Tectonophysics 688 (2016) 119–134

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

# A geophysical potential field study to image the Makran subduction zone in SE of Iran

Maysam Abedi [a,b,*], Abbas Bahroudi [a,c]

[a] Department of Mining Engineering, College of Engineering, University of Tehran, Tehran, Iran
[b] Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, Canada
[c] Department of Geoscience, University of Calgary, Calgary, Alberta, Canada

ARTICLE INFO

*Article history:*
Received 16 July 2016
Received in revised form 19 September 2016
Accepted 21 September 2016
Available online 22 September 2016

*Keywords:*
Makran subduction zone
Jazmurian zone
Magnetic anomaly
Gravity anomaly
Inverse modeling

ABSTRACT

The Makran subduction wedge as one of the largest subduction complexes has been forming due to the Arabian oceanic lithosphere subducting beneath the Lut and the Afghan rigid block microplates. To better visualize the subducting oceanic crust in this region, a geophysical model of magnetic susceptibility from an airborne magnetic survey (line spacing about 7.5 km) over the Makran zone located at southeast of Iran is created to image various structural units in Iran plate. The constructed geophysical model from the 3D inverse modeling of the airborne magnetic data indicates a thin subducting slab to the north of the Makran structural zone. It is demonstrated that the thickness of sedimentary units varies approximately at an interval of 7.5–11 km from north to south of this zone in the Iranian plate, meanwhile the curie depth is also estimated approximately <26 km. It is also shown the Jazmurian depression zone adjacent to the north of the Makran indicates high intensity magnetic anomalies due to being underlain by an ophiolite oceanic basement, while such intensity reduces over the Makran. The directional derivatives of the magnetic field data have subtle changes in the Makran, but strongly increase in the Jazmurian by enhancing and separating different structural boundaries in this region. In addition, the density variations of the subsurface geological layers were determined by 3D inversion of the ground-based gravity data over the whole study area, where the constructed density model was in good agreement with the magnetic one. According to the outputs of the magnetic susceptibility and the density contrast, the Arabian plate subducts to the north under the Eurasia with a very low dip angle in the Makran structural zone.



## 1. Introduction

The collision between Eurasia and Gondwana-derived continental fragments resulted in variety of fold-thrust wedges within Tibet and Iran-Turkish plateaus extending along the southern part of Alpine-Himalayan orogeny (Figs. 1 and 2 showing different fragments constituting two plateaus and fold-thrust belts with various trends in Iran structural map). These fold-thrust belts are: Himalaya, Kashmir, Salt range-Potwar, Suliaman, Makran, Sistan, Zagros, Caucasus, Alborz-Kopeh Dagh. However, this resulted in development of one of the largest accreted wedge complexes in the world, so-called “Makran Accretionary Prism, MAP”. The Makran ranges are forming where the oceanic lithosphere of Gulf of Oman, with a Cenozoic sedimentary cover up to 6 km thick (White and Louden, 1982), is being subducted northward beneath Asia (Arthurton et al., 1992). The dimensions of the MAP are about 1000 and 300 km respectively in the EW and the NS directions (Fig. 2).

The Makran subduction was probably initiated in the Paleocene and accretion started at that time (Platt et al., 1988; Byrne et al., 1992). The modern MAP developed since the late Miocene (Platt et al., 1985, 1988). Two features make such accretionary wedge especially interesting; (1) the thickness of the sedimentary sequences on the oceanic crust is extremely high, (2) the dip angle of the subduction is extremely low about $2-3°$ (Harms et al., 1984; Flueh et al., 1997; Kopp et al., 2000; Schlüter et al., 2002). Despite the northward subduction of the Arabian plate below the Eurasian plate at a convergence rate increasing eastward from 3.6 to 4.1 cm/yr (DeMets et al., 1990), there is no expression of a deep sea trench. This is presumably due to high sedimentary input from the Pakistan and Oman coasts and due to the small dip of the subducting plate (Fig. 3b). Sediment accretion and underplating processes (Platt et al., 1988) caused the uplift of the Makran coast of about 1.5 mm/yr (White, 1983) and a seaward migration of the shoreline. Surprisingly, the number of published geological data and papers of the western segment of the Makran range available in public is very low compared to adjacent ranges, e.g. Zagros fold-thrust belt and the

* Corresponding author at: Department of Mining Engineering, College of Engineering, University of Tehran, Tehran, Iran.
*E-mail addresses:* MaysamAbedi@ut.ac.ir (M. Abedi), bahroudi@ut.ac.ir (A. Bahroudi).

http://dx.doi.org/10.1016/j.tecto.2016.09.025
0040-1951/

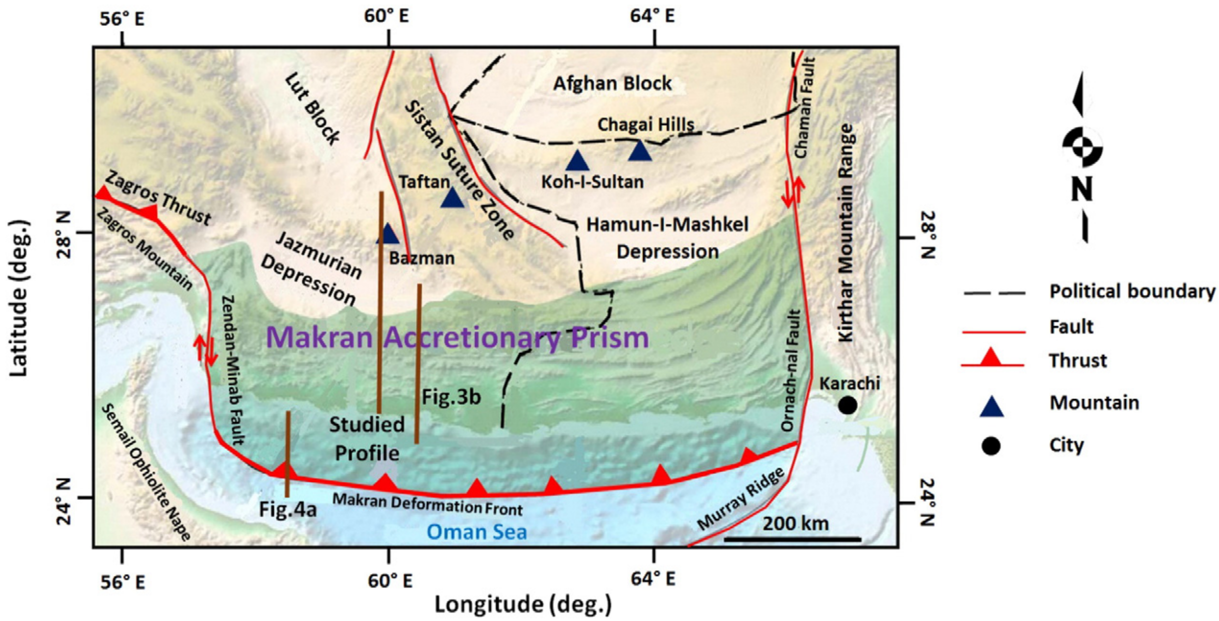


**Fig. 1.** Tectonic setting of the Makran Accretionary Prism (reproduced from Dolati, 2010.
Source Map ETOPO1, http://www.ngdc.noaa.gov/mgg/global/relief/ETOPO1/image/color_etopo1_ice_full.tif.gz).

eastern Markan range. This may be arising from few industrial activities related to hydrocarbon and/or ore-mineralization exploitation in such region.

Due to a few studies on potential field geophysical data (magnetic and gravity) in tectonophysics studies in Iran especially in the Makran, it motivates us to process such geophysical data set in this zone. This study is the first attempt to simultaneously model aeromagnetic and ground-based gravity data over the Makran zone in order to image its subduction based on the models of the magnetic susceptibility and the density variation. Main aims of this study are to investigate the status of the sedimentary thickness and the subduction dip angle in the Makran. Therefore, the potential field data are used to image two physical properties in depth across the Makran. In what follows, at first previous studies in this region are mentioned. Then geological setting is explained in detail. In addition, the potential field data are interpreted in the following section to construct two aforementioned physical properties. Finally, the aims of such study are responded based on the sound pieces of information extracted from the outputs of geophysical data modeling in the discussion section.

## 2. Previous works

The geological characteristics of the MAP in the SE of Iran have attracted geoscientists' attentions from long time ago in various fields of studies. A quantitative model of the Makran arc-trench complex has always been of key interest for the geoscientists, while only a few studies were carried out about geophysical characteristics of such zone (e.g. Namaki et al., 2011). Main investigations in the MAP are pertaining to; (1) its geological setting, tectonic and structural studies also (2) the direction and rate of relative motion of the Arabian plate and the Oman Sea to the north that subducting under the Eurasian continent. The acquired outputs from such studies could provide precious pieces of information that have substantial effects on diverse kinds of analysis such as neotectonics, raised beaches, sediment deformation style, folding and magmatism (Moridi Farimani, 2011).

Geophysical investigations of the Makran subduction zone as an accretionary wedge or prism are required in order to respond to diverse topics about its background geology and tectonics, mostly arising from the unknown subsurface geophysical properties of that area. The common geophysical studies in this area is pertaining to the interpretation of seismic data in order to better evaluate deformation and folding of the Makran zone (e.g. Kopp et al., 2000; Gaedicke et al., 2002; Schlüter et al., 2002; Mouchot et al., 2010; Smith et al., 2012; Abdetedal et al., 2014). Processed seismic sections across the Makran indicate sediment deformation and fault developments (Fig. 4). It was shown that thrust dip of the Makran subduction is mainly to the north and synclines have frequently developed between the trust faults (e.g. Uchupi et al., 2002a, 2002b; Hosseini-Barzi and Talbot, 2003; Hosseini-Barzi, 2010). Namaki et al. (2011) constructed a model of magnetic susceptibility by inverting airborne magnetic data along a flight profile in southeast Iran that intersects the Makran subduction zone and its related geological structures. In addition, they showed a deep oceanic crust remnant that located beneath the sedimentary cover at the Jazmurian depression zone.

Various attempts have been carried out to deal with the automatic inversion of the potential field data to construct models of the magnetic susceptibility and the density variation. As a fundamental study to consider such aim, Last and Kubik (1983) suggested a compact solutions that correctly constructed sharp boundaries of the subsurface sources. Later Li and Oldenburg (1996) proposed a comprehensive approach for 3D inversion of the magnetic field data. Their approach was based on the minimization of a global cost function composed of a model regularizing and a data misfit functions. They also incorporated a depth-weighting function in their proposed method to counteract the spatial decay of the potential field data with depth by giving more weight to deeper sources. Depth weighting has been later embedded in different inversion algorithms in the potential field data studies (e.g. Boulanger and Chouteau, 2001; Chasseriau and Chouteau, 2003; Li and Oldenburg, 1998, 2003; Portniaguine and Zhdanov, 2002; Pignatelli et al., 2006; Caratori Tontini et al., 2006; Abedi et al., 2013; Abedi et al., 2014). The infrequent studies of the aeromagnetic and gravity data in Iran can be found in the works of Snyder and Barazangi (1986), Paul et al. (2006), Abedi and Oskooi (2015) and Oskooi and Abedi (2015),