Supporting Information for

Seismicity and the State of Stress in the Dezful Embayment, Zagros Fold and Thrust Belt

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Contents of this file

Figures S1 to S6
Table S1, and Table S2

Introduction

Five supplementary figures and three tables are presented here as supporting information. Figure S1 illustrates the stratigraphy column of the Dezful Embayment, and Figure S2 shows the mud weight and direct pore pressures data vs the depth of several wells drilled in the Dezful Embayment. The figure also shows that the Gachsaran Formation is a major pressure step when sedimentary formations in the Dezful Embayment are drilled. It is worth pointing out that Figure S2 shows a typical and general pore pressure variation with depth in the sedimentary cover. Figure S3 provides one example of the depths, and orientations of borehole breakouts plus their frequency in CK-9 and LL-29. Figures S5 and S6 show the result of stress inversion for 108 focal mechanisms using the Matlab code developed by Martines-Garzon et al. (2014). Table S3 includes earthquake source parameters used for stress determination and the tectonic regime in the Dezful Embayment of the ZFTB. The table presents seismically maximum horizontal stress (S_{Hmax}) orientations, stress regimes (A_φ) calculated using Simpson's (1997) approach, as well as two nodal planes and other source parameters of the

earthquakes. The preferred nodal plane for each earthquake focal mechanism is highlighted in each row.

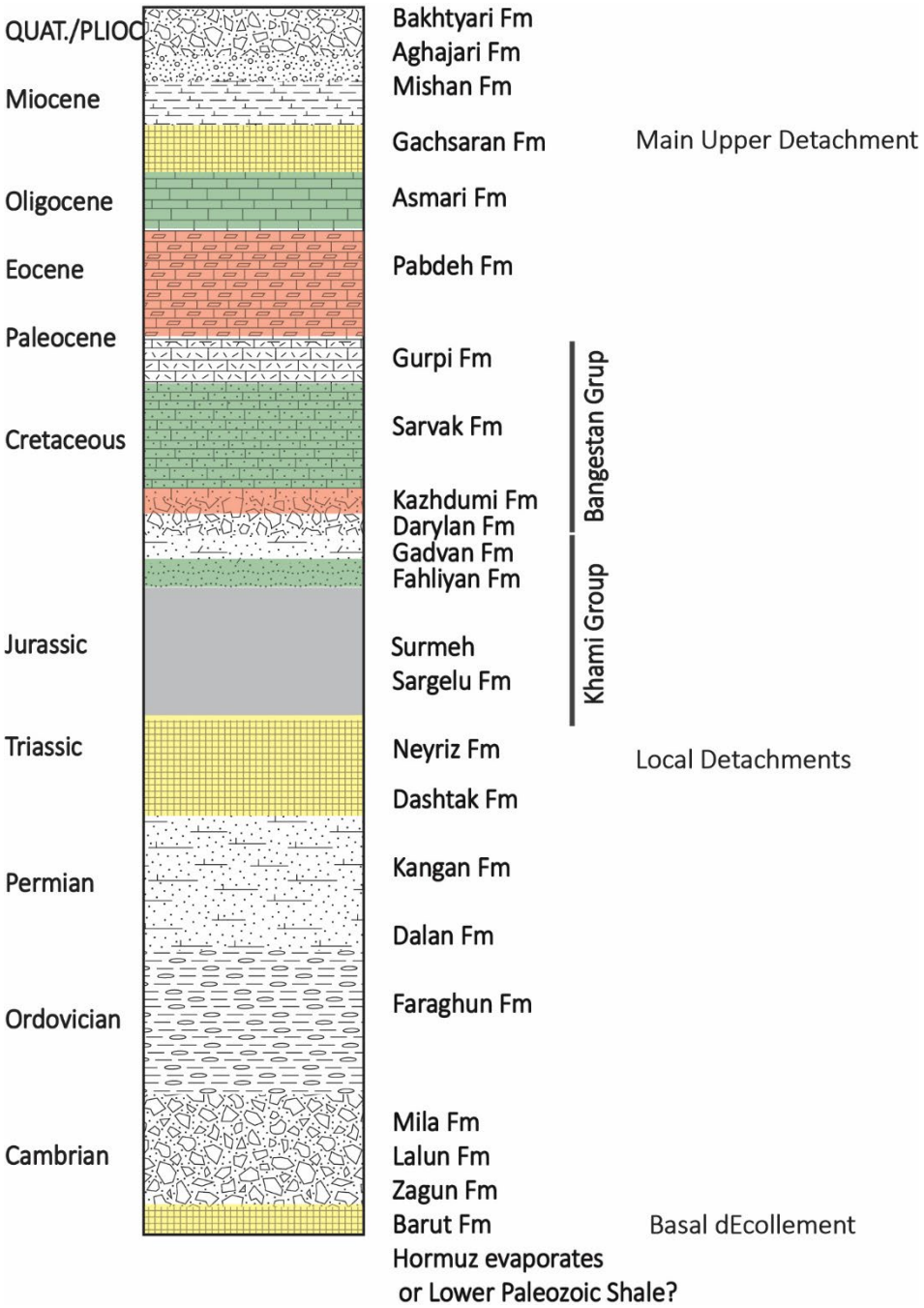

Figure S1. Stratigraphy column, source rocks, and reservoir formations for the Dezful Embayment. The main detachment rocks are indicated in yellow, reservoir rocks in green, and main source rocks in red (modified from Sherkati and Letouzey [1])

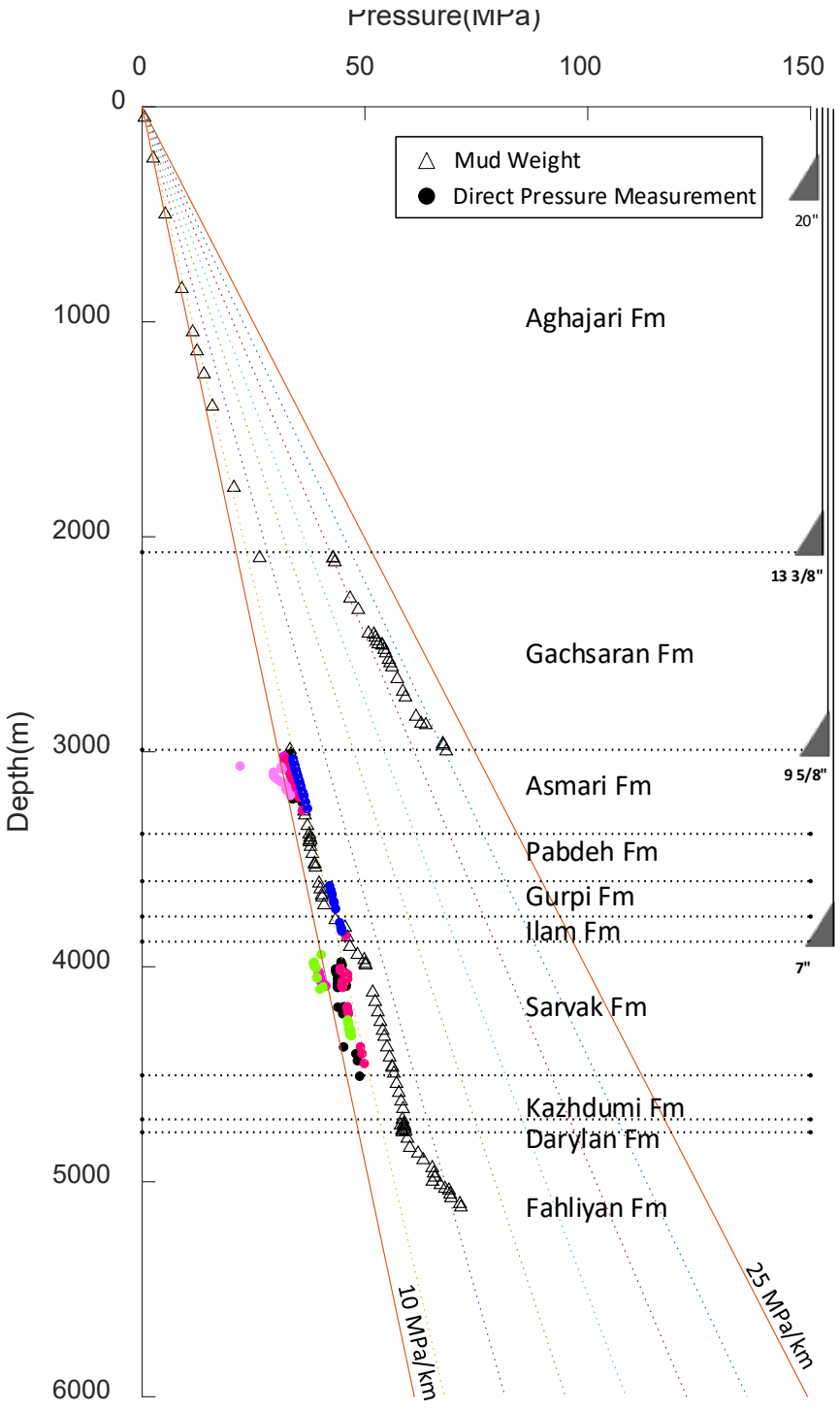

Figure S2. A typical mud weight profile from several wells drilled in the Dezful Embayment. Extremely high pore pressures are observed in the Gachsaran (Fars) Formation, whereas in the formations below and above, there is slightly higher than hydrostatic pressure. The colored dots

represent direct pore pressure measurements at different oil fields in the Dezful Embayment.

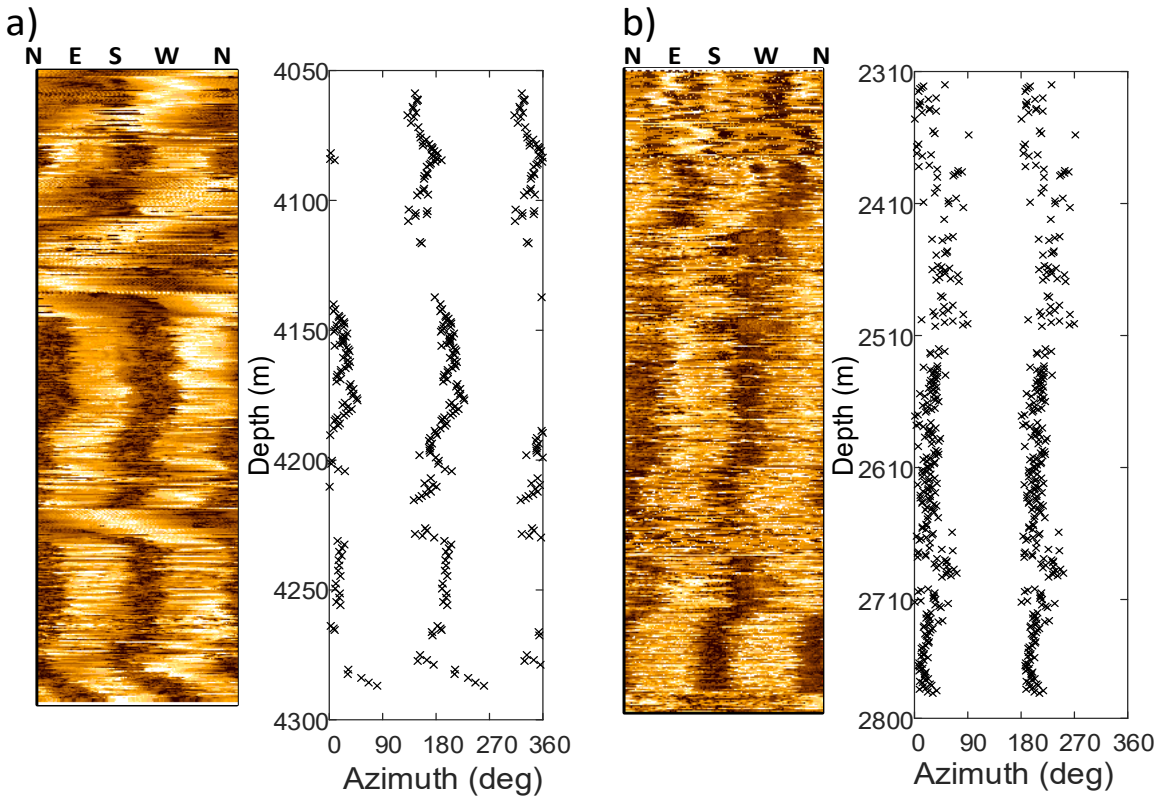

Figure S3. Ultrasonic image logs of a) CK-9 and b) LL-29 along with depth juxtaposed with observations of breakout orientations (minimum principal stress). Breakout orientations terminated abruptly, and then gradually rotated at 4110 m, 4221 m 4242 m, and 4272 m in CK-9. The same pattern occurred in LL-29, with anomalies in breakout orientation observed at 2510 m and 2695 m.

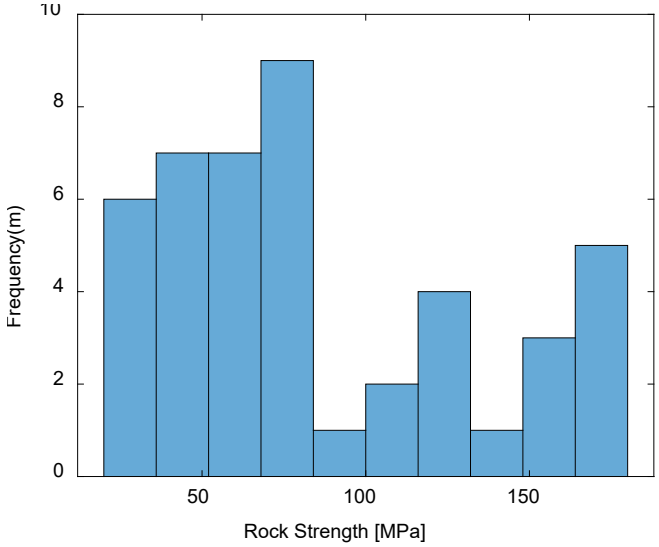

Figure S4: The uniaxial compressive rock strength (UCS) histogram of limestone in the Sarvak and Asmari Formations of the Kupal field (Najibi, *et al.* [2])

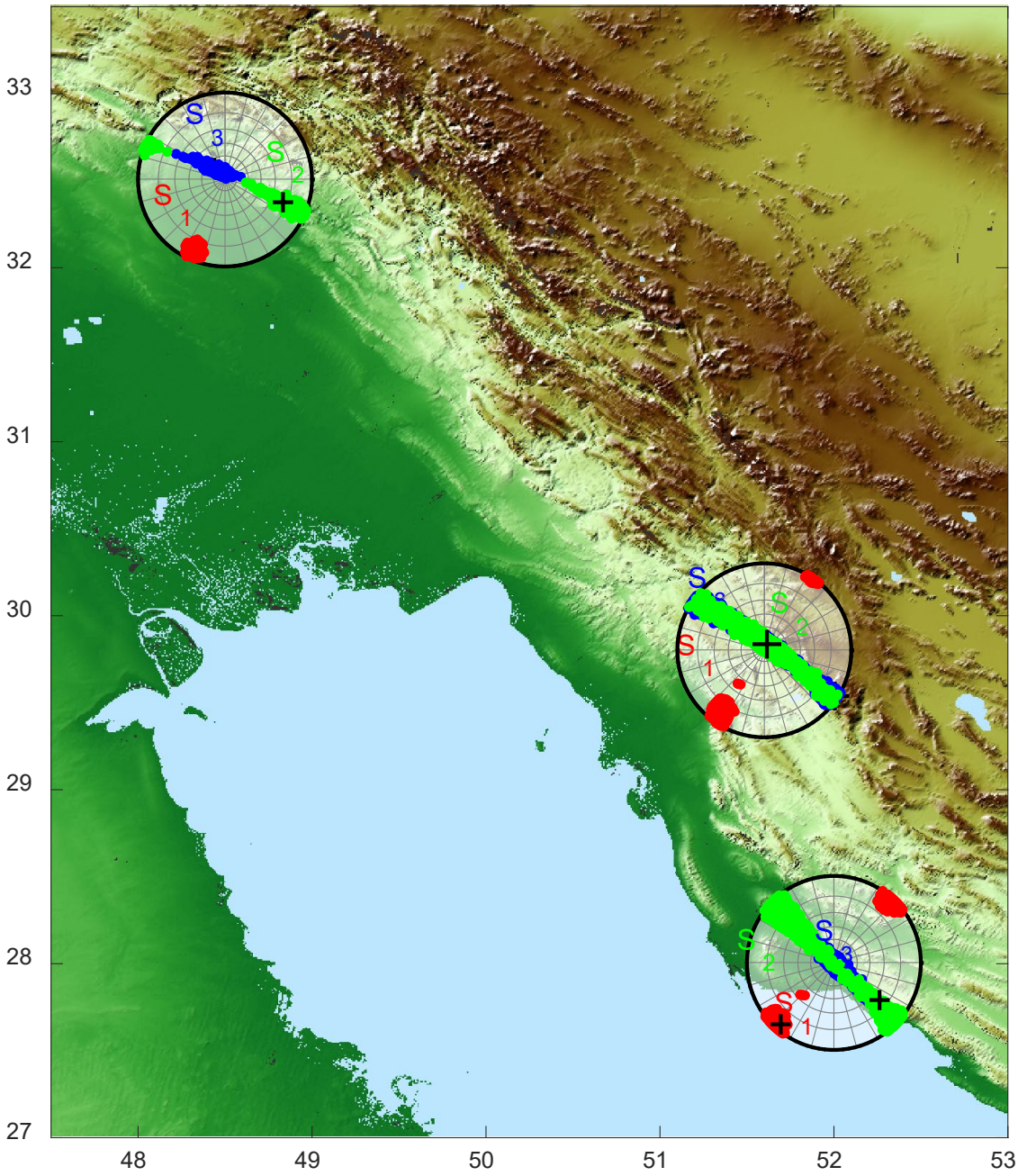

Figure S5. The result of stress inversion of focal mechanisms using the approach developed by Martines-Garzon et al. (2014) in the northern, southern, and around Kazrun fault system (middle) in the Dezful Embayment. Lower-hemisphere stereonets show the distributions of the principal stress orientations (S1-red, S2-green, S3-blue). The "+" symbol presents the best fit of principal stress orientations and colored dots are the 95% confidence of each orientation.

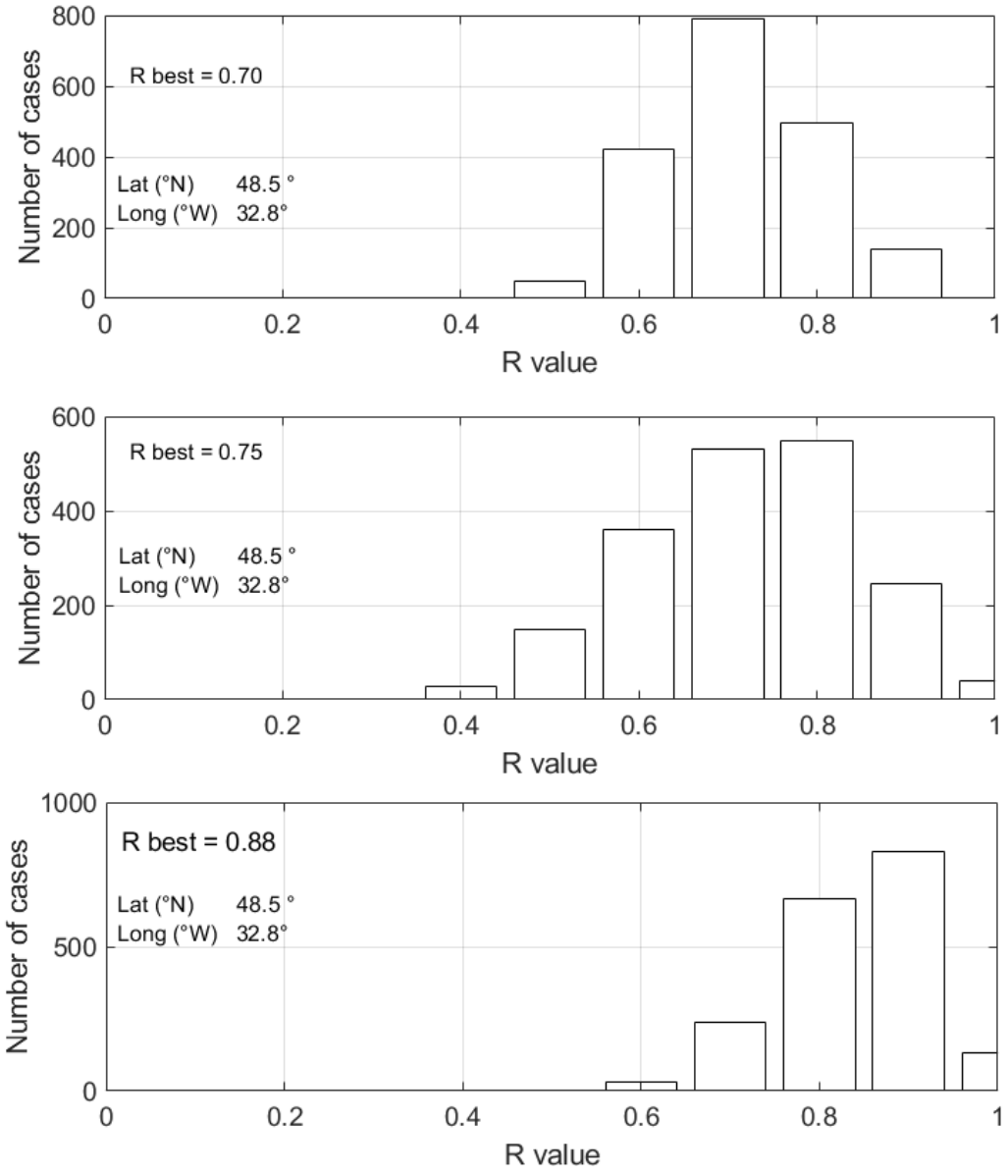

Figure S6. Histogram of R-value (1-ϕ) from the inversion of focal mechanism within the 95% confidence region in the northern (top), southern (middle), and around Kazrun fault system (bottom). Latitude and longitude in each subplot represent the centroid of the corresponding earthquake group.

Table S1. Detailed drilling information on sidetracks of well P-7.

ITEM	SD-1	SD-2
KOP	3928 m	3899 m
Azimuth	2050	2920
Final Inclination	900	900
Duration (Day)	20 Days	15 Days
Mud Weight	70 pcf	63 pcf
Drilled Meter	212 m	711m
Mud Type	OBM	OBM
MD	4140 m	4610 m
TVD	4025 m	4018m
Hole Size	6 1/8"	6 1/8"
Formation	Sarvak	Sarvak

Table S2. Earthquake source parameters used for stress determination and the tectonic regime in the ZFTB of the Dezful Embayment. The columns are: year, month, day, origin time (hr: min), latitude, longitude, depth, strike, dip, rake (nodal plane 1), strike, dip, rake (nodal plane 2), Paxis and Taxis and the result of calculated $\mathbf{A_{\varphi}}$.

Date			Lat.	Lon.	Strike	Dip	Rake	Depth	Mw	Regime	S_{Hmax}	A_{φ}	Reference
1968	6	23	29.74	51.25	136 **319**	45 **45**	88 **92**	9	5.5	TF	47	2.25	Baker, *et al.* [3]
1971	4	6	29.79	51.89	62 **332**	79 **88**	2 **169**	6	5.2	SS	16	1.57	Baker, Jackson and Priestley [3]
1972	6	12	33.04	46.27	114 **306**	56 **35**	83 **100**	11	5	TF	29	2.23	Ni and Barazangi [4]
1972	6	14	33.03	46.13	198 **65**	40 **60**	51 **118**	10	5.3	TF	135	2.24	Jackson and McKenzie [5]
1972	7	2	30.06	50.85	132 **312**	64 **26**	90 **90**	9	5.3	TF	42	3.00	Ni and Barazangi [4]
1976	4	22	28.68	52.12	312 **148**	52 **39**	80 **103**	7	5.7	TF	49	2.12	Ni and Barazangi [4]
1976	11	7	33.19	47.93	138 **269**	58 **43**	121 **51**	10	4.8	TF	26	2.19	Jackson and McKenzie [5]
1977	4	6	31.96	50.65	112 **228**	64 **48**	132 **36**	6	5.9	TF	173	2.24	Baker, Jackson and Priestley [3]
1977	4	26	32.64	48.91	293 **110**	29 **61**	93 **88**	20	5.5	TF	21	2.29	Maggi, *et al.* [6]
1977	6	5	32.62	48.09	293	34	91	12	6.1	TF	22	2.31	Jackson and Fitch [7]

Date			Lat.	Lon.	Strike	Dip	Rake	Depth	Mw	Regime	S_{Hmax}	A_{φ}	Reference
					112	**56**	**89**						
1980	10	19	32.70	48.57	327 **116**	19 **74**	120 **80**	17	5.6	TF	33	2.61	Maggi, Jackson, Priestley and Baker [6]
1983	5	28	32.59	48.58	314 **106**	38 **55**	113 **73**	8	5.5	TF	28	2.18	Ni and Barazangi [4]
1986	7	12	29.91	51.56	4 **268**	73 **70**	-159 **-18**	4±3	5.5	SS	45	1.06	Baker, Jackson and Priestley [3]
1986	12	20	29.90	51.58	344 **81**	65 **75**	163 **26**	8±3	5.3	SS	31	1.82	Baker, Jackson and Priestley [3]
1988	8	11	29.88	51.66	350 **258**	82 **76**	-166 **-8**	9±3	5.8	SS	33	1.20	Baker, Jackson and Priestley [3]
1988	8	11	29.94	51.58	3 **271**	69 **85**	-175 **-21**	7±3	5.5	SS	49	1.35	Baker, Jackson and Priestley [3]
1988	8	30	29.95	51.72	242 **337**	57 **82**	12 **-147**	16	5.1	SS	15	1.31	Maggi, Jackson, Priestley and Baker [6]
1988	12	6	29.89	51.63	357 **262**	74 **73**	198 **-17**	10	5.6	SS	39	1.02	Baker, Jackson and Priestley [3]
1991	11	4	30.69	50.25	135 **6**	80 **16**	78 **140**	5	5.8	TF	55	2.78	Talebian and Jackson [8]
1993	6	22	30.18	50.83	301 **154**	44 **51**	65 **112**	5	5.2	TF	48	2.10	Maggi, Jackson, Priestley and Baker [6]
1994	3	29	29.20	51.36	334 **136**	40 **51**	104 **79**	7	5.1	TF	54	2.09	Talebian and Jackson [8]
1994	7	31	32.68	48.42	288 **108**	17 **73**	90 **90**	14	5.5	TF	18	3.00	Priestley, *et al.* [9]
1995	4	22	30.97	49.93	121 **297**	61 **29**	92 **86**	14	5.1	TF	30	2.06	Talebian and Jackson [8]
1998	6	15	31.60	50.84	78 **294**	68 **26**	75 **123**	5	5	TF	179	2.48	Talebian and Jackson [8]
1998	10	4	33.30	47.22	111 **288**	37 **53**	92 **88**	9	5.2	TF	20	2.46	Talebian and Jackson [8]
1998	10	5	33.28	47.26	290 **119**	51 **39**	84 **97**	7	5.3	TF	24	2.11	Talebian and Jackson [8]
1999	5	6	29.52	51.91	49 **142**	77 **78**	-12 **-167**	7	6.1	SS	5	1.03	Talebian and Jackson [8]
1999	10	31	29.37	51.85	117	34	67	5	5.2	TF	43	2.30	Adams, *et al.* [10]

Date			Lat.	Lon.	Strike	Dip	Rake	Depth	Mw	Regime	S_{Hmax}	A_{φ}	Reference
					324	**59**	**105**						
2000	5	3	29.56	50.81	292 **152**	26 **70**	53 **106**	5	5.1	TF	49	2.55	Talebian and Jackson [8]
2001	3	23	32.98	46.64	337 **121**	10 **82**	126 **84**	7	5.2	TF	36	2.84	Nissen, *et al.* [11]
2001	4	3	32.55	48.02	110 **281**	38 **52**	97 **85**	9	4.9	TF	15	2.15	Nissen, Tatar, Jackson and Allen [11]
2002	2	17	28.08	51.79	288 **126**	68 **23**	83 **107**	6	5.3	TF	23	2.48	Adams, Brazier, Nyblade, Rodgers and Al-Amri [10]
2002	9	25	32.06	49.32	142 **310**	47 **44**	98 **82**	8	5.3	TF	46	2.05	Nissen, Tatar, Jackson and Allen [11]
2008	8	27	32.31	47.35	338 **248**	88 **78**	-168 **-2**	10	5.6	SS	22	1.40	Nissen, Tatar, Jackson and Allen [11]
2010	9	27	29.67	51.66	280 **119**	13 **78**	71 **94**	16	5.6	TF	26	2.71	Nissen, Tatar, Jackson and Allen [11]
2012	5	3	32.74	47.61	299 **97**	44 **48**	106 **75**	10	5.3	TF	18	2.07	IRCS[1]
2012	7	1	31.81	51.02	89 **250**	38 **53**	105 **79**	6.3	5	TF	168	2.12	IRCS
2012	7	24	31.84	51.02	86 **253**	34 **57**	101 **83**	10	4.9	TF	168	2.21	IRCS
2012	10	10	29.33	52.49	311 **98**	60 **35**	108 **62**	8.8	4.7	TF	28	2.28	IRCS
2013	1	12	31.90	51.09	77 **300**	26 **71**	50 **107**	5	4.9	TF	17	2.55	IRCS
2013	4	9	28.47	51.57	151 **317**	39 **52**	101 **81**	11.3	6.3	TF	53	2.10	IRCS
2013	4	9	28.46	51.56	147 **330**	45 **45**	88 **92**	11.1	5.3	TF	58	2.25	IRCS
2013	4	9	28.49	51.58	163 **313**	55 **39**	109 **65**	20	4.5	TF	60	2.17	IRCS
2013	4	9	28.42	51.67	160 **329**	53 **37**	96 **82**	20	4.6	TF	66	2.01	IRCS
2013	4	10	28.34	51.64	332 **63**	84 **77**	167 **6**	20	4.6	SS	17	1.72	IRCS

[1] Iranian Seismological Center (www.irsc.ut.ac.ir)

Date			Lat.	Lon.	Strike	Dip	Rake	Depth	Mw	Regime	S_{Hmax}	A_{φ}	Reference
2013	4	10	28.40	51.64	145 **304**	38 **54**	107 **77**	20	5.5	TF	43	2.16	IRCS
2013	4	10	28.26	51.69	311 **109**	58 **34**	102 **72**	10	5.2	TF	32	2.28	IRCS
2013	4	10	28.41	51.65	161 **315**	53 **40**	106 **69**	20	5.2	TF	60	2.09	IRCS
2013	4	10	28.42	51.64	338 **69**	85 **74**	164 **5**	13.7	4.5	SS	23	1.64	IRCS
2013	4	10	28.24	51.79	317 **114**	57 **35**	103 **71**	16.6	4.4	TF	38	2.21	IRCS
2013	4	11	28.44	51.55	151 **326**	47 **43**	93 **87**	20	4.9	TF	59	2.11	IRCS
2013	4	19	32.78	51.81	94	62	49	10	4	TF	32	2.20	IRCS
2013	4	24	28.44	51.55	138 **331**	42 **49**	80 **99**	13.7	4.5	TF	55	2.05	IRCS
2013	5	1	28.32	51.71	309 **110**	54 **37**	101 **75**	20	4.9	TF	31	2.16	IRCS
2013	5	2	28.25	51.76	319 **107**	51 **43**	111 **66**	16	4.7	TF	34	2.08	IRCS
2013	5	6	28.52	51.67	153 **305**	57 **36**	107 **66**	20	4.9	TF	51	2.26	IRCS
2013	5	12	29.55	52.70	274 **113**	36 **56**	74 **101**	10	4.3	TF	15	2.22	IRCS
2013	5	13	28.41	51.69	281 **180**	53 **76**	18 **141**	10	4.6	SS	55	1.75	IRCS
2013	8	10	28.42	51.69	183 **284**	67 **66**	154 **25**	17.2	4.5	SS	54	1.99	IRCS
2013	8	10	28.40	51.69	176 **321**	55 **41**	112 **62**	14.2	4.6	TF	71	2.12	IRCS
2013	8	14	30.83	50.47	307 **128**	24 **66**	89 **90**	7.1	4.2	TF	38	2.17	IRCS
2013	11	19	28.57	51.55	155 **266**	60 **58**	143 **37**	10	4.2	TF	31	2.03	IRCS
2013	11	28	29.32	51.31	118 **357**	70 **36**	60 **144**	7.8	5.6	TF	50	2.47	IRCS
2013	11	28	29.29	51.32	31 **122**	88 **73**	163 **2**	10	4.2	SS	75	1.53	IRCS

Date			Lat.	Lon.	Strike	Dip	Rake	Depth	Mw	Regime	S_{Hmax}	A_{φ}	Reference
2014	1	28	32.53	50.01	197 **291**	63 **84**	-7 **-153**	6	4.6	SS	151	1.34	IRCS
2014	4	16	28.55	51.61	191 **282**	86 **83**	173 **4**	14.9	4.8	SS	56	1.78	IRCS
2014	5	21	29.60	50.86	126 **306**	57 **33**	90 **90**	19	5.2	TF	36	2.34	IRCS
2014	5	21	29.63	50.86	125 **315**	64 **27**	86 **99**	15	4.9	TF	38	2.34	IRCS
2014	6	20	29.88	50.89	100 **338**	50 **58**	44 **131**	11	4.5	TF	41	2.09	IRCS
2014	8	15	28.49	51.68	276 **7**	87 **69**	-21 **-177**	10	4.6	SS	53	1.41	IRCS
2014	8	17	32.72	47.70	114 **302**	73 **17**	88 **98**	7.5	4.5	TF	26	2.66	IRCS
2014	8	17	32.74	47.64	115 **299**	72 **18**	89 **94**	9	4.6	TF	26	2.62	IRCS
2014	8	18	32.71	47.64	104 **320**	63 **32**	72 **121**	10	6.2	TF	27	2.34	IRCS
2014	8	18	32.76	47.51	113 **297**	70 **20**	89 **94**	12	4.7	TF	24	2.53	IRCS
2014	8	18	32.72	47.69	98 **332**	59 **45**	55 **134**	12	5.7	TF	32	2.17	IRCS
2014	8	18	32.76	47.60	313 **111**	49 **43**	105 **74**	10	4.7	TF	32	2.10	IRCS
2014	8	18	32.64	47.63	102 **323**	38 **59**	56 **113**	8	4.6	TF	36	2.24	IRCS
2014	8	18	32.73	47.60	293 **97**	47 **44**	101 **78**	15	5.1	TF	15	2.05	IRCS
2014	8	18	32.73	47.53	75 **325**	42 **73**	25 **129**	7.4	5.4	TF	28	2.48	IRCS
2014	8	18	32.58	47.61	305 **97**	52 **42**	109 **68**	17.2	5.9	TF	22	2.11	IRCS
2014	8	18	32.71	47.60	283 **124**	41 **51**	74 **104**	12.2	4.6	TF	24	2.13	IRCS
2014	8	18	32.71	47.56	126 **333**	30 **63**	65 **103**	8.9	4.6	TF	54	2.33	IRCS
2014	8	19	32.74	47.53	105	46	74	7.8	5.2	TF	26	2.00	IRCS

Date			Lat.	Lon.	Strike	Dip	Rake	Depth	Mw	Regime	S_{Hmax}	A_{φ}	Reference
					307	**46**	**105**						
2014	8	20	32.64	47.74	115 **305**	77 **13**	88 **99**	17.7	5.6	TF	27	2.75	IRCS
2014	8	22	32.73	47.62	133 **271**	74 **22**	104 **50**	16	4.6	TF	32	2.62	IRCS
2014	8	23	32.72	47.77	105 **344**	61 **47**	51 **139**	20	5.3	TF	42	2.20	IRCS
2014	8	24	32.68	47.79	146 **55**	88 **68**	-158 **-2**	19.4	4.9	SS	8	1.41	IRCS
2014	8	25	32.74	47.71	124 **292**	75 **15**	93 **78**	12	4.7	TF	32	2.60	IRCS
2014	10	15	32.58	47.79	95 **273**	32 **58**	92 **89**	10	5.8	TF	4	2.44	IRCS
2014	10	15	32.51	47.92	78 **313**	66 **38**	59 **139**	12.2	4.4	TF	10	2.38	IRCS
2014	10	16	32.78	47.81	123 **306**	52 **38**	88 **92**	13.7	4.1	TF	34	2.07	IRCS
2014	12	12	30.47	50.48	314 **132**	19 **71**	92 **89**	17.7	4.9	TF	42	2.11	IRCS
2014	12	30	28.73	51.89	205 **340**	26 **71**	132 **72**	11	5	TF	84	2.56	IRCS
2015	1	1	28.73	51.85	235 **6**	18 **78**	137 **77**	10.1	4.5	TF	108	2.76	IRCS
2015	1	10	28.75	51.84	215 **125**	90 **74**	-164 **0**	10	4.6	SS	79	1.48	IRCS
2015	1	14	32.84	46.93	300 **121**	18 **72**	90 **90**	15	4.3	TF	30	2.90	IRCS
2015	2	15	32.78	46.84	125 **276**	71 **21**	100 **63**	8	4.9	TF	27	2.59	IRCS
2015	4	10	28.35	51.83	59 **150**	87 **69**	-21 **-176**	8.5	4.6	SS	16	1.41	IRCS
2015	5	21	33.44	48.39	72 **318**	64 **51**	45 **146**	8	4.3	TF	12	2.19	IRCS
2015	9	25	32.85	46.53	132 **321**	63 **27**	86 **98**	17	5.1	TF	45	2.38	IRCS
2015	11	25	31.89	49.54	312 **130**	3 **85**	92 **90**	12	5.2	TF	0	3.00	IRCS

Date			Lat.	Lon.	Strike	Dip	Rake	Depth	Mw	Regime	S_{Hmax}	A_{φ}	Reference
2015	12	4	28.91	52.02	118 **338**	83 **9**	84 **130**	22	4.7	TF	0	2.96	IRCS
2016	3	31	31.93	50.82	333 **66**	69 **81**	170 **21**	8	5	SS	18	1.73	IRCS
2016	9	23	30.60	50.38	141 **336**	74 **17**	86 **104**	18	4.5	TF	54	2.60	IRCS
2016	9	30	32.45	48.95	98 **283**	61 **29**	88 **94**	15	4	TF	9	2.04	IRCS
2016	10	14	31.09	50.07	120 **2**	77 **26**	67 **150**	10	4.5	TF	48	2.69	IRCS
2017	1	17	29.66	51.50	166 **75**	76 **86**	-176 **-14**	9	4.6	SS	31	1.35	IRCS
2017	9	3	29.06	51.66	144 **305**	41 **51**	104 **78**	9	4.9	TF	44.00	2.13	IRCS

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