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THERMAL ANALYSIS AS A TOOL IN THE STUDY OF GMM IN ANGRA DOS REIS REGION, RIO DE JANEIRO, BRAZIL

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Angra dos Reis/Itaguai region of the state of Rio de Janeiro, Brazil, is a very problematic area due to the instability of slope and landslides, due to geological and geomorphological conditions and to the significant and continuous human occupation over favorable areas is prone to the triggering of landslides. The samples were analyzed by thermogravimetry (TG), derivative thermogravimetry (DTG) and differential thermal analysis (DTA). This paper analyzes and characterizes the clay minerals and presence of water, gravitational mass movements' sites and compares it with sites where gravitational mass movements do not occur. Indeed, this analysis also attempts to verify the presence of minerals.

Keywords: *GMM, landslides, thermal analysis*

Introduction

Landslides are geological/geomorphologic processes of main significance. Even though landslides represent natural relief evolution processes, this can cause accidents, structural damage, and at times, death of people. The social-economic losses caused by landslides may be significant and growing, as a consequence of the occupation of unstable slope areas. Human occupation, in a great number of accidents, may represent an increase factor to the development of these natural processes whereas creating favorable conditions that will likely trigger these events and expose the population to these hazardous areas.

In regions of tropical climate, natural slopes tend to show great thickness of weathered mantles with formation of saprolites and saprolite soils; in which the destabilization mechanisms are controlled by the weathering stages and the anisotropic character of the rock massifs along with several discontinuities, which may be filled by clay material. In these regions, laterization processes may conduce to macro-structures and particular characteristics of resistance, plasticity and texture, which also conduce to differentiated behavior of soils in relation to those of temperate climates.

According to many authors [1–3] landslides in tropical and subtropical regions are associated with the occurrence of clay bed zones, which control the mechanisms and locations of failure and deformation. The weakness and low permeability of these zones provide the development of slip zones, along which the gravitational mass movements (GMM) take place [4]. The study of clay minerals in areas of GMM occurrence has, therefore, capital importance to the understanding of the triggering mechanisms of landslides.

Experimental

Materials

Sites selection and sampling

Sites were selected taking into account the landform, the occurrence or not of GMM and the influence of clay minerals in their deflagration. About 2 kg of clay material samples were collected from each site.

Samples preparation

These samples were dried in air for a week, but samples for TG/DTG analysis were not, because it was necessary to know the amount of water. The samples were reduced to quarter, same times, and mechanically separated by sieve analysis. The material smaller than 0.062 mm (250 meshes) was conducted to the Thermal Analysis, XRF and XRD. Samples at around 15 mg were used to Thermal Analysis and samples with 1 mg were used to chemical analysis by X-ray spectrometry.

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Methods

TG/DTG/DTA measurements

TG and DTG methods were used to analyze the clay material samples. The samples were performed at a Mettler Toledo TG/SDTA. About 15 mg of sample for each analysis were used: at N_2 atmosphere with a flow of 120 mL min^{-1}, heating rate of 10°C min^{-1} from room temperature until 1000°C. TG/DTG and DTA analysis of samples were performed by TA SDT 2960, about 10 mg by sample, at same conditions of previous equipment.

X-ray spectrometry fluorescence

X-ray spectrometry fluorescence was performed by the fusion method using 7 g of lithium tetra/metaborate. The samples were performed at an X-ray fluorescence spectrometer PW 2400 Phillips/sequential in the Geology Department of the Rio de Janeiro Federal University (UFRJ) with an Rh tube of 3 KW, six analyzers crystals and two detectors (sealed and flow). The software used for these analyses was the SemiQ, developed by Phillips. X-ray diffraction was carried out on Bruker AXS 5005, 40 mA, 35 Kv, and rate of 1° min^{-1}. The software used for these analyses was Ditractplus, PDF2, ICDD, 1996.

Loss of ignition

The loss of ignition was determined through weighing the sample before and after its submission during 30 min to 950°C. The elements were detected from the fusion of 1.0 g of the sample powder mixed to 7 g of lithium tetraborate. The analytical conditions to the measuring of elements were: sealed and flow detectors, analyzers crystals PET, Ge, PX1, PX3 and LIF200 and tube power 24 KV and 90 mA, or 50 KV and 50 mA.

Results and discussion

Figure 1 shows TG/DTG curves for MH3 clay sample in nitrogen atmosphere, with three decomposition stages. Water loss (≈6.62%) in the first stage at 100°C, the second at 300°C loss of hydroxyl (≈4.99%) of gibbsite, and in the third decomposition range 510°C [5], mass loss of hydroxyl of kaolinite (≈6.32%). The second stage of decomposition was associated to gibbsite because of DTA curve, the chemical analysis results, and XRD.

Figure 2 shows TG/DTG curves for MH4 clay sample in nitrogen atmosphere, with three decomposition stages. Water loss (≈10.02%) in the first stage at 100°C, the second at 270°C loss of hydroxyl (≈2.32%) of gibbsite, and in the third decomposition range 510 to 520°C, mass loss of hydroxyl of kaolinite (≈7.57%). The second stage of decomposition was associated to gibbsite as Fig. 1.

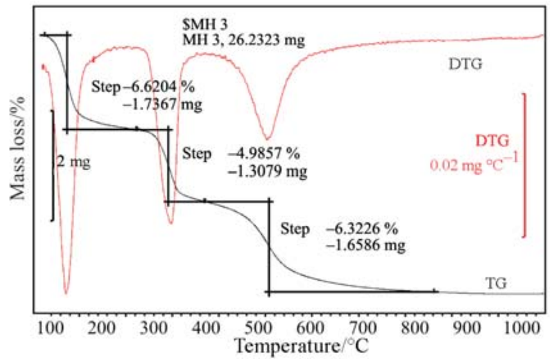

Fig. 1 TG/DTG curves for MH3 sample in nitrogen atmosphere

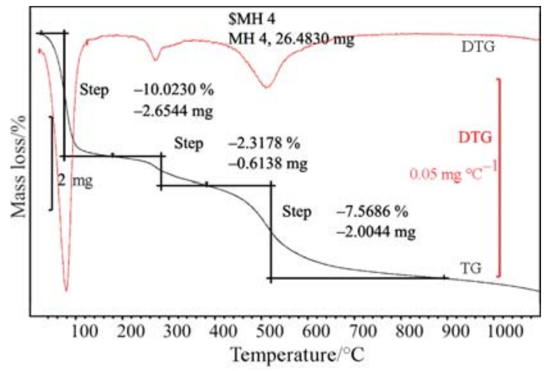

Fig. 2 TG/DTG curves for MH4 sample in nitrogen atmosphere

Figure 3 shows TG/DTG curves for MH5 clay sample in nitrogen atmosphere, with three decomposition stages. Water loss (≈13.50%) in the first stage at 100°C, the second at 270°C loss of hydroxyl (≈2.46%) of gibbsite, and in the third decomposition range 510 to 520°C, mass loss of hydroxyl of kaolinite (≈2.66%). Figure 4 presents DTA curves for MH3, MH4 and MH5 samples. All curves show three endothermic events; which were correlated to the loss of water, dehydroxylation of gibbsite, and dehydroxylation of kaolinite. An exothermic event is present at 970 and it was correlated to mullite nucleation.

The analyses of the clay by XR Spectrometry Fluorescence (Table 1) shows high quantity of Si and Al for all samples; medium of Fe, K and Ca (only MH5); and low Ti, Zr (MH3; MH5), Mg (MH4; MH5), Na (MH5), P (MH5), Mn (MH5) and Sr (MH5); and very low Mg (MH3), P (MH3, MH4), S (MH3, MH5), Ca (MH3, MH4), Mn (MH3, MH4), Rb (MH3, MH4, MH5), Sr (MH3, MH4), Y (MH3, MH4, MH5), Ba (MH3, MH5), Cr (MH4), Nb (MH4), Ce (MH4). Loss of ignition of MH3 was 12.13%; MH4 11.38%; and MH5 6.00%.

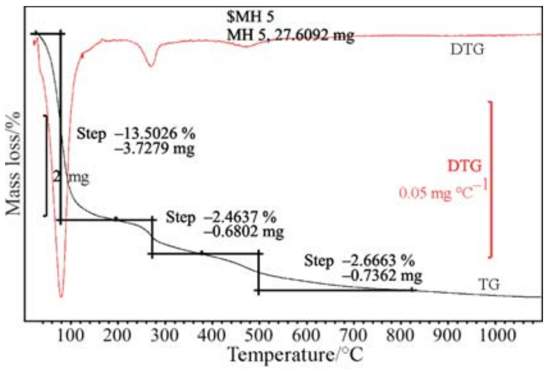

Fig. 3 TG/DTG curves for MH5 sample in nitrogen atmosphere

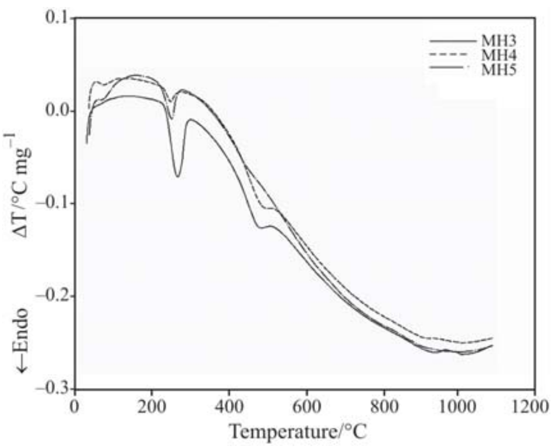

Fig. 4 DTA curves showing three endothermic events

Table 1 Chemical analysis (titration) of clay from samples MH3, MH4 and MH5

	MH3	MH4	MH5
Al_2O_3	36.85	27.78	21.90
SiO_2	51.19	55.66	53.97
K_2O	3.25	3.90	3.17
TiO_2	1.22	1.42	2.30
Fe_2O_3	7.06	9.38	9.05
ZrO_2	0.11		0.27
MgO		1.14	1.84
Na_2O			2.44
P_2O_5			1.37
CaO			3.20
MnO_2			0.22
SrO			0.13

The analysis of the samples by XRD show kaolinite as the principal clay mineral; it appears in all samples. Halloysite is present in samples of MH3 and MH4, and sepiolite is present in MH3 and 5 as gibbsite, Figs 5–7. Other minerals are quartz, ortoclase and biotite.

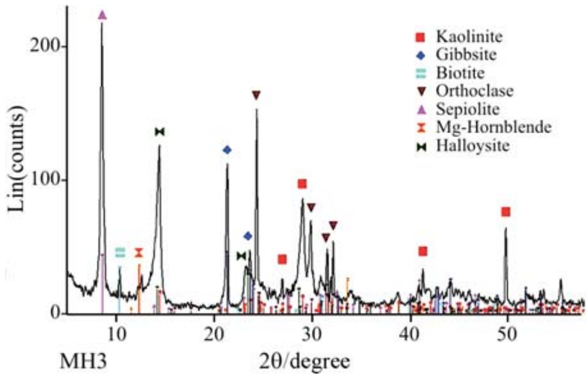

Fig. 5 XRD of MH3 sample

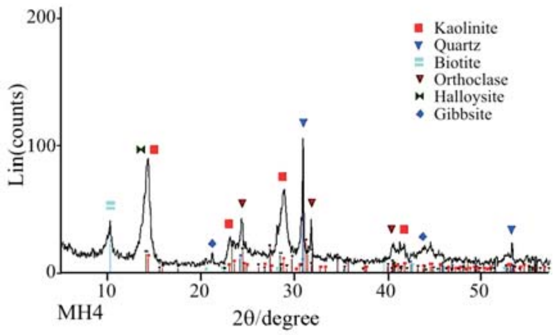

Fig. 6 XRD of MH4 sample

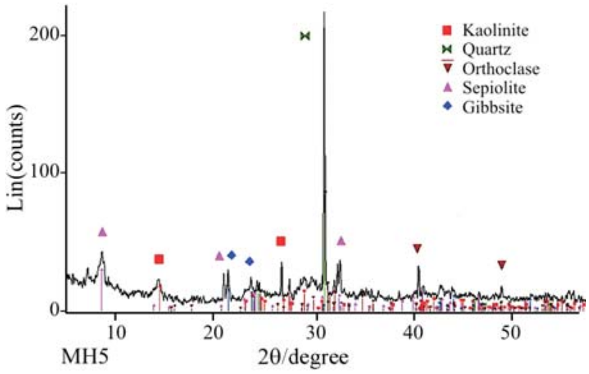

Fig. 7 XRD of MH5 sample

Samples of MH3, MH4 and MH5 had a loss of ignition 12.13; 11.38 and 6.00%, respectively, but TG curves showed that MH5 had more water (13.5%) than MH3 (6.6%) loss. The samples for TG curves were not dried before the analysis, like the samples for loss of ignition.

Conclusions

The results of the thermal analysis allow us to conclude that kaolinite is present in all samples. Other minerals such as haloisite appear in two samples however, in a minor amount, and with less quantities of water; and sepiolite which was present in two samples, but one as trace. An important observation in the samples is the quantity of water, which was found to be higher in the samples with fewer amounts of clay minerals. The high water content presents sharp effect on slope development, triggering abundant landslides in many regions. Heavy rainfall may erode slope surfaces and, when absorbed, increases pore-water pressure and the mass of geologic materials that make up the slope [7]. The role played by gibbsite for the triggering of MMG has not yet been understood, but the presence of this mineral [8], could be used to indicate the weathering degree of soils, through the correlation gibbsite/kaolinite.

Acknowledgements

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