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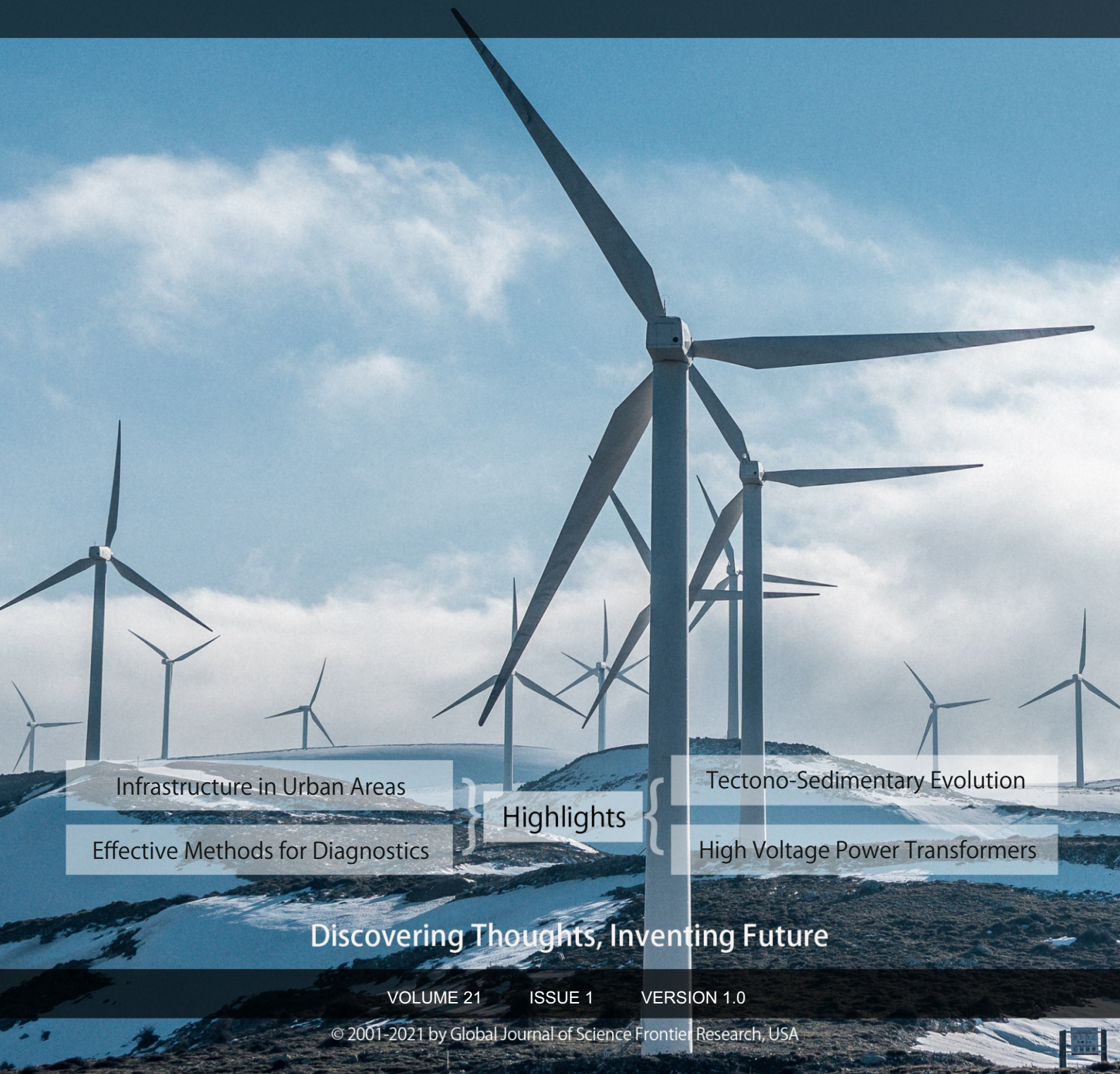

Highlights

- Infrastructure in Urban Areas
- Effective Methods for Diagnostics
- Tectono-Sedimentary Evolution
- High Voltage Power Transformers

Discovering Thoughts, Inventing Future

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Effective Methods for Diagnostics of High Voltage Power Transformers of Large Power Plants

By AS Kudratillaev & RO Rayimov

Abstract- A system for continuous monitoring of the state of insulation and the whole transformer under operating conditions, in addition to standard means for measuring and monitoring the state of transformers, interference-proof high–frequency channels from PIN inputs, from the grounding of the tank and electroacoustic channels for both partial discharges and for detecting mechanical damages, winding displacements, magnetic circuit barriers and other transformer, units that are not detected by other methods, has been developed.

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AS Kudratillaev [α] & RO Rayimov [σ]

Abstract- A system for continuous monitoring of the state of insulation and the whole transformer under operating conditions, in addition to standard means for measuring and monitoring the state of transformers, interference-proof high–frequency channels from PIN inputs, from the grounding of the tank and electroacoustic channels for both partial discharges and for detecting mechanical damages, winding displacements, magnetic circuit barriers and other transformer, units that are not detected by other methods, has been developed.

I. Introduction

High voltage transformers are one of the responsible and expensive equipment of thermal and nuclear power plants. Unfortunately, their accidents are not rare. The causes of accidents are many, but the main one is the developing damage to solid insulation by partial discharges or other processes that can last several months or even years.

To prevent accidents, a large number of methods and devices have been developed and implemented, but, as you can see, they are still insufficient for the long and reliable operation of high voltage transformers. What difficulties are there to resolve this issue. First of all, partial discharge pulses have a very low intensity, that is, their electrical signals are weak against the background of powerful electrical noise present inside the high voltage transformer and penetrating into it from the network from the equipment of substations and high voltage lines.

Secondly, partial and other forms of discharges in a transformer not only manifest themselves with electrical signals, but are also accompanied by optical, sound, mechanical and other phenomena. Unfortunately, they are either not used at all, or due to their insufficient knowledge, they are applied at a primitive level.

Back in the 70s, in addition to the electrical signals of partial discharges, we studied electro-acoustic, optoelectronic, and other manifestations of such discharges in high voltage transformers, because of which instruments and devices for diagnosing oil-filled devices under operating voltage were developed. These devices were introduced in Krasnoyarskenergo, Sverdlovenergo, Uzbekenergo and other power systems to diagnose the status of the main power transformers 500-220 kV of the Krasnoyarsk hydroelectric station, 500 kV substations of the city of Krasnoyarsk, Surgut, Reftinskaya state district power plants. The complex, developed and created by us because of electro-acoustic and electric manifestations of partial discharges, has been successfully used for a long time during acceptance tests of 500 kV transformers after their repair at a specialized factory in Sverdlovenergo.

Over the next few years, taking into account the new designs of transformer assemblies and their inputs, studies of the processes of converting electric energy into other types of energy, work was carried out to improve the diagnostic system for transformers. These systems were used in accreditation testing of hundreds of oil-filled high voltage equipment.

II. A Brief Analysis of the Failures of High Voltage Transformers and the Dominant Processes Leading to Damage to their Components

The main parts and assemblies of high voltage transformers, in which damage most often occurs during their operation, are: windings, their coil insulation and screens; inputs; bends; butter; on-load tap-changer. In addition, oil circulation devices, magnetic circuit, expander, tank, radiators and others add a relatively small share in the occurrence of damage in the transformers.

Damage to the windings and the main insulation of the transformers leads to very serious consequences. Naturally, the insulation of the components and elements of the transformer, both solid and liquid - oil, ages over time and becomes more susceptible to the harmful effects of all factors affecting it. The analysis showed that failures associated with the main isolation of high voltage transformers account for up to 67% of all failures.

The dominant processes for damage and destruction of windings and solid insulation of transformers are: partial discharges; hydration; heat;

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high values of pulses of lightning and internal overvoltage's; through currents of short circuit (deformation and destruction of the design of the windings); aging solid insulation.

III. The Essential Role of Oil in the Failure of High Voltage Transformers in Operating Conditions

This is due to the fact that all internal damage to the transformer leaves traces in it, as if it draws in all the sores and diseases of all components of the equipment. Therefore, by checking the condition of the transformer oil, it is possible to determine local overheating, partial discharges, sparking in the contact joints, humidification, pollution, air ingress and natural aging of both the oil itself and solid insulation.

One of the main components of high-voltage transformers, which are most often destroyed under operating conditions and are the cause of accidents, are bushings.

In operation, there are leaky and sealed oil-filled bushings, as well as bushings with solid insulation. Recently, transformers have been delivered with hermetic and solid insulation bushings as more reliable. It should be noted that in countries with high ambient temperatures, in combination with intense solar radiation and with large differences in air temperature during the day and night, as in Uzbekistan, moisture from the ambient air is sucked into the equipment. This phenomenon is very relevant for inputs, as they do not have devices to maintain the temperature in them. Particular attention should be paid to the condition of transformer bushings, since the proportion of transformer failures associated with input failures remains very high.

An analysis of the damage to the bushings of high voltage transformers shows that the dominant processes leading to their destruction under operating conditions are: wetting and contamination of oil and solid insulation due to violation of their tightness; occurrence and development of partial discharges in oil and in solid insulation of inputs; the appearance of mechanical and other impurities in the oil inlets; general aging of oil and solid insulation.

IV. Transformer Voltage Regulators (On-Load Tap-Changers) Account for a Significant Part of Failures

Faults in the on-load tap-changer arise due to the unsatisfactory state of the contact system: violation of the pressing force, distortion and displacement of the contacts, damage to the components of the structure; moisture and dirt through non-density in his cabinets. For normal on-load tap-change operation, it is necessary first of all to check the quality of the oil from the on-load tap-changer tank, measure the resistance of the circuits to direct current, check the operation of the contactor, check the transformation coefficient at each position of the on-load tap-changer, and periodically scroll the on-load tap-changer.

V. The Magnetic Circuit, Oil Cooling System, Tank, Radiators, Expander and other Components also Contribute to the Transformer Failures

a) Summary of Damage and Failure of High Voltage Transformers

Of the recorded cases of damage to transformers with internal short circuits, explosions and fires accompanied 15%. These damages were mainly caused by damage to the windings, high voltage bushings and on-load tap-changers. In this case, the most severe consequences occur during the development of defects such as: a decrease in the electric strength of the oil channel of high-voltage sealed bushings due to deposition of sediment on the inner surface of porcelain and on the surface of internal insulation, as well as due to aging of the oil; humidification, pollution and wear of insulation of transformer windings; decrease in electric strength of paper-oil insulation of high-voltage leaking bushings due to moisture and pollution; burnout of coil insulation and turns of the windings due to prolonged non-shutdown of the through short-circuit current; installation, repair and maintenance errors.

VI. The Dominant Processes Leading to Damage to the Windings and Solid Insulation

As a whole are partial discharges; hydration; local overheating of solid insulation and oil; through currents of short circuit (deformation and destruction of the design of the windings); aging solid insulation.

Since damage to the coil and main insulation is associated with a variety of causes and serious consequences, the most attention is paid to the timely detection of this type of disturbance in the operation of transformers. In most cases, damage does not occur immediately, but over time. Timely identification of an emerging and developing defect allows you to take measures to prevent its development and maintain a healthy state of the transformer.

VII. The Applied Methods for Monitoring the Condition of Transformers and the Need to Expand them to Increase the Reliability of High Voltage Transformers

For a long time, a system has been used to periodically monitor the condition of high voltage transformers, made before putting the equipment into operation, after major repairs and, periodically, after a certain time, established by regulatory documents, with the transformer disconnected from the network. This system is useful in cases when the equipment is first put into operation, and after major repairs, when the transformer is not required for testing.

Over time, the accumulated experience has shown the low efficiency of such preventive tests, methods have appeared and developed that make it possible to assess the state of insulation and other components of high-voltage transformers without disconnecting it, directly under operating conditions, such as measuring partial discharges in insulation, chromatographic analysis of oil, and especially gases dissolved in oil, the attitude to disconnecting the transformer from the network for routine testing has changed dramatically.

Modern high-voltage transformers, especially very powerful and critical ones, are equipped with a set of diagnostic devices for continuous measurement of partial discharges in the insulation of bushings, windings and other transformer nodes, the capabilities of chromatographic analysis of gases dissolved in oil are actively used, along with standard transformer monitoring devices (temperature measurement and oil level; current, voltage and other electrical characteristics of the transformer; relay protection and automation system, including gas relay and others).

But, firstly, all these currently used methods and devices, although they provide significant assistance in detecting damage that has occurred and are developing in the transformer, do not cover all the partial and other forms of discharges present in it, as well as damage and defects that in principle, cannot be detected by currently used devices because of their insufficient sensitivity for some types of incipient damage. The fact is that, if we consider the methods for identifying the initial and subsequent stages of damage to a transformer by partial discharges, as the main ones, then, due to the attenuation of signals of partial discharges of low intensity along the length of the high voltage winding, and, due to the presence of large levels in the transformer interference, they cannot be detected.

Due to the great sensitivity, the integrity of the principle of operation and the simplicity of the analysis, the method of diagnosing the condition of equipment by analyzing gases dissolved in oil has become one of the important methods for monitoring its condition under operating voltage in operating conditions. At the same time, its shortcomings should be noted: it is difficult to assess the occurrence of damage in their initial stage, since the gas content of a normally working HV transformer varies widely; It is practically impossible to determine partial discharges of low intensity. It is also impossible to detect short and occasionally appearing discharges of high intensity and posing a danger to isolation. This stems from the large volume of oil and the integral essence of the method.

In connection with these shortcomings of the currently used methods for monitoring the state of high voltage transformers, their accidents continue, and even with its explosion. There are cases when during an accident of a responsible transformer entire city and regions were left without electricity.

Secondly, in diagnostics of the condition of transformers there are reserves that are not currently used. It should be noted that in partial discharges, in addition to electrical processes, significant non-electric disturbances also arise due to the conversion of electric energy stored on the equivalent capacitor Cp of the high-voltage insulation section where partial discharges occur to other types of energy, primarily electromagnetic radiation, in a shock wave, creating mechanical disturbances in isolation; gas is released, light emission and a temperature jump appear. These perturbations can be used to detect the arising of partial discharges, determine their location in isolation and measure their intensity.

The need to prevent accidents of critical high-voltage transformers and the impossibility of registering the initial, sometimes even developed stages of damage requires the development, creation and application of a continuous monitoring system for the condition of such equipment with the improvement of currently used methods and the addition of new, and primarily non-electric ones.

System of electrical registration, measurement of partial discharges of low intensity against a background of large interference. As noted above, partial discharges are one of the main processes leading to damage and failure of high voltage transformers. From the point of view of their timely detection, assessment of their real intensity, determination of their geometrical location, as well as from the point of view of actual danger, these processes present many more puzzles and difficulties.

A B

Figure 1: The processes for measuring partial

In this regard, based on the literature data and our own experiments, we thoroughly studied in laboratory conditions the processes of occurrence and development of partial discharges in oil, in paper-oil insulation samples in models of transformer tanks of various sizes in laboratory conditions and at the Chirchik Transformer Plant. In the photographs of figures, Figure 1.shows the processes for measuring partial discharges in transformer tanks in the test shop of this plant. In laboratory conditions, partial discharges in a purely oil medium and in a paper-oil medium were carried out in models of tanks of various sizes.

We studied such electrical parameters of partial discharges as the discharge voltage, the amplitude of the discharge current, the steepness of the current, and the duration of its flow. In this case, the shape of the electrodes, their surface size, and the length of the discharge gap were taken into account.

The objects of research were partial discharge models mounted in metal tanks with sizes of 840x530x640 and 240x140x100, wall thicknesses of 5 and 2 mm, respectively.

Partial discharge models were paper-oil insulation samples with various defects and spark gaps with typical electrode systems “needle-needle”, “needle-plane”, “ball-ball”. The parameters of partial discharges were selected on the basis of published data and preliminary experiments with various types of real partial discharges.

The energy of the channel of partial discharges was regulated by changing the value of the capacitance and the length of the spark gap. Vacuum capacitors of the KV and KM type of small capacity, to which partial discharge models were directly connected, were used as energy storage devices.

In Figure 2 shows the process of studying partial discharges in transformers under operating conditions.

Figure 2: The process of studying partial discharges in transformers under operating conditions

Figure 3: Test installation with a cascade of transformers for 1 million volts with a pilot span of an overhead line 500 kV 300 m long

To determine the value of the discharge voltage U_d, experiments were conducted with the measurement of the electrical characteristics of partial discharges. Based on them, the value of the charge of partial discharges (p.d.) was determined as $Q = I_{p.d.} * t_{p.d.}$ ($t_{p.d.}$ - pulse duration of the p.d.), which was compared with the experimental value $Q = C * U_a$ (U_a is the applied voltage) and, at a known value of the capacitance (C), the value of the discharge voltage was calculated. It was experimentally obtained that the discharge voltage U_d amounts to (60-80) % of the rectified voltage applied to the partial discharge electrodes.

To reduce the influence of the parasitic capacitance of the installation and high-voltage connections, partial discharge models were connected to the voltage source through a resistor with a resistance of 100 MΩ, the dimensions of the discharge circuit were reduced to a minimum. To obtain partial discharges of very low energies (up to 10-10 *J*), we used the capacitance of our own electrodes of partial discharge models and supply wires, the magnitude of which was 6.9-7.1 *pF*. In the electrical circuit of the measuring part of the installation, measures were taken to suppress interference coming from the network. They were suppressed by connecting in-line filters consisting of two capacitive and one inductive elements connected in a Π-shaped circuit to the network test leads.

To measure the magnitude of the partial discharge current and record the shape of its curve, a measuring resistor (50-200 *Ohms*) was connected in series with the discharge circuit, the signals from which were fed to measuring instruments and oscilloscopes via a delay line (t_{del} = 350 *ns*).

All these processes were investigated on these models, the parameters of partial discharges were determined upon their excitation in different sections of paper-oil insulation and in oil. Thousands of oscillograms were obtained characterizing the types of partial discharges occurring in the insulation and on the surface of paper and cardboard. Moreover, in addition to the electrical characteristics of partial discharges, their electromagnetic manifestations were also recorded: wave intensity, frequency characteristics and features of partial discharges arising in various characteristic sections of transformer isolation.

When studying partial discharges in models and recording their characteristics, experiments were also carried out with the measurement of the parameters of partial discharges when superimposed on the measured circuits, noise recorded from the inputs of high voltage transformers directly in operating conditions at substations. In addition, interference was also used from our pilot flight of a 500 kV overhead line 300 m long with power from three-phase regulated alternating current source (Figure 3.).

Moreover, in addition to those actually existing in this electric circuit: 10 kV supply network - voltage regulators - step-up transformers - voltage supply to the measuring cabins at high potential and from them to the pilot span of the 500 kV overhead line, artificially created interference was also created in this circuit in the form partial discharges in the air in separate sections of insulating structures; discharges on drafts; sparking loose contacts.

VIII. Study of Electro-Acoustic Characteristics of Partial Discharges in the Isolation of High Voltage Transformers

Interest in the electro-acoustic method for monitoring the state of insulation of high voltage transformers is increasing every year. Back in the 60s of the last century, we used the electro-acoustic method as the main method for flaw detection of insulation of high-voltage pulse capacitors as part of powerful batteries and in production conditions at the Serpukhov condenser plant. In the early 70s, we developed a 4-channel acoustic-high-frequency device for monitoring the status of high-voltage transformers and with its help examined all transformers 110 kV and above the power system of Uzbekistan, identifying bottlenecks in their insulation. The device was transferred for permanent operation to the isolation service of the Ministry of Energy of Uzbekistan.

Subsequently, taking into account the results of studies of partial discharges and their acoustic manifestations, many nodes of such a device were improved. This allowed us to monitor the insulation status of critical transformers of 500 kV at substations of Krasnoyarskenergo, Sverdlovenergo, including Surgut and Reftinskaya state district power plants, in Tajglovenergo, Yuzhkazenergo and other 500 kV substations. A flaw detector based on electro-acoustic and high-frequency electrical insulation control methods, specially developed for these purposes, was transferred by us to a specialized Sverdlovenergo enterprise for the repair of transformers 220-500 kV, which, judging by its reviews, was successfully used by it after repair, in t. hours capital, during acceptance tests. With its help, latent defects of transformers were discovered [1]. Acoustic-high-frequency devices have also been successfully used in testing head samples of products - high-voltage transformers developed and manufactured by the Chirchik Transformer Plant, during research and certification tests of transformers and other high-voltage equipment in the amount of more than 200 works.

IX. Reception of Weak Acoustic Signals of Partial Discharges when Monitoring the Status of High Voltage Transformers by the Electro-Acoustic Method

Acoustic waves emanating from partial discharges in the insulation of transformers are accompanied by a very high level of interference, consisting of low-frequency (at harmonics of the supply voltage), high-frequency (interference present in the transformer itself and coming from the high voltage

network) electrical and acoustic (vibration of the magnetic circuit, operation of oil pumps, fans and other devices) interference.

An analysis of tens of thousands of waveforms obtained when monitoring the state of 220-500 kV transformers directly under operating conditions, confirming the literature that the spectral components of the acoustic waves of partial discharges of transformers extend from tens of hertz to hundreds of kilohertz, at the same time, revealed a number of new spectral features of these signals, depending on the type of partial discharges, their location and the stage of development of insulation failure.

Theoretical studies have shown that when partial discharge signals are detected, the interference of high-voltage transformers received with the help of piezoelectric sensors and passed through optimal filters that minimize the mean square error can be considered as a stationary random process. And partial discharges in high-voltage transformers can be detected and measured by the magnitude of the fluctuations of the current estimate of the mathematical expectation of the received process.

X. Determining the Intensity of Partial Discharges According to the Electro-Acoustic Control System

When electroacoustic monitoring the insulation state of high voltage transformers, it is important to establish a relationship between the output voltage of the monitoring device (U_{out}) and the energy of partial discharges ($W_{p.d.}$). The output voltage U_{out} depends on the transmission coefficient of the control device (K_{tran}), the sensitivity of the applied sensor and the fractions of the energy it receives, the total energy of the acoustic wave (M), the attenuation coefficient of the acoustic wave propagating from the source to the sensor (S), and the electrical conversion efficiency discharge energy into acoustic (Ψ) and from discharging energy ($W_{p.d.}$). Values (K_{tran}) and M are known, S is determined by the distance between the source and the sensor after finding the place of partial discharges, therefore, the electroacoustic efficiency of partial discharges remains the only unknown, as a result of which determination by the output voltage of the device it is possible to estimate the energy of partial discharges and judge their danger to isolation.

It is known that an acoustic wave during partial discharges appears as a result of a sharp jump in the temperature of the discharge channel, instantaneous decomposition of oil and the emergence of very high pressure — a shock wave, which then turns into a regular acoustic wave. The pressure at the front of the shock wave is directly proportional to the density of energy stored in the discharge channel (plasma), i.e. depends on the rate of energy input into the discharge channel, which is determined by the steepness of the current of partial discharges carrying energy into the discharge channel. Therefore, the steepness of the partial discharge current is an important factor in determining the electro-acoustic efficiency discharge and output voltage of the control device.

The studies were carried out in an oil-filled tank of a transformer model with dimensions of 840x530x640 mm and a wall thickness of 5 mm. For partial discharges in a purely oil medium, vacuum-coaxial capacitors with capacities from 6.5 to 100 pF are used. The discharge gaps (needle-needle; needle-plane and ball-ball) were directly connected to the terminals of the capacitor and, for the convenience of the experiments, they are mounted together on an insulating board, which is easily lowered into the tank with oil by means of a lever mechanism and lifted out of it.

The measuring circuit consists of electro-acoustic and high frequency channels. The acoustic sensor is a piezoelectric sensor (made of ceramic of lead titanate zirconate STS-13 grade), which converts the mechanical vibrations of the tank walls into electrical impulses. In the measurements, a broadband amplifier with a gain of up to 100000 was used. Using the spectrum analyzer, we studied the frequency response of noise and acoustic signals of partial discharges up to 200 kHz.

For partial discharges in oil, the equivalent circuit can be represented, as a circuit with a series connection of C, L, R elements, where C is the capacity of the discharge section, L, R are the inductance and resistance of the discharge circuit, respectively. At $R < 2\sqrt{\frac{L}{C}}$ (for partial discharges in transformers), the current in the circuit is described by the equation

$$i = -\frac{U_C}{\omega_0 L} e^{-bt} \cdot sin\omega_0 t, \quad (1)$$

Where ω_0 is the circular frequency, ,$b = \frac{R}{2L}$ is the attenuation coefficient).

Therefore, at the same voltage value, the steepness of the partial discharge current (Y) or the rate of energy input into the discharge channel is determined by the magnitude of the inductance. Therefore, when studying the effect of current steepness on the value of the signal of an electro-acoustic sensor, the value of the circuit inductance was mainly changed in the range from 1 to 50 μGen. To maintain energy constancy and determine the effect of capacitance on the signal value, the capacitance of the capacitor was changed in the range of 6.5-100 pF, and measures were taken to reduce the magnitude of stray capacitances and inductances of the plant elements.

Thus, the steepness of the partial discharge current in the region of its high values was managed to be regulated by more than an order of magnitude, and the duration of the pulse front was 25–27 nsec.

The dependence of the output voltage of the sensor on the current slope in the range of 107 - 109 A / s for different frequencies (f = 1.7 (1);6 (2); 10 (3); 20 (4); 40 *kHz* (5)) according to the amplitude-frequency characteristic of the sensor signals and at a constant discharging energy is shown in Figure 4. It is seen that with increasing steepness at all frequencies, the values of U_{out} significantly increase. So, for a frequency of 1.7 *kHz* with an increase in the value from 5*107 to 5*108 *A / s* (i.e., by an order of magnitude), U_{out} increased from 2.9*103 to 5.5*104, and for frequencies of 20 and 40 *kHz* with the same range of variation (Y), the value of U_{out} increased, respectively, from 40 and 5.5 to 480 and 50 μV.

From this it follows that the output voltage of the electro-acoustic monitoring device increases by about an order of magnitude with the same increase in the steepness of the discharge current, and, at the low frequencies, it increases faster than at high frequencies.

Studies conducted in the models of oil and paper-oil insulation of transformers showed that the electro-acoustic efficiency of their partial discharges is in the range of 10 - 35% for discharges in oil and 3 - 12% for partial discharges in paper-oil insulation.

When electro acoustic monitoring the state of high voltage transformers to determine the energy of partial discharges, it is important to evaluate the absorption of their acoustic signals by transformer oil, various barriers located between the source of partial discharges and sensors.

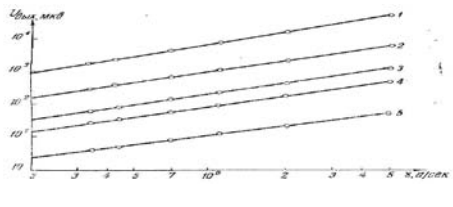

Figure 4: The dependence of the output voltage on the steepness of the current of partial discharges

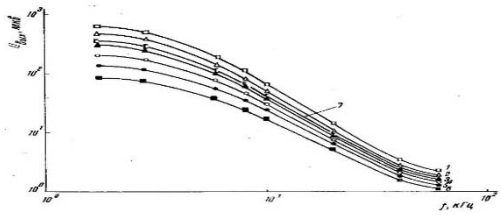

Figure 5: The dependence of the output voltage on the frequency for barriers of various thicknesses, mm.1-0; 2-0.5; 3 to 2; 4-3.5; 5-6; 6-8

In acoustics, the attenuation of waves in liquids and in solids is fairly well understood. The propagation of acoustic pulses in such a complex object as transformer tanks with limited dimensions and an extremely heterogeneous medium has not yet been studied quite strictly. For such an object, the attenuation coefficients of various materials due to wave diffraction can differ significantly from data determined by classical methods. In this regard, based on simplified models, the propagation of waves through a transformer medium was theoretically investigated, and the attenuation coefficients of acoustic pulses introduced by transformer elements were determined experimentally in transformer tanks with real sources of partial discharge waves.

It was revealed that the attenuation coefficient of acoustic waves in oil increases both with increasing frequency and with increasing distance. In contrast to oil, the damping coefficient in the barriers decreases with increasing frequency and the more significant the decrease, the thicker the wall of the barrier. This can be explained by the appearance, at wavelengths greater than the thickness of the barrier, of bending waves having a propagation velocity lower than the speed of sound in oil.

A study of the propagation of acoustic waves through the transformer windings showed that the oil channels in the windings of power transformers play a positive role in the penetration of waves through the windings. When the ratio of the channel area to the corresponding total surface of the winding is more than 10%, the influence of the attenuation coefficient of the winding can be neglected. At lower values of this ratio, the attenuation coefficient increases both with decreasing channel width and with frequency.

The walls of the transformer tank, standing in the way of the movement of waves from the source to the sensor, also contribute attenuation. The research results showed that the attenuation coefficient of the waves from the transformer tank increases both with increasing thickness of the tank, and with increasing wave frequency.

Based on the obtained experimental results on the dependence of the wave attenuation coefficient on the distance over the oil, the thickness of the insulating barriers, the wall of the tank, the type of windings and other elements of the transformer, a generalized formula is derived that allows one to determine the energy of partial discharges by the output voltage of an electro-acoustic monitoring device

$$W = \frac{4\pi S^2}{\eta \rho_{\text{ср}} C_{\text{ср}}} \cdot t_{\text{эф}} \cdot K_C^2 \cdot K_{\text{зат.т.}} \cdot U_{\text{вых}}^2, \qquad (2)$$

where S is the distance between the source of partial discharges and the receiver, m; η - electro-acoustic efficiency of partial discharges $\rho_{\text{ср}} C_{ср}$- acoustic resistance of the medium, H *s / m^3; t_{eff} is the effective discharge time, s; K_c is the coupling coefficient between the pressure of the acoustic wave and the output

voltage of the device; Kzat.t is the total attenuation coefficient of solid barriers.

The study of partial discharges and vibroacoustic interference of transformers under operating conditions showed that even after optimal linear filters, the signal and interference levels are of the same order. For reliable signal estimation, additional post-detector processing is required. An analysis of the structure of the signals and the interference after the filters shows that good results can be obtained by comparing the current average values of the signal plus interference and one interference.

To obtain an unbiased estimate of averaging, it is necessary to introduce a correction factor and use an integrator that implements the following operator:

$$M_{f1}^{*}(t) = \frac{M_f^{*}(t)}{\frac{1}{T}\int_0^T h(t')dt'} = \frac{\int_0^T h(t')f(t-t')dt'}{\int_0^T h(t')dt'}, \qquad (3)$$

where M_{f1}^{*} is the estimate of the current average value of the random process *f(t)*; *h(t)* is the weight function of the integrator.

When a single interference is applied to the integrator's input, the output voltage will change smoothly along the noise envelope, and if there is a signal of partial discharges and interference, it will have more sharp deviations.

To register them, after the optimal filter, two detectors are connected with integrators having different time parameters $h_1(t)$, $h_2(t)$ and transmission coefficients providing a zero response at the output of the subsequent subtract or when only interference is applied and a response *g (t)* proportional to energy partial discharges [3].

The optimal integrator parameters are found by examining the response of g (t) to a maximum depending on the ratio of $h_1(t)$ and $h_2(t)$.

Based on the results of the electro-acoustic properties of partial discharges, analysis of the acoustic signals of partial discharges and the impact of interference, a series of four-channel (DAV-4) and single-channel (DAV-1) electro-acoustic and high-frequency flaw detectors - devices for monitoring the state of high voltage transformers [2] were developed.

Figure 6: 4-channel acoustic-high-frequency device for monitoring the status of high voltage transformers

Figure 7: Single-channel acoustic-high-frequency device for monitoring the state of insulation high voltage transformers

DAV-4 devices, in addition to the high-frequency channel, have 4 electro-acoustic channels with 4 electro-acoustic channels and a signal comparison unit at the output. This allows a preliminary location of the area of partial discharges or mechanical damage to transformer units. Next, by installing electro-acoustic sensors closer to the sensor, which showed the maximum signal value, and comparing the readings of the high-frequency channel, we determine the location of the transformer malfunction.

Single-channel devices DAV-1 are fully assembled on integrated circuits and semiconductor elements, have autonomous power, small weight, small dimensions. Their power is supplied from 2 miniature dry batteries of the Krona type, which ensure their continuous operation for 30 hours. Their power is also provided by small-sized 9 Volt rechargeable batteries.
Small weight of the device, portability, autonomy of power with very low power consumption, ease of installation of a sensor with a magnetic cartridge on the wall of the transformer tank directly under operating voltage without any switching in its circuits greatly facilitates its use for periodic monitoring of transformers by both commissioning and operational personnel of substations.

Its portability and autonomy of power have helped us many times to detect partial discharges and other defects of transformers whose tanks are under very high voltage, including for monitoring the state of cascade transformers at 1 million volts (Figure 3) after major repairs and during preventive tests. Moreover, since the transformer tanks are under voltage of 167; 501 and 833 kV, respectively, the autonomy of the power supply of the device, its small size and high noise immunity were indispensable. The device, along with the sensor, was alternately attached to the walls of the tank transformers, and the observation of the reading of its output meter was carried out using a telescope.

According to the testimony ofDAV-1, in the tank of one of the transformers, after overhaul, partial discharges with an intensity of up to 10^{-9} *Cl* were detected and eliminated. Each time after opening the transformer tank and the work performed therein, the levels of partial discharges were measured with the help of DAV-1 and, when they were exceeded, measures were taken to eliminate them.

Devices assembled according to this principle, not only through electro-acoustic, but also through a high-frequency electric channel using PIN inputs, grounding transformer tanks, have shown high noise immunity and reliability when conducting hundreds of studies to monitor the condition of 220-500 kV transformers in Uzbekistan, Russia and in other CIS countries. It should be noted that in all these devices, except for the pulse mode, there is also a continuous mode of operation, with the help of which the state of fastening of the magnetic circuit, windings and other components of the transformer, which are weakened, deformed and destroyed by through short-circuit currents, especially multiple ones, is estimated.

Here are some examples. In studies, in addition to electro-acoustic channels for receiving and processing partial discharge signals, high-frequency electrical signals from PINs of inputs and grounding of the transformer tank were also used. At one of the 220 kV transformer ODTGA-40,000 / 220, with a capacity of 40 mVA (group power of 120 mVA), at the Kuylyuk substation of the Uzbek power system, partial discharges of 1.2 * 10-10 C were detected. It became known that this transformer was overhauled 3 months ago with the change of high voltage windings. Analysis of the oscillograms and other parameters of the pulses of partial discharges showed that they arise in the paper-oil insulation of the transformer.

In this transformer, partial discharges were regularly studied for 46 days with the recording of oscillograms and all their parameters on a photo and movie camera, as well as on a tape recorder. The dynamics of partial discharges by the 40th day from the beginning of our measurements indicated a steady increase in the intensity of partial discharges to 8.10^{-9}C and, consequently, further dangerous destruction of the insulation. In our opinion, the transformer could not be left in operation. This was reported in writing to the leadership of the Ministry. The transformer was disconnected from the network and type tests were carried out after major repairs.

However, no deviations from the norms were found for them. In this regard, the transformer was turned on under voltage, but according to our measurements made before it was turned off and after connection, and our instructions, the enterprise specified the reserves, developed a consumer unloading scheme and prepared the maintenance and repair personnel for possible consequences with the specified transformer.

Eight days after switching on, this transformer failed due to coil closures of the 220 kV winding near the 110 kV branch, confirming the correctness of our measurements and solutions. This transformer subsequently served as the basis for comprehensive research on the development of partial discharges in real paper-oil insulation of high voltage transformers.

Another typical case of transformer faults in the field. When measuring using the DAV-1 instrument developed by us, at one of the high-voltage transformers at a substation in Chirchik (Uzbekistan), a source of mechanical vibrations of a relatively low frequency but significant intensity was found in the lower part of the transformer tank a height of about 0.5 m from its bottom from the side of the low-voltage inputs of the structure. According to these results, the transformer was disconnected from the network. When it is opened in the zone of the tank volume, determined in advance using the DAV-1 device, a weakening of the winding fastening is revealed due to the falling out of the lower wedges.

According to the results of gas analysis in oil of single-phase transformers 4ATG of a group of 3 АОДЦТН 267000/500/220/20 Reftinskaya GRES district power stations of phase "A" (factory number 83315), the content of gases characterizing the appearance of a defect in it was found. During 3 months of observations, the intensity of these gases grew continuously and reached unacceptable limits. In this regard, the GRES chemical laboratory recommended disconnecting the transformers for overhaul with opening the phase *A* tank. Measurements made by the acoustic-high-frequency device DAV-1 in “pulse” and “continuous” modes, as well as electrical measurements with PIN-s and transformer grounding, showed that the main source of gas evolution are mechanical vibrations that appear when the yoke beams are loosened, pressing rings, tie rods of the magnetic circuit, as well as in unsatisfactory state of fastening of auxiliary nodes of the transformer.

Considering the great difficulties of disconnecting high-power transformers in the autumn-winter period, the possibility of wetting the insulation when opening the tank in an unsuitable room, prolonged lack of electricity and significant costs for incompletely justified opening and repair, we proposed to leave the transformer in operation, but under special control and with measurements of electro-acoustic, high-frequency characteristics of the transformer and gases dissolved in its oil. The proposal was accepted, the transformer worked for a long time before the repair.

When measuring at all substations of 500 and 220 kV, DAV-1 devices showed high noise immunity and stability of their parameters.

The results of studies of the electro-acoustic characteristics of partial discharges, attenuation introduced by transformer elements, and experience with the DAV-4 and DAV-1 flaw detectors made it possible to develop the following methodology for determining the energy of partial discharges according to the output voltage of the monitoring device:

- Registration of partial discharges with an electro-acoustic device, taking readings of the output voltage of the device;

- Preliminary determination of the location of the source of partial discharges inside the transformer tank;
- Determination of the type of partial discharges and their characteristics (slope of the current, the ratio of pulses at positive and negative polarities of the voltage, the phase of occurrence of partial discharges);
- Finding the location of the source of partial discharges relative to the electrical circuit of the transformer;
- Determination of preferred propagation paths of acoustic waves from the source to the sensors (oil distance, total thickness of the barriers, angles of incidence of the wave to the barriers and walls);
- Determination of the acoustic energy of the source from the output voltage of the device and the attenuation data of the wave in the oil and barriers;
- Assessment of electro-acoustic efficiency channel, determining the energy of the discharge channel;
- Estimation of the total energy of partial discharges based on the energy of the channel and the characteristics of the pulses of the partial discharges;
- Assessment of the danger of registered partial discharge pulses for isolation, taking measures to exclude an emergency transformer failure.

The studies we have described above show that to monitor the condition of transformers and other critical high voltage equipment under operating conditions, it is not sufficient to use one or more of the methods used discretely, i.e. occasionally 1 time over a period of time, since the main types of damage to such equipment generate signals in the electrical circuits and in the environment that are random in time and in intensity. These signals can appear and then disappear for many hours or even days, especially in the initial stages of damage development. Therefore, discrete (episodic) measurements (or state monitoring) of the characteristics of these signals may not fix them.

Based on the results of laboratory research and the experience of monitoring the status of critical transformers 500-220 kV in Uzbekistan, Russia, South Kazakhstan and Tajikistan, a concept was developed for continuous monitoring of the condition of the insulation and the entire transformer under operating conditions, in which, besides standard measuring and monitoring tools the state of the transformers includes noise-protected high-frequency channels from PIN inputs, from the tank ground and electro-acoustic channels for both partial discharges and for detecting mechanical damage, displacements of windings, magnetic barriers and other transformer nodes [4]. A simplified block diagram of the continuous monitoring of the status of transformers is shown in Figure 8.

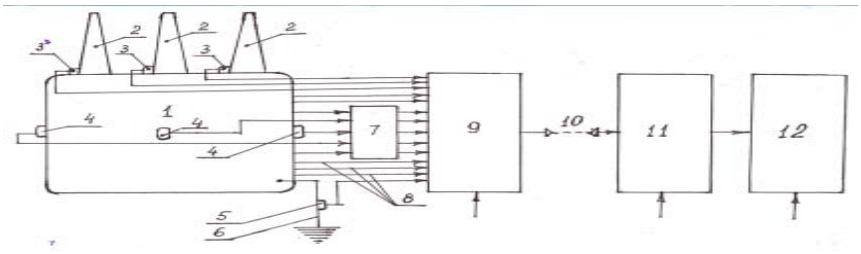

Figure 8: Simplified block diagram of a continuous monitoring system for critical high voltage transformers:1-diagnosed object (VN power transformer); 2-input VN; 3-PINs of inputs; 4-electroacoustic sensors; 5-current sensors; 6-grounding bus; 7-devices for the preliminary processing of acoustic and electrical signals; 8 - sensors for temperature, oil level, the appearance of gases), etc.; 9-a device for processing and converting signals; 10-fiber optic communication cable; 11-multi-channel signal conversion device;12-PC with special programs for signal processing.

XI. Conclusions

1. It is shown that the electro-acoustic method for monitoring the state of insulation and other components of high voltage transformers, along with the electric high-frequency method, is quite promising for a continuous monitoring system of its condition.
2. The results of studies of the processes occurring during partial discharges in oil and in the paper-oil medium of transformers showed the role of the steepness of the currents of these discharges on the shock wave and on the output voltage of the electro-acoustic channel of the control device.
3. The attenuation of acoustic waves during their propagation through the winding, through insulating barriers, through the oil and through the tank wall, studied in transformer models, showed that when the width of the oil channel is more than 10% of the total surface of the winding, the influence of the winding on the attenuation of the acoustic wave can be neglected , the attenuation coefficient of the acoustic (ultra-acoustic) signal when partial discharges occur in the oil increases both with the

removal of partial discharges from the sensor and with increasing frequency; attenuation coefficient increases when there are barriers between the wave source and the sensor.

4. A method has been developed for calculating the energy of partial discharges recorded by electro-acoustic control devices, which makes it possible to assess the danger of these discharges.
5. Electro-acoustic and high-frequency electrical methods, devices for recording and location of partial discharges and other transformer problems, developed by us, which use optimal filters and use the noise-immunity method of receiving weak acoustic and high-frequency signals against a background of high noise, have been successfully used for a long time to control condition of critical transformers 500-220 kV of the Ministry of Energy of Uzbekistan, Krasnoyarskenergo, Sverdlovenergo, including at 500 kV substations of Surgut and Reftinskaya GRES district power plants. With their help, sources of partial discharges and other transformer malfunctions that were not detected by other methods.
6. A system is proposed for continuous monitoring of the state of critical high-voltage transformers, based on in-depth studies of the processes of initiation and development of damage in insulation, in other components of transformers, for more than 40 years of experience in long-term measurements of the characteristics of partial discharges and other transformer malfunctions at substations 500 - 220 kV directly in operating conditions under operating voltage.

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Green Roof as a Measure of Efficiency and Infrastructure in Urban Areas in the City of Recife, Pernambuco, Brazil

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Oswaldo Redig de Campos Filho & Waléria Guerreiro Lima

Abstract- The present work evaluated the applicability of the green roof system in the city of Recife after Municipal Law nº 18,112/2015. For this, a quantitative diagnosis of the architectural projects deferred with the green roof system from the period from January 13, 2015 to September 30, 2019 was carried out. With the data survey, a quantitative analysis was carried out making a relationship with the urban, social and environmental aspects of the region where they operate. It was possible to observe that the years 2016 and 2019 presented a greater quantity in the construction area with a green roof system approved by the Municipality of Recife, in the period from January 13, 2015 to September 30, 2019. In relation to the area of the green roof expected in these projects, 2019 was characterized by the largest available area, followed by 2016. The years 2015, 2017 and 2018 had smaller areas and their values did not differ statistically from each other. The number of projects differs from one period to another, being greater in the last two years of the survey. Within the scope of the territorial outline established by these Political-Administrative Regions, the data also demonstrate that the green roofs had greater representativeness, when analyzed under the quantitative aspect, in buildings of the multifamily type.

Keywords: *quality of life; sustainability; green roof.*

GJSFR-H Classification: *FOR Code: 040399*

GREENROOFASAMEASUREOFEFFICIENCYANDINFRASTRUCTUREINURBANAREASINTHECITYOFRECIFEPERNAMBUCOBRAZIL

Strictly as per the compliance and regulations of:

Green Roof as a Measure of Efficiency and Infrastructure in Urban Areas in the City of Recife, Pernambuco, Brazil

Marisa M. Cavani de Albuquerque [α], Mariana Aragão da Silva [σ], Renata Maria Caminha Mendes de Oliveira Carvalho [ρ], Oswaldo Redig de Campos Filho [ω] & Waléria Guerreiro Lima [¥]

Abstract- The present work evaluated the applicability of the green roof system in the city of Recife after Municipal Law nº 18,112/2015. For this, a quantitative diagnosis of the architectural projects deferred with the green roof system from the period from January 13, 2015 to September 30, 2019 was carried out. With the data survey, a quantitative analysis was carried out making a relationship with the urban, social and environmental aspects of the region where they operate. It was possible to observe that the years 2016 and 2019 presented a greater quantity in the construction area with a green roof system approved by the Municipality of Recife, in the period from January 13, 2015 to September 30, 2019. In relation to the area of the green roof expected in these projects, 2019 was characterized by the largest available area, followed by 2016. The years 2015, 2017 and 2018 had smaller areas and their values did not differ statistically from each other. The number of projects differs from one period to another, being greater in the last two years of the survey. Within the scope of the territorial outline established by these Political-Administrative Regions, the data also demonstrate that the green roofs had greater representativeness, when analyzed under the quantitative aspect, in buildings of the multifamily type. It was also possible to verify that most of the projects are inserted in the agglomerations of vertical buildings, in areas of intermediate temperatures of 24ºC to 26ºC, with a predominance of higher values, in environs with few green areas available in their blocks and still in places with critical flooding problems. In general, the realization of this research allowed us to see, with the results obtained, that the green roof system is still little used in the city of Recife, indicating the need for the Government to adopt incentive measures, through tax deductions or subsidies, such as IPTU (city housing tax) reduction.

Keywords: quality of life; sustainability; green roof.

Resumo- O presente trabalho avaliou a aplicabilidade do sistema de telhado verde na cidade do Recife pós-Lei Municipal nº 18.112/2015. Para isto, foi realizado um diagnóstico quantitativo dos projetos de arquitetura deferidos com o sistema de telhado verde do período de 13 de janeiro de 2015 a 30 de setembro de 2019. Com o levantamento dos dados, efetuou-se uma análise quantitativa fazendo uma relação com os aspectos urbanísticos, sociais e ambientais da região onde estão inseridos. Foi possível observar que, os anos de 2016 e 2019 apresentaram maior quantidade em área de construção com sistema de telhado verde deferidos pela Prefeitura do Recife, no período de 13 de janeiro de 2015 a 30 de setembro de 2019. Já em relação à área de telhado verde prevista nesses empreendimentos, o ano de 2019 caracterizou-se por maior área disponível, seguido de 2016. Os anos de 2015, 2017 e 2018 tiveram menores áreas e os seus valores não diferiram estatisticamente entre si. A quantidade de projetos difere de um período para outro, sendo maior nos últimos dois anos do levantamento. No âmbito do recorte territorial estabelecido por essas Regiões Político-Administrativas, os dados demonstram também que os telhados verdes tiveram maior representatividade, quando analisados sob o aspecto quantitativo, nas construções do tipo habitacional multifamiliar. Também pôde-se constatar que a maioria dos projetos estão inseridos nas aglomerações de edificações verticalizadas, em áreas de temperaturas intermediárias de 24ºC a 26ºC, com predominância de valores mais altos, em bairros com poucas áreas verdes disponíveis em suas quadras e ainda em locais com problemas críticos de alagamentos. De uma maneira geral, a realização desta pesquisa permitiu visualizar com os resultados obtidos que o sistema de telhados verdes ainda é pouco utilizado na cidade do Recife, indicando a necessidade do Poder Público em adotar medidas de incentivos, através de deduções fiscais ou subvenções, como a utilização da redução do IPTU.

Palavras-chave: qualidade de vida; sustentabilidade; telhado verde.

I. Introduction

With the intensification of the industrialization process in the middle of the 20th century, Brazil saw a strong transformation in its form of settlements with the migration of the population from rural to urban areas.

Due to the process of evolution of the guidelines related to the theme of sustainability and to the growing environmental and urban problems presented in the cities, there was the creation and approval of Municipal Law nº 18,112/2015 in the city of Recife, with the objective of contributing to the improvement of the environmental quality of buildings and their surroundings through the mandatory installation of a green roof (for multifamily housing buildings with more than four floors, and non-housing with more than 400 m² of covered area), and the construction of reservoirs to accumulate or delay the

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flow of rainwater into the drainage network (PREFEITURA DO RECIFE, 2015).

Given the relevance of implementing green roofs in urban centers and the need for their effective permanence in buildings, the importance of this research is justified by the fact that it intends to portray the impact of the aforementioned law in the city of Recife. The amount of information available on the demand for projects and construction of buildings after the law is practically null. It is sought, then, with this research, to minimize the existing academic and technical-scientific gap and to stimulate future studies on the theme.

Consequently, the article aims to evaluate the applicability of the green roof system in the city of Recife after Municipal Law nº 18,112/2015. Initially, it identifies, through flowcharts, the steps of the approval procedure of the architecture project with the City of Recife. It draws a quantitative diagnosis of the architectural projects approved with a green roof system after municipal law and presents a correlation of these projects with some urban and environmental aspects of the region where they are located.

II. Bibliographic Reference

The urbanization process occurred quickly and in a disorderly manner, causing several environmental and urban problems, such as water, air and noise pollution, global warming, the formation of heat islands, an increase in the greenhouse effect, floods, increasing soil impermeability, vegetation suppression, among others, changing the quality of life in cities (KOZMHINSKY; PINHEIRO; EL-DEIR, 2016; RANGEL; ARANHA; SILVA, 2015).

During an attempt to preserve and restore what remains of natural resources, the world began, in 1970, to debate in international and national levels about the sustainable development of the planet. The formulation of concepts and documents to point out environmental strategies first appeared in the Brundtland Report in 1987, prepared by a Commission formed by industrialized countries, where sustainable development is conceived as the *development that meets present needs, without compromising the capacity of future generations to meet their own needs* (ROLA, 2008).

These concepts served as a theoretical basis for the preparation of various documents and national meetings such as ECO 92, held in Rio de Janeiro in 1992, which culminated in the creation of the Agenda 21 and the Statute of Cities governed by Federal Law No. 10.257/2001, proposing that each country should draw up its environmental preservation plan for the 21st century. From 1996 to 2002, the Brazilian government began to carry out extensive consultation with the population, resulting, in 2004, in the "Brazilian Agenda 21" document, structured in several objectives, showing, with regard to the sustainability of cities, guidelines for actions to guarantee the governance of the urban space by the metropolitan authority. The City Statute, at the municipal level, is considered a new legal framework for public policies, which, added to the Brazilian Agenda 21, provides Brazilian municipalities with basis for the construction of sustainable cities, making economic and social development compatible with the preservation of the environment (KOZMHINSKY; PINHEIRO; EL-DEIR, 2016; ROLA, 2008).

Moving forward on the agenda of initiatives to ensure sustainable development, the United Nations (UN) held a conference in New York between September 25 and 27 of 2015, outlining a new action agenda to be fulfilled by 2030, entitled "*Transforming Our World: the 2030 Agenda for Sustainable Development*", generating a Declaration that establishes 17 Sustainable Development Goals, supported by three basic pillars: improving people's living conditions, eradicating poverty, promoting prosperity and welfare for everyone, and protect the environment (GARCIA, D.; GARCIA, H., 2016).

The non-stopping actions in searching for new forms of planning, development of technologies and appropriate environmental solutions to guarantee the quality of life in cities, have led many countries to adopt public environmental policies that encourage the implantation of green roofs on the roofs of buildings (SHARMAN, 2014).

Thus, green roofs emerged as an alternative to compensate for the suppression of vegetation in the urbanization process, helping to solve problems in urban centers in relation to quality of life and the environment.

The system presents itself as a constructive technique characterized by a vegetal covering, consisting of grasses and/or plants, implanted in slabs or conventional roofs (RANGEL; ARANHA; SILVA, 2015). These public environmental policies initially started in Europe (in the second half of the 20th century, mainly in Germany), the United States and Canada, where several scientific studies on this emerging topic demonstrate that this technique has been frequently discussed, being in evidence worldwide (BERARDI; GHAFFARIAN HOSEINI; GHAFFARIAN HOSEINI, 2014; LUZ, 2017; RANGEL; ARANHA; SILVA, 2015; SETTA, 2017). Thus, at the end of the first decade of the 21st century, some Brazilian cities also began to create laws, providing tax incentives to the population, and creating other laws, establishing the mandatory installation of the green roof system in buildings (SETTA, 2017).

Visibility in Brazilian territory is due to its sustainable characteristics and the benefits presented, the main ones being: reduction of rainwater runoff (BALDESSAR, 2012; GETTER; ROWE; ANDRESEN, 2007; PINTO, 2014; PEREIRA, 2017; ROWE, 2011), reduction of greenhouse gases and urban heat islands

(BALDESSAR, 2012; CATUZZO, 2013; PEREIRA, 2017; SCHMIDT, 2009), improvement of air quality (GETTER; ROWE, 2009; YANG; YU; GONG, 2008), improvement of rainwater quality (BERNDTSSON; EMILSSON; BENGTSSON, 2006; BORGA, 2012), reducing energy consumption and thermal comfort (JIM; TSANG, 2010; PINTO, 2014).

Among so many contributions, we still emphasize that depending on the proposed architectural project and the desired landscaping, green roofs have various uses, from small lawns, gardens, squares with leisure areas, even spaces for the cultivation of gardens, where the income generation presents itself as an innovative perspective in the use of vegetables, spices, ornamental and medicinal plants, fruit plants and even animals, being necessary to guarantee the integrity of the plants for their consumption and commercialization (ARAÚJO, 2007; GOMEZ; GAJA; REIG, 1998; OSMUNDSON, 1999).

The biggest obstacle to building a green roof is the high initial cost of implementation, depending on several factors, such as geographic location, roof type, size of the green roof, type of vegetation, qualified labor and correct materials to be used. Each green roof presents itself as a unique project (BIANCHINI; HEWAGE, 2012; PEREIRA, 2017). For the implementation of these roofs, it is necessary to use the services of professionals/specialized technical companies (in order to avoid structural problems, as well as leaks and infiltrations), which is one of the biggest problems of this practice, but every year companies specialized in the subject begin to introduce innovative products with specific technology and materials to the market (KOZMHINSKY; PINHEIRO; EL-DEIR, 2016).

Incentives for the implementation of green roofs in Brazilian cities through public environmental policies, as well as the dissemination of this system, are still slow. Only recently have some cities adopted laws to encourage the use of this technology. The promotion and dissemination of the use of sustainable technologies (such as green roofs) by the Government is essential, since it is co-responsible, together with the economic sector and society, for the preservation of the environment. (RANGEL; ARANHA; SILVA, 2015).

It is expected that this research can contribute to a better understanding of the impacts generated by the installation of green roofs in the city of Recife. This research still intends, based on the data obtained, to help stablish general guidelines and actions that should be promoted by the public management in the incentive for the maintenance of green coverings in this city and in the greater dissemination to make the population aware of the use of this technique.

III. Material and Methods

This research is characterized by qualitative and quantitative, descriptive, empirical, cross-sectional analyzes. The study is based on the empirical-analytical method of an observational nature, consisting of the collection, treatment and more in-depth analysis of the data, without carrying out any type of intervention, which may interfere with the natural course of the study.

The research has taken place at the city of Recife, latitude 08° 03'15" South and longitude 34°52'53" West, capital of the state of Pernambuco, Brazil. A seaside town, with an approximate area of 218, 50 km^2, with an estimated population of 1.645.727 inhabitants (IBGE, 2019), all residents in urban areas, being the third most populous municipality in the Northeast and the ninth in the country.

The city is formed by a plain with islands, peninsulas, wetlands and mangroves, bathed by rivers, in the Central-East region and by hills, in the North, West and South, with high relative humidity, abundant rainfall during the year, humid tropical climate and average annual temperature of approximately 26° (and in summer around 30°).

The purpose of this study was to evaluate the applicability of the green roof system in the city of Recife, after the mandatory Municipal Law No. 18,112, of January 12, 2015. The research methodology was guided in four stages and the time horizon of this work was from January 13, 2015 to September 30, 2019.

Initially, from the data listed in Municipal Decrees No. 30,975 / 2017, with its changes validated in Decree No. 31,690 / 2018, flowcharts of the phases of the procedures for the approval of the architectural project with the City of Recife were produced, since the beginning of entry into the said agency until the final phase of the habit (certificate of authorization, issued by the City Hall, allowing the property to be occupied, attesting that it was built according to legal requirements).

In the second stage, the information in this study was obtained through documentary research, for data collection, identifying and quantifying the architectural projects with green roofs approved by the City of Recife, after the mandatory law, object of this study. Therefore, those prior to the law are not counted, nor are those that the law does not require mandatory.

The data collected through the architectural projects, located in the digital processes, electronically, in the period from 2017 to 2019, through the General Management of Geoprocessing and the Urbanistic Licensing Portal of the City of Recife, identified 87 projects with a green roof system, among the 284 deferred projects analyzed. As for the data of architectural projects, in physical environment, from 2015 to 2018, they were collected through a monograph by Mariana Aragão da Silva, entitled Analysis of

Municipal Legislation nº 18,112/2015: a study of the implementation of green roofs as a strategy for sustainable construction in the city of Recife, Pernambuco, in the 06 (six) public archives of the 03 (three) Regional Divisions of the Prefecture of Recife, where 1,076 plants were analyzed that fit the prerogative of being approved from 2015, with 56 projects identified with green roofs (Appendices 1 and 2).

The work of Aragão (2020) aimed to analyze municipal legislation No. 18,112/2015, showing the advantages of using sustainable alternatives for construction, aiming at increasing the quality of life in cities, analyzing the items contained in the text of municipal legislation, checking of the implementation through the survey of the projects in the City of Recife and elaboration of a proposal with suggestions for improvements to incorporate the revision of the legislation, to be presented to the *Instituto da Cidade Pelópidas Silveira*.

In the third research phase, during the month of September 2019, a territorial cut was made, identifying through field research, the situations of the buildings in which the buildings with a green roofing system are found: constructions not started, those started and those completed with housing permit.

With all the surveys completed, the extracted data was processed and analyzed using descriptive and inferential statistical techniques, through the correlation and regression of the collected data, with the aid of the statistical software Statistical Package for the Social Sciences® (SPSS), version 24. The analyzes consisted of hypothesis testing and analysis of variance of the data collected, followed by a mean test for those that had significant results.

Concluding, with the elaboration of maps (with the aid of AutoCAD® 2011 software) identifying through the Geographic Information System of the Municipality of Recife - ESIg, the location of the deferred architecture projects with a green roof, based on the six Recife's Political-Administrative areas (RPA's).

It should also be noted that the maps and information presented here, such as green roofs, building belt stains and critical flooding points, were originated from several sources: *Instituto da Cidade Pelópidas Silveira* ICPS (2018), Recife's Master Plan - PDCR (2018), Urban Cleaning and Maintenance Company - EMLURB (2018).

IV. Results and Discussion

a) Approval procedures for architectural projects

In order to facilitate the understanding of the implementation of green roofs in the city of Recife, flowcharts were created containing the procedures (made available electronically) for the application, processing and completion of the approval of architectural projects - based on the instructions defined in Municipal Decree nº 30.975/2017, with the changes validated in Decree nº 31.690/2018.

Emphasizing that all construction permits (as of December 4, 2017) and all projects (including architecture as of August 28, 2018) are now approved, exclusively through the digital urban planning process (PU) electronically, through the Urban Licensing Portal of the City of Recife. A construction permit or license is defined as: "Document, issued by the City Hall, of a license for the execution of a new work or renovation, based on the architectural project previously approved" (https://licenciamento.recife.pe.gov.br).

As stated in Decree No. 30,975/2017, initially all professionals and companies must register with the Integrated Urban Licensing System (SILUR), through the Licensing Portal, to enable the opening or monitoring of the digital process (PU). This opening will depend on validation, by the Licensing Center, within a maximum period of three calendar days, from the request, for the formalization of the process at SILUR, which flowchart is shown in Figure 01 (DECRETO Nº 30.975/2017).

If this validation is not approved, the process is automatically canceled, making it necessary to make a new request to restart the process. Once the opening has been approved, without any non-conformities, the Municipal Collection Document (DAM) is issued, when appropriate, for due payment, within fifteen consecutive days, from the issue of said document. If payment is not made within the stipulated period, the request will be automatically denied, and the entire opening application must be restarted.

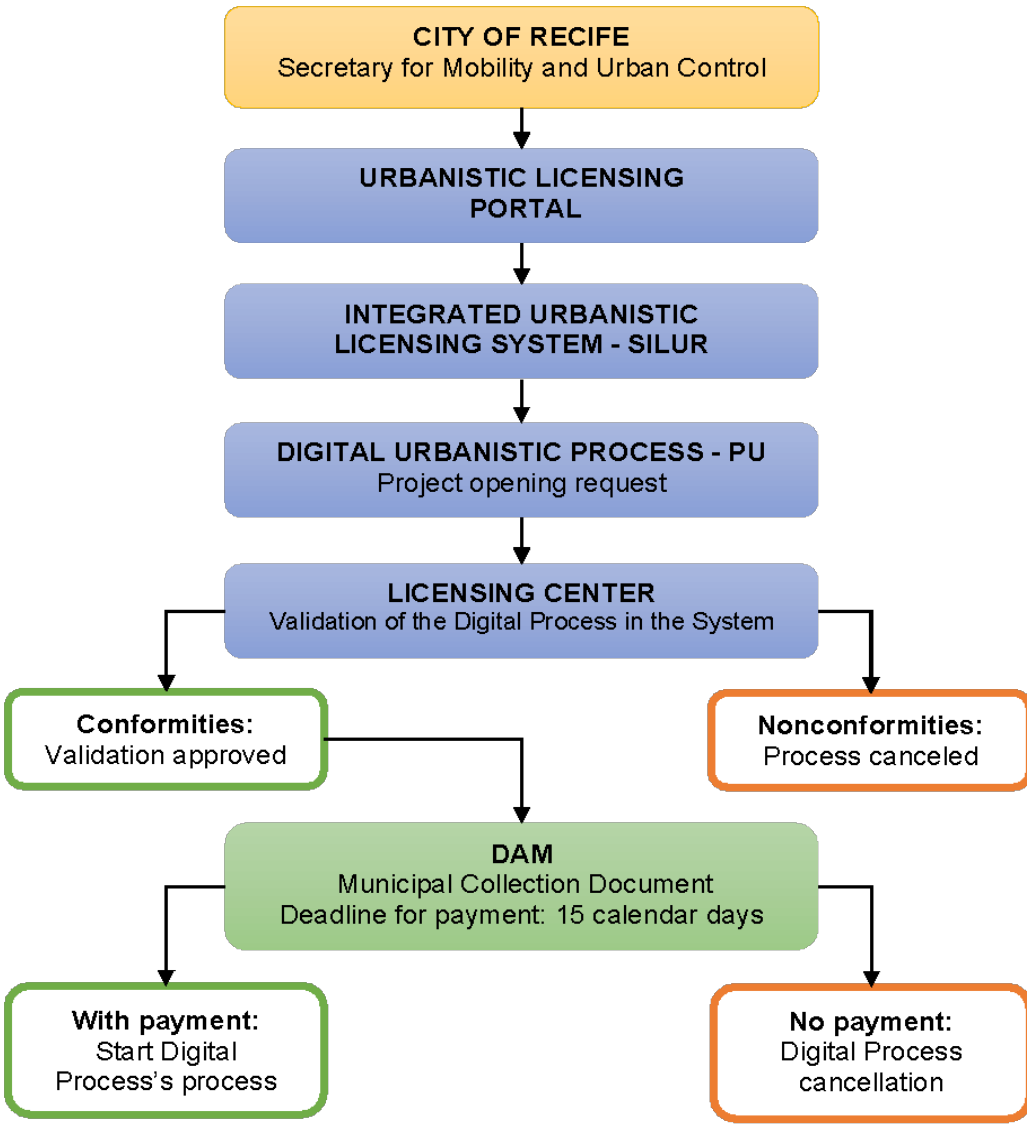

Figure 1: Flowchart of opening digital urban processes

With the opening of the validated digital process, it starts to be processed, through electronic referral, by the Regional Divisions, depending on the location of the environs where it is inserted. When applicable, it is sent to other external municipal units, which, after pronouncement, return to the Licensing Center, where the Head Office distributes it among the project analysts for technical analysis, according to the flowchart shown in Figure 02 (DECREE No. 30.975 / 2017; DECREE No. 31.690 / 2018).

After the payment of the DAM, the Licensing Center has a maximum period of 90 calendar days to complete the approval analysis or not of the process. Does not account for the time elapsed with the fulfillment of requirements by the applicant, with the analysis of bodies external to the Licensing Center, nor with operational problems caused in the electronic system.

In the event of rejection of the process, Decree No. 30,975 / 2017, stipulates the conditions and deadlines for compliance with the requirements. When the process is approved, the plans of the architectural project are available in the electronic system, containing the digital signature of the person responsible for approval. The validity period of the approved architecture project is 01 year, and you can request revalidation for the same period. Having the other complementary projects such as Works of Art, Fire Prevention and Fighting System, Waste Management and others, also already approved by electronic means, you can enter with a request to open a process for Construction Permit, exclusively, through electronic means.

After granting the Permit, it is no longer necessary to revalidate the architectural project, having a validity period of 01 year for works of up to 500 m^2 and

03 years for over 500 m², which can be renewed for equal periods. The Flowchart in Figure 02 ends with the issuance of the Permit to Stay, where the City Hall attests that the building was built in accordance with legal requirements and the property is ready to be occupied.

Thus, this Permit is presented as an important tool of inspection and control of the Municipal Government to ensure that the construction takes place in order to ensure its structural, functional, aesthetic and its relationship with the external environment, providing an improvement in the quality of the built environment.

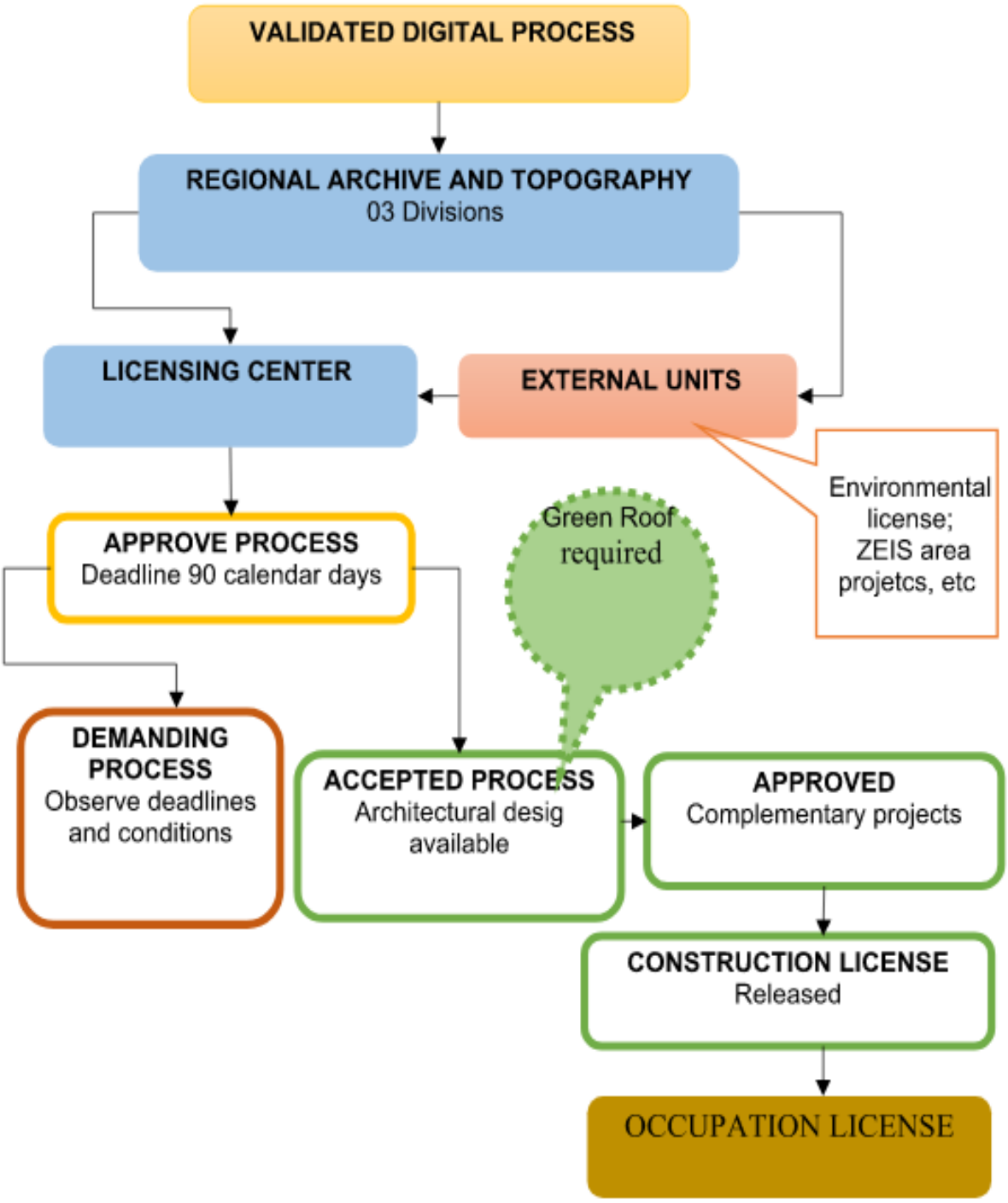

Figure 2: Flowchart of the digital architecture process

b) Analysis of survey data collection

After analyzing the data collected, it was possible to observe that the years 2016 (557,231.94 m^w) and 2019 (641,150.18 m^2) were the ones that had the largest amount in construction area presented in the architectural projects, with a green roof system. , granted by the Recife City Hall, from January 13, 2015 to September 30, 2019, not statistically different from each other, compared to 2015 (214,654.36 m^2), 2017 (154,642.97 m^2) and 2018 (198,830, 54 m^2) that presented similar quantities to each other. In relation to the green roof area planned in these projects, 2019 (36,478.03 m^2) is characterized by the largest available area, followed by 2016 (20,657.08 m^2). The years 2015 (10,900.50 m^2), 2017 (8,849.33 m^2) and 2018 (11,508.39 m^2) had smaller areas and their values did not differ statistically from each other (Figure 03).

The 2015/2016 biennium characterized a period of severe recession in Brazil, immediately affecting civil construction, whose economic activity worsened with "Operation Lava-Jato" as it impacted the operations of national companies linked to this sector. In 2017, the beginning of the economic recovery was foreseen, however, the activity of civil construction remained very retracted and delayed in this recovery. In fact, it started showing signs of improvement from 2018 (TINOCO; GIAMBIAGI, 2018).

Intriguing factor in 2016, as it has a construction area of 557,231.94 m^2 in the midst of a recession in the country. It should be noted that in that year, 70% of the approved projects did not start construction until September 2019 (Tables 01 and 02) and that 20% only started to build in the 2018/2019 biennium (Table 02). As for the construction area found in 2019 in the research period between January and September of that year, the market is heating up in relation to civil construction activities, coupled with more in-depth knowledge of the legislation in force by architects, engineers and construction companies regarding the mandatory installation of a green roof.

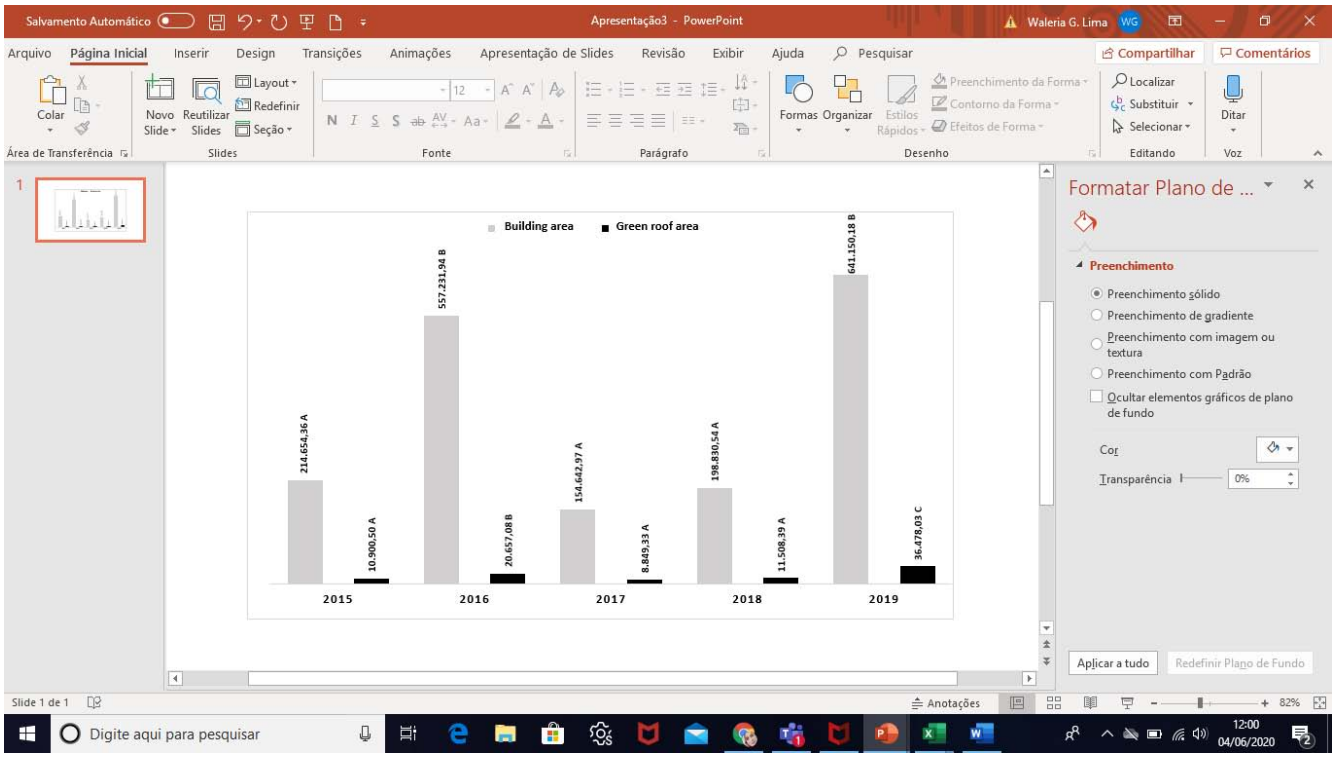

Figure 3: Expected areas of approved architecture projects with a green roof system, from January 2015 to September 2019, for the construction of projects (1,766,509.99 m^2) and green roofs (88,393.33 m^2) in the city of Recife. Averages followed by the same letter, do not differ, by the Tukey Test, at the level of 5% probability

Regarding the type of construction, among the 143 architectural projects surveyed with a green roof system, it was identified that the projects are built with three purposes of use: multifamily housing, non-housing and mixed. As for multifamily housing use, it was possible to observe that the number of developments has seen a significant increase over the years compared to other uses. The same was observed in relation to the total area of green roofs. However, mixed use presented similar building units for the years 2016 and 2019, although, in relation to the green roof area, 2016 (11,618.01 m^2) was higher than 2019 (2,680.09 m^2), which in turn, did not differed statistically from 2017 (2,029.60 m^2) (Table 01; Figure 04).

Table 1: Number of projects and total area (m^2) of green roofs foreseen in the approved architecture projects from January 2015 to September 2019 in the city of Recife, depending on the type of use of the building. Averages followed by the same letter, do not differ, by the Tukey Test, at the level of 5% probability

Type of Use	ear	Number of projects (units)	Total area of Green Roofs (m^2)
Multifamily Housing	015	18 B	8.403,35 B
	016	11 A	5.883,00 A
	017	11 A	6.355,73 A
	018	24 B	9.773,29 B
	019	46 C	25.023,80 C
Non-Housing	015	3 A	2.497,15 B
	016	2 A	3.156,07 B
	017	1 A	464,00 A
	018	4 A	1.341,21 B
	019	7 B	8.774,14 C
Housing and non-housing	015	0 A	0,00 A
	016	7 B	11.618,01 C
	017	2 A	2.029,60 B
	018	1 A	393,89 A
	019	6 B	2.680,09 B

In the 1980s, the urban legislation of the city of Recife did not allow the avenues to build mixed-use typologies, that is, trade and services together with housing use. The residential areas were the ones with the highest coefficients of use on the land. Thus, commerce and some services preferred to renovate the existing single-family housing buildings for their facilities. In this way, real estate agents discouraged as to the construction of these developments, centralized their activities exclusively in the construction of verticalized multifamily housing and business centers (MEDINA, 1996). Added to this, the unrestrained occupation of the urban territory by the growing population, leading to the gradual replacement of single-family housing by multifamily.

As for Figure 04, it is also observed that the green roof area in the different construction types has been gradually increasing since 2017, except for the year 2016, which presents a peak in the mixed used area (11,618.01 m^2). A punctual case appears, considering that six large architectural projects were approved at the time, including only one of them being listed as a project started among the four listed in 2016 (Table 02).

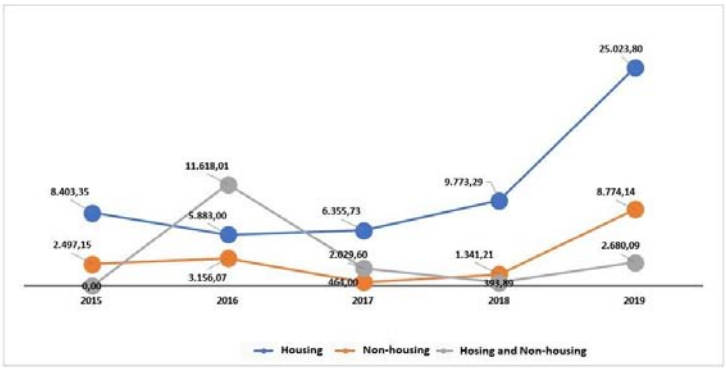

Figure 4: Areas, in m^2, of green roofs provided for in the approved architecture projects from January 2015 to September 2019 in the city of Recife, depending on the type of use of the building.

As shown in Table 02, the works entitled started, although presenting the architectural projects approved in intervals of years between 2015 and 2019, had the month of September 2019 as a research base in relation to the situation of the constructions, that is, of the 21 deferred projects, in 2015, 06 are live and 03 are with works started. In 2016, of the 20 projects, currently, 02 have housing and 04 have started works. For 2017, of the 14 approved projects, there are 01 with housing and 06 started. Still, in relation to the 29 projects in 2018, 01 has a home and 11 are under construction. While, until September 2019, of the 59 deferred projects, for the short period of time, none has yet to be settled, and 04 are started. Totaling, with the completion of the works, an area of 22,926.58 m^2 of available green roofs, improving the quality of life of the population of Recife (BALDESSAR, 2012; CATUZZO, 2013; PEREIRA, 2017; GETTER; ROWE, 2009; YANG; YU; GONG, 2008).

It is also noted that the units of enterprises in the works started in the years surveyed do not differ statistically from each other, with the exception of 2018, which shows a higher quantity, with 11 units, although, in relation to the green roof area, it is the year of 2019 (6,913.05 m^2) with the largest area, where in the years 2016 (3,007.19 m^2), 2017 (2,104.49 m^2) and 2018 (3,913.70 m^2) their values did not differ statistically from each other (Table 02).

Table 2: Number of projects and total area (m2) of green roofs in relation to the construction situation of the buildings in the city of Recife, based on the month of September 2019. Averages followed by the same letter, do not differ, according to the Tukey Test, at the 5% probability level

Construction status in September 2019	Year of architectural design approval	Number of projects (units)	Total area of Green Roofs (m^2)
Not started	2015	12 B	7.497,68 B
	2016	14 B	14.699,08 C
	2017	7 A	6.463,55 A
	2018	17 B	7.241,46 A
	2019	55 C	29.564,98 D
Started	2015	3 A	718,54 A
	2016	4 A	3.007,19 B
	2017	6 A	2.104,49 B
	2018	11 B	3.913,70 B
	2019	4 A	6.913,05 C
	2015	6 B	2.684,28 B
	2016	2 A	2.950,81 B

Occupation License	2017	1 A	281,29 A
	2018	1 A	353,23 A
	2019	0 A	0,00 A

In Figure 05, the impact of the financial crisis faced in the country in 2016 can be seen, with the civil construction activity soon being affected, demonstrated by the works not started this year, with a total area of green roof corresponding to 14,699.08 m^2. The information from the documentary and field research clearly portrays that the market started to react from 2018, where 55 new architectural projects were approved in 2019 with a green roof system (29,564.98 m^2), which for the most part still did not have enough time to start their construction and the four started will make available, at the end of the works, an area of 6,913.05 m^2 of green roofs, this quantity, not seen in previous years, nor in areas with habitation (Table 02; Figure 05).

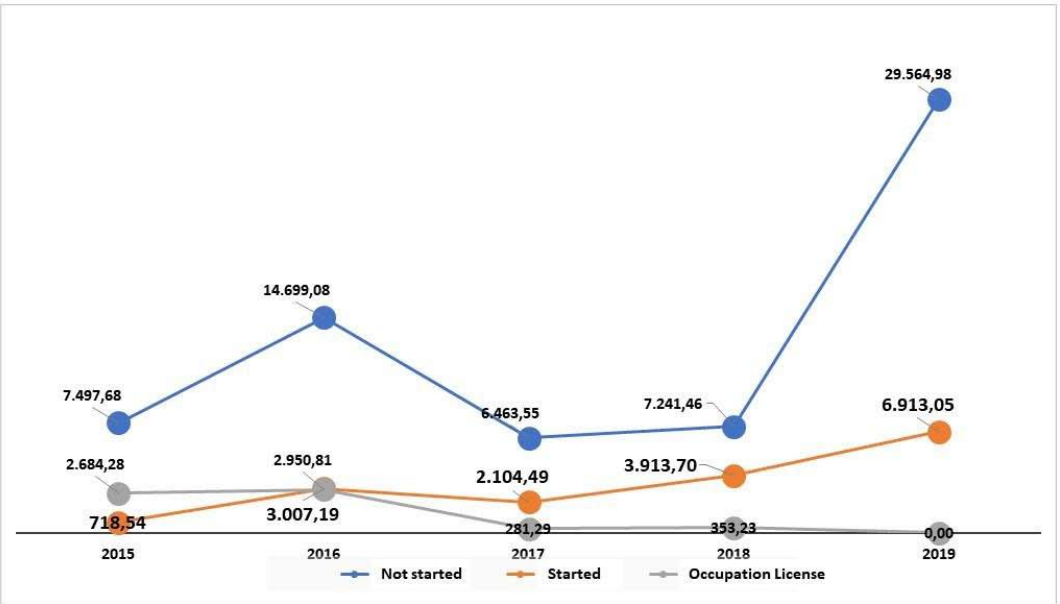

Figure 5: Areas, in m^2, of green roofs in relation to the construction situation of buildings in the city of Recife, based on the month of September 2019

As for the legality of the projects, these can be classified as mandatory, those that are within the scope of the law, and not mandatory, for those that the law does not require the implementation of the green roof, but that the enterprise had this item for landscape purposes and environmental issues. It is observed in Table 03, that of the total area of green roofs presented in the architectural projects raised in this study, 93% fall within the mandatory law. However, of the remaining 7%, projects are not within the profile defined by law. This can be justified by the landscape appeal that brings greater added value to the product, the awareness of the customer that has become increasingly aware of environmental concerns, the reflection of public policies that are being gradually disseminated and adopted in Brazilian cities.

In contrast, of the 10 projects surveyed with housing, 3 units had removed the green roofs of their facilities. Once the maintenance is under the responsibility of the owner, they are susceptible to mischaracterization, making greater incentives and disclosure necessary for the implementation of the system by the Government (Table 03).

The mandatory installation of green roofs in the city of Recife started with Municipal Law n^o 18,112/2015, object of this study, which was sanctioned on January 12, 2015. With the objective of contributing to the improvement of the environmental quality of buildings, makes it mandatory to install the green roof on multifamily housing buildings with more than four floors and non-housing with more than 400 m^2 of covered area and the construction of accumulation or delay reservoirs for the drainage of rainwater to the drainage network (RECIFE, 2015a).

This construction, destined to lots with an area greater than 500 m^2, built or not, and with a waterproofed area greater than 25% of the total area of the lot. These reservoirs may be built in natural soil, corresponding to up to 10% of this area. The accumulation reservoirs aim to accumulate rainwater for

reuse for non-potable purposes, and the delayed ones, to accumulate rainwater for later discharge into the public network (RECIFE, 2015a).

Thus, for the approval of the architectural design of these buildings and the subsequent release of the building permit, it is necessary to provide for the implantation of a green roof on the uncovered pavement intended for vehicle parking, which can also be used as a floor slab for leisure. , and in the leisure areas, when located on a floor slab, in the percentage of 60% of its bare surface and at least 30%, in the leisure areas when on a covered slab. It also mentions that the Green Roof must have a minimum width of 2.00m (RECIFE, 2015b).

According to the law, the green roof may have extensive or intensive vegetation, being preferably native because it adapts better to the tropical climate of Recife, bringing balance to the environment where it is being inserted, improving the landscape aspect, reducing the heat island, retaining and reusing rainwater and positively interfering with the local microclimate.

Regarding the Political-Administrative Regions, in Table 04, it was possible to observe that most of the architectural projects deferred from January 2015 to September 2019 were for RPAs 3 and 4, presenting 26.5% and 23.8 %, respectively, which represents practically 50% of the total, as they have environs that are in increasing real estate speculation. However, RPA 4 (18,624.55 m²) and RPA 6 (18,415.77 m²) have similar green roof areas, especially RPA 1 (26,304.63 m²) for having architectural projects with large projects, mixed use, in São José environs.

Another factor to mention is the relationship of the presence of the enterprises about critical flooding areas. The malfunction of the drainage network causes serious problems to the road system in Recife during rainy periods, leaving flooded streets. The chaotic urbanization process added to the growing impermeability of natural soil aggravates the problem of urban drainage. With the overloading of the existing infrastructure, rainwater cannot run off superficially, accumulating water in the weakest points of the system, generating the critical points of flooding in the city. In addition, the city presents a spatial segregation, more valued environs are much more endowed with infrastructure and urban equipment, compared to the others (EMLURB, 2013). It is observed that RPA 5 is one of the regions with the highest number of critical flooding points, 22 units with only 02 approved projects. Another contrast is observed for RPA 3, which has 38 approved projects and only 09 flooding critical points (Table 04). In the Municipal Law, the object of this research, green roofs are presented as one of the measures that provides a solution for the management of rainwater, as well as the reservoir of delay or accumulation of rainwater, at the lot level. (SILVA JÚNIOR; SILVA, S., 2016).

Table 3: Deferred architecture projects with a green roof system, with and without obligation, post-municipal law No. 18,112 / 15, from January 2015 to September 2019, in the city of Recife. T-Student test for independent samples; ** p 0.01; * p 0.05.

Deferred Processes	Green Roof area (m²)	Environs	Housing	Non-Housing	Mixed	Not started	Started	Occupation License	Kept after housing permit
Mandatory	88.393,33**	34**	110**	17*	16**	105**	28**	10**	7
Not required	5.651,02	15	6	12	1	10	5	4	no information

Table 4: Architectural projects approved with green roof system by RPA and total area (m2) of green roofs planned between January 2015 and September 2019 in the city of Recife. Averages followed by the same letter, do not differ, by the Tukey Test, at the level of 5% probability

RPA	Environs	Deferred Project	Green Roof Area (M²)	Total Projects By RPA	Total Green Roof Area Per RPA (M²)	Critical Flooding Points
RPA1	BOA VISTA	9	3.420,09 B	27	26.304,63	
	ILHA DO LEITE	1	2.800,00 B			
	PAISSANDÚ	1	1.158,41 B			
	RECIFE	1	138,71 A			22
	SANTO AMARO	7	6.802,59 B			
	SÃO JOSÉ	6	11.529,63 C			

	SOLEDADE	2	455,20 A			
RPA2	ARRUDA	1	628,39 A	19	9.370,25	10
	CAMPO GRANDE	6	3.845,53 B			
	ENCRUZILHADA	6	1.956,29 A A			
	HIPÓDROMO	2	1.606,85 A			
	ROSARINHO	4	1.333,19 A			
RPA3	AFLITOS	1	427,13 B	38	13.769,09	9
	CASA AMARELA	11	3.459,72 E			
	CASA FORTE	2	207,68 A			
	ESPINHEIRO	6	1.829,12 C			
	GRAÇAS	7	3.020,13 E			
	PARNAMIRIM	3	1.215,24 C			
	POÇO DA PANELA	1	555,20 B			
	SANTANA	2	265,32 A			
	TAMARINEIRA	5	2.789,55 D			
RPA4	CAXANGÁ	1	781,52 A	34	18.624,55	14
	CORDEIRO	3	2.015,93 C			
	ILHA DO RETIRO	4	2.300,36 C			
	IPUTINGA	3	1.919,15 B			
	MADALENA	8	4.011,35			
	PRADO	2	1.561,49 B			
	TORRE	8	3.125,67 D			
	VÁRZEA	5	2.909,08 C			
RPA5	JARDIM SÃO PAULO	1	1.053,36 B	2	1.909,04	22
	SAN MARTIN	1	855,68 A			
RPA6	BOA VIAGEM	12	5.959,50 A	23	18.415,77	30
	IMBIRIBEIRA	7	5.898,92 A			
	PINA	4	6.557,35 A			
	TOTAL	143	88.393,33	143	88.393,33	107

c) *Relationship between green roofs and the Political and Administrative Regions of the city of Recife*

In the Recife City Development Master Plan (PDCR), the urban space of Recife is divided into six Political-Administrative Regions, as shown in Figure 06, distributed in the central, north, northwest, west, southwest and south regions and formed by 94 environs. The RPA's were defined for the formulation, execution and permanent evaluation of government policies and planning (Lei Orgânica do Recife, Artigo 88, & 1º e 2º, 1990).

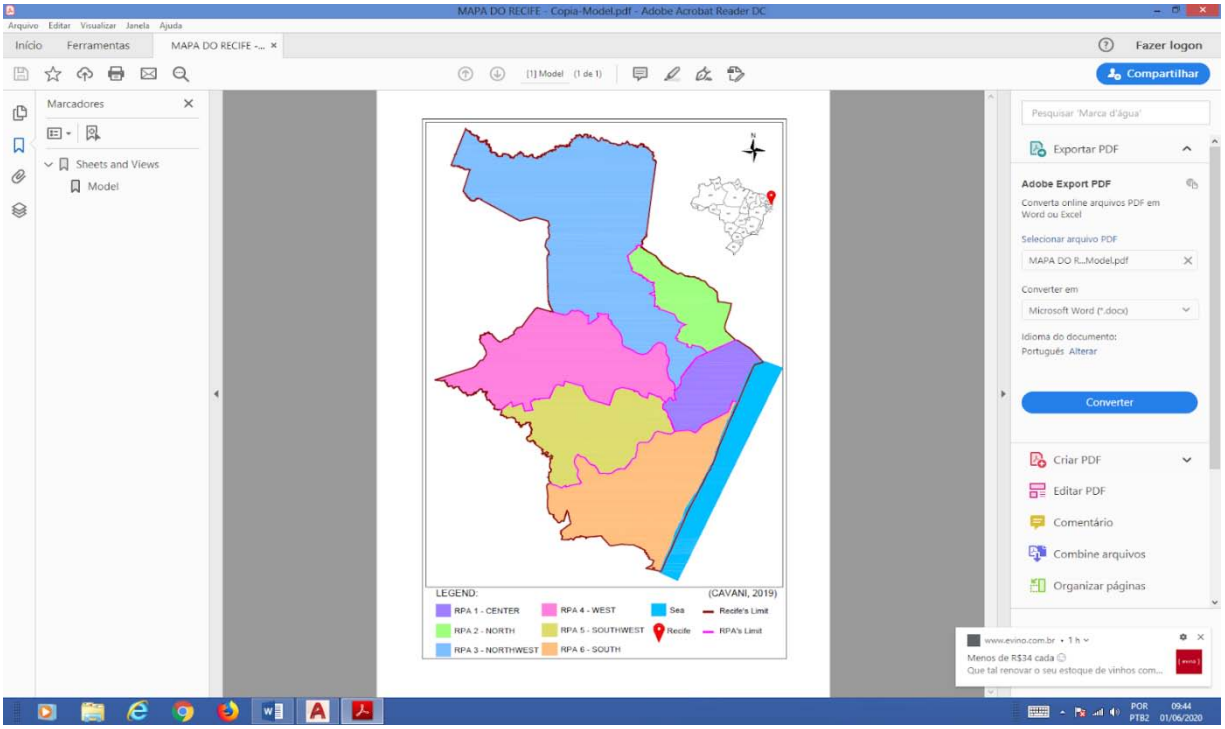

Figure 6: Political and Administrative Regions of Recife

In order to understand the spatial distribution of green roofs in the city's environs, a study was developed in the elaboration of cartograms, resulting in a set of seven maps, one of which is general of the city of Recife and another six, referring to each RPA.

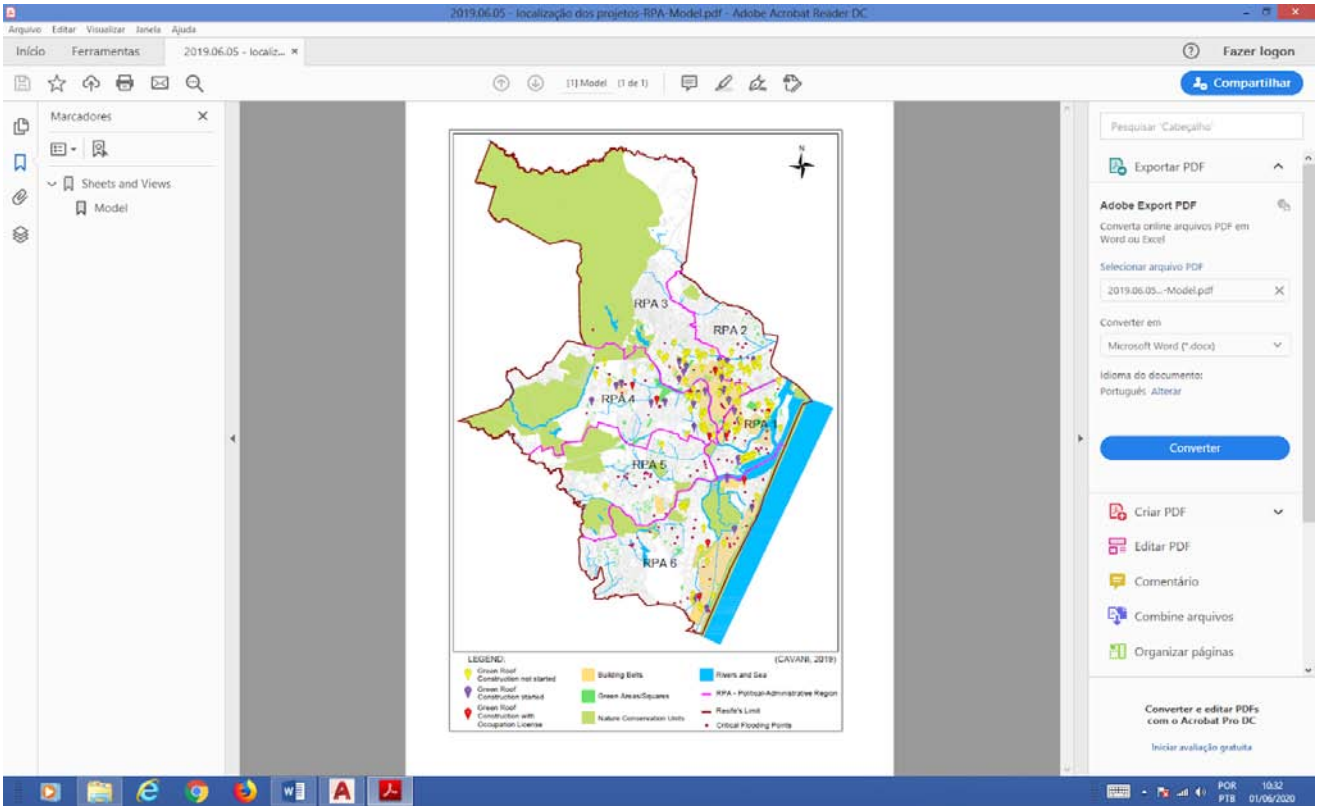

Figure 7: Distribution of green roofs in the city of Recife, located by Political-Administrative Regions

The areas of green roofs, patches of building belts and critical points of flooding presented in Figure 07, although originated from several sources, were computed together, to demonstrate the relationship of these units with the locations of implantation of current and future green roofs.

This general map presents large masses of green areas, called Nature Conservation Units - UCN, which are part of the Categories of Protected Units, being of great importance for the mitigation of the climate. Protected Units are "the spaces and the natural and artificial elements of the municipal territory, under special attention and care due to some specific and / or unique attribute that they present. They have significant environmental and / or landscape interest, necessary to mitigate the climate and intended for the practice of activities: contemplative, cultural, recreational, sports, ecotourism, socializing or leisure, environmental education, scientific research" (MUNICIPAL LAW No. 18014/2014, ART. 6 OF CHAPTER III).

As for the building belts, an urban configuration characterized by the agglomeration of multi-storey buildings built without standardization, they present more predominant spots located, one in the south zone, close to the Atlantic Ocean, in RPA 6 and another, around the Capibaribe River, in the RPA's 1, 3 and 4. It is also possible to observe the disparity in the number of green roofs distributed in these regions, as a result of the evolution of urban occupation in the city and real estate appreciation in some environs.

The urbanization process in the city of Recife took place in a disorderly manner, resulting in an increase in impermeable areas and overloading the existing drainage system, resulting in a total of 107 critical points of flooding in the rainy periods and tidal fluctuations, as indicated in the general map. , the law being the object of this research, pointed out as one of the measures that provides a solution for the management of rainwater (EMLURB, 2018; SILVA JÚNIOR; SILVA, S., 2016; SILVA JÚNIOR et al., 2017).

According to Pinto (2014), there is the possibility of combining the installation of a green roof with the recent solutions for the use of rainwater, cisterns, or underground reservoirs, which may contribute to the complete elimination of runoff. These waters can be reused for non-potable purposes, for example, to feed irrigation systems, reducing water consumption, whether in public or private spaces.

The green roof can improve the quality of life in the city of Recife, which in addition to reducing the impacts of the heat island and the emission of greenhouse gases, has the property of absorbing and releasing part of the solar radiation, reducing the air temperature and raising the humidity of the air (BALDESSAR, 2012). It should be noted that, when applied to urban centers on a large scale, the Green Roofs interact with each other and with the environment in which they operate, constituting a stable, balanced and self-sufficient system, starting to play an important role in the maintenance of this healthy ecosystem (OSMUNDSON, 1999).

i. *RPA 1- Political-Administrative Region - Center*

In Figure 08, RPA 1 is composed of 11 environs, the environs of Recife, the stage of the beginning of the urbanization of the city of Recife, in the 16th century, due to its port location that facilitated the flow of commercial products at that time, Brazil and sugar cane. In the 17th century, with the arrival of the Dutch, there was a great urban intervention, with landfills and construction of bridges, starting the expansion of the island of Recife towards the current environs of Santo Antônio and São José, building palaces, churches, forts and markets. With the withdrawal of the Dutch the economic crisis and competition from the ports of Rio de Janeiro and Salvador put the region in decline, keeping only financial and export services, as well as commercial activities to serve dockers and sailors, gradually removing the population wealth, who starts looking for housing in more distant environs. The environs then undergoes a major emptying from the 1980s, when in 1991, the state government with several partnerships, transformed the environs into a tourist hub, revitalizing the area, being today an area linked to technology and of great importance historical and cultural (EMLURB, 2013; ZANIRATO, 2006).

All the environs belonging to this region are located in lowland areas, totaling 1,606ha, with emphasis on reduced afforestation due to the presence of *Parque 13 de Maio*, *Santo Amaro Cemetery*, *Praça da República*, mangrove area on *Joana Bezerra Island*, *Zeca Island*, taking advantage of the *Capibaribe River* estuary. The climate located in this central region is above 26°C, being warmer around 10°C, compared to the peripheral areas and the conservation units, located in the west of the city of Recife (BARROS; LOMBARDO, 2013; EMLURB, 2013).

The region also has a total of 22 critical flooding points, with the environs of São José and Santo Amaro having the highest number, respectively 10 and 03 occurrences of flooding (EMLURB, 2018). Of the 26,304.63 m² of green roofs planned to be installed in this region, the largest areas will be available exactly for these environs: 11,529.63 m² for São José and 6,802.59 m² for Santo Amaro, contributing to the improvement surface runoff of rainwater and ameliorating the region's hot climate. We also emphasize that the 03 buildings with works started corresponding to 2,424.00 m² of green roofs and those with housing, 3,056.88 m². It is noteworthy that in 1996 the Ilha Joana Bezerra environs had a built area of around 1,500 m², with the implementation of the Judge Rodolfo Aureliano Forum and the headquarters of the Association of Friends with Disabilities (AACD), has grown to 48,300 m² in seven

years. Meanwhile, the Ilha do Leite environs showed an increase of 163% in growth due to the implementation of the Medical Center (EMLURB, 2013).

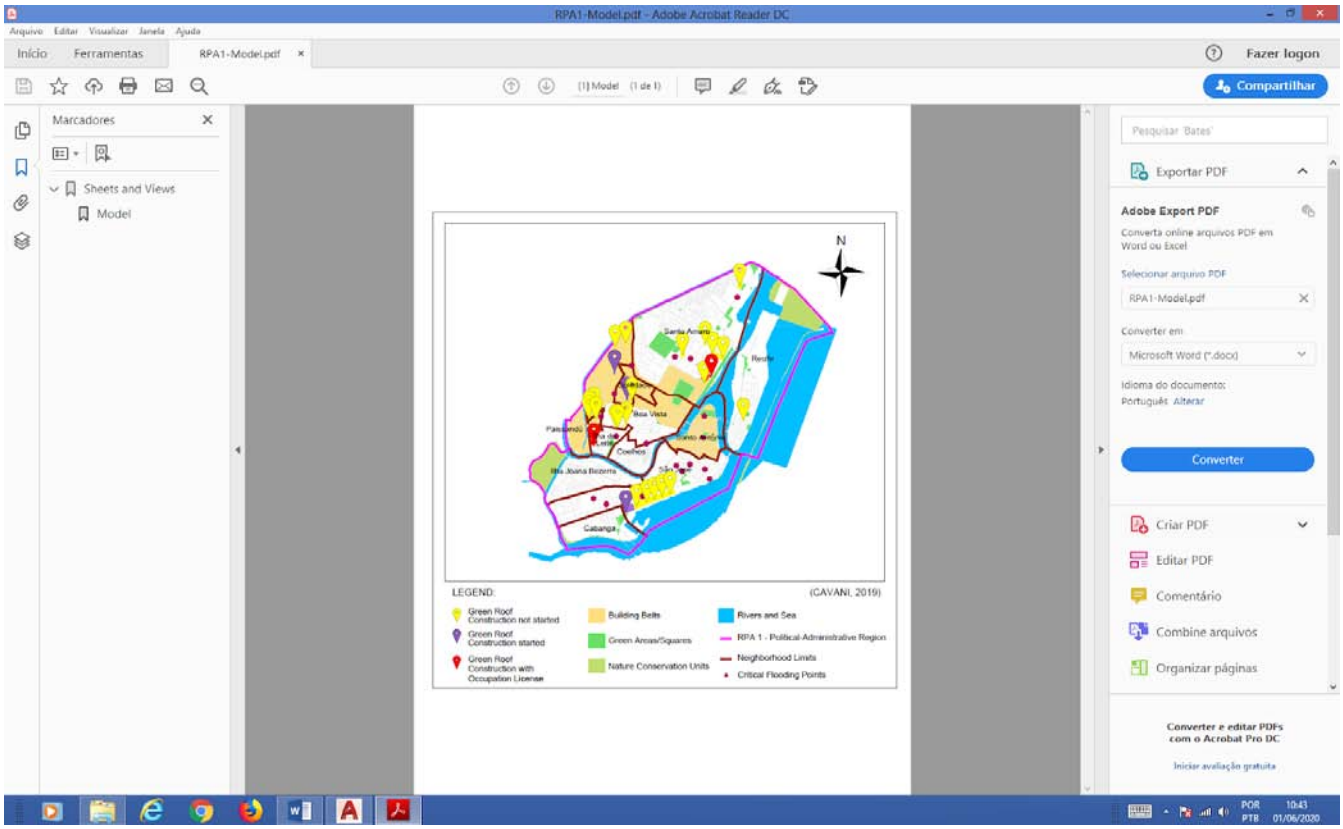

Figure 8: Political-Administrative Region RPA 1 with the location of the green roofs

ii. *RPA 2 - Political-Administrative Region - North*

As shown in Figure 09, RPA 2 is in the northern region of Recife, with 18 environs, the least extensive of the regions, with an area of 1,430 ha. The largest urban concentration begins on the banks of the Capibaribe River, towards the environs of Derby, Graças, Espinheiro and Aflitos, extending to Encruzilhada, Rosarinho and Campo Grande, due to the growing real estate speculation and for presenting a lowland area. RPA 2 has a smaller spatial distribution of green area, represented by the Dois Unidos Nature Conservation Unit, around 50 ha, in addition to squares and other refuges scattered throughout the region (EMLURB, 2013; OLIVEIRA *et al*., 2013).

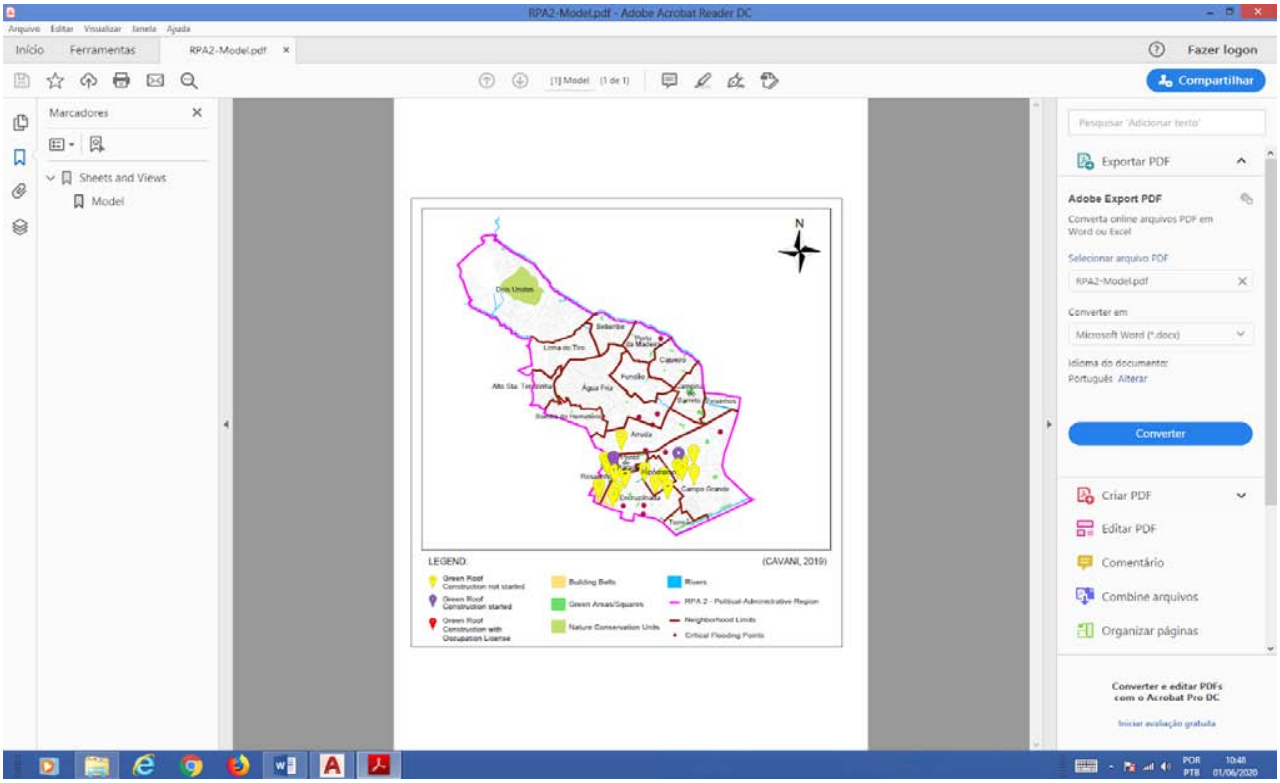

Figure 9: Political-Administrative Region RPA 2 with the location of the green roofs

The temperature of the region is above 26º, finding areas built on plains and coastal boards and hills, where there is an extensive heat island, partly due to chaotic urban occupation, with population density and sparse vegetation , in addition to the low quality of the materials used in the constructions allied to the growing waterproofing of the soil, with the paving of streets and stairs (BARROS; LOMBARDO, 2013).

RPA 2 presents a total of 10 critical flooding points, distributed among the environs of Água Fria, Arruda, Campo Grande and Encruzilhada (EMLURB, 2018). Of the total of 9,370.25 m² of green roofs planned to be installed in this region, it should be noted that most of them are included in the environs: Campo Grande, area of 3,815.53 m², in construction to start and 30.00 m² already started, Crossroads with 1,956.29 m² to start and in Rosarinho, an area of 857.12 m² to start and 476.07 m² of green roof area already started.

iii. *RPA 3 - Political-Administrative Region - Northwest*

Located in the northwest region of Recife, RPA 3, shown in Figure 10, has a greater number of environs in relation to the other regions, 29 units, being the most extensive of the regions, with an area of 7,781 ha, representing 35% of the area of the Recife. Historically, its urban evolution takes shape, from the 18th century, when urban growth begins to expand slowly and radially, starting from the center (RPA 1) towards the interior, due to the lack of interest of wealthy families in the use of the central region for residential purposes and the availability of new traffic routes that are being developed, such as railways and waterways. In this way, several mills installed on the plains gradually gave rise to lots and sites, forming the current environs of Derby and adjacent, up to Apipucos, following the top-hydrographic conditions, close to the Capibaribe River. It is also due to the strong reason for the urban occupation near the river, to the population's attractive to bathe in the river, not having in the middle of the 18th century, habit for bathing in the sea. The replacement of old horizontal houses with buildings for multifamily residential use and real estate investments were gradually starting in 2003, allowing for a building density in the environs of Derby, Espinheiro, Graças, Aflitos and part of Parnamirim and Tamarineira (EMLURB, 2013).

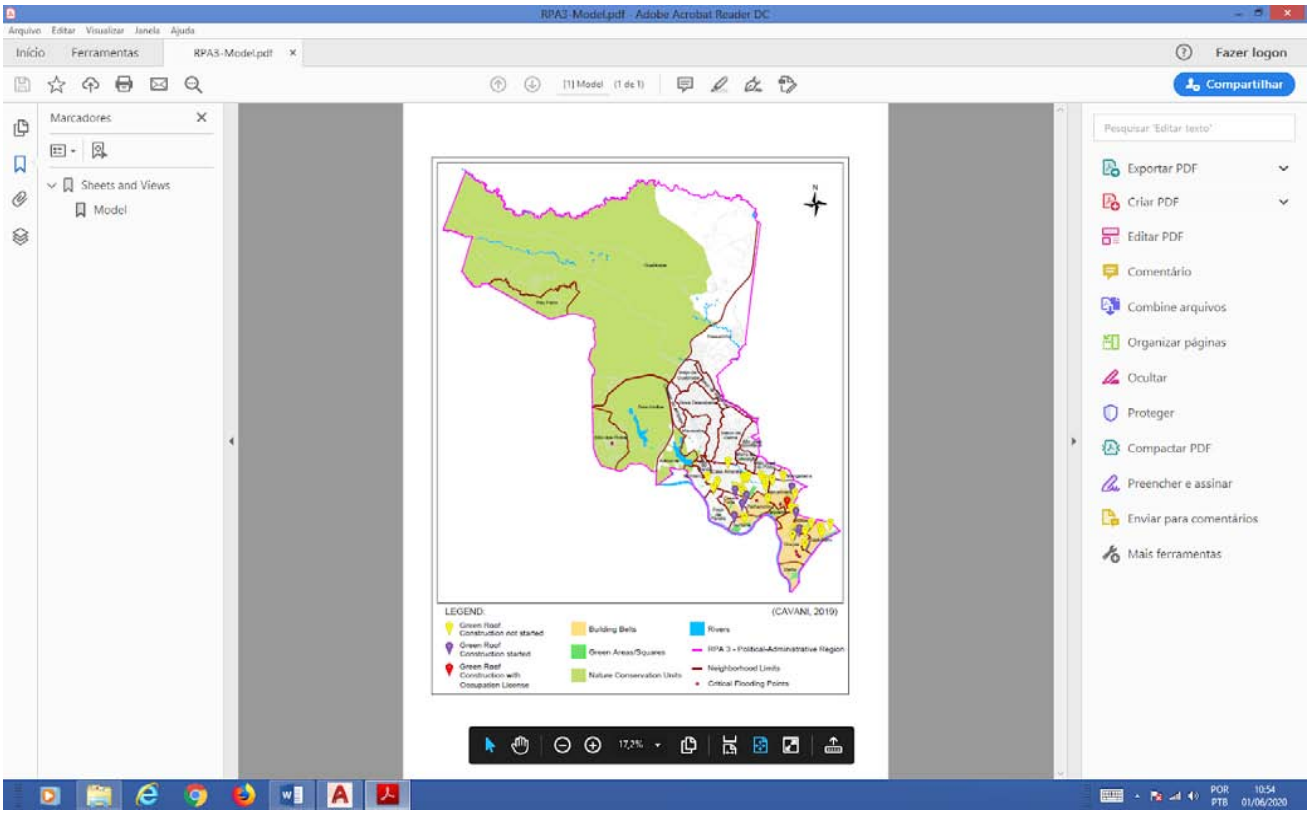

Figure 10: Political-Administrative Region RPA 3 with the location of the green roofs

This region has a vast green patch, representing 49% of the total green area of the city of Recife, represented by the Beberibe Nature Conservation Units, Dois Irmãos, Sítio dos Pintos, Capivaras Park and the Apipucos Weir, in addition to the Parks da Jaqueira and Tamarineira (EMLURB, 2013; OLIVEIRA et al., 2013). The temperature in this region varies from 22º to 26º and may be aggravated by heat waves due to the existing construction network and the growing real estate speculation. (BARROS; LOMBARDO, 2013).

The region has a total of 9 critical flooding points, with 3 concentrated in the environs of Graças (EMLURB, 2018). Of the 38 architectural projects deferred in this region with a total area of around 13,769.09 m² of green coverage, 01 buildings are located at 251.44 m² and 09 are under construction, with a total of 3,111, 51 m² of green roofs, contributing its benefits to make the city more sustainable.

iv. *RPA 4 - Political-Administrative Region - West*

The RPA 4 region, located west of Recife, shown in Figure 11, has 12 environs, the second most extensive in the city of Recife, with 4,214 hectares. Its urban development follows the same guidelines reported in RPA 3, where the installed mills gradually gave rise to lots and sites, initially developing the current districts of Madalena and Torre, also following the topographic conditions, close to the banks of the Capibaribe River, where we can see a greater urban concentration, which will expand towards the Ilha do Retiro environs (PREFEITURA DO RECIFE, EMLURB, 2013).

This area has the second largest spatial configuration of green area, with 46.90% occupied by vegetation, most of which comes from the remaining forests of the old engenhos of Várzea (OLIVEIRA et al., 2013). The temperature fluctuates between 24º and 26º, where the building network located in the environs of Madalena and Torre, are still not very affected by heat pockets because they are close to the Capibaribe River with its mangrove vegetation, contributing to keep the temperature of the your surroundings (BARROS; LOMBARDO, 2013).

The region has a total of 14 critical points with flooding problems, with a greater concentration between the environs of Caxangá, Iputinga and Várzea (EMLURB, 2018). It houses 34 deferred architecture projects, with a total area of 18,624.55 m² of green coverage, where 09 buildings are under construction and 04 with habitation, presenting respectively total areas of 4,338.37 m² and 1,431.89 m² of green roofs, with the districts of Madalena and Torre more representative, due to the real estate speculation that is expanding in that area of the city.

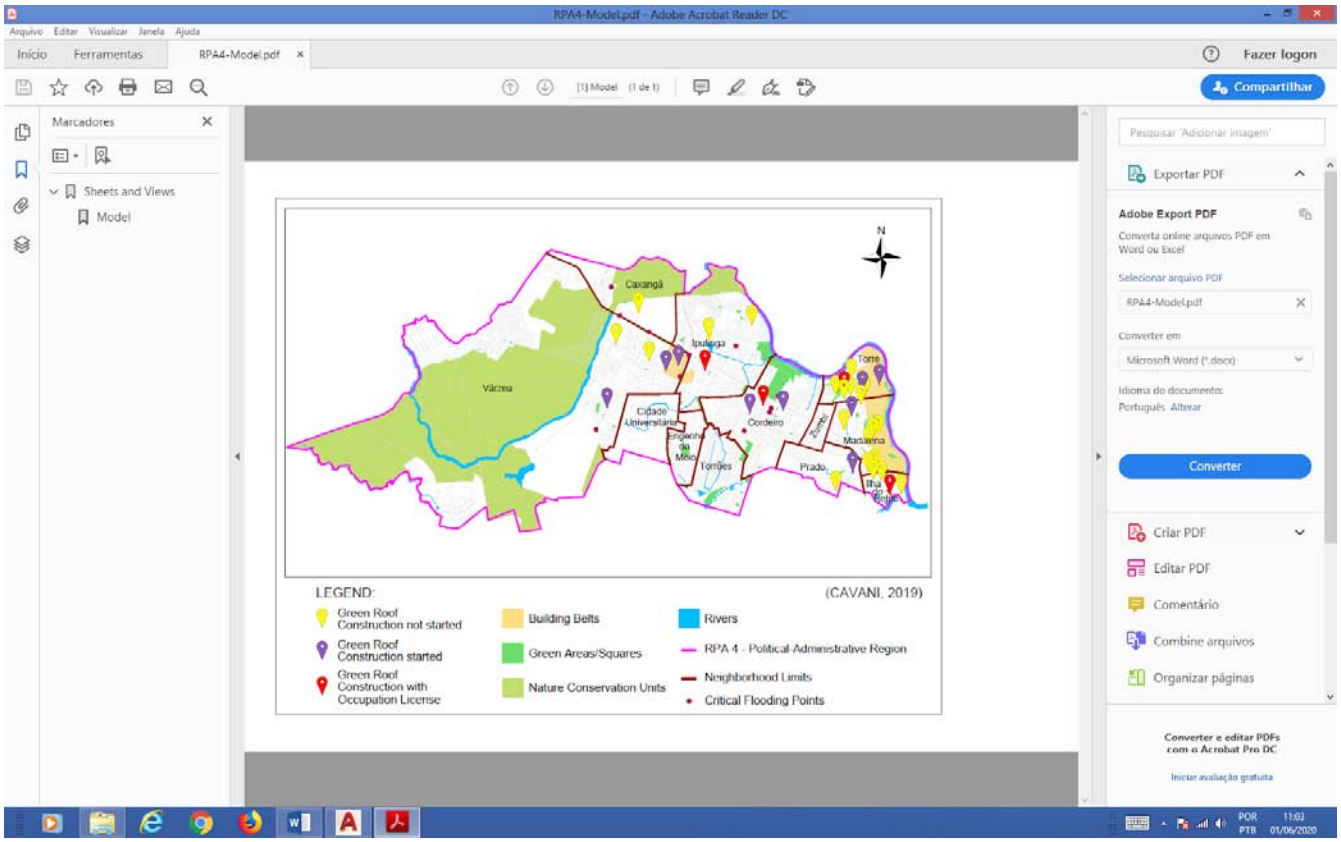

Figure 11: Political-Administrative Region RPA 4 with the location of the green roofs

v. *RPA 5 - Political-Administrative Region - Southwest*

In the beginning of the 20th century, after the first urban and sanitation reform in the city of Recife, there was a population growth of around 46%, where this expansion started to be directed to the Afogados environs, initially extending to Estância and Areias, along the axes of existing urban routes, Av. José Rufino and Rua São Miguel. The urban fabric of Recife is characterized by the uneven layout of its spaces, where the flatter areas are more valued in the real estate market and better served by urban infrastructure, while elevated areas, in some environs such as Barro, Tejipió, Curado, Totó, Coqueiral , present problems of high risk of landslides, due to geological conditions and inadequate urban occupation, generating soil with erosion and little vegetation (BARROS; LOMBARDO, 2013; EMLURB, 2013). Due to the devaluation and lack of real estate interest in the region, there are only two construction projects not started with green roofs in the environs of San Martin and Jardim São Paulo.

Located in the Southwest region of Recife, RPA 5 consists of 16 environs, in an area of 3,025 ha, with its main green patches represented by the Curado forests, Mata do Barro, Jardim Botânico and Campo do Jiquiá. There are also 22 critical flooding points, predominantly in the Estância and Afogados environs (EMLURB, 2018).

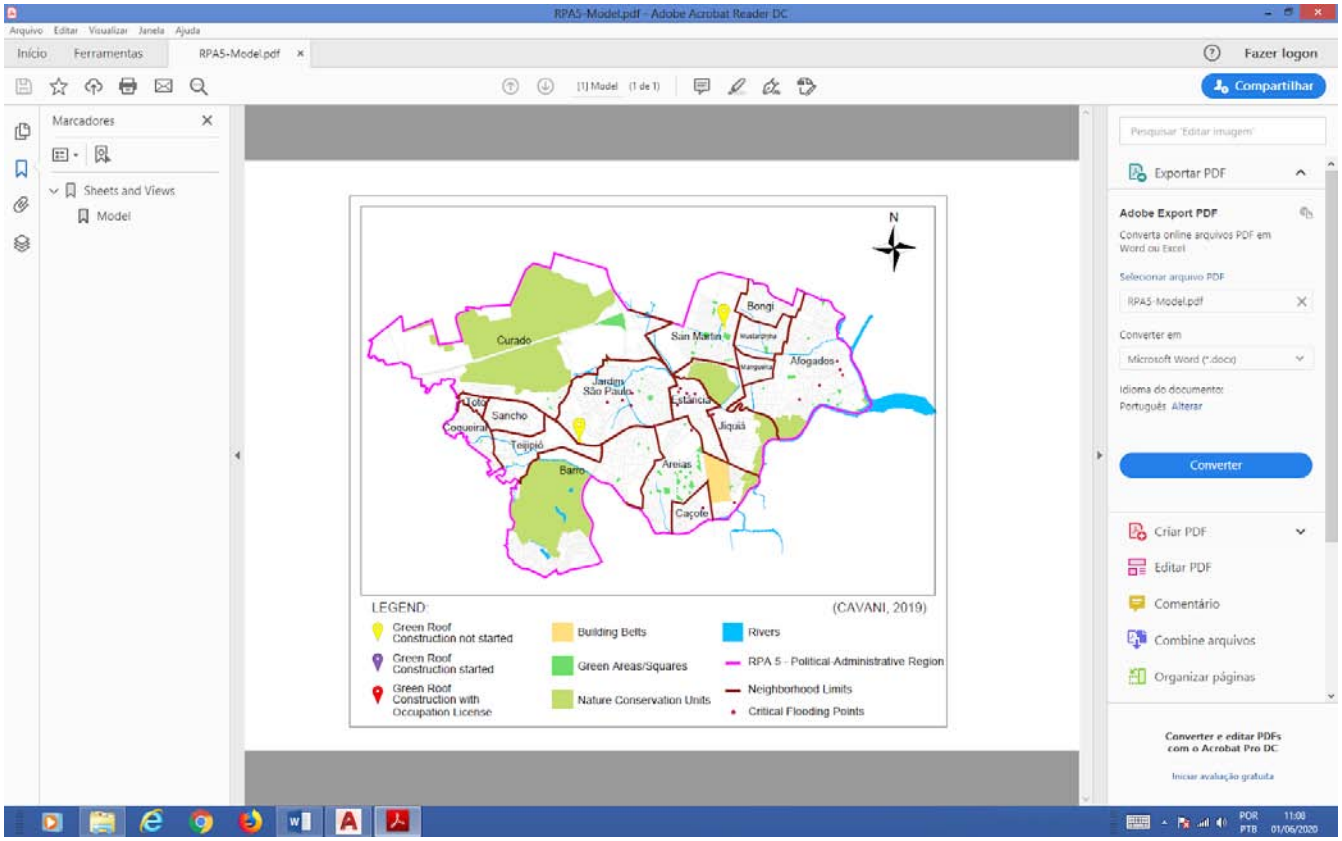

Figure 12: Political-Administrative Region RPA 5 with the location of the green roofs

vi. *RPA 6 - Political and Administrative Region - South*

As shown in Figure 13, RPA 6 is located in the southern area of the city of Recife, formed by only eight environs, with an 8 km long beach, located in the environs of Boa Viagem and Pina. In the middle of the 20th century, Boa Viagem was occupied by a fishing community, a small church and military bases of the Navy and Air Force, because of the Second World War. After a few years, it became a summer place, where some residences started to be built, giving way later to small urban agglomerations. The desire to live on the coast, the demographic increase, combined with the improvement of the environs's infrastructure, with new road accesses and bridge construction, allowed a greater connection with the center of Recife, contributing to the appreciation of the environs and increasing real estate speculation. (COSTA *et al*., 2008).

A major change in the urban landscape began to emerge, where houses were replaced by tall residential and commercial buildings, and by hotel expansion. From the set of existing coastal ecosystems, such as vegetated dunes, mangrove forests, they were gradually transformed into a building belt, leaving two large Protected Nature Units, the Maritime Border and the Mangrove Park, in the Pina environs, great ecological and landscape importance for the city, besides contributing to soften the environs climate (COSTA *et al*., 2008).

The intense verticalization of buildings presented in the region has serious environmental consequences for the surroundings, preventing the action of the wind coming from the sea and creating islands of heat. The professor at the Federal University of Pernambuco, meteorologist Ranyere Nóbrega, conducts research in relation to the heat islands and stresses that some regions of Recife in this summer of 2019 may have a thermal sensation of 39 ° C, places that have replaced the natural environment with asphalt and buildings. Points out the Ipsep and Imbiribeira environs, as one of the hottest areas in Recife (JORNAL DO COMÉRCIO, 2019).

RPA 6 is spread over an area of 3,902 ha, being the most populous in the city of Recife, pointing to a total of 30 critical flooding points, 10 of which are concentrated in the Boa Viagem environs (EMLURB, 2018). Of the 18,415.77 m² of green roof areas foreseen in the 23 architectural projects approved in this region, result in 1,529.40 m² in buildings with housing, in addition to 909.39 m² of green roofs in works already started in the environs of Boa Travel and 5,367.63 m² in the Pina. Still expected to build 5,545.69 m², 4,397.28 m² and 666.38 m² of green roofs in the environs of Imbiribeira, Boa Viagem and Pina, respectively, contributing with their benefits for the reduction of urban heat islands and greenhouse gases. (SCHMIDT, 2009; BALDESSAR, 2012; CATUZZO, 2013; PEREIRA, 2017).

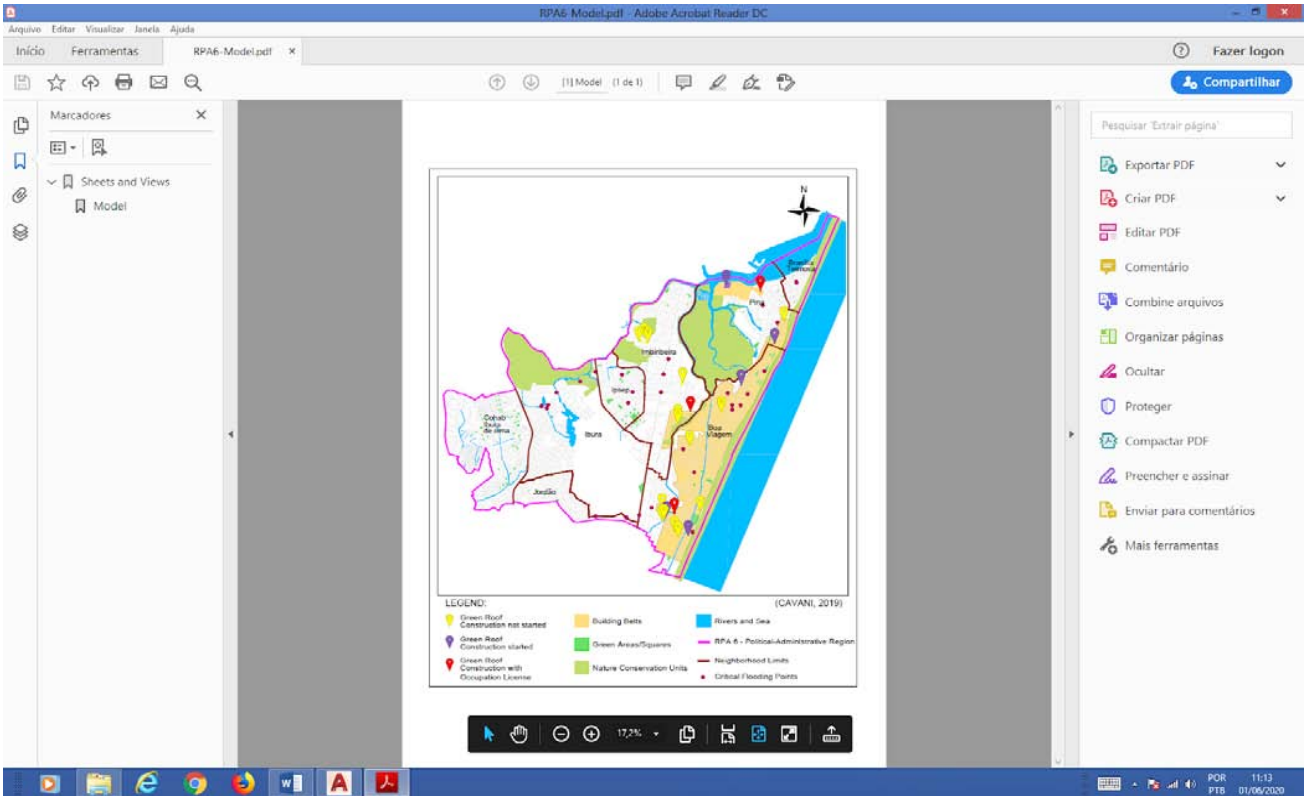

Figure 13: Political-Administrative Region RPA 6 with the location of green roofs

In general, it is observed that in the documentary research, 143 architectural projects approved by the City of Recife with the green roof system were quantified, between January 13, 2015 to September 30, 2019, representing a total area of 88,393, 33 m² of green roofs. However, of this total, in a field survey in the month of September 2019, it was found that the areas of green roofs in buildings with habitation added to those of buildings in the construction process correspond to an area of 22,926.58 m². Of this area, approximately 23.90%, 2.21%, 14.67%, 25.17% and 34.05% are located in RPA 1, RPA 2, RPA 3, RPA 4 and RPA 6 respectively. of the territorial outline established by these Political-Administrative Regions, the data also demonstrate that the green roofs had greater representativeness, when analyzed under the quantitative aspect, in the constructions of the multifamily housing type.

If the other developments are built, the green roof areas to be made available will be 20,823.75 m² (RPA 1), 8,864.18 m² (RPA 2), 10,406.14 m² (RPA 3), 12,854.29 m² (RPA 4), 1,909.04 m² (RPA 5) and 10,609.35 m² (RPA 6). It should also be noted that, of the total area of green roofs (65,466.75 m²) of works not started, around 45% correspond to projects approved in 2019, as a result of the heating of the real estate market, whose construction did not have time to appear in the research as works initiated.

From the data obtained from the quantity of green roofs and their locations in the urban network, it can be seen that most of them are inserted in the agglomerations of vertical buildings, in areas of intermediate temperatures from 24° to 26° C, with a predominance of higher values , in environs with few green areas available in their courts and in places with critical flooding problems, such as São José, Encruzilhada, Graças, Cordeiro and Boa Viagem.

What could be observed after the research carried out on the subject, the field survey, the statistical analysis of the data and, more than that, with the architectural and urbanistic feeling that permeated the entire development of this work, is that, being Recife a city lacking green spaces, with a disorderly urbanization process, unbearable automotive congestion, atmospheric pollution, intense heat, drainage hampered by the lack of basic sanitation infrastructure, the green roof system with its numerous benefits is presented, as one of the attitudes of hopes seeking to improve the environmental quality of the city.

In this context, Municipal Law 18,112 / 2015 proves to be necessary as an instrument to guarantee the applicability of green roofs in the city of Recife, where the Public Power must always create, disseminate and encourage public policies that induce protection to the environment. This Law provides for the obligation, but does not provide incentive mechanisms for the construction and preservation of the green roof

system, through discounts or exemptions in the IPTU, like other cities in Brazil and abroad that have granted tax incentives. And this is justified because, although the burden of implementing the green roof is on the building owners, the benefits are diffuse, it is shared by the whole community, with the improvement made in the quality of life of the city.

As usually happens with every new law, needing time for understandings and adaptations, it was no different with Municipal Law nº 18,112 / 2015, referring to the green roof. It is believed to have gone through a difficult start of application, due to the lack of clear understanding about the conditions and limits of the Law, in view of the need for clarification procedures (SERVICE INSTRUCTION N.001, 2015; RESOLUTION N.01, 2019; MUNICIPALITY OF RECIFE).

This fact was clearly observed in the analysis of the architectural projects surveyed between the years 2015 to 2017 (55 projects), compared to the years 2018 to 2019 (88 projects), where there was a significant growth in their quantity. In addition, the search for sustainable solutions in projects, combined with the best knowledge and applicability of the Law, remains patented in the fact that the projects have adopted green roofs, in addition to the mandatory locations, in those that were not required by law, such as marquees, walkway slabs interconnecting building blocks.

V. Final Considerations

The realization of this research allowed us to see, with the results obtained, that the green roof system is still little used in the city of Recife, indicating the need for the Government to adopt incentive measures, through tax deductions or subsidies, such as the use of IPTU.

However, it is not enough to enforce the Law, it is not enough to demand the approval of projects, it is not enough to put it into practice to allow the inhabitants to live in the building, it is necessary that a system of inspection be implemented by the Government to monitor green roofs, so that they remain as approved, under the penalty of seeing the Law become a greenwashing, counting the green roofs as existing after the inhabit and have actually been deactivated, being a great loss to the city's environment. Greenwashing is understood as "unjustified appropriation of environmental virtues by companies, governments, people, through the use of marketing techniques or public relations, hiding or diverting attention from negative environmental impacts generated by it" (https://pt.wikepedia.org).

That there is greater dissemination of the technique of the green roof system, making the population aware of the need to implant and preserve green to improve the quality of urban life. That future research be carried out, seeking to identify the vegetations that best adapt to the climate characteristics of the city of Recife. Thus, that green roofs can effectively perform their environmental and urban applicability. It is also important to highlight the innovative use of green roofs as a source of food and income generation, so that they can benefit the population with job offers and promote more sustainable food.

It should be noted that the financial crisis that hit Brazil, and the Brazilian real estate sector, brought significant reflections on the volume of data, completed buildings, available for the study. However, this reduction was not able to overshadow the importance of the Law in terms of its relevance for the transformation of the city into a more human and pleasant environment. And it is this importance that must be considered with the ongoing economic recovery so that one can have a better quality of life in the city of Recife.

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Tectono-Sedimentary Evolution of the Uranium Deposits of the Dasa Graben, Northern Niger

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I. Introduction

Located on the western side of the Aïr Mountains, the Tim Mersoï basin is well known for its uranium mineralization hosted in Carboniferous and Jurassic formations. This basin is located in the northeastern part of the much larger Iullemmeden basin (Fig. 1). It is limited to the west by the In Guezzam Ridge and to the east by the Aïr Mountains. Towards the north, it penetrates into the Hoggar Massif in Algeria where it is known as the syncline of Tin Sériline (Fig. 1) (Moussa, 1992, Konaté et *al.*, 2007).

Recent exploration surveys have discovered a highly mineralized graben, the Dajy Surface Anomaly (DASA) which is the object of this study. It is positioned between the Arlit uranium mining area to the North and the Anou-Araren coal trough to the South (Fig. 1). The main purpose of this study is to determine the factors that favored uranium concentrations in the DASA graben.

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II. Geological Setting

The geological history of the Tim Mersoï basin begins early during the Cambrian in the Tin Sériline Syncline (Joulia, 1959). Subsequently, the sedimentation areas moved southward, resulting in the deposition of continental and marginal-littoral detrital formations ranging from Cambrian to Miocene (Fig. 1). Along the western edge of the Aïr, these detrital formations exhibit stratigraphic levels (Fig. 1) from the Devonian to the Jurassic (Clermonté et *al.,* 1991; Moussa, 1992). The Tim Mersoï basin is characterized by detrital infilling, resting unconformably on the pre-Cambrian basement (Fig. 1). The basin was infilled during three successive cycles: Carboniferous, Permo-Triassic to Jurassic and Lower Cretaceous.

The Lower Cretaceous cycle is represented by clayey to sandy- floodplain deposits extending from the west to the center of the previous deposition area, which was gradually rising (Forbes 1989, Clermonté *et al., 1991*).

According to Tauzin (1981), several brittle deformations affected the sedimentary infilling. Three main faults directions have been recognized:

a) The N0° trending lineament of In-Azaoua-Arlit and the N30° trending fault system of Madaouéla. All of the exploited uranium deposits are located in the eastern part of the Arlit Fault, but uranium deposits have also recently been discovered on the western side, (Mamane Mamadou, 2016).

- The N30° fault system. It is expressed some time in the sedimentary cover in the form of flexures, which axes are spaced twenty kilometers apart. The most important N30° trending fault systems in the Tim Mersoï basin are those of Madaouéla (sector of Arlit) and the Adrar-Emoles (sector of DASA).

b) The N130° to N140° trending faults represent the main fault system that affect the Aïr Mountains. In the sedimentary series, these directions are well expressed. The Arlit fault is associated with several N150° striking faults in the Arlit mining area (Mamane Mamadou, 2016).

c) The N70° to N80° trending faults cut the basement intensively and also spread into the sedimentary cover and deposits. The N70° faults are reactivated in dextral strike-slip movements during the Upper Cretaceous (Guiraud et al., 1981). At the regional

scale, the N70° trending fault network plays a fault-damping role on the N30° faults (Gerbeaud, 2006).

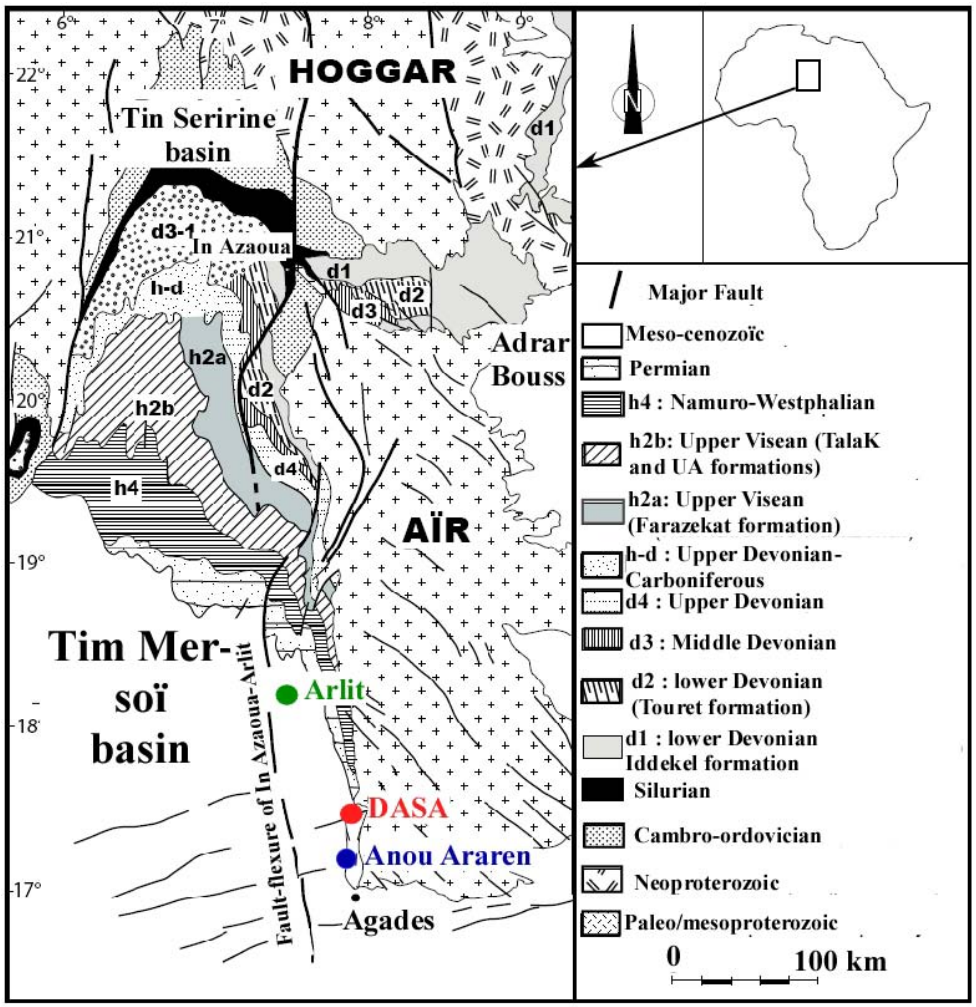

Fig. 1: Location and synthetic geological map of the Tim Mersoï basin (Greigert and Pougnet, 1965, modified)

The DASA graben is located in the Adrar Emoles 3 permit (location in Fig. 2), which covers an area of 121.3 km^2.

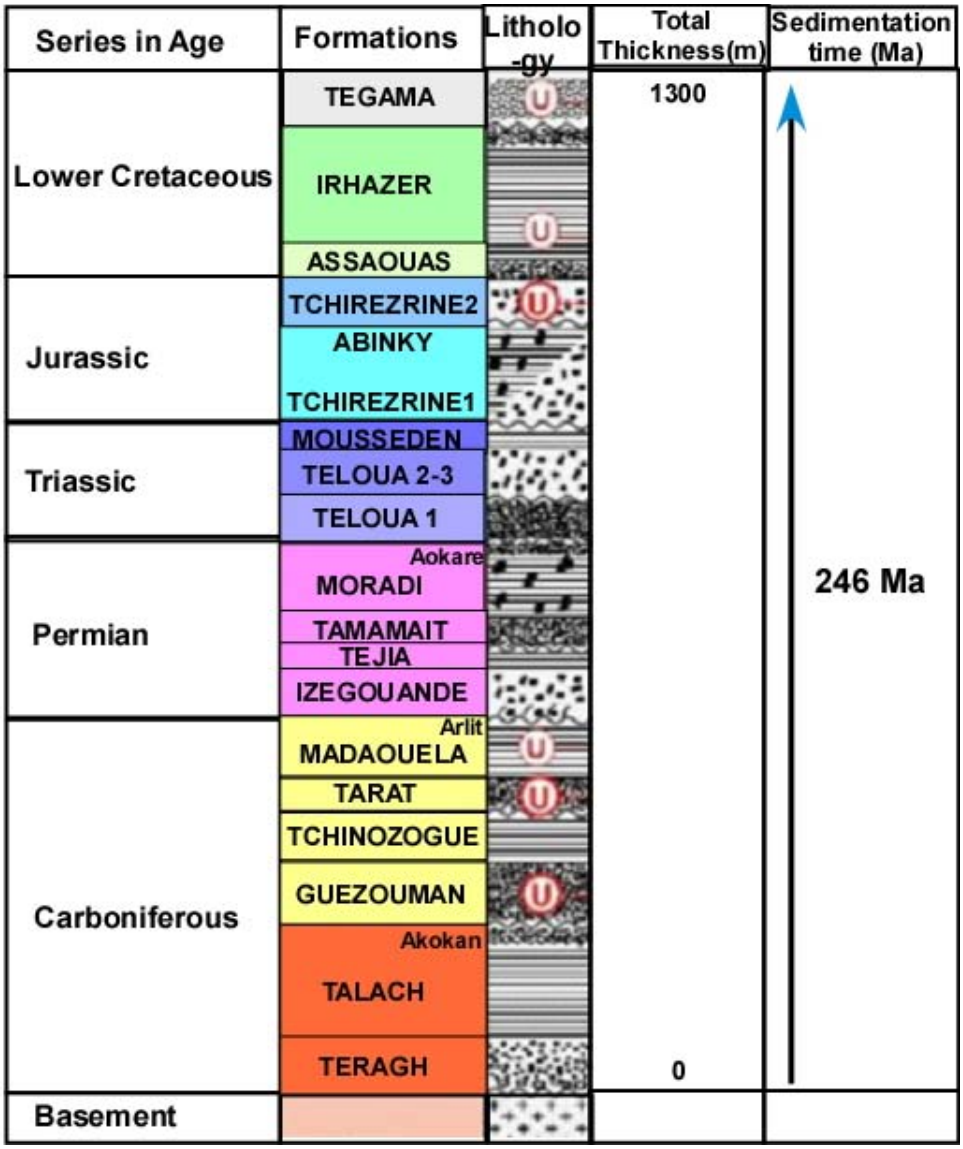

Fig. 2: Lithostratigraphiccolum of the Tim Mersoï Basin

From a stratigraphic point of view, all the sedimentary series observed in the Tim Mersoï basin are also represented in the DASA area. These are Carboniferous, Permian, Triassic, Jurassic and Cretaceous series, (Fig. 3). The main faults observed in the DASA graben are the Azouza fault which mark the border of the trough, the Adrar-Emoles N30° striking fault, and secondary faults N130° to N150° trending and E-W striking, (Fig. 3).

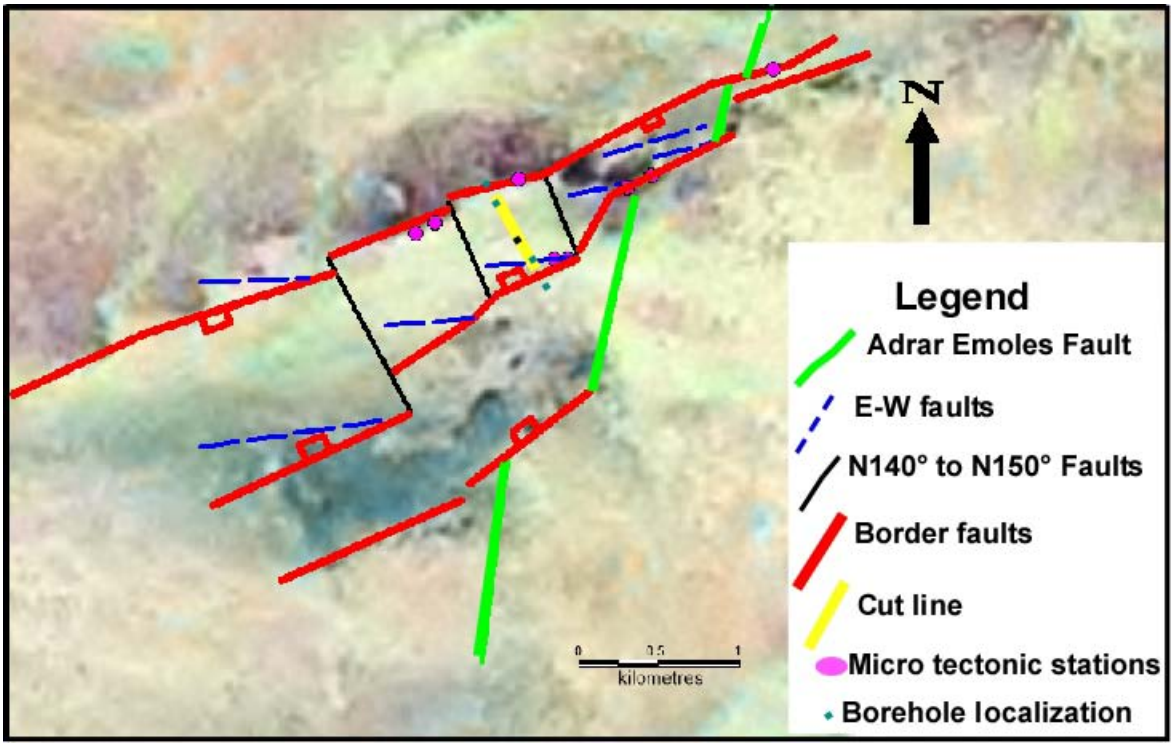

Fig 3: Synthetic representation of the main tectonic structures of the DASA graben

The DASA graben has the same orientation as the Carboniferous coal troughs of the Anou-Araren region, (Fig. 1). These coal troughs are limited by two major N70° trending dextral strike-slip faults: the Isokenwali fault in the northern part and the Aboye fault in the southern part. These two faults belong to the same system as the Tin Adrar N70° striking fault system, which is well represented in the Arlit region (Wright, 1989). Most of the work carried out in the Tim Mersoï basin has focused on the tectono-sedimentary evolution of the Tim Mersoï basin and the uranium metallogeny (Valsardieu, 1971, Sempéré, 1981, El Hamet, 1983, Forbes, 1989, Moussa, 1992, Wagani, 2007, Konaté et *al.,* 2007, Mamane Mamadou, 2016).

III. Materials and Methods

In this study, a multidisciplinary approach involving various tools (e.g., seismic profiles, satellite images, drill cores), software (e.g., MapInfo 11.5, Surfer 11, Canvas 11) and various techniques (e.g., seismic interpretation, well logs correlation, micro tectonic and geochemical investigation) have enabled to:

(1) Make a tectono-sedimentary analysis;
(2) Determine the spatial arrangement of the uranium deposits;
(3) Characterize the basin geometry.

IV. Results

a) Geological Setting of the Study Area

The DASA graben is bounded by faults systems which have controlled the graben structures. Within the DASA graben itself, different directions of secondary faults affected the sedimentary infilling. These are N30°, N130° to N150° and E-W trending faults (Fig. 3).

In the DASA graben, the sedimentary succession has been studied through drilling data obtained during the uranium exploration work. The sedimentary rocks overlying the granitic crystalline basement consist of Devonian to Early Cretaceous series, which are described in the stratigraphic column of the study area (Fig. 4). The sedimentary infilling of the DASA graben is subdivided into five (5) series. These are: Terada series, Tagora series, Permian series, Agades series and Irhazer series (Fig. 4). To better understand the spatial arrangement of the DASA graben infilling, a structural cross-section is provided (Fig. 5) using field observation, well log and borehole data.

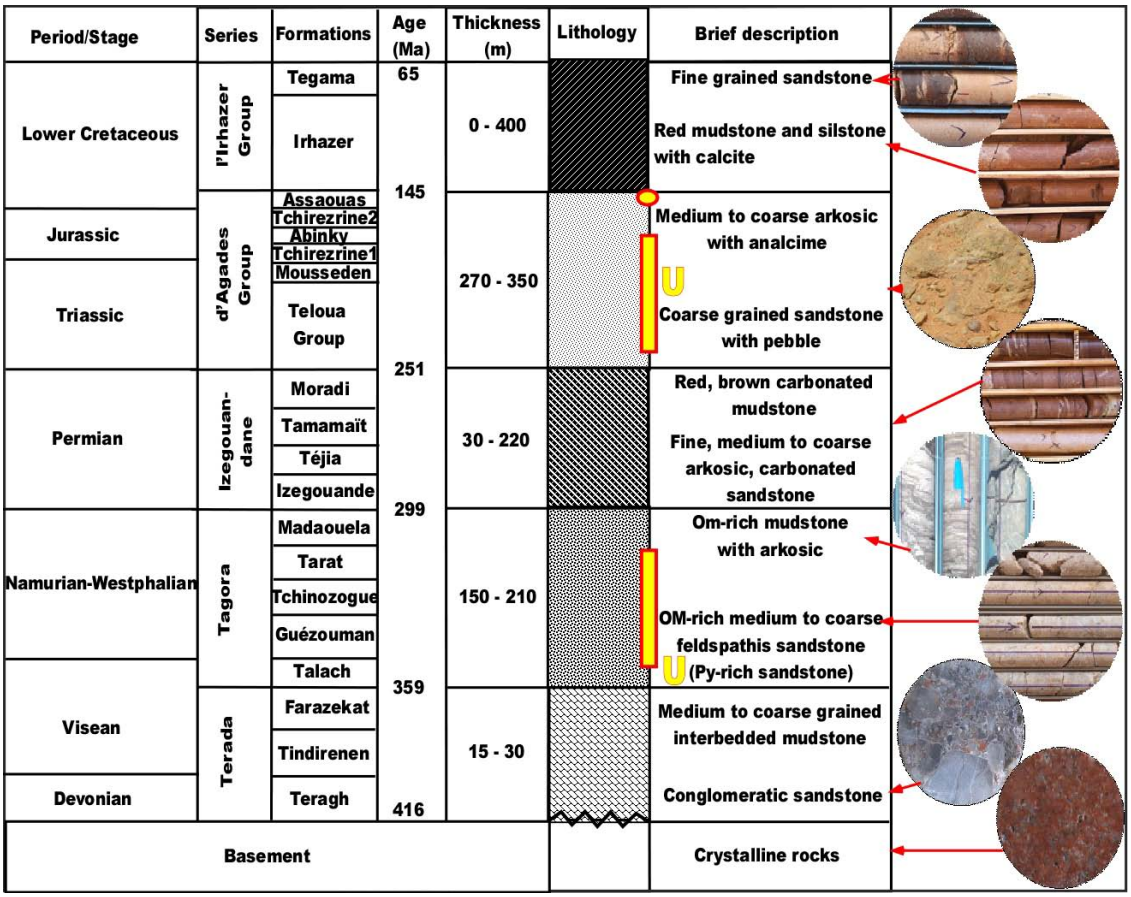

Fig. 4: Lithostratigraphic column of the DASA graben

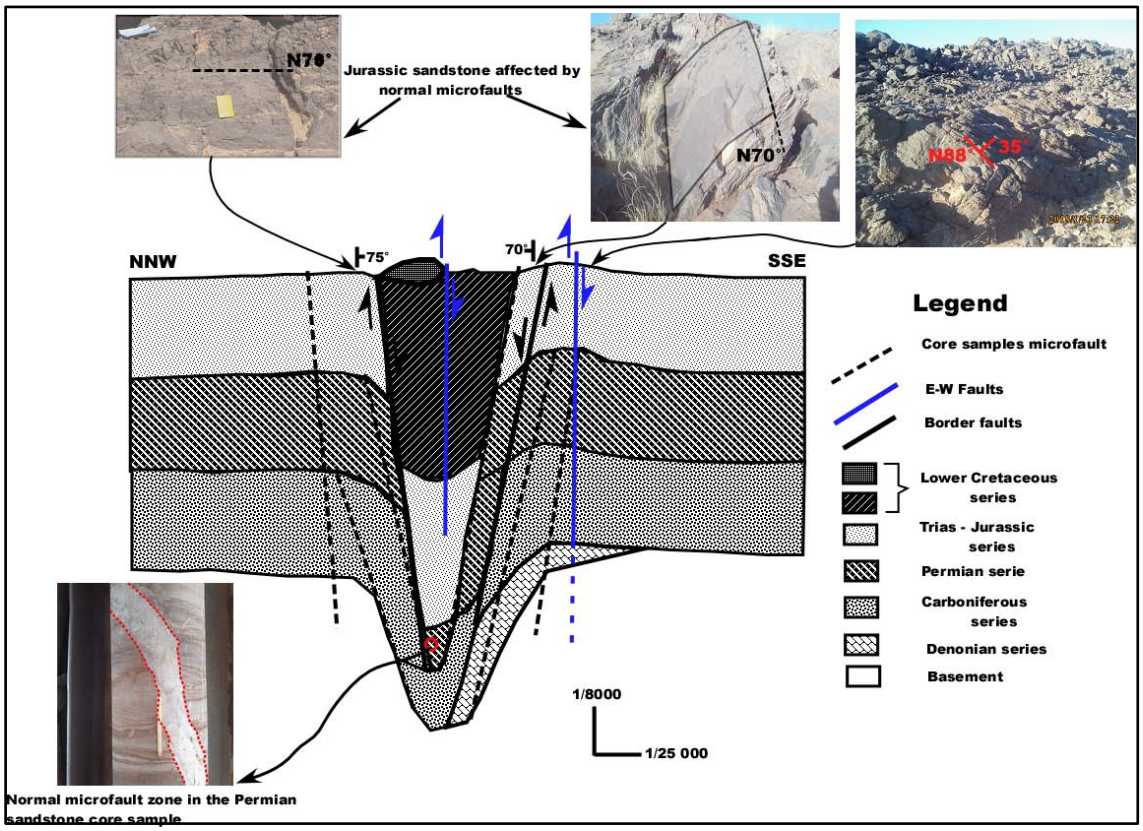

Fig. 5: DASA grabencross section

b) Lithostratigraphic Analysis

A detailed study of the DASA graben drill core samples show highly heterogeneous formations. From the bottom to top the following formations have been distinguished:

i. *Crystalline Basement*

The samples ASDH525-02 and ASDH526-02 from two different boreholes were analyzed. The granitic rocks exhibit granular textures, the quartz shows partial resorption (possibly due to silicic alteration), and feldspars crystals are variably altered. Sample ASDH525-02 is fine to medium-grained granite and is dominated by quartz (73%), K-feldspars (20%) and plagioclase (7%). It exhibits a granular, holocrystalline texture (Figs. 6A1 and A2) while sample ASDH526-01 is fine to medium-grained granite and is dominated by K-feldspars (44%), quartz (34%) and plagioclase (22%) (Figs. 6B1 and B2). The big quartz and feldspar crystals are cemented with a fine-grained matrix of the same minerals and mica. Fine-grained quartz and the matrix also appear as rock fragments in the sample. However, the matrix seems to replace quartz and feldspars in other places. This might indicate that the granite could be affected by hydrothermal alteration and could also be contaminated by rock fragments.

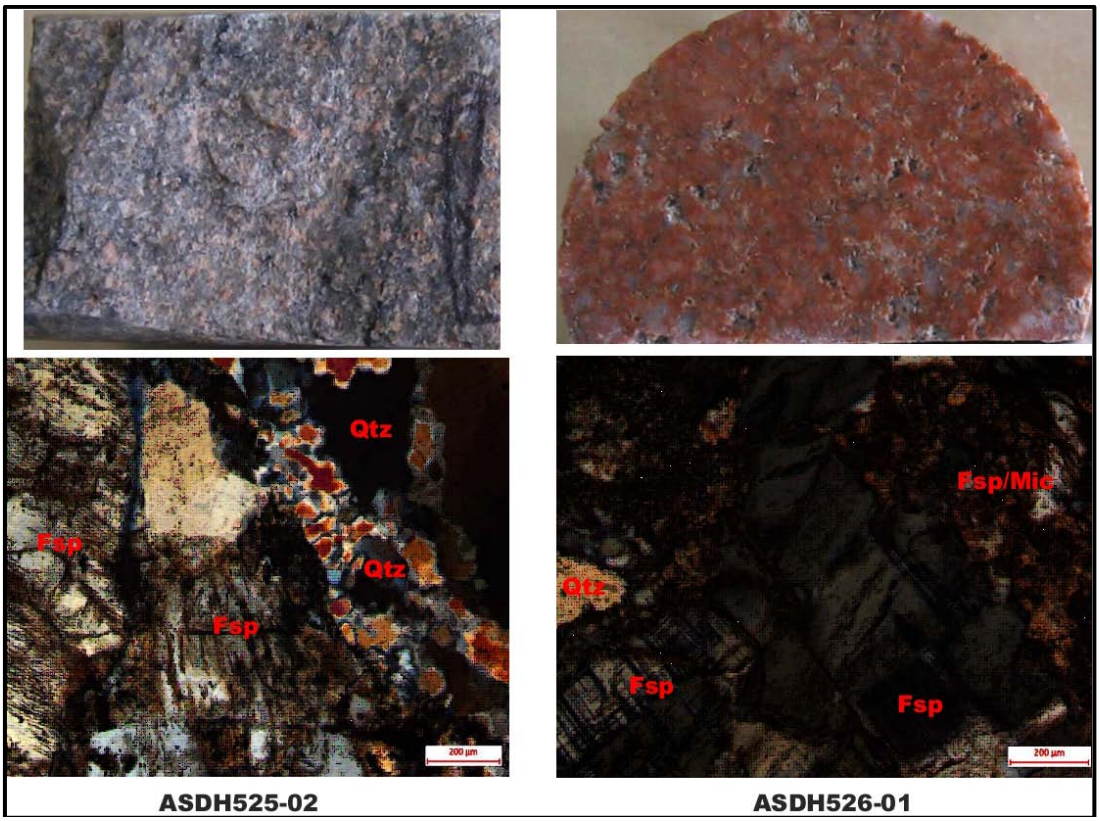

Fig. 6: Core samples and thin-section characteristics of the DASA basement

ii. *Devonian*

It mostly consists of poorly sorted coarse-grained sandstones with gravels of various sizes of the Teragh formation. Two samples taken from one borehole (ASDH526) were analyzed (Figs. 7A and B). The samples are dominated by quartz (89%), K-feldspars (8%) and plagioclase (3%) (Fig. 7C). The grains are cemented by a fine-grained matrix of quartz, feldspar and clay. The Devonian sandstones which are porous in the Tim Mersoï basin become well compacted in the DASA area, suggesting that the original texture was modified by hydrothermal fluid flows.

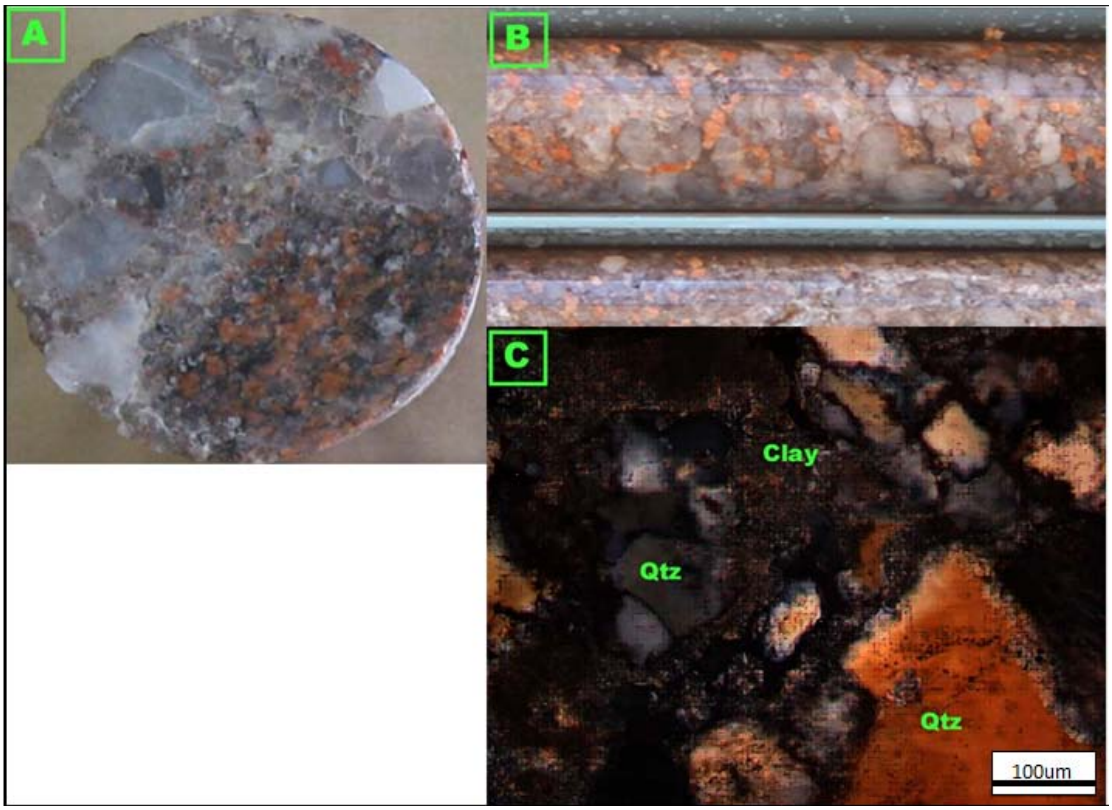

Fig. 7: Core samples and thin-section characteristic of the Teragh formation of the DASA graben (A and B Teragh formation; C= thin-section of Teragh)

iii. *Carboniferous*

This consists of three Lower Carboniferous and two Upper Carboniferous formations subdivided into two sub-groups. These terrains correspond to higher Visean to Namuria to Westphalian.

a. *The Lower Carboniferous (Visean To Namur)*

Three stratigraphic units have been distinguished (Fig. 8 and 9).

1. The marine Talak formation (Visean) corresponds to black shale (Figs. 8A and 9A) ;
2. The fluvio-deltaic Guézouman formation (Namur) consists of medium to coarse feldspathic greyish sandstone (Figs. 8B and 9B). Towards the top, this formation exhibits an alternation of fine grained sandstone and black clay (Figs. 8C and 9C). These alternations display thickness and facies variations;
3. The marine to lacustrine Tchinézogue formation (Namur) is predominantly made up of greyish clayey fine grained sandstone (Figs. 8D and 9D).

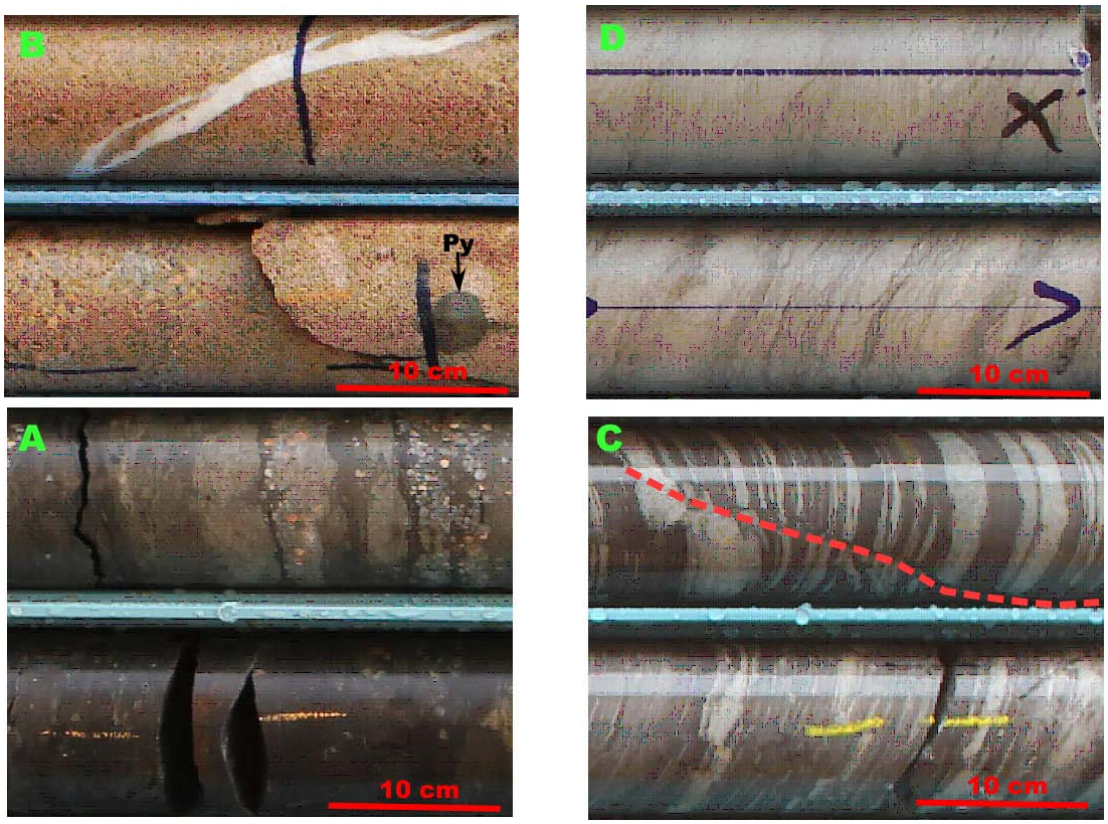

Fig. 8: Core sample characteristics of the Lower Carboniferous sediments (A=Talak, B= Guezouman, C= Guezoumanalternance and D= Tchinozogue formation)

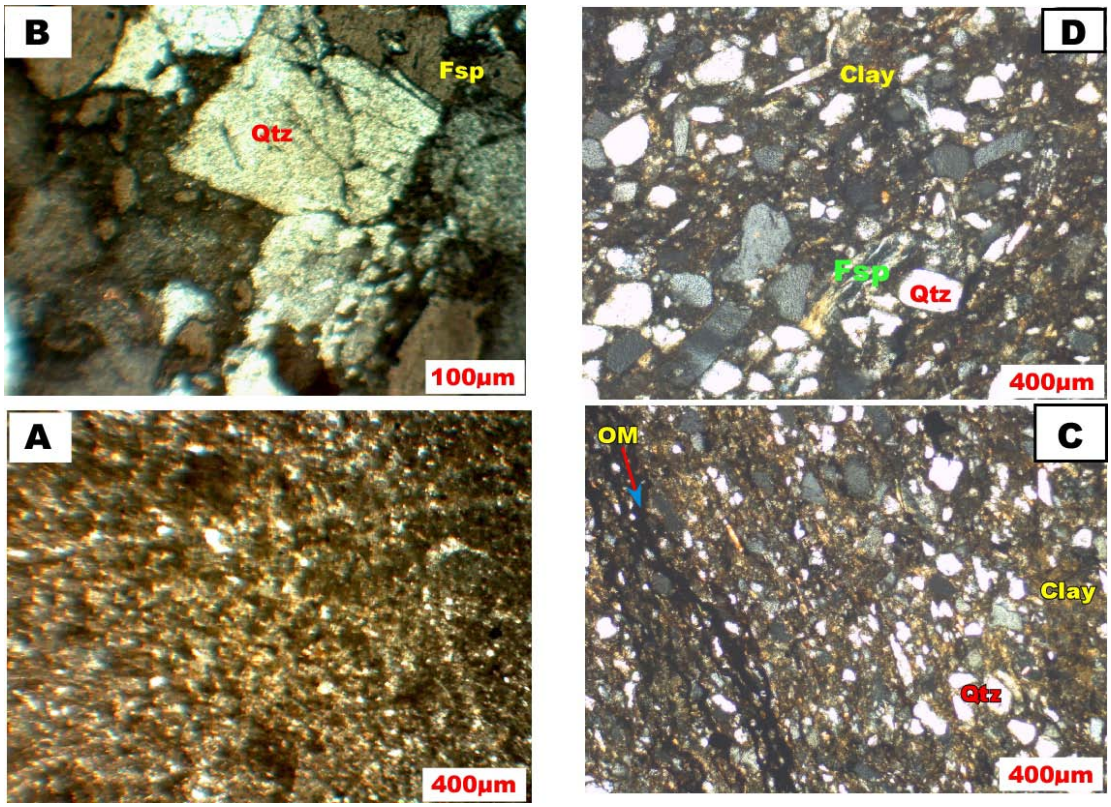

Fig. 9: Thin-section characteristics of the Lower Carboniferous sediments of the DASA graben. (A= Talak, B= Guezouman, C= Guezoumanalternance and D= Tchinozogue formation).

b. *The Upper Carboniferous (Namur to Westphalian)*

They are composed of the following formations (Fig. 10).

a. The fluvio-deltaic Tarat formation, which consists of medium to coarse grained greyish sandstone (Figs. 10 A1 and A2). The quartz elements have mostly rounded to sub-rounded shapes. The Tarat formation frequently contains organic matter and pyrite.

b. The estuarine to marine Madaouela formation consists of alternating arkosic sandstones and brownish to purplish clay (Fig. 10B1). Two types of lithofacies are distinguished:

- ✓ Coarse-grained sandstones that mostly consist of detrital quartz, feldspar and rock fragments (Fig. 10B2). Calcite and mud are acting as dominant cement with quartz and feldspar.
- ✓ Fine-grained sandstone. This lithofacies consists of fine-grained sandstone with sub-angular to rounded and moderately sorted grains. It's represented by quartz, feldspar and lithic rock fragments. The cement is represented by kaolinite and calcite.

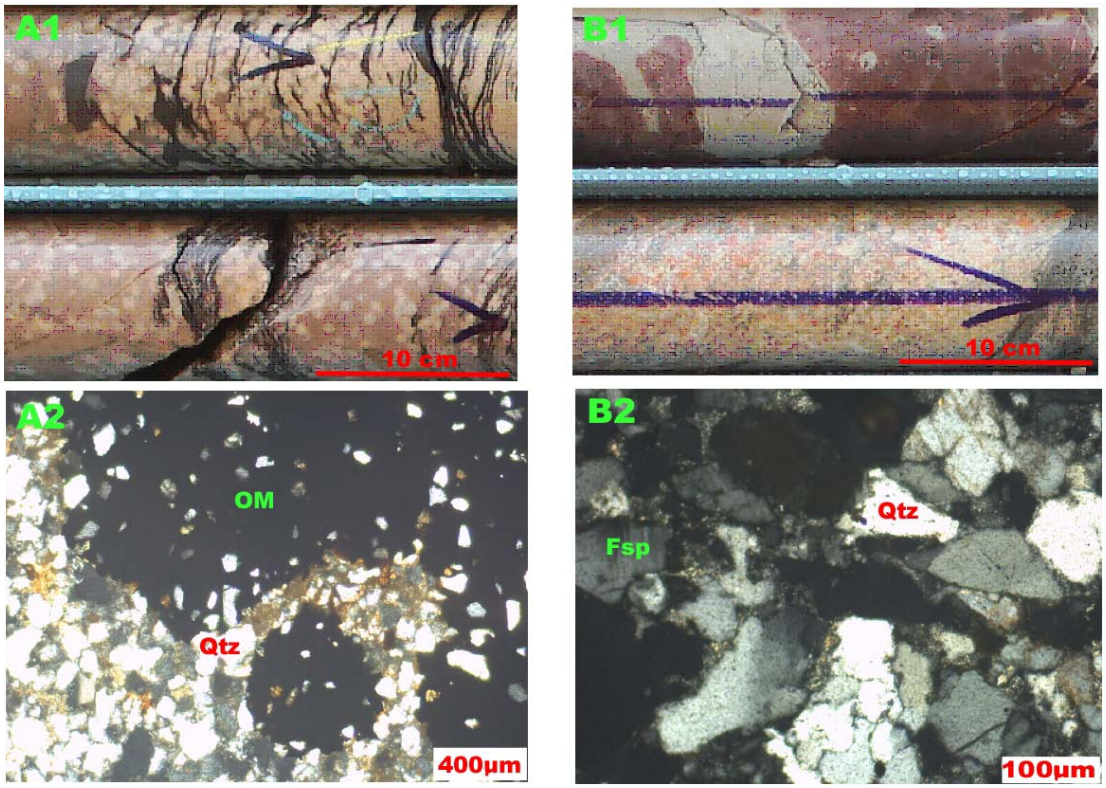

Fig. 10: Core samples and thin-sections characteristics of the Upper Carboniferous (A=Tarat formation and B= Madaouela formation)

iv. *Permian*

The Permian marks the first appearance of the continental fluvio-lacustrine series in the Tim Mersoï basin. These deposits include intercalated pyroclastic levels which originated from the erosion of the Aïr Mountains volcanic rocks. The Permian (Fig. 11) is composed of the following formations.

1. Izégouandane formation. This formation is represented by medium to coarse-grained arkosic sandstone (Fig. 11B). It's composed of feldspar and quartz (Fig. 11B) with various rock fragments and analcimolites. Calcite and clay mineral represent the cement between the feldspar and quartz grains.
2. Téjia formation. This formation consists of carbonated mudstone and siltstone with various colors (red, brown, gray). Fine grained sandstones show inter-laminations of silty and muddy layers.
3. Tamamaït formation. It consists of fine-grained sandstones. The quartz grains have a sub-angular to rounded shape. Kaolinite and calcite constitute the pore filling cement.
4. Moradi formation. This is mostly composed of reddish carbonated mudstones (Fig. 11A) and arkosic analcime-rich coarse-grained sandstones, including intercalations of greyish carbonated siltstones.

The major characteristic of the Permian terrain is the reddish color and the abundance of calcitic cement.

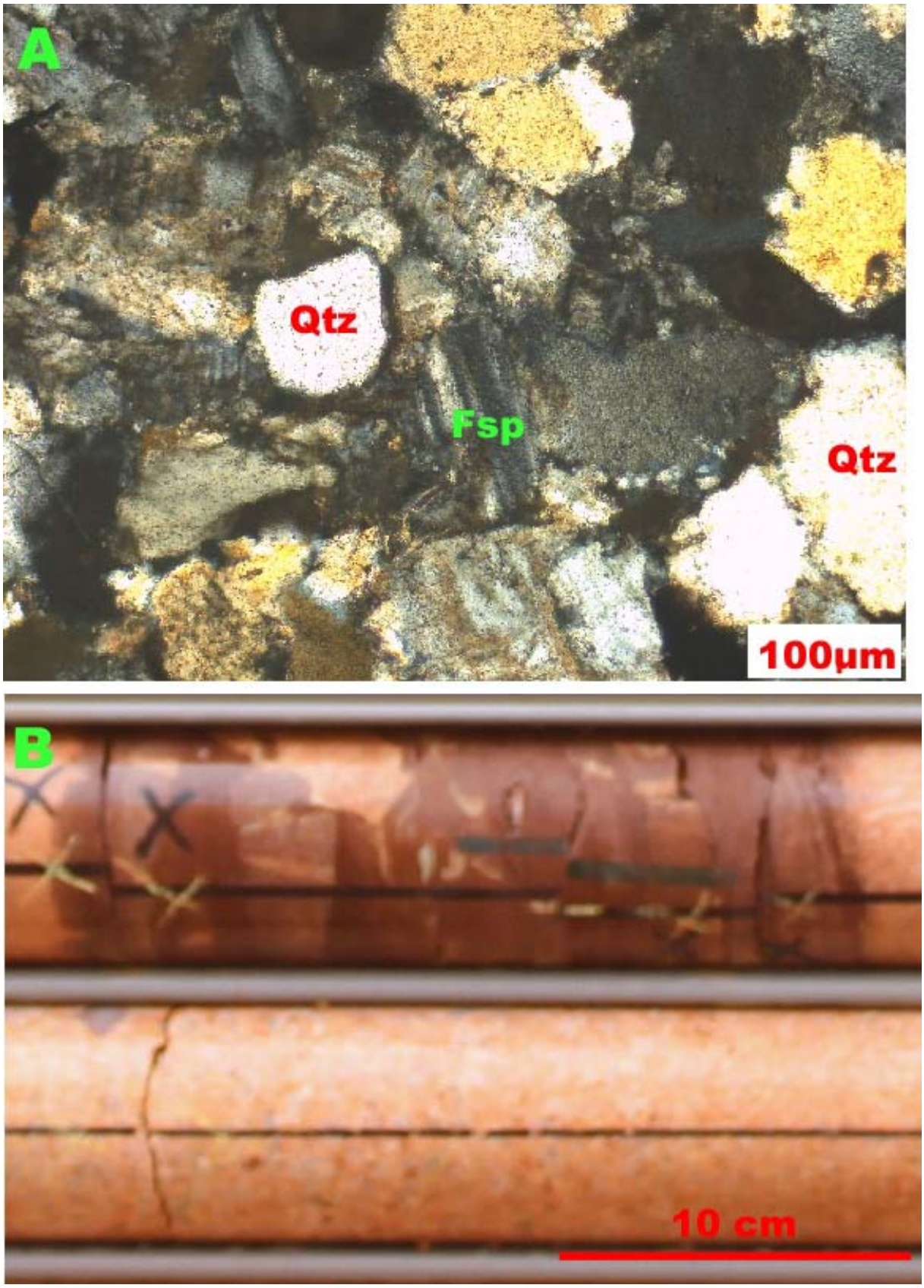

Fig. 11: Core samples and thin-section characteristics of the Permian formation

v. Triassic to Jurassic

It consists of fluvio-lacustrine terrains (Figs. 12 A1 and A2) with volcanic fractions and are composed essentially of quartz and feldspar of various sizes (Fig. 12 A2). Detrital grains exhibit some time tension gashes and cataclastic features. Analcime is frequently observed (Figs. 12B1 and B2).

iv. *Lower Cretaceous*

✓ Irhazer formation. It outcrop over a wide area and are mainly made up of reddish continental claystones and sandstones. They consist from the bottom to top of Irhazer claystones and Tégama sandstones.

✓ The Tégama sandstones constitute the last fluvial sandstones deposits before the Upper Cretaceous marine transgression (Irhazer claystones).

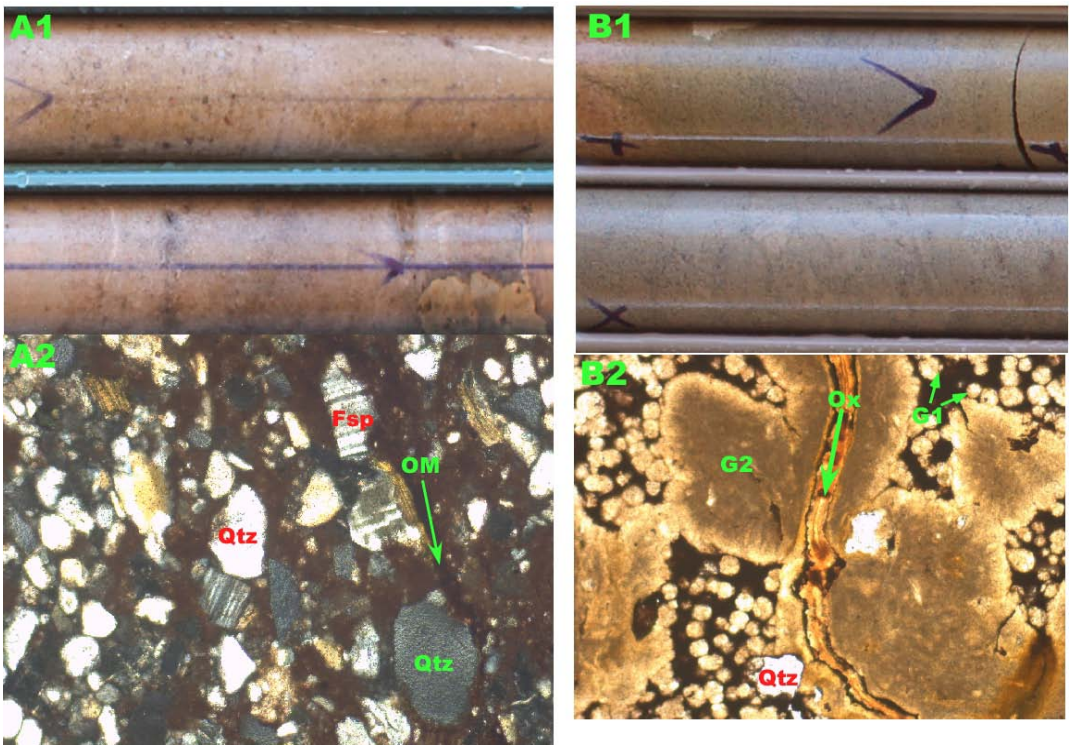

Fig. 12: Core samples and thin-sections characteristics of the Triassic-Jurassic sediments of the DASA graben (A=Triassic formation and B= Jurassic formation)

V. Petrographic Features of the Mineralized Formations

The petrographic features of the mineralized formations of the DASA graben were obtained by using field and thin-section observations.

a) Carboniferous Formations

A detailed study of the Carboniferous formations indicate that they are highly heterogeneous and texturally immature to slightly mature and sedimentation control of the preliminary porosity and effect the post-transformation. A thin-section study reveals that quartz is the dominant detrital mineral and is mostly monocrystalline with a percentage of 70-95% (Fig. 13). The feldspar is the second abundant rock-forming mineral with a content of 2-25%. The third component are lithic rock fragments that range up to 5% . Distinguished lithofacies are:

- Conglomeratic sandstone
- Coarse-grained sandstone
- Medium-grained sandstone
- Fine sandstone alternating with siltstone.

In the Carboniferous formations grains are angular to sub-angular while others are sub-rounded. Similarly, there is a variance in grain size and grain interaction surface. Most of the studied samples show concavo-convex contact (Fig. 13). Sub-angular grains and sub-rounded are dominant while others are elongated with broken grains and showing the dissolution effect (Fig. 13). Rock-forming grains are bonded by different cements. The most abundant cement in the studied thin-sections is clay. The most abundant clays are kaolinite and chlorite. In addition to this type of cement, calcite is also found in some sample as cement or filling fractures followed by iron oxide (Fig. 13). In this DASA graben area, Carboniferous formations are enriched with organic matter and pyrite.

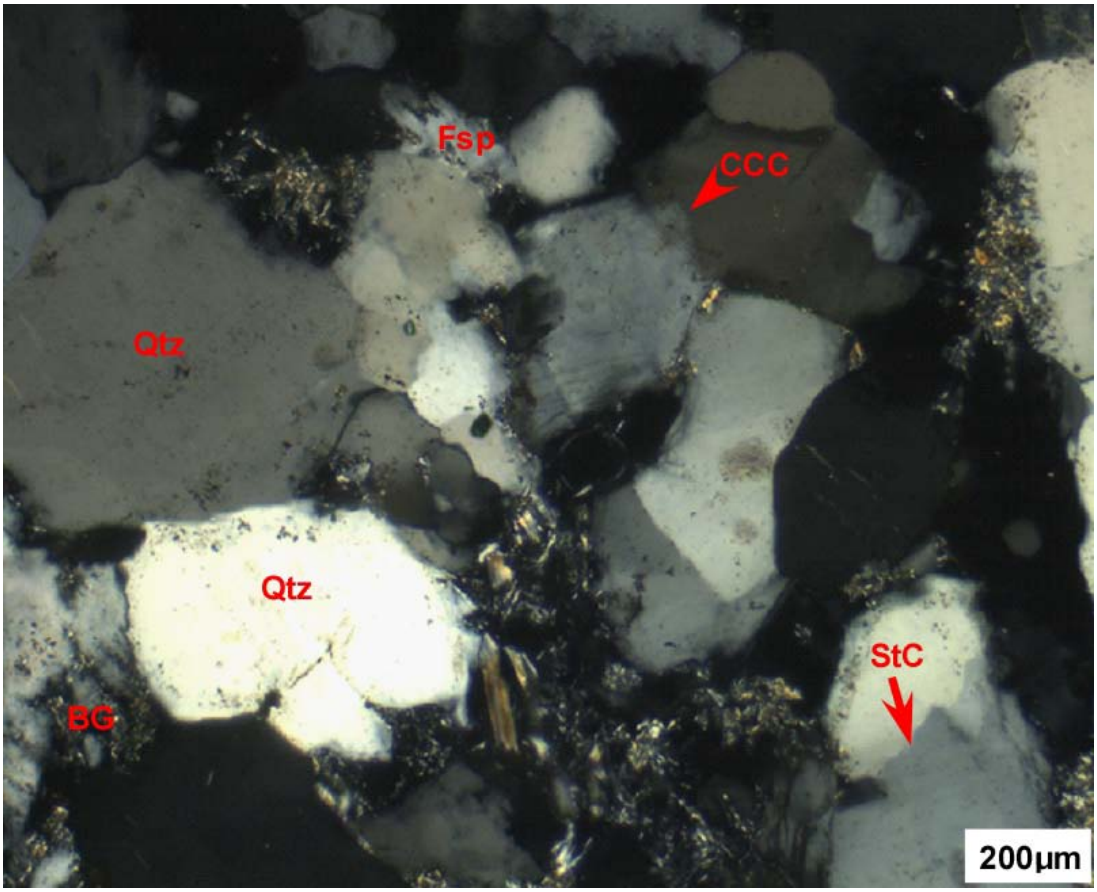

Fig. 13: Thin-section of the Carboniferous mineralized formations showing broken grain (BG), styolithic contact (StC) and Concavo-convex contact (CCC)

b) Triassic Formations

Thin-section analysis of three samples reveals that there are several types of lithofacies. Sedimentary lithofacies consist of:

- Conglomeratic sandstone
- Fine isogranular sandstone
- Medium-grained sandstone with analcimoite
- Siltstone with analcimolites

Field and thin-sections studies show that these lithofacies are moderately sorted with an abundance of detrital quartz and feldspar and rock fragment of analcimolites with clay cement (Fig. 14). Detrital quartz grains are rounded to sub-rounded (Fig. 14). These formations are enriched with analcime and organic matter (Fig. 15).

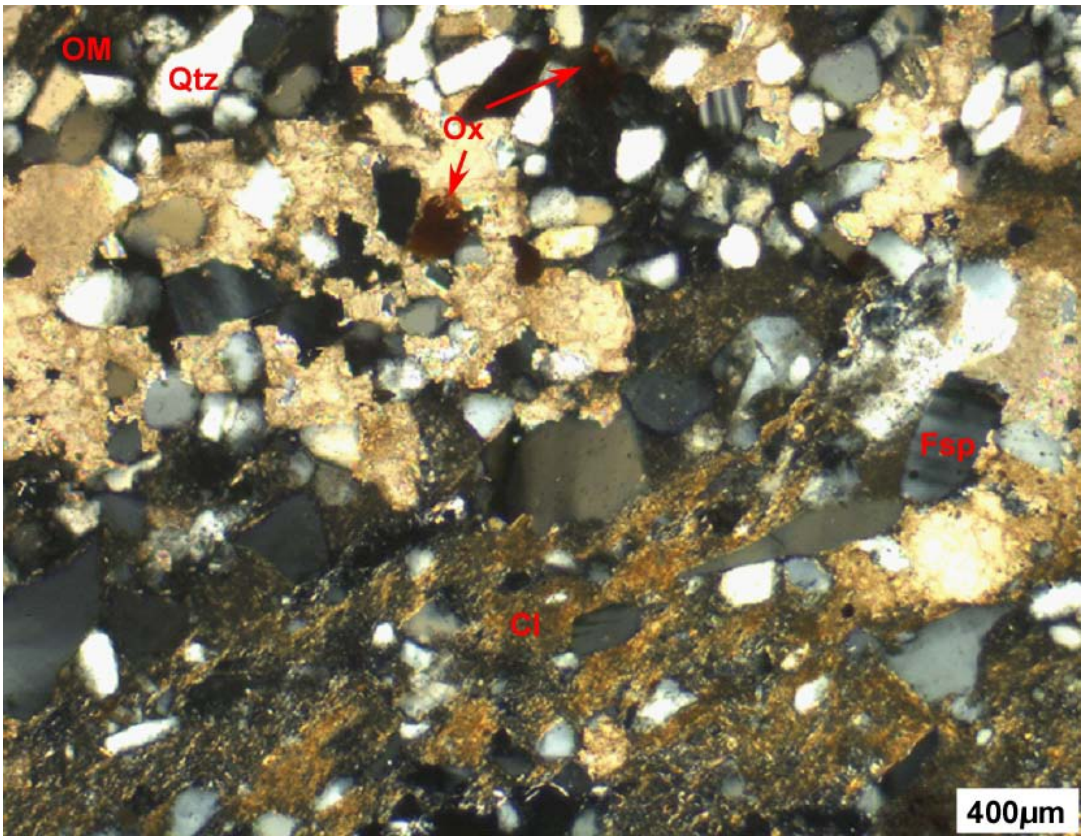

Fig. 14: Thin-section of the Triassicmineralized formation showing organic matter (OM), clay (Cl) and oxides (Ox).

Fig. 15: Organic matter enriched core samples of the Triassic formation

c) Jurassique Formations

Core samples and thin-sections studies show that Jurassic formations consist of:

- Coarse-grained sandstone
- Medium-grained sandstone
- Siltstone/silty-muddy sandstone with analcimolites.

On the basis of petrographic thin-section and field observations, the sandstone of the Jurassic formation hosting the U mineralization are composed of 76–85% quartz depending on the amount of analcime, and quartz cement (5–10%), feldspar (5–10%), clay (2–5%), oxyhydroxides (2–3%), and Cu sulfides in minor amounts (Fig. 16). Some clay and calcite is replaced by iron-oxides acting as a cement in the studied samples (Fig. 16).

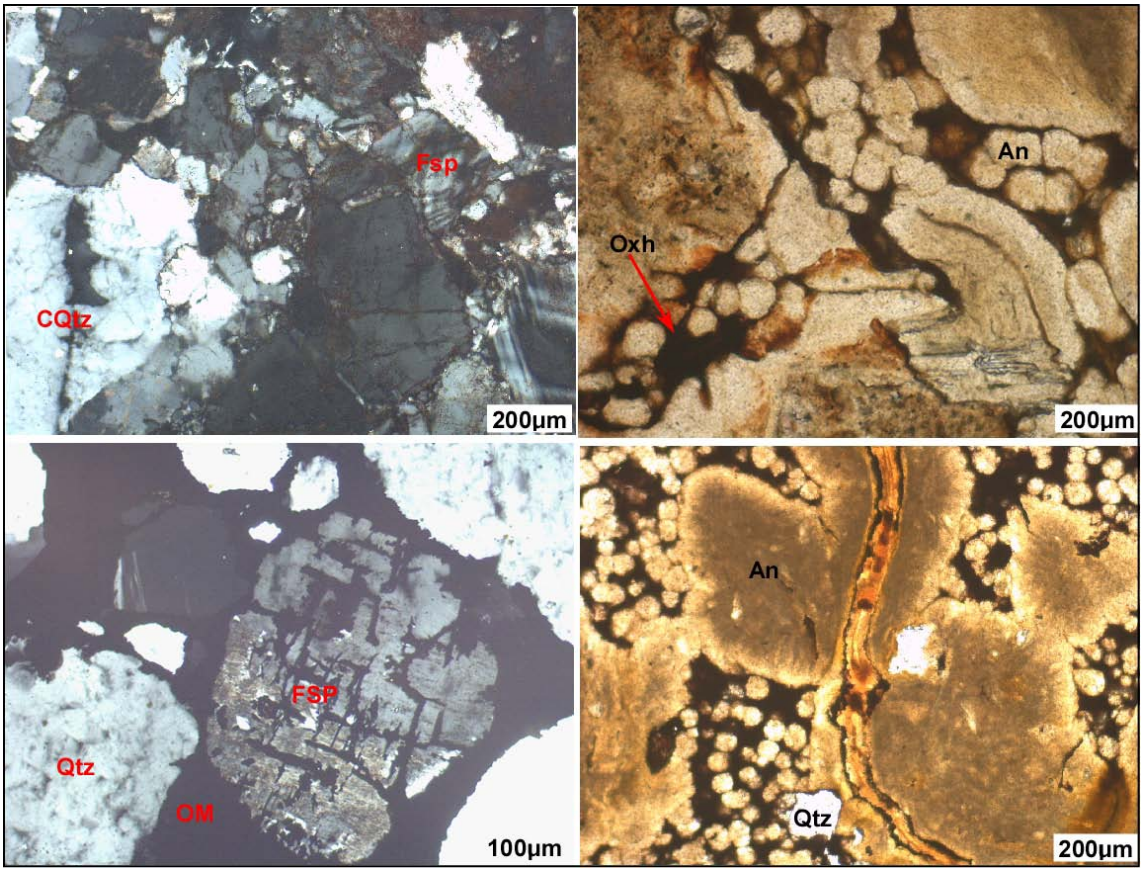

Fig. 16: Different variants of thin-sections of Jurassic series showing analcime (An), quartz (Qtz), cataclased quartz (CQtz), feldspar (Fsp), organic matter (OM) and oxyhydroxides

VI. Tectonics and Sedimentation

To better understand the DASA graben structures, synthetic cross-section (location in Fig. 5) from well log correlation were constructed, (Fig. 17). This approach allowed examining the lateral and vertical succession of the different facies and the relationships between tectonics and sedimentation. The geological cross section obtained shows, that in the axial zone of the DASA graben, the maximum thickness of the sediments is about 805 m (according to the borehole data), for a sedimentation period of 246 Ma (according to the lithostratigraphic column). This implies a lower subsidence of about 3.22 m/Ma (Figs. 3 and 17) compared to that of the Tim Mersoï basin whose subsidence is on average 5.3 m/Ma (Figs. 3 and 17). Most sedimentary series of the DASA graben exhibit variations in thickness on both sides of the border faults (Figs. 3 and 17).

According to Sani et al (2020) the sedimentary infilling of the DASA graben is typified by two periods of subsidence.

a) First Period of Subsidence

This period was characterized by a low subsidence rate (3.75 m/Ma on average), and extends from the Carboniferous to the Permian. The Permian series are particularly marked by a strong reduction in thickness in the axial zone of the graben (30 m) compared to the edge zones (188-215 m) (Fig. 17) (Sani et al (2020)).

b) Second Period of Subsidence

The second period was marked by a strong subsidence rate (4.11 m/Ma) lasting from the Triassic to the lower Cretaceous (Fig. 17). The strongest subsidence rate occurred during the Lower Cretaceous in the axial zone (6.52 m/Ma) while in the border zones the subsidence rate was very low (1.17 to 1.65 m/Ma) (Fig. 17) (Sani et al (2020)).

The subsidence inversions occurring between the axial zone of the DASA graben and the edge zones reflect a morphological inversion related to a change in the tectonic regime.

During the first period, from the Carboniferous to the Permian, the axial zone of the DASA graben was affected by an uplift stage. During the second subsidence the highest thicknesses of the sediments are observed in the axial zone of the graben whereas the thicknesses are lower on the border zones. The DASA sector was affected by a rifting stage.

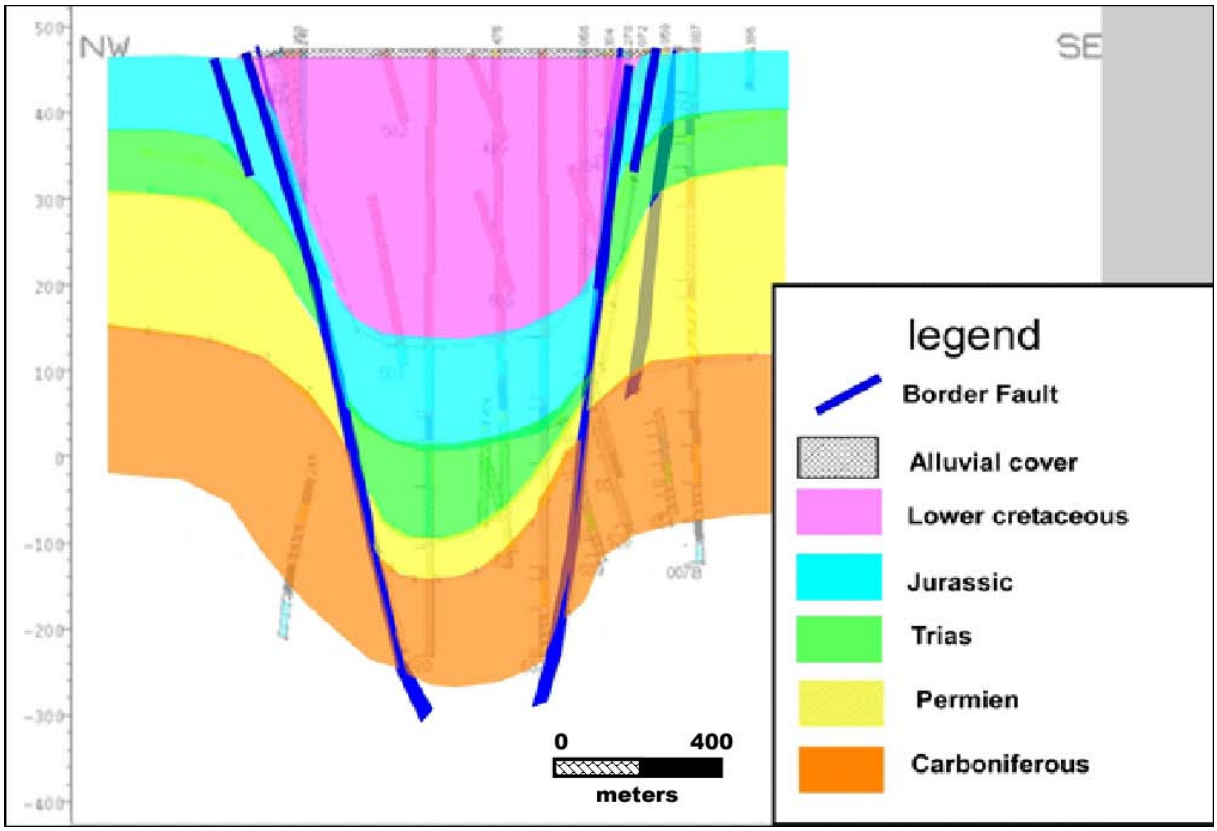

Fig. 17: Geological section of the DASA graben made from survey data

VII. Mineralogy and Uranium Distribution in the Dasa Graben

Results used herewith are of the Jurassic formation in the Tchirezrine 2 near surface mineralization. The description of the mineralization is based on grade, depth and association of U with other elements. The uniqueness of uranium mineralizations in the DASA graben is :

- ✓ All formations known to contain uranium in the Tim Mersoi basin are present at DASA.
- ✓ The grades are higher than in nearly all other uranium deposits in the Tim Mersoi basin (>1%).

The sandstones hosting the DASA uranium mineralization in the Carboniferous are composed of quartz (70-80%), feldspar (10–20%), clay (5–10%), oxyhydroxides (3-5%), organic matter and pyrite while in the Triassic and Jurassic formations the sandstones are composed of quartz (66-75%), feldspar (7-15%), analcime (7-10%), clay(5-7%) and oxyhydroxides (2-6%). In the DASA graben, the highest concentrations of uranium mineralization are observed in its southeastern part (Fig. 18), which corresponds to the most faulted area.

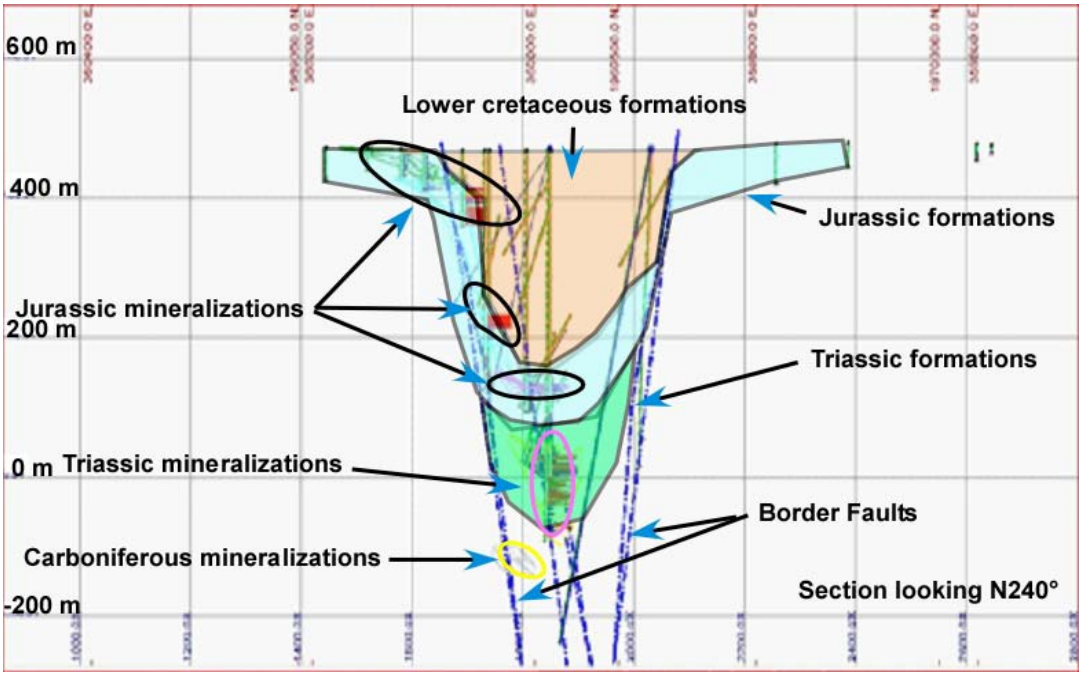

Fig. 18: Uranium distribution in the DASA graben

a) Mineralization In The Carboniferous

The uranium ore in the DASA graben was discovered in Carboniferous formations (Guézouman, Tarat and Madaouéla). The mineralization is hosted in organic matter (Figs. 19 a and b) and /or pyrite rich sandstones. The mineralized zone is 34 m to 82 m thick and U_3O_8 grades range from 0.31 to 0.4% with 1.5% U_3O_8 as the maximum grade (Table 1).

b) Mineralization In The Triassic

In the Triassic formations uranium mineralization is hosted in organic matter and/or pyrite rich sandstones and in analcimerich sandstones associated with fracture infilling with calcite (Figs. 19 c and d). The thickness of the Triassic mineralization is shown in Table 1. It may reach continuous from 24 to 131 m in thickness with grades up to 17.5%. U_3O_8.

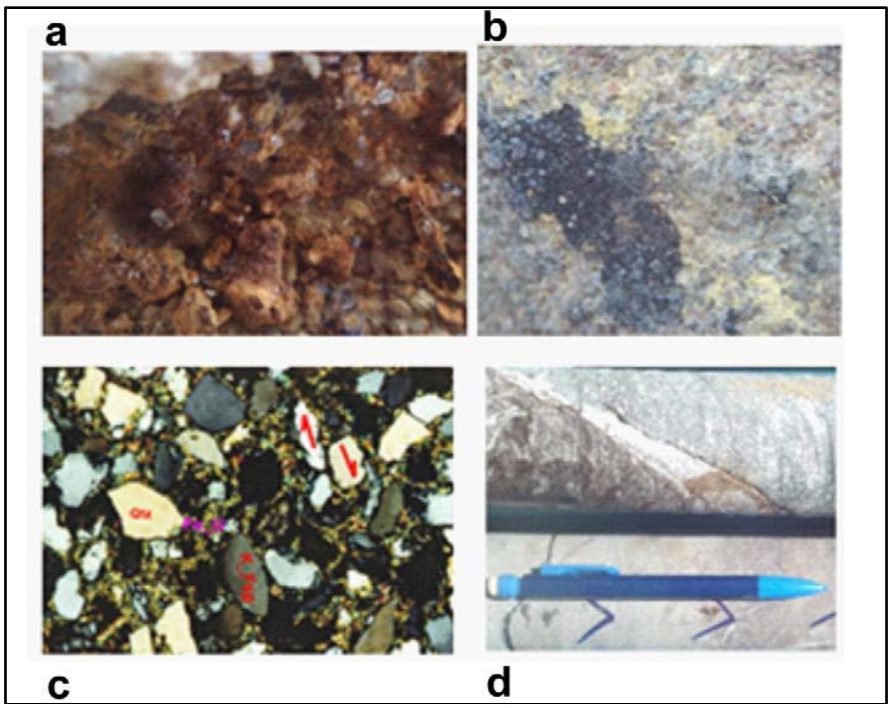

Fig. 19: DASA graben core samples. (a) Oxidized sandstone, (b and c) occurrence of uranium associated with organic matter in DASA sandstone (Carbon or Triassic or Jurassic??), (d) micro fault infilling with calcite

c) Mineralization In The Jurassic

The Jurassic mineralization is sub-surface (5-15 m) on the flanks of the graben, while in the axial zone, the mineralization can reach to a depth of 500 m. It should be noted that most of the Jurassic mineralisation is found in the southern zone of the graben (with thicknesses varying between 20 and 34 m). The grade of this mineralization varies from 0.25 to 0.55% U_3O_8 with 5.08% U_3O_8 as the maximum grade (Table 1). The Jurassic mineralization is mainly hosted within the Tchirezrine 2 sandstones, particularly in the coarser-grained micro-conglomeratic facies of greyish-greenish colour containing frequent sulphides, organic matter and analcime (Figs. 20 and 21). The characteristics of this mineralizations is:

- The mineralization is usually hosted in bottom sets with associated organic matter fragment, pyrite/hematite and analcime.
- The mineralization is controlled by tectonics: uranium mineralization occurs within cataclastic structures and breccia attesting to uranium enrichment related to fluids circulation.

The grades are very high for a sedimentary deposit and are rarely found anywhere else in the world/

Thin section work and petrographic studies on the DASA samples has revealed that the main uranium host rocks are oxidized and analcimolitic sandstones. The main component is angular quartz, some plagioclase and lesser orthoclase. They are cemented by goethite, amorphous iron-hydroxides and various secondary uranium-rich minerals (Fig. 22).

The mineralogical studies of the Tchirezrine 2 show that the composition of the uranium minerals is variable. The analyses performed on the core samples yielded six types of uranium minerals such as: Carnotite; Uranophane; U-rich titanite (possibly rutile); Coffinite; Torbernite; Autunite, U-Ti mineral (possibly brannerite) and U-Si (possibly coffinite) are the main uranium mineral in all samples. The uranium occurrence is complex and observed as uranium remobilisation is present in micro-fractures, discontinuous rims and fine-grained cryptocrystalline inclusions. Trace amounts of uranium minerals are associated with carbonates.

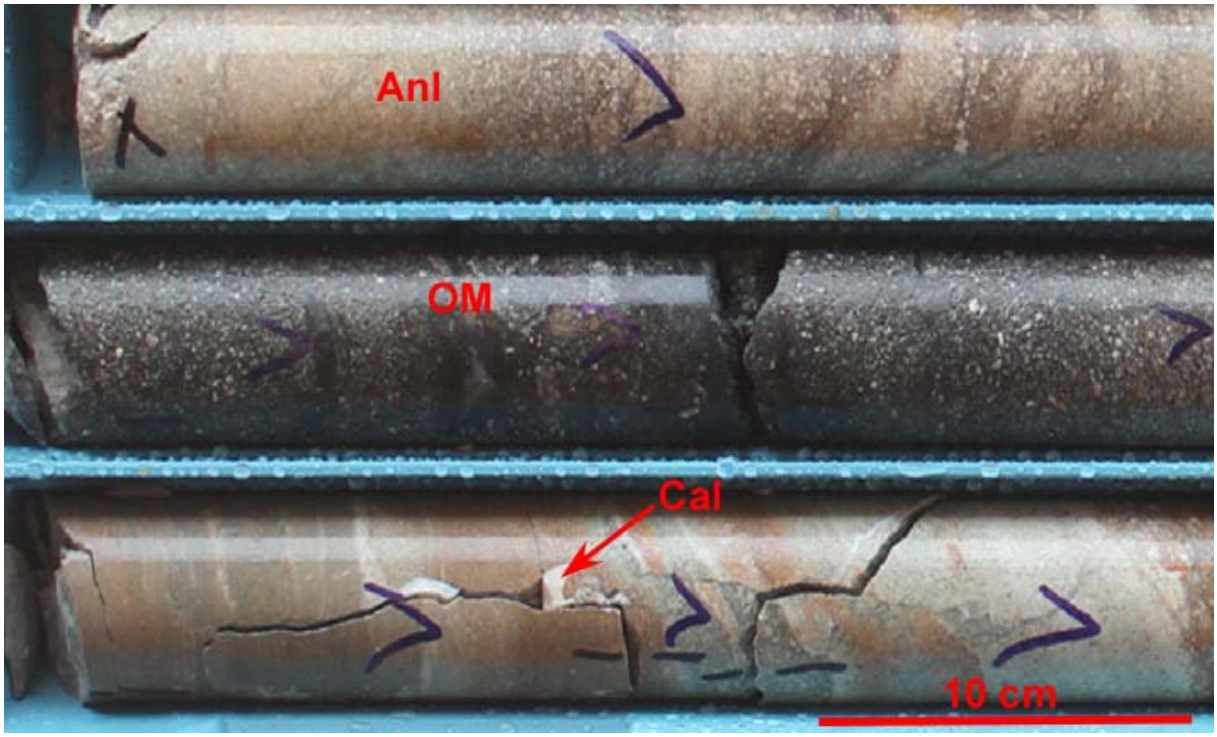

Fig. 20: Triassic formation core sample enriched in organic matter and analcime

Fig. 21: Jurassic formation core sample enriched in organic matter, analcime and oxyhydroxides

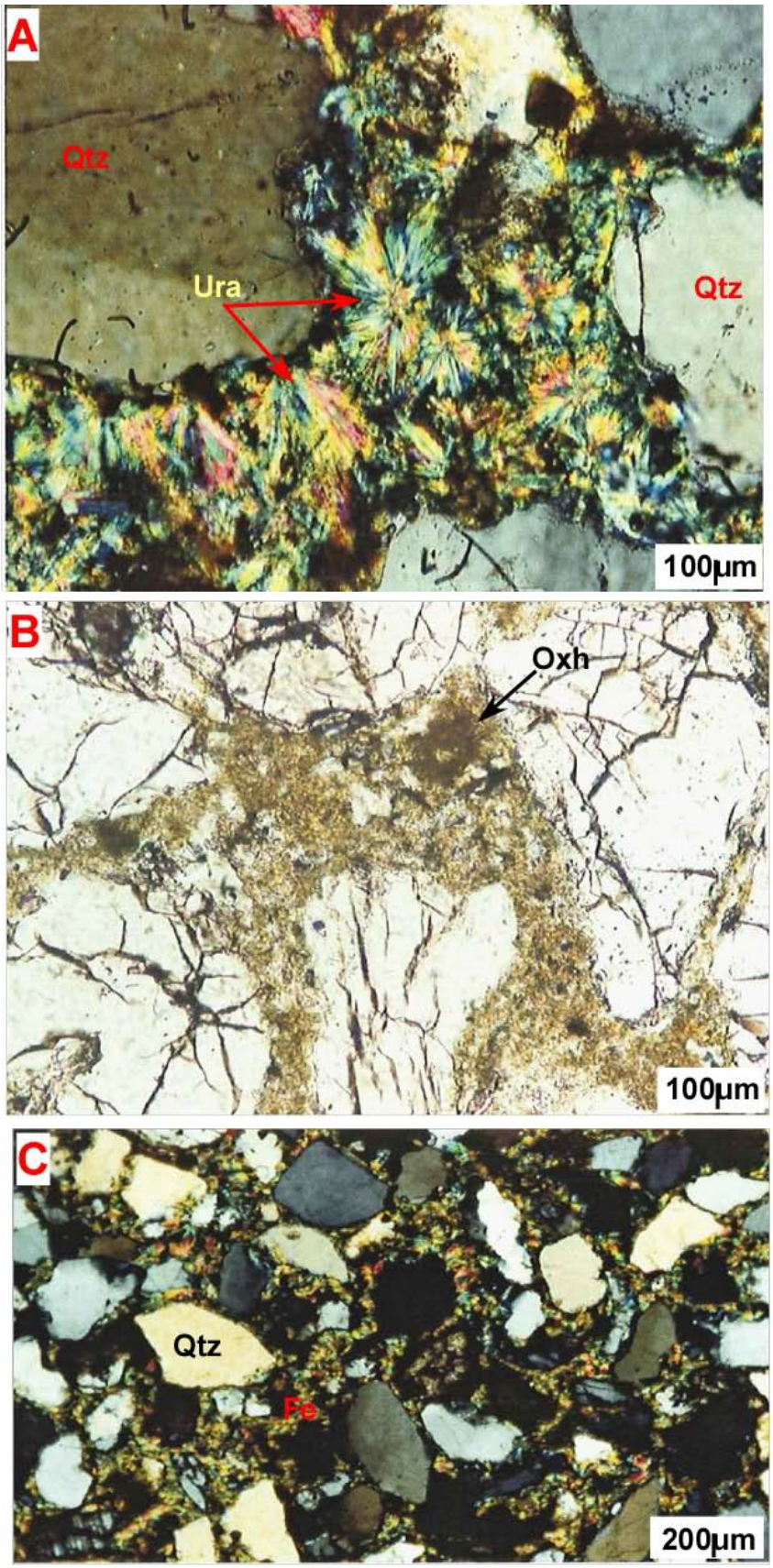

Fig. 22: Thin-sections of the Jurassic formation showing: A= radiant uranophane rosettes partially replacing quartz, B= radiant uranophane rosettes partially replacing quartz, and C= angular quartz clasts in an iron-coloured uranophane matrix

VIII. Microtectonic Analysis

In the DASA graben, the sedimentary deposits are affected by normal microfaults (syn and post sedimentary). The latter locally display micro horst and meso-graben structures (Fig. 23A). Figure 23C (a) shows a synsedimentary microfault affecting the Carboniferous deposits while Figure 23C (b) corresponds to a synsedimentary microfaults affecting the Jurassic deposits. Shown in Figure 23B is a post sedimentary microfault affecting the Jurassic deposits.

The syn-deposition microfaults observed in the DASA graben are generally normal, but may rarely show reverse faults. When exposed, these types of microfaults are recognized by the following characters:

- The patina of the microfaults plane has the same color as the sediment (Fig. 23B);
- The striaes are generally curved (Fig. 24);
- The sedimentary material is not cataclazed;

Jurassic deposits outcropping along the DASA graben are also affected by brittle deformations, linked to late replay of border faults. These late post-deposition microfaults are sometimes characterized by cataclastic zones or by deformation corridors meters in thickness, associated with syncinematic recrystallizations of silica. Microtectonic analysis has allowed to highlight tectoglyphs which, by their characteristics, could be linked to post-deposition deformations. It's about :

- Abrasion or cataclase figures with scales, tear-off lunules (Fig. 24, 25);
- Syncinematic recrystallizations of silica.

In addition to these tectoglyphs, at the level of the DASA graben, post-deposition microfaults are characterized by corridors of millimeter deformations associated with syncinematic recrystallizations of silica and tension fentes (Figs. 26, 27, 28).

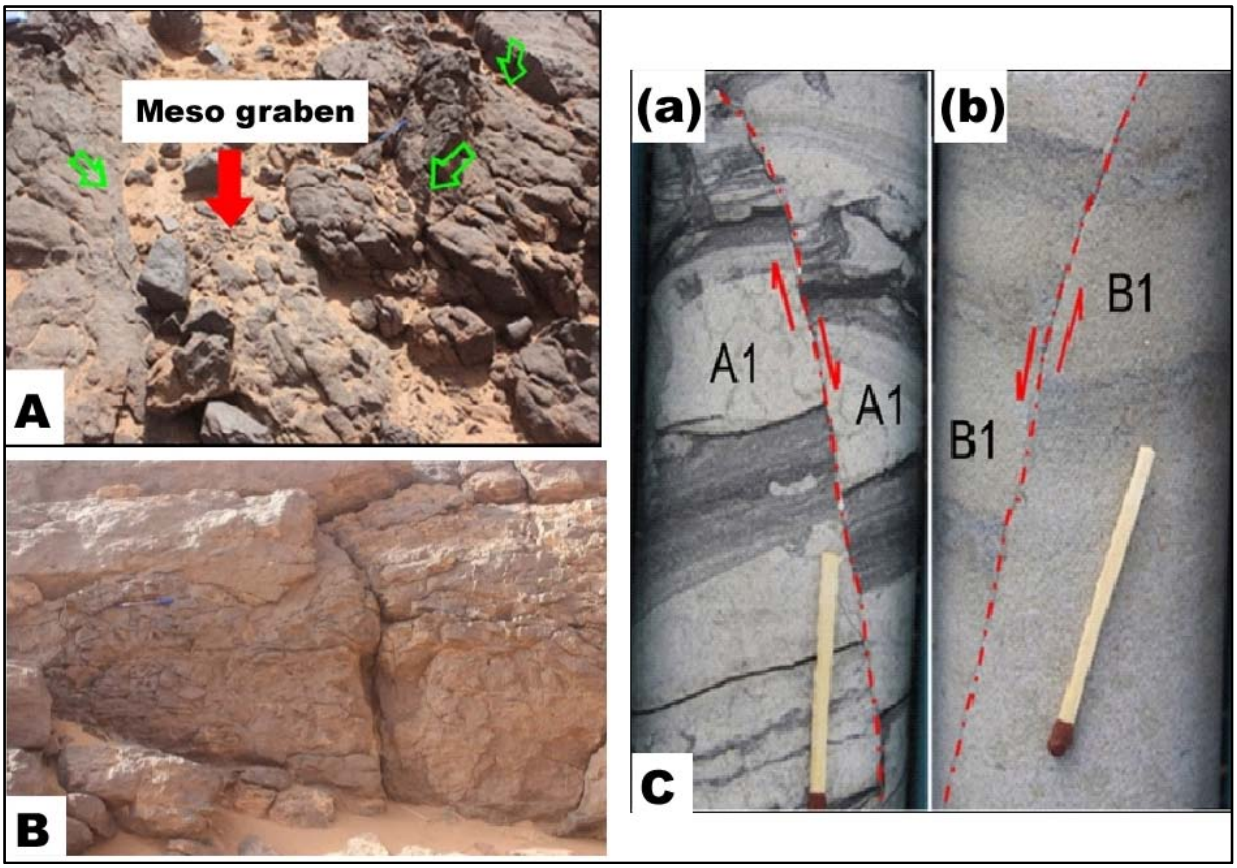

Fig. 23: Microfaults in the DASA graben. A-meso graben, B-cataclazed area in DASA and C-synsedimentationmicrofault on the DASA core. Two criteria are used to distinguish the synsedimentary tectonics. These are, on the one hand levels thickness variations on both side of the microfault and, on the other hand lateral facies variations ((a): in the Carboniferous Tarat formation and (b): in the Jurassic Tchirezrine 2 formation)

Fig. 24: Microfault Plan oriented N70° E, with more or less fluted striations

Fig. 25: Normal micro fault plane N70°. The first generation of vertical striation (pitch ~ 90°) is intersected by secondary fractures planes in irregular striations oblique to horizontal.

Fig. 26: Core sample from the Carboniferous series showing a post-deposition micro-deformation. The sediment is cataclazed

Fig. 27: Thick fault zone, the rock is cataclazed and brecciated over a thickness of about 3m

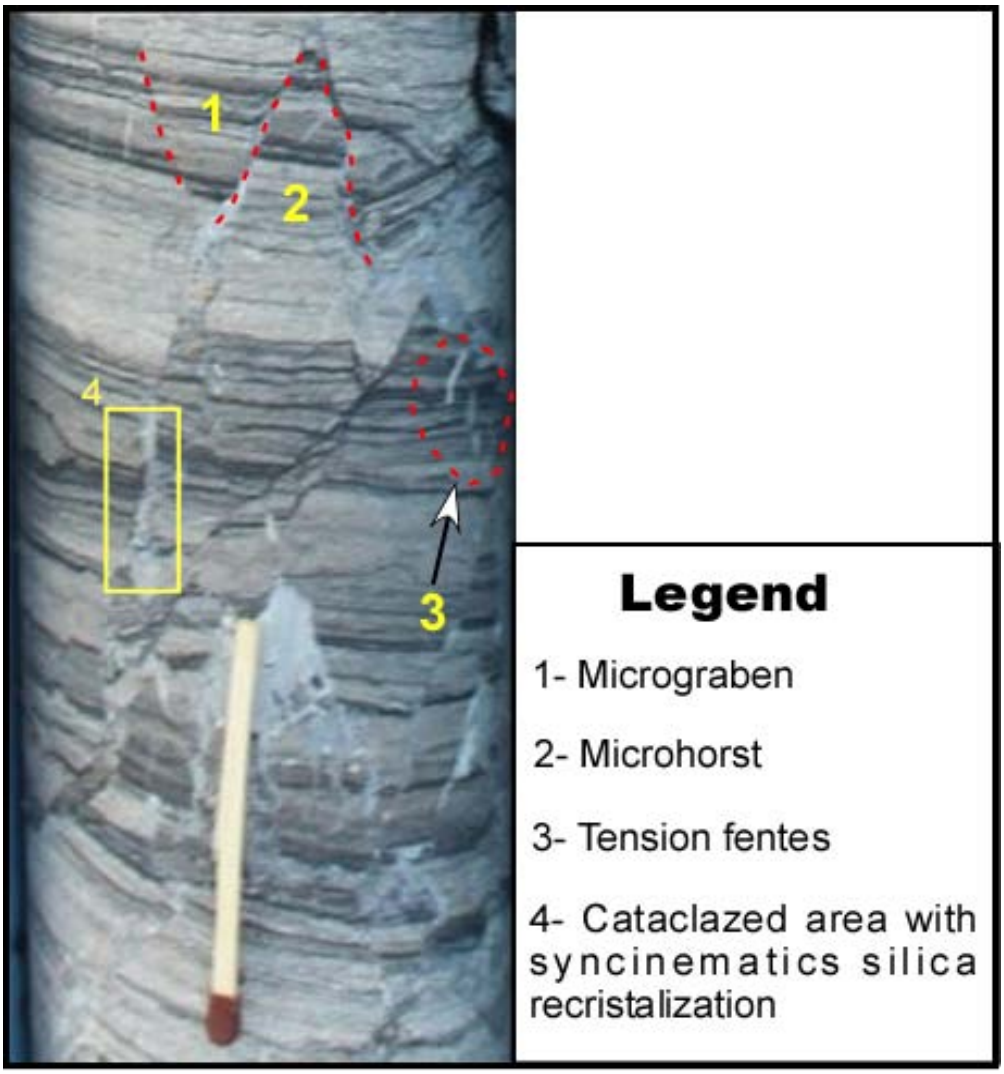

Fig. 28: Carboniferous core sample showing characteristics of post-deposition deformation

IX. Discussion

Comparing the results of this study to those of Moussa (1992), Cavellec (2006) and Mamane Mamadou et al., (2019), it can be concluded that most of the geological formations of the Tim Mersoï basin identified previously work are also represented in the DASA graben.

a) The Dasa Graben Structure

To explain the succession of the two phases of the DASA graben structuring (uplift/rifting) over time, the results of this study are compared to those of other African basins, such as Tim Mersoï, Téfidet (North Niger), Benue trough (Nigeria), Muglad basin (Sudan) and others equivalent troughs in North Africa (Libya and Tunisia).

At the regional scale, the DASA graben has the same orientation as the regional strike slip faults system oriented ~ N75° (Fig. 29), called Agadez Line (Genik, 1992) or the Guinean-Nubian Lineament (GNL) (Guiraud and Bosworth, 1997; Wilson and Guiraud, 1992).

The DASA graben has a singular position between the North troughs (Sirt and Cyrenaica in Libya, in Tunisia) and the South troughs (Benue, Doba, Muglad in the West and Central African Cretaceous rifts called WCARS) (Fig. 29). Most of these rifts (Syrt, Cyrenaica, Gargaf, Termit, Bongor, Doba, Fig. 29) are Cretaceous in age and have a NW-SE to NE-SW trend as has the DASA graben. They thus might have been generated by the same geodynamic event.

During the Carboniferous period a N40° Visean compression phase has been highlighted in Algeria in the Ougarta area by Blès (1969), in the Béchar Basin by Conrad and Lemosquet (1984), in the Illizi Basin by Boudjema (1987) and in the Ahnet Basin by Zazoun (2001). Furthermore, the Paleozoic time of Libya was represented by the Caledonian orogeny (Silurian-Devonian) and resulted in the uplift of the Tripoli-Tibesti uplift along a NW trending direction, and by the

Hercynian orogeny (Permian-Jurassic) which resulted in the NE trend of the Sirt arch. During the Paleozoic time, the area, where the Sirt basin existing today, an arch existed (Shaaban and Ghoneimi, 2001) which represented one of the old Hercynian NE structures. In the Tim Mersoï basin, too, a N25° horizontal shortening, upper Visean in age, was highlighted by Konaté et al. (2007). During the Visean period, the uplifting observed in the DASA graben indicates that the strike-slip sinistral reactivation of the N70° trending faults has a reverse component. A ~N70° transpressive regime would have affected the DASA graben during this period.

The structural evolution of the DASA graben during the Jurassic-Cretaceous period is compared to those of the West and Central African Rift Systems (WCARS). During the Lower Cretaceous, these rift systems were affected by extensive to transtension tectonics regime (Guiraud et al., 1993, Jing Ye., 2016), favoring a strong rate of subsidence (54 m/Ma for the Termit basin (Liu B et al., 2015), 65 m/Ma for the Muglad Basin (Yassin., 2016), 43 m/Ma for the Benue trough (Guiraud., 1992) and 13 m/Ma for the Téfidet trough (Konaté et al., 2019). Unlike the Cretaceous rift systems, the DASA graben has a lower subsidence rate (about 6.52 m/Ma). The WCARS that extends from Mali (Gao trough) to Sudan developed in the earlier stages of the Gondwana break-up, i.e., in the Lower Cretaceous (Konaté et al., 2019). Basins in the WCARS are arranged in three main orientations, NE-SW (BenueTrough in Nigeria), ENE-WSW (Doba, Doseo, Salamat basins in eastern Chad and Baggara Basin in western Sudan), and NW-SE (Muglad Basin in Sudan, and the Ténéré rift system in Niger) (Genik, 1993; Yassin et *al.*, 2017). During the Late Jurassic-Early Cretaceous (144.0-112.2 Ma) the central Atlantic opened between NW Africa and North America, which caused west movement for the African plate relative to the European plate. E-W trough structures developed in Niger and north Cameroun (Anketell, 1996). During this period continental rifting was active in Africa, affecting the NE Brazil-Gulf of Guinea, southern Chad domain (Doba, Doseo, Salamat basins), the Sudan (Baggara Basin), Kenya N and E Niger and the area of the western desert of Egypt (Abu Gharadig basin) and the southern Sirt basin in Libya (Guiraud and Maurin, 1991). The E-W trending structures of the Sarir and Hameimat troughs in the south east of the Sirt basin coincide with this period. This period was attributed to the collapse of the Sirt Arch, as a result of plate movements along a group of forming basement faults, and failed triple junctions in E-W, NW-SE and NE-SW directions (Shaaban and Ghoneimi, 2001). It was associated with deformation in the African plate, which caused development of sedimentary basins within the plate. The tectono-sedimentary evolution of the African basins is characterized by polyphase rifting and assumed to be linked to the opening of the south and equatorial Atlantic. The Sirt basin is one of these basins which developed in this period and is believed to be affected by the opening of the Atlantic Ocean and Tethys Ocean that was formed due to the movement between the Africa and Eurasian plates.

According to this geodynamic context during the Cretaceous period, the extensional tectonic regimes, which affected the DASA graben, could be associated with the opening of the Atlantic that occurred during this period (Genik., 1992, Guiraud et al., 2005, Jing Ye., 2016).

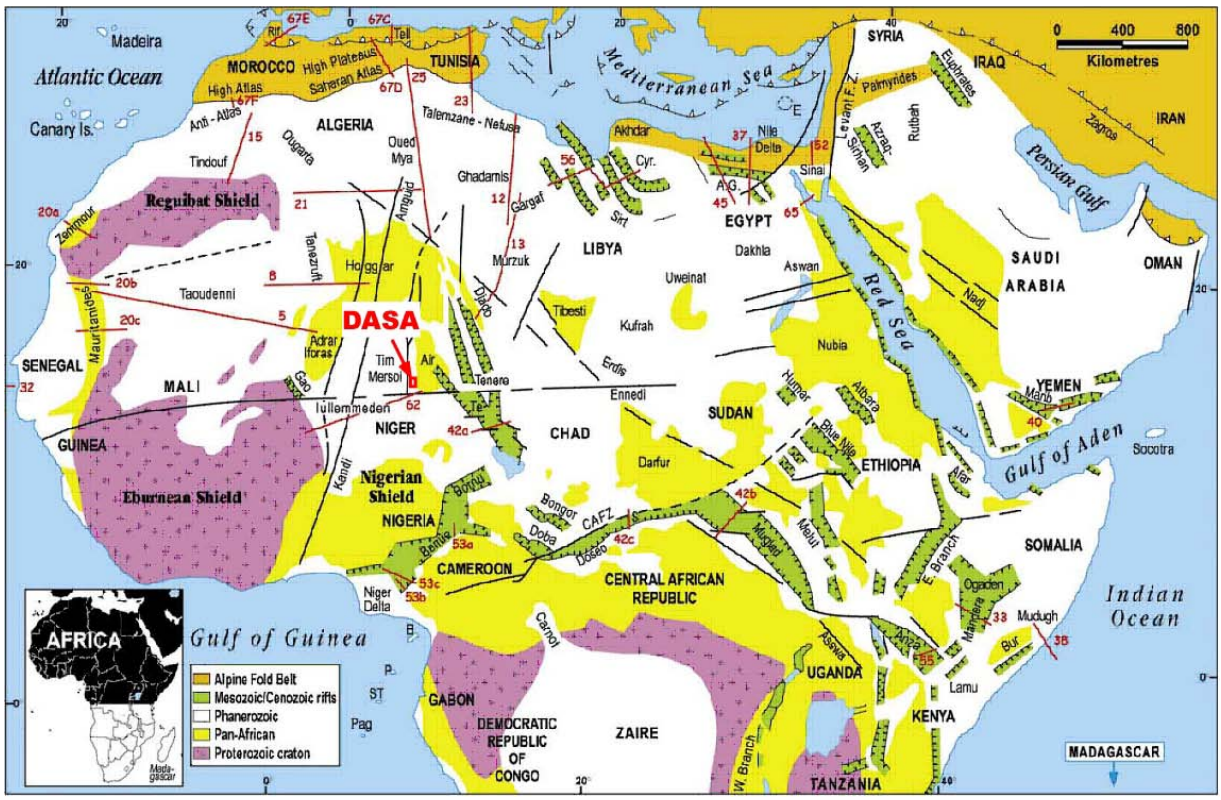

Fig. 29: Schematic geological map of Northeast Africa, Central Africa and Arabia. Compilation of Wilson and Guiraud (1998). The main fault zones and rifts are shown. AG: Abu Gharadig; B: Bioko; CAFZ: Central Africa Fault Zone; CYR: Cyrenaica; SIRTSyrt Basin; E: Eratosthenes island; JP: Jos Plateau; P: Principe; PAG: Pagalu; S: Salamat; ST: São Tomé; TE: Termit; GNL: Guinean-Nubian Lineament; RAG: Raghane shear zone. The red box outlines the location of the DASA graben (Guiraud et al., 2005, modified)

VIII. Uranium Mineralization

In the Tim Mersoï Basin, the main uranium ore deposits are located in the Tagora and Agadez Groups. In the Visean Tagora Group, the Akouta uranium ore deposit near Arlit is hosted by the Guezouman Formation composed mostly of fluvio-deltaic sandstones, and organic-rich channel formations in general (Forbes, 1989; Cavellec, 2006). The other Arlit ore deposit is found in the Tarat Formation of the Tagora Group, that contains fluvial sandstones and organic-rich clays and silts (Sempéré, 1981; Elhamet, 1983; De Rouvre, 1985; Cavellec, 2006). To the South, the Imouraren uranium ore deposit is located in Tchirezerine 2 Formation of the Upper Jurassic featured by continental arkoses and analcime-rich sandstones (Pacquet, 1969; Valsardieu, 1971; Vallance, 2007; Billon, 2014). All the exploited uranium deposits are located on the eastern side of the Arlit Fault, but uranium ore deposits have also been discovered recently in the western side.

All uranium mineralization, recognized in the Carboniferous and Jurassic-Cretaceous formations of the Tim Mersoï Basin, are also found in the DASA Graben. In addition, at DASA area, uranium mineralization is also recognized in Triassic formations. Six types of uranium minerals were identified on samples from the Jurassic sediments of the DASA graben. These are the following minerals: Carnotite, Uranophane, Urano-titanate, Coffinite, Torbernite and Autunite.

Compare to the DASA area, the uranium mineral types identified in Arlit area are Uraninite, Coffinite and Urano-Titanate, while Uranophane and Métatyuyaminite are found in the Imouraren region (Forbes, 1989; Mamane, 2016; Mamane M et al., 2019).

In the DASA graben, many factors are involved in the control of the uranium mineralization. These are:

– *Lithological factor.* Uranium is mainly hosted within the coarser-grained micro-conglomeratic facies of greyish to greenish colored sandstones containing sulfides and organic matter. This characteristic has already been mentioned by Forbes (1989) who shows that organic matter and pyrite bearing sandstones would be a preferential trap for uranium mineralization. Moreover, in the case of the DASA deposit, it also appears that analcime-rich sediments (Triassic to Cretaceous in age) could also be a favorable lithology to the uranium mineralization concentration. This last observation is

in agreement with the results obtained by Billon (2014) in the Tim Mersoï basin.

– *Tectonic factor.* Micro-fractures containing uranium were observed in several core samples. Quartz and feldspar contain micro-fractures partially filled with U-oxide. Some samples are intensely cataclastically deformed by high hydrothermal fluid pressure that gives the rock a granitic like appearance. In the Tim Mersoï basin, this hydrothermal fluid flow has been mentioned by Salze (2008). According to Forbes (1989), the creation of the Arlit fault would have favored putting in contact reduced Carboniferous formations with oxidized Permian formations. This spatial arrangement would have favored the concentration of uranium in the Arlit area Carboniferous formations. A similar arrangement has been observed in the DASA graben, where faults created contact between the Triassic-Jurassic formations with the Permian formations (Figs. 3 and 17). Unlike other deposits in the Tim Mersoï basin (0.04 to 0.05% of uranium grade), in the DASA graben, the higher fracturing density associated with a greater circulation of hydrothermal fluids have favored a higher grade (1% on average) of uranium mineralization (Global Atomic Corporation, 2018).

The tectonic peculiarities of the DASA area are also responsible that the DASA deposit is unique amongst all the known uranium deposits of Niger as it contains itself all the major uranium bearing formations which are either mined or will be mined elsewhere in the Tim Mersoi basin. In the Arlit mining area all formations younger than Permian no longer exists and for the Imouraren area little is known about any mineralization in the Carboniferous.

IX. Conclusion

The tectono-sedimentary and microtectonic analysis suggests that the DASA graben was affected by two major structuring periods.

- The first period was an uplifting stage that prevailed during the Carboniferous-Permian times. It was marked by a ~N70° transpressive tectonic regime.
- The second period was a rifting stage that occurred during the time ranging from the Triassic to the Lower Cretaceous. This period was mainly characterized by a ~N160° extensional regime.

Lithological and tectonic features have controlled the formation of uranium mineralization in the DASA graben.

From a lithological point of view, uranium is mainly hosted within coarse-grained sandstones, containing sulfides and organic matter in Carboniferous deposits or analcime in Triassic to Cretaceous deposits. This study has also shown that successive fracturing phases that affected the DASA graben over time played an important role in the emplacement of the mineralization. This intense fracturing observed in core samples is associated with fracture infilling of sediments with high to very high-grade of uranium mineralization.

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Performance Evaluation of Granite Dust, Dolerite Dust and Woodash as Additivies on the Lateritic Soil of Sagamu-Papalanto Southwestern Nigeria and its Implication for Road Constrcution

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Keywords: *soil, waste, road, sagamu-papalanto, wood ash, dolerite dust, granite dust, geotechnical.*

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I. Introduction

For several years, researchers and engineers have made advances through scientific technique and theories to develop an approach to control inherently existing engineering problems. Soil stabilization is one the numerous methods and techniques that has emerged to fit into the inadequacy. Soil stabilization is the technique of improving individual soil characteristics by various process viz chemical and mechanical in order to give rise to the required engineering soil properties. In general, soils are stabilized to enhance their strength and resilience. The characteristic properties of soil differ in a large amount from place to place or in a definite occasion at a single place. The process of soil stabilization rely on soil testing to determine the natural soil performance. Several techniques are used to stabilize soil and the methods are confirmed in the lab with the soil material prior to putting it in use in the field. Soil stabilization is a significant method used to enhance the characteristic behavior of a soil. This is often carried out when the necessary engineering characteristics required for the soil to be used are not met or an additional enhancement is necessary to attain a needed use.

Norazlan et al. (2014) stated that soil stabilization is the medium of improving the engineering and other components of the soil which includes the compressibility, conductivity of hydraulics, rigidity of strength and density. Techniques connecting to soil stabilization can be grouped in many methods these includes vibration, surcharge load, building up support for structures, grouting and other methods. Different approach can be used for separate purposes (Ozawa and Ōsawa 2006). Ground treatment can improve the bearing capacity of the soil, lowers the likelihood of differential-based settlement, lowers the rate of settlement turn out, decrease the potential of liquefaction with saturated fine sand, hydraulic fills, reduce the hydraulic favorableness, water confinement, and water discharge of the soil (Zhang et al. 2007; Majeed and Taha 2012).

Soil Stabilization can be described as the remodeling of soil properties and characteristics by physical, chemical or non-chemical means, in order to facilitate the improvement of the soil behavior. Soil stabilization enhances the bearing strength and capacity of the soil, its reluctance to weathering process and soil perviousness. The durability and sound functioning of any construction project hinges on the strength of the primary material lying below. Expansive soils can generate remarkable complication for pavements or structures. Therefore, soil stabilization approach is mandatory to ascertain the firmness and stability of soil so as to efficiently carry the load of the structure.

Soil stabilization is also used in lowering the compressibility and permeability of the soil, make it more hardened, reinforce the bearing capacity and to improve the shear strength. The basic fundamentals of

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soil stabilization is applied to regulate the grading and particle size distribution of particles of foundation bases and sub-bases for airfields and highways. Scientist and researchers have implemented several techniques and binders which are extremely costly at moment in Nigeria's market. For instance, binders such as cement, (Osinubi 1999), lime (White 2005; Awasthi et al. 2009), fly ash (White 2005), bitumen (Osinubi 2000), cement kiln dust (Osinubi et al. 2009) etc. have been utilized to enhance the engineering properties soil. Moreover, result from several researches have revealed also that non-convectional binders such as silicates (Osinubi et al. 2009) chlorides (White et al. 2005) have been utilized in different percentages and have accomplished its intended purpose. Fiber reinforcements (Sherwood 1993) and polymers have also appear to be effective in the stabilization of engineering soil. Other researchers have also reported the on the use of admixtures and binders like rice husk ash, bagasse ash, egg-shell ash, palm kernel ash, palm bunch ash, etc. in their varying proportions in stabilizing weak and problematic engineering soil (Feynman 1960). Several studies have been centered on the use of several additives as stabilizers. Conventional materials like lime, cement, and minerals like silica fume, fly ash, and rice husk ash have been used for the enhancement of soil (Hussin et al. 2009; Hossain and Mol 2011).

The current investigation was borne out on the increasing cost of traditional materials, the demand to raise the bonding, the surface reactivation for soil, the demand to clear the surroundings of unwanted solid waste and transform it into usable engineering materials and the need to utilize low cost industrial and agricultural waste into valuable engineering use. This research is aimed at studying the stabilization potentials, performance and interaction of granite dust, dolerite dust and wood. The study area lies within Longitude 3°23´29.627´´E and Latitude 6°53´1.217´´N on the Sagamu–Papalanto highway in Ogun State Southwestern Nigeria. The road stretches up to 60km long. It serves as routes to other cities like Ewekoro, Ibese, Ifo, Lagos -Ibadan express way and other part of the country. The studied area is located on sedimentary Formation of the southwestern Nigeria. It is underlain by the basement complex (Adegoke et al. 1976). It belongs to the Ewekoro Formation which is Tertiary formed during the Paleocene and Eocene period. This also forms a greater depression of the artesian basin for groundwater formation. It is mostly made up of shale/clay (Ubido et al. 2017; 2018).The purpose of this research is aimed at assessing the impact of granite dust, dolerite dust and woodash as additives at varying proportions of 6, 12, 18 and 24% on the lateritic soil of Sagamu-Papalanto Highway.

II. Materials and Methods

Disturbed soil sample was collected using an auger taken at depth of 2.5m from an open pit. The sample was in an air-tight sack bag so as to retain its natural moisture. The soil sample collected was sent to the Lagos state material testing Laboratory. The soil was spread on a mat to ease air drying, all the clods and lumps in the sample was broken down and reduced to fine particles before been subjected to geotechnical tests which includes; sieve analysis, Atterberg's Consistency Limit tests, Specific Gravity, Compaction, California Bearing Ratio (CBR) and uniaxial compressive test UCS tests. The tests carried out was done under BS1377 Code specification. locally available materials was used to stabilize the soil. Wood ash, granitic and dolerite dust was selected as a stabilizer used for the research investigation.

The Granite dust and Dolerite dust used was collected from a local quarry in Abeokuta Ogun state Nigeria. The collected was taken to the laboratory and thereafter, mechanically sieved. The particles passing American standard of testing materials (ASTM) sieve# 200(/751m) was used for the stabilizing process for the geotechnical test.

The wood ash (the residue powder left after the combustion of wood) was acquired from the furnace of a wood-fired oven of a bread bakery in Lagos state. The steps taken in the preparation was in accordance to Okagbue (2007). The wood ash was left uninterrupted for 1h to chill at room temperature after it was removed from the bakery furnace. It was later subjected to pass through BS sieve of 63 μm in order to obtain the needed size for ash clay reaction. It was preserved in an airtight bag to remove any possible reaction with atmospheric carbon dioxide.

About 940 g of the soil and 60 g of the granite dust (equivalent to 94% soil and 6% granite dust) were properly mixed with a hand trowel. The granite dust –soil admixture were distributed into five segments. The engineering geotechnical test were replicated for three more times using 88% soil and 12% granite dust; 82% soil and 18% granite dust; 76% soil and 24% granite dust. Same procedures were replicated for dolerite dust and the wood ash. These admixtures was later subjected to Atterberg limits, specific gravity, linear shrinkage (LS), compaction, California Bearing Ratio (CBR) and UCS. These geotechnical tests were carried out in accordance to BS1377 and ASTMD1557 Code specification. The geotechnical properties of the soil when mixed with varying percentages of additives was determine. The detailed methods of these geotechnical analyses are highlighted in (Shirsavkar 2010; Punmia et al. 2005; Arora 2009; Phani Kumar 2004; Mir and Sirdharan 2013; Al-Rawas 2011).

Geochemical and mineralogical analysis of soil sample, granite dust, dolerite dust and wood ash

admixtures were carried out through the use of X-ray diffraction and Florescence methods. These test were done through the techniques of (Carrol D 1971), the clays minerals were identified and percentage abundance were calculated using the area method (International Joint Committee Properties on Mineral Powder Diffraction Standard 1980).The results of these tests were used to evaluate the efficiency of the additives and also determine geotechnical engineering properties of the soils for its use as stabilizing materials used construction for road.

III. Results and Discussion

Table 1: Geotechnical properties of the natural soil

Property/Unit Quantity	Property/Unit Quantity
% Passing BS No. 200 sieve	35.90
Natural Moisture Content, (%)	17
Liquid Limit, (%)	56.00
Plastic Limit, (%)	35.6
Plasticity Index, (%)	20.5
Linear Shrinkage	17
Coefficient of Curvature Cc= $\frac{D302}{D60 \text{ X } D10}$	2.07
Coefficient of Uniformity, Cu $= = \frac{D60}{D10}$	5.23
Specific Gravity	2.61
AASHTO classification	A-2-7
USCS	GW
Group Index	0
Material	Silty or Clayey Sand
Condition/General Sub grade Rating	Good
Optimum Moisture Content, (%)	24
Maximum Dry Density (g/cm^3)	1.5
California bearing ratio, (%)	5
Unconfined Compressive Strength, (KN/m^2) 28 days	211.77
Unconfined Compressive Strength, (KN/m^2) 14 days	186.11
Unconfined Compressive Strength, (KN/m^2) 7 days	120.26
Colour	Reddish Brown

From Table 1, the result obtained for the moisture content of the soil sample is 17% which in comparison with the with the (underwood 1967) position shows that the sample has slightly unfavorable values of moisture.

- A plasticity index of 20.5% > 17%. This condition satisfies that study area soil is a highly plastic soil. Gopal and Rao (2011) stipulated that plasticity index between 20 and 35% satisfies the condition for high swelling potential and between 25 and41% for a high degree of expansion. Table 1 shows that the plastic limit of the soil is 35.6% whereas the plasticity index is 20.5% .This did not satisfy the Nigerian requirement (FMWH 1997) that proposed that plasticity index should be less than 20%.
- The soil is classified as A-2-7, Table 1 according to AASHTO classification (1978) Fig. 1.The soils in these group is regarded as poorly graded, poor graded(GP) on USCS soil classification with group index of 0 which is of silty, clayey gravel and sand material (Gopal and Rao 2011).

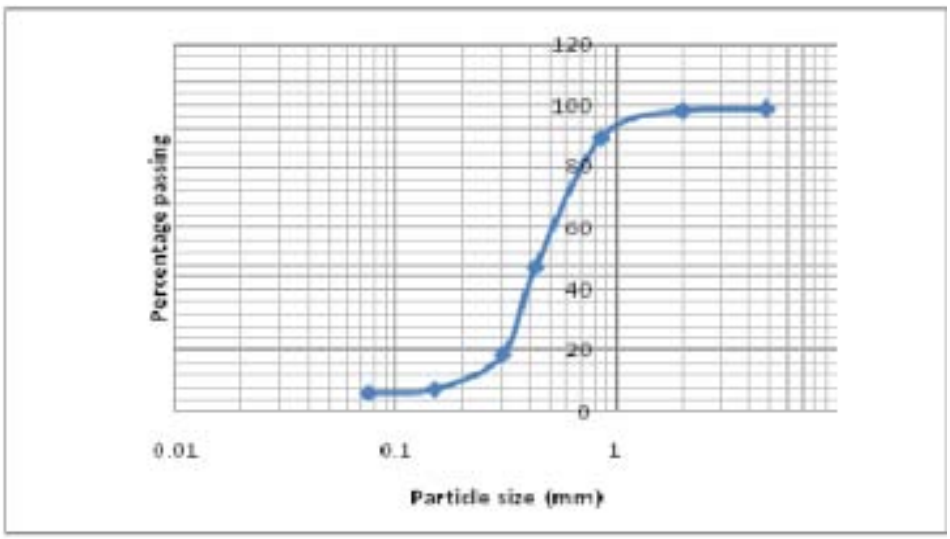

Figure 1: Grain size distribution curve for soil sample

- The linear shrinkage value of the soil is 17 (Brink et al. 1982; Ola 1983) reported linear shrinkage values exceeding 8% will be active and have a serious swelling potential. · The Maximum dry density (MDD) is 1.5g/cm^{3}and Optimum Moisture content is 24%. According to (NGS/FMWH 1997) which recommends that soil should be in the ranges of 1.50 to 1.78 g/m^{3}for the MDD and optimum moisture content (OMC) should range from of 8.56-12.02%.
- Table 1 revealed that the CBR value of the studied location is 5%. This makes it fair for the sub-grade material according to (NGS/FMWH 1997) which states that the CBR for subgrade soil should be greater than 5%. The result also fell below the maximum of 80% recommended by (FMWH 1997) for sub base and base course.
- The Unconfined Compressive Strength (UCS) of the studied soil is 211.77 kN/m^{2}at 28 days curing time Table 1. The result in with the range of 200 and 400 kN/m^{2}stipulated by (Gopal and Rao 2011; NGS/FMWH 1997) which grouped soil within the range as very stiff consistency.

Table 2: Result of geochemical analysis of the natural soil samples.

Constituents	SiO_2	Na_2O	K_2O	CaO	MnO	MgO	ZnO	CuO	TiO_2	Fe_2O_3	Al_2O_3	Total	S/R
% weight in the natural soil	53.98	29.50	2.87	0.14	0.06	0.17	0.01	0.01	0.18	2.87	29.50	98.95	1.66

Table 2 shows soil sample is characterized by high amount of silica and appreciable amount of sesquioxides (Al2O3 and Fe2O3) reasonable amount of bases (K2O and CaO). The other chemical element were all lower than 5% in concentrations.

Table 3: The mineralogy of the selected natural soil samples.

Constituents	Quartz (%)	Kaolinite (%)	Dickite (%)	Microcline (%)	Muscovite (%)	Iron sulfate (%)	Sanidine (%)	Illites (%)
% weight.in the natural soil	47	13	-	-	-	-	-	40

Table 4: Chemical composition and physical properties of wood ash, granite dust and dolerite dust.

S/N	Composition	Granite concentration (%)	Dolerite concentration (%)	Wood ash concentration (%)
	Silica (SiO_2)	71.10	42.20	-
	Alumina (Al_2O_3)	14.03	11.60	-
	Potassium oxide (K_2O)	5.11	0.79	10.34
	Soda (Na_2O)	3.21	2.24	-
	Lime (CaO)	1.02	10.54	67.88
	Iron (Fe_2O_3)	3.12	4.55	2.40
	Iron (FeO)	0.21	7.2	
	Magnesia (MgO)	0.38	18.23	-
	Titanium (TiO_2)	0.38	0.001	
	P2O5	0.01	0.02	3.10
	Water (H_2O)	0.03%	2.73	0.001
	SO3	0.09	0.03	1.82
	TiO2	0.44	0.01	0.38
	V2O5	-	-	0.083
	MnO	-	0.001	2.08
	Cr2O3	-	-	0.03
	Ag2O	-	-	1.15
	BaO	0.149	0.01	0.40
	Re2O7	-	-	0.20
	LOI	0.73	0.11	10.34
	ZnO	-	-	0.19
	CuO	-	-	0.07
	ZrO_2	0.15	-	-
	Minor other oxides	0.14	0.01	-
	Specific gravity (g/cm^3)	2.67	2.75	2.81
	pH	4-6	7-9	12–13

Table 4 shows the chemical composition of the granite dust, dolerite dust and the wood ash. The result revealed that wood ash contains more oxide compounds than the granite and dolerite dust. The chemical composition of wood ash differ appreciably because there are numerous factors that controls it specifically like the type and burn methods, the strain of tree, the tree constitutents and the ignition temperature (Campbell 1990; Etiégni and Campbell 1991; Hakkila 1989; Someshwar 1996; Ayininuola and Oyedemi 2013; Misra et al. 1993; Someshwar 1996; Waring and Schlesinger 1985).

a) *Effect of the additives on the geotechnical properties of the soil*

i. *Effect of the additives on the Consistency Limits of the soil*

Table 5 revealed a general reduction in the liquid (LL) and plastic limit (PL) of the soils on the

addition of the wood ash, dolerite and granite dust in their varying proportions.

The addition of 6% additive proportion on the wood ash resulted to a 12% increase in liquid limit and a 12.2% rise in plastic limit. The addition of 18% wood ash also resulted to a 3% rise in liquid limit and a 22.2% increase in plastic limit (Fig. 2). It was revealed that the greater the increase in plastic limit the more the increase in liquid limit and a reduction in the plasticity index by (19%) on addition of 18% proportion of wood ash. The lowest reduction of 9.5% was noticed in the linear shrinkage on addition of 18% proportion of wood ash. These results agree with those of Bhuvaneshwari et al. (2005), Ismaiel (2006) and Okagbue (2007) who improved the performance of expansive soil using fly ash and wood ash. Terzaghi and Peck (1996) and Nalbantoglu and Gucbilmez (2001) explained that the reduction in plasticity of the soil was due to the reduction in the heaviness of the double surface layer of the clay particles; subsequently, from the cation exchange reaction that resulted to an increase in the attraction force that resulted to the flocculation of the particles.

Fig. 3 revealed that the addition of 6% granite dust resulted to 16.1% decrease in liquid limit, 12.6% decrease in plastic limit and also, the addition of 18% granite dust resulted to a 15.6% decrease in liquid limit and a 10.1% decrease in plastic limit .Fig.4 shows the addition of 6% dolerite dust resulted to a 6.1% decrease in liquid limit and a 4.6% decrease in plastic limit. The addition of 18% dolerite dust resulted to a 13.1% decrease in liquid limit and a reduction by 12.40% in plastic limit. It was also observed that 10.9% decrease in plasticity index of the natural soil was achieved on the addition of 24% dolerite dust. The result revealed that it will require tripled quantity of wood ash and double quantity of granite to reduce the plasticity of the natural soil in comparison to that of the dolerite dust.

The difference observed could be as a result of the chemical composition of the additives Table 4 which revealed that the calcium oxide (Cao) content of wood ash which is (71.88%) is higher than that of dolerite dust (14.14%) and granite dust (1.02%).Wong (2015); Ene and Okogbue (2009); Ku -mar and Sharma (2004); Ismaiel (2006) and Ji-ru and Xing (2002) reported a direct proportion between the calcium oxide content of unconventional expansive soil stabilizers to and its immediate stabilizing ability.

Table 5: Effect of the additives on the geotechnical properties of the soil

S/No	Admixture	Consistency Limits				Proctor compaction test		CBR (%)
		LL (%)	PL (%)	LS (%)	PI (%)	MDD (g/ cm^3)	OMC (%)	
	Soil sample only (S)	56.1	35.6	17	20.5	1.52	24	5
	S + 6% W	68	46	15.5	22	1.49	29	12
	S + 12% W	61	50	10.5	11	1.51	23	16
	S + 18% W	61	50	10.5	11	1.52	22	23
	S + 24% W	62	50	10.9	12	1.51	23	30
	S + 6% G	40	23	16	17	1.48	21	17
	S + 12% G	43.0	27	14	16.0	1.46	20	23
	S + 18% G	40.5	25.5	12	14.7	1.97	18	30
	S + 24% G	30.0	25	11	12.8	1.43	18.5	48
	S + 6% D	50	31	15	19	1.50	25	19
	S + 12% D	47	26.4	13	12.7	1.46	26	29
	S + 18% D	43.0	23.2	12	19.8	1.39	20.5	33
	S + 24% D	37.0	27.4	10	9.6	1.49	25.5	35

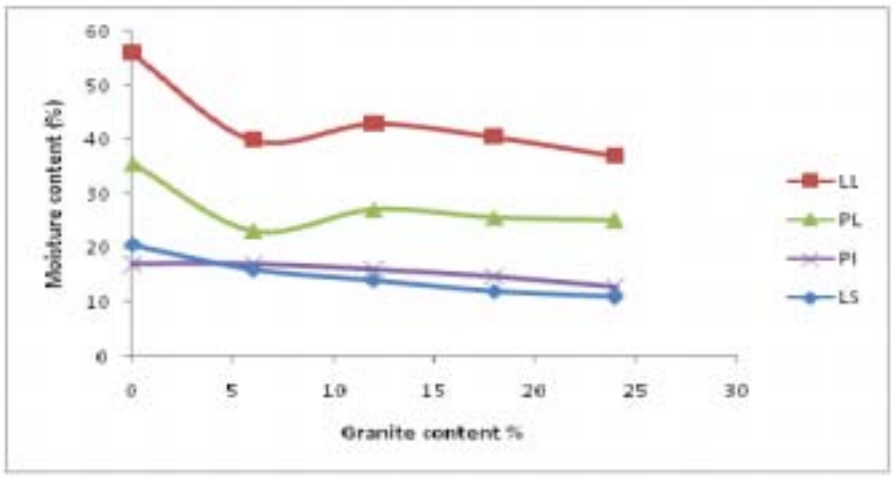

Figure 2: Variation of consistency limit with varying percentages of granite dust.

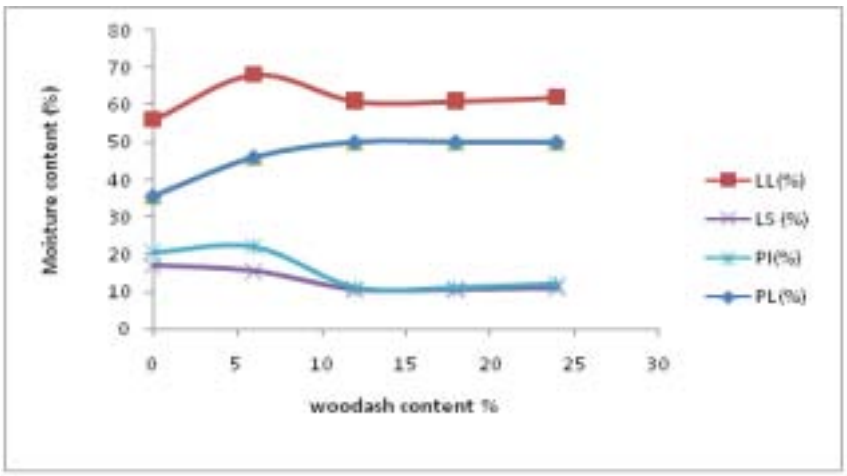

Figure 3: Variation of consistency limit with varying percentages of wood ash.

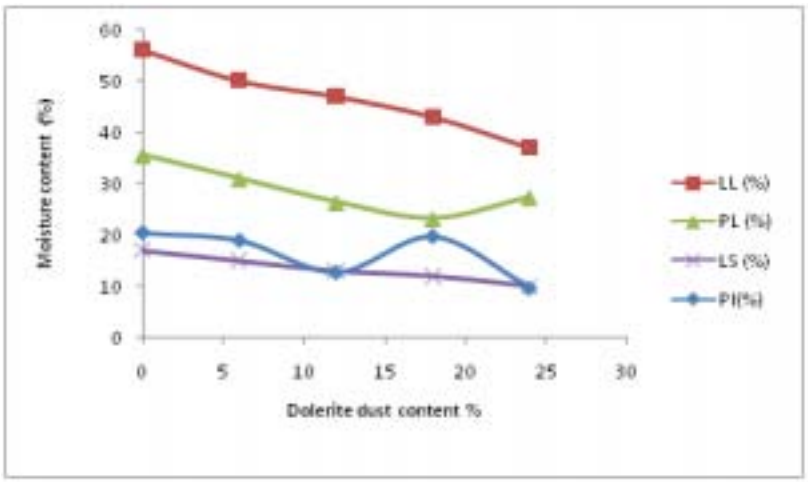

Figure 4: Variation of consistency limit with varying percentages of dolerite dust.

Effect of the Additives on the Compaction Properties of the Soil

The maximum dry density (MDD) and optimum moisture content (OMC) values of the natural soil and samples with varying percentages of additives are presented Table 5. Figs. 5 and 6 revealed that the value of MDD of the natural soil was reduced on addition of 12% of wood ash, granite and dolerite dust. However, there was an increase on the addition 18% proportion of granite dust. This increment continued on for the 24% additive of dolerite dust. However, it decreased when the same percentage of granite dust was added. The decrease and subsequent increase in the value of the MDD on the addition of wood ash, granite and dolerite dust additives was also reported by Okagbue and Yakubu (2000) to have been as a result of flocculation and agglomeration of the clay particles. This is as a result of the chemical reaction between lime and clay minerals. The flocculated particles caused an increase in the void ratio of the admixture; hence, a reduction in the MDD.Furthermore, the MDD is affected by the chemical reaction between lime and clay minerals (Kezdi 1979), the fluctuating phenomenon notice on the addition of granite dust could be as a result of variation in the mineralogical composition of the natural soil. Comparing the three additives, the highest was achieved on the addition of 18% granite dust compared to the 1.49g/cm^3 that was achieved on the addition of 24% dolerite dust.

Similarly, Fig. 6 revealed that there was a gradual decrease in the OMC of the natural soil on the addition of varying additives proportions up till to 18%. However, on the addition of 12% additives, the OMC of the wood ash, the granite dust soil gradually increased and that of the dolerite dust sharply increased. Furthermore, this behavior could be as a result of reaction between the lime and clay minerals. At a lower content of additives, the lime-clay reaction could not be initiated. Thus, at this point the grain size distribution of the clay soil changes to a coarser configuration of silty to sandy soil and hence, a decrease in OMC (Drnevich et al; 2009).In addition, as the percentage of additives increases, the reaction between lime and clay is initiated This process of cation exchange which is exothermic reaction usually result to drying of soil, it makes more water to be required for subsequent reaction which is dissociation of calcium hydroxide into Ca^{2}and OH ions resulting to an increase in OMC (Okagbue and Yakubu 2000; National lime association 2004). However, the lowest reduction in OMC was reached on the addition of 18% additives.

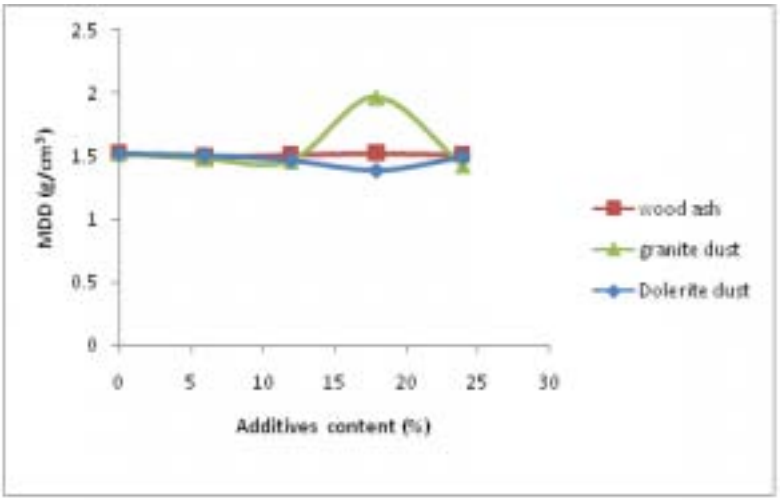

Figure 5: Variation of maximum dry density with varying percentages of additives.

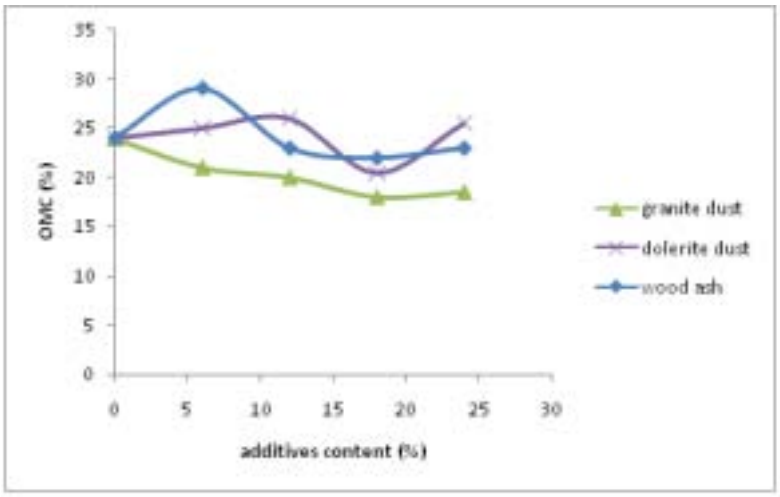

Figure 6: Variation of optimum moisture content with varying percentages of additives.

Effect of the Additives on the California Bearing Ration (CBR) Properties of the Soil

Table .5 shows the result of the California bearing ration (CBR) test conducted on the natural soil with varying proportions of additives. It was revealed that there is a steady increase in CBR values with increasing percentages of the wood ash, granite and dolerite dust in the modified soil Fig.7. Moreover, the addition of the 18% dolerite dust resulted to a steady decrease in the CBR value and a steady increase in wood ash and granite dust proportion. Various authors have reported the reasons for this increase. Croft (1967) stated that the growth and the thickening of the gelatinous reaction products and inter-growth of crystalline, hydrous calcium silicates and aluminates are responsible for cementation in clay-soils stabilized with cement, lime and lime-fly ash. Thompson (1965) reported that the increase in CBR was as a result of cation exchange and agglomeration reactions that occur on the addition of additives to the clay soil. Ene and Okogbue (2009) also attributed it to the formation of bonds of calcium alumina hydrate and silicate hydrate on the addition of additives to the clay soils.

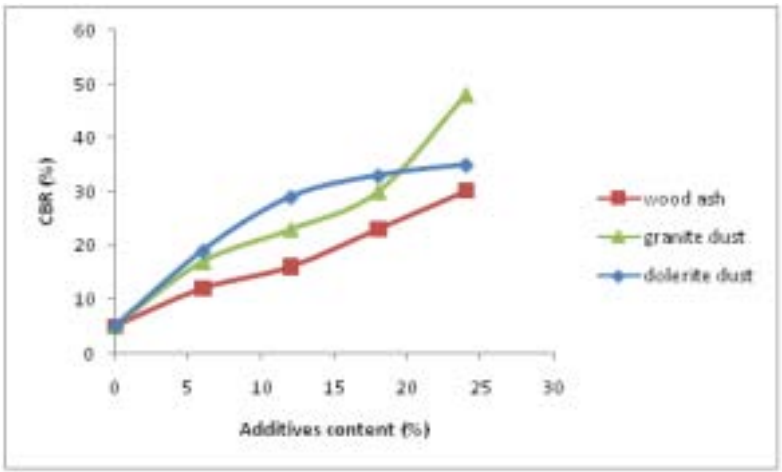

Figure 7: Variation of CBR with varying percentages of additives

Effect of the additives on the unconfined compressive strength (UCS) of the soil

Tables 6-8 and Figs. 8, 9 and 10 show the results of the effect of the additives on the UCS on the stabilized soil. It was deduced that 24% granite dust proportion gave the highest unconfined compressive strength of 398.56 KN/m^2 at 28 days curing time. This satisfies the condition for very stiff consistency soil available for use as a subbase and base course material (Nigeria General Specification 1997; Gopal and Rao 2011). The (6%) wood ash proportion which is the lowest percentage of admixture gave the lowest UCS value of 100.05 KN/m^2 . This satisfies the condition of stiff consistency for use as a sub grade based on (NGS/FMWH 1997; Gopal and Rao 2011). The increase in strength attained is attributed to the spherical

agglomeration of particles in the presence of the highly pozzolanic granite dust, dolerite dust and wood ash. In addition, the presence of the admixtures in the soil increased the frictional angle of the stabilized mixture. This is connected to the physicochemical, pozzolanic attributes of the admixtures and also to its potential to lessen adsorbed water. This process make soils with higher clay content to act like granular soil.

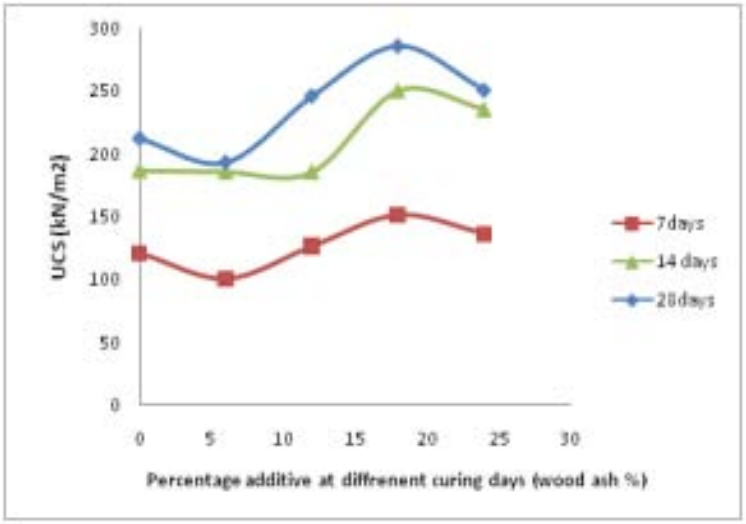

Figure 8: Variation of UCS with varying percentages of additives for wood ash.

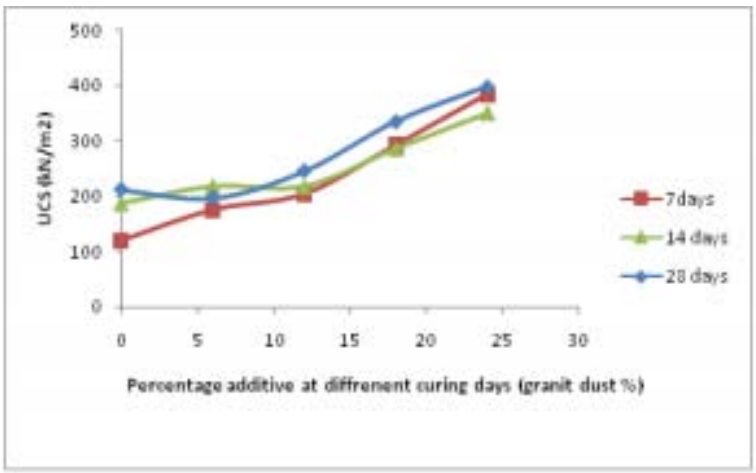

Figure 9: Variation of UCS with varying percentages of additives for granite dust

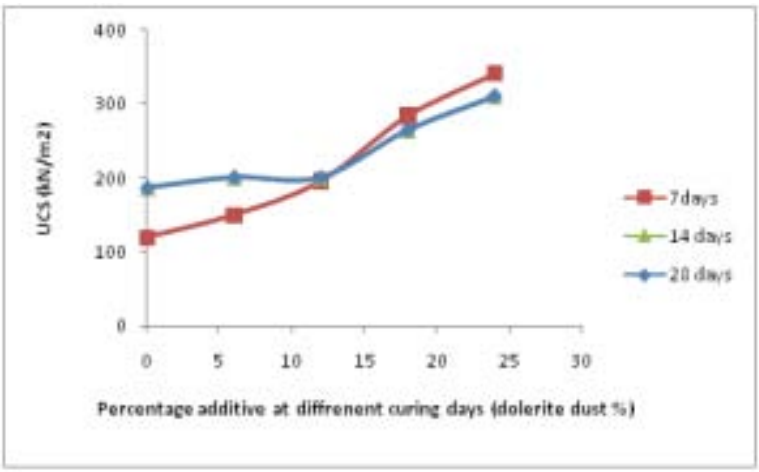

Figure 10: Variation of UCS with varying percentages of additives for dolerite dust.

Table 6: Effect of wood ash on UCS of the soil.

Wood ash Proportion (%)	0	6	12	18	24
At 7 days (kN/m^2)	120.26	100.05	125.89	150.67	135.75
At 14 days (kN/m^2)	186.11	185.01	185.01	250.44	235.45
At 28 days (kN/m^2)	211.77	192.76	245.61	285.45	250.26

Table 7: Effect of granite dust on UCS of the soil.

Proportion (%)	0	6	12	18	24
At 7 days (kN/m^2)	120.26	175.32	203.89	292.07	383.45
At 14 days (kN/m^2)	186.11	217.03	217.03	285.94	350.04
At 28 days (kN/m^2)	211.77	196.97	245.61	335.26	398.56

Table 8: Effect of dolerite dust on UCS of the soil.

Proportion (%)	0	6	12	18	24
At 7 days (kN/m^2)	120.26	150.45	195.85	284.01	340.90
At 14 days (kN/m^2)	186.11	200.34	200.05	264.34	310.05
At 28 days (kN/m^2)	211.77	194.65	225.75	299.49	375.47

Comparison of the geotechnical properties of unstabilized soil and stabilized soils with the Nigerian Standards to determine their suitable for different type of structure

The geotechnical properties of wood ash, granite dust and dolerite admixtures and the natural soil were compared to the Nigerian standards and presented in Tables 9, 10 and 11. Analyses of the wood ash, granite dust and dolerite dust to the natural soil mixtures at varying percentages with reference to the Nigerian standards revealed that the wood ash, granite dust and dolerite dust were potentially effective stabilizing agents for the studied expansive soil. Generally, the natural soils stabilized with 18% and 24% of the granite dust, wood ash and dolerite dust additives proportion measured up to the Nigerian standard for use as materials in general filling, embankment and sub base. However, 24% granite dust additive proportion met the recommended standard stipulated for base materials for road construction in the study area. Wood ash and dolerite at their varying proportions of soil admixture fell short of the Nigerian standard for road as base course materials. It was concluded form this investigation on the stabilization of the natural soil with wood ash, granite dust and dolerite dust that the pozzolanic effect of the soil differ in strength slightly for both categories of additives. The 18% and 24% granite dust met the required standard the base material other additives in varying proportions may be appropriate for other engineering use.

Table 9: Geotechnical properties of the unstabilized soil and granite dust –stabilized soil compared with the Nigeria standards.

Possible use of soil (engineering construction)	Geotechnical Properties of soil	Nigerian specification	Unstabilized soil (0% granite dust)	6% granite dust	12% granite dust	18% granite dust	24% granite dust
General filling and embankment	MDD (g/m$^{3)}$	>0.04	1.52	1.48	1.46	1.97	1.43
	OMC (%)	<18	24	21	20	18	18.5
	Liquid limit (%)	<40	56.1	40	43.0	40.5	37.0
	Plasticity index	<20	20.5	17	16.0	14.7	12.8
Sub-base course	Liquid limit (%)	<35	56.1	40	43.0	40.5	34.0
	Plasticity index	<16	20.5	17	16.0	14.7	12.8
	Unsoaked CBR at OMC	≤25	5	17	23	30	48
Base course	Liquid limit (%)	≤30	56.1	40	43.0	40.5	30.0
	Plasticity index	≤13	20.5	17	16.0	14.7	12.8
	Unsoaked CBR at OMC	≤80	5	17	23	30	48

Table 10: Geotechnical properties of the unstabilized soil and wood ash –stabilized soil compared with the Nigeria standards

Possible use of soil (engineering construction)	Geotechnical properties of soil	Nigerian specification	Unstabilized soil (0% wood ash)	6% woodash	12%wood ash	18% wood ash	24% wood ash
General filling and embankment	MDD (g/m$^{3)}$	>0.04	1.52	1.49	1.51	1.52	1.51
	OMC (%)	<18	24	29	23	22	23
	Liquid limit (%)	<40	56.1	68	61	61	62
	Plasticity index	<20	20.5	22	11	11	12
Sub-base course	Liquid limit (%)	<35	56.1	68	61	61	62

	Plasticity index	<16	20.5	22	11	11	12
	Unsoaked CBR at OMC	≤25	5	12	16	23	30
Base course	Liquid limit (%)	≤30	56.1	68	61	61	62
	Plasticity index	≤13	20.5	22	11	11	12
	Unsoaked CBR at OMC	≤80	5	12	16	23	30

Table 11: Geotechnical properties of the unstabilized soil and dolerite dust –stabilized soil compared with the Nigeria standards

Possible use of soil (engineering construction)	Geotechnical properties of soil	Nigerian specification	Unstabilized soil (0% dolerite dust)	6% dolerite dust	12% dolerite dust	18% dolerite dust	24% dolerite dust
General filling and embankment	MDD (g/m$^{3)}$	>0.04	1.52	1.50	1.46	1.39	1.49
	OMC (%)	<18	24	25	26	20.5	25.5
	Liquid limit (%)	<40	56.1	50	47	43.0	37.0
	Plasticity index	<20	20.5	19	12.7	19.8	9.6
Sub-base course	Liquid limit (%)	<35	56.1	50	47	43.0	37.0
	Plasticity index	<16	20.5	19	12.7	19.8	9.6
	Unsoaked CBR at OMC	≤25	5	19	29	33	35
Base course	Liquid limit (%)	≤30	56.1	50	47	43.0	37.0
	Plasticity index	≤13	20.5	19	12.7	19.8	9.6
	Unsoaked CBR at OMC	≤80	5	19	29	33	35

IV. Conclusion

It can be concluded from the investigations that the natural soil was not suitable for as sub-grade material because it recorded a MDD 1.54 g/cm^3. However, the addition of the right proportions of the additives resulted to an increase in the soil strength. It was revealed also that the addition of wood ash, granite dust, and dolerite dust with the studied soil in their varying proportions resulted to a reduction in the LL, PI and LS of the soil. This is attributed to the calcium oxide content in the wood ash that was not readily available nor sufficient enough for pozzolanic reaction to take place immediate but for a period of at least seven days before notable strength can be achieved in the soil. Furthermore, at the addition of 24% by weight of granite dust, the UCS acquired sufficient strength to meet the requirements for sub-base and base course. However, granite dust, dolerite dust and wood ash which is cheap and readily available and often considered as a waste material can be utilized as stabilizing material for problematic soils. This will lessen the cost of carrying out engineering constructions on expansive soils and also minimize the environmental problems linked with their indiscriminate disposal. Finally, the usage of these additives has proven beyond doubts that it has potentials for use as stabilizers in road construction. The use of the additives at their varying proportions was seen to enhance the engineering properties of the problematic soil.

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Author's contribution

Ubido Oyem Emmanuel carried out the field and Laboratory work drafted the manuscript. Igwe Ogbonnaya and Ukah Bernadette Uche: Conceived the study participated in its design, coordination and gave academic guidance.

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Preferred Author Guidelines

We accept the manuscript submissions in any standard (generic) format.

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

Alternatively, you can download our basic template from https://globaljournals.org/Template.zip

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3. Ensure corresponding author's email address and postal address are accurate and reachable.
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The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

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Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

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Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

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It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

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Tips for Writing a Good Quality Science Frontier Research Paper

Techniques for writing a good quality Science Frontier Research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of science frontier then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
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Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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