Journal of Environmental Sciences

JOESE 5

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Reprint

Volume 52, Number 1: 9-13

(2023)

http://Joese.mans.edu.eg

P-ISSN 1110-192X

e-ISSN 2090-9233

Journal of Environmental Sciences

JOESE 5

ISSN 2090-9233

Journal homepage http://joese.journals.ekb.eg

Original Article

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Article Info

Article history:

Received 12/ 01/2023

Received in revised form 05/02/2023

Accepted 16/02/2023

Keywords: *Porosity, Permeability, Diba, ARIDA. Sirt Basin.*

Abstract

The Oligocene sedimentary succession in Gialo Filed, NC59 Concession, SE Sirt Basin, Libya consists of mixed carbonate and siliciclastic sediments. The studied succession includes Diba and Chadra rock which have very good reservoir characteristics in the studied concession. The main objectives of the present work are to evaluate the petrophysical parameters of the Oligocene succession using the available wireline logs from well A13 _NC 59. The Oligocene facies are mostly clean with some quartzose sandstone, carbonate-cemented sand and limestone intervals. The presence of laminated clays in the upper Oligocene ARIDA and thick shale and siltstone interbeds in the lower Oligocene Diba Formation results in blocking the pay zone connectivity. The Extreme pay zone thicknesses occur in Chadra B and Diba and the zones of best reservoir quality are those enriched in clean sand, non-tight limestone with minimal content of clay and highest effective porosity and lowest water saturation. Dissolution pores are interpreted to be prominent in the Diba Formation and Chadra A, C.

1. Introduction

Sirt Basin is petroliferous sedimentary basins in Libya. It occupies a surface area of approximately 230,000 km2 (Montgomery, 1994b; Hallett and ELGhoul, 1996). The landscape is sandy desert characterized by sand dunes known as sand sea, The Sirt basin ranks 13th among the worldwide petroleum provinces in terms of proven reserves (Klett et al., 1997). The depths of the reservoir intervals range from 700 m to 4000 m with an average depth of 2100 m. The thickness of basin-fill sediments ranges from 1 km in the south near the Tibesti Highlands to 7 km close to Ajdabiya Basin. Cenozoic carbonates (mainly Eocene) represent significant reservoir targets deposited as platforms, while the skeletal uplifts in the eastern part are dominated by the Mesozoic sandstone reservoirs in stratigraphic trap (Ahlbrandt, 2001).

The current study aimed to investigate the petrophysical properties of the Oligocene successions. The properties include the volume of shale, effective porosity, permeability, and water-saturation. Fluid contents and hydrocarbon phase. The vertical distribution, of the petrophysical parameters as well as the lithological nature help to understand the reservoir conditions and the vertical connectivity between the different reservoir compartments and facies. This led to evaluate the hydrocarbon potentiality optimize production and minimize the risk.

2. Area of investigation

The Gialo Field situated in the southeastern part of the Sirt basin. It is positioned in the north-central part of Libya, (Fig. 1). About 369 km south of Benghazi city. It is bounded from the north by the Mediterranean Sea and by the Arc of Tibesti in the south. From the east and west, the studied field is bounded by Cyrenaica Basin and Zlatan Platform, respectively. The first onshore well was drilled. in. There are 19 giant fields in the Sirte Basin out of 21 field. (Ghanush 2016) with huge quantities of oil and gas discovered.

3. Tectonic Framework

Sirt Basin is an epicratonic rift basin in the north central African plate, consisting of complex horst and graben structural patterns during the Early Mesozoic rifting (Hallett and El Ghoul, 1996; Klett et al., 1997). This complex structure evolved as a rifted embayment on the northern margin of the African Plate. The tectonic framework of the Sirt Basin involves thermal arching and repetitive rift episodes that terminated in the Late Cretaceous to Paleocene Early Eocene The rifting phases accompanied by thermal subsidence since the Late Eocene. The basin-fill sediments reflects the influence of the tectonic evolution and related structural patterns interrelated to the Atlantic Ocean's opening the Tethys convergence during the Mesozoic and Tertiary period (Gras and Thusu, 1998). The Sirt Basin was formed due to a series of tectonic events that developed the Sirt Plateau.

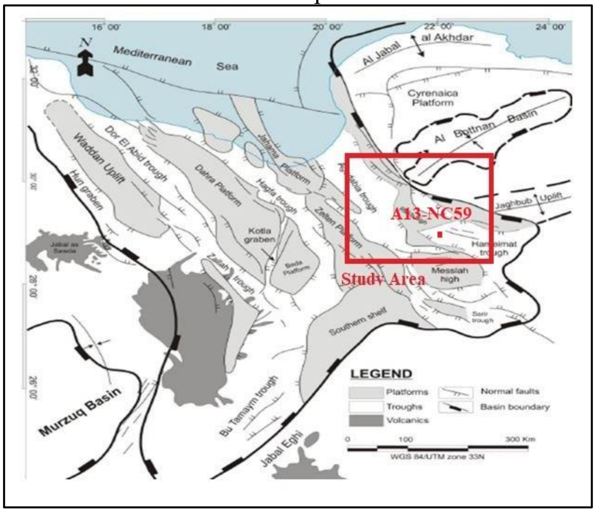

Fig. 1: The tectonic framework of the Sirt Basin and location of the Well A13-NC59 (modified after Mouzughi and Taleb, 1981).

4. Stratigraphy

The basin-fill sediments overlies unconformably the Precambrian basement complex (Fig. 2). The sedimentary succession involves basal continental deposits belonging to Cambro-Ordovician and Early Cretaceous sandstones, which overlap incongruently with Late Cretaceous sediments (Van der Meer and Cloetingh, 1993).

Harding (1984) subdivided the depositional history of the Sirt Basin into three phases: pre-rift, syn-rift and post-rift. The pre-rift succession comprises the pre-Cretaceous continental sediments that overlain the Precambrian basement rocks. The Paleogene section represents the domination of carbonate banks and reefal growths conditions. This exhibits potential hydrocarbon plays possibly charged from Cretaceous source rocks, associated with excellent reservoirs properties sealed with Paleogene shales. Below is a detailed description of the rift basin-fill sediments:

1-Pre-rift succession

The pre-rift sediments consist of siliciclastic continental facies (mainly sandstones) deposited during the pre-Late Cretaceous, that overlay unconformably the Precambrian basement rocks.

2-Syn-rift succession

The syn-rift sedimentary succession comprise rock units ranging from Cretaceous to Eocene and represents the thickest basin-fill sediments. The syn-rift facies consist of siliciclastic and carbonate rocks accumulated during successive phases of sea level fluctuations associated with rift-related tectonism (Barr and Weegar, 1972; Hallett, 2002).

3-Post-rift succession

The post-rift succession of the post-Eocene consists of diverse siliciclastic and carbonate rock units of the Oligocene Arida, Diba formations and the Miocene Maradah Formation.

Oligocene-Neogene sediments (Hallett and Clark-Lowes, 2016) blanket the entire Sirt Basin. The Oligocene characters a major change from dominant carbonate sedimentation of the Eocene to a clastic regime affected by a major marine regression. The Arida Formation is established for a clastic sequence that unconformably overlying the Awjilah Formation in the eastern portion. The type section of the Arida Formation is 400 ft thick, and comprises a sandstone unit representing three or four cycles of fine grained, friable, glauconitic sands separated by thin shales It, overlain by an upper unit of silty and glauconitic shale. The full assemblage represents a nearshore to littoral environment of deposition. The Arida Formation is poorly fossiliferous, however the upper shale unit contains Oligocene foraminifera. The lower sandstone interval exhibits a major oil bearing interval in the Gialo field where it is informally known as the Chadra Sandstone.

The sand thickness reaches a maximum of 300 ft but is very variable and quickly shales-out to north and south. It is oil productive at A-NC 59. The oil pools are sealed by thick shale intervals, 80 ft known as the Arida Shale. This shale contains planktonic and benthonic foraminifera belonging to Oligocene age for this unit.

The Arida Formation is overlain in the A13-NC59 well by a sequence of sandstones and shales named the Diba Formation (Hallett, and Clark-Lowes, 2016). The extremely friable sands are poorly sorted. Glauconite is a common constituent, with rare fossils. The shales are calcareous, soft and frequently silty. Thin stringers of sandy limestone occur near the top of the Diba Formation. The thickness in the type well is 600 ft. No age diagnostic fossils have been found in the Diba Formation, but it is assumed to be Chattian since it overlies the Oligocene Arida Formation and underlies the Miocene Maradah Formation.

The sedimentological model for the Oligocene showed the presence of three depositional environments (Hallett, and Clark-Lowes, 2016). In the south is non-marine clastic facies in which braided fluvial channels pass laterally into meandering channels and ultimately into a deltaic facies. Further north, in a belt extending from Al Bayda field to the Messlah field transitional facies is found in which marine and non-marine deposits are intermixed. Estuarine channels, tidal flats, offshore bars, and barrier islands have all been recognised within this complex. North of the Jalu field, in a broad belt extending from the Cyrenaica Platform to the outcrops on the Zahrah-Hufrah Platform, a third environment of wholly marine rocks is present. Shallow-water limestones and dolomites characterise the Cyrenaica Platform and Amal Spur, which pass rather rapidly into deeper-water marls and mudstones in the Ajdabiya Trough.

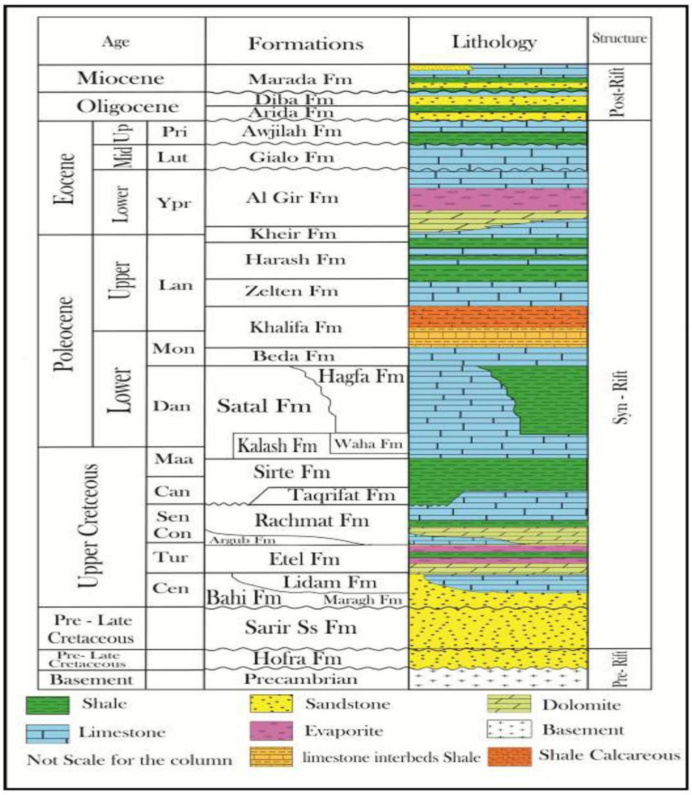

Fig. 2: Stratigraphic section in Eastern Sirt Basin and stratigraphy of the studied formations **(red box)** (modified after Barr and Weegar, 1972 and Hallett 2002**)**.

2. Materials and Methods

The available wireline data is provided in digital LAS file format. A complete dataset for a single well location in the Gialo Field, well A13-NC59, Sirt Basin was employed for this study. The wireline logs dataset includes natural gamma-ray (trace GR, API), self-potential (trace SP, MV), caliper, resistivity logs (trace shallow, RILL, Rdeep, and Rmud), density trace RHOB (g/cm3), sandstone-corrected neutron (trace NPHIss, dec), sonic (trace ΔT, μsec/ft), photoelectric effect (trace PEF), and gamma ray spectrometry traces Th, K, and U. The wireline logging dataset was interpreted using the petrophysical program Techlog 2013.

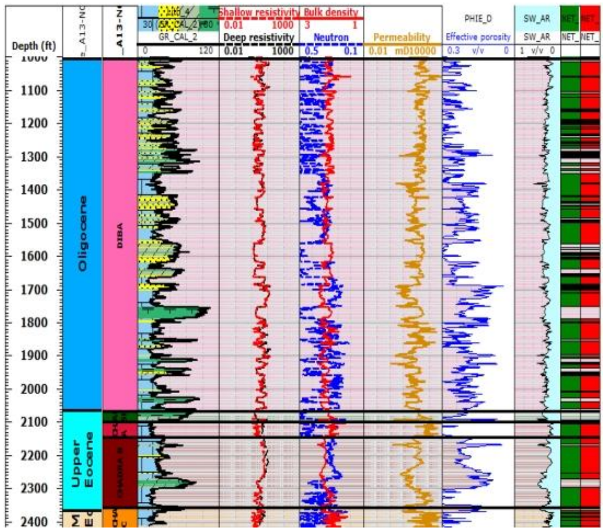

Fig. 3 The estimated water saturation, volume of shale, porosities and present fluid types of the Diba and Chadra reservoirs in the Well A13-NC59.

3. Results and Discussion

A litho-saturation cross-plots track the vertical variations in lithology associated with variation in various petrophysical parameters. The Arida Formation consists mainly of Chadra Stansone with thick (390 ft) mudstone bed. Chadra B consists mainly of Limestone or sandstone with very good reservoir characteristics in terms of low shale volume (Av. 0.21), effective porosity (Av. 0.24), and water saturation (Av. 0.25) (Table 1). The occurrence of the thick mudstone bed in Chadra B results in obstructing the pay zone connectivity and the separation of the pay zone into two main intervals. Chadra B limestone has relatively high resistivity values suggesting their massive composition (Fig .3).

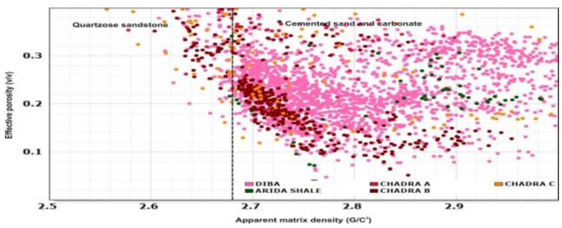

Fig. 4: Effective porosity (RHOB) as a function of Apparent matrix density (NPHI) of "present fluid types in Diba and Chadra formations A13-NC59 Well.

The Chadra A consists also of less massive limestone with relatively lower resistivity values. Mudstone interbeds are absent in Chadra A and therefore the pay zone is more continuous than that in Chadra B. Additionally, Chadra C consists of massive carbonate interbedded with clastic sandstones with high resistivity values. The resistivity separation between shallow and deep resistivity curves in Chadra A, B, C members signifies the presence of movable hydrocarbons. Within the Upper Eocene succession, Chadra B has the greatest net pay thickness of approximately 146.

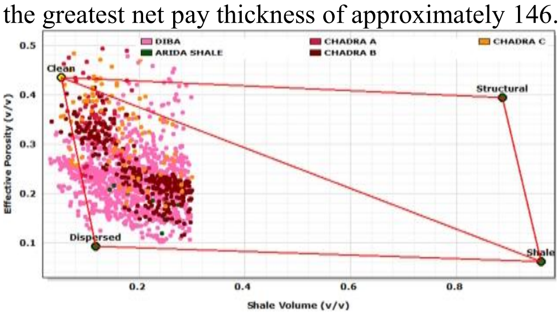

Fig. 5: Shale volume -effective porosity cross plot (Thomas-Stieber plot) Well A13-NC59.

5 ft. Chadra A, C have higher effective porosity of 34% and 32% respectively. They also have lowest contents of shale volume < 20% and therefore have lower values of average water saturation than Chadra B. The greatest value of N/G is observed in Chadra A due to its lowest shale volume, water saturation and highest effective porosity values (Table 1). On the other hand, the Oligocene Diba Formation consists of interbedded sand and limestone beds with thick shale and siltstone intercalations. The sandstone and limestone beds have good petrophysical properties, however, the occurrence of shale intercalations results in blocking the pay zone connectivity (Fig. 3). Oligocene facies have the greatest pay zone thickness of 515 ft with excellent petrophysical properties in terms of effective porosity, clay volume and water saturation (Table 1).

The effective porosity versus shale volume diagram (Thomas-Stieber, 1975) reveals that shale content has the most paramounhtn impact on the effective porosity values (Fig. 5). Similar clean rock types are observed in Diba and Chadra A , C with abundant clean and dispersed clays, whereas, laminated clays are abundant in Chadra B, thus acting at fluid flow barriers blocking the pay zone.

Table 1. Summary of different petrophysical parameters deduced for the studied Oligocene rock units in A13-NC59 Well.

Age	Zones	Gross (ft.)	Net (ft.)	N/G	Av PHI	Av SW	Av VSh
Upper Oligocene	DIBA	1062	515.5	0.48	0.23	0.27	0.19
Lower Oligocene	Chad. A	47	44.5	0.94	0.34	0.21	0.13
	Chad. B	211	146.5	0.69	0.24	0.25	0.21
	Chad. C	130	43.5	0.33	0.32	0.24	0.17

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