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Geology, Occurrence, Characteristics and Paragenesis of the Mixed-Layer Kaolinite/Smectite Clay Deposit in Liloan, Cebu, Philippines

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Abstract

The red-burning clay deposit in Barangay Tayud, Liloan, Cebu, Philippines has its probable formation in paludal environment. Local uplift of the alluvial flat and differential weathering are believed to have played key roles in the genesis of the deposit.

X-ray diffraction (XRD) tests of fine oriented samples, revealed that the red-burning clay is essentially composed of mixed-layer kaolinite/smectite minerals. Basal reflections of the mixed-layer kaolinite/smectite are generally in the average of 16.3 Å which relate to the random order stacking of kaolinite-smectite layers. The ratio of kaolinite to smectite is noticed to be higher at surface horizon and becomes almost of equal proportion with depth. Quartz and feldspar are shown in the x-ray diagrams to be the preponderant minerals in the non-clay fraction.

Images taken from scanning electron microscopy (SEM) of the carbon sputtered and gold-palladium sputtered samples featured thick fluffy masses of mixed-layer smectite/kaolinite with distinct curl edges. The manifestation of numerous blobs postulates the growth of kaolinite crystals on and in smectite crystals as a function of intense weathering under tropical conditions.

Introduction

Early documentations of the clay deposit in Barangay Tayud, Liloan, Cebu, Philippines were conducted by Lauron (1966) and Florendo (1982). Their studies were part of the Bureau of Mines and Geosciences Program on Clay Mineral Explorations which were aimed to provide general overview and

understanding of the deposit's geology, genesis, occurrence, characteristics and economic viability. With lack of necessary equipment and apparatus for detailed clay analyses, their works essentially focused on ocular observations and some physical and chemical determinations of the resource.

This paper constitutes a review of the previous studies and attempts to supplement earlier findings

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by presenting pertinent data recently acquired from x-ray diffraction (XRD) analysis, and scanning electron microscopy (SEM). Emphasis is set on the clarification that the main constituent clay mineral is mixed-layer mineral of kaolinite/smectite. The nature of occurrence of the mixed-layer mineral is described here as well.

Location and Access

The clay deposit nestles on relatively flat to undulating lowlands in Barangay Tayud, Municipality of Liloan, Cebu Province, Philippines, and lies within geographic coordinates 10° 23' 00" to 10° 23' 30" north latitude and 123° 59' 00" to 123° 59' 30" east longitude. It is approximately 14 aerial kilometers north-northeast of Cebu City, the provincial capital.

The study site can be reached by land transport passing through the well-paved Northeast Cebu Coastal Highway and asphalted municipal roadlinks with a travel time of less than an hour.

Topography

The alluvial landscape where the clay deposit occurs, is generally flat to undulating with slopes commonly within 0-8° gradient. The alluvium generally expresses vast and relatively horizontal grounds specifically confined to low elevations barely reaching 15 meters above mean sea level. Gentle to moderate relief is displayed by limestone hills that border the east and west side of the clay area. The limestone formation variably exhibits Karstic topography characterized by sinkholes, solution cavities and subterranean channels. Farther northwest, where the areas are underlain by more complex rock types, the terrain becomes steeper, rugged and mountainous.

Geology

The clay deposit basically sits on extensive tract of alluvium underlain by limestone formation. Figure 1 shows the specific clay area and the disposition of associated rock formations. Brief description of the different lithologies are generally adopted from BMG, 1982.

Tunlob Schist

The Jurassic Tunlob Schist consists of chloritic orthoschist and micaceous paraschist belonging to the albite-epidote-amphibolite facies. It is generally strongly foliated, folded, and faulted. The mineralogical composition is uniform, both laterally and vertically across the foliation.

Serpentinized Peridotite

Serpentinized ultramafic and mafic rocks occurring as diapiric bodies along principal fault zones.

Mananga Group

The Mananga Group consists of the Cansi Volcanics and the Pandan Formation. The Cansi Volcanics is composed of massive flows, breccias, and pillow lavas with composition ranging from typical basalt to basic pyroxene andesite. Texture varies from uniform fine through finely porphyritic to coarsely porphyritic. The Pandan Formation is made up of highly contorted, steeply dipping metamorphosed limestone, shale, sandstone, conglomerate, thin bedded chert and locally intercalated basaltic flows which sometimes exhibit "pillow" lava structures.

Malubog Formation

The formation was named by Corby et al after its type locality in the vicinity of Barrio Malubog, Toledo, central Cebu. The Early Miocene formation consists of mudstone, shale and occasional beds of conglomerate, limestone and coal. Bedding is generally poor and lithologic changes occur rapidly both vertically and horizontally.

Talamban Diorite

Generally medium to fine grained diorite with magnetite-bearing skarn along contact zones. The age is probably Middle Miocene.

Carcar Formation

The formation is a transgressive type of limestone occupying the lower flanks of the ridges and covering practically all the coastal areas. The limestone is typically porous, coralline, poorly bedded or

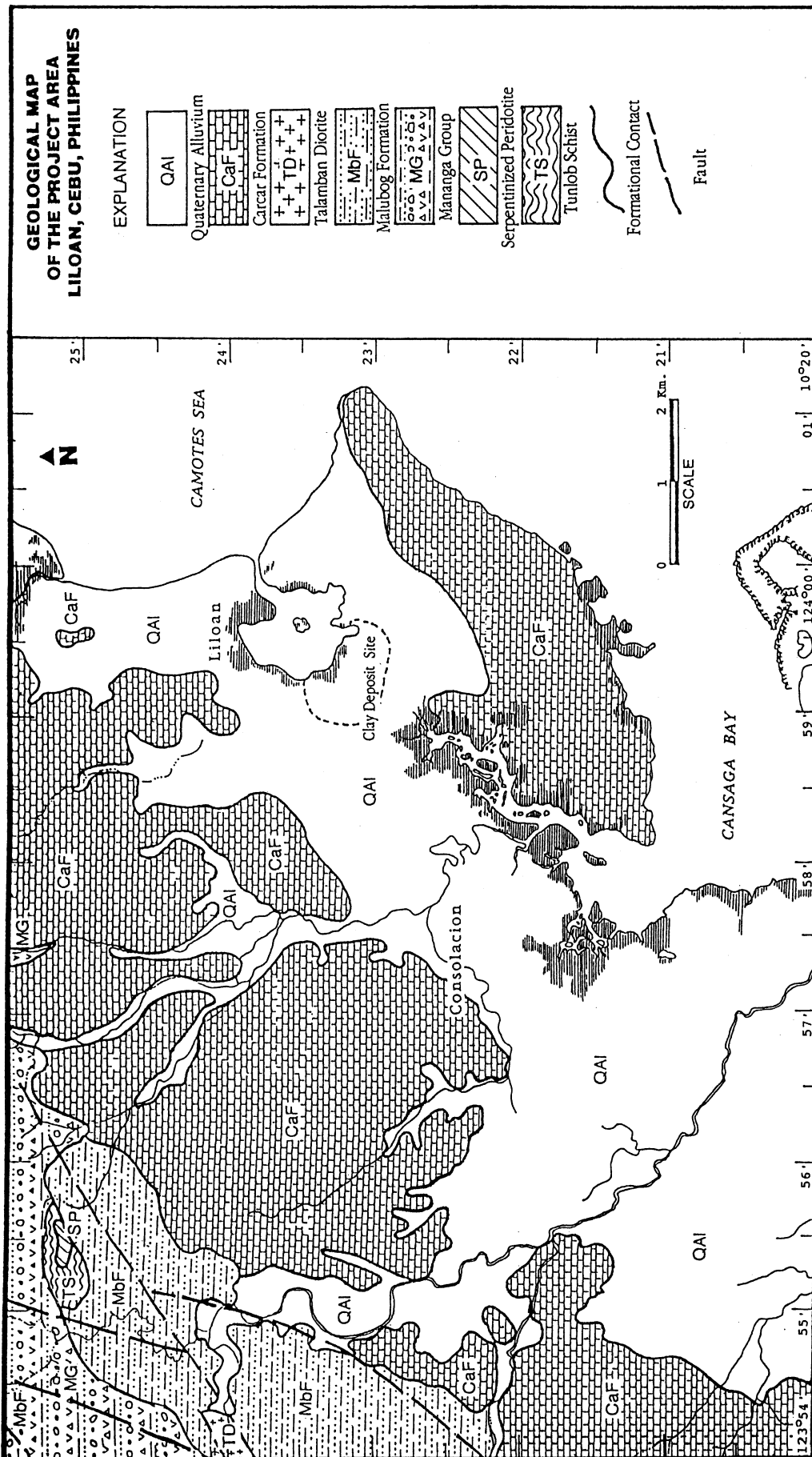


Fig. 1. Geological map of the clay deposit area. Adopted from Philippine Bureau of Mines and Geosciences, geological map of Liloan quadrangle, sheet no.3851-111.

massive and averages 300 meter thick. The Carcar is rich in mollusks, coral stems, algae and Foraminifera indicating a Plio-Pleistocene age and suggesting shallow water deposition.

Quaternary Alluvium

Quaternary alluvium consists of clay, mud, silt, sand and gravel eroded from pre-existing rocks and deposited along river channels, beaches, alluvial flat, delta and estuary. Most of the red-burning clay deposits occurring along the eastern coastline of Cebu are associated with this formation.

Structures

Subject area is virtually unmarked of major structural features. The clay deposit seems not bordered or controlled by major or minor fault or joint structures. The nearest recognizable principal fault and joint patterns are observed several kilometers NW of the clay locality. The observed fracture systems have generally NNE to NE orientation.

Occurrence and characteristics

The clay deposit veneers an aggregate area of approximately 1 to 2 square kilometers (Lauron, 1966). Florendo (1982), however, used 890,000 square meters in their conservative reserve assessment of the deposit. The clay bed has generally varied thickness. Section measurements obtained from test pits and old diggings suggest thickness ranges from around 2 to 3 meters and sometimes even greater. The soil overburden based on outcrops and excavations ranges from few centimeters to rarely 1 meter.

Florendo (1982) classified the occurrence of clay in two forms: as flocculated clay of limited extent, and as weathered feldspathic material of wide areal extent. The most extensively quarried clay is the feldspathic clay used by the thriving pottery industry of Liloan.

The color of the clay is typically gray but due to the presence of limonite derived from apparent breakdown of the ferromagnesian minerals in the sediment, the clay is stained reddish brown or yellowish brown. The inclusion of some amount of

detrital sand grains in some horizons makes the clay semi-plastic and relatively gritty. The clay materials of higher purity usually exemplify moderate to high plasticity when properly wet and display firm hardness and compactness when dry.

The clay at Tayud, for some decades now, has been commonly known and referred to as red-burning clay. In the absence of other advanced laboratory analyses, its other diagnostic properties would not have been known. In view of the current analytical tests, additional data augment the previous results that emphasized mainly on limited chemical and physical character of the clay material.

Newly acquired x-ray diffraction data revealed that the clay is essentially a mixed-layer kaolinite/smectite minerals. X-ray powder diffractograms of fine oriented specimens disclosed a characteristic basal dimension in the average of 16.3 Å (Fig. 2). Ordinary smectite clay generally display basal reflection of about 15 Å to 15.5 Å in pre-treated state (Brown, 1961). The basal distance appeared to show expansion to about 18.5 Å upon saturation with ethylene glycol. Ordinary smectite treated with ethylene glycol expands the basal spacings to constant values near 17 Å (Brindley and Brown, 1980).

Series of heat treatment of the fine samples at low temperature settings revealed that the clay easily regains lost interlayer water in few hours. The clay seems to lost its rehydration ability at temperature of about 700°C or higher. At such temperature the basal distance apparently collapses to about 10 Å.

Mild HCl acid treatment and controlled heat treatment conducted on some fine samples proved the absence of chlorite in the clay assemblage.

SEM photos and images (Fig. 3) show aggregate of thick fluffy particles of kaolinite/smectite mixed-layer projecting subtle hexagonal to irregular outlines. A distinct feature is the appearance of abundant blobs on the surfaces of every flake. This kind of manifestation is typical in clays of hydrothermal origin or clays that have undergone low grade metamorphism.

Previous chemical analysis of a clay sample (Lauron, 1966) showed that SiO₂ was 60.56% and

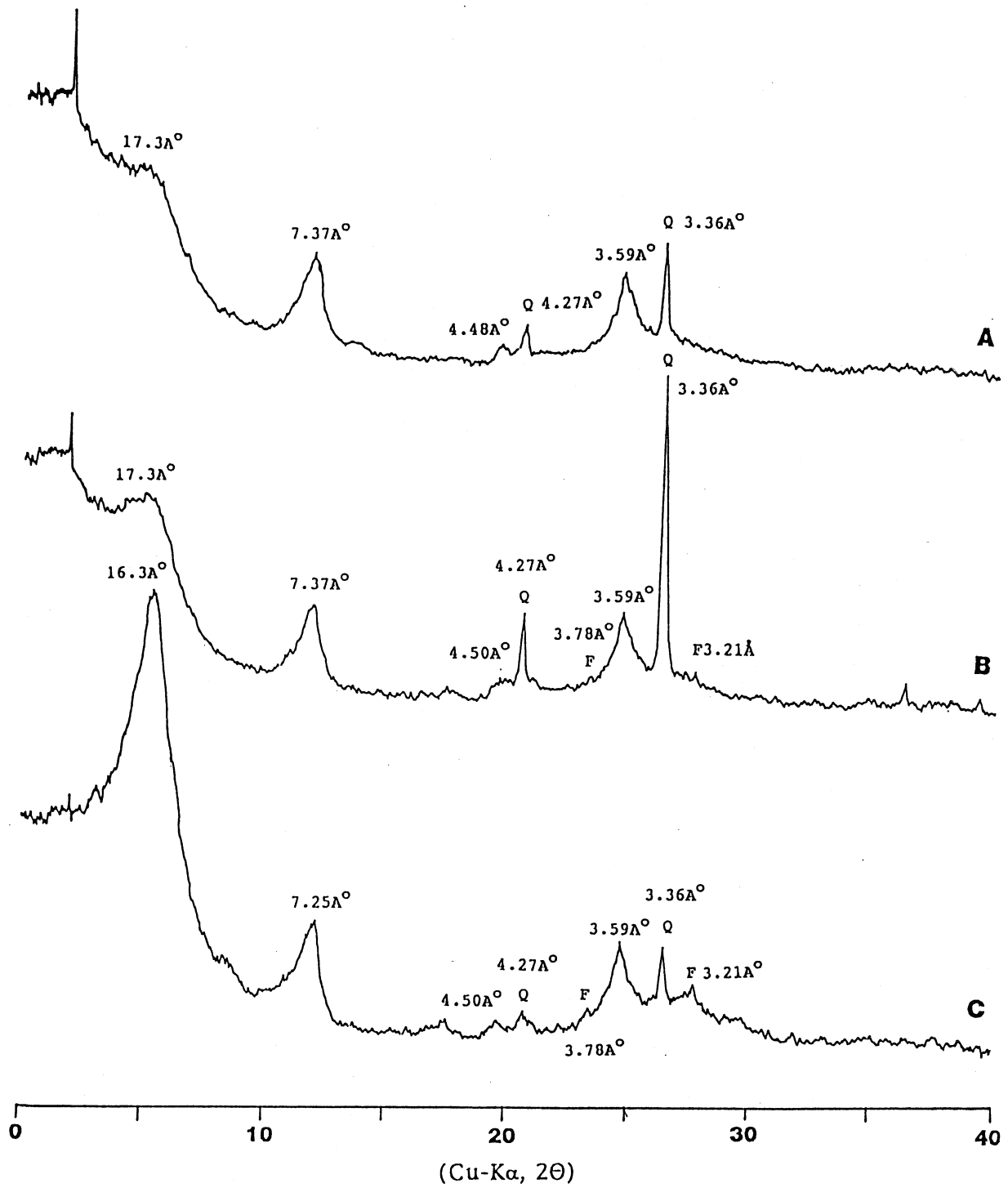


Fig. 2. X-ray diffraction diagrams of pretreated fine oriented samples: A- top horizon, B- middle horizon, C- bottom horizon; Q- quartz and F- feldspar.

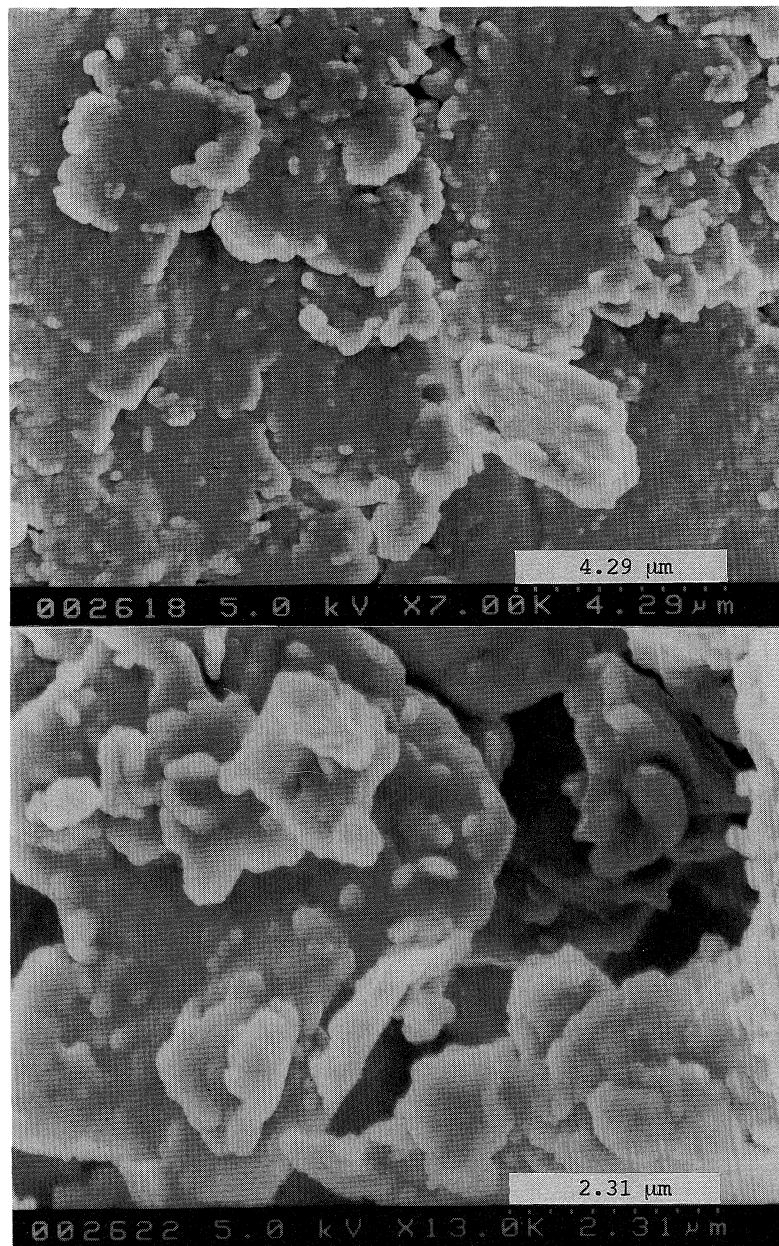


Fig. 3. Electron micrographs of mixed-layer kaolinite/smectite clay minerals, Liloan, Cebu, Philippines.

Al_2O_3 was 18.49%. Iron oxide (Fe_2O_3) was about 6.56% while lime (CaO) was 1.83%. Magnesia (MgO), soda (Na_2O) and potash (K_2O) were 1.36%, 2.14% and 0.11% respectively. Loss on ignition (LOI) was around 6.80% while moisture (H_2O) was 1.75%.

Paragenesis

Lauron (1966), succinctly described that the accumulation of clay in the lowlands is residually

concentrated under normal process of tropical chemical weathering, and this was covered by recently deposited alluvium.

Florendo (1982), ascribed the origin as swamp deposit based on location and field evidences. The sequence of sediment from clay to sand then to limestone rubbles toward the limestone bodies precludes a fluvial origin. A fluvial deposit should display a sequence that is reverse to the above. The configuration of the shoreline off Consolacion and

Liloan, suggests the presence of an uplifted reef, a characteristic feature of an emergent coastline. The lenticular limestone mass with approximate length of 6.5 kilometers trends NNE.

The reefal upliftment produced a lagoon behind it. Remnants of the lagoon occur as a swamp along Cansaga River and as a circular Silut Lake with sea outlet along Yate. Within the protected area, with negligible waves, any suspended sediment in the water brought in by tidal currents and rivers emptying into the sea, have a chance to settle out. Much amount of terrestrial sediments may have been derived from the weathering and erosion of parent materials in the hinterlands under warm tropical climate and high humidity level. Upon upliftment of the alluvial tracts, chemical weathering acted on the sediment. These two processes account for the quantity and quality of the red-burning clay at Tayud.

Very recent examination of the clays by scanning electron micrograph (SEM) technique vividly showed blistered appearance of clays due to numerous blobs on the surfaces of every clay flake. The coalescence of the blobs seems to form new crystals. This manifestation seems to demonstrate the growth of kaolinite crystals on smectite crystals that is probably influenced or induced by high degree of chemical weathering.

Conclusion

1. The red-burning clay in Tayud, Liloan, Cebu, Philippines is dominantly made up of mixed-layer kaolinite/smectite clay minerals as defined by XRD analysis. The random order stacking of the mixed layer in pre-treated condition effected a basal dimension average of 16.3 Å. Non-clay fractions are

composed significantly of quartz and feldspar.

2. SEM photographs exhibit fluffy aggregates of mixed-layer kaolinite/smectite with subtle hexagonal configuration and varied thickness. The prolific appearance of blobs and their apparent coalescence may suggest the growth of kaolinite crystals on and in smectite crystals aided by intense tropical chemical weathering.

3. The formation of the clay deposit is probably in swamp environment with smectite as the original clay mineral. Local uplift of the alluvial flat and differential weathering are believed to be the important processes in the evolution of the deposit. The transformation of the smectite into mixed-layer kaolinite/smectite may highly be the result of chemical weathering.

4. The foregoing analytical results are still partial. Present interpretations may be further supplemented or modified in conjunction with more in-depth scientific experimentations.

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