# Should acid sulfate soils be classified among the inceptisols or the entisols?

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## 1 Summary

In Non Acid Alluvial Soil Materials, physical, chemical and mostly also biological ripening are proceeding about simultaneously, stimulating each other. When sulfidic muds develop into Acid Sulfate Soils, physical ripening will start, but soon stagnates while chemical ripening proceeds very rapidly, producing 'sulfuric' materials. Only very old 'Acid Sulfate Soils' are physically more or less ripe, but most of them have deacidified 'sulfuric' materials that are not longer meeting the pH requirements. Arguments are brought together to classify the physically unripe soils with 'sulfuric' materials with the Aquents (as a different great group) and the physically ripe ones, forming a minority, with the Aquepts as Sulfaquepts.

## Résumé

Dans les vasières des sols alluviaux non acides, la maturation physique, chimique et biologique se développent presque simultanément en se stimulant réciproquement. Des sols alluviaux bien développés peuvent se former à court temps après l'introduction d'un bon drainage.

Dans les vasières sulfurées, la maturation physique est très lente, tandis que celle chimique avance rapidement menant à la formation de l'horizon sulfurique et par conséquent aux sols sulfatés acides. Due â l'intense acidité, l'activité biologique dans ces sols est très maigre, car seulement un nombre limité de plantes et d'animaux peuvent supporter un taux élevé d'acidité. Etant pauvres en espèces floristiques et faunistiques, ces sols ne sont pas brassés et homogenisés ce que fait que la maturation physique et biologique se déroulent très lentement.

C'est ainsi que seulement les sols sulfatés acides très anciens, sont plus ou moins maturé physiquement toutefois rarement plus profondément de 50 cm, tandis que les plus jeunes, sont ou maturés ou semi-maturés, même dans les conditions d'un bon drainage. A cause de l'imperméabilité du sous-sol non-maturé, la dé-acidification ne peut pas avancer et le processus de maturation est stagné.

Une grande partie des sols sulfatés acides anciens ont subi une dé-acidification et leur horizon sulfurique ne satisfait plus à l'exigence d'un pH bas ($>$ 3,5).

En ajoutant des arguments de nature pratique aux principes de classification, l'auteur propose de classifier les sols sulfatés acides physiquement non-maturés dans les Aquents (Entisols) et ceux maturés dans les Aquepts (Inceptisols).

## 2 Introduction

One of the main principles on which the differentiation of the orders of Soil Taxonomy are based, are the results of pedogenetic processes. Entisols are considered to lack or nearly lack soil development, whereas Inceptisols show a certain measurable effect of pedogenesis. Pedogenetical processes, however, are known to be complicate and composed of a number of different soil forming processes acting more or less simultaneously with different intensities and speeds, making soil classification possible as well as complicate.

Considering the initial soil forming processes, physical, chemical and biological ripening (Pons and Zonneveld 1965) in soft sulfidic muds developing into Acid Sulfate Soils, observations have learned that chemical ripening may proceed rapidly and intensely, while both physical and biological ripening are slow and retarded. In 'normal' muds, without potential acidity, however, physical, chemical and biological ripening are developing about simultaneously, producing a cambic horizon, which fits the soils smoothly into the Inceptisols.

The doubt, wheather to choose between the results of physical or of chemical ripening makes it difficult to classify these soils with the Entisols or with the Inceptisols.

This short note will deal with the difficulties to classify the Acid Sulphate Soils in relation with these unequally developing kinds of initial soil formation and will give suggestions to solve the problem.

## 3 The sulfuric horizon

Under rapid dehydrating conditions, e.g. artificial drainage, a soft sulfidic mud will dry out superficially, forming shallow cracks (physical ripening). Air will penetrate into the soil and very soon, pyrite starts to oxidize (chemical ripening), forming sulfuric acid and jarosite mottles and the pH (water) drops below 3.5. When 'the mineral or organic soil material of the horizon has both a pH $< 3.5$ (1:1 in water) and jarosite', Soil Taxonomy (USDA 1975) recognises the sulfuric horizon. Inceptisols, defined as 'physically ripe soils' (n-factor $< 0.7$ to a depth of at least 50 cm), with a sulfuric horizon beginning within a depth of 125 cm have to be classified with the great group of Sulfaquepts, according to the present Soil Taxonomy (USDA 1973).

On 'normal' muds, after some superficially drying up, plants start to grow and penetrate the soil with their roots, accelerating the dehydration of the mud and causing shrinking, stiffer consistencies, deeper cracks, better permeability and development of soil structure. Immediately after, the chemical ripening is following with oxidation, improving the environment for further root development, which accelerates new physical ripening and so on. At the same time the biological ripening starts and is contributing both to the physical as well as to the chemical ripening (Pons and Zonneveld 1965).

In Acid Sulfate Soils, to the contrary, physical and biological ripening are absent or very poor because plant growth is prevented by the toxic environment with the extremely low pH, the high Al-ion concentration and several other adverse conditions. As dehydration by roots is by far the most important way of attracting water, promoting the physical ripening (Zuur, 1961), sulfuric horizons are not ripening and the soils are only developing superficially ripe to half ripe upper horizons. These soils show well pronounced chemical ripening processes. The development of favourable land qualities as waterholding capacity, absence of toxicity, drainage and reasonable burying capacity stagnates as well, giving the soils a 'juvenile' character. Leaching, which would evacuate the acids, permitting a further physical ripening, is also strongly hampered by the adverse chemical and physical conditions, as e.g. the poor developed permeability.

Only after a very long time, when the excess of acids is evacuated by slow leaching, diffusion into floodwater or neutralisation by slowly weathering minerals on a low pH level, the pH will gradually increase to between 3.5 and 4.0 (Figure 1A). Then the roots are beginning to penetrate the 'sulfuric horizon' and the process of physical ripening slowly proceeds. On this moment, however, most 'sulfuric horizons' are not longer meeting the pH requirements of $< 3.5$ and in fact have vanished. Jarosite mottles may yet be visible, but they lack the bright yellow colours.

## 4 Acid sulfate soils and non acid marine soils of different age

In the Bangkok plain fine textured, very young Acid Sulfate Soils, as well as Non Acid Marine Soils are present next to developed and deeply developed old ones (Pons and Van de Keevie 1968; Van de Keevie and Yanmanas 1969; Van Breemen 1976). The last author is given a lot of analytical data, including n-factors. In Figures 1A and B we are presenting some characteristic data of 4 groups of soils respectively: A: Very young, saline Acid Sulfate Soils; B: Young, saline to rather old, fresh Acid Sulfate Soils (Figure 1A); C: Medium old to old, fresh Acid Sulfate Soils and D: Young to medium old, fresh Non Acid Marine Soils (Figure 1B). In these figures the physically ripe soils can be distinguished from the unripe soils by the n-factor at 50 cm depth, the value of which is less than 0.7 for the ripe and more than 0.7 for the unripe soils. The profile morphology and the pH values are also shown.

Group A (Figure 1A) includes soils which are physically unripe. Only the upper soil surface layer of some of them are half ripe. They are undeveloped, saline muds (Bp-1) or very young, saline Acid Sulfate Soils, of which Kd-1 and Ch-1 are possessing a well developed surfuric horizon.

The soils of group B (Figure 1B) are also physically unripe, including young (Ca-1) to rather old (0-1), acid sulfate soils, both with surfuric horizons and 0-1 even red mottled.

Group C (Figure 1A) are old Acid Sulfate Soils with (Ra-1; Ra-2) and without (Ra-3) red mottles. All three soils show sulfuric horizons, which are on the boundary of meeting the pH requirements ($< 3.5$) of the sulfuric horizon and also on the boundary between physically ripe and unripe.

In group D (Figure 1B) the really physically ripe soils are brought together. Bk-1 and T-1 are well developed Non Acid Marine Soils without sulfuric horizons. Na-2 is a very deep, well ripened river levee soil on top of an old Acid Sulfate Soil.

From the numerous data of Marius (1984) may be concluded that Acid Sulfate Soils in Senegal with a well developed sulfuric horizon never are physically ripe. In Guinea-Bissau, only very old Acid Sulfate Soils of the Estuary Terraces are sufficiently ripe to meet the requirements of ripe soils (Pons, these Proceedings; Pons et al, item).

For most of them it is questionable if their sulfuric horizons are meeting the pH requirements.

It may be concluded that the majority of the soils with a sulfuric horizon are 'unripe'. Most of the old, red mottled Acid Sulfate Soils which are definitely ripe, are possessing questionable sulfuric horizons that are on the boundary of the pH requirements. Only very few old Acid Sulfate Soils are 'ripe' and at the same time meeting the pH requirements.

## 5 Discussion

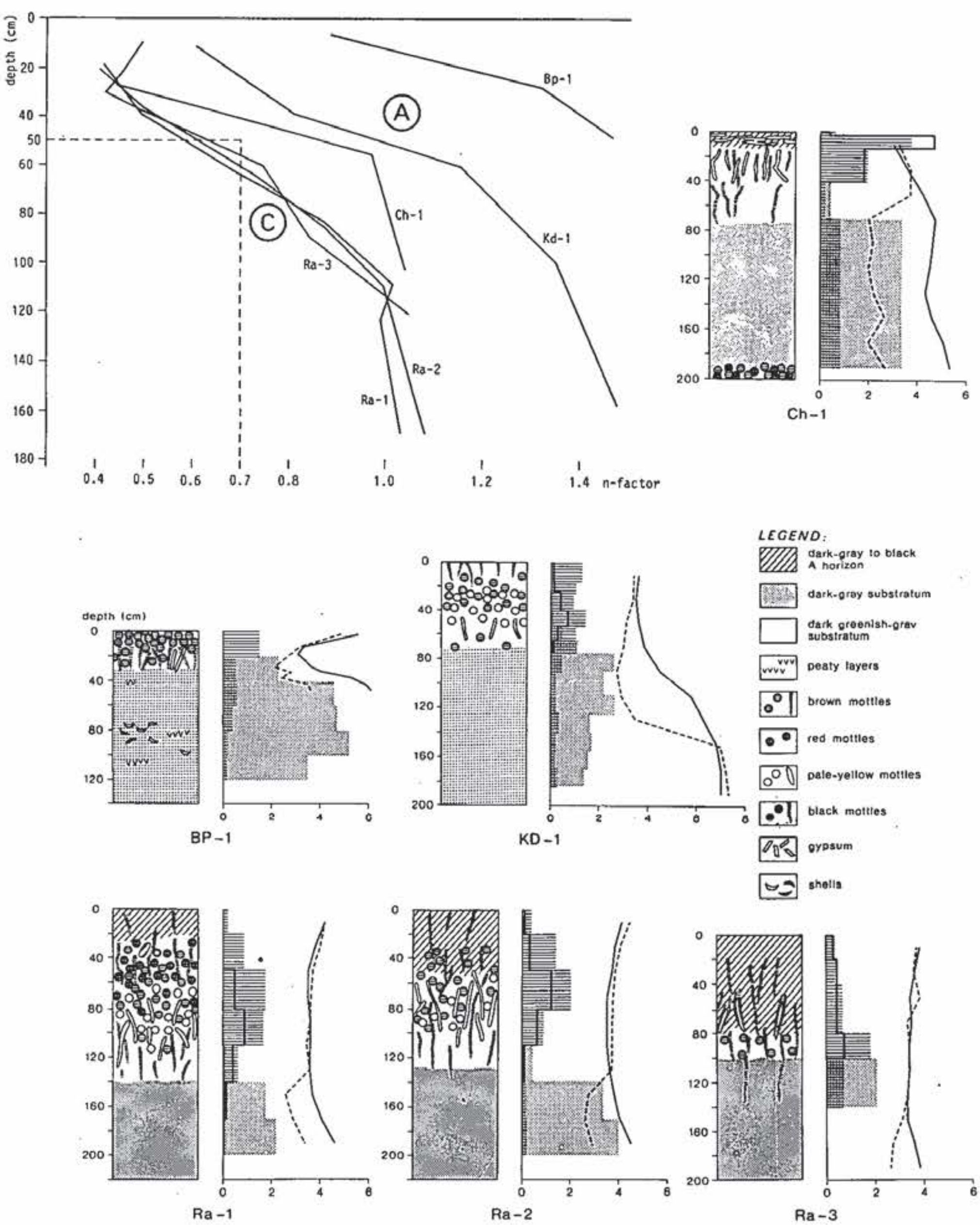
To my feeling the subprocess of physical ripening of soft muds, represents the very beginning of ripening or initial soil formation, and is also the most characteristic subprocess, on which the other depends. Unripe, half ripe and shallow ripe soils with unripe subsoils naturally are at home in the Suborder of Aquents as, no doubt, most soil scientists will agree upon.

According to the present definition of Soil Taxonomy 'Soils with aquic moisture regimes having a sulfuric horizon whose upper boundary is within 125 cm of the mineral soil surface' are excluded from the Entisols and classified as Sulfaquepts. The sulfuric horizon is not a diagnostic criterium in the suborder of the Aquents.

The underlaying thoughts are of course, that a sulfuric horizon is a diagnostic one, which is chemically strongly developed, differing in such an important way from the original sulfidic material, that it meets easily the requirements of altering and losses of bases, comparable to cambic horizons. Soils having chemically so strongly changed must be included in the Inceptisols.

Fortunately the sulfuric horizon is not considered as a kind of cambic horizon. So we are free to handle this horizon apart from the cambic horizon, eventually to consider only sulfuric materials.

As we have seen, most of the real sulfuric horizons don't meet the requirements of physical ripening, which are bringing all other soils in the Entisols. Therefore, classifying them with the Inceptisols seems unnaturally and we propose to bring these soils under the Entisols. We propose further to use 'sulfuric' materials as a diagnostic criterium in the Aquents to distinguish the Acid Sulfate Soils as a subgroup in the Sulfaquents, or, preferably as a new great group, apart from the present Sulfaquents, under the Aquents. 'Sulfuric' materials may be defined in the same way as a sulfuric horizon with the addition 'unripe'. We are getting then Hydraquents, Sulfaquents (both physically and chemically unripe) and the new Aquents-great group with the sulfuric material (chemically developed, but physically unripe). Probably, some Acid Sulfate Soils developed from marine muds, will stay in the Aquepts, together with the ripe Acid Sulfate Soils derived from acid mine spoil materials. This Aquept-great group will then include the physically and chemically ripe Acid Sulfate Soils, a much better solution, not only better adopted to the feelings of most Acid Sulfate Soils specialists, but also better fitted in the concept of Inceptisols as physically ripe soils. In this way the physically unripe 'acid sulphate' Aquents and the physically ripe Sulfaquepts, very different soils will clearly be distinguished, which is favourable because of their strongly different land qualities (bearing capacity, chemical behaviour, permeability, etc.).




Figures 1A and B The physical ripening, expressed as the n-figure, and profile diagrammes showing morphology, distribution of iron and sulphur compounds and pH (both fresh and after incubation) of some marine alluvial soils from Thailand (according to Figure 11, Van Breemen 1976). (The horizontal scale from 0-6 refers to pH, values on it have to be halved for mass fractions of S and doubled for FeO).

Figure 1A A: Unripe, saline sulphidic muds; C: Well developed, old Holocene Acid Sulphate Soils with sulfuric horizons

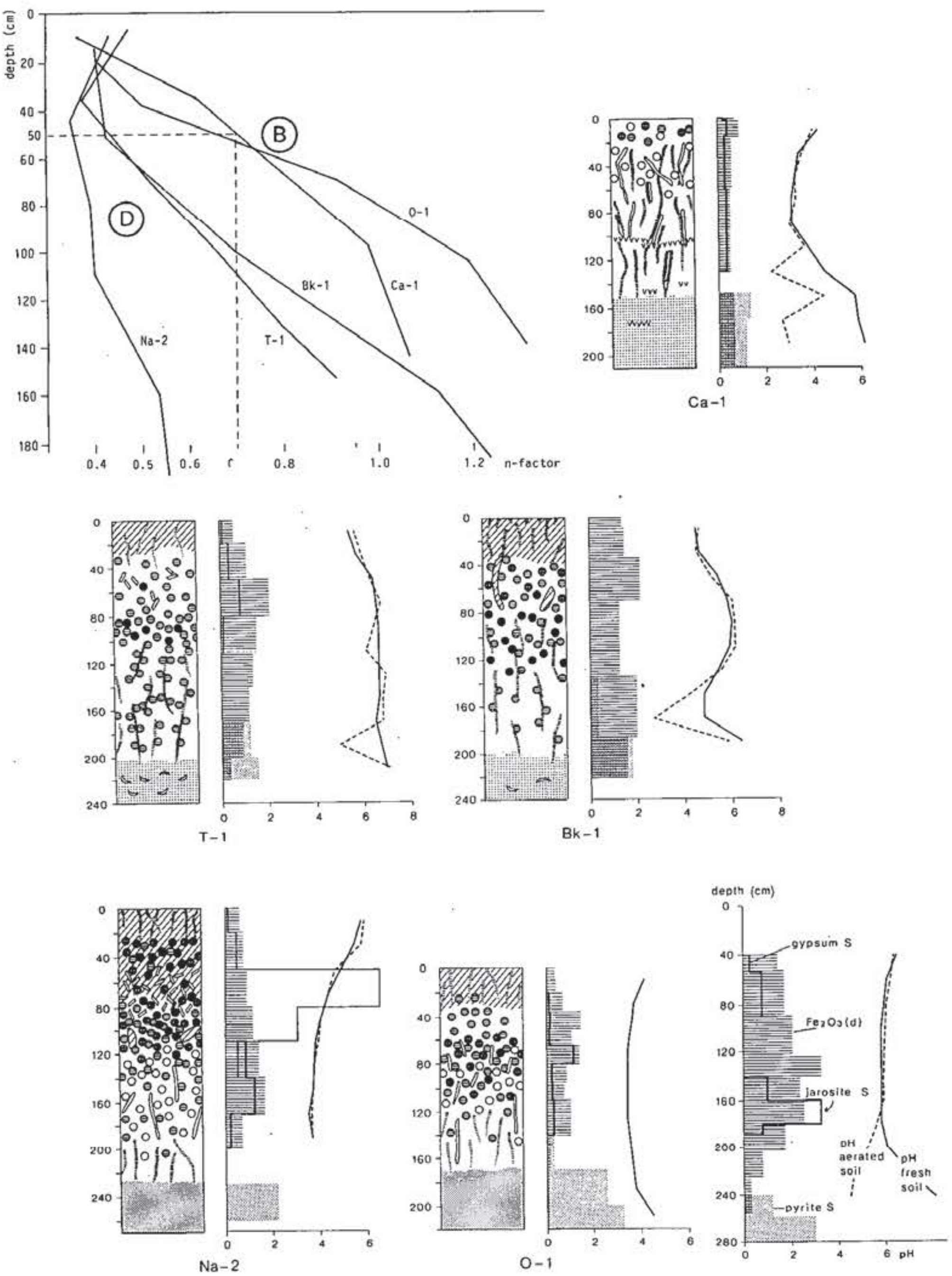



Figure 1B B: Unripe, young to rather old, desalinized Acid Sulphate Soils with sulfuric horizons; D: Ripe, Non Acid Alluvial Soils

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