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Structural imaging of the East Beni Sueif Basin, north eastern Desert, Egypt

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ABSTRACT

The East Beni Sueif Basin is the only tested hydrocarbon-bearing basin on the eastern side of the Nile in Egypt. The basin is located around 150 km to the south of Cairo. This work introduces the first attempt of seismic interpretation and structural patterns of this basin, for which subsurface published works are lacking. Structural imaging of the area is achieved through interpretation of pre-stack time migration (PSTM) seismic cube and data sets of seven wells. The penetrated sedimentary section is represented by Albian-Middle Eocene sediments.

The East Beni Sueif Basin is a type of the whole graben-system and is bounded by two NW-SE bounding faults. These faults had continued activity in an extensional regime associated with fault-propagating folds. The basin is traversed by a N75°E-trending fault system at basement level. This fault system separates the basin into two structural provinces. The Northwestern Province is deeper and shows more subsidence with a predominance of NW-trending longitudinal faults and N60·W oblique faults to the basin trend. The Southeastern Province is shallow and crossed by N14·W-trending faults which are slightly oblique to the basin axis.

Albian time had witnessed the main extensional tectonic phase and resulted in major subsidence along basin-bounding faults associated with growth thickening of basal deposits. During Senonian time, the basin experienced a mild phase of transtensional tectonics, which formed negative-flower structures entrapping different folds along the N75°E and N60·W faults. The timing and style of these structures are similar to the Syrian-Arc structures in several Western Desert oil fields. The basin emerged during the Paleocene with scoured and eroded top Cretaceous sediments. Subsidence was resumed during the Early Eocene and resulted in 1500 m-thick carbonate sediments. Lastly, a mild extensional activity possibly occurred during the Oligocene-Miocene time.

Despite the possible restricted potentiality of the source rock, the main hydrocarbon accumulation risk is attributed to retention in traps of long-span tectonic history. Reaching of main faults to surface through brittle carbonate cap rocks and limited thickness of the shale in the reservoir section risk hydrocarbon sealing. Buried structures of passive setting during the Tertiary show a minor trapping risk.

1. Introduction

The Nile Valley is surrounded by numerous sedimentary basins along its entire path in Egypt (Fig. 1a). The Beni Sueif Basin is located in the northern part of the Nile Valley at a distance of about 150 km south of Cairo. The present work deals with the major part of the basin on the eastern side of the Nile Valley (opposite to Beni Sueif and Maghagha cities).

The East Beni Sueif basin is an underexplored petroliferous basin with oil accumulation in Upper Cretaceous siliciclastic reservoirs. Although several works have been published on the surface geology of the area (Said, 1962, 1971; 1990; Bassiouni et al., 1980; Strougo et al., 1984; Strougo, 1986; Ewais, 1990, 1998; Philip et al., 1991; and Hassan et al., 1978), the subsurface geology of the area is still indistinct, as only two abstracts by Nemec and Colley (1998) and Zahran et al. (2011) have been published and mainly focused on the stratigraphy and hydrocarbon potentiality of the western side of the Nile Valley.

The lacking of subsurface knowledge of the area triggered the

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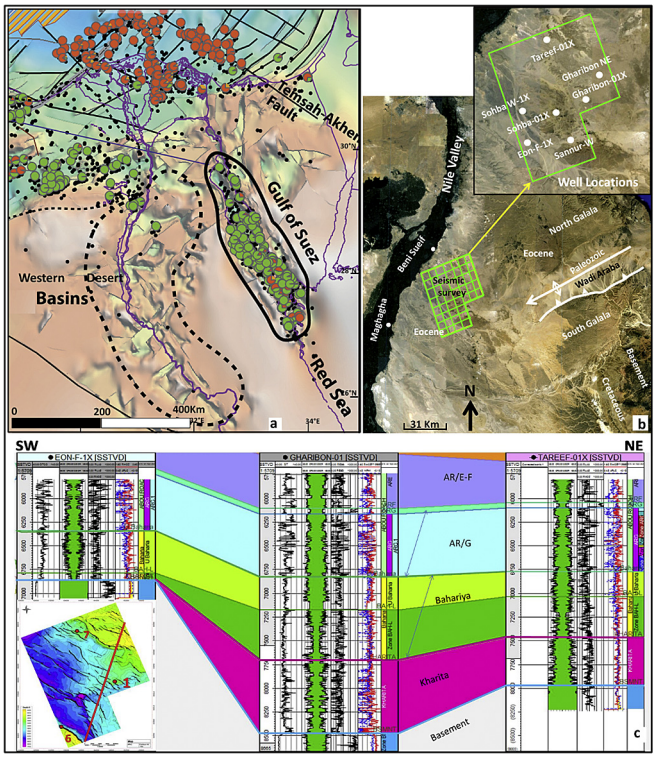

Fig. 1. Shaded basement (SEEBASE map, 2001) relief map showing Nile Valley basins and Egypt's main petroleum basins (after Bentham, 2011; and Dolson et al., 2014). Circles represent producing oil and gas fields, with colors denoting the relative percentages of gas (red) vs. oil (green) ultimately recoverable (a). A Satellite image shows a surface study area in green with the 3D seismic area (green grid) and location of study wells. The Wadi Araba main reverse fault and plunging anticline are indicated (b). Correlation between three wells (c). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

need of introducing this study, which offers the first attempt of subsurface structural imaging and possible tying of those structures with the surface structural pattern. Among several basins to the east of the Nile, three-dimensional (3D) seismic cube is only acquired in the East Beni Sueif Basin and gives a good chance for better structural imaging and deformations of a significant part of the Nile basin. The study is based on Pre-Stack Time Migration (PSTM) class of (3D) seismic cube (Fig. 1b), covering an area of 27 × 34 km and data from seven vertical wells (Gharibon-01X, Gharibon NE-1X, Sohba W -1X, Sohba-01, Sannur W-1X, Eon-F-1X and Tareef-01X), including electric well-logs (GR, density, neutron, resistivity, sonic and check shots) and mud logs. Five of these wells are bottomed in Precambrian basement rocks. Gharibon-01X and Sohba-01 are oil wells. The raw data were delivered by the operating company, however interpretation, description, and findings in this work are not based on internal reports or on the previous view or concept of operating company.

All wells were correlated using electric logs (Fig. 1c) and different stratigraphic levels were checked. Five seismic reflectors were selected and tied with wells by using TDR (Time-Depth Relation) of Sannur- W1X, Gahribon -01X (applied on Sohba wells), Gharibone-NE 1X, and Eon-F-1X wells. TWT (Two Way Time) seismic interpretation of five reflectors was carried out and five TWT structural maps were produced. TWT maps were converted to depth structural maps, using a simple velocity model based on average velocities from wells. Aiming at having more understanding of the structural history of the East Beni Sueif Basin, satellite data with field check and published surface maps were integrated with the produced subsurface depth maps for different stratigraphic levels.

2. Geologic setting

The East Beni Sueif Basin is located on the southwestern side of the giant WSW-plunging anticline of Wadi Araba (Fig. 1b). The steep southeastern limb of this anticline faces a major ENE-trending reverse fault which dates back to the Late Cretaceous Syrian-Arc system (Moustafa and Khalil, 1995). The denudated core of the Wadi Araba anticline includes Upper Paleozoic rocks. The footwall of the major reverse fault is represented by the topographic highlands of the South Galala Plateau which bears a younger Cretaceous-Tertiary section (Kuss et al., 2000; and Guiraud et al., 2001).

The topographic relief generally slopes to the Nile Valley with Eocene carbonate outcrops and local Oligocene-Lower Miocene deposits (Ewais, 1998). Nile silt is restricted to flooding banks of the Nile Valley. Several NW-trending faults were described on the surface of East Beni Sueif and were interpreted as normal faults by Hassan et al. (1978).

The drilled stratigraphic intervals in the East Beni Sueif area are represented in (Fig. 2) against the equivalent section in the Western Desert. The encountered surface and subsurface sections show restriction of Oligocene and Miocene sediments in the East Beni Sueif area relative to the north Western Desert. Moreover, the Paleozoic-Jurassic potential sedimentary section in the Western Desert is completely missing in the East Beni Sueif Basin (Fig. 2a).

The sedimentary column in the West Beni Sueif Basin started with a 500 m-thick Lower Cretaceous black shale overlying Precambrian basement rocks and is regarded as the main high thermal mature source rock in the West Beni Sueif Basin (Zahran et al., 2011). This terrestrial type of source rock has not been drilled in the East Beni Sueif Basin and its presence is unknown in untested deep troughs. Regardless of this black shale, the rest of the general stratigraphic course of these two basins is well correlated (Zahran et al., 2011).

Granitic basement rocks have been drilled in structural high blocks of the East Beni Sueif Basin and are overlain by Albian clastics (Fig. 2b), revealing a long time span of exposure. The drilled part of the Albian Kharita Formation consists of 213 m-thick quartz arenite and arkose, which are kaolinitic in parts, with siliceous

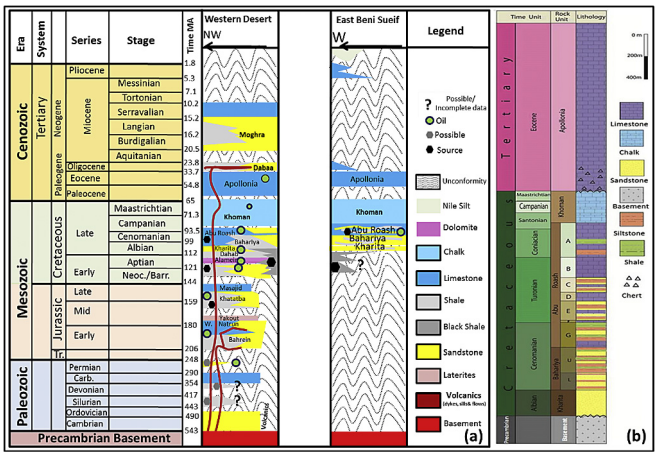

Fig. 2. A General stratigraphic column of the Western Desert (redrawn after Dolson et al., 2014) and East Beni Sueif Basin (a). Changing lithology is inferred in directions labeled on top of columns. General penetrated stratigraphic column in the East Beni Sueif Basin (b).

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