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Mineralogical Characterization of Sedimentary Clays of the Main Wadis of the Region of Meknes - Morocco Statistical Approach

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Abstract

This work aims to characterize the clay phase of aquatic sediments of streams of the three main wadis of the region of the city of Meknes, using the technique of oriented blade, as well as the determination of correlations between minerals that constitute this phase by principal component analysis (PCA) on the one hand, and the models formed by the linear regression on the other hand. For this, we have chosen nine stations located upstream, downstream and at the confluence of wadis Boufekrane, Wislane and Toulal.

This characterization indicates the presence of montmorillonite in the first class followed by illite in great abundance, then kaolinite and chlorite. The amount of montmorillonite increases in sediments of stations upstream to downstream of those three wadis, with decrease in the levels of this mineral after each station after confluence. Similarly, at the level of sediments of Wislane and Boufekrane wadis, whose the illite contents are the most important, where we have a decrease from upstream to downstream. Whereas, kaolinite and chlorite present only low levels with non-significant variations.

PCA results showed that there is a very strong correlation between the montmorillonite and illite, as well as the coefficient of determination found by linear regression (LR) is R^2 = 0.95 in clays of all stations.

Keywords: *Sediment, Watercourses, Linear Regression, Clay, Mineralogy, PCA.*

1. Introduction

Clays with their important physicochemical properties that give them the highest sorption capacity [1] [2] and reaction potentials in the natural state are considered as the most active fraction in soils and aquatic sediments [3] [4]. Indeed, it is at this level that happens a lot of important processes on the physicochemical behavior of the soil, mineral nutrition of plants, the genesis, and evolution sediment [5], and power metal retention [6] [7] [8] [9] as well as other aspects of comparable importance. The influence of clay on the properties of aquatic environments depends essentially on the nature and the quantities of the different mineral species that comprise. Indeed, the various clay minerals have characteristic and very distinct properties [10] since they have layered structures and are considered as host materials [2], therefore the existence of several classes of clays, such as smectites (montmorillonite, saponite), mica (illite), kaolinite, serpentine, pylophyllite (talc), vermiculite and sepiolite [11] which close the clay phase.

Furthermore, it is appropriate to be aware of the importance of region of Meknes, rational management of its water resources and their protection against all forms of pollution that could affect their quality.

So we thought it appropriate to characterize qualitatively and quantitatively the clay phase of aquatic sediments of the main wadis of the region of Meknes, and find correlations between these minerals.

For this, we realized samples of surficial sediments at selected sites upstream, downstream and at the confluence of wadis: Boufekrane, Wislane and Toulal. These samples were taken in April 2012.

2. Study Sites

The site of our work is the subject of the wadis Wislane, Boufekrane and Toulal, which play an important socio-economic role for the region of Meknes; one of the most agricultural regions of Morocco. The wadi Boufekrane is a constant stream of the plain of Sais. It flows through the lake basin of the Meknes plateau, whose substrat is composed of sandy limestone Pliocene, and its cover (agricultural land) is tertiary and quaternary age. It rises west of El Hajeb, in Middle Atlasic plateau at 750 meters altitude. He first named Ain Maarouf, then that of Boufekrane 10 km from the source, until after its confluence with the first wadi Toulal that crosses the town Toulal, and secondly with the wadi Wislane (Figure 1).

The latter belongs to the superficial hydrographic network of the region of Meknès originating in the southeast of the village Boufekrane; the width of its watershed is 5 to 6 km on average. These cross the agricultural plain of the plateau of Meknes thus; they separated the city of the agglomeration through the valleys. These three rivers meet downstream of the city of Meknes to form Oued R'Doom, which flows towards the South to the North West with an average gradient of 2 to 3% to into the El Merja Jouab, north of Sidi Slimane, without joining the Oued Sebou.

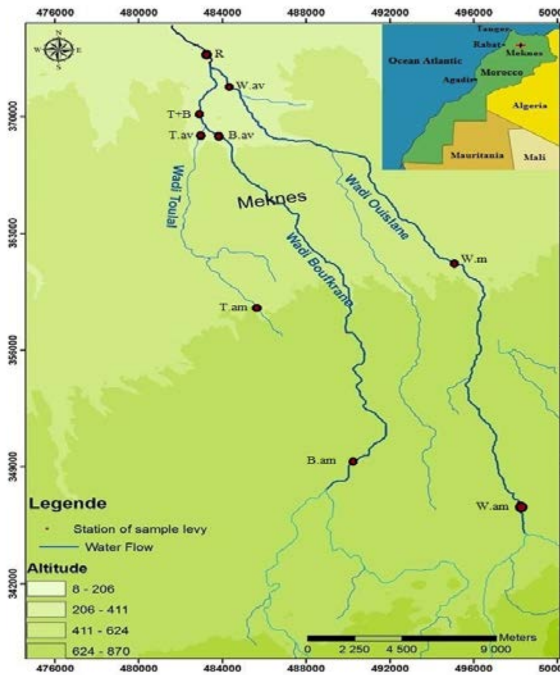


Figure 1 : Location of sampling stations.

3. Sampling

Sediment samples of nine stations located upstream, downstream and at the confluence of watercourses (Table 1) were taken using a plastic grap, taking the precaution to take only the superficial part. This bucket often leads to a quite proper representativeness of the sample from the surface area (3 to 5 cm). Collected sediments are placed in plastic bags, transported in cooler and processed within 24 h

Table 1**:** Appointments stations and their positions relative to the watercourses.

Stations	Watercourse	Situation of the point from the rivers
W.am	Wislane	Upstream
W.m	Wislane	In the Middle
W.av	Wislane	Just before the Confluence of the Wislane Wadi with the Boufekrane Wadi
B.am	Boufekrane	Upstream
B.av	Boufekrane	Just before the confluence of Boufekrane Wadi and Toulal wadi
T.am	Toulal	Upstream
T.av	Toulal	Just before the confluence of the Toulal Wadi and the Boufekrane Wadi
T+B	R'Doom	After the confluence of the Toulal Wadi and the Boufekrane Wadi
R	R'Doom	After the confluence of the Boufekrane and the Wislane Wadi

4. **Materiel and Methods**

The mineralogical study has been done on the fine fraction (<50 microns) isolated from crude sediment by sieving (wet way). To 5 g of this fraction placed in 20 ml of distilled water in a porcelain capsule, we have added 30 ml of a solution of HCl (0.1N). Then we performed an attack with oxygenated water (30 %) overnight at 40°C. After centrifugation at 3000 rpm the mixture submitted to mechanical agitation for 16 h, The sampling of fraction <2 µm is performed using a syringe fitted with a trocar, after decantation of the solution for 50 min. We made the deposit on a glass slide and we let the sedimentary fraction dry on a slightly heated plate (10 C)[12].

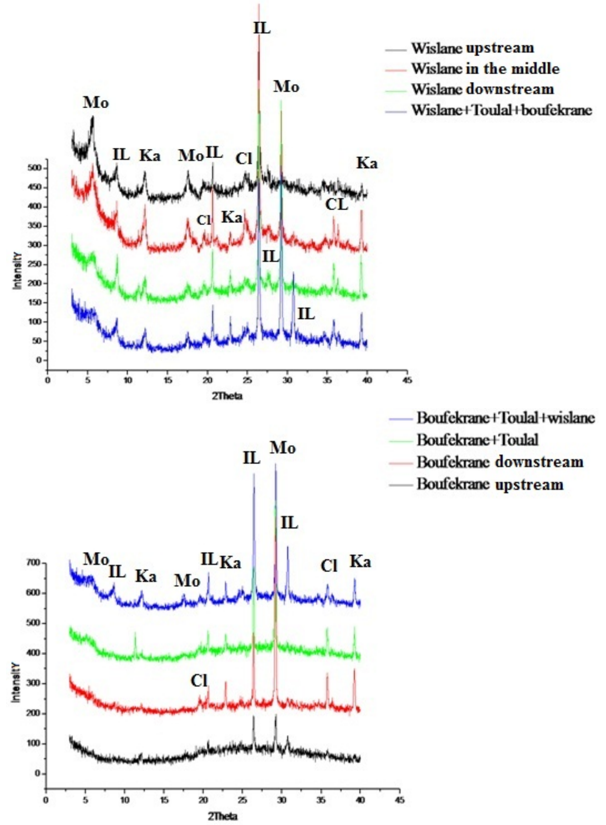
The diffractograms X - ray (XRD) of the analyzed samples were made by a Bruker D8 diffractometer equipped with a copper anticathode (λ = 1.54 Å). The Oriented preparation analysis allowed us to determine the crystalline phases of the samples studied in comparison with those obtained on the listed Crystal references [13].

To determine the relationship that may exist between the minerals, we have chosen to use the (PCA) principal component analysis to the XRD analysis results database. Indeed, the principal component analysis is a statistical method that reduces the size of a data matrix. It transforms a first data set in a second set of smaller dimension compound of new variables, which are linear combinations of original variables [14]. To develop the model that corresponds to the significant correlation found by (PCA) we used the analysis by linear regression to the whole of this correlation data. The analysis by this method involves finding the equation that determines in percentage a clay phase depending on the other phases (polynomial)

5. **Results and Discussions**

The diffractograms in figure 2 correspond to the study sites show that the widespread clay minerals are as follows: Montmorillonite, Illite, Kaolinite, and Chlorite. These minerals are often caused by alteration of feldspars and ferromagnesian minerals or directly by transformation of other pre-existing clay minerals [12].

We mean by: Cl: chlorite; Ka: kaolinite; Mo: montmorillonite; It: illite.



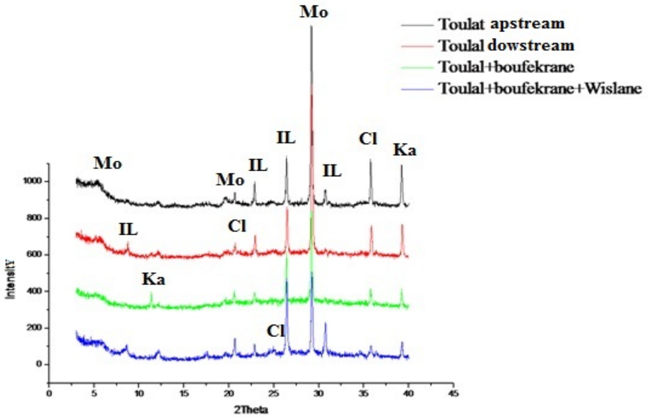


Figure 2 : Diffractograms of the studied clays.

The graphical representation was chosen in a way to illustrate the spatial variation of the upstream to downstream for each wadi also including confluences between these watercourses (Figure 3).

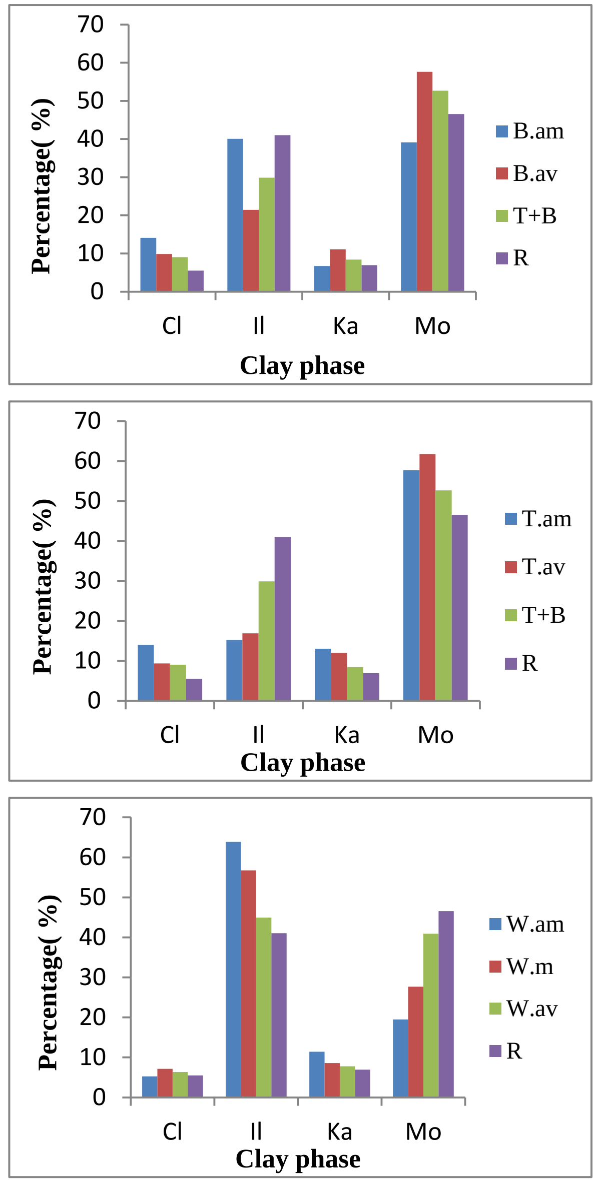


Figure 3: Spatial Variations of the clays, kaolinite, montmorillonite, chlorite and illite of three wadis Wislane Boufekrane and Toulal.

Montmorillonite : It is presented in the clay phase of sediments at all stations with the highest abundance with an average of 44.84% and its percentage varies between 19.48% in the station (W.am) and 61.75% in the (T.Av) station, These quantities increase going from upstream to downstream in the three wadis due to the fact that montmorillonite is a clay mineral of small size that does not exceed 0.1µm, it is transported by rolling over the bottom so that it accumulates the downstream stations. However, we have a decrease of contents in this mineral after each confluence because of the increase in the flow of the water column, so we have a routing by saltation or suspension according to the intensity of flow, Hence the depletion of this mineral in the stations (B+T) and the station (R) representing more lowering. Additionally the Wadi Wislane's stations represent the lowest concentrations in this mineral, Due to the geological nature of the watershed. However, they remain lower than the station (R) located after the last confluence that is enriched by this mineral content coming from the two other wadis.

Illite : Clay widespread in our clay phases, it has been identified in all the samples analyzed present an content with an average of 36.67% and its percentage varies between 15.23% in the station (T.am) and 63.85% in the station (W.am). At the level of Wislane and Boufekrane wadis, wherein the contents of this mineral are the most important, we saw a decrease in the downstream direction probably due to the deterioration of the less rigid detrital mineral during its transport in sediment of our wadis. As for Oued Toulal, illite is presented with slightly lower percentages near 15%, no doubt the conditions of the aquatic environment did not favor the formation of illite that comes with pre-existing mineral transformations. Furthermore, for the stations after the confluences (B+T) and (R), we have an additive concentration aspect of what remains of this mineral maintained during transport in these sediments.

Kaolinite : Probably comes from fine alluvium from the Quaternary, developed in warm climate and hydrolyzing, thus the alteration of feldspars and granites, whose longitudinal variations shows it is not abundant in sediments at all stations, with an average of 9.56% oscillating between 6.75% at the station (B.am) and 13.03% at station (T.am), with a not-significant variation of the percentage of this mineral.

Chlorite : This is a clay mineral from crystalline rocks and cristallophylliennes, the variations show that this mineral is present in the stations with the lower percentages that vary between 5.25% and 14.09% with an average of 8.95% , such as Kaolinite, the contents do not show a significant variation.

6. Statistical Analyses

The results of this analysis showed that the first factor component (F1) explains 65.44% of the variance and the second component (F2) explains 20.27%. Thus the first two components account for nearly 85.71% of the total variance and the other factorial components (F3, F4) have only a small contribution compared to the total inertia, so the only factor plane F1 x F2 to be discussed (figure 4).

Table 2 shows the correlations matrix between these clay minerals. We have put in bold the correlation coefficients values above the critical value Rc, which is given by the usual tables found in the literature in data analysis and statistics[15]. The values Rc depend on the number of individuals n and the confidence interval α_c wanted. In our case n = 9 and α_c = 95% so Rc = 0.70.

This analysis shows a very good negative correlation between montmorillonite and illite, in the studied sediments, with a coefficient of (R = -0.97). Therefore, the study of montmorillonite of sediment can provide information on the illite content of this sediment. So we can say that the longitudinal variations of these two minerals are opposed, indeed any decrease in the proportion of a mineral causes the increase in the proportion of the other. The existence of a highly significant correlation shows that in favorable conditions for the preservation of montmorillonite, we are witnessing the deterioration of illite and vice versa.

Table 2: Correlation coefficients between the variables (R)

Variables	Ch	Il	Ka	Mo
Chlorite	**1**			
Illite	-0.63	**1**		
Kaolinite	0.23	-0.44	**1**	
Montmorillonite	0.48	**-0.98**	0.31	**1**

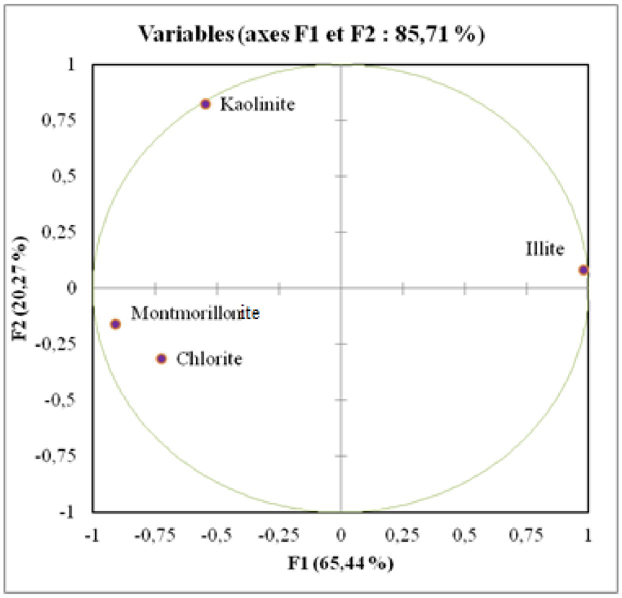


Figure 4: Correlation circle between the clay phases

According to the correlation circle, we remark that there is a very strong inversely proportional relationship between montmorillonite and illite of clays of three wadis in considerations. Indeed. we used linear regression (LR) to determine the determination coefficients of model connecting montmorillonite with illite for each wadi thus for all studied stations (Table 3).

Still, these coefficients between the two minerals calculated from the model. vary between a minimum value R^2= 0.79 to Wadi Boufekrane and a maximum value R^2= 0.98 recorded in Wadi Wislane. Whereas, this coefficient is equal to 0.95 for the application of the LR on all stations studied. this high value of R shows the strong correlation which exist between the montmorillonite and illite. This confirms the results found by the PCA.

Table3: Coefficients of determination R^2 between montmorillonite and illite

Sites	R^2
Wadi Wislane	0.98
Wadi Toulal	0.90
Wadi Boufekrane	0.79
All stations	0.95

7. Conclusion

The mineralogy of sedimentary clays studied superficial of watercourses (<2 .µm), which represents the interest of our research, is characterized mostly by a dominance of montmorillonite in all stations with an average of 44.84%, followed by the illite in great abundance illustrated by an average of 36.67%. While the two other minerals kaolinite and chlorite are in a minority in all stations.

The results of principal component analysis showed that the montmorillonite correlates significantly and negatively with illite thus that the determination coefficient found by the model developed with the linear regression records a value R^2= 0.95. Indeed, the conditions that promote the preservation of montmorillonite, generate the deterioration of illite and vice versa.

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