Journal of African Earth Sciences 99 (2014) 517–528

Contents lists available at ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

Stratigraphy and reservoir quality of the turbidite deposits, western sag, Bohai bay, China P.R.

Oluwatosin J. Rotimi [a,b,*], Bankole D. Ako [c], Wang Zhenli [b]

[a] Petroleum Engineering Department, Covenant University, Ota, Nigeria
[b] Key Laboratory of Petroleum Resources, Institute of Geology and Geophysics, Chinese Academy of Science, Beijing, China
[c] Department of Applied Geophysics, Federal University of Technology, Akure, Ondo State, Nigeria

ARTICLE INFO

Article history:
Received 19 June 2013
Received in revised form 9 May 2014
Accepted 17 May 2014
Available online 13 June 2014

Keywords:
Modeling
Turbidites
Stratigraphy
Electrofacies
Alluvial fan
Hydrocarbon

ABSTRACT

Stratigraphic and subtle reservoirs such as pinchouts, sand lenses and unconformities have been discovered in Bohai basin. These reservoirs occur in sub-basins and sag structures called depressions. A prolific depression is the Liaohe depression that has been filled with rapidly changing mixed alluvial fan deposit of the Cenozoic age. Attempts made at recovering residual hydrocarbon from the subtle reservoir have necessitated the re-evaluation of available data to characterize and model the prolific Shahejie Formation turbidite deposit occurring as pinchouts and sand lenses for hydrocarbon assessment, reservoir quality and possible recovery through enhanced methods. Methods employed covered well logs analysis, clustering analysis for electrofacies and fuzzy logic analysis to predict missing log sections. Stratigraphic and structural analysis was done on SEGY 3D seismic volume after seismic to well tie. Stochastic simulation was done on both discrete and continuous upscaled data. This made it possible to correctly locate and laterally track identified reservoir formation on seismic data. Petrophysical parameters such as porosity and permeability were modeled with result of clustering analysis. Result shows that electrofacies converged on 2 rock classes. The area is characterized by the presence of interbeded sand-shale blanket formations serving as reservoir and seal bodies. The reservoir quality of the formations as seen on the petrophysical analysis done is replicated in simulation volume results. Reservoir rocks have porosity between 0.1 and 0.25, permeability between 1 and 2mD and hydrocarbon saturation as high as 89%. Lithofacies are observed to be laterally inconsistent, sub-parallel to dipping and occurring as porous and permeable continuous beds or pinchouts hosting hydrocarbon. The stochastic stratigraphic model depicts rock units in associations that are synsedimentary. The prevalent configuration gotten from the model gave an insight into exploring and developing the field for enhanced oil recovery of the heavy hydrocarbon of this area.

1. Introduction

The Bohai bay is the edge of the area collectively called Bohai basin. It is a Cenozoic extensional basin along the eastern flank of Northern China as shown in Fig. 1 (Allen et al., 1997). The basin opened up between the younger Cretaceous and Oligocene. These created the parallel basins offshore and onshore. The age of the initial rifting becomes increasingly younger from east to west which makes for Paleocene-Eocene classification for the sub-basins of Bohai basin (Hu et al., 1989; Zhang et al., 1989, Zhiwu et al., 1989; Allen et al., 1997). Bohai basin is second in oil production after Songliao amongst China basins. The tectonic control on this marginal basin was probably subduction roll-back along the pacific plate relative to the eastern margin of Asia (Watson et al., 1987; Northrup et al., 1995 and Allen et al., 1997). The basin has rhombohedral central area and narrow extension trending northeast and southwest. The major sub-basin (Jizhong, Huanghua, Bozhong, Liaohe depression, Linqing depression and Jiyang depression) are initiated by four major internal uplifts (Chengning, Cangxian, Nichuang and Xingheng) as documented in Allen et al., 1997; Liu, 1989.

The various sub-basins and depressions earlier mentioned accepted deposits from older pre-rift strata which have been in turn conformably or unconformably overlaid by recent sediments. Allen et al., 1997, reports that Cenozoic successions of the basin can be divided into 6 Formations with Shahejie formation as the most hydrocarbon prolific. Shahejie formation has 4 members;

* Corresponding author at: Petroleum Engineering Department, Covenant University, Ota, Nigeria. Tel.: +234 8034299349.
E-mail addresses: oluwatosin.rotimi@covenantuniversity.edu.ng, tossynrotimmy@yahoo.com (O.J. Rotimi).

http://dx.doi.org/10.1016/j.jafrearsci.2014.05.010
1464-343X/

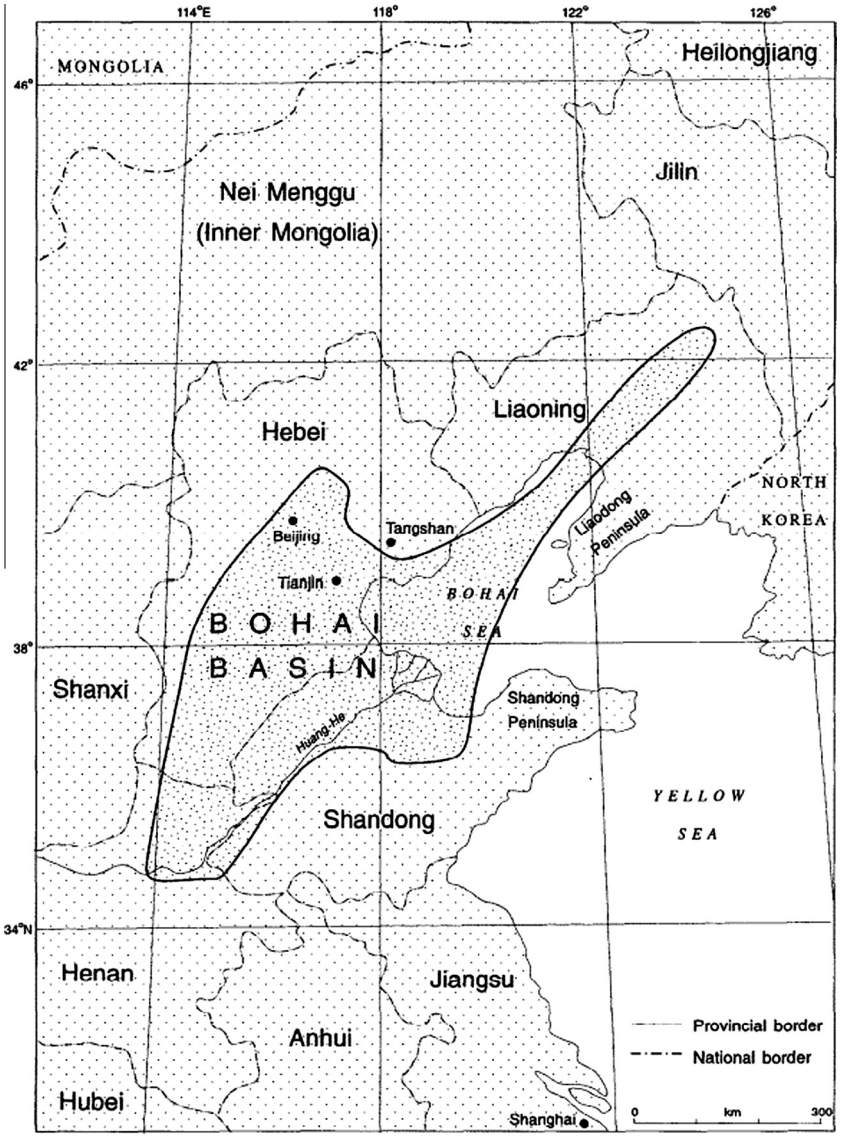

Fig. 1. Regional setting and location of Bohai basin (Allen et al., 1997).

Sha-1, Sha-2, Sha-3 and Sha-4, with Sha-2 and Sha-3 identified, encountered and studied in this work. The Shahejie formation on the average is 2500 m thick, it is a regression deposit probably formed in the time of decrease in tectonism. The upper Sha-2 is a fluvial-deltaic and shallow lacustrine deposit while the lower Sha-3 is characterized by deep water lacustrine with turbidites and Alluvial fan/deltaic sand sediments. They are both composed of organic rich lithified mud rock (shale), fine grained clastics (silts), sandstone and conglomeratic sandstones. Depositional induced association of the above sediments types is responsible for the subtle sandstone reservoirs of the Sha2 and Sha3. The 6 Formations has its' definition averse to standard international definition of stratigraphic units. This is because rock units in this sag structures are not ubiquitous but they include wide varieties of lithologies in different part of the same sag (depression). For instance, the third member of the Shahejie Formation (Sha-3) which is one of the prolific reservoir units contains rocks as diverse as lacustrine turbidite, sub-aerial alluvial fan conglomerates amidst silts and argillaceous rocks within single sag (Yan, 1990).

Over the years and especially in large hydrocarbon basins of China (Songliao and Bohai bay basins), some stratigraphic and subtle reservoirs were also discovered which has necessitated further study and subsurface modeling of reservoir lithologies especially in intra-cratonic basins (Guangming and Quanheng, 1982; Hu et al., 1984, 1986; Chengzao and Yinglin, 2004). Understanding the characteristic diversity observed in these sag deposits for reservoir and non-reservoir rocks is therefore the problem of exploration activities in this area. It is believed that this Tertiary syn-rift strata form the major hydrocarbon source rocks of the basin which are contemporaneous within the rifting. They are also the target for future oil and gas onshore exploration.

Turbidite sequences characterize alluvial fan settings. The Turbidite Cenozoic deposits of the western sag structure in the Bohai bay has been characterized for stratigraphy and reservoir quality. Making use of core data from a centrally located well, petrophysical property for other well locations has been predicted. The result logs constituted part of data used for clustering operation targeted at reflecting the stratigraphy of the deposits and also to match the reservoir quality for exploration purposes. Post-stack seismic volume data assisted in laterally delineating the rapidly changing rock units and also in revealing the prevalent synsedimentary structural pattern (Owoyemi and Willis, 2006; Tong et al., 2008, Bao et al.,