TECHNICAL AND ECONOMIC EVALUATION OF NATURAL GAS RESOURCES FROM CAMPANO-MAASTRICHTIAN NKPORO SHALE OF ANAMBRA BASIN/LOWER BENUE TROUGH

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CERTIFICATION

I certify that this work was carried out by Mr. H. O. Igwilo in the Department of Petroleum Engineering, University of Ibadan, Nigeria.

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ABSTRACT

Nigerian gas reserves is currently characterised by high production/reserves ratio due to increasing demand from liquefied natural gas, power generation plants and other industrial users. There has been increasing efforts at identifying new opportunities for conventional and/or non-conventional gas reserves. The Campano-Maastrichtian Nkporo shale is one of the potential sources of non-conventional gas reserves in Nigeria. Despite geological, geophysical and geochemical evaluations that have been carried out and published, there is sparsity of data on the reserves, engineering, and petrophysical parameters required for possible development and production. This study was designed to obtain engineering and petrophysical data, evaluate the resource volumes and producibility of Nkporo shale gas and to formulate appropriate technical and economic strategies for the development and production.

Published geochemical evaluation results were obtained from literature and interpreted. Log suites and other data such as sidewall cores and bottom hole temperatures were obtained from five wells: Alo-1, Anambra River-2, Ogbabu-1, Oda River-1, Akukwa-2; which were earlier drilled, logged and tested. Engineering and Petrophysical evaluations of the well logs were undertaken to obtain geothermal profiles, porosity, permeability, fluid saturations, compressibility and compressive stresses. The initial in-place volumes, fracturability and producibility of the shale gas were estimated using petroleum industry standard procedures. Data were benchmarked with similar shale systems in USA and Australia. Net Present Value (NPV) and Return On Investment (ROI) were determined at different operating and economic conditions.

Nkporo shale has Total Organic Carbon (TOC) ranging from 0.40 to 3.01 wt % with low average Hydrogen Indices revealing kerogen type III and mixed III/II that is predominantly gas prone. Multiple temperature profiles exist within the formation with gradients ranging from 0.0043-0.0366 ^{o}C/m (0.0142–0.1200^{o}C). Porosity ranges from 5.0–28.1 % while effective permeability ranges from 0.0–95.5 millidarcy. Water saturation ranges from 0.70–0.99. The original gas in place was established at 2.93 million m^3 per km^2 (268.69 BCF/640-acre well spacing) with the potential to increase to 7.33 million m^3 per km^2 (685 BCF/640-acre well spacing). Vertical and horizontal compressive stresses range from 4.6–5.27 and 2.41–2.77 x 10^7 N/m^2 (6673–7646 and 3498–4008 psia) respectively. Maximum production requires high conductivity linear hydraulic fracturing using 20/40 mesh size fluid, and 305 m (1000 feet) fracture length per section of well spacing. The properties of Nkporo shale compared well with some established shale-gas formations in the USA and Australia. Developing the gas reserves profitably requires dual completions to achieve high well off-takes. For wells drilled and completed at $10,000/m and at recovery factors between 10-50 % and gas price of $2.50/MM Scf, NPV varies between 0.0287–0.1420 billion dollars per 640-acre spacing while ROI ranges between 0.43-52 % for interest rates between 10-30 % with development incentive ranging between 1-10% for investors.

There is scope for additional gas reserves from the Campano–Maastrichtian Nkporo shale within the Anambra Basin/Lower Benue Trough. This may apply to other similar shale formations in Nigeria.

Keywords: Shale gas development, Petrophysical evaluation, Hydraulic fracturing, Nigerian gas reserves.

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Above all; I want to give special thanks and all the glory to our Almighty Creator and beloved God who owns and does this Project in Jesus name; Amen.

DEDICATION

To God be the Glory for accepting and supporting me throughout this project.

ABREVIATIONS

Symbol	Description	Unit
TCF	Trillion Cubic Feet	
Gi	Initial Gas in Place	TCF
Ni	Initial Oil in Place	Barrels
D	Depth under Sub-surface ref	FTss
T	Temperature	^{o}F
BHP	Bottom Hole Pressure	Psi
AGV	Associated Gas Volume	TCF
NAGV	Non Associated Gas Volume	TCF
Fm	Formation	
Grp	Group	
SS	Sand Stone	
MFS	Maximum Flood Surface	
SB	Sequence Boundary	
HST	High Stand System Track	
TST	Transgressive System Track	
LST	Low Stand System Track	
MST	Medium Stand System Track	

K_f	Permeability of proppant, md	md
wKf	Conductivity of fracture	md-in
J/Jo	Productivity index ratio(after/before)	
r_e	Drainage radius of well	ft
rw	Well radius,	ft
Cr	Dimensionless fracture Conductivity	
LR	Dinensionless fracture lenght from wellbore	
σh	Total horizontal Stress	Psi
σv	Total vertical Stress	Psi
Q_D	Dimensionless Rate	
K	Permeability	md
T(t)	time	hrs
Ø	Porosity	%
Ct	Total compressibility	Psi^{-1}
X_f	Lenght of one wing of Fracture	ft
t_D	Dimensionless time	
Q	Cumulative Production	mcf
Xe	Distance to drainage boundary	ft
KG6	1.3597*10^-6	

DENS	Layer density from log	gm/cc
KV4	0.000043560	
Sg	gas saturation	%
Sw	water saturation in un-invaded zone	%
Bg	gas formation volume factor	Scf/stb
TAV	Total Assets value	Naira(₦)

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