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► **To cite this version:**

Fariborz Baniadam, Esmail Shabanian, Olivier Bellier. The kinematics of the Dasht-e Bayaz earthquake fault during Pliocene-Quaternary: implications for the geodynamics of eastern Central Iran. *Tectonophysics*, 2019, 10.1016/j.tecto.2019.228218 . hal-02464593

HAL Id: hal-02464593

<https://hal.science/hal-02464593>

Submitted on 3 Feb 2020

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Manuscript Number: TECTO13372R2

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Article Type: Research Paper

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Abstract: The Arabia - Eurasia convergence is accommodated across the Iranian plateau and surrounding mountain ranges. Strike-slip faults play significant roles in the current deformation of the Iranian plateau and were responsible for several moderate to large earthquakes, especially in east of Iran. The sinistral Dasht-e Bayaz fault shows conspicuous seismic and geological activities, while the role of the fault in the accommodation of active convergence is still debated. This paper focuses on the Pliocene-Quaternary to present-day states of stress in the region affected by the Dasht-e Bayaz fault. We applied the fault-slip inversion technique to both kinds of seismologic and geological fault slip data. The inversion results indicate a mean $N045\pm5^{\circ}E$ trending σ_1 in the modern stress field, which agrees with the present-day tectonic regime (regional $N050\pm05^{\circ}E$ trending σ_1) deduced from the inversion of earthquake focal mechanism data. The paleostress state is characterized by a $N135\pm15^{\circ}E$ trending regional mean σ_1 , with a transpressional stress regime; E-W faults of the region such as the Dasht-e Bayaz fault were reverse dextral in this paleostress field. We show that the shift in fault kinematics during the Pliocene-Quaternary times has not been restricted to northeastern parts of the Iranian plateau. The cross-cutting relationship between active N-S dextral and E-W sinistral faults indicates a crosswise to conjugate fault arrangement in the middle and the eastern end of the Dasht-e Bayaz fault. Integrating our results at a larger regional scale, we present a kinematic model in which the region between Lut and Kopeh Dagh is divided by the Doruneh fault into two tectonic domains. In the northern domain, active convergence is taken up by the extrusion of fault-bounded crustal blocks while, in the southern domain the convergence is accommodated through crosswise strike-slip faulting accompanied by reverse/thrust faulting in confining wedges.

Research Data Related to this Submission

1 **The kinematics of the Dasht-e Bayaz earthquake fault during Pliocene-Quaternary:**
2 **implications for the geodynamics of eastern Central Iran**

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8
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31 accommodated through crosswise strike-slip faulting accompanied by reverse/thrust faulting in confining
32 wedges.

33

34 **1. Introduction**

35 The convergence between Arabia and Eurasia is responsible for current deformation in Iran. Nearly
36 all convergence is accommodated across the Iranian plateau and surrounding mountain ranges such as
37 Zagros, Alborz and Kopeh Dagh; the collision boundaries correspond approximately to the political
38 borders of Iran. The Makran tectonic province is the surface expression of the active subduction of Arabia
39 beneath the Iranian micro-continent (e.g., Walpersdorf et al., 2014; Burg, 2018).

40 In the recent decades, different parts of the Arabia-Eurasia convergence zone were studied in detail;
41 the pieces of the puzzle of this convergence are progressively fitting together. Numerous studies have
42 attempted to describe the role of strike-slip faults in the active tectonics of the collision zone (e.g.,
43 Hessami et al., 2003; Karakhanian et al., 2004; Talebian and Jackson, 2004; Walker and Jackson, 2004;
44 Regard et al., 2005, 2006; Authemayou et al., 2006; Meyer and Le Dortz, 2007; Shabanian et al., 2009a,
45 2009b and 2012a; Molnar and Dayem, 2010; Farbod et al., 2011, 2016; Calzolari et al., 2015, 2016,
46 2018). According to these studies, strike-slip faults play significant roles in the current deformation of the
47 Iranian plateau and were responsible for several moderate to large earthquakes especially in east of Iran
48 (e.g., Dasht-e Bayaz 31 August 1968, Koli-Buniabad 27 November 1979 and Zirkuh-Qayen 10 May
49 1997). Since Pliocene (5.3-2.6 Ma), the dominant tectonic regime in the Iranian plateau and surrounding
50 deformation belts has changed from compressional to strike-slip (Regard et al., 2005, 2006; Authemayou

51 et al., 2006; Shabanian et al., 2009a, 2009b, 2010; Farbod et al., 2011, 2016; Ghods et al., 2015; Tadayon
52 et al., 2017, 2018; Taghipour et al., 2018). Even in thrust-fold domains such as the Zagros and Alborz
53 belts, where the main way of accommodation of Arabia-Eurasia convergence is crustal shortening, the
54 role of strike-slip faulting is determinant (e.g., Talebian and Jackson, 2004; Authemayou et al., 2006,
55 2009).

56 The role of major strike-slip faults such as the North Tabriz Fault in northwest Iran (e.g., Cisternas
57 and Philip, 1997; Karakhanian et al., 2004; Ghods et al., 2015), the Main Recent Fault in Zagros
58 (Tchalenko et al., 1974; Braud and Ricou, 1975; Ricou et al., 1977; Berberian, 1995; Talebian and
59 Jackson, 2004), the Minab-Zendan-Palami fault zone at the Zagros – Makran transition (Regard et al.,
60 2005) and the Bakharden-Quchan fault system in Kopeh Dagh (Shabanian et al., 2009a, 2009b) as well as
61 the faults that re-activate the Sistan Suture zone in the east of Iran (e.g., Vernant et al., 2004; Walker and
62 Jackson, 2004) in accommodation of the Arabia-Eurasia convergence is nearly well-known. These strike-
63 slip faults act as block boundaries along which the blocks are moved in accordance with the overall
64 deformation in the Arabia – Eurasia collision zone (e.g., Walpersdorf et al., 2006, 2014; Tavakoli et al.,
65 2008; Shabanian et al., 2009b; Mousavi et al., 2013; Ghods et al., 2015).

66 Recent geodetic (e.g., Vernant et al., 2004; Reilinger et al., 2006; Mousavi et al., 2013;
67 Walpersdorf et al., 2014) and geological studies (Shabanian et al., 2009a, 2009b, 2010, 2012b; Farbod et
68 al., 2011, 2016) in NE Iran have revealed that active deformation is localized along block-bounding
69 crustal faults. In Central Iran, GPS-derived velocity fields (Walpersdorf et al., 2014) and GPS block
70 modeling (Reilinger et al., 2006; Walpersdorf et al., 2014) show that about 90 percent of the 5.7 mm/yr
71 northward motion of the Lut block – Eurasia is transferred to the north of the E-W Doruneh fault (Fig. 1).
72 To the north, the Bakharden-Quchan fault system takes up 4.1 - 4.6 mm/yr of this dextral faulting across
73 the Kopeh Dagh Mountains (Shabanian et al., 2009a, 2009b, 2012b; Mousavi et al., 2013). In other
74 words, this fault system accommodates 80% of Central Iran-Eurasia convergence (~5.1 mm/yr) north of
75 37°N. In this tectonic context, there are other strike-slip faults such as the Doruneh and Dasht-e Bayaz
76 faults which affect the Iranian plateau and are characterized by conspicuous seismic and/or geological

77 activities. Nevertheless, the role of these faults in the accommodation of the active convergence has been
78 a matter of debate (e.g., Farbod et al., 2011, 2016; Nozaem et al., 2013; Calzolari et al., 2015, 2016, 2018;
79 Tadayon et al., 2017 and 2018). Interestingly, these E-W faults are perpendicular to the N-S active block
80 motions in the Lut and separate the N-S dextral strike-slip faults of the Lut borders (the Nayband and
81 Sistan suture zone) to the south from the NW-trending structures of the Binalud and Kopeh Dagh
82 deformation domains to the north (Fig. 1).

83 Our understanding of the processes involved in the plate convergence improves progressively, but
84 we still need to know more about (1) both the pattern and kinematics of deformation in each part of the
85 convergence/collision zone and (2) the role of intracontinental crustal faults in the accommodation of this
86 deformation within the plateau. During the last century, areas such as Dasht-e Bayaz, Tabas, and Bam that
87 were considered as stable areas in the interior of rigid blocks have been affected by large destructive
88 earthquakes occurring on mostly unknown faults (e.g., Walker et al., 2011; Berberian, 2014). After the
89 destructive 1968 Mw 7.1 earthquake, for instance, the Dasht-e Bayaz area has been one of the most
90 seismically active domains in Iran. Right after the Dasht-e Bayaz main shock in 1968, this area has been
91 studied from different points of view. The first studies focused on mapping of the coseismic rupture and
92 post-earthquake observations (e.g. Ambraseys and Tchalenko, 1969; Tchalenko and Ambraseys, 1970;
93 Tchalenko and Berberian, 1975). Meanwhile, more recent studies have focused on the seismology and the
94 active tectonics of Dasht-e Bayaz and surrounding areas in the context of Arabia-Eurasia convergence
95 (Walker et al., 2004; Walker and Jackson, 2004; Walker et al., 2011). However, the main unanswered
96 question regards the role of the E-W sinistral faults such as the Dasht-e Bayaz fault in accommodation of
97 the NNE Arabia - Eurasia convergence (e.g., Vernant et al., 2004; Walpersdorf et al., 2014) between
98 Central Iran and Eurasia. This question can be answered partly through an investigation of the temporal
99 and spatial kinematic evolution of the Dasht-e Bayaz fault and its kinematic interaction with other major
100 structures including the Sistan suture zone. It is also important to know whether the stress field in eastern
101 Iran is due to the stress transfer from the Arabia – Central Iran collision, or is influenced by the geometry
102 and relative motion of individual blocks in eastern Iran (e.g., Jentzer et al., 2017).

103 This paper especially focuses on the Pliocene-Quaternary to present-day states of stress (the last 5
104 Ma) in the region affected by the Dasht-e Bayaz fault (Fig. 1); the paleo-tectonic evolution of the area is
105 of course out of the scope of this study. We applied the inversion technique on both kinds of fault slip
106 data as provided through focal mechanism of earthquakes and fault measurements in the field, with well-
107 known senses and relative chronologies. The level of consistency of our results has been discussed in the
108 light of previous studies on the Cenozoic stress field of the Iranian plateau and surrounding deformation
109 belts. We have then put our results in a larger framework, which we have reconstructed using available
110 kinematic data and results from the east and northeast Iran. This has allowed us to discuss the possible
111 interaction of the Dasht-e Bayaz fault with other active faults of the region. Finally, we have proposed a
112 kinematic scenario to describe the role of strike-slip faulting in the accommodation of active convergence
113 in ENE Iran.

114

115 **2. Geodynamic and seismotectonic framework**

116 According to geological investigations (e.g., Berberian et al., 1999; Walker and Jackson, 2004;
117 Mayer and Le Dortz, 2007; Foroutan et al., 2014) and geodetic Global Positioning System (GPS)
118 measurements (e.g., Vernant et al., 2004; Walpersdorf et al., 2014), the N-striking right-lateral faults in
119 Central Iran, especially on both sides of the Lut block (Fig. 1), accommodate the northward motion of
120 Central Iran relative to Eurasia (Helmand block in Afghanistan). The Distribution of historic records and
121 instrumental earthquake epicenters, as well as the GPS velocity field show that the convergence is mainly
122 accommodated along the block boundaries, while the interior of the blocks (e.g., Lut block) is almost
123 rigid (e.g., Vernant et al., 2004; Walker and Jackson, 2004; Walpersdorf et al., 2014), with low rates of
124 deformation. The crustal-scale dextral shear continues up to the latitude 34°N, north of which E-W left-
125 lateral faults like the Dasht-e Bayaz, Niazabad and Doruneh (further north) are present (Fig. 1). At this
126 latitude, the change in geology is accompanied by a change in active faulting from the N-S dextral faults
127 of the Sistan suture zone to a system mainly constituted by E-W sinistral strike-slip faults (e.g., Berberian

128 et al., 1999). The role of these crustal faults in the accommodation of active deformation perpendicular to
129 the N-S dextral shear has been a matter of debate since, at least, thirty years ago (e.g. Jackson and
130 McKenzie, 1984; Berberian et al., 1999; Walker and Jackson, 2004; Farbod et al., 2011, 2016; Aflaki et
131 al., 2019). The recent works by Nozaem et al. (2013), Calzolari et al. (2015 and 2016) documented
132 Neogene to Quaternary dextral strike-slip deformation along the NE-SW Kuh-e-Sarhangi and the E-W
133 Kuh-e-Faghan faults and have revealed another complexity in the active kinematics of northwest Lut –
134 Central Iran (Fig. 1). The objective of this part is a brief demonstration of the structural schema and the
135 seismotectonic activity of an active fault network, with complex internal interactions; for this reason we
136 only selected some of the most important and crucial seismic activities in the area without pointing out
137 other subsidiary events that have not been assigned to particular faults.

138 Active tectonic and seismological studies conducted in Dasht-e Bayaz and the surrounding areas
139 documented that the active faults, responsible for numerous seismic shocks in the area, are temporally and
140 mechanically in close interaction (e.g., Berberian et al., 1999; Walker et al., 2004; Walker et al., 2011).
141 On 31 August 1968, a tremendous destructive earthquake (Mw 7.1) shocked the area and produced a 70
142 km E-W coseismic rupture; the maximum coseismic displacement (4.5 m left-lateral and 2.5 m vertical)
143 was measured in north of the Nimboluk plain (Tchalenko and Ambraseys, 1970; Tchalenko and
144 Berberian, 1975). The formerly called Dasht-e Bayaz fault was renamed later as the western segment of a
145 now longer Dasht-e Bayaz fault, subsequent to the reactivation of its 55 km length extension to the east.
146 The eastern segment of the Dasht-e Bayaz fault with the same trend and straight geometry attracted
147 attention after 27 November 1979 Mw 7.1 Koli-Buniabad earthquake, only 11 years after the Dasht-e
148 Bayaz main shock (e.g., Berberian et al., 1999).

149 The most remarkable seismic events occurred just 20 hours after the Dasht-e Bayaz main shock
150 during the Ferdows earthquakes of 1st and 4th September 1968 (Mw 6.3 and Mw 5.5, respectively) about
151 70 km west of the Dasht-e Bayaz village. The close proximity (or even overlap) between the domains of
152 impact of the Dasht-e Bayaz and Ferdows earthquakes has prevented researchers from separating their
153 field effects (e.g., Berberian, 2014). Several authors, based on field observations, suggested that the two

154 earthquakes occurred on the NW-trending Ferdows reverse fault (Figs. 1 and 2); the reverse focal
155 mechanisms of the earthquakes were also compatible with this fault (see Berberian, 2014 and references
156 therein). After 11 years and during less than one month, three other destructive earthquakes of Korizan
157 (14.11.1979), Koli-Buniabad (27.11.1979 - e.g., Haghypour and Amidi, 1980) and Kalateh Shur
158 (07.12.1979 - e.g., Haghypour and Amidi, 1980; Ambraseys and Melville, 1982) occurred along the
159 northern part of the Abiz fault, the eastern segment of the Dasht-e Bayaz fault and at the intersection of
160 the two faults, respectively. The Zirkuh earthquake of 1997 May 10 (Mw 7.2), caused by the northern
161 segment of the NNW-striking Abiz fault (Fig. 1), has also been considered as the sequence of seismic
162 events triggered by the Dasht-e Bayaz main shock on 31 August 1968 (e.g., Berberian et al., 1999). The
163 125-km-long surface faulting which, with dextral strike-slip mechanism has occurred during the Zirkuh
164 earthquake is known as the longest surface rupture associated with an Iranian earthquake (e.g., Berberian
165 et al., 1999). This NNW-striking fault segment changes into a NNE-SSW strike (causative fault of the
166 November 14, 1979 Korizan earthquake; see above) near the eastern end of the Dasht-e Bayaz fault and
167 provides its dextral pair of a conjugate-like arrangement (see section 4; Fig. 3A).

168 The 1968, 31 August earthquake of Dasht-e Bayaz is considered as a trigger for the reactivation of
169 the east segment of the Dasht-e Bayaz fault, the Ferdows reverse fault zone and the Korizan fault, causing
170 a sequence of earthquakes (e.g. the Zirkuh, Koli-Buniabad and Ferdows earthquakes). The 1968.09.11,
171 1979.01.16 and 1997.06.25 events did not rupture the surface (e.g. Berberian et al., 1999). The
172 1979.01.16 event showed NW-striking reverse faulting and 1997.06.25 event has produced both the
173 possibilities of N-S right-lateral or E-W left-lateral faulting (Berberian et al., 1999). The calibrated
174 relocations and the body-wave modeling of Walker et al. (2011) showed that the epicenter of the
175 1979.01.16 earthquake is centered on an SW-dipping reverse fault. As for the 1997.06.25 event, Walker
176 et al. (2011) also proposed that, through InSAR results, the rupture had occurred on the N-S trending
177 dextral fault plane without the possibility to attribute it to any of the Boznabad or Pavak faults (Fig. 2).

178 Based on this seismicity, it is concluded that the Dasht-e Bayaz and nearby faults are in close
179 kinematic interaction to accommodate the active deformation of the area. This sequence of the Dasht-e-

180 Bayaz, Ferdows and Zirkuh earthquakes (occurred between 1968 and 1997) presents one of the most
181 remarkable examples of temporally clustered continental seismicity in the world (e.g., Berberian et al.,
182 1999; Walker et al., 2011). These consecutive destructive earthquakes could have been triggered by the
183 31 August 1968 Dasht-e Bayaz main shock (e.g., Berberian et al., 1999 and references therein) and
184 occurred along the faults with different kinematics.

185

186 **3. Methodology**

187 **3.1. Inversion of fault-slip data**

188 Following the method proposed by Carey and Brunier (1974), determination of a deviatoric stress
189 tensor from fault slip data is based on the stress-slip relationship described by Wallace (1951) and Bott
190 (1959). Computer programs, developed for the inversion of fault slip data, compute a mean best fitting
191 deviatoric stress tensor from a group of striated fault planes by minimizing the angular deviation (misfit
192 angle) between the observed striation and the shear stress resolved on the fault plane (Carey and Brunier,
193 1974, Carey; 1979; Angelier, 1990). The inversion results are revised and refined iteratively to reach the
194 smallest misfit angle while involving the highest possible number of measured homogenous fault slip
195 data. The meaningful process of stress determination (deviatoric reduced stress tensor) from both
196 geological and seismological fault slip data is a delicate challenge requiring good quality of data,
197 meticulous observations and data separation as well as adequate knowledge on both kinematics and
198 mechanics of faulting (see Allmendinger et al., 1989; Shabanian et al., 2010; Hippolyte et al., 2012;
199 Tranos, 2018). A blind use of abundant computer programs (whatever the software is used) seems very
200 simple, but it would lead to mathematic results without geological significance (see Hippolyte et al., 2012
201 and Tranos, 2018 for details).

202 The method we used is principally invented (Carey and Brunier, 1974; Carey-Gailhardis and
203 Mercier, 1987) for the analysis of multiphase heterogeneous fault slip datasets measured in natural fault

204 outcrops which contain a variety of new created and preexisting fault planes reactivated in distinct stress
205 states. This method easily works with both new created conjugate fault pairs and preexisting faults with
206 unknown geometric relationships and is independent of conjugate fault arrangements for resolving
207 reduced stress tensors (see Carey-Gailhardis and Mercier, 1987 and 1992; Bellier and Zoback, 1995;
208 Regard et al., 2005; Shabanian et al., 2010 for more details). As a main aspect of the program we have
209 used (i.e., FCALC – Geodyn-Soft; Carey-Gailhardis and Mercier, 1987), there is no way for automatic
210 separation of fault slip data and this job have to be done through detailed geological field observations
211 and individual notes on the quality, reliability and chronological relationships (cross-cutting or
212 overprinting) of the structural elements measured in the field, as well as mechanical compatibility of the
213 fault slip data to the resolved stress tensor. Interestingly, the well-known misfit angle, which is an
214 essential criterion for the computer software during the iteration and minimization processes, is the last
215 parameter we consider for the analysis of a heterogeneous fault dataset. This considerably reduces the
216 effect of geologically incompatible slip data in resolving a deviatoric stress tensor. This is simply because
217 an apparently homogenous dataset (separated without reliable geological considerations) could be
218 synthesized through optimizing the misfit angle distribution of the stress model and an arbitrary selection
219 of data mainly based on this criterion. While, that dataset could comprise fault slip data which in reality
220 belong to different tectonic regimes but apparently are compatible with an artificial mean stress tensor
221 resolved from marginal data from those different datasets. Therefore, the misfit angle only shows the
222 level of compatibility of data with a given stress model regardless its geological reliability!

223 Principal inputs are fault-slip data from geological faults measured in the field or seismologically
224 determined focal mechanism of earthquakes including attitudes (e.g., strike/dip/dip quadrant) of striated
225 fault planes and associated striations with well-known sense of movement. As a great advantage,
226 acquisition of field data is feasible almost everywhere and a careful inversion analysis of good quality
227 fault slip data, with known chronological relationships, would lead to a reliable reconstruction of the
228 kinematic history of an area (e.g., Angelier, 1984; Carey-Gailhardis and Mercier, 1992; Hippolyte et al.,
229 1993; Bellier and Zoback, 1995; Regard et al., 2005; Shabanian et al., 2010). The main outputs of this

230 method are orientations (trend and plunge) of principal stress axes $\sigma_1 \geq \sigma_2 \geq \sigma_3$ (corresponding maximum,
231 intermediate and minimum stresses, respectively) and “ $R = (\sigma_2 - \sigma_1) / (\sigma_3 - \sigma_1)$ ”. This linear parameter (R)
232 equals $1 - \phi$, ϕ being another commonly used stress ratio (e.g., Angelier, 1979; Zoback, 1989; Ritz and
233 Taboada, 1993), and describes relative stress magnitudes ranging from 0 to 1 (e.g., Carey and Brunier,
234 1974; Mercier et al., 1991; Bellier and Zoback, 1995, Shabanian et al., 2010 and references therein).
235 Different combinations of Andersonian stress arrangements (vertical principal stress axes of σ_1 , σ_2 and σ_3
236 for pure extensional, strike-slip and reverse faulting, respectively) and R values lead to various stress
237 regimes responsible for different kinds of faulting (see Ritz and Taboada, 1993; Shabanian et al., 2010 for
238 more details). We used the method originally proposed by Carey (1979); the results deduced from
239 inversion of fault-slip data measured in individual sites along the Dasht-e Bayaz fault and nearby areas
240 are presented in Table 1 (see Figs 3 and 9 for site locations).

241

242 **3.2. Relative chronology of fault slip data and data separation**

243 According to an important assumption accepted in fault kinematic inversion methods, a distinct
244 stress tensor ($\sigma_1 \geq \sigma_2 \geq \sigma_3$ and “R”) can create only one slip direction on a given fault plane. The
245 complications of data separation are normally revealed when different sets of heterogeneous fault-slip
246 data are collected from fault planes. Several generations of striae on a single fault plane are surely the
247 result of changes in angular relationships between the fault plane and principal stress axes. Nevertheless,
248 the nature of such changes could either be (1) due to temporal variations in the stress field or (2) could
249 imply the rotation of the fault plane during deformation. In both cases, the chronology of striae is usually
250 determined through the crosscutting relationships of striations and/or fault planes complemented by
251 geological field observations. Except for some probable mistakes in measurements and individual cases of
252 local rotations due to progressive deformation, the fault slip data are usually classified into homogenous
253 sub-groups. In some of related studies, the automatic or semi-automatic methods have also been proposed
254 or utilized to separate heterogeneous fault slip data (e.g., Nemcok and Lisle, 1995; Salvini and

255 Storti, 1999; Fry, 1999; Rossetti et al., 2002; Shan et al., 2003; Tranos, 2015, 2018), however, in this study
256 we preferred to take advantage of techniques concerning data separation based on geological observations
257 and kinematic rules (see Shabanian et al., 2010). Figure 8 shows an example of this strategy which is
258 based on crosscutting relationships, field observations and kinematic considerations. The 10 measurement
259 sites were chosen in outcrops of different stratigraphic ages, ranging from Triassic to Quaternary (Figs 3
260 and 10); almost half of the measurements (a total number of 170 fault slip data) were done on fault planes
261 affecting Pliocene and Quaternary deposits (see Table 1). Relative chronologies of different generations
262 of striations on a fault plane or in an outcrop has been determined based on the superposition of striations
263 and/or crosscutting relationships between fault planes affecting the outcrop. In a given outcrop, usually,
264 there are few fault planes showing direct chronological indicators for different generations of striations,
265 while the majority of planes only express one direction of striation with unknown relative chronology (see
266 Shabanian et al., 2010 for more details). In such the case, fault slip data of different generations have
267 primarily been separated using the well-known relative chronologies observed in the field and then, other
268 compatible fault planes with only one striation were added to each data set based on their kinematic and
269 mechanical compatibilities with the data set, as well as the geological field notes on each fault plane
270 (Fig. 8). The final chronology of the resolved deviatoric stress states (defined as paleo, intermediate or
271 modern stresses) has been determined considering the age of youngest rock units affected by each stress
272 state and chronological cross-relations between different stress tensors.

273 Certain criteria should be met in order to determine reliable stress solutions (e.g. Etchecopar, 1984;
274 Carey-Gailhardis and Mercier, 1992; Belier and Zoback, 1995; Shabanian et al., 2010): (1) we need at
275 least 4 fault planes with different attitudes that are well-distributed in the space. A higher number of fault
276 planes and a good spatial distribution will result in a more constrained stress solution, (2) the inversion
277 results will theoretically be reliable when at least 80 percent of deviation angles are under 20° , that means
278 a confidence level of 68 per cent in a Gaussian probability distribution (3) the measured fault planes must
279 show good mechanical compatibility with the stress tensor solution. For instance, a set of transtensional
280 faults cannot be explained by a compressional stress tensor even if output parameters of the tensor to be

281 excellent, (4) a reliable stress solution needs fault slip data of good quality; it greatly depends on the
282 details of field observations, the tectonic history of the measurement site and user's experiences of data
283 measurement and inversion analysis. Considering these criteria, A, B and C were assigned to well-
284 constrained, constrained and poorly-constrained stress tensor solutions, respectively. For solutions from
285 less than four well-distributed fault planes, we used a fixed solution (Bellier and Zoback, 1995) in which,
286 one principal stress axis is fixed as vertical. In this study the quality of fixed solutions has been
287 considered the same as C and they were marked as CF; the stress ratio "R" is not valid for this kind of
288 solutions.

289 According to the abovementioned method, the measured fault slip data were separated into three
290 homogeneous groups of slip generations and were analyzed. This analysis has provided basic information
291 for describing the last kinematic evolution of the Dasht-e Bayaz fault during the Pliocene and Quaternary
292 times. We compared the pattern of kinematic changes along the Dasht-e Bayaz fault with similar studies
293 in nearby regions in E and NE Iran (e.g. Shabanian et al., 2010; Farbod et al., 2011; Javidfakhr et al.,
294 2011; Jentzer et al., 2017; Tadayon et al., 2017), which has allowed us to place our results in a larger
295 geodynamic scale (see the discussion).

296

297 **3.3. Inversion of earthquake focal mechanism data**

298 We determined the present-day state of stress in the Dasht-e Bayaz area through the inversion of
299 focal mechanisms of medium to large ($7.1 > M > 5.5$) earthquakes applying the method described by Carey-
300 Gailhardis and Mercier (1987). These earthquakes have occurred between 1968 and 1997 comprising the
301 Dasht-e Bayaz main shocks. We have only used focal mechanism solutions that had been relocated and
302 modeled using body waves by Walker et al. (2004, 2011). With this method, we analyzed two orthogonal
303 nodal planes for each earthquake focal solution taking into account that only one plane was reactivated
304 during the earthquake due to the regional stress state. The final selection among each pairs of nodal planes
305 can be done by (1) direct observation of the surface rupture of the earthquake, (2) seismological

306 investigations of the rupture process, (3) the spatial distribution of aftershocks and (4) the inverse
307 computation by selecting the nodal plane that results in greater consistency with the regional stress field
308 (Carey-Gailhardis and Mercier, 1987). For determining the regional state of stress, the importance of the
309 main shocks (even a single datum) is significantly greater than that of the aftershocks because small
310 earthquakes would probably reflect kinematic instabilities due to heterogeneous deformation and
311 independent faulting in small-scale bodies (e.g. Carey-Gailhardis and Mercier, 1992). For some of the
312 main shocks, we have direct information on the rupture geometry from field observations (Tchalenko and
313 Ambraseys, 1970; Berberian et al., 1999). This serves as a reference for evaluating the compatibility (in a
314 geometric sense) of other events using inverse computation. This method was successfully applied to
315 determine the causative fault plane of the second event of August 2012 earthquake doublet (Mw 6.4, 6.2),
316 that had occurred in the Ahar-Varzaghan complex fault system in NW Iran (see Ghods et al., 2015 and
317 Momeni and Tatar, 2018).

318

319 **3.4. Active fault mapping**

320 During the four last decades, several studies have focused on different aspects of the Dasht-e Bayaz
321 earthquake fault providing structural maps of the fault at different scales and at distinct aims (e.g.,
322 Tchalenko and Ambraseys, 1970; Tchalenko and Berberian, 1975; Walker et al., 2011). However, the
323 specific scope of our study on kinematic aspects of the fault and its interaction with other neighboring
324 main faults has led us to prepare a detailed fault map using the high resolution satellite images (Bing
325 images in SAS Planet, <http://sasgis.org>; 1 m resampled pixel size) of the area. A simplified version of this
326 map is shown in Figure 3, while the more detailed maps are centered on the fault terminations and
327 intersection zones (Figs 4-7), where additional information are needed to describe the structural
328 characteristics of the Dasht-e Bayaz fault. Thanks to our new fault mapping, we reinterpreted the
329 structural relationships between the main fault and other structures interacting with from the eastern
330 termination westwards along the Dasht-e Bayaz fault (see below).

332 **4. Active tectonics and structure of the Dasht-e Bayaz fault**

333 The Dasht-e Bayaz fault is a 120-km-long sinistral fault in the north of the Lut block (Fig. 1). The
334 E-W Dasht-e Bayaz fault, with an almost straight geometry, is a structural assemblage of several fault
335 strands with different orientations ranging from N070°E to N110°E (e.g., Tchalenko and Ambraseys,
336 1970; Fig. 3). This particular structural arrangement forms various contractional and extensional
337 mesoscale structures and the associated morphotectonic landforms such as pull-apart basins, pressure
338 ridges and en-echelon folds at different scales along the fault zone; the same structural patterns were
339 seismically created during the 31 August 1968 Dasht-e Bayaz main shock (Tchalenko and Ambraseys,
340 1970; Berberian et al., 1999). In addition to these variations in the fault geometry, the Dasht-e Bayaz fault
341 is affected by N-S dextral faults which are in close interaction with the main fault (Figs 3 and 4).

342 At the eastern end, the Dasht-e Bayaz fault intersects the NNE-striking Korizan segment of the
343 Abiz fault (Fig. 3). As an important verified observation, north of 34°N, it is difficult to define any
344 relative dominance for the N-S Korizan or the E-W Dasht-e Bayaz faults while south of this latitude, the
345 N-S dextral faults are dominant and cut both the E-W sinistral and the NW-SE reverse faults of the region
346 (e.g., Berberian et al., 1999). Near the village of Buniabad in the south of Kheybar Kuh-e Kuchek (i.e.,
347 Little Kheybar Mountain), these faults join together into a single ENE-WSW trend (Fig. 3). Farther
348 northeast, however, the sinistral Niazabad fault runs parallel to the Dasht-e Bayaz fault and looks like a
349 left-hand stepping segment in a larger E-W sinistral fault system (Fig. 1), which is apparently dominating
350 the N-S dextral fault system of the Sistan suture. The northern parts of the Korizan fault are partly
351 covered by eolian deposits, while the overall fault trace in the south of Buniabad village (Fig. 3) cuts the
352 Quaternary alluvial fan surfaces. Our mapping of the intersection area shows a deforming wedge between
353 the main traces of the Dasht-e Bayaz and Korizan faults (Fig. 3a); the conjugate arrangement of the main
354 faults implies active contraction inside the wedge. Interestingly, N-S fault traces appear again in a
355 discontinuous way in the northern side of the Dasht-e Bayaz fault trace, cutting through Kheybar Kuh-e

356 Kuchek. Except for a few places (see Walker et al., 2011), the N-S fault strands cut the bedrock and there
357 is no way to evaluate their Quaternary activity. Nevertheless, systematic dextral geomorphic offsets of
358 main streams along these faults could indicate their activity during, at least, the Pliocene time.

359 Another structural node along the Dasht-e Bayaz fault occurs where it intersects with the N-S
360 Mahyar fault (Fig. 4). In fact, the Mahyar fault (e.g. Berberian, 2014) separates the western and eastern
361 earthquake segments of the Dasht-e Bayaz fault (ruptures of the 31 August 1968 and 27 November 1979
362 earthquakes, respectively). Our detailed mapping of the intersection area (Fig. 4) shows that the cross-
363 cutting dextral Mahyar fault and the sinistral Dasht-e Bayaz fault form a typical crosswise (nearly
364 orthogonal) fault arrangement in the middle part of the Dasht-e Bayaz fault trace. These coexisting faults
365 have displaced each other in the sense of their movement of about 1.5 km (Figs 3 and 4). Following the
366 opposite shear senses of the crosswise faults, double-coupled extensional and contractional domains have
367 been formed in the quarters of this intersection. In the NW and SE extensional quarters, there are two
368 relatively lowlands with an average elevation of 1300 m, while the adjacent NE and SW contractional
369 quarters occupy higher areas with the average elevation of 1400 m (Fig. 4). The NE contractional quarter
370 is occupied by nearly E-dipping reverse faults which join the main trace of the eastern Dasht-e Bayaz
371 fault, southwards (Fig. 4).

372 In the same area, around the Dasht-e Bayaz and Mahyar faults intersection zone (Fig. 4), different
373 sets of dioritic and andesitic dikes have intruded in folded rocks of Jurassic to Eocene ages (Alavi Naini
374 and Behruzi, 1983; Fauvelet and Eftekhar-Nezhad, 1991). Pliocene deposits cover these post folding
375 dikes and define their stratigraphic age of post Eocene – pre Pliocene. We have mapped 379 dikes
376 through the analysis of Bing Map (SAS Planet©) satellite images of the area. The clear crosscutting
377 relationships of the dikes show three generations of which the oldest set (microdioritic dikes;
378 Mohammadi Gharetapeh et al., 2014) is the most frequent, with a dominant orientation of $N330\pm 10^\circ E$
379 (Fig. 4). Two younger minor populations of dikes (pyroxene andesitic with $N345\pm 15^\circ E$ and $N10\pm 10^\circ E$
380 preferred orientations) are less abundant in the area and clearly cut through the oldest generation where
381 coexisted.

382 Our new mapping of the 1979 earthquake rupture reveals that the main trace of the coseismic
383 rupture dies out westward into a N-S reverse fault zone, with a dextral component of faulting (Figs 4
384 and 5). Other parallel reverse/thrust faults are observed in this quarter, but those haven't been picked up
385 by the coseismic rupture (Fig. 5). In contrast, the adjacent NW extensional quadrant hosts the extensional
386 termination of the 1968 coseismic rupture (Fig. 5). In this area, the E-W trend of the 1968 rupture dies out
387 eastwards into a NE-striking normal fault zone of which a 615-m-long array of surface rupture can be
388 mapped in recent satellite images (Figs 4 and 5). The alignment of several SE-facing landslides (with
389 fresh free-faces recognizable on images) along this part of the rupture is coherent with the extensional
390 character of the rupture termination.

391 Farther west, the Dasht-e Bayaz fault reaches an E-W, pull-apart basin (the Chah Deraz pull-apart
392 basin), which possesses an elongated shape (~3900 m in length and ~870 m in width), with the length to
393 width ratio of 4.5. The almond-shaped geometry of the pull-apart basin, in addition to its symmetric
394 curved boundaries (Fig. 6) implies that the basin was formed in a releasing bend (e.g., Dooley and
395 Schreurs, 2012) along the Dasht-e Bayaz fault. Considering the lack of Quaternary activity along the
396 southern border of the basin and the coseismic reactivation of the northern master fault during the 31
397 August 1968 earthquake (Fig. 6), we suggest that the pull-apart basin has entered a new stage of
398 evolution, by a shift in active extension from the central part to the northwest margin of the basin (Fig. 6).

399 Further to the west, the Dasht-e Bayaz fault controls the contact between Quaternary deposits and
400 Mesozoic sedimentary rocks. In the north of Nimboluk plain, there are outcrops of Miocene marls
401 armored by Quaternary deposits; the dense cultivation and human-made changes in the Quaternary
402 surfaces, cut by the fault, precluded us from following the trace of the coseismic rupture. The detailed
403 rupture maps of Tchalenko and Ambraseys (1970) and Tchalenko and Berberian (1975) show that about
404 12 km westwards from the Chah Deraz pull-apart, the fault trace encounters another structural complexity
405 (Fig. 7). After a 5-km-long en-echelon fracture zone, the main rupture trace turns southwest and continues
406 to the west for ~20 km. This coseismic fault rupture (Mozdabad fault branch) crosses between Dasht-e
407 Bayaz and the Khezri villages and, in the southwest of Mozdabad village, it joins the Ferdows reverse

408 fault array at the western flank of the Kuh-e Kamarkhid and Kuh-e Kalat mountains (Figs. 2 and 3).
409 Interestingly, the main fault trace, visible in the geomorphology of Quaternary alluvial fans, can be
410 directly traced to the west of the Chah Deraz segment, while only a small part of this Quaternary fault has
411 been reactivated during the 1968 earthquake. This branch of the Dasht-e Bayaz geologic fault continues
412 westwards for 13 kilometers, where it bends towards the northwest and joins the north dipping reverse
413 faults in the middle of Kuh-e Kamarkhid (Fig. 2 and 7A). In that area, a series of en-echelon pressure
414 ridges and folds have been formed due to a restraining curvature along the Dasht-e Bayaz fault (Fig. 7).

415 In summary, our new detailed mapping of the Dasht-e Bayaz fault trace and the related structures
416 (thanks to the available very high resolution satellite images and other facilities) reveals that the Dasht-e
417 Bayaz fault is a complex fault zone in which several fault strands with different orientations and
418 kinematics are actively interacting. In this context, N-S dextral and E-W sinistral faults play a significant
419 role in both the structural pattern and active tectonic deformation along the main fault zone.

420

421 **5. Fault kinematics and states of stress in the Dasht-e Bayaz area**

422 **5.1. Modern state of stress**

423 The analysis of the youngest group of fault slip data were measured in ten sites (Table 1, Figs 9 and
424 11) including the last coseismic kinematics of the Dasht-e Bayaz fault (for example, sites 2, 5 and 6 in
425 Figs 10a, 10e-f and 10h, respectively). Except for sites 4, 5b and 6, the maximum stress axis (σ_1) has the
426 average trend of $N045\pm 5^\circ E$ (Fig. 13C) and the deviatoric stress tensors indicate a homogenous strike-slip
427 stress field in the area including the Dasht-e Bayaz fault (Figs 9 and 11). The trend of the σ_1 axis locally
428 changes in sites 5b, 6 and 4, with an orientation of $\sim N070^\circ E$ (see the section 6.1 for more details).

429 To avoid local stress changes caused by structural rotations in fault zones and local stresses
430 produced at structural complexities such as fault bends, fault relay zones and fault-bend terminations, we
431 have analyzed together the youngest set of fault-slip data only from main fault planes (MFP) measured

432 over the study area (Figs 10 and 11). A main fault plain is the most prominent structure which controls
433 overall deformation in a given outcrops (for instance, fault planes marked in Figs 10a, 10c, 10f- j) and is
434 usually distinguished from other subsidiary fault planes in the outcrop during field measurements. The
435 inversion analysis of such a particular data set leads to a mean regional stress state responsible for the
436 reactivation of different main fault planes regardless their geographic location and structural setting. The
437 resulting stress tensor specifies a mean regional strike-slip stress regime characterized by a $N42\pm05^\circ E \sigma_1$
438 axis (Fig. 11). This regional mean σ_1 axis is very close to the average orientation of $N45\pm05^\circ E$ for the σ_1
439 that we have independently obtained in 8 individual sites (Fig. 14C). Almost all the stress tensors (except
440 for sites 5A, 6 and 7) were resolved from the analysis of strike-slip fault planes, with pitch angles less
441 than 20° (Fig. 11), showing different dextral or sinistral dominant component of faulting in accordance
442 with their orientation with respect to the principal stress axes (Fig. 11). This strike-slip character is also
443 consistent with the regional mean stress tensor deduced from the inversion of main fault planes (MFP in
444 Fig. 14) and is confirmed by the mean R value of ~ 0.54 for the tensors with Andersonian strike-slip
445 arrangement (Fig. 11 and Table 1). Accordingly, a prominent pure strike-slip regime is representative for
446 the modern stress field over the study area.

447

448 **5.2. Paleostress state**

449 In 8 sites along the Dasht-e Bayaz fault, we have observed signatures of the oldest generation of
450 fault slip data. These older data, which were naturally fewer than the younger data, were carefully
451 differentiated and analyzed regarding both our field observations and cross-relation of different individual
452 data in each site. For example, our field observation in site 7 indicates the signature of two distinct
453 deformation stages in Neogene deposits (Figs 8 and 12). A total number of 20 fault planes were measured
454 in site 7. The SE-striking fault planes show an older dextral reverse kinematics (striation 1 in Fig. 8)
455 overprinted by a younger pure reverse kinematics (striation 2 in Fig. 8). The younger fault slip data set is
456 compatible with the modern stress state, while the older data set defines an older reduced stress tensor

457 characterized by a NW-trending maximum compression (Fig. 8C). E-W planes in this data set are
458 oblique-slip dextral reverse faults (right-hand stereogram in Fig. 8C).

459 In six of eight sites, which are well distributed over the study area, the oldest data sets comprise
460 sufficient data to give independent deviatoric stress tensors (Figs 9 and 12; Table 1). These individual
461 stress tensors represent a paleostress state characterized by a homogeneous $N135\pm15^\circ E$ trending mean σ_1 .
462 As for the dominant stress regime, except for two stress tensors resolved for sites 6 and 7, the other
463 tensors are fixed solutions, with less than four differently oriented fault planes (see the methodology
464 section). In this case, the tensors cannot be used for determining the stress regime. However, the majority
465 of fault planes analyzed in these paleostress tensors is oblique-slip with a dominant reverse component
466 (Fig. 12) and are coherent with a transpressional stress regime as indicated by the B-Quality tensor 7 in
467 Figure 12. In this paleostress regime, the E-W fault planes, which were measured on the earthquake fault
468 trace of Dasht-e Bayaz or on other faults parallel to it, are oblique-slip reverse dextral faults and show a
469 transpressional character (Fig. 8d).

470

471 **5.3. Intermediate state of stress**

472 In addition to these paleo and modern states of stress, the signature of an intermediate stress field
473 was also measured in three sites along the Dasht-e Bayaz fault (Figs 8, 13; Table 1). This intermediate
474 stress is characterized by a $\sim N009^\circ E$ mean σ_1 and a strike slip stress regime (Fig. 14B). However, the
475 insufficient number of stress solutions for this stress state precludes us considering it as an independent
476 regional stress field (see the discussion).

477

478 **5.3. The present-day state of stress deduced from inversion of earthquake focal mechanisms**

479 We have used 15 earthquake focal mechanisms that have been recorded in the Dasht-e Bayaz and
480 nearby areas and have been modeled by Walker et al. (2004, 2011) using body wave modeling (Table 2).
481 The final stress tensor was resolved through the inversion of fault slip data from several earthquakes

482 affecting a vast area around the Dasht-e Bayaz fault and is therefore representative of the present-day
483 regional state of stress in the northern Lut block. This solution indicates a single strike-slip tectonic
484 regime, which characterized by a regional $N050\pm05^\circ E$ trending σ_1 (Fig. 15) responsible for the active
485 deformation (whatever reverse or strike-slip fault mechanism) throughout the region.

486

487 **6. Discussion**

488 **6.1. Regional versus local stress changes in the Dasht-e Bayaz and close vicinity**

489 In this study, the spatiotemporal changes in the state of stress were investigated through the inversion
490 of fault slip data measured in ten sites along the Dasht-e Bayaz fault. Based on the inversion of
491 independent sets of geologic fault slip data (a $N045\pm05^\circ E$ compression with strike-slip regime) and
492 earthquake focal mechanisms (a single strike-slip tectonic regime, with a regional $N050\pm05^\circ E$ trending
493 σ_1), the present-day state of stress in the Dasht-e Bayaz area is characterized by a mean regional
494 $N050\pm05^\circ E$ trending σ_1 accommodated by strike-slip tectonics (Fig. 15). The consistency of these results
495 reveals (1) the absence of remarkable change in the modern state of stress during the late Quaternary time,
496 (2) the prevalence of a homogeneous stress field in the brittle crust (above the ~ 17 km depth of
497 seismogenic layer) of the Dasht-e Bayaz region and (3) the lack of stress perturbation due to the activity
498 of the Dasht-e Bayaz fault.

499 The main strike-slip stress regime deduced along the eastern and middle parts of the Dasht-e Bayaz
500 fault changes into a compressional stress regime at the western end of the fault (sites 6 and 7 in Figures 9
501 and 11). These two distinct stress regimes are coherent with different structural settings of the resolved
502 stress tensors. In fact, despite the strike-slip character of the fault that is clearly expressed along its
503 eastern and central portions (e.g., Tchalenko and Ambraseys, 1970), the kinematics of the Dasht-e Bayaz
504 fault changes to oblique-slip sinistral reverse at its western end. In this area, the strike-slip character of the
505 Dasht-e Bayaz fault disappears near the NW-SE Ferdows thrust (Berberian, 1981 and 2014) where the E-

506 W strike of the fault turns into NW. This change in strike is in accordance with the compressional stress
507 regime obtained from site 7. As for site 6, it is inspected along a pressure ridge formed along a branch of
508 the main fault. In that area, the fault branch locally accommodates the contractional deformation induced
509 by left-lateral faulting along the main fault trend. In other words, this compressional stress regime
510 expresses the local variation in regional stress at structural complexities along the fault. Besides these
511 local changes, the paleostress state deduced from the oldest generation of fault slip data measured in
512 Pliocene and older rock units is characterized by a $N135\pm 15^\circ E$ trending mean σ_1 , with a transpressional
513 stress regime. During the prevalence of this stress field, the E-W Dasht-e Bayaz fault was an oblique
514 reverse dextral fault.

515 In the kinematic analysis, an important issue is the possibility of structural rotations due to
516 progressive deformation. Evaluating such a possibility, we have used arrays of dikes intruded in the
517 folded strata of the area (section 4; Fig. 4). Aside for the amazing similarity in trends of the oldest
518 generation of dikes ($N330\pm 10^\circ E$) and the paleo- σ_1 we have obtained ($\sigma_{\text{hmax}} = N315\pm 15^\circ E$), the overall
519 orientation of the dikes does not significantly vary along and across the strike of both the Mahyar and
520 Dasht-e Bayaz faults (Fig. 4). The same orientations of the first set of dikes close to, and beyond the main
521 fault traces indicates insignificant structural rotations due to the post injection strike-slip faulting.
522 Therefore, in the absence of signs of gradual changes in geological markers like post Eocene dikes (see
523 Figure 4), our results indicate a drastic change in the regional state of stress and in other words, a
524 kinematic switch from dextral to sinistral faulting along the Dasht-e Bayaz fault during the Pliocene-
525 Quaternary time. Currently, the Dasht-e Bayaz main fault zone, reactivated on 31 August 1968, contains
526 several roughly E-W fault strands characterized by a coseismic sinistral mechanism superimposing the
527 older reverse dextral kinematics of the main fault (Figs 8, 11 and 12).

528

529 **6.2. Late Cenozoic stress fields in the Iranian Plateau, Alborz and Kopeh Dagh mountains**

530 One of the most interesting issues concerning the accommodation of Arabia-Eurasian convergence
531 in the Iranian plateau is the history of the evolution of stress regimes during Pliocene and Quaternary.
532 Thanks to modern techniques, such as the inversion of focal mechanisms of earthquakes, our knowledge
533 about the present-day state of stress has progressed. Whereas, there is still some ambiguity left concerning
534 the interpretation of long-term changes in stress regime and the transition between successive stress
535 regimes.

536 Temporal changes in the stress field of the Alborz range, Kopeh Dagh Mountains and north of the
537 Lut block, as well as northwest Iran have been reported by several authors (e.g., Tchalenko et al., 1974;
538 Abbassi and Shabanian, 1999; Jackson et al., 2002; Allen et al., 2003; Guest et al., 2006; Zanchi et al.,
539 2006; Yassaghi and Madanipour, 2008; Abbassi and Farbod, 2009; Landgraf et al., 2009; Shabanian et
540 al., 2010, 2012a; Farbod et al., 2011; Javidfakhr et al., 2011; Tadayon et al., 2017; Aflaki et al., 2018a,
541 2018b). The rate and style of deformation in north and northeast Iran have significantly changed during
542 the late Cenozoic (e.g., Ritz et al., 2006; Shabanian et al., 2009b, 2010). The systematic fault kinematics
543 studies in these regions have shown that the late Cenozoic stress changes had been drastic (e.g.,
544 Shabanian et al., 2010; Javidfakhr et al., 2011)

545 As for temporal changes, Tchalenko et al. (1974), during tectonic studies in the Tehran region, have
546 noticed the possible occurrence of a post-Pleistocene change in the orientation of maximum horizontal
547 compression (σ_1) from NW to NE, based on the pattern of post Eocene dikes, the style of folding and
548 faulting in the alluvial formations. In the same region, Abbassi and Shabanian (1999) have found three
549 distinct states of stress and a clockwise rotation in the stress field through the inversion of fault slip data
550 mostly measured in Pliocene-Quaternary alluviums. According to their research, the oldest stress field
551 was characterized by a NW-trending σ_1 that has changed into a N-S and then, into a NE-directed
552 maximum compression affecting late Pleistocene to Holocene alluviums. Another interesting research in
553 west-central Alborz (Axen et al., 2001), has led to the attainment of the first chronological framework for

554 a major tectonic reorganization in the Alborz Mountains. They have reported a dextral transpressional
555 movement along main faults parallel with the range (between 56 Ma and 7 Ma) before onset (ca. 3.4 Ma)
556 of the modern sinistral faulting on these faults.

557 In the Kopeh Dagh and Binalud mountains, the inversion of fault slip data measured in 39 sites
558 revealed temporal clockwise changes in the state of stress since 3.6 Ma (Shabanian et al., 2010); those
559 include the horizontal σ_1 oriented N140±10°E, N180±10°E and N30±15°E for the paleo, intermediate and
560 modern states of stress, respectively. Similar drastic temporal changes were reported in NNE Iran,
561 including the eastern Alborz and western Kopeh Dagh mountains (Javidfakhr et al., 2011). The analysis
562 of fault slip data in 48 sites led Javidfakhr et al. (2011) to characterize the three homogenous stress fields
563 as the maximum horizontal stress σ_1 orientated N135±20°E (paleostress), N185±15°E (intermediate) and
564 N36±20°E (modern stress) in the transitional zone between the eastern Alborz and western Kopeh Dagh
565 mountains. Farther south, Farbod et al. (2011) showed that a Pliocene-Quaternary older state of stress,
566 with a σ_1 orientated N150±20°E, was changed into a modern maximum compression of N45±15°E,
567 responsible for the active sinistral kinematics along the Doruneh fault system.

568 Other study reveals the same pattern of change in the stress field of northwest Iran (the Mianeh-
569 Mahneshan basin; Aflaki et al., 2018a). The NW-trending fold axes in the Upper Red Formation, folded
570 at the end of Middle Miocene, have been overprinted by two younger generations of NE and NW trending
571 folds in a time interval between Pliocene to Quaternary. The inversion results of fault slip data in this
572 region affirm that a compressional paleostress regime (Pliocene-Quaternary), with a N138°E trending σ_1 ,
573 has affected the area before the dominance of the present-day NE-oriented compression.

574 The recent study in the Sistan belt of eastern Iran (Jentzer et al., 2017), however, obtained three
575 distinct deformation stages during late Cenozoic, including (1) an E-W (N087±5°E) direction of σ_1
576 probably in the Late Miocene, (2) a late Pliocene ENE-WSW (N059±8°E) direction of σ_1 and (3) a late
577 Pliocene to present-day maximum compression (N026±8°E). The same authors proposed that during the
578 last ~10–5 Ma, the direction of compression has rotated about 60° counterclockwise in Sistan. The
579 kinematics of this region, especially from the regional geologic and geodynamic points of view, is

580 debatable. However, there is no other similar study in the Sistan belt enabling a comparison and the
581 evaluation of the accuracy of their results.

582 In summary, even though several studies confirm the occurrence of drastic changes in the dynamics
583 and consequently, in the kinematics of the north, east and northeastern Iran, these results are
584 geographically sparse and need absolute age-based chronologies in order to drawing firm conclusions on
585 the time of dominance and the geodynamic causes of the change in the context of the Arabia – Eurasia
586 convergence.

587

588 **6.3. Integration of our results at the regional scale**

589 After presenting a brief history of the related studies on the evolution of Late Cenozoic stress state
590 in the north, east and northeast of Iran, here, we put our results in a regional tectonic context in order to
591 evaluate the consistency of the results with other similar studies in the north, northwest and west of the
592 Dasht-e Bayaz area.

593 The results of inversion on both geological and seismological fault slip data indicate the dominance
594 of an active strike-slip tectonic regime characterized by a $N45\pm05^\circ E$ trending σ_1 in the Dasht-e Bayaz
595 area. There is a good consistency between this stress regime and the modern state of stress with an
596 average compression of $N045^\circ E$ reported along the Doruneh fault (Farbod et al., 2011). Farther north,
597 Shabanian et al. (2010) reported a modern state of stress in the Kopeh Dagh and Allah Dagh-Binalud
598 mountains (Fig. 15) characterized by a mean regional $\sim N030^\circ E$ trending σ_1 axis. According to the results
599 of Javidfakhr et al. (2011), this modern state of stress prevails on the eastern Alborz and western Kopeh
600 Dagh mountains (mean regional $\sim N036^\circ E$ trending σ_1 axis). Interestingly, the results mentioned above
601 cover geological domains with different structural patterns, geological histories and active tectonics,
602 while except for some local perturbations due to structural complexities, the modern state of stress
603 remains homogenous throughout the region.

604 As for the intermediate stress regime in the Dasht-e Bayaz area, the related maximum horizontal
605 compression obtained in two sites was oriented as \sim N009°E. Despite the few number of these stress
606 solutions, at a larger scale, our results are completely in accordance with other studies done in the
607 northeast of Iran (N180±10°E - Shabanian et al., 2010; Javidfakhr et al., 2011). Although there is no
608 report of intermediate state of stress by Farbod et al. (2011) along the Doruneh fault region, Tadayon et
609 al. (2017) presented structural evidences for the prevalence of a penultimate N-S compression during the
610 Plio-Quaternary time (see also Tadayon et al., 2018).

611 We have obtained a compressional stress regime characterized by a N135±15°E trending mean σ_1
612 as paleostress state, indicating that the currently left-lateral Dasht-e Bayaz fault had been reverse right-
613 lateral during a certain period of time. As an example, the coseismic rupture of the 1968 earthquake cuts
614 along the main fault trace at the northern border of the Chah Deraz pull-apart (Figs 3 and 6). In that area,
615 S-shaped sigmoidal lenses within the fault core (Fig. 10d) indicate an older dextral component for the
616 main fault. A similar paleostress state has been reported in the Kopeh Dagh and the transition zone
617 between the Alborz and Kopeh Dagh mountains (N140±10°E trending σ_1 - Shabanian et al., 2010;
618 Javidfakhr et al., 2011). A close stress orientation (N150±20°E trending σ_1) and structural configuration
619 were also determined along the Doruneh fault (Farbod et al., 2011; see also Javadi et al., 2013, 2015;
620 Tadayon et al., 2017 and 2018). It is worthy to note that farther west, along the Kuh-e Sarhangi and Kuh-e
621 Faghan faults, Nozaem et al. (2013) and Calzolari et al. (2016 and 2018) have reported a NW-SE directed
622 maximum compression which is responsible for dextral faulting along these faults during the Quaternary
623 time and should not be compared to the paleostress σ_1 direction we are discussing here.

624 The general consistency between the results on the kinematic history of the east, northeast and
625 north of the Arabia-Eurasia collision zone (Abbassi and Shabanian, 1999; Abbassi and Farbod, 2009;
626 Shabanian et al., 2010, 2012b; Farbod et al., 2011; Javidfakhr et al., 2011; Javadi et al., 2013, 2015;
627 Aflaki et al., 2017; Tadayon et al., 2017, 2018; this study) implies a homogenous transfer of stress during
628 different periods of time, regardless of the geodynamic boundaries. Our results confirm that the Zagros
629 collision zone, and its hinterland domain were mechanically coupled during, at least, late Miocene-

630 Quaternary times (e.g., Tadayon et al., 2018). Such kinds of systematic regional change in the late
631 Miocene to present-day states of stress and kinematics of crustal-scale faults discard the possibility of
632 systematic block rotations around vertical axes in the region between Dasht-e-Bayaz, Doruneh and Koppeh
633 Dagh.

634 Despite the coherency between our results and those obtained in the northern regions, the history of
635 stress changes along the Dasht-e Bayaz fault differs from what is recently obtained along the Sistan
636 Suture zone (Jentzer et al., 2017). Jentzer et al. (2017) presented different sets of fault slip data related to
637 three successive stress states indicating an anticlockwise rotation in the direction of maximum
638 compression from a Late Miocene E-W directed σ_1 to a late Pliocene to present-day maximum
639 compression directed $N026\pm 8^\circ E$ (see the section 6.2 for more details). Their anticlockwise rotation
640 pattern is contrary to the history we found around the Dasht-e Bayaz and Abiz faults.

641 As for the age, there is no general consensus on the timing of the aforesaid changes in the stress
642 state; for example, according to the morphotectonic analysis along the Mosha and Taleghan faults in
643 Alborz, Ritz et al. (2006) suggested that the change from a N-S compression (compressional tectonic
644 regime) to the present-day NNE-trending compression should have occurred between 1 and 1.5 Ma.
645 Shabanian et al. (2012a) showed geological evidence for late Cenozoic volcanism (dikes and volcanic
646 domes) coeval with the prevalence of the paleostress state (a NW trending maximum compression) in the
647 transition zone between the Koppeh Dagh and Binalud mountains. The last phase of volcanism was dated
648 at 2.4 Ma (Ar-Ar dating of dacitic volcanic domes) and subsequently, a volcanic dome has been right-
649 laterally displaced by the N-S Chakaneh Fault, reactivated in the modern stress state (Shabanian et al.,
650 2009b, 2012a). Accordingly, they proposed a maximum age of 2.4 Ma (close to the border of Pliocene
651 and Quaternary) for the end of the paleostress prevalence. In the Mahnesan area (NW Iran; Fig. 15),
652 Aflaki et al. (2018a) proposed that the last drastic change in the stress regime into the present-day stress
653 state (a NE trending maximum compression) has taken place at the Pliocene-Quaternary boundary.
654 Around the Doruneh fault (north of the Lut Block), however, Tadayon et al. (2018) suggested that the
655 switch from an early NW-oriented σ_1 to the penultimate N-S maximum compression has occurred at the

656 Miocene-Pliocene boundary (5-6 Ma) and this change has been the source of an important
657 cooling/exhumation in the area.

658 Nowadays, a drastic change in the Plio-Quaternary tectonic regime throughout the Iranian plateau
659 and the surrounding deformation domains is a geological fact, thanks to different researches carried out
660 during the last two decades (e.g., Abbassi and Shabanian, 1999; Regard et al., 2005; Shabanian et al.,
661 2010, 2012a; Javidfakhr et al., 2011; Farbod et al., 2011; Tadayon et al., 2017; Jentzer et al., 2017; Aflaki
662 et al., 2018a). The regional extent of these similar changes in distant Pliocene-Quaternary stress fields
663 clearly discards the possibility of block/stress rotation during progressive deformation. However, the
664 possible causes of change in stress regime, especially in E and N of Iran, remains unclear. This change
665 may be due to the onset of the northward subduction of the South Caspian Basin, and/or changes in the
666 structural configuration or in the lithospheric characteristics of N and NE Iran during an evolving
667 collisional convergence (Shabanian et al., 2012a). In other words, it may correspond to a major regional
668 reorganization of the plate boundary, following the transition from an infant to a mature stage of
669 continental collision (Tadayon et al., 2018).

670

671 **6.4. Tectonic scenario and kinematic model**

672 According to the model frequently applied in the east and northeast of Iran, originally proposed by
673 Jackson and McKenzie, (1984), an uneven distribution of N-S right-lateral shear between Central Iran and
674 Afghanistan and its westward decrease caused a clockwise rotation of fault bounded blocks north of
675 ~34°N (Walker et al., 2004; Walker and Jackson, 2004). The model tends to explain the structural
676 features of the northern Lut block by the concept of clockwise rotation around vertical axes (for the basic
677 assumptions of the model see Farbod et al., 2011). This block rotation model was questioned about its
678 lack of ability in explaining the prominent curvature and the other complexities along the Doruneh Fault
679 System (see Farbod et al., 2011 for detail). For example, Farbod et al. (2011), showed that to attain the
680 present-day geometry of the DFS, the fault trace needs to rotate clockwise in the eastern part and

681 counterclockwise in the western part. It is noteworthy that structural deflections and internal deformation,
682 due to local dragging or compression caused by faults or thrust zones, have usually been interpreted as
683 systematic block rotations around vertical axes (e.g., Walker et al., 2004).

684 The occurrence of pre-Pliocene dextral faulting on E-W trends distributed across Central Iran (Javadi
685 et al., 2013, 2015; Nozaem et al., 2013; Bagheri et al., 2016; Calzolari et al., 2016, 2018; Tadayon et al.,
686 2017) and the Quaternary kinematic shifts along the Doruneh and Dasht-e Bayaz faults (Farbod et al.,
687 2011; Javadi et al., 2015; this study), which clearly indicate a homogenous regional stress field
688 distribution and coeval evolution of the intracontinental deformation in Central Iran, are not coherent with
689 the block rotation model (see Tadayon et al., 2018 for discussion). The paleomagnetic data of Mattei et al.
690 (2012) also do not show any systematic clockwise rotation over the Neogene in the region. The most
691 recent study by Mattei et al. (2019) provides new paleomagnetic data on the Kopeh Dagh. They report
692 that paleomagnetic rotations (the mean of $11.3 \pm 9.4^\circ$ clockwise rotation) occurred in the Kopeh Dagh belt
693 between $\sim 6\text{--}4$ Ma and ≈ 2 Ma, before the onset of the westward extrusion of the South Caspian Block. In
694 their studies, Mattei et al. (2017 and 2019) also emphasize that their oroclinal model does not correspond
695 to the present-day kinematics of the studied areas (Alborz and Kopeh Dagh) and the rotation was stopped
696 before the onset of the present-day kinematics at ~ 2 Ma.

697 In our tectonic scenario (Figs 16 and 17), right-lateral shear is considered as the main mechanism for
698 the accommodation of the Arabia-Eurasia convergence, but it is not necessarily the case everywhere in E
699 and NE Iran. As for the Lut block, the GPS velocity vectors show a northward ($N013^\circ E$) block motion
700 with respect to Eurasia (Walpersdorf et al., 2014). In the north of latitude of $34^\circ N$ (corresponding to the
701 E-trending Dasht-e Bayaz fault), the N-S right-lateral shear interrupts and does not continue to the north.
702 Beyond this latitude, the convergence is mainly accommodated by crustal shortening across NW-trending
703 reverse/thrust faults. The Ferdows reverse fault zone, the Jangal and Khaf thrust faults and the eastern
704 reverse termination of the Doruneh fault (Farbod et al., 2011) as well as the restraining fault terminations
705 in the southern flank of Binalud (Shabanian et al., 2012b) and the Fariman area (Aflaki et al., 2019) are

706 among the most important NW-striking reverse faults confirming our tectonic scenario in northeastern
707 Iran.

708 To the north and approximately at the latitude 36°N , the right-lateral shear gradually appears along
709 the NE boundary of the Arabia – Eurasia collision zone and involves the NNW-trending faults (instead of
710 the N-S dextral faults to the south) going through the Kopeh Dagh Mountains. The distance between these
711 two fault systems is occupied by a soft-linking restraining relay zone (Binalud-Fariman-Torbat-e Jam;
712 Aflaki et al., 2019) in which the mechanism of faulting is preferably reverse to revers dextral, while
713 farther north in the Kopeh Dagh, it is pure dextral strike-slip. In other words, the N-S right-lateral shear
714 between Iran and Afghanistan that had been interrupted in the latitude 34°N (corresponding to the Dasht-
715 e Bayaz fault) is recuperated gradually around the latitude of $\sim 36^{\circ}\text{N}$, but this time along the NW-trending
716 faults and against the Turan platform instead of the Helmand block (Afghanistan).

717 The integrated geological, seismological and InSAR investigations done by Aflaki et al. (2019), in
718 the area affected by the 5th April 2017 Sefid Sang earthquake (M_w 6), showed that the dextral shear
719 along the NNW-striking faults (i.e., Bakharden-Quchan and Hezar Masjed fault systems) is transferred
720 southeast into WNW-striking transpressional terminations in the region between the Binalud Mountains
721 and Doruneh fault (Fig. 17). The CMT and the first polarity solutions of the main shock and the two
722 aftershocks of this seismic event, which occurred close to the southern termination of the Hezar Masjed
723 fault system near the town of Fariman (Fig. 15), indicate a mainly reverse mechanism with a small dextral
724 component (See Aflaki et al., 2019 for details). This event clearly reveals the dominance of reverse
725 faulting in the southeastern end of Kopeh Dagh and the eastern termination of the Doruneh fault.

726 In summary, we suggest that the outstanding changes in the structural pattern of these regions are the
727 cause of a significant change in the accommodation mechanism of convergence. It means major fault
728 zones in the E and NE Iranian regions guide and control lithospheric block motions and their related
729 velocity fields. In the offset and/or overlapping areas of these major fault zones the convergence is
730 accommodated by internal deformation and shortening through reverse/thrust faulting and active folding

731 (e.g., Farbod et al., 2011; Aflaki et al., 2019). For instance, the pure strike-slip Doruneh fault becomes a
732 typical reverse fault at its eastern end parallel to the other NW-trending reverse faults such as Ferdows,
733 Khaf and Jangal. In this context the role of E-W sinistral faults such as the Doruneh, Dasht-e Bayaz and
734 Niazabad faults can be explained through their setting in the regional structural pattern.

735 The Khaf and Jangal thrusts have been considered as probable sources for the Zuzan historical
736 destructive earthquakes (Berberian, 2014) of 19 and 21 October of 1336 A.D., respectively. The 1 and 4
737 September 1968 Ferdows earthquakes (M_w 6.8 and M_w 5.5) also indicate significant tectonic activity of
738 these reverse fault zone. The study of magnetic foliation vertical and oblique to the bedding of post
739 Miocene folds in the Ferdows fault zone (Rashid et al., 2015) suggests that a cleavage system, not visible
740 at the outcrop scale, has been developed as a consequence of recent shortening related to the activity of
741 this thrust zone. All these observations reveal that, in the northern Lut, the NW-trending reverse/thrust
742 fault zones accommodates substantial portion of the active deformation perpendicular to their strikes. The
743 E-W strike-slip faults such as the Dasht-e Bayaz and Niazabad faults therefore retain their complementary
744 role in the crustal shortening between these thrust zones (Fig. 2). It is worth mentioning that our
745 kinematic model generally describes the northeastern border of Arabia-Eurasia collision zone and clearly
746 it does not include the distant regions such as the eastern Alborz and internal blocks of Central Iran.

747 Summarizing all these observations on both the structural configuration and the present-day relative
748 velocity field (Eurasia fixed) in east-northeast Iran, the Doruneh fault is a major boundary separating two
749 distinct northern and southern domains (Fig. 16). Angular relationships between N-S dextral and E-W
750 sinistral faults obviously change in these tectonic domains such that the northern domain is characterized
751 by NNW-striking dextral and ENE-striking sinistral faults (e.g., Tchalenko and Berberian, 1975;
752 Shabanian et al., 2009a, 2010; Javidfakhr et al., 2011), while, N-S dextral, E-W sinistral and NW-SE
753 reverse/thrust faults are dominant in the southern domain. These different structural patterns lead to (1)
754 the NNW extrusion of both Central Iran and western Kopeh Dagh towards the South Caspian Basin
755 (Hollingsworth et al., 2006; Shabanian et al., 2009b) and (2) block translation and internal deformation

756 through crosswise strike-slip faulting accompanied by reverse/thrust faulting in confining wedge in the
757 north and south of the Doruneh fault, respectively.

758 The details of these different processes are shown in Figure 17. The process of wedge confining at
759 the edges of north-going blocks (Fig. 17a; due to a NE-trending compression) allows accommodating the
760 internal deformation not absorbed by the lithospheric scale northwards motion of Central Iran relative to
761 Eurasia. The block adjustment requiring for the accommodation of this internal deformation is done
762 through crosswise faulting along N-S dextral and E-W sinistral faults (Fig. 17b-d). The active crosswise
763 pattern of the faults and the almost symmetrical deformation in the four quadrants around their
764 intersection zones (Figs 4 and 17) indicate the same structural significance for the N-S and E-W faults.
765 However, the simultaneous activity of these crosswise fault sets is mechanically impossible; therefore, the
766 fault sets must be operating in sequence (e.g., Freund, 1974). The sequence of recent seismic activities,
767 producing sinistral faulting along both the western and eastern segments of the Dasht-e Bayaz fault and
768 right-lateral faulting in the south of this system, could confirm this interaction (see Berberian et al., 1999;
769 Walker et al., 2011). This active crosswise faulting also leads to the development of contractional
770 (reverse/thrust) fault zones perpendicular to the overall direction of Arabia – Eurasia convergence
771 accommodating two northward and eastward components of the convergence (Fig. 17).

772 We emphasize that this tectonic scenario is based on different geological and seismological
773 observations (this study and the references cited above) on the eastern and northeastern boundaries of the
774 Arabia – Eurasia convergence zone. We do not apply this scenario to kinematic complexities reported in
775 other places in Central Iran. For example, dextral faulting along the Kuh-e Sarhangi and Kuh-e Faghan
776 faults in the northwest margin of the Lut block (Nozaem et al., 2013; Calzolari et al., 2016 and 2018) has
777 been explained as a consequence of an excess dextral shear generated in the intrafault block bordered by
778 the Doruneh fault to the north and the Dasht-e-Bayaz fault to the south. In this context, the Ferdows
779 reverse fault zone partly accommodates internal deformation of the intrafault block (Nozaem et al., 2013).
780 At first glance to our tectonic scenario, one may make a similar conclusion by assuming a component of

781 westward extrusion for the northern block of the Dasht-e Bayaz fault. However, deducing such the
782 conclusion needs detailed information on the difference of slip rates on the Doruneh and Dasht-e Bayaz
783 faults as well as the contribution of the Ferdows reverse fault zone in the accommodation of this
784 differential slip rate.

785 **7. Conclusion**

786 Our inversion analysis of fault kinematics data revealed signatures of three distinct stress fields in
787 the Dasht-e Bayaz area during Plio-Quaternary. Before the onset of the active left-lateral faulting along
788 the Dasht-e Bayaz fault, an old stress state characterized by a $N135\pm 15^{\circ}E$ trending σ_1 was responsible for
789 the dextral transpressional movements. The consistency between the inversion results of both modern
790 geological fault slip data and the earthquake focal mechanisms reveals: (1) the absence of remarkable
791 change in the modern state of stress during the late Quaternary time, (2) the prevalence of a homogeneous
792 stress field in the brittle crust (above the ~17 km depth of seismogenic layer) of the Dasht-e Bayaz region
793 and (3) the lack of long-term stress perturbation due to the activity of the Dasht-e Bayaz fault.

794 Our observations indicate that the kinematic changes during the Pliocene – Quaternary times have
795 not been restricted to the northeastern part of the Iranian plateau. The general consistency between the
796 results on the kinematic history of the east, northeast and north of the Arabia – Eurasia collision zone
797 implies that a homogenous transfer of stress during, at least, late Miocene – Quaternary times, has taken
798 place due to the mechanical coupling of the Zagros collision and its hinterland domains.

799 We suggest that the region between Lut and Kopeh Dagh is divided by the Doruneh fault into two
800 northern and southern distinct tectonic domains. The northern domain is characterized by the extrusion of
801 fault-bounded blocks towards the north-northwest, while in the southern domain, the northward motion of
802 the central Iranian blocks occurs through structural and kinematic interactions between N-S dextral, E-W
803 sinistral and NW-striking reverse/thrust faults at the block boundaries without a need for symmetric block
804 rotations around vertical axes.

805 **Acknowledgements**

806 We would like to thank to Mr. Koreie and Mr. Fotovati from Geological Survey of Iran for their
807 support and logistic assistance. We are grateful to municipality of Khezri-Dasht-e Bayaz and Sangan Iron
808 Ore Complex for their support during field trips. We thank Mr. Lhôte and the staff of French Embassy in
809 Tehran. We appreciate to A. Ghods and F. Sobouti in Institute for Advanced Studies in Basic Sciences in
810 Zanjan. Very careful and insightful reviews by Federico Rossetti and two anonymous reviewers have
811 greatly improved the manuscript. We are indebted to Editor Ling Chen for handling the manuscript.

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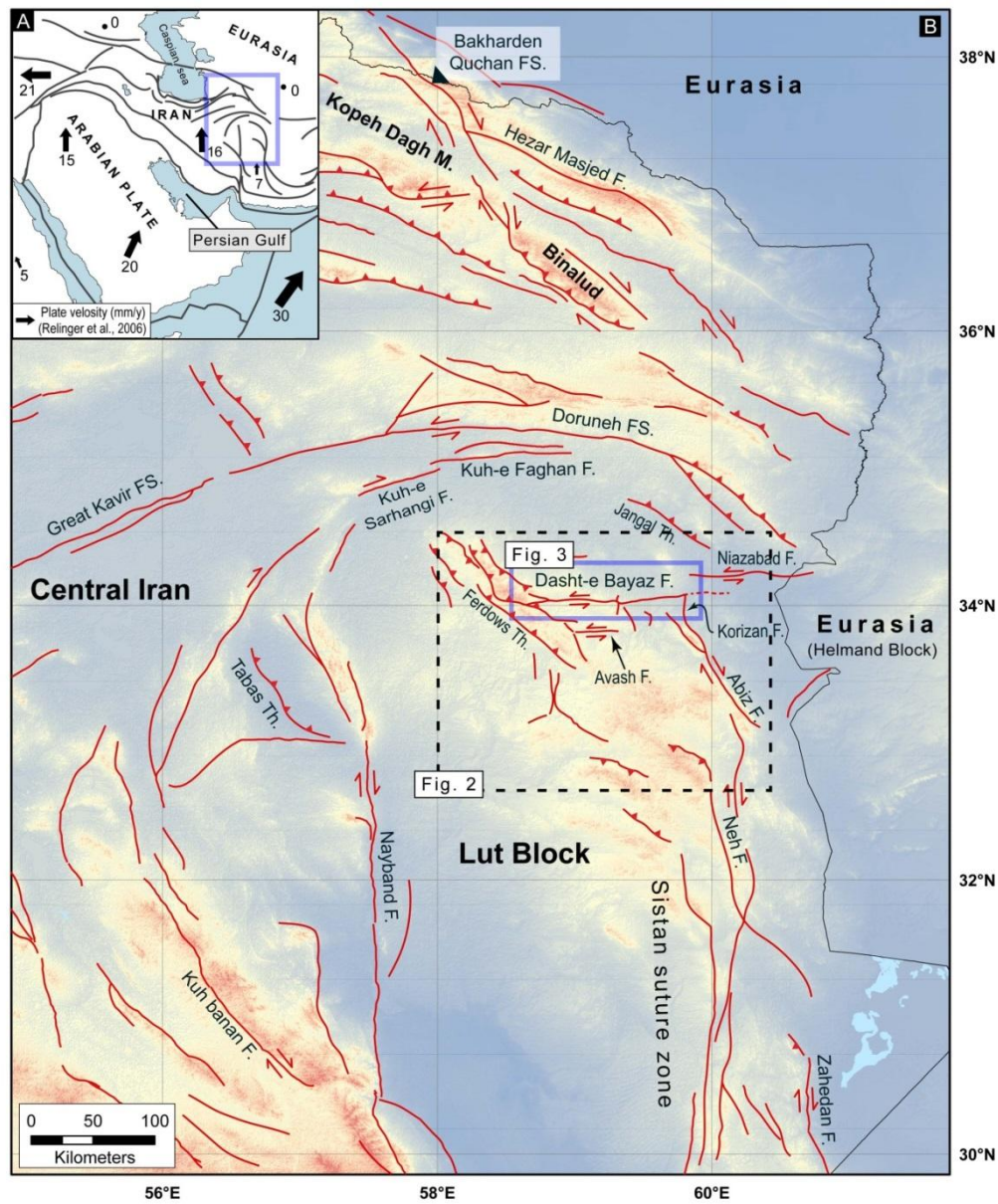
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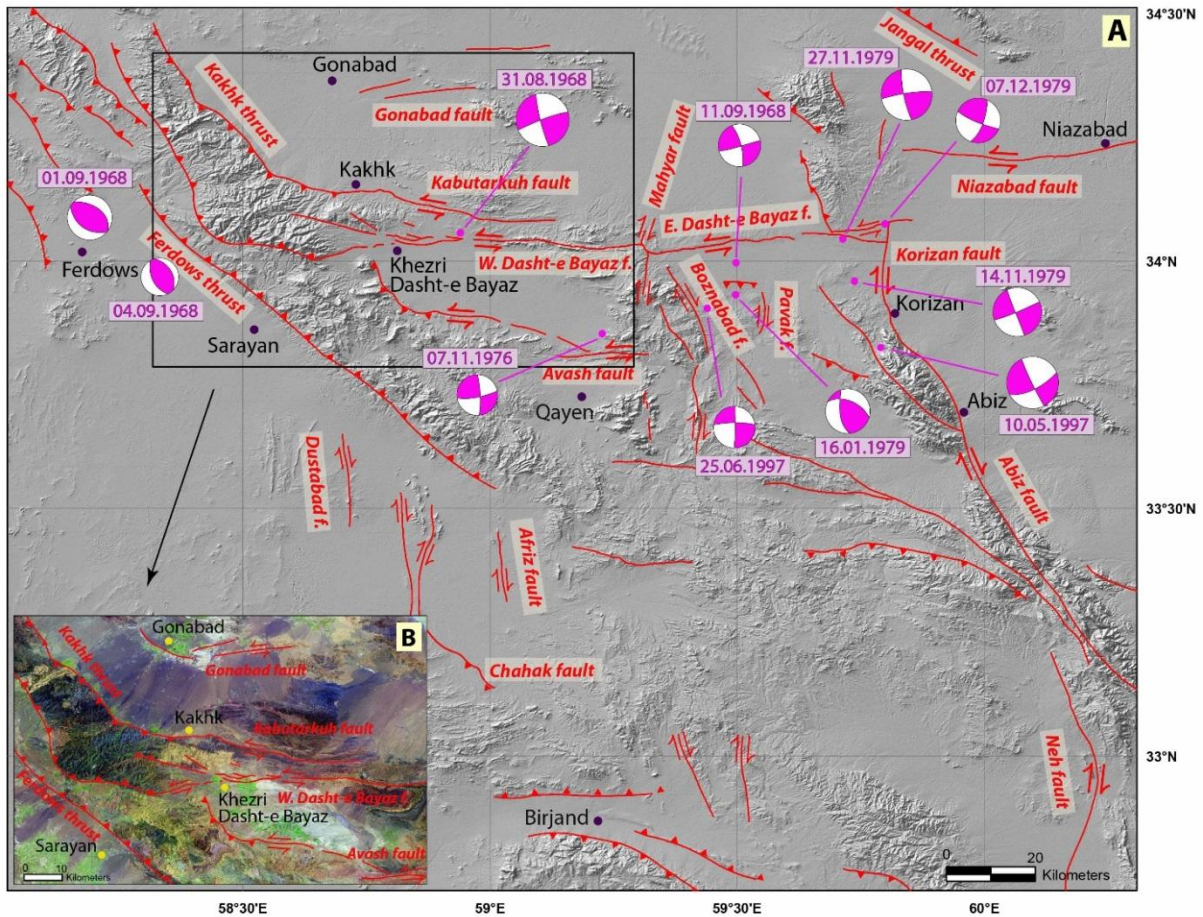
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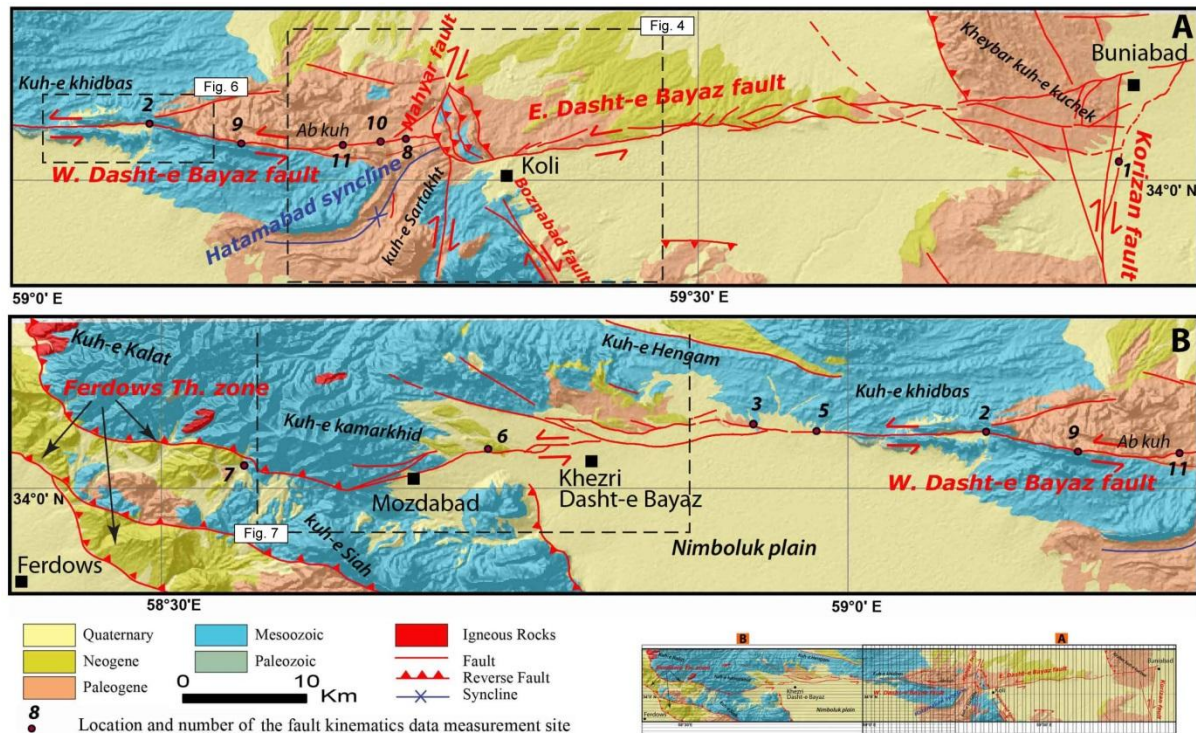
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1103
 1104 **Figure 1.** General tectonic map of the east and northeastern Iran. (A) The location of the study area
 1105 (blue rectangle) in the Arabia–Eurasia collision framework (after Shabanian et al., 2010). Grey arrows
 1106 and associated numbers represent Arabia–Eurasia plate velocities (mm/yr) after Reilinger et al. (2006).
 1107 Solid lines are boundaries of plates or major blocks. (B) GTOPO30 topographic image showing the
 1108 regional tectonic setting and the major active faults (red lines) in E and NE Iran. The study area of Dasht-
 1109 e Bayaz is marked by the black dashed rectangle. Reverse/thrust faults are marked by small triangles
 1110 pointing to the fault hanging wall. The fault map is based on Hessami et al. (2003), Walker and Jackson
 1111 (2004), Shabanian et al. (2010), Farbod et al. (2011), Nozaem et al. (2013), Calzolari et al. (2015) and this
 1112 study.

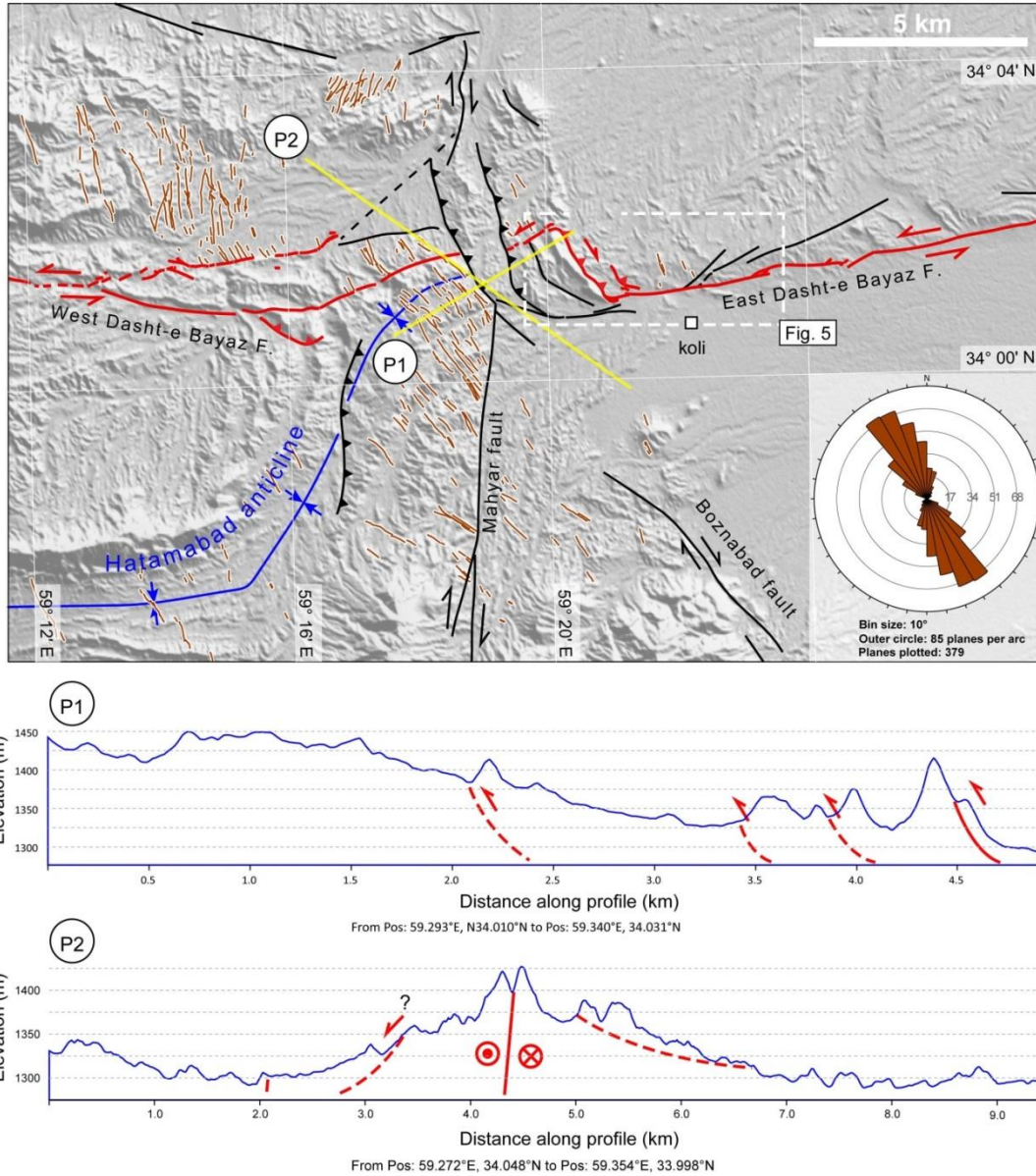


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 1114 **Figure 2.** Map of the major active faults around the Dasht-e Bayaz area. (A) Major fault zones and
 1115 their structural interactions in the area of interest. Focal mechanism solutions belong to the major
 1116 earthquakes of the study area (redrafted from waveform modeling of Walker et al., 2004 and 2011). (B)
 1117 LANDSAT ETM satellite overview (RGB, 541) of the area emphasizing the western termination of the
 1118 left-lateral Dasht-e Bayaz, Kabutar kuh and Avash faults.
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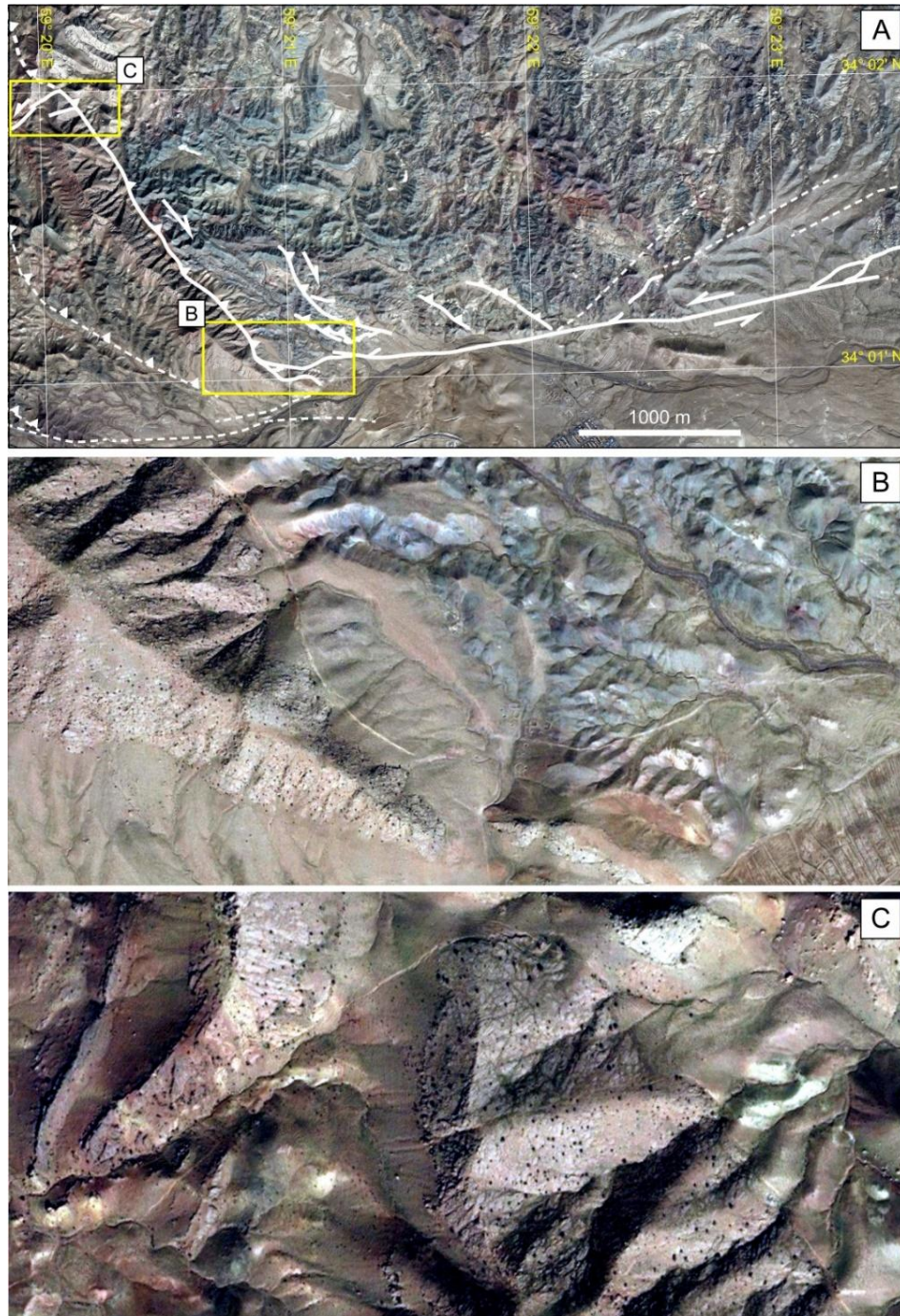
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1121 **Figure 3.** Simplified geological map of the Dasht-e Bayaz area based on published geological maps
 1122 of the area (Alavi Naini and Behruzi, 1983; Fauvelet and Eftekhar Nezhad, 1991). Fault traces were
 1123 extracted from satellite images complemented by field observations; we used Tchalenko and Berberian
 1124 (1975) maps for the co-seismic ruptures in the northern Nimboluk plain, which currently is under
 1125 cultivation.



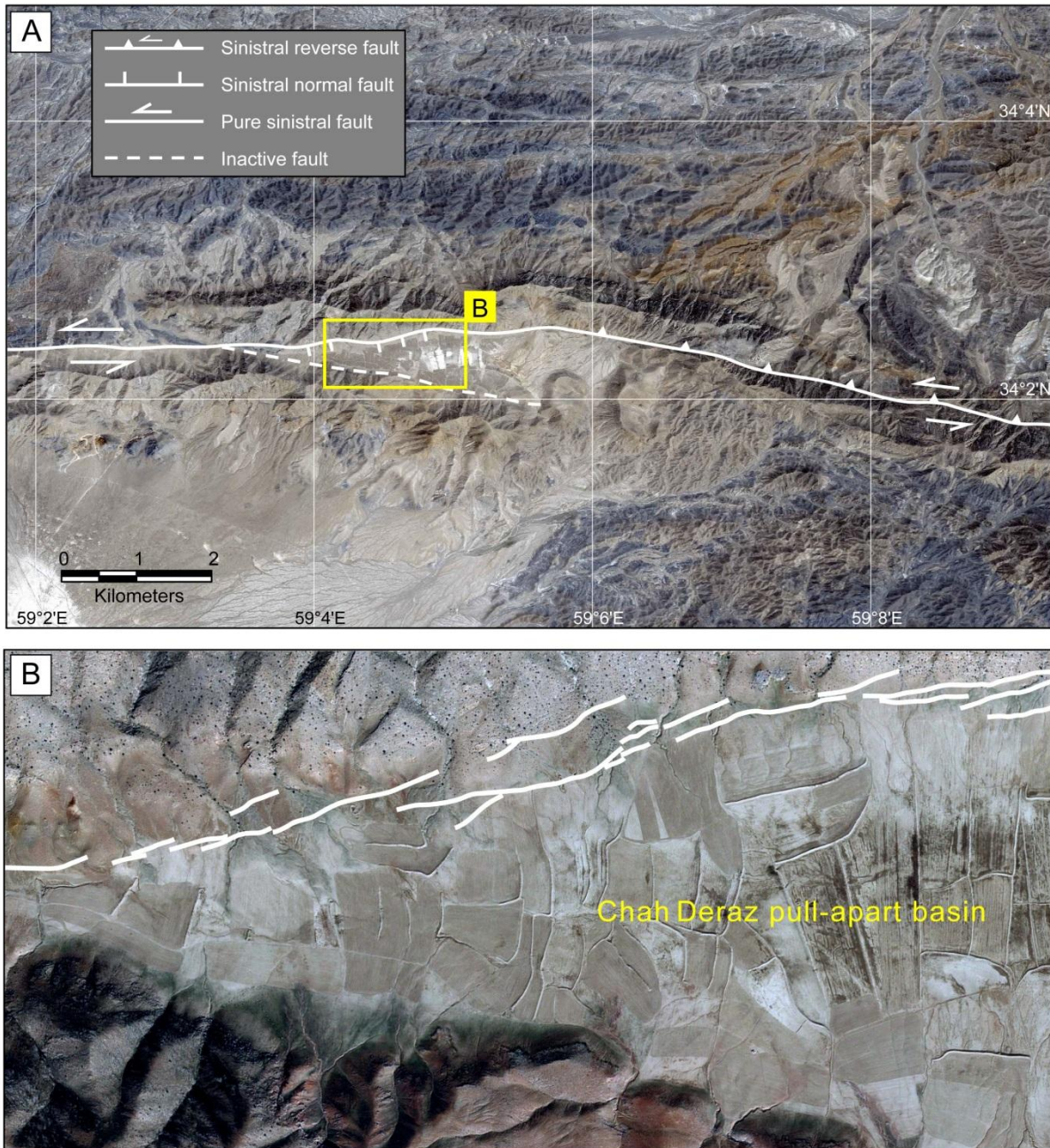
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1127 **Figure 4.** Morpho-structural map of the central intersection zone along the Dasht-e Bayaz fault. (A)
 1128 Detailed fault map of the interaction zone of the Mahyar and the Dasht-e Bayaz faults. Solid black line is
 1129 geological fault; inferred fault is shown by dashed black line. Red solid line is the coseismic rupture of
 1130 the Dasht-e Bayaz 1968 (west of the Mahyar fault) and 1979 (east of the Mahyar fault) earthquakes. The
 1131 N-S dextral and E-W sinistral fault zones displaced each other in the sense of their movement of about
 1132 1.5 km; see Figure 17 for more details on the structural configuration of this zone. The lower right rose
 1133 diagram (rosette) indicates the frequency of orientations of post-folding dikes (cut by strike-slip faults)
 1134 concentrated around the intersection zone; note that the overall orientation of $N330\pm 10^\circ E$ does not
 1135 significantly vary along the strike-slip faults. Two topographic profiles across the contractional (P1) and
 1136 extensional (P2) quadrants are shown.



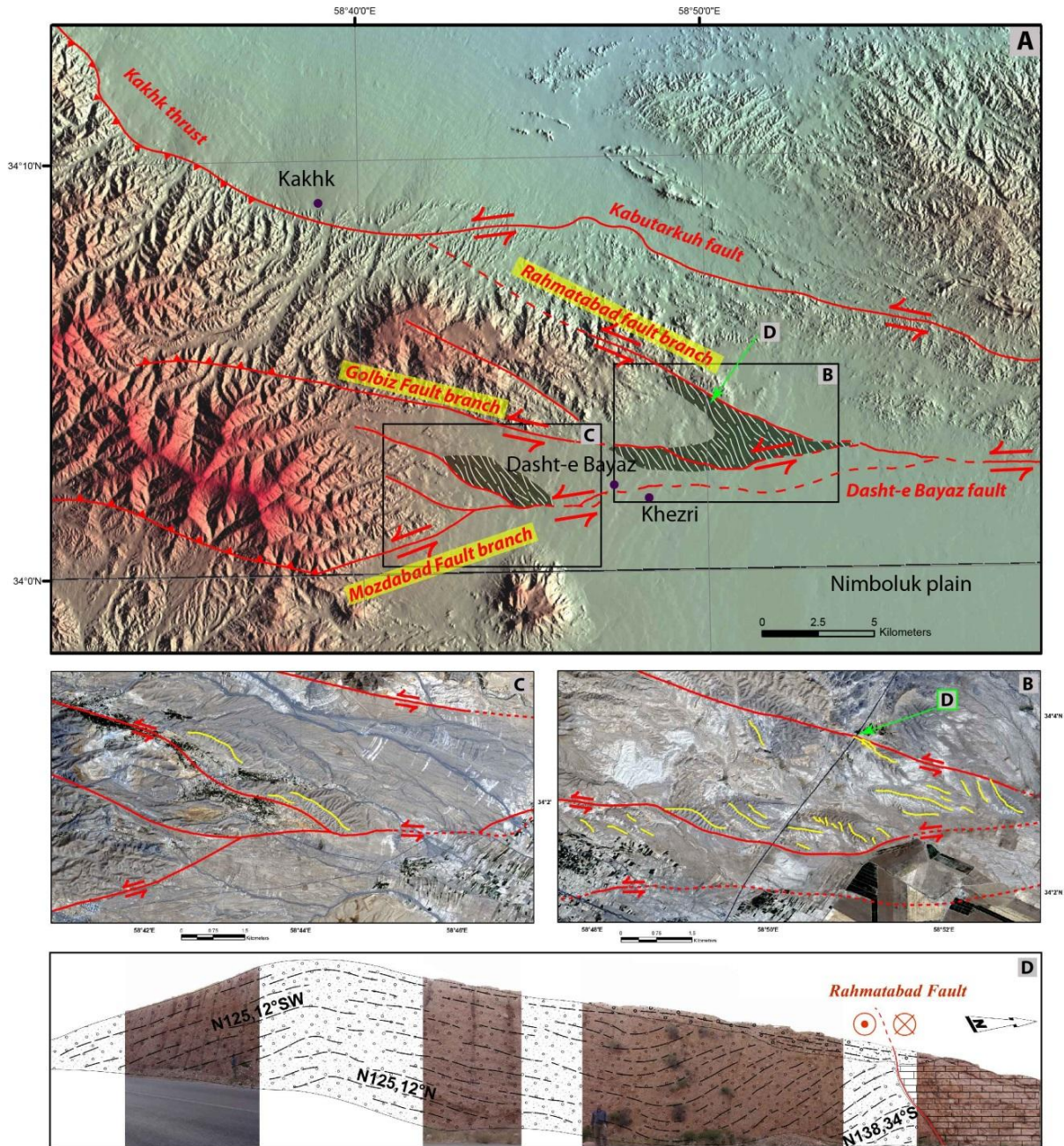
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1138 **Figure 5.** Bing Map image (SAS.Planet© 2015-2017) centered on the western termination of the
 1139 East Dasht-e Bayaz fault. See Figure 3 for location. (A) Detailed fault map of the area. Solid white lines
 1140 are coseismic rupture traces and dashed white lines are geological faults not reactivated during the 1979
 1141 Dasht-e Bayaz earthquake. (B) Close-up view of the sinistral rupture that terminates in a NE-dipping
 1142 reverse segment. (C) Close-up view of the northern end of the reverse fault segment due to intersection
 1143 with a SW-trending sinistral segment.



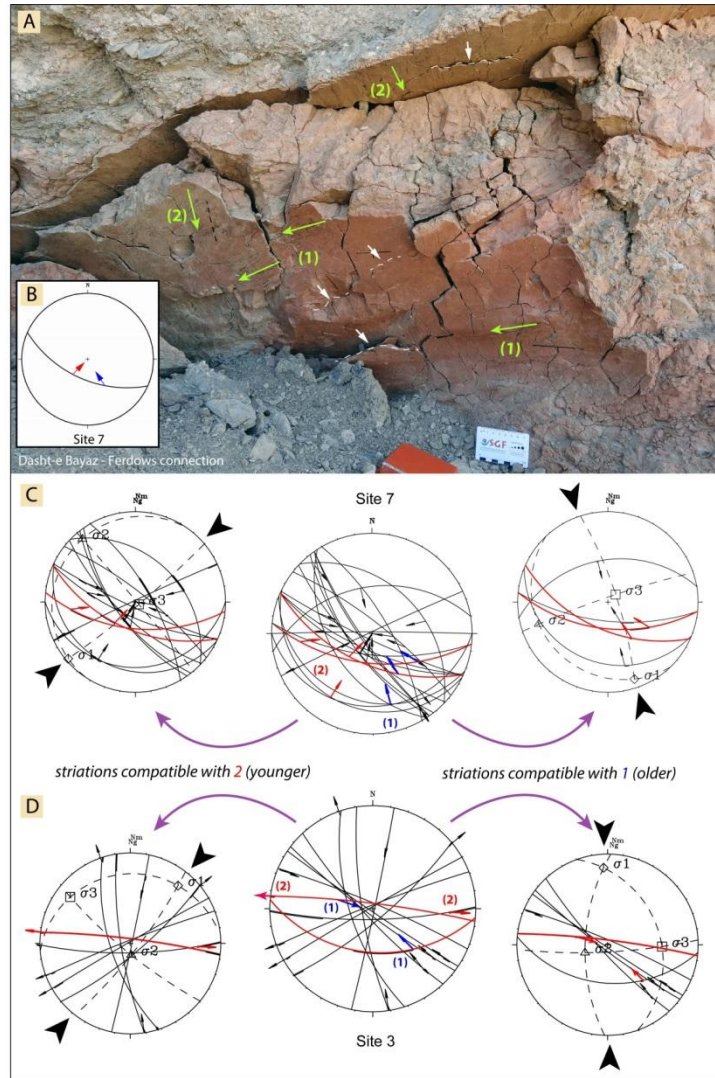
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1145 **Figure 6.** SPOT image of the Chah Deraz pull-apart basin along the west Dasht-e Bayaz fault. (A)
 1146 the active trace of the fault passes at the northern margin of the basin, while the southern one is inactive.
 1147 (B) close-up view of the coseismic rupture (1968 Dasht-e Bayaz earthquake) at the northern margin of the
 1148 basin.



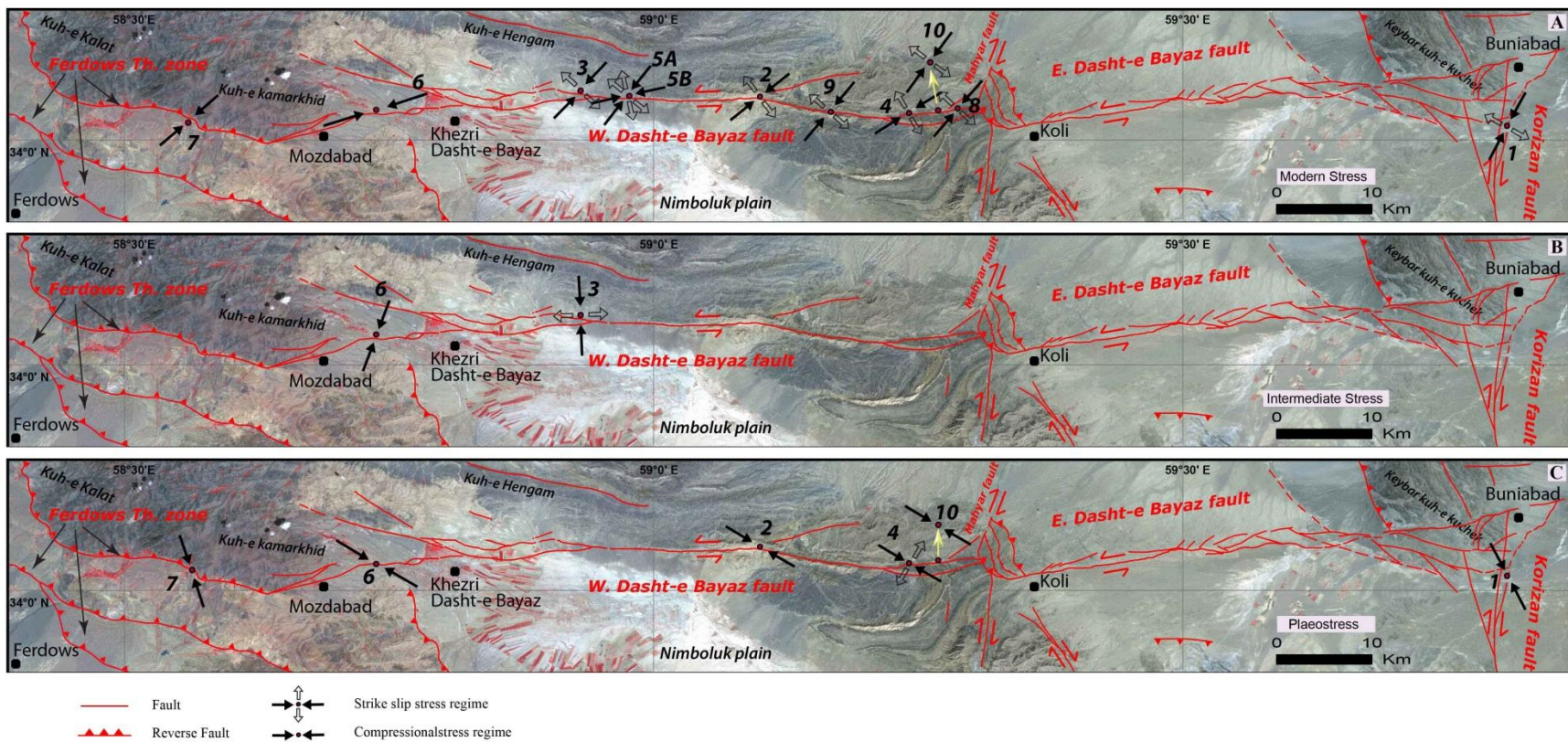
1149

1150 **Figure 7.** Tectonic features of the western portion of the west Dasht-e Bayz fault. (A) Shaded relief
 1151 image of the northern Nimboluk plain and structural map of this area including different fault branches of
 1152 the Dasht-e Bayz fault. The hatched polygon shows areas involved in en-echelon folding and pressure
 1153 ridges. (B) and (C) SPOT image of the Northern Nimboluk plain. Fold axes shown as yellow lines. (D)
 1154 West looking photographs and reconstructed section across the Rahmatabad fault branch and associated
 1155 folding of Plio-Quaternary deposits in the footwall.



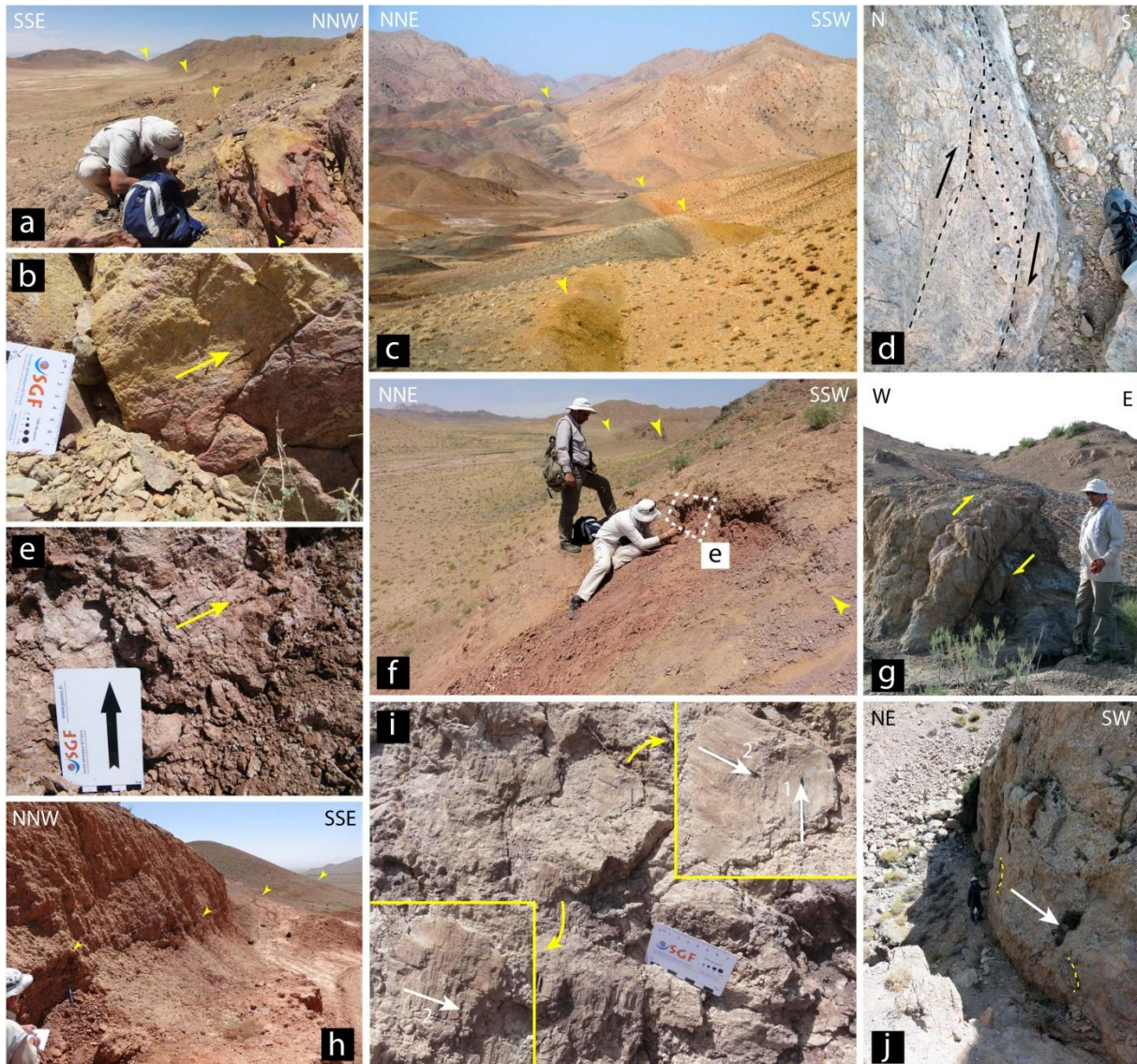
1156

1157 **Figure 8.** Distinct fault slips related to the modern and intermediate states of stress and a summary of
 1158 data separation strategy applied in this study. (A) SE looking field photograph a fault plane (site 7) that
 1159 includes two generations of striations and (B) a stereoplot of these striations. (1) and (2) refer to older and
 1160 younger relative chronologies, respectively, of the striations on the fault plane in the Neogene mudstone.
 1161 This site is along the western end of the Dasht-e Bayaz fault where it merges the Ferdows reverse fault
 1162 zone. (C) The schmidt lower hemisphere stereographic projection of the fault slip data measured in site 7.
 1163 (D) The lower hemisphere stereographic projection of the fault slip data measured in site 3. The middle
 1164 diagram is non-separated data set including all fault slip data. (1) and (2) refer to the older and younger
 1165 relative chronology of the striations. The stereograms (1) and (2) indicate relative chronology of two
 1166 distinct sets of data. The relative chronology of striations is according to cross-cutting relationships
 1167 observed on fault planes (colored as red). This strategy is applied to other sites for separation of fault slip
 1168 data into homogenous data sets.



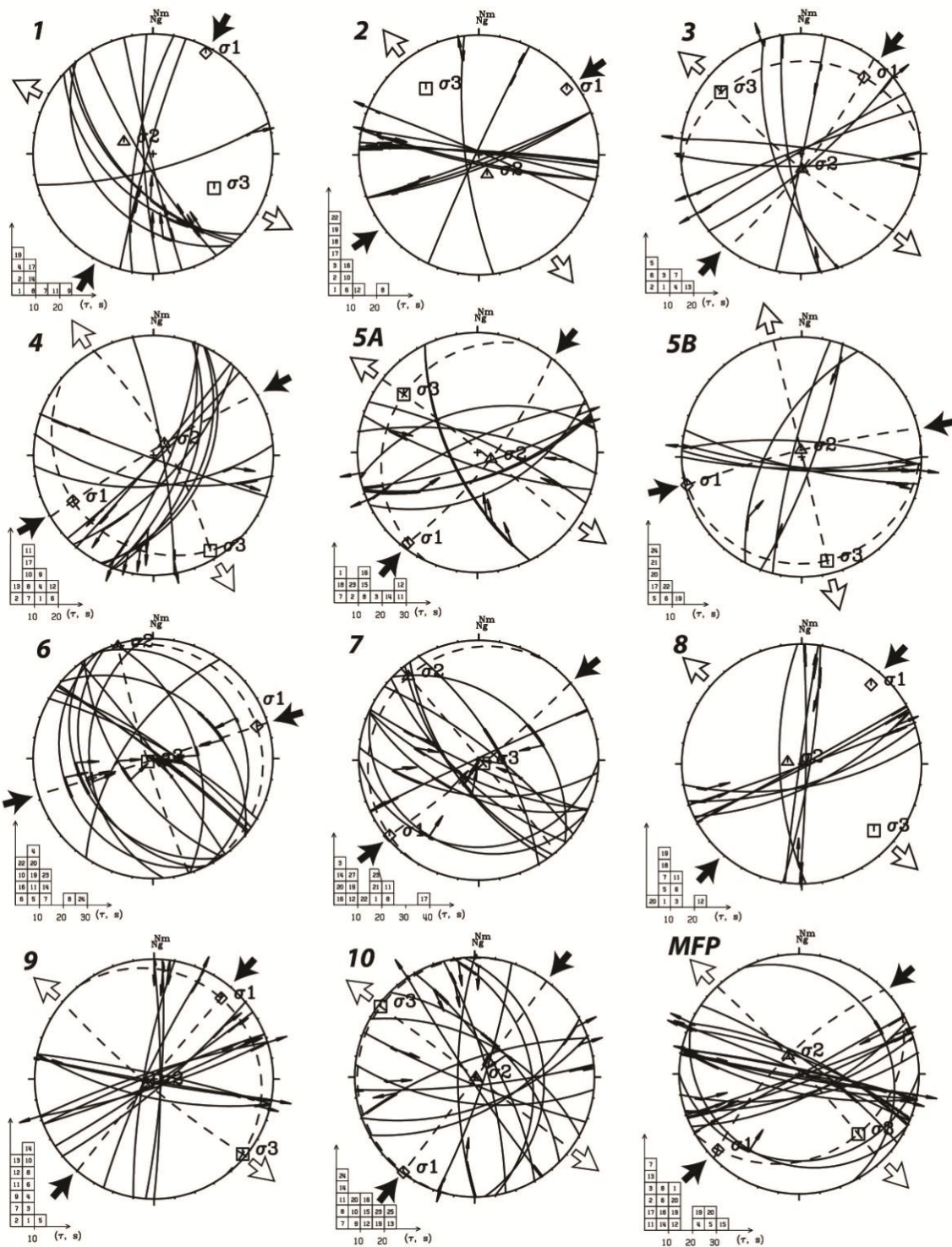
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1170 **Figure 9.** Reconstruction of the Plio-Quaternary stress fields in the Dasht-e Bayaz area, the base is ASTER image (RGB, 321). Direction of
 1171 Maximum horizontal stress axis (σ_1) for different stress fields showing dominant stress regimes including strike-slip, compressional and
 1172 extensional deduced from inversions of fault kinematics data in each sites (see Table 2). (A) Modern state of stress (B) Intermediate state of
 1173 stress (C) Paleostress state of stress.



1174

1175 **Figure 10.** Field photographs of some of sites we have inspected for the measurement of fault
 1176 slip data along the Dasht-e Bayaz fault. (a) Site 2 at the northern margin of the Chah Deraz pull-apart
 1177 basin. (b) A northwards view of the fault plane and the associated sinistral striation in site 2. (c)
 1178 general view of the Dasht-e Bayaz earthquake rupture to the west of the intersection zone. (d)
 1179 structural evidence of an ancient dextral faulting along the main trace of the Dasht-e Bayaz fault in the
 1180 Chah Deraz pull-apart basin. (e) and (f) fault plane and striation of the fault measured along the
 1181 coseismic rupture. (g) An outcrop of the northern continuation of the Korizan fault in site 1. (h) The
 1182 reverse-sinistral fault trace in Neogene deposits in site 6. (i) a fault plane with two distinct generation
 1183 of striations in site 10. (j) a metric scale sinistral fault plane along the main fault zone in site 9.



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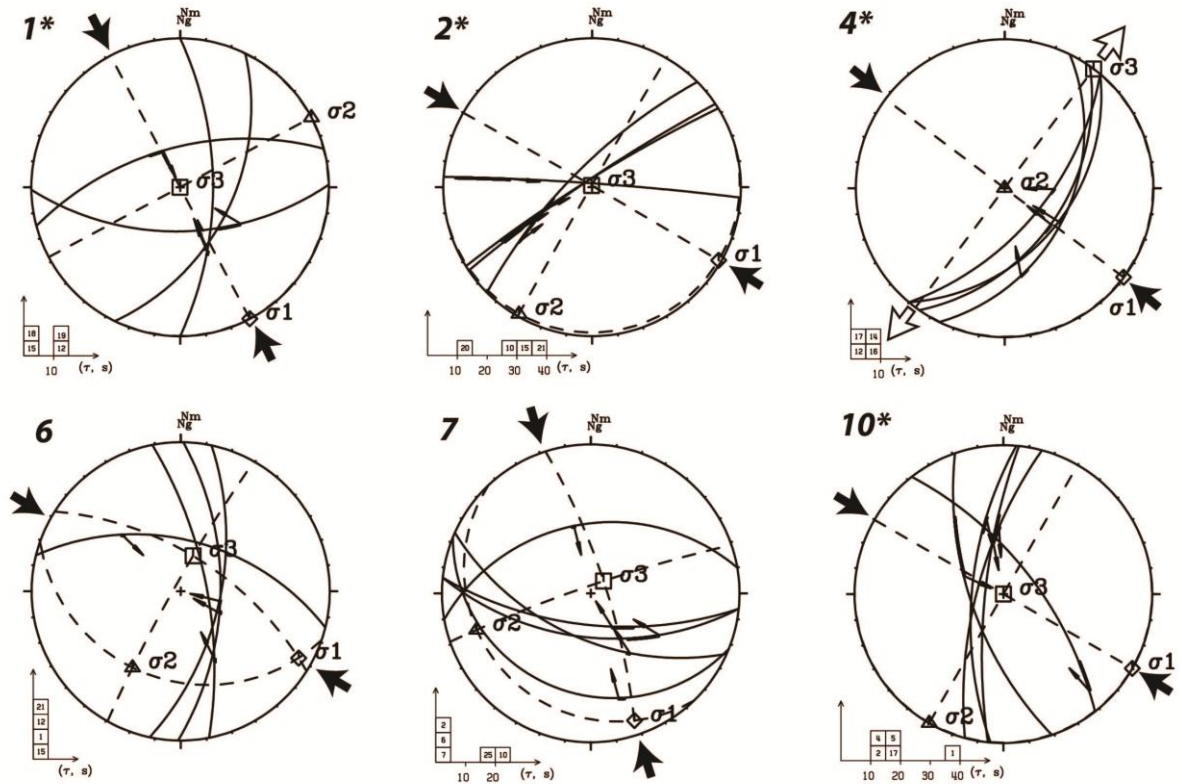
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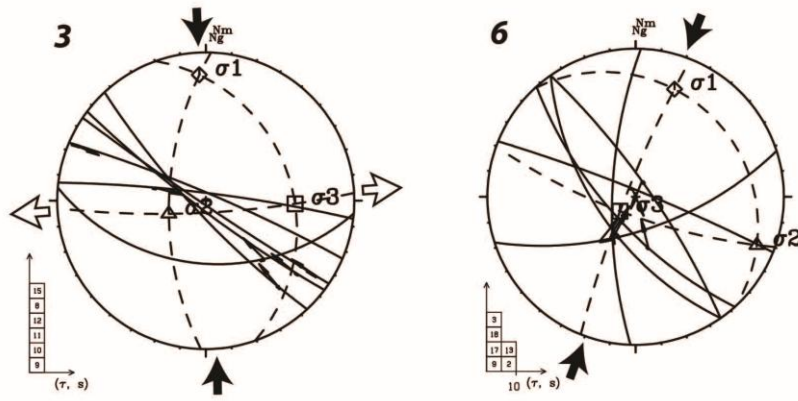
Figure 11. Lower hemisphere stereograms of fault slip data with inversion results of the modern state of stress presented in Table 1. Fault planes and measured slip vectors (arrows on fault planes) are plotted. Large arrows outside stereograms represent the direction of minimum (σ_3 , divergent, white arrows) and maximum (σ_1) horizontal stress axes. Histograms show distribution of deviation angles between the measured and calculated slip vectors (e.g., *Bellier and Zoback, 1995*). Numbers on top left of stereograms refer to site marked in Figure 9 as well as in Table 1. MFP refers to result of inversion of major fault plane data.



1192

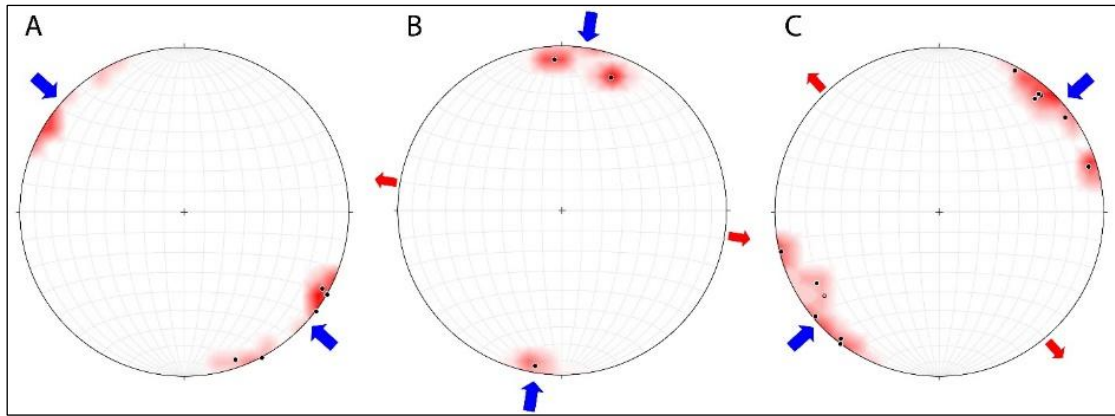
1193 **Figure 12.** Lower hemisphere stereograms of fault slip data with inversion results of the
 1194 paleostress state presented in Table 1. Numbers on top left of stereograms refer to site marked in
 1195 Figure 9 as well as in Table 1. The stereograms indicated by asterisk are the “fixed” solutions (Bellier
 1196 and Zoback, 1995) for fault data populations comprised of less than four well-distributed fault
 1197 directions. See the caption of Figure 11 for stereoplot descriptions.

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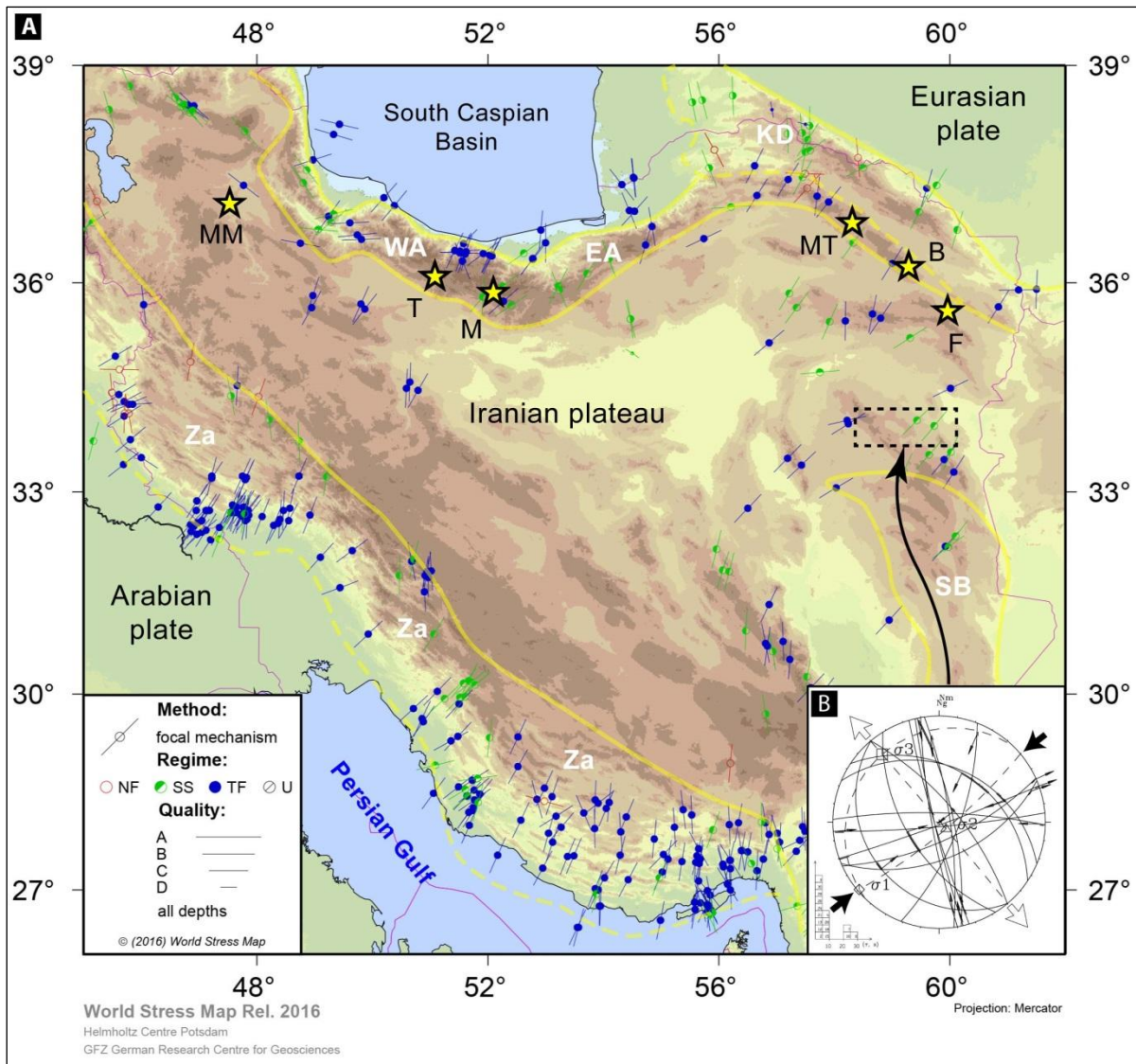
1200 **Figure 13.** Lower hemisphere stereograms of fault slip data with inversion results of the
 1201 intermediate state of stress presented in Table 1. Numbers on top left of stereograms refer to site
 1202 marked in Figure 9 as well as in Table 1. See the caption of Figure 11 for stereoplot descriptions.
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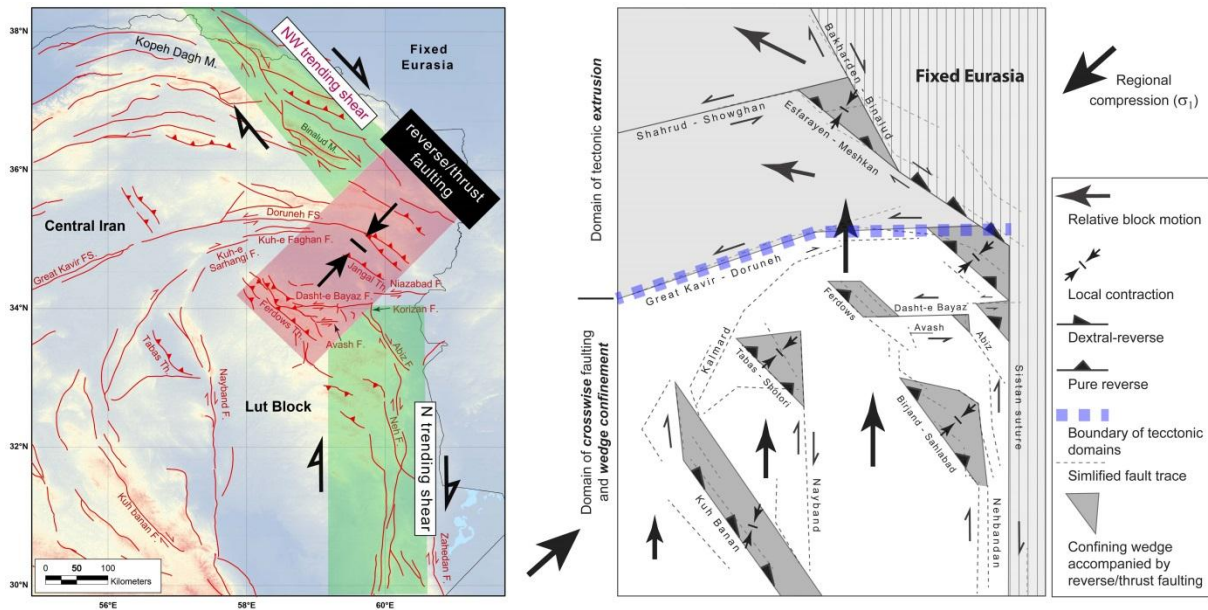
1205 **Figure 14.** Lower hemisphere stereograms showing statistical analysis of the preferred direction
 1206 of the maximum horizontal stress axis (σ_1) corresponding to (A) paleostress state ($N135 \pm 15^\circ E$), (B)
 1207 intermediate state of stress ($N009 \pm 10^\circ E$) and (C) modern state of stress ($N45 \pm 05^\circ E$); all calculated in
 1208 PBT axes method (Marrett and Allmendinger, 1990; Allmendinger et al., 2013). Blue and red arrows
 1209 indicate the mean direction of σ_1 and σ_3 , respectively.

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1211

1212 **Figure 15.** Stress map of the Iranian plateau and surrounding mountain belts. (A) S_{Hmax}
 1213 orientations deriving from some of earthquake focal mechanisms in the Iranian plateau created by
 1214 online stress map creator: <http://www.world-stress-map.org/casmo/> (see Heidbach et al., 2016 and
 1215 references therein). Abbreviation is: TF, thrust faulting; SS, strike-slip; NF, normal faulting; U,
 1216 unknown; B, Binalud; KD, Kopeh Dagh; EA, eastern Alborz; WA, western Alborz; MT, Meshkan
 1217 transition zone; F, Fariman town; SB, Sistan belt; Za, Zagros; M, Mosha; T, Taleghan; MM,
 1218 Mahneshan - Mianeh . Different tectonic regimes are characterized by different symbol colors. NF
 1219 and NS data is printed in red, SS data in green, and TF and TS data in blue. Data with an unknown
 1220 regime is printed in black. (B) Our inversion results ($N050\pm05^{\circ}E$ trending σ_1) showing the present-
 1221 day state of stress in Dasht-e Bayaz area, source parameters were used from instrumentally recorded
 1222 earthquakes that have been modeled using body waves (Walker et al., 2004), see the caption of Table
 1223 2 for more details. We put into practice inversion of focal mechanisms by using moderate to large
 1224 earthquakes ($7.1 > M > 5.7$) and employing the method proposed by Carey-Gailhardis and Mercier
 1225 (1987).



1226

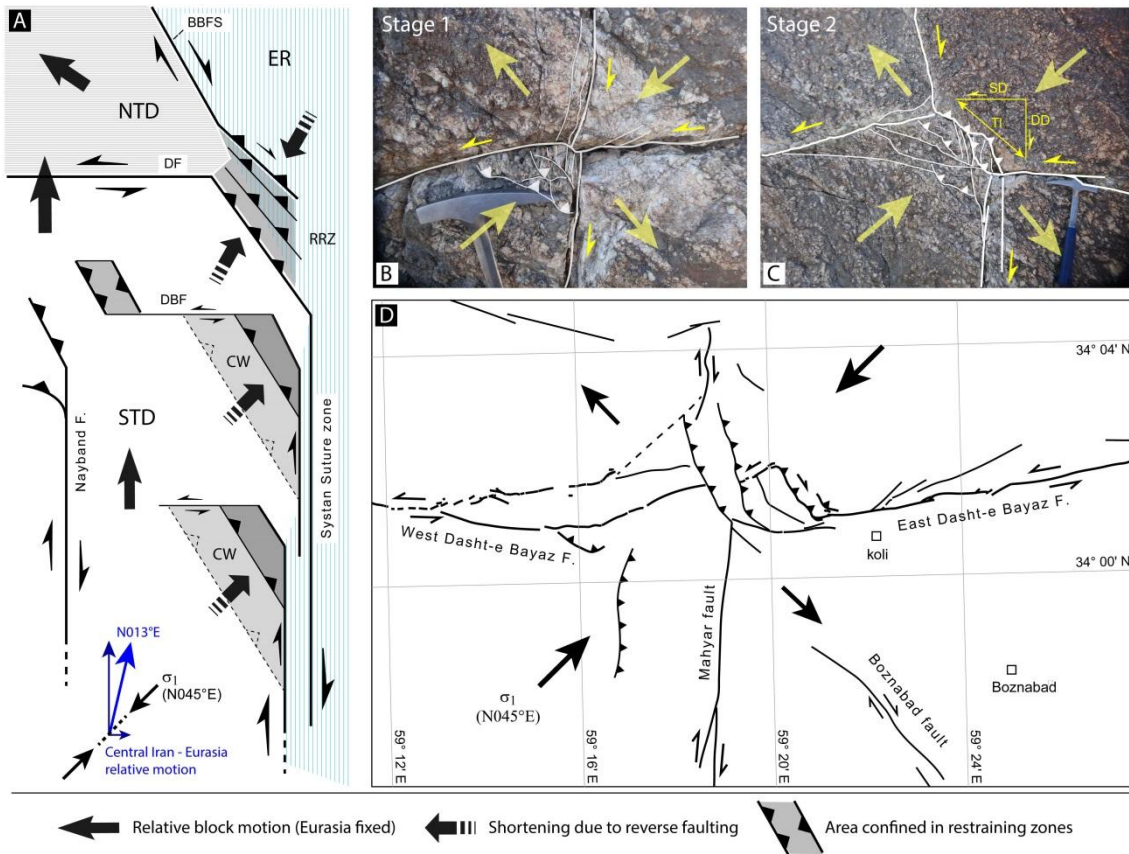
1227 **Figure 16.** A brief explanation of our model about the northern Lut block and the southern
 1228 Koppeh Dagh domain. (A) Up to latitude 34° N the majority of convergence is accommodated by right-
 1229 lateral shear between Iranian plateau and fixed Eurasia. To the north of latitude 34° N, an interruption
 1230 in right-lateral shear takes place and in the absence of right-lateral shear, convergence is
 1231 accommodated by reverse/thrust faulting. (B) Schematic model emphasizing the role of separated
 1232 thrust zones, as confining wedges at the termination of N-S dextral fault, in accommodation of the
 1233 Arabia-Eurasia convergence. See text for more information.

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1239 **Figure 17.** Details on the processes involved in the accommodation of Lut – Eurasia
 1240 convergence in the NE and E Iranian regions. (A) The process of wedge confining at the edges of
 1241 north-going blocks and the associated secondary sinistral faulting along E-W faults such as the Dasht-
 1242 e Bayaz and Niiazabad. The overall N013°E direction of Lut – Eurasia motion (Walpersdorf et al.,
 1243 2014) is mainly taken up by lithospheric N-S dextral shear translating the southern tectonic domain
 1244 (STD) northwards. Shortening at the opposing edges of the main blocks (STD against ER) is
 1245 accommodated through reverse faulting in a restraining relay zone (RRZ in “A”; Farbod, 2012; Aflaki
 1246 et al., 2019), while internal deformations due to sub-block adjustments is taken up by crosswise
 1247 dextral and sinistral faulting accompanied by contractional deformation at their terminations (CW,
 1248 confining wedge); BBFS, Bakharden – Binalud fault system; DF, Doruneh fault; DBF, Dasht-e Bayaz
 1249 fault. (B) And (C) Site-scale examples for the evolution of crosswise faulting; (B) illustrates the initial
 1250 stage of crosswise faulting and (C) shows the structural configuration of crosswise dextral and
 1251 sinistral faults after development of contractional quadrants. “TL” is the length of the main thrust fault
 1252 zone developed perpendicular to the compression and is proportional to the amount of dextral (DD)
 1253 and sinistral (SD) displacements of the main crosswise fault traces. (D) The intersection zone between
 1254 the Dasht-e Bayaz and Mahyar faults; note to the analogy between this structural configuration and
 1255 the typical crosswise faulting illustrated in (C). Such kind of kinematic interaction accommodates the
 1256 overall convergence oblique to the faults without a need for rotations of faults and blocks around
 1257 vertical axes.

Table 1

The fault kinematic inversion results characterizing the Pliocene-Quaternary stress regimes in the Dasht-e Bayaz area.

Site	Long. (°E)	Lat. (°N)	Paleostress							Modern Stress							Intermediate Stress							Lithology	Age			
			Stress axis(trend/plunge)			R	N	Q	Rm	Stress axis(trend/plunge)			R	N	Q	Rm	Stress axis(trend/plunge)			R	N	Q	Rm					
			σ_1	σ_2	σ_3					σ_1	σ_2	σ_3					σ_1	σ_2	σ_3									
1	59.807	34.013	152/00	62/00	295/90	0.595	4	CF	C	28/03	293/61	119/29	0.51	10	B	S	-	-	-	-	-	-	-	-	-	-	Andesite	Paleo-Eocene
2	59.101	34.041	120/01	210/01	345/89	0.500	4	CF	C	53/05	157/70	321/19	0.47	12	A	S	-	-	-	-	-	-	-	-	-	-	Sandstone	Triassic
3	58.931	34.048	-	-	-	-	-	-	-	40/11	176/75	308/10	0.55	8	A	S	357/9	250/60	92/28	0.44	6	C	S	Conglomerate	Quaternary			
4	59.248	34.026	127/00	303/90	37/00	0.327	4	CF	S	240/15	43/75	149/04	0.43	12	A	S	-	-	-	-	-	-	-	-	-	Andesite	Paleo-Eocene	
5A	58.977	34.043	-	-	-	-	-	-	-	218/03	116/76	308/14	0.66	12	A	S	-	-	-	-	-	-	-	-	-	-	Conglomerate	Quaternary
5B	58.977	34.043	-	-	-	-	-	-	-	256/01	354/83	166/07	0.714	8	A	S	-	-	-	-	-	-	-	-	-	-	Conglomerate	Quaternary
6	58.738	34.028	119/05	212/28	19/62	0.452	4	C	C	73/06	343/01	241/84	0.23	14	B	C	20/15	112/07	227/74	0.12	6	A	C	Conglomerate	Pliocene			
7	58.561	34.017	161/06	252/12	46/76	0.696	5	B	C	230/02	320/05	124/85	0.78	14	A	C	-	-	-	-	-	-	-	-	-	-	Conglomerate	Pliocene
8	59.281	34.032	-	-	-	-	-	-	-	41/07	279/76	133/11	0.96	10	A	S	-	-	-	-	-	-	-	-	-	-	Tuff	Paleocene
9	59.168	34.027	-	-	-	-	-	-	-	40/07	232/82	130/2	0.530	14	A	S	-	-	-	-	-	-	-	-	-	-	Dolomite	Triassic
10	59.274	34.028	120/00	210/00	354/90	0.6	5	CF	C	217/00	103/89	307/01	0.624	15	A	S	-	-	-	-	-	-	-	-	-	-	Limestone	Paleocene

Note: Site numbers and their geographic coordination refer to Figure 9. The results of inversion of fault slip data are including trend and plunge of principal stress axes (σ_1 , σ_2 , σ_3 (matching maximum, intermediate and minimum stress axes, respectively) and stress ratio " $R = (\sigma_2 - \sigma_1) / (\sigma_3 - \sigma_1)$ " shows the relative stress magnitude. N, number of fault slip data involved in stress calculations; Rm points out to stress regimes: C, compressional; S, strike-slip; Q indicates the quality of stress tensors: A, well-constrained; B, constrained; C, poorly-constrained solutions. CF quality represents data sets consist of less than four spatially well-distributed fault slip data, for this kind of data sets a "fixed" solutions (Bellier and Zoback, 1995) is used, in which the principal stress axes were fixed to lie in horizontal and vertical planes. In site 5, two deviatoric stress tensors (5A and 5B) were obtained.

Table 2

Earthquake source parameters used in the focal mechanism inversion.

Date	Time (UTC)	Y	X	Depth (km)	Magnitude (Mw)	Strike	Dip	Rake	Reference
1968.08.31	10:47	34.068	59.018	17	7.1m	254	84	5	5
1968.08.31	10:47	34.068	59.018	10	6.4	320	70	90	5
1968.09.01	07:27	34.099	58.155	9	6.3	115	54	85	3
1968.09.04	23:24	34.042	58.244	9	5.5	148	56	81	3
1968.09.11	19:17	34.031	59.472	6	5.6	78	90	16	1
1976.11.07	04:00	33.836	59.171	8	6.0m	84	79	12	1,4
1976.11.07	04:00	33.836	59.171	10		67	52	-7	1
1979.01.16	09:50	33.961	59.501	11	6.5m	293	34	46	1,4
1979.01.16	09:50	33.961	59.501	13		257	88	5	1
1979.11.14	02:21	34.017	59.78	10	6.6m	160	89	-177	1,4
1979.11.14	02:21	34.017	59.78	6		85	85	1	1
1979.11.27	17:10	34.056	59.769	8	7.1m	261	82	8	5
1979.12.07	09:24	34.13	59.889	10	5.9	113	84	21	1
1997.05.10	07:57	33.88	59.815	13	7.2	156	89	-160	2
1997.06.25	19:38	33.972	59.459	8	5.7	181	87	170	2

Note: In this research we used the source parameters of instrumentally recorded earthquakes in the Dasht-e Bayaz region that have been modeled by Walker et al. (2004) with body wave methods. References are the same as they used in their modeling, including: (1) Baker (1993), (2) Berberian et al. (1999), (3) Walker et al. (2003), (4) Jackson (2001) and (5) Walker et al. (2004). An (m) after of some of Mw means a multiple event. For more information see Table 1 of Walker et al. (2011).

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[Click here to download Table: Table 1.docx](#)

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Site	Long. (°E)	Lat. (°N)	Paleostress							Modern Stress							Intermediate Stress							Lithology	Age				
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			σ1	σ2	σ3					σ1	σ2	σ3					σ1	σ2	σ3										
1	59.807	34.013	152/00	62/00	295/90	0.595	4	CF	C	28/03	293/61	119/29	0.51	10	B	S	-	-	-	-	-	-	-	-	-	-	-	Andesite	Paleo-Eocene
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5A	58.977	34.043	-	-	-	-	-	-	-	218/03	116/76	308/14	0.66	12	A	S	-	-	-	-	-	-	-	-	-	-	-	Conglomerate	Quaternary
5B	58.977	34.043	-	-	-	-	-	-	-	256/01	354/83	166/07	0.714	8	A	S	-	-	-	-	-	-	-	-	-	-	-	Conglomerate	Quaternary
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7	58.561	34.017	161/06	252/12	46/76	0.696	5	B	C	230/02	320/05	124/85	0.78	14	A	C	-	-	-	-	-	-	-	-	-	-	Conglomerate	Pliocene	
8	59.281	34.032	-	-	-	-	-	-	-	41/07	279/76	133/11	0.96	10	A	S	-	-	-	-	-	-	-	-	-	-	Tuff	Paleocene	
9	59.168	34.027	-	-	-	-	-	-	-	40/07	232/82	130/2	0.530	14	A	S	-	-	-	-	-	-	-	-	-	-	-	Dolomite	Triassic
10	59.274	34.028	120/00	210/00	354/90	0.6	5	CF	C	217/00	103/89	307/01	0.624	15	A	S	-	-	-	-	-	-	-	-	-	-	-	Limestone	Paleocene

Note: Site numbers and their geographic coordination refer to Figure 9. The results of inversion of fault slip data are including trend and plunge of principal stress axes (σ_1 , σ_2 , σ_3 (matching maximum, intermediate and minimum stress axes, respectively) and stress ratio “ $R = (\sigma_2 - \sigma_1) / (\sigma_3 - \sigma_1)$ ” shows the relative stress magnitude. N, number of fault slip data involved in stress calculations; Rm points out to stress regimes: C, compressional; S, strike-slip; Q indicates the quality of stress tensors: A, well-constrained; B, constrained; C, poorly-constrained solutions. CF quality represents data sets consist of less than four spatially well-distributed fault slip data, for this kind of data sets a “fixed” solutions (Bellier and Zoback, 1995) is used, in which the principal stress axes were fixed to lie in horizontal and vertical planes. In site 5, two deviatoric stress tensors (5A and 5B) were obtained.

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