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Research paper

Fault-related domes: Insights from sedimentary outcrops at the northern tip of the Gulf of Suez rift, Egypt

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A R T I C L E I N F O

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A B S T R A C T

Domes may develop with various mechanisms in different types of rocks. Knowing the geometries and occurrences of domes is an important concern in classifying different types of domes. A number of fault-related domal structures are outcropped at the northern Gulf of Suez rift, Egypt and they are easily visualized on satellite imagery. Detailed surface geological field mapping is carried out at several localities to assess types and origins of these domes. Three main subdivisions of fault-related domes are suggested in the present study. These are: (1) domes formed in strike-slip zones (D-SZ), (2) domes formed by drag along normal fault arrays (D-DF) and (3) domes formed at transfer zones of normal faults (D-TZ). Structural analysis of the studied domes reveals that each dome type has its own geometric parameters, structural style and tectonic setting. The obtained results are without doubt interesting for the analysis of similar domes at the subsurface and other exposures worldwide.

1. Introduction

The term “dome” or “doubly plunging anticline” is used for describing convex upward structures with roughly circular or somewhat elongate, closed outcrop patterns. Domes form attractive hydrocarbon traps and shape some of the world's large hydrocarbon traps because they have four-way dip closure.

There are many probable mechanisms responsible for the formation of domes, the principal of which are post-impact uplift (e.g. Lana et al., 2003; Buchner and Kenkmann, 2008; Jahn and Riller, 2009; Ferrière et al., 2011; Retzler et al., 2015; Herrmann, 2017), plutonism (e.g. Brun, 1983; Teyssier et al., 2002; Verner et al., 2014; Erkül et al., 2017), refolding (e.g. Allen et al., 2001; Grujic et al., 2002; Benavente-Marín and Jabaloy-Sánchez, 2017), and diapirism (e.g. Dixon, 1975; Woidt, 1978; Talbot and Jackson, 1987; Brewer and Kenyon, 1996; Dewing et al., 2016). Also, domes vary in shapes as they can be circular (e.g. Stewart, 2015), elliptical (e.g., Withjack and Scheiner, 1982), or elongated (e.g. Martínez-Martínez et al., 2002, 2004; Alcalde et al., 2013).

The knowledge of dome geometry is a basic requirement to investigate its development mechanisms (e.g. Zulauf et al., 2017). Due to the presence of this type of structure in nature, it is necessary to have classifications which allow information about dome geometry to be organized and analyzed.

Therefore, the main objective of the present article is to (1) describe the geometry of different types of fault-related domes at the northern tip of the Gulf of Suez rift, especially their pattern and style of deformation, and (2) to improve our understanding of the primary controls on the development of such important structures. Several well-exposed domes are presented herein and can be used for constraining subsurface interpretations of other areas, as well as constraining theoretical models. The study was achieved through detailed surface geological field mapping of several localities (Fig. 1) from Cairo-Suez District (CSD) and the westernmost part of Sinai Hinge Belt (SHB).

2. Regional structural setting of the Gulf of Suez rift

The Gulf of Suez rift is an inactive continental rift between the Sinai microplate and the African plate. It extends for about 300 km in a NNW direction towards Suez city and is dominated by NNW-SSE- to NW-SE-oriented normal faults bounding tilted fault blocks. Prerift (pre-Miocene) and synrift (Miocene) rocks dip at an average angle of about 10–15° but locally become steeper as much as 45° in the southern part of the rift because of increase in extension from northwest to southeast (e.g. Garfunkel and Bartov, 1977; Colletta et al., 1988; Richardson and Arthur, 1988; Patton et al., 1994; Bosworth and McClay, 2001). The Gulf of Suez rift comprises three half grabens which, from northwest to southeast, are Darag, October and Zeit. The fault blocks dip towards the SW in the northern half graben and changes to the NE and back to the SW in the central and southern half grabens, respectively (Moustafa, 1976). Structurally complex transfer zones separate these half grabens (from northwest to southeast) namely; Zaafarana and Morgan transfer zones. The half grabens are bounded by major normal faults on their downdip sides (e.g. Moustafa, 1976; Moustafa, 1993).

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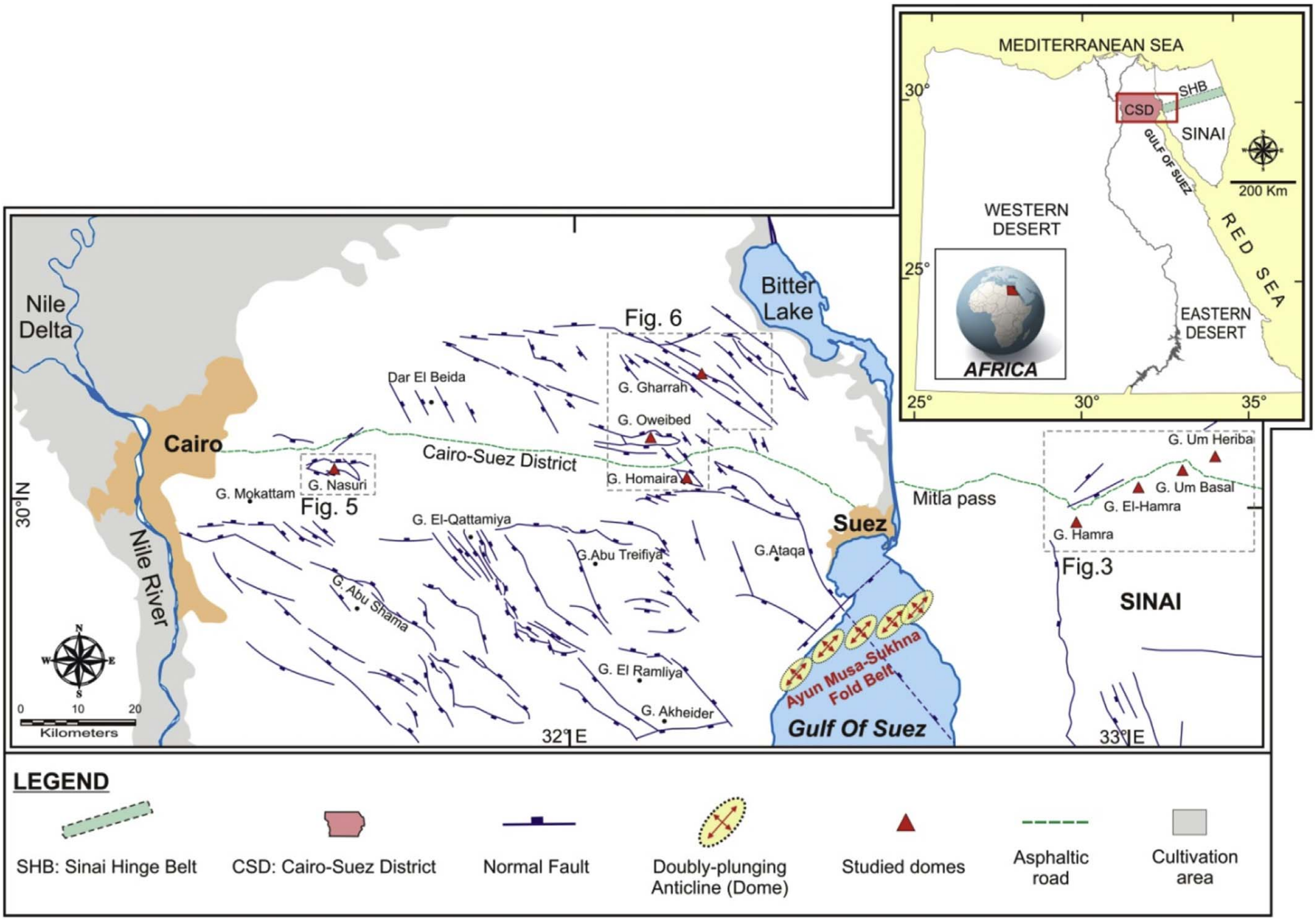

Fig. 1. Simplified structural map of the northern tip of the Gulf of Suez rift and the locations of the studied domes (compiled from Said, 1962; Moustafa et al., 1985; Moustafa and Abd-Allah, 1991; Patton et al., 1994; Moustafa and Khalil, 1995; Maqbool et al., 2014; present study).

The northern tip of the Gulf of Suez rift belongs to the northern half graben (Darag Basin). It is significantly affected by a reduced amount of extension. There is an agreement that the northward termination of the Gulf of Suez rift led to westward transfer of the extension toward the Cairo-Suez District (CSD), which was accommodated by NW-SE normal faulting (e.g. Nelson, 1987; and Moustafa and Abd-Allah, 1992; Bosworth and McClay, 2001; Hagag, 2016). The NW-SE oriented normal faults of the CSD are adjoined by several belts of E-W-oriented faults, which represent the western continuation of the Sinai Hinge Belt. Moustafa et al. (2014) stated that the termination of the northward propagation of the Gulf of Suez rift by the Sinai Hinge Belt have played a role during the Neogene rifting and tectonic evolution of the Gulf of Suez-Red Sea rift system.

Folds are common structures in the Gulf of Suez rift, which are among the main structures that play an important role as excellent hydrocarbon traps. They have different geometries and kinematics which control the hydrocarbon accumulations. At the northern Gulf of Suez rift, Moustafa and Khalil (1995) expected the presence of en echelon fold belt (Ayun Mousa-Sukhna fold belt, Fig. 1). Their study based on borehole data due to rareness of data at the northern Gulf of Suez rift, which is quite poorly-explored area. They indicated that this fold belt is the subsurface SW continuation of the Sinai Hinge Belt (Fig. 1).

3. Methodology

The studied areas were investigated with ETM+ Landsat, Google Earth imagery, and field investigations. Satellite images are the best way for representing domal structures due to the difficulty of imaging them in the field. Structural data of the selected domes were analyzed by stereographic analysis. The geometric characteristics of each dome were determined through analysis of pairs of adjacent structural domains. Domains were defined by the attitudes of the bedding planes and the location of fold axes in such a way that the strike and dip data of each domain are consistent. These divisions of the each dome into structural domains allowed for stereographic analysis throughout the construction of Beta Diagrams. These Beta Diagrams were constructed by plotting the poles to planes of adjacent domains using Stereonet 9 (Allmendinger et al., 2012). Best fits were then found to approximate each limb, allowing for the determination of the strike and dip of the axial planes.

Domes identified from satellite image analysis were grouped using aspect ratio calculated from fold width and hinge length. The aspect ratio (hinge length: fold width) can be used to separate fold types and was calculated for each dome.

Furthermore, attitudes of the faults have been measured, classified into fault arrays and plotted on rose diagrams. In addition, the strikes of the axial planes have been correlated to those of the nearby (boundary) faults.

4. Fault-related domes in the northern Gulf of Suez rift

Detailed structural field mapping north of the studied areas led to the identification of three main types of fault-related domes according