12 cm, gradual if within 7.5–12 cm, clear if within 2.5–7.5 cm, abrupt if within < 2.5 cm.

[5] macro structures: wc pm = weakly coherent porous massive; sc pm = strongly coherent porous massive; sbk = subangular blocky; abk = angular blocky (scalloppy); sp = strong polyhedric (nutty); pr = prismatic; cpr = columnar.

[6] structure index: aggregate stability as measured by the fraction (in %) of the total clay that cannot be dispersed by simple shaking with water.

The identification of subtypes has also an educational value. It allows soil science students to better visualize the complex of diagnostics and properties that go with major natural units, as the result of pedogenetic processes in varying combinations and strengths. The pathway of development can be illustrated in the following scheme:

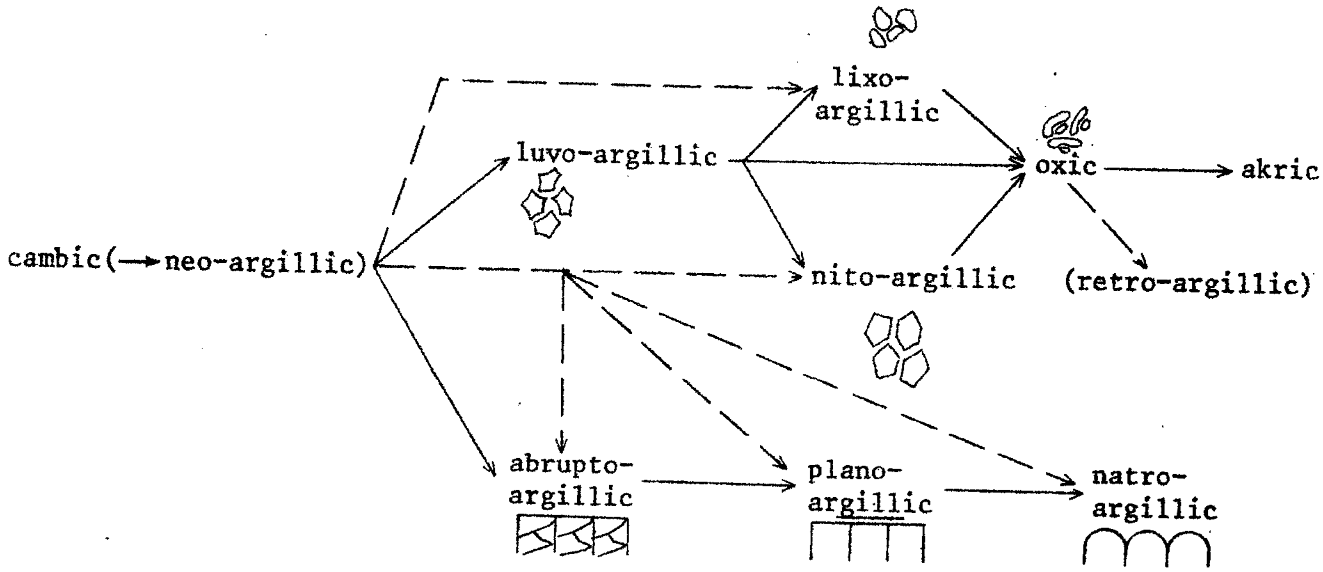

Fig. 1 Pathways of development of subtypes of the argillic horizon

The luvo-argillic horizon would have *illuviation* as main soil forming processes, a process which in an extreme form results in the abrupto-argillic; the natro-argillic would have *illuviation + sodification*, the plano-argillic would have *illuviation + ferrolysis*, the lixo-argillic would have "*appauvrissement*" + *some illuviation* and the nito-argillic would have *metallisation** + *some illuviation*. In the oxic horizon, any previous soil forming process would have been completely overtaken by the *ferralitization* process, while the akric can be considered to be the result of a *bauxitization* process.

The use of subtypes may also restore confidence in the usefulness of soil classification systems among both soil survey field staff and soil management specialists, who at present are often baffled and disgusted by the endless discussion of soil correlation specialists at soil pit sides on seemingly minor details like the presence or absence of a few elusive clay skins.

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*A surmised process only; referring to the metallic, shiny appearance of the polyhedric peds concerned.

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