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Comparison of Strain Ellipsoid Shape in the South of Ardabil Range (NW), Based on the Results of the Magnetic Susceptibility Anisotropy and Paleostress Methods

Ramin Sadeghi[1*], Abdollah Saeedi[2], Mehran Arian[1], Manochehr Ghorashi[2,3], Ali Solgi[1]

[1]Department of Geology, Science and Research Branch, Islamic Azad University, Tehran, Iran
[2]Research Institute for Earth Sciences, Geological Survey, Tehran, Iran
[3]Department of Geology, North Tehran Branch, Islamic Azad University, Tehran, Iran
Email: [*]raminsadeghi54@gmail.com

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Abstract

In recent years, the method of magnetic survey as one of the new techniques in geological and geophysical studies is known. In this study to determine the shape of the stress field of the two methods, Anisotropy of Magnetic Susceptibility (AMS) and paleostress have been used. Paleomagnetism is the characteristics of magnetic rocks. Some issues in associated with the past places of continental and oceanic plates can be solved. AMS is one of the paleomagnetism methods that pay to measurement of parameters (which are reflector of the magnetic fabrics rocks). It is presenting an ellipsoid with three-axis perpendicular to each other that defines magnetic ellipsoid. In this regard, the number of 12 stations in different rocks (Jurassic to Quaternary) in the southern region of Ardebil sampling was conducted. In this connection, the study of magnetic fabrics has shown an elliptical magnetic susceptibility with the prolate shape. For the separation of paleostress phases in the Khalkhal area using the analysis of the paleostress based on the study of heterogeneous fault-slip data and sliding lineaments. Firstly, data were picked from 10 stations, and after their analysis, the elliptical shape (prolate) has been determinated. The shape of the ellipsoid, based on AMS and paleostress methods and their results show that in both methods the shape of the stress field is prolate.

Keywords

Paleostress, Anisotropy, Inversion Method, Strain Ellipsoid, Iran

[*]Corresponding author.

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1. Introduction

Ardabil province has got different geological properties from the other parts of Azerbaijan region and Iran. The faults that are origin of the earthquakes in this area may be affected by rotation of the western Alborz. Therefore calculation of stress direction and estimation of stress field shape will be unrealistic. In this article by using the paleomagnetism and paleostress methods, some of the unknowns including dominant stress trend of the region, phase separation of the stress and strain ellipsoid have been prepared.

1.1. Location

The study area (**Figure 1**) is located in the southern range of Ardebil in the West Alborz Mountain. Alborz mountain belt with several thousand kilometers between the Caspian Sea and the Central Iran has situated. It is a part of the Alpine-Himalaya belt that located between Eurasian and Cimmerian plates.

Alborz Mountain is a result of the above collision since the late Triassic. Extensional phases in Alborz Orogeny in the study area have created a collection of volcanic rocks, including lava flows, and pyroclastic generally entitled Karaj formation.

Magmatism has been active in particular in Oligocene and Neogne and the injection of magma has been in the host rocks of Eocene rocks, especially in the domed shape with the composition of Rhyoliite and Dacite. Ardabil region is located in the bend of Alborz on the West Talesh Mountain, and based on structural and stratigraphic situations different from the other parts of Iran. It has been the more complex and the evidence of metamorphism in rocks is common.

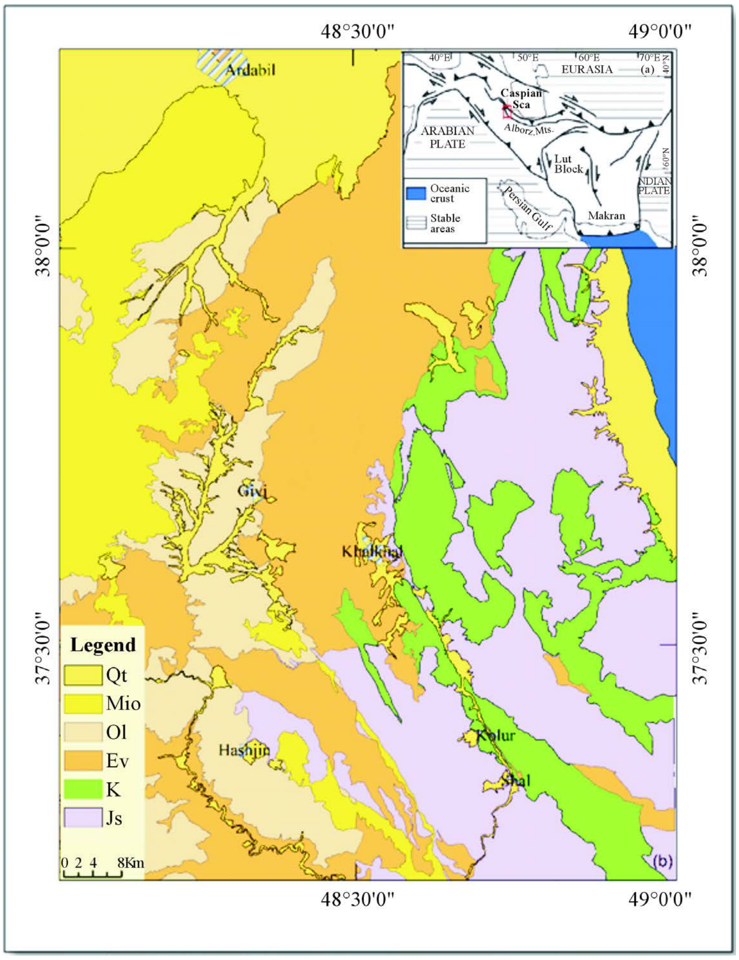

Figure 1. Schematic tectonic map of Iran (insert map) and schematic geological map of the Ardabil region.

1.2. Tectonic Setting

The study area has located in West-Central Alborz-Lesser Caucasus physiographic province (**Figure 1**). Dominant structural trend in this province is NW-SE. From tectonics view, it contains deformed zone (fold and thrust belt) of Cimmerian miniplate that formed in northern active margin until late Triassic. Then it has rifted by tension in a back arc basin of Neotethyian subduction zone in the south margin of Cimmerian miniplate. Development of that rift stopped in the late Cretaceous and then, renewed in the Eocene by spreading in submarine arc basin of Neotethyian subduction zone. In other words, this hinterland is a result of a magmatic arc system spreading in the evolutional back arc basin. After that, West-Central Alborz and Lesser Caucasus hinterland has formed by deformation and regional uplift from SW part of Caspian Sea to Black Sea [1]-[3]. Based on previous works on the salt and mud diapirism [4]-[15] and neotectonic regime in Iran [16]-[21], Zagros in south Iran is the most active zone [22]-[42]. Then, Alborz [43]-[82] and Central Iran [83]-[98] have been situated in the next orders.

There is evidence of two young tectonic phases during Cenozoic in study area. The first phase in late Eocene in the posterior with compressional stress has been NE-SW trend and the second phase in the Middle Miocene (Sarmatin) compressional phase has been SE-NW trend that caused the evolution of the thrusts with N-S trend in this area. The tectonic events causing the Eocene to the Quaternary have been the formation of the current morphology of this part of the crust of Iran block. In this area structural trend has changed from Northwest-South East to the North-South. The tectonic evidence of the region shows that the west sector (West block) has been stretched in the mid Paleocene and after the collision with Arabian plate, a depression has created towards the Eastern block. This depression has located widely under the volcanic scrambling that formed the northern part of Azerbaijan. This scrambling volcanic-magmatic has been extremely high since the late Paleocene and throughout the early Eocene. Then, it has decreased in the Miocene and Oligocene and there was a big scrambling under the influence at the beginning of the Quaternary across the study area. Morphotectonic units of the study area can be separated and classified as following from North to South (**Figure 2**).

1) Moghan foreland basin as a portion of South Caspian-Black sea foreland basin.

2) Arasbaran, Qarah Dagh, Hashtchin, volcano-plutonic belt that imply to southward subduction [99].

3) Tectono-magamatic reactivated zones in Neocene (with oblique trend related to Paleogene volcano-plutonic arc) that formed the volcanoes (like the Sabalan) and uplifting intrusive doming (Qusheh Dagh).

4) Subsidence zone between the mountain and the volcanoes.

The tectonic units have been bounded by the main faults. These faults are Aras fault in the North, Tabriz fault in the West, Talysh and Astara fault system in eastern boundary, and also, magnetic lineament East Meyaneh in the South-East border and Bozquosh fault in the South (**Figure 3**).

2. Material and Methods

For studies of stress by examining the geological maps and satellite images and field operations 5 range which they fault and fracture surfaces are visible and were selected and measured data page was picked up fractures (**Figure 4** and **Figure 5**). Then the data was processed and value and with the use of the software Fault Kin,

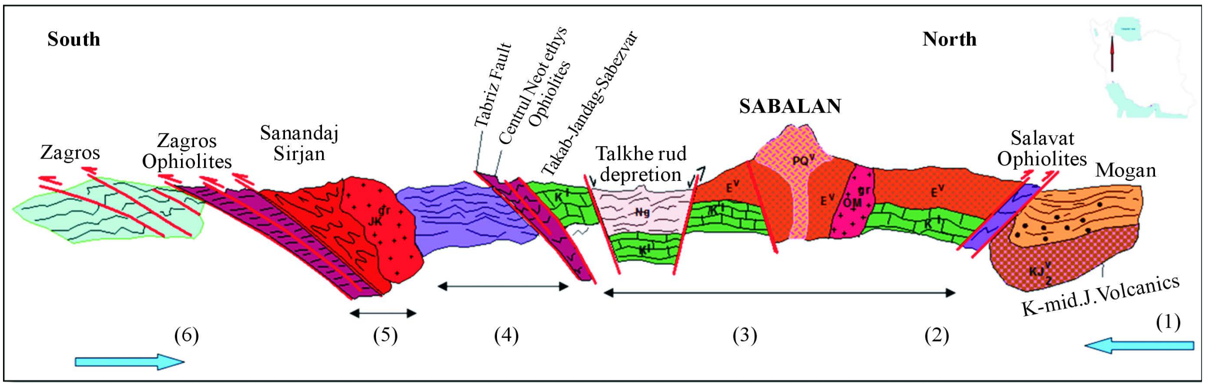

Figure 2. Schematic of the structural represents the main structural elements from the Zagros Mountains to the Caucasus can be seen in it study the area.

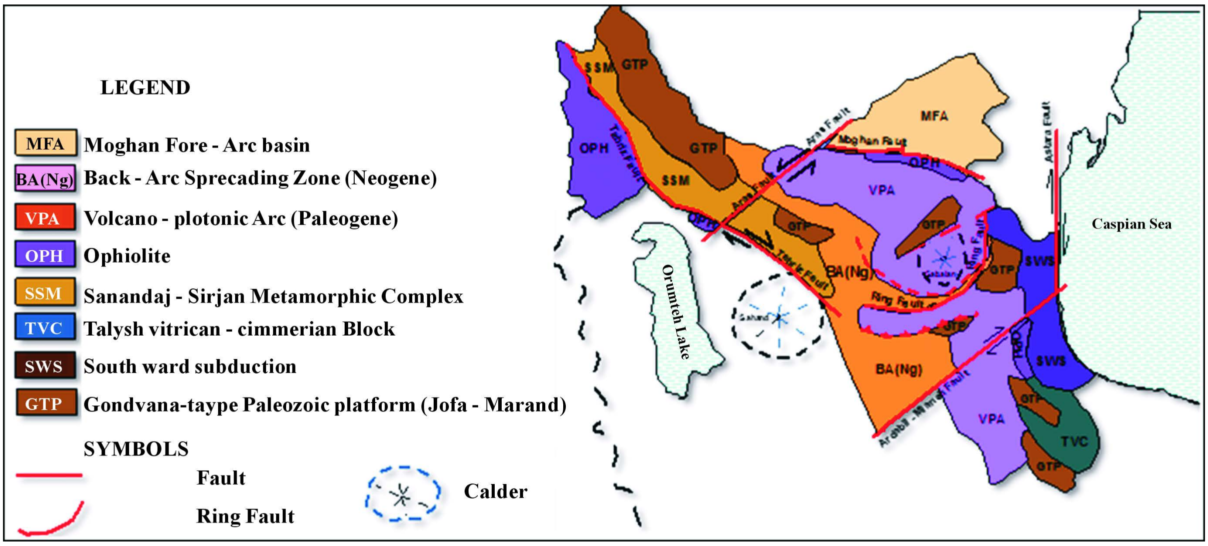

Figure 3. The structural map of the studied range and North West of Iran.

Tectonic FP data for import into software was ready for Win Tensor, and for each region were paleostress analysis [100].

After the regionalization study area in each range of data after processing with the use of the software was paid to the distinction between phases of stress Win Tensor that specifications relating to each phase in **Table 1** is be the position of the main maximum stress σ_1 and σ_3 minimum tension each phase on the range of elliptical has been demarcated. Each pair of main stress perpendicular to the arrow tip, large and small shows each phases.

3. Results and Discussion

In the study area, from about 12 stations, in the longitude the range of 48˚ to 49˚ samples were that's part of the Talysh Mountains and Western Alborz belt (**Figure 6**). Stations in place of the Talysh Mountains turns bending in place rotate the belt West Alborz and changing trend of the structures of the North East to the South West of the South-North-South, South East and South West of Ardabil province are focused. Because of possible impact of the magnetic minerals on lands and changing the chemical composition or spin them in the vicinity of faults the choice of the sampling stations at a distance of at least of the main fault. Most stations (PS1, SP2, S1, S2, S3, S4) of the igneous units includes basalt up to andesite from the Eocene period of up to quaternary. And the number of stations of the unit stone includes marl shale, and sandstone (S6, PS3, SP3, S7, S3) was removed from any station 15 - 8 sample preparation and from sample of every sample was obtained manually (**Table 2**).

With the use of the software Anisoft 4.2, the magnetic parameters can determine the magnitude of anisotropy (**Table 3**), including the shape parameter or T that describes the magnetic elliptical shape parameter [101]-[111]. The value of this parameter in the range of between change the −1 to +1 the shape of the elliptical shape of the prolate to form a pancake (pancake elliptical) changed if T from 0 to 1 [112]. Magnetic elliptical shape would be prolate or have a smoker, in this case $K1 > K2 \geq K3$.

If T is in the range between be 0 to +1 magnetic elliptical shape is Oblate and will be $K1 \geq K2 > K3$ .When $K1 = K2 = K3$ Magnetic elliptical shape will be the spherical.

Therefore we can be determined some samples of higher susceptibility that they have been rated the study on the range field shape or T Parameter a range of values shows for −0/720 to −0/164. According to **Figure 7** more samples obtained from stations PS1, S2, S3, S4 and S5 the field shape shows ($0 > T > -1$) prolate shape.

4. Conclusions

There are two fault systems with two dominant strikes (North West-South East and North East-South West) and the main conclusions of this research are:

- The direction of the magnetic lineation by using of AMS method shows elongation in North East-South West trend.

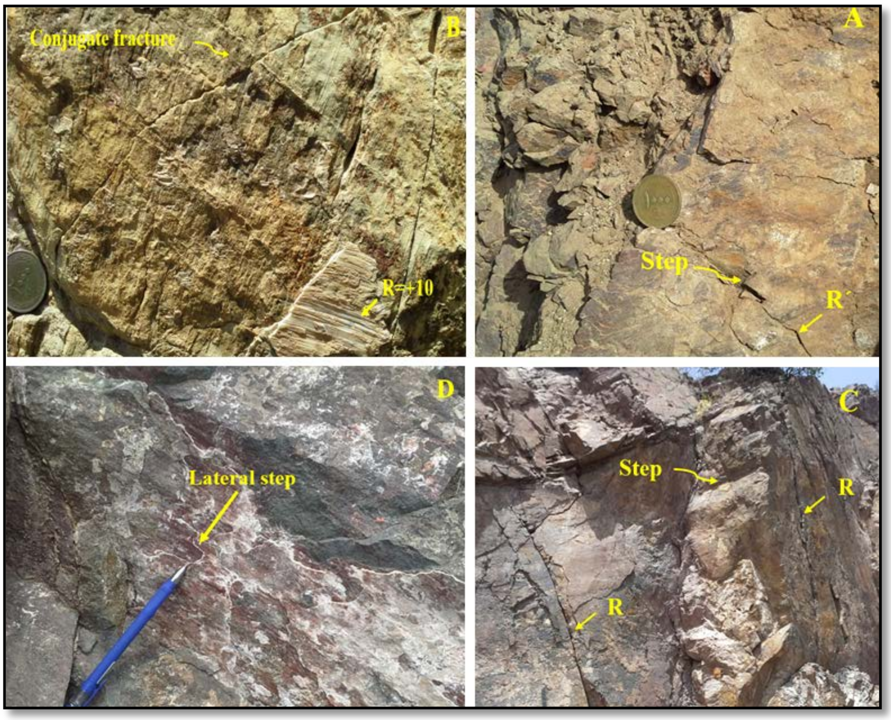

Figure 4. (A) and (C) R and R' fractures along with the fault step, (B) and (D) the amount of the rick angle and scratches line on the surface of the fault.

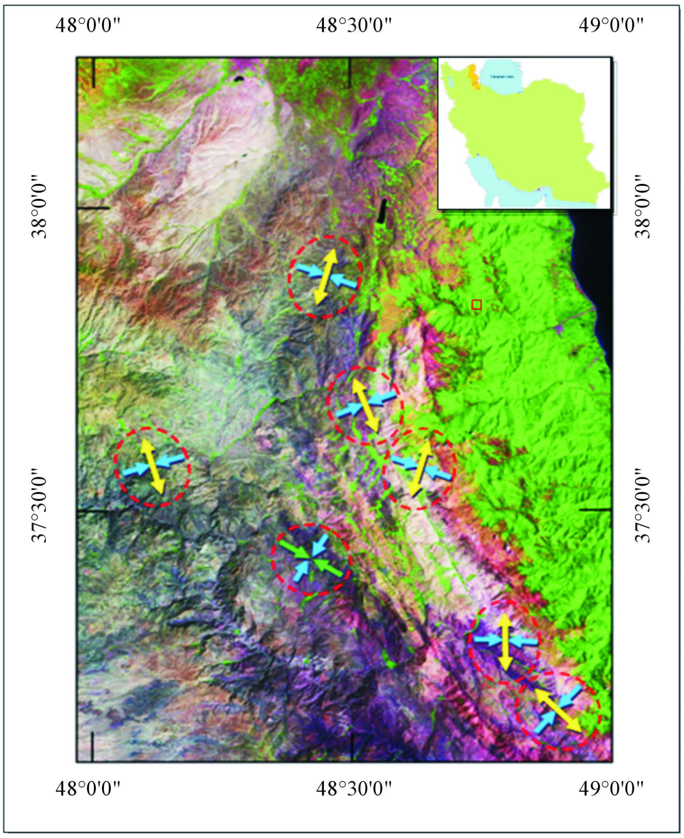

Figure 5. The average position the main tension and elliptical shape in each domain.

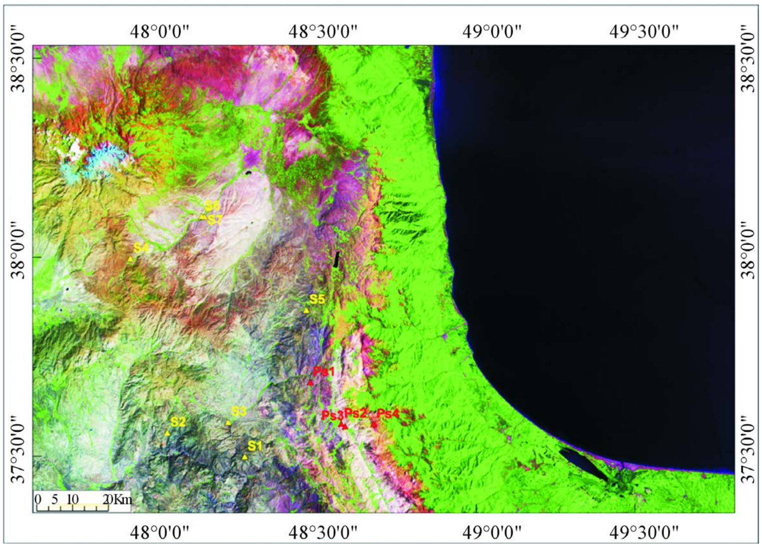

Figure 6. The position of picked up stations for sampling paleomagnetism.

Table 1. Separated phases the position of the main axes; the size of the field shape factor fault numbers related to each phase.

Station	Phases	Sigma 1		Sigma 3		R	N
		Trend	Plunge	Trend	Plunge		
1	1	075	08	344	05	0.5	87
	2	248	10	343	10	0.6	23
2	1	330	00	86	060	0.7	15
3	1	100	07	191	05	0.5	171
4	1	076	08	345	05	0.5	128
5	1	147	26	024	08	0.48	77

Table 2. Geological characteristics, harvested stations, 4 experimental station (PS), and 8 main station (S).

Station	Position (GPS)	Number samples	Lithology	Relative age
PS_1	N 37˚41'16" E 48˚28'33.6"	8	Eocene volcanic andesite to basalt	Eocene
PS_2	N 37˚34.5'22" E 48˚40.6'03"	8	Cretaceous volcanic silt	Upper Jurassic
PS_3	N 37˚34'60" E 48˚34'36"	7	Lime ston	Jurassic
PS_4	N 37˚34'43" E 48˚34'55"	8	Lime ston	Jurassic
S_1	N 37˚30'11.1" E 48˚15'52.4"	15	Andesite	Oligocene
S_2	N 37˚34'03" E 48˚00'59"	15	Andesite	Oligocene
S_3	N 37˚35'27.7" E 48˚13'20.9"	12	Basalt	Eocene
S_4	N 37˚00'14" E 48˚54'27.7"	8	Basalt	Quaternary
S_5	N 37˚52'47.6" E 48˚28'37.2"	10	Andesite	Eocene
S_6	N 38˚06'19.4" E 48˚08'04.8"	17	Brown marl	Neogene
S_7	N 37˚06'16.9" E 48˚54'34.1"	10	Red sandstone	Neogene
S_8	N 37˚07'38.2" E 48˚09'26.3"	15	Red sandstone	Neogene

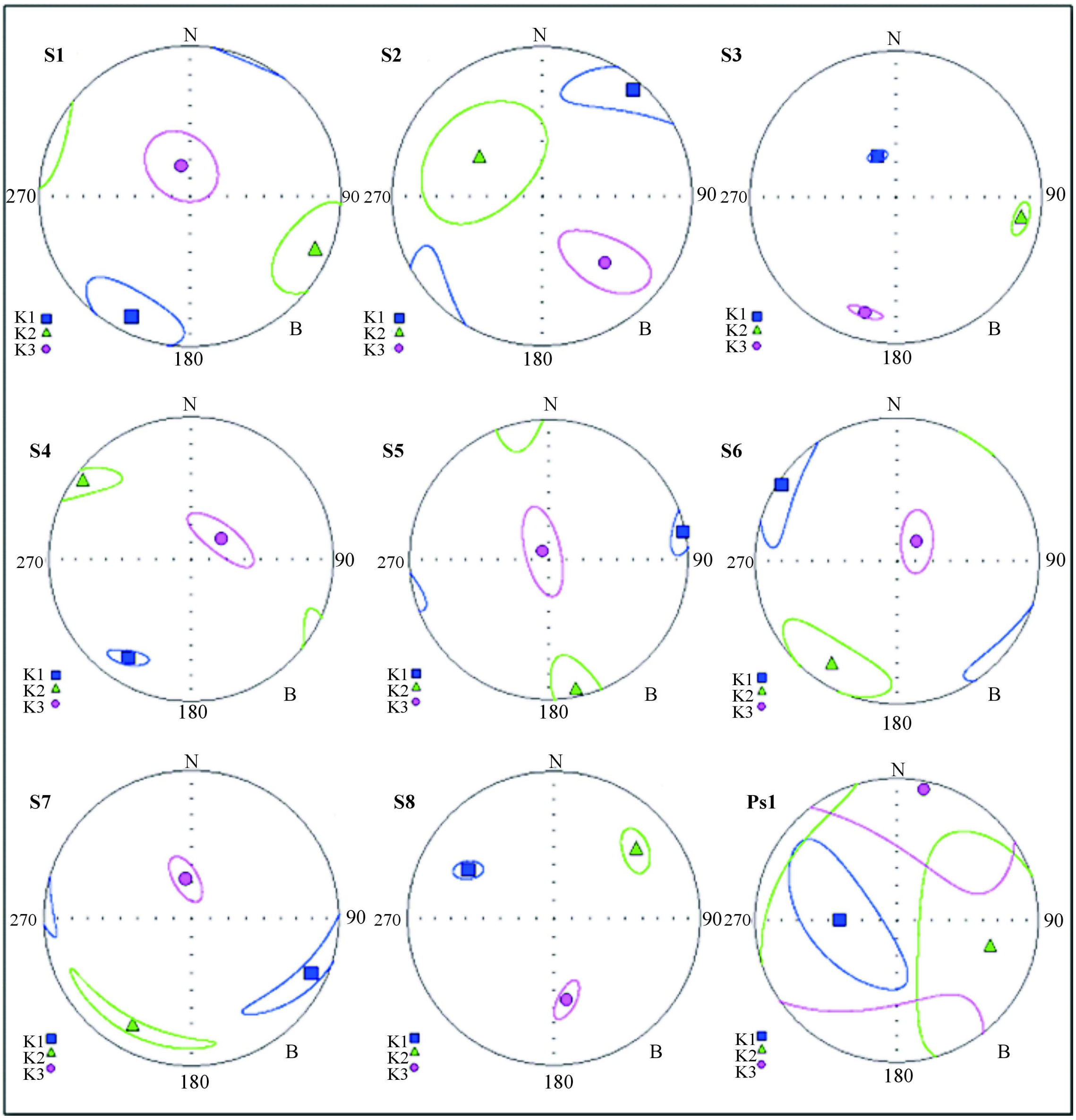

Figure 7. The image of the main axes of the elliptical magnetic susceptibility for three types of magnetic fabric.

Table 3. The measured anisotropy parameters for the study area. Declination and inclination values have separated by comma.

Station	N	k_m (μSI)	L	F	P_J	T_J	Dec, Inc. (K_{min})	Dec, Inc. (K_{max})
PS1	8	3.83 E	1.001 (0.001)	1.004 (0.002)	1.004 (0.030)	−0.169 (0.3380)	12.7	271.56
S1	14	9.69 E	1.004 (0.002)	1.007 (0.004)	1.011 (0.004)	0.306 (0.388)	322.71	211.67
S2	15	4.65 E	1.005 (0.004)	1.004 (0.005)	1.009 (0.466)	−0.056 (0.446)	136.39	40.8
S3	12	5.52 E	1.006 (0.001)	1.005 (0.002)	1.011 (0.002)	−0.139 (0.163)	195.20	330.65
S4	9	2.25 E	1.003 (0.002)	1.003 (0.001)	1.007 (0.002)	−0.035 (0.267)	56.72	211.16
S5	9	2.43 E	1.008 (0.001)	1.003 (0.003)	1.012 (0.002)	−0.164 (0.234)	323.83	78.2
S6	13	6.4 E	1.007 (0.004)	1.055 (0.013)	1.045 (0.017)	0.652 (0.122)	44.74	303.3
S7	9	1.23 E	1.008 (0.002)	1.052 (0.026)	1.066 (0.029)	0.720 (0.129)	301.68	114.12
S8	15	9.27 E	1.002 (0.009)	1.043 (0.016)	1.065 (0.022)	0.349 (0.221)	171.43	299.33

- The trend of magnetic lineation is the same with the direction tension, based on the results of both paleostress and paleomagnetism methods.
- The value of R in the paleostress method is variable from 0.5 to 1 and with the implementation of the [112] diagram field shape is obtained to be prolate.
- The value of TJ in the anisotropy of magnetic susceptibility (AMS) is variable between 0 and −1 and with the implementation of [113] and [114] field shape is prolate.
- The results of both paleostress and anisotropy of magnetic susceptibility (AMS) methods for field shape of Strain ellipsoid are the same.

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