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Physico-chemical characterisation of a Moroccan clay of Chichaoua's bassin in the perspective of erosion studies

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ABSTRACT

The objective of this work is the characterization and identification of natural Moroccan clay from the High Atlas region of Morocco, "Oued de Seksaoua, province of Chichaoua". The analyses were carried out as a precaution by X-ray diffraction, infrared, and scanning microscope observations. The results obtained show that this clay is a mixture of Kaolinite, Quartz in very important proportion, and Illite. By elementary chemical analysis, we noted that the predominant constituents are: silica, Calcite, and aluminum. The ratio SiO2/ Al2O3=3.2 is a characteristic index of free quartz. SEM analysis showed the presence of dispersed clay sheets in the form of rods and some clusters of aggregates, which may be due to the presence of carbonates within the clay. EDX analysis presence of the chemical elements Si, Al, Mg, Fe, K, P, S, Ca. A strong presence of silicon is to be noted due to the presence of a majority of Quartz.

Key words: Clay, characterization, X-ray diffraction, SEM, IR.

INTRODUCTION

Clays play a major role in all sedimentary rocks. Clay rocks are formed from mixtures of clay minerals, to which allogenic minerals (quartz, feldspars, micas, heavy minerals) or authentic minerals (anatase, sulfates, etc.) are associated. Clay minerals are only beginning to be well known; this is the result of technical progress, in particular of methods: differential thermal analysis and above all X-rays, which make it possible to determine the structure of minerals. The arrangement of atoms in the elementary layers of clay minerals is the only possible basis for classification.

In the literature, different definitions of clay are proposed. For example, Eslinger & Beaver define

clays as a mineral that dominates the fine fraction < 2 microns in rocks and soils.

In contrast, Weaver groups all phyllosilicate minerals without any size connotation and proposes to use the term "physics" to avoid confusion. The mineralogical and Physico-chemical properties of clays are of particular interest in many applications, including soil erosion, which is associated with land degradation are Spatio-temporal phenomena that is increasing in several countries of the world. [4 ,7]

Soil erosion is an inescapable natural phenomenon that becomes a serious environmental and economic problem when accelerated by human activities . [2 ,5]

Water erosion phenomena have accelerated worldwide [1].

The interest in the study of clays in recent years by many laboratories around the world is justified by their abundance in nature, their low cost, the presence of electrical charges on this surface, and especially the exchangeability of interfoliar cations. The behavior of clays in the context of clay/erosion interaction explains the numerous works concerning exchange reactions in the clay-soil system.

Clays play various roles through their particular Physico-chemical properties; through their negative charges, they fix the cations in the exchangeable form; with the organic matter they contribute to a structural organization favorable to the circulation of water and air; through their capacity to absorb water between the layers (swelling clays).

All these properties make clay an exceptionally good material. Several previous works around

the world has shown that clay minerals such as smectite, montmorillonite, bentonite, illite, vermiculite, kaolinite, or sepiolite have adsorption capacities for heavy metals in effluents and eroded areas. Recently, studies conducted on mixtures of natural clays have shown their effectiveness for erosion. The most important parameter controlling water absorption. Indeed, this study was conducted to evaluate the potential of locally available clays in the High Atlas region of Morocco, which is the highest mountain range in Morocco, including Mount Toubkal at 4167 m. This mountain range is structured in a multitude of watersheds that constitute a real water tower for the surrounding arid plains. However, the different areas of the High Atlas are subject to strong constraints that negatively affect their hydrological functioning and make this mountain ranges a natural environment particularly sensitive to anthropogenic actions . [6]

These constraints include a very uneven topography, soils poor in organic matter and thin, impermeable parent rocks, friable substrates, a harsh and sometimes brutal climate, and an often sparse vegetation cover, which makes it very exposed to erosion [6].

The objective of this work is, therefore, to carry out a chemical and mineralogical characterization of this clay to conclude on the possibility of using it to analyse and spatialise the various factors involved in the phenomenon of erosion, and to produce a map of the risks of erosion and soil losses in the Oued de Seksaoua (Chichaoua province).

MATERIAL AND METHODS

The study area:

Oued de Seksaoua, The Chichaoua region, which is the subject of this study, is part of the large basin of the Oued Tensift. It covers an area of 20,222 ha and belongs entirely to the territory of the province of Chichaoua (Figure 1). This basin is limited by:

- To the North: by the Oued Tensift watershed

- To the East : The watershed of the Seksawa wadi (Jbel Bou Ibawene and Jbel Ourgous) and the Assif Elmal watershed

- To the West: by the Oulad Bousbaa plain. Jbel Lemgo and Jbel Oussoud

- South: through the High Atlas Mountains, Jbel Gourzatine The Chichaoua upstream perimeter is part of the physiographic unit of the high-Atlasic piedmont with an altitude of approximately 339 m. It consists of the low terraces along the

Chichaoua wadi and its tributaries.

With a surface area of 2690 km², the Chichaoua basin is part of the Oued Tensift hydraulic system, which comprises ten or so basins of varying importance. Of these, the Chichaoua basin is located the furthest west in the Haouz Mejjat basin (Fig.1).

The Chichaoua basin has an area of about 660 km², located downstream of the basin in an intermediate position between the latter and the Assif ElMal basin. Together, the Chichaoua basin and the intermediate zone cover an area of about 3350 km², which represents about 18% of the Haouz-Mejjate basin.

Preparation of the clay sample:

Within the framework of this study, the experimental study was carried out on samples coming from the 2 branches of the Oued Seksaoua of the Chichaoua watershed.

The samples were sampled with a shovel to avoid any possible contamination. They were then stored in plastic bags.

Source

The sample was taken in the High Atlas region of Morocco, "the Chichaoua watershed, Chichaoua province"(figure2).

Weighing, Drying and grinding :

The sample taken underwent the following unit operations:

- These samples were weighed (100g per sample) in order to calculate the water content Drying in the oven for 24 h (T = 105°C),
- Crushing of the clay sample pieces by a mortar,
- Sieve the sample powder (50µm sieve) and put it in well identified pillboxes.

Analytical methods

- X-ray diffractometer (DRX) :

The X-ray diffraction (XRD) mineralogical analysis method is generally used for the identification of the different crystalline mineral phases contained in a solid sample. This technique is used in this study to determine the crystalline phases present in our samples.

This technique allows to determine the state of crystallisation of the samples and to identify the different crystallised solid phases

- Scanning Electron Microscopy (SEM) :

Scanning electron microscopy provides high-resolution images of the surface of the samples.

This method can count particles ranging from a few tens of nanometres to several hundred microns.

Chemical analysis (composition) of particles is possible for particles of the order of 0.3 μm. It allows obtaining statistics on a large population of particles (typically 500 to 10,000 particles)

- Fourier transform infrared spectroscopy (FTIR) :

Fourier transform infrared spectroscopy (FTIR) is based on the absorption of infrared radiation by the material being analysed. By detecting the characteristic vibrations of chemical bonds, it allows the analysis of the chemical functions present in the material.

RESULT AND DISCUSSION

- ***X-ray diffractometer :***

Figure 3 shows the DRX spectra of the samples. These spectra are characteristic of the nature of the crystallised minerals that constitute the samples (Figure 3).

The analysis of the diffractograms obtained for the samples highlights the presence of the following crystalline phases quartz (SiO2: 3.35 /2.80 Å) and calcite (CaCO3: 3.04 / 2.89Å***)*** as main phases.

The analysis also revealed the identification of some minority phases such as Dolomite (CaO MgO 2CO2: 2.4 Å), and Kaolinite (Al2Si2O5 (OH)4: 2.5 Å). (figure3)

We also notice that the diffractograms of the 3 samples are almost similar at all levels (lattice distances and intensities).

It is therefore concluded that either the areas or the 2 branches of Oued de Seksaoua keep the same constituent elements.

Scanning Electron Microscopy (SEM) :

Scanning electron microscopy analysis of the samples provides an overview of the grains with their composition (Figure4).

Figure 4 shows the structure of the sampled sludges where different zones can be identified, zoomed in at 20μm.

Heterogeneity of the sludge studied is observed.

Each type of constituent appears in the SEM in a particular form; it is possible to know the distribution of the different elements in each of the identified areas.

Carbonates (calcites, dolomites) have a variable shape, rarely rhombohedral, they have a transparent aspect. The silica grains consist of spherical quartz with a shiny vitreous appearance. The classic ovoid shape of phosphate grains is observed.

On the images, we were, therefore, able to detect the main majority compounds already determined by the DRX method, namely :

- carbonate grains ;

- Silica/quartz grains;

Scanning electron microscopy allows to observe the texture of the clay sample and to characterise mineralogical assemblages. The images obtained by scanning electron microscopy of the clay sample with different magnifications are shown in figure 5. The clay particles appear as clusters of fine aggregates and rod-shaped platelets with irregular contours as shown by TEM. This is a morphology encountered in both poorly crystallised Kaolinites and Illites as observed by Konan. The image in Figure 3e and in agreement with what we obtained in XRD, there is no doubt about the presence of carbonates and Quartz in

In parallel with the SEM images, we carried out semi-quantitative EDX analyses (Figure 5) of the sample to determine the chemical composition of the clay analysed. Figure 5 shows the chemical elements contained in the clays (Si, Al, Mg, Fe, K, P, S, O, Ca, C), the copper, and the carbon coming from the sample support grid. It should be noted that a strong presence of silicon is mainly due to the majority presence of Quartz in the sample studied. These results confirm those obtained by X-ray fluorescence analysis and X-ray powder diffraction, which the presence of these chemical elements in the form of oxides: Al2O3, SiO2, Fe2O3, MgO, CaCO3, K2O.

- ***Fourier Transform Infrared (IR) Analysis :***

This technique complements the X-ray diffraction characterization in the case of poorly crystallised materials. In Table 4, we summarise the characteristic bands, by infrared spectrometry, of the phases present in the material studied. (Table 1)

Figure 6 below shows the IR spectra of the samples respectively. The obtained IR spectra confirm once again that the composition does not change.

These spectra identify the presence of Calcite, Dolomite, and Silica in the samples studied.

The bands observed at 3700-3600 cm-1 correspond to the valence vibrations of the O-H bond. The band at about 3480.3150 - 1700.1600 is attributable to the angular deformation of H-O-H.

A more intense hook at 1460.1430 - 880.850 - 720.680 cm-1 reveals the presence of the radical CO32-, resulting from the adsorption of carbon dioxide, which leads to the formation of CaCO3.

The band located at 1032.29/1076.85 cm-1 reveals the presence of the PO43- radical.

The bands at 2520.49/2519.17 and 875.07/874.97cm-1 are the least intense, characteristic of valence vibrations of the Ca-O bond.

The well-marked doublets at 573.07/574.99cm-1, 473.13/473.33, and 793.56/792.48 cm-1 correspond to the angular deformation of O-Si-O. (Table 1)

Table 1: IR (**Infrared)** identification of solid phases present in the samples

RADICAL	**Provenances**	**WAVE NUMBERS (frequencies), cm-l**
$CO_3$2-	Calcite : $CaCO_3$	1 460.1 430 - 880.850 - 720.680
HC03-	Dolomite : CaO MgO 2CO_2	2 600.2 400 - 1 020.980 - 850.830 - 720.680 - 670.650
O-Si-O	Silica : SiO_2	1 150.1 080 - 1 020.980 - 680.600 - 500.420 1250.1 200 - 1 100.1 050 - 800.770 - 620.580 - 460.440

H-O-H	H_2O (water of hydration)	3 480.3 150 - 1 700.1 600
OH-	H_2O (water of constitution)	3 700.3 600

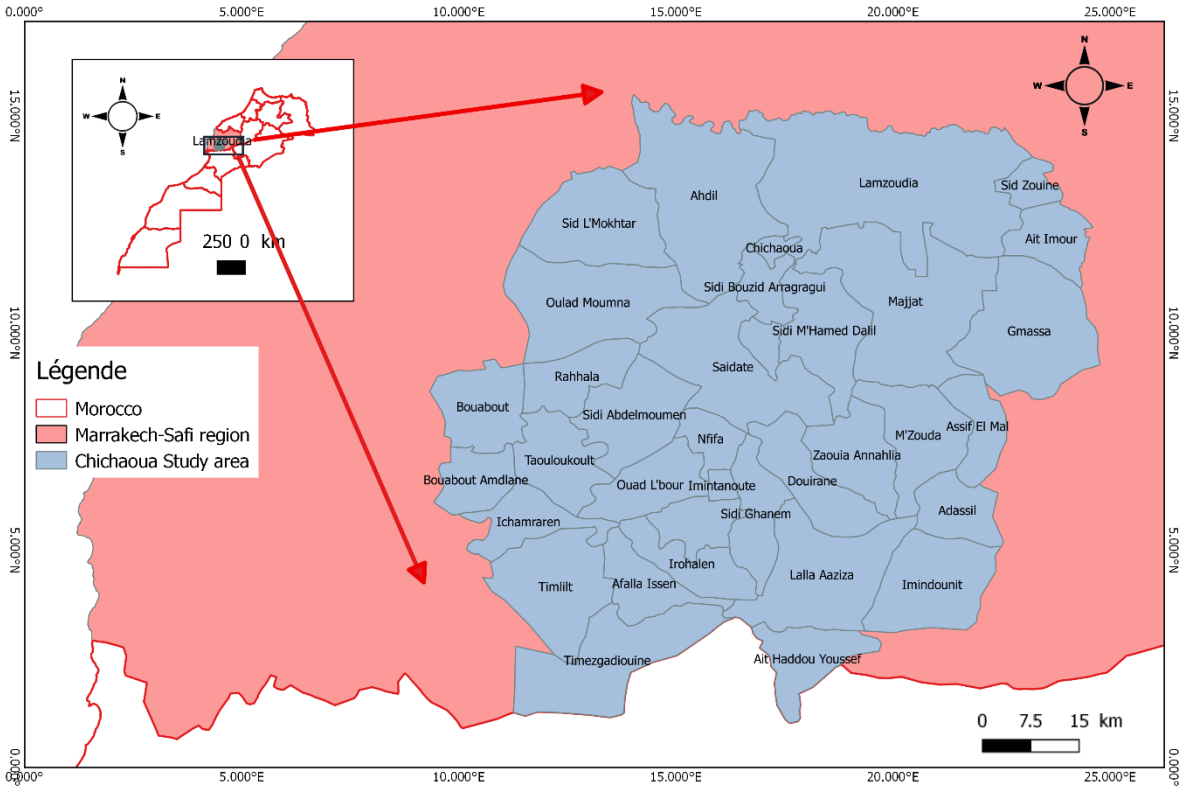

Figure 1: geographical location of the Chichaoua catchmen

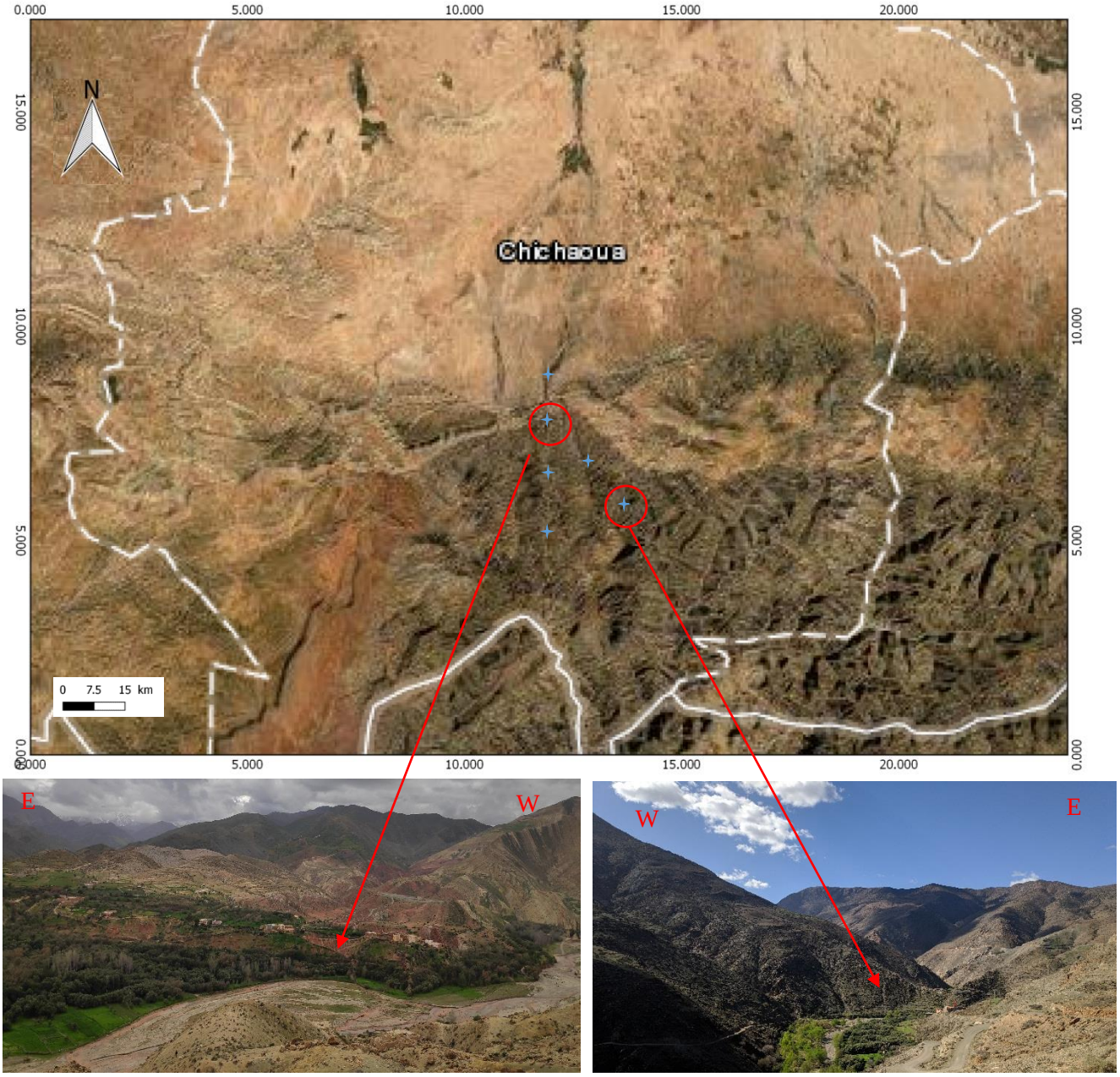

Figure 2: The positions of the samples.

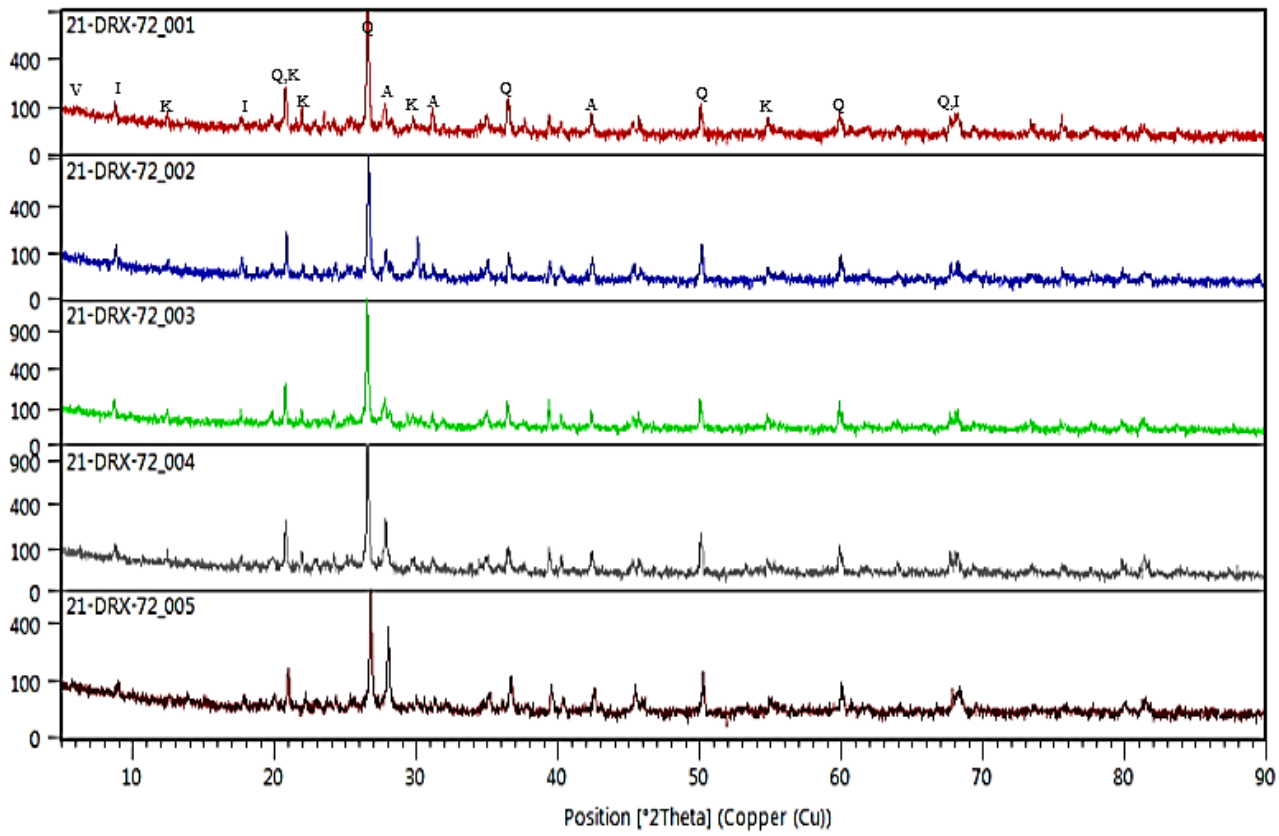

Figure 3: X-ray diffractogram of the raw clay, with K = Kaolinite, I = Illite, Q = Quartz, C= Calcite, V= Vermiculite. Q : SiO2 /Quartz, C : CaCo3 / Calcite, D : CaO MgO 2CO2 / Dolomite, K : Al2Si2O5 (OH) 4 / Kaolanite

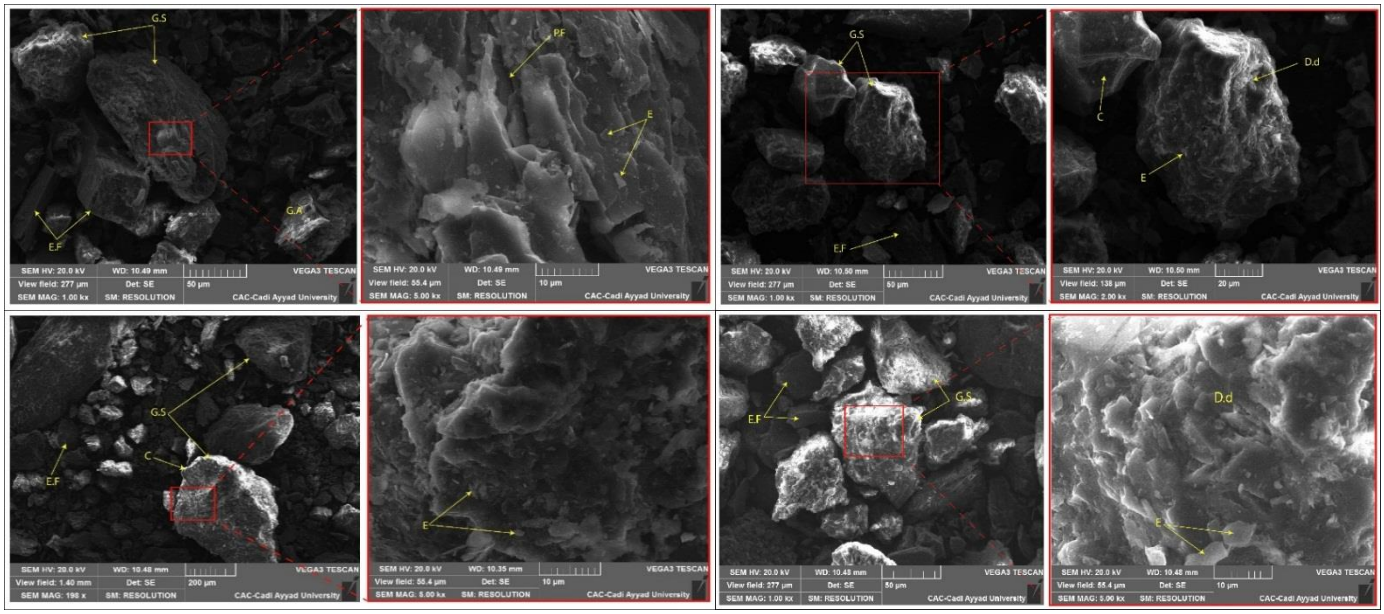

Figure 4: Microscopic observations of samples

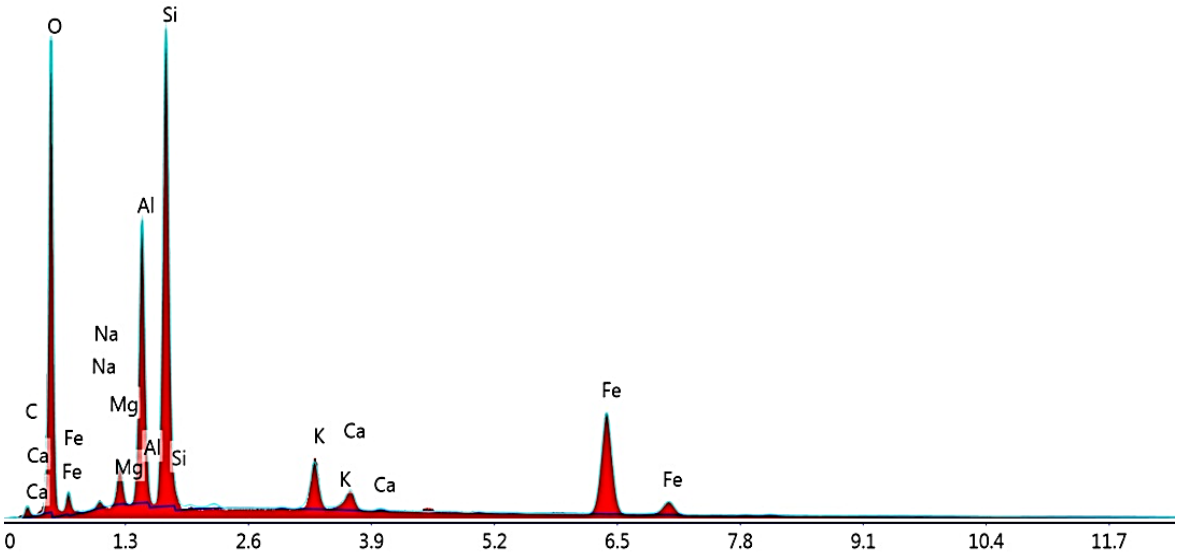

Figure 5: Energy Dispersion Spectrum (EDX) of the raw clay.

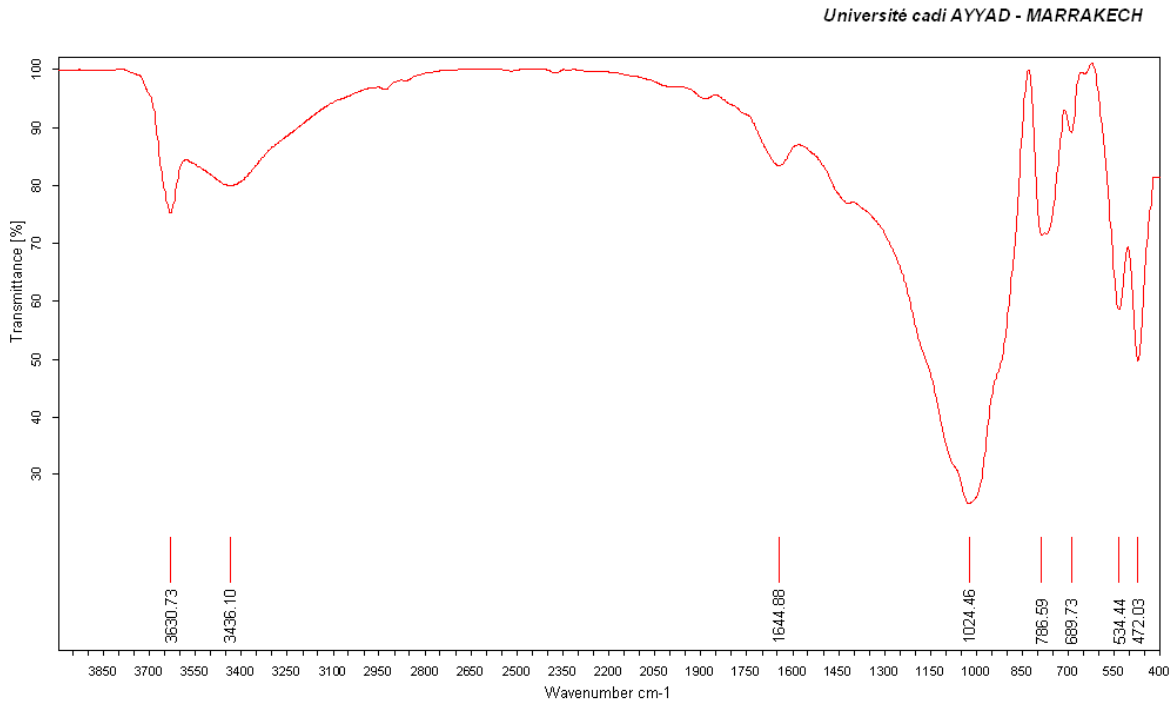

Figure 6: IR (**Infrared)** spectra of Seksaoua Wadi samples.

CONCLUSION

In a conclusion, the different mineralogical characteristics reveal that these samples of either Oued de Seksaoua, its mineralogical distributions constitute several minor elements. Among these elements, we find C, Ca, O, Si, Na, K, Al, S, Mg, P, and Fe. The XRD diffractograms show the presence of the following major phases: quartz SiO2 and carbonates which are in the form of Quartz CaMg(CO3)2 and calcite CaCO3, and minority phases such as Kaolinite, illite, and vermiculite.

As long as, the analysis of the SEM-EDX results shows that each type of constituent has a particular shape; it is possible to know the distribution of the different elements in each of the identified zones. The carbonates (calcites, dolomites) have a variable shape, are rarely rhombohedral, and have a transparent appearance. The silica grains are made up of quartz of spherical form and filamentous and vitreous brilliant aspect.

On the images, we were, therefore, able to detect the main majority compounds already determined by the DRX method, namely: carbonate grains and Silica/quartz grains;

In addition, the results of the Fourier Transform Infrared (IR) analysis. The infrared spectra obtained confirm once again that the composition of these samples does not change almost identically.

These spectra make it possible to identify the presence of Calcite, Dolomite, and Silica in the samples studied.

Thus, the experimental techniques used allowed us to highlight the phyllite and mineral phases as well as the chemical composition of the analysed sample. We have thus established that this clay is also composed of Kaolinite, Illite, and Calcite. These results contains the richness of this clay in Quartz and a high proportion of Silica, and that the clay has low porosity. This study was therefore required before any application of this type of clay in erosion studies.

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Disclosure statement:

Conflict of Interest: The authors declare that there are no conflicts of interest.

CONFLICT OF INTEREST

None Declare

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