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Tectono–Magmatic Evolution of Alkaline Volcanics at the Kırka–Afyon–Isparta Structural Trend, Sw Turkey

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Abstract: The youngest Alpine magmatism (Miocene to Quaternary) in Western and Central Anatolia is represented by three coeval assemblages from West to East. They are the Western Anatolian Volcanic assemblage (WAV), the N-S trending Kırka-Afyon-Isparta Alkaline Volcanic assemblage (KAIAV) and the Central Anatolian Volcanic Provinces (CAVP). The WAV and CAVP start with calc-alkaline volcanics and continue after Middle Miocene with shoshonitic to alkaline products of graben volcanism, while the KAIAV are all alkaline in character, without any former or later calc-alkaline contributions. The KAIAV are emplaced in three steps of alkaline volcanic activities which exhibit southward younging along the N-S Kırka-Afyon-Isparta Structural Trend (KAIST). These three periods from N to S are represented by the Kırka (21-17 Ma), Afyon (14-8 Ma) and Isparta (4.7-4.0 Ma) alkaline rocks. In all of these localities volcanic evolutions begin similarly with a rhyolitic-trachytic main part (potassic 'K') and are followed by high-potassic (HK) or ultra-potassic (UK) dykes and domes.

The KAIAV along the KAIST represents a fault controlled border zone between Western and Central Anatolia, where the WAV and the CAVP are located, respectively. Additionally the same fault system (KAIST) is also valid as a border zone between the Hellenic Arc (HA) and Cyprus Arc (CA) systems. The oblique character of this fault system (normal fault + strike slip component) is well known. Therefore, the KAIST is herein interpreted as a transform fault system between the HA and the CA. The KAIST separates also two allocthonous crystalline massifs of Anatolia, i.e. Menderes and Kırşehir massifs located in Western and Central Anatolia, respectively. It may also indicate the important role of the subductional-postcollisional tectonic regimes related to the metamorphic (core complex ?) areas involving former calc-alkaline volcanics of the WAV and the CAVP. The KAIAV along the KAIST are characterised by the absence of the calc-alkaline period, and indicate a different tectonic regime and source material than those of the WAV and the CAVP.

The KAIST is an en echelon, oblique fault system with normal and strike-slip (dextral) periods. The last dextral period overlapped temporarily with the Isparta volcanics where the blocks of the Anatolian plate (and also Afyon volcanics) were pushed to the north over a stable (?) magma source. This magma source could be considered either as a fixed hot spot or plume on the intersection point of two main fault systems. The N-S emplacement of plum material along the KAIST may also be considered as an other alternative mechanism of southwards younging of the KAIAV. The tectonic periods before and after the production of the Isparta volcanics are represented by graben and half-graben systems. They seem like fertile and sterile periods of volcanic activities over the transform fault systems of the KAIST between the HA and the CA. While the normal faulting periods represent the sterile areas, the change to dextral movements resulted in small decompressions in the mantle and gave rise to the production of alkaline (K, HK, UK) volcanics, which are also observable in the latest stage of the WAV.

Key Words: Potassic–Ultra Potassic Volcanism, Alkaline Volcanics, Tranform Fault.

Kırka–Afyon–Isparta Yapısal Trendi Boyunca, Alkali Volkanitlerin Tektono–Magmatik Evrimi

Özet: Batı ve Orta Anadolu'daki en genç alpin magmatizma (Miyosen - Kuaterner),batıdan doğuya doğru, özgün istifler sunan, üç ayrı yaşıt volkanik topluluk olarak sınıflandırılır. Bunlar sırası ile Batı Anadolu Volkanik Birliği (WAV) , KG uzanımlı Kırka - Afyon - Isparta Alkali Volkanitleri (KAIAV) ve Orta Anadolu Volkanik Birliği (CAVP) olarak tanımlanırlar. WAV ve CAVP istifleri kalk alkali volkanizma ile başlarlar ve Orta Miyosen sonrasında, genç grabenler içinde yüzlekleyen şosonitik - alkali kayalara dönüşerek eylemlerini sürdürürler. Oysa KAIAV istifi, baştan sona, hiçbir kalk alkali katkı olmaksızın, tümü ile alkali karakterlidir. Bu alkali dizilim, en kuzeyde Kırka' dan başlayarak, güneye doğru, Kırka-Afyon-Isparta Yapısal Çizgiselliği (KAIST) boyunca üç aşamada, gençleşerek yüzlekler (Kırka 21-17 m.y., Afyon 14 -8 m.y. ve Isparta 4.7-4.0 m.y.). Volkanizma her üç bölgede, önce riyolitik-trakitik ana kütle ile (potasik "K") başlar ve izleyen yüksek potasik (HK) ve ultra potasik (UK) dayk ve domlar (fonolit, lösit fonolit, lösitit, lamproitik kayalar vb.) ile son bulur. KAIST Batı ve Orta Anadolu arasındaki, fay ve volkanizma denetimli, KG uzanımlı sınır çizgisidir. Aynı çizgisellik, Helenik ve Kıbrıs yayları arasındaki konumu ile bu iki yayı ayıran sınır çizgisi olarak da tanımlanabilir. Bu nedenle, oblik karakterli ve KG uzanımlı olan bu fay sistemi, ilk kez bu çalışma kapsamında, Helenik ve Kıbrıs yay sistemlerini birbirinden ayıran, transform fay sistemi olarak tanımlanmıştır.

Aynı çizgisellik (KAIST), Menderes (B. Anadolu) ve Kırşehir (Orta Anadolu) masifleriiçin de ayrım çizgisi olarak düşünülebilir. KAIAV istifinde gözlenemiyen kalk alkali volkanizmanın, B. ve Orta Anadolu'da (Menderes ve Kırşehir Masifleri) volkanizmanın başlangıcında, önemli boyutlarda yeralmasının, masifler ile kalk alkalilerin ilişkilerini yansıtan bir anlamı olması beklenir. Bir başka anlatımla, WAV ve CAVP volkanizması ile, KAIAV ürünlerinin, farklı tektoniklerin ve farklı kaynak malzemelerinin türevleri olması gerekir.

KAIST oblik bir sistem olarak, normal faylanmalar sürecinde sedimenter yığışımları, doğrultu atımlı faylanmalar (dekstral) sürecinde ise, alkali volkanitlerin yüzleklemesini gerçekleştiren hareketler olarak tanımlanır.

Anahtar Sözcükler: Potasik–Ultra Potasik Volkanizma, Alkali Volkanitler, Transform Fay.

Introduction

The most recent part of alpine magmatism in Western and Central Anatolia is represented by three coeval (Miocene to Quaternary) volcanic provinces with different tectonic and geochemical evolutions. The volcanic assemblages are (Fig. 1);

1- Western Anatolian Volcanics (WAV)

2- NS-trending Kırka-Afyon-Isparta, alkaline (potassic "K", high-potassic "HK" and ultra-potassic "UK") Volcanics (KAIAV) and

3- Central Anatolian Volcanic Province (CAVP)

1) The WAV represent the eastern part of the widespread Aegean magmatism (Francalanci et al., 1990 and references therein) beginning with the Eocene at the north and becoming younger towards the south (Fig. 1).The southern part of the WAV are recognised to represent post collisional volcanism (Yılmaz, 1989) starting with K-dominant calc-alkaline volcanics and their plutonic equivalents in Early to Middle Miocene (21-14 Ma) (Savaşçın, 1990). Two different opinions regarding the regional tectonic regime during the emplacement of these volcanics are still in discussion. The calc-alkalines were interpreted either to be related to compressional tectonics (Yılmaz, 1989, Savaşçın, 1990, Savaşçın and Güleç 1990) or as to extensional tectonics started by the Early Miocene, or earlier (Kaya, 1981, 82; Kissel et al., 1986; Seyitoğlu and Scott, 1992). The volcanism is controlled mostly by NE and partly NW trending fractures.

After the 3-4 Ma interruption in volcanism , the second phase of the WAV magmatism occurred in shoshonitic to alkaline composition together with its plutonic equivalents (Fig. 1). In addition to their new chemical composition (shoshonitic to alkaline) their relation to younger (~10 Ma) graben systems are characteristic. The volcanic products of the second phase are widespread in Western Anatolia without any relation with the southwards younging of the calc-alkalines of the first phase. They are located in general, along the NS and NW trending boundaries of the younger graben systems all over Western Anatolia from north to south in the same interval of time. Although former calc-alkaline volcanics have built larger sized strato-type centers; the following alkalines are characterised by small sized lavas and domes in association with thickly developed pyroclastics.

In the third phase of the WAV (Pliocene-Quaternary), alkaline volcanism changed into hyper-alkaline in character (Banakite of Akhisar "ultrapotassic" and phonotephrites of Kula "hypersodic", both with mantle xenoliths).

1. The KAIAV to the east of the WAV (Fig. 1), however, in the same interval of time (21- 4 Ma) developed in completely potassic-alkaline character (K, HK, UK) without any calc-alkaline component (Savascın et al., 1994). The southward younging of the KAIAV is associated with quite different tectonic conditions than that of the WAV and is the main subject of this paper.

2) To the east of the KAIAV, the Central Anatolian Volcanic Province (CAVP) was formed with a certain similarity to the WAV with respect to time and composition. Beside the Karadağ and the Erenler volcanics, the Galatia volcanics (GV) and the Cappadocian Volcanic Province (CVP) are the two important and widespread elements of the CAVP, where the small sized younger alkaline volcanics are parallel to the main fault systems of the region and are evolved wider than the WAV.

Two eruptive cycles are clearly recognised within the GV of NW Central Anatolia (Fig. 1). The older volcanics of Eocene to Early Miocene age, are generally considered to characterise a continental margin arc related to plate convergence (calc-alkaline). In contrast, the younger sequence comprises extension related alkaline basalts of Late Miocene age (Tankut, 1993) with outcrops parallel to the North Anatolian Fault (NAF).

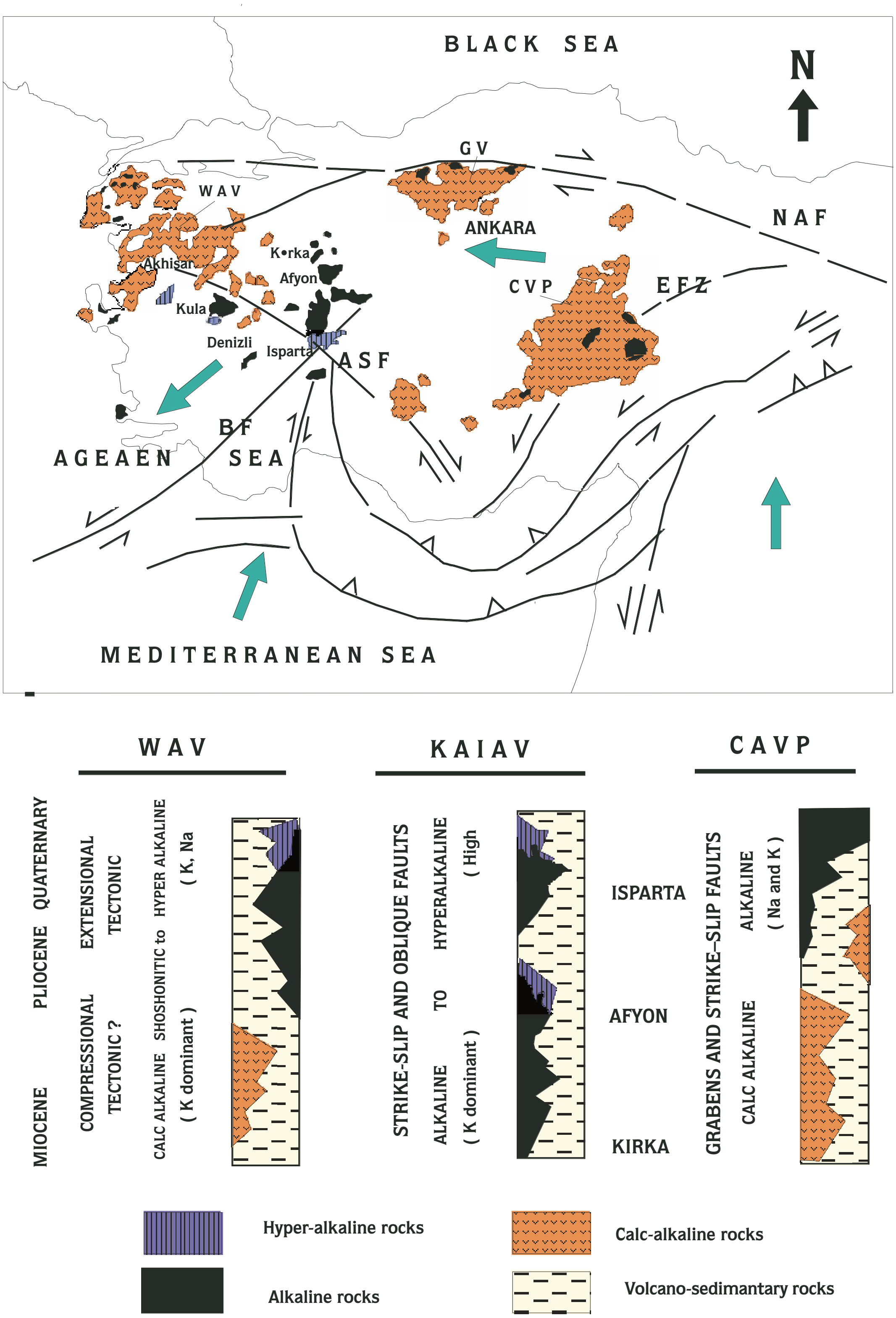

Figure 1. The most recent part of alpine volcanism and their three coeval assemblages in the Western and Central Anatolia.

The CVP is a Neogene-Quaternary volcanic field which extends for a length of 300 km and a width of 20-50 km in a NE-SW direction in central Anatolia. Geochemical, petrographical and geochronological characteristics and ignimbrite emplacement in the province were studied by Le Pennec et al.(1994) Druitt et al.(1995) and references therein. According to these published data, the Cappadocian volcanics are calc-alkaline in character and their formation is attributed to the convergence between the Eurasian and Afro-Arabian plates, occurring in the eastern Mediterranean.

Description of the KAIAV

To the south and north of Kırka, volcanics commencing with very thick sediment, tuff, alkaline-rhyolite to trachyte alternation and ignimbrite deposits (Keller and Villari, 1972) and ending with alkaline basic products such as phonolitic tephrites, appear to be 21 - 17 Ma in age (Bessang et al., 1977; Sunder, 1982, Savaşçın et al. 1994), (Fig. 2).

Further south, the Afyon volcanics, are also characteristically underlain by poorly sorted clastic sediments of rapid deposition. The alkaline-rhyolitic, latitic and trachytic lavas and domes (Keller, 1983) around Afyon are intercalated with tuff, agglomerates, fluvial to lacustine volcanosedimentary deposits, poorly sorted clastic sediments and paleosoils (Middle-Upper Miocene; Özturk, 1989).

The last stage of the Afyon volcanics to the south of Afyon are represented mostly by leucite, sanidine and Ba-feldspar bearing K, HK and UK dykes and domes, such as leucititic-phonolite, tephrite, phonolite, leucitite and partly lamproitic associations. The N-trending dykes and domes cut generally rhyolitic,trachytic rocks of the first stage,and are located in the southern part of the area. The age of the Afyon volcanics ranges from 14 to 8.7 Ma (Fig.2).

The most southern part of the KAIAV is represented by N-trending volcanics to the north and south of Isparta. Besides thickly bedded pyroclastics with alkaline rhyolite and intermediate trachyte composition in the northern part, younger phonolitic tephrites, tephritic-phonolites and lamproitic rocks are located further south of Isparta (Lefevre et al., 1983; Özgür et al., 1990; Savaşçın et al., 1994). All rocks are K, HK and UK alkaline in composition. Leucitites with high Al_2O_3 and low MgO, which occur as dominantly UK-rocks of Afyon, are not known in Isparta, while lamproite (high MgO, low Al_2O_3) a rare type of Afyon's UK rocks are well developed to the south of Isparta. The basic products, include unmetasomatized and pyroxenitic mantle xenoliths and syenitic and basaltic material. Sedimentary enclaves are also present.

The age of volcanism ranges from 4.70 to 4.07 Ma (Lefevre et al., 1983).The fluorine enrichments of the sediments and granitic waters (Özgür et al., 1990), sulphur deposition and occurrence of sodium sulphate brine (Savaşçın and Birsoy, 1993) in the surrounding areas are the products of this volcanic activity.

Tectonic Setting of the KAIAV

In the eastern Mediterranean region, the boundary between the African and Eurasian plates is delineated by the Hellenic arc and the Pliny-Strabo trench in the west and the Cyprus arc and diffuse fault systems in the east (Mc Kenzie, 1970; Rotstein, 1984; Dilek et al.,1990; Anastakis and Kelling, 1991; Taymaz et al., 1991). The two arcs (Fig. 3) are perpendicular to the relative motion of Africa with respect to Eurasia and so are primarily subduction zones. Various tectonic units within the northern parts of these two N-dipping subduction zones form the Isparta Angle (IA) in the SW of Turkey.

The Isparta Angle (IA) is known as the main geographic region (north of the Antalya Gulf, Fig. 3) which is formed by NE and NW-trending oblique faults (Yağmurlu et al., 1997). The NE-trending Burdur and NW-trending Alasehir-Simav faults (Burdur Fault and Akşehir-Simav Fault are normal faults with left and right lateral components respectively) are the main fault systems of this region which bound the IA in the W and E. These two oblique faults developed parallel to the older suture zones (Dilek and Rowland, 1993) during the Late Maastrichtian and are represented by the reactivated neotectonic lineation (Yağmurlu et al., 1997). In this system, N-trending faults (Fig. 3a) which extend from Kırka to Antalya, will be recognised as a transform type faults-system between two arcs (Fig. 3c, Hellenic and Cyprus arcs).

According to Barka et al., (1997), GPS measurements made in Turkey (1988-1992) indicate that the IA has very little or no motion relative to Eurasia. In contrast, central Anatolia (east of IA) moves westward at about 15mm/yr and western Anatolia (west of IA) moves in a SW direction at about 30 mm/yr (Fig.3).

The KAIST (Kırka-Afyon-Isparta Structural Trend) which separates western Anatolia (with a motion of 30 mm/yr to the southwest) from central Anatolia (with a motion of 15 mm/yr to the west (Fig.3), and it lacks

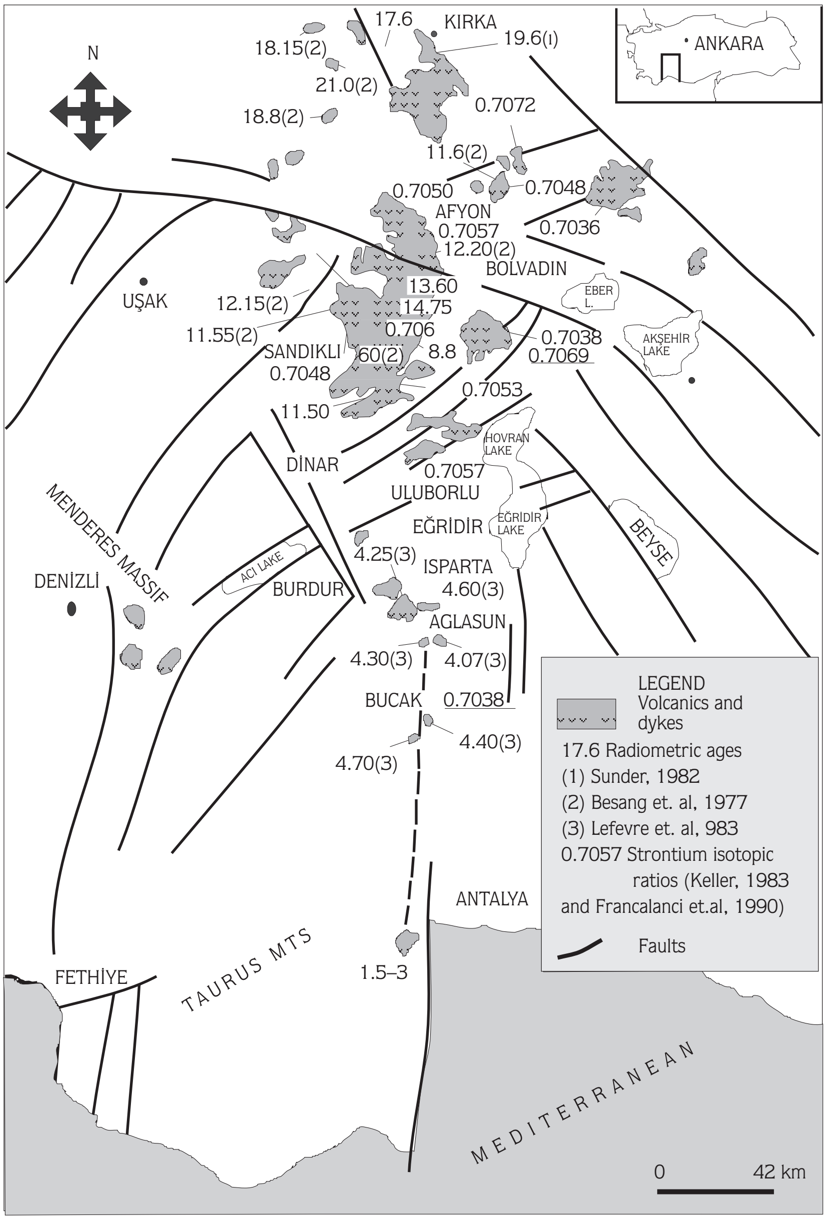

Figure 2. Distribution of alkaline rocks of KAIV with related fault systems, Sr isotope ratios, and radiometric age data determined on the volcanic rocks (modified after Savaşçın et al. 1994).

motion on itself (Barka et al., 1997).Therefore the KAIST can be considered as a regional discontinuity or transform fault system between the HA and the CA as suggested here.

Alkaline volcanic centers of the KAIAV (Fig. 1) are oriented generally N-S, and are located parallel to the west of the Eğirdir-Kovada graben (Savaşşın et al., 1994).

According to Glover and Robertson (1995), during the early Pliocene the area south of Isparta underwent predominantly dextral deformation characterised by narrow dextral shear zones and more diffuse zones where shear distribution resulted in clockwise block rotations. During the late Pliocene and the early Quaternary, normal faulting formed a half-graben, which tilted the Pliocene sediments towards the west. Based on this data, the Afyon volcanites may be considered as being pushed northward during the early Pliocene, while the Isparta volcanites were extruded under the control of dominantly dextral faults. The situation seems to be the result of periodic northward tectonic movement of the Anatolian Plate during the dextral faulting periods over a stable mantle rise (or intersection points; or hot spots).

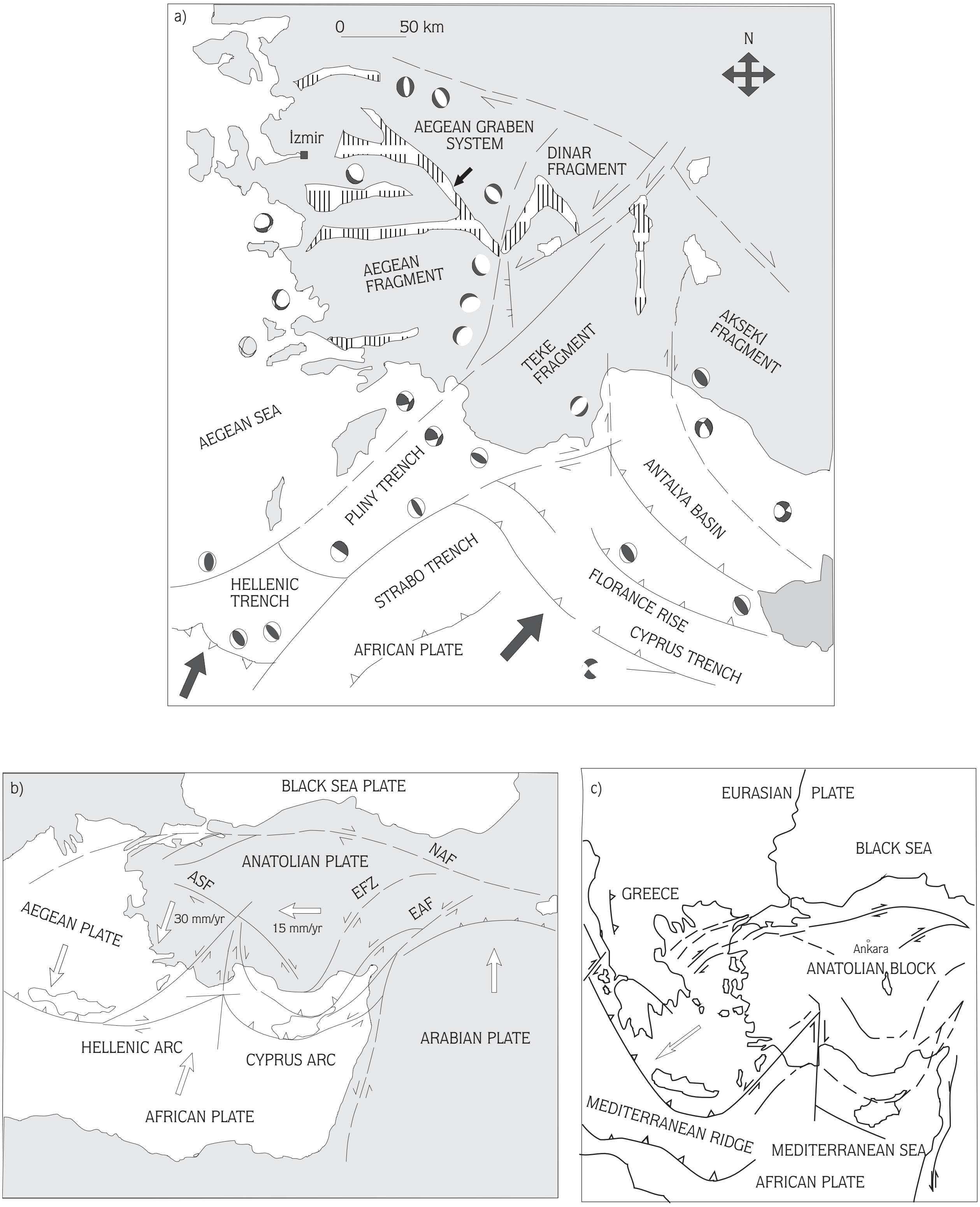

Figure 3. Main tectonic features of SW-Anatolia and adjacent areas, showing the relation between the Hellenic and Cyprus arcs, and distribution of continental fragments within the Isparta Angle (Modified after Yağmurlu et al. 1997).

This might have resulted in the tearing off of the Anatolian plate in a N-S direction, giving rise to the Kirka-Afyon-Isparta structural trend (KAIST) and welded to the former KAIST main fault by later volcanics. Because of this welding, the main N-S fault has migrated further east (Kovada graben). Hence, the KAIST, probably the eastern boundary of western Anatolia and also the Menderes Massif, may replace McKenzie's (1970) tectonic boundary passing through the middle part of the Menderes Massif. This means that the KAIST is an important structural boundary between western and central Anatolia where the Menderes and Kırsehir Massif are located, respectively. Deeply rooted NS trending dextral faults of the KAIST gave rise to the emplacement of the KAIAV to the surface without any former calc-alkaline activity. Whereas the WAV and the CAVP are characterised by the former calc-alkaline sequences due to lithospheric processes influences (hybridisation, contamination,......) of the subductional tectonic regimes. The evolutionary model of the KAIAV is given in Fig 4. The uplifted astenosphere is recognised as a stable mantle rise (or hot spot or intrusions from a plume through the fractures of a KAIST) triggered by the intersection of two main NE and NW-trending oblique fault systems where the Anatolian plate moves to the north during the dextral periods of the KAIST together with the emplacement of the KAIAV.

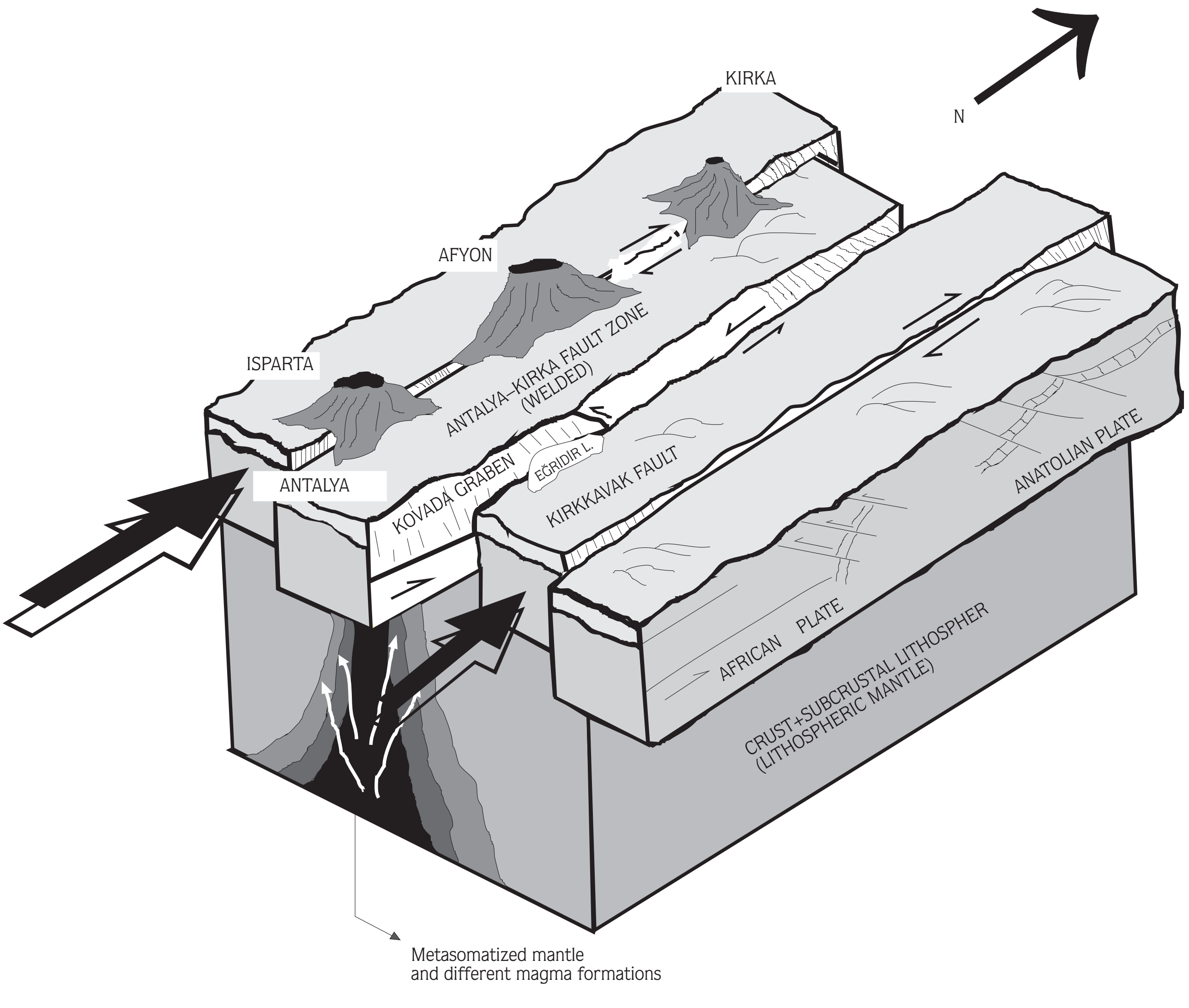

Figure 4. Tectonic evolution of the transform type NS-trended fault systems between two arcs (Hellenic and Cyprus) in the southern parts of the Anatolian plate and related alkaline volcanic occurrences.

Petrography and Geochemistry

Classification of the Kırka, Afyon and Isparta volcanics on the alkaline versus silica diagram is given in Fig 5.

KAIAV rocks are alkaline with a general potassic character but show complex petrographic and chemical variations (Savaşçın et al., 1997). The Afyon samples belong

1) Undersaturated trend from UK-type foidite and leucitite (leucite, aegirine-augite, paracelcian, apatite, nosean, perovskite calcite and opaque minerals)* to tephriphonolite (sanidine, aegirine-augite, biotite, calcite, apatite, opaque minerals), phonotephrite (leucite, sanidine, aegirine-augite, apatite, nosean, calcite, opaque minerals) and trachyandesite (aegirine-augite, sanidine, plagioclase, biotite, lamprobolite, apatite, sphene, nosean,opaque minerals) and,

2) saturated trend of the most widely exposed rock types of Afyon, varying from shoshonite to trachyte-trachyandesite (sanidine, aegirine-augite, biotite, apatite, sphene, plagioclase, calcite, lamprobolite, opaque minerals) and to rhyolite through latite. Further information on the mineralogical compositions of the rocks are given in Table 1 and Table 2.

* Mineralogical compositions of rocks are given in decreasing order.

Rocks of UK-foidite and leucitite are characterised by very high trace element enrichments (BaO; 1.23-0.50 % or 11016-4506 ppm Ba, 3781-2071 ppm Sr) and high Al_2O_3 (20.77-14.65 %), low MgO (1.78-3.91 %) contents.

Among the Afyon samples, just below the foidite and leucitite (Fig.5a) two lamproitic UK rock samples were found, which are characterised by high MgO (9.39-6.16 %), low Al_2O_3 (10.33-11.69 %) and high trace elements enrichments (BaO; 0.26-0.55 % or 2329-4926 ppm Ba, 795-1294 ppm Sr) lower than the values of leucitite. The Isparta samples are concentrated in two areas (Fig.5b): (1) mostly tephriphonolite and phonolitic tephrite (sanidine, clinopyroxene, biotite, plagioclase, chlorite, apatite, calcite, leucite, opaque minerals) and (2) partly rhyolite, trachyte and trachyandesite (amphibole, clinopyroxene, plagioclase, biotite, sanidine, opaque minerals). Rocks of the first group are also UK-type lamproitic in character, however, leucititic UK-rocks of Afyon do not exist in Isparta. The lamproitic group of Isparta volcanics (Al_2O_3; 12.27-9.49 %; MgO; 11.94-7.77 %) do not contain a high enough Ba concentration (2354-1466 ppm) to form Ba-feldspar as Afyon

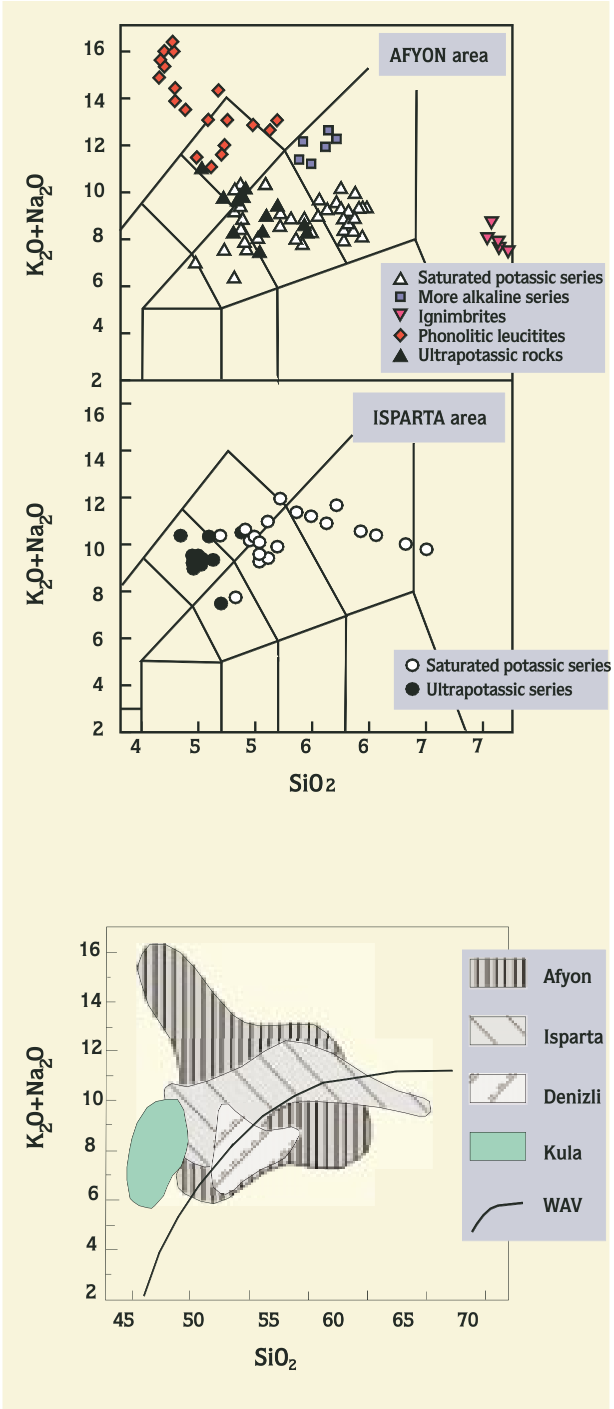

Figure 5. Classification of the Kırka-Afyon (a), Isparta (b) volcanics and their correlation with Western Anatolian (WAV) and Kula, Denizli volcanics on the alkaline versus silica diagram (c. 5(a) and 5(b) is taken from Savaşçın et al. 1997.

Table 1. Microprobe analysis of some minerals from leucitite (Nr. SH 1) and lamproite (Nr. SH 24) samples of Afyon.

LAMPROITE								
SH24								
CLINOPYROXENE								
(Aegirine-Augite		$Ca_{0.85}$	$Na_{0.07}$	$Fe_{0.22}$	$Mg_{0.87}$	$(Al_{0.02}\ Si_{1.97}\ O_6)$		
CLINOPYROXENE								
	Core	$Ca_{0.86}$	$Mg_{0.92}$	$Fe_{0.19}$	$(Al_{0.02}$	$Ti_{0.02}\ Si_{1.96}\ O_6)$		
Kaersutitic	Rim	$K_{0.51}$	$Na_{1.27}$	$Ca_{1.05}$	$(Fe_{0.89}$	$Mg_{3.63})$		$OH\ (Al_{0.30}\ Ti_{0.41}\ Si_{7.15}\ O_{22})$
BIOTITE		$K_{1.56}$	$Fe_{1.14}$	$Mg_{3.53}$	$Al_{1.88}$	$Si_{5.08}$	O_{20}	$(OH)_4$
(Meroksene)								
GARNET		$Fe_{1.03}$	$Mg_{1.2}$	$Ca_{0.17}$	$Al_{1.39}$	$Si_{3.75}$	O_{12}	
		$Fe_{0.87}$	$Mg_{1.41}$	$Ca_{0.17}$	$Al_{0.85}$	$Si_{4.1}$	O_{12}	
SPINEL		$Fe_{1.0}$	$Mg_{1.19}$	$Ca_{0.16}$	$Al_{1.38}$	$Si_{3.75}$	O_{12}	
OLIVINE		$Mg_{1.5}$	$Fe_{0.48}$	$(Si_{0.99}\ O_4)$				
SH24-2								
AMPHIBOLE	Core	$Na_{1.39}$	$Ca_{0.86}$	$K_{0.48}$	$Mg_{3.51}$	$Fe_{0.93}$	$(OH)_2$	$(Al_{0.33}\ Ti_{0.49}\ Si_{7.11}\ O_{22})$
Phlogopitic	Rim	$K_{1.51}$	$(Mg_{3.48}\ Fe_{1.12})$		$(Al_{1.85}\ Ti_{0.76})$	$Si_{5.12}$	$O_{20}\ (OH)_4$	
CLINOPYROXENE								
	Core	$Ca_{0.87}$	$Mg_{0.90}$	$Fe_{0.18}$	$(Al_{0.02}\ Ti_{0.02}$	$Si_{1.96}\ O_6)$		
Phlogopitic	Rim	$K_{1.75}$	$(Mg_{3.39}\ Fe_{1.20})$	$(Al_{0.15}\ Ti_{0.86})$		$Si_{4.30}$	$O_{20}\ (OH)_4$	
GARNET		$Fe_{1.44}$	$Mg_{1.13}$	$Ca_{0.15}$	$Al_{1.41}$	$Si_{3.5}\ O_{12}$		
LEUCITITE								
SH-1								
PARACELSIAN		$K_{0.55}$	$Na_{0.04}$	$Ba_{0.42}$	$Al_{1.35}$	$Si_{2.56}\ O_8$		
LEUCITE		$K_{1.01}$	$Al_{1.01}$	$Si_{1.97}$	O_6			

The analyses were made by Gloria Vaggielli at the University of FIRENZE, Dept. of Earth Sciences with JEOL JXA 864 with 4 spectrometer under the conditions of 15 K volt acceleration voltage, 10 mA cup current, natural minerals as standards, counting times 15 on the peak, 15 on the background.

leucitites. According to Savaşçın et al. (1997), the most abundant rocks of the Afyon area belong to the saturated series, which varies from shoshonites to trachytes, through latites (Fig. 5). Passing from mafic to more evolved rocks, the silica saturation increases from normative lc+ne<10 % to q around 20 % in the trachytes (Fig. 6).

Savaşçın et al., (1997) argue that in spite of their high leucite content, these highly undersaturated rocks are not typical leucitite, because they have an evolved character, with low MgO (generally lower than 3.0 wt%; Fig 5, 6) and a leucocratic modal composition. Thus, they are here named as phonolitic leucitites (PLct), further to be distinguished a more alkaline sub-set (A-PLct), represented mostly by the silica - undersaturated rocks.

The PLct and A-PLct samples are characterised by extremely high enrichments of Ba (11000-4500 ppm), Rb (480-1500 ppm) and Sr (1800-3800 ppm). These high Ba contents are petrographically testified by the presence of the already mentioned paracelcian (up to 20 wt% of BaO) phenocrysts.

Subduction - related (enrichment of LIL and negative Nb, Ti anomalies), fertile (Leucititic UK rocks; high Al_2O_3: low MgO) and depleted (lamproitic UK rocks; low Al_2O_3: high MgO) magma classes for Afyon and withinplate related lamproitic UK rocks for Isparta with depleted and shallow mantle origin (Francalanci et al., 1990; Savascın et al., 1997) are compatible with the results of the present study. The general occurrence of lamproitic rocks (all over the world only 24 localities) in fossil subduction zones associated with rifting (Mitchell and Bergman, 1995) suggest a similar tectonic setting for Afyon and Isparta areas. However, in a modified sense, a transform from subduction to within-plate environment could be involved (Francalanci et al.,1990; Savaşçın et al.,1997).

Table 2. Mineralogical composition of the volcanic rocks from Afyon-Isparta complied from Savascın et al. 1997.

AFYON					
Potassic to Ultra–potassic rocks 52–71 % SiO_2					
UNDERSATURATED SERIES			SATURATED SERIES		
lc+nl=50–70% Phonolitic Alkaline leucitite to Phonolitic Leucitite PLct, A–PLct	lc+nl=10–35% Phono–tephrite & tephri– phonolite	Trachybasalt e–shoshonite	latite	Trachyte	Alkaline– Trachyte
lct, paracels, cpx Ba–sa, aeg–aug, lct, ap, melil, opq	lct, cpx, Ba–sa, cpx, lct, ap, ti, opq	Cpx, phl, hbld, plag, cpx, phlo, lct, opq	plg,.. ap	Sa, Plg, cpx , bi, sa, plg, c px bi, ap, opg	lct, ti, opg plg, lct
ISPARTA					
Undersaturated to Saturated Oversaturated Lc+ne=20–0% q up to 20 SiO_2 52% SiO_2 63% SiO_2 71%					
UK lamproite	Tephri– phonolite	Shoshonite	trachyte	Silica rich trachyte	rhyolite
Mg–Ol, ti, phlo (Al– poor), cpx, phlo, lct, sa, opq	cpx, plg, bi, sa, ap, cpx, plg, bi, sa, ap, lct, opq	cpx, phlo (resorb), ap plg, lct, opq	cpx, hbl, sa, lct	Plg, sa, cpx, bi, ap, opq, ti, sa	sa, hbl,

Explanation: plg: plagioclase as pheno or microphenocrystal
plg: plagioclase in matrix

Quaternary hyper sodic, tephritic, tephri-phonolitic Kula samples from western Anatolia (Fig.1) are situated just to the left of the area of Isparta samples (Fig. 5c). The Kula samples have been assumed to be the best representatives of mantle (Gulen, 1990). Distribution of UK samples of Afyon and Isparta given in the discrimination diagram of Foley et al. (1987) and diagram of MgO versus normative q-(lc+ne) (Fig. 6) shows clearly the continual passage from leucititic UK samples of Afyon to lamproitic UK samples of Isparta.

The development of the Afyon and Isparta volcanics with different UK-types can be controlled by various factors besides the shallow and deep magma sources. At the last stage of the Afyon volcanism, lamproitic dykes were formed. In the Isparta area, where the volcanics are the youngest period in the south end of the study area, completely lamproitic (depleted source) types of rocks are exposed. In other words, Afyon, first used up its fertile source and then at the following stage Isparta was fed from this depleted source. This model can only work if the Anatolian plate (and also Afyon volcanics) moves towards the north along the KAIST (Fig. 4), over a stable magma rise (~1cm/yr ; Savaşçın,et al. 1994) during the dextral periods of the KAIST (and also during the emplacement of the Isparta volcanics Fig. 7).

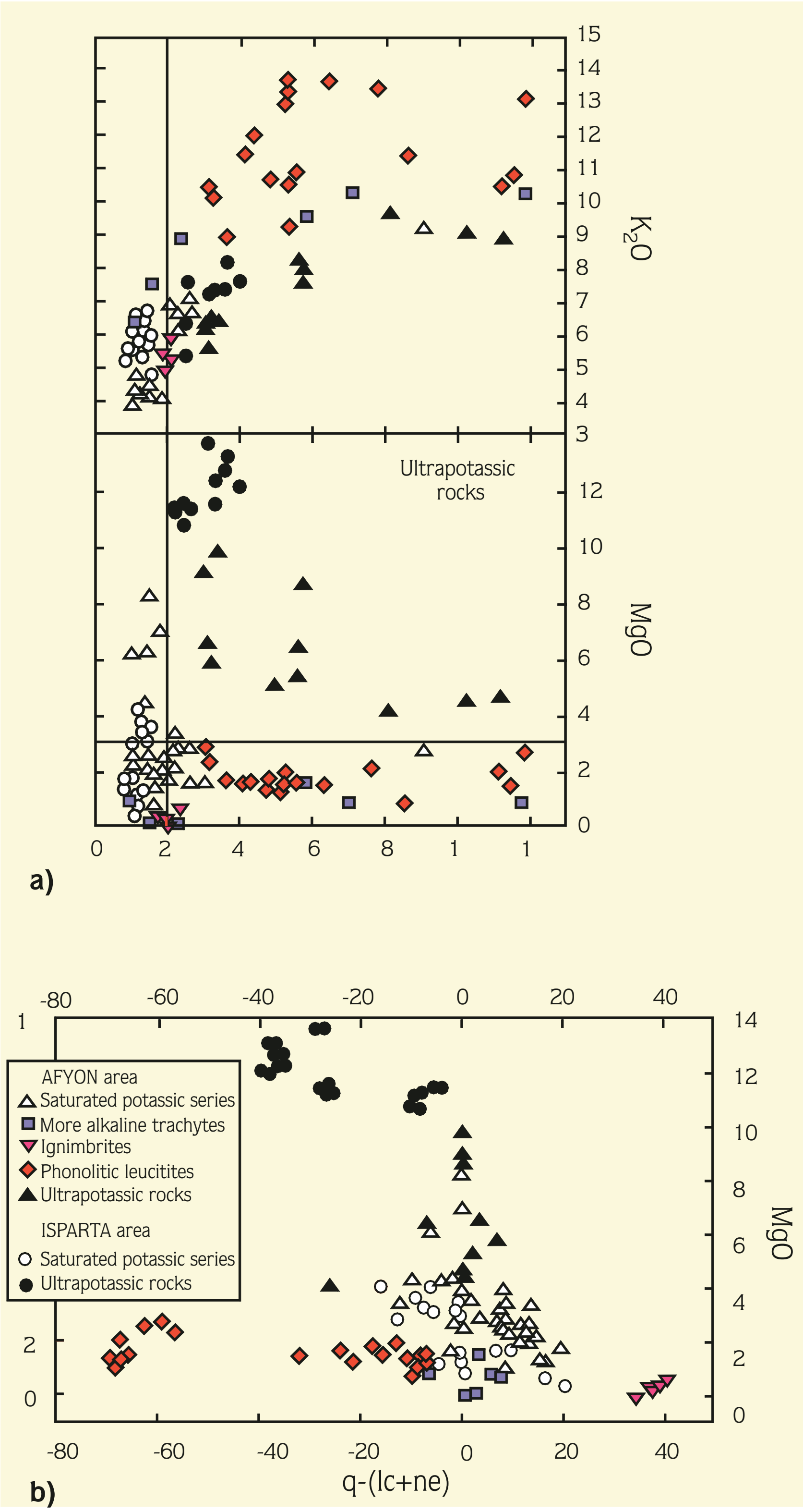

Figure 6. (a) K_2O/Na_2O versus MgO and K_2O for separating of the ultra potassic rocks (Foley et al., 1987) and (b) MgO versus normative q-(lc+ne) showing the degree of silica saturation of the KAIV rocks (taken from Savaşçın et al. 1997). Datas are reported on water free bases. Ultrapotassic rocks of Afyon exhibit an evolutionary trend from fertile leucitite to depleted lamproites of Isparta.

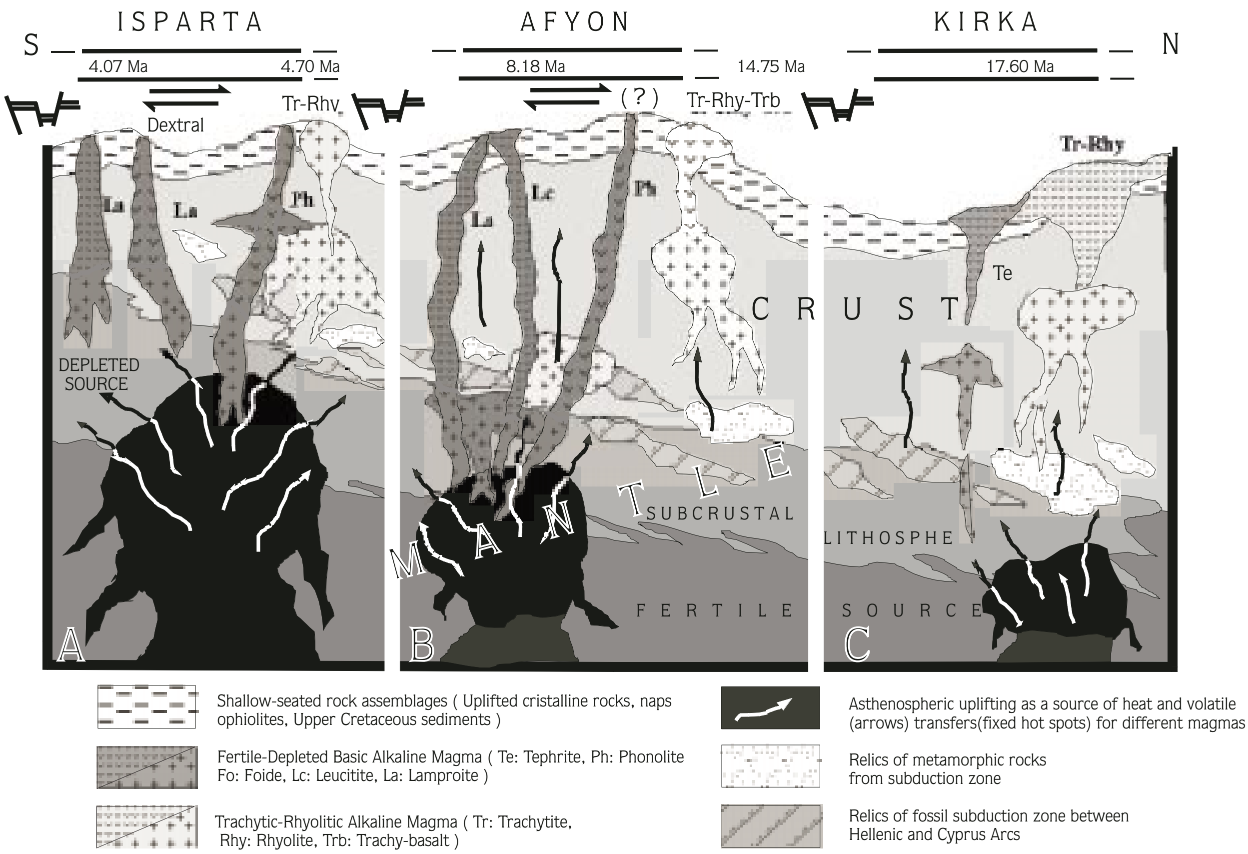

Figure 7. Three temporal evolutionary sections of NS oriented Kırka (A), Afyon (B) and Isparta C) trend which illustrates the evolution of a stable magma rise in the subcrustal lithosphere (lithospheric mantle) in three stage.

Conclusion

The NE-trending Burdur Fault and NW-trending Akşehir-Simav faults are the continental continuation of the Hellenic and Cyprus arc systems respectively which are bounding the Isparta Angle (IA) to the west and east. These two oblique fault systems (normal faults with dextral and sinistral components) were developed parallel to the older suture zones and represent the reactivated neotectonic fractures. This system demonstrates the effect of the pre-existing geological features on the neotectonic evolution.

The NS trending Kırka-Afyon-Isparta structural trend (KAIST) going through the hinge zone of the IA occurs at the intersection of the two main trenches and collusional thrust fault systems with opposite vergence. It will be recognised as a dextral transform fault system with normal fault periods between the Hellenic and Cyprus arcs (Fig. 3c).

The southwards younging of Kırka (21-17 Ma.), Afyon (14-8 Ma) and Isparta (4.7-4 Ma) alkaline volcanics (KAIAV) with approximately 3 to 4 Ma time gap between the volcanic activities (Fig. 4) seems to be the result of periodically northward tectonic movement of the Anatolian plate in the time intervals of the dextral tectonics on a stable mantle rise (or astenospheric uplifting or plume or hot spot) due to the intersection of two main NE and NW trending fault systems. While volcanic activities replaced in the periods of the dextral faults, the time gap periods without volcanics are represented with the grabens and half grabens of the normal faultings. The change of the tectonic regime from normal faulting to strike-slip (dextral) gave rise to the generation of the alkaline volcanics due to only a little decrease of the pressure in the mantle area. Hence, as a transform fault system, the KAIST is an important structural boundary between western and central Anatolia where the Menderes and Kırsehir Massifs (allocthonous core complexes) are located respectively.

The rhyolitic lavas to the north of Afyon, which contain metamorphic enclaves might have originated by accompanying high crustal contribution. This may indicate the continuity of the massifs (Menderes or Kırsehir (?) across the KAIST, on its northern part).

The present study on the relationship between pure alkaline volcanism and active tectonics of the KAIST is a novel approach based on the coeval calc-alkaline / alkaline volcanics (WAV and CAVP) in the west and east of the KAIST, respectively (Fig. 1).Therefore, the lithospheric subductional-postcollisional tectonics of the Western and Central Anatolia (areas of the Menderes and the Kırsehir massifs) might have an important role as a part of source materials for the older calc-alkaline periods of the WAV and the CAVP. While the alkaline rocks of the WAV are uplifted definitely through the younger (Middle-Upper Miocene, approximately 10 to 4 Ma) grabens, the KAIAV should have emplaced on the horsts of dextral faults of the KAIST.

In the last stage of the WAV alkaline volcanics gain either UK or hyper sodic character (banakite of Akhisar “UK” and Quaternary hyper sodic, tephritic-tepriphonolitic Kula volcanics).The Kula volcanics are the best representatives of mantle material from the WAV (Gulen,1990). Also Banakite of Akhisar and Kula samples contain metasomatized pyroxenitic mantle xenoliths like the lamproitic UK products of Isparta, while the leucititic rocks of Afyon have no xenolithic mantle enclaves. This can be interpreted generally by mantle plume (also in Western Anatolia) and assigns similar tectonic behaviours to the WAV and the KAIAV at the last phase.

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