THE ANALYSIS OF SEISMIC STRESS REGIME IN AHAR- VARZEGHAN REGION, NORTHWESTERN IRAN

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ABSTRACT

We analyze stress state in northwestern Iran which includes Ahar-Varzeghan region by determining the focal mechanisms of 15 earthquakes using the moment tensor inversion method of ISOLA and also by focal mechanisms of other large and moderate earthquakes determined by GCMT. The events have moment magnitudes higher than 4 and encompass latitudes between 34- 40° N, and longitudes between 43- 51° E, during the period 1976-2013. We calculate the principal orientations of stresses in the region by multiple inverse method. The result shows the stress model with σ_1 direction equal to 136.7 degree. In contrast, the direction of the principal stress is almost north-south in eastern Anatolia and east-west in western Caspian sea. This difference in geodynamic regimes in the study area may be attributed to the north Tabriz fault.

INTRODUCTION

Northwestern Iran is one of the seismically active regions with a high seismic risk in the world endorsed by historical background and instrumental earthquakes. This area is part of the complex tectonic system due to the interaction between Arabia, Anatolia and Eurasia and comprises the North Anatolian Fault, the East Anatolian Fault, the Caucasus Mountains, and the Main Recent Fault which bounds the Zagros Mountains.

Our knowledge of stress state in a region is useful for a better understaning of different rupture mechanism. Stress is the main cause of earthquake and studying the present day stress regime in the crust is very important for understanding the current deformation in each area and specially in this region considering its dense population. The focal mechanism of an earthquake is one of the important source parameters which is needed for studying stresses and their variations as well as analyzing stress field. Using Earthquake focal mechanisms could help us investigate the stress regime. The big advantage of the focal mechanism solutions is the ability to study the stress regime at depth in the lithosphere. By inversion of all the available solutions we determine the best fitted reduced stress tensor by grouping focal mechanisms.

DATA AND PROCEDURE

We use ISOLA software for moment tensor inversion in time domain using waveform modelling to determine focal mechanisms. The method was first offered to calculate the source parameters at teleseismic distances (Kikuchi and Kanamori, 1991). It was developed later for regional and local distances by Zahradnik et al. (2005). In this method, Green's functions are calculated by discrete wave number method (Bouchon, 1981). We used the broadband stations of Iranian Seismological Center (IRSC), International Institute of Earthquake Engineering and Seismology (IIEES) and also stations of several other countries bordering - northwestern Iran (table 1). We employ the 5- layer crustal model of IRSC shown in table 2 and determine the source parameters of 15 earthquakes by waveform modelling (table 3).

Table 1. Positions of used stations in this study

Station	Lat (N °)	Long (E °)	Seismic Network
BZA	34.4696	47.8605	IGUT-IRSC
DOB	33.78744	48.17747	IGUT-IRSC
HAGD	34.822	49.139037	IGUT-IRSC
HSRG	35.2418	48.2787	IGUT-IRSC
KCHF	34.275	47.0404	IGUT-IRSC
KFM	33.52444	47.84694	IGUT-IRSC
KMR	33.5178	48.3803	IGUT-IRSC
KOM	34.1761	47.5144	IGUT-IRSC
QABG	35.70846	49.58238	IGUT-IRSC
QALM	36.4321	50.64646	IGUT-IRSC
MAHB	36.7666	45.7054	IGUT-IRSC
TABZ	38.0568	46.3266	IGUT-IRSC
TAHR	38.49	47.051	IGUT-IRSC
TVRZ	38.504	46.668	IGUT-IRSC
ZNGN	32.1174	50.8542	IGUT-IRSC
ASAO	34.548	50.025	IIEES-BIN
CHTH	35.908	51.126	IIEES-BIN
GHVR	34.48	51.295	IIEES-BIN
GRMI	38.81	47.894	IIEES-BIN
KHMZ	33.739	49.959	IIEES-BIN
MAKU	39.355	44.683	IIEES-BIN
SNGE	35.093	47.347	IIEES-BIN
THKV	35.916	50.879	IIEES-BIN
ZNJK	36.67	48.685	IIEES-BIN
AGRB	39.5755	42.992	GFZ
GNI	40.149	44.7414	GFZ
KARS	40.6276	43.0788	GFZ
SIRT	37.5011	42.4392	GFZ
VANB	38.595	43.389	GFZ

Table 2. Crustal model of Iran (IRSC)

Depth of layer top (km)	Vp (km/s)	Vs (km/s)	Density (g/Cm3)	Qp	Qs
0.0	5.38	3.057	2.776	600	300
7.0	5.95	3.381	2.890	600	300
12.0	6.15	3.494	2.930	600	300
20.0	6.42	3.648	2.984	600	300
47.0	8.06	4.580	3.312	600	300

Table 3. Determined focal mechanisms in this study

NO.	Origin Time & Location Parameters						DC %	variance reduction %	Nodal Planes		
	Date	Time	Latitude (°N)	Longitude (°E)	Depth (Km)	MW			strike (˚)	dip (˚)	rake (˚)
1	20120811	12:23:15	38.43	46.81	6	6.4	67.0	80	84	90	138
									174	48	0
2	20120811	12:34:33	38.46	46.84	16	6.3	65.7	80	81	87	-175
									351	85	-3
3	20120811	15:21:14	38.42	46.8	6	4.8	82.9	50	86	84	-176
									355	86	-6
4	20120811	15:43:19	38.46	46.73	10	4.8	85.4	50	31	67	69
									255	31	130
5	20120811	22:24:02	38.43	46.75	10	5.3	77.7	60	352	64	9
									258	82	154
6	20120813	1:56:10	38.47	46.66	10	4.7	91.3	60	266	90	-175
									176	85	0
7	20120819	1:58:30	38.41	46.65	10	4.3	61.7	60	82	88	174
									172	84	2
8	20121027	3:56:41	38.39	46.64	8	4.3	61.4	50	83	71	166
									178	77	20
9	20121107	6:26:31	38.46	46.75	10	5.8	75.1	80	271	82	-174
									180	84	-8
10	20121116	3:58:28	38.49	46.66	6	4.9	95.7	50	280	81	-169
									188	79	-9
11	20121223	6:38:57	38.48	44.93	14	5.2	91.6	70	76	82	174
									167	84	8
12	20121223	7:12:31	38.41	44.84	20	4.1	64.3	80	83	61	147
									190	62	34
13	20130706	17:07:49	37.63	48.96	10	4.0	77.7	60	97	90	-175
									7	85	0
14	20130927	10:02:43	37.33	44.94	18	4.4	65.8	70	75	59	107
									224	35	64
15	20131108	10:12:34	37.8	47.17	6	4.4	96.0	70	21	67	-10
									115	81	-157

The acquired and GCMT focal mechanisms are shown in figure 1, respectively in blue and red. Using the information of these events containing strike, dip and rake angles, we study the state of stress in the region. For this purpose, we use multiple inverse method that was originally proposed by Yamaji (2000). The method is a numerical technique to separate stresses from heterogeneous fault– slip and focal mechanism data. The method employs the inversion of earthquake focal mechanism to determine the principal stress orientations. The regions of azimuth and plunge of principal stresses; σ_1 and $\sigma_{3;}$ and also stress ratio for the specified regions are depicted by blue lines in figure 1, and numbered in table 4. The green arrows present the direction of principal stress; $\sigma_{1;}$ in each specified region.

Stress ratio is defined as a ratio between the principal stress differences and expressed as Eq. 1.

$$\varphi = \frac{\sigma_2 - \sigma_3}{\sigma_1 - \sigma_3} \qquad (1)$$

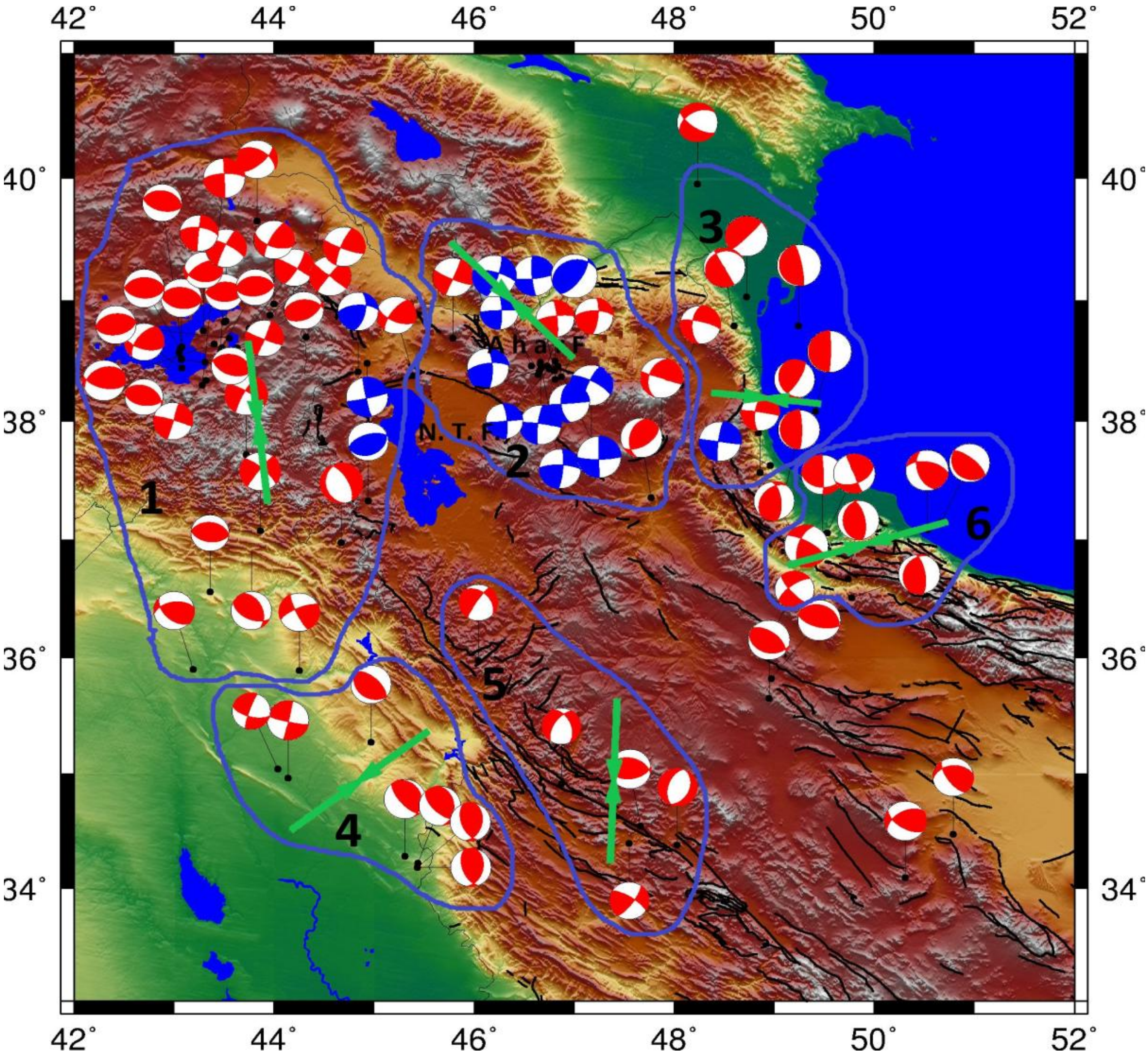

Figure 1. Determined focal mechanisms in this study (blue) during the period 2012-2013 and by GCMT (red) during the period 1976-2013. The blue lines present determined regions of different stress states in this study. The green arrows depict the directions of principal stress, $\sigma_{1,}$ in each region.

Table 4. Calculated azimuth and plunge of principal stresses, σ_1, σ_3 and also stress ratio in each specified region of figure 1.

Region	Azimuth σ_1	Plunge σ_1	Azimuth σ_3	Plunge σ_3	stress ratio
1	173.6	4.7	60.3	78.2	0.27
2	136.7	0.1	46.7	4.8	0.34
3	96.1	51.4	256.6	37	0.18
4	53.1	3.2	315	68.1	0.26
5	182.4	0.6	272.6	13.8	0.64
6	74.1	17	191.8	56.7	0.34

CONCLUSIONS

As it is presented in figure 1 and table 4, the stress regime in Ahar-Varzeghan region is completely different from other surrounding areas. Most of the focal mechanisms are right lateral strike- slip and the direction of principal stress, $\sigma_{1,}$ is 136.7°. Zagros, Alborz and Talesh mountains have different geodynamic regimes. Toward the west and in eastern Anatolia, the direction of principal stress, $\sigma_{1,}$ is almost north-south. In contrast, the direction of this principal stress changes to east-west in western Caspian Sea. This difference in geodynamic regimes in the study area with the surrounding regions may be attributed to the north Tabriz fault.

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