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Full Length Research Paper

Paleomagnetic studies on Anatolian plate and some geodynamic implications

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The study area is located in some areas in the Anatolian plate (Afyon, Nevşehir, Hasandağı-Melendiz Dag, Karadag, Karacadağ, Karapınar sites). For the paleomagnetic study, it was taken oriented 324 core samples from 36 locations. First of all, natural remanent magnetizations of all samples were measured by Spiner magnetometer and then thermal demagnetization treatment was applied to each sample by MMTD60 instrument. All paleomagnetic parameters and diagrams were calculated and drew by IAPD Release 92 computer program. Pliocene aged AF and KK sites from Afyon region have anti-clockwise rotations, respectively 200 and 39°. Miocene aged rock samples from same region represent 55 ° anti-clockwise rotations. Plio-Quarternary aged sites (AS and OD) from Nevşehir volcanic region volcanism have anti-clockwise rotations, respectively, 18° and 7°. Upper Miocene aged rock samples (Ağıllı-Çakıllı, OC) show 26 ° anti-clockwise rotations. The amount of anti-clockwise rotation of Plio-Quarternary aged two locations from Hasan Dağ (HD) and Melendiz Dağı (MD) are 13° and 11°. Pliocene aged sites from Karadağ Volcanism have 6°anti-clockwise rotations. Plio-Quarternary aged site (KRP) from Karapınar area represents 22°anti-clockwise rotations. 11.9 My aged rock samples (KRC) from Karacadağ show 18° anti-clockwise rotations. In the second phase of study, all data, with other paleomagnetic data in and around region, was evaluated to obtain tectonic and structural implications about region. The evaluation of all data, in general, shows that rotations obtained in region could be an evidence of local tectonic events and/or the region, in this actual short geologic time, may be exposed to the active deformations.

Key words: Paleomagnetism, Neogene volcanism and tectonic deformations, Anatolian (Turkish) plate.

INTRODUCTION

The westward motion of Turkey relative to Euroasia is related to the collusion between Arabia and Euroasia in the Caucasus and Eastern Turkey, which is thought to have began about 12 Myr ago in the Mid-Miocene. The Thickened crust in eastern Turkey provides the gravitational potential energy, or buoyancy force, that drives Turkey westwards; most of these motions being accommodated on the North and East Anatolian strike slip fault systems (McKenzie 1972; Oral et al 1995; Taymaz et al, 1991). In the northern Anatolia, total demise of the Tethian Ocean between the Sakarya continent and the Taurides created a compressional system which began affecting the region from the late cretaceous onward. The N-S shortening deformation continued until the late eastern Anatolia transfered to the N-S compression toward the west from Late Miocene onward. In this escape regime the north and east Anatolian strike-slip fault systems have played important roles. The N-S shortening deformation regime was replace by a N-S extensional system in the western part of the Anatolian plate as a result of the escape tectonism study area of our study located in Anatolian (Turkish) Plate (Western Anatolia and Central Anatolia).

One of the most important features of convergent plate margines is existence of strong calc-alcalen magmatism related to the main collusion zones. During the Neogene and Quarternary periods, volcanic activity of Turkey presents one of the most striking examples related to the continental collusion (Pasquare et al., 1988). Volcanism of central anatolia, with the petrographic characteristics, was carried out by much more researcher (Pasquare ve diğ., 1988; Pasquare, 1968; Keller and Villari, 1972; Innocenti et al., 1975;1976; 1980; 1982a, b; Keller et al., 1977) and generally, it was developed with a serious event related to the collusion between Africa-Arab and Eurasia.

The subduction of the Continental Arab Plate into the Eurasia Plate was caused to form the large strike slip faults (North Anatolian Fault which is 13 million aged and is still active (Ambraseys, 1970; Şengör, 1979; Sengör and Yılmaz, 1981) and east Anatolian Fault also which is still active (McKenzie, 1976). Generally accepted plate tectonic models on these areas suppose that Anatolian micro-Plate escape to the west along this strike slip fault systems (McKenzie, 1972; 1978; Dewey and Sengör, 1979; Sengör, 1979; Sengör and Yilmaz, 1981; Boccaletti and Dainelli, 1982; Dewey et al., 1986). Under the convergence process between Eurasia and Arab plates, a strongly segmented volcanic arc was developed in Neogene and Quarternary times (Pasquare et al., 1988). This collusion presents a geometric relation with the main structural elements. Volcanic activity results from large volume products of calk-alcalen and potassium calk-alcalen rocks (Innocenti and Diğ, 1975; 1976; 1980; 1982a, b).

From paleomagnetic data, Piper et al. (2002) implies that the Isparta Angle (IA) has been subject to only small additional closure (< 10 degrees) since Late Miocene time. A smaller amount (c. 6 degrees) of clockwise rotation within the IA since Early Pliocene times is associated with an ongoing extensional regime and reflects an expanding curvature of the Tauride arc produced by southwestward extrusion of the Anatolian collage as a result of continuing northward motion of Afro-Arabia.

Piper et al. (2006) have compiled a database of neotectonic paleomagnetic results from Anatolian to analyze this deformation. They conclude that large rotations (up to 5 degrees/10,000 yr) of small fault blocks along the intracontinental transform faults but do not extend away from these zones and show that seismogenic upper crust is decoupled from lower continental lithosphere undergoing continuum deformation. Avsar and Isseven (2009) interpreted in terms of dextral motion of a tectonic block bounded by two strands of the NAF. Their palaeomagnetic data also indicate that the Eocene rocks of the Armutlu Peninsula were emplaced at a palaeolatitude statistically identical to the present and we conclude that northward movement of this sector of the Anatolides since Eocene times has been below the limits of palaeomagnetic detection.

Comparison of palaeomagnetic data from 46 sites in the Eocene volcanics from different blocks indicate that each fault-bounded block has been affected by vertical block rotations (Isseven and Tuysuz, 2006). Although, clockwise rotations are dominant as expected from dextral fault-bounded blocks, anticlockwise rotations have also been documented.

They are interpreted in these anticlockwise rotations as due to anticlockwise rotation of the Anatolian block, as indicated by GPS measurements, and the effects of unmapped faults or pre-North Anatolian fault tectonic events.

Gursoy et al. (2099) show the results from the volcanic suites sited on the stable shield are compared with other results from the Arabian Plate to conclude that it did not rotate significantly following closure of the Bitlis Suture until Late Miocene-Early Pliocene times since when it has rotated anticlockwise at a rate of similar to 1.0 degrees/Myr. The aim of study is to present and to review some paleomahgnetic data on Anatolian plate and some geodynamic implications.

MATERIALS AND METHODS

Field studies

Field study for paleomagnetic sampling was carried out in the inner part of western Anatolia and Central Anatolia in 1998 (Figure 1). Region is divided into four parts (Afyon Volcanism, Nevsehir Volcanism, Hasandag-Melendiz Dag Volcanism and Karadag - Karacadag-Karapinar Volcanism).

Afyon sites

From three different sites (AF, KK and MT) within Afyon volcanism, the samples were taken. KK sites represent Karakaya Basalts which is Pliocene aged rocks. MT sites represent Merhemkaya Tepesi which is located in Bolvadin town. In this region, volcanic activity was begun in upper Miocene and so on.

Nevsehir sites

From the Nevsehir volcanism in three different aged sites samples were taken (AS= Asiklidag, OD=Oyludag and OC=Agilli-Cakilli). Volcanic activity in this region and vicinity began in end of the Middle Miocene. Asikli Dag (AS) basalts is outcropped on Oyludag and Asiklidag hills in southwestern part of Nevsehir. Oyludag (OD) basalts are located in southwestern part of Nevsehir. Agilli-Çakilli (OC) sites includes andesitic lavas which is upper Miocene aged (13.7 - 6.5 Mys).

Hasan Dagi-Melendiz sites

From volcanism of Hasan Dagi-Melendiz Dagi region, 6 sample were taken (HD= Hasan Dag, MD=Melendiz Dagi).

Karadag - Karapinar- Karacadag sites

From Karadag-Karacadag-Karapinar Volcanoes, tree different sites were sampled by 11 samples (KRP= Karapinar, KRC=Karacadag and KRD=Karadag).

Laboratory studies

The cores were one-inch in diameter. The total number of samples collected from 36 sites, near 350. A Molspin spinner magnetometer was used to measure magnetization. Intensities of natural remanent magnetization (NRM) of samples ranged from 0.1-2.0 × 10^{-3} A/m. The natural remanent magnetization of the samples was resolved by thermal demagnetization and at least twelve steps of heating were carried out between room temperature and 580C$^{\circ}$. The Zijderveld and Wulf projections of remanent magnetization directions and moment-temperature variation curves of some pilot

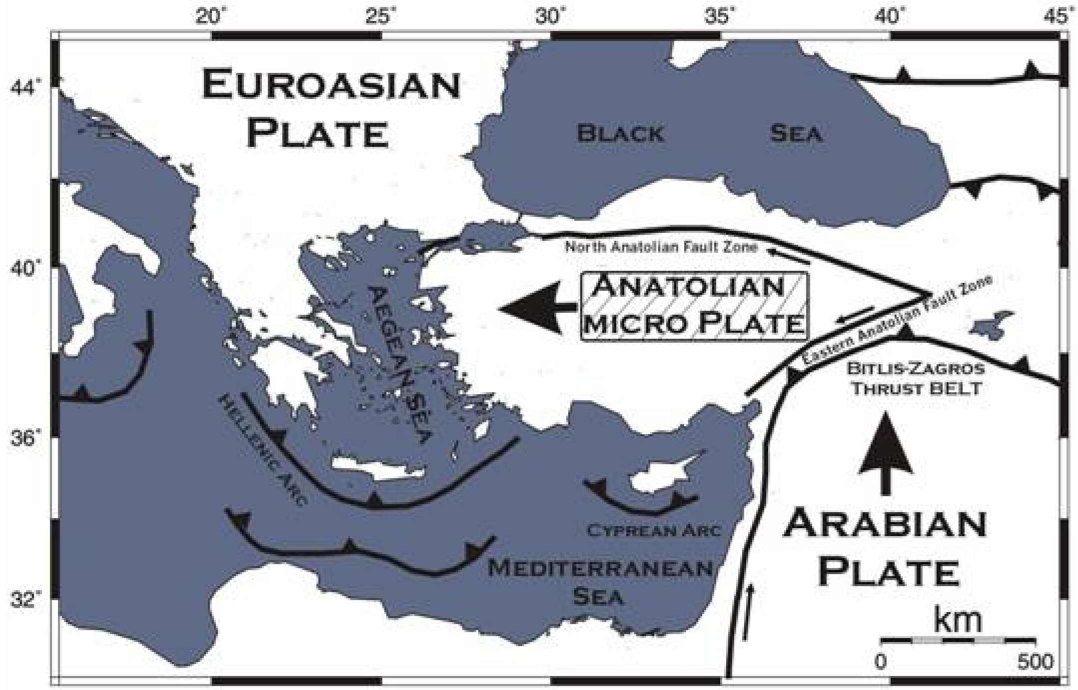


Figure 1. Study area and plate relations.

samples are shown in Figure 2 and 3. Individual directions, but not intensities can be plotted by Wulf projections (Figure 2). Declination is measured clockwise from North and inclinations are measured from the equator. Zijderveld projection (Figure 3) allows components of remanence to be plotted, thereby, including both intensities and directions of a vectors as it is progressively demagnetized.

In Figure 2, for KRD4 (Karadag) andesite sample (Pliocen Aged), natural remanent magnetism and remanent magnetism after demagnetization treatment at 400°C were given. For this site, pilot sample (KR-1A) was cleaned at 350 - 400°C (Figure 3). For another sample KK4 (Lower Pliocene aged rock sample from Afyon site), natural remanent magnetism and remanent magnetism after demagnetization treatment at 500°C were given in Figure 4.

For this site pilot sample was cleaned at 450 - 500°C (Figure 5). After demagnetization, site mean directions and statistical parameters of our studies were listed in Table 1. Previous studies on the region and their parameters were given in Table 2.

Previous paleomagnetic studies

Figure 6 and 7 show the paleomagnetic studies from the eastern and western side of present study. Eastern and northern sides of the present study were carried out by the different researchers (Orbay and Bayburdi, 1979; Van der Voo, 1958/1968; Baydemir, 1982; Saribudak, 1989; Karavul, 1985). Paleomagnetic rotations in the region were generally interpreted as a result of escape tectonics due to the collusion between Arab and Eurasia Plates. Similarly, western sides of present work were investigated by different research groups (Laj et al, 1982; Kissel et al., 1986; Dolachieva et al., 1986; Nazharov et al., 1990; Westphal et al., 1991; Orbay et al., 1993a, b; 1995, 1996,; 1997a, b, 1998).

Previous studies point out that there are anti-clockwise rotations along the North Anatolian Fault Zone which is northern boundary of Anatolian (Turkish) Plate (Baydemir, 1990; Platzman et al., 1994; Tatar et al., 1995; Piper et al., 1996). Rock formations with ages more than middle Miocene was formed during the paleotectonic development period and cumulative rotations of this process is related both Paleotectonic and Neotectonic deformations. Crustal deformations in southwestern side of the study could be considered in the connection with Isparta angel. From Langhian and Eocene to present, Kissel et al. (1986); Kissel and Poisson (1986, 1987) found 30° anti-clockwise rotations and 40° clockwise rotations, respectively, in the western and eastern side of the Angel.

Paleomagnetic investigations on the western Anatolian grabens began with the works of Lauer (1984) and continued with the works of Kondopoulou and Lauer (1984); Kissel (1986); Kissel et al. (1986). They focused mostly on the coastal region. These studies suggest approximately 30° counter-clockwise rotation from İzmir-Bergama and Gulf of Edremit (Kissel et al., 1986). Contrary to these, similar works were later carried out by Orbay et al. (1997a, b, 2000). They report many clockwise rotations in the west. In the western side of our study area were found both clockwise and anti-clockwise rotations (Figure 7).

Anti-clockwise rotations (Figure 6) generally are domi nant in the eastern side of the study (Karavul, 1995). Similarly there are anti-clockwise rotations in the previous studies in Central Anatolia (Gürsoy et al, 1998; Platzman et al, 1998). These last results are in agreed with our present study.

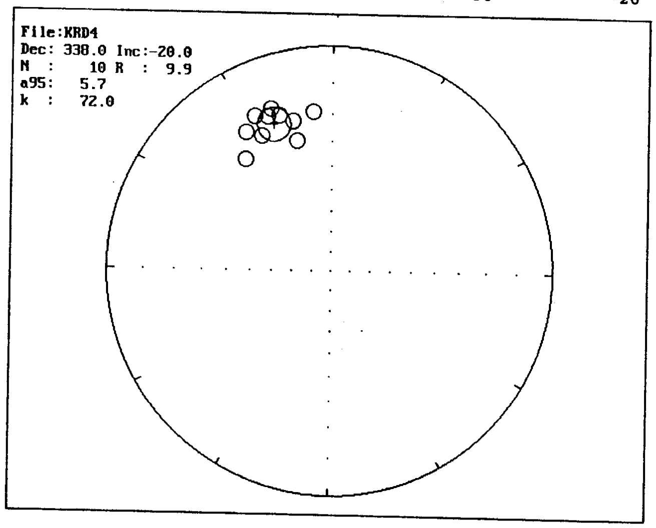
RESULTS AND DISCUSSIONS

In our present study, it is found that (Figure 8):

(i) Pliocene aged sites (AF and KK) from Afyon region

FILE:KRD4

Sample	Site	RANGE	Dec	Inc
x	0 - 0	0	-15	-28
x	0 - 0	0	-15	-21
x	0 - 0	0	-7	-19
x	0 - 0	0	-23	-17
x	0 - 0	0	-28	-22
x	0 - 0	0	-19	-18
x	0 - 0	0	-21	-15
x	0 - 0	0	-32	-18
x	0 - 0	0	-27	-15
x	0 - 0	0	-38	-26



FILE:KRD4-400

Sample	Site	RANGE	Dec	Inc
x	0 - 0	0	-7	46
x	0 - 0	0	-8	44
x	0 - 0	0	-8	47
x	0 - 0	0	-9	45
x	0 - 0	0	-13	45
x	0 - 0	0	-16	43
x	0 - 0	0	-8	48
x	0 - 0	0	-1	47

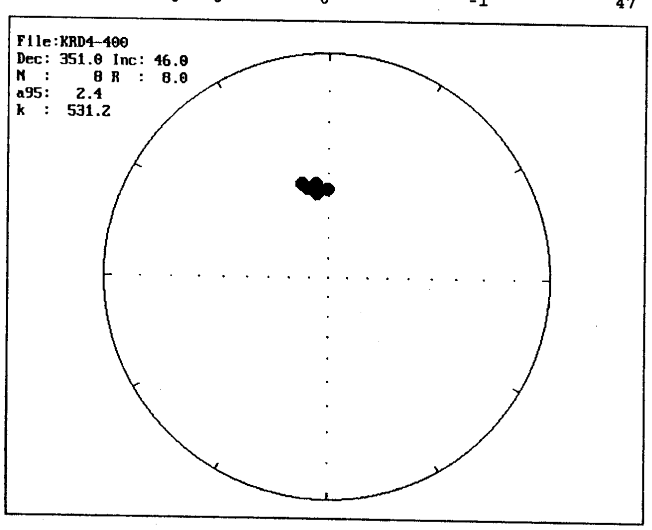
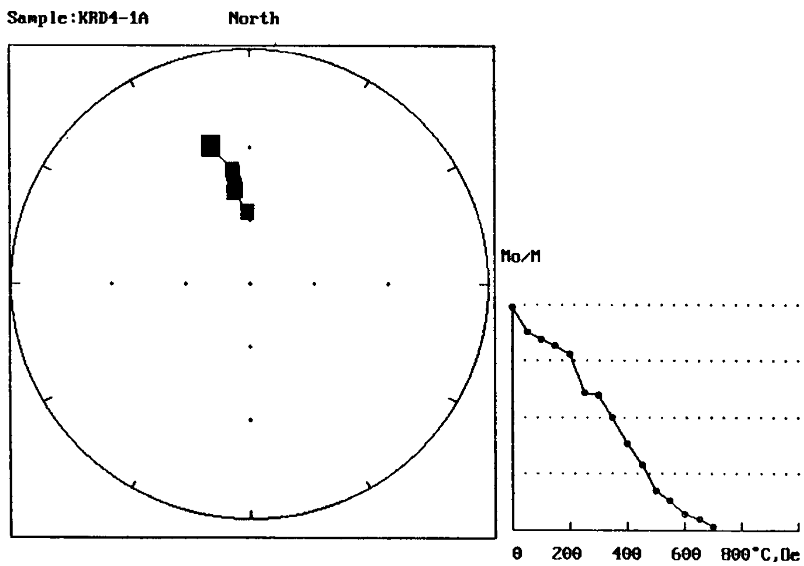


Figure 2. Natural remanent magnetism and remanent magnetism after demagnetization treatment at 400°C were given for KRD4 (Karadag) Andesite sample (Pliocene aged). Where dec, inc are declination and inclination, respectively.

HEADER: KRD4-1A 0.0 0.0 0.0 0.0 11.56 1 100

Temp	CoreDec	CoreInc	GeoDec	GeoINc	Intensity	%Int	a95	Comment/
0	0.0	0.0	-15.0	28.0	2133.000	100	0.0	K.INPU
50	0.0	0.0	-8.0	38.0	1893.000	89	0.0	K.INPU
100	0.0	0.0	-8.0	40.0	1820.000	85	0.0	K.INPU
150	0.0	0.0	-8.0	44.0	1763.000	83	0.0	K.INPU
200	0.0	0.0	-8.0	46.0	1681.000	79	0.0	K.INPU
250	0.0	0.0	-8.0	46.0	1321.000	62	0.0	K.INPU
300	0.0	0.0	-8.0	46.0	1288.000	60	0.0	K.INPU
350	0.0	0.0	-8.0	47.0	1075.000	50	0.0	K.INPU
400	0.0	0.0	-8.0	47.0	828.000	39	0.0	K.INPU
450	0.0	0.0	-8.0	47.0	631.000	30	0.0	K.INPU
500	0.0	0.0	-9.0	47.0	377.000	18	0.0	K.INPU
550	0.0	0.0	-9.0	47.0	288.000	14	0.0	K.INPU
600	0.0	0.0	-9.0	47.0	158.000	7	0.0	K.INPU
650	0.0	0.0	-9.0	47.0	108.000	5	0.0	K.INPU
700	0.0	0.0	-1.0	57.0	38.000	2	0.0	K.INPU



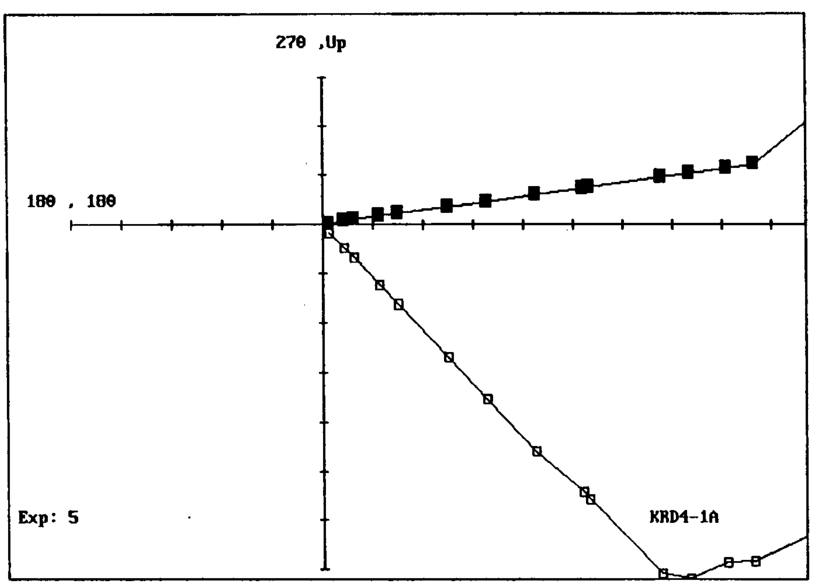
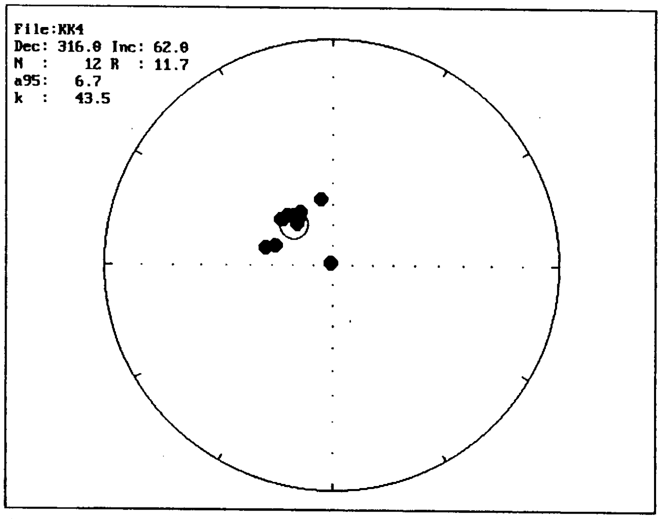


Figure 3. Demagnetization and Zijderveld curves were given for pilot sample (KR41-A).

FILE:KK4

Sample	Site	RANGE	Dec	Inc
x	0 - 0	0	-49	56
x	0 - 0	0	-43	57
x	0 - 0	0	-76	56
x	0 - 0	0	-42	57
x	0 - 0	0	-31	59
x	0 - 0	0	-10	57
x	0 - 0	0	-48	57
x	0 - 0	0	-41	63
x	0 - 0	0	-71	60
x	0 - 0	0	-38	59
x	0 - 0	0	-39	88
x	0 - 0	0	-35	61



FILE:KK4-500

Sample	Site	RANGE	Dec	Inc
x	0 - 0	0	-46	51
x	0 - 0	0	-45	54
x	0 - 0	0	-44	53
x	0 - 0	0	-42	51
x	0 - 0	0	-43	54
x	0 - 0	0	-44	53
x	0 - 0	0	-42	52
x	0 - 0	0	-41	54
x	0 - 0	0	-46	57
x	0 - 0	0	-44	51
x	0 - 0	0	-46	50

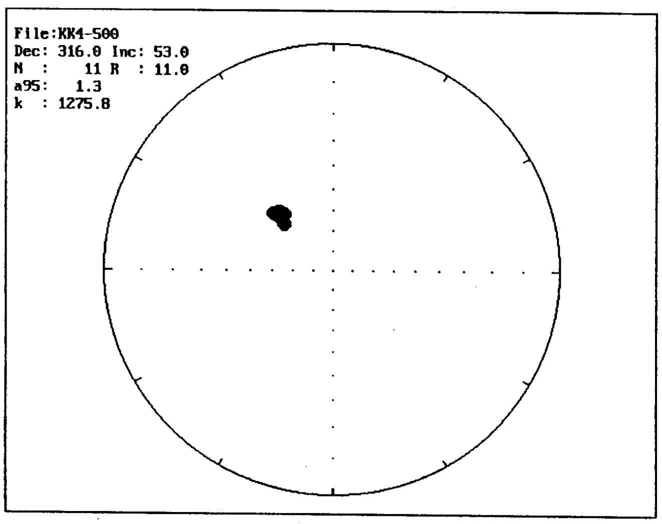


Figure 4. Natural remanent magnetism and remanent magnetism after demagnetization treatment at 500℃ were given for KK4 (Afyon Site) Basalt sample (Pliocene aged).

HEADER: KK4 0.0 0.0 0.0 0.0 11.56 1 100

Temp	CoreDec	CoreInc	GeoDec	GeoINc	Intensity	%Int	a95	Comme
0	0.0	0.0	-42.0	57.0	1435.000	100	0.0	K.INI
50	0.0	0.0	-43.0	56.0	1438.000	100	0.0	K.INI
100	0.0	0.0	-48.0	53.0	1504.000	105	0.0	K.INI
150	0.0	0.0	-47.0	53.0	1489.000	104	0.0	K.INI
200	0.0	0.0	-47.0	51.0	1425.000	99	0.0	K.INI
250	0.0	0.0	-40.0	54.0	1407.000	98	0.0	K.INI
300	0.0	0.0	-35.0	56.0	1388.000	97	0.0	K.INI
350	0.0	0.0	-38.0	54.0	1358.000	95	0.0	K.INI
400	0.0	0.0	-43.0	52.0	1337.000	93	0.0	K.INI
450	0.0	0.0	-44.0	51.0	1292.000	90	0.0	K.INI
500	0.0	0.0	-46.0	50.0	1109.000	77	0.0	K.INI
550	0.0	0.0	-47.0	51.0	722.000	50	0.0	K.INI
600	0.0	0.0	-49.0	53.0	576.000	40	0.0	K.INI
650	0.0	0.0	-50.0	54.0	102.000	7	0.0	K.INI
700	0.0	0.0	-56.0	55.0	49.000	3	0.0	K.INI

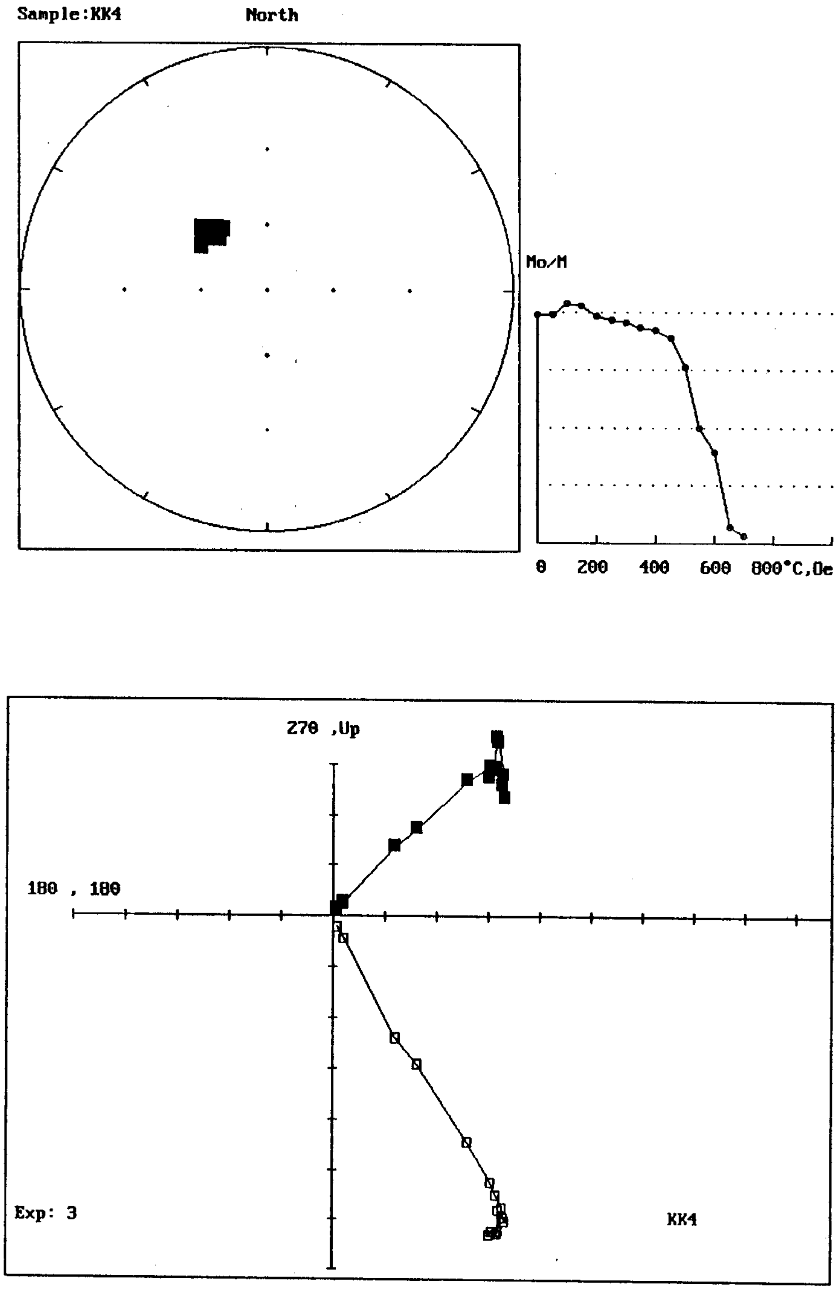


Figure 5. Demagnetization and Zijderveld curves were given for pilot sample (KK4).

Table 1. Site mean directions and statistical parameters after demagnetization procedure. N and n represent the number of specimens. (*) The remanent magnetization directions of these samples are converted to normal polarity. An and Ba represent and esite and Basalt respectively.

After the demagnetization							
Site	**Rock**	**N**	**Age**	**D**	**I**	**α_{95}**	**K**
AF1	An	7	Pliocene	341	8	1,0	4870
AF2	An	9	Pliocene	347	23	2,1	728
AF3	An	9	Pliocene	330	20	5,1	140
AF(Mean)				340	17		
KK1	Ba	8	Pliocene	310	73	3,3	333,9
KK2	Ba	9	Pliocene	322	54	2,2	665,4
KK3	Ba	9	Pliocene	323	51	3,2	264
KK4	Ba	12	Pliocene	316	53	1,3	1275
KK(Mean)				321	58		
MT1	An	14	Miocene	125 (305)	-25 (25)	2,7	236
MT2	An	8	Miocene	116 (296)	-24 (24)	4,9	118,9
MT3	An	9	Miocene	131 (311)	-27 (27)	5,1	101,6
MT4	An	12	Miocene	125 (305)	-30 (30)	1,6	846,6
MT(Mean)				125 (305)	-27 (27)		
AS1	Ba	8	Plio-Quarternary	171 (351)	-54 (54)	2,3	599
AS2	Ba	7	Plio-Quarternary	148 (328)	-45 (45)	3,7	327,3
AS3	Ba	11	Plio-Quarternary	166 (346)	-74 (74)	11, 3	19,4
AS(Mean)				162 (342)	-58 (58)		
OD1	Ba	12	Plio-Quarternary	168 (348)	-42(42)	3,5	154,4
OD2	Ba	11	Plio-Quarternary	182 (2)	-35 (35)	4,9	89,3
OD3	Ba	7	Plio-Quarternary	168 (348)	-45 (45)	1,3	2077,1
OD(Mean)				173 (353)	-40 (40)		
OC1	An	10	Upper Miocene	340	51	4,6	112,1
OC2	An	11	Upper Miocene	341	46	6,6	48,2
OC3	An	5	Upper Miocene	319	37	4,7	263
OC(Mean)				334	45		
MD1	Ba	10	Plio-Quarternary	338	47	2,3	424
MD2	Ba	7	Plio-Quarternary	339	59	4,6	169,5
MD3	Ba	8	Plio-Quarternary	368	46	3,7	220,9
MD(Mean)				349	52		
HD1	Ba	7	Plio-Quarternary	348	26	6,4	110,7
HD2	Ba	7	Plio-Quarternary	346	31	2,8	455
HD3	Ba	8	Plio-Quarternary	345	37	2,3	570,3
HD(Mean)				347	31		
KRP1	An	7	Plio-Quarternary	350	72	3,2	574,3
KRP2	An	7	Plio-Quarternary	342	60	8,9	47,4
KRP3	An	5	Plio-Quarternary	-36	68	3	670,1
KRP(Ort)				338	67		
KRC1	An	7	Neogene	155 (335)	-35 (35)	2,8	478,8
KRC2	An	7	Neogene	163 (343)	-54 (54)	2,1	854,9
KRC3	An	11	Neogene	170 (350)	-39 (39)	3,7	154,5
KRC (Ort.)				162 (342)	-43 (43)		
KRD1	An	9	Pliocene	175 (355)	-42 (42)	4,4	140,9
KRD2	An	6	Pliocene	172 (352)	-50 (50)	5,8	132,5
KRD3	An	6	Pliocene	172 (352)	-50 (50)	4,6	216,4
KRD4	An	8	Pliocene	351	46	2,4	531
KRD (Ort.)				174 (354)	-48 (48)		

Table 2. Previous paleomagnetic results and their parameters.

Site	Age	D (Mean)	I (Mean)	Reference
Aksaray region	2.5 My	345	56	Platzman et al (1998)
Kayseri region	2.5 My	356	58	Platzman et al (1998)
Konya region	6.9 My	355	39	Platzman et al. (1998)
Konya region	4.7 My	4	54	Platzman et al (1998)
Konya region	-	349	61	Platzman et al. (1998)
Konya region	5.98 My	196 (16)	-47 (47)	Platzman et al. (1998)
Nevşehir region	O.08 My	180	53	Platzman et al. (1998)
Sarkisla region	Neogene	147 (327)	-55 (55)	Gürsoy et al. (1998)
Gemerek Bölgesi	Neogene	119.9 (299.9)	-60.8 (60.8)	Gürsoy et al. (1998)
Karaman Bölgesi	Neogene	174.3 (354.3)	-51.8 (51.8)	Gürsoy et al. (1998)
Karapınar region	Neogene	156.9 (336.9)	-42.2 (42.2)	Gürsoy et al. (1998)
Karacadag region	Neogene	177.6 (357.6)	-57.6 (57.6)	Gürsoy et al. (1998)
Hasandag region	Neogene	170,1 (350)	-57.6 (57.6)	Gürsoy et al. (1998)
Yozgat	Eosen	336	64	Karavul (1995)
Nevsehir region	Upper Miocene	341	38	Karavul (1995)
Sivas region	Paleocene	331	55	Karavul (1995)
Kırsehir region	Upper Cretaceous	-90 (270)	-	Sanver and Ponat (1980)
Kırsehir region	Eocene	-10/-15		Sanver and Ponat (1980)

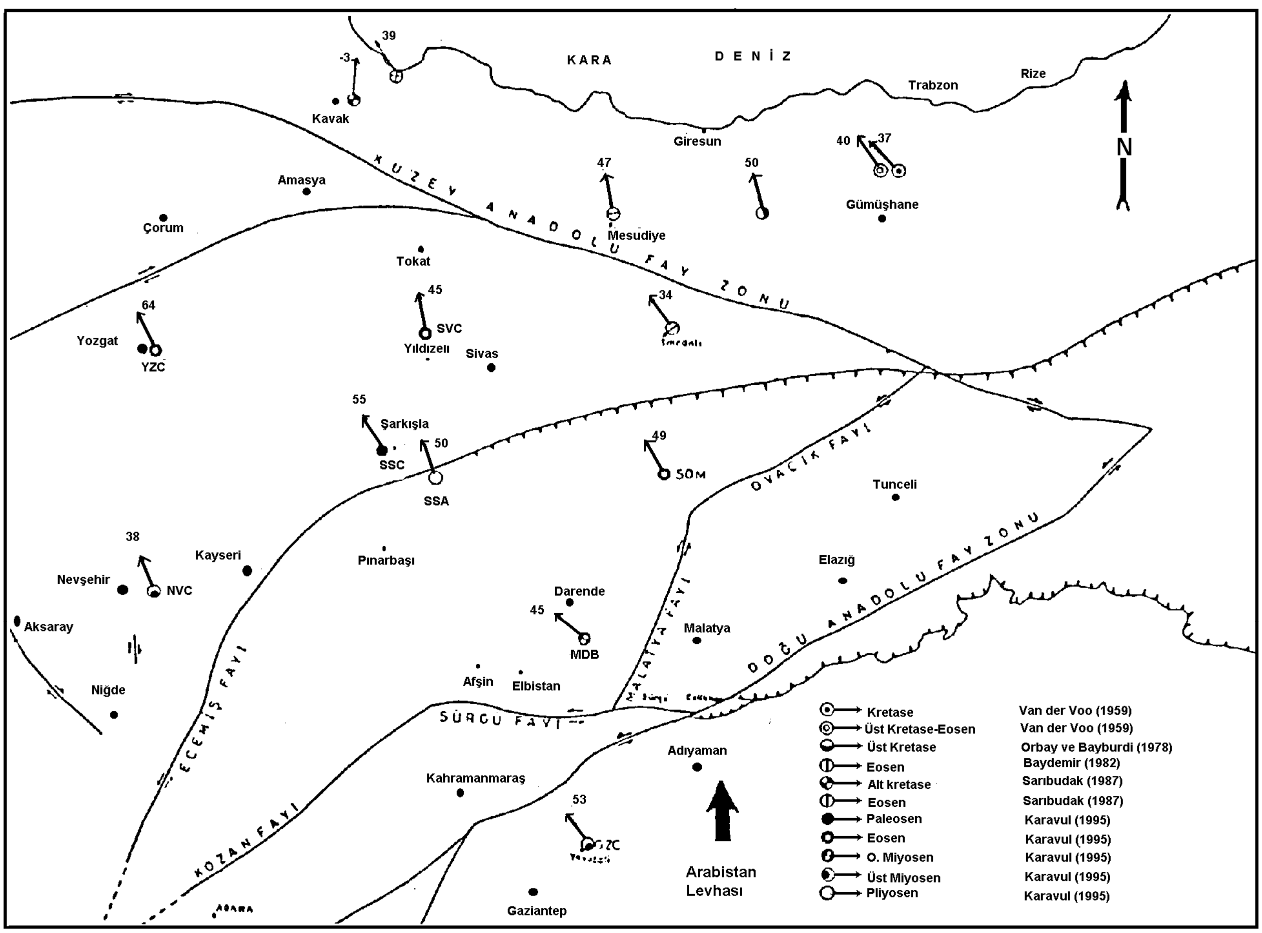


Figure 6. Paleomagnetic studies from the eastern side of the present work (modified from Karavul, 1995).

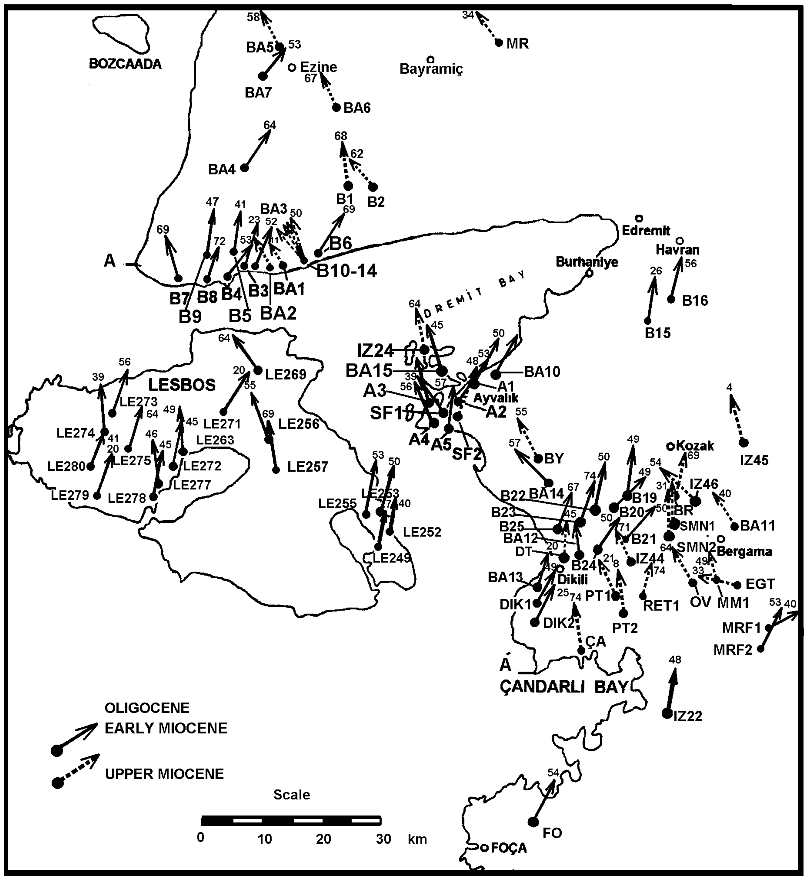


Figure 7. Paleomagnetic studies from the western side of present work (Orbay et al., 2001).

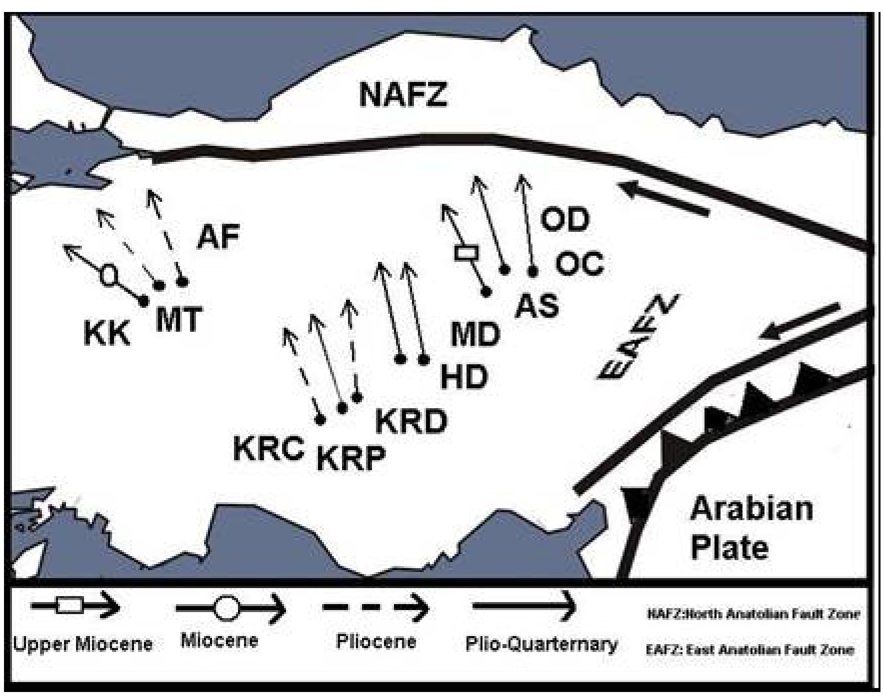


Figure 8. Obtained paleomagnetic results.

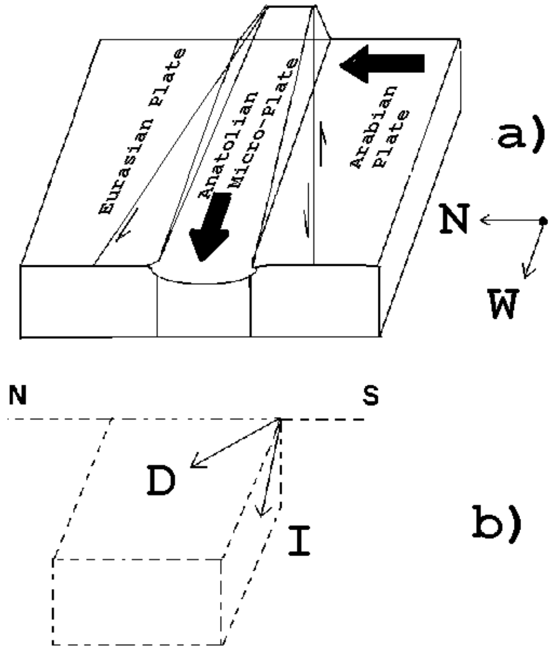


Figure 9. Escape of the Anatolian (Turkish) Plate (a) and Paleomagnetic Rotations (b).

have anti-clockwise rotations, respectively, 20° and 39°. Miocene aged rock samples (MT) from same region represents 55° anti-clockwise rotations.
(ii) Plio-Quarternary aged sites (AS and OD) from Nevşehir volcanic region volcanism have anti-clockwise rotations, respectively 18° and 7°. Upper Miocene aged rock samples (OC) show 26° anti-clockwise rotations.
(iii) The amount of anti-clockwise rotation of Plio-Quarternary aged two locations (HD and MD) from Hasan Dag and Melendiz Dag are 13° and 11°.
(iv) Pliocene aged sites (KRD) from Karadag Volcanism have 6° anti-clockwise rotations. Plio-Quarternary aged site (KRP) from Karapinar area represents 22° anti-clockwise rotations. 11.9 My aged rock samples from (KRC) Karacadag show 18° anti-clockwise rotations.

If we removed cumulative effect of the time, in Miocene, mean anti-clockwise rotations increase from East (Nevsehir, 8° - 19°) to West (Afyon, 16° - 35°). This implies that, there are two different tectonic styles or systems in the region.

While Western Anatolia have both clockwise and anti-clockwise rotations due to the Aegean Extension System, the evaluation of all Neogene paleomagnetic data of Central Anatolia shows that anti-clockwise rotations are dominant and this can be interpreted as escape of Anatolian Block (or Plate) to West (Figure 9). When we evaluated all rotation data, there are tree possible explanations/interpretations:

(a) All rotation data may be related local tectonic behaviour.
(b) Perhaps, unexpected rotations may be related fast deformation in a short time. Also, GPS data in this region (Melengiclik, respect to Euroasia) indicate an activity with 15 mm/year of movement (Oral et al 1995).
(c) Lastly all local and regional tectonic development caused a combine effect.

When we look all Neogene Paleomagnetic data, anti-clockwise rotations is one of the most striking facts. For abnormal rotations (Figure 9), reasonable or possible explanations could be really or hypothetically clarified by tree way:

(1) Local effects of regional faults (one of strong impression)
(2) Interpretations as a result of escape of Turkish (Anatolian) plate due to the collusion between Arab and Eurasia Plates (one of strong impression; Figure 9)
(3) Rotation of Central Anatolia as a separate Micro-Plate within Anatolian (Turkish) Plate (weak impression, Figure 10).

All of tree reasonable and/or possible explanations may be reacted in different forms or different time scales. Anti-clockwise rotations in the Anatolian plate are mainly the result of the plate tectonic interactions in which were initiated by middle Miocene time. On a regional scale, rotations were produced by escape of Anatolian lithosphere.

Different kind of fragmentations of the crust and rotation of individual blocks on a smaller scale probably also occurred in Aegean region. In this region, three are both clockwise and anti-clockwise rotations. The existing data are to confirm it and distinguish such blocks (Orbay et al., 1995, 1996). The paleomagnetic and GPS studies show that the Anatolian plate was subjected to considerable displacement. For western and central Anatolian, from the Oligocene to the present, paleomagnetic data revealed approximately 30 - 40° and 15 - 20° counterclockwise rotations.

As Piper et al (2006) point out, although, the regional coverage of neotectonic rotations is still incomplete (and is indeed largely constrained by the distribution of young volcanic rocks), the picture emerging is one of distributed crustal deformation with considerable regional variation. They also agree that most rotation has occurred during the last few m.y. and presumably succeeded the crustal thickening that followed late Miocene collision with Arabia along the Bitlis suture zone.

As a result, Anatolian plate paleomagnetically has two micro-plate behaviours: (1) complex behaviour in Aegean region with clockwise and anti-clockwise rotations and (2) ordinary behaviour with only clockwise rotations in central Anatolia. One of the reasons of these behaviours may be two different type of micro-plate within the Anatolian plate (Figure 10).

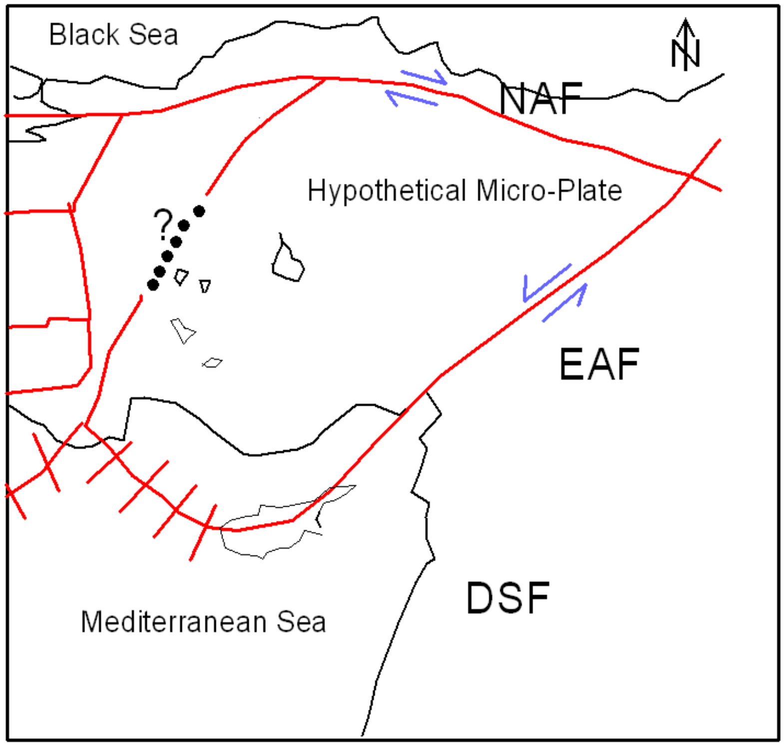


Figure 10. Hypothetical microplate within the Turkish Plate. NAF= North Anatolian. Fault; EAF= East Anatolian fault and DSF = Dead Sea fault (Figure modified by McKenzie, 1972).

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