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RESEARCH PAPER

Structural characteristics and petroleum exploration of Levant Basin in Eastern Mediterranean

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Abstract: By using geologic and seismic data, this study restored the proto-type basins and lithofacies paleogeography of the Levant basin in Eastern Mediterranean during main geological periods, carried out comparison analysis on the basin architecture characteristics, and based on careful examination of the characteristics of discovered gas reservoirs, established the reservoir forming pattern and discussed the favorable reservoir forming combinations and future exploration direction in this region. Three structural architectures can be identified in the basin, the early-stage faults, the mid-stage faults and the late-stage faults. The early-stage faults are mainly controlled by intercontinental depression, which were less influenced by later compression stress in the southern deep water area of the basin. Controlled by the lateral structural stress and the Syrian Arc Fold Belt, the mid-stage faults became less active from north to south and from east to west. Influenced by the collision and/or Dead Sea strike-slip Fault Zone, the late-stage faults were active but did not pierce the thick Upper Miocene evaporites. Combined with the discovered reservoirs and outcrops, the Mesozoic sandstones and carbonates in deep water area near Eratosthenes seamount of Israel offshore and the Cenozoic carbonates and Tamar sands of Lebanon offshore are the main petroleum exploration targets in the next step.

Key words: Eastern Mediterranean; lithofacies paleogeography; basin architecture; Levant Basin; deep water sedimentation; petroleum exploration direction

1. Introduction

Global deepwater large oil and gas fields discovered in the past five years are mainly located in passive continental margin basins[1] (Table 1). After Nobel Energy Inc. found the Tamar gas field in 2009 in the Levant basin of eastern Mediterranean (Fig. 1), major oil and gas discoveries have been made in this area successively[1–6], suggesting good exploration prospects of deepwater oil and gas in the basin. Similar to the passive continental margin basins in East Africa[7–8]. The Levant basin is low in overall exploration degree, and the existing oil and gas discoveries are mainly located in Israel offshore in the southern part of the basin, but the Lebanon offshore in the northern part of the basin has not been explored yet.

Previous studies on the eastern Mediterranean mainly focused on the aspects such as regional geology[2–4, 9–12] and sedimentation[4, 13–15], but rarely covered the basin evolution, tectonics, sedimentation and filling, and hydrocarbon accumulation characteristics, and the future exploration direction remains unclear. In this study, based on the analysis of the prototype basin and restoration of lithofacies paleogeography in the Levant basin and the surrounding area. Through comparative analysis of tectonic features and dissection of reservoirs discovered in the basin, we have investigated the favorable plays and future exploration direction in this area, in the hope to provide references for the strategic target selection and new venture evaluation in deepwater area of passive continental margin with low exploration level and data acquisition difficulty.

2. Overview of the study area

2.1. Exploration background

The exploration activities along the eastern Mediterranean coast started in 1968[1], mainly in the shallow water of the Nile delta basin to the west of the Levant basin. The Levant basin has a water depth of more than 1 000 m and a total area of 4.85×10^4 km^2 (Fig. 1). Since the commercial drilling starting in 2008, there are 19 wells already, with a successful drilling rate of more than 80%. The Nobel Energy Inc., as the major operator, has found 7 commercial gas fields with cu-

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Table 1. Reserve statistics of deep water giant fields in passive continental margin from 2010 to 2015[1]

Region	Basin	Country	Field	Type	Discovery year	Water depth/m	Reserve/10^8 t
Eastern Mediterranean	Levant basin	Cyprus basin	Aphrodite	Gas	2011	1 689	1.29
		Israel	Leviathan		2010	1 634	4.80
	Nile basin	Egypt	Salamat		2013	649	0.72
			Zohr		2015	>2 000	5.01
South Atlantic	Santos basin	Brazil	Iara Entorno	Oil, Gas	2013	2 230	0.84
			Buzios	Oil	2010	2 100	6.43
			Carcara		2012	2 027	0.72
			Libra		2011	1 964	8.32
	Kwanza basin	Angola	Block 21	Oil	2012	1 744	0.82
			Lontra	Gas	2013	1 275	1.06
	Campos basin	Brazil	Pao de Acucar	Oil	2012	2 788	1.09
			BM-C-33	Oil, Gas	2010	2 708	1.54
East Africa	Ruvuma basin	Mozambique	Mamba	Gas	2012	1 690	13.18
			Coral		2012	2 261	2.58
			Agulha		2013	2 492	1.24
			Prosperidade		2010	1 548	6.19
			Golfinho		2012	1 027	4.74
		Tanzania	Mzia	Gas	2012	1 639	1.30
			Jodari		2012	1 295	1.02
	Tanzanian basin	Tanzania	Tangawizi		2013	2 490	0.94
			Lavani		2012	2 490	0.94

Note: The PP reserve is oil equivalent and the same below

mulative proved and probable recoverable reserves of 0.91×10^{12} m^3. Even so, this region is still low in exploration degree, and all of the discoveries are concentrated in the Israel offshore in the southern part of the Levant basin. The blocks with exploration wells cover an area of 0.33×10^4 km^2, accounting for 6.8% of the entire basin[1].

2.2. Geologic settings

Since the Paleozoic, the African plate and the Arabian plate has been a part of the Gondwana land[16]. Till the Miocene, the Arabian plate gradually departs from the African plate from south to north along the Red Sea[17]. The eastern Mediterranean, including the Nile delta basin in the northeast of the African Plate and the Pleshet basin and the Levant basin in the northwest of the Arabian Plate (Fig. 1), have been in relatively stable tectonic environment since late Paleozoic[16, 18]. The Levant basin, bounded by the eastern Mediterranean normal fault zone and the eastern Mediterranean strike-slip fault zone, shows a wedge-shaped morphology from north to south (Fig. 1). The basin was formed in late Paleozoic and experienced a prototype basin evolution process of intra-continental fault-depression, intra-continental-inter-continental rift, and the passive continental margin, and contains mainly marine sediments (Fig. 2).

3. Proto-type basin evolution and lithofacies palaeogeography

3.1. Intra-continental fault-depression prototype basin

Since the late Carboniferous, the Pangea supercontinent began to form gradually[16] and its southern part was called the Gondwanaland. As the rifting of the Gondwanaland continued through Phanerozoic, a number of small blocks coexisted, but not fully merged, with the Pangea supercontinent. Affected by the opening of the Paleo-Tethys ocean, extensional structures were developed at the north margin of the Gondwanaland (Fig. 2a). The fault-depression was formed with the sandstone sediment within the Levant basin in the north margin of the Gondwanaland.

3.2. Intra-continental-inter-continental rift prototype basin

Since the Triassic, the eastern Mediterranean region has become a continuous sedimentary basin, the product of the separation of the Apulia-Turkey massif from the Africa-Arab continent. During late Triassic and early Jurassic, the earth crust within the craton started to expand along the present North African coast, forming the extensional faults, crossed the present Levant and Syria, and reached the margin of the Neo-Tethys Ocean (Fig. 2b), with the carbonate sediment.

In the Jurassic, the Apulia block to the west of the Levant basin rotated and was separated from the African plate, leading to the formation of the Jurassic trough covering Egypt, Israel and Lebanon (Fig. 2c). The trough was dominated by the shallow marine carbonate and shallow-moderate marine mudstone[1] (Fig. 3).

3.3. Passive continental margin prototype basin

In the early Cretaceous, the eastern Mediterranean basin was 300–400 km wide and became a small oceanic basin with