DOI: http://doi.org/10.4038/jgssl.v23i1.64 Journal of Geological Society of Sri Lanka Vol. 23-1 (2022), 1-8

PRELIMINARY INVESTIGATIONS ON MURUNKAN CLAY DEPOSIT IN SRI LANKA

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(Received 22nd May 2022; accepted 30th July 2022)

ABSTRACT

Montmorillonite (MMT) is a layered aluminosilicate with a higher specific surface area. Montmorillonite is the most abundant of the smectite clays that have a spectrum of advanced applications. Characterization of Murunkan deposit (i.e. known as a potential for MMT clay) is poorly investigated. Therefore, the main objective of the current study is to characterize clay minerals present in the Murunkan area. Three core samples were collected from in and outside the Giant's Tank reservoir at Murunkan. Samples of each core were cut into 0.125 m intervals. Mineralogical and geochemical characteristics of the Murunkan clay deposit were evaluated using X-ray diffraction, Fourier Transform Infra-Red, and X-ray fluorescence techniques. X-ray diffraction analysis indicates almost similar patterns in each clay sample, dominated by MMT peaks in comparison with the Sigma-Aldrich commercial standard. Kaolinite and illite were also identified as potential clay minerals in the Murunkan area. Fourier Transform Infra-Red spectra of analyzed clay samples show transmittance bands mostly matching with the standard data of kaolinite and MMT. X-ray fluorescence results indicate that the average compositions of clay samples taken from Core 1 and Core 2 are comparable with that of the Sigma-Aldrich MMT clay. Geological observations of the core samples showed that the clay deposit was formed mainly due to in-situ weathering of bedrock and long-term accumulations of sediments. The washbasins/depressions in the Murunkan area can thus be identified as prospective locations for MMT clay.

Keywords: *Murunkan clay deposit, Clay minerals, Montmorillonite, Characterization techniques*

INTRODUCTION

Clay minerals are hydrous layer aluminosilicates of the phyllosilicate group of minerals with a particle size of less than 0.002 mm. Clay minerals are an important component of soils and sediments that form through weathering under the influence of climate, drainage, and rock type (Uddin, 2017; Zhou et al., 2018; Ndzana et al., 2019). Clays are generally classified according to layer type, and layer charge such as kaolin (1:1), smectite (2:1), illite (2:1), etc. Clay minerals are characterized by a wide spectrum of applications due to their high cation exchange capacity, swelling capacity, strong adsorption capacity, and high surface areas (Liu et al., 2008; Thuc et al., 2010; Krupskaya et al., 2017). Consequently, clay minerals can be used as fillers in paints, plasticizers in sand casting, drilling muds, synthetic rubber, and electrical, heat and acid-resistant ceramic materials (Eisenhour and Brown, 2009). Moreover, novel and advanced applications of clay minerals have increased recently in the field of nanotechnology. For example, pollutant fixation (waste confinement), heavy metal trapping, and catalysis have been the focus of many researchers due to the large surface area (750 m^2/g) of nano-clay (Tiwari et al., 2008; Uddin, 2008, 2017; Eloussaief et al., 2011; Vinati et al., 2015).

Several terrestrial clay deposits are distributed in Sri Lanka as primary/residual deposits (due to in-situ weathering of bedrock) or secondary deposits (followed by transportation and deposition of sediments). For example, the

Murunkan clay deposit is located northwest of Sri Lanka that has been identified as a potential montmorillonite deposit (Figure 1). Montmorillonite is the most abundant clay mineral of the smectite group, and has a generalized formula of $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2.nH_2O$ (Liu et al., 2008). However, this clay deposit is poorly investigated for its composition, form (size, shape), and genesis. Therefore, the objectives of this case study are to analyze spatial and depth variations of clay mineralogy in the Murunkan deposit and to assess their qualitative characteristics for possible future exploration.

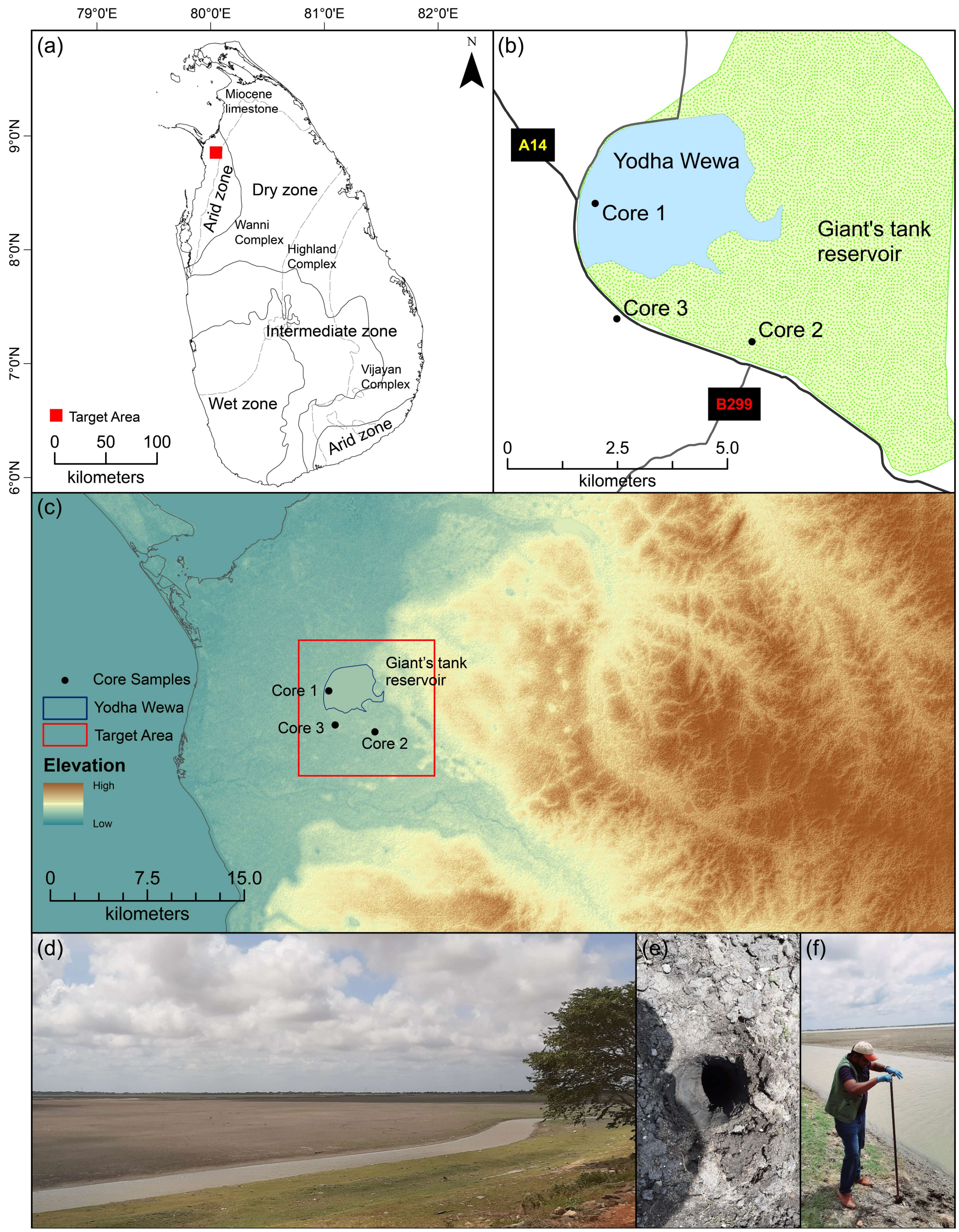

***Fig. 1.** Map of (a) Sri Lanka showing (b) study area, (c) regional Digital Elevation Model (DEM) of Murunkan area, photographs of (d) Giant's Tank reservoir, and (e) and (f) sampling location and sampling.*

MATERIALS AND METHODS

MATERIALS

Three core samples were collected using a hand auger, covering the prospective montmorillonite deposit in the Murunkan area. Core 1 and Core 2 were collected about 1 km apart within the reservoir area of the Giant's Tank (Figure 1). Core 1 and Core 2 reached penetration depths of 2.0 and 1.2 m, respectively. These two core samples consist of clay sediments from bottom to top. Core 3 collected outside the Giant's Tank reached a depth of 1.7 m (Figure 1). In Core 3, the bottom part (0.5–1.7 m) is composed of completely weathered rock, and it is overlain by a ca. 0.1 m thick clay layer. The upper part of Core 3 (0.0–0.4 m) consists of a topsoil layer.

METHODS

Sample Preparation

Undisturbed samples of Core 1 and Core 2 were cut into 0.125 m intervals. Coarse particles (e.g. stones, gravel) were hand-picked, and clay samples were used for further processing. Clay samples were wet-sieved using 53 µm sieve, and oven-dried at 105 ºC for 24 hours to remove moisture. These samples are referred to as raw samples in the text.

A representative sample taken at a depth of 1.25 m from Core 1 was dried and manually ground into a fine powder using mortar and pestle. This sample was then wet sieved again using the 53 µm sieve. Finally, this clay sample was ignited at 550 °C for 24 hours using a Muffle furnace for the removal of organic matter. This sample is named the purified sample in the text.

Material Characterization

Each powdered clay sample was placed in the ground glass depression in the sample holder and was then flattened using a glass slide to form a smooth and well-packed sample surface. The X-ray diffraction analysis was carried out for the commercial standard of montmorillonite (i.e. Sigma-Aldrich), raw samples, and a purified sample using a Rigaku Ultima IV X-ray diffractometer with Cu Kα radiation (λ = 1.54056), operated at 40 kV and 30 mA. The diffractograms were recorded at a scanning rate of 0.02º/second, in the range from 0º to 90º 2θ (e.g. Goonetilleke et al., 2021).

The KBr pellet method was used to prepare clay samples for FTIR analysis. Powdered samples were mixed with potassium bromide (KBr) at a ratio of 1:10. FTIR-grade dried KBr (assay ≥ 99%) was used as the alkali halide. Approximately 0.10% of powdered samples were mixed with KBr powder. Pellets (1 mm in thickness, and 7 mm diameter) were prepared for mixed KBr/powdered sample, using a hand press pelletizer. Pellets of the commercial standard montmorillonite (i.e. Sigma-Aldrich), raw samples, and a purified sample were placed directly in the beam of a Bruker Alpha spectrophotometer over the range of 500–4000 cm^{-1} (e.g. Goonetilleke et al., 2021).

The filter samples were removed from cold storage and loaded into the sample spinner cups. The instrument was prepared for analysis by entering each filter aliquot number into the method tray list within the WinTrace software followed by energy calibration using a ThermoNoran copper (Cu) calibration standard. Chemical compositions (n = 19) were thus determined using the Rigaku ED XRF spectrometer of the Gem and Jewellery Research and Training Institute, Sri Lanka.

RESULTS AND DISCUSSION

MATERIAL CHARACTERIZATION

Figures 2 and 3 show the X-ray diffraction pattern of clay samples taken from Cores 1 and 2, respectively. Representative samples from every 0.125 m depth were compared to identify the availability of different clay mineral phases. Accordingly, montmorillonite (M), kaolinite (K) and illite (Il) mineral phases can be suggested in drilled core samples in the Murunkan deposit. These X-ray diffraction patterns are also comparable with the previous studies (Adikary et al., 2015). Moreover, these clay mineral phases were distributed from bottom to top of Cores 1 and 2. Therefore, clay deposit is distributed over more than 1 km in the Murunkan area.

Figure 4 shows the comparison of the Sigma-Aldrich montmorillonite sample (commercial standard) with a purified clay sample taken at 1.25 m depth of Core 1. The diffraction patterns show that montmorillonite in the Murunkan clay samples has been enriched after wet sieving and purification.

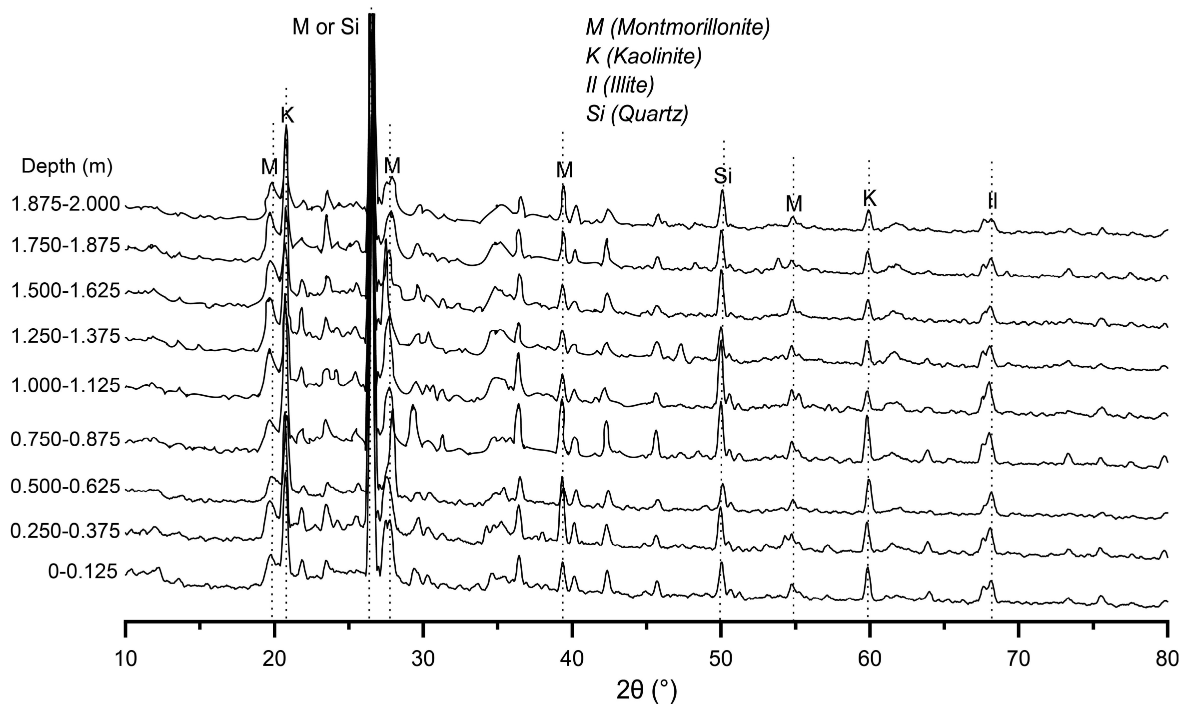

Fig. 2. *X-ray diffraction patterns of Core 1 samples.*

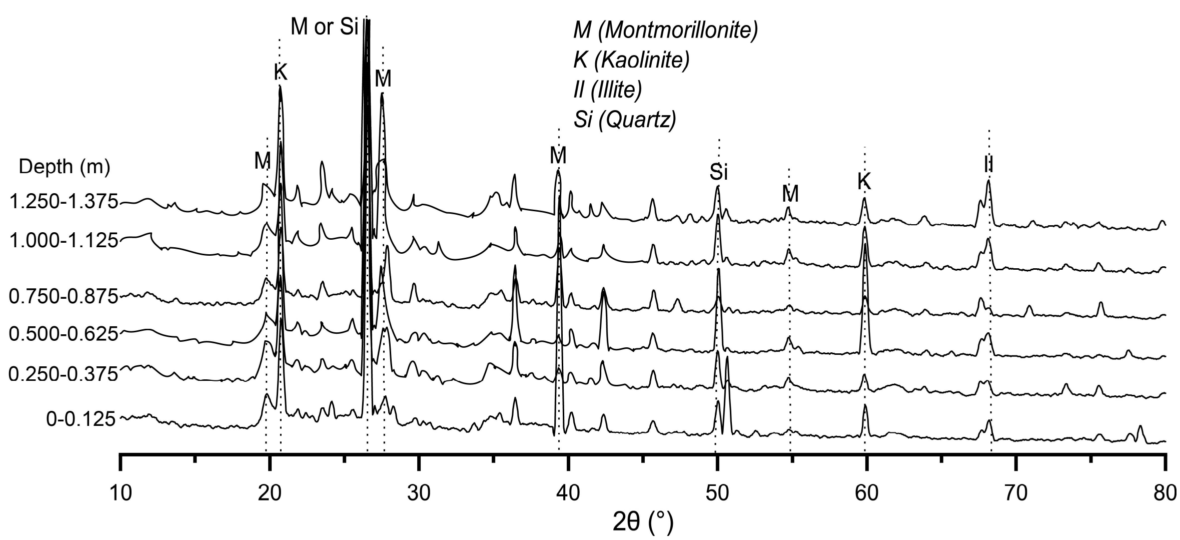

Fig. 3. *X-ray diffractogram of Core 2 samples.*

The IR transmittance spectrum of the purified clay sample (i.e. taken at 1.25 m depth of Core 1) was compared against that of the Sigma-Aldrich montmorillonite clay sample as shown in Figure 5. The broad bands in the range 3400 to 3700 cm^{-1} in both spectra can be assigned for stretching vibrations of —OH groups coordinated with the octahedral cations such as Al^{3+} (Patel et al., 2006; Akpomie and Dawodu, 2016). Similarly, the sharp minima around 1610 cm^{-1} in each spectrum suggest the —OH bending vibrations. The peak doublet around 2400 cm^{-1} is due to the surficial attached carbon dioxide in each sample. The slight peaks in the broadband in the range of 1000 to 1200 cm^{-1} can be ascribed to Si—O in-plane and out-of-plane stretching vibrations, and the minimum of around 520 cm^{-1} in each transmittance spectrum can be assigned to Si—O bending vibration. Consequently, the other minima indicated in Figure 5 are the representations of AlAlOH (~ 920 cm^{-1}), AlFeOH (~870 cm^{-1}) and AlMgOH (~830 cm^{-1}), respectively (Patel et al., 2006; Akpomie and Dawodu, 2016). These results can be further confirmed by comparing them to those reported in the literature (e.g. Adikary et al., 2015).

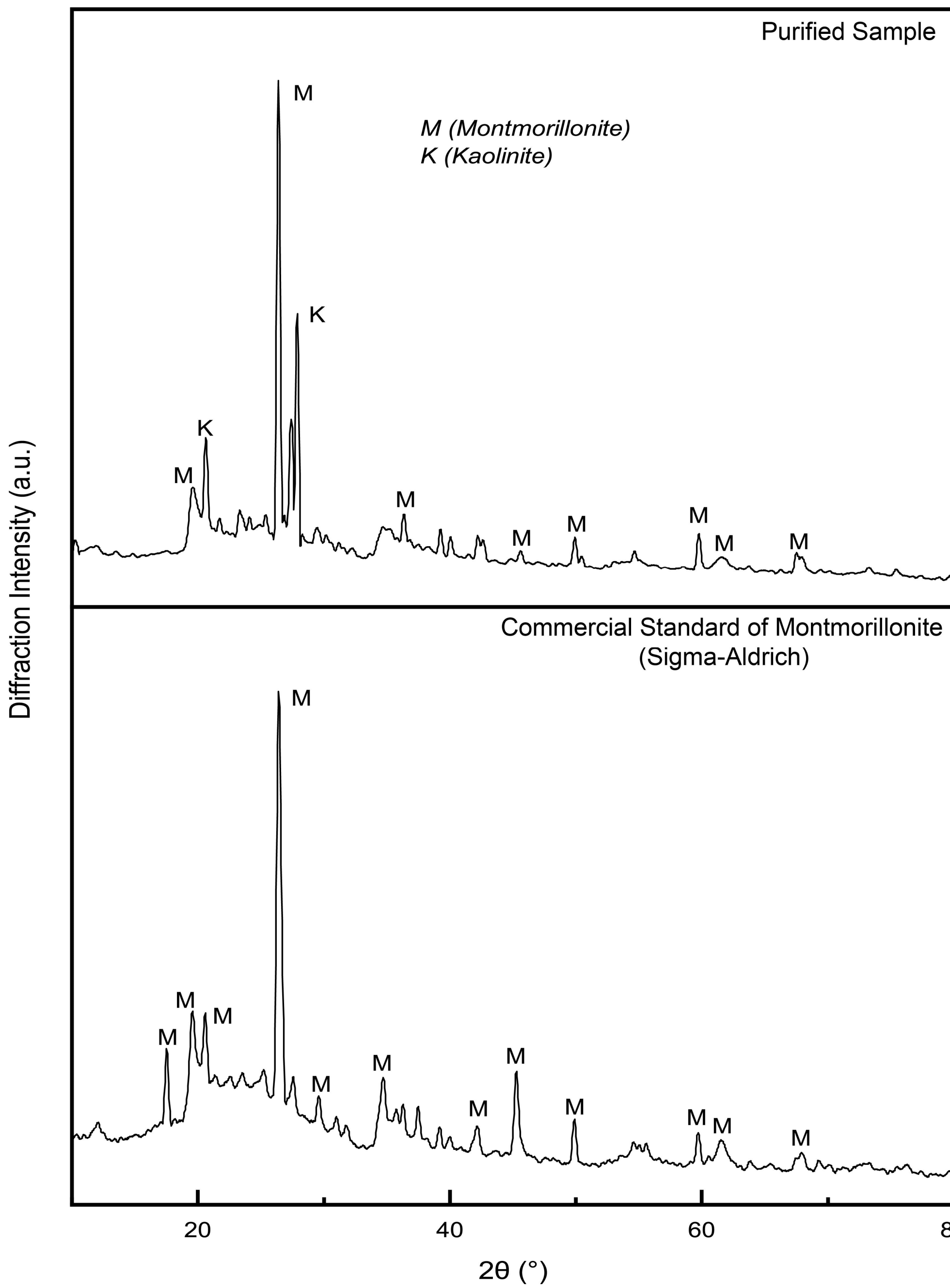

Fig. 4. *Comparison of X-ray diffraction patterns of a representative purified sample and Sigma-Aldrich montmorillonite.*

Figure 6 shows the comparison of the average chemical compositions of raw clay samples collected from Core 1 and Core 2 to the Sigma-Aldrich clay sample. Accordingly, ~57% SiO_2, ~19% Na_2O, ~10% Al_2O_3, ~5% Fe_2O_3, ~2% CaO, ~2% MgO and ~1.5% K_2O are present as major oxides in Murunkan clay samples. These compositions are almost comparable to pure montmorillonite. These observations suggest that the purification of this clay can provide a higher yield of MMT.

GENESIS OF CLAY DEPOSIT

The Giant's Tank reservoir can be identified as a washbasin/depression in the Murunkan area (Figure 1). Core 3 is located outside the Giant's Tank reservoir, and the clay layer thickness is only ~0.1 m. This clay layer is overlain by completely weathered rock. According to the geological map of Talaimannar-Palampiddi (sheet number 3) (GSMB, 2004), the watershed of Giant's Tank reservoir is mainly composed of

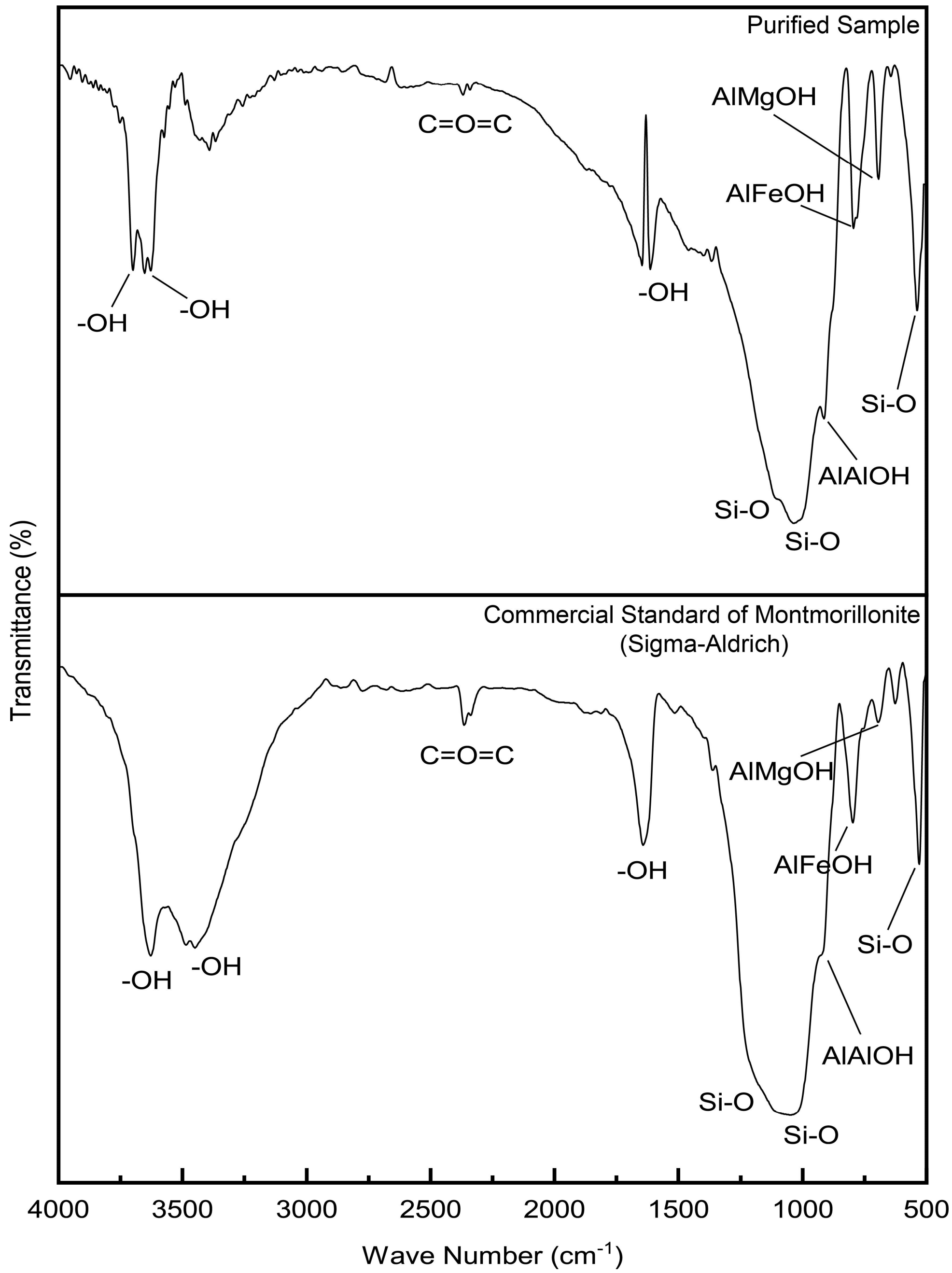

Fig. 5. *IR transmittance of a representative purified sample and Sigma-Aldrich montmorillonite recorded as KBr pellet and band assignments.*

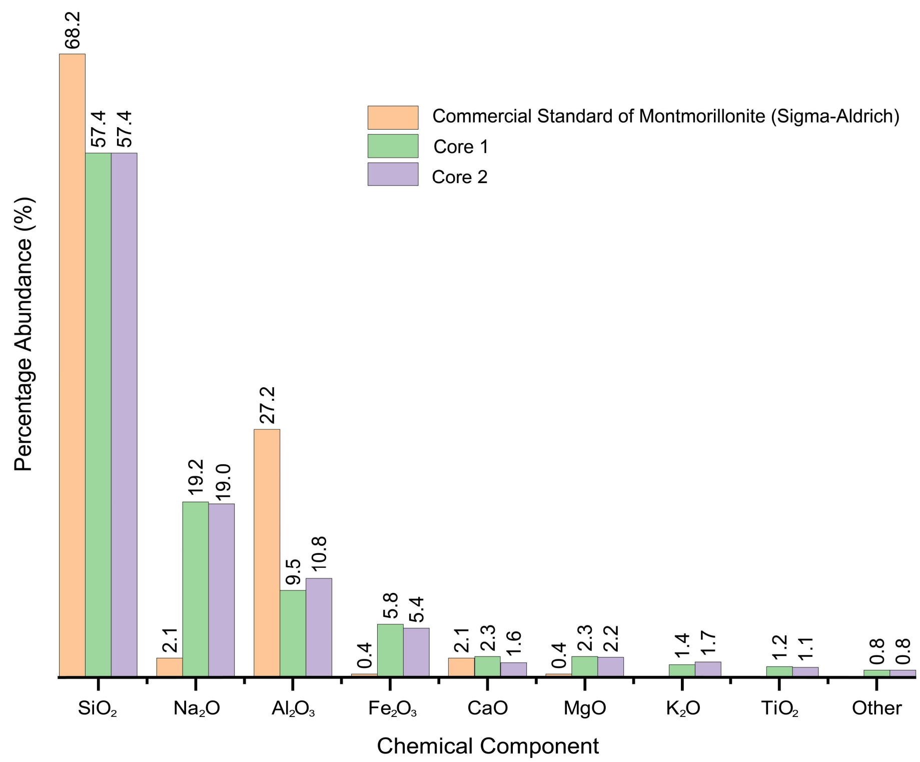

Fig. 6. *Comparison of the average chemical composition of Cores 1 and 2 in the Murunkan deposit with Sigma-Aldrich montmorillonite.*

alluvium and Red Beds. Therefore, weathering of regional bedrocks can be identified as an important process (e.g. Foley, 1999) for the formation of Murunkan clay. These weathered products can be transported and deposited in a small depression like Giant's Tank reservoir. Core 1 and Core 2 drilled in the depression reached over 1.2 m of clay deposit thickness. The analyzed clay sediments (Figures 2–4 and 6) indicate that the basin is prospective for montmorillonite clay. However, the commercial interest in the Murunkan MMT clay deposit is possibly limited to a narrow area in the Giant's Tank reservoir.

CONCLUSIONS

Characterization techniques such as XRD and FTIR analyses suggested the presence of a thick MMT layer (over 1.2 m) in Core 1 and Core 2. X-ray diffraction analysis showed the presence of kaolinite and illite as other clay minerals in the Murunkan deposit. The X-ray fluorescence analysis of the commercial standard montmorillonite sample (Sigma-Aldrich) and raw clay samples confirmed somewhat similar results for major oxides. The clay deposit has been probably formed due to the weathering of bedrock and the subsequent accumulation of sediments. Consequently, washbasins/ depressions in the Murunkan area can be identified as a potential source of MMT clay. The determination of the exact spatial variation and thickness of the clay deposits will be future work.

ACKNOWLEDGMENTS

We gratefully acknowledge the financial support for this study of an Accelerating Higher Education Expansion and Development (AHEAD), Development Oriented Research (DOR) grant.

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