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Stress regimes in the northwest of Iran from stress inversion of earthquake focal mechanisms

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ABSTRACT

Northwestern Iran is one of the seismically active regions with a high seismic risk in the world. This area is a part of the complex tectonic system due to the interaction between Arabia, Anatolia and Eurasia. The purpose of this study is to deduce the stress regimes in the northwestern Iran and surrounding regions from stress inversion of earthquake focal mechanisms. We compile 92 focal mechanisms data from the Global CMT catalogue and other sources and also determine the focal mechanisms of 14 earthquakes applying the moment tensor inversion. We divide the studied region into 9 zones using similarity of the horizontal GPS velocities and existing focal mechanisms. We implement two stress inversion methods, Multiple Inverse Method and Iterative Joint Inversion Method, which provide comparable results in terms of orientations of maximum horizontal stress axes SHmax. The similar results of the two methods should make us more confident about the interpretations. We consider zones of exclusion surrounding all the earthquakes according to independent focal mechanisms hypothesis. The hypothesis says that the inversion should involve events that are far enough from each other in order that any previous event doesn't affect the stress field near the earthquake under consideration. Accordingly we deal with the matter by considering zones of exclusion around all the events. The result of exclusion is only significant for eastern Anatolia. The stress regime in this region changes from oblique to strike slip faulting because of the exclusion. In eastern Anatolia, the direction of maximum horizontal stress is nearly north-south. The direction alters to east-west in Talesh region. Errors of σ_1 are lower in all zones comparing with errors of σ_2 and σ_3 and there is a trade-off between data resolution and covariance of the model. The results substantiate the strike-slip and thrust faulting stress regimes in the northwest of Iran.

1. Introduction

Studying the stress state in the crust can provide a better understanding of current deformation in each area specially in northwest of Iran considering its complex seismotectonic settings. Zamani (2013a) investigated the stress state in Siahcheshme-Khoy fault zone. The average stress implied a dominant strike-slip tectonic stress regime in the studied area. The result showed the stress ratio equals to 0.41 for the regional average stress tensor. This result is in correspondence with McKenzie (1972) that indicated the existence of two series of conjugate reverse and strike-slip faults in east Turkey and the Caucasus. Zamani (2013b) also studied the area between 36 and 40°N, and 44- 49° E and analyzed the stress state in the region. The result manifested a strike-slip stress regime in western boundary of the studied area and a compressive stress regime in northern and eastern boundaries. Zarifi et al. (2014) estimated the magnitude and directions of maximum principal stress and strain rates in Iran using the focal mechanisms of crustal earthquakes in the period 1909–2012 and GPS velocities, derived from the data collected between 1999 and 2011. In this study, we investigate the stress regimes of the northwest of Iran and surrounding areas by stress inversion of earthquake focal mechanisms. We try to find as much focal mechanism solutions as possible with moment magnitude greater than 4. We also determine the focal mechanisms of 14 earthquakes applying the moment tensor inversion code ISOLA (Sokos and Zahradník, 2008). Focal mechanism data (Table 1) and horizontal GPS velocities (Fig. 1) show that this region is structurally complex and we cannot separate different stress states from the collective focal mechanism data. We therefore divide the studied area to 9 zones. Considering the limited number of data in some zones, we calculate the reduced stress tensor using two different methods, multiple inverse method (Yamaji, 2000), and iterative joint inversion method (Vavryčuk, 2014) to achieve more confidence. The orientations of maximum horizontal stress axes in each zone are calculated and the results of the two methods are compared.

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Table 1
The focal mechanism solutions used in this study except those from Global CMT.

NO.	Origin Time & Location Parameters						Nodal Plane 1			Nodal Plane 2			reference
	Date	Time	Latitude (°N)	Longitude (°E)	Depth (Km)	M_W	strike (°)	dip (°)	rake (°)	strike (°)	dip (°)	rake (°)	
1	19620901	19:20:00	35.7	49.8	10	7	311	42	113	100	52	70	Priestley et al. (1994)
2	19830722	02:41:00	36.93	49.24	10	5.5	120	35	83	308	55	94	Priestley et al. (1994)
3	20040821	13:53:16	35.49	49.43	2.5	4.3	140	77	173	232	83	13	Ansari et al. (2015)
4	20041017	21:31:03	35.62	48.96	13.5	4.7	272	26	66	118	66	101	Ansari et al. (2015)
5	20041108	20:03:19	35.73	48.88	17.5	4.5	149	71	146	251	58	22	Ansari et al. (2015)
6	20050202	23:26:53	37.75	43.62	18 ± 4	4.1	312	71	−137	205	50	−25	Abdulnaby et al. (2013)
7	20070708	13:44:34	36.26	44.77	18 ± 4	4.4	80	80	5	349	85	170	Abdulnaby et al. (2014)
8	20070918	20:53:32	35.61	44.63	18 ± 4	4.3	295	80	−35	32	56	−168	Abdulnaby et al. (2014)
9	20080323	12:11:32	37.31	48.51	14.5	4.7	182	54	9	87	83	143	Ansari et al. (2015)
10	20080327	06:48:00	35.81	48.86	6.5	4.1	273	48	65	129	48	115	Ansari et al. (2015)
11	20080713	22:30:09	37.84	48.2	12.5	4.1	338	86	−150	246	60	−5	Ansari et al. (2015)
12	20081201	10:18:38	35.29	46.17	14 ± 3	4	320	5	115	115	85	88	Abdulnaby et al. (2014)
13	20100908	05:30:32	36.82	49.45	17.5	4.1	245	62	156	347	69	30	Ansari et al. (2015)
14	20110903	00:30:51	37.55	47.82	7.5	4	154	90	169	244	79	0	Ansari et al. (2015)
15	20111206	15:46:28	37.3	43.94	15 ± 4	4.2	139	81	−155	45	65	−10	Abdulnaby et al. (2013)
16	20120318	02:38:15	36.75	49.08	27	4.3	13	84	166	105	76	6	IRSC
17	20120811	12:23:15	38.43	46.81	6	6.4	84 + / − 12	90 + / − 22	138 + /- 8	174 + / − 16	47 + /14	0 + / − 35	This study
18	20120811	12:34:33	38.46	46.84	16	6.3	81 + / − 12	87 + /- 5	− 175 + /-14	351 + / − 10	85 + / − 5	− 3 + /-18	This study
19	20120811	15:21:14	38.42	46.8	6	4.8	86 + / − 5	84 + / − 5	− 176 + /-14	355 + / − 5	86 + / − 5	− 6 + /-15	This study
20	20120811	15:43:19	38.46	46.73	10	4.8	31 + / − 12	67 + / − 9	69 + / − 12	255 + / − 18	31 + / − 8	130 + / − 23	This study
21	20120811	22:24:02	38.43	46.75	10	5.3	352 + / − 8	64 + / − 5	9 + / − 11	258 + / − 8	82 + / − 7	154 + / − 10	This study
22	20120813	01:56:10	38.47	46.66	10	4.7	266 + / − 12	90 + / − 5	− 175 + /-14	176 + / − 11	85 + / − 5	0 + / − 12	This study
23	20120814	14:02:25	38.45	46.88	10	5.1	92	83	−176	1	86	−7	IRSC
24	20120819	01:58:30	38.41	46.65	10	4.3	82 + / − 11	88 + / − 6	174 + / − 16	172 + / − 13	84 + / − 7	2 + / − 17	This study
25	20120912	23:29:38	37.21	43.57	22 ± 7	4.1	55	25	−20	163	82	−114	Abdulnaby et al. (2013)
26	20120913	02:42:21	36.99	43.72	13 ± 5	4.4	60	85	−20	152	70	−175	Abdulnaby et al. (2013)
27	20121027	03:56:41	38.39	46.64	8	4.3	83 + / − 10	71 + / − 9	166 + / − 20	178 + / − 14	77 + / − 11	20 + / − 20	This study
28	20121107	06:26:31	38.46	46.75	10	5.8	271 + / − 10	82 + / − 7	− 174 + /-13	180 + / − 10	84 + / − 10	− 8 + /-18	This study
29	20121116	03:58:28	38.49	46.66	6	4.9	280 + / − 8	81 + / − 9	− 169 + /-8	188 + / − 7	79 + / − 7	− 9 + /-10	This study
30	20121223	06:38:57	38.48	44.93	14	5.2	76 + / − 10	82 + / − 5	174 + / − 14	167 + / − 14	84 + / − 6	8 + / − 13	This study
31	20121223	07:12:31	38.41	44.84	20	4.1	83 + / − 13	61 + / − 10	147 + / − 16	190 + / − 11	62 + / − 10	34 + / − 13	This study
32	20130313	06:23:03	36.66	43.38	19 ± 6	4.5	295	90	−70	25	20	−180	Abdulnaby et al. (2014)
33	20130927	10:02:43	37.33	44.94	18	4.4	75 + / − 13	59 + / − 8	107 + / − 16	224 + / − 15	35 + / − 4	64 + / − 19	This study
34	20131016	08:49:32	35.24	49.71	3	4.6	314	44	−168	215	81	−47	IRSC
35	20131108	10:12:34	37.8	47.17	6	4.4	21 + / − 13	67 + / − 11	− 10 + /-20	115 + / − 13	81 + / − 9	− 157 + /-19	This study
36	20131123	23:26:20	34.25	45.58	10	4.7	165	58	92	341	32	86	IRSC
37	20131124	18:03:13	34.29	45.59	13	4.6	140	65	28	38	65	152	IRSC
38	20150302	06:08:41	35.75	48.94	3	4.2	284	63	97	88	28	76	IRSC
39	20150510	22:08:58	36.69	49.86	11	4.3	25	68	165	121	76	23	IRSC
40	20160622	16:56:58	38.5	44.86	9	4.3	304	88	−166	214	76	−2	IRSC