Türkiye Jeoloji Bülteni **Cilt 45, Sayı İ, Şubat 2002**
Geological Bulletin of Turkey *Volume 45, Number 1, February 2002*

Evidences of Extensional Tectonics at the Southern Boundary of the Galatean Volcanic Province, NW Central Anatolia

*Galatya Volkanik Bölgesinin (KB İç Anadolu, Türkiye) Güney Sınırında Kabuk Açılmasına Ait Veriler**

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Abstract

Crustal extension directions trending NNE-SSW and NW-SE to NNW-SSE are documented at the southeastern boundary of the Galatean Volcanic Province (GVP), located at the NW central Anatolia, and at the north of the Aegean Region, in Turkey. Extension affects a continental volcano-sedimentary sequence deposited between the Early Miocene to Pliocene (?) time. Field observations suggest syntectonic volcanism and sedimentation, and extension may begin in the Early-Middle Miocene time. Similar Miocene crustal extension directions are known from the Aegean Region. Both zones have also comparable Miocene magmatic evolutions, characterized by production of Lower-Middle Miocene calc-alkalic and Upper Miocene alkalic magmas.

The GVP is presently bounded at the north by the North Anatolian fault (NAF), the most important active fracture zone of the Anatolian block. The stress fields associated with the GVP extensions and the NAF movements clearly are different. This implies that the GVP extensional regime must have ended prior to the NAF initiation at the Early Pliocene.

Based on the structural and magmatic similarities, we propose that the Aegean and GVP zones were parts of the same block, during possibly much of the Miocene, until the Early Pliocene NAF inception.

Keywords: Aegean Zone - Galatean Volcanic Province - Anatolia - North Anatolian fault - Crustal stretching

ÖZ

Arazi çalışmaları, Galatya Volkanik Bölgesi (GVB) güney-doğu kesiminin KB-GD ila KKB-GGD ile KKD-GGB doğrultulu ve açılmalı (ekstansiyonel) bir tektonik rejim geçirdiğini göstermektedir. Yerel volkanotortul istifin dizilimi ve bu istifi kesen kırıkların durumu (Toprak vd., 1996), bu açılmanın Pliyosen (?) sonrası olabileceğine işaret etmektedir. Buna karşın, arazi gözlemleri, volkanizma ile eşzamanlı olduğu bilinen çökelmenin aynı zamanda fay I anma ile de eşzamanlı olabileceğine dikkat çekmektedir.

Belirlenen doğrultulardaki kabuk uzamalarının Ege Bölgesini de, Miyosen'de veya günümüzde etkilediği bilinmektedir. Bu yapısal benzerliğin yanı sıra, hem Ege'de (Yılmaz, 1990) hem de GVB'de (Tankut vd., 1998), erken-orta Miyosen'de kalk-alkali magmalar, geç Miyosen'de ise alkali magmalar üretilmiştir. GVB'yi etkileyen açılma, yörenin *en önemli fayı olan Kuzey Anadolu fay (KAF) zonuna ilişkin güncel gerilme koşullarına aykırıdır. Diğer bir deyiş ile, bu açılmayı sağlayan yapılar, KAF'ına ait gerilmeler ile açıklanamaz. Dolayısı ile, bu açılmalı rejimin güncel KAF rejiminden önce gelişmiş ve bitmiş olması gerekir. KAF'ın olasılıkla Pliyosen'de oluştuğu bilindiğine göre, bu açılma rejiminin Pliyosen öncesinde son bulduğu ortaya çıkar. GVB'den sağlanan radyometrik yaş verileri, en genç alkali bazaltik kay açların 9-11 milyon yıl yaşında olduğunu göstermektedir (Tankut vd., 1998). Yazarlar, bu kay açlar in jeokimyasal olarak kıta içi rift bazaltlarına benzediklerini belirtmektedirler. Eğer bu kayacın magmatik oluşumu / püskürmesi yörede saptanan açılma ile ilişkili ise, açılma rejiminin bu devirde, yani 9 - 11 My önce, varolduğu söylenebilir, Bir tarajian yapısal diğer taraftan da magmatik etkinliklerin benzerlikleri, GVB'nin Miyosen (?)'de, blok kinematiği anlamında Ege bölgesine bağlı olduğunu düşündürmektedir.*

Anahtar kelimeler: Ege Zonu - Galatya Volkanik Bölgesi - Anadolu - Kuzey Anadolu fayı - Kabuk uzaması

Introduction

Located at the NW Central Anatolia, the Galatean Volcanic Province (GVP) represents the Miocene activity of a Tertiary volcanic zone, generated in junction with events associated with the closure of the Neotethyan ocean (Koçyiğit, 1998; Görür et al., 1998) (Fig. 1). Data concerning the stratigraphy, sedimentology and structural geology of the volcano-sedimentary rocks for some areas within the GVP are given in Toprak et al. (1996) and Gökten et al. (1996). Data concerning the geochemistry and radiometric age determinations on the GVP rocks can be found in Keller et al. (1992), Wilson et al. (1997) and Tankut et al. (1998), These workers describe the GVP as a volcanic complex, with volcanic rocks of calc-alkaline character, dated as Early to Middle Miocene, and basaltic rocks of alkaline character erupted in the Late Miocene. In the SE sector of the GVP, fluvio-lacustrine sedimentation, fed partially by volcanic clasts and intercalated, or intruded by lava flows and dikes, builds up a volcano-sedimentary sequence (the Pelitçik sequence) with a thickness exceeding 900 meters, in the Pelitçik basin. This deposition occurs in the Early Miocene time, contemporaneously with volcanites dated as 18 to 20 Ma, and continues until the Pliocene (?) time (Toprak et al., 1996). The southern boundary of the basin is cut by the E-trending, ca. 20 km long Bayındır normal fault, having accommodated N-S crustal extension. The age of this fault is regarded to be Pliocene or younger (Toprak et al,, 1996). Gökten et al. (1996) report the presence of several lava flows and dikes, in the GVP, and relate their formation to a regional, NNW-SSE directed shortening, that took place between the Oligocene (?) and the end of the Early Pliocene.

The southern parts of the GVP is covered by the fluvio-lacustrine deposits of the Beypazarı-Nallıhan basin. Stratigraphic and structural studies of this basin establish a 1200 m thick sedimentary pile deposited during the Middle-Late Miocene, in a N-S extensional environment (Yağmurlu et al., 1988; inci, 1991). According to these authors, the ENE-trending growth faults, produced by extensional tectonics, may have initiated in the Early Miocene and were active until the end of the Miocene sedimentation. Extension changed to a NW-SE directed compressional regime, at probably Late Miocene or Early Pliocene time, due to the development of the North Anatolian fault (NAF), a major neotectonic structure of the Anatolian block, and bounding the GVP from the north (Fig. 1).

Two structurally opposite views explain the GVP generation. One of them associates the GVP activity to the transtensional movements along the NAF, (Wilson et al., 1997; Tankut et al., 1998). According to Tankut et al. (1998), the Middle Miocene volcanic hiatus, and the change in the eruptive style and geochemical characteristics in the Late Miocene indicate a geodynamic modification, in the GVP. They believe this to be due to the onset of transtensional tectonics associated to the NAF. There are numerous and fairly conflicting age propositions for the NAF initiation (e.g. Şaroğlu, 1988). However, ages of the fault-related basins, and ages estimated using some fault displacements and present-day slip rates, assuming, of course, constant fault velocities in the past, point out to a Plio-Quaternary formation age (Şaroğlu, 1988) or to about 5 My (earliest Pliocene, Barka and Kadinsky-Cade, 1988). In the GVP, the youngest eruptional event is dated as 9 My (Late Miocene, Tankut et a1, 1998). We see that for most, if not all, of the GVP activity period, the NAF is not active, and thus, the genetic link thought to exist between the NAF and GVP activity has to be reconsidered.

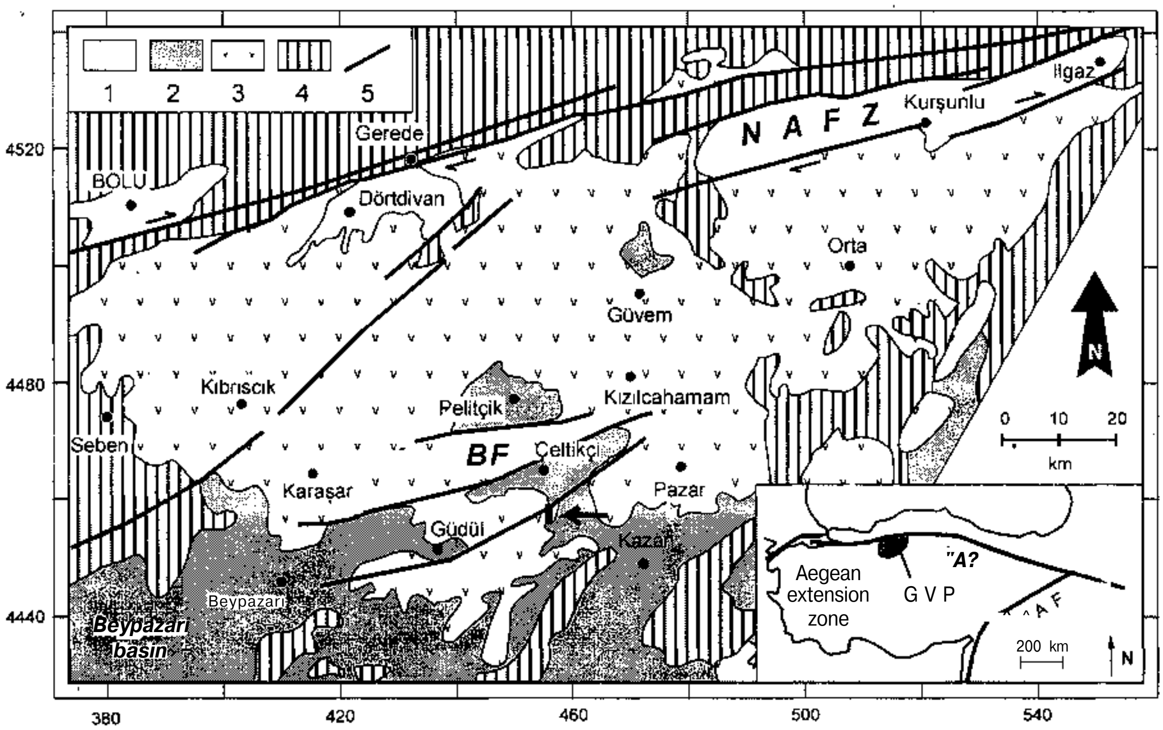

Figure 1. Geological map of the Galatean Volcanic Province (GVP). Lower right inset shows the location of the GVP in Turkey. EAF: East Anatolian fault. NAF: North Anatolian fault. Key to the legend: 1) Plio-Quaternary deposits; 2) Neogene continental deposits; 3) volcanic and volcaniclastic rocks of GVP; 4) pre-Miocene basement rocks; 5) Faults. Redrawn by simplification after Toprak et al. (1996). Added coordinates are in UTM. The approximately 3 km long study outcrop is drawn in heavy black rectangle, immediately south of Çeltikçi town (indicated by an arrow). BF: Bayındır fault; NAFZ: North Anatolian fault zone.

***Şekil** 1. Galatya Volkanik Bölgesinin (GVB) jeoloji haritası. Alt sağ kesimdeki harita GVB'nin Türkiye'deki konumunu göstermektedir. EAF: Doğu Anadolu fayı. NAF; Kuzey Anadolu fayı. 1) Pliyo-Kuvaterner çökeller; 2) Kıtasal Neojen çökelleri; 3) GVB'nin volkanik ve volkanoklastik kay açları; 4) Miyosen öncesi temel kay açları, 5) Faylar. Toprak vd. (1996)'dan sadeleştirilerek alınmıştır. Koordinatlar UTM s is temindedir. Yaklaşık 3 km uzunluğundaki mostra alanı, Çeltikçi'nin hemen güneyinde, okla işaretlenen bir siyah dikdörtgen ile gösterilmiştir. BF: Bayındır fayı; NAFZ: Kuzey Anadolu fay zonu.*

The other view considers the GVP internal depositional areas, like the Pelitçik and Çeltikçi basins (Fig. 1), developing as thrust-fault bounded basins, in a post-collisional environment continuing up until the Middle Pliocene (Koçyiğit et al., 1995). This is criticized by Seyitoğlu et al. (1997) on field data arguments. The style of deformation that affects the GVP interior basin fills, and the time of the GVP extension, if constrained, may provide data to this discussion.

In this paper, we present fault data collected at the southern boundary of the GVP, some 15 km south of where Toprak et al. (1996) worked the Bayındır fault zone, southern limit of the Pelitçik basin. Extensional block faulting is clearly displayed in good exposures along the road cuts of the Ankara-Bolu highway. Fault lineation analysis confirms the N-S extension that was previously recognized along the Bayındır fault. This direction is very similar to that now occurring in the Aegean region, a seismically active region at the west of Turkey (Fig. 1). We thus compare structural characteristics of the GVP extension to the Aegean one, noting that discussion exists on the initiation age of the Aegean extension. There are two different views: I) the Aegean region experiences extension since late Oligocene-Early Miocene time (Seyitoğlu et al., 1992; Hetzel et al., 1995), 2) the Aegean N-S extension begins at the Middle-Late Miocene time (Yılmaz et al., 2000).

It is well known that extensional and compressional faults, and other structures (e.g. folds, tensional fractures) may exist in an area experiencing simple shear deformation. Following this, one may argue that the GVP extensional faults occurring close to the NAF have a second-order structural significance. This can be understood by checking the possibility of mechanical coexistence between the extension and the NAF movements. In the case of incompatibility, we should accept that extension is replaced by the stress field imposed by the present-day NAF movements. In the same time, the lower limit of the NAF initiation age, i.e. the early Pliocene time, (Barka and Kadinsky-Cade, 1988) will correspond to the upper limit of the extension age, in the GVP.

Field observations

Field data is collected at the south of the Çeltikçi trough, along the Istanbul-Ankara highway road cuts, at approximately 10 km south of the Çeltikçi derivation (Fig. 1). GPS coordinates of each fieldwork station are given in the corresponding figure caption.

Volcanic rocks specimens collected in the field are analyzed by X-ray spectrometry and X-ray diffraction tools, in the Geological Engineering Department of the Hacettepe University, for quantitative and qualitative purposes.

The observation area consists of several large fault compartments (Fig. 2), made up of layered pyroclastic rocks, intercalated with lava flows (of

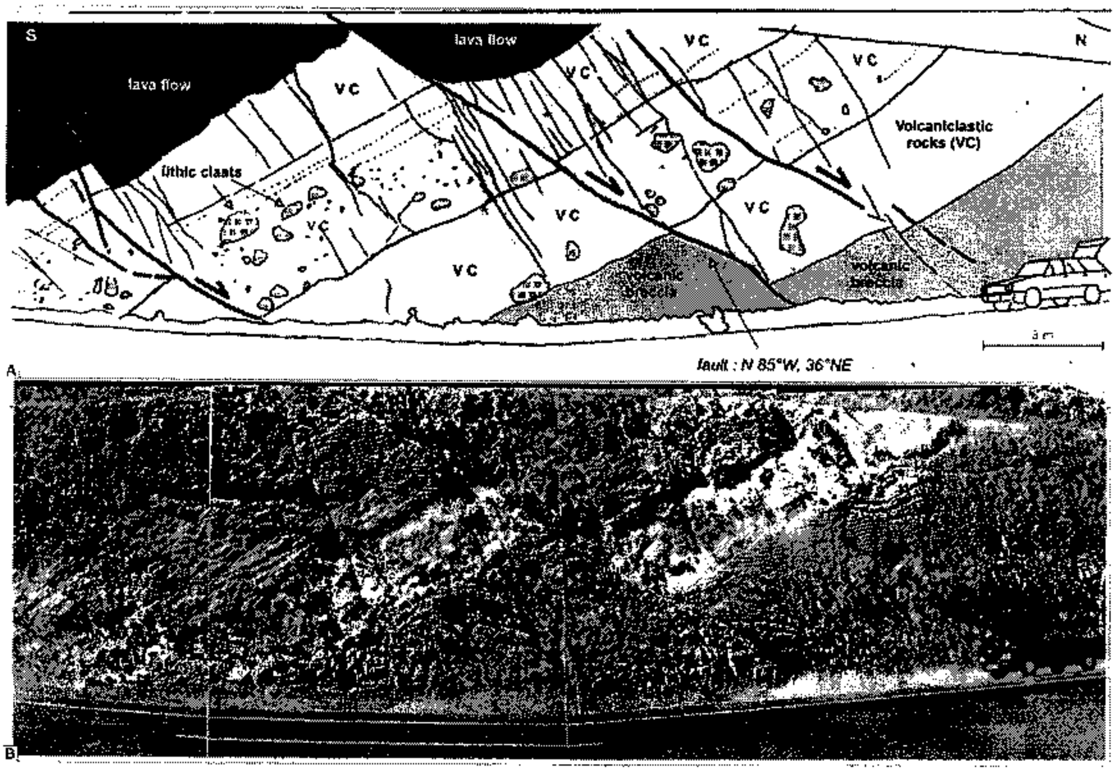

Figure 2. A) Outcrop showing the general view of the volcaniclastic rocks, deformed by normal faults. B) Interpretation. GPS UTM 36 T zone coordinates: Easting 456.031, Northing 4458.357

Şekil 2. A) Normal faylarla kesilen volkanoklastik kayaçların genel görünümü. B) Yorum. GPS UTM 36 T zon koordinatları: Doğu 456.031, Kuzey 4458.357

likely andesite-dacite composition since % SiO_2 is 61.81 to 64.86). Pyroclastic rocks comprise mostly sand-sized, dark-colored volcanic clasts and whitish pumice fragments. Blocks of volcanic rocks, up to 2 m size, are very frequently observed likely andesite-dacite composition since % SiO_2 is within the layers (Figs. 2, 3, 4). In several places, the block impact structures (Figs. 3, 4) developed at the base of these blocks attest for a deposition contemporaneous with volcanic activities.

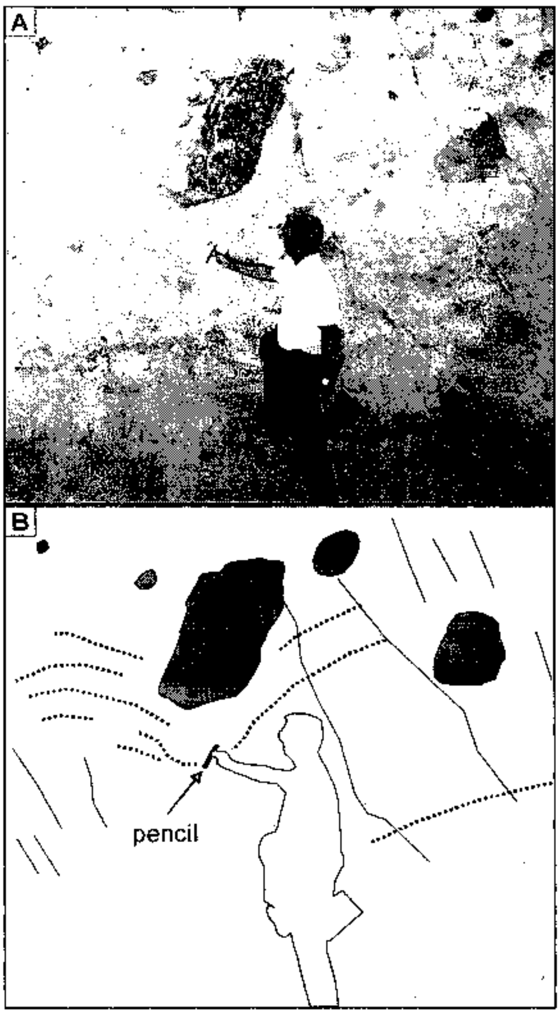

Figure 3. A) A mafic volcanic clast having deformed the sedimentary strata. The pencil held by the worker under the clast shows the possible impact direction. B) Interpretation. GPS UTM 36 T zone coordinates: Easting 455.615, Northing 4456.715.

Şekil 3. A) Tortul tabakaları deforme eden bir mafik volkanik parça. Parçanın altında, araştırmacının elindeki kalem olası çûrpma doğrultusunu göstermektedir. B) Yorum. GPS UTM 36 T zon koordinatları: Doğu 455.615, Kuzey 4456.715.

This volcano-sedimentary aspect of the outcrop resembles much to the level 2 of the Pelitçik sequence described by Toprak et al. (1996).

The Figure 2 illustrates the block faulting frequently observed in the field. The outcrop rocks are dissected by several, mostly oblique-slip faults (F1 and F2 in Fig. 2) showing clear normal separations. Net slip is approximately 3 meters along the F2 surface. Lineations on striated surfaces suggest a NNE-SSW trending crustal extension.

Veins and dikes are common features of the study area. They are filled mostly with silicified, yellow to green colored material. Their trends vary between N 45°E and N 75°E. One of them is filled with light-colored material (~ 0.9 m thick) of possibly rhyolitic composition (Fig. 5). Within the dike, a N 50° E trending, black- light brown colored silica vein developed. The dike has a N 45°E direction and outcrops close to a NNE-SSW trending fault zone, with segments indicating normal separations. One of them is a slightly (pitch 4°) transtensional fault. Dike and vein geometry suggests an extension trending NW-SE to NNW-SSE. The transtensional fault is one of the fractures interpreted as accommodating strike-slip motion of the NNE-SSW extensional tectonics. This suggests that the area is stretched in two different orientations: NNE-SSW and NW-SE to NNW-SSE.

We observe synsedimentary faulting in two locations. One observation deals with a fault structure composed of two bifurcating segments, the SI and S2 (Fig. 6). The SI segment has partially deformed the outcrop deposits, and terminates in a place above which there is no indication of faulting. The other S2 segment separates from the S1 segment, changes slightly its orientation relative to SI, and cuts the whole outcrop. The outcrop geometry suggests a deformation mechanism with synsedimentary faulting. The SI segment should operate first, followed by the activity of segment S2. Normal separation along the S2 is about 60 centimeters. We measured one fault movement as N 43°E, 58° SE, 22° NE (strike and dip of the fault surface and pitch of the fault lineation), with a probable left-lateral slip sense. We do not know if this measurement reflects the SI or S2 segment fault kinematic attitude. The corresponding slip vector suggests a NE-trending extension.

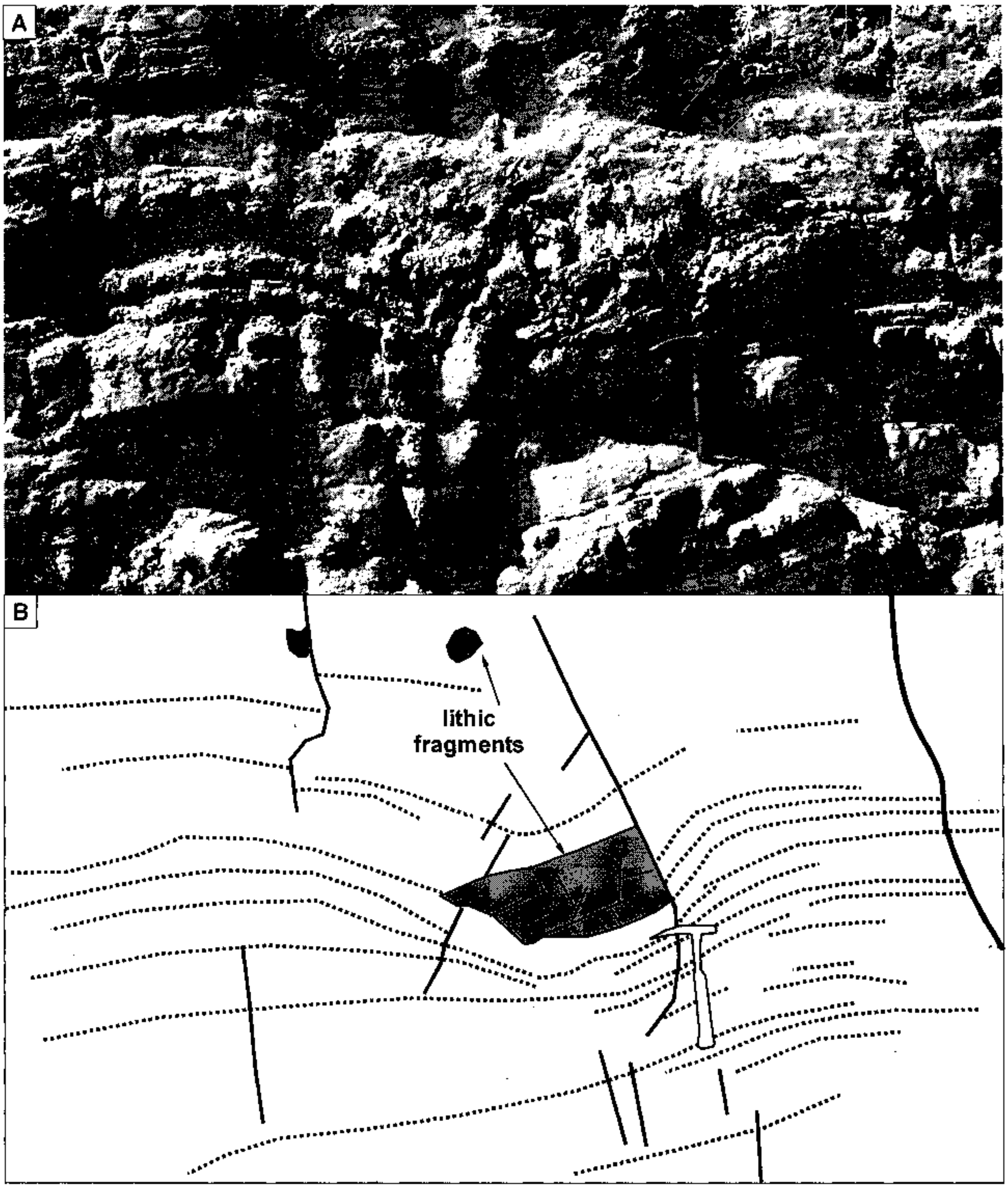

Figure 4. A) Another block impact figure within the sedimentary rocks. B) Interpretation. Location near Figure 3.
Şekil 4. *A) Tortul tabakalar içinde diğer bir blok çarpma yapısı. B) Yorum. Yer: Şekil 3 yakını.*

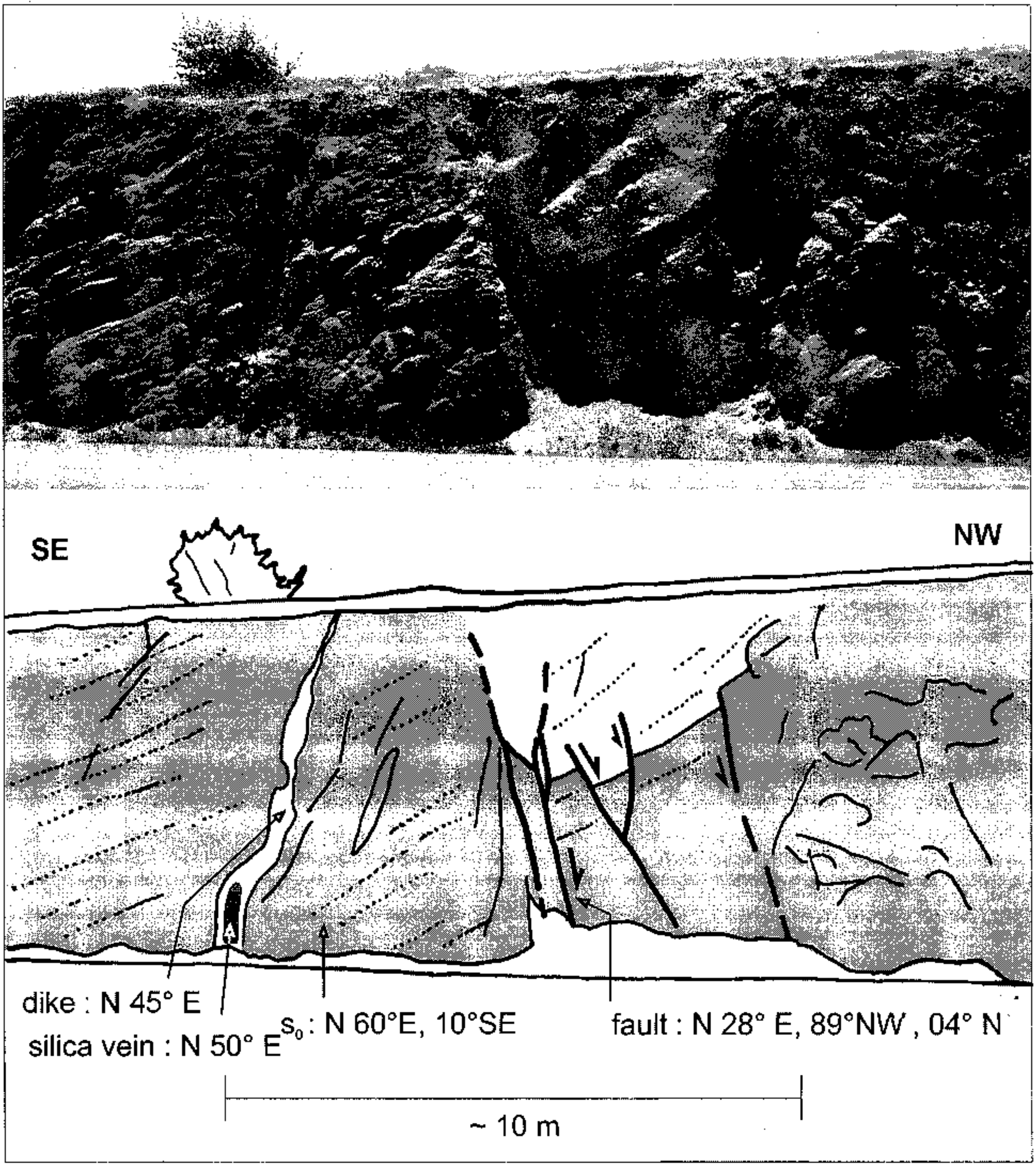

Figure 5. A possibly rhyolitic dike and nearby transtensional faults. A) Photography and B) Interpretation. GPS UTM 36 T zone coordinates: near Easting 455.604, Northing 4456.748.
Şekil 5. Olası bir riyolit daykı ve yakındaki normal bileşenli yanal atımlı faylar. A) Fotoğraf ve B) Yorumu. GPS UTM 36 Tzon koordinatları: Doğu 455. 604, Kuzey 4456.748.

In the other location, a paleotopographic high, filled with pyroclastic material (Fig. 7), is covered by lithic material of the later eruptions. Its geometry seems to be that of a horst, elevated by normal or transtensional faults, like those in its northern vicinity. The horst may be buried by further eruptional activities, suggesting syntectonic volcanism.

Plotted in a stereogram (Fig, 8), the majority of the fault striations, in particular those of the transcurrent faults, form an ensemble suggesting a NNE-SSW orientated crustal stretching (horizontal cr3 and vertical a1). A few normal/trantensional faults suggest a NW-SE trending extension, as indicated also by the geometry of the dike and veins.

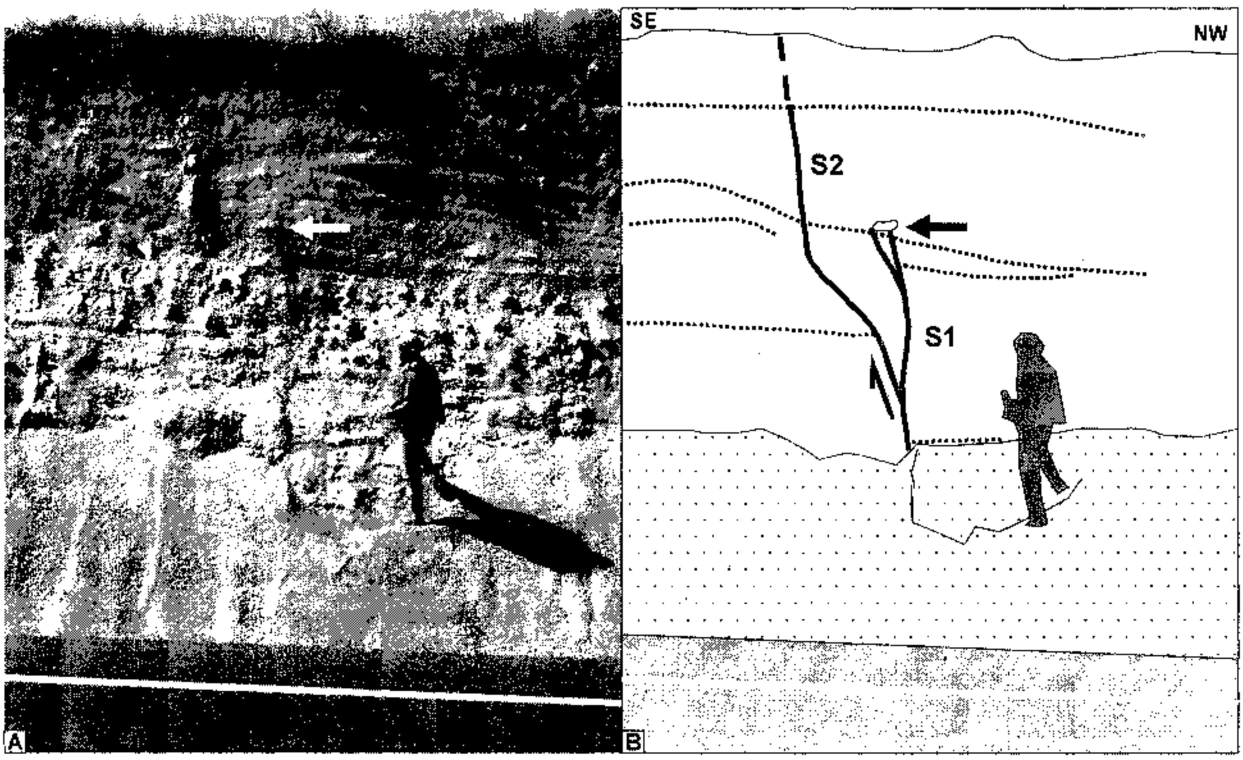

Figure 6. A) Photography and B) Interpretation of a synsedimentary fault segment (SI). The white arrow (in A) indicates the place where the SI segment ceased its activity. The fault should be reactivated along the more recent S2 segment. GPS UTM 36 T zone coordinates: near Easting 455.782, Northing 4456.486.

Şekil 6, Çökelmeyle eşzamanlı birfay segmenti içeren bir yapının A) Fotoğrafı, B) yorumu. A'dahi beyaz ok, Sİ segmentinin etkinliğini durdurduğu yere karşılık gelmektedir. Fay, daha genç S2 segmenti boyunca hareketini yenilemiş olmalıdır. GPS UTM36 Tzon koordinatları: Doğu 455.782, Kuzey 4456.486.

Comparison with the North Anatolian fault stress pattern

In this part, we verify if the extension directions found in the GVP could be attributed to the NAF activity. In Fig. 9A, the heavy line trending N 70° represents the plan view of the local NAF trace. The stereoplot of the GVP faults measured in the field (GVP in Fig. 9A) is superimposed to this line. We construct the two horizontal principal stress axes to generate dextral strike-slip fault movements along the NAF trace by assuming that the greatest principal stress (a1) axis makes an angle of 45° with the fault trace. This angle is in good agreement when considering alternatively the fault plane solutions of the nearest NAF earthquakes (Fig. 9B) (Eyidoğan et al., 1991). The least principal stress (a3NAF) axis orthogonal to the al axis is very close in direction to the NNE-SSW trending GVP crustal extension (a3GVP-l). The other NW-SE to NNW-SSE trending extension direction, shown as a3GVP-2, is almost orthogonal to the NAF trace, and cannot be generated by the NAF stress field. The a3NAF direction is also remarkably close to that determined by the focal mechanism of the Eskişehir earthquake, a seismic event that reflects the extensional characteristics of the Aegean region nearest to the GVP (event 7 in Fig. 9B). However, the ca. N30°-trending dextral strike-slip faults of the GVP extensional regime are not compatible with the N70°- trending dextral NAF. In other words, these faults cannot. be generated within the NAF-related stress field. We therefore conclude that the extensional faults of the GVP and the NAF mechanically are incompatible structures. This implies that the two regimes are distinct and occurred in different times. The present-day NAF-related stress regime should have developed after the extensional phases, in the GVP.

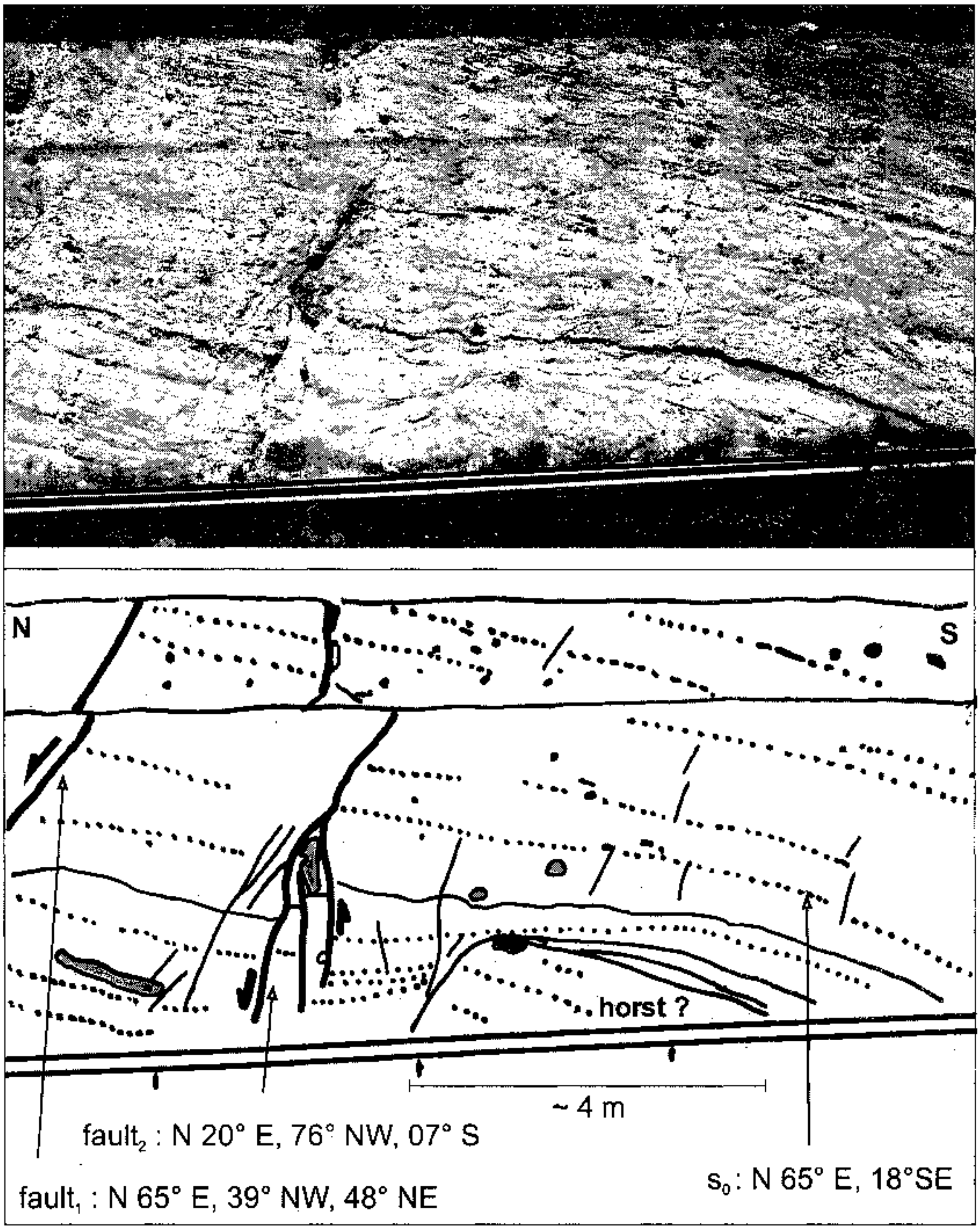

Figure 7. **A)** Photography and B) Interpretation of a paleohigh within pyroclastics. GPS UTM 36 T zone coordinates: near Easting 455.604, Northing 4456.748.

Şekil 7. Piroklastikler içinde) olası eski bir horstu gösteren bir paleoyükseklïğin A) Fotoğrafı B) yorumu. GPS UTM 36 Tzon koordinatları: Doğu 455.604, Kuzey 4456.748.

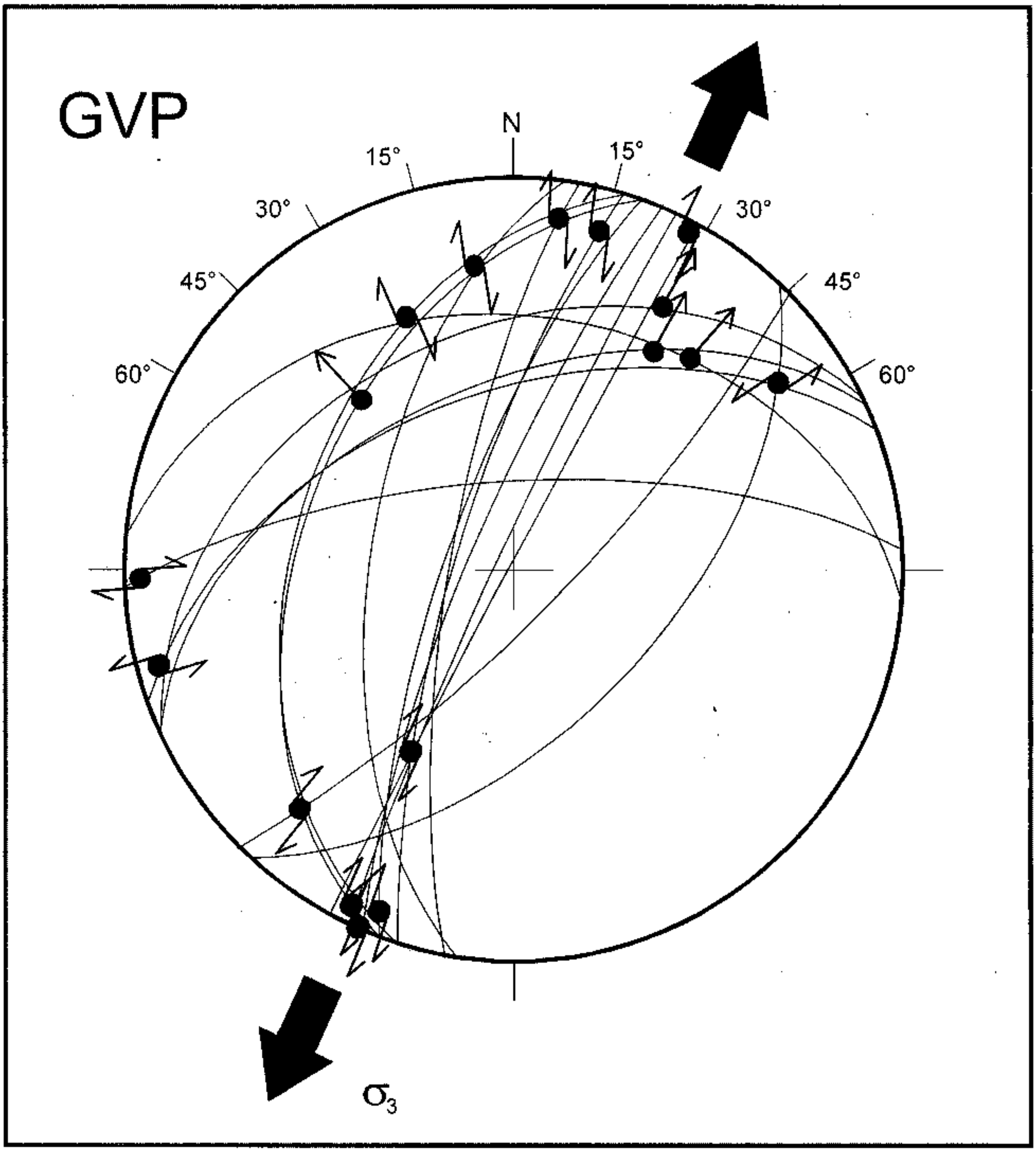

Figure 8. Lower hemisphere stereogram of the fault surfaces and lineations collected in the field. Single centrifugal arrow corresponds to normal fault movement. The two-arrowed figure represents strike-slip fault movement. The large black arrows give the direction (NNE-SSW) of the crustal stretching (horizontal G3 and vertical a1), estimated essentially on the direction of the NNE-trending strike-slip faults.

Şekil 8. Arazide ölçülen fay düzlemleri ve çiziklerinin alt yarı küredeki izdüşümleri, izdüşüm merkezinden uzaklaşan tek ok, normal fay, iki oklu şekiller ise doğrultu atımlı fay hareketine karşılık gelmektedir. Geniş siyah oklar, esas olarak doğrultu atımlı fayların uzanımından hareketle saptanan ve kabuğun KKD-GGB uzama doğrultusunu (yatay o3 ve düşey al) gösteren açılma eksenini belirtmektedir.

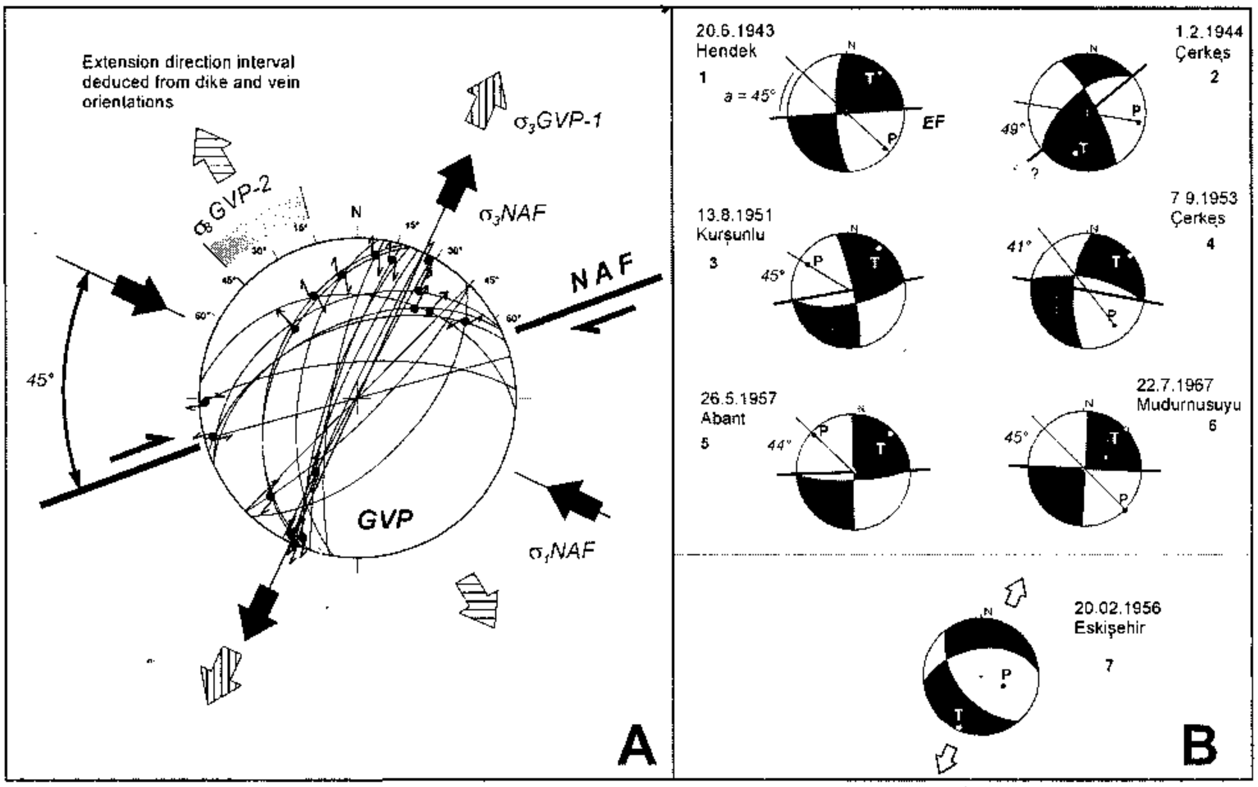

Figure 9. Comparison of the local extension with the stress field related to the North Anatolian fault (NAF) movements. A) Local trace of the NAF is shown by a N70° trending heavy black line. The al stress axis is supposed to make an angle of 45° with this trace, so as to generate dextral slip. The a3 (a3NAF) is orthogonal to the a3. The stereoplot corresponds the structural data in Fig. 8. G3GVP-1: extension direction found by majority of the measured fault striations. a3GVP-2: extension direction drawn by a gray heavy line and found by dike and vein geometry. B) Comparison of the local estimated NAF-linked stress field with those suggested by the present-day fault movements. Fault plane solutions 1 to 6 are from earthquakes associated with the NAF movements nearest to the GVP. Plot 7 represents the focal mechanism of an earthquake along the Eskişehir fault (7), a structure that accommodates most probably the Aegean extensional fault movements. Dates and names of the earthquakes, and seismic parameters are from Eyidoğan et al. (1991). P (in white quadrant) and T (in black quadrant) are the tectonic compressional and extensional axes, respectively. The trend of the compression axis is shown by a thin line, "a" is the acute angle between the compressional axis trend and the direction of the fault assumed to generate the earthquake along the NAF zone (EF), shown by a heav*' line. Except event 2, the shear angle is close to 45°. Note the remarkable similarity in the extension directions deduced from the Eskişehir earthquake (event 7) and the a3GVP.

Şekil 9, *Yerel açılmanın (extension) Kuzey Anadolu fayı (KAF)'na bağlı gerilme koşulları ile karşılaştırılması. A) KAF'ın yerel izi kalın ve siyah bir çizgi ile gösterilmiştir, al gerilme ekseni, KAF üzerinde sağ atım ve KAF izi ile 45°lik bir kesme açısı yapacak şekilde çizilmiştir. a3 (aSNAF) bu eksene diktir. Stereografik izdüşüm ile Şekil 8'de sunulan yapısal veriler yansıtılmıştır. o3GVP-l: fay çiziklerinin çoğunun işaret ettiği açılma. O3GVP-2: gri kalın bir çizgi ile gösterilen ve dayk-damar geometrisi ile bulunan açılma. B) Varsayılan yerel ve KAF'a ilişkin gerilme alanı ile, güncel fay hareketlerinden saptanan gerilme alanlarının karşılaştırılması. 1 ila 6 numaralı odak ınekani&fıaları, Galatya Volkanik Bölgesine (GVB) yakın ve KAF'a ait depremlerden elde edilmiştir. 7 ise, Ege ağılma bölgesine ait olduğu düşünülen Eskişehir fayına ait bir depremin odak mekanizmasıdır. Deprem tarih ve isimleri ile sismik parametreler Eyidoğan vd. (1991)'den alınmıştır. P (beyaz kadranda) ve T (siyah kadranda) tektonik sıkışma ve açılma eksenlerinin izdüşümlerine karşılık gelmektedir. Sıkışma ekseni doğrultusu ince bir doğru parçası ile gösterilmiştir, "a" açısı, sıkışma ekseni doğrultusu ile KAF boyunca depremi oluşturduğu varsayılan kalın çizgili hattın (EF) doğrultusu arasındaki dar açıdır. 2 numaralı depremin dışında, diğer kesme açıları 45° civarındadır. Eskişehir depreminden elde edilen (7 numaralı odak mekanizması) açılma ekseni ile bu çalışmada ortaya konan açılma ekseninin doğrultularının yakınlığı dikkat çekicidir.*

Comparison with the Aegean Extensional Province

Although Toprak et al. (1996) find no link between the N-S extensional tectonics and the formation of the Pelitçik basin, we think that the Volcanism and deposition of the volcaniclastic rocks benefited from a contemporaneous extensional regime, at least in our investigation area. It would to be difficult to exclude an Early-Middle Miocene extension in order to create a volcanic complex covering now a large surface of about 7,000 km2 (Tankut et al., 1998). This extension may be the NNE-SSW trending one observed at the study area, and also farther north (Toprak et al., 1996). Pre-Middle Miocene (?) N45°W directed basaltic dikes observed at about 8 km N of Güdül (Gökten et al., 1996) may be among the volcanic products associated to this extension.

In the fault geometry exposed in Fig. 2, the 36° dipping F2 fault may be considered as a listric fault, which may have accommodated a significant amount of crustal stretching. The ca. 30° local tilting of the strata suggests that this fault initially had a 66° dip. Using the relationship (3 = sin tO / sin tl (Jackson and McKenzie, 1988), where tO = 66°, and tl = 36°, a relatively high (3 value of 1.55 is obtained. A (3 value of 1.5 is similarly obtained from a station near the one illustrated in Fig. 7. The crust stretched during possibly the Oligocene (?)-Early Miocene to pre-Middle Miocene (Gökten et al., 1996), or to Late Miocene (Inci, 1991) may have caused astenospheric upwelling, followed by formation of asthenosphere-sourced basaltic magmas, in Late Miocene (Wilson et al., 1997).

The NNE-SSW trending paleoextension is documented in the Aegean Extensional Province (AEP) by several workers, both from its brittle and ductile domains (Angelier et al., 1981; Hetzel et al., 1995). Hetzel et al. (1995) report a 19.5 ± 1.4 My isotope age for the syntectonic granitic rocks from the Alaşehir graben, intruded in a NNE-SSW directed extension. This age is supported by the palynological age of 20-14 My of the basin fill (Seyitoğlu and Scott, 1996). Noting that discussion still continues on the development age of the Aegean grabens (e.g. Yılmaz et al., 2000), we suggest that in the GVP, N-S extension and related volcanism begin by the Early Miocene time. Yağmurlu et al. (1988) suggest the same age for the onset of the growth faulting in the Beypazarı-Nallihan basin. Late Miocene magmatism is of alkaline character, in both regions. Miocene tectonomagmatic characteristics of the AEP and GVP are significantly comparable, and we propose that both zones had kinematically similar attitudes, during possibly much of the Miocene time.

Comparison with the Ankara Orogenic Phase

The age of the early deposits of the Pelitçik basin is established by the radiometric dating of the syndepositional volcanic rocks (20 to 18 Ma, Burdigalian: Early Miocene, Toprak et al., 1996). The only tectonic regime recorded from the Pelitçik basin interior, its southern boundary (Toprak et al., 1996) and in more southern areas (near Çeltikçi basin, this study) is extensional. For* these localities, we find no sedimentologic or structural evidence of thrust fault-bounded basin boundaries as claimed by Koçyiğit et al. (1995).

Discussion and Conclusions

Fault data, and vein/dike orientations suggest crustal stretching directions trending NNE-SSW and NW-SE to NNW-SSE, near the SE boundary of the Galatean Volcanic Province (GVP).

There are some evidences of syntectonic volcanism and pyroclastic deposition in the study area. Therefore, extension may be coeval with the Early-Middle Miocene GVP eruptions (Toprak et al., 1996). The GVP extension may possibly begin in the Early Miocene as it seems to be the case for the development of the growth faulting in the adjacent Beypazarı basin (Yağmurlu et al., 1988). The GVP crust may be stretched by a P factor of 1,5. The later asthenosphere-sourced alkaline basaltic magmatism (Tankut et al., 1998) may be the result of such a crustal stretching and thinning. Extension in the GVP may have lasted until the

Late Miocene, as indicated by the cessation of the sedimentation in the Beypazan-Nalhhan basins (e.g. Inci, 1991), and by the end of the eruption of alkaline continental-rift type basalts possibly at about 9 My (Late Miocene, Tankut et al., 1998).

Mechanic analysis shows incompatibility between the GVP extension and the North Anatolian fault-related stress field. This requires that extension should have terminated prior to the NAF formation at possibly the Early Pliocene time (Barka and Kadinsky-Cade, 1988).

Structural and magmatic characteristics of the GVP are similar to the Aegean Extensional Province, for the Miocene time (Wilson et al., 1997).

Field observations of the Pelitçik basin and southern areas (S of the Çeltikçi basin, this study) do not provide data to support the thrust faults drawn by Koçyiğit et al. (1995).

The age of extension obtained from the Beypazarı basin analysis (Yağmurlu et al., 1988) and our field data, corroborate the view of Seyitoğlu et al. (1997) who criticized the opinion of Koçyiğit et al. (1995) that the compression prevailed until the Late Neogene, in the NW Central Anatolia. Similarly, the view of Gökten et al. (1996) that compression acted regionally during Oligocene (?) - Early Pliocene is also incompatible with the results reached from the Beypazarı basin analysis and our study.

Combining data from Toprak et al. (1996) and this study, we propose that GVP formed in a N-S extensional tectonic regime developed from Early to Late Miocene time. Miocene tectonomagmatic similarities between the Galatean Volcanic Province and the Aegean Region suggest similar kinematic attitude, during this time. The tectonic regime changed in Galatia when the North Anatolian fault zone formed at about 5 My ago (Barka and Kadinsky-Cade, 1988).

Acknowledgments

The authors are thankful to Gürol Seyitoğlu and Kadir Dirik, for their valuable critics on an earlier version of this paper. We are also thankful to Cem Saraç for his efficient editing work. The field work is financed by a research project (number 99 01 602 007) of the Hacettepe University.

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