# Clay Mineral Composition of Paddy Soils in Thailand

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## Introduction

Concerning the clay mineral composition of soils in Thailand, Sorasith et al.[16] conducted a pioneer work in 1962. Later, some detailed studies were carried out by Hattori et al.[3] and Kawaguchi and Kyuma[11] with a view to clarify the general clay mineralogical characteristics of paddy soils. Furthermore, Hattori[4,6,7,8] studied the clay minerals of Thai soils in more detail in relation to the genesis and physiography of the Quarternary deposits in the Northern Basin and the Central Plain. Charoen[2] attempted clay mineral classification of paddy soils based on the contents of different clay mineral species as related with parent materials and fertility studies.

In the present study, the experiments were carried out with an aim of expanding the knowledge of clay mineralogical characteristics of paddy soils in Thailand with special reference to soil forming process.

## Materials and methods

*1) Materials*

Soils for clay mineralogical analysis were selected to cover each soil group from each region. Surface soils and subsoils were taken from the total of 31 profiles shown in Table 1, by sampling each surface soil and subsoil from the same profile, and were used for X-ray diffraction analysis.

*2) X-ray diffraction analysis*

For a quantitative determination of clay mineral composition, several methods have been proposed[1,10,18] but they are rather complex and laborious. In this study, the method employed by Hattori et al.[3] was adopted with some modifications for a semi-quantitative assessment of clay mineral composition.

The separated clay fraction (less than 2 $\mu$ in diameter) after removal of organic matter, was treated with dithionite after Mehra and Jackson[14] to remove free sesquioxides, and then was saturated with either potassium acetate or magnesium acetate. A small portion of the K-clay or Mg-clay suspension was placed on a clean glass slide and allowed to dry in the air to prepare oriented clay specimens. X-ray diffraction analysis was done with X-ray diffractometer using Cu–$K\alpha$ radiation. X-ray diffraction patterns were obtained for the K-clay both before and after heating (at 300°C and 600°C) and for the Mg-clay both with and without glycerol treatment.

*3) Determination of the clay mineral composition*

The relative abundance of the layer silicate

**Table 1. Soil samples for X-ray diffraction analysis**

| Soil group | Profile number | Location |
|---|---|---|
| | **Central Plain** | |
| Marine Alluvial Soils | 12 | Samut Prakan, Bang Phil |
| Transitional from Marine Alluvial Soils to Brackish Water Alluvial Soils | 2 | Phra Nakhon, Bangkhen |
| Brackish Water Alluvial Soils | 55 | Pathum Thani, Klong Luang |
| Fresh Water Aluviall Soils | 37 | Pitsanulok, Muang |
| Fresh Water Alluvial Soils | 73 | Ptechabun, Lom Sak |
| Fresh Water Alluvial Soils | 140 | Sukhothai, Si Samrong |
| Low Humic Gley Soils | 3 | Saraburi, Muang |
| Low Humic Gley Soils | 132 | Nakhon Navok, Muang |
| Low Humic Gley Soils | 135 | Chachoengsao, Phanom Sarakham |
| Low Humic Gley Soils | 138 | Kamphaeng Phet, Klong Khlung |
| (Hydromorphic) Non-Calcic Brown Soils | 6 | Suphan Buri, Muang |
| (Hydromorphic) Non-Calcic Brown Soils | 11 | Nakhon Pathom, Muang |
| Grumusols | 23 | Lop Buri, Muang |
| | **North-eastern Region** | |
| Fresh Water Alluvial Soils | 42 | Nakhon Ratchasima, Phimai |
| Fresh Water Alluvial Soils | 48 | Non Khai, Si Chiang Mai |
| Low Humic Gley Soils | 45 | Khon Kaen, Chum Pae |
| Low Humic Gley Soils | 107 | Nakhon Phanom, Muang |
| (Hydromorphic) Non-Calcic Brown Soils | 114 | Ubon Ratchathani, Muang |
| | **Northern Region** | |
| Fresh Water Alluvial Soils | 27 | Chiang Mai, Sam Kampheng |
| Fresh Water Alluvial Soils | 146 | Nan, Muang |
| Fresh Water Alluvial Soils | 152 | Chiang Rai, Mae Chan |
| Low Humic Gley Soils | 26 | Chiang Mai, Mae Taeng |
| Low Humic Gley Soils | 33 | Chiang Rai, Phan |
| Low Humic Gley Soils | 148 | Phrae, Song |
| Low Humic Gley Soils | 154 | Lampang, Muang |
| Low Humic Gley Soils | 158 | Chiang Mai, Fang, Ping Tam |
| Humic Gley Soils | 31 | Chiang Rai, Mae Sai |
| | **Southern Region** | |
| Fresh Water Alluvial Soils | 174 | Phatthalung Khuan Khanum |
| Low Humic Gley Soils | 176 | Satun, Muang |
| Low Humic Gley Soils | 179 | Patthani, Khok Pho |
| Low Humic Gley Soils | 182 | Narathiwat, Muang |

clay minerals in the clay fraction was approximately determined with the Mg-clay air-dried specimens by measuring the intensity of diffraction peaks at $2\theta=12°$, 8.8° and 6–5°, which corresponded, respectively, to the basal spacing of kaolinites with 7Å layer, mica clay minerals (10Å) and 14Å minerals. In this report, however, some modifications were made by correcting the relative intensity of diffraction peaks using an intensity ratio, R, (for example, R: I(15Å Mt)/I(10Å Mc)=3, I(17Å Mt)/I(10Å Mc)=4, I(14Å Ch)/I(10Å Mc)=1, I(14Å Ch)/I(10Å)=1, I(7Å Kt)/(I(10Å Mc)=3), as reported by Wada.[17] Otherwise, 10Å minerals, in particular, seemed to be extremely underestimated in quantity. The 14Å minerals, which comprised various kinds of 2: 1 or 2: 2 type minerals, were grouped into montmorillonite, vermiculite, Al-interlayered minerals, chlorites and interstratified mixed layered minerals for convenience sake in this report. The relative abundance of 14Å minerals was expressed by the symbols (⧻, ⧺, +, ±, −) according to the changes in the intensities and positions of X-ray diffraction peaks after the various treatments. The symbols show the relative abundance of clay species only within the same clay fraction of each sample, as follows: ⧻ abundance, ⧺ moderate, + small;

**Table 2. Clay mineral composition of paddy soils in the central Plain**

| No. | Location | Horizon | Depth | Relative abundance | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 7 Å | 10 Å | 14 Å | | | | | |
| | | | cm | (%) | (%) | (%) | Mt | Ver | Al-int | Ch | Int |
| 2. | Phra Nakhon | Apg | 0—15 | 30 | 45 | 25 | +++ | + | ± | ± | ± |
| | Bang Khen | C1g | 50—65 | 25 | 40 | 35 | +++ | + | ± | ± | + |
| 12. | Samut Prakan, | Apg | 0—15 | 30 | 50 | 20 | +++ | + | ± | — | + |
| | Bang Phli | C1g | 35—55 | 25 | 40 | 35 | +++ | + | — | — | + |
| 55. | Pathum Thani, | Apg | 0—17 | 40 | 40 | 20 | ++ | + | ± | + | — |
| | Klong Luang | C1g | 35—65 | 35 | 30 | 35 | ++ | + | ± | + | — |
| 37. | Pitsanulok, | Apg | 0—14 | 60 | 15 | 25 | ± | ++ | + | ± | ± |
| | Muang | B21g | 25—50 | 55 | 5 | 40 | — | ++ | + | ± | + |
| 73. | Petchabun, | Apg | 0—17 | 20 | 15 | 65 | ++ | ++ | ± | + | + |
| | Lom Sak | B22g | 38—52 | 30 | 15 | 55 | ++ | ++ | + | + | ± |
| 140. | Sukhothai, | Apg | 0—10 | 25 | 60 | 15 | + | ++ | + | + | ± |
| | Si Samrong | Cg | 34—60 | 25 | 55 | 20 | + | ++ | + | ++ | ± |
| 3. | Saraburi, | Apg | 0—12 | 65 | 10 | 25 | + | ++ | + | + | ± |
| | Muang | B2g | 25—55 | 60 | 5 | 35 | + | ++ | + | + | ± |
| 132. | Nakhon Nayok, | Apg | 0—13 | 65 | 15 | 20 | + | ++ | + | ± | ± |
| | Muang | B21g | 20—60 | 70 | 10 | 20 | + | ++ | + | ± | ± |
| 135. | Chachengsao, | Apg | 0—14 | 45 | 25 | 30 | + | ++ | ++ | — | — |
| | Phanom Sarakham | Cg | 29—68 | 40 | 25 | 35 | + | ++ | + | — | — |
| 138. | Kamphaeng Phet, | Apg | 0—18 | 55 | 40 | 5 | — | ++ | ± | — | — |
| | Klong Khlung | Cg | 38—70 | 55 | 40 | 5 | — | ++ | — | — | — |
| 6. | Suphan Buri, | Apg | 0—15 | 45 | 50 | 5 | ± | + | + | + | — |
| | Muang | B2g | 25—40 | 45 | 45 | 10 | + | + | + | + | — |
| 11. | Nakhon Pathom, | Apg | 0—15 | 30 | 65 | 5 | + | + | ± | — | — |
| | Muang | B1g | 15—45 | 30 | 60 | 10 | + | + | ± | — | — |
| 23. | Lop Buri, | Ap | 0—13 | 15 | 0 | 85 | +++ | ± | ± | — | — |
| | Muang | A13 | 13—60 | 15 | 0 | 85 | +++ | ± | ± | — | — |

Composition: 7 Å, kaolinite minerals; 10 Å, mica clay minerals; Mt, montmorillonite; Ver, vermiculite; Al-int, aluminium interlayered minerals; Ch, chlorite; Int, interstratified mixed layer minerals.
Abundance: +++ abundant; ++ moderate; + small; ± very small; — not detected.

± very small, — not detected.

## Results and discussion

*1) Soils from the Central Plain*

Clay mineral composition of paddy soils from the Central Plain is summarized as shown in Table 2.

The clay fraction of Marine Alluvial Soils was composed of mica clay minerals, kaolinite minerals and 14Å minerals in a nearly even quantity (7–10–14Å even type). The 14Å minerals consisted of a large amount of montmorillonite and a small amount of vermiculite and mixed layered minerals. Brackish Water Alluvial Soils showed nearly the same clay mineral composition as those of Marine Alluvial Soils, except for the presence of a small amount of chlorites, which exhibited a low peak at 14Å for the K-clay after heating at 600°C.

Clay mineral composition of Fresh Water Alluvial Soils greatly varied from one place to another depending on the nature of the parent materials. For example, the soils of Profile No. 37 (Pitsamulok, Muang) derived from the fresh water deposits of the Nan River, contained a large amount of kaolinitic minerals, while the soils of Profile No. 140 (Sukhothai, Si Samrong) derived from fresh water sediments of the Yom river were composed predominantly of 10Å minerals and showed a rather clear peak at 14Å for K-clay specimens heated at 600°C, particularly in the subsoil. On the other hand, the soils of Profile No. 73 (Petchabun, Lom Sak) derived from fresh water deposits of the Pasak River were characterized by a large amount of 14Å minerals, which consisted mainly

**Table 4. Clay mineral composition of paddy soils in the Northern Region**

| No. | Location | Horizon | Depth | Relative Abundance | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 7 Å | 10 Å | 14 Å | | | | | |
| | | | cm | (%) | (%) | (%) | Mt | Ver | Al-int | Ch | Int |
| 27. | Chiang Mai, | Apg | 0—15 | 65 | 30 | 5 | ± | ++ | ± | — | ± |
| | Sam Kampheng | B21g | 30—65 | 65 | 30 | 5 | ± | ++ | ± | — | ± |
| 146. | Nan, | Apg | 0—10 | 35 | 50 | 15 | + | ++ | + | — | ± |
| | Muang | Cg | 23—65 | 35 | 45 | 20 | + | ++ | + | — | ± |
| 152. | Chiang Rai, | Apg | 0—15 | 55 | 35 | 10 | ++ | + | ++ | — | ± |
| | Mae Chan | B22g | 25—40 | 55 | 35 | 10 | ++ | + | + | — | ± |
| 26. | Chiang Mai, | Apg | 0—15 | 40 | 55 | 5 | + | + | — | — | — |
| | Mae Taeng | B21g | 25—45 | 40 | 55 | 5 | + | + | — | — | — |
| 33. | Chiang Rai, | Apg | 0—15 | 50 | 30 | 20 | ± | ++ | ± | + | ± |
| | Phan | B22g | 45—65 | 50 | 25 | 25 | ± | ++ | ± | ± | — |
| 148. | Phrae, | Apg | 0—13 | 20 | 60 | 20 | + | + | ± | + | ± |
| | Song | B2g | 23—65 | 20 | 55 | 25 | ++ | + | ± | + | + |
| 154. | Lampang, | Apg | 0—8 | 45 | 25 | 30 | +++ | + | ± | — | — |
| | Muang | b2g | 15—50 | 40 | 20 | 40 | +++ | + | ± | — | — |
| 158. | Chiang Rai, | Apg | 0—15 | 50 | 40 | 10 | ± | ++ | ± | — | — |
| | Fang, Ping Tam | B1g | 20—30 | 30 | 60 | 10 | ± | ++ | ± | — | — |
| 31. | Chiang Rai, | Apg | 0—15 | 50 | 40 | 10 | ± | ++ | + | + | ± |
| | Mae Sai | B2g | 40—60 | 45 | 40 | 15 | ± | ++ | + | + | ± |

Legends are the same as in Table 2.

**Table 5. Clay mineral composition of paddy sois in the Southern Region**

| No. | Location | Horizon | Depth | Relative abundance | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 7 Å | 10 Å | 14 Å | | | | | |
| | | | cm | (%) | (%) | (%) | Mt | Ver | Al-int | Ch | Int |
| 174. | Phatthalung, | Apg | 0—17 | 75 | 10 | 15 | — | + | ++ | — | — |
| | Khuan Khanum | B21g | 30—60 | 80 | 10 | 10 | + | ++ | + | — | — |
| 176. | Satun, | Apg | 0—17 | 60 | 35 | 5 | ± | + | ± | — | — |
| | Muang | B2g | 28—70 | 65 | 30 | 5 | ± | + | ± | — | — |
| 179. | Patthani, | Apg | 0—12 | 75 | 20 | 5 | ± | + | ± | — | — |
| | Khok Pho | B2g | 23—35 | 80 | 15 | 5 | ± | + | ± | — | — |
| 182. | Narathiwat, | Apg | 0—15 | 80 | 15 | 5 | ± | + | ± | — | — |
| | Muang | B2g | 30—40 | 80 | 15 | 5 | ± | + | ± | — | — |
| | | IICg | 60—90 | 70 | 25 | 5 | ± | + | ± | — | — |

Legends are the same as in Table 2.

and Phrae basins. The soils of Profile No. 154 located at Lampang, Muang, which belonged to Low Humic Gley Soils, contained a relatively large amount of 14Å minerals, which consisted chiefly of montmorillonite.

The clay fraction of Humic Gley Soils (Profile No. 31, Chiang Rai, Mae Sai) was composed of kaolinitic minerals and mica clay minerals in a nearly even quantity, and the amount of 14Å minerals with a predominance of vermiculite was rather small.

*4) Soils from the Southern Region*

Clay mineral composition of the soils in this region is shown in Table 5. Clay mineralogical characteristics of paddy soils of the Southern Region were quite different from those of soils of the other three regions. They were characterized by a predominance of kaolinite minerals, irrespective of the soil groups, along with a small amount of mica clay minerals and by traces of 14Å minerals, consisted of vermiculite and Al-interlayered minerals.

of montmorillonite and vermiculite, and by a relatively low content of both kaolinitic minerals and mica clay minerals. The peak intensity in X-ray diffraction of the specimens from this profile was weak and rather broad, indicating that clay minerals were low in crystallinity, especially for the surface soil probably due to younger pedogenetic age.

Most of the soils taken from Low Humic Gley Soils were composed predominantly of kaolinites. In these soils both mica clay minerals and 14Å minerals showed marked fluctuations ranging from 5% to 40% and from 5 to 35%, respectively. The 14Å minerals contained large amounts of vermiculite and a small amount of Al-interlayered minerals and montomorillonite.

(Hydromorphic) Non-Calcic Brown Soils in the Central Plain showed a comparatively high content of both mica clay minerals and kaolinitic minerals, and few 14Å minerals, which consisted mainly of vermiculite and partly of chlorite. The clay fraction of Profile No. 23 (Lop Buri, Muang) belonging to Grumusols developed on marly sediments was highly montmorillonitic (roughly 85%) in its clay mineral composition.

### 2) *Soils from the North-eastern Region*

Soils distributed along the Mekong River in this region can be sharply distinguished in their clay mineral composition from the other soils of this region as readily seen in Table 3.

The soils of Profile No. 45 (Nong Khai, Si Chiang Mai) belonging to Fresh Water Alluvial Soils derived from fresh water sediments of the Mekong River were characterized by a large amount of mica clay minerals and by an abundance of chlorites among 14Å minerals. The soils of Profile No. 107 (Nong Khai, Muang) developed on the old levee of the Mekong River, which belongs to Low Humic Gley Soils, showed nearly the same clay mineralogical characteteristics as those of Profile No. 45, but the peak intensity at 14Å indicating the presence of chlorite was more striking. Hattori[5)] pointed out that Cambodian paddy soils derived from recent Mekong sediments also contained a high amount of illite (corresponding to mica clay minerals).

On the contrary, soils which were not considered to be affected by the sediments of the Mekong River, were characterized by very low mica clay mineral contents and by aboundant Al-interlayered minerals among the 14Å minerals irrespective of the soil groups.

### 3) *Soils from the Northern Region*

In general, clay mineral composition of paddy soils from the Northern Region was characterized by a high content of either kaolinitic minerals or mica clay minerals and a rather low content of 14Å minerals, which consisted mainly of vermiculite as given in Table 4.

Soils with predominance of kaolinitic minerals were found to be distributed in the Chiang Mai and Chiang Rai basins, while soils with predominance of mica clay minerals in the Nan

**Table 3. Clay mineral composition of paddy soils in the North-eastern Region**

| No. | Location | Horizon | Depth | Relative abundance | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 7 Å | 10 Å | 14 Å | | | | | |
| | | | cm | (%) | (%) | (%) | Mt | Ver | Al-int | Ch | Int |
| 42. | Nakhon Ratchasima, | Apg | 0—15 | 80 | 0 | 20 | − | + | ++ | − | ± |
| | Phimai | B2g | 40—75 | 75 | 0 | 25 | − | + | ++ | ± | ± |
| 48. | Nong Khai, | Apg | 0—15 | 30 | 55 | 15 | ± | + | ± | ++ | ± |
| | Si Chiang Mai | Cg | 30—55 | 30 | 40 | 20 | ± | + | ± | ++ | ± |
| 45. | Khon Kaen, | Apg | 0—10 | 50 | 5 | 40 | − | ++ | ++ | − | + |
| | Chum Phae | Cg | 40—75 | 50 | 5 | 40 | − | ++ | ++ | − | + |
| 107. | Nakhom Phanom, | Apg | 0—12 | 30 | 45 | 25 | − | + | + | +++ | ± |
| | Muang | B21g | 23—42 | 30 | 50 | 20 | − | + | + | +++ | ± |
| 114. | Ubon Ratchathani, | Apg | 0—10 | 50 | 5 | 45 | − | ++ | +++ | ± | + |
| | Muang | B1g | 15—23 | 50 | 0 | 50 | − | ++ | +++ | ± | + |

Legends are the same as in Table 2.

Table 6. **Clay mineralogical classes of paddy soils in Thailand**

| | Clay mineral composition | Central Plain | | North-eastern | | Northern | | Southern | |
|---|---|---|---|---|---|---|---|---|---|
| | | Surface | Subsoil | Surface | Subsoil | Surface | Subsoil | Surface | Subsoil |
| 7 Å-dominant type | 7 Å | | | ○ 42 | ○ 42 | | | ○ 174<br>● 179<br>● 182 | ○ 174<br>● 179<br>● 182 |
| | 7—10 Å | ● 138 | ● 138 | | | ○ 27<br>○ 152<br>● 33<br>● 158<br>△ 31 | ○ 27<br>○ 152<br>● 33<br>△ 31 | ● 176 | ● 176 |
| | 7—14 Å | ● 3<br>○ 37<br>● 132<br>● 135 | ● 3<br>○ 37<br>● 132<br>● 135 | ○ 48<br>▼ 114 | ○ 48<br>▼ 114 | ● 154 | ● 154 | | |
| 10 Å-dominant type | 10 Å | | | | | | | | |
| | 10—7 Å | □ 12<br>■ 55<br>○ 140<br>▼ 6<br>▼ 11 | ○ 140<br>▼ 6<br>▼ 11 | ● 45<br>● 107 | ● 45<br>● 107 | ○ 146<br>● 26 | ○ 146<br>● 26<br>● 158 | | |
| | 10—14 Å | | | | | ● 148 | ● 148 | | |
| 14 Å-dominant type | 14 Å | ▲ 23 | ▲ 23 | | | | | | |
| | 14—7 Å | ○ 73 | ○ 73 | | | | | | |
| | 14—10 Å | | | | | | | | |
| 7—10—14 Å even type | | □ 2 | □ 2<br>□ 12<br>■ 55 | | | | | | |

Figures show the profile number.
□ Marine Alluvial Soils,
○ Fresh Water Alluvial Soils,
△ Humic Gley Soils,
▼ (Hydromorphic) Non-Calcic Brown Soils.
■ Brackish Water Alluvial Soils,
● Low Humic Gley Soils,
▲ Grumusols,

5) *Classification of clay mineral composition*

The clay mineral composition of paddy soils in Thailand was classified into 10 types based on the relative abundance of 7Å, 10Å and 14Å minerals according to the method proposed by Kawaguchi and Kyuma.[12] Table 6 gives the profile number corresponding to each class for each region.

As seen from the table, more than half of the total number of soils examined here corresponded to 7Å mineral-dominant types. However, 10Å mineral-dominant types also were widely distributed especially in the Central Plain and the Northern Region. These experimental results show that the content of mica clay minerals was much higher than that obtained by Hattori et al.,[3] and Kawaguchi and Kyuma,[11] who reported that Thai paddy soils, in general, were characterized by a high content of kaolinite minerals and a low content of illite. This discrepancy is probably due to the difference in the estimation of mica clay minerals, that is, the relative intensity of diffraction peak at 14Å was corrected by using an intensity ratio, "R", as already described in this report. In considering soil fertility, the presence of mica clay minerals at high contents in Thai paddy soils plays an important role as one of the sources of plant nutrients, especially potassium, during the weathering process of these minerals. In fact, the beneficial effect of potassium fertilizer in increasing rice yield was not recognized in many farmers' fields by simple fertilizer trials.[13]

Another difference from the results reported by Kawaguchi and Kyuma[11] is the presence of chlorites. The chlorites were commonly found in the soils along the Mekong River in the North-eastern Region nd various soil groups from other regions except the Southern Region. Mitsuchi[15] suggested that the formation of chlorites from vermiculite in the plowed layer of paddy soils was regulated by the seasonal cycle of reduction and oxidation during rice cultivation. Inoue et al. revealed the possible occurrence of chlorite from montmorillonite caused by acidic irrigation water. However, it was assumed that the chloride in Thai paddy soils may not be resulted from the paddy soil forming process, but from inheritance of the parent materials.

The clay mineralogical characteristics of a soil are closely related to the characteristics of parent material, and the clay mineral composition reflects the weathering history of the soil. Among the various types, the 7Å mineral-dominant type may be regarded as the most highly weathered, the 14Å mineral-dominant type and especially the 10Å mineral-dominant type as the least weathered one, and the 7-10-14Å mineral even type as being intermediate between the former two. In this regard, the soils from the North-eastern Region except those affected by the sediments of the Mekong River and the Southern Region are considered to be highly weathered. In such soils, Al-interlayered minerals are predominant among 14Å minerals. In the Central Plain, and the North-eastern Region, soils containing a large amount of kaolinitic minerals are commonly found in Low Humic Gley Soils developed on low terraces derived from old alluvium. On the other hand, soils of the 10Å mineral-dominant type and 14Å mineral-dominant type are found in the low-lying area in the Central Plain and basins in the Northern Region. Most of these soils are refreshed every year by flooded water with a large amount of soil particles. The 14Å minerals of these soils are mainly montmorillonite and/or vermiculite.

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## Summary

More than half of the total number of soils examined belonged to 7Å mineral dominant type in clay mineral composition. However, some distinct characteristics were recognized among different soil groups and different regions.

Marine Alluvial Soils in the Central Plain were composed of mica clay minerals, kaolinite minerals and 14Å minerals, consisted mainly of montmorillonite, in a nearly equal quantity. Brackish Water Alluvial Soils were not different from Marine Alluvial Soils in their clay mineral composition, except for the presence of a small amount of chlorites.

The clay mineral composition of Fresh Water Alluvial Soils and Low Humic Soils varied markedly with the regions. For example, various types of clay mineral composition ranging from 7Å to 14Å mineral-dominant type were found in the Central Plain, and their 14Å minerals consisted mainly of montmorillonite and vermiculite, depending on the nature of the parent materials and the weathering history of the soils. Soils from the North-eastern Region were characterized by a high content of kaolinite minerals and the absence or presence of a small amount of mica caly minerals, and their 14Å minerals were mainly Al-interlayered ones. But, the soils distributed along the Mekong River were dominanted by mica clay minerals, and chorite was the main component of their 14Å minerals. Soils from the Northern Region were either of the 7Å or 10Å mineral-dominant types. Clay mineral species composed of 14Å minerals were mainly vermiculite and partly montmorillonite. Soils from the Southern

Region were more kaolinitic than those of the other three regions. A low content of 14Å minerals was a feature probably common to soils in this region, except for Marine Alluvial Soils and Brackish Water Alluvial Soils.

Humic Gley Soils locally distributed in Chiang Rai Basin were similar in clay mineral composition to other soil groups found in this basin. (Hydromorphic) Non-Calcic Brown Soils were either of the 7Å or 14Å mineral dominant types, and their 14Å minerals consisted mainly of vermiculite and partly of chlorite in the Central Plain, while mainly of Al-interlayered minerals in the North-eastern Region. Grumusols derived from marly sediments, which are locally distributed in Lop Buri in the Central Plain, were highly montmorillonitic in their clay mineral composition.

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