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## Existence of the Oman Line in the Empty Quarter of Saudi Arabia and its Continuation in the Red Sea

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**Abstract:** The broad structural discontinuity known as the Oman Line extends NNE from Oman across the Strait of Hormuz and divides the flysch-rich eugeosynclinal sediments of the Makran Ranges in the east from the miogeosynclinal shelf sediments of the Zagros Mountain Ranges to the west. The Zagros Crush Zone, west of the Oman Line, marks the location of a continent/continent-style active margin where the Arabian Platform has collided with the Eurasian Plate to the north. To the east, the active margin is a continent/ocean-style boundary where the oceanic lithosphere of the Indian Ocean is being subducted beneath the Central Iranian Microcontinent and other more easterly microcontinental blocks. Geological investigations in the Arabian Plate indicate the presence of a NE-SW trending lineament. This lineament is also recognized on geophysical maps by aligned highs and lows, steep contours gradients and linear offset of trends. There are some indications suggesting that this lineament could represent a SW extension of the Oman Line from Oman across the Empty Quarter (Rub al Khali) of Saudi Arabia to eventually form a transform fault in the Red Sea.

**Key words:** Oman Line, Iran, Saudi Arabia, Red Sea, tectonics, geology

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### INTRODUCTION

Regional projects are conducted at small scales and may cover large areas of tens or hundreds of thousands of square kilometers. There is very little published works on the large scale geomorphological analysis of tectonic landforms<sup>[1-9]</sup> and this is the first study of its kind to concentrate on landscape interpretation by detection of a broad structural lineament known as the Oman Line. This study examines a vast area extending over  $1 \times 10^6$  km<sup>2</sup> of the Southern and Eastern Arabian Plate northeastward from the Red Sea spreading center via the drainage divide within the Rub al Khali desert of Arabia to the western extremity of Oman's Ophiolites and thence northwards to Iran. This study outlined a structural lineament related to some morphotectonic features on the Arabian Platform.

### DISCUSSION

Anticlinal or domal structures in the sedimentary sequence of the Northeastern Arabian Platform and its offshore extension contain all the known oil and gas fields of Saudi Arabia<sup>[10]</sup>. These currently comprise some 56 oil fields and 4 gas fields (Fig. 1), all of which owe their origin

to deep-seated tectonic movements in the Precambrian crystalline basement<sup>[11]</sup>. The thickness of the sedimentary sequence increases from 4500 to 13700 m by gradual northeasterly thickening. Underlying these sediments in most of onshore Northeastern Saudi Arabia, there is a faulted Precambrian basement characterized by horsts and grabens along a N-S Arabian Trend. This is the "old grain" of the Arabian Peninsula formed by repeated E-W extensional tectonism<sup>[12]</sup>. As a result, almost all the oil fields on the northeastern Arabian Platform are elongated along a general N to NE direction affiliated with strike slip faulting in the basement. These faults have also penetrated the salt beds of the Infracambrian aged Hormuz Series causing diapiric salt-wall structures at depth<sup>[13]</sup>. Uplifting of the overlying strata to form elongate doubly plunging anticlines has produced negative gravity anomalies related to basement faulting. Rupture of Hormuz Series salt beds, has resulted in deep-seated diapirism and consequent structural growth. Figure 2 shows the late Precambrian Salt Basins of the Persian Gulf and of the Arabian Peninsula. It will be noted that, the eastern boundary of Southern Gulf Salt Basin, portions of the western boundary of Fahud Salt Basin, Gaba Salt Basin and South Oman Salt Basin appear to have been

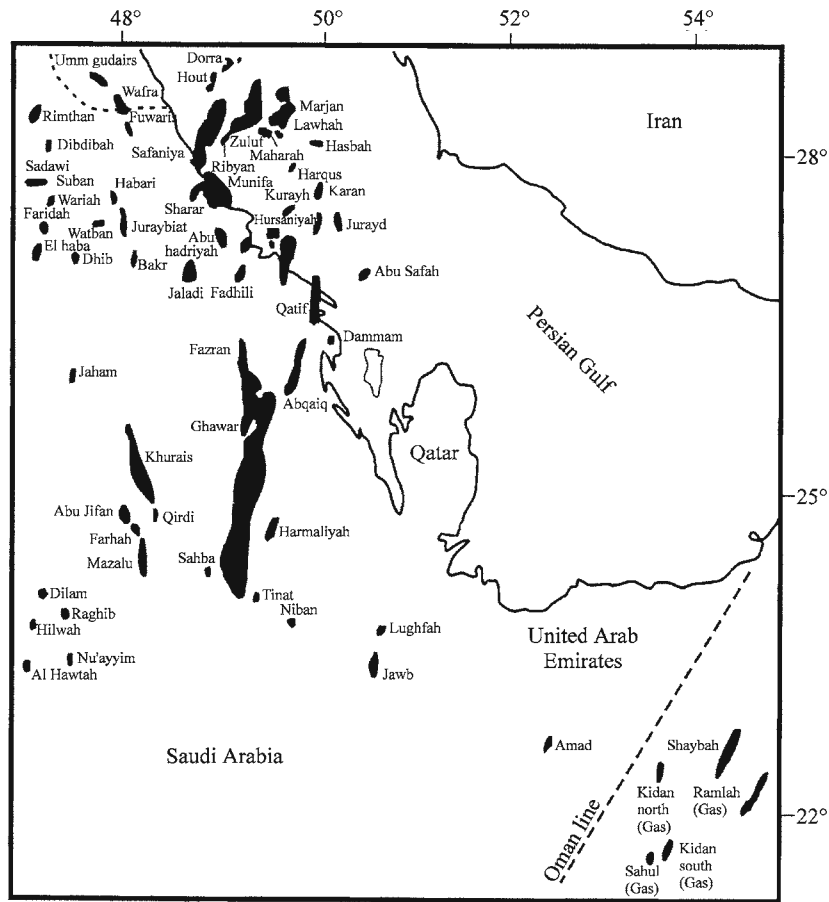


Fig. 1: Oil and gas fields of Saudi Arabia. Some of the oil and gas fields, which have elongated along a NE direction due to strike slip faulting in the basement such as Shaybah, Kidan North, Kidan South, Sahul, Ramlah and Amad could be affected by Oman Line<sup>[11]</sup>

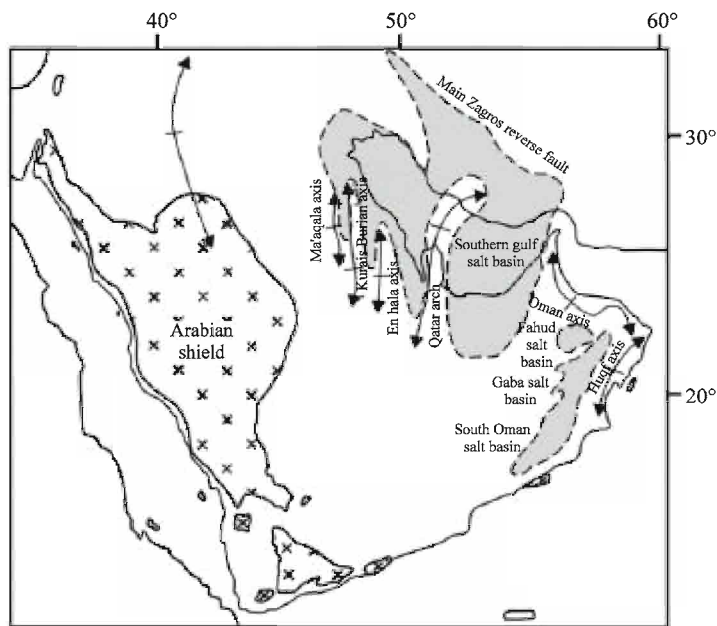


Fig. 2: The eastern boundary of Southern Gulf Salt Basin and almost the western boundary of Fahud Salt Basin, Gaba Salt Basin and South Oman Salt Basin seem to have been controlled by a lineament crossing them northeastward along their boundaries<sup>[11]</sup>

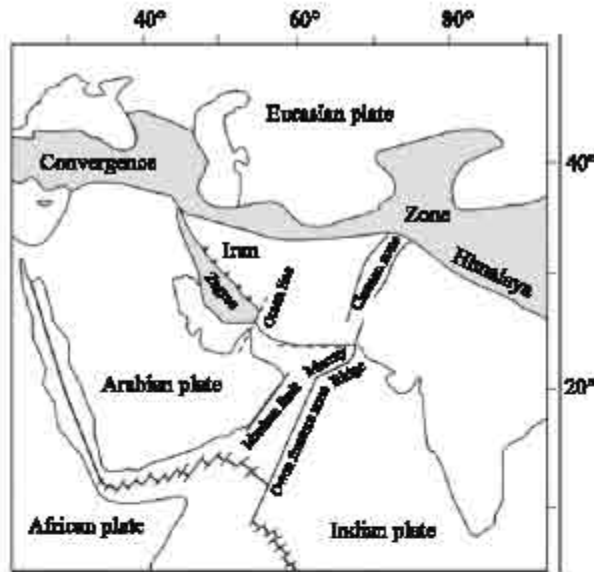


Fig. 3: Plate tectonic setting of Arabia<sup>[11]</sup>

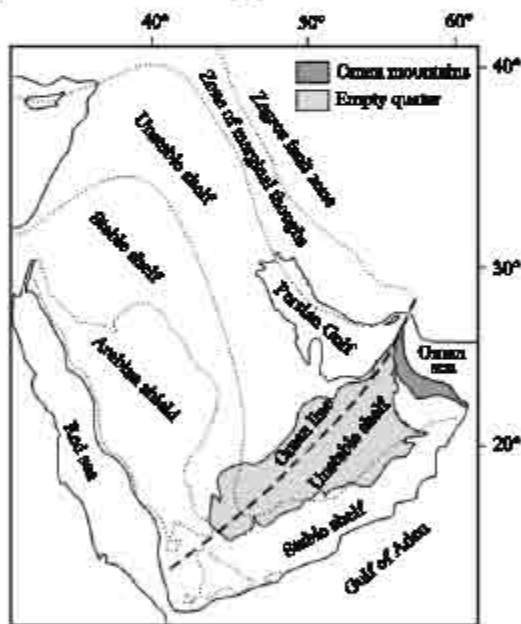


Fig. 4: Major tectonic zones of Arabia and locations of Empty Quarter and Oman Mountains in the Arabian Peninsula. Oman Line crosses the Empty Quarter along its deepest part and deviates the western end of Oman Ophiolites. The flexure of southeastern boundary of Unstable Shelf and Stable Shelf, the eastern boundary of zone of Marginal Troughs and the southeastern end of the Main Zagros Reverse Fault coincide with the path of Oman Line

controlled by a NE trending lineament along their boundaries.

Some of the oil and gasfields, with axial trend in a NE direction result from strike slip faulting in the basement. Fields including Shaybah, Kidan North, Kidan South, Sahul, Ramlah and Amad, are separated from the gas fields to the NW by this Oman Line (Fig. 1).

The oil field areas of Saudi Arabia, both onshore and offshore, are all located in a tectonostratigraphic province referred to as the Arabian Platform, or Unstable Shelf<sup>[12]</sup>. It is composed of a sedimentary sequence which is virtually subhorizontal except for a few basement-induced and diapiric folds<sup>[4]</sup>. To the southwest of the Arabian Platform, the NE-dipping, scarp-forming, Mesozoic and Paleozoic strata form the Interior Homocline, which rests unconformably on the northeast edge of the Arabian Shield, rocks of which have been recognized beneath both the Interior Homocline and the Arabian Platform from few deep wells which have cored crystalline basement<sup>[11]</sup>. On the northeast side of the Persian Gulf and especially in southern Iran and northeast Iraq, the Zagros Fold Belt<sup>[4,15]</sup> forms a separate tectonostratigraphic province of NW-SE trending anticlines. The main Zagros Reverse Fault<sup>[16,17]</sup> sometimes called the Zagros Thrust, limits the Zagros Fold Belt along its northeast margin and separates it from the Iranian Plate.

All these tectonic units (Fig. 3) from the Red Sea, across the Arabian Shield to the Interior Homocline, Arabian Platform, Zagros Fold Belt, Zagros Thrust, Iranian Plate, Convergence Zone and the Eurasian Plate, form part of a dynamic plate tectonic system<sup>[12]</sup>. The separation of the Arabian Plate from Africa along the Red Sea, which is widening at the rate of 1.2 cm per year in a NNE direction<sup>[11]</sup>, has propelled the Arabian Plate towards Iran, with the consequent folding and faulting of the Zagros Range sediments which are ultimately subducted beneath the Iranian Plate along a zone coincident with the Main Zagros Reverse Fault. In the major tectonic zones of Arabia (Fig. 4), the flexure marking the southeastern boundary of the Unstable Shelf and Stable Shelf, the eastern boundary of the zone of Marginal Troughs and the southeastern end of the Main Zagros Reverse Fault (Fig. 3) coincide with the lineament crossing those zones northeastward. Within the Saudi Arabia (Fig. 1), there are many folded structures paralleling the Zagros Folded Belt. A few gently folded structures are seen in an indistinct ridge, joining Damman-Bahrain and northern Qatar and in some NW-SE trending anticlinal fold along the northeastern coast of Saudi Arabia, form the Marifa Oil Field. However, the major fold structures in the Arabian Platform trend almost N-S along the Arabian Trend and

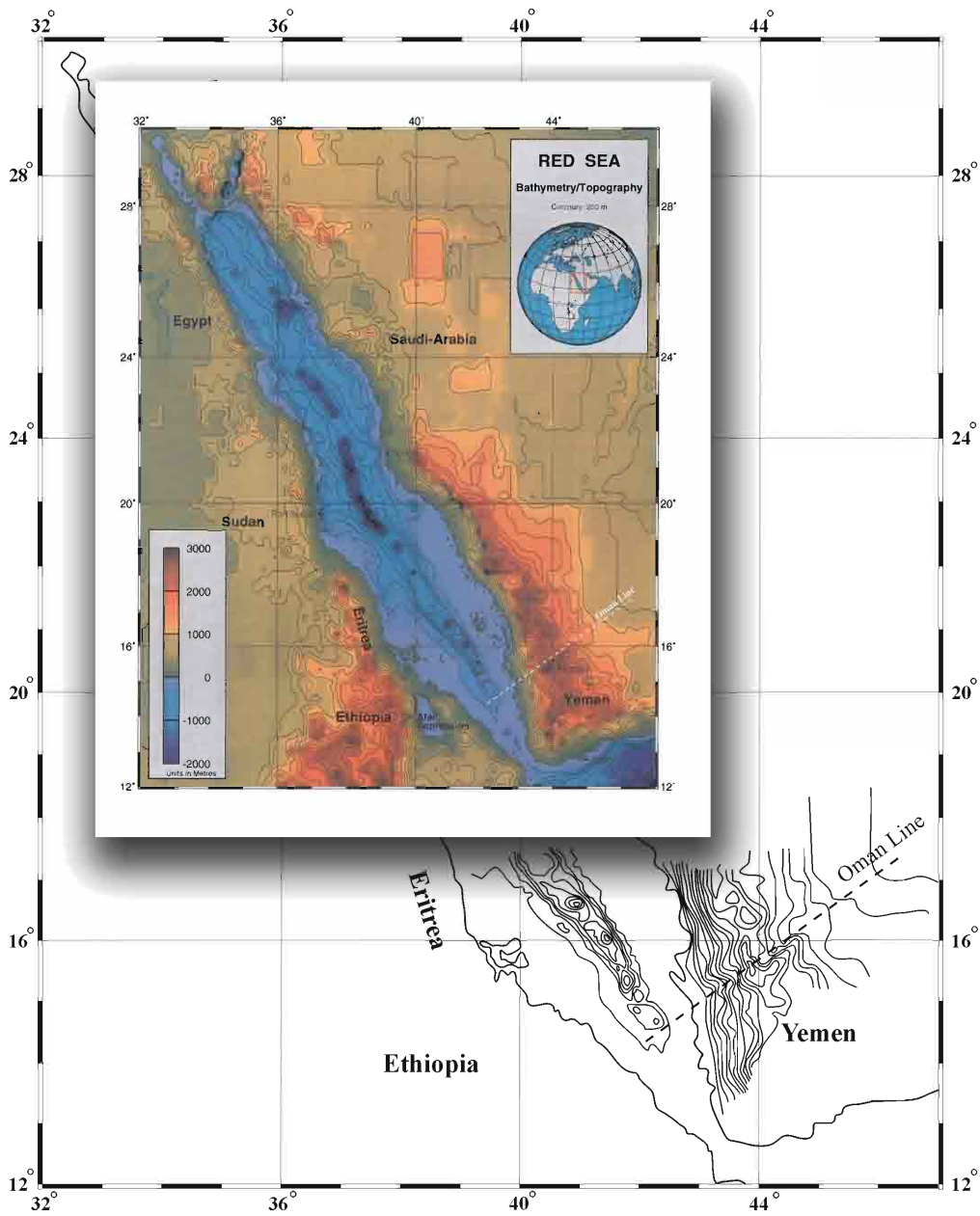


Fig. 5: Bathymetry and topography of the Red Sea. Note the change elevation in the north of Sanaa and of water depths in the Red Sea axial areas and the trend of Oman Line<sup>[26]</sup>

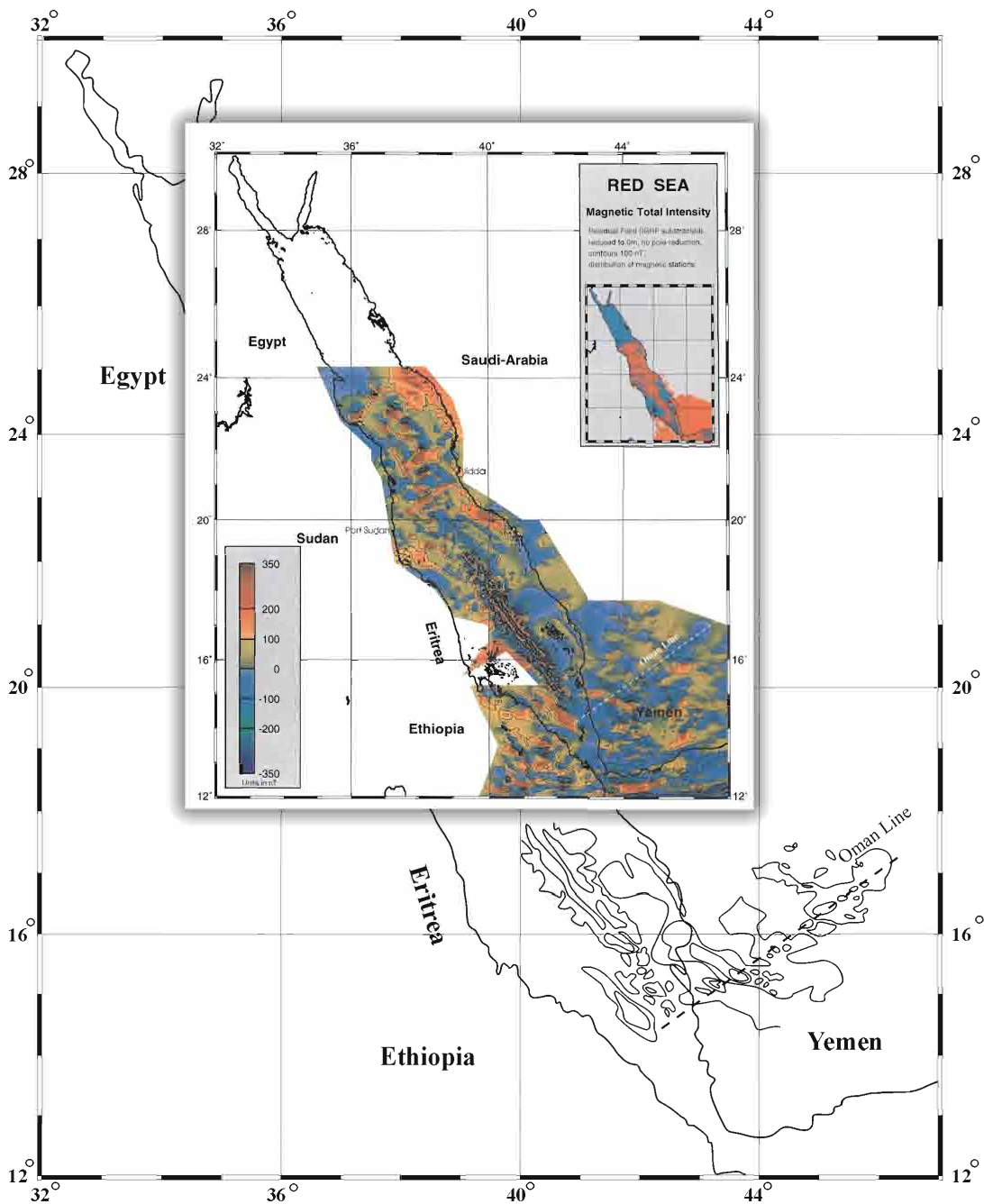


Fig. 6: Total intensity residual magnetic map of the central and southern Red Sea and adjacent coastal regions. The longer wavelength-lower amplitude anomalies onshore Yemen and southeastern end of strong dipolar linear magnetic anomalies that correlate with the sea-floor spreading zone of the axial graben of the Red Sea explain the trend of Oman Line<sup>[26]</sup>.

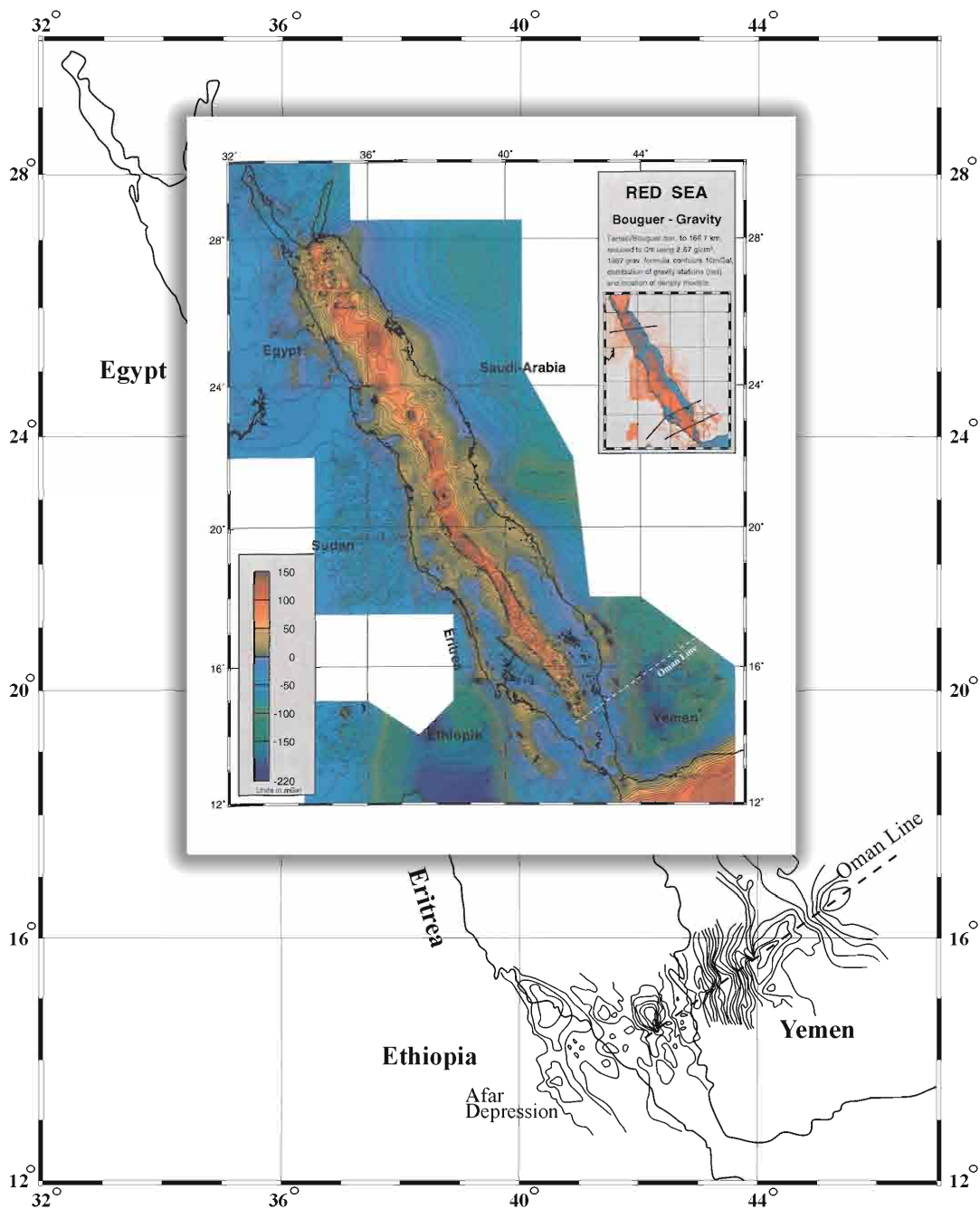


Fig. 7: Bouguer gravity map of the Red Sea region. Observes and digitized data points shown in red color in the legend, reduced to 0 m with  $2.67 \text{ g/cm}^3$ . Maximum values of  $>100 \text{ mGal}$  occur in the axial region of the Red Sea, minima exceeding  $-200 \text{ mGal}$  are found on the Ethiopian and Yemen plateaus. Note that contour lines direction and also the relative negative anomalies on the eastern flank of the southern Red Sea correlating with NE-SW strike of the Oman Line (modified form Al-Subbary et al., 1998).

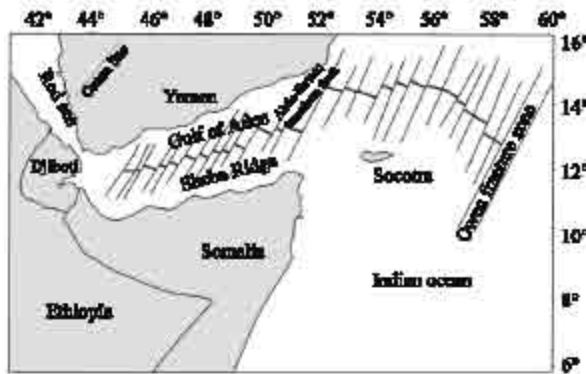


Fig. 8: Alula-Fartaq transform fault and the segmentation of the axial oceanic Sheba Ridge in the Gulf of Aden with the transform faults that have the same trend as that of the Oman Line

result from extensional faulting of the crystalline Precambrian basement. This has produced major elongated, doubly plunging anticlinal oil fields, such as Ghawar (140 km long), Khurais (75 km long), Qatif (55 km long) and numerous other N-S directed oil fields of the basement origin, such as Abu Jifan, Mazalij, Harmaliyah, Bakr, Juraybi'at, Wan'ah, El Haba, Faridah, Rimthan, Dibdibah and Jaham (Fig 1).

Although in the east and the northeast of Saudi Arabia and in the Saudi offshore portion of the Persian Gulf, different structural trends and structural types exist, they are all basement related. These structural types and trends could be separated from each other by a NE trending lineament, in the east where major growth structures with N to NE trends are clearly seen west of the lineament and other deviated trends, due to basement faulting in the eastern part. This lineament crosses the Empty Quarter along its deepest part and deviates the western end of Oman ophiolites (Fig 4).

The existence of this lineament may be hinted at by the deviation of some growth structures in the Empty Quarter. Bathymetric and topographic data from the Red Sea and southeastern Arabian Plate (Fig. 5) suggest the continuation of this lineament southwestward to the Red Sea. Magnetic total intensity (Fig 6) and Bouguer gravity (Fig 7), also confirm the trend of this lineament. The transform faults in the Red Sea have exactly the same trend as that of the Oman Line. It is parallel to Alula-Fartaq transform fault in the Gulf of Aden too (Fig. 8).

Furthermore, the transform faults that have segmented the axial oceanic Sheba Ridge in the Gulf of Aden<sup>19,251</sup> have the same trend as that of the Oman Line (Fig. 8).

## CONCLUSIONS

Oman Line, the broad structural discontinuity, which has been mapped only west of the Oman ophiolites and southern Iran, could be extended southwestward across the Arabian Plate to eventually form a transform fault in the Red Sea. Some features that suggest the presence of the Oman Line in the Empty Quarter of Saudi Arabia and its continuation in the Red Sea are: manifest in the Empty Quarter along its deepest part as deviation of some growth structures, the changing of the oil field trends from N-S in the west of the Oman Line to NE-SW in the east, the deviation of the western end of Oman's ophiolites, parallel alignments of the Alula-Fartaq and Sheba ridge transform faults in the Gulf of Aden with the Oman Line, magnetic total intensity trend, Bouguer gravity situation, bathymetric and topographic trends within the Red Sea and the Arabian Plate and the control of the eastern boundary of the Southern Gulf salt basin and western boundary of Fahud, South Oman and Gaba salt basins.

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