

Classification of Acid Sulfate Soils of Peninsular Malaysia*

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ABSTRAK

Tanah-tanah asid sulfat adalah salah satu kumpulan tanah yang penting di Semenanjung Malaysia, khususnya di Pantai Barat. Tanah-tanah tersebut terbentuk daripada bahan-bahan endapan marin estuarin dan air payau. Ia boleh dibahagikan kepada dua kumpulan mengikut sistem pengelasan Taksonomi Tanah — tanah potensi asid sulfat dan tanah asid sulfat yang sebenarnya. Pengelasan tanah-tanah mengikut sistem pengelasan di Malaysia juga dibincangkan. Walaupun sistem pengelasan di Malaysia berasaskan kepada konsep-konsep Taksonomi Tanah, tetapi ia telah diubahsuai mengikut keadaan tempatan. Dua jujukan tanah asid sulfat telah diperkenalkan di Semenanjung Malaysia. Satu kunci untuk menentukan siri-siri tanah asid sulfat juga disampaikan dalam kertas ini.

ABSTRACT

Acid sulfate soils form an important group of soils in Peninsular Malaysia, particularly on the West Coast. These soils developed over marine, estuarine and brackish water deposits can be divided into two groups — the potential acid sulfate soils and the true acid sulfate soils using the definitions established in Soil Taxonomy. The classification of these soils in accordance to the Malaysian system is discussed. The Malaysian system though based on the concepts of Soil Taxonomy has been modified to suit local conditions. Two sequences of acid sulfate soils have been recognized in Peninsular Malaysia. A key to the identification of these acid sulfate soils is also presented in the paper.

INTRODUCTION

The west coast of Peninsular Malaysia is dominated by clayey deposits of marine and brackish water origin. These coastal clays extend as an almost continuous block along the west coast and are only broken by occasional islands of sedimentary and igneous rocks. This coastal plain which varies in width from about 10 to 50 km often grades into peat swamps. The coastal

plain averages in height from 0–15 m above mean sea level and is used extensively for agriculture after the construction of a coastal bund to prevent inundation by the sea, and the construction of drains to lower the waterable. The crops commonly grown on these areas include oil palm, coconut, cocoa, rubber and rice. The drainage of these coastal clays created problems in many areas and were often associated with the development of acid sulfate soils.

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LITERATURE REVIEW

The lack of details given in many papers and the lack of an accepted definition of acid sulfate soils makes it difficult to decide when acid sulfate soils were first recognized in Peninsular Malaysia.

Pratt (1911) reported that in the Krian rice growing area patches of soil gave very poor yields due to lack of drainage. He added that the distribution of these patches was irregular but that the waterlogging caused the development of sourness and that the rice plants turned yellow. This is possibly due to the formation of acidity. Dennett (1933) recognized that soils with high concentrations of acid were associated with the nipah palm and Wilshaw (1940) reported the occurrence of acid conditions on draining coastal soils. Coulter (1952) referred to soils containing considerable amounts of pyrite as *gelam* (*Melaleuca leucodendron*) soils.

As in many countries where such soils occur, the lack of uniform definitions makes interpretation of published work very difficult. A mixture of circumstantial and intrinsic soil properties was originally used to distinguish potential and actual acid sulfate soils from soils not showing or not expected to develop extreme acidity on drainage and cultivation. Thus in Peninsular Malaysia, the presence of acid sulfate soils in an area can often be suspected by the presence of *gelam* tree (*Melaleuca leucadendron*) or by a nipah (*Nipah fruticans*). If the area has been cleared, a sedge grass (*scleria* family?) and the grass *fimbristylis* are common (Kanapathy, 1976). The presence of reddish brown deposits (iron-organic complex) is also common along drains in acid sulfate areas. Subsequently an acid sulfate layer as a diagnostic horizon was taken to be one with a pH of about 3.3 or less (air dried soil) and which has soluble sulfate content in the air dried soil exceeding 0.1% (Coulter, 1967). The introduction of the Soil Taxonomy (Soil Survey Staff, 1975) and its earlier drafts proposed more rigid definitions for sulfidic materials and the sulfuric horizon. These were tested for Malaysian conditions when systematic semi-detailed mapping of the coastal plain areas

was initiated by the Soil Survey Section of the Department of Agriculture in West Johore. These studies (Gopinathan, 1973; Joseph and Maarof, 1975 and Paramanathan, 1976) provided a better understanding of acid sulfate soils in the country. Thus soil sequences of acid sulfate soils on both marine and brackish water deposits were proposed (Paramanathan, 1976; Paramanathan and Gopinathan, 1981). Since that time more data has been collected. Detailed studies (Noordin, 1980, 1981) of the acid sulfate soils in the coastal plain of Perak provided some important information pertaining to the genesis, classification, mineralogy and micromorphology of acid sulfate soils in the country. The objective of this paper is to present the current status of the criteria used for the mapping and classification of acid sulfate soils in Peninsular Malaysia.

DEFINITIONS

As mentioned earlier, the major difficulty in interpreting published data is the lack of uniformity of the definitions of acid sulfate soils. Today the criteria used in Peninsular Malaysia is based on those given in Soil Taxonomy (Soil Survey Staff, 1975).

Sulfidic Materials

Sulfidic materials are waterlogged mineral or organic soil materials that contain 0.75% or more sulfur (dry weight) mostly in the form of sulfides and have less than three times as much carbonate (CaCO_3 equivalent) as sulfur.

Sulfidic materials accumulate in a soil that is permanently saturated, generally with brackish water. The sulfates in the water are biologically reduced to sulfides. Sulfidic materials commonly occur along the coastal areas which are inundated by sea-water; the pH, which may be near neutral before drainage may drop to as low as 2.5. On drainage the sulfides are oxidized to form sulfuric acid which then reacts with the soil to form iron and aluminium sulfates (e.g. yellow jarosite). This oxidation can take place within a few years. Often yellow jarosite mottles may occur in sulfidic materials along old root

traces where localized oxidation has taken place. However, such materials still have a high 'n' value or are 'unripe'.

As the definition of sulfidic materials is mainly chemical, total analysis for determining the sulfur content is by far the most reliable method. However, this determination is not only laborious but seldom carried out as a routine analysis in laboratories in Malaysia. In the field, a few criteria can be used to recognise the presence of sulfidic materials. Material which is rich in sulfides often give off a smell of rotten eggs (H_2S) and the soil materials often changes black on exposure due to the formation of some intermediate oxidation product. With time this black coating turns yellow (jarosite) if the material is allowed to dry for about two weeks. On a pit face sulfidic material often may already show yellow jarosite deposits along old root channels. Another quick field test is to oxidize the soil sample by boiling it in concentrated hydrogen peroxide and measuring the drop in pH. This test however is dangerous especially if high amounts of organic matter are present. In the laboratory, a sample is left in an open soil sample bag placed under shade. This sample is moistened regularly as it dries in the shade. If the material is sulfidic, after about a month there should be a drop in pH by more than one unit. It must be pointed out, however, that a drop in pH *per se* may not be sufficient to classify the soil as sulfidic. This is particularly true if the material is rich in organic matter.

Sulfuric Horizon

The sulfuric horizon is composed either of mineral or organic soil material that has both a pH of less than 3.5 (1:1 in water) and jarosite mottles (the colour of fresh straw that has a hue of 2.5 Y or yellower and a chroma of 6 or more). A sulfuric horizon forms as a result of artificial drainage and oxidation of sulfide-rich mineral or organic materials. It is necessary to add another criteria to the two already given in Soil Taxonomy i.e. that the 'n' value must be less than 1.0. The 'n' value refers to the relation between the percentage of water under field conditions and the percentage of inorganic clay and humus.

The 'n' value can be estimated in the field by squeezing a sample of the soil in the hand. If the soil flows with difficulty between the fingers, the 'n' value is between 0.7 and 1.0 and if it flows easily between the fingers, the 'n' value is 1 or more. The 'n' value is necessary to exclude sulfidic materials which may have jarosite mottles along old root channels.

During field mapping in Malaysia, when a soil has an 'n' value of less than 1.0 and if jarosite is readily recognised in a horizon, then the horizon is taken to be sulfuric. Only in some is the pH determined. Thus even if the pH happens to be more than 3.5, it is still mapped as a sulfate soil. This is done to avoid the establishment of a number of soil series depending on the pH (Paramanathan and Gopinathan, 1981) and to facilitate field mapping.

CLASSIFICATION OF ACID SULFATE SOILS

From the definitions given above, it can be seen that two groups of soils can be defined depending on the diagnostic horizon present. If a soils is waterlogged, has no profile development, and has sulfidic materials within 50 cm of the surface it would be a potential acid sulfate soil — potential in the sense that if it is drained, it would develop into soils with a sulfuric horizon. Soils which have been drained and have a sulfuric 'B' horizon would be true acid sulfate soils.

Classification According to Soil Taxonomy

The Soil Taxonomy is a morphogenetic classification. It therefore attempts to separate soils using their profile morphology and their genesis. Hence the potential acid sulfate soils i.e. those with sulfidic materials within 50 cm of the soil surface are separated from soils having a sulfuric horizon.

Since sulfidic materials may occur both in mineral and organic soils, two great groups are recognized viz. Sulfaquents and Sulfihemists. Mineral soils which have sulfidic materials within 50 cm of the soil surface are classified as

Sulfaquents. These are recent or young mineral soils which due to their high water table are poorly drained and show no profile development. They have sulfidic materials within 50 cm of the soil surface. All organic soils which are poorly drained and which do not have a sulfuric horizon, whose upper boundary is within 50 cm of the soil surface but have sulfidic materials within 100 cm are classified as *Sulfihemists*. In mineral soils, if the sulfidic materials are present, between 50 to 100 cm, it is considered at the sub-group level.

In the case of soils with a sulfuric horizon, the depth at which these occur is used at different levels in Soil Taxonomy to reflect the severity of the acid sulfate conditions. Mineral soils, which have a sulfuric horizon whose upper boundary is within 50 cm of the mineral soil surface, are classified into the Great Group of *Sulfaquepts*. These are soils which have some profile development, have an aquic moisture regime and a sulfuric horizon within 50 cm of the mineral soil surface.

On the other hand, if the soil has jarosite mottles within 50 cm of the mineral soil surface but the pH is between 3.5 and 4.0 and therefore does not qualify for a sulfuric horizon, then the soil is classified at the Sub-Group level as a *Sulfic Trophaepte*. Also placed into this Sub-Group are soils where jarosite mottles occur between 50 – 150 cm and which also has a pH of less than 4.0. Organic soils which have a sulfuric horizon whose upper boundary is within 50 cm of the surface, are classified as *Sulfohemists*.

Classification in Peninsular Malaysia

In general the classification of acid sulfate soils in Peninsular Malaysia follows closely that used in Soil Taxonomy. However, some slight modifications were found necessary in order to facilitate field mapping and the interpretations of the soils for agricultural use. In the classification discussed here, the organic soils are not considered as our knowledge of these soils is still inadequate.

In principle, the definition of sulfidic materials used in Peninsular Malaysia is similar to that used in Soil Taxonomy. As mentioned earlier, although we accepted the definition of the sulfuric horizon used in Soil Taxonomy, in practice when we see jarosite in a horizon we assume that the pH in that horizon is less than 3.5.

Soils with Sulfidic Materials A soil is considered to be a potential acid sulfate soil if it has sulfidic materials within 50 cm of the soil surface. These potential acid sulfate soils are then sub-divided using the 'n' value and presence of an organic soil layer (histic epipedon) at the surface. Only three mineral soils which are potential acid sulfate soils have been identified to date (see Figure 1).

In the case of organic soils with sulfidic materials, we prefer to deviate somewhat from the Soil Taxonomy. In Soil Taxonomy, all organic soils having sulfidic materials within 100 cm are placed into the Sulfihemists irrespective of the nature of fibres. Our thinking in Peninsular Malaysia is that we should have three Great Groups i.e. Sulfifibrists, Sulfihemists and Sulfisapristis. It is our opinion that in addition to the presence of sulfidic materials, the stage of

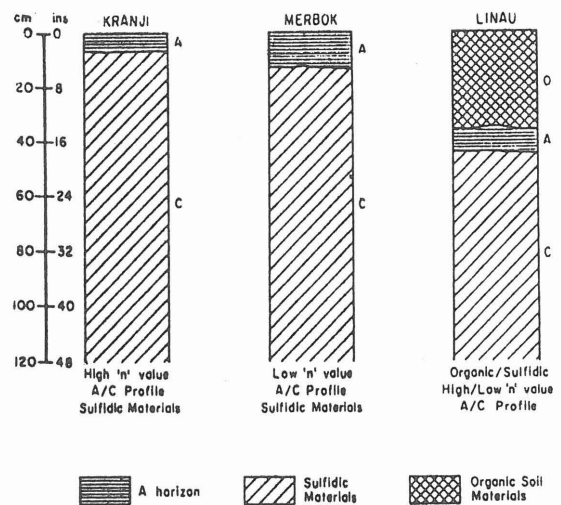


Fig. 1: Soils with sulfuric materials in Peninsular Malaysia

decomposition of the organic material is also important.

Soils with a Sulfuric Horizon In Soil Taxonomy, if a sulfuric horizon occurs within 150 cm of the soil surface, it is taken into consideration in the classification of the soil. If the sulfuric horizon occurs within 50 cm, then it is used at the Great Group level e.g. Sulfaquepts or Sulfohemists. On the other hand when the sulfuric horizon occurs between 50 to 150 cm then it is used at the sub-group level e.g. Sulfic Tropaquept.

In Peninsular Malaysia, if the sulfuric horizon occurs below 100 cm it is not considered in the classification. This is because in our opinion, any soil feature below 100 cm seldom affects soil suitability. Like in Soil Taxonomy, the soils are separated initially on whether the top of the sulfuric horizon occurs within 50 cm or between 50 to 100 cm. These two broad groups are then sub-divided using the depth at which the marine clay, the C horizon occurs and the nature of the B horizon. Humus rich B horizons have friable consistence and are well structured while others are sticky, weakly structured and low in organic matter (see *Figures 2 and 3*). In the case of soils having a sulfuric horizon within 50 cm of the surface, four soil series viz. Kuala Perlis, Parit Botak, Guar and Sedu have been identified (*Figure 2*). When the sulfuric horizon occurs between 50 to 100 cm, then another four soil mapping units viz. Telok, Tongkang and Jawa (shallow) and Jawa have been identified to date (*Figure 3*).

Soil Sequence of Acid Sulfate Soils Soil surveys carried out in Peninsular Malaysia indicate that these soils form a drainage sequence. This was first recognized by Paramanathan (1976). Subsequent work and redefinition of soil series made it possible to improve the sequence. Generally two sub-sequences occur in these coastal plains. Near the coast soils which are poor in organic matter and which have coarse angular blocky structures, sticky consistence and light gray matrix colours are common. The sequence begins with the areas outside the coastal bund which are inundated by sea water.

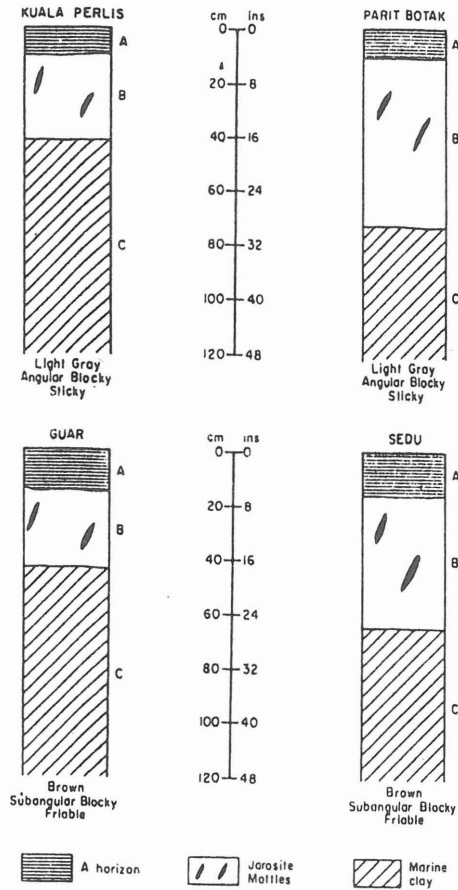


Fig. 2: Soils with a sulfuric horizon within 50 cm in Peninsular Malaysia

Inside the bund drainage produces soils which have a sulfuric horizon at varying depths (see *Figure 4*). Further inland where the coastal plain merges with the peat swamps, the soils are enriched in organic matter and this results in soils with a friable consistence, moderate structures and generally brown colours. Near the peat swamps, the soils are undeveloped potential acid sulfate soils with a surface organic layer. Away from the peat swamps where drainage has been effected, the soils have a sulfuric horizon at varying depths (*Figure 4*).

IDENTIFICATION OF ACID SULFATE SOILS

As a means of assisting soil surveyors and agronomists to understand the properties of acid

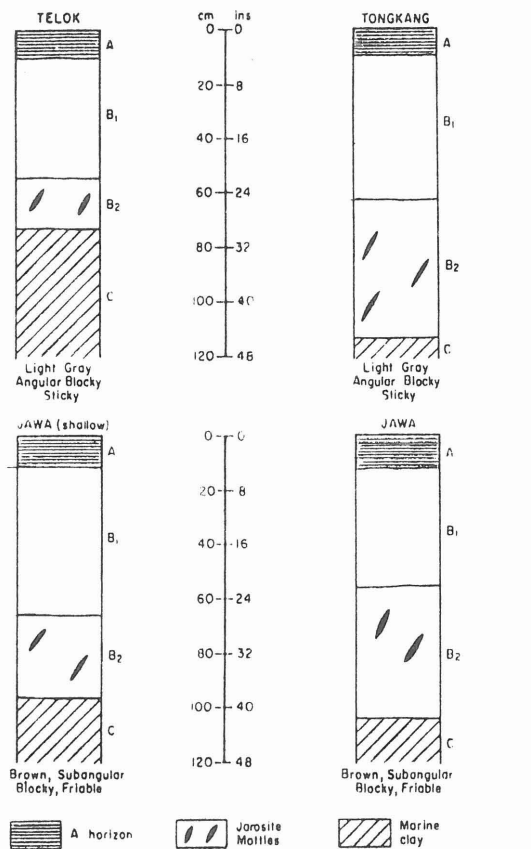


Fig. 3: Soils with a sulfuric horizon between 50 to 100 cm in Peninsular Malaysia

sulfate soils in Peninsular Malaysia, Paramanathan (1981) has prepared a "Key to the Identification of Soils on Marine, Estuarine and Brackish Water Deposits". This Key includes both acid sulfate and non-acid sulfate soils. An identification table for the acid sulfate soils extracted from this Key is given in Table 1.

It must be pointed out that many workers consider the Lubok Itek Series mapped on the Kelantan Plain to be an acid sulfate soil. This soil has a massive clay overlying an organic deposit with its upper boundary between 50 to 100 cm from the soil surface. This organic layer often has a pH of less than 3.5 and hence it has been assumed to be a sulfuric horizon. However, as this soil is often under water, no jarosite mottles have been reported. Thus it is possible that this layer contains sulfidic materials but since it is a mineral soil and the sulfidic materials occur below 50 cm, it is not considered to be diagnostic and therefore not even a potential acid sulfate soil. Furthermore, no sulfur determinations have been reported to confirm if the materials are sulfidic. It is possible that the low pH is due to organic acids.

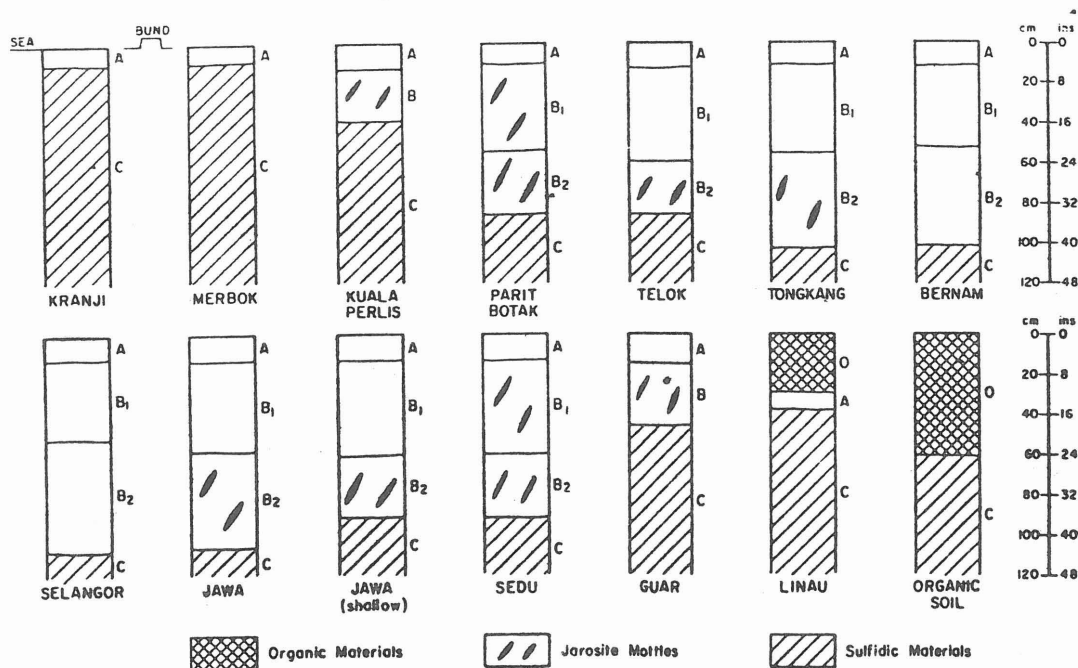


Fig. 4: Acid sulfate soil sequences in Peninsular Malaysia

TABLE 1
Table for the identification of acid sulfate soils of Peninsular Malaysia

Horizonation	A/C or O/A/C		A/B/C		A/B/C
Diagnostic horizon/material	Sulfidic material		Sulfuric		Cambic
'n' value or depth to sulfuric horizon	High 'n' value (>1.0)	Low 'n' value (<1.0)	Less than 50 cm	50 – 100 cm	No sulfuric horizon to 100 cm
Subsoil Matrix light gray, angular blocky and sticky	Kranji	Merbok	Kuala Perlis ¹ Parit Botak ²	Telok ² Carey ² Tongkang	Bernam
Subsoil Matrix brown subangular blocky and friable	—	Linau	Guar ¹ Sedu ²	Jawa (shallow) ² Jawa	Selangor
Taxonomy	Typic Sulfaquent	(Typic) Sulfaquent	Typic Sulfaquept	Sulfic Tropaquept	Typic Tropaquept

Notes: ¹marine clay within 50 cm

²marine clay 50 – 100 cm

^aloamy textured soils

CONCLUSION

The knowledge of acid sulfate soils of Peninsular Malaysia has increased greatly over the last few years. However, the mapping of these soils still presents a lot of problems as these soils often occur as pockets within areas of non-acid sulfate soils. The need for analytical data to support soil surveys cannot be over-emphasised in the mapping of these soils. The distribution of these soils, however, cannot be assessed from the earlier maps as the definitions used for soils were different or have since been modified.

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