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Textural and Petrographic Characterization of the Soil of Amtiman (South-East Chad)

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Abstract

The textural and petrographic characteristics of the soils of the city of Amtiman and their behavior on swelling and shrinkage are presented here.

The soils of the town of Amtiman (Chad) have a predominantly clay texture and the clays are mainly exposed on the surface. The results of this work include characterizing the type of clay present in the city. These are the heterogeneous layers of clayey soils consisting mainly of surface-bound illites but also of kaolinite intercalation at depth.

These results suggest that the phenomenon of shrinkage of the clays (Illite and kaolinite) of the city of Amtiman is very low and that this city belongs to the sedimentary basin of Salamat.

Keywords: Amtiman, Chad, characterization, clays, illite, kaolinite, low absorbent

1. Introduction

A good knowledge of the textural and petrographic properties of soils allows us to understand the geological context and their behavior in various applications. Geological surveys in the town of Amtiman, the chief place of the Salamat region, are almost absent and not detailed except for the geological reconnaissance map of Chad (Fig.1). The present study was initiated in order to contribute to the textural and petrographic characterization of the soil of the city. It consisted of carrying out analyzes on soil samples of the city of Amtiman at the Laboratory of the International University of Africa in the Republic of Sudan.

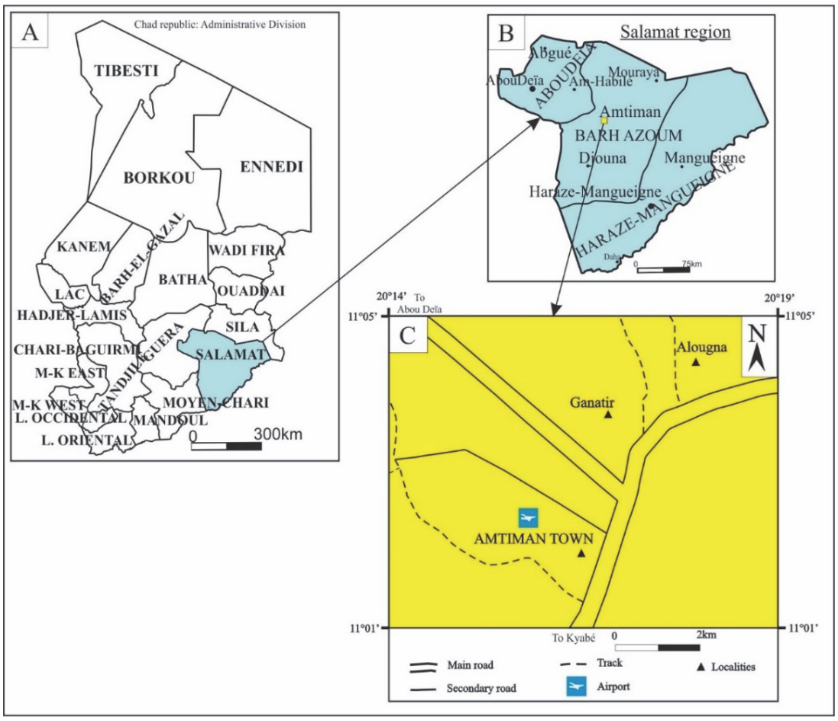

Figure 1. Location map of the study area. (Extracted from the Chad Administrative Division map and communication channels at the scale of 1/7 000 000 INSEED, 2009). A: Map of Chad. B: Map of the Salamat region. C: Study area

2. METHODOLOY

2.1 Location of Study Sites and Sampling

In order to have representative samples of the city, the sites were chosen in different parts of the city (Fig. 2). The sampling was carried out by core sampling (Fig. 3). The reworked samples (Fig. 4) were used for mineralogical and textural analyzes.

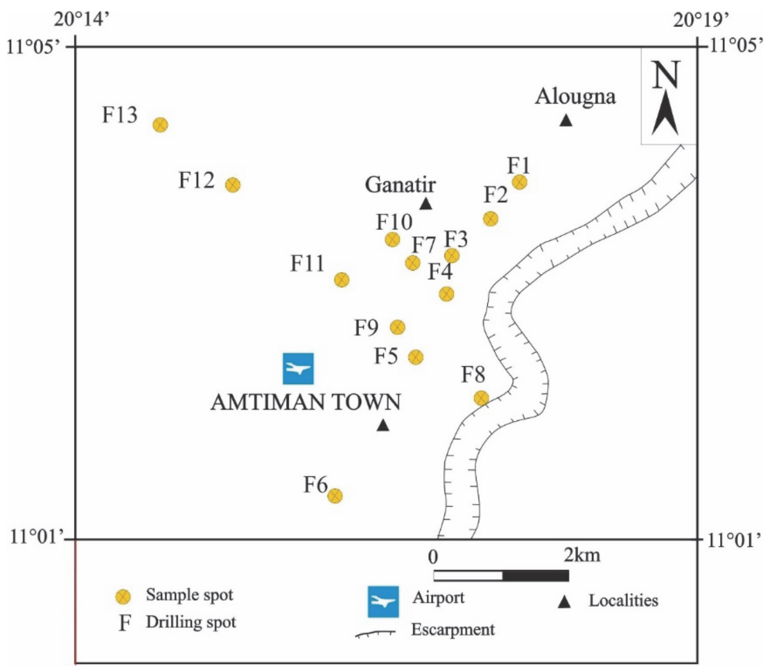

Figure 2. Sampling map

Figure 3. Clay samples from drilling

Figure 4. Samples of sand from drilling

2.2 Experimentation

The petrographic study was carried out by the macroscopic description of the sequences (Fig. 5).

The texture of the soil studied was determined according to the following procedure:

42 grams of soil dried for 72 hours previously passed through a 2 mm sieve, to which 50 ml of sodium hexametaphosphate $(NaPO_3)_6$ are added, are introduced into a glass tube. The mixture is allowed to stand for ten minutes. This mixture is then introduced into the tube of the electric stirrer and kneaded for at least 5 minutes. The kneaded material is introduced into a 1000 ml test piece and distilled water is added to the 1000 ml graduation; the whole is stirred with a mechanical stirrer for 10 strokes. In addition, a control sample consisting solely of sodium hexametaphosphate $(NaPO_3)_6$ and distilled water is prepared. Reading is carried out after 40 seconds for the preparation as well as for the control by means of a densimeter and the corresponding temperature is taken with the aid of a thermometer. A second reading is made after 2 hours.

The percentage determination of particles is made by the following formulas:

$$R_1 = \frac{(Lm1 - Lt1) \pm (T° - 19{,}4)\ 0{,}36}{Msec} \text{ x } 100 \text{ and } R_2 = \frac{(Lm2 - Lt2) \pm (T° - 19{,}4)\ 0{,}36}{Msec} \text{ x } 100$$

Where Lm1 and Lm2 designate the reading of the preparation after 40 seconds and 2 hours respectively;

Lt1 and Lt2 respectively indicate the reading of the control after 40 seconds and 2 hours;

T ° temperature at 40s and at 2 hours depending on the case; 19.4: Temperature of the hydrometer; 0.36: conventional temperature factor; Msec: Mass of the sample in the dry state.

With R1 = clay + silt; R2 = Clay and Sand = 100 - R1

The percentages of the silts, sands and clays obtained are plotted in the textural classification diagram. The classification used is that of WRB (FAO, 2006) which defines thirteen (13) texture classes according to the relative proportions of sand, silt and clay (Table 2 and Fig. 6).

The mineralogical composition obtained by the X-ray diffraction analysis was carried out only on the fine fraction obtained by decantation. The X-ray diffraction devise is Philips type operating at 40 kv and 50 mA. It is connected to a computer that directly gives the diffractogram. The analysis of the diffractogram is done using the X'PERT DATA VIEWER software. The results are shown in Table 1.

3. Results and Discussion

3.1 Macroscopic Description of the Sequences

The soils of the study area have heterogeneous layers as a function of depth. Two representative sequences have been chosen and presented in figure 5.

The lithology of borehole 6 (Fig.5a) has six (6) levels from top to bottom:

- level 1: layer of brown clay, one (1) m thick from 0 to 1m deep;
- level 2: gray to green clay, one (1) m thick from 1 to 2 m deep;
- level 3: clayey layer, black in color, 3m thick, from 2 to 5m deep;
- level 4: brown clay with a thickness of 4m ranging from 5 to 9m deep;
- level 5: sandy clay, the thickness of which is 3m, from 9 to 12m deep;
- level 6: sandy layer with mixed grains, 8m thick from 12 to 20m deep;

The lithology of borehole 8 (Figure 5b) also shows six (6) levels from top to bottom:

- level 1: clayey layer, gray in color, 3 m thick, ranging from 0 to 3 m deep;
- level 2: clay layer, black in color, 4 m thick, 3 to 7 m deep;
- level 3: clayey layer, gray in color, 3m thick (7 to 10m) deep;
- level 4: sandy clay, 4m thick, ranging from 10 to 14m deep;
- level 5: sandy coarse layer, with a thickness of 2 m and a depth of 14 to 16 m;
- level 6: sandy layer with mixed grains, 4m thick, ranging from 16 to 20m deep.

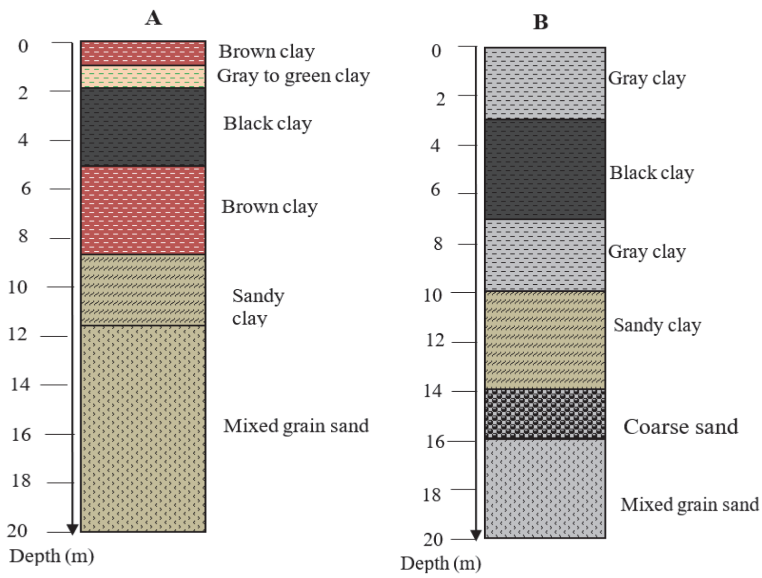

Figure 5. Lithological logs. A: Drilling 6; B: Drilling 8

This description shows that the soil has heterogeneous layers in most of the boreholes. This agrees with the description of Boudlal Omar (2013).

3.2 Mineralogy

The mineralogical analysis of the fine fraction carried out on twenty (20) samples reveals that the minerals identified are in decreasing order of abundance: illite, kaolinite, interstratified, chlorite and smectite. These results are summarized in Table 1. The results obtained are consistent with the study by Berezantsev et al. (1961) which shows that the most prevalent minerals are kaolinite, montmorillonite and illite. The illite abundance of these soils shows their low absorptive capacity as well as swelling. The kaolinite and illite clays are relatively more stable with respect to their adsorption and absorption capacity (Eslinger et Peaver, 1988). Likewise, they are stable clays with a swelling-shrinkage effect, and can thus be used in the foundations of dwellings (Parker et Rae, 19890; Maison, 2011). The difference in cation exchange capacity values of kaolinite and illite is small (Laribi et al., 2009).

Table 1. Mineralogical Composition of Amtiman fine soils

Nº	Sample	Depth (m) (m)	Kaolinite (%) (%)	Smectite (%) (%)	Illite (%) (%)	Chlorite (%) (%)	Smectite/Illite (%) (%)
1	F1c	1-2.5	19.62	0.08	80.10	0.12	0.08
2	F2a	0-1	12.88	0.09	86.79	0.14	0.09
3	F2b	1-2	24.33	0.08	71.13	0.12	4.34
4	F3a	0-3	18.71	0.10	77.52	0.15	3.51
5	F3c	4-9	28.63	0.13	70.93	0.19	0.13
6	F4a	0-1,35	24.33	0.07	75.42	0.11	0.07
7	F4f	5-6	93.81	0.79	3.44	1.17	0.79
8	F5b	1-2	19.62	0.08	80.10	0.12	0.08
9	F5d	3-4	92.75	0.93	4.03	1.37	0.93
10	F5h	7-8	95.19	0.61	2.67	0.91	0.61
11	F6h	9-12	96.88	0.40	1.73	0.59	0.40
12	F7f	7-11	94.93	0.65	2.82	0.96	0.65
13	F9b	2-3	21.25	0.11	78.37	0.16	0.11
14	F10c	4-5	34.28	0.12	65.31	0.18	0.12
15	F11a	0-1	26.56	0.07	73.21	0.10	0.07
16	F11b	1-2	21.61	0.07	78.13	0.11	0.07
17	F12a	0-2	14.36	0.12	85.23	0.17	0.12
18	F12b	2-5	13.55	0.06	86.23	0.10	0.06
19	F13a	0-1	16.83	0.06	82.96	0.09	0.06
20	F13c	2.65-4	17.30	0.07	82.45	0.10	0.07

These results do not agree with those of Gourouza et al. (2003), according to which the mixed clays of Niger consist of 34% montmorillonite, 24% kaolinite, 17% illite and 25% interstratified illite / smectite.

3.3 Textural Classification

Physical parameters are used to characterize a soil on the physical plane. The classification is generally used for fine soils whose particles are classified according to their dimensions into three (03) fractions: sand, silt and clay. Indeed, clays are very abundant in nature and cover about 42% of the volume of the Earth's crust (Wakim, 2005; Qlihaa et al., 2016).

The WRB classification (FAO, 2006) defines thirteen (13) texture classes according to the relative proportions of sand, silt and clay. These are loamy clays, clays, silty clays, sandy clays, clay loams, fine clay loams, sandy clay loams, silts, fine silts, very fine silts, sandy loams, silty sands, sand. Each texture class defines a range in a triangular diagram whose vertices are occupied by clay, silt and sand and is called a textural triangle (Fig. 6). After physical analysis of a soil, its textural class is determined by projecting the relative proportions of each fraction into the textural triangle.

Ninety-eight (88) samples from 13 boreholes were analyzed and the results are shown in Table 2.

Table 2. Fine particle size distribution of clay materials.

Samples	Clay (%)	Silt (%)	Sand (%)	WRB Classification
Borehole 1				
F1b	53.14	35.00	11.86	Clay
F1c	53.14	35.00	11.86	Clay
F1d	45.64	38.00	15.61	Clay
F1f	61.89	8.75	29.36	Clay loam
F1g	59.39	15.61	25.00	Clay
F1h	51.89	13.75	34.36	Clay
Borehole 2				
F2a	26.89	21.25	51.86	Sandy clay loam
F2b	40.64	47.50	11.86	Fine clay loam
F2c	39.39	52.50	8.11	Fine clay loam
F2c	46.89	41.50	11.86	Loam clay
F2d	81.89	6.25	11.86	Clay loam
F2e	83.14	5.00	11.86	Clay loam
Borehole 3				
F3a	29.74	41.25	29.01	Loam clay
F3a	42.24	40.00	17.76	Loam clay
F3a	25.99	26.25	47.76	Sandy clay loam
F3b	50.99	45.00	4.01	Clay loam
F3c	70.99	10.00	19.01	Loam clay
F3c	67.24	15.00	17.76	Loam clay
F3c	57.24	26.25	16.51	Clay
Borehole 4				
F4a	39.04	30.00	30.96	Clay loam
F4b	32.79	23.75	43.46	Clay loam
F4d	80.29	18.75	0.96	Loam clay
F4e	86.89	1.25	11.86	Loam clay
F4f	86.89	1.25	11.86	Loam clay
F4g	85.29	13.75	0.96	Loam clay
F4H	86.89	1.25	11.86	Loam clay
F4i	64.04	10.00	25.96	Loam clay
F4j	64.04	5.00	30.96	Loam clay
Borehole 5				
F5a	69.74	26.25	4.01	Loam clay
F5b	47.04	25.00	27.96	Clay
F5c	72.24	18.75	9.01	Loam clay
F5d	69.74	22.50	7.76	Loam clay
F5e	72.24	23.75	4.01	Loam clay
F5f	67.04	26.25	6.71	Loam clay
F5g	72.24	23.75	4.01	Loam clay
F5h	54.54	12.50	32.96	Clay
F5i	54.74	21.25	24.01	Clay
F5j	59.54	17.50	22.96	Clay
Borehole 6				
F6a	54.54	38.75	6.71	Clay
F6b	54.54	27.50	17.96	Clay
F6d	70.79	18.75	10.46	Loam clay
F6e	67.04	26.25	6.71	Loam clay
F6f	67.04	22.50	10.46	Loam clay
F6h	34.54	15.00	50.46	Sandy clay loam
F6h	39.54	17.50	42.96	Clay loam
Borehole 7				
F7a	36.54	62.50	0.96	Fine clay loam

Samples	Clay (%)	Silt (%)	Sand (%)	WRB Classification
F7a	56.54	30.00	13.46	Clay
F7a	36.54	45.00	18.46	Fine clay loam
F7b	81.54	17.50	0.96	Loam clay
F7c	81.54	17.50	0.96	Loam clay
F7d	72.79	13.75	13.46	Loam clay
F7e	44.04	25.00	30.96	Clay
F7e	44.04	25.00	30.96	Clay
Borehole 8				
F8a	52.04	35.00	12.96	Clay
F8a	32.04	50.00	17.96	Fine clay loam
F8b	73.29	21.25	5.46	Loam clay
F8c	77.04	17.50	5.46	Loam clay
F8d	73.29	18.75	7.96	Loam clay
F8f	55.64	20.00	24.36	Clay
Borehole 9				
F9a	35.64	57.50	6.86	Fine clay loam
F9a	25.64	42.50	31.86	Silt
F9b	64.39	31.25	4.36	Loam clay e
F9c	65.64	25.00	9.36	Loam clay
F9c	64.39	31.25	4.36	Loam clay
F9e	18.14	64.00	16.86	Fine silt
F9e	25.64	42.50	31.86	Silt
Borehole 10				
F10a	34.04	65.00	0.96	Fine clay loam
F10a	65.29	23.75	10.96	Loam clay
F10b	66.54	12.50	20.96	Loam clay
F10c	64.04	15.00	20.96	Loam clay
F10d	30.29	12.50	57.21	Sandy clay loam
Borehole 11				
F11a	70.29	21.25	8.46	Loam clay
F11b	34.04	26.25	39.71	Clay loam
F11c	28.14	13.75	58.11	Sandy clay loam
F11e	39.04	17.50	43.46	Clay loam
Borehole 12				
F12a	38.14	8.75	53.11	Sandy clay
F12a	28.14	11.25	60.61	Sandy clay loam
F12b	20.64	13.75	65.61	Sandy clay loam
F12c	35.64	3.75	60.61	Sandy clay
Borehole 13				
F13a	62.79	30.00	7.21	Loam clay
F13b	43.14	45.00	11.86	Clay loam
F13c	30.29	33.75	35.96	Clay loam
F13c	38.14	53.75	8.11	Fine clay loam
F13d	26.54	10.00	63.46	Sandy clay loam
F13d	22.79	13.75	63.46	Sandy clay loam
F13e	22.79	1.25	75.96	Sandy clay loam
F13e	20.64	7.50	71.86	Sandy clay loam

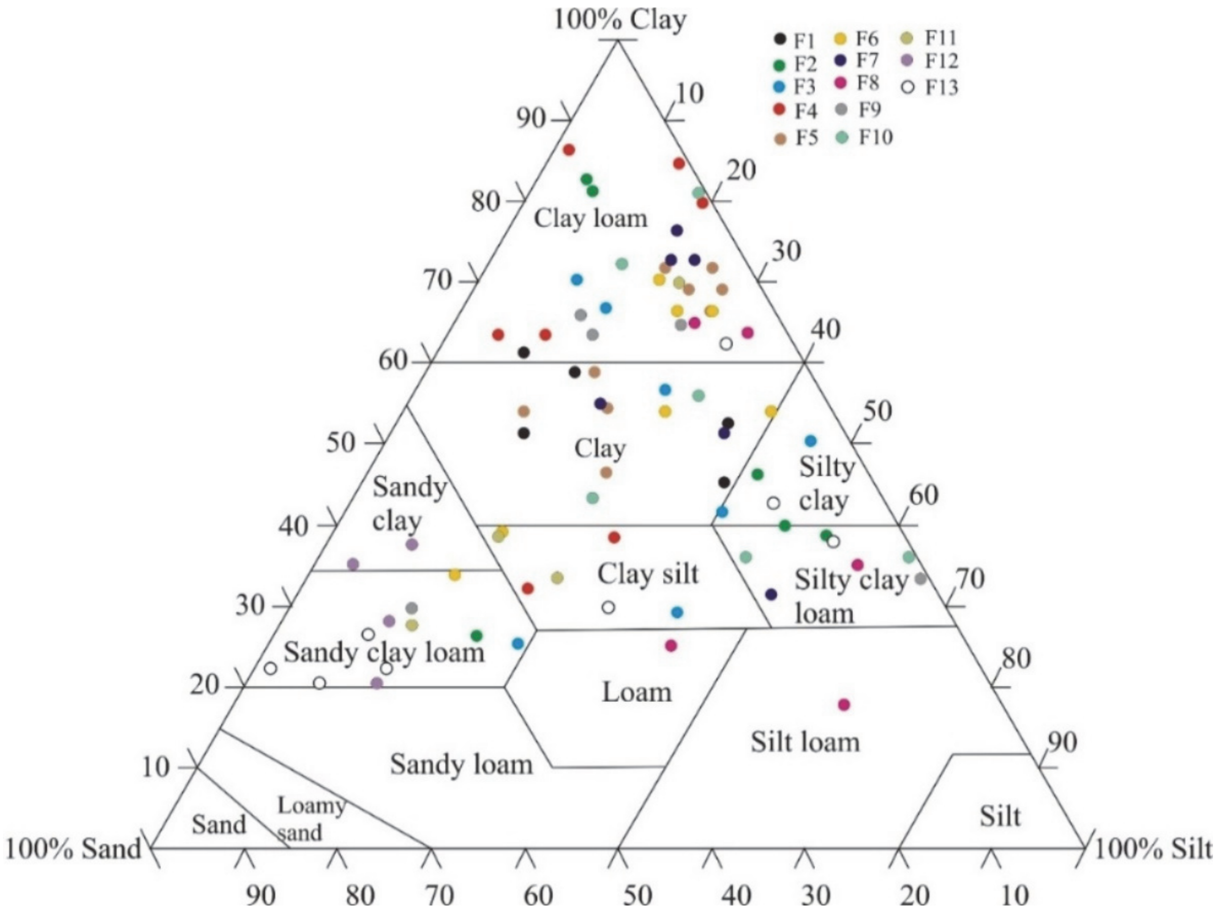

Figure 6. FAO textural Classification Scheme

From the diagram in figure 6, the soil of the town of Amtiman consists largely of (more than 61%) loam clay and clay. The presence of silty clay, clay loam, clayey-sandy clay, sandy clay, and silt and fine silt is also noted to a lesser extent. This confirms that the study area is a clay zone. Moreover, it has an insignificant percentage of fine silts and silts (Fig. 6).

4. Conclusion

The town of Amtiman the capital of the Salamat region in southeastern Chad, with more or less flat relief, has a Sahelo-Sudanese climate and mainly wooded vegetation. The present work shows that the soil of this city belongs to a large part to the class of fine soils, from clays to illite and kaolinite, mostly plastic to very plastic, with a degree of settlement that is more or less low, absorption. The soil of the town of Amtiman would be very inactive to the phenomenon withdrawal swelling. The use of this soil as a foundation requires a careful study of the mechanical characteristics in order to develop proposals for a rational dimensioning of the structures.

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