





**International Institute of Earthquake
Engineering and Seismology (IIEES)
Seismological Research Center**

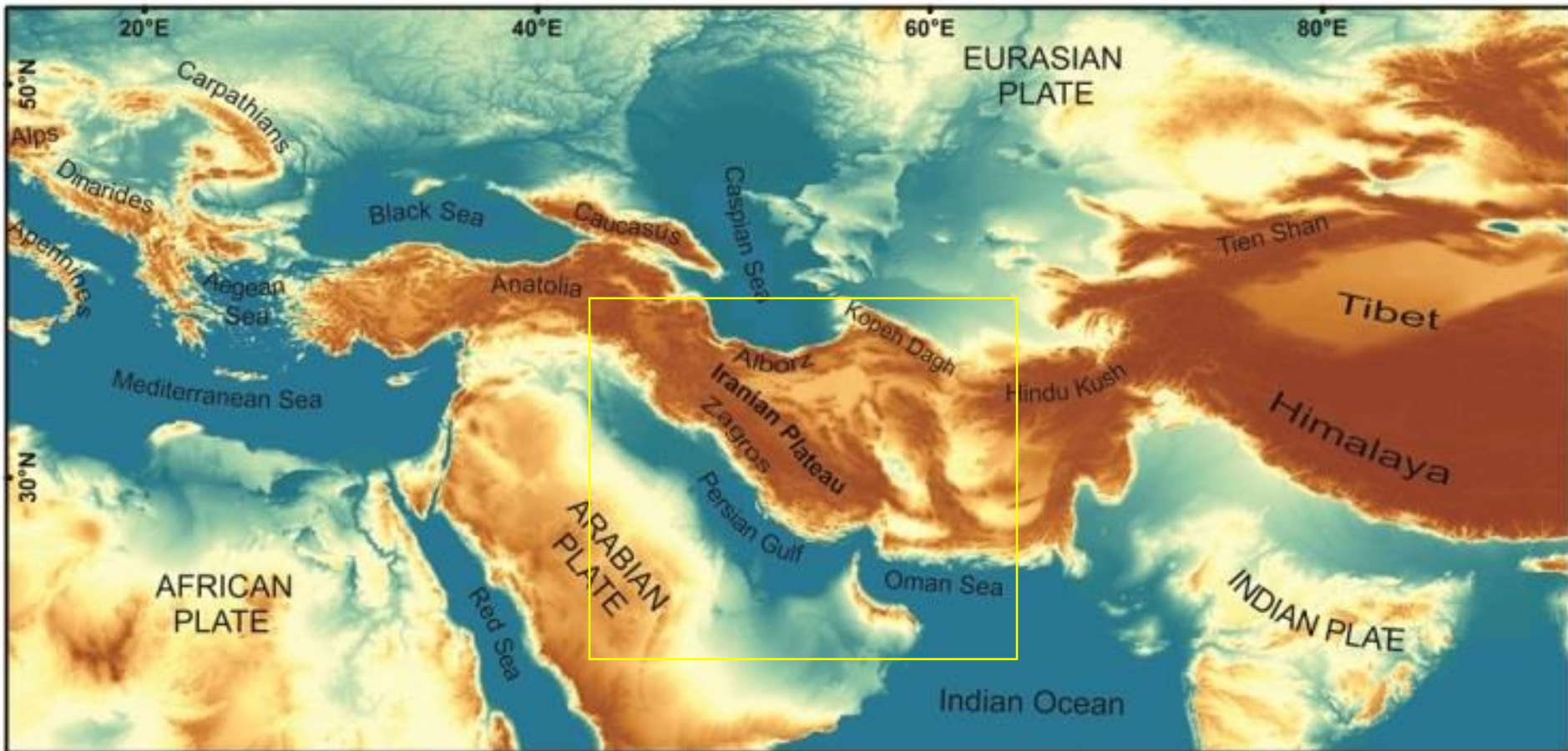
Monthly lecture on

**Time Constraints on the Late Cenozoic Fault Evolution
Along the Northern Margin of the Iranian Plateau in the
Arabia-Eurasia Collision Zone**

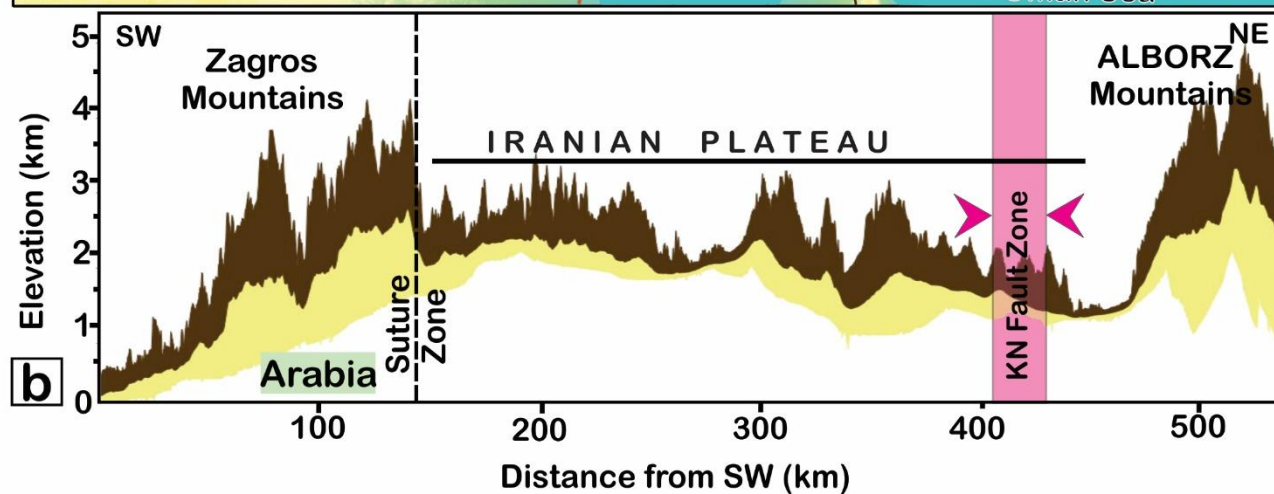
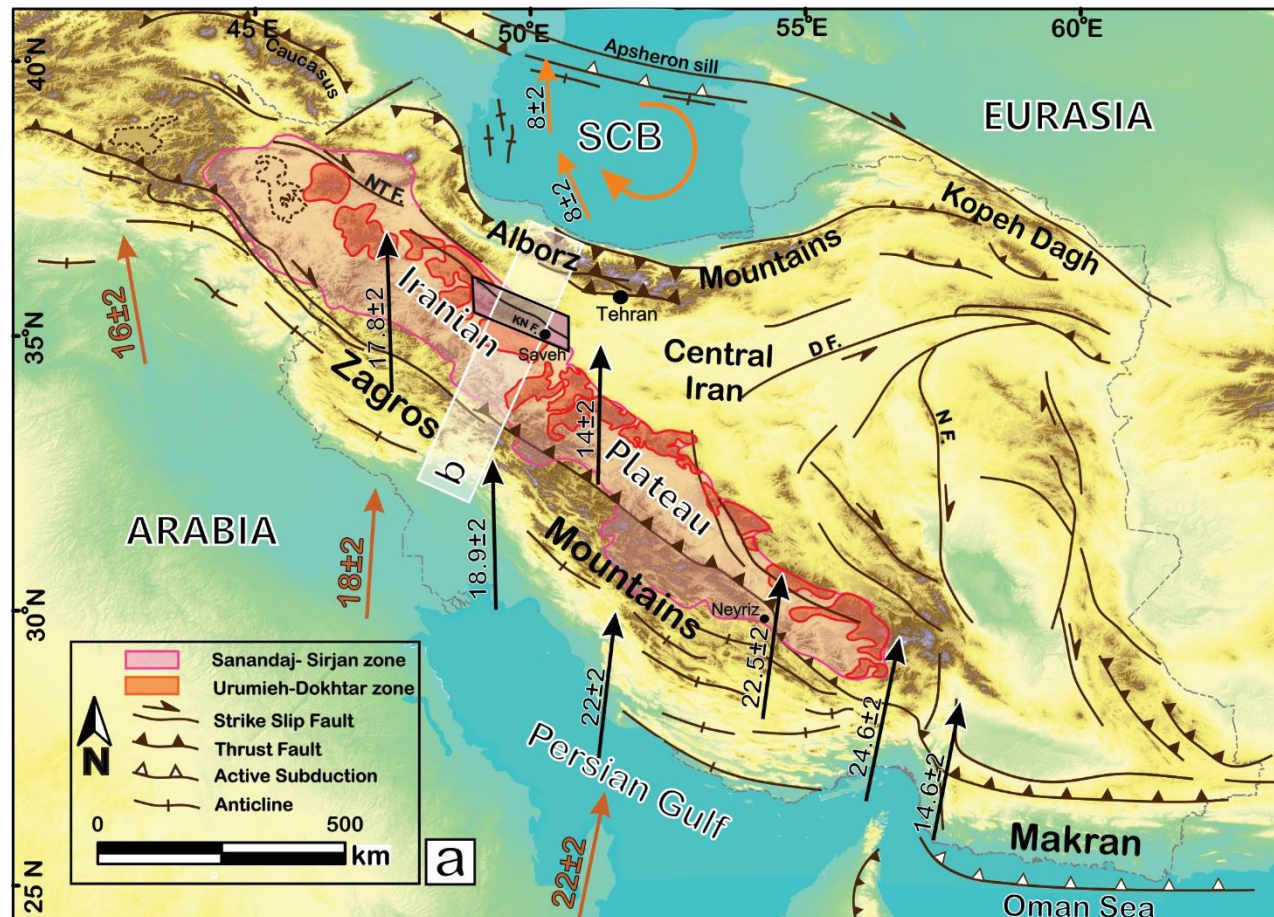
**by:
Sedigheh Khodaparast**

Khordad 1405

Introduction



Introduction ➡ Iranian Plateau



Introduction **Deformation reorganization in Alborz Mountains**
(Slip sense inversion in the **Central** and **Western** parts of **Alborz**)

- **left lateral transpression after upper Miocene or Pliocene** (Taleghan, Mosha and North Tehran faults) (Trifonov et al., 1996; Jackson et al., 2002; Allen et al., 2003; Guest et al., 2006; Hollingworth et al., 2008; Abbassi & Farbod, 2009; Solaymani Azad et al., 2011; Ehteshami & Yassaghi, 2007).
- **Very young left lateral transtension in Pleistocene** (Taleghan, Mosha and Firuzkuh Faults) (Ritz et al., 2006).

The Deformation reorganization has been attributed to:

- Westward motion of the South Caspian Basement (SCB) block relative to Iran (Allen et al, 2003)
- Clockwise rotation of (SCB) relative to Iran (Jackson et al., 2002; Ritz et al., 2006).

Introduction Sudden motions (earthquakes)

- Buin Zahra earthquake, 1962

Ipak Fault ($M_w = 7.2$) Reverse kinematic with 60 cm left lateral strike slip displacement (Ambraseys, 1963 ; Bachmanov et al., 2004; Berberian, 1967; Berberian et al., 1362)

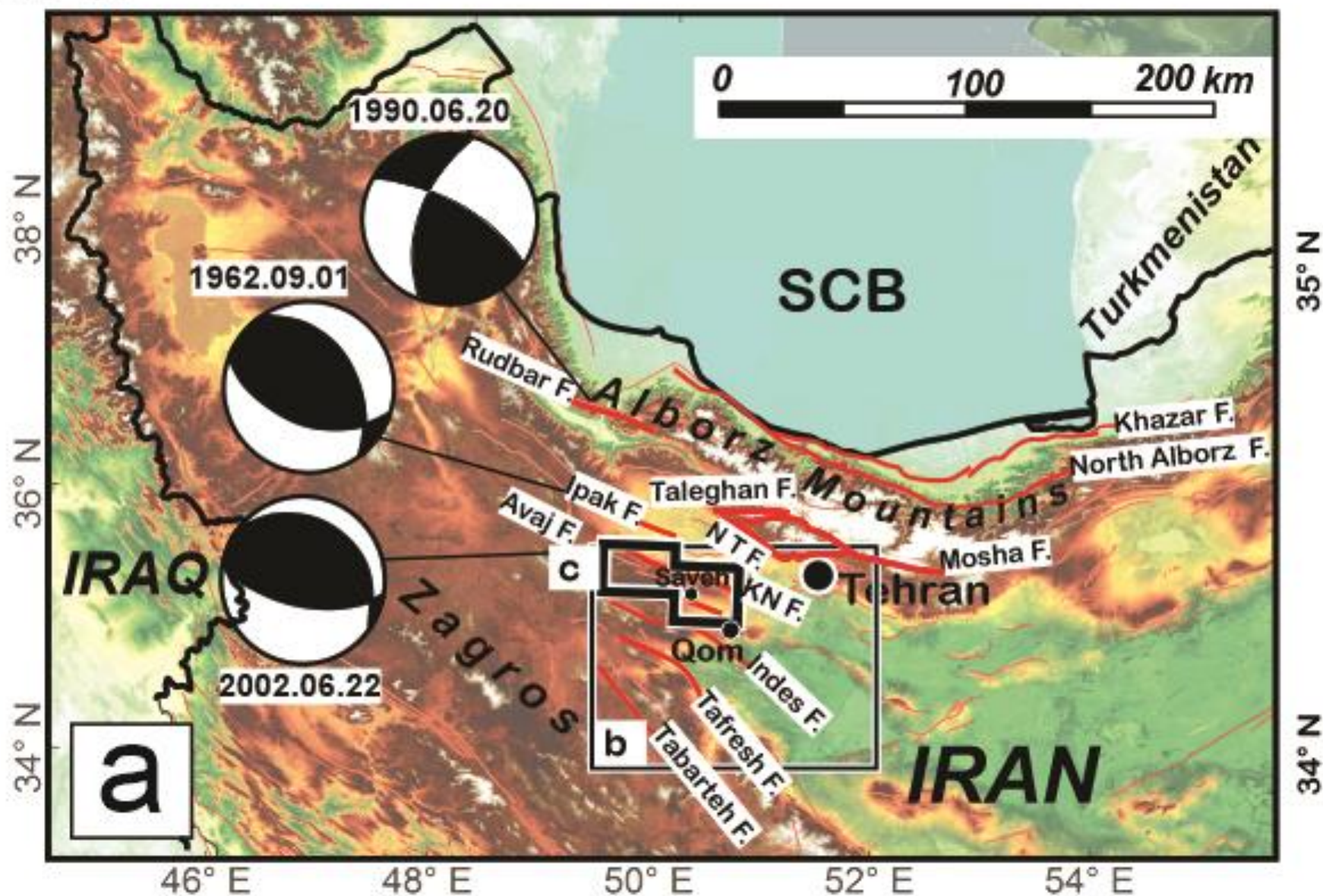
- Rudbar earthquake, 1990 (Berberian & Yeats, 2001)

Rudbar Fault ($M_w = 7.4$) left lateral strike slip kinematic with reverse component

- Avaj (Changureh) earthquake -2002

Avaj Fault ($M_w = 6.3$) Reverse kinematic with 30 cm left lateral strike slip displacement (Walker et al., 2004; Gheitanchi, 2004; Soleymani & Fegghi., 1381)

49° 30'

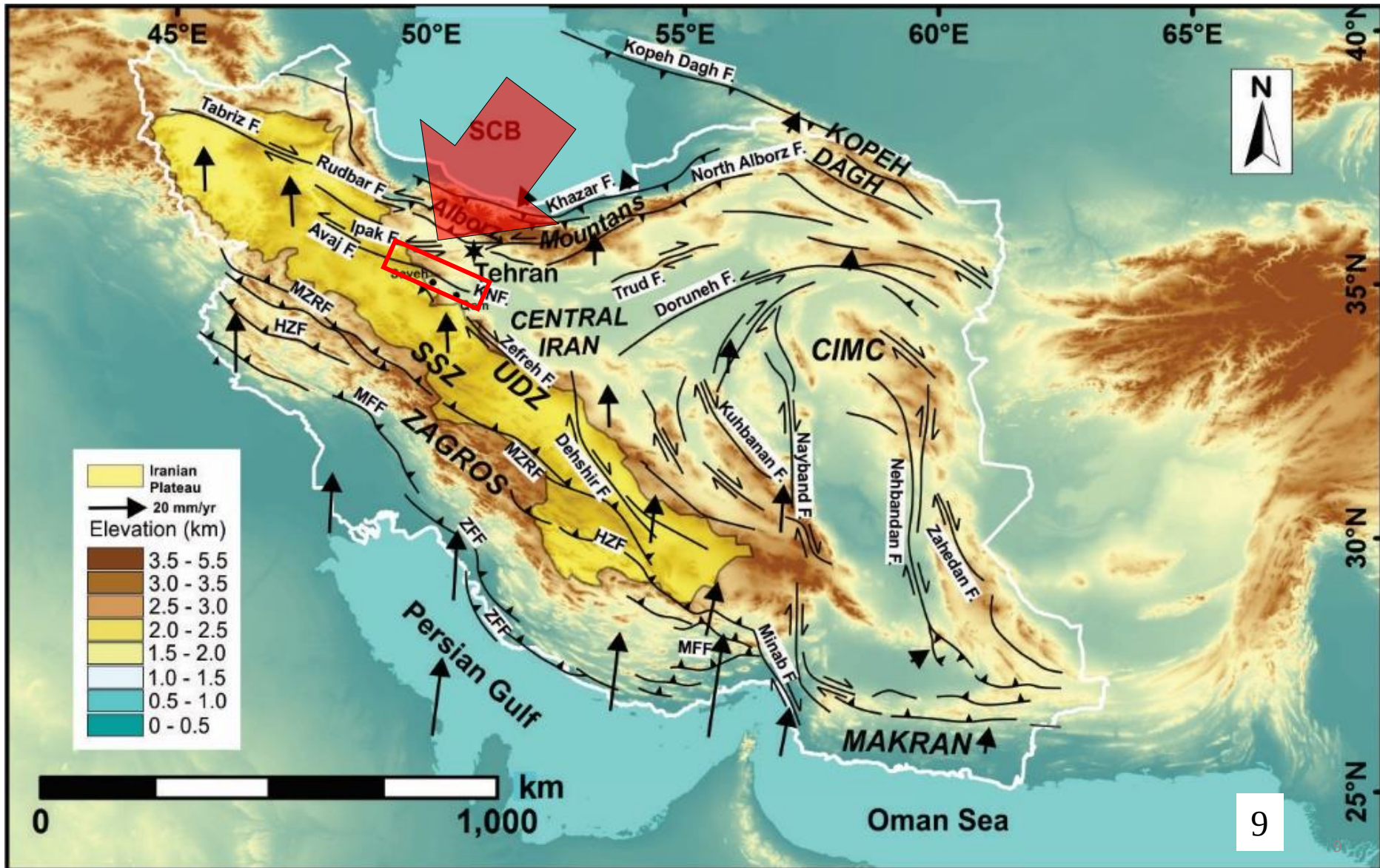


Introduction ➡ Previous studies on Kushk-e-Nosrat Fault zone

- Reverse Fault with southern part uplift (Soder, 1959)
- Left lateral strike slip fault with reverse component (Ghalamghash et al., 1377)
- Primary normal fault that inverted during the Neogene (Gest et al., 2007)
- Primary normal to recently right lateral strike slip fault (Morley et al., 2009)
- Right lateral strike slip fault (Babaahmadi et al., 2010)
- Slip Sense inversion from right to left lateral strike slip kinematic (Orang et al., 1393)

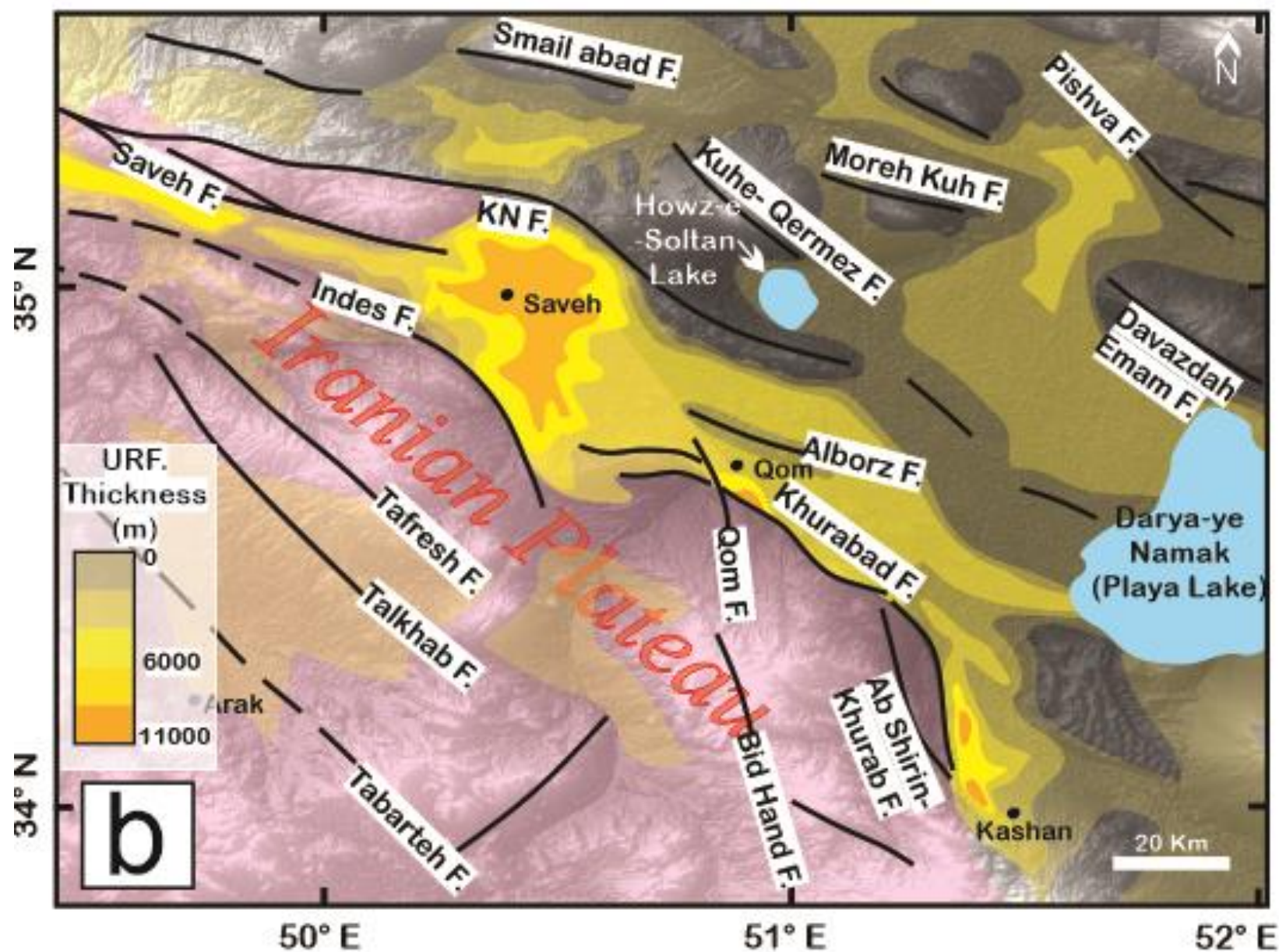
The question is :

Where is the southernmost boundary of the region experienced fault slip sense inversion?



Introduction Sedimentary basins around the fault

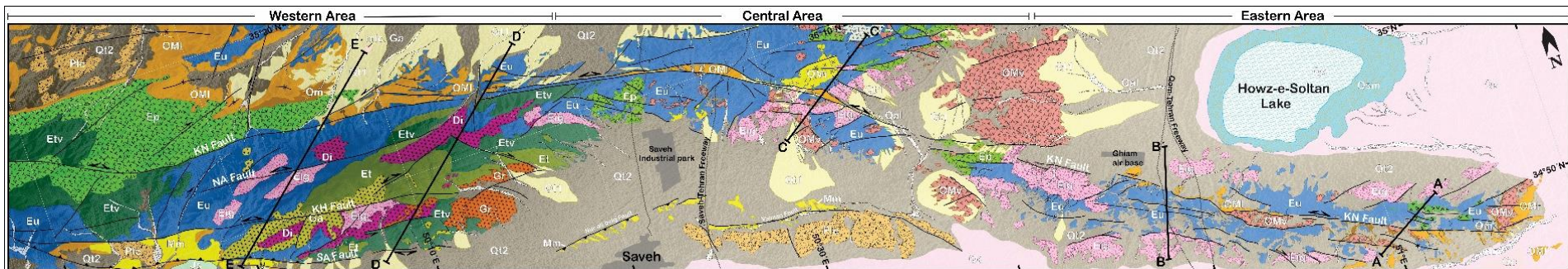
- Why does local curvilinear bedrock (Eocene) expose within the Iranian Plateau??
- What causes the local thickening of the Oligocene–Miocene sediment cover in the northern and southern plains?
- What controls the occurrence of scattered residual Qom Formation deposits exclusively near the KN Fault trace?
- Do regional extension due to back-arc basin extension or thermal subsidence (Biralvand et al., 2023; Morley et al., 2009; Mouthereau et al., 2012) provide good reasons?



Introduction Methods

- Structural analysis ----- 523 Fault data
- Tectonostratigraphy ----- Correlation of tectonostratigraphic columns
- Low temperature Thermochronometry ----- 19 samples
- Active tectonic ----- Satellite images+ field evidence

lithology



Legend

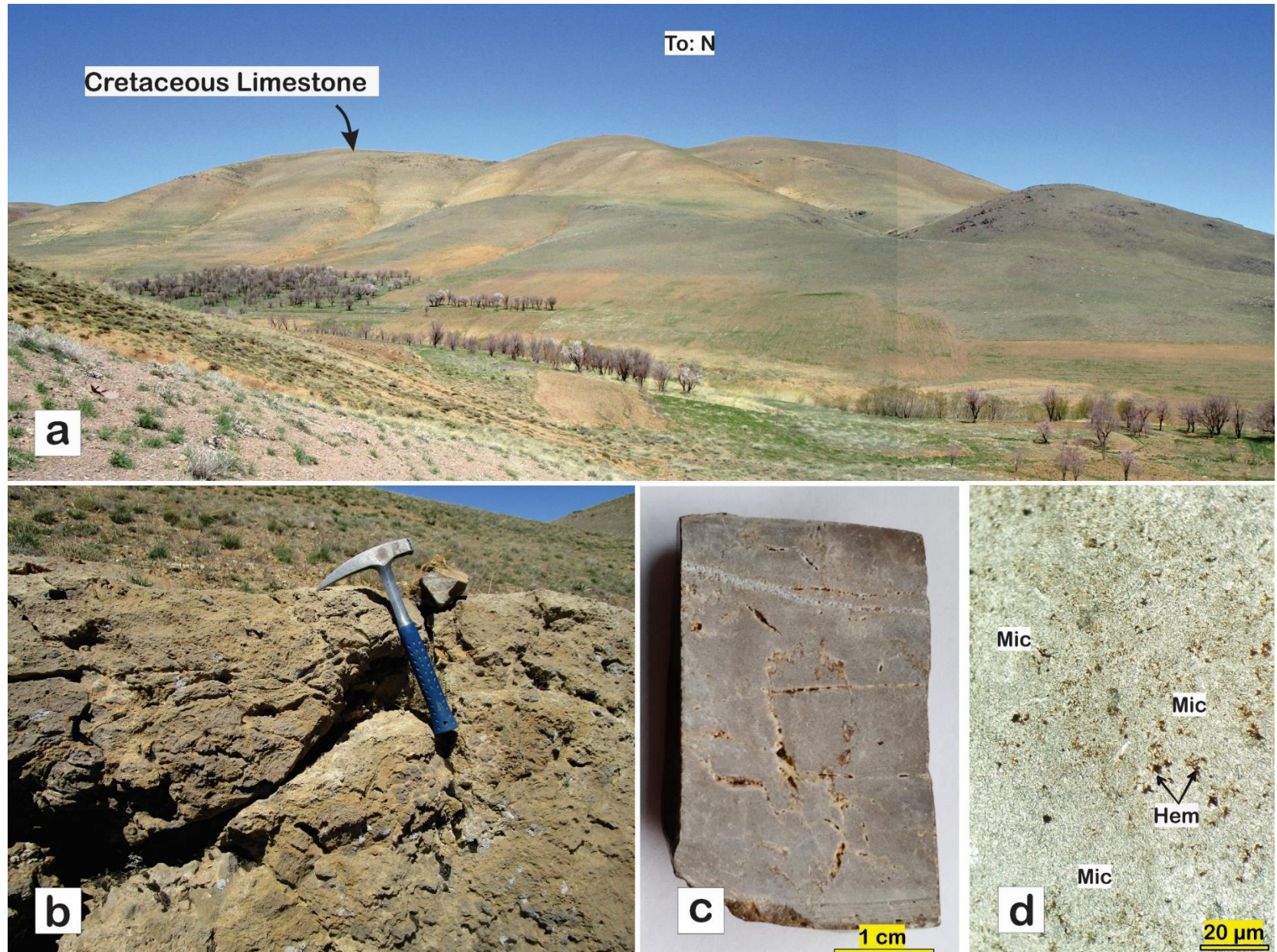
	Qal	Recent river deposits
	Qs	Salt flat
	Qsm	Salty mud
	Qt2	Clay flat
	Qt1	Young terraces & fans
	Qv	Old terraces & fans
	PLC	Basaltic lava
	PLC	Conglomerate
Quaternary		
	Mm	Sandstone- Upper Red Fr.
	OMI	Limestone- Qom Fr.
	OMv	ignimbrite
	OMi	Andesitic lava
	Om	Marl- Lower Red Fr.
Oligo - Miocene		
	Eu	Andesitic- basaltic lava
	Ep	Breccia & lava
	Eig	Ignimbrite
	Etv	Rhyo-dacitic tuff
	Et	Andesitic lava & tuff
Eocene		
	Js	Shale & siltstone
Jur.		

A — A'	Geological section
	Reverse fault
	Major strike slip fault
	Anticline axes
	Syncline axes

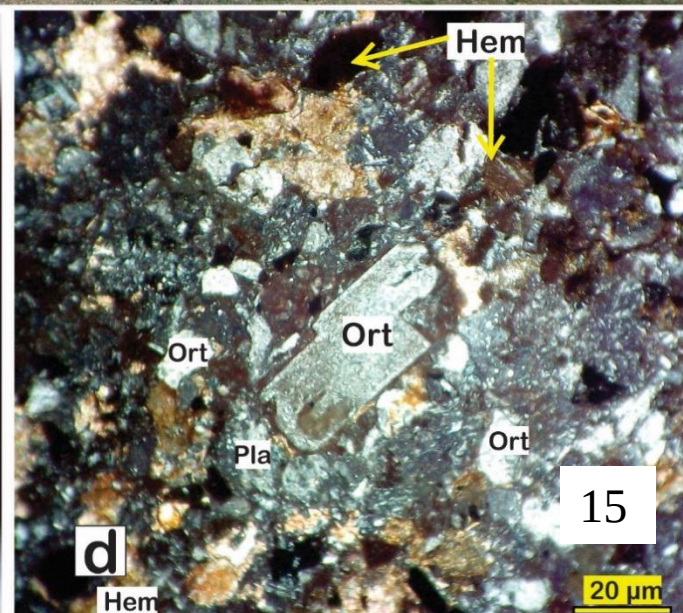
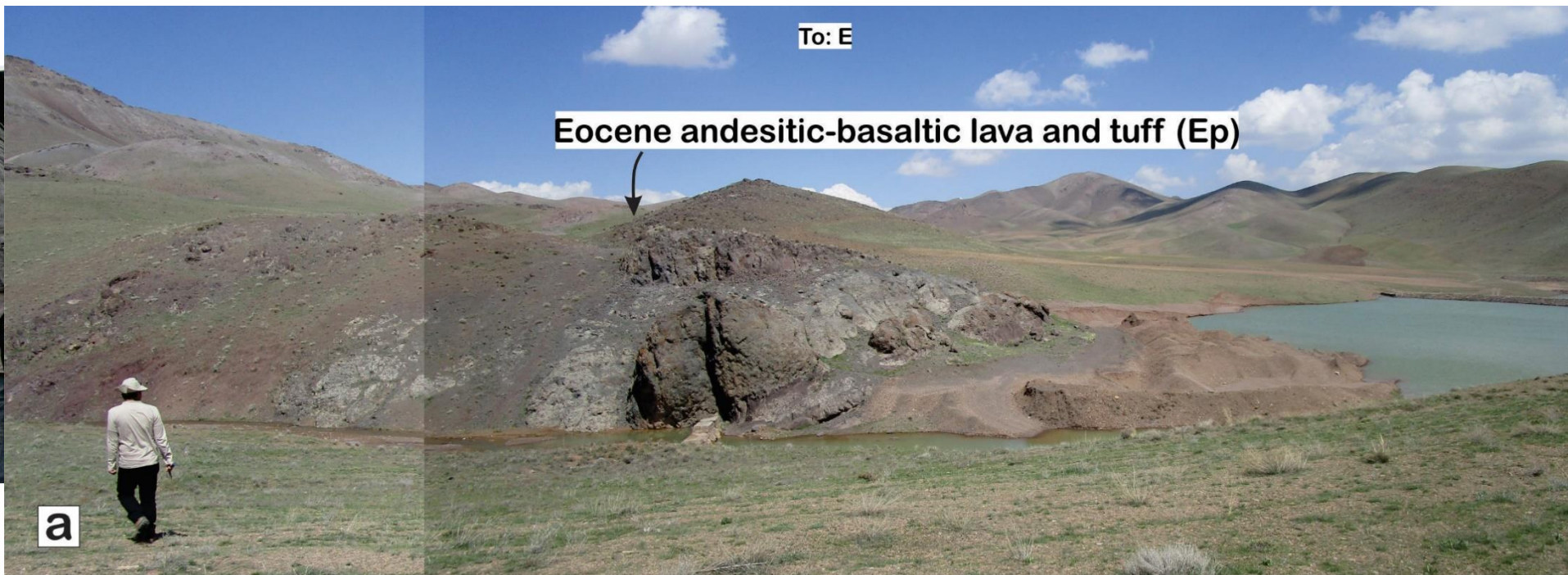
Intrusives

Gr	Granite
Di	Diorite
mic. Ga	Micro Gabbro
Ga	Gabbro

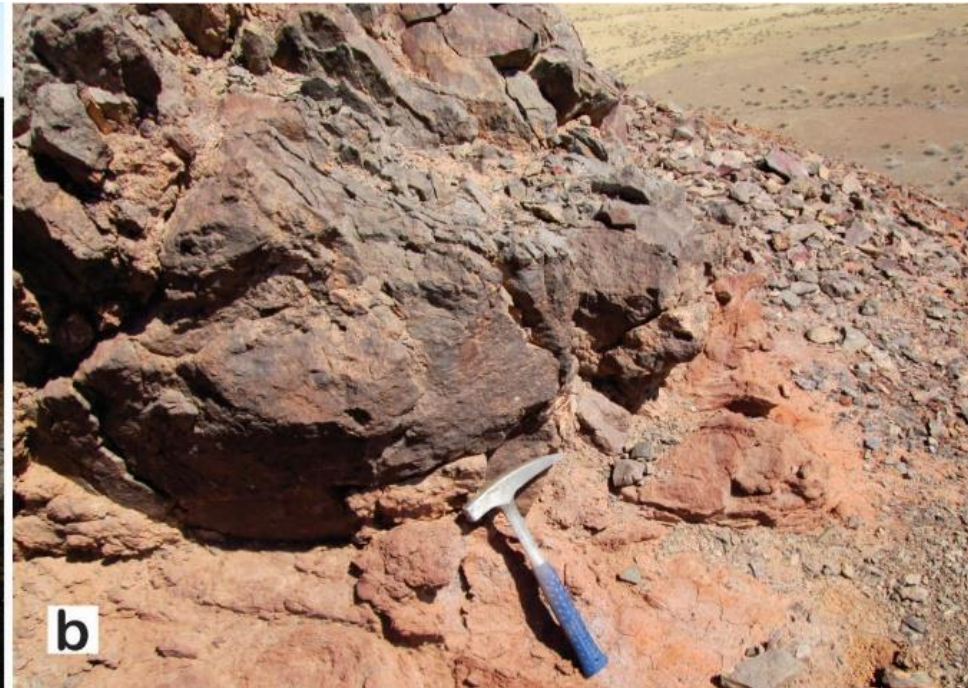
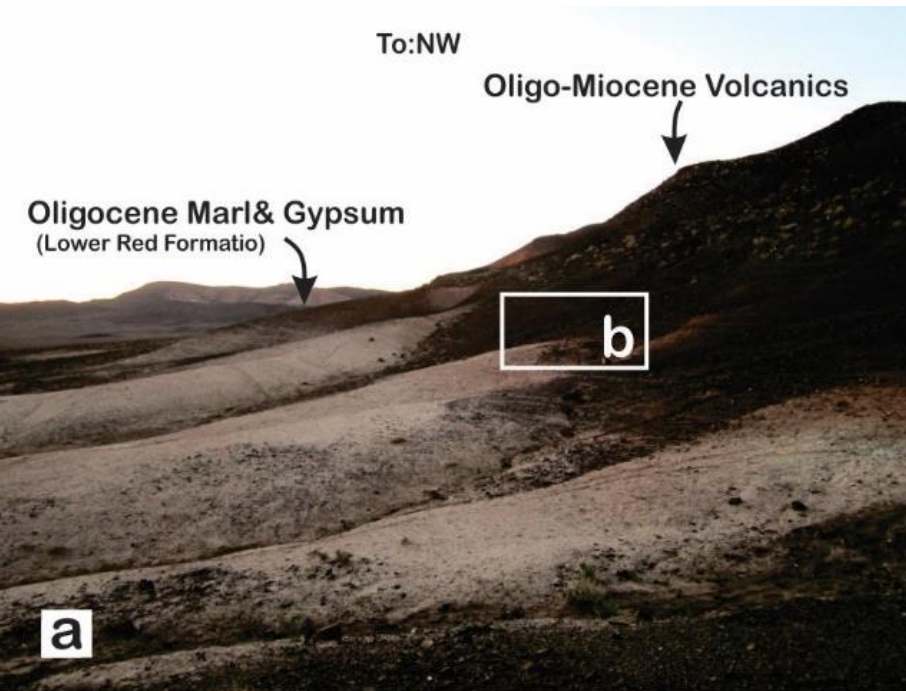
Lithology ➡ Jurassic / Cretaceous



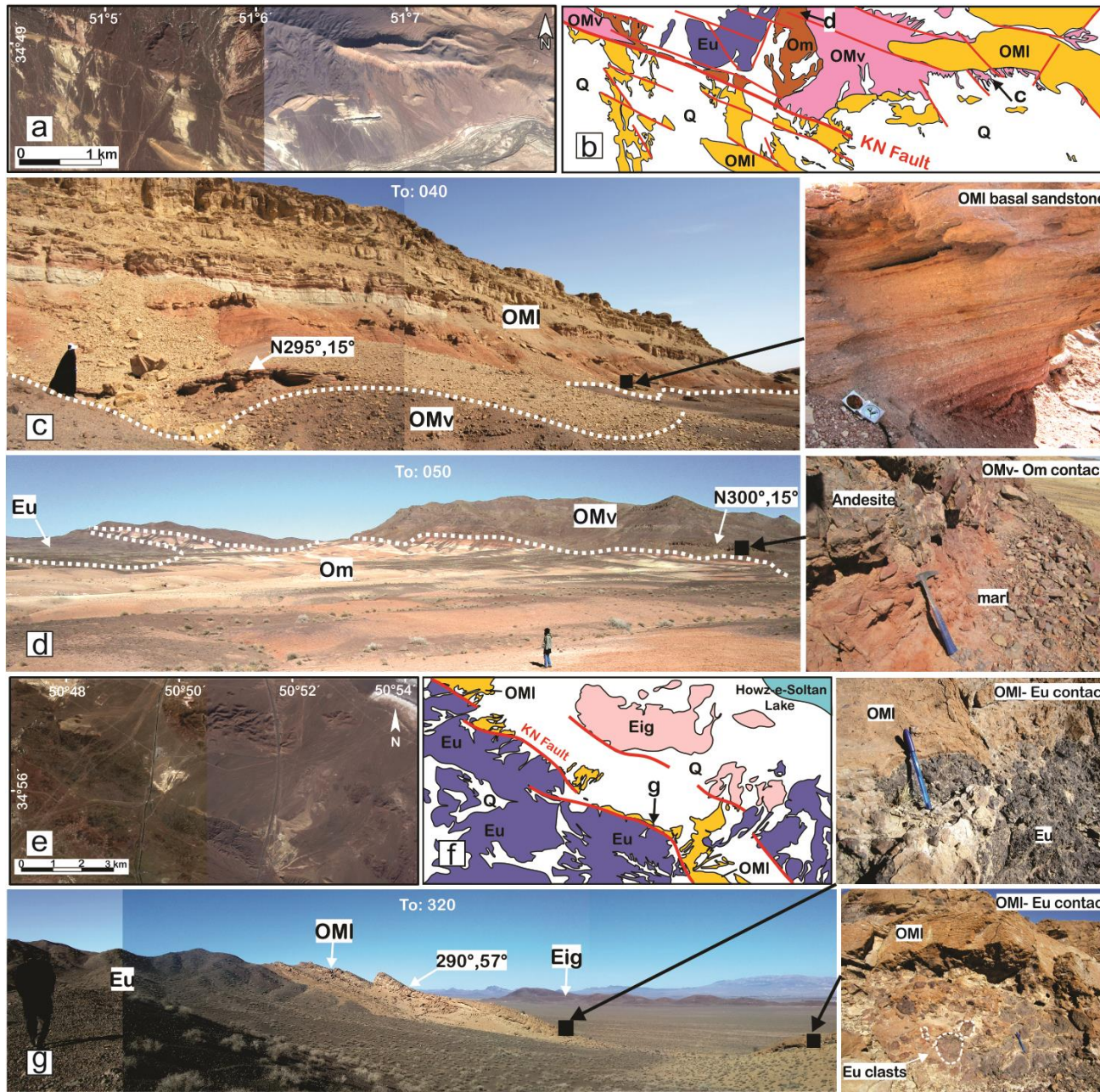
Lithology ➡ Eocene volcanic and tuff



Lithology ➡ Oligocene – Miocene ➡ Lower Red Fm.



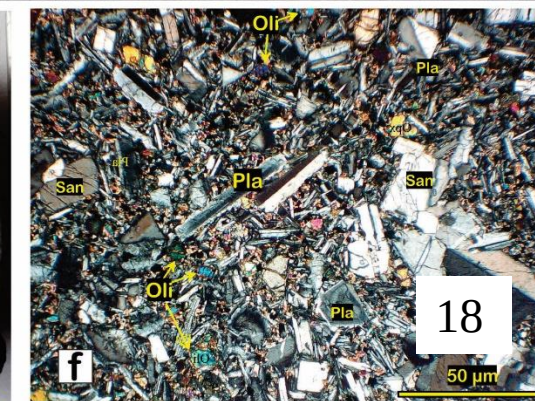
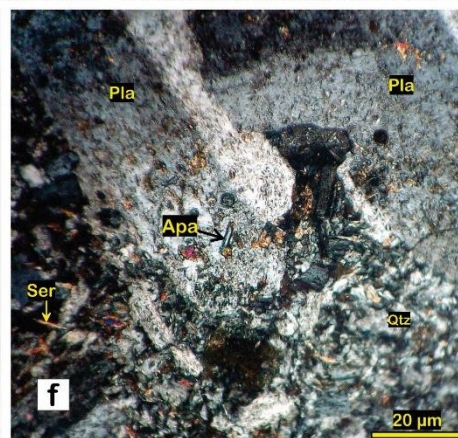
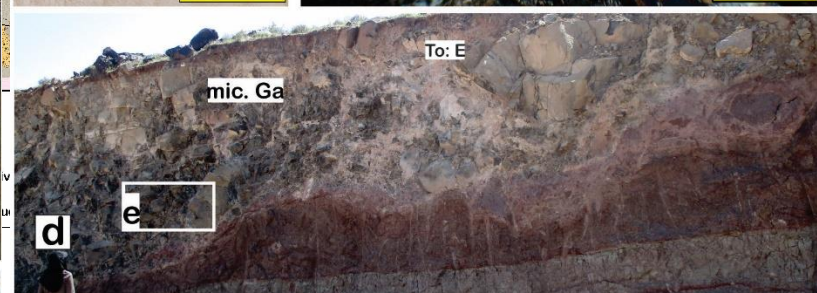
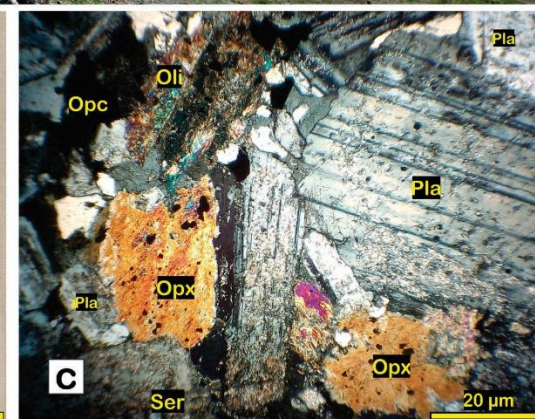
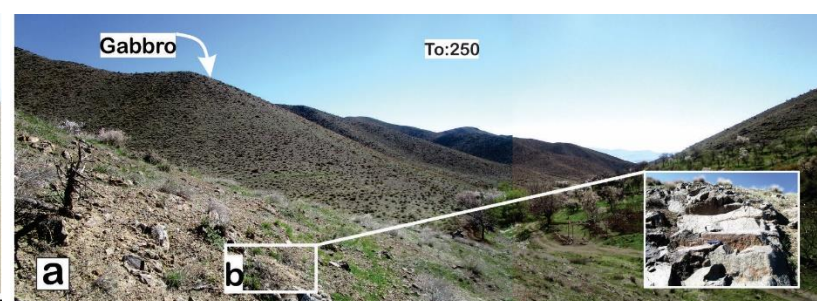
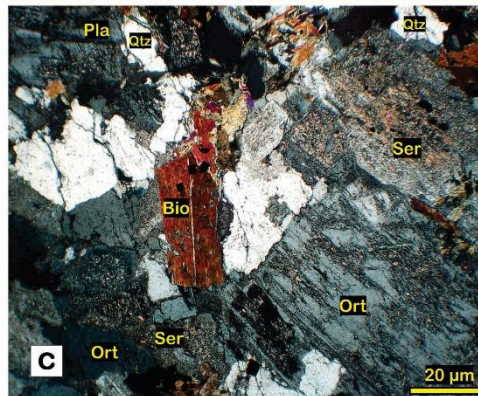
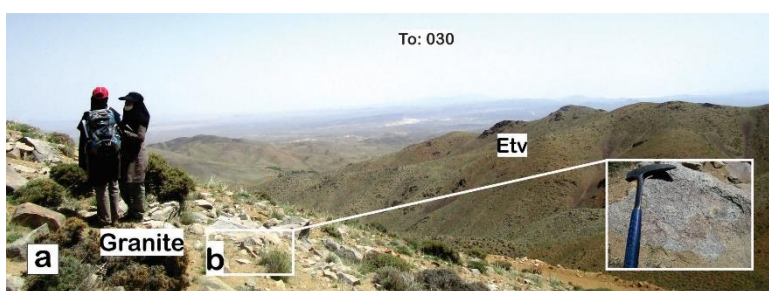
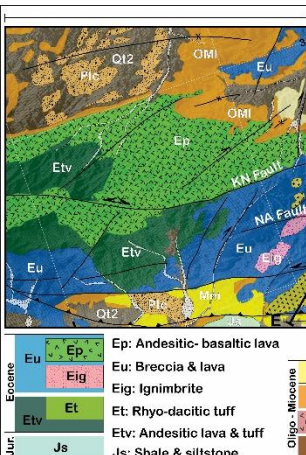
Lithology ➡ Oligocene – Miocene ➡ Qom Fm.



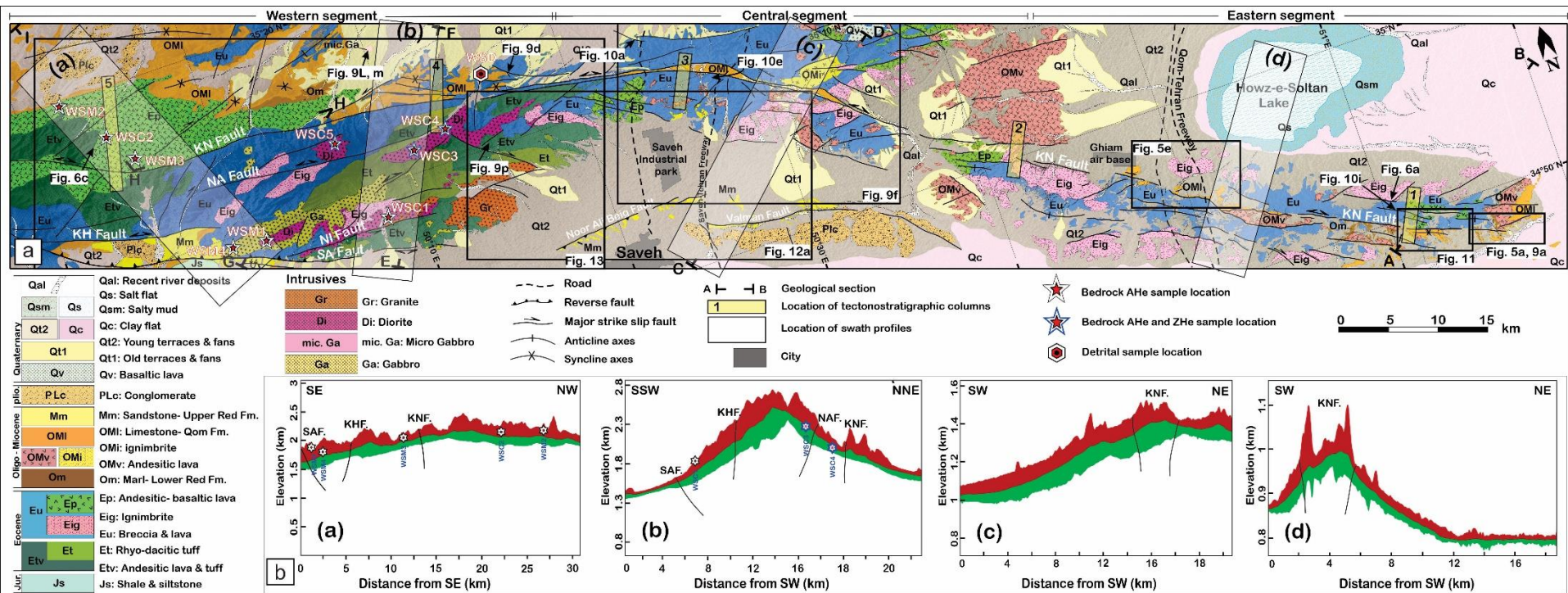
Lithology



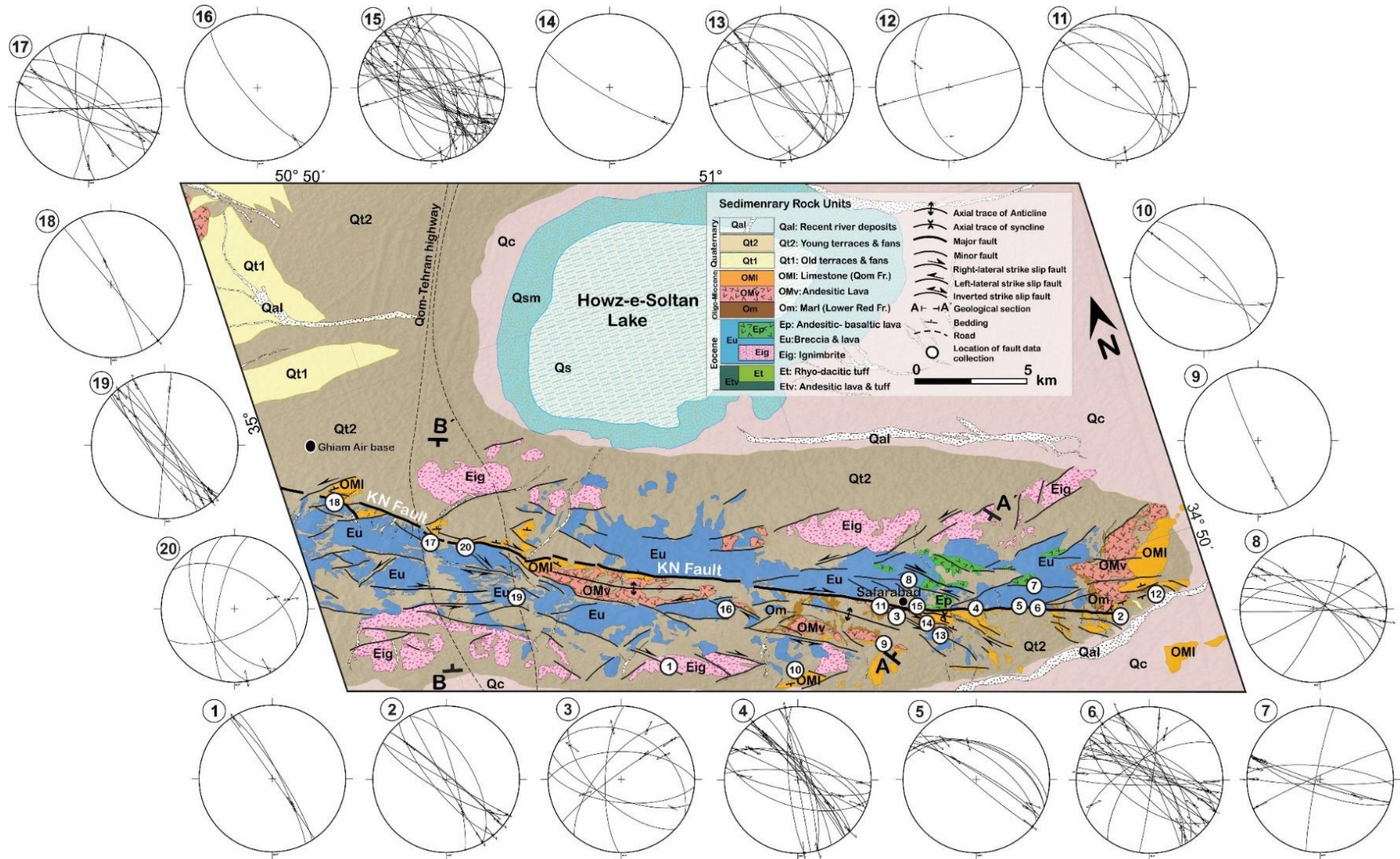
Eocene
Intrusive
bodies



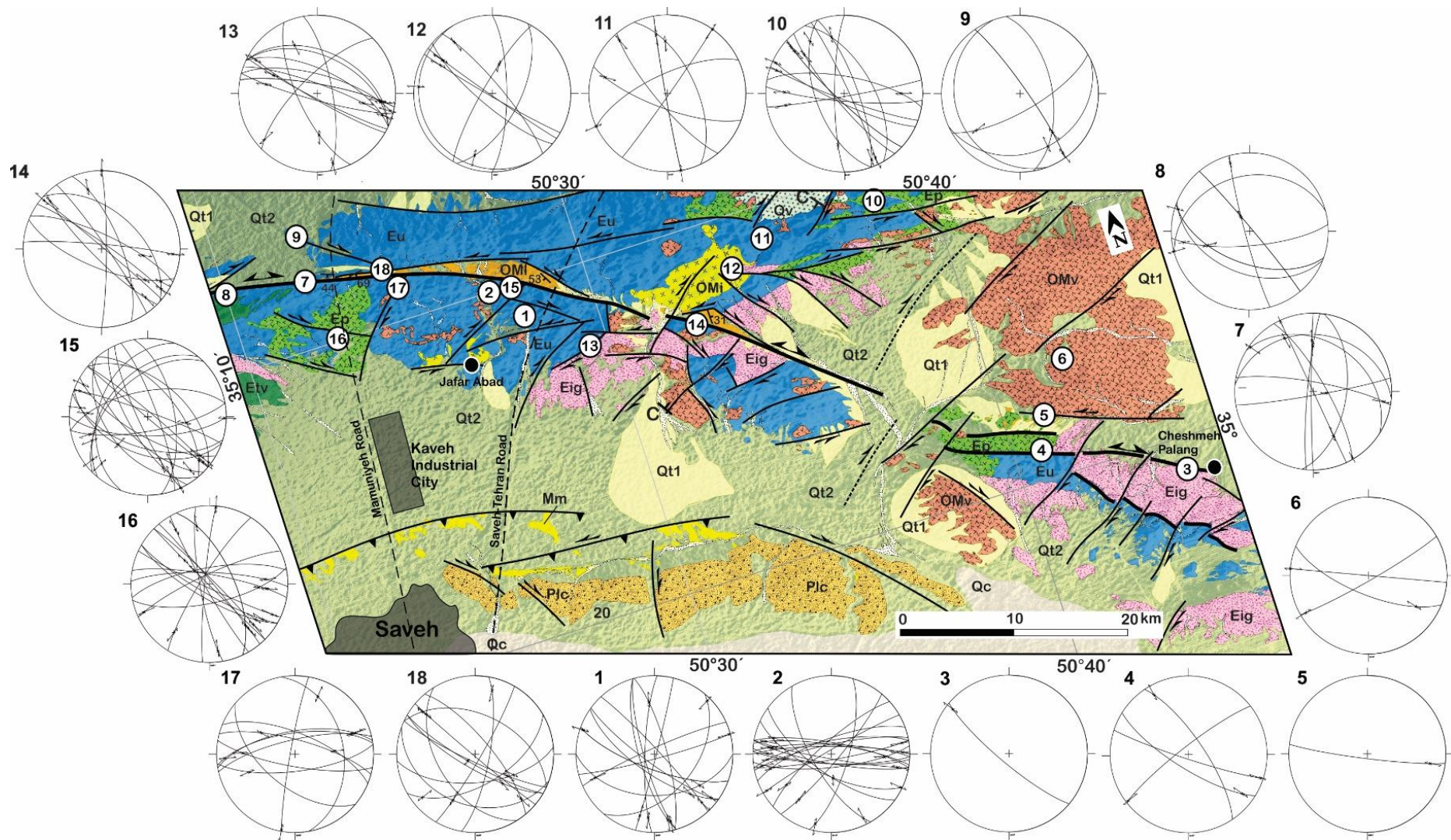
Structural analysis



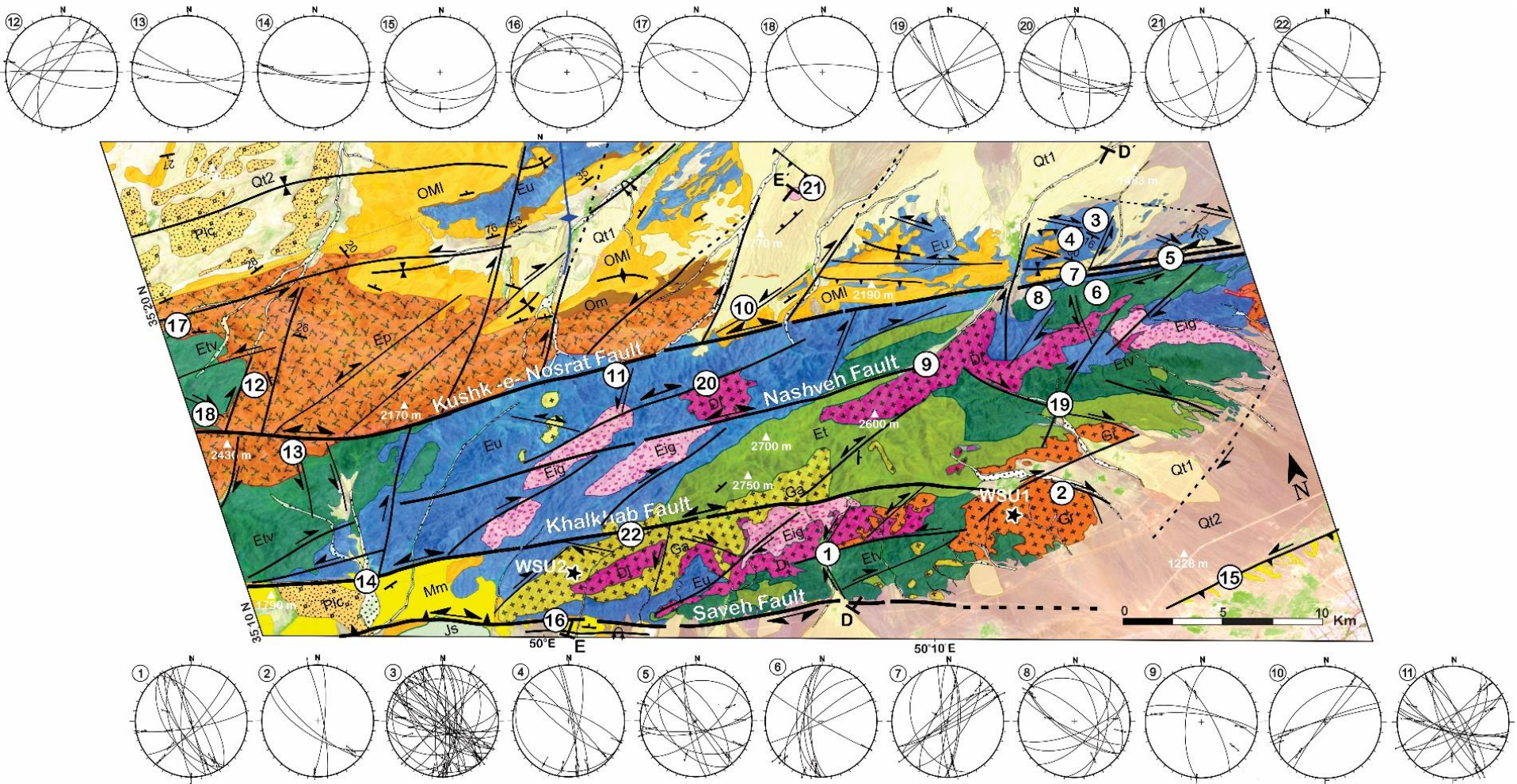
Structural analysis → Eastern part



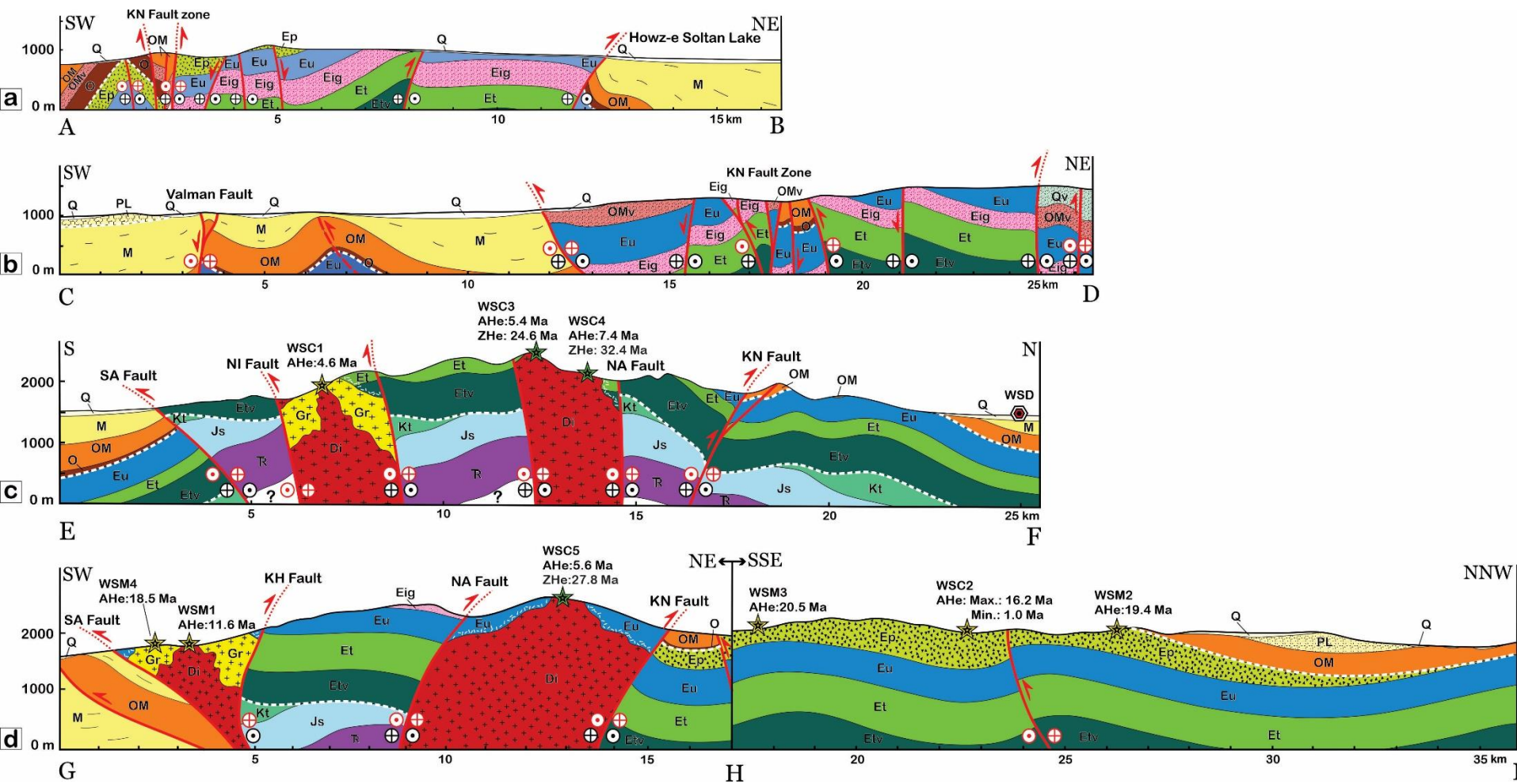
Structural analysis → Central part



Structural Analysis ➡ Western part



Structural Analysis ➡ Sections

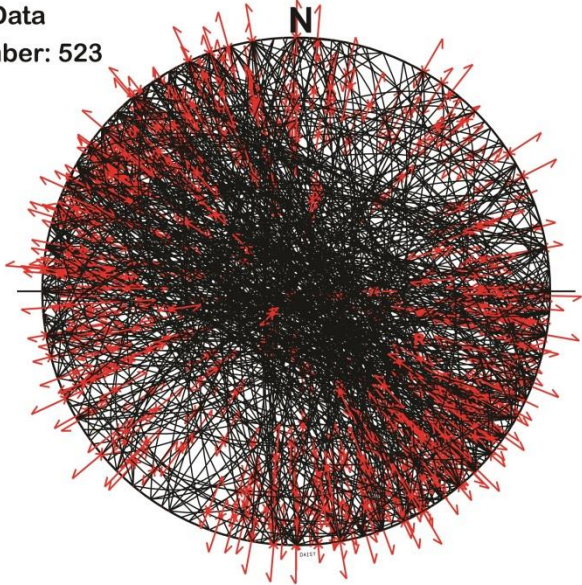


Structural analysis



Stereorigraphic analysis of fault population data

All Fault Data
Data Number: 523

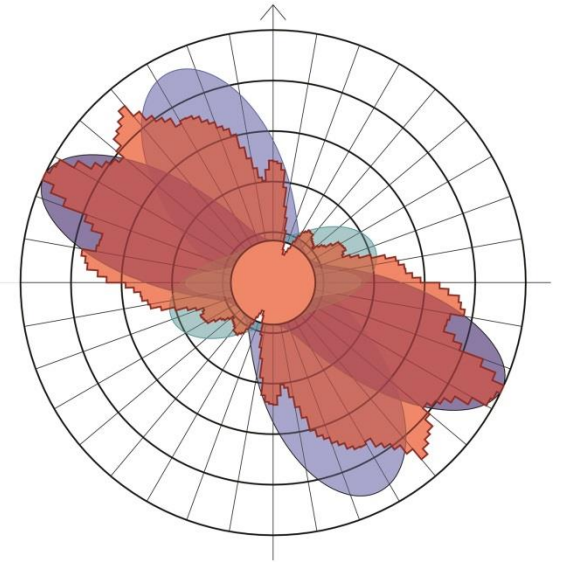


Smoothed Azimuth
Frequency Gaussians

Total Data: 523
mean: 126.580
sd: 3.662
mode: -40
RMS = 0.5718876

GAUSSIAN PARAMETERS

#	%	Azimuth	sd
1	29.37	-65.21°	15.42°
2	33.68	-26.79°	19.35°
3	12.32	71.79°	20.76°
4	2.897	-91.00°	6.82°

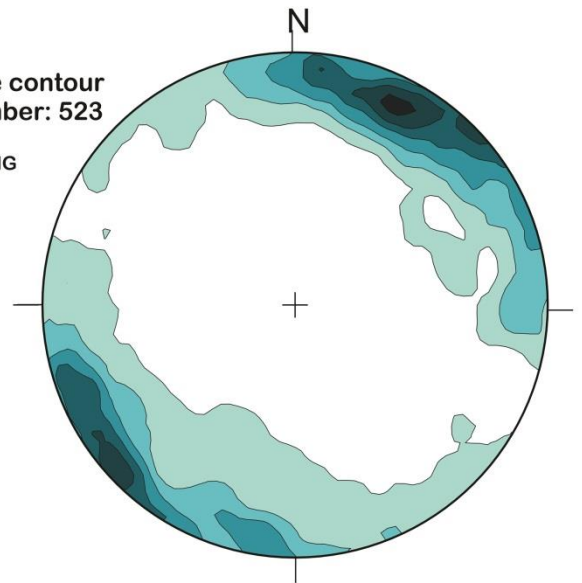


a

b

Fault pole contour
Data Number: 523

CONTOURING

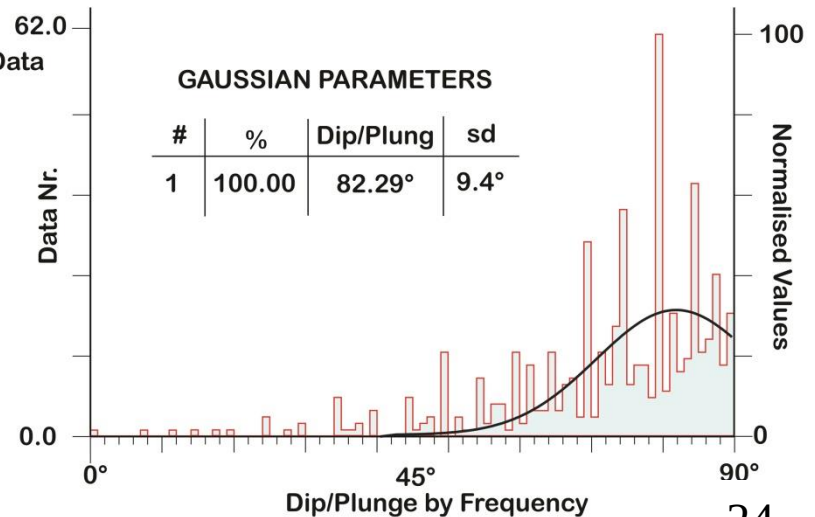


Fault Dip Frequency Data

Total Data: 523
max: 62
min: 0
mean: 72.795
sd: 14.934
mode: 80

GAUSSIAN PARAMETERS

#	%	Dip/Plunge	sd
1	100.00	82.29°	9.4°



c

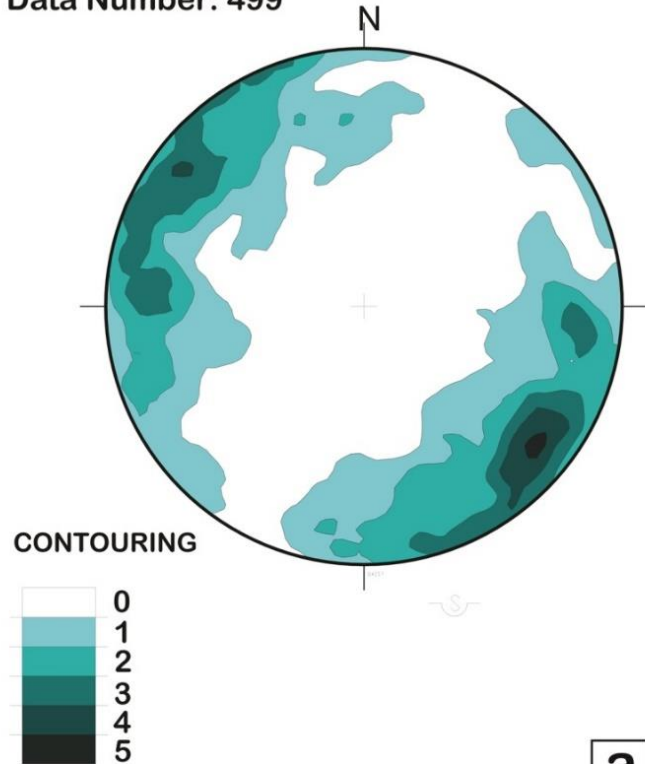
d

Structural analysis



Slickenline data

Slickenline contour
Data Number: 499

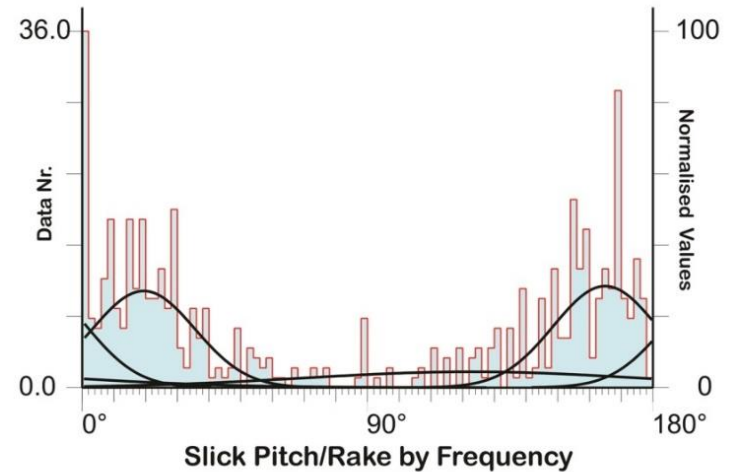


Slick Pitch/Rake
Frequency Data, Gaussians
Total Data: 499
max: 36 min: 0
mean: -0.267 sd: 2.814
mode: 2

GAUSSIAN PARAMETERS

#	%	Slick Pit	sd
1	42.08	165.0°	13.62°
2	39.64	19.40°	13.47°
3	9.206	122.7°	44.0°

b

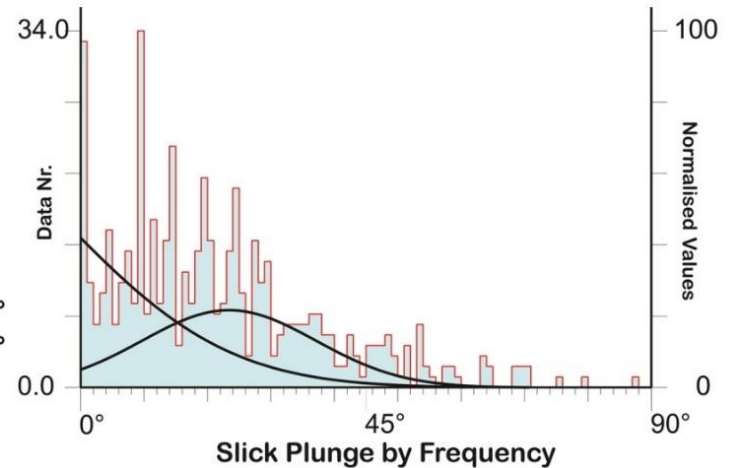


Slick Plunge
Frequency Data, Gaussians
Total Data: 499
max: 34 min: 0
mean: 22.125 sd: 16.422
mode: 10

GAUSSIAN PARAMETERS

#	%	Slick Plu	sd
1	100.00	-27.35°	21.12°
2	51.30	23.35°	11.54°

c



Structural analysis Fault Data Classification

- 523 Fault data
- Different strike slip motions
- Classify in to 4 categories:

- 1) **Oldest dextral transtension**
- 2) **Old dextral strike- slip**
- 3) **Young dextral transpression**
- 4) **Recent sinistral kinematics (Slip sense inversion)**

Based on:

- Sedimentary and tectonostratigraphic evidence (dextral transtension)
- Cross-cutting relation
- The superposition of kinematic indicators

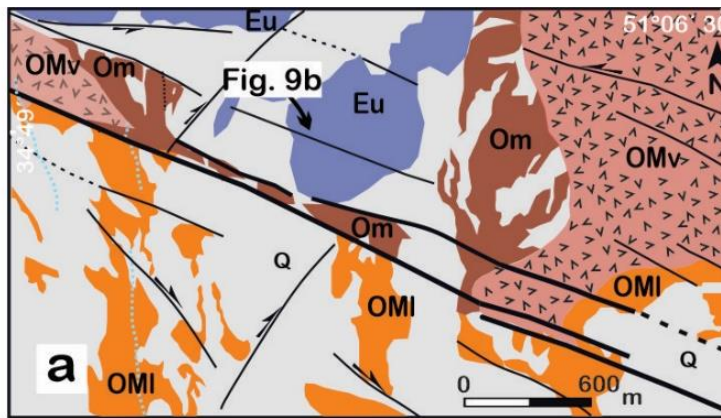
Structural
analysis



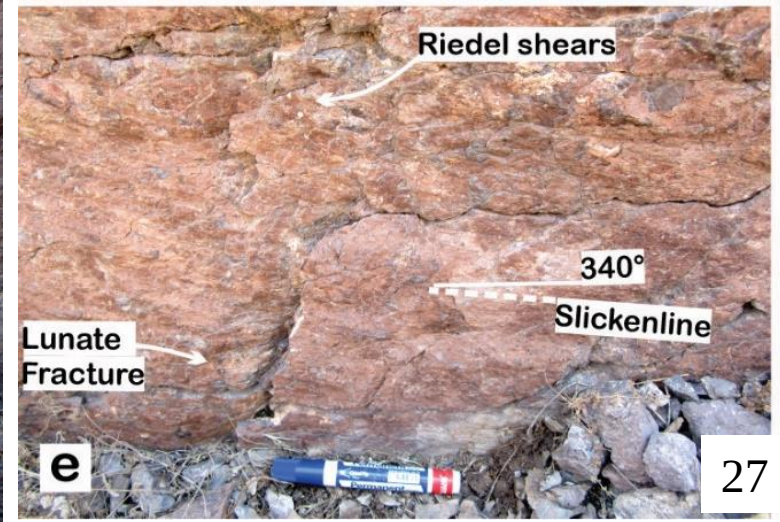
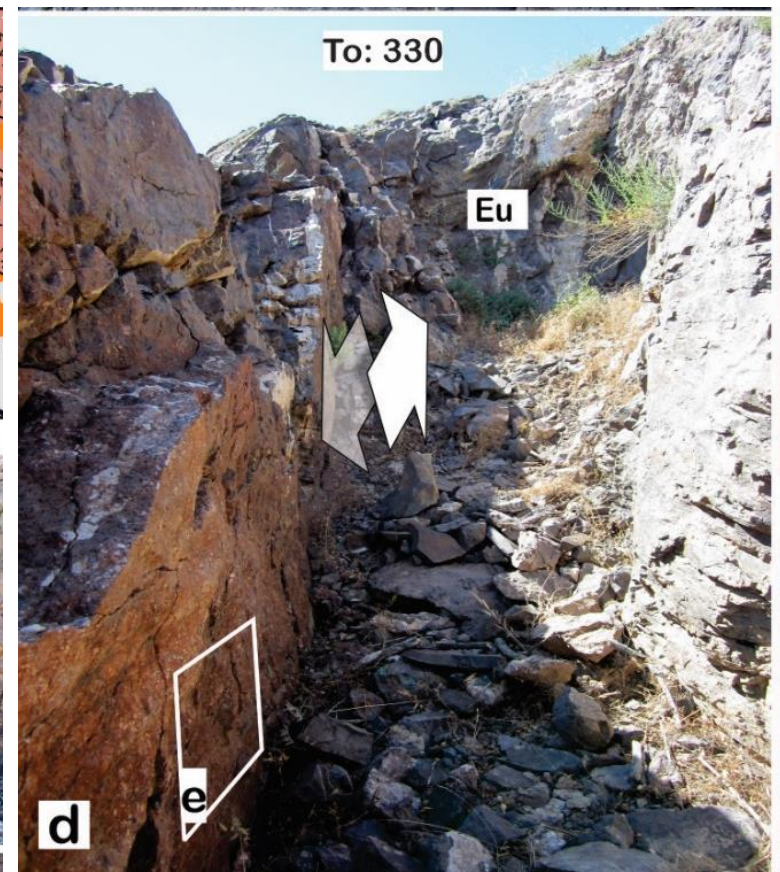
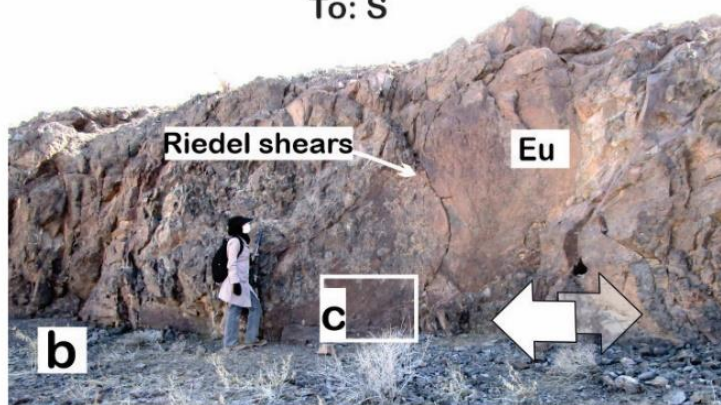
fault data
classification



Dextral
transtension
motion
structural
evidence



To: S



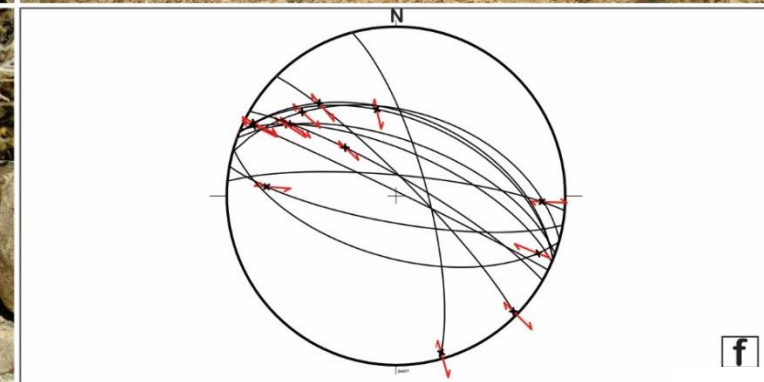
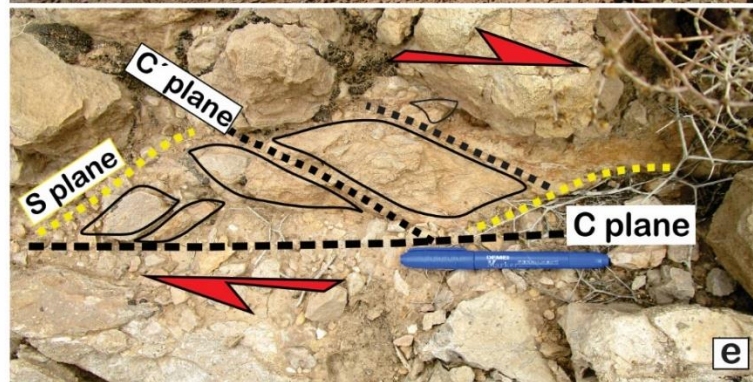
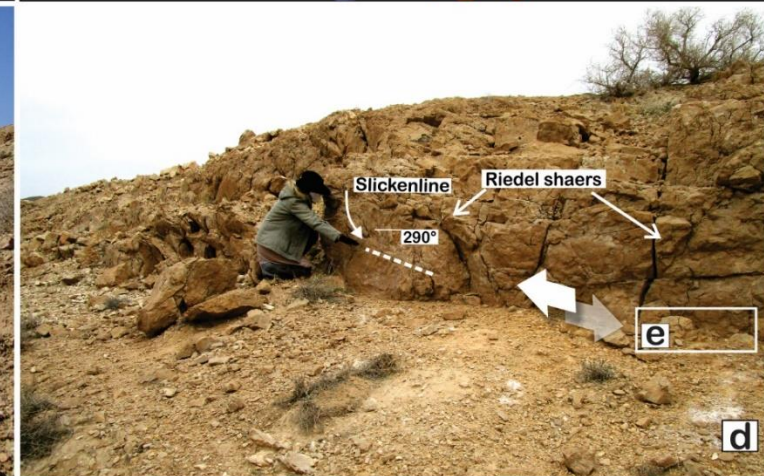
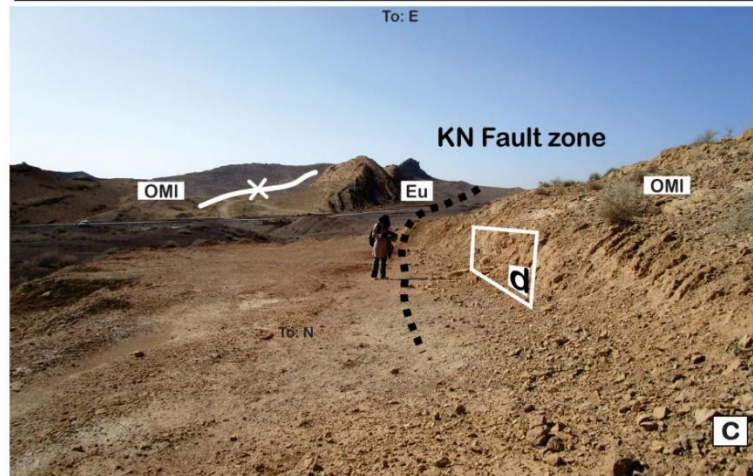
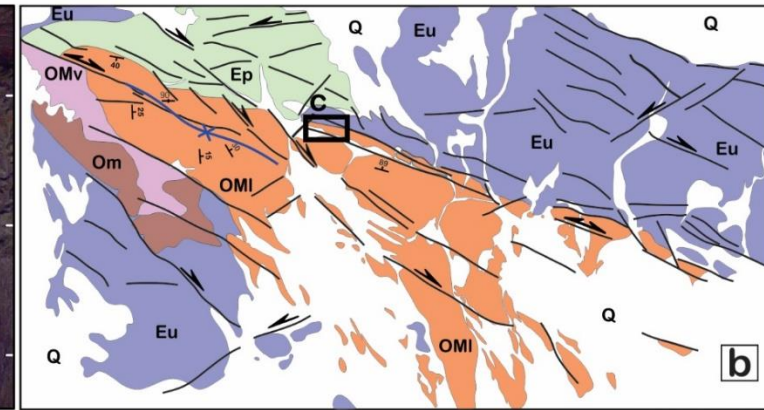
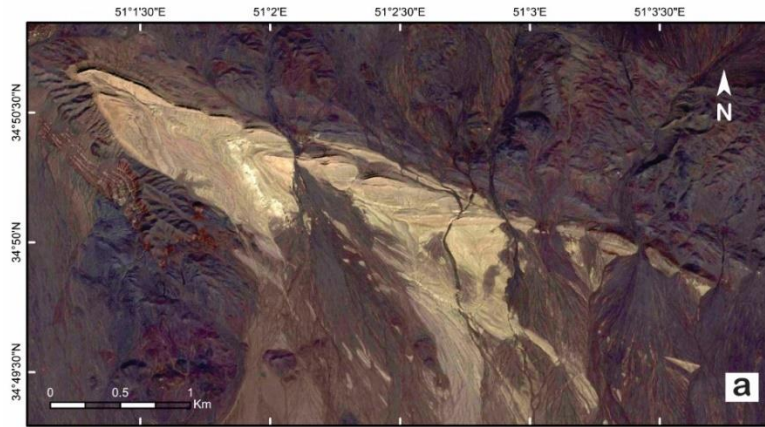
Structural
analysis



fault data
classification



Dextral
motion
structural
evidence



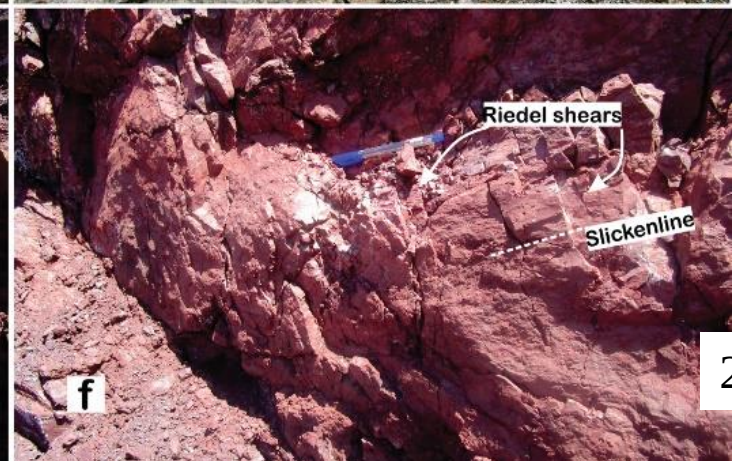
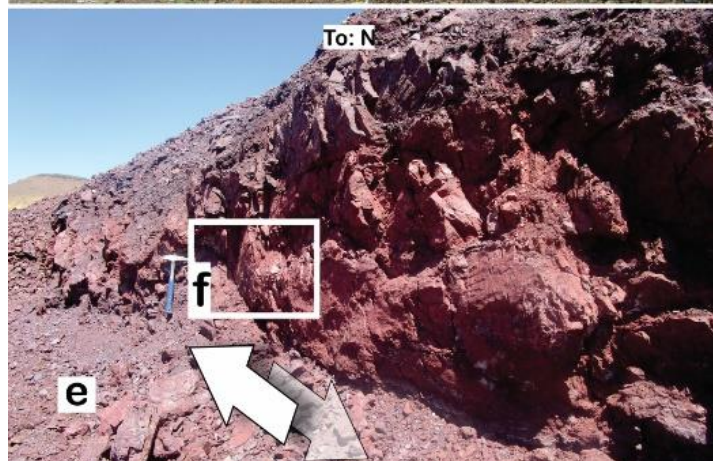
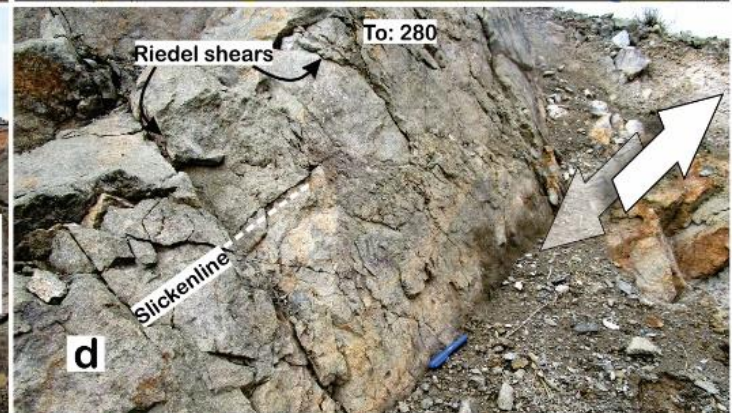
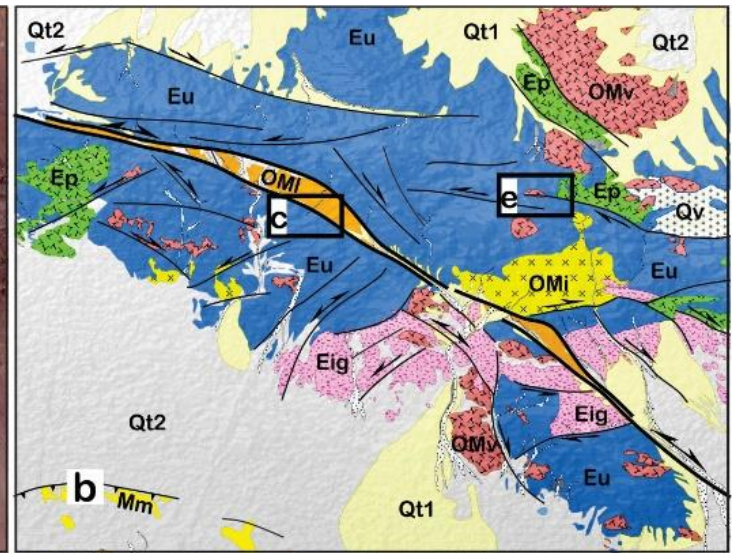
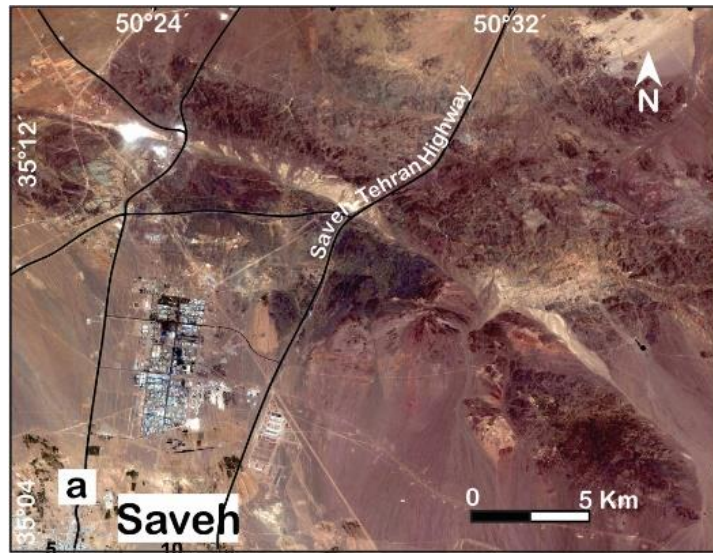
Structural analysis



fault data classification



Dextral motion structural evidence



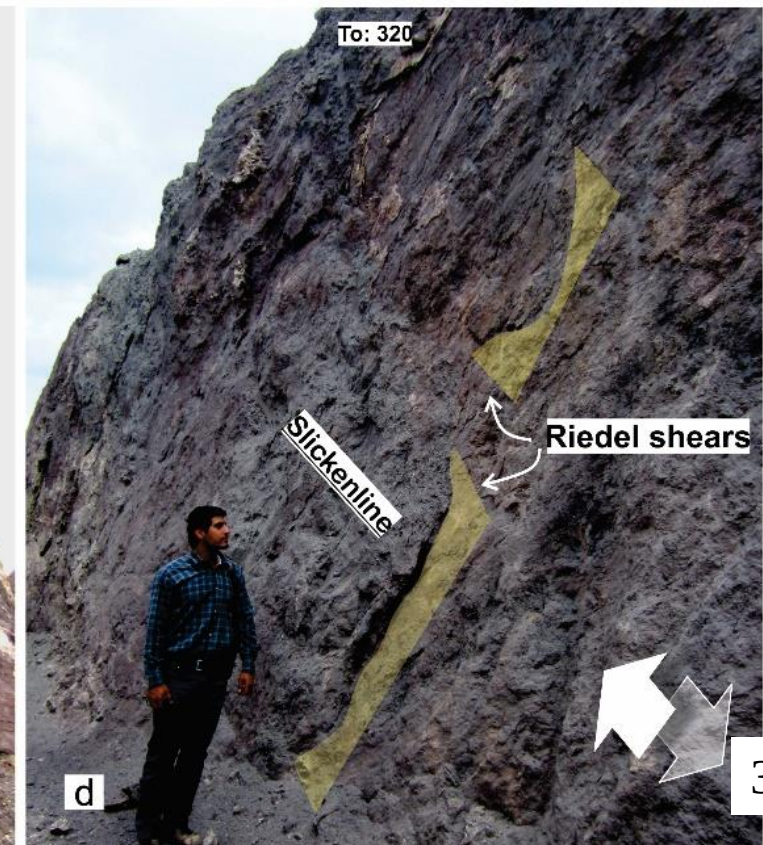
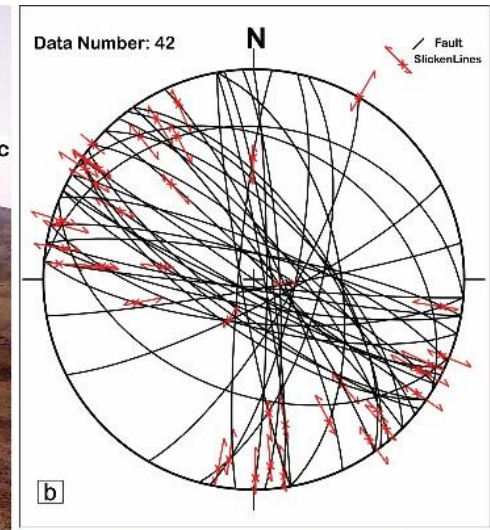
Structural analysis



fault data classification



Dextral motion structural evidence



Structural
analysis



fault data

classification

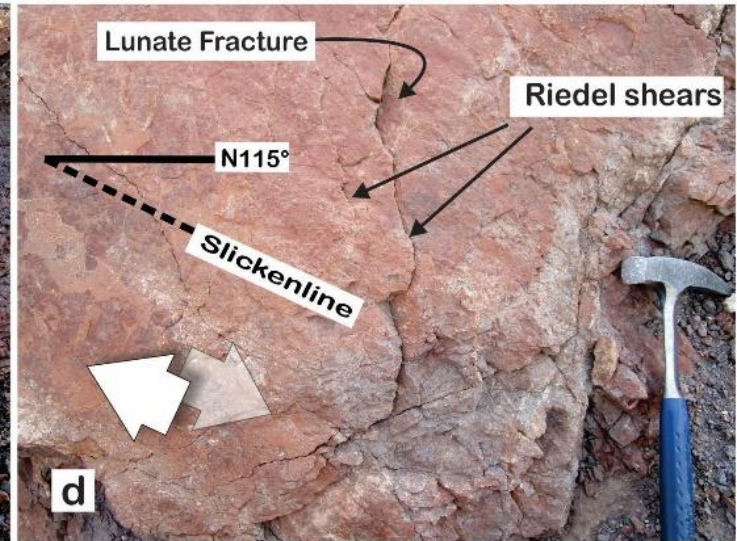
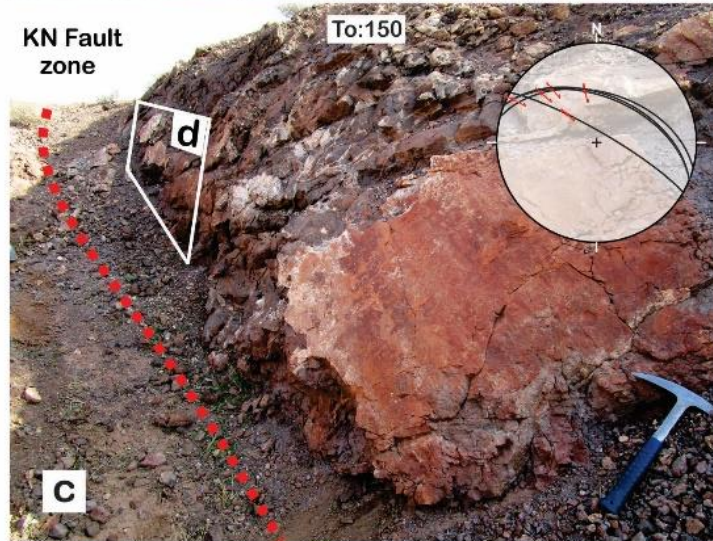
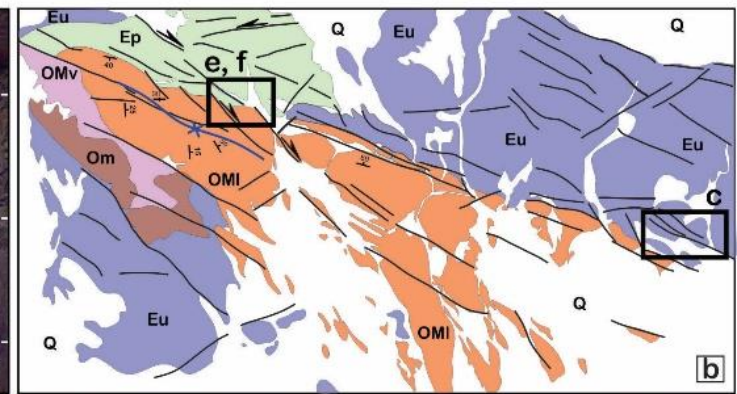


Dextral
transpression

structural
evidence



Eastern part



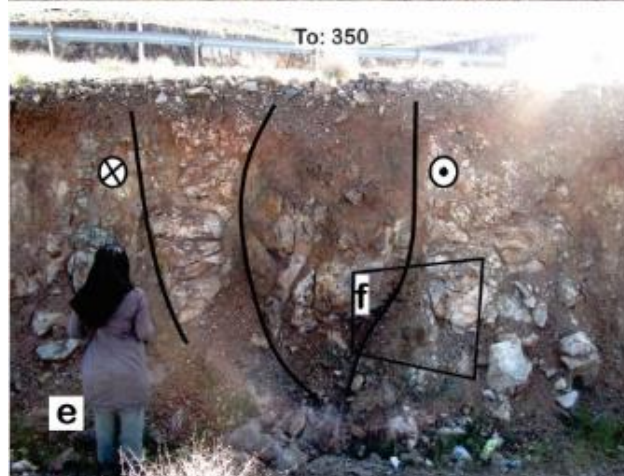
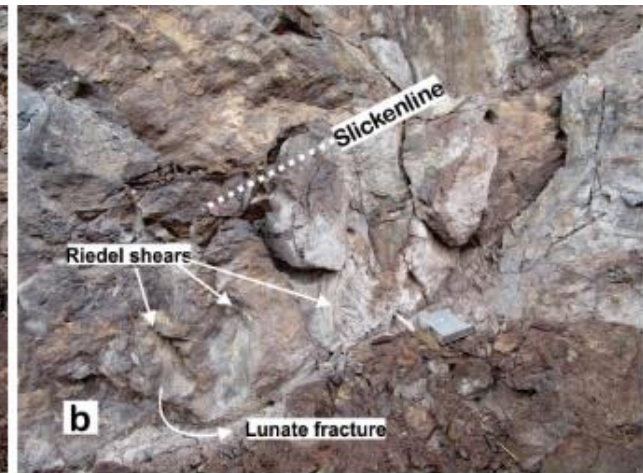
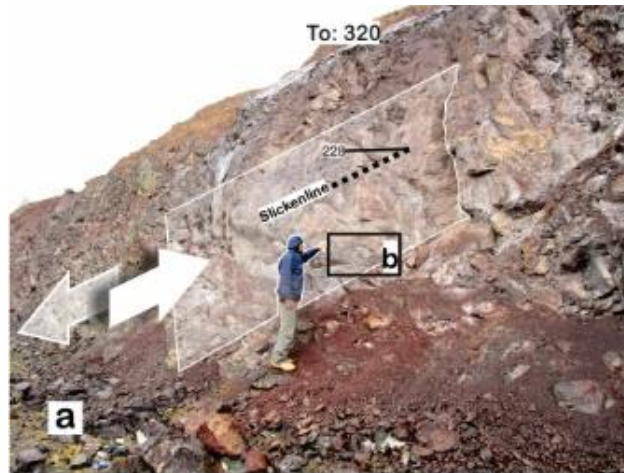
Structural
analysis



fault data
classification



Dextral
transpression
structural
evidence



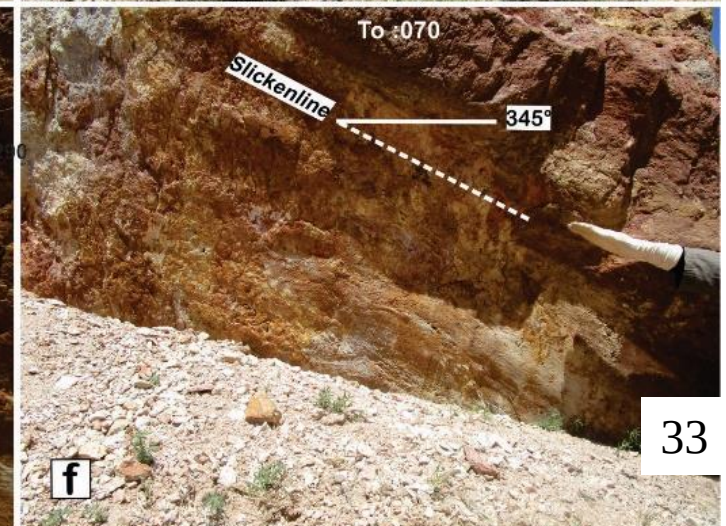
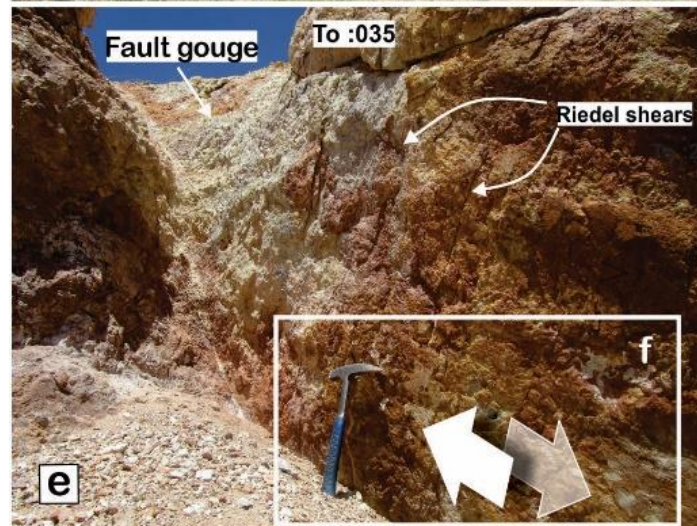
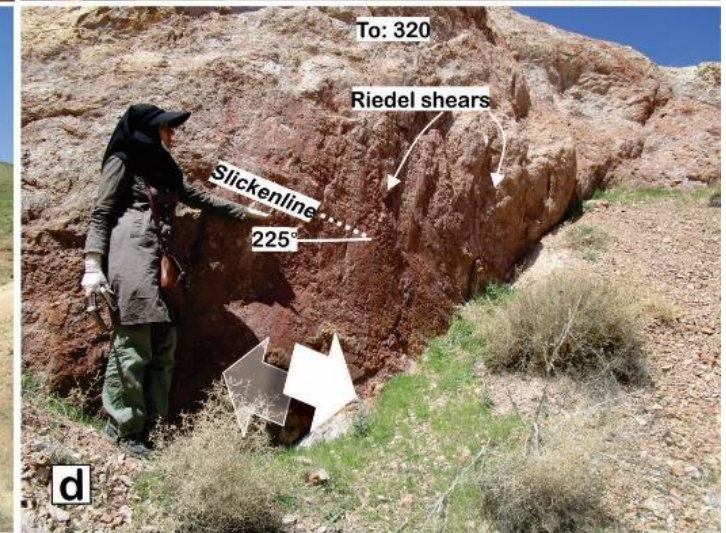
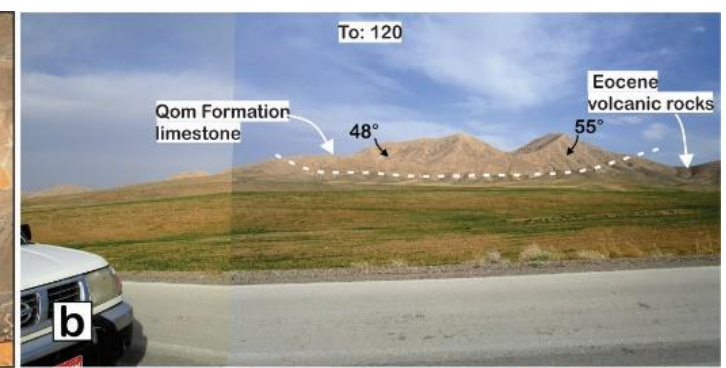
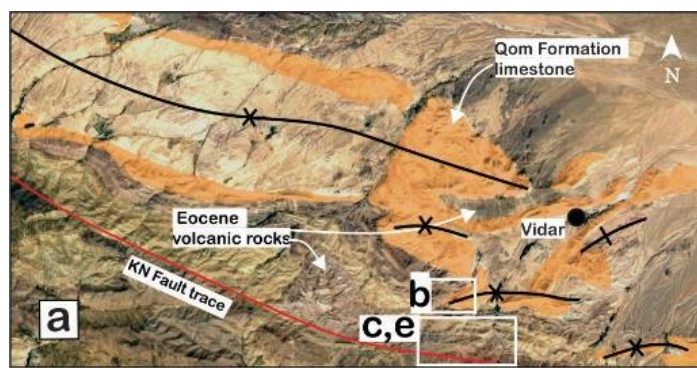
Structural analysis



fault data classification



Dextral transpression structural evidence



Structural
analysis

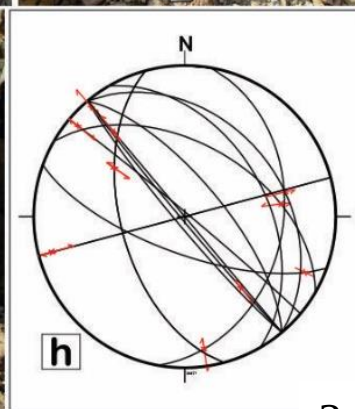
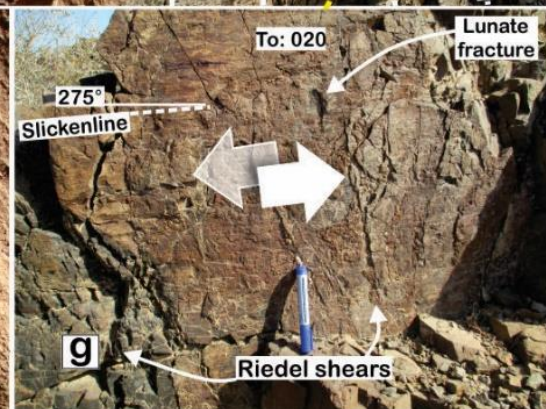
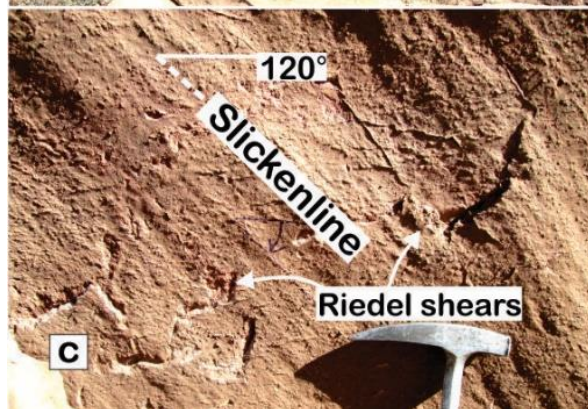
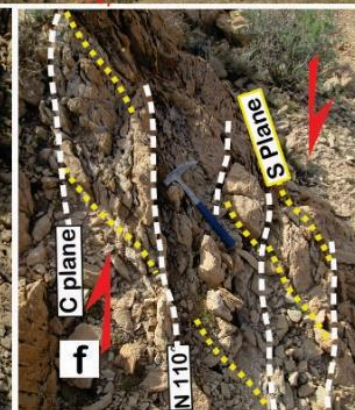
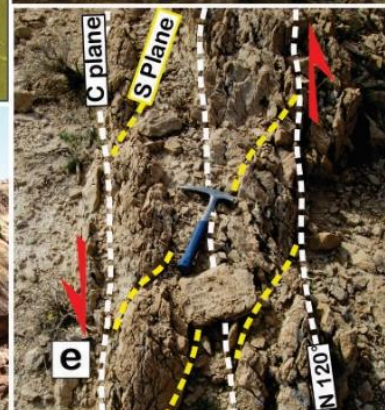
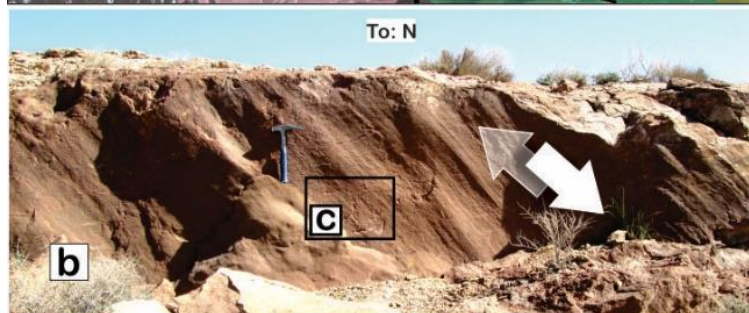
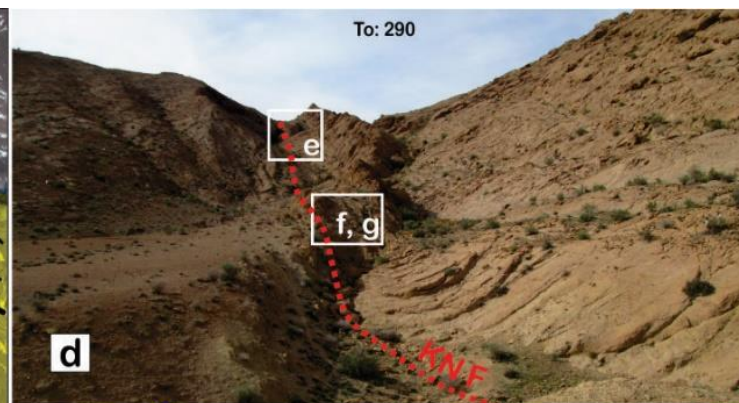
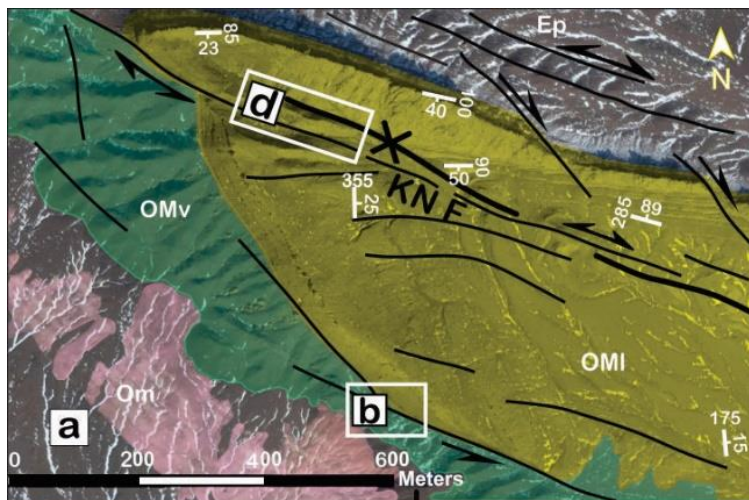


fault data
classification

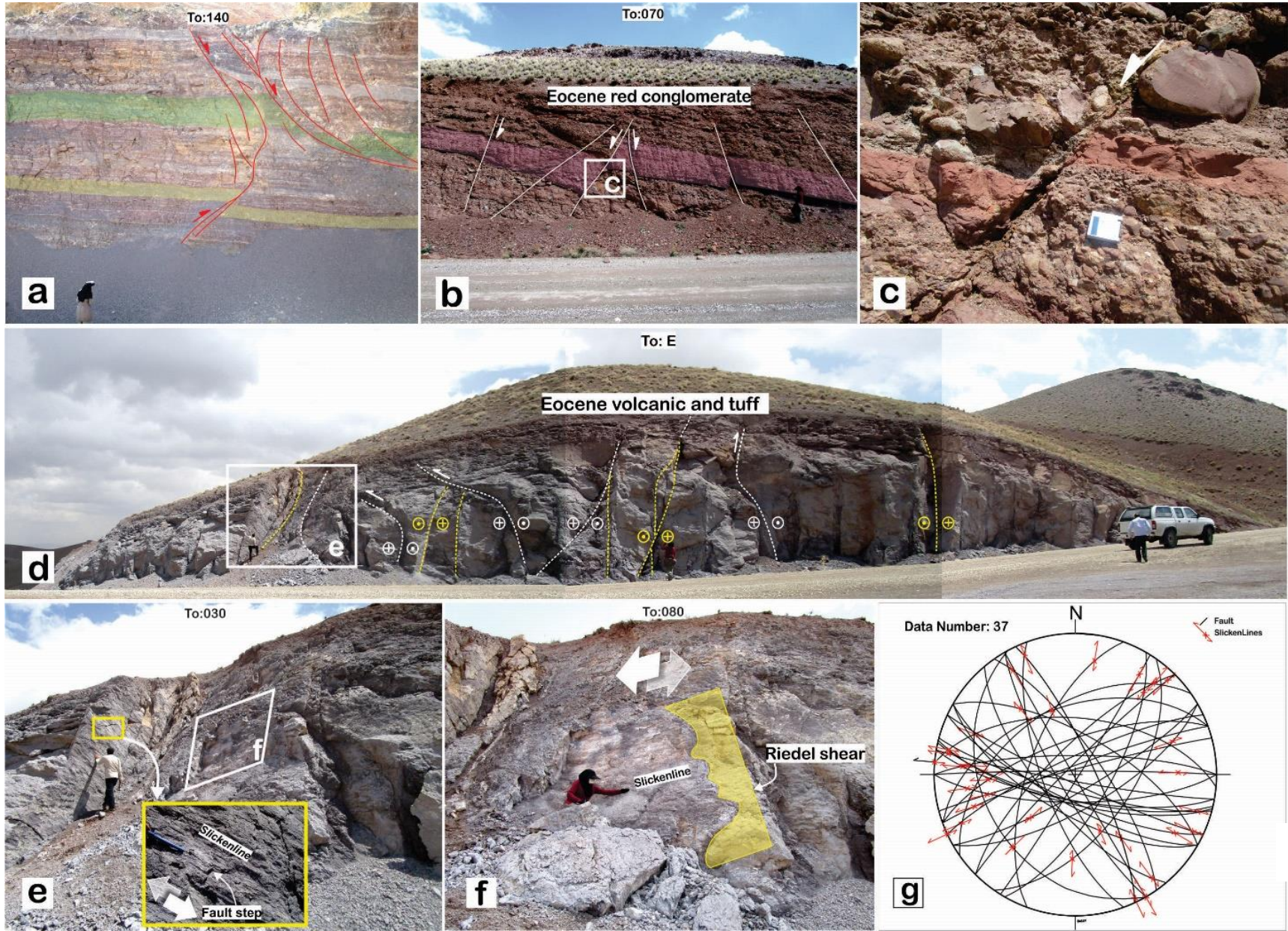


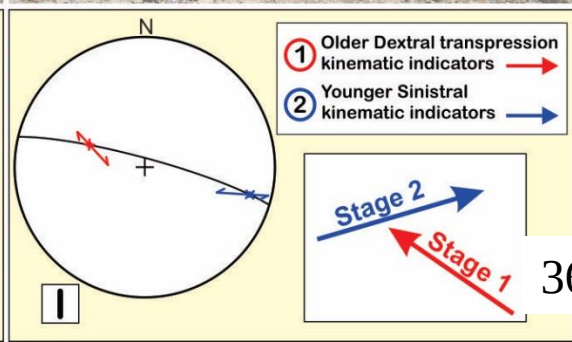
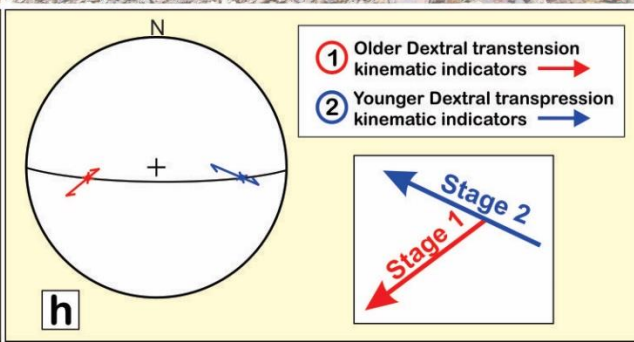
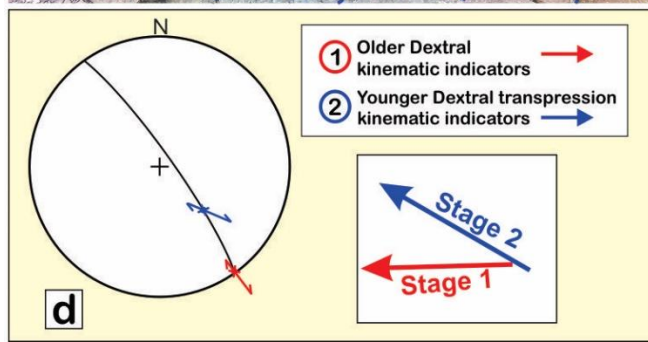
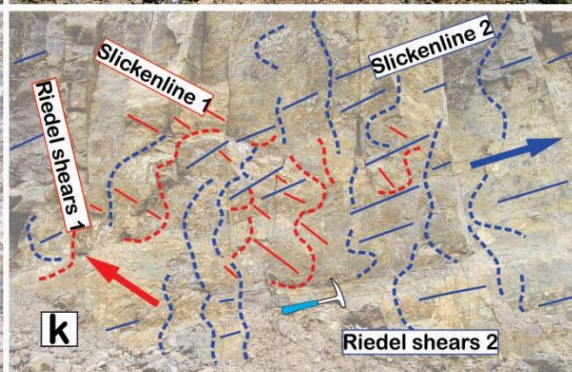
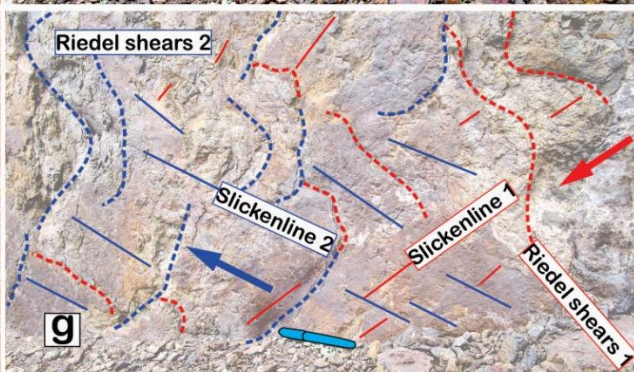
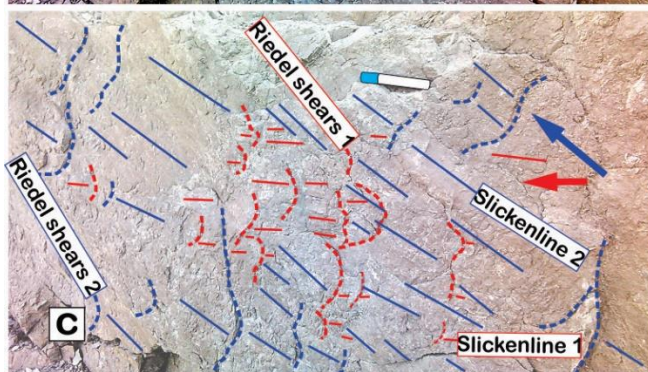
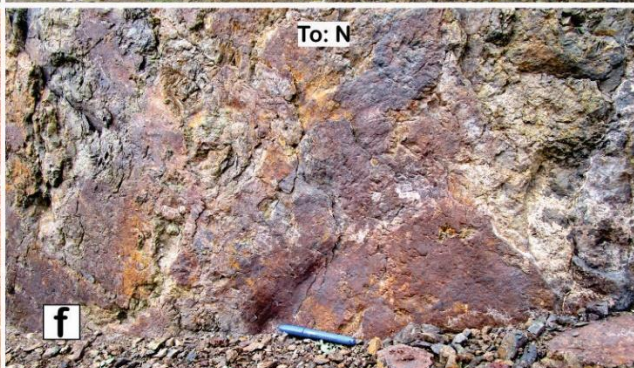
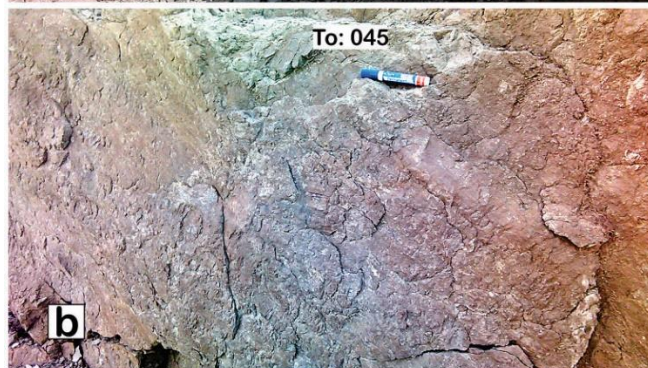
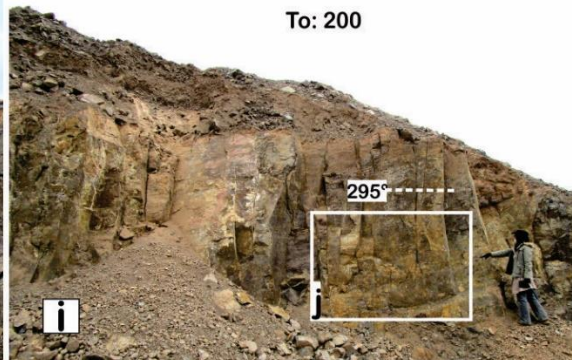
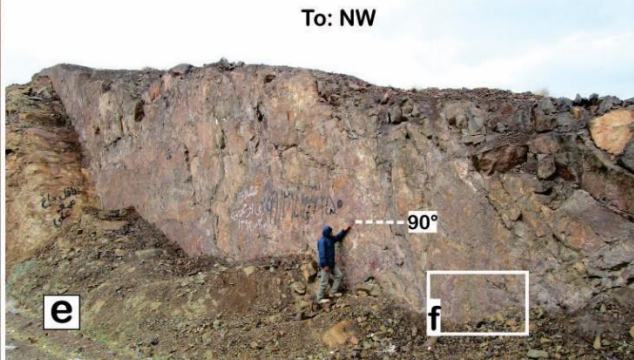
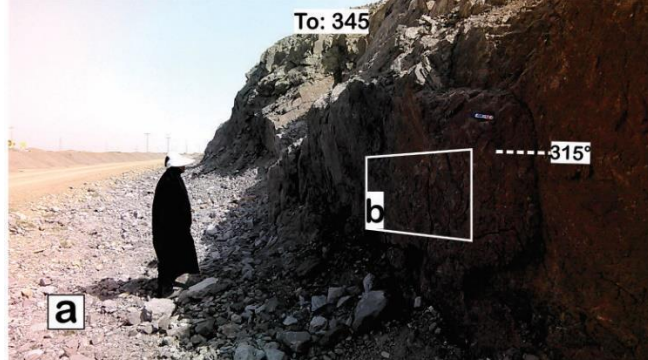
Sinistral
motion

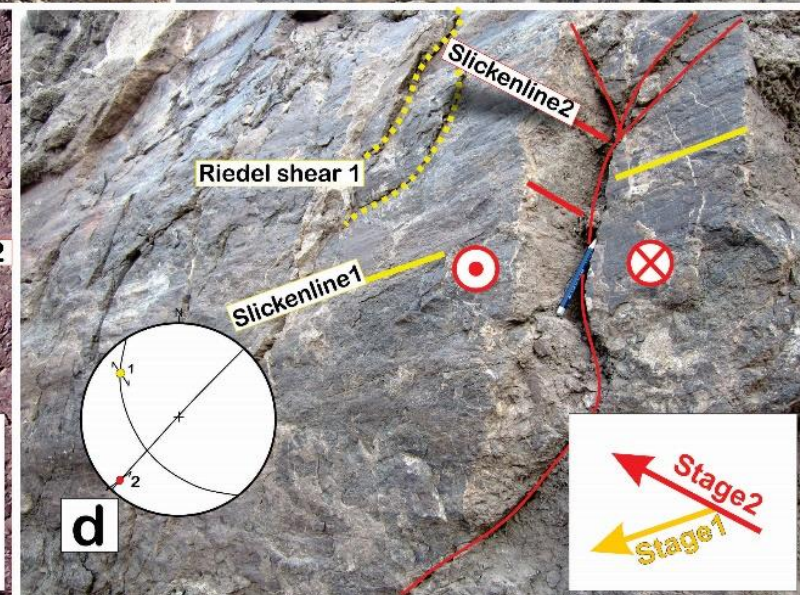
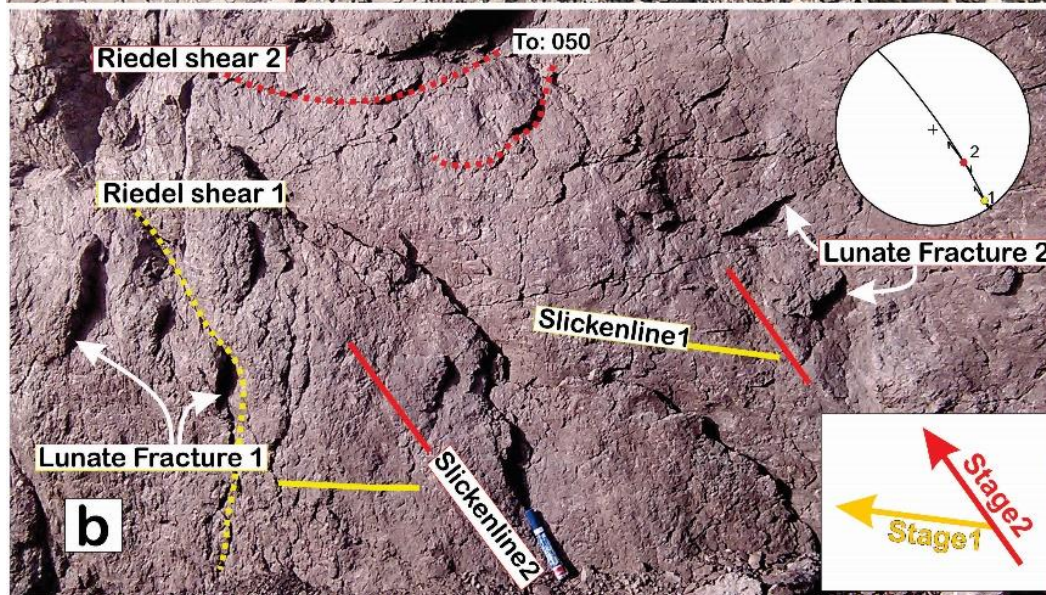
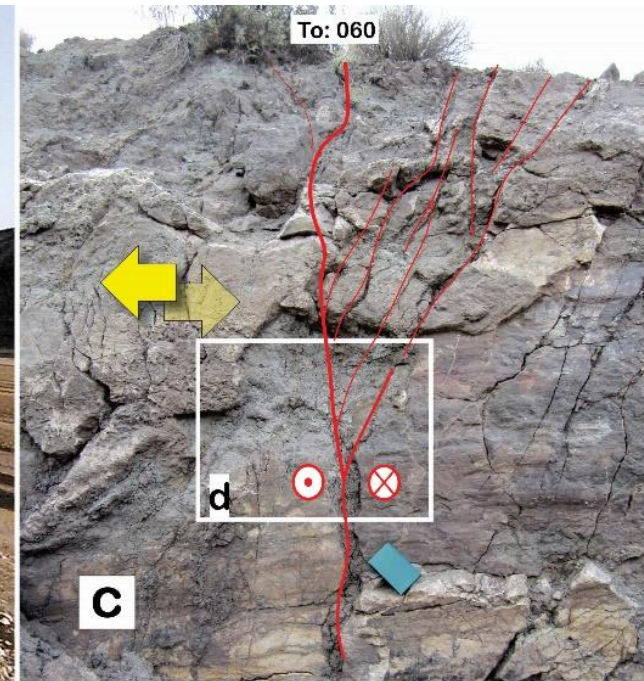
structural
evidence

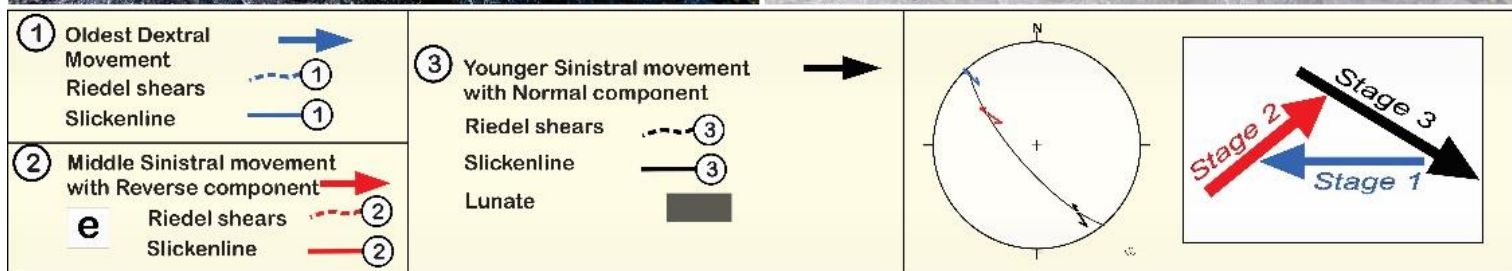
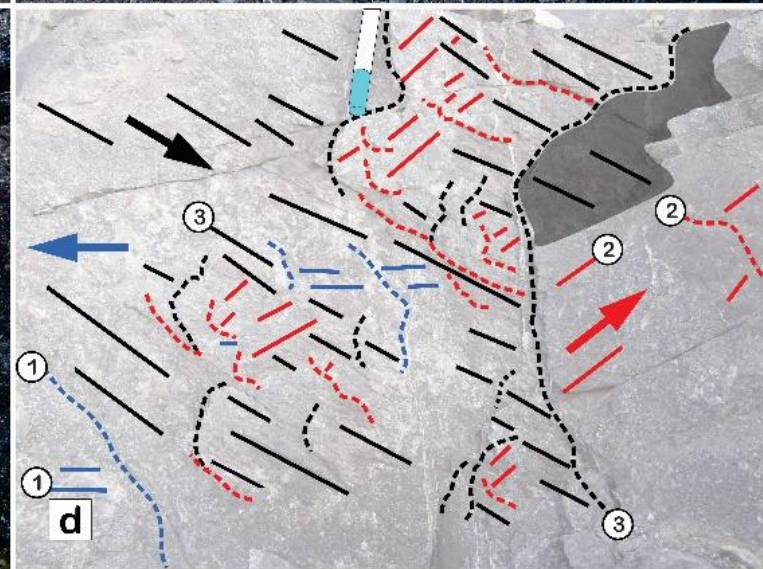
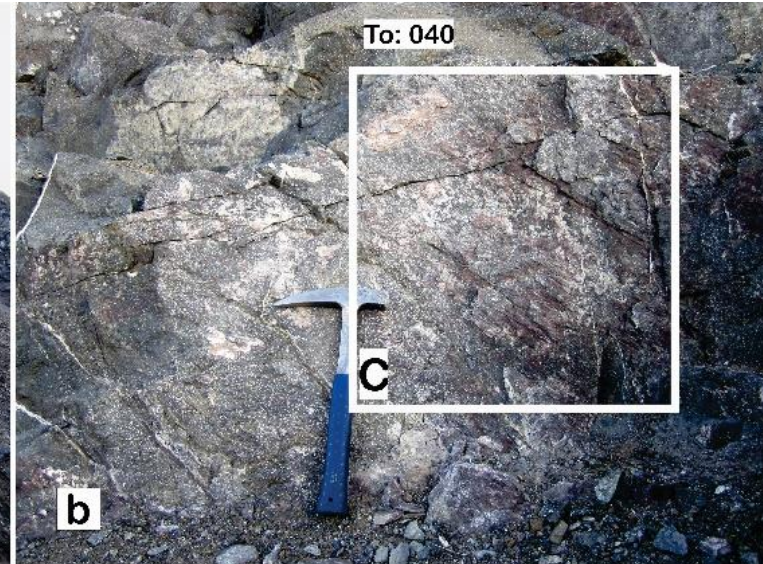
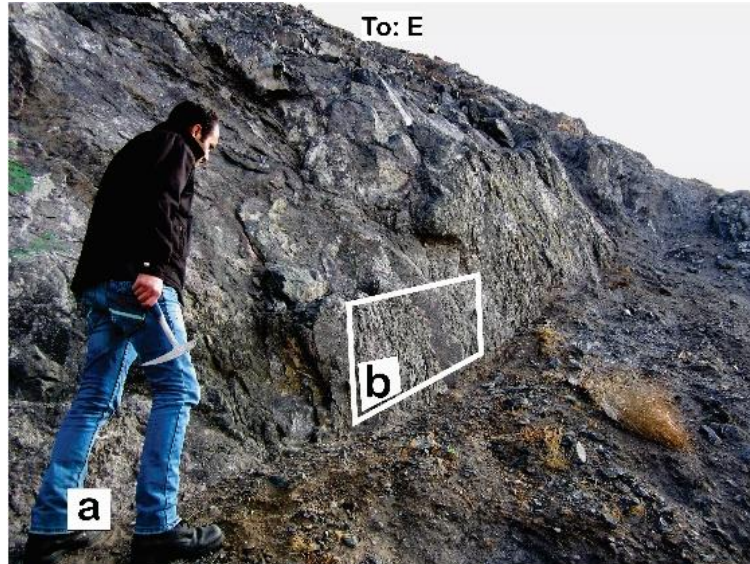


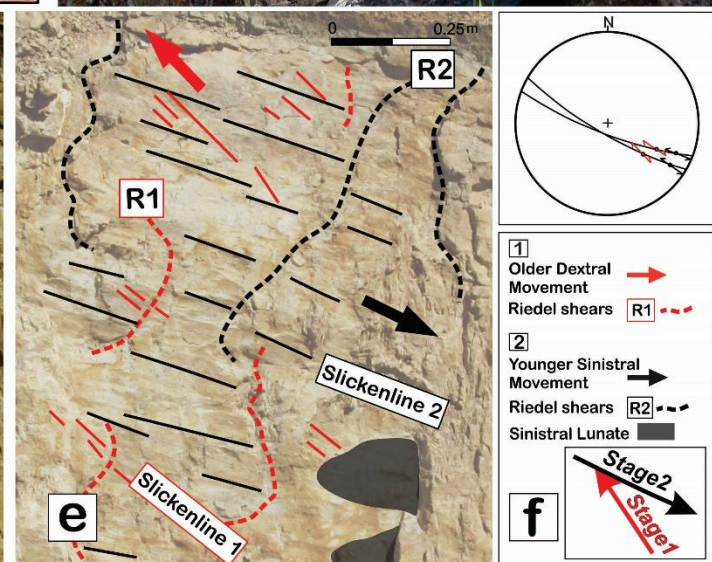
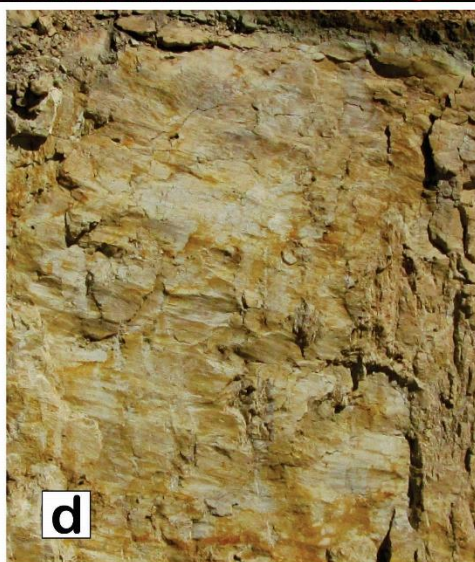
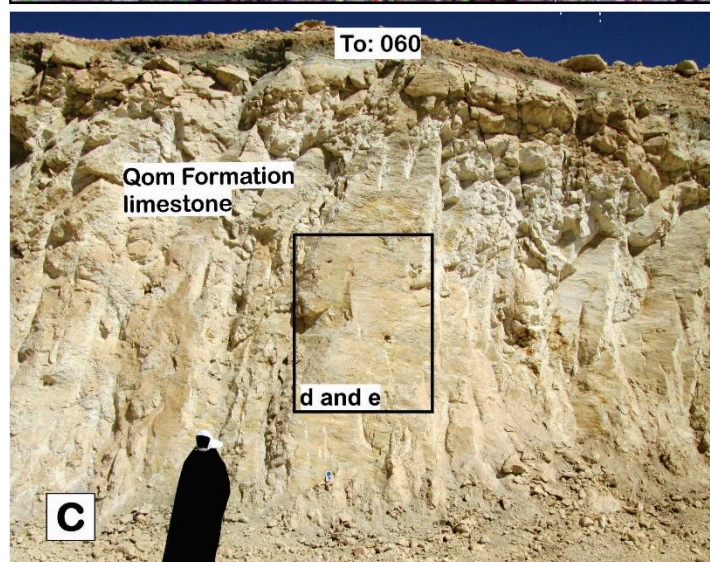
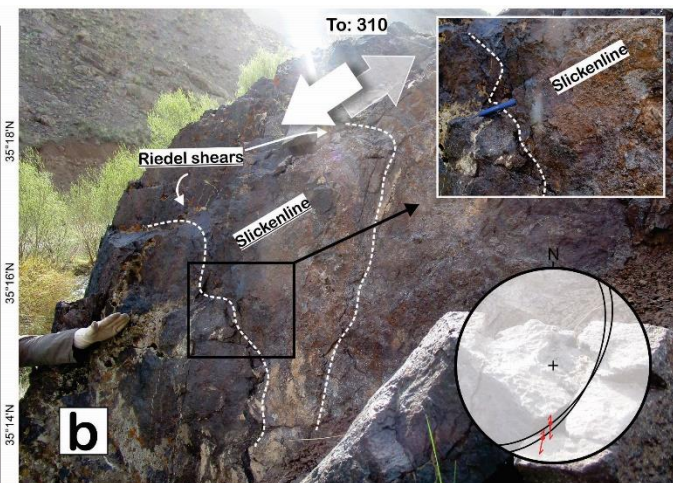
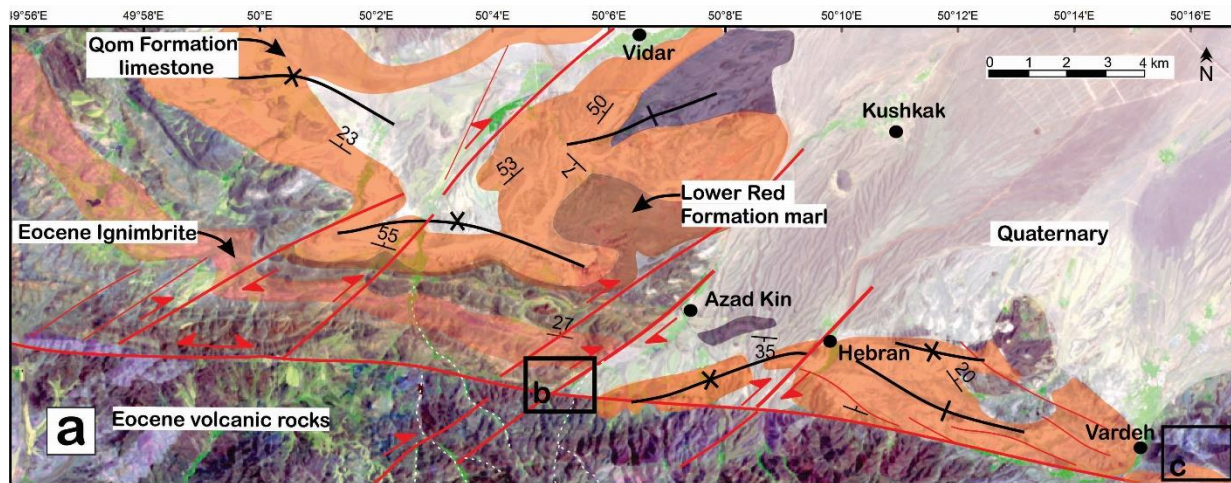
Structural analysis ➡ fault data classification
 ➡ **Sinistral motion** structural evidence

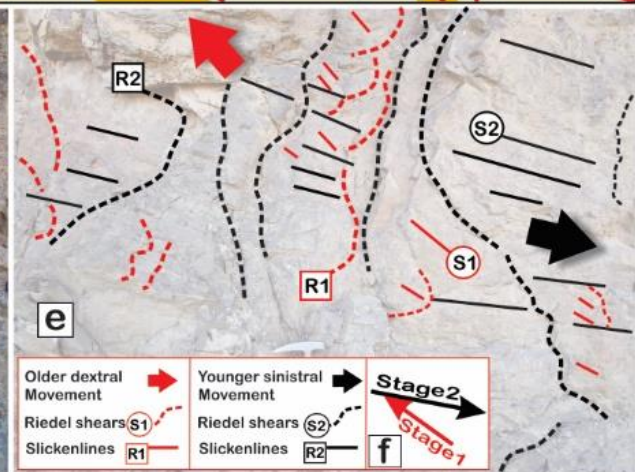
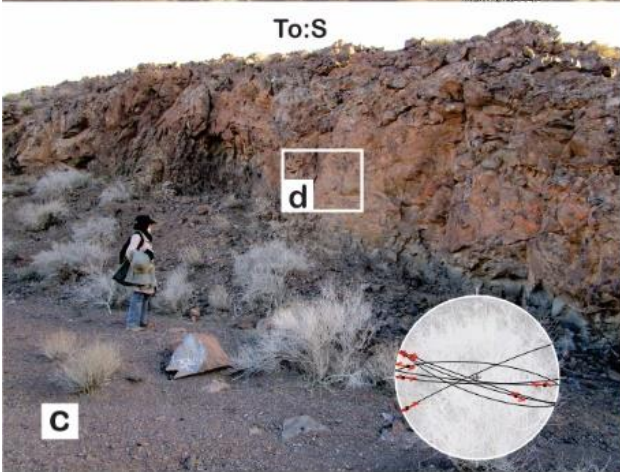
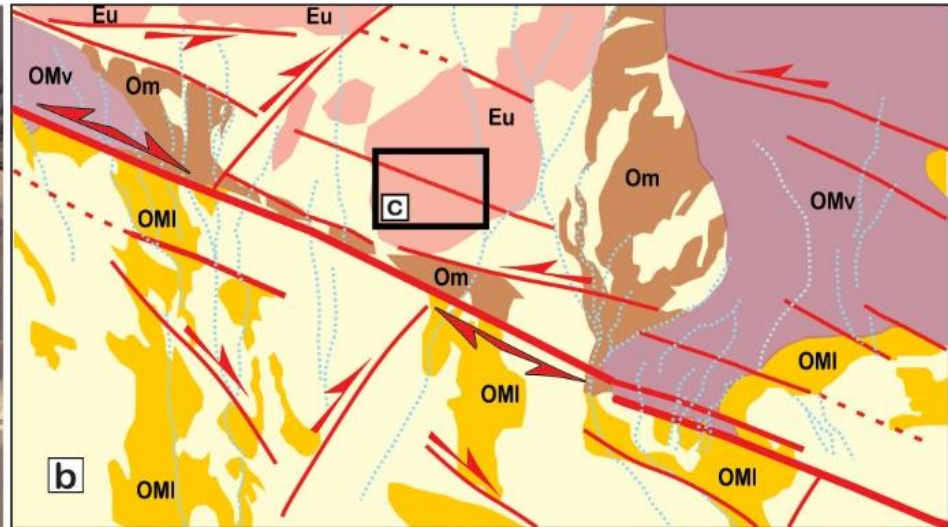
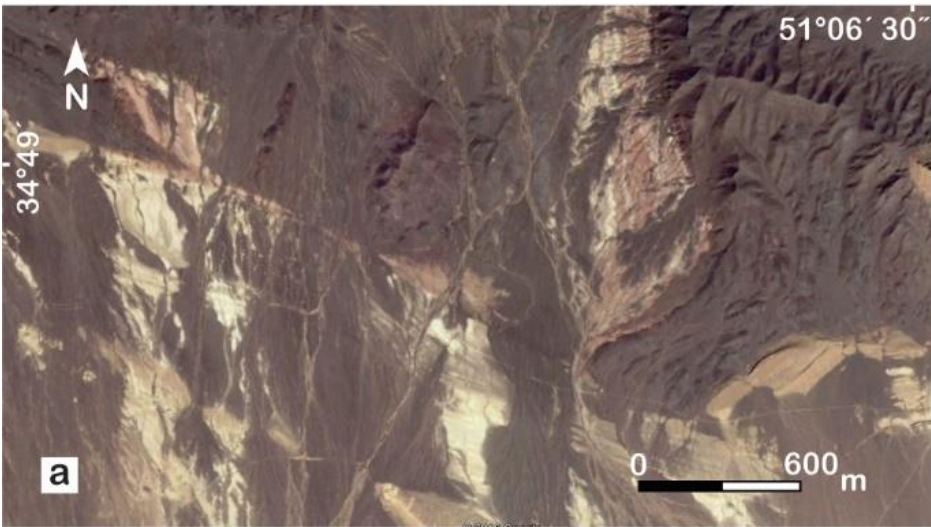


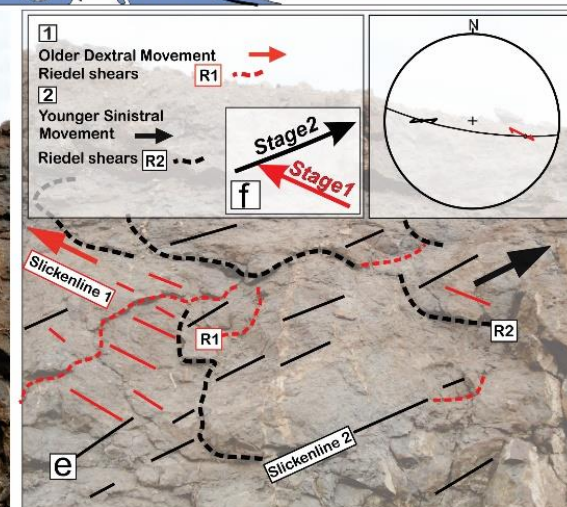
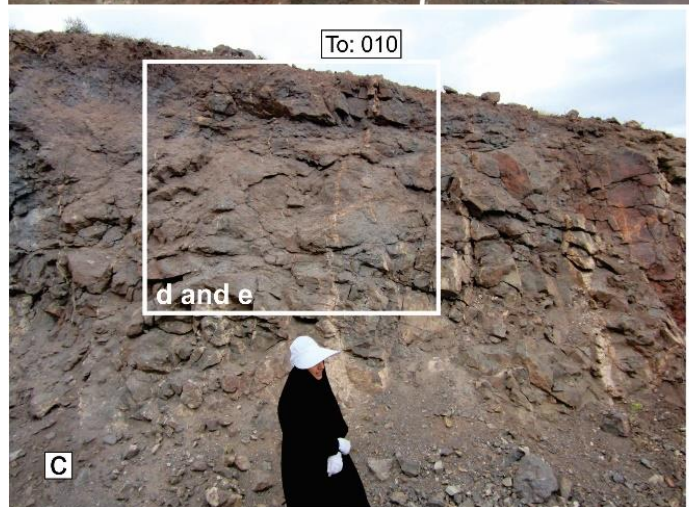
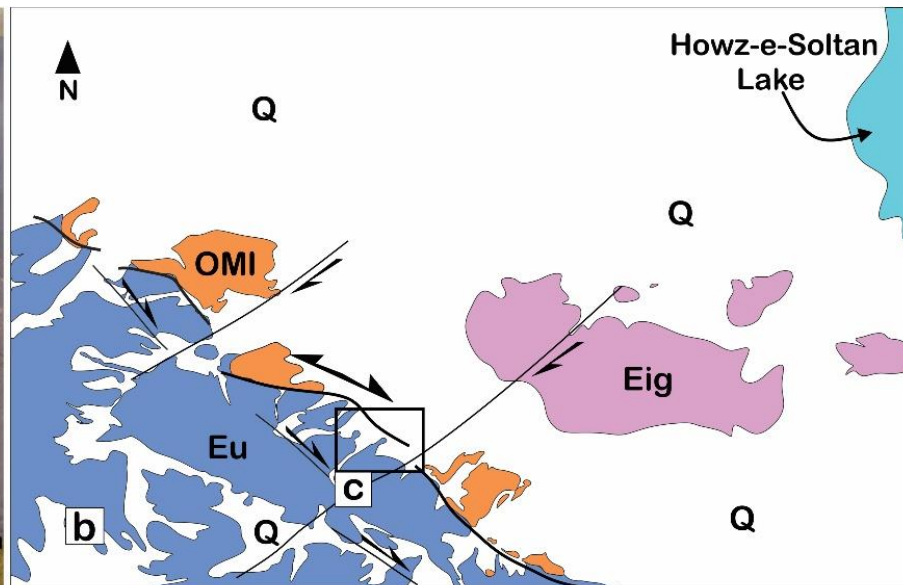
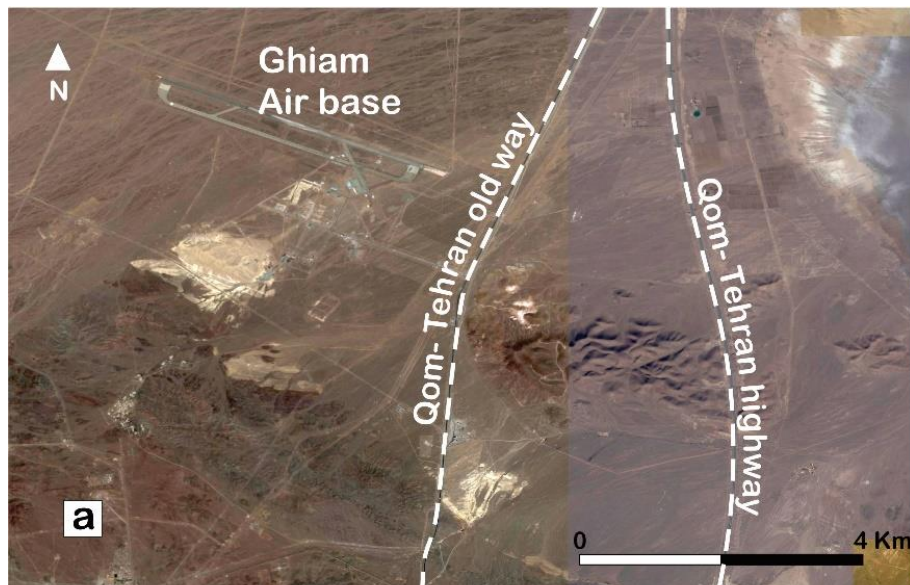












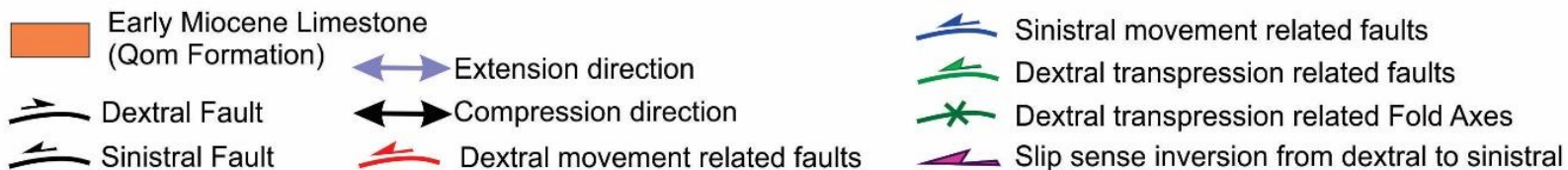
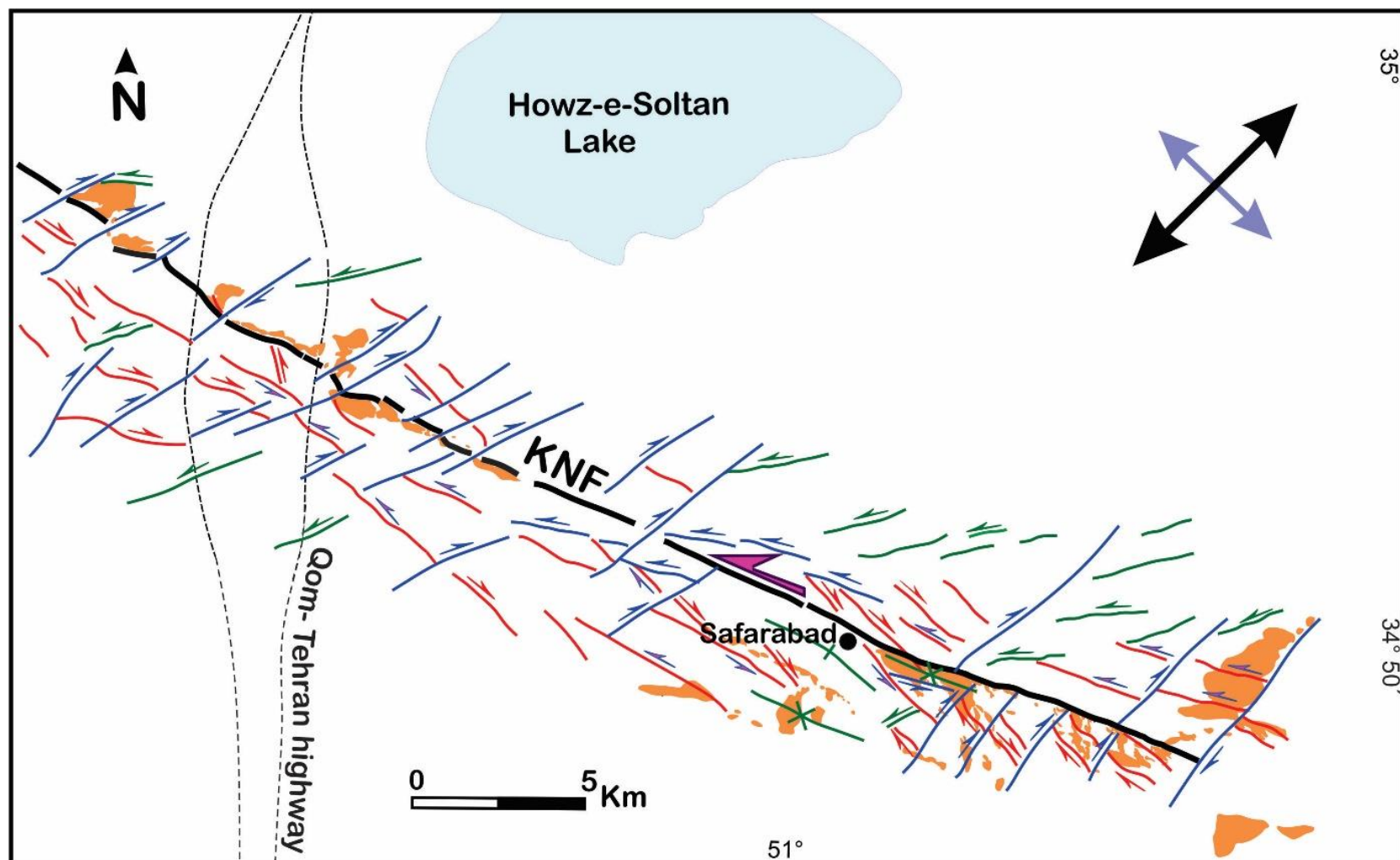
Structural analysis



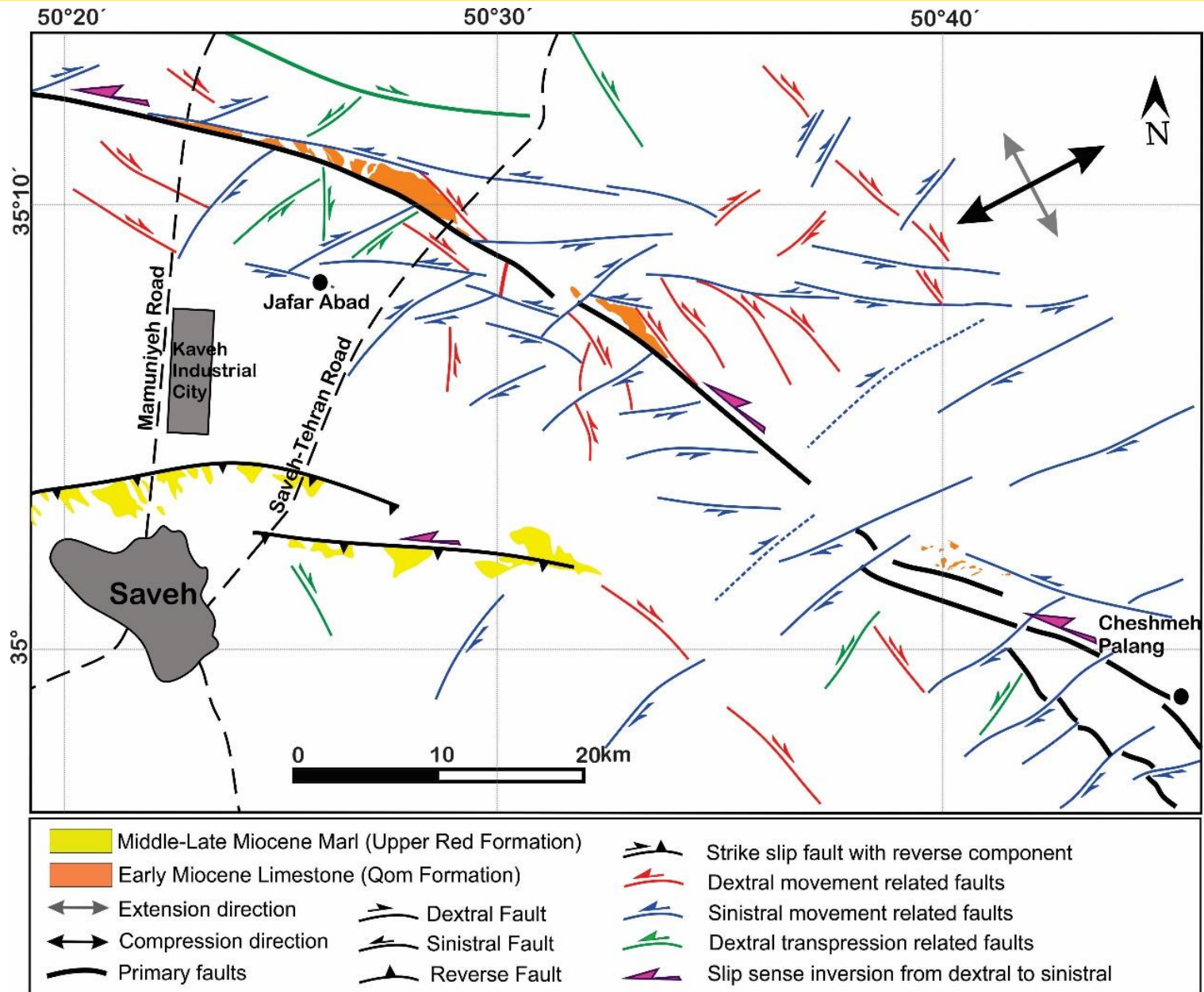
structural evolution map



Eastern part



Structural analysis ➡ structural evolution map ➡ Central part



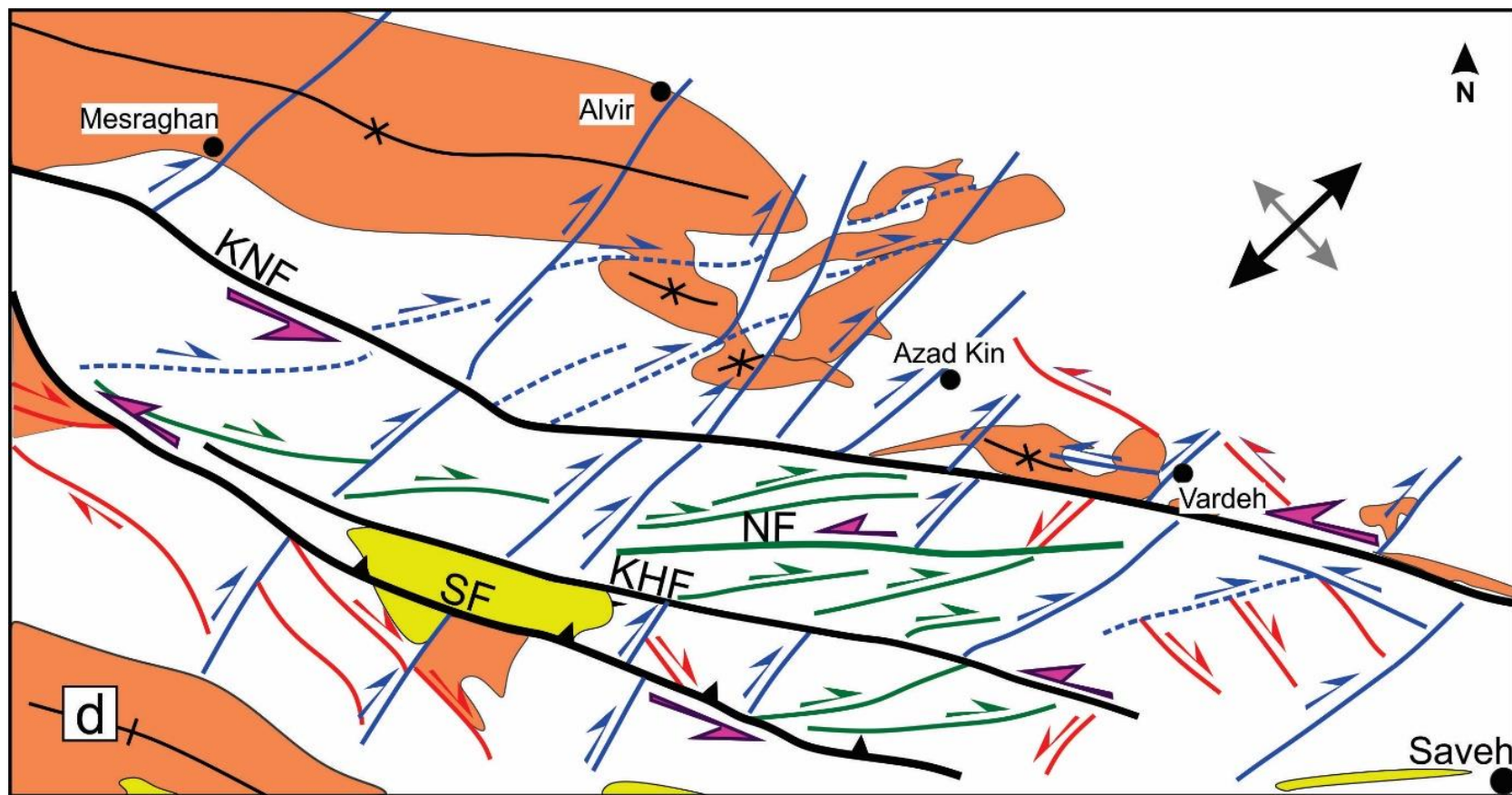
Structural analysis



structural evolution map



Western part

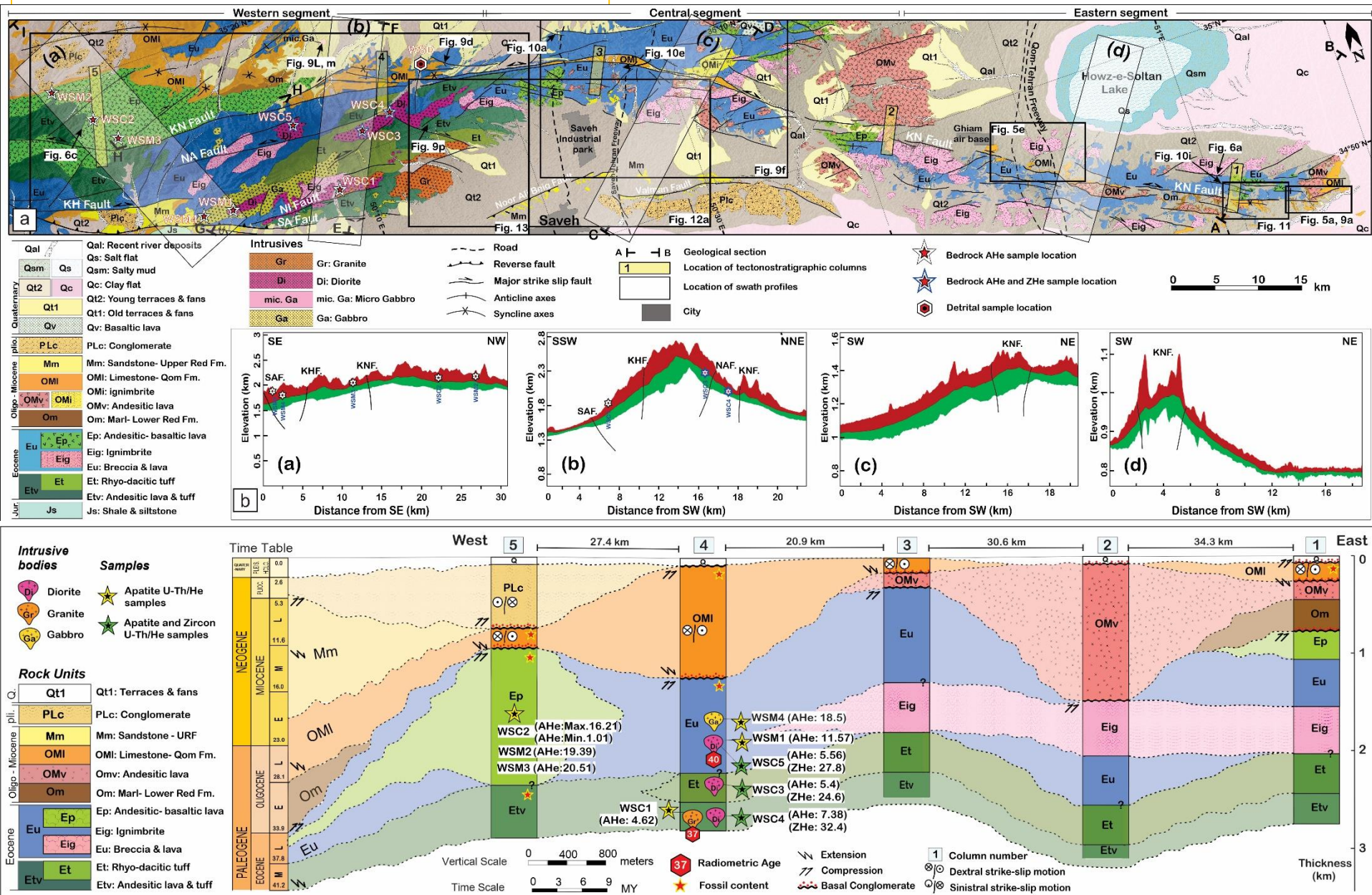


- Early Miocene Limestone (Qom Formation)
- Middle-Late Miocene Marl (Upper Red Formation)
- Dextral Fault
- Sinistral Fault
- Reverse Fault
- Strike slip fault with reverse component
- Normal Fault
- Inverted normal fault
- Primary faults

- Dextral movement related faults
- Sinistral movement related faults
- Dextral transpression related faults
- Dextral transpression related Fold Axes
- Slip sense inversion from dextral to sinistral
- Extension direction
- Compression direction

0 10 20km

Tectonostratigraphic specifications



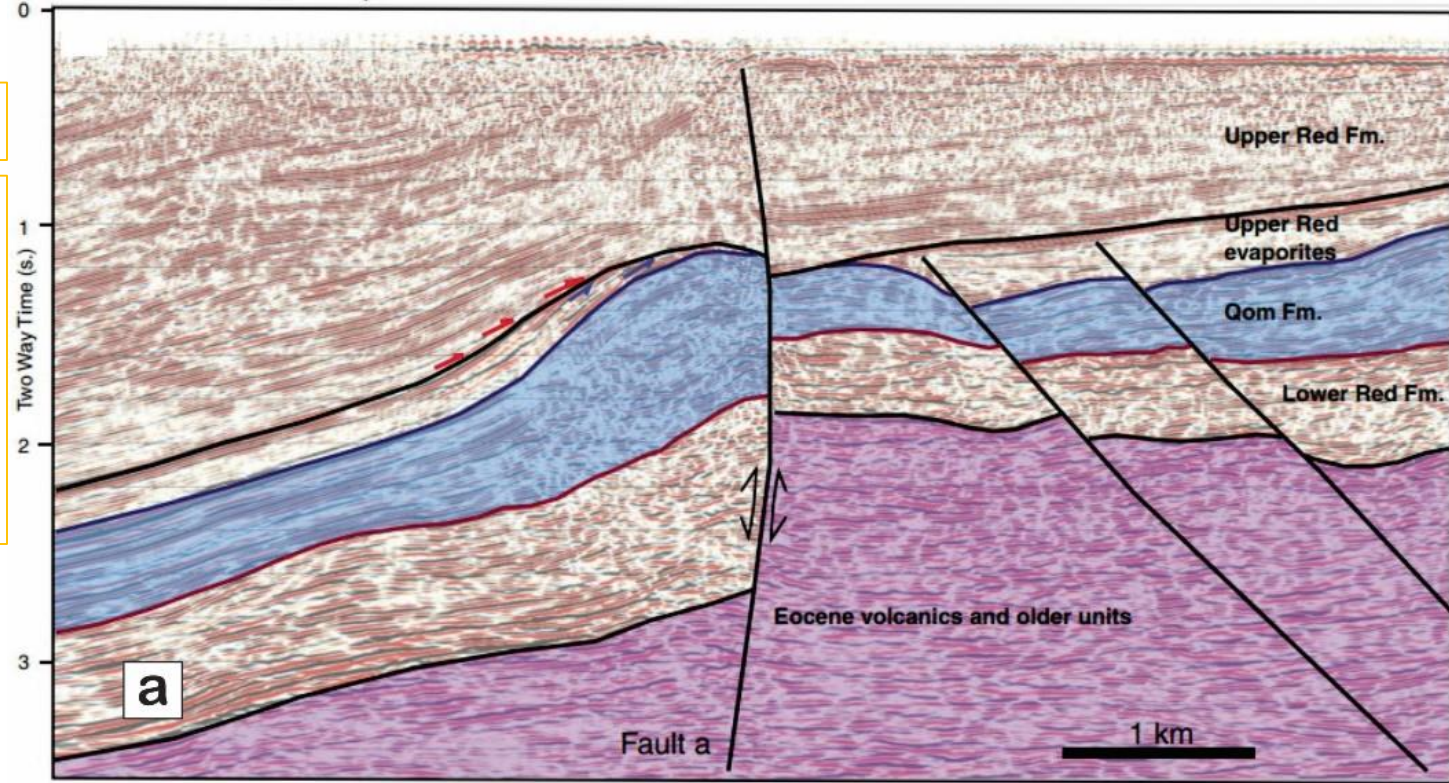
- **Five unconformities:**

1. Eocene
2. Early Oligocene
3. Late Oligocene–early Miocene
4. Middle-late Miocene
5. Late Miocene–early Pliocene

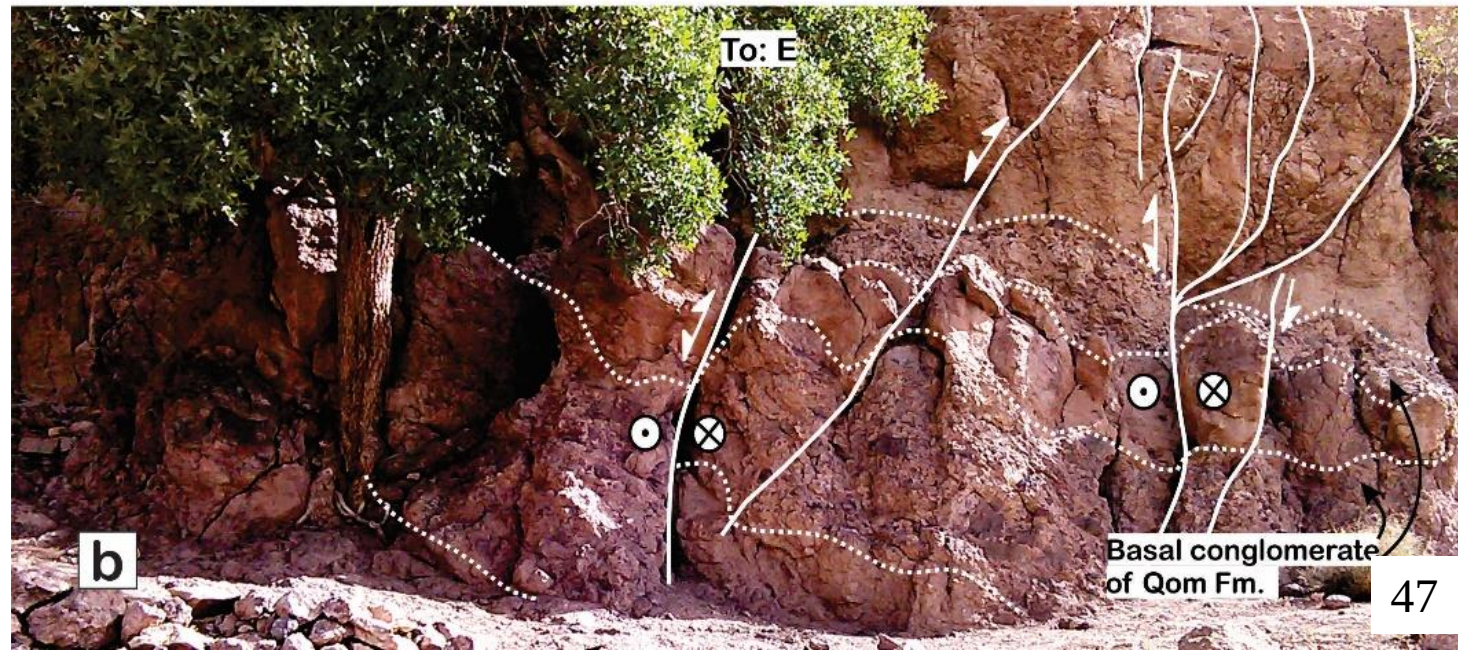
all representing deformation events

Tectonostratigraphy

a) Synsedimentary normal faulting of Qom Fm. and Upper red Fm. (Morley et al., 2009)

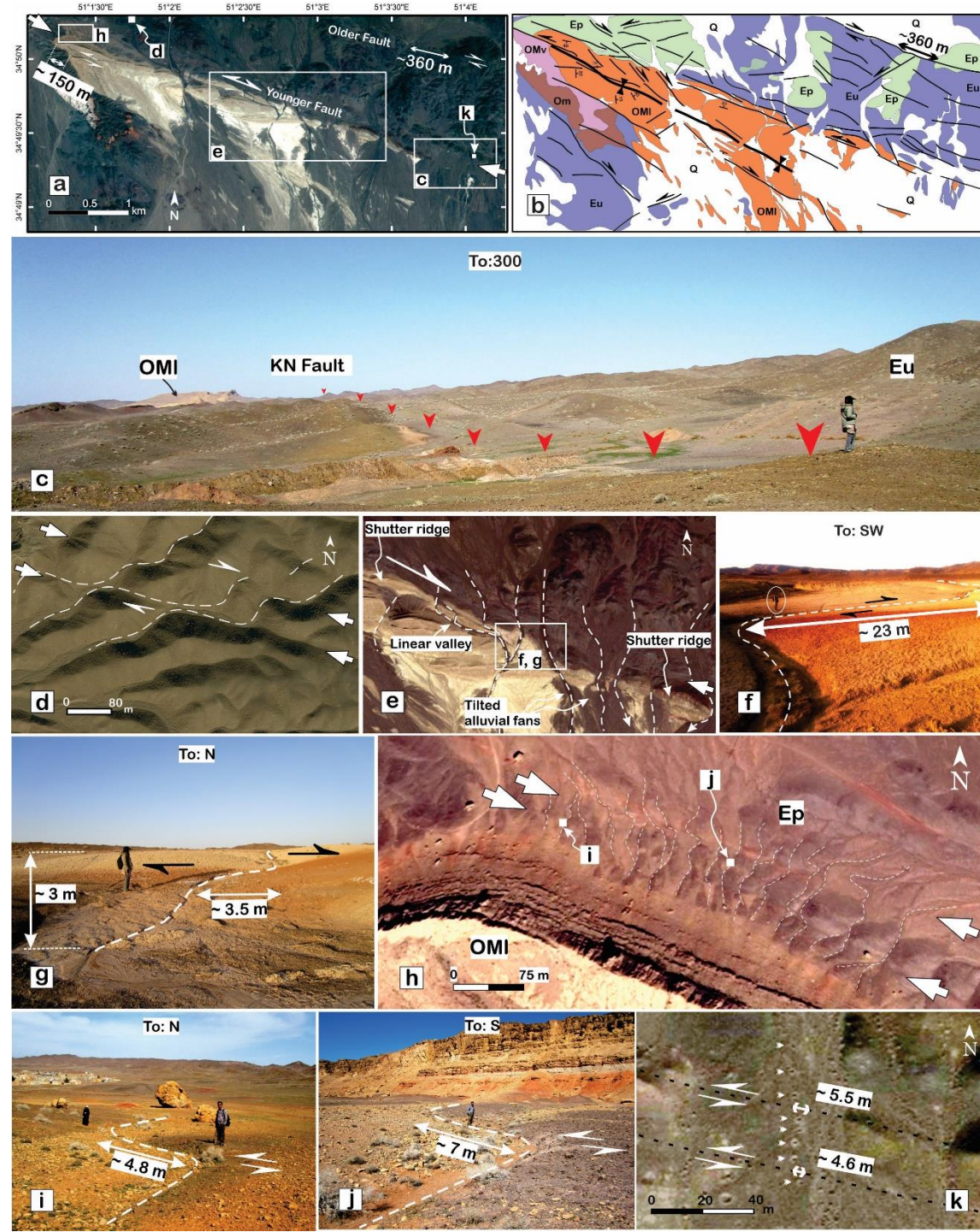


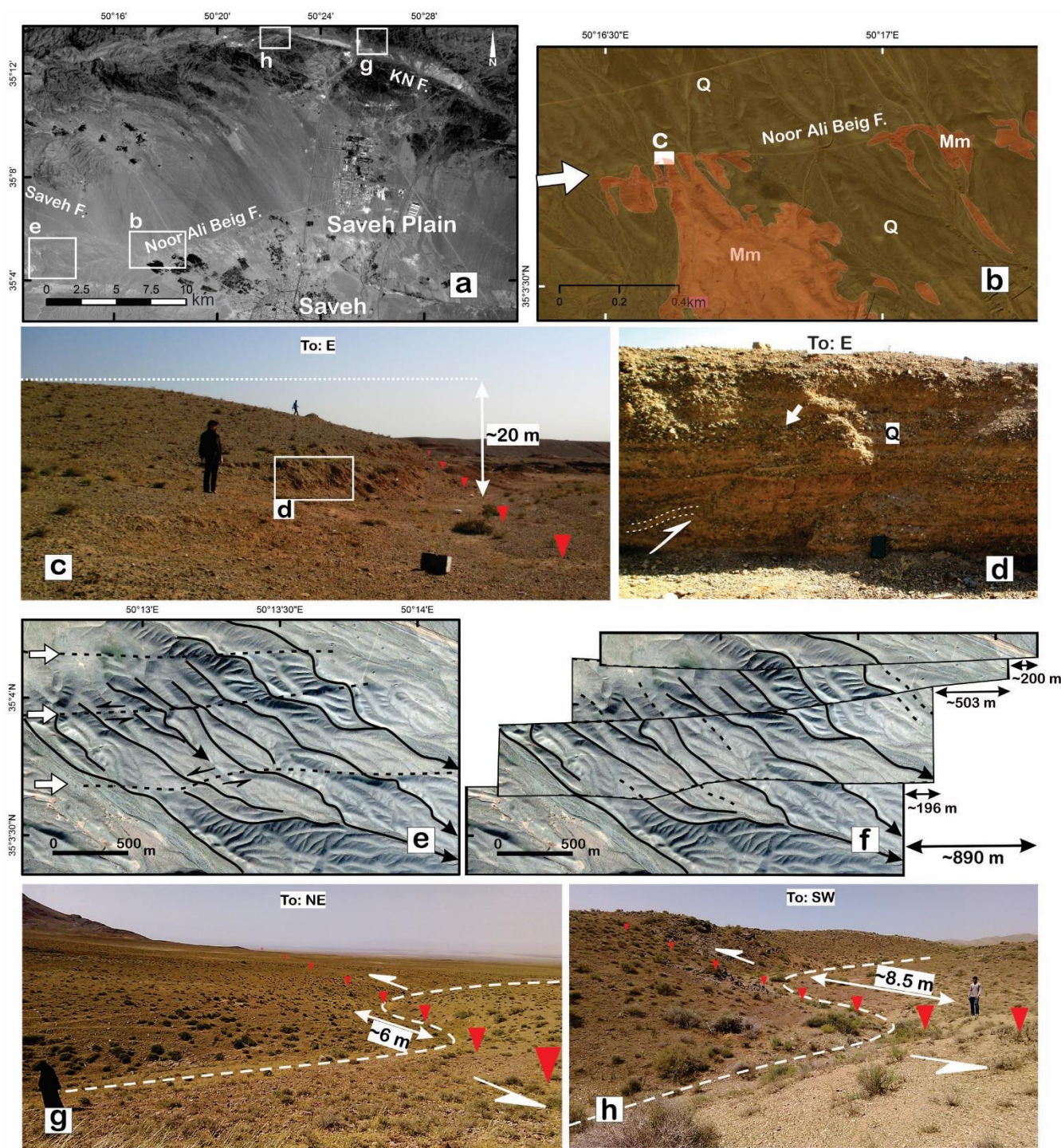
b) Synsedimentary normal faulting in basal conglomerate of Qom Fm.

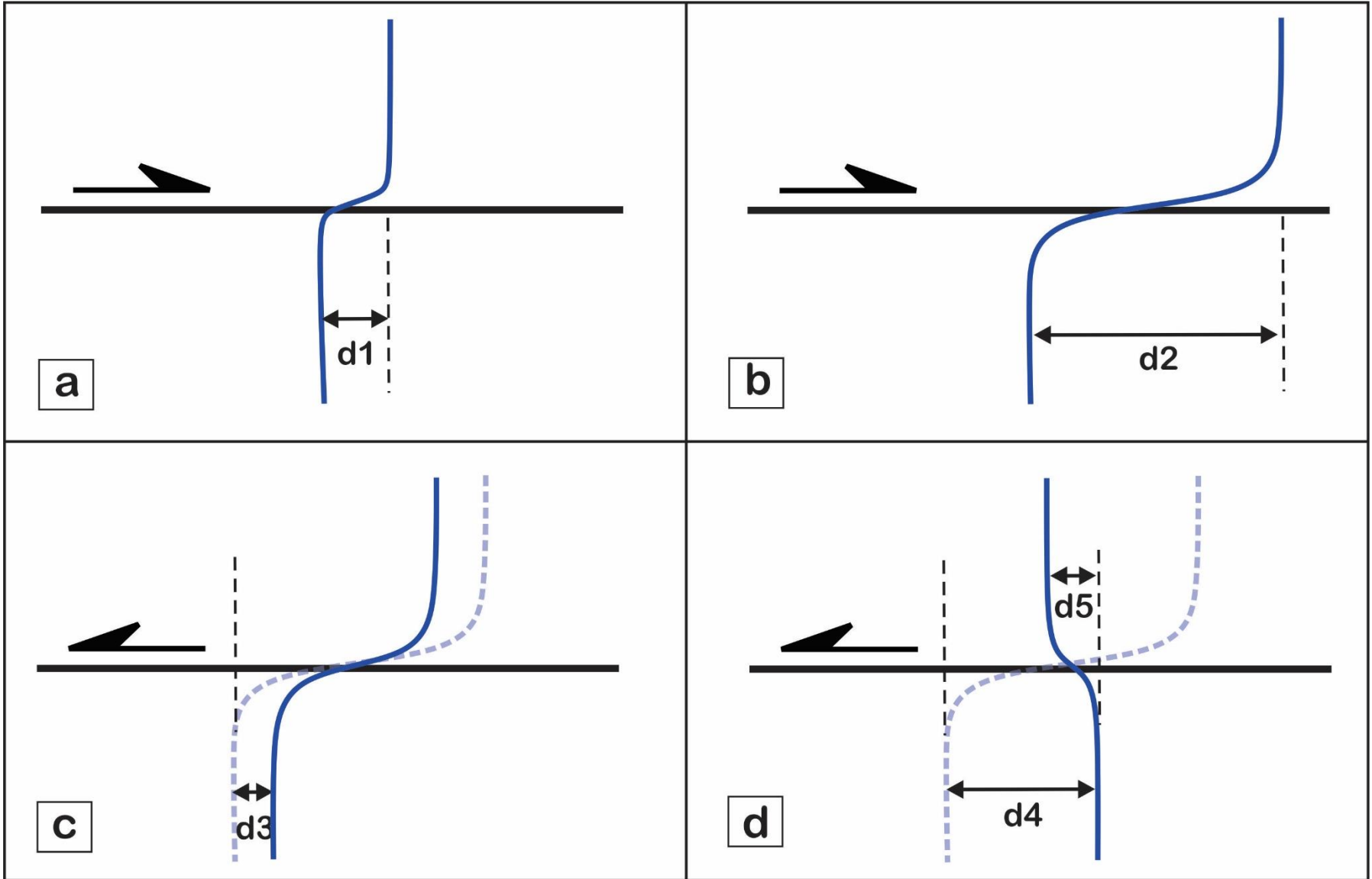


Active tectonic

- **Active faults** definition
- **Morphotectonic** method Can be used to reach the **young deformation changes** along active strike slip faults.
- Using distribution and Evolution of **drainage network**.







- Conclusion:

Oldest dextral transtension

Old dextral

Middle dextral transpression

Recent sinistral kinematics.

- The question is:

When the dextral activity have been started and slip sense inversion happened along KN Fault zone?

- **Thermochronometry** is the best approach to detect the **onset of deformation**

Low-temperature Thermochronometry

- There is a **local highland region with ~ 1 Km local relief along KN Fault restraining bend.**

1- Apatite fission track (AFT) → Detrital sample

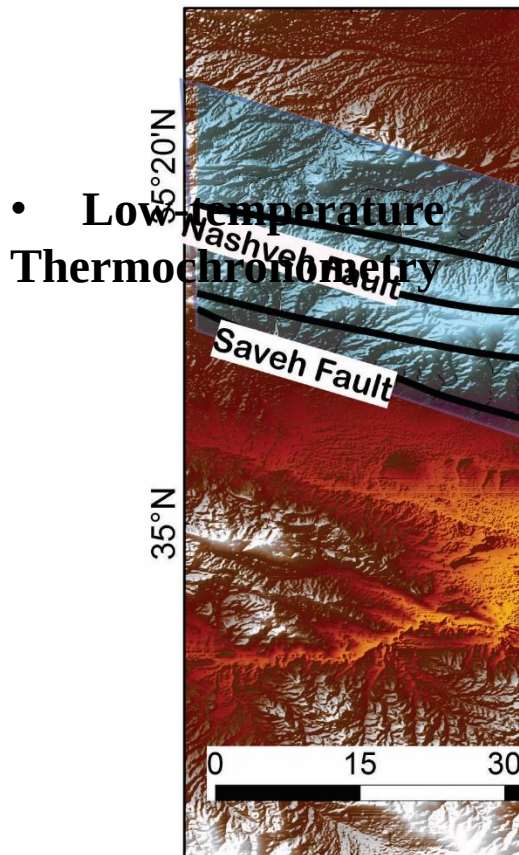
- general outlook of cooling events
- Is the push up area reset after the formation of rock units?
- Closure temperature of ZHe system (110-160° =6 Km)

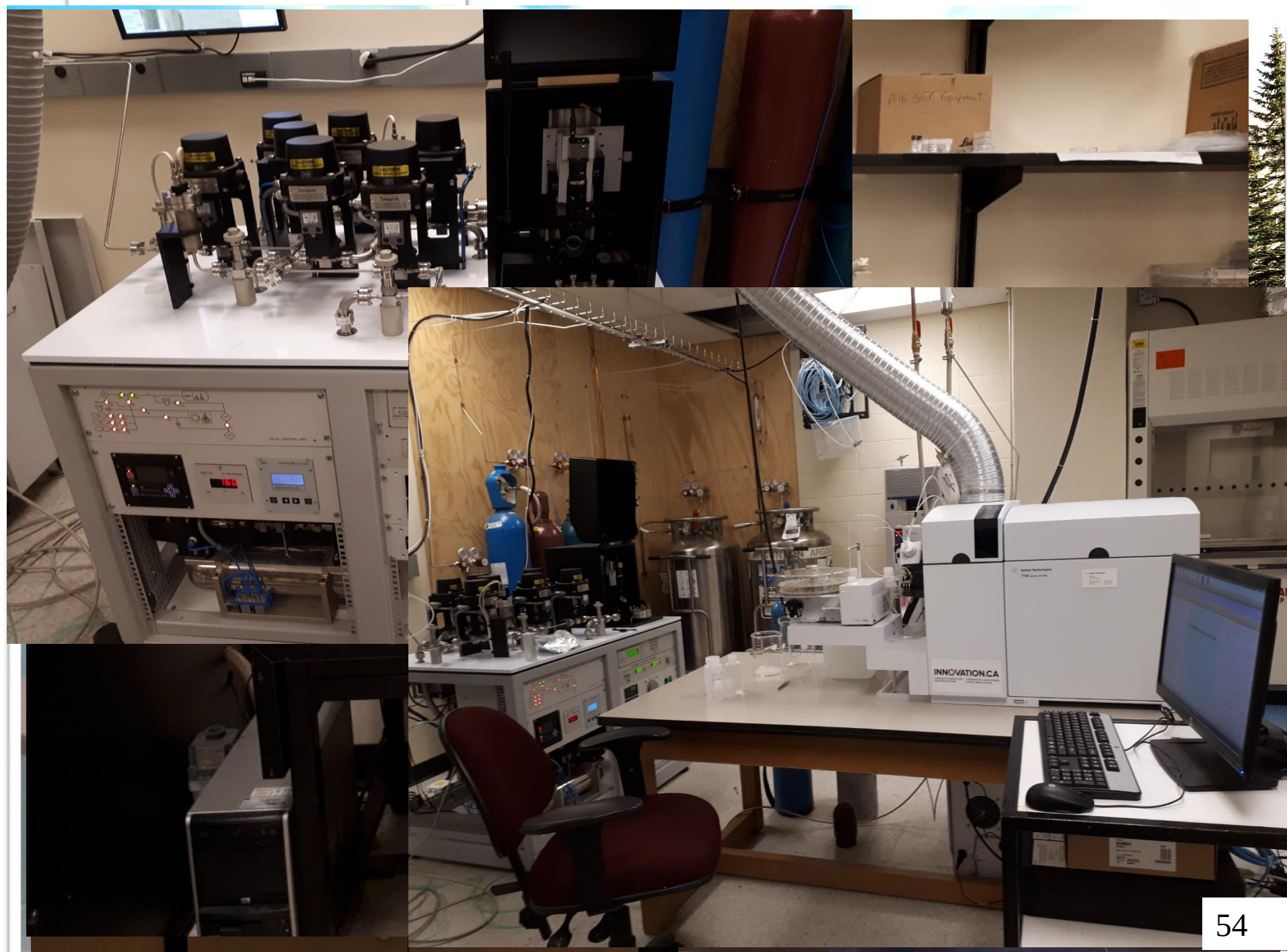
2- Apatite U-Th/ He (AHe) → Bedrock samples

- Low closure temperature of AHe system (75° =3 Km)
- Young rock units exhumed along KN Fault zone (Eocene and younger)
- Young (Miocene) deformation Along KN Fault as a part of Arabia- Eurasia collision zone.

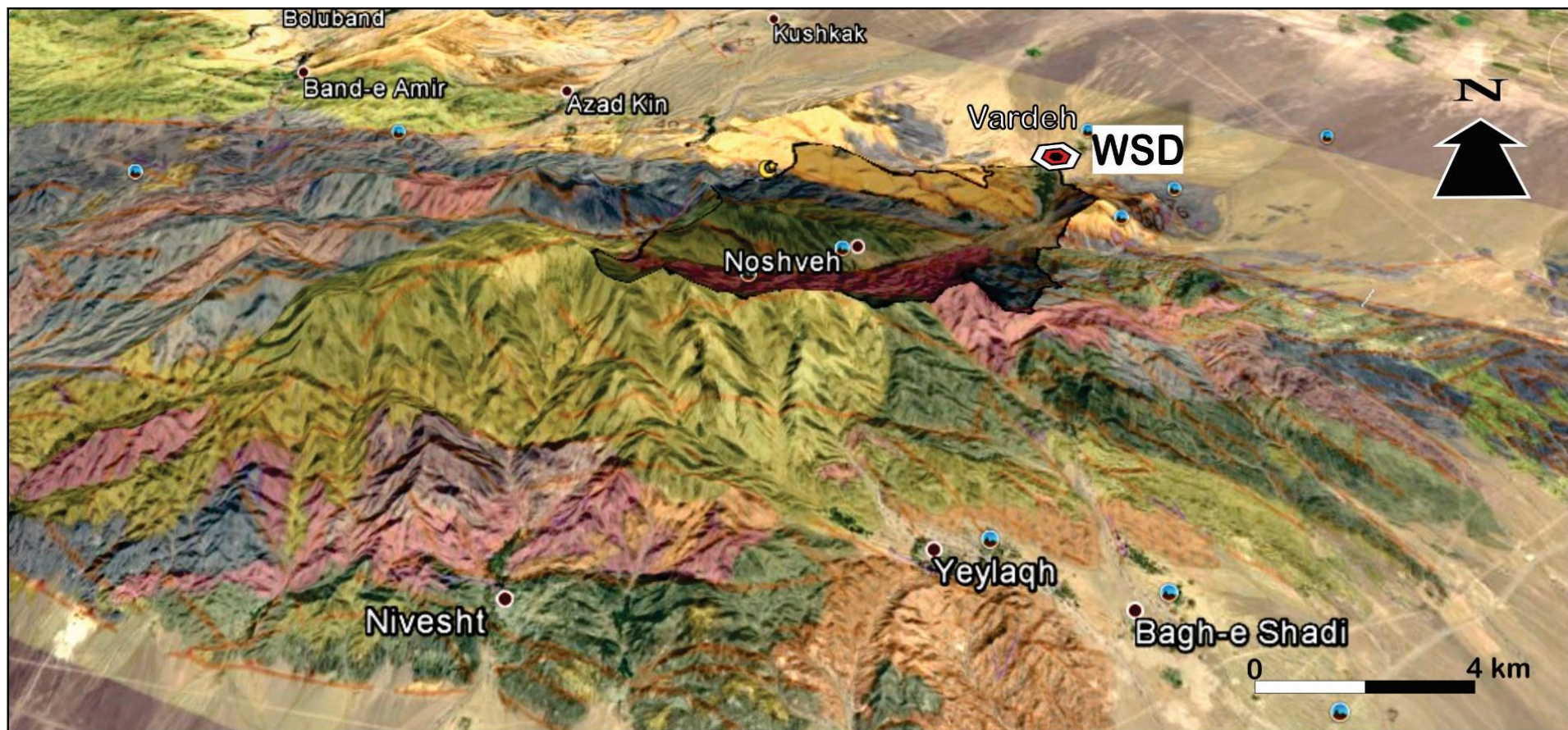
3- Zircon U-Th/ He (ZHe) → Bedrock samples

- Tracing the cooling path of the intrusive bodies
- Determining the burial limit by Neogene sediments
- Closure temperature of ZHe system (200-230° =9 Km)

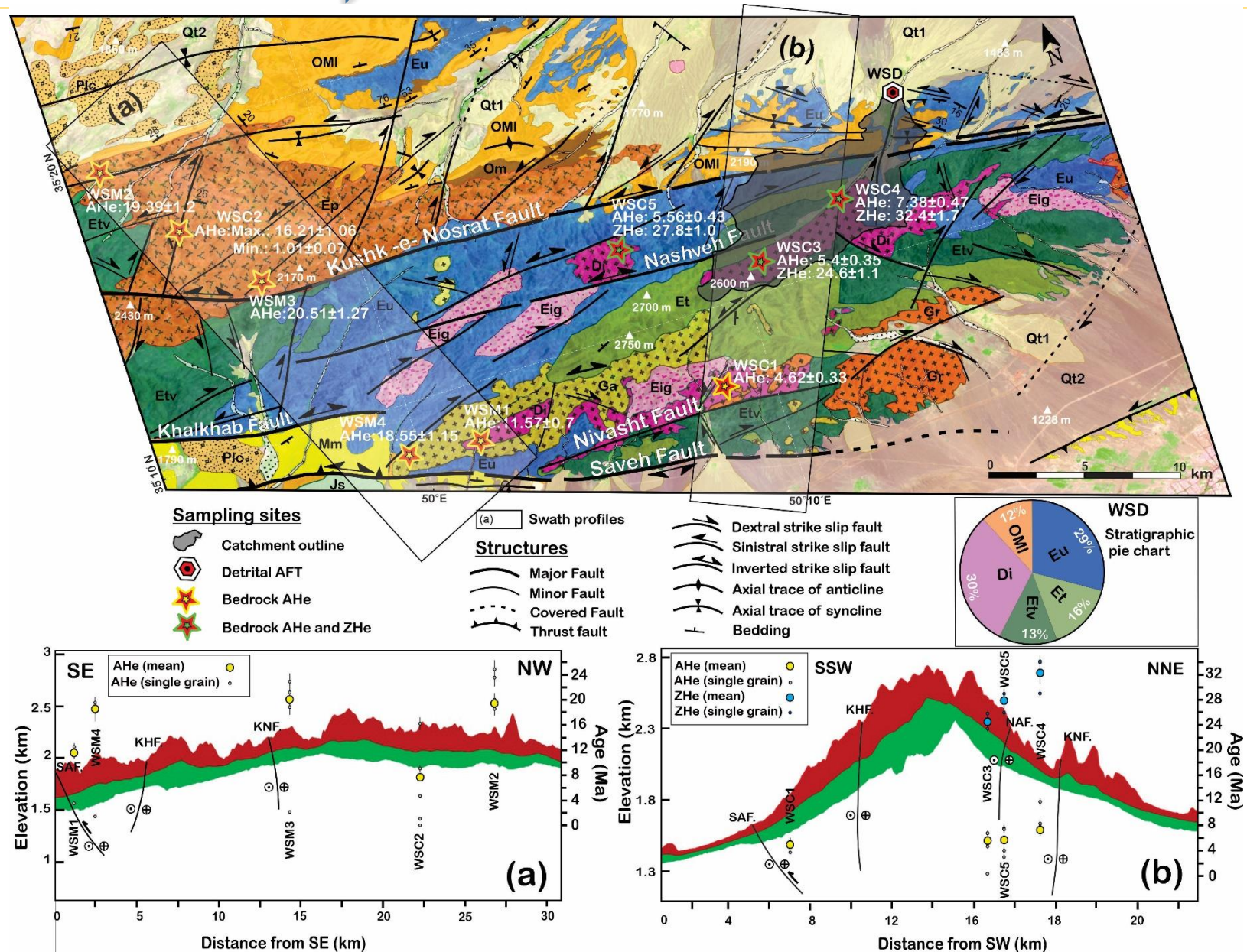




Low-temperature Thermochronometry ➡ **Detrital Thermochronometry (AFT)**



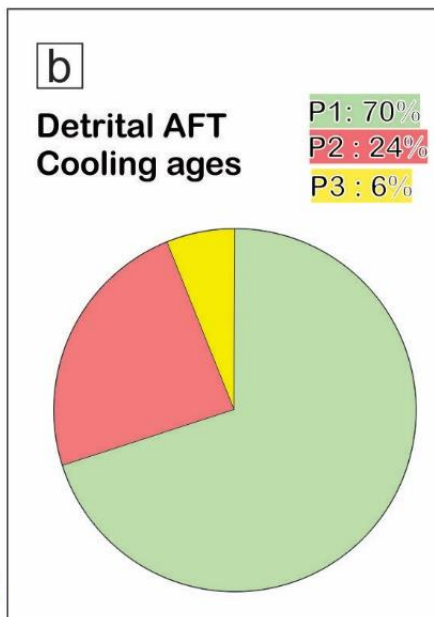
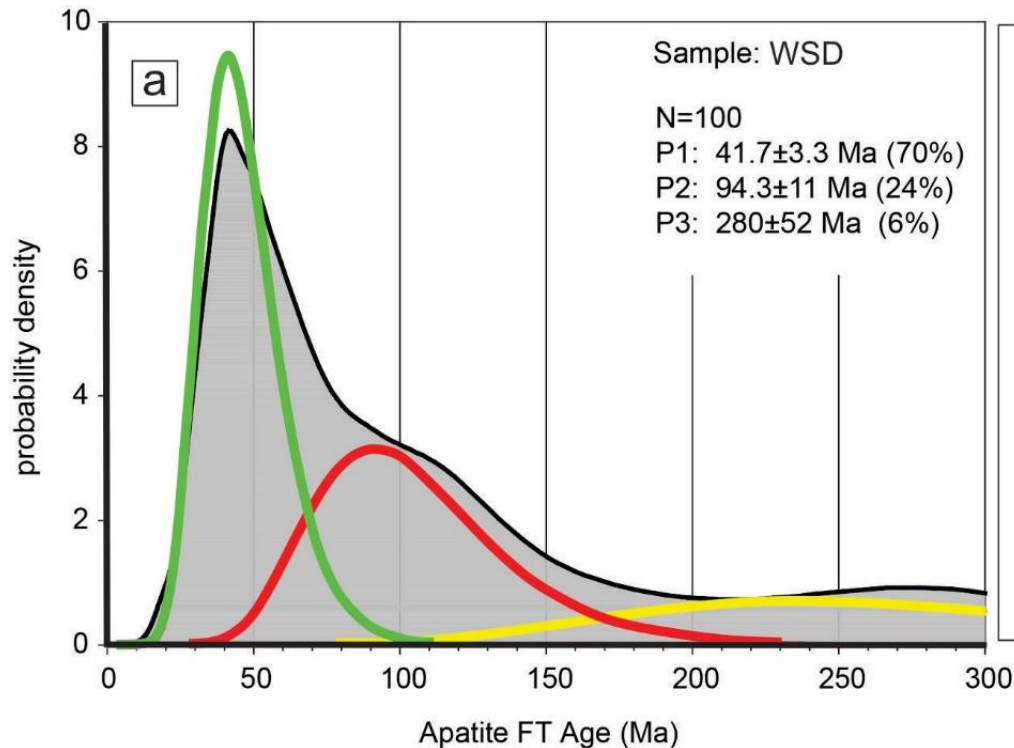
Low-temperature Thermochronometry → Detrital Thermochronometry River Catchment → Stratigraphic pie chart



Low-temperature Thermochronometry

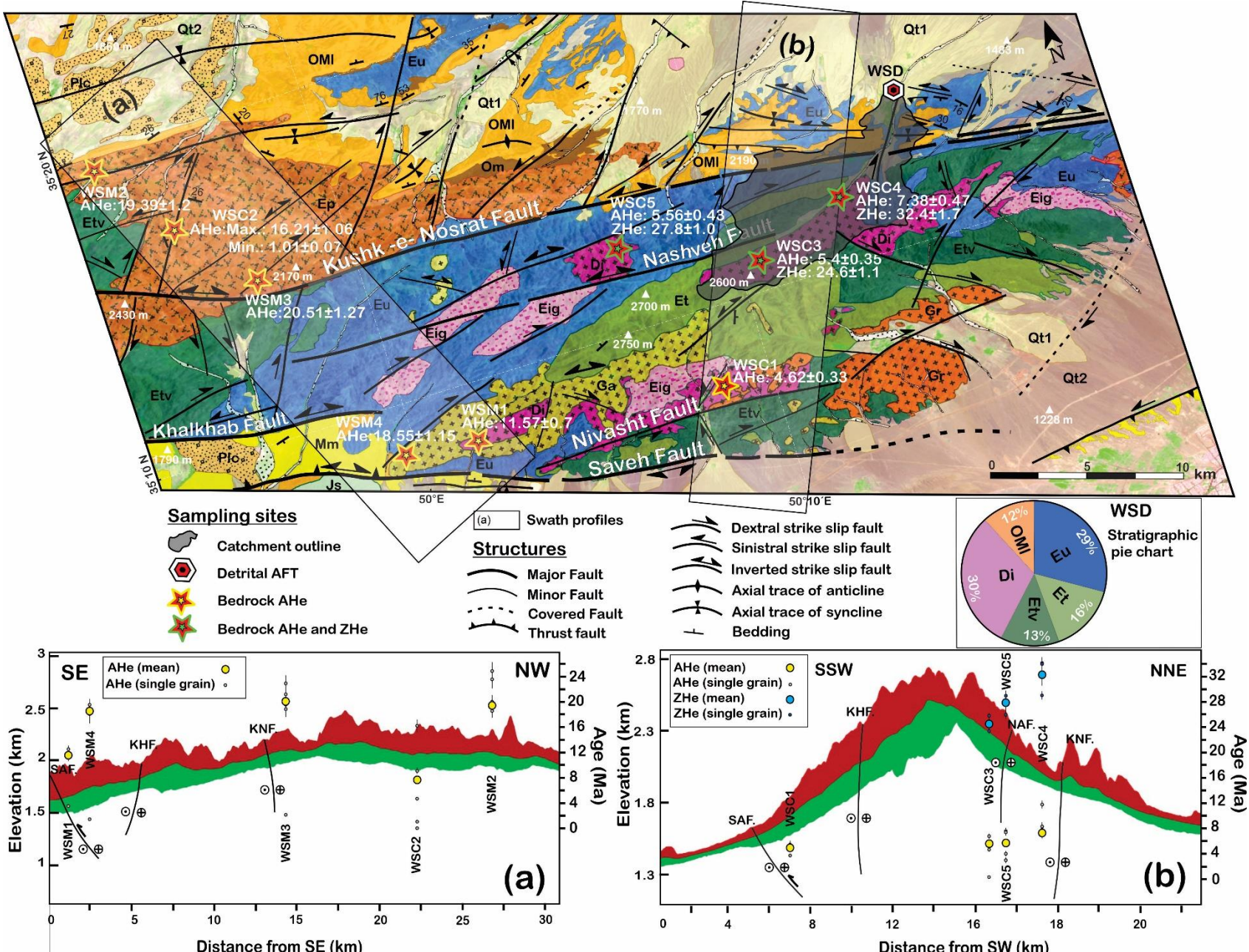


Probability density plot of
AFT cooling ages



74-12 WSD	N _d	N _e	ρ _m	ρ _h	N _a /N _i	ρ _a (cm ³)	ρ _h	Age (Ma)
1	41	8	1.71E+06	3.33E+05	5.125	1.03E+06	230	581.9
2	34	54	8.50E+05	1.35E+06	0.630	1.03E+06	230	74.4
3	34	13	1.42E+06	5.42E+05	2.615	1.03E+06	230	303.5
4	68	27	1.62E+06	6.43E+05	2.519	1.03E+06	230	292.5
5	9	47	3.75E+05	1.96E+06	0.191	1.03E+06	230	22.7
6	27	65	2.70E+05	6.50E+05	0.415	1.03E+06	230	49.2
7	81	189	1.00E+06	2.33E+06	0.429	1.03E+06	230	50.7
8	26	22	4.33E+05	3.67E+05	1.182	1.03E+06	230	138.9
9	13	51	4.33E+05	1.70E+06	0.255	1.03E+06	230	30.2
10	12	58	7.50E+05	3.63E+06	0.207	1.03E+06	230	24.5
11	18	35	1.91E+05	3.72E+05	0.514	1.03E+06	230	60.8
12	24	41	4.80E+05	8.20E+05	0.585	1.03E+06	230	69.2
13	16	28	4.00E+05	7.00E+05	0.571	1.03E+06	230	67.5
14	27	73	1.13E+06	3.04E+06	0.370	1.03E+06	230	43.8
15	12	12	3.00E+05	3.00E+05	1.000	1.03E+06	230	117.7
16	19	63	3.52E+05	1.17E+06	0.302	1.03E+06	230	35.7
17	27	60	4.82E+05	1.07E+06	0.450	1.03E+06	230	53.3
18	23	40	6.48E+05	9.82E+05	0.575	1.03E+06	230	68.0
19	24	24	1.00E+06	1.00E+06	1.000	1.03E+06	230	117.7
20	37	109	1.54E+06	4.54E+06	0.339	1.03E+06	230	40.2
21	32	58	6.53E+05	1.18E+06	0.552	1.03E+06	230	65.2
22	25	76	5.00E+05	1.52E+06	0.329	1.03E+06	230	39.0
23	6	12	2.00E+05	4.00E+05	0.500	1.03E+06	230	59.1
24	26	51	5.91E+05	1.02E+06	0.510	1.03E+06	230	60.3
25	28	80	3.30E+05	1.00E+06	0.250	1.03E+06	230	43.5
26	28	97	3.88E+05	1.35E+06	0.289	1.03E+06	230	34.2
27	17	66	5.48E+05	2.13E+06	0.258	1.03E+06	230	30.5
28	21	74	1.05E+06	3.70E+06	0.284	1.03E+06	230	33.6
29	20	18	1.00E+06	9.00E+05	1.111	1.03E+06	230	130.7
30	25	39	6.25E+05	9.75E+05	0.641	1.03E+06	230	75.7
31	7	17	2.33E+05	5.67E+05	0.412	1.03E+06	230	48.7
32	27	68	9.84E+05	2.43E+06	0.397	1.03E+06	230	47.0
33	41	44	8.20E+05	8.80E+05	0.932	1.03E+06	230	109.8
34	43	124	1.75E+06	5.17E+06	0.347	1.03E+06	230	41.1
35	10	28	5.00E+05	1.40E+06	0.357	1.03E+06	230	42.3
36	26	32	6.67E+05	1.07E+06	0.813	1.03E+06	230	95.8
37	14	21	6.75E+05	1.31E+06	0.667	1.03E+06	230	78.7
38	34	119	1.70E+06	5.90E+06	0.286	1.03E+06	230	33.9
39	16	89	1.87E+06	6.84E+06	0.261	1.03E+06	230	30.9
40	12	13	4.80E+05	5.50E+05	0.823	1.03E+06	230	108.8
41	20	37	5.00E+05	9.25E+05	0.541	1.03E+06	230	63.9
42	12	52	4.80E+05	2.08E+06	0.231	1.03E+06	230	27.4
43	13	54	4.33E+05	1.80E+06	0.241	1.03E+06	230	28.5
44	15	32	3.75E+05	8.00E+05	0.469	1.03E+06	230	55.5
45	3	22	5.00E+04	3.67E+05	0.136	1.03E+06	230	16.2
46	30	64	5.00E+05	1.07E+06	0.469	1.03E+06	230	55.5
47	33	63	2.20E+06	6.53E+06	0.337	1.03E+06	230	39.3
48	20	55	4.08E+05	1.12E+06	0.364	1.03E+06	230	43.1
49	68	91	7.58E+05	1.01E+06	0.747	1.03E+06	230	88.2
50	8	14	1.80E+05	2.80E+05	0.571	1.03E+06	230	67.5
51	5	9	8.25E+05	1.13E+06	0.556	1.03E+06	230	65.7
52	20	9	8.00E+05	3.60E+05	2.222	1.03E+06	230	258.8
53	23	12	9.20E+05	4.80E+05	1.917	1.03E+06	230	223.8
54	15	15	1.50E+06	1.50E+06	1.000	1.03E+06	230	117.7
55	16	23	3.33E+06	4.79E+05	0.696	1.03E+06	230	82.1
56	20	44	5.00E+05	1.10E+06	0.455	1.03E+06	230	53.8
57	10	27	3.57E+05	9.64E+05	0.370	1.03E+06	230	43.9
58	54	133	2.70E+06	6.65E+06	0.406	1.03E+06	230	48.1
59	31	27	5.64E+05	4.91E+05	1.148	1.03E+06	230	135.0
60	47	97	6.71E+05	1.39E+06	0.485	1.03E+06	230	57.3
61	37	113	1.54E+06	4.71E+06	0.327	1.03E+06	230	38.8
62	45	80	4.30E+05	3.00E+05	1.500	1.03E+06	230	175.8
63	44	116	2.10E+06	5.52E+06	0.379	1.03E+06	230	44.9
64	37	38	1.76E+06	1.81E+06	0.974	1.03E+06	230	114.7
65	15	7	6.00E+05	2.80E+05	2.143	1.03E+06	230	249.7
66	66	194	1.32E+06	3.88E+06	0.340	1.03E+06	230	40.3
67	19	53	6.33E+05	1.77E+06	0.358	1.03E+06	230	42.5
68	2	1	3.33E+05	1.67E+05	2.000	1.03E+06	230	233.4
69	7	14	1.52E+05	3.04E+05	0.506	1.03E+06	230	59.1
70	16	64	2.67E+05	1.07E+06	0.250	1.03E+06	230	29.6
71	14	34	3.88E+05	9.44E+05	0.412	1.03E+06	230	48.7
72	33	49	1.10E+06	1.63E+06	0.673	1.03E+06	230	79.5
73	24	29	3.43E+05	4.14E+05	0.828	1.03E+06	230	97.6
74	16	16	2.67E+05	2.67E+05	1.000	1.03E+06	230	117.7
75	10	26	5.00E+05	1.30E+06	0.385	1.03E+06	230	45.5
76	14	33	2.33E+05	5.50E+05	0.424	1.03E+06	230	50.2
77	31	68	5.17E+05	1.47E+06	0.352	1.03E+06	230	41.7
78	38	78	7.50E+05	1.56E+06	0.487	1.03E+06	230	57.6
79	21	41	2.10E+05	4.10E+05	0.512	1.03E+06	230	60.6
80	24	56	4.29E+05	1.00E+06	0.429	1.03E+06	230	50.7
81	11	47	2.75E+05	6.75E+05	0.407	1.03E+06	230	48.2
82	14	47	4.67E+05	1.57E+06	0.298	1.03E+06	230	35.3
83	21	55	4.20E+05	1.10E+06	0.382	1.03E+06	230	45.2
84	5	17	9.00E+04	1.70E+05	0.234	1.03E+06	230	34.9
85	7	50	7.98E+04	5.88E+05	0.140	1.03E+06	230	16.6
86	16	18	4.00E+05	4.50E+05	0.889	1.03E+06	230	104.8
87	17	56	1.05E+06	3.50E+06	0.304	1.03E+06	230	36.0
88	14	57	2.80E+06	1.14E+06	0.246	1.03E+06	230	29.1
89	11	44	1.10E+06	4.40E+05	0.250	1.03E+06	230	29.6
90	45	54	7.50E+05	9.00E+05	0.833	1.03E+06	230	98.3
91	12	42	2.40E+05	8.40E+05	0.286	1.03E+06	230	33.9
92	13	23	6.19E+05	1.10E+06	0.565	1.03E+06	230	66.8
93	19	34	5.94E+05	1.06E+06	0.559	1.03E+06	230	66.1
94	9	24	6.00E+05	1.60E+06	0.375	1.03E+06	230	44.4
95	19	119	3.80E+05	2.38E+06	0.160	1.03E+06	230	18.9
96	17	64	3.40E+05	1.28E+06	0.266	1.03E+06	230	31.5
97	15	61	1.88E+05	7.63E+05	0.246	1.03E+06	230	29.2
98	21	58	3.00E+05	8.29E+05	0.362	1.03E+06	230	42.9
99	9	37	2.50E+05	1.03E+06	0.243	1.03E+06	230	28.8
100	23	74	2.88E+05	9.25E+05	0.311	1.03E+06	230	36.8

Low-temperature Thermochronometry → Bed rock Thermochronometry (AHe/ZHe)



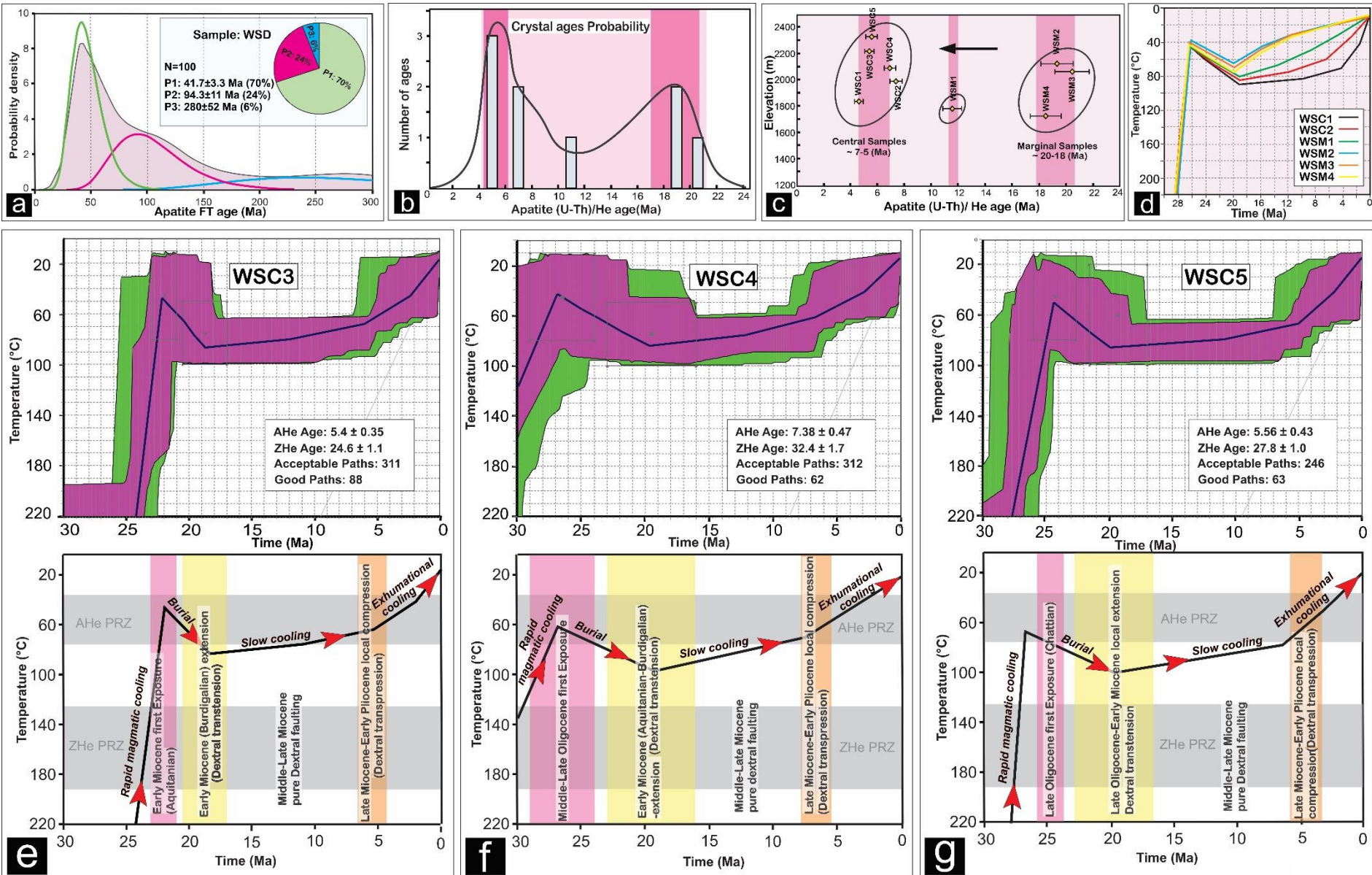
Apatite (U-Th)/He cooling Ages range varies from 20.51 to 1.01 (Ma)

Sample Id	Lat. N/ Long. W	Elevation (m)	Rock type	Crystal Number	Crystal length (μm)	Crystal width(μm)	Ft Correction age (Ma)	U (ppm)	Th (ppm)	4He (ncc/g)	SD	Corrected AHe age (Ma)± σ	ESR (μm)	Mean AHe age (Ma) ± σ
WSM1	35.152349 50.02366	1786	Diorite	1	116.92	118.83	12.16	4.28	12.22	7758.74	0.58	12.16 ± 0.75	55.45	11.57 ± 0.7
				2	151.8	89.44	10.99	3.27	11.49	5569.19		10.99 ± 0.65		
				3	229.61	127	3.54	3.37	7.23	1717.88		3.54 ± 0.24		
WSM2	35.331312 49.877682	2118	Ignimbrite	1	164.74	126.39	19.74	1.86	10.63	8089.72	3.5	19.74 ± 1.25	63	19.39 ± 1.2
				2	152.52	91.47	24.88	3.58	10.91	13073.41		24.88 ± 1.44		
				3	259.98	100.99	18.47	1.52	17.47	9547.98		18.47 ± 1.15		
				4	252.24	90.34	19.96	1.98	14.10	9384.35		19.96 ± 1.20		
				5	225.83	123.62	23.59	2.15	19.64	15271.98		23.59 ± 1.52		
WSM3	35.257148 49.932156	2064	Andesite	1	168.01	122.09	18.67	3.24	9.78	9614.28	1.83	18.67 ± 1.18	63.15	20.51 ± 1.27
				2	149.68	125.05	19.42	3.98	12.56	12473.61		19.42 ± 1.22		
				3	139.9	108.36	22.77	4.27	12.75	14743.65		22.77 ± 1.38		
				4	131.62	116.88	21.19	3.65	10.79	11818.83		21.19 ± 1.30		
				5	157.04	145.72	2.16	3.23	11.92	1248.68		2.16 ± 0.16		
WSM4	35.149985 49.985635	1722	Diorite	1	160.2	83	1.37	3.97	13.03	812.17	0.83	1.37 ± 0.15	64.48	18.55 ± 1.15
				2	140.99	89.92	18.1	3.99	13.89	11237.69		18.10 ± 1.06		
				3	189.46	103.79	18.04	2.85	9.39	8329.05		18.04 ± 1.12		
				4	265.01	136.1	19.52	3.30	11.59	11614.47		19.52 ± 1.29		
WSC1	35.135307 50.134244	1834	Granite	1	420.72	194.79	5.59	7.27	14.54	6290.98	1.03	5.59 ± 0.4	98.99	4.62 ± 0.33
				2	190.05	157.04	3.54	2.25	9.78	1598.92		3.54 ± 0.25		
				3	366.44	153.14	4.72	2.77	9.62	2416.13		4.72 ± 0.33		
WSC2	35.29163 49.910741	2091	pyroclastic	1	190.23	103.24	9.13	11.08	45.89	18111.39	6.53	9.13 ± 0.56	67.34	(7.77±0.49 ?) Max.: 16.21 ± 1.06 Min: 1.01± 0.07
				2	233.65	102.34	1.01	10.85	41.59	1916.75		1.01 ± 0.07		
				3	220.74	130.33	16.21	9.22	34.49	27109.31		16.21 ± 1.06		
				4	224	117.99	4.74	7.91	28.70	6569.43		4.74 ± 0.30		
WSC3	35.190097 50.178461	2215	Diorite	1	201.7	143.68	5.12	3.29	13.48	3245.99	0.83	5.12 ± 0.35	65.45	5.4 ± 0.35
				2	245.83	110.24	5.46	5.74	11.00	4265.14		5.46 ± .036		
				3	188.11	103.3	6.51	6.13	16.57	5938.17		6.51 ± 0.41		
				4	146.57	95.52	4.51	9.39	22.39	5760.70		4.51 ± 0.28		
WSC4	35.200286 50.206533	1989	Diorite	1	204.56	115.19	6.77	7.95	12.81	6957.14	0.677	6.77 ± 0.45	65.08	7.385 ± 0.47
				2	190.16	106.55	6.85	9.40	13.91	7958.13		6.85 ± 0.44		
				3	163.9	122.99	11.51	1.30	5.77	2878.59		11.51 ± 0.76		
				4	263.94	105.94	7.8	6.62	11.33	6695.43		7.80 ± 0.50		
				5	230.29	101.26	8.12	5.94	9.81	6071.02		8.12 ± 0.51		
WSC5	35.21992 50.115345	2323	Diorite	1	261.15	148.87	3.06	0.13	2.43	215.63	2.3	3.06 ± 0.32	78.43	5.56 ± 0.43
				2	225.76	106.85	4.16	0.49	4.71	616.62		4.16 ± 0.35		
				3	242.92	159.69	13.07	3.46	13.01	8568.25		13.07 ± 0.88		
				4	282.7	126.88	11.14	0.52	26.09	7260.60		11.14 ± 0.73		
				5	288.72	126.21	7.6	0.70	4.39	1282.58		7.60 ± 0.51		
				6	289.89	117.7	7.43	0.24	2.60	606.68		7.43 ± 0.54		

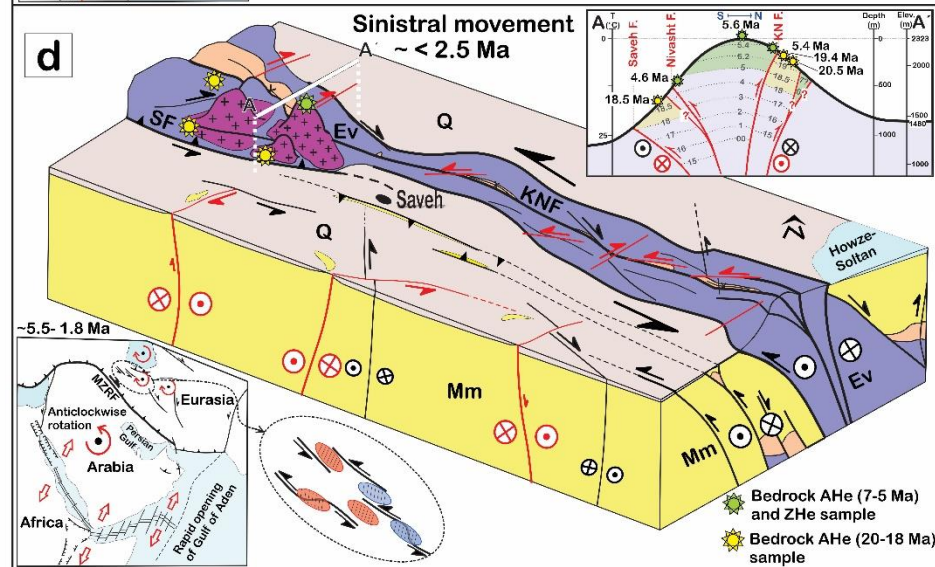
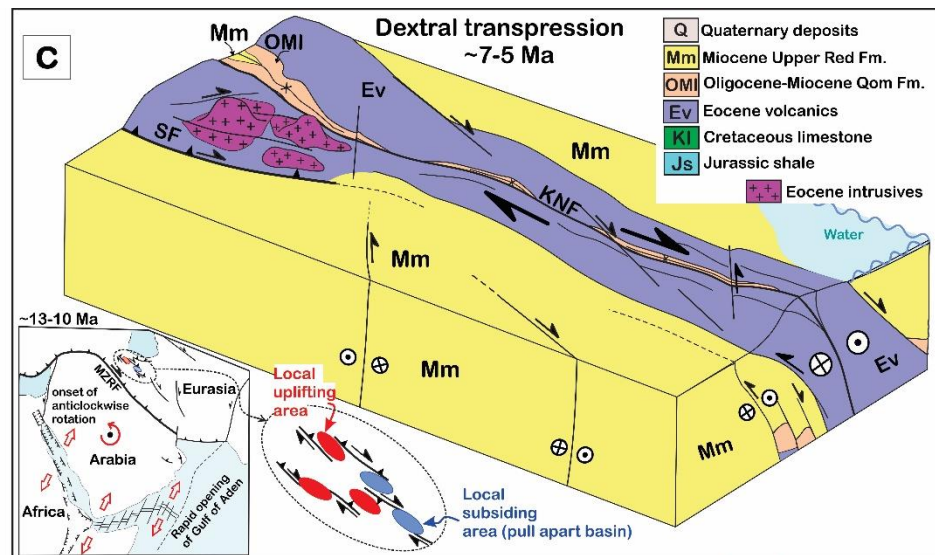
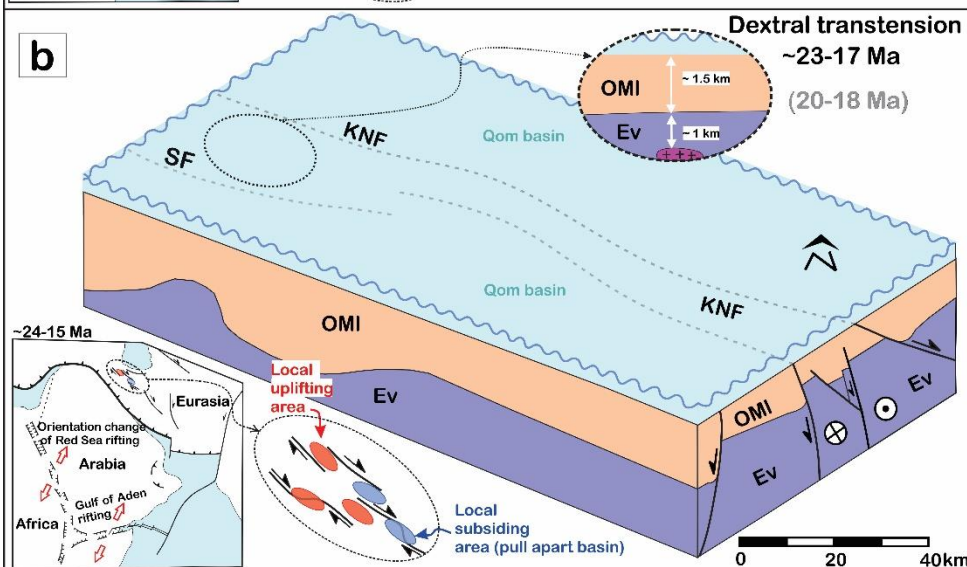
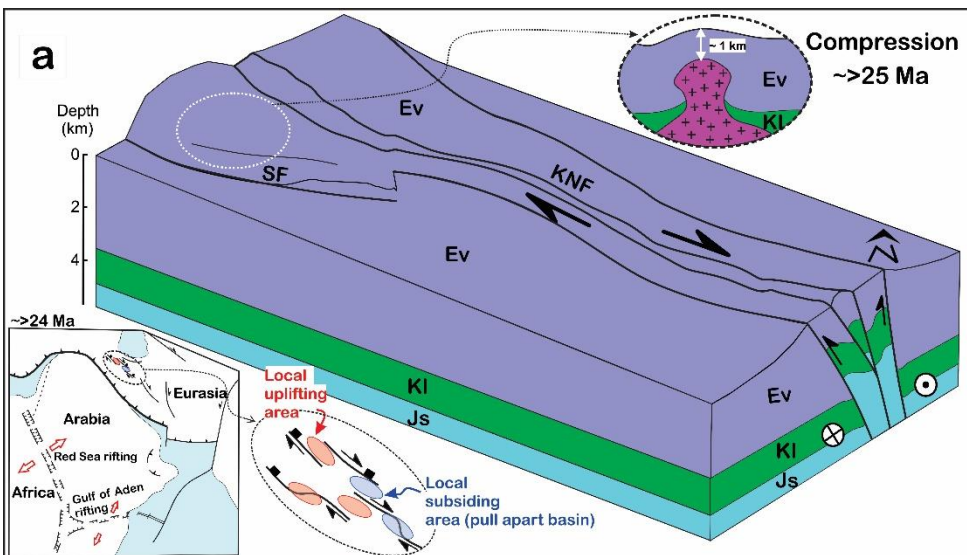
Zircon (U-Th)/He
cooling Ages range varies from 24.6 to 32.4 (Ma)

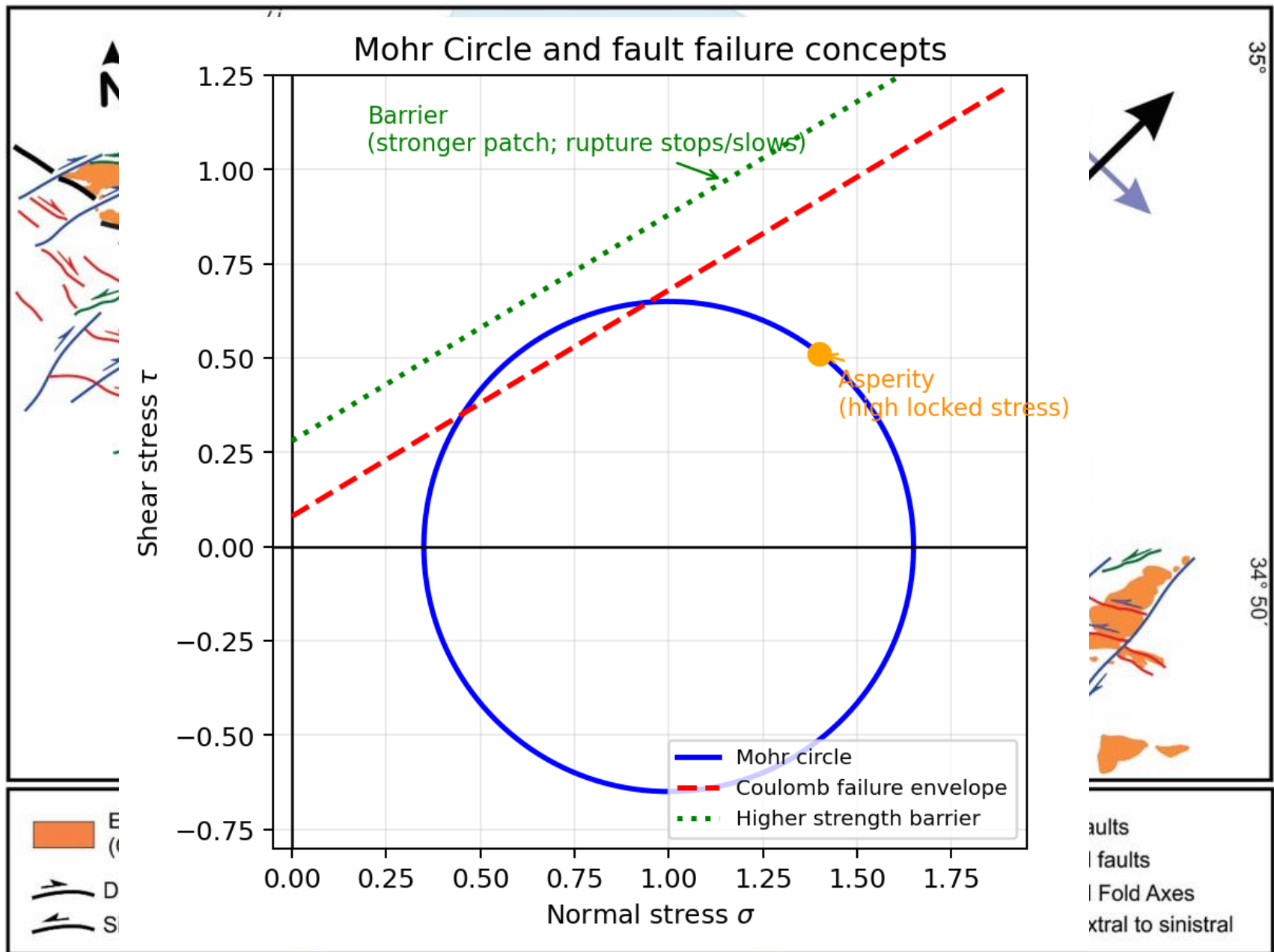
Sample Id	Elv. (m)	Crystal Number	Mass (mg)	Ft	4He (ncc/gr)	U (ppm)	Th (ppm)	Th/U	Corrected ZHe age (Ma) $\pm \sigma$	Mean ZHe age (Ma) $\pm \sigma$
WSC3	2215	1	0.16	0.786	22233.60	8.11	4.43	0.6	25.7 $\pm$ 0.5	24.6 $\pm$ 1.1
		2	0.14	0.769	28362.03	11.42	7.07	0.6	23.4 $\pm$ 0.4	
		3	0.12	0.768	78029.32	14.13	8.44	0.6	52.3 $\pm$ 0.9	
WSC4	1989	1	0.12	0.757	60964.28	16.92	11.30	0.7	34.2 $\pm$ 0.9	32.4 $\pm$ 1.7
		2	0.12	0.766	37805.41	10.12	8.23	0.8	34.0 $\pm$ 0.6	
		3	0.14	0.770	33807.64	11.04	6.52	0.6	29.0 $\pm$ 0.6	
WSC5	2323	1	0.17	0.786	12252.53	3.64	3.53	1.0	28.9 $\pm$ 0.5	27.8 $\pm$ 1.0
		2	0.18	0.799	8107.63	2.67	2.55	1.0	25.8 $\pm$ 0.5	
		3	0.17	0.801	12617.31	3.85	2.98	0.8	28.8 $\pm$ 0.6	

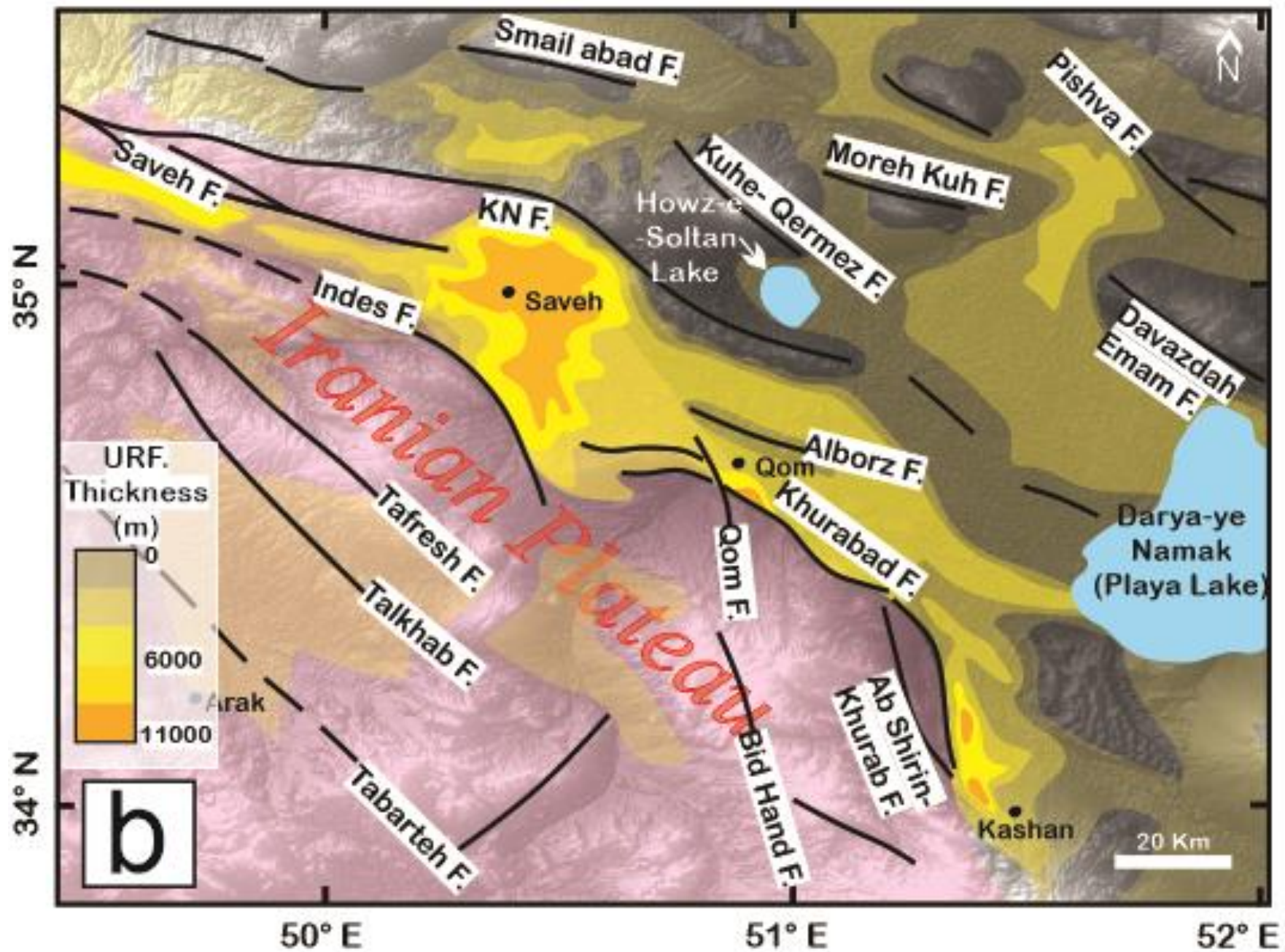
Thermal modeling history



Final model (Graphical abstract)







باسمکرا از توجه شما

