

Clay Minerals in the Weathering Profile of a Quartz-Muscovite Schist in the Seremban Area, Negeri Sembilan

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ABSTRACT

Difraktogram-difraktogram pancaran-X menunjukkan bahawa mineral-mineral lempung ilit-montmorilonit berinterstratifikasi rawak dan kaolinit ditemui di dalam horizon-horizon morfologi atas profil peluluhawaan, semasa mineral lempung ilit ditemui di dalam horizon morfologi bawah. Difraktogram-difraktogram juga menunjukkan bahawa mineral-mineral lempung kaolinit, ilit dan ilit-montmorilonit berinterstratifikasi rawak terdapat di dalam horizon-horizon morfologi perantaraan. Peningkatan kandungan kaolinit dan ilit-montmorilonit berinterstratifikasi rawak atas profil peluluhawaan dan pengurangan kandungan ilit mencerminkan penambahan kesan proses-proses peluluhawaan. Perkecaian dan perpisahan mineral-mineral muskorit dan serisit di dalam bahan batuan asal mengakibatkan ilit, semasa ilit-montmorilonit berinterstratifikasi rawak dan kaolinit berasal daripada larutan lesap ilit.

ABSTRACT

X-ray diffractograms show that randomly interstratified illite-montmorillonite and kaolinite are the clay minerals present in the upper morphological horizons of the weathering profile, while illite is the only clay mineral present in the lowest morphological horizon. In the intermediate morphological horizons, the diffractograms show that kaolinite, illite and randomly interstratified illite-montmorillonite are the clay minerals present. Increasing amounts of randomly interstratified illite-montmorillonite and kaolinite up the weathering profile, and a corresponding decrease of illite, reflect increasing effects of weathering processes; disaggregation and disintegration of muscovites and sericites within the original bedrock material initially resulting in illite, followed by development of the randomly interstratified illite-montmorillonite and kaolinite through leaching of the illites.

INTRODUCTION

There is a general lack of published literature on the clay minerals of weathering profiles over quartz-mica schist bedrock in Malaysia, except for Yeow (1975) and Siti Zauyah (1986). Yeow (1975) studied two well-drained weathering profiles; one over a quartz-phengite schist (exposed at a 8 m high slope cut), and the other over a graphitic muscovite-quartz schist (exposed at a 10 m high slope cut). In the profile over the quartz-phengite schist, Yeow (1975) concluded that kaolinite formed where rapid leaching of potassium and iron from the phengite occurred, though where the rate of removal of these ions was slow, a mixed layer phengite-montmorillonite

was formed. In the profile over the graphitic muscovite-quartz schist, Yeow (1975) concluded that muscovite altered to kaolinite and halloysite, though the rate of decomposition was slow. Siti Zauyah (1986) investigated a well-drained weathering profile (exposed at a 8 m high slope cut) over a graphitic quartz-sericite schist and concluded that sericite altered to kaolinite.

In studying the characterisation (for engineering geological purposes) of a weathering profile over a quartz-muscovite schist bedrock, samples were collected at various depths and their clay fractions investigated by x-ray diffraction studies. Results of these studies are presented in this paper together with a discussion

on the origins of the clay minerals present in the weathering profile.

SAMPLING SITE - GEOLOGICAL SETTING

The selected weathering profile is exposed at a slope cut, excavated between 1974 and 1975, located on the north side of the Kuala Lumpur - Seremban Highway at Km 67.9 (Fig. 1). The highway here cuts across a low hill and trends in a general west to east direction across an undulating terrain of low hills and flat-bottomed, alluviated valleys. The cut is of an approximately symmetrical shape with a length of about 150 m along its base and a maximum vertical height of 20 m at its centre. The cut, which has an overall

angle of 40°, is benched, with the benches of some 2.75 m vertical height and face angles of 50°, separated by horizontal berms of variable width. The lowest bench, however, is about 6 m high with a face angle of 80°.

At this cut a weathering profile developed over an original bedrock mass is exposed consisting mainly of light grey to buff coloured, quartz-muscovite schists inter-layered with thin bands and lenses of dark grey, graphitic-quartz-muscovite schist. These schists, which contain several quartz veins and pods, are strongly folded with variable strikes and dips and have been correlated with the Lower Palaeozoic Dinding Schist of the Kuala Lumpur area (Khalid 1972).

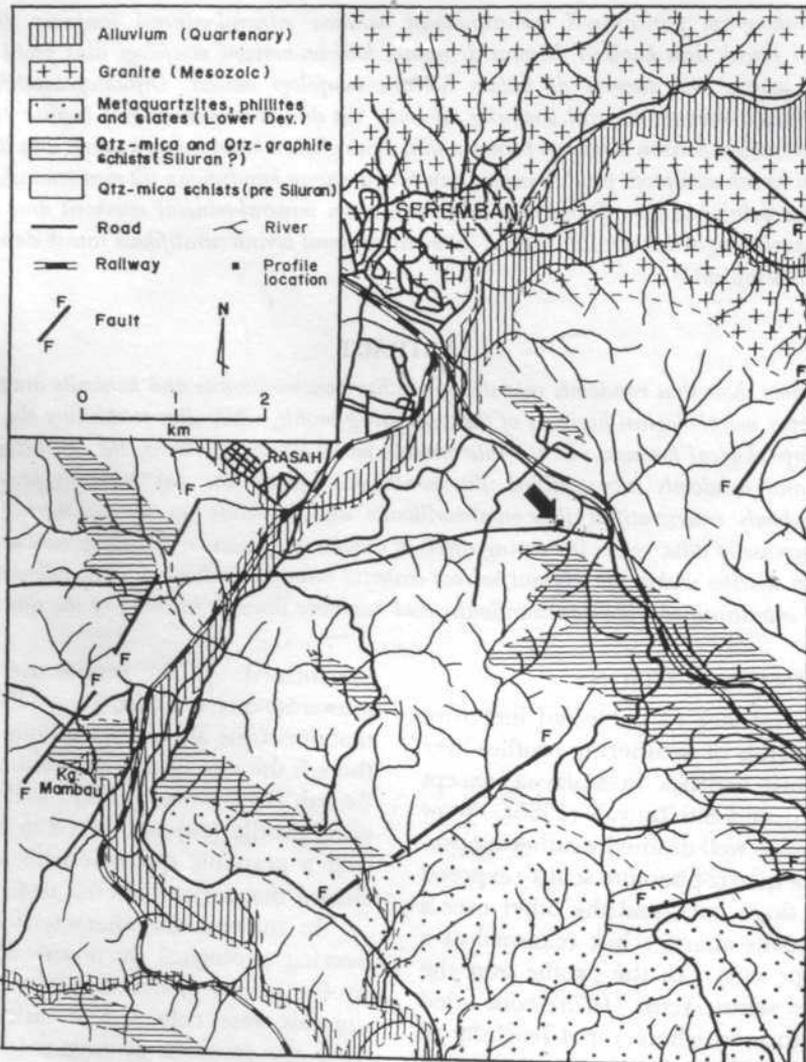


Fig. 1: Geological sketch map of the Seremban area. (After Khalid 1972)

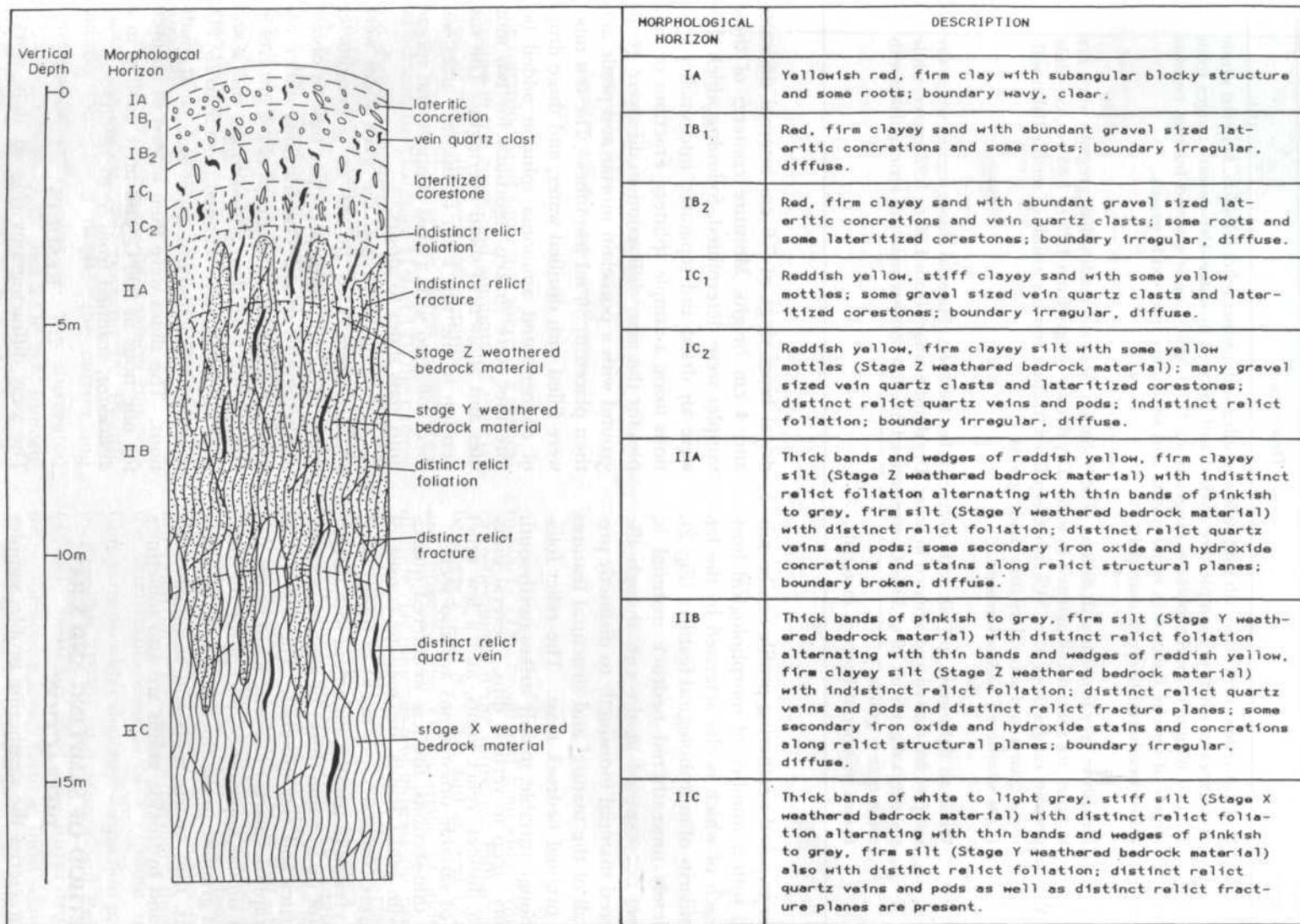


Fig. 2: Schematic sketch, and field description, of morphological horizons within the weathering profile over the quartz-muscovite schist.
 Note - Stages of weathering are defined in Table 1

TABLE 1
Later stages of weathering of the quartz-muscovite schist bedrock material

Stage	Description
Z	Reddish yellow, firm clayey silt with yellow mottles and instinct relict foliation. Material slowly disaggregates when dry samples are soaked and agitated in water. Dry density ranges from 1.7 to 1.85 gm/cc, while porosity ranges from 32 to 38%. Coarse-grained fraction consists largely of sericite flakes with some quartz and secondary iron oxide grains. (Most weathered bedrock material).
Y	Pinkish to grey firm silt with distinct relict foliation. Material readily disaggregates when dry samples are soaked and agitated in water. Dry density ranges from 1.75 to 1.85 gm/cc, while porosity ranges from 32 to 34%. Coarse-grained fraction consists mainly of sericite flakes with some quartz and secondary iron oxide grains. (Less weathered bedrock material).
X	White to light grey, stiff silt with distinct relict foliation. Material disaggregates when dry samples are soaked and agitated in water. Dry density ranges from 1.80 to 1.92 gm/cc, while porosity ranges from 29 to 39%. Coarse-grained fraction consists mainly of sericite flakes with some quartz grains. (Least weathered bedrock material).

The exposed weathering profile can be subdivided into a number of morphological horizons, each of which is characterised by the lateral similarity of morphological features (Fig. 2). Completely unweathered bedrock material is, however, not exposed at the cut, though the weathered material indistinctly to distinctly preserves all of the textural and structural features of the original bedrock mass. The relict foliation, though variable, mainly strikes north-south with very steep to vertical dips. Several indistinct to distinct, relict joints, and a few relict faults, of variable orientations are also seen.

In thin-sections, the less weathered quartz-muscovite schist bands are seen to consist of thin layers (some 0.5 mm thick) of fine-grained quartz crystals in parallel alignment with thicker layers (of up to 5 mm thick) of aligned sericites, muscovites and clay minerals. The less weathered graphitic-quartz-muscovite schist bands also show a similar appearance, except for the presence of graphite in the thick layers. In the thin-sections, thin quartz veins and secondary iron oxide and hydroxide grains are also sometimes seen.

METHOD OF SAMPLING AND X-RAY DIFFRACTION

To characterise the weathering profile, samples of the weathered materials were collected at various depths (Fig. 3) using thin-walled, cylindrical

brass rings of 7.6 cm internal diameter and 4 cm height. Moisture contents of these samples were determined, following which they were air dried and separated into smaller fractions using a sample splitter. Fractions of samples for the x-ray diffraction studies were gently ground with a porcelain mortar and pestle and then placed in 30 ml test tubes. The test tubes were filled with distilled water, and three drops of concentrated ammonia solution added before they were shaken vigorously for two minutes and allowed to stand overnight. The suspension in the top 1 cm of the test tubes was then collected with a glass dropper and spread onto glass slides to air-dry.

Following air-drying, the glass slides were scanned from 5° to $28^\circ 2\theta$ at a goniometer speed of $1^\circ/\text{min}$ using a copper tube to obtain diffractograms of the clay fractions under untreated conditions. Two drops of 6% glycerol in ethyl alcohol were then added to the slides, and after air-drying, were scanned from 5° to $15^\circ 2\theta$ to obtain diffractograms under glycolated conditions. The slides were then heated in an oven for one hour at 500°C , and after cooling in a desiccator, scanned from 5° to $15^\circ 2\theta$.

RESULTS

The x-ray diffractograms (Fig. 4) show several reflections that indicate the presence of a number of clay minerals. These reflections are of vari-

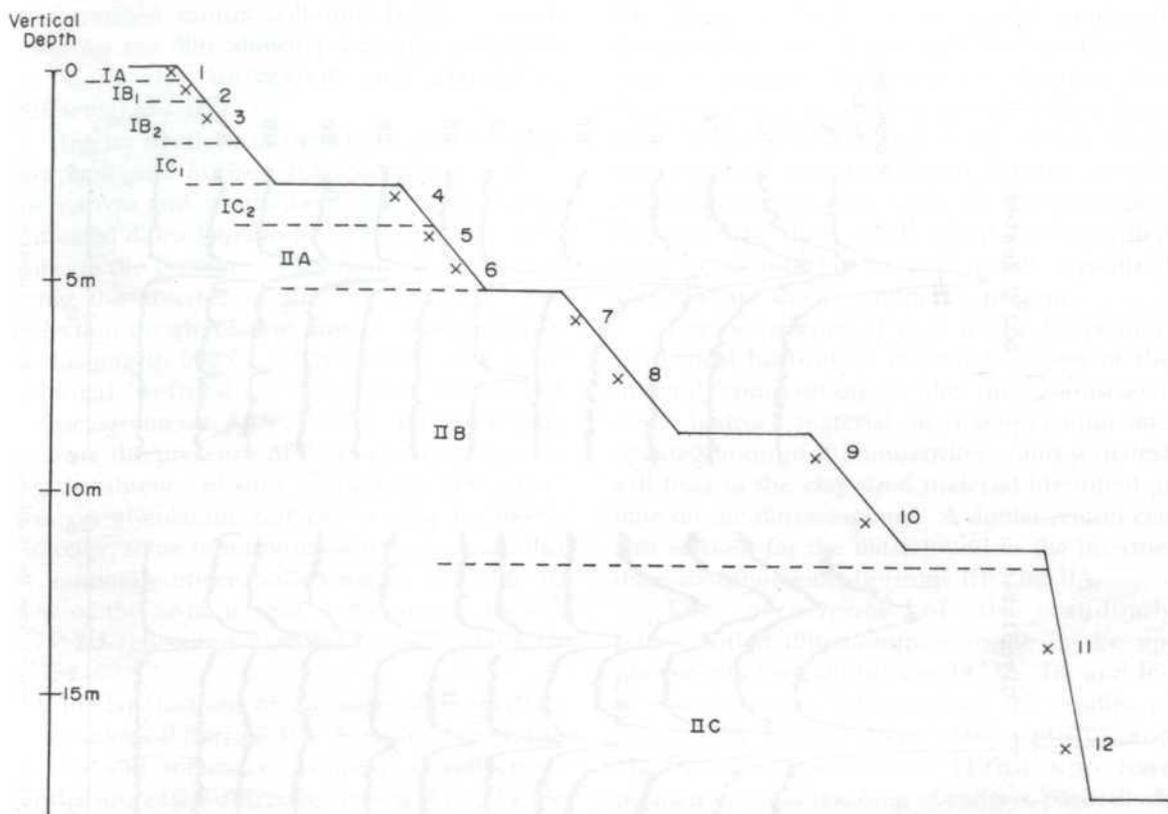


Fig. 3: Sample locations, and lateral extensions of morphological horizons, within the weathering profile over the quartz-muscovite schist.

Note (x' - sample number and location).

able intensities and show that there is a vertical variation in the types, and amounts, of the clay minerals within the weathering profile.

In clay fractions of the lowest morphological horizon IIC (Samples 11 and 12), the narrow and slightly asymmetrical reflections on the untreated diffractograms at 8.75° , 17.75° and 26.7° 2θ , indicate the presence of illite; confirmation being the absence of shifts of the 8.75° 2θ -reflection on glycolation and on heating to 500°C (Fig. 4). The term 'illite' is here used in the sense proposed by Grim, Bray and Bradley (1937) i.e. as being a general name for mica-like clay minerals.

In clay fractions of the top-most morphological (or pedological) horizons IA, IB₁, IB₂ and IC₂ (Samples 1 to 4), the narrow and symmetrical reflections on the untreated diffractograms at 12.25° and 24.8° 2θ , indicate the presence of kaolinite, confirmation being the absence of shift of the 12.25° 2θ -reflection on glycolation and its disappearance on heating

to 500°C . The broad and somewhat asymmetrical reflections on the untreated diffractograms between 7° and 8.5° 2θ , and around 17.8° 2θ are, however, not characteristic of individual discrete clay minerals and indicate the presence of an interstratified (or mixed-layered) clay mineral. As the broad reflections between 7° and 8.5° 2θ shift towards low 2θ -angles on glycolation, and drop to around 8.5° 2θ on heating to 500°C , it is considered that this clay mineral is an interstratified illite-montmorillonite (Moore and Reynolds 1989). The absence of other reflections at lower 2θ -angles on the untreated diffractograms furthermore, shows that the interstratification is of a random nature. Comparisons with calculated diffraction patterns in Reynolds (1980), and Moore and Reynolds (1989), indicate that the interstratified montmorillonite layers form at most some 10% of the randomly interstratified clay mineral. In the clay fraction of morphological horizon IC₂ (Sample 4), however, the content of the

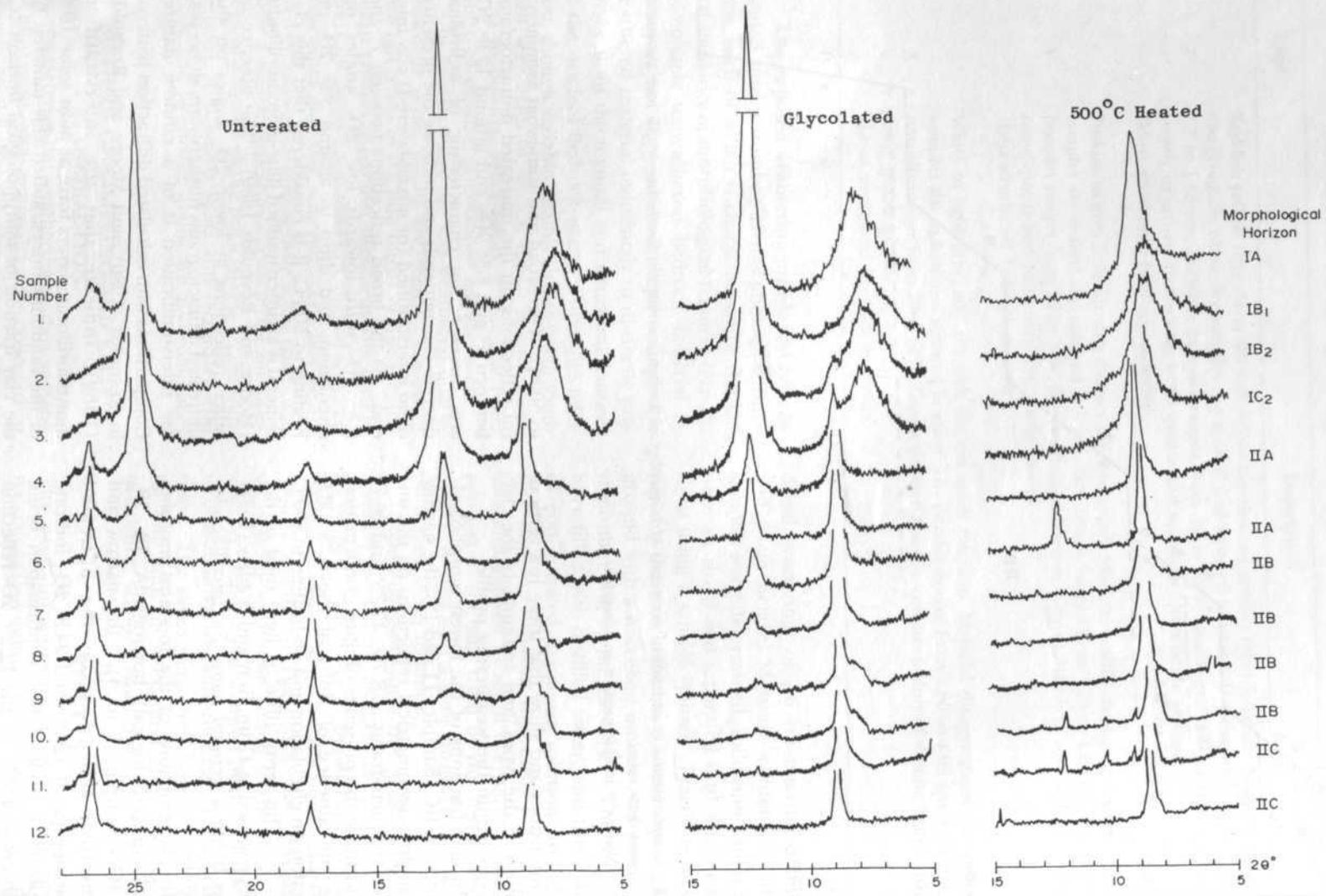


Fig. 4: Untreated, glycolated and 500°C heated X-ray diffractograms of the clay fractions of samples from the weathering profile over the quartz-muscovite schist

interstratified montmorillonite layers is much lower for the illite showing a distinct reflection on both the untreated and glycolated diffractograms (Fig. 4).

In clay fractions of the upper, intermediate morphological horizon IIA (Samples 5 and 6), the narrow and symmetrical reflections on the untreated diffractograms at 12.25° and 24.8° 2θ , indicate the presence of kaolinite, confirmation being the absence of shift of the 12.25° 2θ -reflection on glycolation and its disappearance on heating to 500°C . The narrow and asymmetrical reflections on the untreated diffractograms at 8.75° , 17.75° and 26.7° 2θ , indicate the presence of illite, confirmation being the absence of shift of the 8.75° 2θ -reflection on glycolation and on heating to 500°C . However, some montmorillonite layers may also be randomly interstratified within the illite in view of the asymmetrical (towards low angles) 8.75° 2θ -reflections (von Reichenbach and Rich 1975).

In clay fractions of the lower, intermediate morphological horizon IIB (Samples 7 to 9), the narrow and somewhat symmetrical reflections on the untreated diffractograms at 8.75° , 17.75° and 26.7° 2θ , indicate the presence of illite, confirmation being the absence of shift of the 8.75° 2θ -reflection on heating to 500°C . There is, however, the possibility that there are some montmorillonite layers randomly interstratified within the illite, as the low angle part of the 8.75° 2θ -reflection shifts slightly on glycolation and disappears on heating to 500°C (von Reichenbach and Rich 1975). The narrow to broad, symmetrical reflections on the untreated diffractograms at about 12.25° and 24.8° 2θ , indicate the presence of kaolinite, confirmation being the absence of shift of the 12.25° 2θ -reflection on glycolation and its disappearance on heating to 500°C . In the clay fractions of Samples 9 and 10 it is very likely that the kaolinite present is poorly crystallized or very fine grained as it shows low and somewhat broad reflections on the untreated diffractograms.

DISCUSSION

From the results, it can be seen that there is a vertical variation in clay mineralogy within the weathering profile. In the lowest part of the weathering profile (in morphological horizon IIC), illite is the only clay mineral present, while in the top-most part (in pedological horizons IA,

IB₁, IB₂ and IC₂), kaolinite and randomly interstratified illite-montmorillonite are the clay minerals present. At intermediate depths within the weathering profile, in morphological horizon IIA, kaolinite and illite (with some interstratified montmorillonite layers) are the clay minerals present, while in morphological horizon IIB, illite (with some interstratified montmorillonite layers) and poorly crystallized kaolinite are the clay minerals present.

The occurrence of illite in the lower morphological horizons is expected in view of the mineral composition of the quartz-muscovite schist bedrock material, as disaggregation and disintegration of the muscovites (and sericites) will lead to the clay sized material identified as illite on the diffractograms. A similar reason can also account for the illites found in the intermediate morphological horizons IIB and IIA.

The occurrence of the randomly interstratified illite-montmorillonite in the upper morphological horizons IA, IB₁, IB₂ and IC₂ is also expected, following on the studies of Droste and Tharin (1958), Millot (1970), and MacEwan and Ruiz-Amil (1975) who have pointed out that leaching of cations, particularly K⁺, from illite structures, and the entrance of water, give rise to randomly interstratified illite-montmorillonite. The presence of some randomly interstratified montmorillonite layers within the illites of the intermediate morphological horizons IIA and IIB can also be attributed to these processes. Increasing effects of these processes within the weathering profile are clearly shown in the diffractograms (Fig. 4) with the gradual broadening and asymmetry of the 8.75° 2θ -reflections up the profile. Interestingly the randomly interstratified illite-montmorillonite only becomes clearly discernible in the diffractogram of the clay fraction from pedological horizon IC₂; this horizon constitutes the *solvum* (or parent material) for the overlying pedological soil horizons.

The occurrence of kaolinite within the weathering profile is somewhat unexpected as the mineral composition of the quartz-muscovite schist is bedrock material. Increasing amounts of kaolinite up the weathering profile, and its absence in the lower morphological horizon IIC, however, show that it has developed as a result of weathering processes. In the intermediate morphological horizons IIB and IIA broadening of the 8.75° 2θ -illite reflection is seen to correspond with

an increase in the heights of the 12.25° 2θ-kaolinite reflection and indicates that the development of the kaolinite is associated with leaching of the illite. Such an origin for kaolinite has been proposed by several other workers including Loughnan (1969), Weaver and Pollard (1973), Yeow (1975) and Siti Zauyah (1986).

CONCLUSION

It is concluded that randomly interstratified illite-montmorillonite and kaolinite are the clay minerals present in the upper morphological horizons of the weathering profile, while illite is the only clay mineral present in the lowest morphological horizon. In the intermediate morphological horizons, kaolinite, illite and randomly interstratified illite-montmorillonite are the clay minerals present. It is also concluded that increasing amounts of kaolinite and randomly interstratified illite-montmorillonite up the weathering profile, and a corresponding decrease of illite, reflect increasing effects of weathering processes; disaggregation and disintegration of muscovites and sericites within the original bedrock material initially result in illite, followed by development of the randomly interstratified illite-montmorillonite and kaolinite, through leaching of the illites.

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