EFFECT(S) OF LOWER CRUST FLOW AND RECENT TECTONIC ACTIVITIES IN ZAGROS

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ABSTRACT

Seismicity in Zagros Fold and Thrust Belt is known as an enigma Most of the located earthquakes lay between sedimentary cover rocks and basement in upper crust located in depths of 10-15km Subduction of Arabian plate has not been confirmed by geophysical investigation or by GPS measurements Indeed, the suture zone is not tectonically active as it is usual in area of continental underthrusting The decision making to attribute earthquake events to cover or basement is also debated Geophysical and geological studies across the belt, however, detected a weak thickened lower crust The role of a fluid lower crust and its interaction with upper crust is known as an interested subject in continental collision domains in last two decades With the use of bouguer gravity anomaly obtained by Snyder and Barazangi (1986) and calculating admittance and coherency, this study puts documents forward to show (in Zagros) the upper crust and lower mantle decoupled It then concludes the vertical pressure induced by lower crust injection and horizontal pressure running by Arabia is responsible for recent configuration of seismic activity in Zagros Finally, this paper discusses why the seismicity is different in salients respect to reentrants

INTRODUCTION

The Zagros fold-and-thrust belt in SSW of Iran (Fig 1) is amongst the world's most seismically active mountain ranges, and is significant in our understanding of continental collisions To date, the evolution of structure of Zagros has been looked mostly by two defaults: presence or absent of Hormoz formation (a 1km-thickness of Precambrian salt) and fracture patterns inherited since or before early Triassic when the NeoTethys started opening between Arabia and Central Iran by which a passive margin in north of Arabia evolved Seismicity is as a result of reactivation of these fractures (Jackson, 1980) Most of the earthquakes locate 10 – 15 km depths range: the depth between basement and sedimentary cover rocks The mechanisms controlling seismicity, however, attributed to thin- to thick-skinned tectonics Therefore, the depths of the sources deceive the researchers That is, somebody relate active deformation to the faulting within sedimentary cover rocks (Bahroudi and Koyi, 2003; McQuarrie, 2004, Nissen et al, 2011) some other suggest the origin is lower in basement (eg, Molaniro et al, 2005a; Berberian, 1995, Hatzfeld et al, 2010, Tartar et al, 2006) Although until an integrated study, by which a high resolution survey of active deformation in surface and depth would be produced, the debates will be remained, this paper, on the other hand, addresses an alternated possibility to explain the active deformation in point of view of flexural rigidity

In the last studies to find reasons for upper mantle dipping (5 to 17°) in place of suture zone laying along Main Zagros Reverse Fault, Snyder and Brazangi (1986) and Paul et al, (2006), in their flexed upper mantle, replaced higher density of lower crust material instead of upper crust to reconcile the flexure of upper mantle with this density contrast In the other word, the thickened lower crust is a consequent of weakening of upper mantle and vice versa This, in turn, causes decoupling of upper mantle with upper crust

Indeed, the lower crust behaves as a fluid under pressure that causes the mantel is flexed down and upper crust pushed up thereby Snyder and Barazangi [1986] proposed that isostatic and elastic flexure forces are acting together with hydraulic thickening of the plastic lower crust due to horizontal compression to produce the observed localized crustal thickening I use admittance and coherency methods first to find the effective elastic thickness (EET) in both of salient and reentrant is relatively low and second to show in the salient the Te is less than that of reentrants The results may account for the flexed upper mantle and/or be a constraint on the thickened upper crust and its consequents on active tectonics

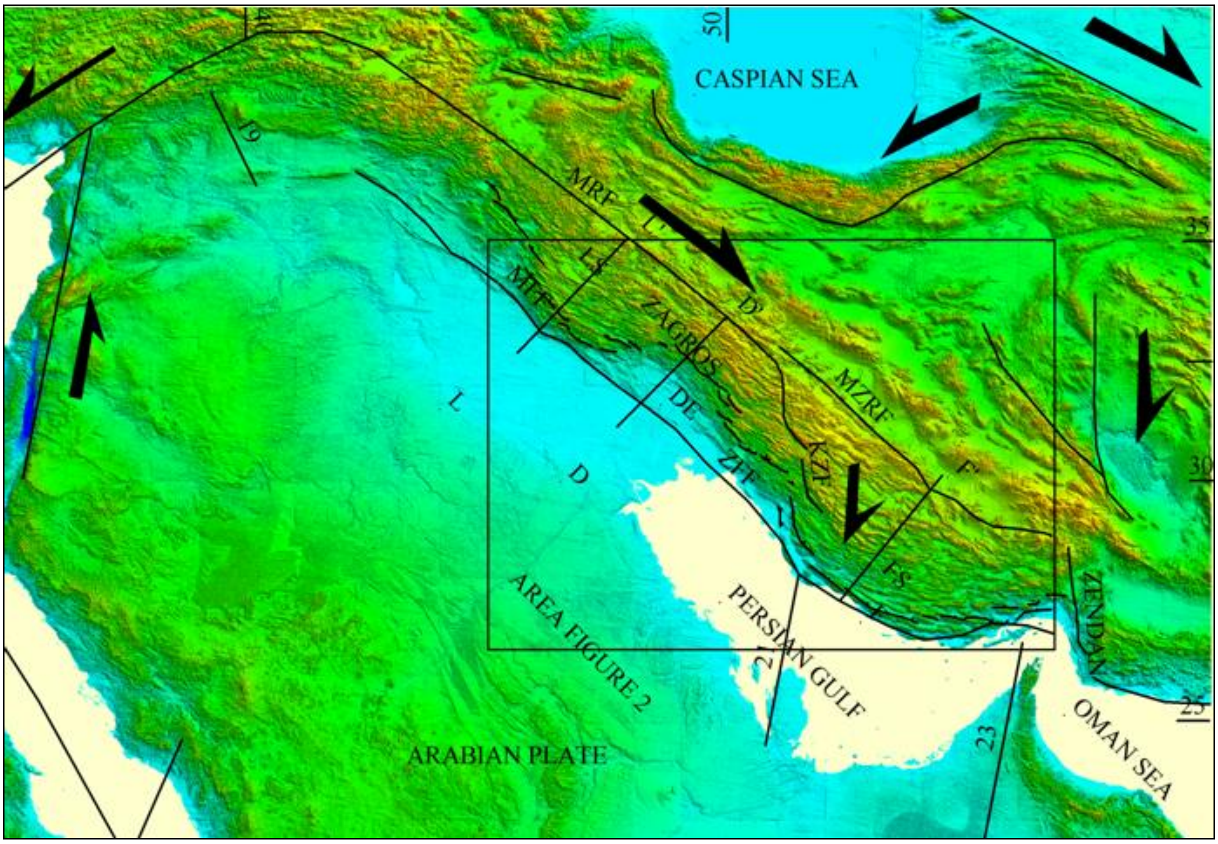

Figure 1 tectonic map of Middle East and main structural elements plotted on shaded relief map of GTOPO digital elevation model Arrows show the rate of Arabia motion in mm/year are adapted from Vernant et al, (2004) The black thick arrows show strike-slip faults and lines with dog teeth indicate thrust faults
Abbreviations are: MZRF: Main Zagros Reverse Fault, MFF (Mountain Frontal Fault), KZF (Kazerun Fault), MRF (Main Recent Fault), and ZFF (Zagros Fore deep Fault)

Among the main factors involved in deformational pattern in an orogenesis are internal friction, basal friction, and lithosphere flexural rigidity An increase in frictional strength or decrease in basal friction cause lower deflection of underlying plate concluding a narrower taper In Dezful embayment (west central Zagros) it is suggested the Hormoz salt (a significant de'collement layer) is absent (eg, Bahroudi and Koyi 2003) Therefore, it can be expected a large basal friction and, conclusively, large deflection The more deflection implies weaker crust that is more prone to decouple

In the Zagros the most of deformation is recently absorbed by Mountain Frontal Fault (MFF) The deformation front, however, is represented by ZFF (Berberian, 1995) The distance between the two active faults (ie MFF and ZFF) is indirectly implied to the spaces between two active deformations on the level of thin- and thick-skinned tectonics respectively (Malekzade, 2007) As the name implies, in salient, this space is less than the space in reentrants It, based on admittance and coherency results, permits me to suggest the lower crust flow or decoupling of upper mantle and upper crust stopped in front of reentrants Worth noting is that the elevation around reentrants is higher (Fig 3) implying the foreland in reentrants is stronger (eg Maggi et al, 2000, Clark and Royden, 2000)

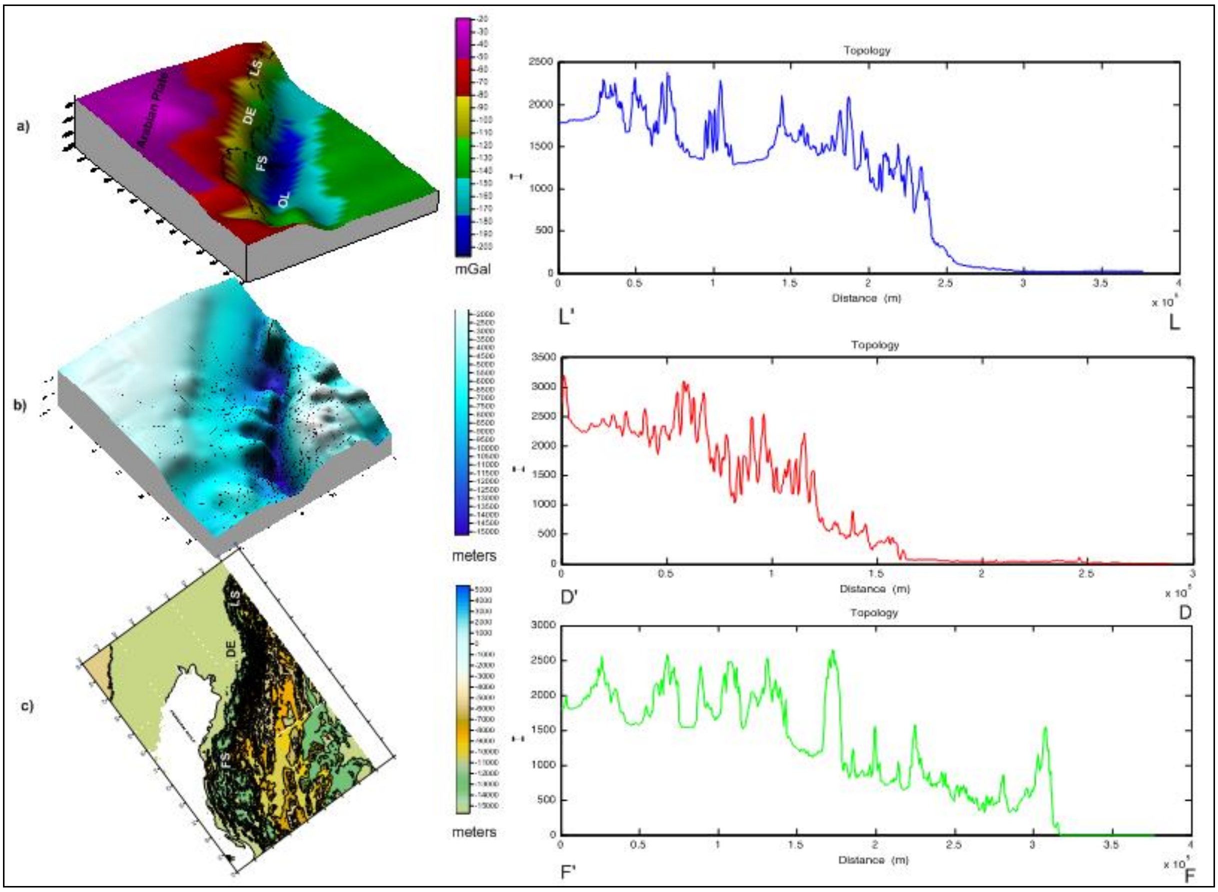

Figure 2on the left hand of the figure three aspects of gravity (a), basement topography (b) and surface topography (c) with scale bars show the inhomogeneous Arabian plate margin those are Lurestan salient (LS), Dezful Embayment (DE), and Fars Salient (FS) from north to south are shown On the right hand of the figure three topographic sections of LS, DE, and FS from top to down with offset from MZRF, that their locations are shown in Fig 1, represent the different morphology (shape and latitude) of DE reentrant from two salients of LS and FS

DATA

In the analyses, the Bouguer gravity anomaly data adopt from Snyder and Barazangi (1986) and the topographic data derive from GTOPO digital elevation model To have better constraint on effect of gravity on topography and according to McKenzie and Fairhead (1997) the Bouguer gravity anomaly changed to the free-air gravity anomaly Fig 2 shows different aspects of basement and surface topography associated with Bouguer gravity anomaly to highlight the significance of plate margin geometry and its influences on deformational pattern that is the aim of present study

METHODOLOGY

As pointed out in last session this study uses admittance and coherency method (McKenzie and Faihead, 1997) to find the flexural rigidity As a general role, to maintain equilibrium, the density contrast in crust and mantle is compensated by isostasy (Airy and Pratt idiom), flexural response of rigid part of crust or upper mantle, and dynamic forces that, in the case of this study, is applied vertically by bringing up lower crust and horizontally by tectonic compression The logic behind of this method is that, at least for the Tertiary trains (Bird, 1991), the topography can be compare to gravity Parameter corresponds two quantities is wave number (k) that is inverse of wavelength ($1/\lambda$) So, correlation of the two can lead to constrain the k values that they match This is performed by calculation of observed admittance:

$$z_f^{obs} = \frac{C(k)}{E_b(k)} \quad (1)$$

Where c (k) is cross spectrum of Fourier transform of gravity (G (k)) and conjugate of Fourier transform of topography (B (k)) $E_b(k)$ is power spectrum of the topography

$$C(k) = \frac{1}{N}\sum_{r=1}^{N} G(k).B(k)^* \quad (2)$$

N is number of profiles

$$E_b(k) = \frac{1}{N}\sum_{r=1}^{N} B(k).B(k)^* \quad (3)$$

Admittance is strongly biased toward low values if subsurface density variations are not taken into account (Macario et al, 1995 and references therein) Therefore, the nonlinear transfer function between topography and gravity so called Coherency (Forthys, 1985) is calculated as below:

$$\gamma_{(k)}^2 = \left(N.\frac{C(k).C(k)^*}{E_g(k).E_b(k)} - 1\right)/(N-1) \quad (4)$$

Where :

$$E_g(k) = \frac{1}{N}\sum_{r=1}^{N} G(k).G(k)^* \quad (5)$$

is power spectrum of gravity

As mentioned above k is reciprocally related to wavelength as:

$$k = \frac{2\times\pi}{\lambda} \quad (6)$$

In Eq (6), k depends on sampling frequency and length of profile For example the profile across Dezful (DD' in Fig1) has 334km and number of sampling is 1024 and sampling spacing is 326m so the wave numbers are in range of 00093 to 0 307

Finally the theoretical flexural rigidity is evaluated and compare with observed value for different elastic thicknesses:

$$z(k)^{flex} = (2\pi G(\rho_c - \rho_s)e^{-kd}(1 - \varphi_e'(k)e^{-kT_c} \quad (7)$$

Where:

$$\varphi_e'(k) = \left(\frac{Dk^4}{(\rho_m - \rho_c)g} + 1\right)^{-1} \quad (8)$$

and:

$$D = \frac{ET_e^3}{12(12-\upsilon^2)} \quad (9)$$

To calculate and present the results I wrote a cod in Matlab software In this code, and the above mentioned equations ρ_c , ρ_m ‹ρ_s are density of crust, mantle and sedimentary cover respectively The other parameters in the equations are G ‹g ‹v ‹E ‹D ‹d ‹T_c those are: global constant gravity of the earth (equal to $66726*10^{-11}$ $N{\cdot}m^2/kg^2$), acceleration due to gravitation, Poisson coefficient, elastic modulus, elastic thickness, and shear modulus respectively The values for these parameters included in Table 1

Table 1 The values of parameters used in the equations

Parameter	Definition	Value
E	Young Modulus	10^{11} N/m^2
υ	Poisson's ratio	025
G	Gravitational constant	66726*10^{-11}N·m^2/kg^2
g	Gravitational acceleration	981 m/sec^2
ρ_c	Crustal density	2800 kg/m^3
ρ_m	Mantle density	3400 kg/m^3

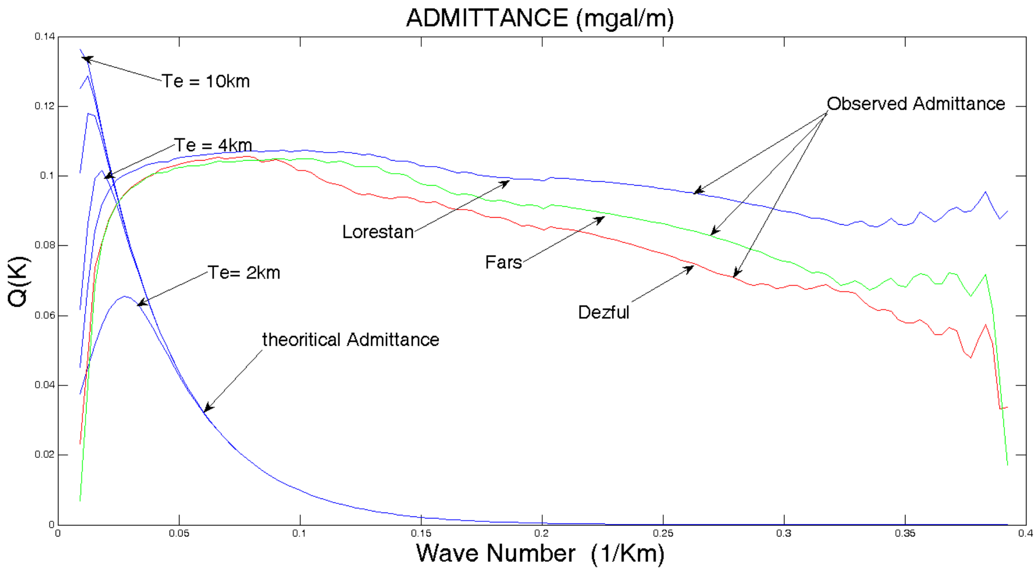

Figure 3 the result of calculation observed and calculated admittance versus wavenumber of Bouguer anomaly implying the lithosphere lower than 10 km thickness

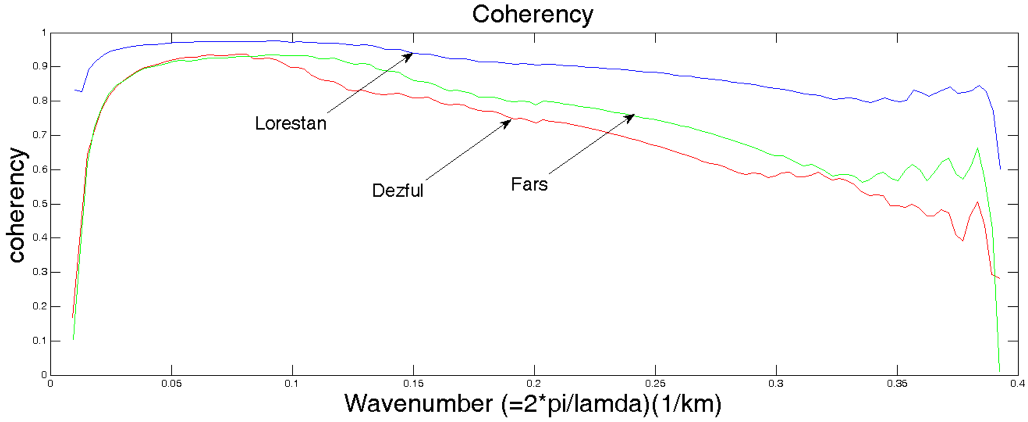

Figure 4 the result of calculation coherency versus wavenumber implying the lithosphere of Dezful has higher wavenumber at the same coherency denoting a higher elastic thickness

CONCLUSIONS

Admittance results of data across salient and reentrants (Fig 3) show the EET is small in all along Zagros and coherency, on the other hand, shows the Dezful embayment, among the all profiles, has higher wave number at the same gravity energy (Fig 4) So, I conclude the EET in Dezful is comparatively higher The low EET may suggest the decoupling of upper crust and upper rigid mantle by a fluid like of lower crust This case has also been presented by Snyder and Barazangi, (1986), Paul et al, (2006) and Yaminifard et al, (2006) It, in turn, may imply the lower crust flow is not propagated in reentrants while it is easier in salient In the other word Dezful embayment behaves as an obstacle and its foreland is too strong to permit the lower crust fluid to propagate more southward This not the case for salients especially for Fars Province where the upper crust decoupled from upper mantle by Poiseuille flow (a planar channel flow as described by some workers as Bird, 1991) This process permits upper crust to be activated in the thick-skinned tectonic regime while, on the other hand, the limitation for such flow in Dezful provide facility to have a thin-skinned tectonic instead The main role in both cases is being played by MFF In fact, MFF is an end member structure playing role as lower crust flow front and therefore I propose a lower crust flow pinched out along MFF instead of salt flow pinched out that has been suggested for this frontal fault by some workers eg Bahroudi and Koyi (2003)

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