[PS]Static Reservoir Modeling of the Valanginian Depositional Sequence of Gamtoos Basin, Offshore South Africa*

Oluwatoyin L. Ayodele[1], Tapas K. Chatterjee[1], and J. M. van Bever Donker[1]

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Abstract

Gamtoos Basin is an echelon sub-basin under the Outeniqua offshore Basin near the South coast of South Africa. Gamtoos Basin is a complex rift type basin with onshore and offshore components, and consists of relatively simple half grabens bounded by a major fault to the northeast. The basin fill comprises organic-rich shale of considerable thickness that is considered responsible for generation of hydrocarbons in this area. This study is mainly focused on formation evaluation of the reservoir heterogeneity of the Valanginian depositional sequence. The prime objective of this work is to generate a 3D static reservoir model for better understanding of the spatial distribution of discrete and continuous reservoir properties (porosity, permeability and water saturation) of the depositional sequence. The methodology adopted in this work includes an integration of 2D-volume seismic data and well log data from six selected wells. These data were used to construct 3D-models of lithofacies, porosity, permeability and water saturation through petrophysical calculation, upscaling, Sequential Indicator Simulation (SIS) and Sequential Gaussian Simulation (SGS) algorithms, respectively. The statistical analysis model revealed that the effective porosity, permeability and water saturation concentration ranges between 8% to 19%, 0.1 mD (< 1.0 mD) to 1.0 mD, and 30% to 45% respectively across the study area from the north to the south in the basin. The result shows that the Valanginian depositional sequence is a potential hydrocarbon bearing reservoir revealed by the water saturation cut-off value, with good to poor porosity and poor permeability from the north to the southern part of the basin.

Static Reservoir Modeling of the Early Cretaceous Valanginian Depositional Sequence, Gamtoos Basin, Offshore South Africa.

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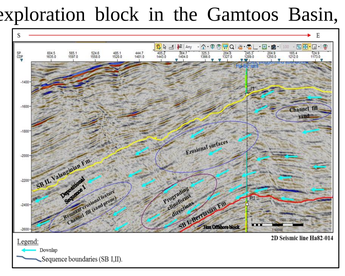
Introduction

- An understanding of uncertainties entailed in reservoir modeling is a crucial tool to support decision making in the petroleum industry.
- The reservoir modeling is an effective technique that plays a major role in assisting reservoir managements for any decision relates with the development and reduction of hydrocarbon reserves, which must be taken into a consideration regards to the uncertainties of the formation involved. In this study, these concepts were applied within an exploration block located in the Gamtoos Basin, offshore South Africa, to contribute an understanding of the reservoir heterogeneity of the hydrocarbon exploration.
- The study focuses on formation evaluation of the reservoir heterogeneity using well log and 2D seismic data respectively.
- Objectively to generated 3D-dimentional static modeling reservoir technique for better insight of the spatial distribution of discrete and continuous reservoir properties of porosity, permeability and water saturation) of the six drilled wells Ha-N1, Ha-I1, Ha-G1, Ha-A1, Ha-K1 and Ha-B2, study from the north to the south in the early Cretaceous (Valanginian) depositional sequences of the basin, by using Petrel Software 2014© and IP "interactive Petrophysics software" work station respectively. Based on this presentation, three wells Ha-G1 Ha-B2, and Ha-K1 from the north to the south shall be focused respectively in the study area.

Study Location and Geology

The study area is within an exploration block in the Gamtoos Basin, Offshore South Africa.

Figure1: Location of Study Area, 2D Seismic lines grids and wells, surface map (Valanginian sequences) acquired offshore Southern Coast, South Africa.



The Figure 2: showing the map window processed 2D seismic line mapped horizon Valanginian sequence (Yellow line) a crossed the well utilized for the interpretation of the surface model for the study area.

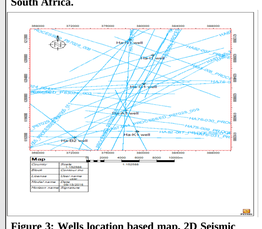


Figure 3: Wells location based map, 2D Seismic lines grids of the study area, acquired offshore Southern Coast, South Africa.

- The Gamtoos Basin, located on the south-east margin of South Africa and extended from onshore areas to the offshore region, covers about 5,038 sq. km, attains a throw of 12km in the distal offshore, the eastern flank of the St. Francis arch along the Southern coast. It is a late Mesozoic basin which lies at the southernmost tip of the African plate (Malan, 1993).
- Its evolution occurred during the late Jurassic and earliest Cretaceous, but has been initiated in the Middle Jurassic (Malan, et al., 1990). The basin is structurally complex and severely faulted as a result of its proximity to the Agulhas-Falkland Fracture Zone (AFFZ) (Broad, 1990; Bate & Malan, 1992).
- It consists of relatively simple half grabens, bounded by a major fault to the northeast and containing comparable thicknesses of sediments. The oldest sediments encountered during the drilling dated to be Kimmeridgian (late Jurassic).
- The early and late rift subsidence sequences of these half grabens consist of thick sediments containing Kimmeridgian-to-Portlandian-to- Hauterivian (D to 6At1) wet gas to oil prone shale with sandstone reservoir potential in the Valanginian.
- In addition, the late rift subsidence during the Hauterivian also enabled deposition of thick sediments of organic-rich shale rock for petroleum generation (Malan, et al., 2009; McMillan, et al., 1997).

Methods

Interpretation & Results

THE PETROPHYSICAL PROPERTIES DETERMINATION

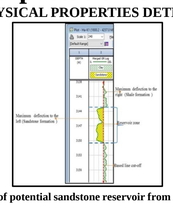
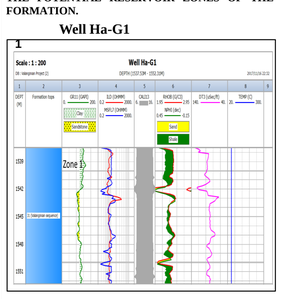
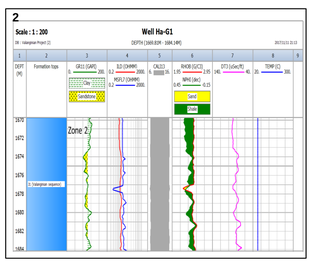


Figure 4: illustrating an example of potential sandstone reservoir from one the well Ha-K1 study area.

THE POTENTIAL RESERVOIR ZONES OF THE SELECTED WELLS STUDY IN THE VALANGINIAN FORMATION.

Well Ha-G1





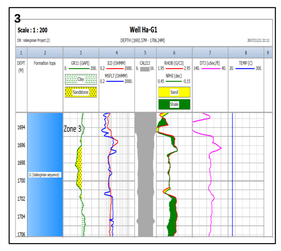


Figure 5 (1-3): Indicate the reservoir zones 1-3 of Well Ha-G1, 1537.53m – 1552.31m, 1669.81m – 1684.14m, and 1692.37m – 1706.24m depths respectively, of Valanginian formation.

Well Ha-K1

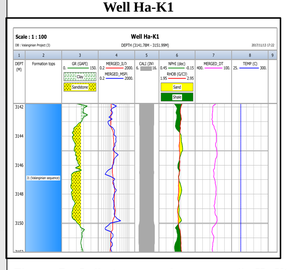


Figure 7: Indicate reservoir zone well Ha-K1, 3141.78m. – 3151.99 m depth of the Valanginian formation.

Well Ha-B2

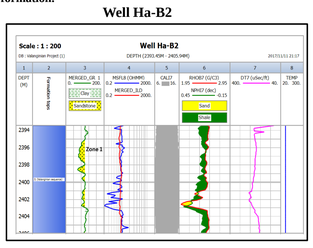
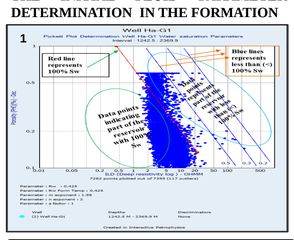
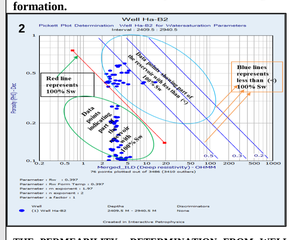


Figure 6: Indicate reservoir zone well Ha-B2, 2393. 45m – 2405.94 m depth of the Valanginian formation.

THE INITIAL FLUID PARAMETER DETERMINATION IN THE FORMATION





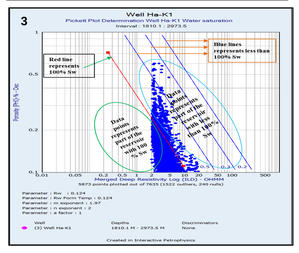


Figure 8 (1-3): Indicate the Pickett plot of Wells Ha-G1, Ha-B2, and Ha-K1, respectively for the fluids parameters of the formation.

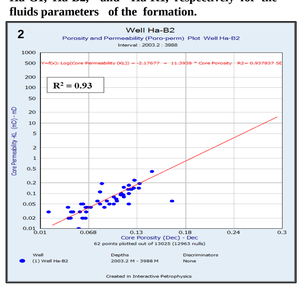
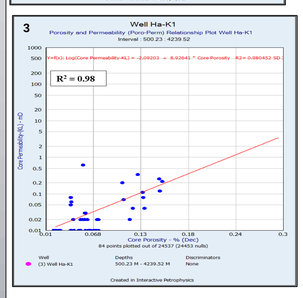
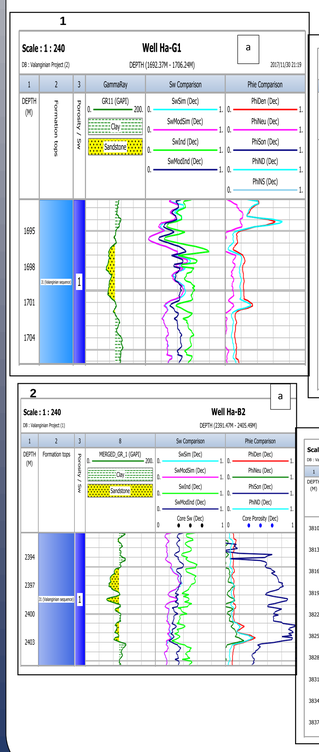


Figure 9 (1-3): Indicate the Porosity versus Permeability (poro-perm) cross plot of well Ha-G1, Ha-B2 and Ha-K1 respectively and regression equations used to calculated the permeability of the formation



THE POROSITY AND WATERSATURATION DETERMINATION FOR THE FORMATION .



THE PERMEABILITY DETERMINATION FROM WELL LOG FOR THE FORMATION OF THE SELECTED WELLS STUDY.

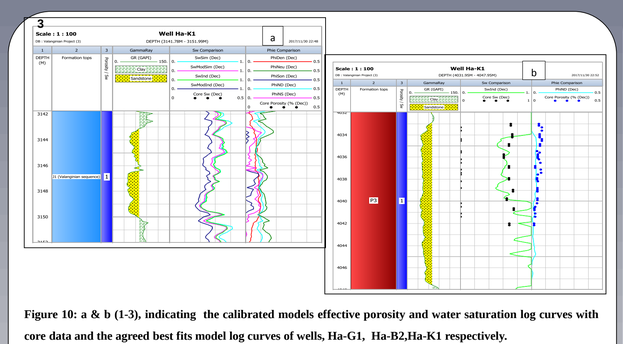
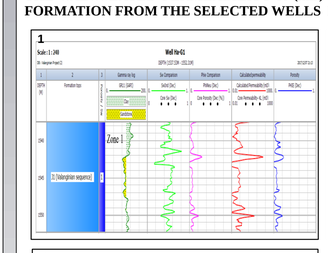
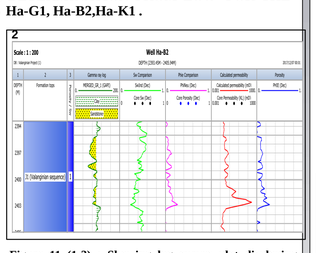


Figure 10: a & b (1-3), indicating the calibrated models effective porosity and water saturation log curves with core data and the agreed best fits model log curves of wells, Ha-G1, Ha-B2,Ha-K1 respectively.

THE CALCULATED PERMEABILITY K (mD) DETERMINATION FROM LOG FOR THE FORMATION FROM THE SELECTED WELLS Ha-G1, Ha-B2,Ha-K1 .





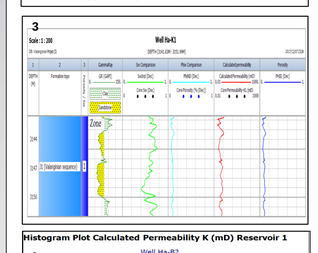
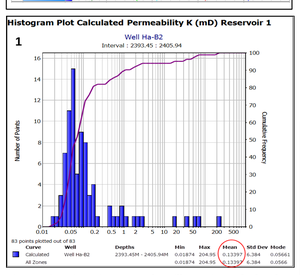
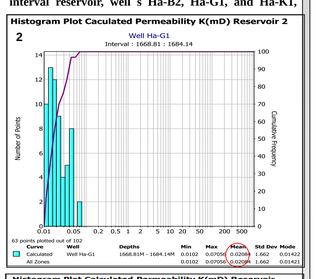


Figure 11 (1-3) ; Showing log curves plot displaying calculated permeability K (predicted K, mD) (track 7) interval reservoir, well s Ha-B2, Ha-G1, and Ha-K1,





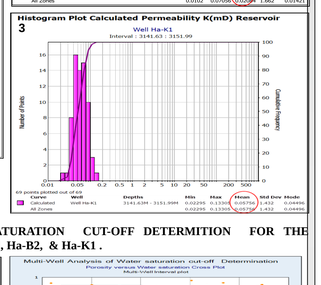
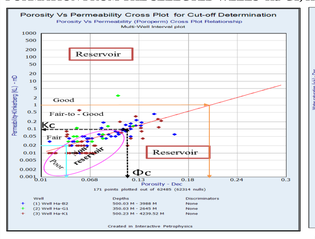


Figure 12 (1-3): Histogram plots illustrating calculated permeability K (predicted K, mD) intervals reservoir of the selected wells Ha-B2, Ha-G1, Ha-K1, respectively.

THE POROSITY, PERMEABILITY & WATER SATURATION CUT-OFF DETERMITION FOR THE FORMATION FROM THE SELECTED WELLS Ha-G1, Ha-B2, & Ha-K1 .



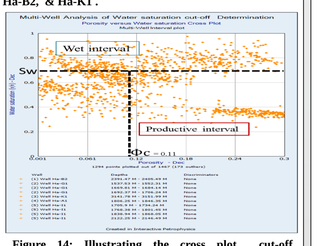
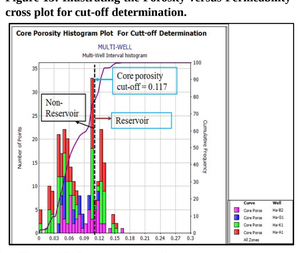


Figure 13: Illustrating the Porosity versus Permeability cross plot for cut-off determination.

Figure 14: Illustrating the cross plot cut-off determination for Multi-well Porosity against Watersaturation.



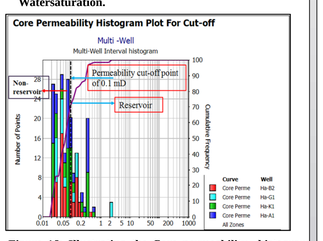


Figure 15: Illustrating the Core porosity histogram plot for the selected wells.

Figure 16: Illustrating the Core permeability histogram plot for the selected wells.

THE 3D RESERVOIR PROPERTY MODEL OF THE FORMATION

THE UPSCALING OF THE PARAMETERS WELL LOG (POROSITY, PERMEABILITY AND WATERSATURATION

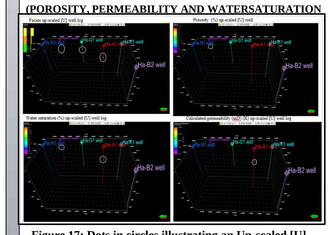


Figure 17: Dots in circles illustrating an Up-scaled [U] well logs parameters along the well path.

THE TIME(ms) STRUCTURE MAP SURFACE MODEL OF THE VALANGINIAN FORMATION.

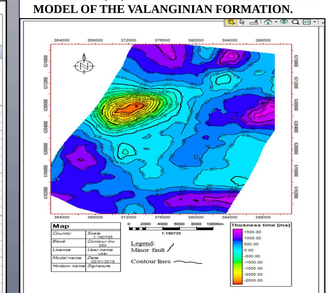


Figure 19: Illustrating the 3D View of the time (ms) structured thickness map model of the Valanginian depositional sequence of the study area.

THE SIMPLE 3D GRID CELLS MODEL

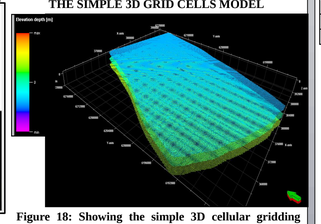


Figure 18: Showing the simple 3D cellular gridding cells (207 *238*21) area built through structural gridding .

THE DEPTH(m) STRUCTURE MAP SURFACE MODEL OF THE VALANGINIAN FORMATION.

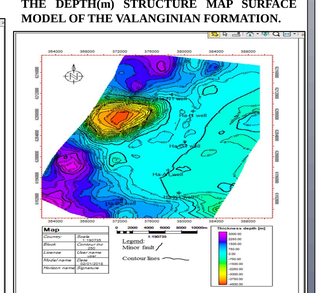


Figure 20: Illustrating the 3D View of the Depth (m) structured thickness map model of the Valanginian sequence of the study area.

THE POROSITY MAP MODEL OF THE VALANGINIAN FORMATION.

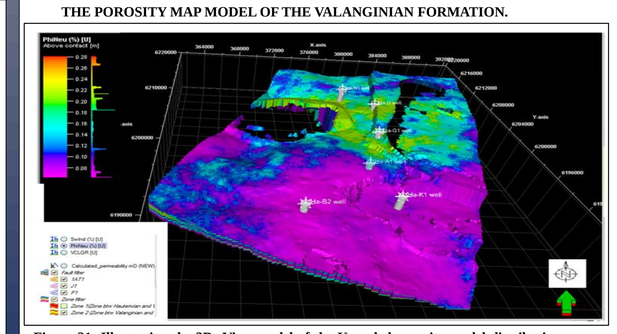


Figure 21: Illustrating the 3D View model of the Upscaled porosity model distributions across the Valanginian depositional sequence of the study area.

THE WATERSATURATION MAP MODEL OF THE VALANGINIAN FORMATION.

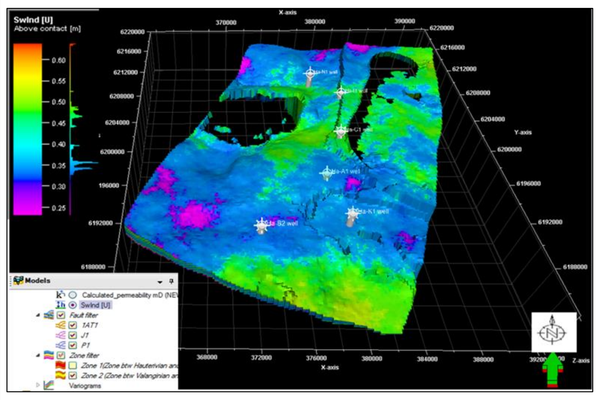


Figure 22: Illustrating the 3D View model of the Upscaled Watersaturation model distributions across the Valanginian depositional sequence of the study area.

THE PERMEABILITY MAP MODEL OF THE VALANGINIAN FORMATION.

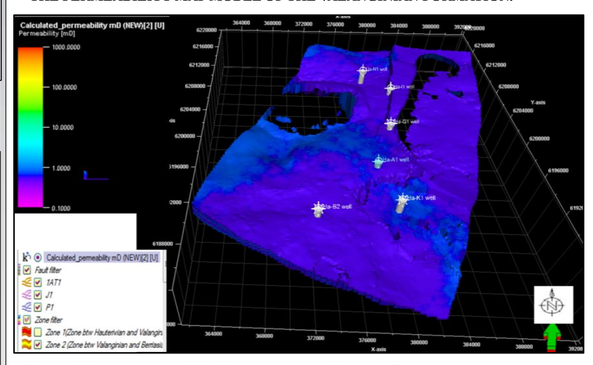


Figure 23: Illustrating the 3D View model of the Upscaled Permeability model distributions across the Valanginian depositional sequence of the study area.

THE LITHOFACIES MAP MODEL OF THE VALANGINIAN FORMATION.

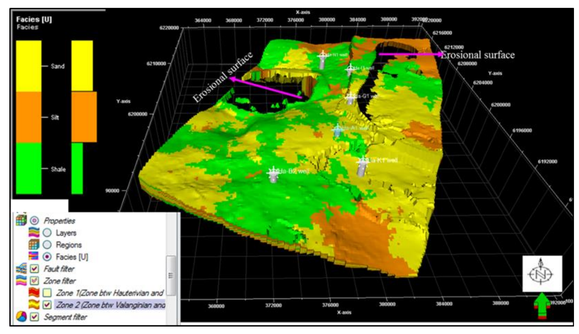


Figure 24: Illustrating the 3D View model of the Upscaled Lithofacies model distributions across the Valanginian depositional sequence of the study area.

Table 1.0: The basic log analysis parameters summary calculated from the standalone picket plots for the fluid saturation parameters of the wells study respectively.

Well name	Top depth (m)	Bottom depth (m)	Rw	m	n	a
Ha-B2	2409.5	2940.5	0.397	1.97	2	1
Ha-G1	1242.5	2369.9	0.425	1.98	2	1
Ha-K1	1810.1	2973.5	0.124	1.97	2	1

Table 2: The Predicted permeability summary result evaluated for the reservoirs of each selected study wells.

Well names	Top depth (m)	Bottom depth (m)	Reservoir/Zones names	Permeability Value (mD)
Ha-B2	2393.45	2405.94	1	0.133
Ha-G1	1537.53	1552.31	1	0.082
Ha-G1	1668.81	1684.14	2	0.020
Ha-G1	1692.31	1706.24	3	0.107
Ha-K1	3141.63	3151.33	1	0.057

Conclusions

- The 3D static reservoir model of the Valanginian formation depositional sequence of Gamtoos Basin, offshore South Africa has been studied for better understanding of the spatial distributions of discrete and continuous reservoir heterogeneity properties of the formation.
- By integrating of 2D-volume seismic data and petrophysical well log data from three selected wells, using Sequential Indicator Simulation (SIS) and Sequential Gaussian Simulation (SGS) algorithms model respectively.
- The statistical analysis model reveal the effective porosity, permeability and water saturation concentration ranges between 8% to 19%, 0.1mD (< 1.0 mD) to 1.0 mD and 30% to 45% respectively across the study area from the north to the south in the basin.
- The result shows that the Valanginian depositional sequence is a potential hydrocarbon bearing reservoir revealed by the water saturation cut-off value, with good to poor porosity and poor permeability from the north to the southern part of the basin.

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