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STRUCTURAL CHARACTERISTICS OF KIRAZLI DISTRICT, ÇANAKKALE, TÜRKİYE

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Abstract

The Biga Peninsula, which geologically evolved in relation with the the closure of the Tethyan oceans during pre-Cenozoic and subsequent syn-, post-collisional extensional tectonic regime throughout the Cenozoic located in the northwestern Türkiye. The Kirazlı district and and surrounding regional study area covers the central part of Biga Peninsula where Permo-Triassic Rhodope and Sakarya Zones sutured during closure of Paleo-Tethyan marginal seas along Intra-Pontide Suture (IPS). Neo-Tethyan northward subduction and closure, limit the Biga Peninsula from south along İzmir-Ankara-Erzincan Suture (IAES). Following syn- and post-collisional, slab break-off, slab roll-back events accompanied by crustal extension, metamorphism, core-complex formation, southward retreat of subduction front and resulted in generally southward younging magmatism. Field observations showed that Kirazlı district was exampled both Rhodope and Sakarya basement rocks along its eastern sector those were covered by Oligocene volcanic sequence at the rest of district. Resultant Cenozoic structural architecture of post-collisional tectonic regime includes three and four predominant fault orientations respectively in regional and district scale study areas. Investigating the tectonic characteristics of these faults at both regional and district scales will be instrumental in unveiling the temporal and spatial relationships among Cenozoic structures. To achieve this goal, the study examines and discusses the tectonic properties associated with the identified predominant fault orientations.

Keywords: Biga Peninsula, Kirazlı district, Tethyan oceans, Subduction, Cenozoic extension, Rhodop zone, Sakarya Zone, Structural architecture

KİRAZLI SAHASININ YAPISAL KARAKTERİSTİĞİ, ÇANAKKALE, TÜRKİYE

Özet

Jeolojik evrimi, Tetis okyanuslarının Senozoyik öncesi dönemde kapanması ve takip eden Senozoyik sırasınca çarpışma ve çarpışma sonrası açılmalı tektonik rejim ile ilişkili olan Biga Yarımadası, Türkiye'nin kuzeybatısında yer almaktadır. Kirazlı sahası ve çevresindeki bölgesel çalışma alanı, Pontid İç Süturu (IPS) boyunca Paleo-Tetis kenar denizlerinin kapanması sırasında Permo-Triyas Rodop ve Sakarya zonlarının kenetlendiği Biga yarımadasının merkezini kapsamaktadır. Kuzeye doğru dalan ve çarpışan Neo-Tetis, Biga yarımadasını İzmir-Ankara-Erzincan Süturu boyunca güneyden sınırlamaktadır. Takip eden çarpışma ve çarpışma sonrası slab break-off ve slab roll-back olaylarına, kıtasal genişleme, metamorfik çekirdek kompleksi oluşumu, yitim cephesinin güneye çekilmesi eşlik etmiş ve genellikle güneye doğru gençleşen bir mağmatizmaya sebep olmuştur. Saha gözlemleri Kirazlı sahasının doğu kesiminde hem Rodop hem de Sakarya temel kayalarının bulunduğunu, sahanın geri kalan kısmında bu temelin Oligosen yaşlı volkanik istif tarafından ötüldüğünü göstermektedir. Çarpışma sonrası tektonik rejim sonucu ortaya çıkan Senozoyik yapısal mimarisi, bölgesel ve Kirazlı sahası ölçeğindeki çalışma alanlarında sırasıyla üç ve dört baskın fay oryantasyonu içerir. Bu bölgesel ve lokal ölçekteki fayların tektonik özelliklerini incelemek, Senozoyik yapılar arasındaki zamansal ve mekânsal ilişkileri ortaya çıkarmak için faydalı olacaktır. Bu amaçla, bu çalışma belirlenen baskın fay yönelimlerinin tektonik özelliklerini inceleyip tartışmaktadır.

Anahtar Kelimeler: Biga yarımadası, Kirazlı sahası, Tetis okyanusları, Yitim cephesi, Senozoyik genişleme, Rodop zonu, Sakarya zonu, Yapısal mimari

Cite

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1. Introduction

Kirazlı district is situated in the central Biga Peninsula where the Permo-Triassic basement is intruded by Cenozoic plutons and coeval volcanic rocks (Figure 1). The geological evolution of the Biga Peninsula determined by geodynamic events during closure of the Neo-Tethys ocean, including continental collision and the subsequent syn/post-collisional extension since the early Eocene and combined dextral strike-slip tectonics since Plio-Quaternary respectively [1-7]. The tectono-magmatic processes were accompanied by post-collisional extension prevailing throughout the region during Cenozoic [5, 8, 9]. The Cenozoic structures in the region are integral component of regional fault systems that are suggested to contribute to the emplacement of the plutonic intrusions, coeval volcanic sequences and mineralization along extensional basins [5, 9-11].

Studies conducted in the region generally either deal with the geological evolution of the region from a broad structural and magmatic framework, or work specifically on the mineralization events in the region. We have investigated the structural characteristics of Kirazlı district and surrounding area covering the central Biga Peninsula based on structural mapping, spatial distribution and geometries of structures, and district scale geological mapping. Based on field data by the present work and compiled data from previous studies, this research links the temporal and spatial relations between Kirazlı district and surrounding area with the geological evolution of Biga Peninsula.

2. Geological Setting

Biga Peninsula represents the northern part of western Anatolia where several tectonostratigraphic units amalgamed during the closure of Paleo- and Neo-Tethyan oceans [5, 12-15]. Intra-Pontide suture separates Rhodope Zone and western end of Sakarya Zone from northeast to southwest along Biga Peninsula (Figure 1A-B).

2.1. Metamorphic Basement

The metamorphic basement in the Biga Peninsula is comprised of NE-SW trending terranes called Rhodope Zone and Sakarya Zone (Figure 1A) containing low to high grade metamorphic rocks. These are separated by Intra-Pontide Suture (Figure 1A-B).

The Rhodope Zone contains Çamlıca Metamorphics-Kemer Micaschists, Denizgören Ophiolites and Ezine Group, and is exposed in the northwestern tip of Biga Peninsula [16-21]. Yet, recent studies proposed that Çamlıca Metamorphics and Kemer Micaschists are isolated blocks of passive margin from Sakarya Zone or may not be part of Rhodop Zone [22, 23]. The dominant rock types forming the Çamlıca Metamorphics include quartz micaschists, calc-schist, phyllite, marble, amphibolite, and quartzite [16]. The Denizgören Ophiolite consisting of serpentinized harzburgite, tectonically situated on Çamlıca Metamorphics along NE trending thrust zone. The Denizgören Ophiolite also rests on the Ezine Group to east [19]. The Ezine group that consisted of Permo-Triassic sedimentaries forms the boundaries of the Çamlıca Metamorphics on the western side and the Kemer Micaschist on the eastern side. [5, 16, 19].

The Sakarya Zone includes Kazdağ Core Complex, Karakaya Complex and Çetmi Melange. The Karakaya Complex consists of partly metamorphosed and moderately to strongly deformed, Permo-Triassic clastics, carbonates, and metaconglomerates [16, 24, 27]. The composition refers an accretion complex that developed within forearc basin of an active continental margin [26]. The Karakaya Complex is divided into two tectono-stratigraphic units: the upper unit, which contains Hodul, Orhanlar Graywacke, and Çal units, and the lower unit, which includes the Nilufer unit [25, 27, 28]. These two units are juxtaposed to each other by thrust fault almost everywhere in the Sakarya Zone [28]. The Kazdağ Core Complex, a double plunging NE-trending dome bounded by detachment faults from north and south, is represented by exhumed metamorphic rocks [29, 30]. Lithological composition of the Kazdağ Core Complex from bottom to top characterized by gneiss, amphibolite and marble; meta-ophiolites; paragneiss and migmatites [30-32]. Kazdağ Core Complex exposes in a large area at the southwestern part of the Biga Peninsula as a tectonic window under the Karakaya Complex [11, 16, 30]. The Cretaceous Çetmi ophiolitic melange which is unconformably overlained by Cenozoic sedimentary and volcanic rocks, is thrusted over the Kemer Micaschists to north and Kazdağ Core Complex to south [33]. The Çetmi ophiolitic melange consists of deformed blocks of altered basaltic to andesitic and pyroclastic rocks, blocks of late Triassic neritic and pelagic limestones, slices of serpentinite/listvenite, exotic lenses of garnet–micaschists and eclogite, blocks of radiolarite/red mudstone alternations to Middle Triassic limestones [33].

2.2. Tectonic Evolution of Biga Peninsula

The Basement lithologies represent margins of Back-arc basins (Meliata, Maliac, Pindos, Karakaya) which were opened during the closure of Paleo-Tethys and closed during the Permo-Triassic Rhodop-Pontide subduction [21, 34]. Subsequent collision which formed the Intra-Pontide Suture in the Biga Peninsula, endured from 69 Ma [32] until early Eocene (52 Ma) [20] and resulted in syn-collisional uplift of basement rocks (Figure 2).

Neotethyan subduction-collision events in western Turkey and Greece is pronounced as Hellenic subduction system [35] (Figure 2). The Hellenic subduction is due to closure of the remaining Neo-Tethyan Ocean in response to convergence between the Eurasian and African plates. The subduction of the African lithosphere beneath the Aegean Sea and Anatolide-Tauride is accompanied by slab rollback and/or slab break-off and trench retreat [36-38]. This appears to have caused transition from the compressive to extensional tectonism, and southward

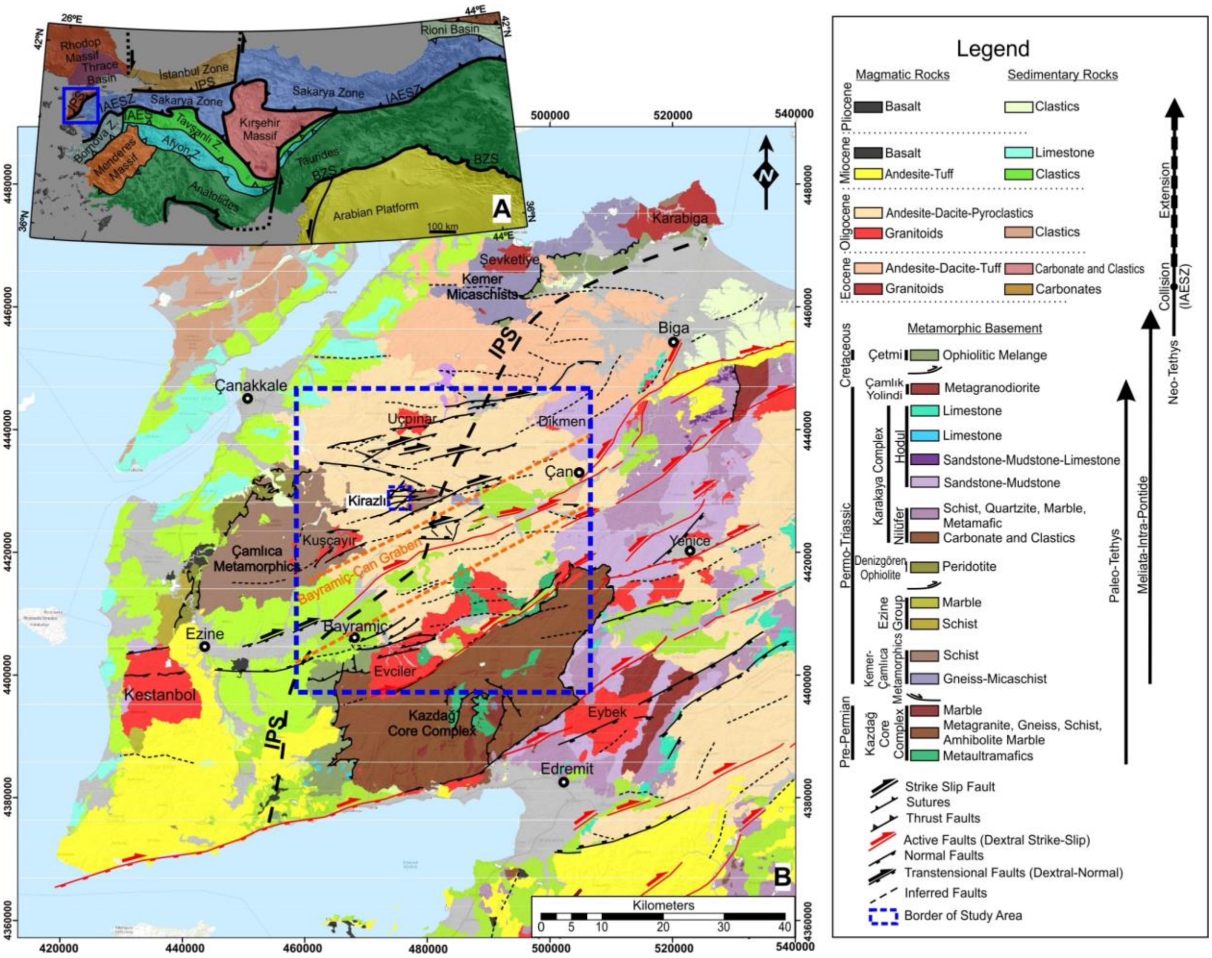

Figure 1. A) Major tectonic units of Türkiye [11, 31, 39], B) Geological map of the Biga Peninsula (modified from [31]), (IAES = Izmir-Ankara-Erzincan Suture, IPS= Intra-Pontide Suture, BZS= Bitliz-Zagros Suture, the name of intrusive is as shown.)

migration of the arc magmatism since the middle-late Eocene, that caused crustal thinning and extension (post-collisional and back-arc extension) (Figure 2) resulting in active grabens in western Türkiye. The extension of the continental crust was resulted in the basement shear zones in the lower crust and regional extensional fault systems in the upper brittle crust [40, 41]. The early phase of extension resulted in the footwall exhumation of NE-SW trending Kazdağ Core Complex, followed by the generation of NW- and NE-trending extensional half-graben basins during Eocene-Oligocene within Biga Peninsula [15, 37, 40, 42-44]. The extensional basins are bordered by NE-SW trending strike-slip and dextral-extensional oblique faults that are southern extend of North Anatolian Fault System and reactivation of former extensional faults as product of westward migration of Anatolian plate [1, 6, 7, 45]. Since Plio-Quaternary, it is suggested that the region experienced a combination of extension and shearing due to the right lateral movement of the North Anatoian Fault System (NAFS) [1-8]. The NAFS comprises three branches at the northern, central and southern Biga Peninsula respectively: (1) traversing the Sea of Marmara, (2) stretching from northeast to southwest along the Biga Peninsula, and (3) along the northern coast of the Edremit Bay [2, 3, 16, 46] (Figure 1). Between the northern branch of NAFS along Marmara Sea and southern branch along Edremit bay, the Biga Peninsula includes Biga-Çan, Bayramiç-Çan, Sarıköy, Bekten, Yenice-Gönen and Evciler faults as dextral strike-slip active faults along pull-apart and extensional basins [31]. Effect of collisional and extensional tectonic regimes is manifested in the Kirazlı district as middle Eocene to Miocene magmatism and dextral, NE-SW dextral-transtensional faults and E-W normal faults.

2.3. Tectonomagmatic Processes and Cenozoic Magmatism

Tectono-magmatic processes in the Biga Peninsula are result of subduction and extensional events since the early Eocene. The early-middle Eocene timeframe marks the onset of Hellenic subduction that was transformed from northward advancing subduction front to southward retreating plate boundary that was related to back-arc crustal thinning [45]. The Cenozoic magmatism in the Biga Peninsula mimics the subductional and extensional events. The stretching and thinning of the continental crust by the basement shear zones in the lower crust and regional extensional fault systems in the upper brittle crust, played a part in the emplacement of

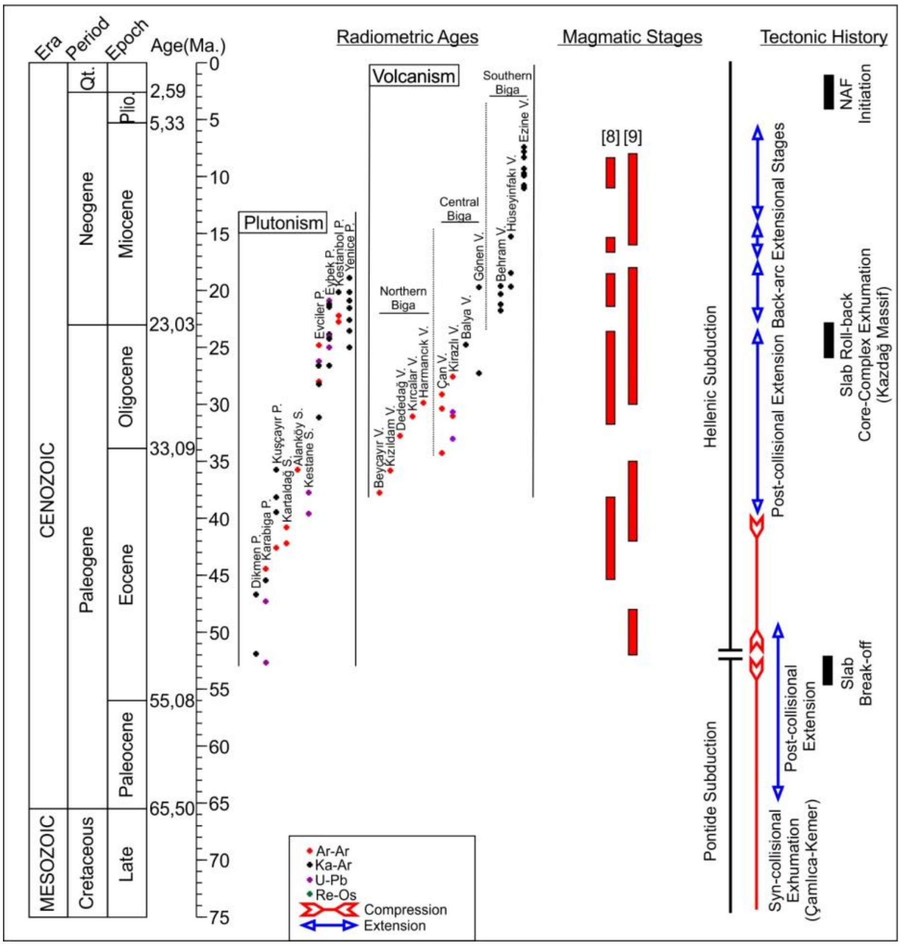

Figure 2. Temporal relationship between Cenozoic magmatism and tectonic history of Biga Peninsula (References for Plutonism = [9-11, 20, 47-51]; Volcanism = [8, 9, 39, 44, 47, 52-54]; Magmatic stages = [8, 9]; Tectonic history = [1-8, 12-15, 40]).

magmatic rocks onto the basement [40, 41]. In western Anatolia, magmatic rocks were generated during the collisional and extensional periods (Figure 2). The magmatism by collisional period refers to arc-magmatism formed during early stage of Hellenic subduction [8-15, 20, 39, 40, 44-54]. The magmatism by extensional period was emplaced along sub-parallel arcs within footwall blocks of basin-border normal faults and hanging-wall basins in Eocene, Oligocene, early-middle Miocene to Pliocene [13, 15, 47, 55, 56] (Figure 2).

The Cenozoic magmatic events took place between of Paleocene to Early Eocene (~65–49 Ma), Middle-Late Eocene (~49–35 Ma), Late Eocene-Oligocene (~35–23 Ma), Late Oligocene-Middle Miocene (~23–14 Ma) and Late Miocene-Pliocene (14–5 Ma) [5, 9].

The exhumation of metamorphic rocks by core complexes also enabled the generation of syn-tectonic intrusive (Eybek and Evciler plutons) and volcanic rocks [5, 9].

2.4. Local Geology

Kirazlı district contains metamorphic rocks both pre-Cenozoic basement and Cenozoic volcanic rocks (Figure 3). Pre-Cenozoic basement of Biga Peninsula crops out at eastern sector of the district, and they represent lithologies from the Rhodope Zone and Karakaya Complex. From bottom to top, they are composed of Permo-Trissic Çamlıca Metamorphics, Denizgören Ophiolites and Karakaya Complex (Hodul Unit) [57]. The metamorphic rocks the Rhodope basement consists of well foliated, quartz augen mica-schists (Figure 4A) of the Çamlıca Metamorphics and overthrusting dark blue-green serpentinized ultramafic rocks (Figure 4B) of the Denizgören Ophiolite (Figure 3) Pre-Triassic fine-grained, gray, well-sorted sandstone (Figure 4C) and thickly bedded polymictic rounded conglomerate (Figure 4D) of Karakaya Complex (Hodul) lies tectonically on the Rhodopean basement (See the cross-sections in Figure 3).

Cenozoic volcanic rocks unconformably overlies the basement rocks. They collectively form the cover sequences, and cover most of the study area on center and to west (Figure 3). They are the main host rocks for the epithermal Au and porphyry Cu style mineralization in the Kirazlı deposit [57, 58]. The volcanic sequence consists of lava flows from bottom to tuff and pyroclastic rocks (Figure 4E-F) with increasing proportion to the top. [57] and [58] reported that volcanic rocks have andesitic-dacitic composition. The pyroclastic rocks are mostly tuff in composition. The

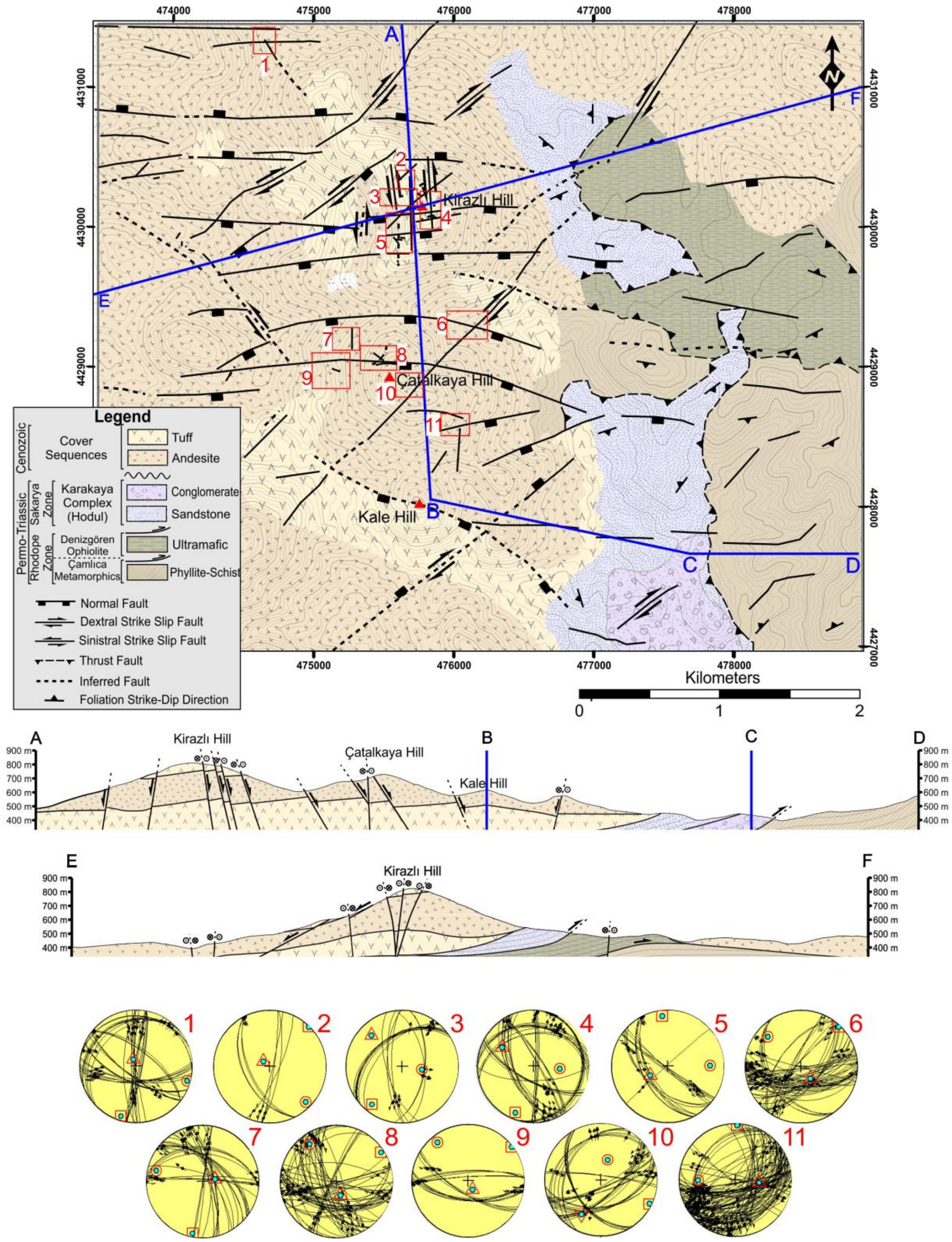

Figure 3. Geological map and cross-sections of Kirazlı deposit. Yellow stereoplots represent the measured fault planes and slip senses (small arrows on arcs of planes) from the sites indicated on the map by red rectangles.

phreatic and phreatomagmatic breccias dominates the pyroclastic rocks mainly at the Kirazlı Hill [57, 58]. Within the district epithermal Au-Ag mineralization is hosted by phreatic and phreatomagmatic breccias. Although, the intense alteration generally obliterates the original textural and mineralogical features (Figure 4B), the breccia is composed of polymictic angular to subangular lithic fragments (Figure 4A). For the andesitic and pyroclastic assemblage exposing in the Kirazlı district, 37.6-38.7 Ma age reported by [52].

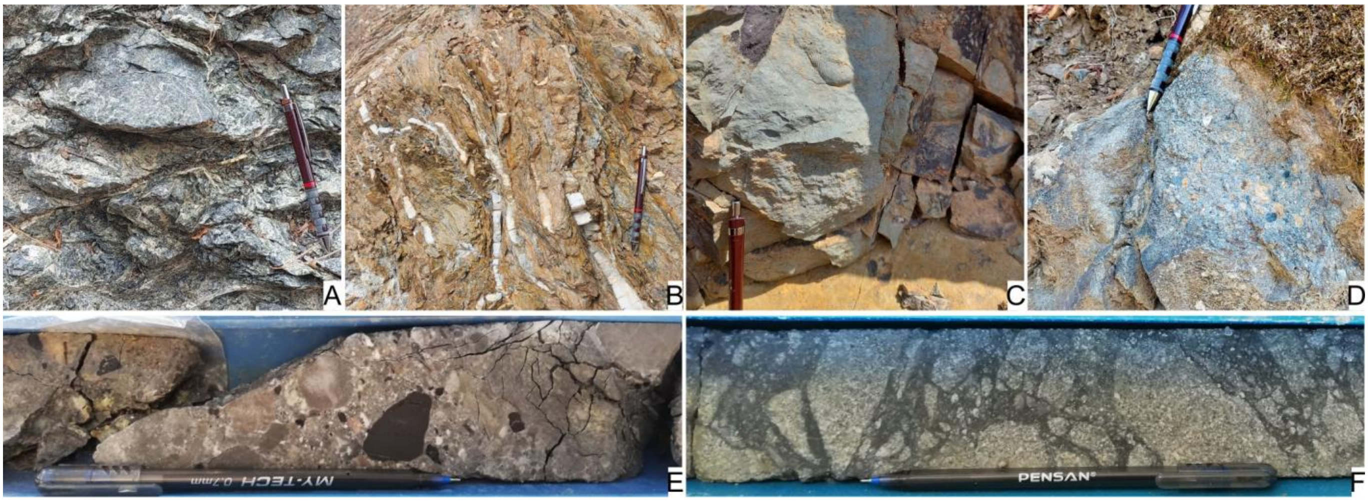

Figure 2. A) Dark blue-green serpentinized ultramafic rocks, B) Well foliated and folded, quartz augen mica-schists, C) Fine-grained, gray, well-sorted sandstone, D) Polymictic rounded, matrix-supported conglomerate, E) Volcanic breccia composed of polymictic angular to subangular lithic fragments, F) Intensely altered volcanic breccia.

3. Structural Works

The field works include both regional and deposit scale fault mapping and collecting the fault data in order to determine spatial distribution of faults and predominant fault geometries within approximately 900 km^2 area around Kirazlı district, including Uçpınar Pluton to north, Kuşçayır Pluton to west, Evciler Pluton to south and Dikmen Pluton to east (Figure 1A). Regional field works have focused on the areas with known fault zones and areas containing significant lineaments from satellite image and DEM (Digital Elevation Map). In the course of regional field studies, 33 locations were visited with the aim of mapping faults and gathering data on fault geometry and slip sense. (Figure 5). During the district scale structural works, previously determined lineaments with the help of SRTM-DEM and satellite imagery, were ground checked and 11 sites were visited for measurements and mapping (Figure 3). The regional and district scale mapped faults by this work, and previously mapped faults within study area are presented in Figure 3 and 5. Recorded data from field studies include fault plane attitude (strike, dip direction, dip amount) and slickenside striae orientation (trend, plunge, rake) and slip sense data. Obtained data by these measurements, computed and stereoplots-roseplots established. Predominant fault orientations were determined and grouped according to most frequent directions from plotted data (Figure 6). Slip senses were plotted for each fault plane (Figure 3,5) and accounted for kinematic character of predominant fault orientations.

3.1. Fault Geometry and Spatial Distribution of Regional-scale Faults

According to field measurements (Figure 5), predominant regional scale fault geometries form three distinct groups as 1) N70°E-N85°W, 2) N45°-60°E and 3) N45°-60°W (Figure 6A-B) between northwestern flank of Kazdağ Complex to southeast and Uçpınar Pluton to northwest (Figure 5). The faults located in the central and northern part of the study area, between the Bayramiç-Çan graben and the Uçpınar Pluton, are dominated by steeply dipping parallel to subparallel group-1 ENE-WSW and NE-SW striking Group-2 regional faults in the central Biga Peninsula. In the southern part of the study area between Bayramiç-Çan graben and Kazdağ Core Complex, regional scale faults exemplify the same predominant strike and dip directions of Group-1 and Group-2 faults. Along the Bayramiç-Çan graben dominated by NE-SW trending Group-2 faults and NNW-SSE striking Group-3 faults.

3.2. Fault Geometry and Spatial Distribution of Deposit-scale Faults

Kirazlı deposit and its vicinities are located within the deformational zone consisting of normal and oblique faults to the north of the south-dipping faults (Figure 5) that bound the Bayramiç-Çan graben at the north. Based on the district-scale field observations and measurements on the fault plane, the stereo-plots, rose diagram of strikes and contour diagram of poles of faults are presented in Figure 3., Figure 6C-D. According to the results, four major fault sets were identified. These fault sets are; 1) N80°W-N80°E, 2) N45°-60°E, 3) N50°-60°W and 4) N10W-N20W. The group-1 ENE-WNW faults bisects the Kirazlı Mountain from north to south parallel to each other and marks the E-W trending elevation changes on the topography (See sections in Figure 3). Group-2 NE-SW faults traverse the northwest of Kirazlı Mountain and Çatalkaya Hill (Figure 3). NW-SE striking Group-3 faults are frequently observed along western boundary of deposit area and showing parallel orientation with the topographical orientation of Kirazlı Hill. NNW-SSE striking Group-4 faults are frequently observed as small dissected segments between nearly E-W trending group-1 faults on Kirazlı Hill (Figure 3).

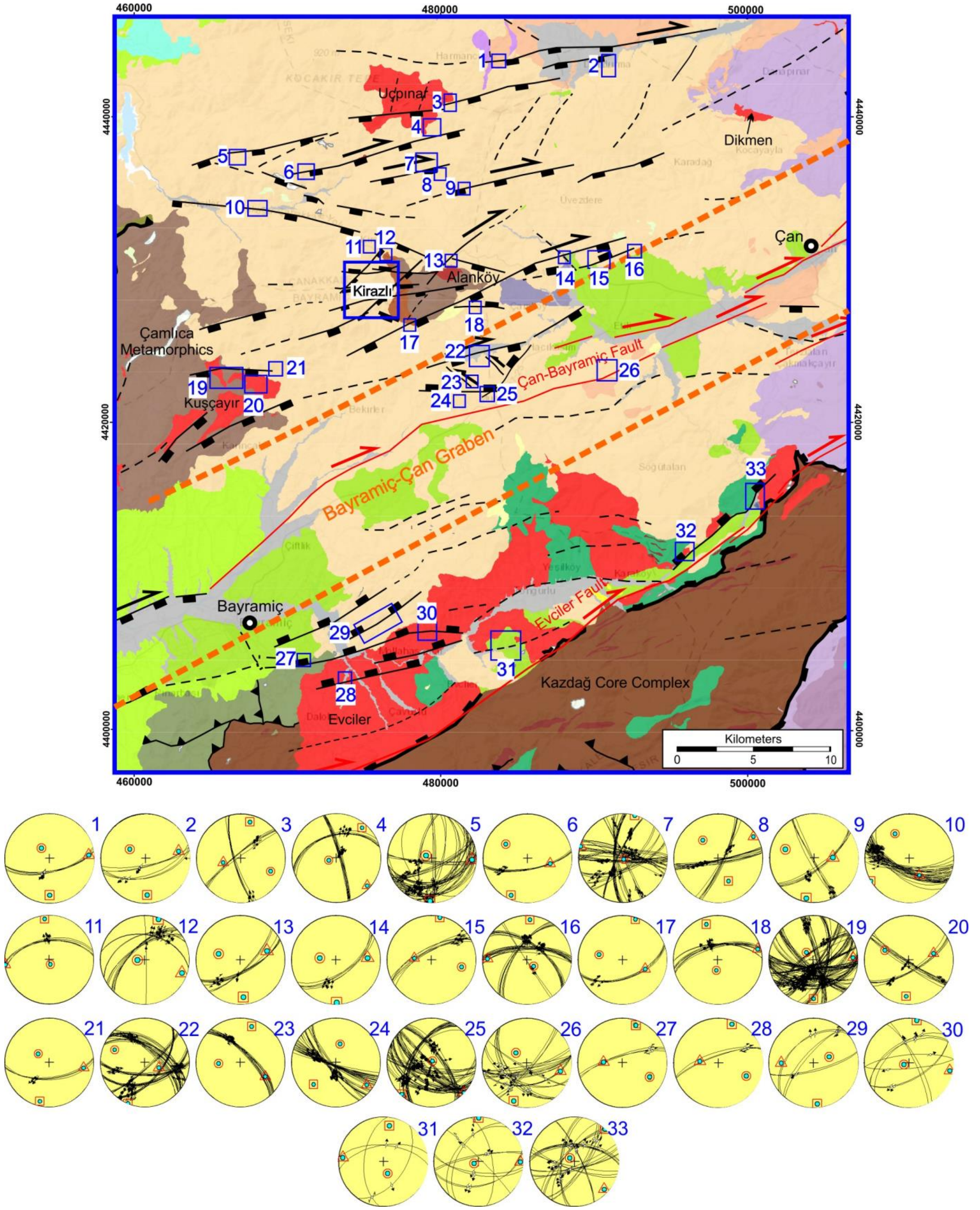

Figure 3 Geological map of regional study area. Yellow stereoplots represent the measured fault planes and slip senses (small arrows on arcs of planes) from the sites indicated on the map by blue rectangles. (See the Figure 1 for explanations.)

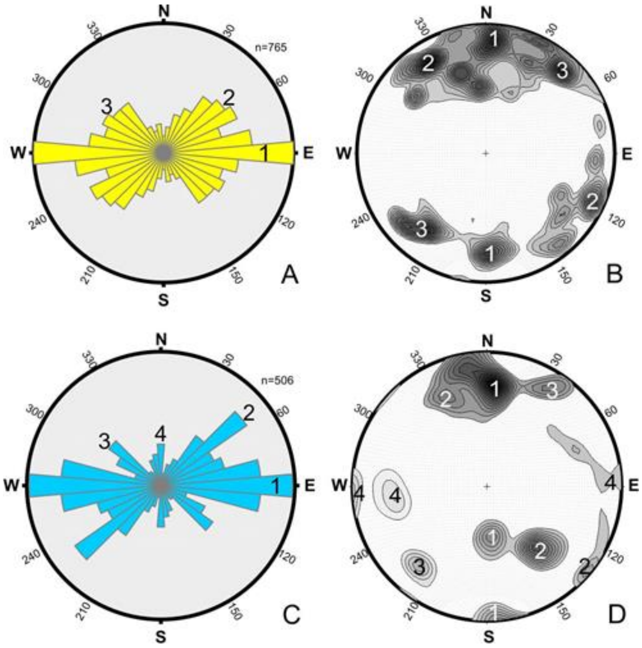

Figure 4 A and B respectively represent the rose-diagram of strike data and contour-diagram of poles of regional-scale fault planes. C and D respectively represent the rose-diagram and contour-diagram of poles of deposit-scale fault planes. Numbers are representing the fault groups according to orientations.

4. Discussion and Conclusion

Kirazlı district includes the basement units of both Rhodope (Çamlıca Metamorphics) and Sakarya (Karakaya Complex) Zones (Figure 3A) indicating that the Kirazlı district located within the IPS Zone. Like throughout the Biga Peninsula the Cenozoic volcanics unconformably overlie the Permo-Triassic basement within the Kirazlı district (Figure 3). The link between Cenozoic magmatism and the extensional tectonic regime following the closure of Neo-Tethys along the IASZ has been established by many researchers [5, 9, 39, 51, 53, 60]. The transition from collisional tectonic regime to post collisional extensional tectonic regime occurred as a result of slab break-off and orogenic collapse in early Eocene and promoted by slab roll-back that took place in Oligo-Miocene [5, 9, 51, 59, 60]. Slab roll-back and retreating subduction front mark the emplacement of southward younging magmatic formations (Figure 2 and References there in).

The slip vectors of faults observed on a regional scale generally point to two distinct directions: N-S and NE-SW (Small arrows on fault plane arcs in Figure 5). Slip vectors indicating N-S extension are more frequent on ENE-WSW striking Group-1 faults and NE-SW striking Group-2 faults in the regional scale measurement sites especially close to the northern flank of the Kazdağ Core Complex (Sites 29-33 in Figure 5) which was exhumed around 25 Ma [40]. NE-SW and ENE-WSW structures most common structures revealing the N-S extension in region (Figure 5). Also magmatic and volcanic lithologies which formed during Cenozoic extension aligned along NE-SW trend and juxtapose with the basement along same trend in region (Figure 5). Nevertheless, previous researchers [10, 60] reported that NW-SE trending structures are the earliest in the region parallel to retreating subduction front and the structures determined as Group-3 faults in this study. Besides, SW directed younging direction of Cenozoic volcanics and NW-SE trending age boundaries between volcanics support the same idea (Figure 1B). Three distinct extension axes have been observed for regional scale Group-3 faults, namely NNW-SSE (sites 16, 19, 22, 25, 26), N-S (sites 19, 22, 23, 26, 30), and NE-SW (sites 5, 6, 19, 20, 25, 26, 32, 33) (Figure 5). Among these extension axes, the N-S and NE-SW directions exhibit commonalities with the extension axes of Group-1 and 2 faults (sites 16,19, 20, 25, 33 in Figure 5).

Within the Kirazlı district, indicators of the post-collisional N-S extension less common to observe (Stereoplots in Figure 3). District scale measurements more frequently examples strike-slip and oblique-slip sense of movement on the ENE-WSW (Group-1) and NE-SW (Group-2) fault orientations with respect to regional scale faults with the same orientation. Deposit scale fault measurements conducted where the Oligocene volcanic sequence host high-sulfidation epithermal and porphyry type mineralizations known as Kirazlı Deposit [41, 52, 58]. The age of hosting volcanics and porphyry mineralization reported as respectively 37,6-38,7 Ma and 31,4-33,0 Ma and it is specified that HS clay alteration is younger [52]. Intense alteration may obliterate most of the indicators of possibly pre- or syn-mineral approximately N-S post-collisional Eocene-Oligocene extension at the Kirazlı district. Initiation of strike-slip tectonic regime of NAFS post-dates the both, mineralization in district and previous extensional regime. Measurements of NW-SE striking Group-3 and NNW-SSE Group-4 faults similarly example the strike-slip character both in district and regional scale except several sites (Sites 10,11 in Figure 3; Sites 10,16,23 in Figure 5). In the district, the temporal sequence between faults in terms of crosscutting relations is uncertain due to initiation of subsequent NAFS causing reactivation of faults.

The compiled and obtained data presented in this study aims to explain general features of regional and district scale faults by comparing their orientations and observed slip vectors. Within the Kirazlı district, cross-cutting relationships between faults create a difficult situation in terms of establishing the temporal order between dominant fault directions. Nevertheless, it is possible to say that NW-SE structures parallel to pronounced retreating-arc and boundaries between Eocene-Oligocene-Miocene are post-dated by ENE (Group-1) and NE-SW (Group-2) oriented faults which are most prominent structures both in regional and district scale suggesting that they controlled the final geometries of topography and Cenozoic magmatism.

5. Acknowledgment

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