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Geological Modelling of Sandstones Formations and Petrophysical Characterization of Hydrocarbon Reservoirs in the Termit Basin, Eastern Niger: Case of the Goumeri Prospect

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Abstract

The general objective of this study, which focuses on the geological modelling of sandstone formations and petrophysical characterization of hydrocarbon reservoirs in the Termit basin, is to build a geological model to visualize the geometry of reservoir formations. Its specific objectives are: (**1**) determine the extension of promising reservoir formations, (**2**) establish models of petrophysical parameters (porosity, permeability and saturation). The methodology implemented is based on the integration of lithological data and petrographic parameters from the logs into the Petrel software. The interpretation of the results obtained on geological modelling shows; geometry and extension of reservoir formations in the form of sand lenses of varying thickness from one prospect to another. Petrophysical parameter models including porosity and permeability models have made it possible to understand the vertical distribution of the different reservoir units.

Keywords: Geological modelling, porosity, permeability, Termit basin

I. Introduction

The Termit Basin is a fractured intraplate basin with an NW-SE direction (Genik, n.d.; B. Liu et al., 2015) (Figure 1), and belongs to the West African Rift Subsystem (WAS) which itself belongs to the West and Central Africa Great Rift System (WCARS) (Genik, n.d.) . It is a Meso-Cenozoic Rift basin filled with a Cretaceous age lower than the Holocene-Pleistocene (*Du_Gondwana_a_latlantique_sud_les_connex.pdf*, n.d.) . The Termit Basin is an intracontinental basin between Niger, Nigeria and Chad. It is one of the largest basins in Eastern Niger which straddles the Bornou Basin in Nigeria and the Doba-Bangor Basin in Chad (Genik, n.d.) . This basin was developed during the opening of the Atlantic Ocean (*Chad-Petroleum-Sector-Diagnostic-Report.pdf*, n.d.; Genik, n.d.) . The sediments filling the Termit basin are Cretaceous in the Quaternary age (Genik, s. d.; B. Liu *et al.*, 2015). The thickness of terrigenous clastic sediments is between 300 to 2500 m in the Lower Cretaceous, between 800 and 4200 m of marine clay, sandstone and silts intercalated with weak calcareous banks in the Upper Cretaceous, between 350 to 2500 m of sand in the Cenozoic (Figure 2) (Genik, n.d.; Wan et *al.*, 2014). Oil exploration began in the Termit Basin around the 1970s by Conoco, whose first oil showings were discovered in the Chad Basin specifically in the Termit Basin near Lake Chad around 1974 (Genik, n.d.; Harouna & Philp, 2012; Sarki, 2021). The target reservoir formations are the Eocene and Late Cretaceous sandstones (Genik, n.d.; Harouna & Philp, 2012). Structurally, the Termit Basin has mainly fault families of NO-SE and NNO-SSE directions(Liu *et al.*, 2012; Zhou et *al.*, 2017). A first family of faults is said to be early formed in the early Cretaceous (NO-SE faults) (Ahmed *et al.*, 2020; Konaté et al., 2019), and a second family of faults is said to be late Paleogene formed (NNO-SSE faults) (Liu *et al.*, 2012; Zhou et *al.*, 2017). TheTermit Basin is subdivided into ten (10) structural units: Iagiil Platform, Western Shelf, Eastern Shelf, Dinga Fault Zone, Dinga Depression, Yogou West Slope, Fana Uplift, Moul Depression, Araga Graben and Trakes East Slope (Lai and *al.*, 2020; J. Liu et *al.*, 2019).

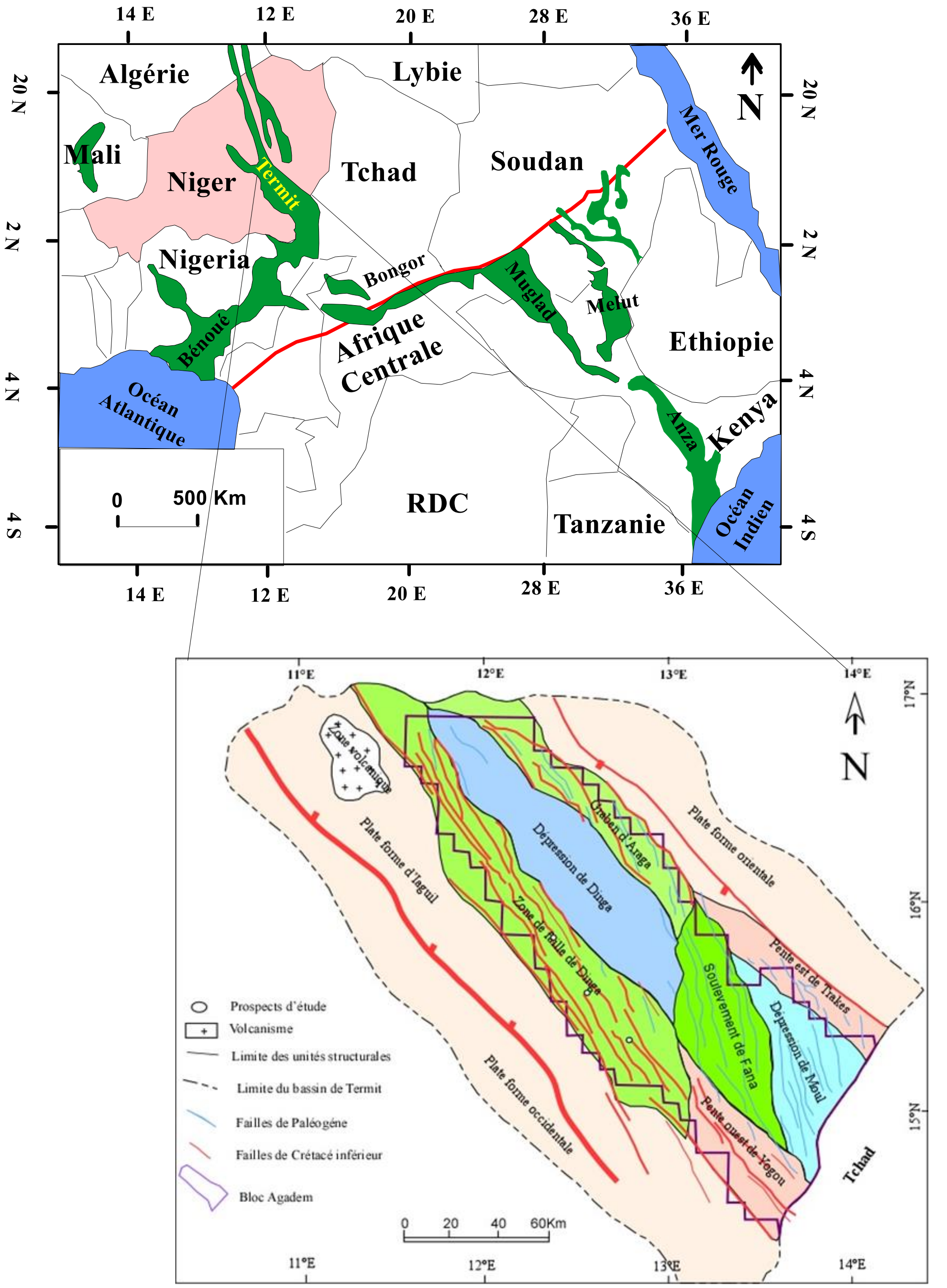

Figure 1. Study Area Location and Termit Basin Structural Units (*Genik 1993.pdf*, n.d.; B. Liu et *al.*, 2015; J. Liu et *al.*, 2019).

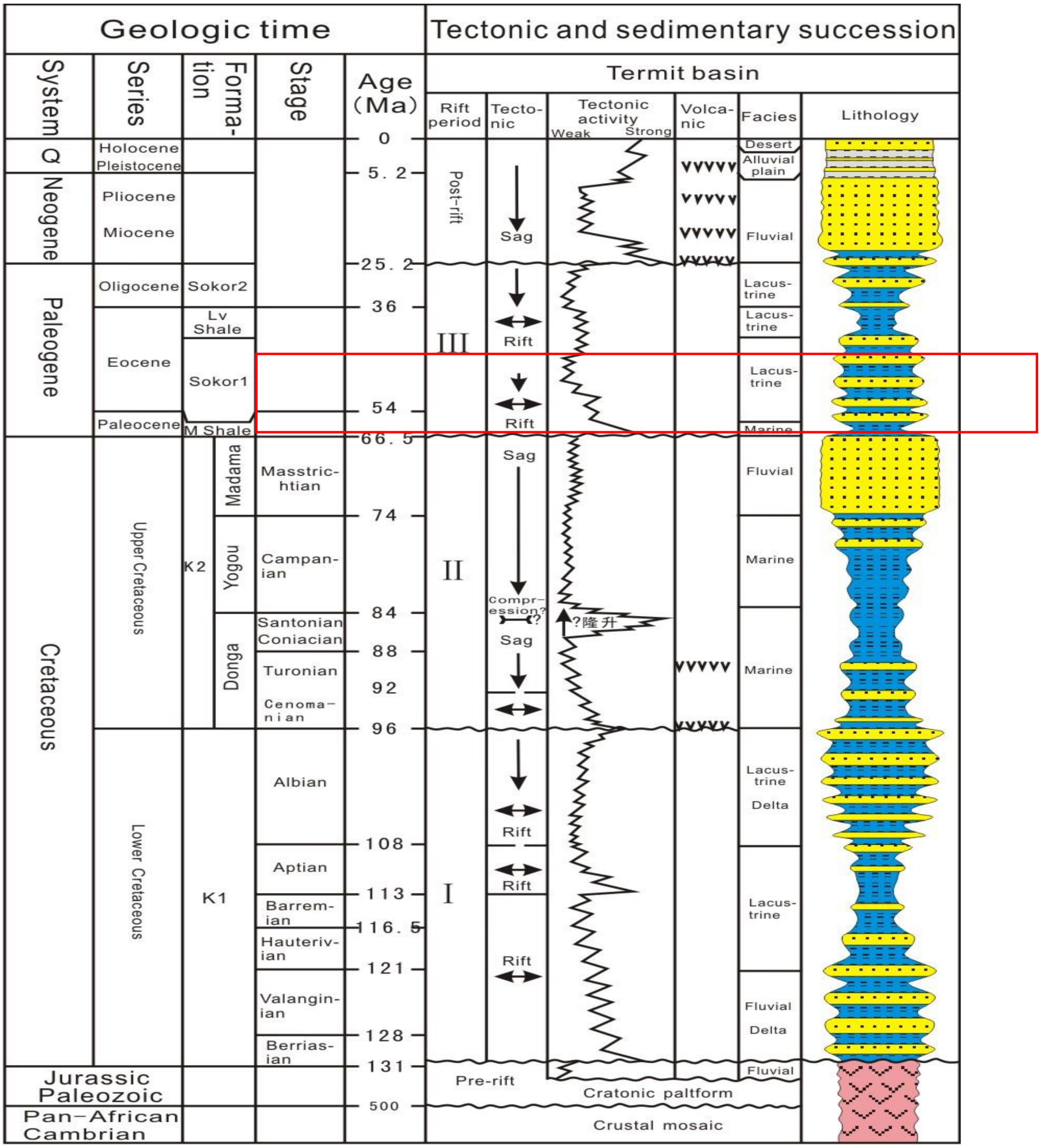

Figure 2. Litho-stratigraphic column of the Termit basin (B. Liu *et al.*, 2015).

II. Methodological approach

The methodological approach implemented in this work consists intransferring stratigraphic, lithological and petrophysical parameter data into the Petrel geomodelling software. This software makes it possible to build geological models of the study area. The petrographic data used in this research come from a few wells of the Goumeri prospect (Goumeri Well E-

1,10,11... etc) (Caumon *et al.*, 2009; Makhloufi et*al.*, 2013). The data relate to the values of porosity, permeability and stratigraphic and lithological data of the wells of the study prospects. To model the heterogeneity of reservoir formation facies, approaches using Petrel's stochastic methods were applied (*Thomas_2020_GFEJ_AG_2020.pdf*, n.d.) .These approaches make it possible to construct the different geological layers as well as their extension from north to south of the study prospect (Makhloufi *et al.*, 2013).

III. Results and discussion

1. Facies model

The model (Figure 3) of the facies shows the variation in thickness of the sandstone layers in the reservoir formation of unit E1 of the Goumeri prospect wells that constitutes the lithofacies (Chang & Zung, 2017). This facies corresponds to deposits from the channel bottom and infill of the river channel in the lower part (Fea *et al.*, 2022).

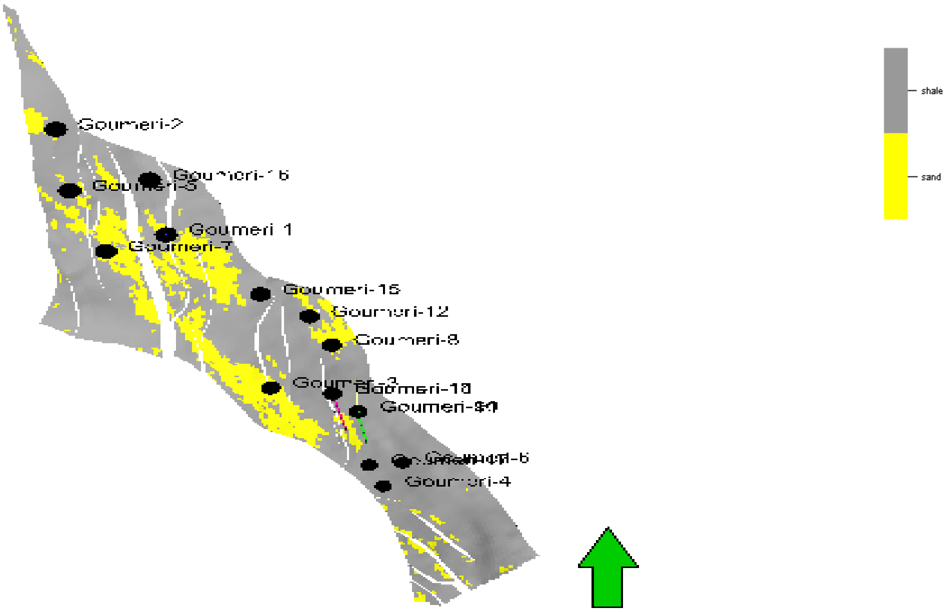

Figure 3. Facial details showing the variation in sedimentation thickness (yellow: sand and black: clay).

2. Porosity model

The porosity model indicates the spatio-lateral variation of porosity of the reservoir unit E1 of the wells of the Goumeri prospect. Within a well the porosity of unit E1 varies according to the lithology and the percentages of the different figurative elements constituting the formation.

According to this model (Figure 4), good porosities (>15.10%) are concentrated in the northeast zone of the prospect (Goumeri wells-6, 8, 12 and 2); low porosities (<10.2%) are concentrated in the eastern zone of the

prospect (Goumeri well-E1,10,11....). This low porosity is explained by the fact that the intergranular spaces of quartz grains are filled by the different types of cement (siliceous, clayey, ferruginous and carbonate).
The model in Figure 5 shows a litho-stratigraphic section of the Goumeri prospect. According to this model, all wells intersect NW-SE direction faults. Thus, the Goumeri-6 well crosses a Normal NW-SE fault.

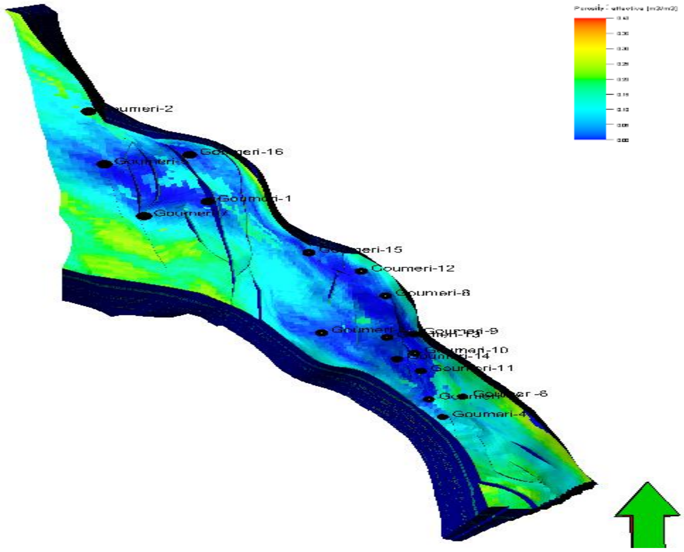

Figure 4. Porosity model showing the spatial distributions of the pressure within the wells of the Goumeri prospect

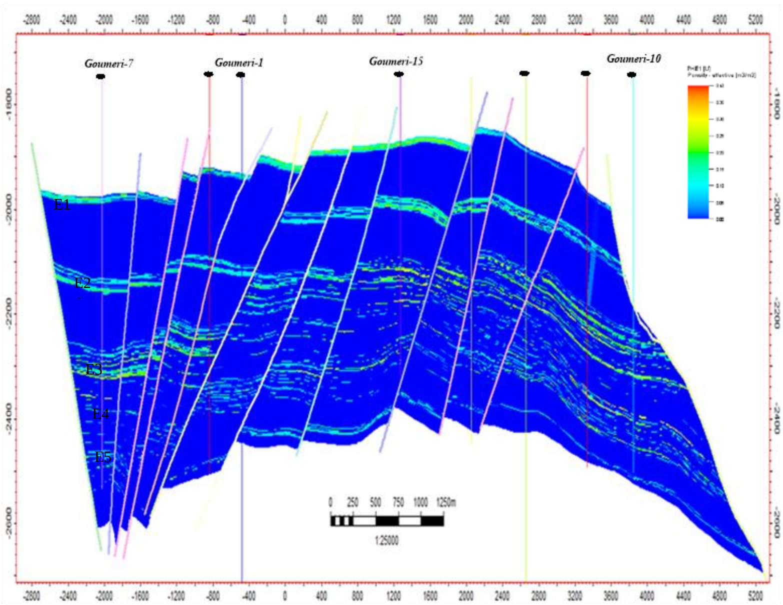

Figure 5. Geological section of the Goumeri prospect showing the porosity of the reservoir units and the normal faults of NW-SE direction.

3. Permeability model

The model in Figure 6 shows the special permeability distribution of the wells of the Goumeri prospect. This model illustrates the concentrations of permeabilities within the reservoir units of the Sokor-1 formation. According to this model, good permeabilities (>,479.3 mD) are concentrated in the northeast zone of the prospect (Goumeri Wells-6, 8, 12 and 2); low permeabilities (<100 mD) are concentrated in the East Zone of the prospect (Goumeri Well E-1,10,11 **...**). This permeability varies in the wells and the different reservoir levels of the Goumeri prospect depending on the mineralogical composition of the rocks

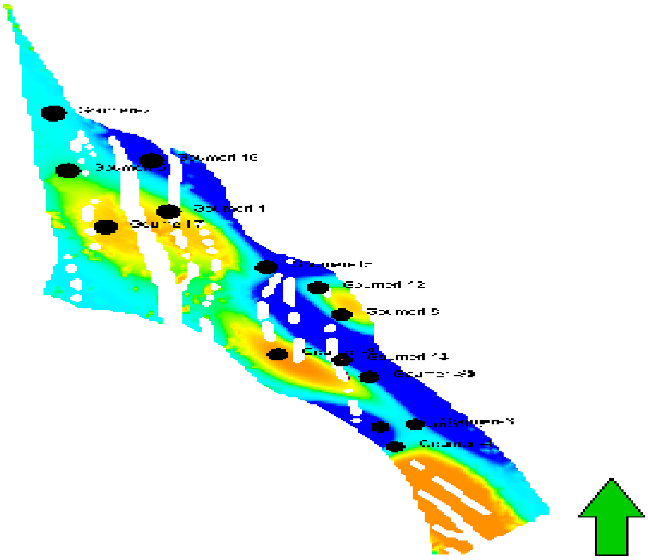

Figure 6. Permeability model showing spatial distributions of permeability within the wells of the Goumeri prospect

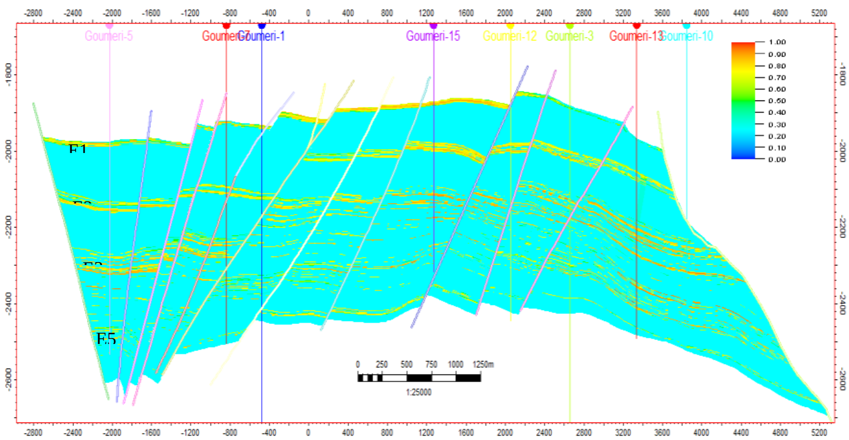

Figure 7. Permeability model showing the distribution of permeability within the reservoir units of the Goumeri well and

Conclusion

The main results of this research work based on the geological modeling of sandstone formations and their petrophysical characteristics at the Goumeri prospect of the Termit basin, have made it possible to understand that:

- Sandstone tank units are compartmentalized in tank units or levels interspersed with clay banks;
- Formation (Sokor-1) corresponds to a period of transgression/regression marked by a contribution of detrital sediments;
- The petrophysical parameters (porosity and permeability) of the reservoir units show good to excellent values (respectively >15.10% and > 479.3 mD) and low water saturation in the northeastern part of the basin.
- Geological models show the geometry and extension of theSokor-1 reservoir formation, according to this model the sandy facies are more concentrated in the center of the basin.

Through this study, the extension and geometry of thesand and clay facies were determined as well as the vertical distribution of the different reservoir levels.

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