KINGDOM OF THAILAND

SOILS OF NORTHEASTERN THAILAND

A KEY TO THEIR IDENTIFICATION AND SURVEY

by

F.R. Moormann, Sarot Montrakun

and

Samarn Panichapong

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I. INTRODUCTION

In 1962, a first edition of the Key to the Soils of Northeastern Thailand appeared in a mimeographed form as report No. 9 in the series Miscellaneous Soil Reports of the Ministry of Agriculture. Since, the Key has been used in surveys of diverse nature in typical northeastern provinces such as Khon Kaen, Kalasin, Maha Sarakam, Roi Et and Nakon Rajsima (Korat). At the category of classification for which this Key was devised, e.g. the series level, the results have been very satisfactory. Most series definitions and descriptions were found to cover the soils, actually surveyed in those areas.

It therefore seems opportune to print a new edition of this Key in a more final form, with corrections and adaptations base on the results of more than one year's intensive field work in the region. It should, however, be pointed out that large parts of northeastern Thailand remain to be surveyed or even, have as yet not been visited by soil technicians. The northern sector of the Northeast with, apparently a predominance of laterite soils is hardly better known now than at the time of the first Key. Thus, the new Key is, of necessity, still incomplete. New series may have to be added when surveys in new areas are taken up and corrections in the definition of existing series may have to be made, especially when more analytical data will become available.

II. REVIEW OF PREVIOUS LEGENDS

On the general soil map by R.L. Pendleton,* a limited number of soil units, commonly called "soil series" has been distinguished. Apart from the soils on hills (units 42 and 30), following mapping units were used for Northeastern Thailand:

unit 5 : Korat fine sandy loam, including Kumpawapi sandy loam
unit 6 : Roi Et fine sandy loam
unit 21 : Gula Ronghai silt loam
unit 56 : Bankok dark heavy clay
unit 10 : Chiangmai loam
unit 18 : Tachin clay

Other soils, described and classified by Pendleton and Sarot Montrakun, but not incorporated in the provisional soil map, are; Yasotawn loam and Sakon loam.

These soil units should by no means be considered as "soil series", as defined in the Soil Survey Manual, USDA hand book No. 18. Rather, these units are broad generalizations, usually on the level of the great soil group, or of the

* See : R.L. Pendleton and S. Montrakun: The soils of Thailand: Proceedings Ninth Pacific Science Congress, Vol 18, Bangkok, 1962.

sasociation of two or more of such groups. In modern soil classification, such soils would not be named after a type-location, but be given the name of the relevant great soil group or groups. According to our observations, the soil units, mentioned above are more or less equivalent to following great soil groups*

Korat fine sandy loam	:	Mainly gray podzolic soils but including also regosols, red-yellow latosols, red-yellow podzolic soils and non calcic brown soils.
Roi Et fine sandy loam	:	Mainly low humic gley soils (also called gray hydromorphic soils) but including some solonetz soils.
Gula Ronghai silt loam	:	Low humic gley soils and alluvial soils.
Bankok dark heavy clay	:	Alluvial soils, hydromophic, and probably some solonchack and solonetz soils.
Chiang Mai loam	:	Alluvial soils, less hydromophic.
Tachin clay	:	Alluvial soils, peat and muck soils, strongly hydromorphic.

Sarot Montrakun, in subsequent surveys in the Northeast has modified this basic legend on several points :

(1) The Bangkok dark heavy clay unit was dropped and instead, the unit of Phimai clay was introduced for the clayey alluvial soils.

(2) The Tachin clay unit has not been used and instead, a miscellaneous land type of intermittent lakes and marshes was indicated on the maps.

(3) A unit, Sakon loam was introduced locally for soils with consolidated lateritic formations at very shallow depth.

(4) The Ponpisai loam unit was introduced locally for soils with lateritic gravels at shallow to medium depth.

(5) The Chiang Mai unit was confined to soils of the river levees, with variable texture but without poor drainage.

The legend by Pendleton and Sarot, though providing an important body of knowledge on the soils of Thailand, was never devised to be used in soil surveys of a more detailed nature. While arranging this Key, the problem arose as to what point the original units should be incorporated and what to do with the type-location names. It was subsequently decided to use, whenever possible, the original names but only for those soils, corresponding to the central concept of the unit. For soils, differing too much from the concept, a new series name was introduced. Pendleton's use of texture designations after the unit name, e.g. "Roi Et find sandy loam", was dropped altogether in view of recent developments in international soil classification and also because such designations very often are not confirmed by field observations.

* For description of most of the great soil groups, mentioned below, see : R. Dudal and F.R. Moormann ; Major soils of South-East Asia : M.S.R.-8-1962 Bangkok.

It thus should be emphasized that, for instance, the Roi Et series of this Key is not synonymous to the previous map unit 6, Roi Et fine sandy loam. Rather, the Roi Et series includes soils which would have been called Roi Et fine sandy loam, but excludes many soils, previously also surveyed as Roi Et fine sandy loam.

In 1960, soil scientists of the French firm SOGREAH carried out a reconnaissance soil survey of parts of the Khon Kaen, Udorn and Kalasin provinces.* The legend, used for the soil map of this report is quite different from the traditional legends used in this country and is based on the following considerations:

(a) The main subdivision is made according to "genetic soil groups" as conceived by Aubert and collaborators in the former French territories in Africa.

(b) The genetic soil groups or subgroups are subdivided, according to the geomorphologic "landform", in basin soils, levee soils, soils of old terraces, etc.,

(c) The lowest subdivision in the legend is based on soil morphology, mainly texture but also depth and development of the surface horizons.

Whereas this type of legend is useful under certain circumstances and while the quality of the map appears good, it seems less indicated to follow this system in Thailand. The mixing of such diverse elements as soil genesis, physiography and soil morphology tends to make a legend more or less incomprehensible for the agronomist who has to use the map.

Incidental surveys of irrigation project areas were carried out by technicians of the Royal Irrigation Department, assisted by U.S. soil specialists. The legend for these maps, which remained mostly unpublished, is based on the land classification legend of the US Bureau of Reclamation, partly corrected to suit local conditions. The present-day philosophy among soil technicians in Thailand is to reject this approach to soil survey and classification as inadequate. It is believed that only after a basic knowledge of soils and soil conditions is obtained through modern methods of soil survey, the landclassification for whatever purpose should follow as the next step.

III. LANDFORMS AND PARENT MATERIAL

The importance of a better knowledge of surface geology and landforms in regard to soil survey is being recognized increasingly by soil scientists. Most soil series have a relatively narrow range in landform; the same series may be recognized in one, two, but rarely more different landforms. Hence, a better understanding of the geomorphology of a given area will facilitate the soil survey and improve the accuracy of the maps.

The normal procedure for the soil surveyor is to name and describe landforms in standard terms, making use of the physiographic and geomorphologic monographs that apply to the survey area. In Thailand, very few such studies are

* SOGREAH ; Agro-pedological study of the upper Nam-Chee basin, 1960,

available, and in fact, the most reliable data on geomorphology of Northeastern Thailand have been obtained during soil survey activities in that area. As an introduction to the better understanding of the soil in its environment, a general review of these findings is given below.

Northeastern Thailand, also designated as the Korat Plateau, is described* as a young, saucer-shaped plateau, tilted to the southeast, limited on the north and the east by the Mekong river, on the west by the Petchabun mountains and Dong Phya Yen, and on the south by the San Kamphaeng range and the Dong Rek scarp. A line of hills lies between the plateau proper and the Mekong on the north and the east. The elevation of the plateau ranges from somewhat over 250 meters in the north and the west to about 100 meters in the vicinity of Ubon. The surface of the interior of the plateau is gently undulating, with low hills occurring, as well as numerous small shallow lakes.

The deeper bedrock of Northeastern Thailand is mainly formed by a thick deposit of continental sandstones, siltstones, shales, and conglomerates of Triassic and Jurassic age and belonging to the geologic Korat series, Minor inclusions of limestone are found as well as basalt outcrops, e.g. to the south of Sisaket and Buriram, whereas some paleozoic rocks of varying composition are present in the northwest.

Earlier writers have assumed that the unconsolidated surface materials, covering the bedrocks were directly derived from these rocks by weathering in situ. Thus, Pendleton indicates that the Korat fine sandy loams have been weathered from the "redbed" sandstones of the (geologic) Korat series. Our studies and surveys in Northeastern Thailand, however, have brought to light that by far the largest part of the surface deposits in this part of the country are transported materials or **alluvial sediments** of varying age and composition. Only in places where the bedrock is exposed or found at shallow depth, as in the hills and in deeper erosion valleys, some residuum is found. But even here, most of the unconsolidated cover over the bedrock has been dislocated by erosion and by landslides, being thus of colluvial nature.

Although the bedrock locally influences the surface forms, topography and drainage pattern, it must be emphasized that the geomorphologic features of the Northeast are predominantly determined by the tremendous alluvial deposits of the Mekong river and its tributaries, of which the main one is the extensive system of the Mae Nam Mun.

The sedimentation of the alluvial deposits has taken place in several well separated phases. Between each phase of sedimentation, a period of erosion is noticeable during which part of the alluvial deposits were eroded away, with new valleys being formed. Each sedimentation and erosion phase has left its traces which

* Geologic Reconnaisance of the Mineral Deposits of Thailand; U.S. Geological Survey Bulletin no 984, Washington DC 1951,

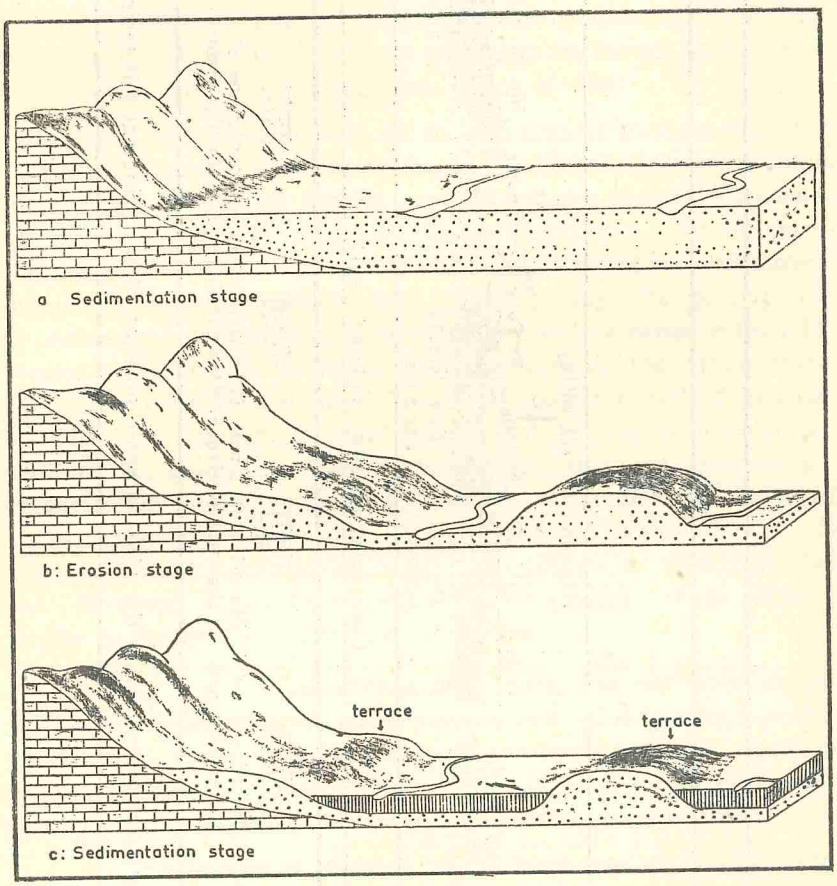

Fig. 1: Cycle of sedimentation and erosion, resulting in the formation of terraces.

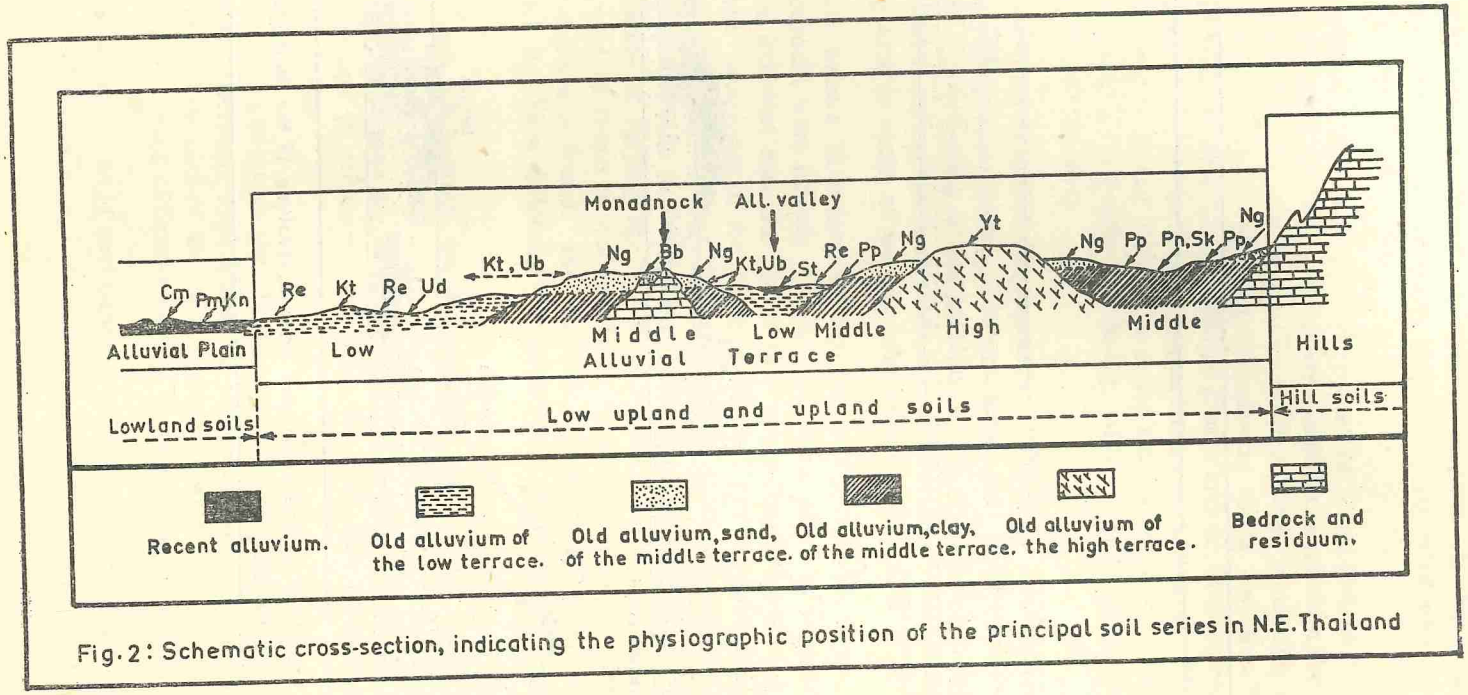

Fig. 2: Schematic cross-section, indicating the physiographic position of the principal soil series in N.E. Thailand

can be recognized in the present-day landscape in Northeastern Thailand. The block diagram, fig. 1 shows schematically, the cycle of sedimentation and erosion and the consequent formation of different terrace levels.

During the soil survey in Northeastern Thailand, four main levels of sedimentation were recognized, which, together are largely determining the landforms in this part of the country. These levels include the present day **alluvial plains** of the rivers and creeks, and three main stream terraces which, in this publication, have been called **low terrace, middle terrace** and **high terrace.** Figure 2 gives a schematic cross section of these levels of sedimentation as they may be observed in Khon Kaen province. Further geomorphologic studies may well disclose other terrace levels, as well as sublevels in the main terraces, though such finer subdivisions are less important from the soil surveyors' point of view.

Each sedimentation level has its own general gradient, but all slope down from the north and the west to the southeast, reaching their lowest elevation in Ubon province. The difference in general gradient of the various sedimentation levels strongly affects the general topography of the Northeast. For instance, north of Khon Kaen, the summits of the middle and the high terrace are well above the level of the low terrace and the alluvial plain. Consequently, the general relief here is sharply undulating to even rolling, with rather deep valleys incised in the middle and the high terrace formations. In Roi Et and Ubon provinces, the top of the middle and the low terraces appear to be situated only a few meters above the level of the alluvial plains, to the effect that the general relief here is flat to slightly undulating. It was observed that the gradient of the low terrace formations is somewhat greater than that of the recent alluvial formations, whereas the gradient of the middle terrace formations is distinctly steeper than that of the younger formations. So little is left of the high terrace formations, that it is difficult to determine their general gradient. However, it may be assumed that the gradient of the latter is at least comparable to the gradient of the middle terrace.

Dating the sedimentation-erosion cycles has not been possible as yet. Whereas the present-day alluvial plains are even now being formed, it may be assumed that the previous cycles date back from corresponding climatic cycles during the Pleistocence, ("Ice age"), with the low terrace being of Upper Pleistocene age, and the high terrace being Lower Pleistocene, or possibly even Pliocene.

Another important element in the landscape of Northeastern Thailand are the **hills and ridges,** mostly formed by sandstones, conglomerates, etc. of the geologic Korat series (Trias). These formations occur as outcrops, questas and monadnocks in many places and are close to the surface in others, influencing the surface topography to a varying degree.

Other land forms are known to occur in Northeastern Thailand. These, however play only a relatively minor role in the landscape. **Alluvial fans** are formed where creeks with a rather steep gradient enter in a wider plain (fig. 3). Here,

the water quickly losses its sediment charge which is deposited in a fan around the point of entry of the creek. Alluvial fans, both recent and old, are observed in Northeastern Thailand.

Fossil **lake bottoms** are present on difference terrace levels. Sediments here are finely stratified, as is the case around the Han Lake near Sakon Nakhon.

Of great importance in the Northeast are **colluvial formations**. These formations are present in almost any place with some relief but especially on the footslopes of the hilly areas and of the escarpments of the different terrace levels towards a lower level. On slopes, the surface sediments have the tendency to move down. Thus, the upper slopes lose part of their sediments which are deposited on the lower slopes and in the valleys. In such a way, the upper parts of the soil profiles on the lower slopes and even the entire profiles in valleys are composed of colluvium, locally derived from the material of the higher slopes. Differentiation between the sediments "in situ" and the colluvium is, in most cases difficult, if not impossible. Only when the sediments on the upper slopes have a different lithology from those down below, can the colluvial nature of the surface-sediments be established with certainty.

A summary description of the main landscapes in Northeastern Thailand is given below.

a. **The alluvial plains**

The wider alluvial plains of the Northeast usually show the landforms, schematically indicated in fig. 4. In such a plain, the main geomorphologic land forms are the river levees and the basins. The river levees are the higher parts directly adjacent to the river. Most river levees in the Northeast are composed of a series of parallel higher and lower strips, often with cut-off and partly silted-in meanders (ox bows) in the lower parts. Such a pattern has come into existence because of periodic shifting of the course of the river. The basins are further away from the present or previous riverbeds. Quite typical in the Northeast are the very low parts in the basins which form swamps and intermittent or permanent lakes.

Narrow alluvial valleys of brooks do not show this pattern; they are lowest in the middle and have a U shaped bottom, in which no river levees are apparent. Transitions between the two forms occur.

The material, deposited in the wider alluvial valleys is usually fine-textured. Clays and heavy clays dominate and even the river levees are mainly composed of clay loam or clay. Only in spots, lighter material usually loam or sandy loam, can be observed in the river levees. The material in the narrow valleys which is derived directly from the adjacent areas is, on the average much lighter, with medium textures (loam, sandy loam) dominating. Where the adjacent material is very sandy, the alluvial deposits of the creeks usually are also sandy.

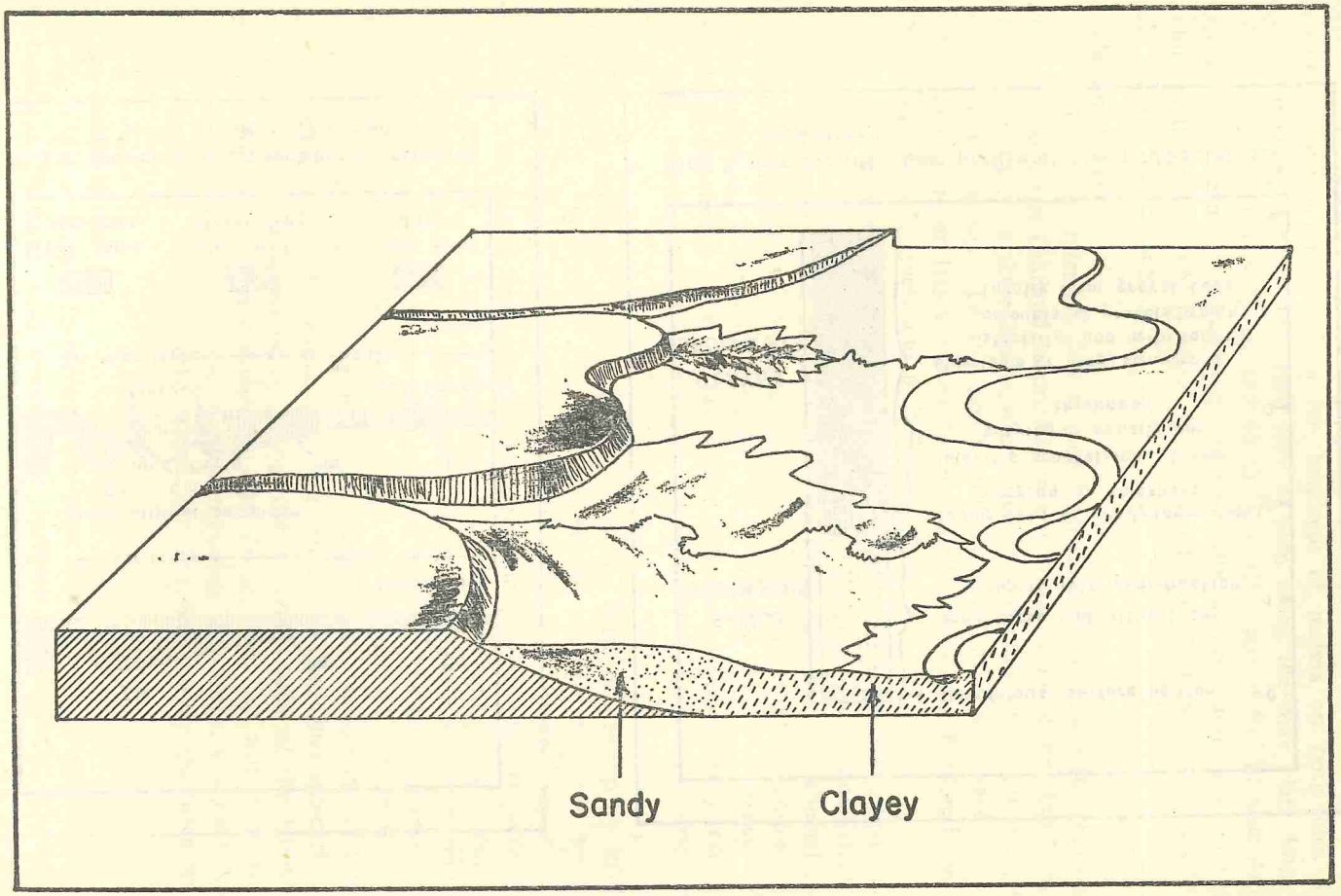

Fig 3. Alluvial fans being built out in an alluvial plain

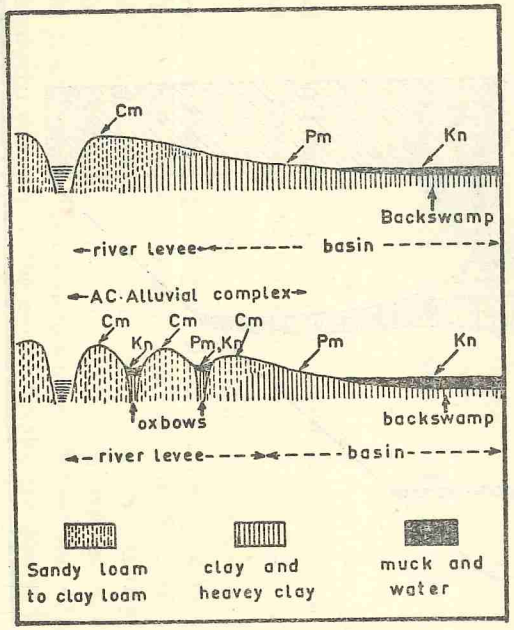

Fig. 4 Schematic cross sections of alluvial plains in N E Thailand

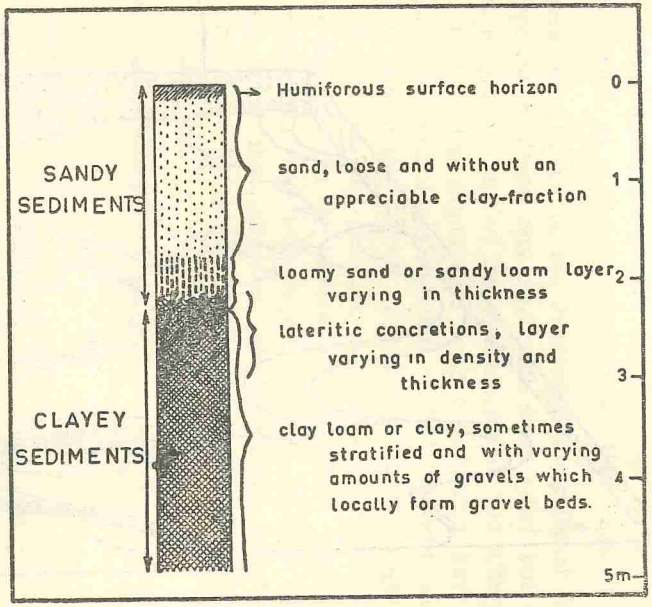

Fig.5:Schematic lithologic profile of the middle terrace formations

A peculiar feature of the alluvial plains in Northeastern Thailand is their variation in width. Many of these plains present themselves as a series of more or less closed depressions, connected by river valleys, incised in older formations and which have a width of only a few hundreds of meters on both sides of the river. Narrow passages of this kind may be seen along the Mae Nam Mun, east of Korat, and again near Ubon and on the Lam Chi, east of Roi Et near Amphoe Selaphum. The general hydrography and especially the deep and prolonged yearly flooding of the river plains is certainly connected with this pattern of alternating plains and narrow passages.

b. The low terrace

The most extensive low terrace formations are found in the southeastern part of Northeastern Thailand; especially in the lower basins of the Mae Nam Mun and the Lam Chi. In these basins, wide, slightly undulating plains are occupied by low terrace formations. To the north and the east, the low terrace plains are narrower and more or less confined to elongated depressions, bordered on both sides by older terrace levels and by hills.

Where the low terrace formation occupies wide plains, the alluvial pattern of sedimentation can occasionally be recognized. Sometimes, abandoned streambeds of former rivers are visible on air photos. In connection with this alluvial pattern, the slightly higher parts of the landscape are mainly composed of medium to light textured sediments, whereas in the lower parts medium heavy to heavy deposits dominate in the surface layers. This pattern of sedimentation is easily recognizable in the field, because both soil conditions and agricultural land use are closely related to it.

The landscape of the low terrace has been broken up by geological erosion in only a few places; this may notably be the case near the present-day valley of the Mekong river. Mostly, however, the low terrace level is more or less stable, with neither new sedimentation nor geologic erosion taking place. Recent studies in Roi Et by Tanit Tongchuta, Prompan Snitwong, et al. point to the existence of two sub-levels of the terrace. The lower one is most clayey and shows series of distinct abandoned river channels (ox bows). The fossil charactor of this formation is clearly indicated by the fact that the soils in and outside the old beds are both developed soils, having undergone considerable weathering and leaching after the deposition of the sediments a long time ago. The higher sublevel is mostly sandy, at least in its upper parts, giving rise to sandy soils of the Ubon series. Here also, abandoned river branches may be found, filled up with sediments that usually are more clayey than those of its surrounding. Nowhere, a distinct boundary exists between the two sublevels, which for practical survey purposes were not separated.

c. The middle terrace

Middle terrace formations are most extensive in the northern part of Northeastern Thailand, with considerable surfaces being present in other parts.

Reconnaissance surveys indicate the predominance of middle terrace formations, roughly north of a line Khon Kaen - Kalasin - Amnat Charoen.

Middle terrace formations are quite diverse and, contrary to the low terrace, no fossil alluvial pattern can be recognized. In places where the terrace formations are more or less complete, e.g. where they have not been attacked strongly by erosion, the geological profile of the terrace shows distinctly two different kinds of sediments, the upper strata being sandy and the lower ones being clayey. This is schematically shown in figure 5. The upper deposits are composed of homogeneous sand, which contains a very low amount of clay particles. Towards the base of this stratum, the clay content may increase somewhat and loamy sand to sandy loam textures are frequently encountered (textural B horizon?).

In a strip, situated along the Nam Phong valley, north of Khon Kaen, the upper layers are predominantly composed of gravel beds. Such gravel deposits may occur elsewhere also; they should be considered as local facies of the sandy upper stratum of the middle terrace. The transition to the lower, clayey material is mostly very abrupt and often characterized by the presence of numerous hard laterite gravels or even continuous laterite pans. The laterite may extend somewhat downwards in the clayey stratum. The clayey material usually is composed of clay loam, sandy clay loam or clay which, when not weathered due to exposion, is of a light gray colour, showing reddish, ocre or yellow mottling. The clay usually contains varying amounts of rounded pebbles of alluvial origin. In some places (old streambeds) the pebbles are so numerous as to occupy the major part of the soil-mass. In several places these pebble-beds are excavated for road-material. Sandy middle terrace formations predominate north of Khon Kaen to near Udon. This predominantly sandy landscape with its characteristic open dipterocarps (yang) forest, extends far to the east, bordered by the hilly area in the east of Kalasin and Roi Et provinces.

In this zone as well as in other sandy middle terrace areas of Northeastern Thailand, the relief is undulating to rolling with most of the higher parts of the landscape being sandy, while lateritic and clayey deposits are only found in strips, flanking the lower erosion valleys.

Further north, in an area including most of Nong Khai, Udon, Sakon Nakhon and Nakhon Panom provinces, the sandy upper strata of the middle terrace appear to have been mostly stripped away by erosion, leaving only local sandy spots. In this vast, undulating area, the surface formations, are hence formed predominantly by the gravelly clay and the laterite, characteristic for the deeper strata of the middle terrace. These clay and laterite formations are very typical, for instance, along the road from Udon to Nakhon Panom.

d. The high terrace

High terrace formations occupy only a relatively small surface of the Northeast. Whereas, originally, this terrace may have covered most of the landscape, it subsequently has been eroded away, leaving only smaller "islands", somewhat higher than and surrounded by the younger terrace formations. These island-terraces

have been found in several provinces. Typical spots can be observed along a line starting north of Khon Kaen and going east to a point north of Kalasin. These remnants were mapped as ferruginous soils in the upper Nam Chi survey (op. cit. page 3) Other spots were observed southeast of Khon Kaen, along the road from Ban Phai to Maha Sarakham and near Yasothon, Ubon province. South of Korat, larger surfaces of this high terrace are present and it is not excluded that other areas will be found elsewhere in the Northeast.

The surface layers of the high terrace formations are mostly composed of loamy sand; deeper down they are much more clayey, having generally a sandy clay loam or sandy clay texture. Quite typically, these formations show a red colour which continues to a great depth and which is apparently the result of soil forming processes. Soils on these sediments are red-yellow latosols. With the exception of the surface layers, the composition of the high terrace sediments appears to be homogenous but gravel beds occur locally. In deep exposures near the Huai Si Thon dam, north of Kalasin, approximately 12 meters of homogeneous sandy clay loam was found, resting on bed rock. Only towards the base of the formation, stratified layers, containing rounded pebbles as well as a thin lateritic pan were observed. Elsewhere, lateritic layers may be present in the high terrace formations, as is the case north of Khon Kaen.

e. The hills

Hill ranges border Northeastern Thailand towards the west and the south. Furthermore, several low ridges and massives can be observed throughout the area. The most extensive hilly areas are found to the southwest and south of Sakon Nakhon where the highest tops are situated at appr. 640 meters, e.g. some 400 meters above the surrounding plains. Usually these outcropping older formations lay well above the level of the various terraces, but in places (e.g., north of Khon Kaen and north of Amnat Charoen) they are barely higher than the level of the high or middle terrace. In such cases, rocky outcrops can often be observed in erosion valleys in the terrace. Ridges, slightly covered by terrace formations retain their influence on the configuration of the landscape, more in particular on the course of creeks and drainage ways. The terrace-covered sandstone and conglomerate ridges in the Nam Phong area are reflected in the pattern of the soils, though true outcrops occupy only minor surfaces.

The hill and stony parts of the Northeast are of a very limited value for agriculture. Thuswise, a detailed knowledge of their geomorphology and soil conditions is of restricted importance for agricultural development purposes and study of these characteristics should be given only minor emphasis in the framework of the overall soil survey of Northeastern Thailand. Exception to this may be the limestone formation to the west of Khon Kaen and the basalt formations near Buriram, on the weathering products of which better soils are observed.

IV. SOIL UNITS

1) Categories of classification and scale of survey

The categories of classification, to be used on any soil map depends on several factors, the main of which are the scale of mapping and printing of the map and the purpose to which the map is made. The legend itself depends furthermore on what kind of classification system is used.

For Thailand in general and for the Northeast in particular, it was decided to use a system which is largely inspired by the work of the U.S. Department of Agriculture, as set forth in the "Soil Survey Manual", USDA Handbook No. 18, 1951 and which was partly redefined in 1960 (Soil classification, a comprehensive system, 7th approximation). In the 7th approximation, the categories of classification are orders, suborders, great groups, subgroups, families, and series.

The categories or combinations thereof, to be represented on any given soil map, depend mainly on the kind and scale of mapping. Abritrarily, following types of maps have been distinguished for this country:

General soil map: survey on scales varying from 1:40,000 to 1:250,000; drafting on a scale of 1:1,000,000 or smaller. Pendleton's map is an example of a general soil map. On such a scale, mostly the high categories of classification such as orders, suborders and great groups can be represented. However, in a few cases, units of a lower category can be shown, if they occupy larger surfaces and if it is worthwhile to distinguish them.

Reconnaissance soil maps: survey on scales varying from 1:40,000 to 1:250,000; drafting on a scale of 1:250,000. On this scale, the mapping units will be generally associations of soil series. Some single soil series may be represented but part of the units will be complexes and miscellaneous land types, without a well defined category-level.

Detailed reconnaissance maps: survey on a scale of 1:40,000 (airphotos) or 1: 50,000 topographic maps; drafting on a scale of 1:100,000. Like on the previous type of maps; the mapping units will often be associations of soil series, but more single soil series can be represented. In certain cases, a further subdivision of the soil series (soil phase) can be indicated to represent sloping soils, shallow soils, etc. The number of soil complexes and miscellaneous land types will be rather restricted.

Semi-detailed soil maps: survey on a scale of appr. 1:20,000 (enlargements of airphotos); drafting on a scale of 1:50,000. The basic unit for this type of survey is the soil series. Soil phases will be indicated where and when necessary and feasible. Other units, to be used sparingly are soil complexes and miscellaneous land-types.

Detailed soil maps: survey on a scale of 1:10,000 or larger; drafting on a scale not larger than 1:20,000. Soil series will be indicated on these maps, but several of the map-units may be subdivisions or phases of the series.

On very detailed maps, e.g. of experimental stations and plots, morphometric units may be used, in accordance with, for instance, the classification system of the US Bureau of Reclamation or with the system of the US Soil Conservation Service.

For the systematic survey of Northeastern Thailand and eventually of the whole country, the detailed reconnaissance type of survey is proposed. Semi-detailed surveys, which take much time and man power should be restricted to selected areas and be carried out only for special purposes, as irrigation projects, land settlement, etc. The detailed type of survey has, of necessity, to be used even more sparingly, e.g. for experimental plots, pilot farms and the like.

The kinds of map-units, to be used in the current semi-detailed and detailed reconnaissance soil surveys of Northeastern Thailand can be defined as follows:

Soil series : a collection of soil individuals that are alike in most characteristics, as there are arrangement of genetic horizons, texture, drainage colour, parent material, etc.

Soil phase : a subdivision of the soil series on the basis of differences in one or more characteristics, like slope, depth of the profile, thickness of the humiferous surface-horizon, stoniness, presence at some depth of lateritic concretions, etc.

Soil (series) association : a group of two or more soil series, regularly geographically associated in a defined proportional pattern.

Soil complex : a soil association, the member-series of which cannot be separated individually on a detailed soil map.

Miscellaneous land types : areas of land that have little or no natural soil, that are inaccessible for examination of the soil or where, for other reasons it is not feasible to classify the soil.

2) **Nomenclature and map symbols**

The nomenclature of the different mapping units is in accordance with the system in use for most large scale USDA maps. The series are indicated by place name; sometimes river or creek names. Preferably a new series should be named after the Changwat or Amphoe where it is first observed or where it occurs prominently. Sometimes however, a name of another locality has to be chosen.

The symbol of the series on the map consists of two letters, usually the first letter of two syllables but sometimes the first and the last letter, in case the two-letter symbol has been used elsewhere :

Example : Ks : Kamphaeng Saen Series.
Kn : Kalasin Series.

Spelling of the locality - name is in accordance with the spelling used on the AMS topographical maps, scale 1:250,000 or 1:50,000.

It should be noticed that locality - names, used by Pendleton have been retained in part (e.g. : Roi Et, Korat). The series so named, however are not equivalent to the map units of Pendleton's map. Rather, these series represent only

a segment, if possible the most typical one, of the original unit. Hence, for instance, Pendleton's "Korat fine sandy loams" and the new Korat series are not equivalent, the Korat series representing only part of the early "Korat fine sandy loams".

The soil phases are indicated by a letter subscript after the series symbol, for instance Kt-s : Korat series sloping phase.

Soil associations are indicated by combining the symbols of the two main series of the association, for instance : Kt/Re : Korat - Roi Et association : Ng/Ub : Nam Phong - Ubon association.

Soil complexes are usually not given names of the individual series, but are indicated by separate names, of a locality or of the land form.

Example : SC : Slope complex (soils of the hills, not differentiated).

Miscellaneous land types are named according to kind, e.g. ditches and spoil banks, dumps, rock land, swamp, urban land. The list, proposed in the Soil Survey Manual (page 306-311) may be used for this.

Certain characteristics of the soil landscape, such as small rock outcrops, local gullying, saline spots, etc, which cannot be correctly delineated on the soil map, may be indicated by special symbols. (See Soil Survey Manual, between page 120 and 121).

3) **The legend of the soil maps**

The legend of the soil map should list all mapping units, represented on the map. Whereas in many cases the list of units : soil series, associations, phases, etc, may be quite extensive, the units can be arranged in groups, with the understanding that these groups are **not an element of the classification** but rather an organization of the map units in such a way that the geographic distribution of the soils and the land use in the surveyed area can be more easily read on the soil maps.

For the Northeast, the following tentative grouping of the map units is proposed :

a. **Lowland Soils :** Series, associations, etc. of the alluvial plains, subject to flooding by rivers and creeks.

b. **Low Upland Soils :** Series of the different terrace levels, in use for submerged rice cultivation and hence having a particular water regime and showing hydromorphism in the surface layers of the soils.

c. **Upland Soils :** Series of the different terrace levels and, eventually, of plateau areas, not in use for submerged rice cultivation and not showing particular hydromorphism in the surface layers of the soils.

d. **Hill and Mountain Soils :** Series, complexes, etc. of the areas with a pronounced relief, either in hills and mountains or situated on escarpments of plateaus and terraces.

A separate group is formed by : e. **Miscellaneous land types.**

Special distinctions, mentioned above will be grouped under the heading **special symbols.**

4) Description of the mapping units

Cm : **Chiang Mai series**

The name of this series is given in accordance with Pendleton's map unit 10 : Chiang Mai loams. The series covers only a small part of the soils, grouped in the original unit.

Soil of the Chiang Mai series are confined to the natural levees of the rivers in the Northeast. It should be pointed out, however that many of the levees of the Northeast present the broken-up relief, indicated in fig. 4. In such cases, the Chiang Mai series cannot be represented separately on the map.

Chiang Mai soils have no distinct genetic soil hcrizons other than an A_1 or Ap horizon, but on somewhat older river levees, a beginning of the formation of a textural B horizon can be observed. Texture of these soils is quite variable, but heavy clay and sand are only exceptionally found in these soils. The modal Chiang Mai soils should be medium-textured throughout, generally with some stratification. Most of the Cm soils in Northeastern Thailand however, are heavier e.g. composed mainly of clay loam or silty clay loam with clay layers occurring frequently. The Chiang Mai soils are moderately well to well drained. No or little mottling and gray spots occur in the A horizon and usually the profile is free of gley over a greater depth with brown or yellowish brown colours dominating. No surface gley, due to inundation under paddy cultivation is observed. Chiang Mai soils which are used for paddy growing should go with another series, probably with the Rat Buri series.

Cm soils in the Northeast are usually subject to yearly flooding, however for much shorter periods than the adjacent lower soils (Rat Buri, Phimai, Kalasin).

The Cm soils of Northeastern Thailand are slightly acid with a pH of 5 to 6.5 being dominant. pH figures tend to be higher in the subsoil.

No laterite has been formed in these soils but commonly, small soft iron nodules are found scattered in the profiles.

Mostly, the Cm soils of Northeastern Thailand are not in agricultural use because they are situated on levees with a rough micro-relief (alluvial complex). Where used for agriculture, they grow excellent garden crops as well as upland crops with a short growing season. Their inherent fertility is relatively high.

Rb : **Rat Buri series**

This series was described and named in the Mae Klong Irrigation Project area ;* it was subsequently introduced in the Northeast for soils, adjacent to the river levees or also for such soils of the floodplain, not having as poor a drainage as the soils of the Phimai series (see below). In plains, where both the

* See : F.R. Moormann : Report on the preliminary soil survey of the Mae Klong Irrigation Project area; MSR-1-1962, Bangkok.

Phimai and Rat Buri series occur, the Rb soils are situated slightly higher than the Phimai soils, but below the level of the Chiang Mai soils, forming a transitional zone between the river levees and the river basins. In other valleys, with a better general drainage during an important part of the year (e.g. the valley of Lam Phra Phloeng), Rb soils may occupy the entire valley bottom with the exception of the river levees.

Rb soils have no distinct genetic horizons other than an A_1 or Ap horizon, which usually is moderately well developed. Most commonly, the texture of Rb profiles is clayey throughout, but locally they may contain thin, lighter textured layers at varying depth. Even more unusual is the presence of a sandy subsoil. Colours are dark gray to dark gray brown in the Ap, and gray brown to brown below. The brownish colour distinguishes these soils from the Phimai soils, which have a predominantly gray colour.

Rb soils are somewhat poorly drained, with mottling throughout. Often the mottling is most pronounced in the surface layers, because of the use of these soils for submerged paddy cultivation. Mostly, the Rb soils are subject to periodic flooding.

The soils are usually slightly acid, with a slight increase of pH values with depth.

Rb soil are in use for irrigated rice land and give exellent yields, provided the crop is not damaged by periodic flooding. Occasionally, second crops are grown on these soils during the dry season as, for instance watermelons near Kalasin.

Whereas this series should be represented separately on detailed and semi-detailed soils maps, this is mostly not possible when the survey is of the detailed reconnaissance or reconnaissance type. In such case, the Rat Buri and Phimai series are mapped together as the Rat Buri - Phimai association,

Soils, originally belonging to the Chiang Mai series, but which have been brought under paddy cultivation, should be surveyed with the Rat Buri series. It is thought that the extended periods of submerged conditions changes the morphology and drainage conditions of the original Chiang Mai soil to such an extend, that its morphology corresponds closely to that of the Rat Buri soils.

Pm : **Phimai series**

The name of this series was introduced by Sarot Montrakun for the low laying clayey soils of the river basins. The present Phimai series is largely equivalent of the original unit of Phimai clay but is exclusive of soils of the Rat Buri series which also have been called Phimai clays.

Soils of this series are mostly situated in the wider alluvial plains and in some narrower ones. They have a low topographical situation and are distinctly below the level of Chiang Mai soils and of the adjacent soils on the terraces.

Whereas most of the Pm soils are found on sediments of the recent alluvial plains, some may have formed on particularly heavy clay of the low terrace, and more especially of the most recent phase of this terrace level. Hence, some Pm soils are found in isolated depressions of the low terrace, which are hardly or not at all connected with the recent alluvial plains.

Pm soils have no distinct genetic horizons other than an A1 or Ap horizon, which usually is well developed and rather humiforous. Texture of these soils is clayey throughout with clay loam dominating in the surface layers and with heavy clay being found at some depth. Somewhat lighter textured strata may occur occasionally, but on the whole, the profiles should be clayey in order to be grouped with this series. The clayey character of these soils is clearly demonstrated in the field by the distinct cracking of the surface, when dry.

The Pm soils are poorly drained; they show mottling in the dark gray to blackish surface layers. Below, the dominant colours are gray or olive gray with distinct mottling. Sometimes, neutral gray reduction colours can be observed in the subsoil. Certain Pm soils of somewhat greater age, show strong reddish mottled horizons at varying depth.

The soils are subject to periodic flooding which often is of a prolongued duration due to the use of these soils for irrigated paddy. In many valleys, deep flooding of short duration may occur in the rainy season.

The Pm soils are slightly acid, but pH values vary from valley to valley. In some valleys the pH of the subsoil may be near neutral; in others the pH is from 5 to 6 throughout the profiles.

Generally, the Pm soils are in use for irrigated rice land. As such they give good results on condition that the crop is not damaged by high flash floods. Yields may be as high as 40 tangs per rai, and potentially the Pm soils are among the best rice-growing soils in Northeastern Thailand.

In detailed reconnaissance and reconnaissance surveys, the Pm soils are often mapped in association with the Rb soils.

St : **Si Thon series**

This series was named after the Huai Si Thon, a creek which joins the Lam Pao river at Kalasin. These soils were not distinguished in any previous legend but were mapped both with the Phimai and Roi Et series.

Soils of this series are mainly situated in the narrow alluvial valleys of the creeks and brooks. They have a low topographical situation in regard to the surrounding lands but are situated above the level of the flood plains of the main rivers. The soil are formed on alluvial sediments deposited by the creeks, but partly also on colluvial material, washed from sides of the valleys. Thus, quite often, the valley-bottoms are not entirely flat in cross-section, but show a weak U shape.

The St soils, like the soils of the previous series show no distinct genetic horizon other than A_1 or Ap. They are composed of materials of varying texture, usually sandy to loamy. Clay layers, if present, should not dominate in the first 50 cm of the profile because in that case the soils should go with the Phimai series. These soils are normally poorly drained with mottling occurring throughout the profile. The surface layers are dark gray to black, the deeper layers are grayish, usually somewhat lighter coloured when the material is sandy. When the parent-material is predominantly formed by colluvial material from the slopes, colours may be gray brown to pinkish gray. pH values vary but mostly the St soils are somewhat acid.

The Si Thon soils are flooded occasionally after heavy rains which cause flash-floods in the valleys and depressions. However, flooding does not continue over long periods.

Generally, the St soils are in use for paddy growing, giving good to medium results, depending on the texture and the local water supply.

Kn : **Kalasin series**

This is a newly introduced series, covering, at least in part, the Tachin clays of Pendleton's map, used for several low depressions or backswamps in the main river valleys of the Northeast.

The soils of this series are mainly situated in the alluvial plains and on the low terraces, but may occur occasionally on the middle terrace and even on the high terrace. In all cases, the Kn soils have in common that they are situated in depressions without or with a very poor drainage, which are flooded for the larger part of the year. These flooded places are often indicated on the topographical maps with the name "nong", meaning pond. In some cases, part of the nong remains flooded throughout the year, even at the end of the dry season. Such spots, through not soil in the proper sense, are usually surveyed with the Kalasin series, since it is difficult to decide if a given pond will dry up in the course of the year. Only the deeper ponds should not be indicated with the Kn symbol on the field maps.

All soils of the Kn series are very poorly drained, usually showing completely reduced, blueish to neutral gray soil layers at shallow depth. Due to the poor drainage, the surface layers are relatively thick, rich in humus of a black colour. In some cases, the surface material may be mucky or even peaty.

Texture of these soils varies strongly. When situated in the backswamps or in abandoned oxbows of the alluvial plains, the soil material is mostly composed of clay. On the different terrace levels, however, clayey Kn soils are only rarely found and medium textured material is the rule. Kn soils, composed mainly of loamy sand or sand are also found on the terraces.

Other soil characteristics, like pH, base saturation, etc. are variable and of little diagnostic value, the main characteristic of these soils being their very poor drainage.

Kn soil are only rarely used for agriculture. The borders of some Kn depressions may occasionally be used for growing rice, but in general, these depressions bear a natural marshy vegetation. Whereas drainage is difficult and mostly too costly, the agricultural potential of these soils is negligible. Some ponds on the low terrace might be used for fish cultivation; others could, on a limited scale be put to use for cultivating water vegetables or green manure for use on the higher lands.

Tt : **Ta Tum series**

This series covers most of the soils, called Kula Ronghai silt loams by Pendleton.

The Tha Tum series is found in the very flat, grassy plains (tung) of the Mae Nam Mun basin, where paddy cultivation is impossible or difficult, due to recurrent flash floods. It is now believed that, with the exception of the surface layers, Tt profiles are composed of low terrace sediments. Due to their relatively low situation, parts of the low terrace in the Mae Nam Mun valley are inundated during high floods in the valley. The surface layers of the Tt soils are composed of semirecent to recent alluvium, deposited during these high floods.

The younger surface layers vary in thickness from appr. 10 to 50 cm and in texture from loamy sand to (fine) loam. When dry, these layers have a light gray aspect; moist colours are (dark) gray brown. Mottles are indistinct or absent. The older subsoil material shows much likeness to that of the soils of the Roi Et series, to be described below. This subsoil is most commonly composed of clay, light gray in colour with very distinct yellow to red mottling.

Organic matter under grass is considerable in the top few cm, but the humiforous layer (A_1) is shallow. pH values are usually between 5 and 6, both for the surface and the subsoil,

Laterite concretions may be present in spots.

Tt soils are very dry in the dry season, with the groundwater level dropping to 2 m or more below the surface layer. In the wet season, groundwater rises to near the surface, with flooding occcurring in ertain years. Because of deep flooding, use for rice land of these soils is very hazardous, so that most of the Tt soils are not in agricultural use.

On condition of flood control, the agricultural value and potential would be very similar to that of Roi Et soils, to which these soils have a distinct likeness.

In practical survey, it may not be always possible to separate the Tha Tum series from the Roi Et series. In doubtfull cases, the Re denotation should have priority.

Re : **Roi Et series**

Pendleton's unit "Roi Et fine sandy loams", comprises the majority of the soils, grown to paddy in Northeastern Thailand. The present Roi Et series covers only a part of the original unit.

The Re soils occur mainly on the low terrace formations, where they occupy wide plains. The minority of the Re soils are found in narrow, low laying depressions and valleys. On the clayey middle-terrace formations, some Re soils are found which have somewhat aberrant characteristics and which, in the future may have to be surveyed as a separate series.

The Re soils have a clearly developed profile with an Ap horizon, usually a leached A2 horizon and also with an illuvial horizon which contains more clay than either the A_1 or A2 horizons. In Re profiles which are medium-textured throughout, the illuvial or Bt horizon may be difficult to recognize.

The textural profile of the Re soils is a diagnostic characteristic; soils should show material, heavier than sand or loamy sand at a depth of less than 50 cm. Within this definition however, a wide texture variation is permissable. The typical or "modal" Re soil shows a surface layer, composed of sandy loam to loam below which, at less than 50 cm depth, clay-loam or even clay is found. This deeper layer is strongly mottled with vivid red, brown and yellowish spots. The pH throughout profile is of the order of 4.5 to 5.5 with no distinct tendency to increase with depth. The surface layer is grayish, usually with an organic matter content of 1% or less, The dry surface material has a characteristic whitish or light gray colour. Many variations on this modal concept are at present admitted in the series.

The surface material can be sandy : loamy fine sand or even fine sand. Alternatively, it may be loam or even clay loam. Frequently, the Re soils with a sandy surface horizon are situated higher in the landscape than the Re soils with a loamy surface horizon. Thus it appears possible in several parts of the Northeast to survey two distinct phases of the Roi Et series,* e.g.,

Re-s : Roi Et series; phase with a sandy surface soil (relatively high situation)

Re-1 : Roi Et Series; phase with a loamy surface soil (relatively low situation)

Recent survey in Roi Et province indicates that this subdivision may be even applied in the detailed reconnaissance survey of areas where larger surfaces of Re soils occur. Mostly, but not always, the subsoil of the Re-s soils is somewhat lighter textured (loam, clay loam) than the subsoil of the Re-1 soils (clay loam, clay). Sometimes, Re profiles are found which are medium textured throughout, without a distinctly more clayey subsoil.

* See : Tanit Tongchutha and Somnung Nonthabund: Report on the Soil Survey of a pilot area in Changwat Roi Et. MSR-13-1963, Bangkok.

Whereas the "modal" Re profile is acid, especially in the subsoil, profiles may be found in certain depressions which are near neutral or even slightly alkaline. Frequently, these higher pH values are related to subsoil salinity. It is usually difficult to separate the acid and neutral or basic Re soils, even when working on a detailed scale, because acid and neutral Re soils may alternate in a very intricate pattern. When, however, certain depressions contain exclusively the neutral or basic variant of the Re series, this may be indicated by a separate phase, e.g.,

Re-b : Roi Et series, phase with neutral or basic subsoil.

Roi Et soils, formed on middle terrace formations usually have a multi-coloured subsoil, with gray, yellow and red colours dominating. Because of their relatively high position, such Re soils may be distinguished as a separate phase, e.g.,

Re-h : Roi Et series; phase with a relatively high topographic situation.

Usually, however, the introduction of this phase in hardly feasible or worthwhile, because the surfaces, occupied by such soils are very small.

Laterite or lateritic concretions, when present in quantity, occur at a depth of more than 50 cm. Most Re soils show little or no laterite at less than 100 cm depth, but in areas where the Re series is found in association with the On series, laterite is commonly observed at medium depth.

According to gley phenomena, the Re soils are poorly drained with mottling occurring throughout the profile. Because of their use as paddy land, they are temporarily flooded, which flooding results in the formation of a strong surface gley. In the dry season, the Roi Et soils dry out deeply, with the true groundwater level found at several meters depth. In that season, they appear to be too dry for any cultivation, unless supplementary irrigation water is provided for.

The Re soils are rice-producing soils of medium quality. Minimum yields are as low as 12 tangs of paddy per rai, whereas the best yields, found on the clayey profiles, are as high as 35 or even 50 tangs per rai. The average yields however, observed in most cases, vary from 15 to 22 tangs of paddy per rai in a normal year and without application of fertilizers.

On : **On series**

The soils of this series, which show soft (active) groundwater laterite at a depth of less than 50 cm, were formerly grouped with the Sakon loams (Pendleton and Sarot Montrakun).

On soils occur exclusively on very flat, more or less clayey parts of the low terrace; always in association with soils of the Roi Et series. Their morphology, except for the groundwater laterite is comparable with that of Re soils. Surface layers are loamy sand to sandy loam, passing to heavier materials in the subsoil.

The moist colour of the Ap is gray brown, mottled, whereas the matrix of the illuvial or Bt horizon is light gray to pinkish gray with distinct yellowish brown to reddish brown mottling. At a depth of more than 10 cm, but less than 50 cm, a horizon of groundwater laterite begins, which is of varying thickness, but usually well over 50 cm. This groundwater laterite contains hardened dark brown nodules, but the mass is soft when freshly dug. The material is multicolored with gray, yellow and red parts and hardens irreversibily when exposed to the air. This hardening to a massive laterite sheet can be observed in roadcuts. A typical characteristic of the groundwater laterite layer is its wavy surface; the depth at which it starts may rapidly vary from appr. 15 cm to more than 1 meter. When found at more than 50 cm depth, the profile is grouped with the Re series, since it is assumed that in such case, the laterite has very little influence on the properties and capacities of the soil.

Because of the irregular depth pattern of the laterite, the On series cannot usually be surveyed as a separate series but has, up to now been mapped in association with the Roi Et series and, occasionally, with the Ubon series (Re-On and Ub-On associations).

Below the groundwater laterite, the material is clayey, lightgray, with multicoloured mottles. pH. values are slightly acid to acid in the non-lateritic material, but vary in the laterite layer, with values from 5 to 8 being measured.

These soils are exclusively used for paddy growing. Yields are comparable to those on the adjacent Roi Et soils. General drainage of the areas in which the On soils occur is not to be recommended, because this may well cause irriversible drying and hardening of the groundwater laterite.

Ub : **Ubon series**

The soils of this series used to form a part of Pendleton's Roi Et fine sandy loams but are now recognized as a separate series because they differ too much from the central concept of the soils belonging to the Roi Et series.

The Ub soils are found both on the low and on the middle terrace. Topographically, they take an intermediate position between the depressions with predominantly Roi Et soils and the higher parts of the landscape with different soil series, not in use for rice cultivation. In areas with a predominance of sandy middle-terrace formations, they are usually confined to the valleys and lower slopes along these valleys.

The genetic horizons are mostly not distinct. An A_1 (Ap) horizon can always be recognized, but below that, the leached or A_2 horizon and the illuvial or Bt horizon are only weakly pronounced and can, quite often, not be recognized while studying the profile with an auger.

The textural profile is a main diagnostic characteristic. Soils of the Ubon series are composed of sand or loamy sand over a depth of at least 50 cm. In most cases, the sandy material continues to more than 120 cm, but medium textured material and, rarely, clay loam are sometimes encountered between 50 and 120 cm depth.

The surface layer is gray-brown, showing mottling due to the use of the land for rice cultivation. Its thickness is rarely more than 20 cm, and the content of organic matter is mostly well below 1%; often as low as 0.35%. Below the mottled surface horizon, the sandy material is usually not or only weakly mottled, with colours varying from yellowish brown to pale brown, light gray and pinkish gray. Deeper, the gley, shown as mottling, increases and becomes more distinct.

pH values in the Ub soils are not characteristic; they vary easily because of the low buffering capacity of the sandy material: However, at middle depth, the usual pH value is between 5 and 5.5.

Although these soils are used as rice-land and show gley phenomena in the surface layers, their drainage can be called excessive. In a normal year they become flooded by impounded rainwater well after the beginning of the rainy season. Usually, rice can only be transplanted several weeks later than on the heavier Re soils. In dry years or in years with a normal rainfall but with prolonged dry spells, not enough water may be available and many fields are then left fallow. Towards the end of the wet season the rice fields on Ub soils become dry much earlier than the fields on the heavier soils so that in total the period for growing rice does net exceed three or four months. In the dry season, the Ub soils dry out over a great depth, the groundwatertable being found at more than 4 meters below the surface.

The Ub soils are rice-growing soils. Often, rice cultivation is interrupted for one or several years by fallow, especially in years with an unfavourable rainfall. In several cases, the soils are cultivated in rice only for a few years and are then abandoned for good. When the gley phenomena in the surface soils start to disappear, such soils should not be surveyed with the Ubon series but, rather, should be indicated as Korat or Nam Phong soils.

Productivity of the Ub soils is low. In a year with normal rainfall, the rice yields are usually from 7 to 12 tangs per rai, but in a dry year, total or partial crop failures are common. Taking into account the recurrent fallow practiced on these soils, the Ub rice lands are definitely to be considered as marginal in the economic sense of the word. Productivity limitations are caused by both the poor plant nutrient status and the unfavourable water-economy of these sandy soils.

Ud : **Udon series**

This series was not distinguished as such previously, but part of the Ud series may have been included with the Tachin clays of Pendleton's provisional soil map. Udorn soils are mainly found in shallow depressions of the low terrace but are known to occur also in recent alluvial plains.

The main diagnostic characteristic for this series is its salt content, which is so high that agricultural production is very severely hindered or altogether impossible. In the dry season, the soils is covered with a thin salt crust, giving it a whitish outlook. Also, due to its high salt content, the dry surface soil has a typical fluffy structure. During the rainy season, the salt goes in solution, but the high salt content is easily recognizable by the salt taste of the inundating water and the lack of vegetation.

Textural profiles are variable, but loamy sand or sandy loam is usually found in the surface layers. The pH of these soils is mostly neutral to slightly alkaline throughout the profile. These soils are dry to some depth in the dry season, but are water saturated during most of the rainy season, with mottling showing throughout the profile.

It should be noted that the Ud series is not a "stable" one. When sufficient rain or flood water is available, the fresh water cover, impounded in rice fields, has the tendency to leach the salt down to an extend that it hardly interferes with the growth of the rice-plants. Such soils, at present, are not surveyed with the Ud series, but become soils of the Roi Et or the Ubon series. Many of the Roi Et and Ubon soils with a neutral to alkaline subsoil, may have been saline Udon soils in the past. When not in use for rice land or also if the level of the watertable is increased (e.g. below a dam), these "alkaline" Roi Et and Ubon soils would automatically become saline throughout and thus revert to the Udon series. In areas with potentially saline Ubon and Roi Et soils, many small saline spots can be observed. These spots, which in effect belong to the Ud series, are mostly too small to be delineated on the map and, hence, are indicated by a special symbol (x).

Recognizing and surveying more or less saline areas in the Northeast is usually facilitated by the presence of numerous primitive salt works; hollowed trees in which the salt-containing earth is leached for producing brine.

Ud soils, at present, have very little agricultural value. Because of their low situation, they usually cannot be drained. Only if sufficient rainwater or good quality irrigation water can be impounded, the salt could be leached down, and the soils would then become Roi Et or Ubon soils.

Pn : **Phen series**

This unit covers a part of Sarot Montrakun's Phon Phi Say sandy loams, notably those soils which are in use as paddy land. Soils of this series are found where the lower, clayey part of the middle terrace is exposed. These soils occur in shallow depressions and on the lower slopes in the landscape, occupied by the middle terrace. In this they differ from the soils of the On series which, though having morphologic affinities to the Phen soils, occur exclusively on very flat low terrace formations.

The profiles of the Phen soils show the presence of an illuvial or Bt horizon.

The textural profile of the Phen soils is rather variable. The surface layers are usually sandy loam or loam, sometimes more sandy or clayey and composed mainly of colluvium, derived from the surrounding higher areas. At a depth of less than 50 cm, lateritic gravel is found in a layer of varying thickness. The unconsolidated lateritic gravel may be so dense that the auger cannot penetrate deeper. Usually, the lower part of the laterite is imbedded in clay loam or clay which is gray to light gray and generally shows a strong multicoloured mottling. The presence of important quantities of unconsolidated lateritic gravel at a depth of less than 50 cm is diagnostic for this series. Occasionally, the lateritic gravel may occur in the surface layers but usually, the topsoil is relatively free of concretions.

Phen soils are mottled throughout, showing a distinct surface gley due to their use as paddy land. While flooded in the wet season, they dry up to some depth in the dry season. Average pH values should be around 4.5 to 5, but higher values may occur occasionally.

The Pn soils are used for paddy growing, the yields being variable but usually better than on the Ubon soils and somewhat less than on the heavier Roi Et soils.

The soils have been incompletely studied; definition of the diagnostic characteristics stands in need of further observational data.

Sk : **Sakon series**

The Sakon series covers part of the unit of Sakon loams. described by Pendleton and Sarot Montrakun.

The most typical Sk soils are found on low terrace formations, e.g. on the lake deposits of Nong Han, north of Sakon Nakhon. Spots of Sk soils may be observed in association with soils of the Phon Phi Say series, on middle terrace formations. Extensive areas of Sk soils were observed outside of Northeastern Thailand proper, notably in the region, east of Kabin Buri, Changwat Prachin Buri.

The principal diagnostic characteristic of the Sakon series is the presence, at very shallow depth or even at the surface, of sheets or slabs of consolidated laterite. The laterite may be broken to a certain extend, but in an area, mapped as Sk series, the majority of the borings should show the hard, consolidated laterite within the first 50 cm of the profile. Areas of Sk soils are usually characterised by laterite outcrops, ranging in size from a few dm^2 to several m^2.

The material, overlaying the laterite is usually medium textured, with a pH from 4.5 to 5.5. It may contain laterite concretions,

Sk soils are not normally in agricultural use, they bear an open, poor quality shrub or forest of dipterocarps. These soils have little or no potential agricultural value.

Kt : **Korat series**

Extensive areas in the Northeast and elsewhere in Thailand have been indicated as Korat fine sandy loams on Pendleton's provisional soil map. In Northeastern Thailand, this unit appears to include most of the upland areas which are not in use for rice land and which are not stoney or hilly. The map unit of Pendleton and Sarot includes the more sandy Kumpawapi sandy loams which have not been indicated separately on the general soil map.

The new Korat series covers only a part of the original unit which is too broadly defined for use in more detailed surveys.

The soils of the Korat series have a genetic soil profile, showing an A_1 horizon, a leached or A_2 horizon and an illuvial or Bt horizon. Profile development is usually not very distinct, especially when the parent material is rather sandy and in such cases the presence of the illuvial horizon can only be observed in roadcuts or profile pits but not by auger alone.

The textural profile is diagnostic for the series. The first 60 cm should not consist of pure sand but rather of loamy sand or medium textured soil material. Apart from this limitation, rather wide variations in texture are permitted. The typical or "modal" Korat soils show surface layers, composed of loamy sand or sandy loam. At medium depth, the texture becomes finer with sandy loam or loam usually being found. Quite frequently, however, the whole profile is composed of fine loamy sand or of sandy loam. On the other hand, the material of the middle portion of the profile may be of a clay loam texture.

The surface layer, with around 1% organic matter is gray brown to dark gray brown when moist but has a typical light gray aspect when dry. The deeper horizons are uniformily coloured, normally in the brown or yellowish brown ranges. Somewhat redder colours occur, but such redder soils may be transitional to the Yasothon series which is discussed below.

Gley phenomena are not or only weakly visible in the surface layers of these soils. Mottling may be absent altogether or only developed in the lower part of the profile. Especially when the lower part of the profile is somewhat clayey, mottling may be rather distinct. Natural drainage conditions in these profiles vary accordingly from somewhat excessive (sandy profiles) to moderately well (low laying profiles and profiles with a clayey subsoil). In the long dry season of the Northeast, however, these soil dry out strongly and deeply. Normal pH values of the Korat soils vary from 4.5 to 5.5 or 6 at medium depth. Usually, the surface soil has a higher pH. Sandy profiles may have a pH of 6 or higher throughout, but in the sandy material, the pH value has not much meaning. C.E.C. values of the soil material are low to very low.

The Korat soils observed in and around villages differ quite substantially from the Korat soils under natural vegetation or under cultivated land. The soils of the inhabited areas are definitely richer in organic matter as well as in plant nutrients, especially phosporus.

Most of the Korat soils are under secondary forest and savanna. Diverse upland crops are grown in a shifting cultivation pattern. It should be observed that the shifting cultivation is mostly not of the classical type. Once used for a few years, these soils are abandoned for an indefinite period and mostly, no definite cultivation-fallow rotation seems to exist. Continuous cultivation of the Korat soils occurs only rarely. In terms of permanent agricultural use, Korat soils are poor soils, with a low natural fertility and with poor physical properties, such as a low waterholding capacity and a susceptibility for surface structure collapse and for micro-eroson. Yet, the zone occupied by these soils is the most importance area on which the increasing population of the Northeast can find new agricultural land. Hence, studies to obtain systems of permanent agriculture which do not lead to complete depletion and deterioration of the Kt soils, are of fundamental importance for the agriculture and economy of Northeastern Thailand.

Ng : **Nam Phong series**

In the older surveys, these soils were grouped with the Kumpawapi sandy loams and the Korat fine sandy loams. Recent surveys however have indicated the necessity to recognize these soils as a separate series.

Nam Phong soils are mainly found on the sandy formations of the upper part of the middle terrace. Some may be found on sandy low terrace formations, but this has to be verified by further surveys. The Ng soils are found on the higher parts of undulating or rolling landscapes and frequently occupy larger uninterrupted surfaces.

The genetic profile development, if any, is weak. An illuvial or Bt horizon may be present, but it can rarily be observed with an auger.

The textural profile is diagnostic for this series. The Ng soils consist of at least 60 cm of sand, which is loose without any appreciable cohesion. When dry, this sand may be cemented somewhat. At a depth of more than 60 cm, a transition to loamy sand or even to medium textured material may occur but more often than not, the Ng soils are composed of sand for at least 120 cm.

The surface horizon in poor in organic matter (usually well below 1%) and gray brown or light gray brown in colour. When dry, this horizon is light gray to whitish. Below, the sand varies in colour from brownish-yellow to reddish yellow and pinkish, with no mottling being apparent.

pH values, which in this sandy material are no typical indication, vary rather widely. Usually, the surface has a pH of 6 or more while the subsoil is more acid. However, in many profiles, the pH is between 5.5 and 6.5 throughout. The C.E.C. of the soil material is negligible.

These soils are excessively drained and become dry even after short spells of dry weather during the rainy season. Agriculturally speaking, the Ng soils

are extremely poor, both because of their very low inherent fertility and because of their low water-holding capacity. Even the natural vegetation on these soils is usually a poor dipterocarp-forest with little groundcover, which has a very restricted value. Only rarely are these soils reclaimed for dry land crops and if so, they are abandoned after one or two years of cultivation only. Within the present-day economic framework, these soils can be considered as almost useless.

Pp : **Phon Phi Say series**

The soil of this series have been distinguished by Pendleton and Sarot as Ponpisai sandy loam. Pp soils are restricted to areas where the lower, clayey middle terrace formations are exposed or close to the surface. Some Pp soils appear in narrow bands on the lower slopes of the landscapes with predominantly sandy middle terrace formations. Here, the relief is more or less accentuated with slopes of 4% or more. Larger and flatter surfaces of the Pp soils are found in areas more to the north, where the sandy upper part of the middle terrace has disappeared by (geologic) erosion.

The soils of this series show a distinct textural B horizon, predominantly reddish or yellowish red in colour but sometimes with a variegated aspect.

The surface layers are sandy to loamy and usually composed of local colluvial material. At less than 50 cm depth, lateritic gravel is found in a layer of varying thickness and density. The presence of this laterite is diagnostic for the series. The lower part of the laterite is imbedded in dense clay loam or sandy clay loam, usually containing varying amounts of rounded pebbles. The deeper subsoil is generally formed by dense, light gray clay loam or sandy clay.

These soils, because of the presence of clayey material at shallow depth, have an impeded drainage. In the wet season, the surface layers are wet, as indicated by the presence of mottling in or just below the A_1 horizon. In the dry season, the upper layers dry out considerably but the gray clayey subsoil apparently remains moist.

pH values are normally around 4.5 to 5 in the subsoil, but some profiles with a higher pH were observed.

Agricultural use of the Pp soils is restricted. It may well be that the presence of the laterite and the rather compact clayey material poses management difficulties to the farmers of the Northeast, who use to work on light and medium textured soils. Though certainly not excellent, the Phon Phi Say soils are believed to have a moderate agricultural potential. They are much better soils than the Nam Phong soils or than most of the Korat soils.

Yt : **Yasothon series**

This series may be roughly equivalent with the Yasothawn loams mentioned by Pendleton and Sarot. The Yasotawn loams were not indicated on Pendleton's provisional soil map.

Yasothon soils are found exclusively on the high terrace formations. Mostly, their topographical situation is well above the soils of the lower terrace levels.

The genetic profile developement is that of a Red Latosol, with an A_1 horizon and a very thick, rather featureless red or red-yellow B horizon (oxic horizon).

Most Yasothon profiles are more or less sandy (loamy sand to sandy loam) in the topsoil, which has a dark reddish brown colour. Below, the material gradually becomes more clayey (sandy clay loam or sandy clay), with a typical red or yellowish red colour. This red colour is diagnostic for the series. When situated on slopes, the red sandy clay loam or sandy clay may begin close to or in the surface layers.

The pH values, observed in the B horizon are rather constant and vary from 4.5 to 5. The C.E.C. of the soil material is low. The Yt soils are well to somewhat excessively drained, with no mottling appearing in the profiles. They retain a certain amouth of moisture for longer periods, even in the dry season.

When underground water for domestic purposes is available in the neighbourhood, these soils are usually cultivated, either in a shifting cultivation pattern or permanently. In the latter case, they often are used for the growing of fruit trees, especially bananas. Large areas of non-cultivated Yt soils are found where no water for domestic purposes is available close by.

The Yt soils have a moderate quality for agriculture; they are definitely better than the Nam Phong and Korat soils.

Bb : **Borabu series**

The soils of this series have, in part, been grouped in Pendleton's unit 42 (Shallow soils from quartzitic sandstones).

This series covers the more or less shallow soils on residuum of sandstones or on colluvium derived from such residuum. The presence of numerous rockfragments at a depth of less than 50 cm is diagnostic for these soils. The material, in which these rockfragments are inbedded, varies a great deal, but loamy textures dominate; usually with a distinct coarse sand fraction. Profiles with alternating layers of different texture are common, as is the occurrence of varying quantities of laterite gravels. The colour of the surface horizons is gray brown. Below, the gravelly material is often multicoloured, with reddish to reddish purple spots being prominent.

Generally, the Bb soils occur in association with numerous rock outcrops on slightly elevated knolls or along footslopes of hills. Hence it is usually not practical to survey Bb soils as a separate series. On recent maps (e.g. in the Nam Phong area), the Bb series is included with the rock outcrops and with occasional spots of other soils (Ng and Kt series) in a complex (BbC : Borabu complex)

The Bb soils are not in use for agriculture; they bear a poor dipterocarp forest. Their agricultural potential is negligible.

Lb : **Lop Buri series**

Soils of this series, as well as of the following series, are only sporadically found in Northeastern Thailand.

These soils were recognized as Lopburi clay by Pendleton and Sarot. They have been developped on residuum or colluvium derived from limestones and from marls. The Lb soils are characteristically composed of heavy clay which is black to moderate depth and which shrinks and swells strongly upon drying and wetting. The pH of these soils is near neutral to slightly alkaline, frequently with secondary lime concretions at the base of the black A horizon. The C.E.C. of the soil material is high. These soils, when wet, are impervious and have a poor internal drainage. However, when dry, drainage proceeds because of the formation of deep cracks. Additional characteristics are the presence of slicken slides, formed by churning of the soil material and a gilgai relief, which however is not always visible. These soils belong to the great soil group of grumusols.*

The Lb soils have a high inherent fertility but pose severe management difficulties. They are difficult to work, both when dry and wet. The agricultural potential of these soils is considerable, both for rice and for upland crops such as cotton and tobacco.

Br : **Buriram series**

This series covers part of Pendleton's Chaibadan clays. Buriram soils were only observed on the basaltic formations near Buriram, but may be present in isolated spots, elsewhere in the Northeast. The parent material is clay, weathered from basalt under humid conditions. Profiles are usually composed of black heavy clay to a depth of more than 100 cm. In dry conditions, the clay cracks deeply, becoming impervious and sticky when wet. When under paddy, a yellowish, mottled surface layer of not more than 15 cm may develop. Profiles are near neutral throughout. In spots, laterite gravels may be present.

Like the soils of the Lop Buri series, the Br soils are grumusols; thus the two series have many characteristics in common.

The Br soils are in use for rice (yields less than 10 tang/rai) and for vegetable growing, the latter with excellent results. On condition of a regular water supply, the Br soils should be excellently suited for most upland crops.

Pc : **Pak Chong series**

Soils of this series have been called Pakchong loams. However, Pendleton's unit is believed to include other soils, derived from shales as well.

* It is now known that most of the black soils of the Lop Buri area are no grumusols.

The Pc soils are developed on residuum or colluvium, derived from limestone. They have an A horizon and a textural B horizon. The texture is clayey throughout, with usually a somewhat lower clay content in the surface layers. These soils have a dark reddish brown colour. The pH is slightly acid to neutral in the surface soil and neutral to slightly alkaline in the subsoil. The C.E.C. of the soil material is moderately high. These soils are well drained. They are excellently suited for agriculture on a permanent basis. However, many of these soils in the Pak Chong area become less productive after several years of continuous maize-cultivation. On condition of erosion control and a suitable rotation, the Pc soils should remain productive for a long time to come.

Other map units

Two miscellaneous map units or soil complexes were introduced, to be used for semi-detailed and detailed reconnaisance surveys.

Ac : **Alluvial Complex**

This is the soil complex, found in many of the wider alluvial valleys in the Northeast, bordering the streams and rivers. The complex is mainly composed of Chiang Mai, Phimai and Kalasin soils which are found so close to each other that they cannot be separately indicated on the soil map. The micro-relief is strongly accentuated.

The AC areas are mostly not cultivated but locally, some rice fields and gardens are found. The rough micro-relief and the periodic flooding make a further extension of agriculture a poor proposition. However, there is a definite possibility that permanent pasture could be established which would be productive through most of the year.

Sc : **Slope complex**

This is the soil complex, found in the hilly parts of the Northeast. The complex is composed of many different soils, but the shallow phases of the Borabu series dominate in many places.

Because of the strong relief and the generally shallow and poor soils, the agricultural potential of these areas is negligible.

* * * * *

A summary of diagnostic characteristics of the different series is given in table 1.

5. **Morphometric legend, soil phases, and soil associations**

a : **morphometric legend**

While describing the observed soil profiles in the note book, a strongly simplified **morphometric symbol** can be used. In very detailed surveys the morphometric symbol could be indicated on the map. It should be noted that the morphometric symbol is not equivalent to the map coding system which was introduced for soil conservation surveys. Further standardizing of the morphometric symbols remains necessary.

In the note book, morphometric symbols are added to the symbol for the series, e.g. Pm $\frac{CC}{1}$, Kt $\frac{S5L}{3c}$, Yt $\frac{S3L7C}{4}$, etc. The morphometric symbol indicates three groups of characteristics of the observed profiles, notably the texture profile, the general drainage conditions and all others, if necessary. The textural profile is indicated above the line; drainage condition and other characteristics are placed below the line.

(*i*) *Formula for the texural profile:*

The soil material is grouped in the three broad textural categories:

S (sandy), includes sand and loamy sand,

L (loamy), includes sandy loam, loam, and silt loam,

C (clayey), includes sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay and clay.

A profile, showing a uniform texture throughout is indicated by two letters, eg. LL: profile with a uniform loamy texture. When the texture changes, two or more letters are used, the depth being indicated in dm with a numeral. Examples: S3L: Sandy material, passing to loamy material at a depth of approximately 30 cm; L4C9S: loamy, passing to clayey at 40 cm, passing to sandy at 90 cm. Organic material (peat) is indicated with the letter O. When a profile is composed of many layers of different texture, the letter V is to be used. R is indicated, when bedrock is encountered within auger depth.

(*ii*) *Symbol for the drainage condition:*

Five broad drainage classes are recognized, which are indicated below the line by a numeral

0: Very poorly drained, strong gley throughout, often reduced; flooded or waterlogged for most of the year. Eg. Kalasin series.

1: Poorly drained, mottling throughout but no reduction at shallow depth. Flooded or waterlogged during and immediately after the wet season. Eg: Phimai and Roi Et series.

2; Somewhat poorly drained (imperfectly drained). Mottling starting below the surface or A horizon, often weak in the upper part of the pofile; no long periods of flooding or waterlogging.

3: Moderately well drained. Mottling starting roughly between 50 and 100 cm depth, no flooding or long periods of waterlogging.

4: Well to excessively drained. No mottling in the profile, no flooding or waterlogging.

A complication is caused by the use of certain soils for paddy cultivation The lower paddy lands have soils which would belong to class 1, even if not used for wet rice cultivation. Many of the higher ones would, in natural conditions

belong to class 2, 3 or sometimes even 4. When used for rice, a typical gley with rusty mottling develops in the surface layers. If the original drainage class was 2, the irrigated land will usually become 1 with mottling throughout the profile. If the original drainage class was 3 or 4, there is quite often a "gap" without mottling between the surface layer and the gleyed horizon, deeper in the profile. This is more in particular the case with most soils of the Ubon series which, under natural conditions were in dranaige class 3 or, sometimes 4. The presence of the "artificial" surface gley should be a indicated by a letter written in front of the drainage numeral.

eg = Ub $\frac{SS}{r3}$ (sandy profile, drainage class 3, with a surface-gley due to the use for riceland).

(iii) Symbols for other characteristics :

Any and all other soil characteristics could eventually be indicated in the formula. However, such characteristics which are diagnostic for the series can readily be omitted. For instance, it is not necessary to indicate the presence of concretions in Phon Phi Say soils : they should be there anyhow. On the other hand, concretions in Roi Et soils or Korat soils, which are not usually found in soils of those series, should be indicated. The red colour of the Yasothon soil is a diagnostic characteristic which is not indicated in the morphometric symbol, but the red colour in the subsoil of some Korat soils should be noted. These special characteristics which sets the soil profile in question somewhat apart from the normal or "modal" concept of the soil series to which it belongs, are indicated by letter subscripts below the line and after the numeral used for the drainage class. The list of letter subscripts will have to be completed during further detailed surveys; at present only a few "special" characteristics have been recognized:

b : neutral or slightly alkaline subsoil in a normally acid profile.
c : lateritic concretions in the subsoil of soils which are normally free of such concretions.
f : covered fossil soil profile at some depth.
n : surface soil blacker and richer in humus than normal.
r : red colour in the subsoil.

b **Soil phases**

The principal soil phases, recognized up to now, have been indicated in the descriptions of the various series. Such phases are distinguished by letter subscript, after the series symbol; eg. Re-s. In survey of detailed nature it may often be necessary to introduce local phases of the surveyed series, without it being necessary that such phases should be recognized elsewhere in the Northeast. If possible, existing letter subscripts should be used but when no letter exists to cover the situation; any other letter can serve, provided it is well defined in the legend of the soil map. Letters, suggested for use in symbolizing phases are :

s : sandy phase.
l : loamy phase.

t : clayey phase.

g : gravelly phase.

c : phase with (laterite) concretions.

cc : phase with many (laterite) concretion.

p : sloping phase.

pp : strongly sloping phase.

b : phase with a near neutral to slightly alkaline subsoil.

r : phase with a reddish coloured subsoil.

n : phase with a humiforous, blackish top soil.

h : phase with a relatively high topographical situation.

c **soil associations**

Soil associations are commonly used in detailed reconnaissance and reconnaissance surveys, when certain series occur side by side in a well defined geographical pattern and cannot be separatelly indicated on the map, either because the scale is too small or because there is not sufficient time to survey the exact location of the individual series. Common associations in detailed reconnaissance surveys in Northeastern Thailand are: Rb/Pm, Yt/Kt, Re/On. Others, which have been used more locally, include Cm/Rb, Kt/Re and Re/Pm. The use of associations should be mostly avoided if the survey is of a semi-detailed or detailed nature.

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