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Contribution to the Numerical Geological Mapping of the Paleocene in the Western Part of Thiès (Senegal)

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Abstract

The locality of Thiès has significant mining and hydrogeological resources that are of major economic interest and necessitates a sustainable management. Most of these resources are contained in the Paleocene. For a better assessment of Paleocene, we elaborated a spatial model using available seismic lines, oil and hydraulic drills. The data were integrated using interpolation, mainly natural neighbor method. The obtained model should make it possible to understand the variation of the lithostratigraphic parameters of the Paleocene. The extraction from the model of the upper and the lower limits showed that the Paleocene is shallow and is outcropping to sub-out-cropping in the area of Thiès. The model was validated using previously available geological map. Also, a crosscorrelation of the predicted and the observed data showed that the model is accurate.

Keywords

1. Introduction

The geological setting of the Paleocene in the area of Thiès is linked to the stratigraphy of the Senegal-Mauritanian sedimentary basin. Senegal-Mauritanian basin is a large passive margin basin, limited in the East and Southeast by the Mauritanides mountain belt and in the South by the Bové basin [1]. The basin is formed of a

thick sedimentary sequence, mainly marine deposits, aged from the Trias-Lias to Quaternary deposited on the basement represented by West African Craton. The Paleocene is generally met in Thiès where it consists of sandy and karstic shelly limestones used for Portland cement manufacturing or as building aggregates [2]. Furthermore, the lithostructural characteristics of the limestone of the top of the Paleocene and the impermeable marls at its base make it an important aquifer, for large urban centers water supply [3].

The aim of this work is to build a geological model of the Paleocene basing on the spread available data, using spatial analysis techniques [4]. The obtained model should allow mapping the geological layers of the Paleocene. In fact, the flat topography and the superficial weathering under tropical climate induce a lack of geological outcrops, what makes difficult the geological mapping. Moreover, the obtained model could be a flexible and updatable tool with high research and mineral resources management interests.

The lower limit of the Paleocene in the locality of Thiès is represented by a clast-supported conglomerate deposited in angular unconformity on the Maastrichtian [5]. The upper limit corresponds locally to an erosional unconformity on the shelly limestones [6]. The Paleocene is mostly calcareous and settled in major parts during the Dano-Montian [7] with two sedimentary sequences.

The first sequence consists of grey limestones showing sometimes crypto-crystalline dolomite lenses. The base of the sequence shows a sandy and shelly level with ferrugineous, phosphatic and/or glauconitic grains. The higher levels contain small benthic foraminifera (*Rotaliidae*, *Discorbidae*) and green algae, mainly *Halimeda*. Petrographic textures show mudstone, wackestone and packstone alternation. Early dolomitization and synsedimentary breccia associated to the described sedimentary textures allow considering a peritidal depositional environment [7].

The second sequence consists of bioclastic limestone with molluscs, echinoderms and bryozoa. Annelida tubes, corals and benthic microfauna as *ostracodes* and *foraminiferas* are more rarely met throughout the sequence. The Lagenidae appear for the first time indicating a deepening of the depositional environment [8]. Planktonic foraminifera as *Morozovella velascoensis* found in the last meter of the Paleocene deposits, allowed dating the top of the sequence to Thanetian. Petrographic textures show mainly packstone that is an evidence of the end of the detrital sedimentation corresponding to the immersion of the horst of Dias [8]. The thanetian limestone in the Mont-Rolland FP12 probes is white, yellowish or grey, with rich shell fragments content [9]. The top contains weathered marls with a rich microfauna, mainly planktonic foraminifera [10] and rare fragments of echinorderms. At the base, the limestone is marly and sandy, with bad preservation of the existing microfauna.

2. Data and Methodology

The investigated area covers an area of 1197.486 km^2. The modeling of the Paleocene in this part of the basin is performed through three steps:
- The compilation phase that consists of gathering the whole data using a common spatial reference.
- The processing phase including spatial interpolation and vectorization of the data.
- The cartographic production phase where the developed model is used for geological mapping of the Paleocene.
- To perform these steps, a database is built gathering reflection seismic profiles, oil [11] and hydraulic drills. The seismic profiles were interpreted combining *Geographix Discovery Wellbase* module, containing the database of the available wells, with *Seisvision* software. The seismic interpretation was performed through the following steps [12]:
- The pointing of reflection markers in the seismic profiles.
- The tuning of the top of layers for one or several wells with the seismic sections markers.
- The correction of misties between the crossing seismic profiles. These misties appear given that the interpreted seismic data result from several survey with different phases.
- The mapping of the time values (*or estimated depth*) generally into isochronal, isobath and/or isopach charts.

The time to depth conversion of seismic profile was possible using available seismic well logging data. Having the mean velocity of the wave (V) and knowing the time (t), we can calculate the depth (P) of the top or the base of Paleocene the (P) using the relation P = Vt. In addition to the seismic data, those resulting from the hydraulic drill reports allowed the inventory of all the works carried out in the sector of study, which cross the Paleocene.

The seismic profiles, oil and hydraulic drills data are finally gathered in the same database using *ArcGIS*

software. Each element of the database is a three coordinates point corresponding to the geographic longitude (X) and latitude (Y), and the depth of the top or base of the Paleocene (Z). The main steps of the process are shown on the flow diagram in (**Figure 1**) and the location of the seismic lines and oil/hydraulic drills in (**Figure 2**).

3. Results and Discussion

3.1. Mapping the Bottom of the Paleocene

The dataset allowing the modeling of the base of the Paleocene consists of 12,544 records extracted from the data (seismic lines and the oil and hydraulic drills) that have reached the base of the Paleocene.

A first interpolation using natural neighbor [13] reveals shifts, in particular in the intersections of the seismic lines. In an iterative way, the corrections were carried out based on reference seismic lines and/or drills. The reference seismic lines correspond to those showing maximum conformity with the wells. The resulting model, corresponding to the spatial distribution of the base of Paleocene in the sector, is represented on (**Figure 3**).

We noticed that the base of the Paleocene is sub-outcropping to outcropping in the center and the South of the investigated area, and is deepening towards the Northwest. On the axis Kayar-Gorom1 see (**Figure 3**), we observed a progressive deepening of the base of the Paleocene. This phenomenon can also be observed along the line Mbawane-Khar Yalla-Bayakh. This is probably linked to the Sebikotane major fault orientated NE-SW with 100 meters slip determined between Yene and Kayar, putting into contact the Ypresian marls of the Sebikotane horst with the clays and sands of the top of Maastrichtian [14]. Our model allowed showing, the progressive deepening of the Paleocene (**Figure 4**) that is in accordance with the existence of listric faults linked to the passive margin context.

3.2. Mapping the Top of the Paleocene

A set of 12 492 records allowed the modeling of the top of the Paleocene. The processing steps are similar for the base of Paleocene. The resulting model, corresponding to the spatial distribution of the top of Paleocene is represented on (**Figure 5**).

We noticed that the top of the Paleocene is sub-outcropping to outcropping in the center and the South of the investigated area, and is deepening towards the Northwest. On the axis Notto-Pout, the top of the Paleocene describes a sharp deepening. The spatial configuration of the top of the Paleocene is almost similar to the base, with a weak shift towards the East that confirms the presence of listric faults.
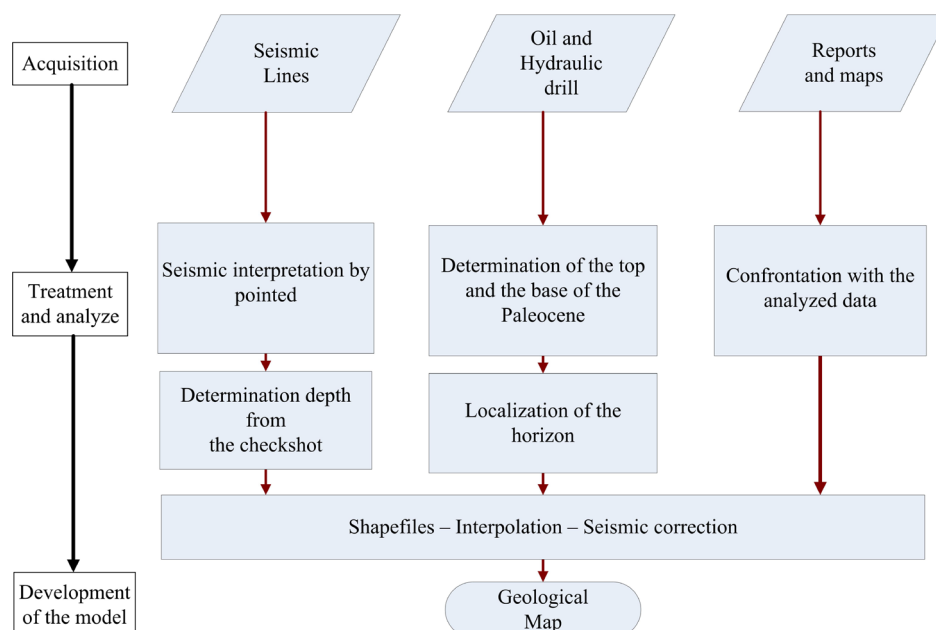
Figure 1. Flow diagram of the main steps of the model building and the subsequent geological mapping.
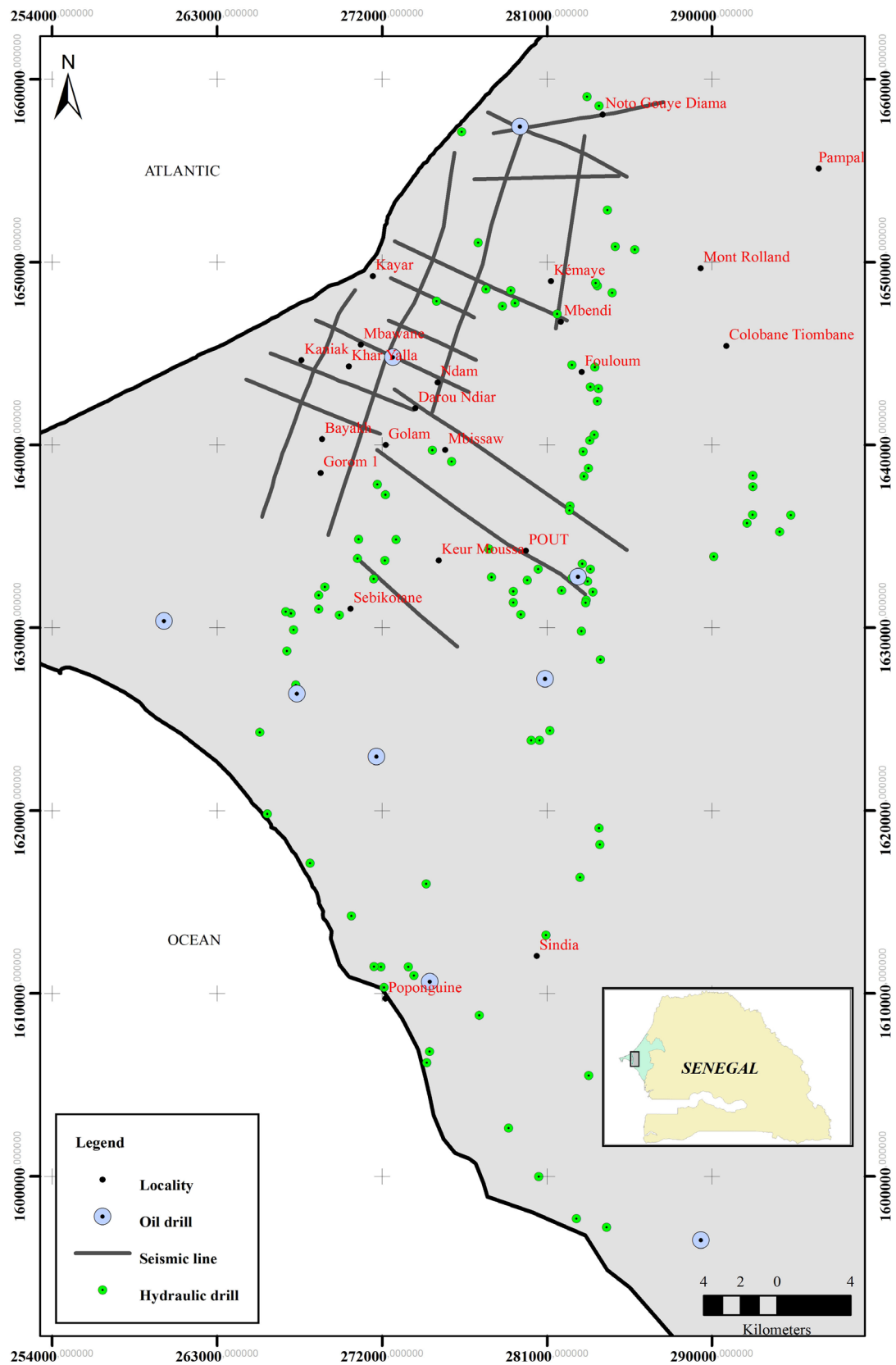
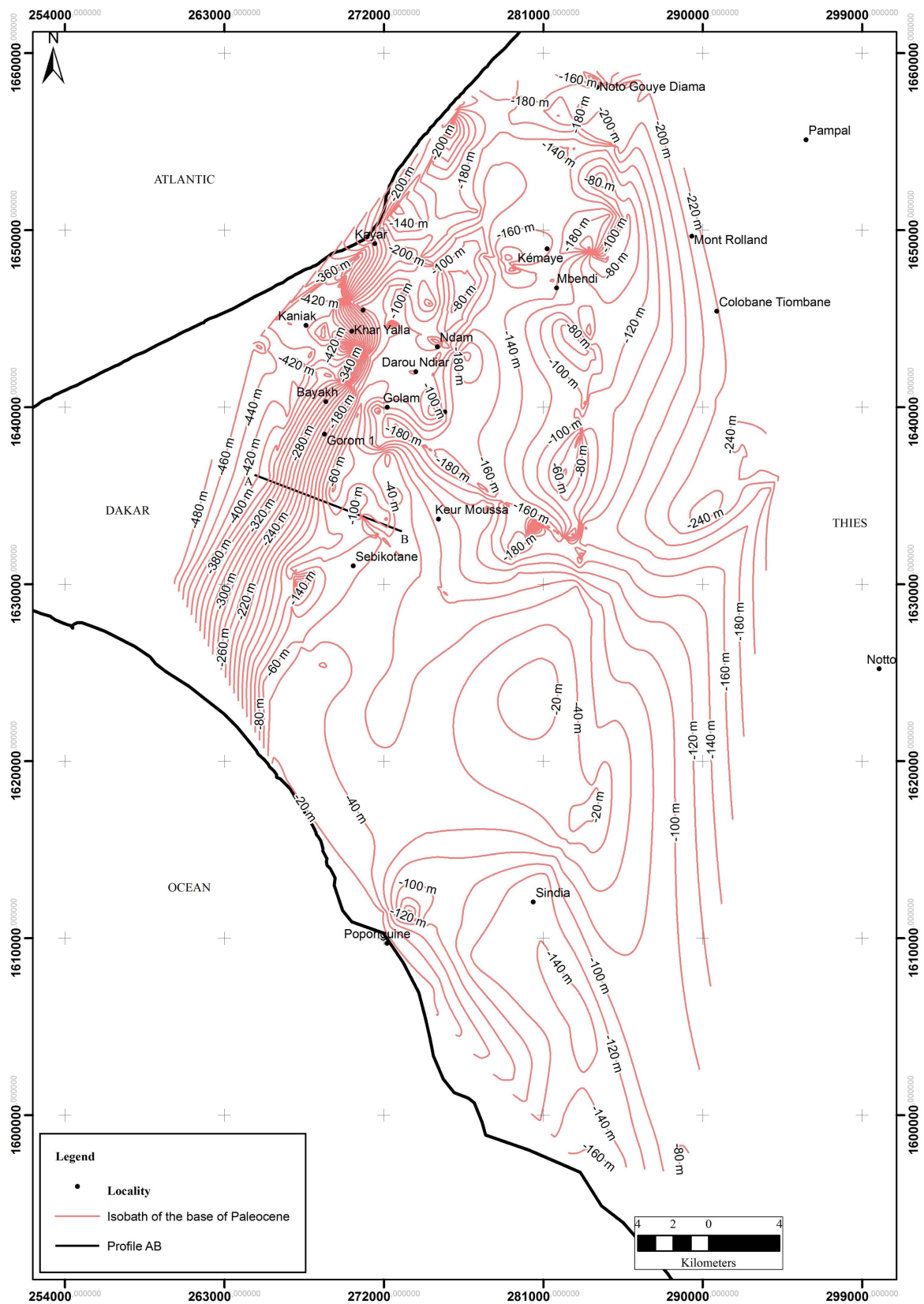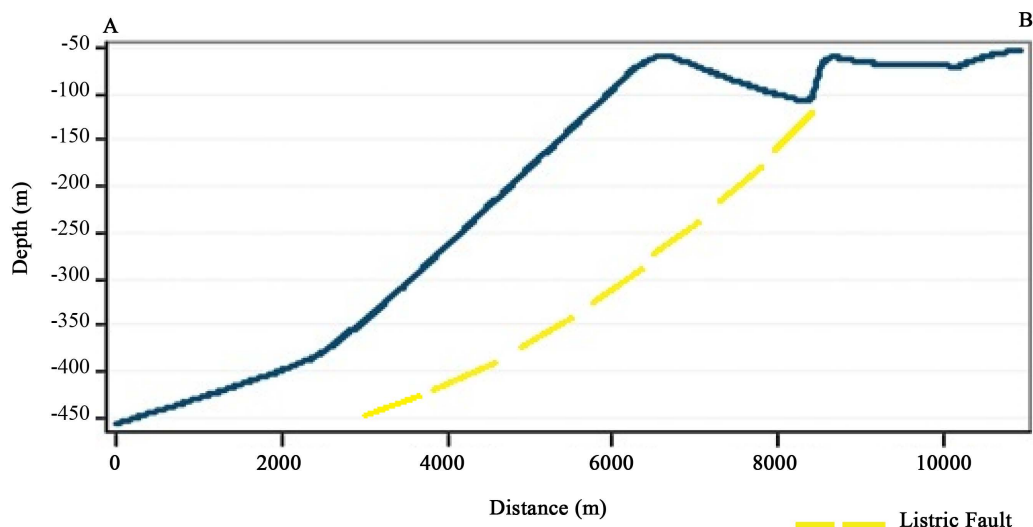**Figure 2.** Spatial distribution of the data of the Paleocene.

Figure 3. Spatial distribution of the bottom of the Paleocene.

Figure 4. Profile of variation of the depth of the bottom of the Paleocene between Sebikotane and Gorom1.

The combination of the top and the bottom maps of the Paleocene gives the thickness map of the Paleocene (**Figure 6**). It shows that the Paleocene is very thick in the Northwest and thins towards the South and the center of the investigated area. This configuration substantiates our model for the base and the top of the Paleocene. The low thicknesses in the South, the East and the center could be explained, in addition to the presence of lystric faults, by the exposition to erosion around the horst of Dias and cliff of Thiès.

3.3. Error Estimation

The accuracy of the model has been assessed using crosscorrelation between the predicted depth and the observed depth for the top and the base of the Paleocene. The results are shown on (**Figure 7**).

The computed Pearson r-square is 0.9938 for a number of samples N = 12544 and is statistically significant at 99% confidence level. The crosscorrelogram (**Figure 7**) shows that outliers are present in the interval −100; −50 m and more rarely around the interval −325; −225. These outliers are linked to the various datasources that use more or less accurate depth measurement techniques.

The analysis of the various results shows that the Paleocene is suboutcropping in the horst of Dias and the cliff of Thiès. Towards the Northwest, it is deepening gradually due to the tectonic activity that has affected this part of the Senegalese sedimentary basin [15].

3.4. Geological Mapping

The spatial overlay of the top and the base of Paleocene allowed a better geological mapping of the spatial variation of this epoch. It allowed also locating the gab of deposit of Paleocene. In the Northern part of the line Pout-Keur Moussa-Sébikotane, the model seems to be more accurate than the Southern part. This is linked to the density of the data points that becomes low in the South. This situation motivated, for more reliability, to limit the geological mapping in the North of the line Pout-Keur Moussa-Sebikotane (**Figures 8**).

4. Conclusion

The obtained model in this study allowed following the lateral variation of Paleocene in the area of Thiès, with an accuracy depending on the density of the available data. Therefore, the resultant model can be divided into two parts, along the axis Pout-Keur Moussa-Sebikotane: a first region in the Northern part of this axis with a high concentration of datapoints; and a second region in the South with low density of data. For more precision, the resulting geological map relates only to the area, in the North of this axis. The obtained model could be an important tool for research or decision-making. For researchers, the model should allow a better understanding of the Paleocene. For decision makers in many engineering fields, the model will make it possible to direct the
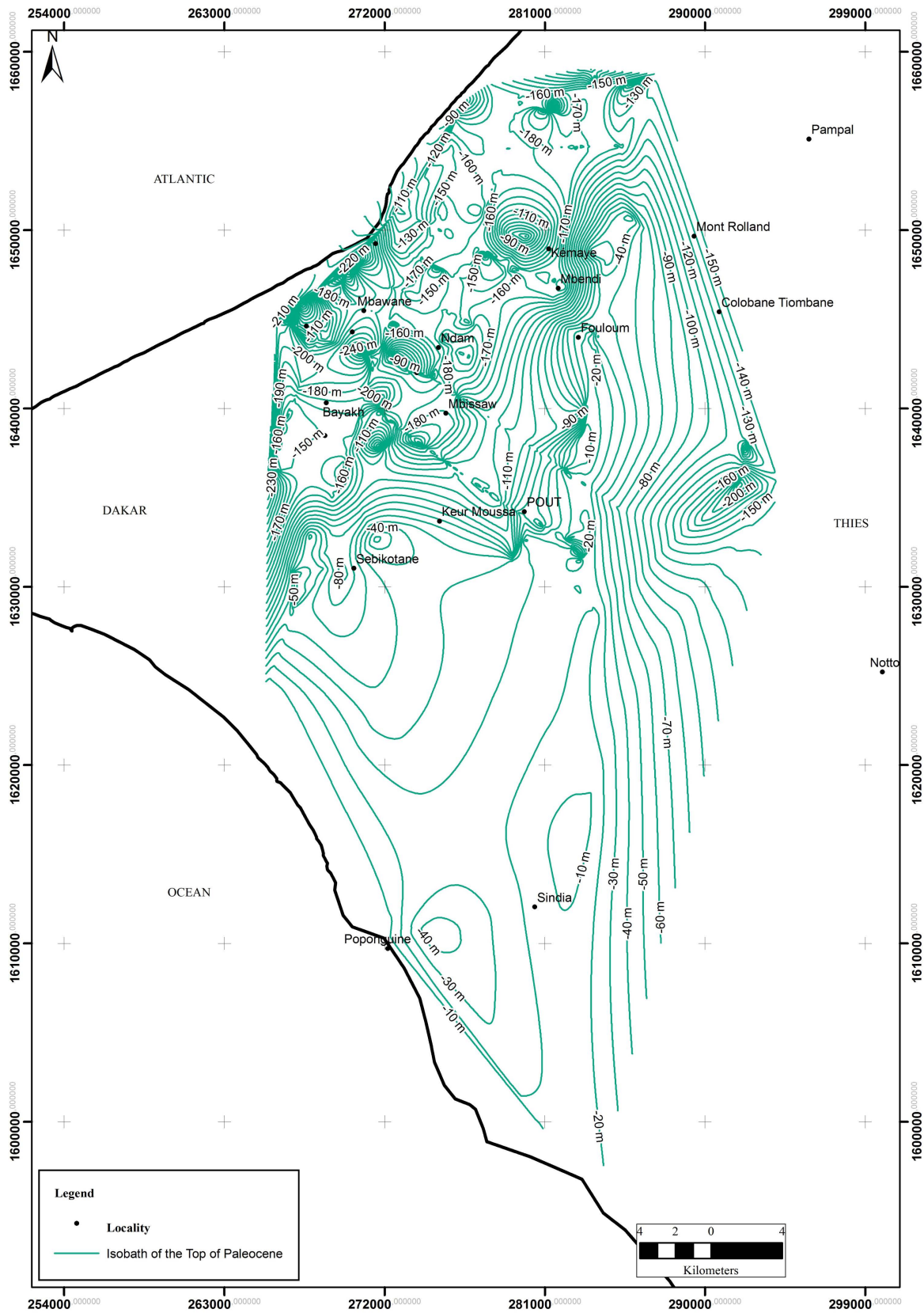
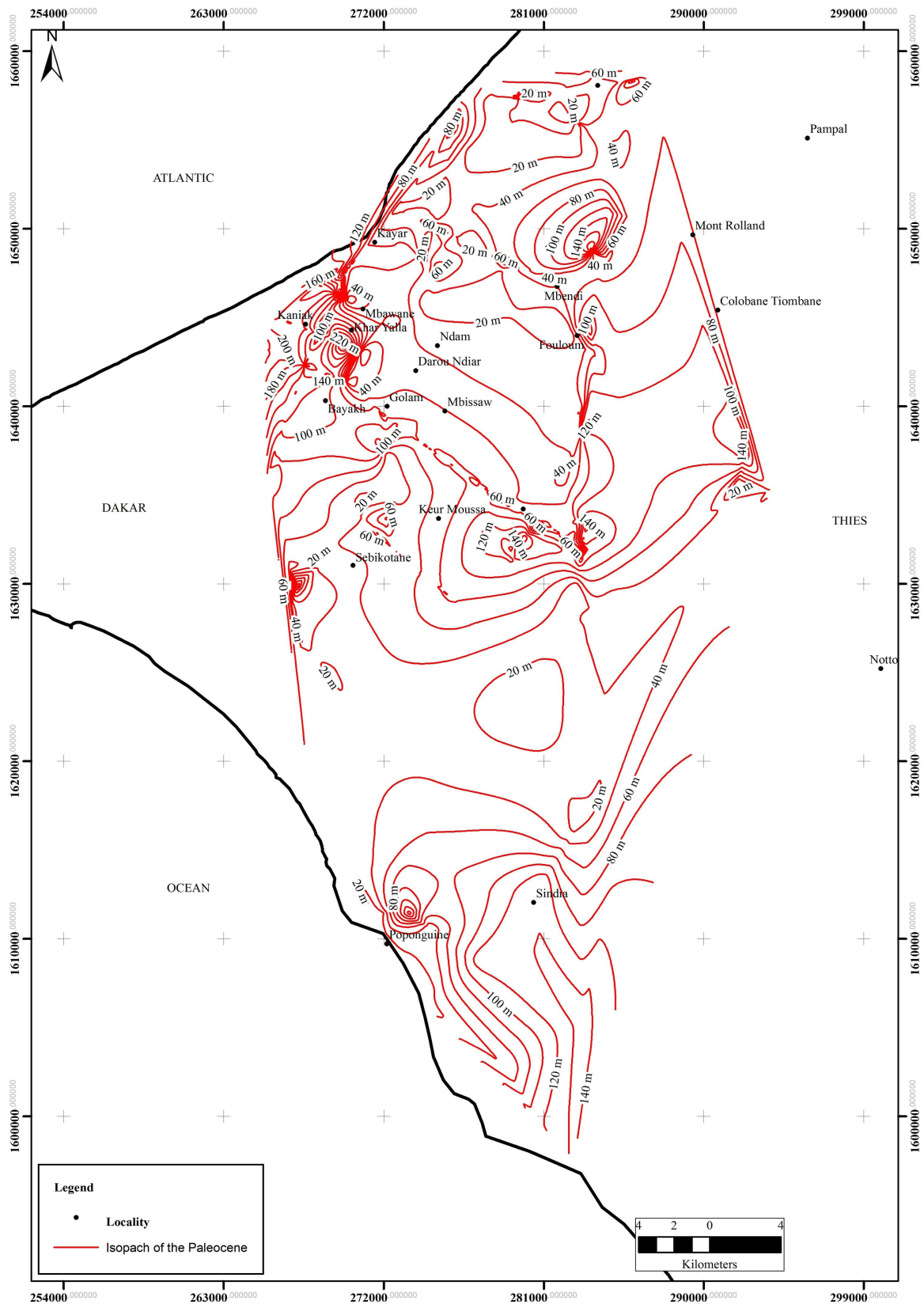**Figure 5.** Spatial distribution of the top of the Paleocene.

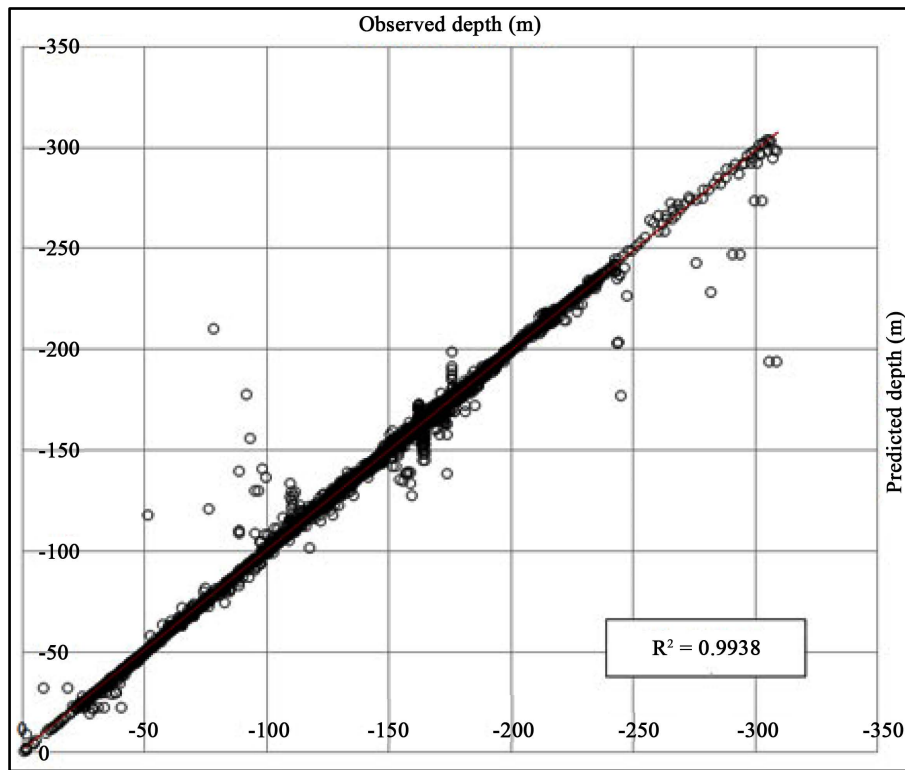**Figure 6.** Map of the thickness of the Paleocene.

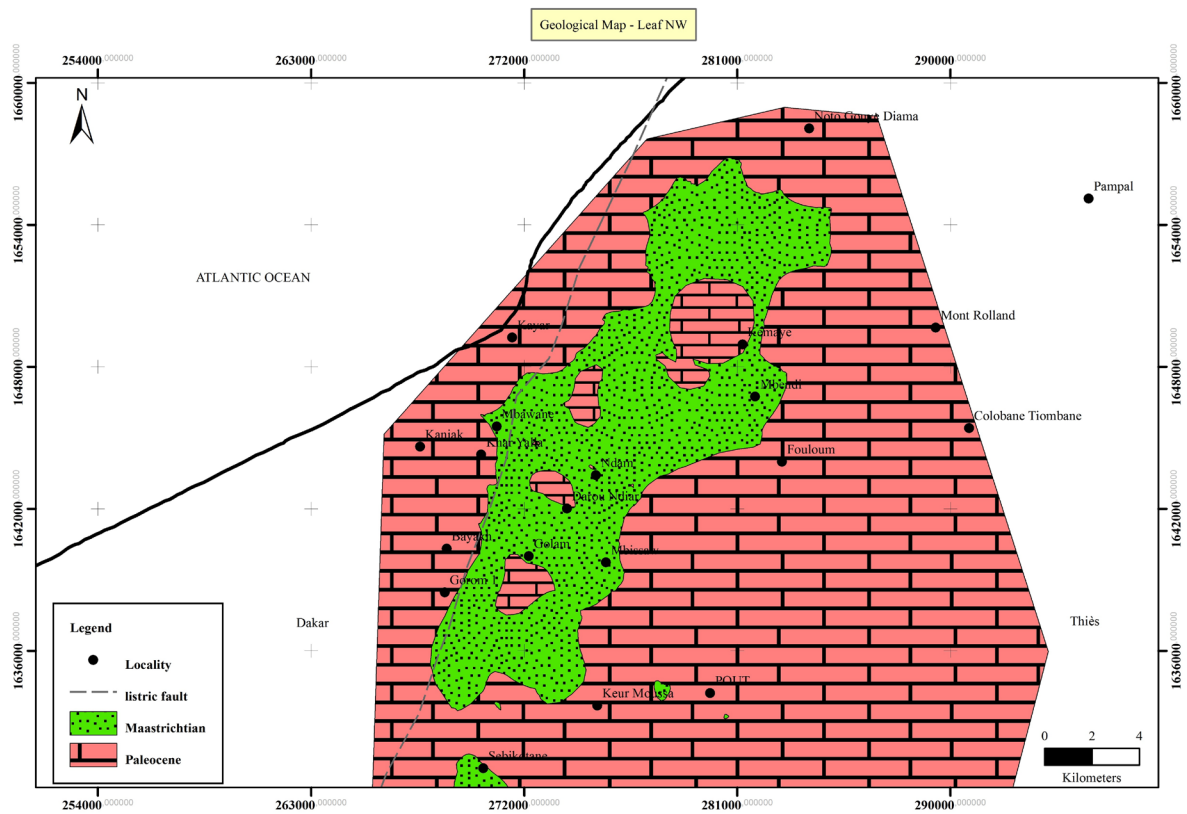**Figure 7.** Crosscorrelation between predicted and observed depth.

Figure 8. Geological map in the north west of Thiès.

projects towards sectors that are of optimal interest.

Acknowledgements

References

[1]   Bellion, Y.J.C. (1989) Histoire géodynamique Post-Paléozoïque de l'Afrique de l'Ouest d'après l'étude de quelques bassins sédimentaires (Sénégal, Taoudenni, Lullemmeden, Tchad) Thèse Université d'Avignon, 292 p.

[2]   Dione, A., Fall, M., Berthaud, Y. and Ba, M. (2013) Estimation of Resilient Modulus of Unbound Granular Materials from Senegal (West Africa)—Scientific Research. *Geomaterials*, **3**, 172-178. http://dx.doi.org/10.4236/gm.2013.34022

[3]   Aranyossy, J.F., Moller, K., N. and Diene, M. (2001) Synthèse des données géologiques et structurales. Application à la définition des systèmes aquifères. Rapport de travail n 03. République du Sénégal—Ministère des mines, de l'Energie et de l'Hydraulique, 62 p.

[4]   Kaufmann, O. (2010) Cartographie géologique du Canton de Genève par système d'information géoréférée: Conception et réalisation de modèles 2D et 3D avec leurs applications, 193 p.

[5]   Tessier, F. (1952) Contribution à la stratigraphie et à la paléontologie de la partie Ouest du Sénégal (Crétacé et Tertiaire). *Bulletin de la Direction des Mines de l'AOF*, **14**, 1-267.

[6]   de Spengler, A., Castelain, J., Cauvin, J. and Leroy, M. (1966) Le bassin secondaire et tertiaire du Sénégal. *Symposium New Delhi* 1964, Coord. D. Reyre, 80-94.

[7]   Diop, A. (1982) Contribution à l'étude de la plateforme carbonatée paléocène de la région de Diass, Sénégal occidental. Thèse de 3$^{\grave{e}}$ Cycle, Université Paris-Sud, Orsay.

[8]   Diop, A. et Purser, H. B. (1991) Environnements sédimentaires des quartz de la série paléocène du dôme de Diass (Sénégal occidental). *Géodynamique*, **6**, 177-190.

[9]   Sarr, R. (1995) Etude biostratigraphique et paléoenvironnementale des séries d'âge Crétacé terminal à Eocène moyen du Sénégal occidental. Systématique et migration des ostracodes. Thèse Doctorat d'Etat ès Sciences, Université Cheikh Anta Diop de Dakar, 335 p. + Annexes.

[10] Sarr, R. (2013) Ostracodes nouveaux du Paléogène du Sine Saloum (Sénégal, Afrique de l'Ouest): Biostratigraphie, paléoenvironnement. *Revue de Paléobiologie*, **32**, 569-588.

[11] Shlumberger, G. (1996) Final Report on the Processing of Land 2D Seismic Data from Sebikotane, Senegal from Tullow Oil PCL, 14 p.

[12] Blekou, A.T. (2009) Caractérisation géologique et structurale de la zone nord de Diamniadio/Kabor à partir des données sismiques 2D de Tullow Oil—1995. Mémoire de DEA en Géosciences, Département de Géologie, Faculté des Sciences et Techniques Université Cheikh Anta Diop de Dakar, 89 p.

[13] Sukumar, N., Moran, B., Yu Semenov, A. and Belikov, V.V. (2001) Natural Neighbor Galerkin Methods. *International Journal for Numerical Methods in Engineering*, **50**, 1-27. http://dx.doi.org/10.1002/1097-0207(20010110)50:1<1::AID-NME14>3.0.CO;2-P

[14] Mpassi, R. D. (2004) Contribution à l'étude de la partie occidentale du bassin sénégalo-mauritanien. Thèse de 3$^{\grave{e}}$ Cycle de Géologie, Université Cheikh Anta Diop de Dakar, 344 p.

[15] Faye, A. (1983) Contribution à l'étude géologique et hydrogéologique du horst de Diass et de ses environs (Sénégal) Thèse de docteur de spécialité en géologie appliquée. Université de Dakar, 175 p.