Analysis of the behavior of Tunja diatoms, before dispersive effect, acidity and suction

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Abstract. The present article analyzes some physical and chemical properties, which can influence the behavior of the diatoms present in the eastern part of the city of Tunja, by identifying and exploring three outcrops arranged in the territory, three characteristics to be evaluated and defined their respective laboratory tests were carried out in order to be able to estimate their behavior, analyzing parameters such as the dispersive effect using the pinhole test, acidity with hydrogen potential measurement and suction using the filter paper method. Prior to this, general characterization tests were developed, that is: Atterberg limits, specific gravity and hydrometer granulometry, carried out according to the respective regulations, the analysis of the results obtained and the pertinent recommendations are made in a particular way for each outcrop and in general form for the deposit of the city, defining the predominant values of the characteristics considered.

1. Introduction
The eastern part of the city of Tunja, capital of the department of Boyacá, has an important urban development, generating an anthropological interaction with the strong environment; the eastern fringe presents particular landscape, erosive, physiographic and geological qualities, such as the presence of diatomite deposits, these sedimentary rocks composed of diatoms that correspond to unicellular, eukaryotic and photosynthetic aquatic plants, belong to the bacillariophyceae family, some 100,000 have been described species [1], its extensive industrial use derived from its particular physical and chemical characteristics makes it an element of great interest, this allows to give greater value to the natural resources of the area, consolidating a line of research to strengthen and collect the information or knowledge about this deposit as the work done by Naranjo et al. [2], on the other hand, the application of knowledge of unsaturated soils, erodability and acidity, as characteristics not commonly analyzed, foster the interest for the realization of this research work.

In the project of cartography and characterization of diatoms sector Tunja, Soraca, Oicata, Tuta, department of Boyacá, Colombia, developed by the mines and energy ministry, an estimated resource of 2818792 t of diatomite was obtained, which corresponds to an area of 1.18 km², evidencing the important influence that this deposit generates in the city, understanding that in the area where this deposit is present, at present urban development projects are developed, where this material generates a close relationship with the population soil [3].

Acidity plays important roles in the behavior of soils as a descriptive value of the mineral solubility, the mobility of ions that the soil can present and the viability of the soil, being a determining factor for the vegetation of the area, the degradation of the soil can be observed as
nutrient depletion, erosion, low bioactivity and contamination of the soil [4-7], some of which are present in the area; the particular characteristics of the study site, the topographic and geomorphological configuration, the high slope colliding with an alluvial valley [8], the presence of gullies, furrows and superficial disintegration of the materials, shows an erosion degree of importance, the erosive sensitivity. It can have a large number of factors including soil dispersivity, its evaluation is done through the pin-hole analysis or erosion in tunnel [9], in this way the subsurface erosion processes are related, the development of the process of its fusion is the formation of a network of subpurfial ducts of variable size [10], in 1976 an objective measurement method was proposed for hydraulic works as dams, called pin-hole test [11], which is regulated by American standards [12].

On the other hand, the characteristic mechanical suction of partially saturated soils, the study of the same had its origin in the sixties in the United States and Canada, in order to study the behavior of some problem soils, expansive or collapsible type [13], this area of soils, as many authors mention, is not part of classical mechanics, where it is little studied; however, at present this type of analysis has taken on importance, taking into account the values of triaxial cutting tests and trials. The total suction is referred to as the amount of energy associated with the capacity of the soil to retain water [14], its measurement can be done by different methods, among them the measurement with filter paper which involves a special filter paper and a detailed process for its execution.

2. Experimental development
In The samples of diatoms were extracted by means of pits, in three outcrops located in the city of Tunja, in the sectors of San Antonio, Xativilla and Terminal, where four samples were taken for each of these sites, coding them with initial letter of the place of exploration and the sample number, for the pH procedure a potentiometer starter 3100 table-type meter was used, as for the test of pinholle a Humbolt HM-3930 was used, finally for the filter paper method 42-size Whatman paper was used, in addition to this process, carry out a chemical characterization using X-ray fluorescence tests, scanning with an electron scanning microscope and physical characterization.

2.1. Fluorescence of X-rays
The respective test was performed on the selected sample, where the following results were obtained, Table 1 noting that the main element corresponds to silica with 83.3%, followed by iron with 11.3% and Magnesium 4.1%. In the same way in Figure 1, the spectrum obtained is shown.

| Compound | Mg% | Si% | S% | K% | Ti% | Fe% |
|----------|-----|-----|----|----|-----|-----|
| Conc.    | 4.1 | 83.3| 0.50| 0.45| 0.35 | 11.3 |

Figure 1. Result spectra diatomaceous.
2.2. Scanning electron microscope

The scanning electron microscopy (SEM) was used for the determination of: morphospecies, size of the frustules and diameter of the areolas (pores) of the diatoms, as well as the identification of associated minerals.

The most abundant species is the Aulacoseira granulata (Ehrenberg) see Figure 2, in these, the frustules are cylindrical, are joined forming straight and long chains, and have circular valves. The union between neighboring valves is given by thorns that are in the edge, the thorns are widened in the base and they are embedded in the adjacent valve. There are long spines which attach in longitudinal grooves that are between the lines of the areolas of the mantle of the neighboring diatom. The areolas of the mantle are arranged in diagonal rows. The diameter of the areoles is 506.0 nm, the length of the frustule is variable from 10.00 μm to 21.38 μm, and its width is from 9.44 μm to 19.00 μm.

![Figure 2. Images of diatoms in SEM. (a) General image of the sample at 1.0 X, (b) Aulacoseira Granulata at 5X, (c) Morphology Aulacoseira Granulata at 3X, (d) Aulacoseira Granulata at 5X, (e) Staurosirella pinnata (Ehrenberg) at 10X and (f) Staurosirella pinnata at 10X.](image-url)
This species grows on muddy substratum, on and around submerged aquatic vegetation, lives in lakes, ponds and rivers, in freshwater environments, with very restricted salt concentrations. In environments with high concentration of nutrients (eutrophic) and temperatures between 15 °C and 30 °C [15]. In general, the Aulacoseira granulata has a very wide distribution. In Colombia they are found in relatively shallow lakes. Four other types of structures that are shown in Figure 3 are also highlighted.

![Figure 3. Other types of diatoms observed in SEM. (a) Gomphonema sp3, (b) Staurosirella leptostauron (Ehrenberg), (c) Navicula radiosa and (d) Navicula radiosa and Aulacoseira Granulata (Ehrenberg).](image)

3. Results and data obtained
The results obtained for each of the proposed tests are the following:

3.1. Limits of Atterberg and specific gravity
The values obtained for each of the samples are values of great magnitude and are shown in Table 2.

3.2. Acidity hydrogen potential
The Table 3 shows the statistical results obtained for each site, including as a whole, having the lowest range in the Xativilla sample where the hydrogen potential (PH) values was 3.98 and the highest range in the Terminal sample where the PH is 4.61, however the average value recorded in the area is PH the 4.06.

3.3. Pinhole test
The respective pin hole tests were performed on unaltered samples, where the results obtained from San Antonio and Xativilla remained intact until the flow of water until the end of the test, indicating that these soils are not susceptible to dispersion, however, the samples taken from the Terminal
showed dispersion of particles in the water at different pressure heads as follows, T1 and T3 at 7 in, T2 at 2 in, T4 at 15 in, indicating a medium susceptibility to dispersion.

| Sample | Liquid limit (%) | Plastic limit (%) | Plastic index (%) | Specific Gravity |
|--------|-----------------|------------------|------------------|-----------------|
| S1     | 121.93          | 90.90            | 31.03            | 2.294           |
| S2     | 120.63          | 88.30            | 32.33            | 2.555           |
| S3     | 109.24          | 69.24            | 40.00            | 2.320           |
| S4     | 99.74           | 68.96            | 30.78            | 2.475           |
| X1     | 97.01           | 66.29            | 30.72            | 2.673           |
| X2     | 78.21           | 53.40            | 24.81            | 2.719           |
| X3     | 164.78          | 86.91            | 77.87            | 2.799           |
| X4     | 132.21          | 81.20            | 51.01            | 2.564           |
| T1     | 94.76           | 59.54            | 35.22            | 2.376           |
| T2     | 80.24           | 56.10            | 24.14            | 2.357           |
| T3     | 95.78           | 49.67            | 46.11            | 2.394           |
| T4     | 63.84           | 56.88            | 6.96             | 2.578           |

Table 3. Statistical analyzes for PH values.

| Measure                    | San Antonio | Xativilla | Terminal | Total |
|----------------------------|-------------|-----------|----------|-------|
| Count                      | 16          | 16        | 16       | 48    |
| Average                    | 3.98        | 3.58      | 4.61     | 4.06  |
| Standard deviation         | 0.25        | 0.06      | 0.24     | 0.47  |
| Coeff. of variation (%)    | 6.17        | 1.54      | 5.28     | 11.58 |
| Minimum                    | 3.49        | 3.49      | 4.15     | 3.49  |
| Maximum                    | 4.32        | 3.70      | 4.93     | 4.93  |
| Range                      | 0.83        | 0.21      | 0.78     | 1.44  |
| Std. Skewness              | -2.10       | 0.63      | -1.01    | 1.08  |
| Std. kurtosis              | 0.60        | 0.29      | -0.40    | -1.67 |

3.4. Suction test

The suction values with the salt equilibrium method have a different behavior for all samples, especially the San Antonio sample, showing a decrease in the value of the suction, see Table 4 and Figure 4, it also shows higher values corresponding to the samples from Xativilla and the samples from San Antonio, in addition to the moisture content of the samples for each environment were different.

![Suction behavior response of studied sites.](image)
Table 4. Suction obtained in different moisture content and their respective saturation.

| Sample      | Wn % | Suction (KPa) | Saturation (%) |
|-------------|------|---------------|----------------|
| Xativilla   | 18.45 | 15237.86     | 49.62          |
|             | 23.47 | 10886.69     | 63.10          |
|             | 47.32 | 6245.58      | 127.25         |
|             | 20.87 | 8233.04      | 50.32          |
| San Antonio | 22.58 | 9718.50      | 54.44          |
|             | 33.82 | 2993.68      | 81.53          |
|             | 18.74 | 11117.95     | 45.47          |
| Terminal    | 21.68 | 10167.98     | 52.61          |
|             | 27.57 | 9072.53      | 66.88          |

4. Conclusions
According to the three studied sites it was found that the samples taken from Terminal show an erosive behavior, typical of the conditions of the area and that influence the behavior of the area manifested by an intense effect generating gullies in the area of location.

All the PH values are in a range of between 3.49 and 4.93; they are located in the acid range being less than 7.0, which would suppose a cation activity.

The values obtained for suction reflect that despite being in the same environment the samples showed differences in their moisture, their range is between 15.2 MPa and 2.99 MPa, for moisture 18.45% and 33.82%.

The direct relationship between compaction and suction energy is related to the number of pores, the greater the compaction, the lower percentage of pores, which means that at a lower percentage of pore, the soil matrix increases its suction value.

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