

Stratigraphy of the MSGBC Basin in the Western Part of Thies by Pixelation and Website Simulation (Senegal, West Africa)

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Abstract

During this research work we developed another approach to digital mapping using the pixelation technic. This unprecedented digital mapping of the basin MSGBC in Senegal required the compilation of numerous geological data consisting of seismic lines and oil and hydraulic log reports. These spatial reference data include geological information from the surface to the top of the Campanian. The mapped terrains are composed of the Post-Paleocene Complex (PPC), the Paleocene, the Maastrichtian, and the Campanian. The nearest neighbor method has been used to establish the spatial distribution of the different geological formations. Histograms of values were used to determine the confidence intervals of the mapping. They were used to locate areas of low relative error and to apply the 3D digital mapping technique. For instance, Diender Guedj has been mapped at 1:25,000. The result of this mapping is extracted and processed using the DBMS (MySQL) software. The latter allowed both to determine Paleocene gap and update data. And then the database is processed. The programming languages PHP and Javascript have been used to simulate a website.

Keywords

MSGBC, Digital Mapping, Pixelation, Website Simulation

1. Introduction

Because of its geographical position, Senegal is the West-most country in Western Africa with economic activities focused mainly on agriculture, fishing, tourism, road infrastructure, mining... Within the framework of management re-

source and territory that the National Geomatics Plan was implemented in Senegal in August 2008 following a memorandum of understanding signed with Canada. This National Geomatics Plan is based on the Senegal Spatial Reference System (SSRS) [1] and [2]. However, this reference only takes the elements of the surface into account. Whereas the Senegalese subsoil is full of mining and energy resources whose knowledge would allow sustainable development.

For the geologist, trying to reconstruct the subsoil was often difficult and risky. This often caused many problems like preventing natural risk in the field when carrying out engineering works in spite of capital invested in research [3].

That's the reason knowledge of the subsoil is a major challenge for all countries. In France, after the launch of a geological mapping program, a geological repository will be established to provide 3D geological information in a homogeneous and coherent digital format for the whole country. This is a 30-year challenge representing an investment of 300 million euros [4].

In our study area, knowledge of geology can be part of the geodynamic context of the Mauritania-Senegal-Gambia-Bissau-Conakry (MSGBC) sedimentary basin. It is an area where the subsoil consists mainly of sedimentary layers. Their lithological characteristics make them natural resources that are often exploited by quarries and chemical industries. In order to manage the resources in a sustainable way, it is important to map the subsoil. We will focus on the Campanian, Maastrichtian, Paleocene and most recent Quaternary layers. However, we have put together the layers from the Eocene to the Quaternary under a Post-Paleocene Complex (PPC) for practical reasons related to the lack of spatial data on each of them and the complexity of their geometry [5]. The mapping of the PPC is of great importance because it allows us to determine the thickness of the surface cover of the Paleocene, Maastrichtian and Campanian whose mineral and water resources are important.

The digital mapping or vectorization that we have developed during this work will allow at any point in our study area to have log stratigraphic from the surface to the top of the Campanian. This will show us a three-dimensional evolution of the MSGBC basin in our study area. After processing, our digital mapping technique will allow us to directly see not only the spatial distribution of the different geological layers, but also the points of sedimentation gaps or erosion. Within the framework of our study, these points of gap concern the Paleocene. The latter is transgressive and unconformity on the Maastrichtian.

Digital mapping is a multidisciplinary application. It is an essential tool for decision making in many projects using 3D technology. In addition to conceptual and technical approaches, knowledge of geology is needed to provide the basis for the development of spatial models [6].

It was noted that access to databases is often not easy. We thought to construct a website for the result of the digital mapping. The purpose of this website will be to facilitate access and the display of stratigraphic information for a given point in our study area. In this step of think about, we go to simulate a website in order to appreciate the accessibility of the results.

2. Geological Settings

The research carried out on the basin has contributed a lot to its knowledge. The Campanian outcrops in the quarries of Paki and Cap de Naze in the south of Horst de Diass [7] [8] and [9]. These outcrops are reported at the Paki Formation [10]. In the west of the Horst de Diass, the Campanian is in the form of thick clay deposits with sandstone interlayers rich in planktonic and benthic foraminifera and ostracods [11] [12] and [13]. The terminal Campanian is known at the outcrop and corresponds to Unit I of the Cap de Naze cliff which belongs to the Paki Formation. It includes a succession of clays, siltites and limestone arenites at the top [14]. In most of the basin, the Maastrichtian consists of sandy clay with sandy foraminifera and often unidentifiable ostracods [15]. In the west of Diass, the sands change into sandy-clayey facies in Diamniadio and then into clays at Lake Retba where their thickness increases considerably to 2000 m [16]. This thickening is explained by the set of syn-sedimentary cracks at the edge of the horst. The bedrock of Maastrichtian is often difficult to fix in the absence of characteristic microfauna, although it is considered transgressive on the Campanian [11]. In the Lower Maastrichtian, the sands are predominant in the centre and east of the basin with intercalations of lignite and conglomeratic past. The Maastrichtian is 100 m thick in Dakar and thickens in the Rufisque graben, notably at Lake Retba where it reaches nearly 2000 m. This thickness is reduced in the Horst de Diass and gradually passes to the East to lignite sands which constitute the top of the “aquifer sands of Senegal” [12]. [17] fixed the top of the Maastrichtian in the Thiès region at the presence of a level of glauconious fossiliferous to clay past limestone.

The bedrock of the Paleocene is locally marked by a discordant class-support conglomerate on the Maastrichtian. In the Thiès region, its top corresponds to the lower Eocene gully unconformity on karstified shell limestone. The limestone dominated Paleocene has two transgressive sequences in the region, all now gathered in the Cabo Verde Group [18]. It is essentially limestone and was mostly deposited during the Dano-Montian period. The Thanetian limestone in the FP12 survey at Mont-Rolland is white, yellowish or grey, rich in shell debris. The top contains marly past with rare echinid debris and a rich microfauna. At the base, the limestone is marly and sandstone, the microfauna poorly preserved [19], and the Maastrichtian and Paleocene are outcropping to sub-sharp in the western part of the Thiès region [5] and [20].

3. Methods

The database used for digital mapping derives not only from the compilation, processing, and interpretation of seismic sections but also from the exploitation of oil or hydraulic drilling reports and geological maps of the area. **Figure 1** shows our study area in the senegalese sedimentary basin, more precisely at the western end of the Thiès region. In this figure we also have the spatial distribution of the database in our study area.

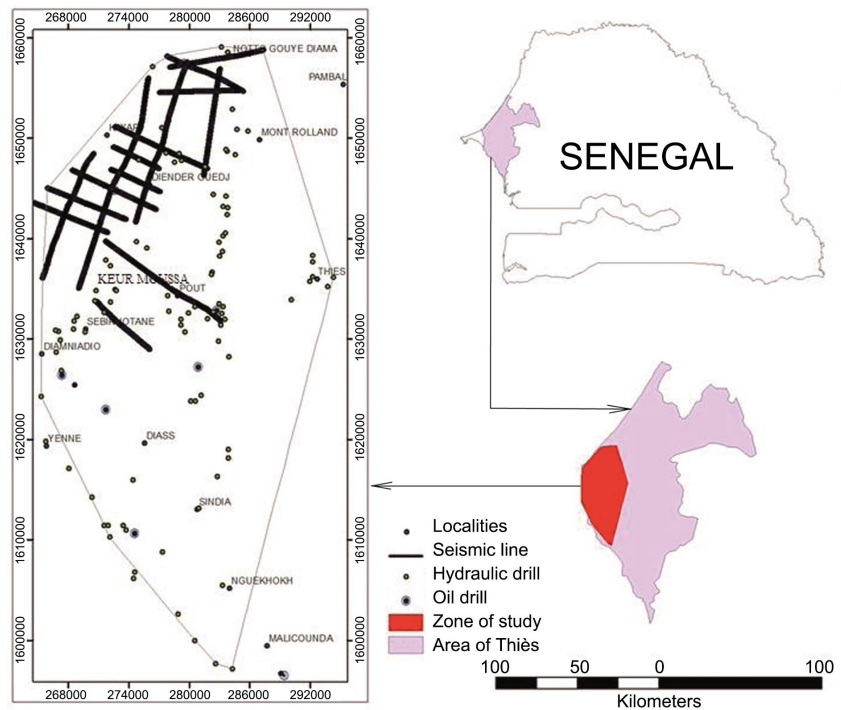


Figure 1. Location of the study area and database.

Deep time conversion at the seismic section level is made possible by these seismic cores. It is therefore possible to determine the average velocity of the wave (V) and knowing the time (t), we can calculate the depth (P) of the top or base of the stratum considered.

All seismic data is exported and organized into tables. In addition to these seismic data, those from the exploitation of hydraulic drilling reports made it possible to list all the engineering works carried out in the study area which crosses the various geological strata.

Seismic profiles, oil drilling, and hydraulic drilling are grouped around the same *WGS 1984* spatial datum and each element of the database presents the attributes of position X (longitude in meter), Y (latitude in meter), and Z the depth of the top or base of the geological layer. For convenience reasons, we have worked with *Universal Transverse Mercator (UTM) Zone 28 North* coordinate system.

This database allows us to carry out first the digital mapping of isobaths which then is brought back to the topographic level. This shows the three-dimensional evolution of the subsoil.

3.1. Digitization

Once the database has been established, the first phase of the mapping method consists of transforming the data into a vector structure. This transformation takes place in several steps:

- The interpolation: Following tests on different interpolation methods, it appears that the nearest neighbor approach with a 20 m meshing meets our ex-

pectations the best because of the spatial configuration of the data. The result is the digital mapping of the isobaths of the tops of the PPC, the Paleocene, the Maastrichtian and the Campanian;

- Extraction of pixel values from isobaths: the *extract values to table* tool of the *Geostatistical Analyst Tools* module made it possible to extract X, Y and Z values after spatial modeling and to organize them in table form;
- A relationship is determined between the shapefile and the table resulting from the interpolation by a joining technique between the different primary key fields: These different steps are carried out on the top and base of each geological layer. The second phase consists of placing the different geological layers in the topographical context of the area. The aim is to establish the stratigraphy for any point of altitude Z, from the most superficial layers of the PPC to the deep layers of the Campanian.

To do this, relationship is established between the DEM and extracting values from the digital map of the different layers. This relationship has allowed us to perform subtraction operations between the negative depths and the topographic level of the DEM. Thereafter, all the geological layers are superimposed and the product called stratigraphic block allows a better representation in perspective of the different geological layers. This stratigraphic block is defined to facilitate spatial analysis of strata and minimize handling errors if strata were analyzed individually.

3.2. Pixelation

Pixelation is carried out on the stratigraphic block. It is a mapping technique that compiles the geology of the stratigraphic block into a matrix [5]. The matrix can be likened to a window divided into several cells or pixels. Each point or pixel on the matrix will have its stratigraphic succession. The pixelation technique can be regarded as a fishing net where the size of the meshes (cells) can be adjusted according to a fixed aim. It can be divided into three steps:

- The first step is to define the pixelation matrix. With *ArcMap* 10, we have loaded all the layers involved in the stratigraphic block. We defined the map scale and pixelation cell size using *fishnet* tool, and then save the pixelation matrix as a *shapefile*;
- At the second step, with the *Zonal statistics as table* tool, we have loaded the Z values of the different rasters of the geological layers into the shapefile;
- The last step allows to establish correspondences between the different data extracted from the rasters and the geolocalized cells of the pixelation matrix through a joining technique.

Thus, pixelation makes it possible to group all stratigraphic information in a single file.

We have established the spatial distribution of the top for each geological layer. The advantage of this choice is that if we consider the superposition of the geological layers forming the subsoil in our study area. Any spatial processing of

the top also means processing the wall of the overlying layer. It is important to highlight that in any spatial modelling, quite often, there are errors or residues. These so-called relative errors raise questions in most cases about the degree of validity of geo-reference data modelling.

3.3. Determination of Relative Errors

ArcMap 10 includes *Geostatistical analyst tool* which allowed us to determine the spatial distribution of the relative errors. Also, we have used *Statistica 8.0 software* to carry out all the statistics analyses. Following an irregular database distribution, kriging variance is the method in geoscience and digital analysis to estimate values and determine relative errors in non-sampled areas [21] [22] [23] and [24]. The kriging variance does not depend on the value of the data but only on the covariance and sampling scheme [21] [25] and [26]. **Figure 2** represent the flow diagram of our cartographic technique from pixelation to website simulation.

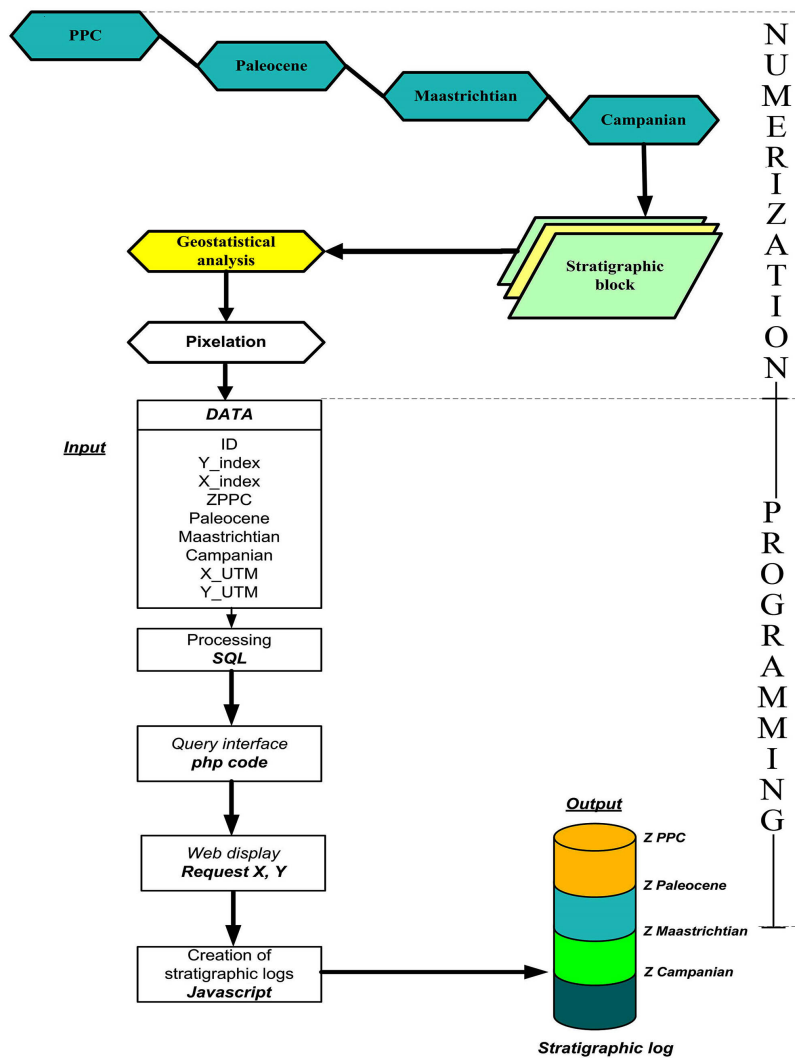


Figure 2. Flow diagram from pixelation to website construction.

3.4. Data Management and Website Simulation

The importance of the mapping result in the fields of engineering and research leads us not to limit ourselves to the use of spatial analysis software for their exploitation, but to put them online for simple and free access. In addition, with data processing and web programming, we can correct some limitations of spatial interpolation methods, namely the location of areas with sedimentation or erosion gaps. For this reason, we require the processing of the database resulting from digital mapping before putting it online.

To manage the data obtained from pixelization, we used MySQL. It is a free relational database management system, based on the SQL language (Structured Query Language). MySQL is very flexible. It can run on almost any operating system and any type of hardware [27].

The PHP language (Hypertext Preprocessor) was created in 1994 by Rasmus Lerdorf. It is a programming language, very close to the C language, intended to be integrated into HTML pages. It is mainly intended for the production of dynamically generated HTML pages [28].

To begin the simulation of website we coded results mapping under a file named *index.php*. It is through this file that the connexion with the server is set up. The result of the digital pixel mapping will be displayed on the web for any geolocalized point (X and Y Cartesian coordinates). Our web page interface is created using an open-source program rehabilitation. It is called ZingChart and includes HTML, JavaScript, CSS, bootstrap twitter... JavaScript is a developed programming script that can be included in HTML or PHP pages for the most common web browsers. With this kind of script, interactive pages can be written. JavaScript allows some control over interactions that would be too cumbersome to ask a server [27]. The AJAX technology package (Asynchronous JavaScript and XML) and the asynchronous requests it introduces have reinforced the dynamism of websites, by specifically updating content elements without refreshing entire pages [29].

4. Results and Discussion

4.1. Numerical Geological Layer

All the geological layers were modelled using the nearest neighbour method with a mesh size of 20 m. After an initial phase of interpolation, we observed shifts particularly at the intersections of the seismic lines. To correct this, iteratively, we repositioned the lines at the same level, using the seismic line that shows the maximum compliance with oil drilling as a reference. The results of the digitization of the tops of the PPC, Paleocene, Maastrichtian and Campanian are shown in **Figures 3-6** respectively.

To determine the top of the PPC, we used a database of contour lines and dimensioned points. So, we used topographic maps of (Dakar and Thiès 1: 200,000) as a support. With *ArcMap* 10.0 software, contour lines and elevation points were digitized.

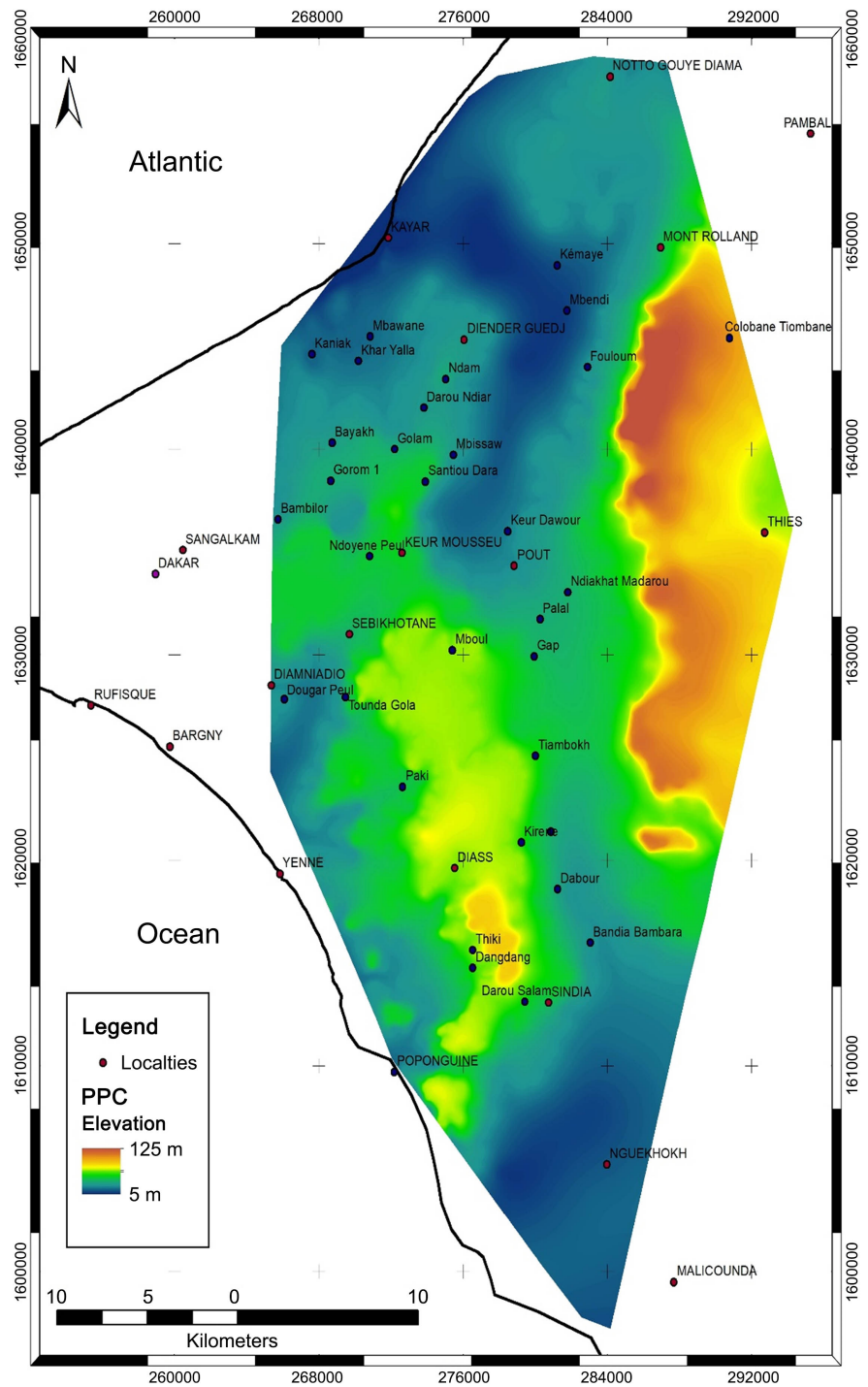


Figure 3. Spatial distribution of the Post-Paleocene Complex top.

Once this part is completed, the contour lines and dimensioned points are saved in vector format. The latter is used for modelling the surface part of the PPC (DEM). On the DEM, we notice the presence of two large structures that are the cliff of Thiès and the Horst de Diass. It is at these levels that we record the highest altitudes. By stratigraphic correlation, it is also in these areas that the coverage on the Paleocene is also important. The cartographic analysis clearly

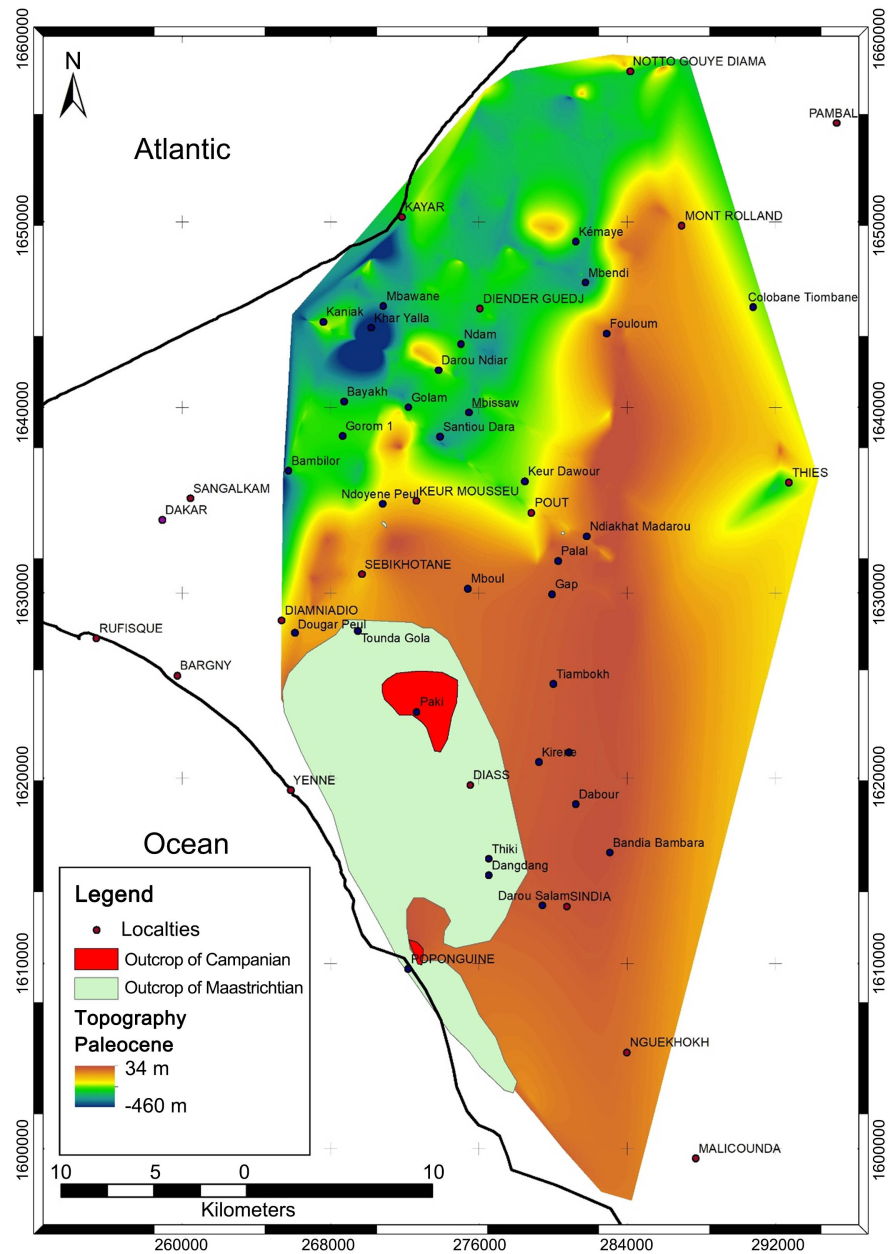


Figure 4. Topographic evolution of the Paleocene top.

shows areas of depression surrounding the Thiès cliff and the Horst de DIASS. This depression is maximum between Kaniak—Mbawane—Kémaye—Mbendi—Fouloum—Keur Dawour—Mbissaw—Diender Guedj—Kayar. This can be explained by the fact that these localities surround Lake Mbawane and the area is also under the influence of the Kayar Canyon, which causes the inflection marked by the shoreline at Kayar [30]. The pit has an average depth of 3300 m and a maximum width of 9 km [31]. It passes to the North-West and the West of Kayar, and is then diverted to the South under the influence of the volcanic platform of the Cabo Verde Islands. Around 3600 m of the pit is transformed into a series of channels which lead to the Gambia’s abyssal plain [32].

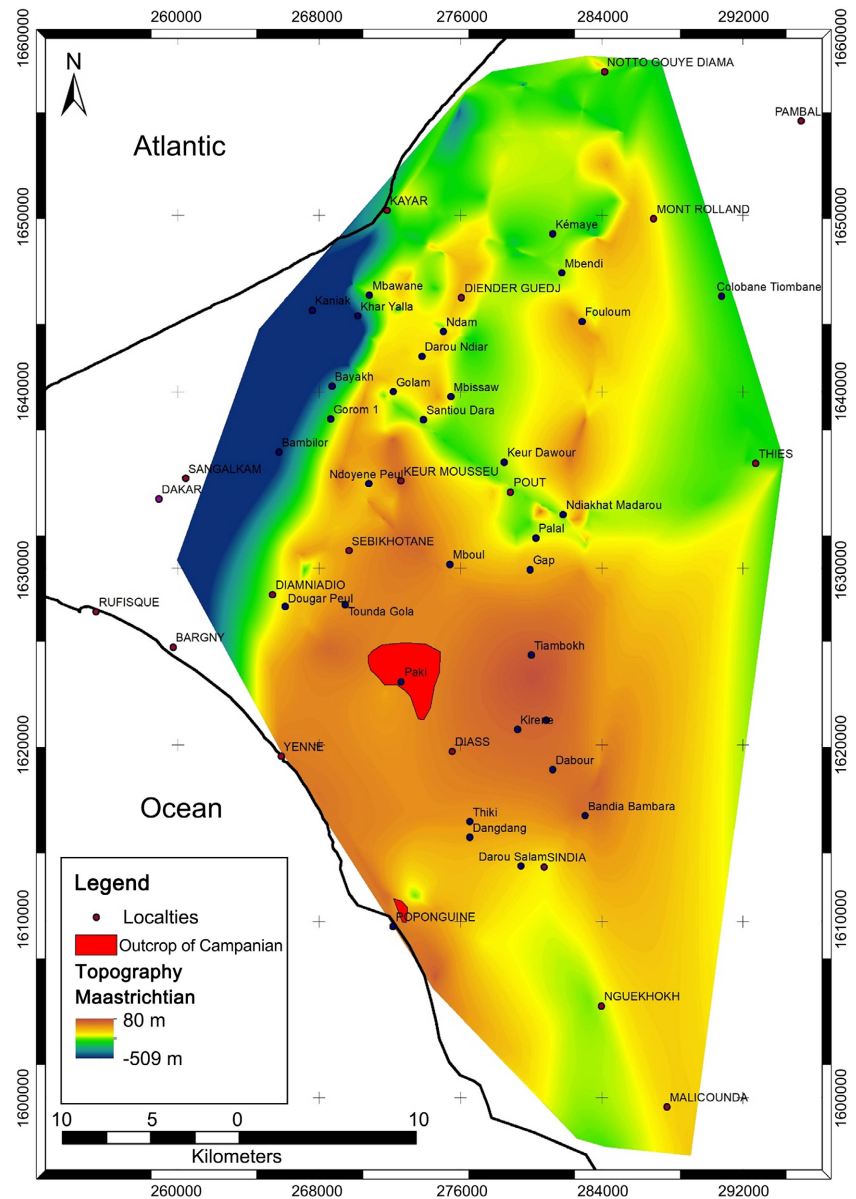


Figure 5. Topographic evolution of the Maastrichtian top.

The terrain being modelled, our digital cartography will have altitudes between 0 and 125 m from the surface. Therefore, the depths of the Campanian, Maastrichtian and Paleocene will be reported at the topographic level to determine the morphology of the sedimentary basin in our study area from the surface to the top of the Post-Paleocene Complex. The Paleocene series with a topographic level of +34 m to -460 m is transgressive and discordant on the Maastrichtian. This geological phenomenon has meant that the Maastrichtian cover is partially weak and that the Paleocene is locally showing sedimentation or erosion gaps. The evolution of the Maastrichtian top from +80 m to -509 m makes this floor a largely important Campanian top. This Campanian with a topography between +56 m and -2110 m indicates the subsidence of the MSGBC basin in the West-side of Thies.

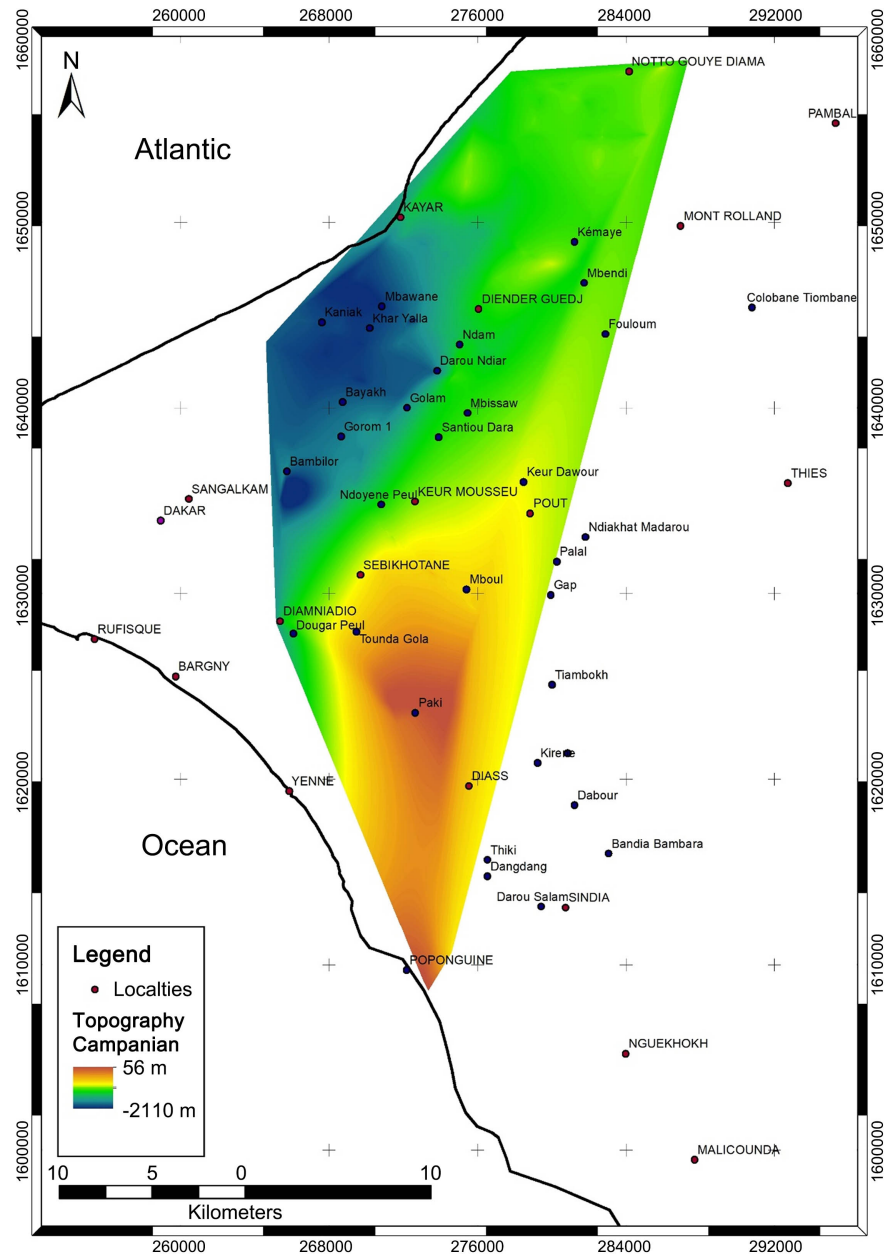


Figure 6. Topographic evolution of the Campanian top.

4.2. Relative Errors

All the geological layers are wedged in relation to the PPC and in a purpose to develop a correct 3D geological pattern. The comparison both observed altitudes and measured altitudes shown that our choice of interpolation by using nearest neighbour is correct (see Figure 7). The value histograms describe a heterogeneity of the different altitudes as confirmed on the different maps. The most important altitudes are in the range 100 and 140 m. There are the altitudes at the cliff of Thies and the Diass horst. The negative altitudes are located at the level of the depression left by Lake Tamna north of the study area. The mean altitude in our area is 37.73 m.

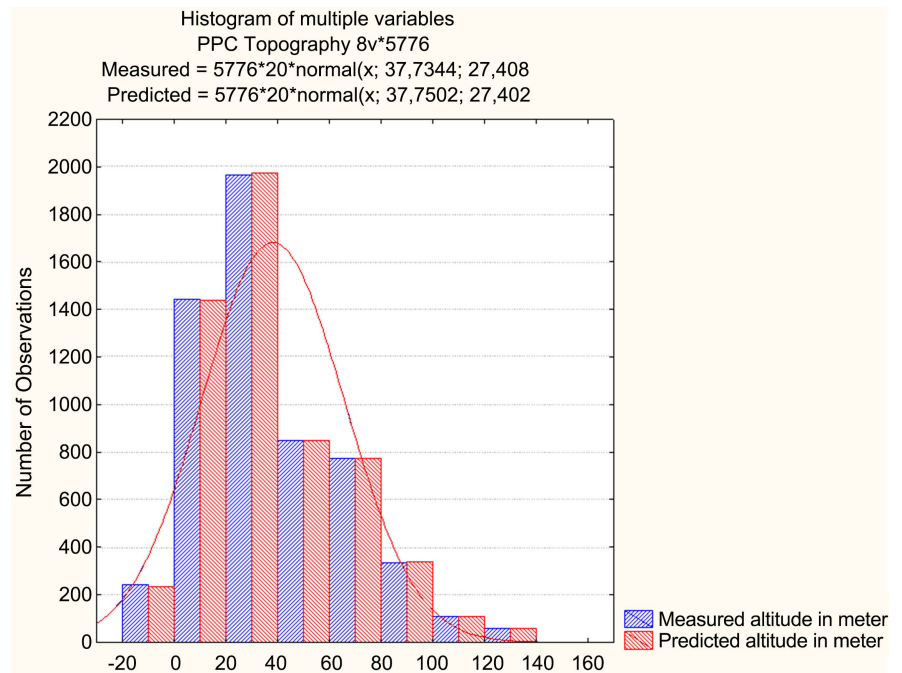


Figure 7. Comparison measured altitude vs predicted altitude.

That is confirmed by values of the means (x) and standard deviation (σ) which showed weak differences:

- Measured altitude: $x = 37.7344$ m, $\sigma = 27.408$
- Predicted altitude: $x = 37.7502$ m, $\sigma = 27.402$

We also can tell that the nearest neighbor interpolation didn't extrapolate beyond geological phenomena.

The results of the analysis are grouped respectively in **Figure 8** and **Figure 9** for the distribution of the relative errors of PPC, Paleocene, Maastrichtian and Campanian as well as their corresponding histograms.

4.2.1. Post-Paleocene Complex Analysis

For the PPC with $N = 5776$, the minimum relative error is -25 m and the maximum relative error is 24 m. By considering different intervals on corresponding histograms, we obtain the following relative errors:

- 22% of the sample, for an error of ± 2 m,
- 25% of the sample, for an error of ± 4 m,
- 29% of the sample, for an error of ± 6 m,
- 14% of the sample, for an error of ± 8 m,
- 10% of the sample for an error of ± 10 m.

In order to better define and facilitate the analysis of the residue map, an error classification was performed. We found that 76% of the sample covers the error interval $[-6$ m; $+6$ m]. This error interval covers more than 75% of the interpolated area. In the North of the corridor Sébikotane—Keur Moussa—Pout where the density of the database is high, we note a constancy in the spatial distribution of these small errors.

4.2.2. Paleocene Analysis

The residue map and relative error distribution of the Paleocene (N = 12,652)

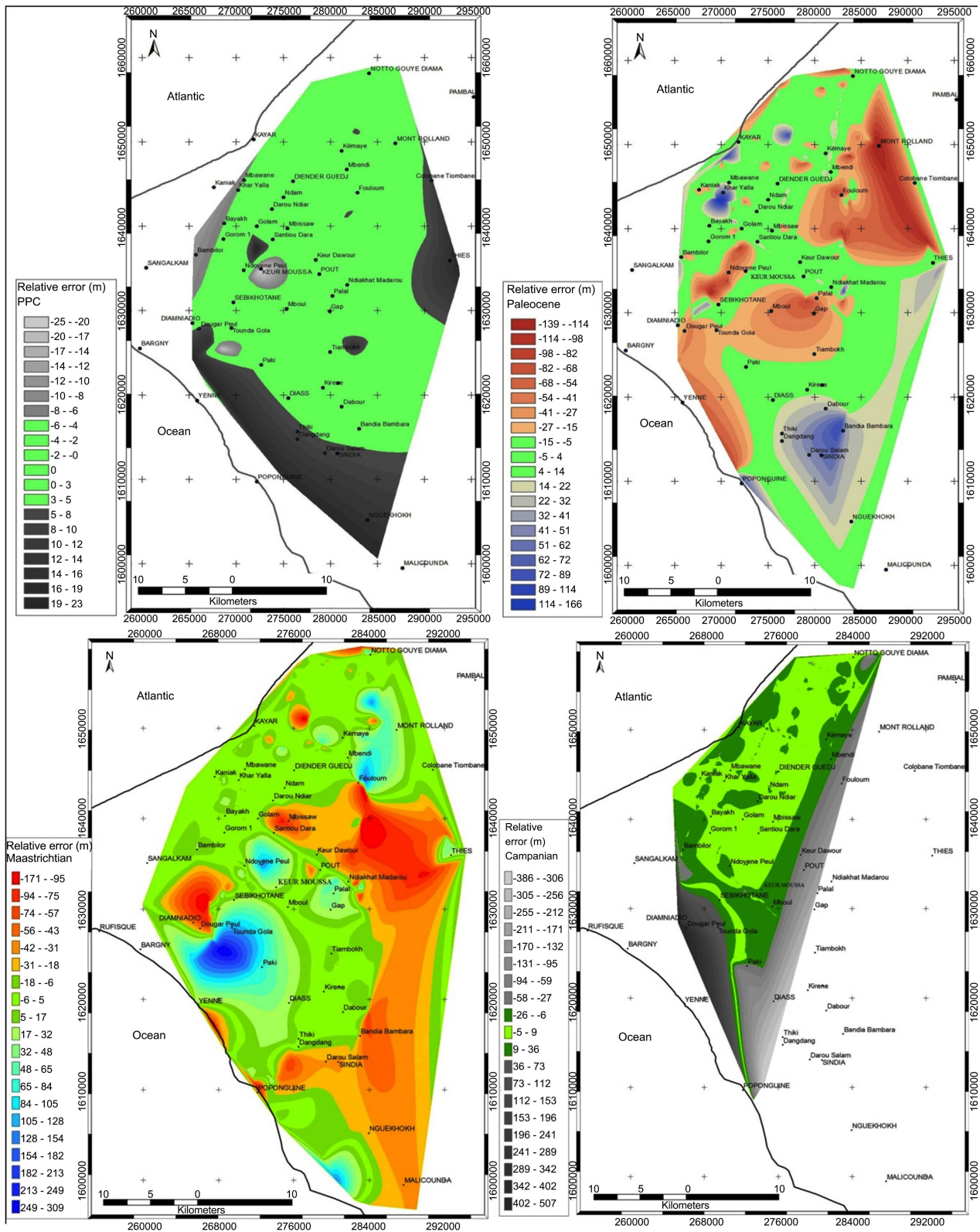


Figure 8. Residue maps of the various layers.

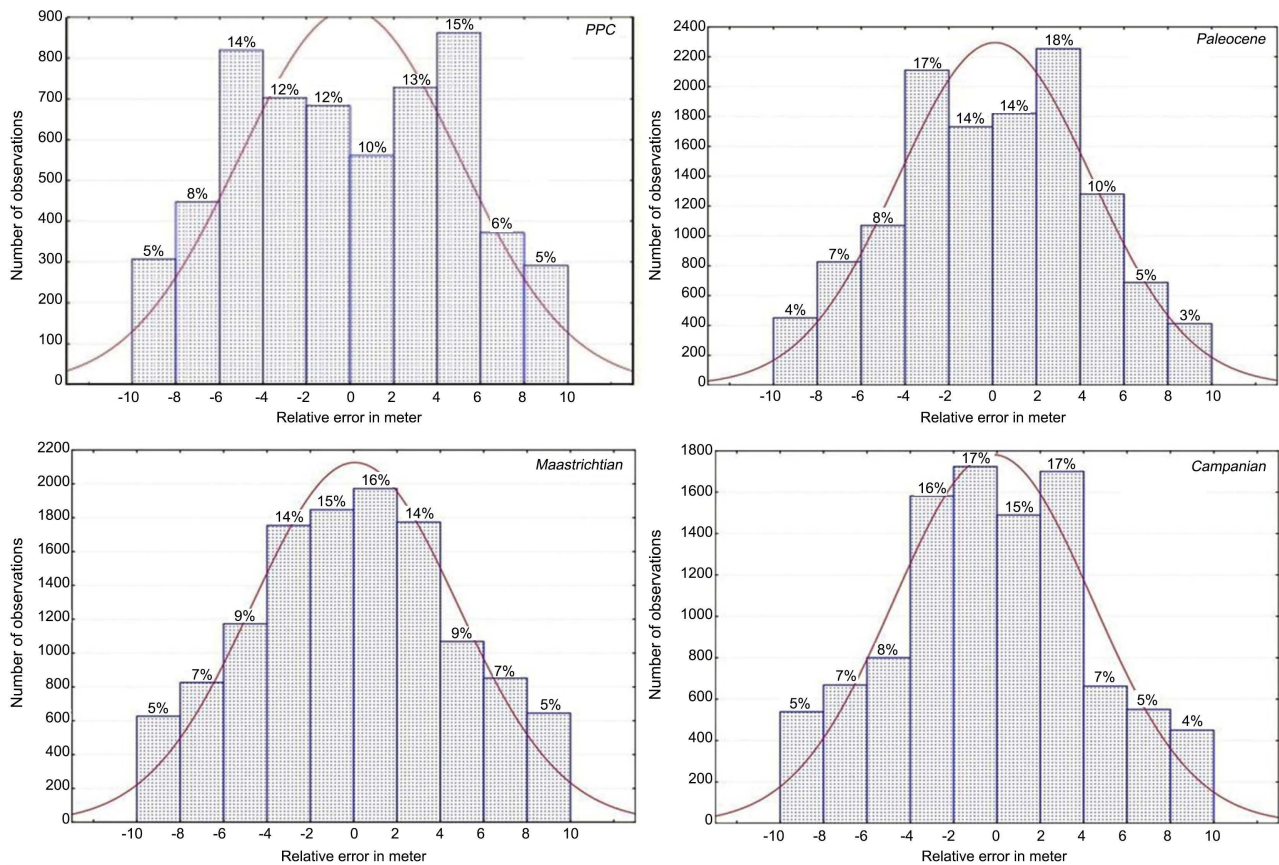


Figure 9. Histograms of the estimation of the relative errors of the different layers

gives a minimum relative error of -139 m and a maximum relative error of 105 m for the series.

Different error intervals can be considered depending on the percentage:

- 28% of the sample has an error of ± 2 m,
- 35% of the sample has an error of ± 4 m,
- 18% of the sample has an error of ± 6 m,
- 12% of the sample has an error of ± 8 m,
- 7% of the sample has an error of ± 10 m.

We find that 81% of the sample has an error within the interval $[-6$ m; $+6$ m]. Always considering the North of the corridor where the density of the database is high, the distribution of this error interval is not that constant. The explanation we can give is that the Paleocene in that part of the basin presents many gaps of erosion or sedimentation.

4.2.3. Maastrichtian Analysis

The results of the geostatistical analysis show for the Maastrichtian ($N = 12,556$) a minimum relative error of -171 m and a maximum relative error of 309 m. Depending on the error intervals we note:

- 21% of the sample has an error of ± 2 m,
- 28% has an error of ± 4 m,
- 18% has an error of ± 6 m,

- 14% has an error of ± 8 m,
- 10% of the sample has an error of ± 10 m.

The error interval $[-6$ m; $+6$ m] covers 67% of the sample. A constancy is also noted in the North of our corridor of reference Sébikotane—Keur Moussa—Pout; except for the area surrounded by the localities of Golam, Mbissaw, Santiou Dara and Keur Dawour.

4.2.4. Campanian Analysis

With $N = 10,171$ the Campanian top in this part of the sedimentary basin has a minimum relative error of -386 m and a maximum relative error of 507 m. It can be seen that the relative error on the basis of the data increases with depth. Different error intervals can be determined:

- 32% of the sample has an error of ± 2 m,
- 33% has an error of ± 4 m,
- 15% of the sample has an error of ± 6 m,
- 12% gives an error of ± 8 m,
- 9% has an error of ± 10 m.

For this stage of the terminal Cretaceous, we have 80% of the sampling that covers the error interval $[-6$ m; $+6$ m]. Again, consistency in error distribution is noted in the northern zone.

4.3. Pixelation

Based on the errors analysis results, we selected the locality of Diender Guedj (**Figure 10**) to apply pixelation. This locality has a low interpolation error for all layers. The pixelation is performed at a scale of 1:25,000. The matrix is divided into cells of 20 m side, for a perimeter of 80 m and a surface area of 400 m². The

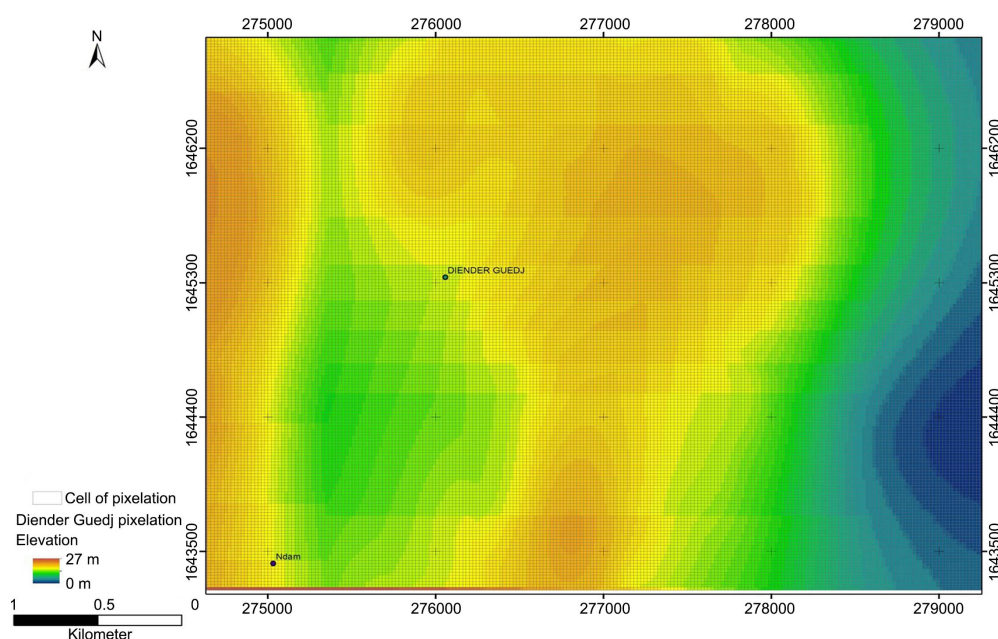


Figure 10. Geological mapping by 1:25,000 pixelation in the Diender Guedj area.

position of a cell in the matrix is determined by the parameters *X_index* (row number) and *Y_index* (column number). Each cell in the matrix behaves like a stratigraphic log. Diender Guedj's matrix contains 79,550 geolocalized cells. It covers a surface area of 31.82 km² and a perimeter of 24.6 km. We found that a decrease in scale significantly increases the number of cells. This requires more memory from the computer.

However, at this mapping level, the mapping results cannot be used solely through spatial analysis software. To allow a simple access for all users, we carried out the web programming.

4.4. Website Simulator

By pixelation at different scales, digital mapping made it possible to extract a geological database for the Diender Guedji locality. **Table 1** is an extract from the Diender Guedj database at 1:25,000. It shows the structural organization of the geological information.

In this table, the data are organized into structural information (*ID*, *Y_index* and *X_index*) and geolocalized geological information (*ZPPC*, *ZPaleocene*, *ZMaastrichtian*, *ZCampanian*, *X_UTM* and *Y_UTM*). The data are grouped into two types: integer (int) or double. The int type presents data in integers and the double type allows to integrate data in alpha-numeric format. The Identifier (ID) parameter is used to differentiate and identify specific information. Identification is done automatically when the database is integrated. To do this with *Easy PHP server*, simply add a column called ID and enable the *Auto-Increment* option. Diender Guedj's database at 1:25,000 consists of 79,655 geo-located Ids the double type with his *Null* option. In database management systems, the term *Null* means *no data*. This made it possible to provide treatments on the Paleocene, Maastrichtian and Campanian. To highlight the different areas of Paleocene sedimentary gap and the unmapped areas of the Campanian, let's take point ID5 in **Table 1**, positioned on the matrix in row 5 and column 184. It is located on the Diender Guedj area at longitude 272,070 and latitude 1,643,250. The point is located at a ZPPC altitude of 17 m, the Paleocene has a sedimentation or erosion gap, the Maastrichtian is recorded at -102 m and the Campanian at -1541 m. To achieve this result, we used the *UPDATE* module of Easy PHP Server. As an Example for our database, the following query is asked:

Update "diender_25k" **SET** "Paleocene" = null **WHERE** "Paleocene" <= "Maastrichtian".

This SQL query corrects the database extracted from Diender Guedj's digital mapping by replacing the Paleocene gap points with the Null code. When the Paleocene value obtained by spatial interpolation is less than or equal to the Maastrichtian value, the Paleocene is replaced by null.

Given the importance of the mapping result in the fields of engineering and research, we will not be limited to a spatial analysis software for the exploitation of the mapping result. We carried out a web programming for a simple and fast access of the mapping result.

Table 1. Diender guedj pixelation settings and data extract.

<i>Column</i>	<i>Type</i>	<i>Null</i>	<i>Gap</i>
<i>ID</i>	Int (11)	No	--
<i>Y_index</i>	Int (11)	No	--
<i>X_index</i>	Int (11)	No	--
<i>Z_CPP</i>	Int (11)	No	--
<i>ZPaleocene</i>	Double	Yes	NULL
<i>ZMaastrichtian</i>	Double	Yes	NULL
<i>ZCampanian</i>	Double	Yes	NULL
<i>X_UTM</i>	Int (11)	No	--
<i>Y_UTM</i>	Int (11)	No	--

<i>ID</i>	<i>Y_index</i>	<i>X_index</i>	<i>ZPPC</i>	<i>Zpaleocene</i>	<i>Zmaastrichtian</i>	<i>Zcampanian</i>	<i>X_UTM</i>	<i>Y_UTM</i>
1	184	0	17	Gap	-104	-1541	271,990	1,643,250
2	184	1	17	Gap	-103	-1541	272,010	1,643,250
3	184	2	17	Gap	-103	-1541	272,,030	1,643,250
4	184	3	17	Gap	-103	-1541	272,050	1,643,250
5	184	4	17	Gap	-102	-1541	272,070	1,643,250
6	184	5	17	Gap	-102	-1540	272,090	1,643,250
7	184	6	17	Gap	-102	-1540	272,110	1,643,250
8	184	7	18	Gap	-102	-1539	272,130	1,643,250
9	184	8	18	Gap	-101	-1539	272,150	1,643,250
10	184	9	18	Gap	-101	-1538	272,170	1,643,250
11	184	10	18	Gap	-101	-1538	272,190	1,643,250
12	184	11	18	Gap	-101	-1537	272,210	1,643,250
13	184	12	18	Gap	-100	-1536	272,230	1,643,250
14	184	13	18	-99	-100	-1536	272,250	1,643,250
15	184	14	18	-96	-100	-1535	272,270	1,643,250
16	184	15	18	-94	-100	-1534	272,290	1,643,250
17	184	16	18	-92	-99	-1533	272,310	1,643,250
18	184	17	18	-89	-99	-1532	272,330	1,643,250
19	184	18	18	-87	-99	-1531	272,350	1,643,250
20	184	19	18	-85	-99	-1530	272,370	1,643,250
21	184	20	18	-83	-99	-1529	272,390	1,643,250
22	184	21	19	-81	-98	-1528	272,410	1,643,250
23	184	22	19	-79	-98	-1527	272,430	1,643,250

Through *index.php* the connexion with the server is set up. The connexion of the mapping database with the server is made through various requests. Programming is a combination of html-php code. As a result, each point recorded in the database corresponds to a stratigraphic column going from the surface to the top of the Campanian.

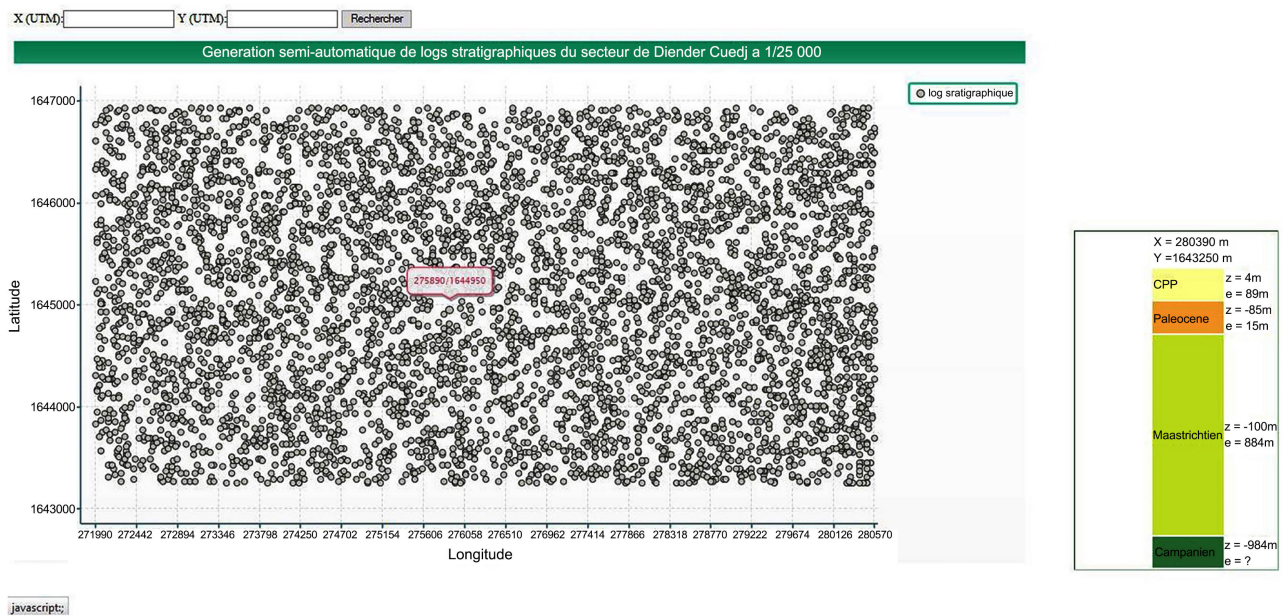


Figure 11. Presentation of Diender Guedj database at 1:25,000.

Figure 11 shows the result of simulation the Diender Guedj database online under *Easy PHP Server* at 1:25,000.

We have a choice on the web display (**Figure 11**). Either we go to the query interface and enter the X and Y coordinates or click on a point in the mapped domain. For example, by entering the coordinates $X = 280,390$ m and $Y = 1,643,250$ m, we obtain the result displayed as a stratigraphic log with the topographic level of the layer (Z) and its thickness (e):

- PPC: $Z = +4$ m, $e = 89$ m;
- Paleocene: $Z = -85$ m, $e = 15$ m;
- Maastrichtian: $Z = -100$ m, $e = 884$ m;
- Campanian: $Z = -984$ m with a lower limit uncertainty, hence $e = ?$

Therefore, it is a very dynamic and interactive method for quick and easy access to geological data.

5. Conclusions

The subsoil in the western part of the Thiès region is characterized by more or less complex geological formations. To understand their spatial distribution and facilitate access to the results, we developed the digital mapping method.

The database allowed us to monitor the topographic evolution of the MSGBC basin in our study area. Errors can occur in the spatial interpolation of data. The residue maps from the error analysis clearly show areas of low data densities where the interpolation error is significant. This has strongly influenced the choice of areas where digital mapping is applied. This mapping is presented in a window called a matrix divided into cells or pixels. Each cell behaves like a stratigraphic log.

Digital mapping has become a solution to problem of locating areas where

there is a sedimentation or erosion gap. Applied to the stratigraphic block, it facilitates the extraction of geological data that are processed through SQL queries. These are used during the integration of the results in a Database Management System and enable to locate these various gaps areas.

Digital mapping by pixelation is becoming an essential tool for the exploration of subsoil structures and its use is of great importance in various applied fields: mining, geotechnics, civil engineering, identification of risk areas in land use planning, study of climate and environmental evolution...

It is a powerful decision support tool in many fields of geoscience.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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