SEISMIC FACIES ANALYSIS AND HYDROCARBON POTENTIAL EVALUATION OF PARTS OF ORANGE BASIN, OFFSHORE SOUTH AFRICA

AyobamiABEGUNRIN

(SCP13/14/H/2457)

B.Sc. (Hons.)Geology, OAU.

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CERTIFICATION

This is to certify that this work was carried out by **ABEGUNRIN Ayobami** (SCP13/14/H/2457)in the Department of Geology, Faculty of Science, Obafemi Awolowo University, Ile-Ife. The M.Sc. thesis has been assessed and approved by us.

Dr. S. A. Adekola

(Supervisor)

Dr. S. A. Adekola

(Chief Examiner)

(Date)

(Date)

DEDICATION

All lives are precious but those that end suddenly and too soon are remembered forever in a special place in our minds and hearts. This research work is dedicated to the loving memory of one of those lives. His name is Raph Ogunwale (April 12, 1975 to February 14, 2004). He will be continually missed.

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ABSTRACT

The study identified, mapped and named all the depositional sequences defined on the seismic data, described each sequence in chronostratigraphic order, produced a regional/local scale characteristics of each sequence, described the seismic facies properties of each identified sequences and analyzed maps for closures that poses efficient trapping style for hydrocarbon accumulation. This was with a view to assessing the hydrocarbon viability of each of the depositional sequences.

The study materials which included a set of processed 2-D seismic, core, biostratigraphic as well as a suite of composite well log data were analyzed using Petrel version 2009 and IHS Kingdom Advanced software. Structural and seismic sequence stratigraphic framework were developed and used as input for seismic facies interpretation. Reflection attributes were used to discriminate between different seismic facies. A structure map was generated for surface of interest and analyzed for closures capable for holding hydrocarbon. The hydrocarbon potential of each depositional sequence were then assessed and integrated into the regional dip line so as to make predictions beyond the study area.

Ten (10) seismic sequences (sequences B through K) representing either individual or composite depositional sequences were delineated within a spectrum of environments and their regional/local scale characteristics described in chronostratigraphic order. Seismic interpretation revealed NE-SW and NW-SE trending faults which terminated against major sequences boundaries notably the 22At1 and 15A2t1 surfaces. All the mapped sequence boundaries were relatively continuous except for where they were truncated by erosion and they also exhibited strong reflections which qualified them as major stratigraphic markers. No well penetrated sequence K and little was deduced about its hydrocarbon potential. Sequences J, I and H

represented a composite transitional to drift successions. They contained facies that were potentially important reservoir rocks (sequence J) and condensed sections (Aptian shale of sequence I) that included significant source rocks known to be responsible for most of the hydrocarbon generation within the basin. The structure map for the top of sequence J revealed a fault dependent closure with an areal extent of about 50 km^2 and the inter-bedded shale within this sequence serves as prospective seal. Sequences G and F contained essentially no mature source rocks and reservoir quality sands but constituted a regional seal within the study area. Sequences E, D, C and B represented a drift succession characterized by argillaceous sediments in which there were no interval of organic enrichment and reservoir potential combinations. Careful integration of present work into the regional dip line enabled the correlation of seismically interpreted sections into the bathyal region of the basin. This region may represent frontier area for future exploration works.

The study concluded that the deeper portion of the Orange Basin correlated to the identified distinct depositional sequences could be more viable for hydrocarbon prospectivity within the basin.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Asthesearch for hydrocarbon is becomingincreasingly more difficult and expensive, the history of petroleum exploration and exploitation has shown that there will always be enough possibilities of finding more oil and gas, if more accurate exploration techniques are employed in the right place. Even as more exploratory works move deeper offshore into the deep and ultra-deep waters, sequence stratigraphy and carefully calibrated seismic facies mapping haveturned out to be among such extraordinary helpful techniques in identifying exploration prospects and predicting reservoir and seal quality in both stratigraphic and structural prospects. The former attempt to recognize genetically related volumes of strata, deposited during discrete intervals of geologic time while the latter involves interpretation of depositional facies from seismic reflection data. Combining these tools provides the potential to define mappable volumes of lithofacies deposited in genetically depositional system, which enable geologists to reconstruct basin evolution as a function of sea level, subsidence and sediment supply (Houseknecht and Schenk,1999).

This approach involves the integration of seismic data, well logs, high resolution biostratigraphic data, core and outcrop data for provision of chronostratigraphic framework for the analysis, correlation and mapping of sedimentary packages. It encompasses the identification of the key bounding surfaces, systems tracts, depositional sequences and sedimentary cycle deposition; assigning ages tothe identified key bounding surfaces as well as correlating genetically related chronostratigraphic surfaces (Reijers*et al.,*1996, Van Wagoner *et al.,* 1987, 1988).

This technique of seismic facies analysisis generally believed to give oil companies a competitive advantage and substantially reduce their risk in bidding offshore blocks by allowing them to properly evaluate new and previously-leased blocks (Vail and Wornardt, 1990). Seismic facies analysis provides a logical and useful aid in exploration ranging from frontier areas with limited well control to exploration in mature areas with many wells, and production applications (Sangree*et al.,* 1990).Frontier area exploration uses include identification of the age of strata and the extension of limited well and outcrop control into the subsurface to define plays, locate stratigraphic prospects and to predict reservoir and seal quality on structural prospects while mature exploration areaapplications includerecognition of detail stratigraphic trap prospects in regions where the potential for larger structural traps are largely exhausted.

The Orange Basin, which is the focus of this study, covers an area of roughly 145,000 km^2 (Gerrard and Smith, 1982) and has roughly one well drilled for every 4000 km^2. The basin has proven hydrocarbon reserves and potential for further discoveries and thus, it is of critical importance to assess the petroleum potential of the region.

The search for an appropriate representation of petroleum reservoirs using seismic, well log, core data and pattern recognition skills has been the subject of several scientific publications (Dumay and Fournier, 1988; Schultz *et al.*, 1994; Fournier and Derain, 1995, Walls *et al.,* 1999; Johann *et al.,* 2001; Saggaf*et al.*, 2003). There is, therefore, the need to carry out detailed seismic facies analysis of seismic volumes for the purpose of identifying petroleum systems and exploring its implications on petroleum potentialsin the Orange Basin, offshore,South Africa.

1.2 SEISMIC OVERVIEW

Seismic exploration for oil and gas utilizes the fact that elastic waves travel with different velocities in different rocks. The principle is to initiate such waves at a point, then detect and record at a number of other points, the time of arrival of energy using different acquisition geometries. The recorded energy is partially reflected by the discontinuities between different rock formations. This enables the positions of the discontinuities to be deduced. Discontinuities of exploration interest are interfaces between different types of rocks. These include faults, unconformities, anticlines, channels, pinch – outs anddiapir structures which constitute locations (traps) favourable for hydrocarbon accumulation (Neves*et al.,* 2004).

Hydrocarbon habitats of the geological provinces of the world are associated with structure and stratigraphy found in sedimentary basins, compressional (thrust fold belts) and extensional provinces (rifted areas), and strike-slip regimes. These habitats (high impedance, low impedance, clean and unclean formations) are characterized by linear displacement of rock forms generally called faults. The faults constitute traps, which, in turn, become reservoir rocks when fluids arising from chemical decomposition of organic matter at depth (source rock) are impeded from further movement by a barrier (cap rock) after accumulation. The nature of the reservoir rock formed is dependent on the play fairways and petroleum systems of the geological province concerned. The reservoirs are, on the basis of scale, classified as structural (anticline, syncline, mega – fault) or stratigraphic (reef i.e. skeletal remains of coral, algae or similar shallow water organisms,