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Present-day tectonic stress regime in Egypt and surrounding area based on inversion of earthquake focal mechanisms

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ABSTRACT

Stress field inversion is performed in Egypt on the basis of 219 focal mechanism solutions in the period from 1955 to 2007. For this purpose Egypt is divided into six seismotectonic zones: the northern part of the Gulf of Suez, southern Gulf of Suez, and Gulf of Aqaba, Cairo-Suez district, Dahshour zone and the Aswan Zone. The entire Gulf of Suez is currently under extensional stress field, with NE–SW trending horizontal extension. In the Gulf of Aqaba, the strike-slip regime predominates with sub-horizontal σ_1 and σ_3 axes trending NNW and ENE, respectively. A normal dip slip with small strike-slip component due to a nearly sub-vertical σ_1 and sub-horizontal NNE striking σ_3 characterizes Cairo-Suez district and Dahshour zone. Aswan seismic zone shows mainly strike-slip stress regime with a slight extension component (horizontal NW σ_1 and NNE σ_3). The stress field derived in this study indicates a prevailing tension stress (σ_3 horizontal) which agrees well with the general tectonic frame of northeastern African, which is subjected to tensional stresses. Generally, extensional and/or extensional-strike slips are dominating the Egyptian territory. These regimes are compatible with the kinematics of the Red Sea–Gulf of Suez rift and Gulf of Aqaba transform plate boundary. Furthermore, the inferred stress in the present study (SHmin directed NNE–SSW) for the Cairo-Suez, Dahshour, and Aswan areas is similar to the East African Rift stress fields “Congo and Sudan” especially (Bosworth et al., 1992; Delvaux and Barth, 2010), whose origin is attributed to the far field effects of ridge push in the Atlantic and Indian Oceans (Zoback, 1992).

1. Introduction

Observation of the present day stress field in the crust represents an important task for understanding the driving forces for the current deformation and the style of deformation itself. Earthquake focal mechanism solutions represent one of the main sources of information about the stress in the crust. An important advantage of the focal mechanism solutions is the ability to obtain the stress regime information at depth in the lithosphere. As the focal mechanism data becomes more numerous, the inversion of all the available solutions can be applied to determine the best fitting stress tensor by combining the information among the several families of the stresses associated with a population of focal mechanisms. The final result is to estimate the orientations of the principal stress axes and a ratio for the principle stresses, for a certain region of interest.

This study can be considered as an extension of those proposed by several authours; using the inversion of focal mechanisms (e.g., Abou Elenean, 1997; Badawy, 2001,2005; Salamon et al., 2003) and fault kinematics data (Angelier, 1985; Bosworth and Taviani, 1996; Bosworth and Strecker, 1997; Bosworth, 2008). This works complements the earlier work of Delvaux and Barth, 2010 which considered the southern half of the Red Sea and the East African rift system further to the south.

In this work, we attempt to estimate the best uniform stress field in Egypt, based on fault planes solutions, collected from various local and regional studies as well as global catalogs during the time period 1951–2007. The identification of the recent stress field and of the different tectonic regime which represent the new tectonic period is a prerequisite.

2. Geodynamic and tectonic setting

Egypt is located along the southeastern edge of the Eastern Mediterranean region, at the northeastern corner of the African plate (Fig. 1), which is in contact to the east with the Arabian plate

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and to the north with the Eurasian Anatolian plate. These plates are involved in the geodynamic reconstructions of Egypt as well as the southern part of eastern Mediterranean, which provide an accurate tectonic framework and reveal the current plate movements and crustal deformation in both regions. To the north convergent tectonics is dominated by N–S subduction of the African plate beneath the Eurasian plate. To the east extensional tectonics associated with the opening of the Red Sea dominates.

Several plate tectonic models based on the analysis of global seafloor spreading, global positioning system (GPS), fault systems and earthquake slip vectors have been adopted to explain the tectonic process in this region (e.g. DeMets et al., 1990; Jestin et al., 1994; McClusky et al., 2003). These models indicate that the African plate is moving northward relative to the Eurasian plate at a slip rate of ∼10 mm/yr (DeMets et al., 1990, 1994) while the Arabian plate is moving north–northwest relative to Eurasia, at a rate of about ∼18–25 mm/year (DeMets et al., 1990, 1994; Jestin et al., 1994). These movements cause crustal spreading along the axis of the Red Sea and left-lateral slip along the Dead Sea transform zone. The differential motion between Africa and Arabia (∼10–15 mm/yr) is considered to be taken up partially by left-lateral motion along the Dead Sea transform Fault (McClusky et al., 2003; El Fiky, 2000). Moreover, new GPS observations in the Eastern Mediterranean indicate that Anatolia converges with Sinai at a slightly lower rate of 7–8 mm/yr (Wdominski et al., 2006) in a slightly more northern direction to its convergence with African 8–9 mm/yr along the Cyprean arc.

The detailed subsurface studies supported by surface data (Abdel Aal et al., 1994; Mosconi et al., 1996; Korrat et al., 2005; Bosworth et al., 2008) indicated that northern Egypt underwent three subsequent tectonic phases from early Mesozoic to present. The first tectonic phase is the Neotethys rifting which formed the North Africa Passive Margin in the early Triassic to Early Jurassic with the development of an extensive system of generally E–W trending rift basins located inboard from the continental margin. During the early Cretaceous, a new phase of extension reactivated the E–W Jurassic basins as Abo Gharadig Basin in the Western Desert and formed new NW–SE trending rifts as Beni Suef, Asyut and Khomombo basin straddling the modern Nile Valley. This phase of extension is mainly due to the clockwise rotation of the stress field in North and Central Africa associated with the opening of the South Atlantic. The first phase resulted in a system of E–W to ENE–WSW faults either as normal (Abdel Aal et al., 1994) or strike slip with a left lateral motion (Meshref, 1990) in addition to NW–WNW oriented normal faults. During late Cretaceous, the relative motion between Africa and Eurasia changed from sinsitral divergent to dextral convergent. As a consequence the far field compressional stresses resulting from the arc collision with the northeast coast of Africa–Arabia in late Santonian (Savostin et al., 1986) and later similar pulses through much of the Cenozoic transmitted across entire Africa (e.g. Bosworth et al., 1999; Guiraud and Bosworth, 1997). These compressional events developed a number of inversion related features including localized folding and wrench faulting, igneous activity and coupled episodes of uplift, erosion and offshore deposition. The resulting deformation extends from Libya to the Levant. A train of ENE folding associated with thrust faults (Syrian Arc Structure) (Moustafa and Khalil, 1990) and NW to NNW extension faults parallel to the major contraction force was developed from the eastern region of the Western Desert (Sehim, 1993) and across Sinai (Moustafa and Khalil, 1990).

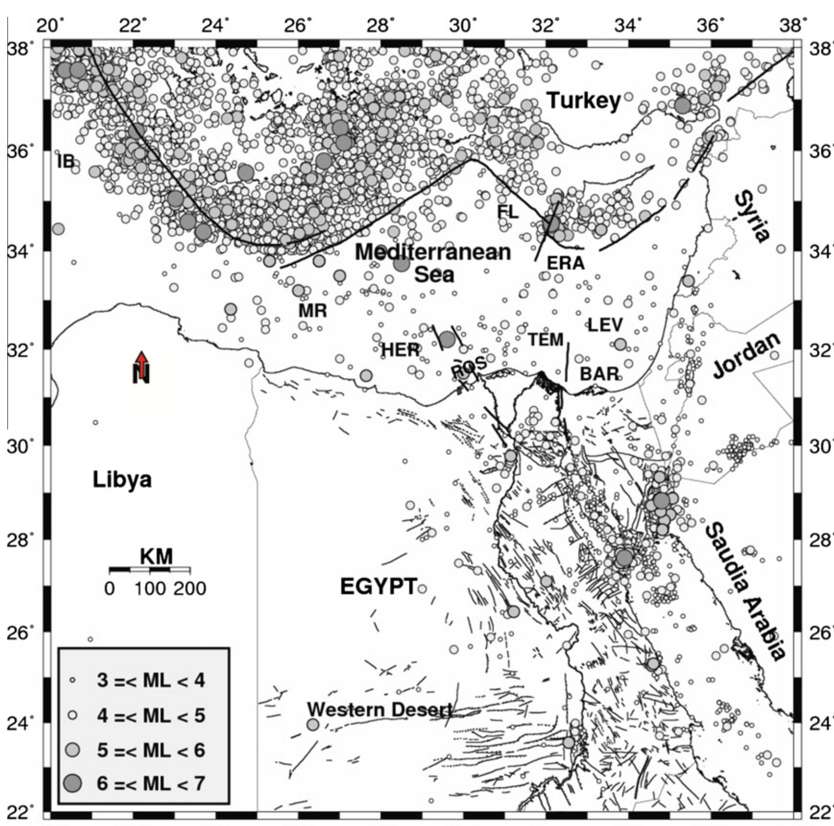

Fig. 1. Tectonic boundaries of the Eastern Mediterranean Region (compiled by Abou Elenean and Hussein (2007)). Compiled tectonic elements after Egyptian Geological Survey (1981), Sofratome Group (1984) and Salamon et al. (1996). Seismicity data ($2 \leqslant mb < 6.8$) are compiled after Egyptian National Seismological Network; ENSN, NEIC and Abou Elenean and Hussein, 2008 from 1900-2007. The following Acronyms represent: ERA-Eratosthenes Seamount; FL – Florence; IB – Ionian Basin; MR – Mediterranean Ridge; LEV – Levantine Basin; TEM, Temsah; BAR, Bardawil; HER-Herodotus Basin; ROS; Rosetta.