MULTIFRACTAL ANALYSIS OF SEISMOGENIC DECOMPOSED LINEAMENTS IN NORTH AND NORTH-WEST OF TEHRAN

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ABSTRACT

According to geophysical assessments, Structural lineaments are usually decomposed and made a hidden complex pattern for seismic interpretations in the northern seismic region of Tehran. Fractal geometries provide a chaos-based method for resolving geometrical, mechanical, and mathematical ambiguities of seismic ruptures. While the faulted regions simply assumed as planar zones, the macroscopic structures show smoothened fabrics with self-similar segmentations. In a fractal framework, structures are irregular with discrete features incline to heterogeneous characteristics on various scales. Most of destructive earthquakes have pre-seismic evidences of which frequently triggers subject to deterministic chaos. Multi-fractal analysis of geophysical databases is a nonlinear statistical solution for revealing hidden decomposed lineaments as the relevant structures producing pre-seismic activities. Several cases for studying north Tehran faulted regions have been performed since 1965, but it is theoretically updated in this research by discriminating coherent structures as a deep but relevant to seismicities from other lineaments (incoherent). The available geo-databases including geological features and attributes (table data) have been processed by Arc-GIS for producing magnetic and gravimetric gridded maps of which contours indicated to paternal gradient of the hidden lineaments (coherent seismic structures) in coincidence with earthquake catalogues and active faulting zonation according to seismotectonics investigations. A minimal set of geophysical databases including seismic, aeromagnetic and airborne gravimetric are needed for reducing decomposition effects of the lineaments. It is widely accepted that spatial disordering of geophysical gradients may be affected by the ruptures. Like a case in northern region of Tehran, both magnetic and gravimetric gradients uses for revealing nonlinear features at the end members of seismogenic lineaments.

INTRODUCTION

Most of the earthquakes have severe long term processes in a continuum solid states assumption before responding to triggering movements near hypocenters (Datta, 2005). In Fractal, there is a major competent framework in association with mathematical nature of faulted regions (Mandelbrot, 2006). Faults are not regular planar Euclid zones and never extended in a continuum solid state (Turcotte, 2007). Also there is no focuses on granular aspects of faulted structures of which faulted zones are discrete and strongly behave heterogeneously (Kagan, 1994, Newman et al., 2005). In this framework the fundamental structures are irregular with significant discrete features, which have strongly heterogeneous characteristics in various scales. The fractal structures follow a power law frequency-size distribution which is reported to characterize important brittle deformation in the crust over several bands of length scales. This research focused on nonlinear processes with an optimized geophysical database for multi-fractal frequency modeling the structures in north of Tehran. Processes involve two types of power law relationships which realized number of decomposed lineaments related to Tehran seismicity. The city is located in active region near central

Alborz. Faulted regions are extended in northern and documented as a Quaternary rupture moved repeatedly at the recent geological time (Ashtari Jafari, 2010). At least two destructive earthquakes have been recorded in northern regions of Tehran according to catalogue. Table1 shows the major events (after 743AD) and related seismicity after 743AD (Berberian & Yeats, 1999).

Table 1.Historical earthquakes (734AD– 2004AD; Ms≥6.0) at r≤200 Km –Tehran (Berberian & Yeats, 1999)

Row	Longitude	Latitude	Ms	Year (AD)	Month	Day	r (Km)	Ref
1	52.2	35.5	7.2	743			74.08	AMB
2	51.5	35.6	7.1	855	5	22	13.25	AMB
3	51.1	36	7.7	958	2	23	44.08	AMB
4	50	36.38	6.5	1119	12	10	148.55	AMB
5	50.7	35.7	7.2	1177	5		65.16	AMB
6	53.2	36.1	6.7	1301			166.7	AMB
7	50.5	36.7	7.2	1458	8	15	138.41	AMB
8	50.5	36.4	7.6	1608	4	20	113.59	AMB
9	52.1	35.7	6.5	1665	6	25	61.54	AMB
10	52.6	36.3	6.5	1687			125.5	AMB
11	51.3	34	6.2	1778	12	15	188.91	AMB
12	52.5	36.3	6.5	1809			117.95	AMB
13	52.6	36.1	6.7	1825			115.4	AMB
14	52.5	35.7	7.1	1830	3	27	97.74	AMB
15	52.5	34.9	6.4	1868	8	1	132.38	AMB
16	53.32	36.36	6.8	1935	4	11	186.24	AMB
17	52.47	36.07	7	1957	7	2	103.31	AMB
18	49.81	35.71	7.2	1962	9	1	145.7	AMB
19	50.65	34.47	6.2	1980	12	19	153.46	IGUT
20	52.97	35.9	6	1990	1	20	141.85	IGUT
21	51.65	36.37	6.4	2004	5	28	76.94	IGUT

Ref : AMB : Ambrayses , Mervil , 1982

Ref : IGUT : Institute Geophysics , University of Tehran , 1983

Most of the seismic patterns are decomposed and therefore require to be revealed by geophysical interpretations (Ashtari Jafari, 2010, Mehrnia, 2011). Because of chaotic natures of which patterns are realized in historical earthquakes , study of decomposed lineaments has not been detailed and therefore, a multi-fractal solution is applicable for reconstructing the seismogenic patterns in north of Tehran (Mehrnia, 2011).

STATEMENTS

In the most of earthquakes, active regions contain a set of seismogenic lineaments with scale invariant properties (Mandelbrot, 2006). Frequency-magnitude equation is an applicable statement for obtaining the nonlinearity of magnitude variations and therefore can be related with earthquake parameters, including structures and fabrics (Turcotte 2007). These parameters are usually affected by deformation processes and subsequently disqualified for seismic interpretations. In such cases, a power law relationship that is generated by logarithmic recursive functions is a mathematical choice for reducing ambiguities of the seismicities. Turcotte et al. (2006) showed that relationship between the length of faulting breaks and the encircled areas of the faulting region can be introduced by power law function as Eq. (1):

$$N_{CE} = B \cdot r^{-2b} \quad (1)$$

where N_{CE} is the cumulative number of earthquakes with a magnitude greater than or equal to M; B is constant and b-value is the slope of the log-linear relationship that is known as fractal dimension (FD) [15]. $r = \sqrt{A}$ is the length of the fault break and A is the area of the fault break. Then 2b = FD is the dimension of seismic activity for regions from which the data were collected (Turcotte 2007). Studying on fragmentation processes yield a power law relation of frequency-size distribution with D= 2.5 [18]. In practice, there is a nonlinear but growing algorithm in the most faulted regions by D=1.585. Therefore, a multi-fractal distribution of the faulted regions can be easily implies to multi-fractal distribution of the epicenters. Turcotte (2007), showed that a power-law relationship holds true at least for both magnetic and gravimetric field values while anisotropies are insensible for invariant scales. Anisotropy is an ordinary specification which produces different types of non-momentum orientations between the surfaces. Therefore bigger anisotropy causes bigger ambiguities in earthquake lineaments and give rise to BIASES due to interpretations (Newman et al, 2007). For S-A model, the relationship between the encircled areas of spectrums A(≥E) and related spectral values (E), can be represented by Eq. (2):

$$A\ (\geq E) = E^{-\beta} \quad (2)$$

where (β) is the values of slope variations and calculated by plotting the log A (≥E) versus log (E) [34],[35].

DATABASES

Airborne geophysics containing aeromagnetic and gravimetric databases in addition to seismic evidences have been used for tracing the lineaments and reducing their decomposition effects. An spatial disordering of geophysical gradients may be happened by the ruptures along faulted regions. Like a case in northern regions of Tehran, both magnetic and gravimetric gradients can be used to revealing the nonlinear features as the relevant end members of the seismogenic lineaments. Meanwhile, locations of the large asperities can be recognized by geophysical interpretations and easily implemented to rupturing models.
Magnetic and gravimetric values have been collected by aircraft measurements due to several systematic flights over the city. Important geometrical parameters represented in Table 2, and updated spatial information also standardized by updated Worldwide Geodetic System (WGS84) using decimal degrees (dg).

Table 2. Geometrical - Statistical parameters of geophysical datasets for Tehran region

Airborne Gravimetric Dataset								
Entity Unit: dg, Sys: WGS84, Zone: 39N				Z valu Unit: mgal		Z value Statistics		
Longitude		Latitude						
Xmin	Xmax	Ymin	Ymax	Zmin	Zmax	Mean	SD	Skewness
50.8557	51.7037	35.1873	36.0603	39358.95	39648.05	39503.51	69.47	2.73

Airborne Magnetic Dataset								
Entity Unit: dg, Sys: WGS84, Zone: 39N				Z value Unit: n.t		Z value Statistics		
Longitude		Latitude						
Xmin	Xmax	Ymin	Ymax	Zmin	Zmax	Mean	SD	Skewness
50.8557	51.7037	35.1873	36.0603	-156.62	-103.99	-125.62	11.62	-0.35

Berberian and Yeats (1999), reported 21 destructive earthquakes since 743 AD. In this catalogue (see Table 1), two seismic records have been located in northern regions of the city with approximate epicenters and lack of geometrical association with the instruments.
Comparing seismogenic lineaments with the observed structures, I have focused on updated seismotectonics map issued by Berberian et al (1999). In this map, North Tehran Fault (NTF) is an active structure with several decomposed lineaments covered by Quaternary formations with no significant fabrications.

ANALYSES

A power law relation has been used for analysis of the structures based on the scale invariant properties in a self-organized spectrum. Most of the geophysical fabrics indicate to time dependent relationships. Also their geometrical properties subject to power spectra statements in spatial domains. Inverse Distance Weighting (IDW) and Polynomial regression (PR) are two geo-statistical methods used for interpolation. Fig.1 shows two gridded maps containing 0.001 dg of cell values with 853 columns and 875 rows as geometrical parameters.

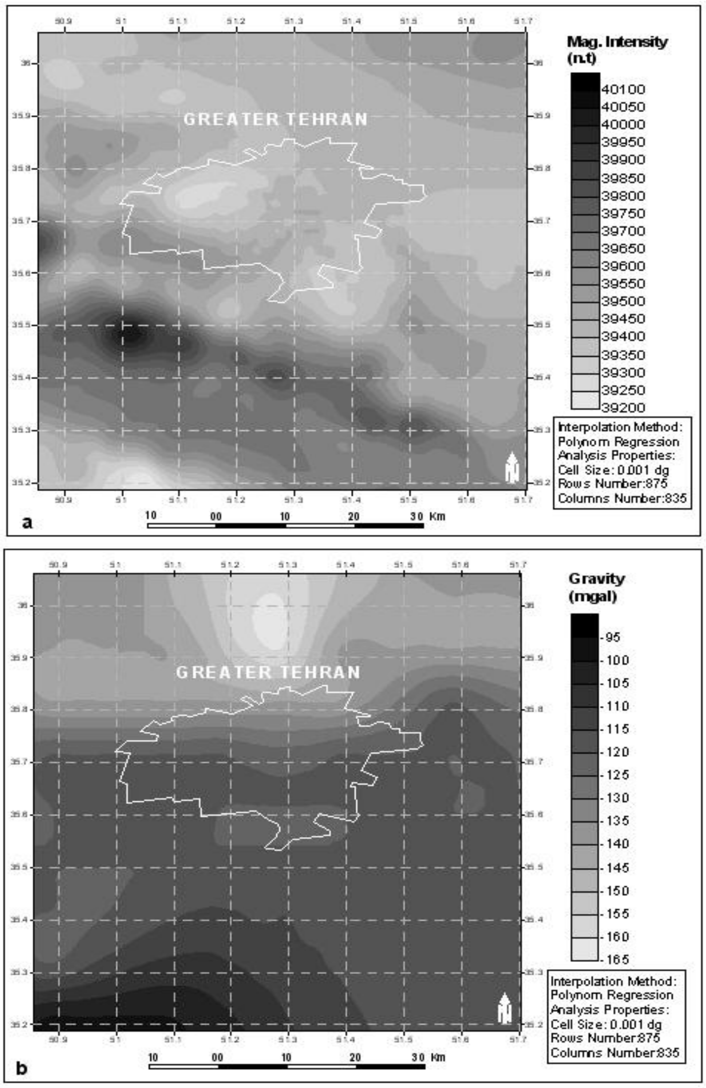

Figure.1. IDW results for Magnetic (a) & Gravity (b) Residual values – Greater Tehran

Gridding results showed that the northern region has significant potential for East-West fabrications. Magnetic and gravimetric gradients are dense enough with complicated contours across the northern region. Correlative interpretations have been well done for recognizing the seismogenic lineaments by the logistic algorithm. South of Tehran is also affected by NW-SE structures; however, a lack of isotropic gradients in addition to lesser gravimetric abnormalities, cause to lesser opportunities for meaningful interpretations.
Airborne intensities (magnetic and gravimetric) are well functioned by S-A log-log plots (Eq.2) for obtaining fractal density functions of the frequency signatures.
For magnetic density function, a filter value=-0.45 indicates to moderate discriminations between backgrounds (Log Area < -0.45) and anomalous regions (Log Area > -0.45), while in gravimetric function, filter value=-0.10 indicates to meaningful discrimination between background (Log Area < -0.10) and anomalous region (Log Area > -0.10). Most of the hidden fabrications may be revealed and considered as the earthquake lineaments after S-A model applied. It is the most important reason for using fractal - spectral solution for revise in seismic structures of the north of Tehran.

MODELING

Applying binary filters to frequency images can provide a relatively high and low power-spectrum without regularly bounds on Fig. 2 (a, b). In a binary map, coherent appointments are known as continuum values of extended frequencies which not only their attributes imply to linear distribution of geophysical responses, but cumulative appearances (such as aggregated contours) can be referred to topological associations with deep seismic resources.

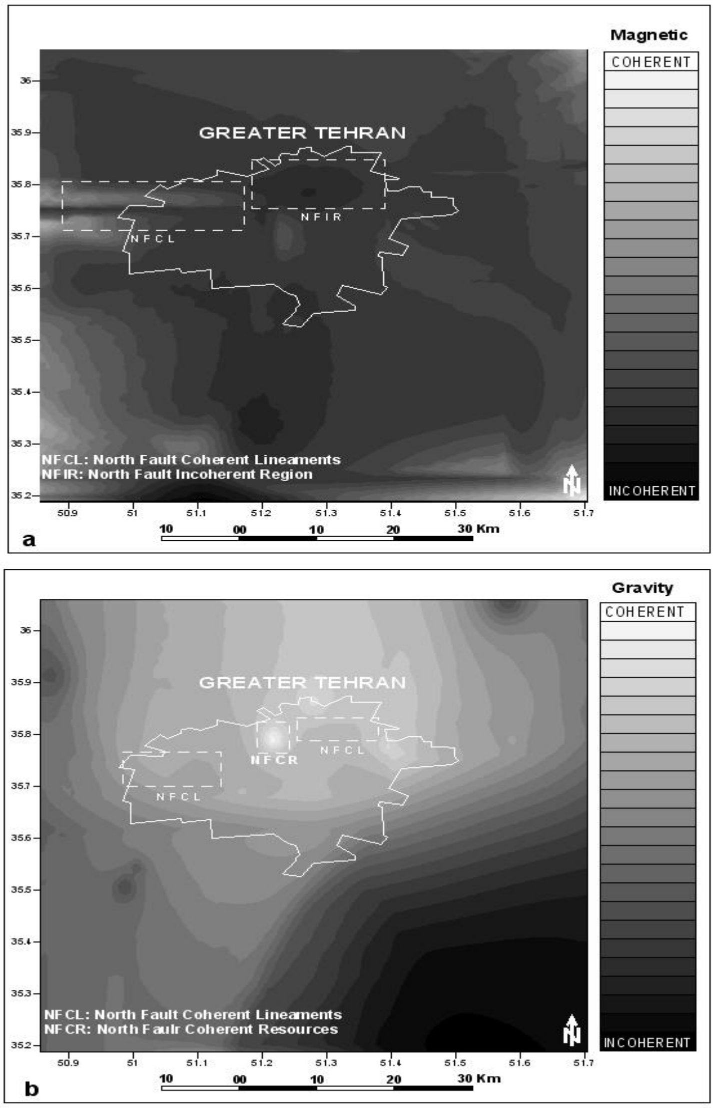

Figure 2.IDW results for Magnetic (a) and Gravimetric (b) spectrums.
Coherent Vs. incoherent subsets have been recognized by Power Spectra relationship

Fig.2 has two plots that is gridded by IDW technique and converted back to spatial domain by Inverse Fourier (IF) algorithm. Fig. 2a shows magnetic wavelet variables converted to spatial after filter area > -0.45 applied. Fig. 2b is a gravity wavelet converted to spatial with a same method and filter area > -0.10 applied.

For Geophysical intensities, unique coherencies have been found along North Tehran Fault (NTF). Coherent magnetic and gravimetric segmentations can be seen at western part of NTF. This segments located in tuffaceous formation between Tehran-Karaj cities. Another aggregation was happened in the Eastern part of NTF. Except above mentioned coherencies, more than 75% NTF shows incoherent lineaments in a weakened or non-fabricated subset.

As it is shown in Fig.3, coherent and incoherent lineaments are two possible spectral subdivisions according to magnetic and gravimetric spectral differentiations in north of Tehran. As it is shown in Figure.3, Coherent Component Nonlinear Analysis (CCNA) of decomposed lineaments in north and northwest of Tehran provided a new seismic pattern can be used for discriminating deep seismic structures (Bold lines) from incoherent. It is an introducing to update Hazard Analysis Program (HAP) by reducing in structural complexities for Greater Tehran.

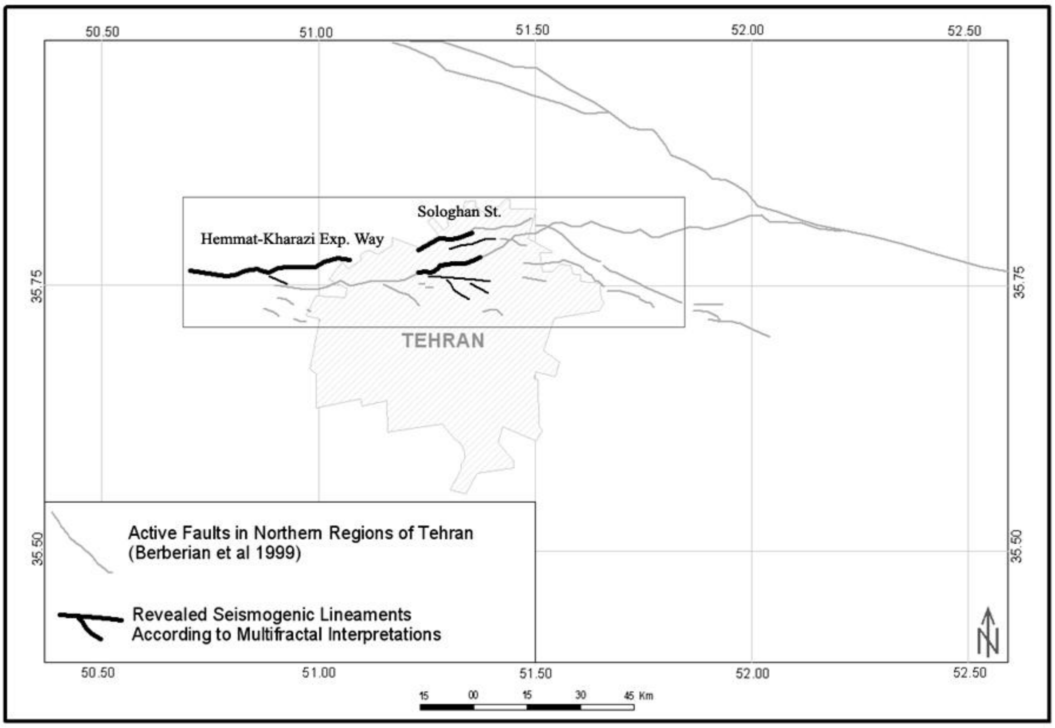

Figure 3. CCNA integration result for revealing seismogenic lineaments in north & northwest of Tehran

Actually, it is a vectorized integrative model that is represented to seismic, magnetic and gravimetric databases after CCNA technique applied in north and northwest of Tehran (Berberian & Yeats 1999). The first segments (bold lines) are located between the longitudes: 50.75 – 51.25 and latitudes: 35.75 – 35.78. Also a long segmented lineament has been located between longitudes: 51.25 – 51.35 and latitudes: 35.71 – 35.79 as the second.

The revealed seismogenic lineaments have spatial association with deep and stable structures (next to hypocenters). The first seems to be directly originated from North Tehran Fault (NTF) in Sologhan station but the second is mostly extended toward North West of the city and therefore increases earthquake hazards for recently developed constructions in Hemmat-Kharrazi Exp. way.

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