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Structural characteristics and tectonic evolution of the northwestern margin of the Nile Delta, Egypt

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ABSTRACT

The Interference between the northeast, East–West, and northwest oriented faults imposed a complex structural setting of the northwestern margin of the Nile Delta, Northeast Africa. The pre-existing faults were reactivated during the evolution of the Nile Delta by two tectonic events. These events took place during the Late Miocene–Early Pliocene and Late Pliocene–Early Pleistocene times and were coeval with two falls in the sea level pattern. Some of these faults have continued to affect the bottom sea sediments and increased the northerly slope of the upper surface of the delta body. The thickness of the Pliocene-Recent sediments and the location of the pre-existing faults controlled these reactivations. The mechanical contrast of these sediments and fault displacements controlled the geometry of the reactivated faults. The rotated displacement on some of these faults is associated with growth units upward. The northwest sinking (bending) of the outer part of the African continental margin under the Eurasian plate at the Hellenic subduction Arc has induced a tangential northwest trending extension (an average of N37°W–S37°E trend) in the outer zone of the northern African margin that is responsible mainly for the reactivations of the pre-existing faults.

1. Introduction

The Nile River in the Egyptian terrains bifurcates at Cairo city into two branches, enclosing the Nile Delta (Fig. 1a). The width of the delta increases progressively northward (Fig. 1b) under the Mediterranean Sea to form its offshore part. The delta body consists mainly of sand and clays that resulted from the activities of Nile River in the Pliocene-Quaternary time. These sediments are capped by the Holocene silty clay layer that increases in thickness northward. This layer contains several sand lenses and sand wedges, particularly toward the offshore part (Said, 1981, 1990). The Cretaceous-Miocene rocks have been drilled under the delta sediments (Kellner et al., 2009) and are exposed in the Western Desert fringes. As, the Eocene–Miocene rocks are exposed to the southeast of the delta.

In addition to its agricultural and population potentialities, the Nile Delta is one of the main petroleum provinces in Egypt. The structural and combination traps have produced the hydrocarbon (Dolson et al., 2001). The thickness of the Miocene and Pleistocene hydrocarbon targets increases toward the offshore part (EGPC, 1994).

Structurally, the Plio-Pleistocene sediments of the Nile Delta are dissected by the East–West, north–south, northwest (Temsah trend), and northeast (Rosetta trend) striking faults (Harms and Wary, 1990; Sarhan and Hemdan, 1994; Abdel Aal et al., 1994; Sarhan et al., 1996). The northwest and northeast oriented faults dissect mainly the northeastern and northwestern margins of the delta, respectively. The northwest and northeast oriented faults intersect together at the southern boundary of the huge Messinian salt basin (Fig. 1b), in central Mediterranean Sea (Abdel Aal et al., 2001). The onshore part of the delta is affected by several East–West trending fault systems that extend into the other regions of Northeast Egypt (e.g. Sestini, 1984; Moustafa et al., 1998; Hussein and Abd-Allah, 2001; Abd-Allah, 2008).

The structural elements affecting the northern margin of Egypt, including the Nile Delta, were formed during the tectonic evolution of the southern part of Eastern Mediterranean basin (cf. Garfunkel, 1998; Guiraud and Bosworth, 1999; Abdel Aal et al., 2001; Abd-Allah, 2008). This region represents the Northeast African continental margin that is covered by the Nile Delta sediments. Likes the other deltas in the World, the largest Nile Delta has attached attentions of several hydrocarbon companies. Owing to its hydrocarbon occurrences and structural characteristics, the northwestern margin of the Nile Delta has been selected to be the target of the present study (Fig. 1). This study is addressed to map the structures affecting the Upper Miocene-Recent rock units, analyze the different fault trends and their structural development, and determine the tectonic evolution of this part of the African margin.

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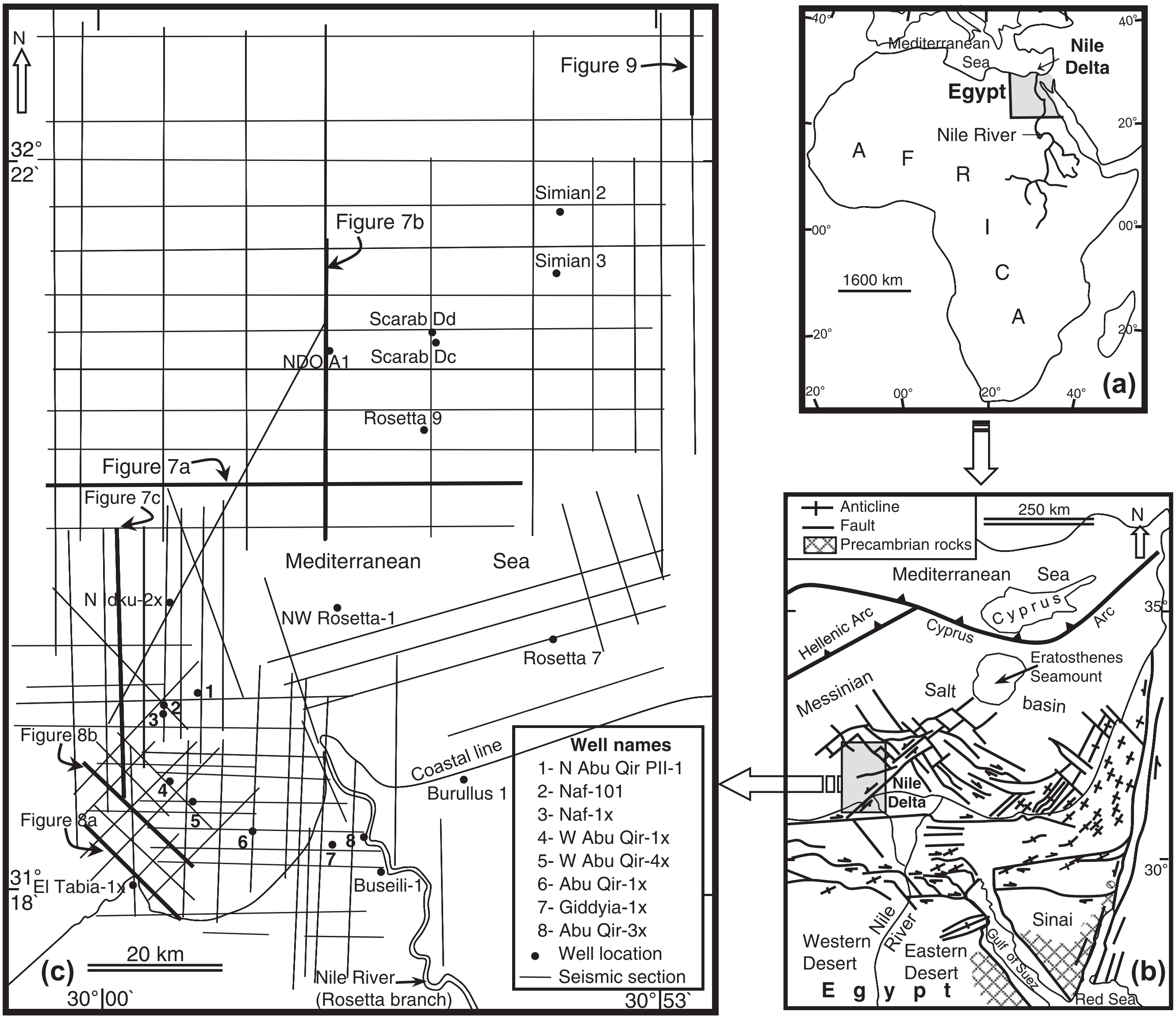

Fig. 1. Location maps of the northwestern margin of the Nile Delta (maps a and b). The faults, anticlines, and convergence arcs (map b) are compiled by Abd-Allah (2008). The seismic sections and wells used in the present study are plotted on map (c). This map shows the locations of the interpreted seismic sections in Figs. 7–9.

2D seismic sections (63 section between 1982 and 1987) and 20 wells (Fig. 1c) were used to achieve this study. These subsurface data were given by the Egyptian General Petroleum Corporation (EGPC). The slip data of some exposed faults in the northeastern part of the Western Desert have been used to compare between the exposed and subsurface faults.

2. Stratigraphy

The lithostratigraphic classification of the Miocene-Recent succession in the northwestern margin of Nile Delta is based on the analysis of the boreholes data, which were drilled between 1975 and 2002 as well as the seismic startigraphic analysis to trace the lateral continuity of each unit. However, much of the previous stratigraphic works are restricted to relatively small areas, rather than providing a more regional view that included in the present study. Ten formations have been formally recognized within the Middle Miocene-Recent stratigraphic interval in the study area (Fig. 2); they are arranged in the following order:

The type section of Sidi Salem Formation is Sidi Salim-1 well (onshore central delta), where its thickness attains 446 m. In the study area, the thickness of this formation ranges from 65 to 813 m, with a maximum thickness at the southwestern part of the study area and decreases northward. Sidi Salem Formation rests on the Lower Miocene Moghra Formation (Fig. 2a) and is overlain by the Abu Madi Formation or by the Rosetta Anhydrite (Rosetta-7) or Qawasim formations (Burullus-1) (Fig. 2b). The upper boundary of Sidi Salem Formation coincides with a regional unconformity, while its lower boundary encountered in few wells. Sidi Salem Formation consists mainly of claystones with some intercalated sandstones and siltstones (Fig. 2). In the central part, the formation contains intercalations of shale, sandstone, claystone and limestone beds. In the northern part, the formation was not penetrated, where the identified seismic facies are the claystones and shales. Based on the planktonic foraminifera detected by Abdel Naby (2004), Sidi Salem Formation is of Middle Miocene age although it may also extend into the Late Miocene.

The type section of Qawasim Formation is the Qawasim-1 well (onshore central delta), where it attains a thickness of 933 m. The thickness of this formation is between 25 and 100 m in the southern part of the study area, where it exists under the Rosetta Anhydrite (Naf-101 and Burullus-1 wells, Fig. 2). The formation