[PS]Integration of Petrographic and Petrophysical Analyses to Characterise Reservoir Quality of Lower Cretaceous Sediments in the Orange Basin, South Africa*

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Abstract

Commercial hydrocarbon production relies on porosity and permeability which is crucial for the storage and flow capacity estimation of the reservoirs. Petrographic and Petrophysical studies over the years has proven to be a reliable approach to assess the quality of the reservoirs. It is upon this basis that a need arises to integrate petrographic and petrophysical well data to study in detail the impact of the clay diagenesis on the quality of the selected sandstone reservoirs. Thus, this study gives first-hand information about the reservoir quality for hydrocarbon producibility. Five wells were studied, and sandstone reservoirs were identified from wireline log curves. Eighty-three sandstone samples were collected from these reservoirs for petrographic analyses within Hauterevian to Cenomanian sequences. Thin section analyses revealed pore restriction by quartz and feldspar overgrowths and pore filling by siderite, pyrite, kaolinite, illite, chlorite and calcite. These diagenetic minerals occurrence has reduced intergranular pore space to almost no point count porosity in well K-A2 whilst in A-J1, A-D1, A-H1 and A-K1 porosity increases at some zones due to secondary porosity. Volume of clay, porosity, water saturation, permeability, storage capacity, flow capacity and hydrocarbon volume were calculated within the reservoir interval. The average volume of clay ranged from 6% to 70.5%. The estimated average effective porosity ranged from 10% to 20%. The average water saturation ranged from 21.7% to 53.4%. Permeability ranged from a negligible value to 411.05mD. Storage capacity ranged from 6.56 scf to 2228.17 scf. Flow capacity ranged from 1.70 mD-ft to 31615.82 mD-ft. Good to very good reservoir qualities were observed in some zones of well A-J1, A-K1 and A-H1 whereas well A-D1 and K-A2 presented poor qualities. We recommend Well K-A2 for reservoir stimulation to increase capacity.

References Cited

Brown, Jr., L.F., J.M. Benson, and G.J. Brink, 1995, Sequence Stratigraphy in Offshore South Africa Divergent Basins: AAPG Studies in Geology, No. 41.

Hill, S., and N. James-Rutledge, 2005, Distribution and Reservoir Quality of Cretaceous Sandstones in the Southern Orange Basin, Offshore West Coast South Africa: Prepared for BHP Billiton, Integrated Reservoir Solutions, Project No. J1164. p. 1-49.

Hirsch, K.K., M. Scheck-Wenderoth, D.A. Paton, and K. Bauer, 2007, Crustal structure beneath the Orange Basin, South Africa: South African Journal of Geology, v. 110/2-3, p. 249–260.

INTERGRATION OF PETROGRAPHIC AND PETROPHYSICAL ANALYSES TO CHARACTERISE RESERVOIR QUALITY OF LOWER CRETACEOUS SEDIMENTS IN THE ORANGE BASIN, SOUTH AFRICA.

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Introduction

This study assesses reservoir rock properties (such as mineralogy, porosity, permeability and saturation) of the Lower Cretaceous sediments to predict reservoir quality, estimate storage, flow capacity and estimates hydrocarbon reserves. This work was encouraged by Hill and James-Rutledge (2005) who observed that Cretaceous reservoir properties are poor and can inhibit hydrocarbons flow capacity due to quartz overgrowth and Illite cementation that occurred during diagenesis with increasing burial depth of the sediments. To unravel these sedimentological effects this work engage the integration of quantitative petrographic analyses (Thin sections and SEM) and petrophysics to characterize the quality of the reservoir rocks and determine the effect of mineralogy on reservoir properties.
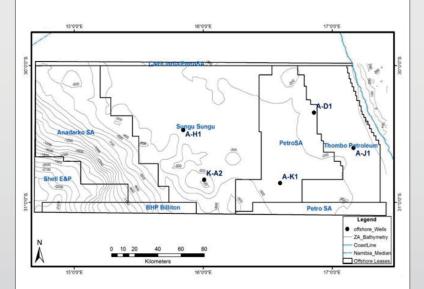
Study Location And Geology

Figure1: Map showing the location of the study area with the wells selected for this study.

The study area is situated within the Orange Basin in the West Coast of South Africa. Water depth varies from 175m to 2300m in the deep locality. This study focuses on A-D1, A-J1, K-A2, A-K1 and A-H1 wells.

The Orange Basin is a typical passive margin and owes its origin to breakup of the African craton from Gondwana land, followed by rifting and drifting of the African and South American plates that resulted in the opening of the South Atlantic Ocean during Jurassic / Early Cretaceous and the generation of oceanic basement (Brown et al., 1995) Hirsch et al., 2007 observed that the stratigraphic record in the basin ranges from the lithospheric extension and rift tectonics throughout a fully evolved post-break-up setting. The stratigraphy comprises a pre-rift successions (older than Late Jurassic, >~130Ma), that is overlain by syn-rift deposits of Late Jurassic to Hauterivian age (~121 to ~117.5Ma), and in turn by sediments of early drift stages up to Aptian age (~113 to ~103Ma) (Figure 2) (Hirsch et al., 2007).
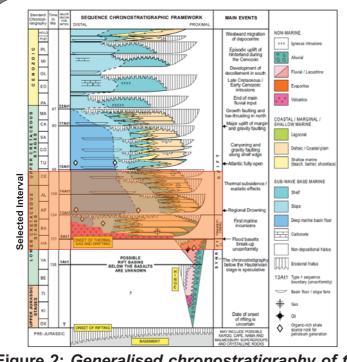

Figure 2: *Generalised chronostratigraphy of the South African offshore Mesozoic basins (Broad et al., 2005), with the indication of target interval in this study.*

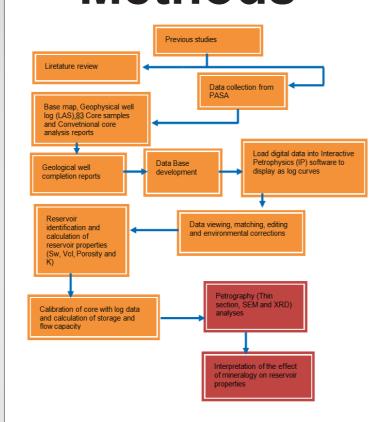# Methods

Figure 3: The flow chart of the research methodology.

Permeability determination
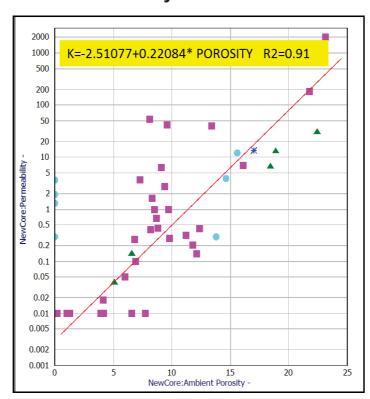

K=-2.51077+0.22084* POROSITY R2=0.91

Figure 4. Multi-well crossplot of porosity vs permeability cross plot.
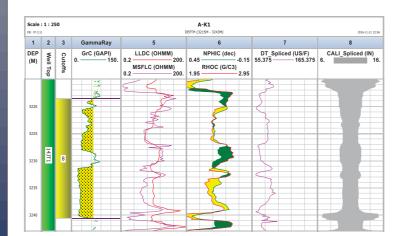
Results

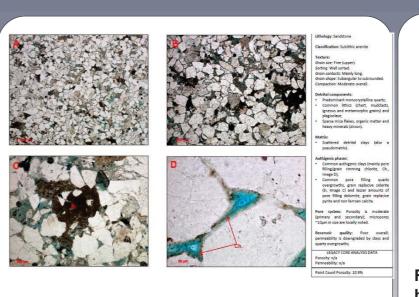**Figure 5:A-K1 selected reservoir interval between 3219 – 3241 m in the post-rift (Albian age) sequence.**

Figure 6: Thin-Section micrographs of A-K1 sandstone at 3236m (A: 1000µm, B: 500µm, C: 200µm and D: 50µm), φ = 10.9%, k = 40mD.
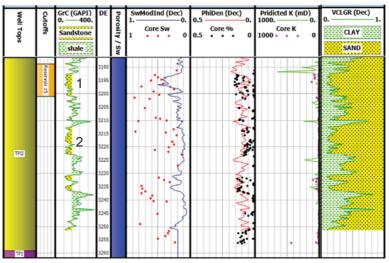

Figure 7: calibration of wireline log with core data in AJ1 well.

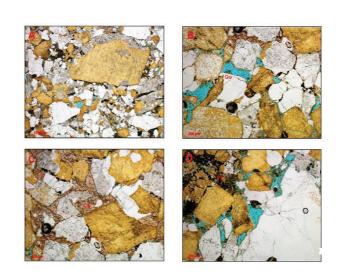**Figure 8:Thin-Section micrographs of AJ-1 sandstone at 3215.29m (A: 1000µm, B: 500µm, C: 200µm and D: 200µm), φ = 9.1%, k = 6.3mD.**
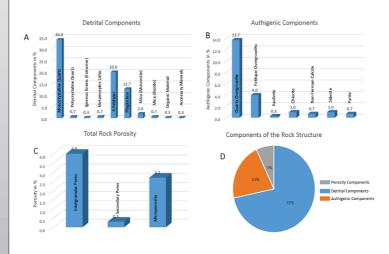

Figure 9:AJ-1 sandstone at 3215.29m, total rock constituents composed of (A) detrital components, (B) authigenic components, (C) rock porosity and (D) aggregate of rock structure.
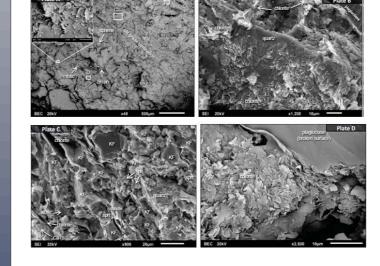

Figure 10:SEM micrographs of AJ-1 sandstone at 3195.35m showing detrital and authigenic minerals occurrences: Quartz and plagioclase (B,D), Chlorite pore filling (B,D); feldspar overgrowths (C). Zircon occurrence (A).
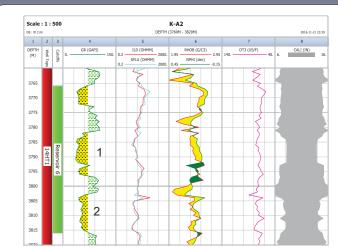

Figure 11: K-A2 selected reservoir intervals between 3765 – 3815 m in the post-rift (Albian age) sequence.
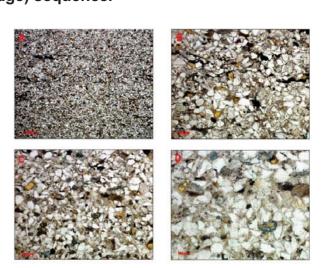

Figure 12: *Thin-Section micrographs of K-A2 sandstone at 3810m (A: 1000µm, B: 200µm, C: 200µm and D: 100µm), φ = n/a, k = n/a.*

Table 1. Petrophysical summary results of the selected reservoirs.

Well ID	Zone Name	Top (m)	Bottom (m)	Gross (m)	Net (m)	Porosity (%)	Permeability (mD)	Water saturation (%)	Volume of clay (%)
A-K1	8	3219	3241	22	10.8	10.1	64.83910.8	45	33
A-J1	1	3188	3201	12.2	5.64	14.1	6.35	55	28.3
A-J1	2	3213	3223	11	5.01	14	0.8	35	34
K-A2	1	3782	3797	15	-	2	negligible	60	72
K-A2	2	3803	3815	12	-	-	negligible	59	70
A-D1	1	2906	2920	13.7	0.88	20.8	0.31	42	31.4
A-H1	1	2790.6	2872.8	82.2	2.28	24	2.37	44.8	29.9

Table 2. Summary results of the calculated flow and storage capacity.

Well ID	Zone Name	Net (m)	Net (ft)	Porosity (%)	Storage Capacity (scf)	K (mD)	Flow Capacity (mD-ft)
A-K1	8	10.8	35.4	10.1	357.54	64	2265.6
A-J1	1	5.64	18.5	14.1	260.85	6.35	89.5
A-J1	2	5.01	16.4	14	229.6	0.8	13.1
K-A2	1	2	6.5	2	13	-	-
K-A2	2				-	-	-
A-D1	1	0.88	2.88	20.8	59.9	0.31	0.89
A-H1	1	2.28	7.5	24	180	2.37	56.3

Conclusions

❑ Thin section analysis from the cored reservoirs revealed 60 – 80% major contributions of detrital mineralogy that constitutes quartz (monocrystalline and polycrystalline), lithics (Igneous, metamorphic and sedimentary), mica (muscovite and biotite), feldspar, plagioclase, organic material, Accessory grains (such as zircon) and detrital clay.

❑ Porosity and permeability reduction of these reservoir rocks was caused by diagenetic mineral occurrence that accounted 13 – 24 % to the total rock.

❑ Well A-K1 proved to have the best reservoir rock whereas A-K2 proved to have the poor reservoirs

References

Brown, L.F. Jr, Benson, J.M. & Brink, G.J. 1995: Sequence Stratigraphy in Offshore South Africa Divergent Basins. American Association of Petroleum Geologists, Studies in Geology, 41.

Hill, S and James-Rutledge, N., 2005: Distribution and Reservoir Quality of Cretaceous Sandstones in the Southern Orange Basin, Offshore West Coast South Africa. Prepared For BHP Billiton. Integrated Reservoir Solutions. Project No. J1164. 1 - 49.

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