Journal of African Earth Sciences 112 (2015) 150–162

Contents lists available at ScienceDirect

Journal of African Earth Sciences

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

An overview on selected Middle Miocene slope channel complexes, offshore east Nile Delta of Egypt

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A R T I C L E I N F O

Article history:
Received 28 March 2015
Received in revised form
23 August 2015
Accepted 16 September 2015
Available online 26 September 2015

Keywords:
Miocene
Turbidite channels
Seismic interpretation
Offshore Nile Delta

A B S T R A C T

Middle Miocene turbidite channel reservoirs offshore Nile Delta of Egypt are difficult to develop efficiently. The depositional mechanism of these channels defines sand bodies with variable thickness and quality over short distances.

Akhen Field is a turbidite high pressure and high temperature reservoir offshore in the East Nile Delta, Egypt. The turbidite deposits at Akhen area reflect varied depositional fabrics from poorly to moderately sorted and non-graded to graded. Well logs and core data suggest at least 3 sand packages in a cyclic pattern. Each package exhibits variable sedimentological and petrophysical properties and forms a separate reservoir, sealed by shale.

A conceptual geologic model showing facies geometry based on 3D seismic mapping and core analysis was used for evaluation of the reservoir quality of the Field. Integrating sedimentologic and other subsurface data such as seismic attributes, pressure data, core analysis, was crucial to predict the fluid flow between the different reservoir units.

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1. Introduction

Turbidite reservoirs are one of the most significant targets of deep-water hydrocarbon exploration worldwide (e.g. offshore Gulf of Mexico, Angola, Egypt, Brazil … etc.). Recent exploration activities and application of advanced technologies resulted in understanding of the depositional architectures and facies distribution of the turbidite reservoirs.

Despite drilling and development challenges associated with pre-Pliocene prospects offshore Nile Delta of Egypt, Middle Miocene reservoirs are considered to have the greatest potential for hydrocarbon exploration (Dolson et al., 2001). These challenges are low-resolution of seismic data due to the masking effect of the overlying Messinian evaporites, overpressure due to thick overlying rock column, and limited number of drilled wells. Middle Miocene turbidite reservoir geometries, interpreted from 3D seismic data, are critical for future development of this area, particularly where the well data is missing. The best examples of these reservoirs are the Akhen and the Temsah Fields which are estimated to contain more than 2 TCF of recoverable reserve (Bertello et al., 1996).

Regional analogs of turbidite channel architectures are used to understand the geology of Akhen channels. Among these examples are, Flood and Damuth (1987), Babonneau et al. (2002), Mayall et al. (2006), Kolla et al. (2007) … etc. Similar work published by Roberts and Compani (1996), Kolla et al. (2001), Posamentier and Kolla (2003), Samuel et al. (2003), Deptuck et al. (2003, 2007) and Kolla et al. (2007), Cross et al. (2009), Sharaf et al. (2015) is also important to understand the channel geometries using 3D seismic attributes and well logs.

Facies variation within the different channel segments can be used to predict the reservoir quality and fluid flow through the turbidite reservoirs (Slatt, 2006; Schwarz and Arnot, 2007). Pressure data obtained from the different channel segments particularly the fine grained lithology is a good indicator of potential path for hydrocarbon flow through the reservoir (Holman and Robertson, 1994; Kendrick, 2000).

The objectives of this article are to: (1) interpret the depositional architecture and facies distribution and reservoir geometry of the Middle Miocene channel-levee and sheet system at Akhen Field area, and (2) speculate on the patterns of connectivity and dynamic flow through the Akhen Field.

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http://dx.doi.org/10.1016/j.jafrearsci.2015.09.011
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Akhen is a gas and condensate Field, discovered by BP Amoco in 1996 by the drilling of Akhen 1 exploratory well. The Field lies beneath 80 m (262 ft) of water and is located approximately 56 Km (34.8 mile) north east of Damietta promontory (Fig. 1). The Field lies within the Ras El Bar concession on the western flank of the NW–SE Temsah-Akhen structure. All reserves come from Middle Miocene, Sidi Salem, sand reservoirs (Fig. 2). Production commenced through the first appraisal well, West Akhen 1 (WA1) that was drilled in 2001. Subsequently, two more wells (Fig. 3); West Akhen 2 (WA2) and West Akhen 4 (WA4), were drilled in 2002 and 2004 respectively. The reservoir intervals at Akhen Field are called Sand 1, 2a, 2b, 3a, 3b and 3c (Figs. 4 and 5)

A subsurface study of the Middle Miocene reservoirs at the Akhen-Temsah area (Fig. 1) was initiated by Bertello et al. (1996) and followed by Carbonara and Lottaroli (2003) and Marten and Shaan (2004). The nearby Temsah Field (25 Km) is considered as a good analog to Akhen Field (Fig. 1), as it includes the same stratigraphic intervals and depositional architectures of the reservoir packages. However, limited cores, low quality of seismic data particularly at Temsah area and absence of consistent stratigraphic markers complicate the lateral correlation between the two Fields. Rapid lateral facies changes, paleo-topography and accommodation rate differences complicate the basin architecture Carbonara and Lottaroli (2003).

The stratigraphy of Akhen reservoir is based of high resolution biostratigraphic analysis of cores and selected cuttings from the reservoir intervals. The stratigraphic analysis includes analyzing the identified foraminiferal, nanno-planktonics and palynologic fossil groups. The identified biozones did not help to define a consistent biostratigraphic framework along the Akhen reservoir. Few nanno-planktonic zones tied with seismic interpretation and were used to date the Akhen sand. The age of Akhen sand is bounded between Langhian – Serravallian ages (Fig. 2), NN5a and NN6 biozones.

2. Geological setting

The geologic evolution of the Nile Delta can be traced back to the Late Eocene–Oligocene time when deltaic facies occurred west of the present Nile Delta as a result of a northwest shift in the discharge of the ancestral Nile (Said, 1990). This fluvio-deltaic setting continued through the Early Miocene with a possible increase in the rate of subsidence of the North Delta Block (current offshore Nile Delta) that was dominated by sandy fine-grained turbidites. During the Middle Miocene, the North Delta Block was dominated by listric faults and half grabens that developed in the central and eastern areas (Fig. 2). The depositional environment continued to be outer neritic to bathyal (Said, 1990; Khaled et al., 2014). The other areas to the west and south of the Nile delta were affected by a regional uplift with an eastward shift of the deltaic deposition (Sestini, 1989).

The Tortonian is characterized by marked uplift of the southeast hinterland with active erosion of the Nubia Sandstone and basement rocks that resulted in dominance of coarse-grained sand deposits. The Tortonian clastics indicate significant syn-depositional movements along the flexure zone with development of a few depocenters. The facies distribution reflects considerable variability of marginal, deltaic to lagoonal environment (Sestini, 1989). The Messinian was marked by thick evaporite deposits associated with desiccation of the Mediterranean Sea (Hsu, 1983). The eastern side of the Nile Delta is marked by unconformity surface between the Middle Miocene and Pliocene, particularly at the Akhen-Temsah area, as indicated by the drilled wells. Few wells penetrated relics of Messinian evaporites. An Early Pliocene marine transgression extended inland and submerged up thrown faulted blocks of the Nile Valley. The Late Pliocene was marked by regional deltaic progradation and fluvial deposition due to humid conditions and regression of an Early Pliocene sea northward (Dixon and Robertson, 1984).

Akhen Field lies across a large compressional NW–SE anticline of Middle Miocene age (Fig. 3) and represents an along-strike extension to the Temsah Field (Khaled et al., 2014). The reservoir forms a combined structural-stratigraphic trap of deep-water channel-levee and sheet complex system draped over structural closures. The Akhen reservoir unconformably overlies the Lower Miocene, Qantara flooding surface. In the Akhen Field area, where dissolution of the Messinian evaporites was active, the Middle Miocene reservoirs are sealed on top by the Lower Pliocene unconformity. The top seal at the Temsah Field area is the Messinian evaporites (Barsoum et al., 1996).

3. Seismic interpretation

The structure of Akhen Field is covered by two 3D seismic data

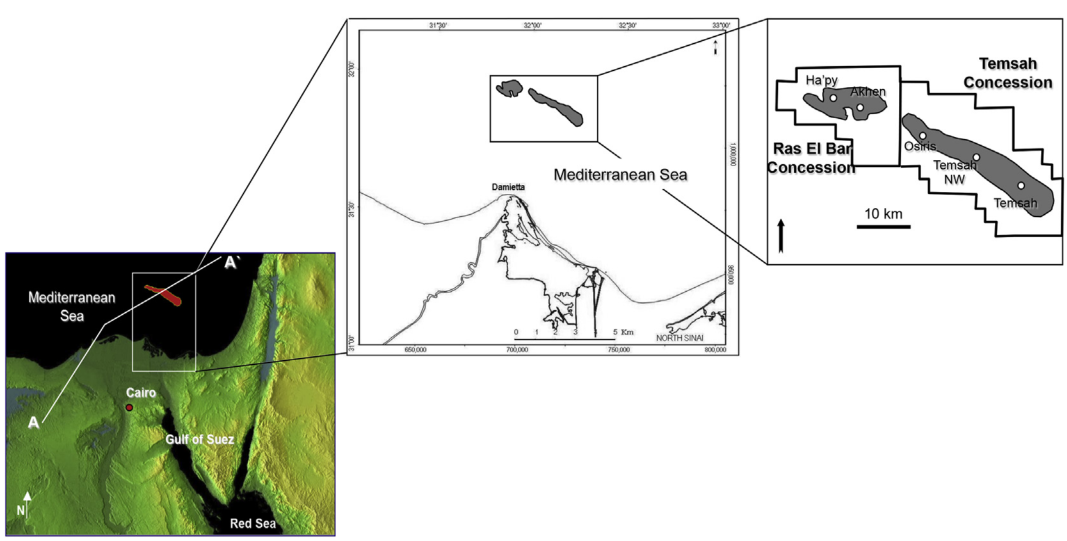

Fig. 1. Map showing the location of Akhen field and its surrounding Temsah field. The A–A′ line shows the direction of the cross section illustrated in Fig. 3.

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