Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı, S. 528-551, Nisan 2020

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue, pp. 528-551, April 2020

Research Article

The Stratigraphic and Petrographic Properties of the Rocks in Davut – Tazekent Vicinity, Diyadin-Ağrı-Turkey*

Gürsel Kansun [1†], Ahmad Omid Afzali [2], Fatih Üçgün [3]

[1] Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geology Engineering, Konya, Turkey (ORCID: 0000-0002-4581-6076)
[2] Afghanistan Academy of Sciences, Department of Geosciences, Kabul, Afghanistan
[3] Geothermal Energy Engineering and Consultancy Services, İzmir, Turkey

(Conference Date: 5-7 March 2020)

(**DOI:** 10.31590/ejosat.araconf68)

ATIF/REFERENCE: Kansun, G., Afzali, A. O., & Üçgün, F. (2020). The Stratigraphic and Petrographic Properties of the Rocks in Davut – Tazekent Vicinity, Diyadin-Ağrı-Turkey. *European Journal of Science and Technology*, (Özel Sayı), 528-551.

Abstract

The study is located in vicinity of Taşbasamak, Tazekent, Davut, Boyalan, Kuşburnu and Ulukent villages in the south of Diyadin district of Ağrı city. In the study area, Paleozoic aged Batıbeyli metamorphites which consist of crystallized limestones which contain calc-schist interlevels are observed at the bottom. The Upper Miocene aged Alibonca formation composed of conglomerate, trachyandesitic tuff-agglomerate, sandy limestone, marl, dolomite-dolomitic limestone and lacustrine limestone are located unconformably on these metamorphites. Upper Miocene aged Sekirdağ volcanites consisting of dacitic - rhyodacitic tuffs, agglomerates and lavas are observed by lateral - vertical transition over the Alibonca formation. Higher up, Lower Pliocene aged Solhan volcanites are composed of alkaline basaltic lavas are observed. The Solhan volcanites are covered by Upper Pliocene aged Hamur volcanites consisting of trachyandesitic lava and ignimbrite. Higher up, Upper Pliocene-Pleistocene aged Kale pyroclastics consisting of lapilli tuff, ash, volcanic bomb, slag and agglomerate with alkaline basalt composition are observed. These pyrolastics are covered by Upper Pliocene-Pleistocene aged Tutak volcanites which are composed of alkaline basalts. At the top, travertine and alluvium are found.

Calcite + dolomite ± quartz ± muscovite mineral paragenesis is observed in metacarbonates belonging to Batıbeyli metamorphites. The tuffs belonging to the Kuşburnu pyroclastic member include *quartz, plagioclase, sanidine, clinopyroxene (diopside/augite), biotite, amphibole (hornblende), sphene*, *opaque mineral, volcanic glass and litic fragment*. These tuffs were named as *lapillistone and ash tuff* "according to grain size", *trachyandesite tuff* "according to composition and grain size", *lapillistone, ash tuff and lapilli tuff* "accoding to percentage distribution of grains" and *vitric tuff* "according to glass-crystals-lithic fragments composition". The tuffs of Sekirdağ volcanites contain *quartz, plagioclase, sanidine, biotite, amphibole (hornblende), opaque mineral, volcanic glass and litic* fragment. The dacitic and rhyodacitic lavas belonging to these volcantecs include *quartz, plagioclase, sanidine, biotite, amphibole (hornblende), opaque mineral, plagioclase microlites and volcanic glass*. Tuffs belonging to Sekirdağ volcanites were named as *lapillistone and ash tuff* "according to grain size", *rhyodacitic tuff and dacitic tuff* "according to composition and grain size", *lapillistone and ash tuff* "according to percentage distribution of grains" and *vitric tuff* "according to glass-crystals-lithic fragments".

Alkaline basalts of Solhan volcanites include *quartz, olivine, clinopyroxene (diopside/augite), apatite, opaque mineral and plagioclase microlites. Plagioclase, sanidine, amphibole (hornblende), clinopyroxene (diopside/augite), apatite, opaque mineral, plagioclase and sanidine microlites* are observed in trachyandesites belonging to Tazekent trachyandesite member. *Plagioclase, hornblende, clinopyroxene, sanidine, pumice fragments, litic fragments and volcanic glas*s are located in ignimbirites belonging to Dalören ignimbirite member. The tuffs of Kale pyroclastics include *plagioclase, clinopyroxene (diopside/augite), olivine, opaque mineral, volcanic glass and litic fragmen*t. Agglomerates of Kale pyroclastics *include plagioclase, olivine, clinopyroxen (diopside/augite), orthopyroxen (enstatite), apatite, opaque mineral, volcanic glass and litic fragment*. These tuffs were named as *lapillistone* "according to grain size", *basaltic tuff* "according to composition and grain size", *lapilli tuff* "according to percentage

---

* This paper was presented at the ***International Conference on Access to Recent Advances in Engineering and Digitalization (ARACONF 2020)***.

† Corresponding Author: Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geology Engineering, Konya, Turkey, ORCID: 0000-0002-4581-6076, gkansun@ktun.edu.tr

distribution of grains" and *vitric tuff* "according to glass-crystals-lithic fragments composition". The agglomerate is in *basaltic agglomerate* composition "according to composition and grain size". Alkali basalts belonging to Tutak volcanites include *plagioclase, olivine, clinopyroxen (diopside/augite), orthoproxen (enstatite), apatite, opaque mineral and plagioclase microlites.*

Keywords: Diyadin (Ağrı), Stratigraphy, Petrography, Volcanic rocks, Pyrcoclastic rocks

Davut – Tazekent Civarındaki Kayaçların Stratigrafik ve Petrografik Özellikleri, Diyadin-Ağrı-Türkiye

Öz

İnceleme alanı Ağrı ili Diyadin ilçesinin güneyinde Taşbasamak, Tazekent, Davut, Boyalan, Kuşburnu ve Ulukent köyleri civarında yeralır. Çalışma alanında tabanda, kalkşist aradüzeyli kristalize kireçtaşlarından yapılı olan Paleozoyik yaşlı Batıbeyli metamorfitleri gözlenir. Bunun üzerinde konglomera, trakiandezitik bileşimli tüf-aglomera, kumlu kireçtaşı, marn, dolomit-dolomitik kireçtaşı ve gölsel kireçtaşından yapılı Üst Miyosen yaşlı Alibonca formasyonu uyumsuzlukla yeralır. Alibonca formasyonu üzerinde dasitik – riyodasitik bileşimli tüf, aglomera ve lavlardan oluşan Üst Miyosen yaşlı Sekirdağ volkanitleri yanal-düşey geçişle gözlenir. Üste doğru alkali bazaltik lavlardan oluşan Alt Pliyosen yaşlı Solhan volkanitleri yeralır. Solhan volkanitleri trakiandezitik lav ve ignimbiritten oluşan Üst Pliyosen yaşlı Hamur volkanitleri tarafından örtülmüştür. Üste doğru alkali bazalt bileşimli lapilli tüfü, kül, volkan bombası, cüruf ve aglomeradan oluşan Üst Pliyosen-Pleistosen yaşlı Kale proklastikleri gözlenir. Bu proklastikler alkali bazaltlardan oluşan Üst Pliyosen-Pleistosen yaşlı Tutak volkanitleri tarafından örtülür. En üstte ise traverten ve alüvyonlar yeralır.

Batıbeyli metamorfitlerine ait metakarbonatlarda *kalsit + dolomit ± kuvars ± muskovit* mineral parajenezi gözlenir. Kuşburnu proklastik üyesine ait tüfler *kuvars, plajioklas, sanidin, klinoproksen (diyopsit/ojit), biyotit, amfibol (hornblend), sfen, opak mineral*, *volkanik cam* ve *kayaç parçası* içerir. Bu tüfler "tane boyuna göre" *lapilli kayacı* ve *kül tüfü*, "bileşim ve tane boyuna göre" *trakiandezitik tüf,* "tanelerin yüzde dağılımına göre" *lapilli kayacı*, *kül tüfü* ve *lapilli tüfü,* "cam-kristaller-kayaç parçaları bileşimine göre" *vitrik tüf* olarak adlandırılmıştır. Sekirdağ volkanitlerine ait tüfler *kuvars, plajioklas, sanidin, biyotit, amfibol (hornblend), opak mineral volkanik cam* ve *kayaç parçası* içerir. Bu volkanitlere ait dasitik ve riyodasitik lavlar *kuvars, plajioklas, sanidin, biyotit, amfibol (hornblend), opak mineral plajioklas mikrolitleri ve volkanik cam* içerir. Sekirdağ volkanitlerine ait tüfler "tane boyuna göre" *lapilli kayacı* ve *kül tüfü*, "bileşim ve tane boyuna göre" *riyodasitik tüf* ve *dasitik tüf,* "tanelerin yüzde dağılımına göre" *lapilli kayacı* ve *kül tüfü,* "cam-kristaller-kayaç parçaları bileşimine göre" *vitrik tüf* olarak adlandırılmıştır.

Solhan volkanitlerine ait alkali bazaltlar *kuvars, olivin, klinoproksen (diyopsit/ojit), apatit, opak mineral* ve *plajioklas mikrolitleri* içerir. Tazekent trakiandezit üyesine ait trakiandezitler içerisinde *plajioklas, sanidin, amfibol (hornblend), klinoproksen (diyopsit/ojit), apatit, opak mineral, plajioklas ve sanidin mikrolitleri* gözlenir. Dalören ignimbirit üyesine ait ignimbiritler içerisinde *plajioklas, hornblend, klinoproksen, sanidin, pomza parçaları, kayaç parçaları* ve *volkanik cam* yeralır. Kale proklastiklerine ait tüfler *plajioklas, klinoproksen (diyopsit/ojit), olivin, opak mineral*, *volkanik cam* ve *kayaç parçası* içerir. Kale proklastiklerine ait aglomeralar *plajioklas, olivine, klinoproksen (diyopsit/ojit), ortoproksen (enstatit), apatit, opak mineral*, *volkanik cam* ve *kayaç parçası* içerir. Bu tüfler "tane boyuna göre" *lapilli kayacı*, "bileşim ve tane boyuna göre" *bazaltik tüf,* "tanelerin yüzde dağılımına göre" *lapilli tüfü,* "cam-kristaller-kayaç parçaları bileşimine göre" *vitrik tüf* olarak adlandırılmıştır. Aglomera ise "bileşim ve tane boyuna göre" *bazaltik aglomera* bileşimindedir. Tutak volkanitlerine ait alkali bazaltlar *plajioklas, olivin, klinoproksen (diyopsit/ojit), ortoproksen (enstatit), apatit, opak mineral* ve *plajioklas mikrolitleri* içerir.

Anahtar Kelimeler: Diyadin (Ağrı), Stratigrafi, Petrografi, Volkanik kayaçlar, Proklastik kayaçlar

1. Introduction

The study area covers the area of 135 km^2 including Günbuldu, Dibekli, Taşbasamak, Tazekent, Davut, Boyalan, Taşkesen, Kuşburnu, Yukarı Dalören and Ulukent villages in the south of Diyadin district of Ağrı province (Figure 1). The aim of this study is to determine the stratigraphic and petrographic properties of the units which are commonly made of volcanic - pyroclastic rocks and outcrops in the region including Diyadin geothermal field.

The study area is an area where dense volcanic activity is observed in Neogene - Quaternary young volcanics (Figure 1). Turkey is located along the Alpine-Himalayan orogenic belt which form a part of Tethys Ocean.

The grabens, faults, volcanoes and hydrothermal alteration zones and related geothermal activities with these are observed throughout this belt (Şimşek, 1997). Turkey's continental crust was shifted northward from Oligo-Miocene with the movement of the Arabian plate and was fractured as Anatolia sub-plate in Pliocene (Irrlitz, 1972; Şengör and Kidd, 1979; Şengör and Yılmaz, 1981; Koçyiğit et al., 2001). This fragmentation provided magma penetration into Eastern Anatolia and was concluded with formation of various stratovolcanoes including Ağrı, Nemrut, Süphan and Tendürek volcanoes as a result of wide volcanic activity (Şaroğlu et al., 1980).

Previous studies in the region can be summarized as follows: Lambert et al. (1974) divided into two parts as “containing high itriyum” at calc-alkaline feature and “containing low itriyum” at calc-alkaline - tholeitic feature to andesitic-dacitic-rhyolitic lavas observed in Ağrı Mount. Kıral and Çağlayan (1980) stated that Plio-Quaternary aged volcanic and pyroclastic rocks which are tuff, agglomerate, basalt, andesite, dacite and rhyolite were composed in Ağrı, Kağızman and Taşlıçay vicinities and that the basaltic lavas occured in three separate phases. Innocenti et al. (1981 and 1982) said in their study in Erzurum and Kars vicinities that volcanic rocks which were 8-13 million years old in the region were mostly calc-alkaline and relatively alkaline character and that Tertiary volcanism in Eastern Anatolia was effective to northerly about 6 million years ago.

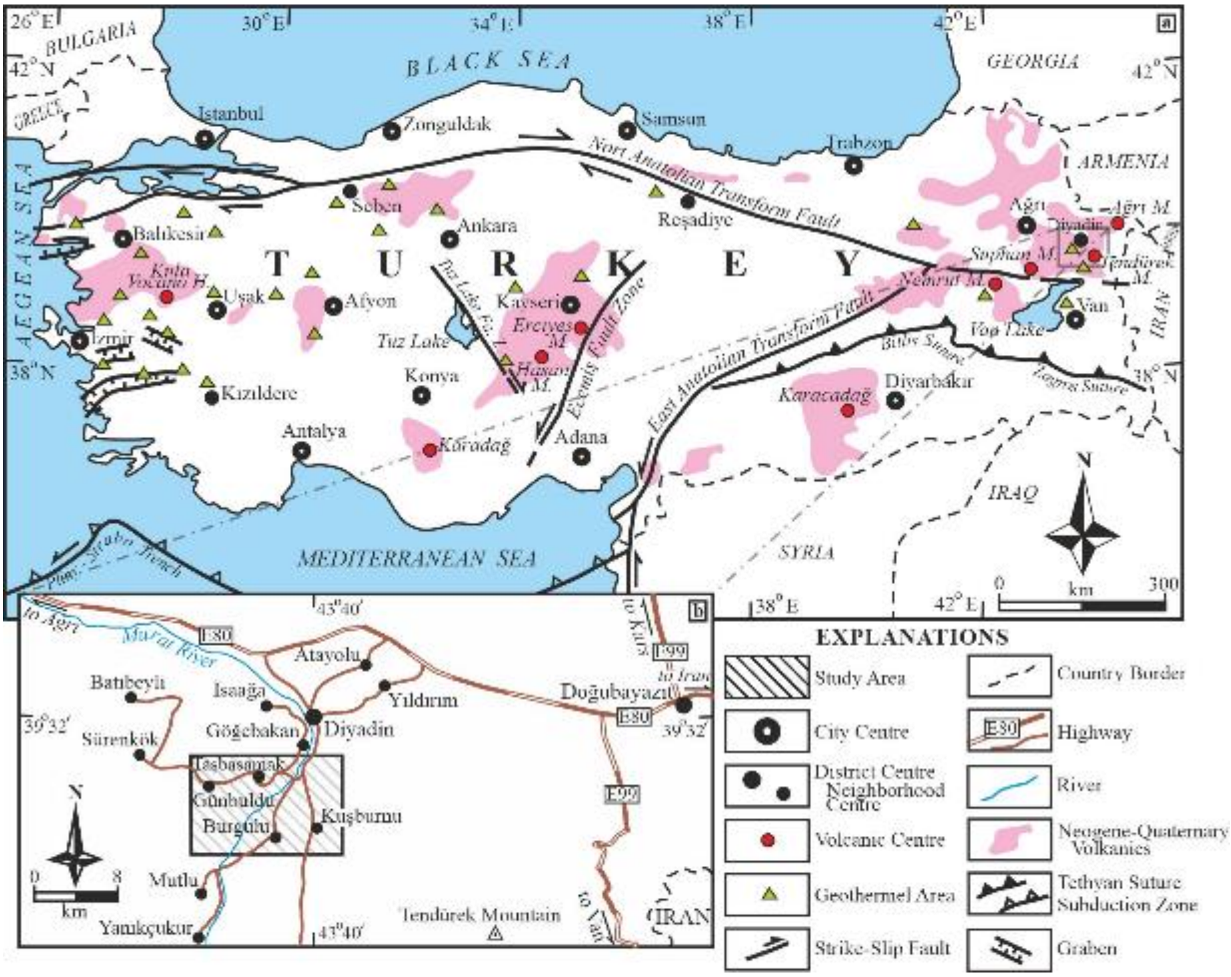

Figure 1. a) The general tectonic features and the young volcanic belts of Turkey (revised from Güleç et al. (2002) and Pasvanoğlu and Chandrasekharam (2011)), b) The location map of the study area

Bilgin (1984 and 1987) stated that Miocene aged volcanites in the vicinity of Serçeme (Erzurum) have the composition ranging from basalt to rhyolite and that they occur as a result of Himalayan type orogenic events developed during the East Anatolian compressional zone in Middle-Upper Miocene. Güner and Şaroğlu (1987) said that Ağrı Mountain completed its formation in 11 different volcanic phases and that the last phase developed towards the end of Upper Quaternary and that hornblende basalts, hyalo andesites and volcanic clays emerged in this last phase. Yılmaz et al. (1987a and 1987b), in petrochemical investigations which they made in volcanic rocks in Bingöl and Muş regions, suggested that the neotectonic period that started in Middle Miocene was formed as a result of the compression regime that started with the continental-continental collision in Eastern Anatolia. These researchers stated that Solhan volcanites were the first products of this phase in the region and that the magma in alkaline character originated from the upper mantle.

Buket (1989) said that the Upper Miocene-Lower Pliocene aged Hamurpet volcanites around Varto (Muş) are composed of basaltic andesite, trachybasalt, trachyandesite, andesite, latite and dacite and these are in alkali, calc-alkaline and partly tholeiitic composition. Pearce et al (1990) suggested that volcanic rocks in Kars and Ağrı vicinity have the ages of 7 - 0.5 Million years and that these volcanites occur as a result of subalkaline basalt-andesite-dacite-rhyolite fractionation. Ercan et al. (1990) said that the volcanites in Eastern Anatolia were generally upper continental crust, partly lower crust and rarely mantle origin. These researchers stated that the crust fragments belonging to the Arabian plate which had plunged to the bottom before the collision of the Anatolian and Arabian plates mixed with the magma forming these volcanites.

Türkecan et al. (1992a) were distinguished the Upper Oligocene - Lower Miocene aged Üryanbaba volcanites, the Middle-Upper Miocene aged Cemalverdi volcanites and the Upper Miocene aged Sekirdağ volcanites in Patnos-Hamur (Ağrı) and Tutak (Van) vicinities. Türkecan et al. (1992b) stated that the lavas observed in Hamur (Ağrı) region were the three levels and that the alkaline silicic volcanites were composed of lava, obsidian and ignimbrite and that peralkaline ignimbrite had the very widespread outcrop. Ercan and Asutay (1993) said that Bingöl volcanites consisted of basaltic lava flows, tuffs, agglomerates and trachytes and they are formed by partial melting in the mantle.

Ercan et al. (1994) stated that basic rocks consisting of schist, marble, ophiolite and the young units consisting of claystone, tuff and marls surfaced in Diyadin, Zilan and Çaldıran regions. Erişen et al. (1996) said that Paleozoic aged marble, Neogene aged limestone, lava, tuff and volcanic sandstone surfaced in Diyadin region and that the dominant tectonic regime in the region was NE-SW, N-G, NW-SE trending.

Sümengen (2009a), in the study which he made in Karayazı (Erzurum), Aras (Iğdır) and Tahir (Ağrı) regions, stated that Paleozoic aged Akdağ metamorphites consisting of gneiss, amphibolite, schist and marble and Kağızman complex consisting of ophiolite and rock types of sedimentary origin form the bottom in the region. The researcher said that the Çullu formation, which is composed of Late Miocene aged tuff, tuffite, sandstone and marl interlevels, was conformably observed on the Late Miocene aged Yastıktepe formation consisting of alternation of conglomerate, sandstone and marl. This researcher stated that the Late Miocene aged volcanites in the region are represented by Kaletepe volcanites consisting of pyroclastics and andesitic lavas and Sekirdağ volcanites consisting of dacite, rhyodacite, pyroclastic and andesite. He claimed that the Plio-Quaternary aged Karayazı volcanites are composed of basalt and andesite and same aged Tutak volcanites are composed of basalt, hawaiite and mugearite.

Sümengen (2009b) states that the Kağızman complex is located on the Paleozoic aged Akdağ metamorphic rocks which form the bottom in Patnos (Ağrı) and Malazgirt (Muş) vicinities. This researcher said that Middle-Late Miocene aged Cemalverdi volcanites, which consist of andesites and dacites, are unconformably overlain by Pliocene aged sediments and volcanites. This researcher stated that Upper Miocene aged units is represented by Karaali formation consisting of alternation of sandstone, claystone, shale and gypsum, Alibonca formation consisting of conglomerate, mudstone, siltstone and gypsum and Sekirdağ volcanites at calc-alkaline feature consisting of andesite-dacite type lavas in the region. This researcher said that the Solhan volcanites, which consist of Early Pliocene aged basalt, mugearite, hawaiite and benmorite type lava flows, were lateral - vertical transition with Pliocene aged Zırnak formation consisting of conglomerate, sandstone, claystone and limestone. This researcher indicated that the Plio-Quaternary aged Bulanık formation and Tutak volcanites are unconformably observed on Pliocene aged Hamur volcanites consisting of dacite, trachyte and ignimbrite in the region. This researcher suggested that the volcanism in the region started in the alkaline character and then ended with Süphan volcanites, which showed calc-alkaline character.

Açlan and Turgut (2017) stated that plutonic and volcanic units are observed around Şekerbulak (Ağrı). They said that the plutonic units were represented by Taşlıçay Granitoid consisting of tonalite, granodiorite, monzogranite and granite. They indicated that Yeltepe trachyandesite and Yuva rhyolite are formed the volcanic units. These researchers suggested that volcanic units showed subalkalic, calcalkalic, high K series and shoshonitic features.

In addition, some of the studies on the Diyadin geothermal field in the study area were described by Alpman (1974), Ercan et al. (1994), Erişen et al. (1996), Eşder (1997), Burçak et al. (1997), Keskin (1998), Eltez et al. (2001), Pasvanoglu (2013) and Mutlu et al. (2013). Çolakoğlu et al. (2011) studied the geology and isotope geochemistry of Diyadin (Ağrı) gold formation.

2. Material and Method

In the field studies, detailed geological map of the study area was prepared on Doğubayazıt - I 51-d3, Doğubayazıt - I 51-d4, Doğubayazıt - J 51-a1 and Doğubayazıt - J 51-a2 numbered the topographic maps at the 1/25000 scale by using the geological map which was made by Burçak et al. (1997) (Figure 2). The stratigraphic cross section of the study area was made by taking into consideration ages, stratigraphic positions and boundary relations of the units which outcrops in the study area (Figure 3). During the field studies, 85 rock samples were taken from different units. Thin sections were made from 52 of these samples in Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geological Engineering.

Volcanic rocks were classified in “double triangular diagrams of Streckeisen (1967)” according to their mineralogical composition. In addition, these rock classications were supported with the geochemical analysis results which were made from these rocks. The pyroclastic rocks were denominated by taking into consideration the grain size, the mineralogical composition and the volcanic glass-lithic fragments composition in the naming diagrams for pyroclastic rocks of Schmid (1981), Pettijohn et al. (1987) and Le Maitre (2005). The mineralogical composition and texture-structure characteristics of the metamorphic rocks are taken into consideration at the nomenclature of metamorphic rocks. The classification diagrams of metamorphic rocks at low and high temperature of Winkler (1979) and percent mineral contents of metamorphic rocks were used in these naming. Also, the structural features of the metamorphic rocks were also taken into consideration in these names. The classification diagrams of Folk (1962) and Dunham (1962) were used in the nomenclature of clastic and carbonate sedimentary rocks.

3. Results and Discussion

3.1. Stratigraphy and Petrograpy

3.1.1. Batıbeyli Metamorphites

It is composed of crystallized limestones with calcschist interlevels. The unit was named as Batıbeyli metamorphics by Çakır (1994). In this study, these metacarbonates were defined as Batıbeyli metamorphites. Batıbeyli metamorphites are observed in Ulukent Village, Ortadüz Ridge and the southwest of Kuş Ridge in the southwest of the study area (Figure 2).

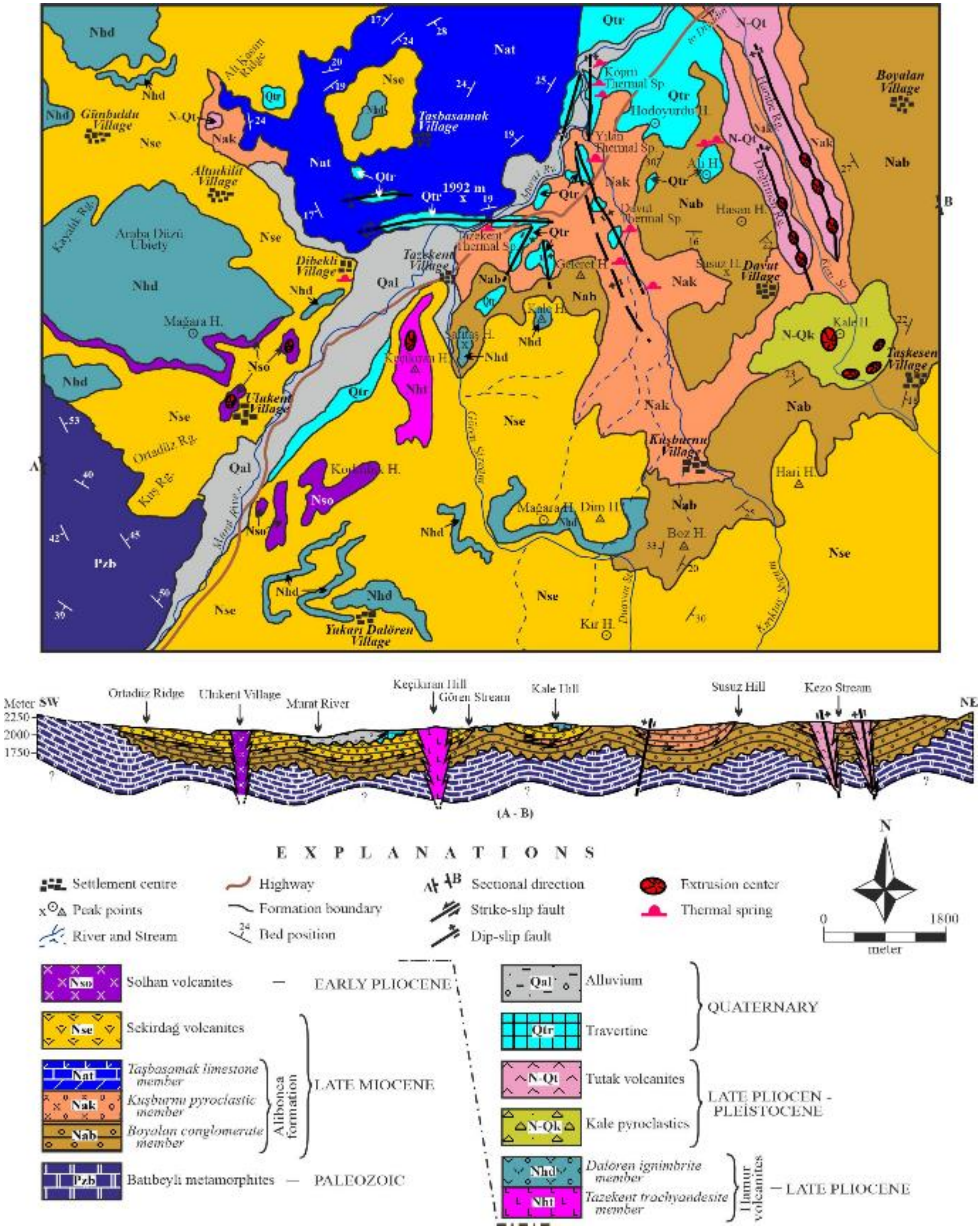

Figure 2. Geological map (revised from Burçak et al. (1997)) and horizontal geology section of the study area

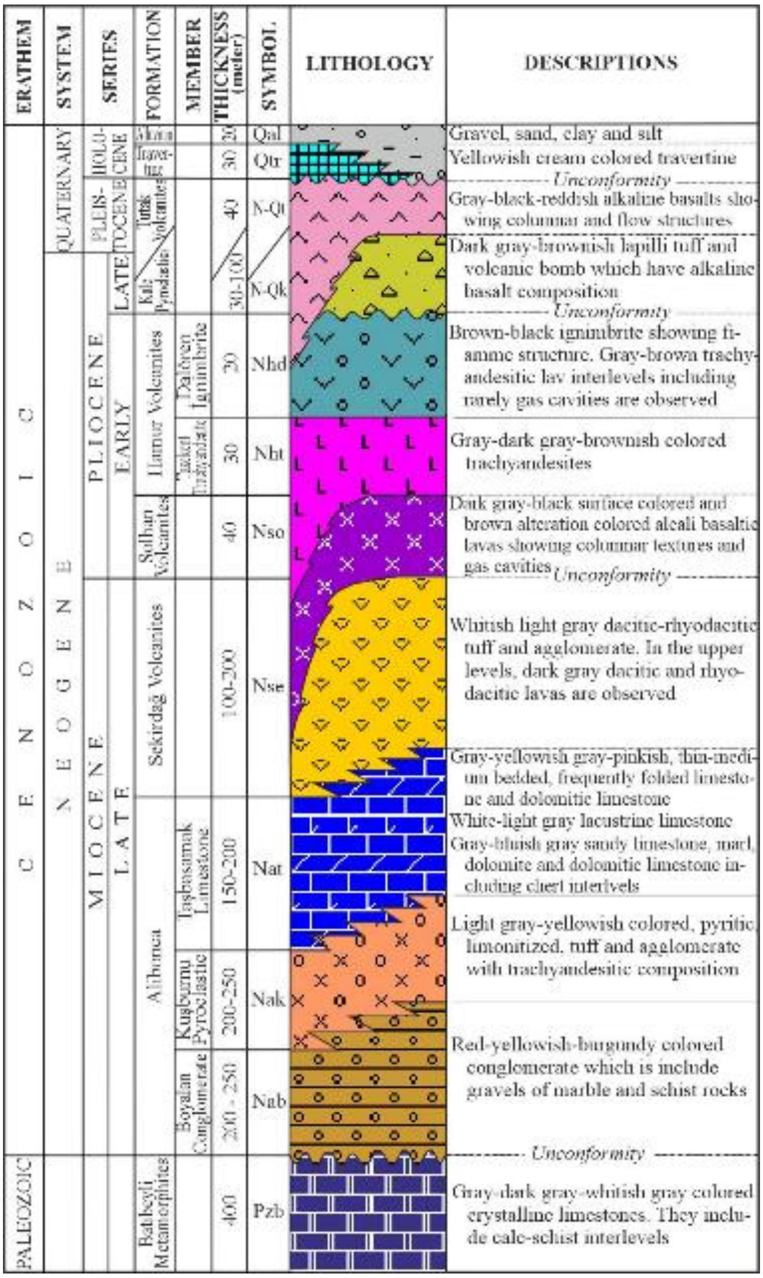

Figure 3. Stratigraphic cross section of the study area

In the unit, dolomitic limestone and calcschist interlevels are observed. Crystallized limestones are gray, dark gray, whitish gray in color, generally layered and sometimes blocky in appearance (Figure 4). Layer thicknesses vary between 10-30 cm. They are mostly coarse and sometimes fine grained. Secondary calcite veins are sometimes observed in crystallized limestones. Dolomitic limestones, which are observed as interlevels in crystallized limestones, are gray-dark gray colored and thin-medium bedded. Layer thicknesses vary between 10-25 cm. Dolomitic limestones are very hard and medium-coarse grained. These metacarbonates are operated as marble and crushed stone. Metacarbonates belonging to Batıbeyli metamorphites contain yellowish greenish gray colored calcschist interlevels. The calcschists have schistosity structure due to the phyllosilicate minerals such as muscovite and chlorite.

Figure 4. Crystallized limestones belonging to Batıbeyli metamorphites observed in the southwest of the study area

Especially in metacarbonate levels, overturned and oblique isoclinal folds are observed in some places due to deformation effect. In addition, abundant small scale faults were found in the unit. As a result of these tectonic movements, metacarbonates gained dense fractured structures at vertical and oblique position to bedding.

Calcite + dolomite ± quartz ± muscovite mineral paragenesis is observed in metacarbonates belonging to Batıbeyli metamorphites. These metacarbonates, characterized by their massive structures, are typically granoblastic in texture. *Calcite + chlorite (ripidolite-picnochlorite) + muscovite ± quartz ± opaque minerals* are observed as interlevels between metacarbonates (Figure 5).

The calcite crystals are more than 90% in the crystallized limestones (Figure 5-a). 73-82% calcite and 16-24% dolomite crystals is observed in dolomitic limestones. Calcites, commonly observed in these metacarbonates, are generally xenoblastic, and have high-very high birefringence and distinct duplex cleavage in some crystals. Dolomite crystals observed in dolomitic limestones are generally xenoblastic and sometimes typical with romboeder appearance. Quartz and muscovite crystals in metacarbonates are observed in minor ratios (1% quartz, 1% muscovite).

Calcites, which constitutes the main component of the calcschists, are 52 - 65% in these rocks. The muscovites (15-24%) observed in the calc- schists are platy-shaped and show flat extinct. Chlorites, which are observed as 12-18%, are leafy-platy-shaped, green colored and probably in "ripidolite-picnochlorite" composition. Muscovite and chlorite elongated in one direction within the calcschists gave these rocks a granolepidoblastic texture (Figure 5-b).

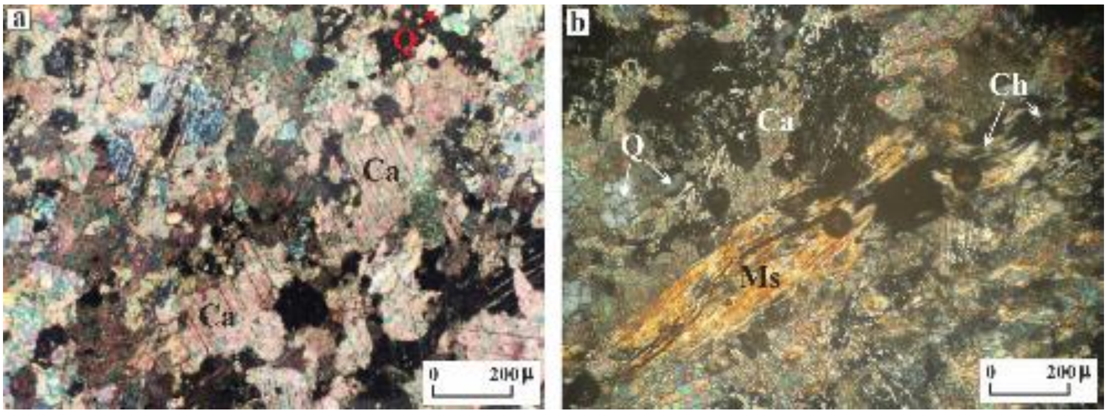

Figure 5. The view from crystallized limestone (a) and calcschist (b) belonging to Batıbeyli metamorphites. Ca: Calcite, Q: Quartz, Ch: Chlorite and Ms: Muscovite, // Nicol

Batıbeyli metamorphites, which form the basis of the study area, show dense folds due to their intense deformation effects. That the unit form the basis and it shows folded structure complicate to give real thickness to the formation. On the other hand, when the outcrops in the study area of the unit and tectonic structures (folds) of the metacarbonates take into account, the formation presents a visible thickness of approximately 400 m. Batıbeyli metamorphites, whose bottom surface cannot be observed in the study area, are unconformably overlain stratigraphically by Alibonca formation (Figures 2 and 3). The unit is unconformably overlain by Sekirdağ volcanites and Dalören ignimbrites belonging to the Hamur volcanites in the southwest of the study area (Figure 2). Batıbeyli metamorphites are Paleozoic aged according to Çakır (1994). Batıbeyli metamorphites show comparable properties with the metacarbonate levels of the Akdağ metamorphites outcropping in Patnos (Ağrı) and Malazgirt (Muş) vicinities.

3.1.2. Alibonca Formation

Conglomerates (Boyalan conglomerate member) are observed at the lower levels of this formation. Higher up trachandesitic tuffs and agglomerates (Kuşburnu pyroclastic member) take place in lateral-vertical transition. At the top, crystallized limestones and dolomitic limestones (Taşbasamak limestone member) are observed by lateral-vertical transition (Figure 3). Alibonca formation was first named by İlker (1966). This researcher states that the Alibonca formation consists of conglomerate, mudstone, sandstone, siltstone, marl, clayey limestone, gypsum and pyroclastic rocks.

3.1.2.1. Boyalan Conglomerate Member

The unit is made up of conglomerates. It was named as Boyalan conglomerate member within Alibonca formation in relation to Boyalan Village in the northeast of the study area where typical outcrops are observed. The unit is observed particularly in the vicinities of Boyalan Village, the nort of Davut Village, Geleref Hill and Taşkesen Village in the east the examination area (Figures 2 and 6).

Boyalan conglomerate member consists of reddish-yellowish burgundy colored conglomerates. The sandstone and mudstone interlevels are observed sometimes within the unit. Marble, schist, chert and tuff pebbles are seen in the conglomerates. The pebbles are generally semi-angular and semi-round, and the grain sizes of pebbles are quite variable. Conglomerates show medium-thick bedding and medium-good grading (Figure 6). They contain material ranging from mud size to large block size. The matrix of the conglomerates generally consist of carbonates. The sandstone levels in the unit are medium bedded, and the layer thicknesses of these levels vary between 5-10 cm. The lamination and cross stratification are prominent in sandstones.

Figure 6. Conglomerates belonging to the Boyalan conglomerate member observed around Boyalan Village

In the conglomerate sample taken from Boyalan conglomerate member, the grains are formed from chert fragments, crystallized limestone pebbles and magmatic rock pebbles (Figure 7-a). In this rock containing carbonate matrix, the ratio of matrix is more than 1%. The grains are round and close to the round. Since the pebbles in this conglomerate come from outside the deposition basin, they are named as "*epiclastic conglomerate"*. The naming according to textures of conglomerates is "*paraconglomerate*". That the grains which form conglomerate are very different indicate to "*polymictic conglomerate*". They was named as "*extraformational conglomerate*" according to the origin of the grains.

In the mudstone sample taken from Boyalan conglomerate member, sparite (47%), micrite (35%), extraclast (quartz, rock fragment, opaque beads) (15%), allochem (intraclast (3%), pellet (3%), fossil (3%)) and porosity (3%) were observed. This rock was named as "*crushed poorly sorted pel-bio-intrasparite*"according to Folk (1962) and as "*mudstone*" according to Dunham (1962) (Figure 7-b).

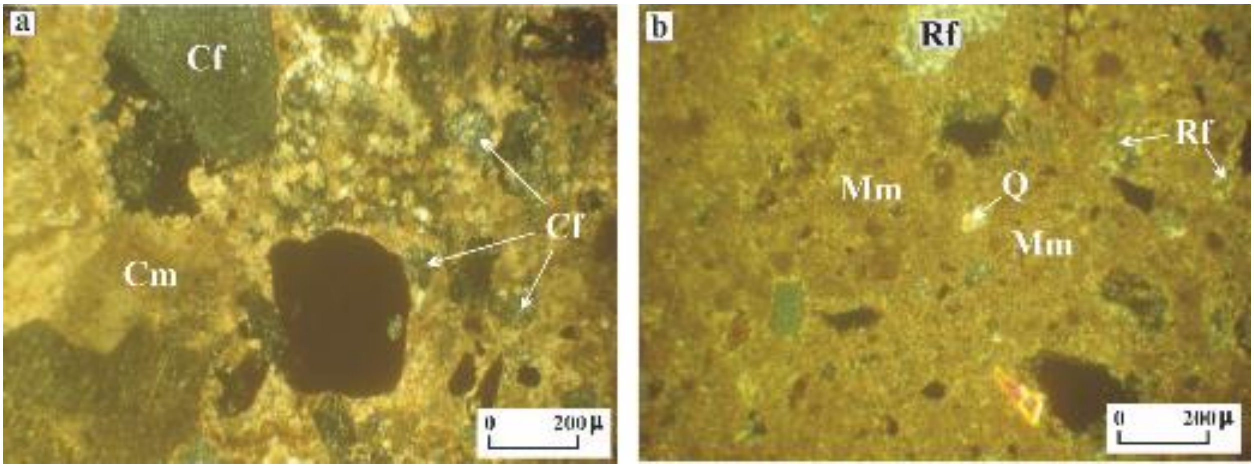

Figure 7. The views of the conglomerate (a) and mudstone (b) belonging to Boyalan conglomerate member. Cf: Chert fragment, Cm: Carbonate matrix, Rf: Rock fragment, Mm: Micritic matrix. // Nicol

Boyalan conglomerate member presents a visible thickness of 200-250 m in the study area. The unit is observed unconformably stratigraphically over Batıbeyli metamorphites from below. On the other hand, stratigraphically it is covered with lateral-vertical transition by Kuşburnu pyroclastic member which is formed tuffs and agglomerates belonging to Alibonca formation (Figure 3). The Boyalan conglomerate member is unconformably overlain by Sekirdağ volcanites in Taşkesen Village vicinity and Kale pyroclastics in Kale Hill vicinity in southeast of the study area. The unit is unconformably covered by ignimbrites belonging to Hamur volcanites in Sarıtaş Hill vicinity (Figure 2).

Boyalan conglomerate member shows similar features with Yastıktepe formation which defined in Karayazı (Erzurum) region by Sümengen (2009a) and with conglomerate-mudstone levels of Alibonca formation which defined in Bulanık (Muş) region by

Sümengen (2009a). Upper Miocen age was given to Yastıktepe formation according to stratigraphic position of this formation and Ostragod fossils, such as *Cordona angulata*, *Ilyocypris bradyi* and *Cyprinotus salinus*, by Sümengen (2009a).

3.1.2.2. Kuşburnu Pyroclastic Member

The unit is composed of tuffs and agglomerates in trachyandesitic composition. It was named as Kuşburnu pyroclastic member in Alibonca formation since it was observed typically in Kuşburnu village vicinity. It is also observed in the western and eastern parts of Davut Village, in the Davut Thermal Spring, Tazekent Thermal Spring and Yılanlı Thermal Spring vicinities and on the eastern and western slopes of Harabe Ridge (Figure 2).

The tuffs, tuffites and agglomerates which are light gray - yellowish colored and in trachyandesitic composition are observed in Kuşburnu pyroclastic member (Figure 8). The tuffs are easy dispersible feature. The tuffites show good bedding and bed thickness vary. Disseminated pyritic zones are observed within the unit. It is seen that these pyrite turn sometimes into limonite at alteration result.

Figure 8. A view from the tuffs belonging to Kuşburnu pyroclastic member observed in the vicinity of Kuşburnu Village

The tuffs and tuffites were formed by fusion of ash and lapilli grains. Gray colored quartz, whitish colored plagioclase, whitish gray colored and shiny looking sanidine and black - brown colored - platy-shaped biotite are observed in these rocks. In addition, these rocks have a fine-grained phase (matrix) which can not be seen by eye in macro samples. These rocks are composed of different grain sizes and show porphyritic texture.

Agglomerates were formed by attaching with a matrix composed of a volcanic material of volcanic rock fragments which are pebble-block size. The volcanic matrix consists of ash-sized materials. Within the agglomerates, the volcanic material which is observed in block size consists of trachyandesites. These trachyandesites are gray - dark gray in color and consist of plagioclase, sanidine, biotite, hornblende, pyroxene phenocrystals and matrix. These rocks show porphyritic texture.

The tuffs belonging to Kuşburnu pyroclastic member contain *quartz, plagioclase, sanidine, clinopyroxene (diopside/augite), biotite, amphibole (hornblende), sphene, opaque mineral* in the phenocrystalline phase and *volcanic glass* in matrix phase and also *lithic fragments*. The components, grain sizes and classifications of tuffs belonging to Kuşburnu pyroclastic member are shown in Table 1.

Table 1. The components, percent values, grain sizes and classifications of three tuff samples belonging to Kuşburnu pyroclastic member

			Sample Number		
			L12-16	**L11-15**	**L21-27**
The Name of Component	**Phenocryst**	Quartz	% 1	% 2	-
		Plagioclase	% 12	% 4	% 15
		Sanidine	% 7	% 6	% 11
		Clinopyroxene (Diopside/Augite)	% 2	% 5	-
		Biotite	% 7	-	% 5
		Amphibole (Hornblende)	-	% 2	% 3
		Sphene	-	-	% 2
		Opaque mineral	% 1	% 1	% 2
	Matrix	Volcanic glass	% 66	% 75	% 58
		Litic fragments	% 4	% 5	% 4
Grain Size (in macro sample)		Size (mm)	mostly 2-64 mm	mostly < 2 mm	mostly 2-64 mm
Distribution of percentage of grains (in macro sample)		< 2 mm	% 07	% 88	% 38
		2 – 64 mm	% 90	% 10	% 60
		> 64 mm	% 3	% 2	% 2
Classification		**According to Grain Size**	*Lapillistone*	*Ash tuff*	*Lapillistone*
		According to Composition and Grain Size	*Trachyandesitic tuff*	*Trachyandesitic tuff*	*Trachyandesitic tuff*
		According to Percentage Distribution of Grains	*Lapillistone*	*Ash tuff*	*Lapilli tuff*
		According to Glass-Crystals-Litic Fragments Composition	*Vitric tuff*	*Vitric tuff*	*Vitric tuff*

The grain size of two tuff samples is mostly between 2-64 mm and the grain size of one tuff sample is mostly < 2 mm belonging to Kuşburnu pyroclastic member (Table 1). Therefore, these rocks are defined as "lapillistone" and "ash tuff " when they are evaluated *in grain size classification diagram of pyroclasts* of Schmid (1981). These rocks are in "trachyandesite" composition according to chemical analysis results (Kansun and Üçgün, 2019) and mineralogical compositions of these. When these tuffs are evaluated in the triangular diagram of Le Maitre (2005) *according to percentage distribution of grains in pyroclastic rocks*, they are named as "lapillistone", "ash tuff " and "lapilli tuff" (Figure 9-a). The tuffs are seen in "vitric tuff" area *in glass-crystals-lithic fragments diagram* (Pettijohn et al., 1987) (Figure 9-b).

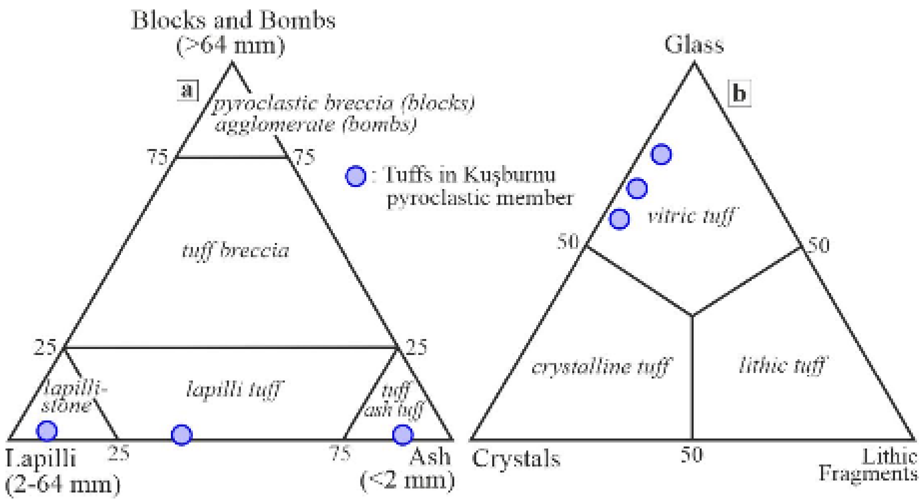

Figure 9. Classification diagrams according to percentage distribution of grains (a) and according to glass-crystals-lithic fragments composition (b) for the tuffs belonging to Kuşburnu pyroclastic member. Diagram a was gotten from Le Maitre (2005), and Diagram b was gotten from Pettijohn et al. (1987)

Plagioclases observed in tuffs are generally long prismatic and sub-idiomorphic. Plagioclases show polysynthetic and albite-karlsbad twins. Sanidins typically have karlsbad twins and low angle oblique extinction. Sericitization is observed in places in these feldspar. Biotites which are mafic mineral observed in tuffs are brown colored and platy-shaped (Figures 10-a and b). Clinopyroxenes are very pale green colored and prismatic shaped and show oblique extinction at 45^{o}-48^{o} angle. With these properties, it is thought to have diopside / augite composition of these clinopyroxenes. Amphiboles, which are another mafic mineral in tuffs, are brown colored and show oblique extinction 24^{o}-27^{o} angle and generally long prismatic shape. Amphiboles are probably in hornblende composition. Oxidation in biotites and hornblendes and opacitization in clinopyroxenes and hornblendes are observed. Volcanic rock fragments form to rock fragments in the tuffs (Figures 10-c and d). Tuffs consisting of phenocrystals, volcanic glass and rock fragments show porphyritic texture (Figure 10). Since the matrix in the tuffs consists entirely of volcanic glass, the tuffs have also of vitrophyric porphyritic texture.

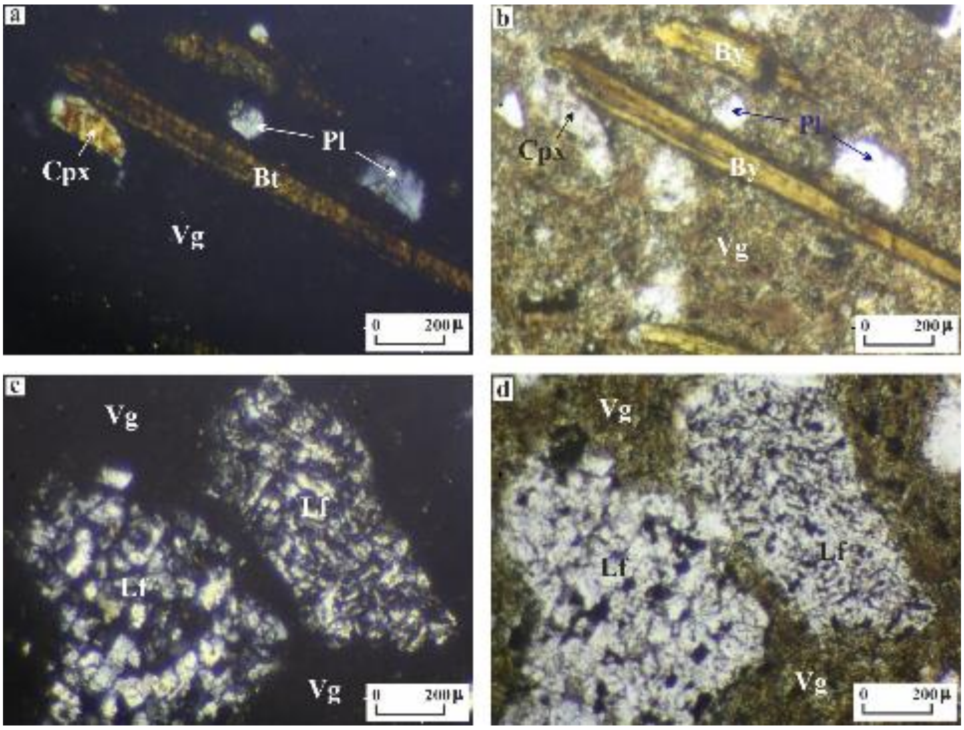

Figure 10. Lapilli tuffs belonging to Kuşburnu pyroclastic member. By: Biotite, Pl: Plagioclase, Cpx: Clinopyroxen, Vg: Volcanic glass, Lf: Litic fragment. a and c: // Nicol, b and d: / Nicol

Kuşburnu pyroclastic member shows an apparent thickness of 200-250 m in the study area. The member shows lateral-vertical transition with Boyalan conglomerate member belonging to Alibonca formation from below. It is overlain stratigraphically with a lateral-vertical transition by Taşbasamak limestone member belonging to Alibonca formation (Figure 3). The unit is cut by alkali basalts belonging to Tutak volcanites in Harabe Ridge vicinity in the northeast of the study area. The unit is unconformably covered by Kale pyroclastics in Kale Hill vicinity in the east of the study area (Figure 2).

Since the trachyandesitic tuffs and agglomerates show lateral-vertical transition with Upper Miocene Boyalan conglomerate member, the age of Kuşburnu pyroclastic member is Upper Miocene. Kuşburnu pyroclastic member offers comparable features with Upper Miocene aged pyroclastics (Sümengen, 2009b) in Patnos (Ağrı) and Malazgirt (Muş) vicinities.

3.1.2.3. Taşbasamak Limestone Member

The unit consists of lacustrine limestone, dolomite and dolomitic limestone. It is named as Taşbasamak limestone member within the Alibonca formation, since it is observed typically in Taşbasamak Village vicinity in north of the study area.

The unit deposited in lacustrine environment starts with sandy limestone, marl, dolomite and dolomitic limestone which contain white, gray, bluish gray chert interlevels at the lower levels. Higher up, It passes to white, light gray colored limestone and gray, yellowish gray, pinkish colored and thin-middle bedded limestone and dolomitic limestones (Figure 3). Limestones, marls and dolomitic limestones observed in the lower and middle levels of the unit show thin-medium-thick bedding. The lignite veins and conglomerate interlevels are observed in limestone containing Planorbis. These carbonate rocks show a transition to clayey limestones and marls with increasing clay content. Marns are distinguished from limestones by their easy brittleness. The weathering colors of the marls observed in light gray color are greenish gray. Marns contain plant clastics and show alternation with limestones which are sandy-clayed, with abundant micro fossils and thin bedded. The limestones and dolomites observed at the upper levels of the member are thin-medium bedded and show occasionally folded structures.

In the dolomitic limestone sample taken from the Taşbasamak limestone member; micrite (76%), sparite (10%) and fossil shells (14%) are observed (Figure 11-a). The rock was formed by attaching allokems (fragments of the fossil shells) with a micritic matrix. A small amount of sparite greater than 10 microns is also present in the rock. It was found that 65% of micrites and sparites was calcite and 35% of these was dolomite crystals. Neomorphism is observed in the rock. As a result of the neomorphism, the fossil shells were dissolved and they filled with sparite again (Figure 11-a). The grain sizes of the shell fragments in the rock vary from thin to large (Figure 11-a). Sparite crystals in the rock are anhedral and show very high birefringence. In some sparite crystals, bi-directional oblique cleavages are evident. The rock show cracked stucture. These cracks developed in several directions. The cracks were subsequently filled by the secondary sparite. This rock, which is named as “dolomitic limestone” in the macro observations, is named as “biomicrite” according to the limestone classification of Folk (1962) considering the above mentioned components in micro (thin section) observations. Since fossils more than 10% are observed in the rock, it can be named as “wackestone” according to the classification of Dunham (1962).

As a result of the thin section study made from another limestone sample taken from Taşbasamak limestone member; sparite (50%), skeletal grain (17%), micrite (25%) and pellet (8%) were observed in the rock. This rock was named as “wackstone” according to Dunham (1962), and as “pel-biosparite” according to Folk (1962) (Figure 11-b).

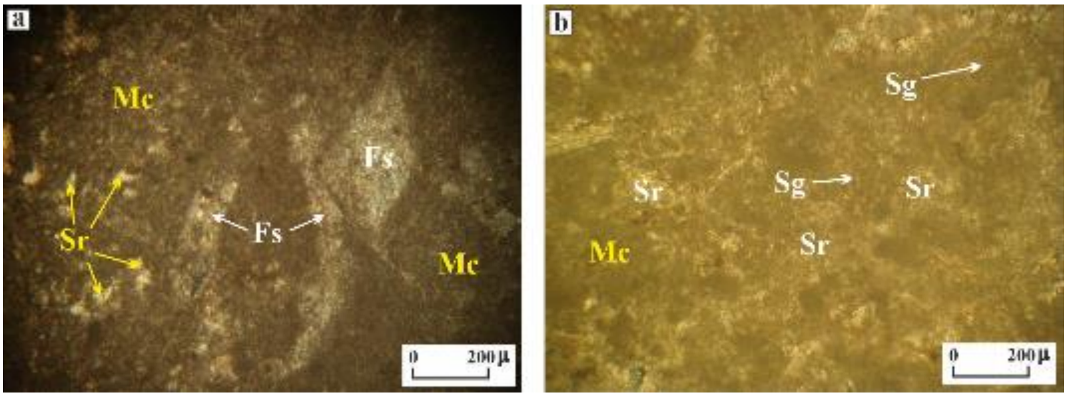

Figure 11: The views from biomicrite (a) and pel-biosparite (b) belonging to Taşbasamak limestone member. Mc: Micrite, Sr: Sparite, Fs: Fossil shell, Sg: Skeletal grain. // Nicol

Taşbasamak limestone member presents a visible thickness of 150-200 m in the study area. The unit stratigraphically shows lateral - vertical transition with tuffs and agglomerates of Kuşburnu pyroclastic member belonging to Alibonca formation from the bottom and with dacitic and rhyodacitic tuffs and agglomerates belonging to Sekirdağ volcanites from the top (Figure 3). The unit is unconformably overlain by Travertine in the western parts of Köprü Thermal Spring (Figure 3).

Taşbasamak limestone member presents comparable features to clayey limestone and marl levels of Upper Miocene aged Alibonca formation in the vicinities of Patnos (Ağrı) and Malazgirt (Muş) (Sümengen, 2009b). In the study area, Taşbasamak limestone member belonging to Alibonca formation shows lateral - vertical transition with Upper Miocene aged Kuşburnu pyroclastic member belonging to the same formation (Figure 3). Therefore, the age of Taşbasamak limestone member is Upper Miocene.

3.1.3. Sekirdağ Volcanites

The unit is composed of dacitic and rhyodacitic tuff, agromera and sometimes lava levels. The unit was first named as Sekirdağ volcanites by Türkecan et al. (1992a) according to typical outcrops in Sekirdağ vicinity observed in south of Eleşkirt (Ağrı). Sekirdağ volcanites is observed in vicinities of Günbuldu Village, Altınkilit Village, Dibekli Village, Ulukent Village, Yukarı Dalören Village, Dim Hill, Mağara Hill, Kır Hill and Hari Hill in the sudy area (Figure 2). Sekirdağ volcanites are composed of whitish light gray colored dacitic-rhyodacitic pyroclastics and dark gray-gray colored dacitic-rhyodacitic lavas (Figure 12). Lava levels are observed in the upper levels of Sekirdağ volcanites. Pyroclastic precipitated from time to time in a water-containing environment. The majority of pyroclastic are agglomerates. Tuffs were formed by fusing ash and lapilli sized grains. The rock fragments of dacites and trachyandesites are common in tuffs. Plagioclase, quartz, sanidine and biotite phenocrysts are prominent in some tuff samples. Volcanic glass forms the fine grained section of the tuffs. The agglomerates were formed by attaching with a volcanic matrix which had ash size of the dacite and trachyandesite rock fragments in the size of gravel and block. The dacitic-rhyodacitic lavas observed in the upper levels of Sekirdağ volcanites are dark gray-gray colored and the flow structures are particularly prominent in the dacitic levels. These rocks, which are characterized by porphyritic textures, are generally thin and rarely medium grained. Quartz, plagioclase, sanidine, hornblende and biotite phenocrysts can be distinguished in these rocks.

Figure 12. a) The tuffs belonging to Sekirdağ volcanites observed in the northern parts of Ulukent Village, b) The tuffs and lavas belonging to Sekirdağ volcanites observed in the northeastern part of Dim Hill

The *tuffs* belonging to Sekirdağ volcanites contain *quartz, plagioclase, sanidine, biotite, amphibole (hornblende), opaque minera*l in phenocrystal phase and *volcanic glass* in matrix phase and also *litic fragments*. The *dacitic and rhyodacitic lavas* belonging to Sekirdağ volcanites contain *quartz, plagioclase, sanidine, biotite, amphibole (hornblende), opaque mineral* in the phenocrystal phase and *plagioclase microliths* and *volcanic glass* in matrix phase. Tuffs show vitrophyric porphyritic texture, and lavas show hypocrystalline porphyritic texture. The components, grain sizes and classifications of tuffs and lavas belonging to Sekirdağ volcanites are shown in Table 2.

Table 2. The components, percent values, grain sizes and classifications of two tuffs and two lavas samples of Sekirdağ volcanites

			Sample Number			
			L19-25	**L15-21**	**L32-2**	**L41-5**
The Name of Component	**Phenocryst**	Quartz	% 6	% 5	% 8	% 10
		Plagioclase	% 11	% 13	% 26	% 14
		Sanidine	% 9	% 4	% 6	% 10
		Biotite	% 4	% 2	% 17	% 4
		Amphibole (Hornblende)	% 2	% 3	% 10	% 5
		Opaque mineral	% 1	% 1	% 1	% 1
	Matrix	Plagioclase microlites	-	-	% 1	% 2
		Volcanic glass	% 59	% 62	% 31	% 54
		Litic fragments	% 8	% 10	-	-
Grain Size (in macro sample)		Size (mm)	mostly 2-64 mm	mostly < 2 mm	thin-medium grained	thin-medium grained
Distribution of percentage of grains (in macro sample)		< 2 mm	% 17	% 88	-	-
		2 – 64 mm	% 79	% 9		
		> 64 mm	% 4	% 3		
Classification		**According to Grain Size**	*Lapillistone*	*Ash Tuff*	*Dacite*	*Rhyodacite*
		According to Composition and Grain Size	*Rhyodacitic tuff*	*Dacitic tüf*		
		According to Percentage Distribution of Grains	*Lapillistone*	*Ash tuff*		
		According to Glass-Crystals-Litic Fragments Composition	*Vitric tuff*	*Vitric tuff*		

The grain size of one tuff sample which is examined belonging to Sekirdağ volcanites is mostly between 2-64 mm and the grain size of the other tuff sample which is examined is mostly < 2 mm (Table 2). Therefore, these rocks are defined as "lapillistone" and "ash tuff" when they are classified in *the grain size classification diagram* of the pyroclasts of Schmid (1981). When the chemical analysis results (Kansun and Üçgün, 2019) and the mineralogical compositions (Table 2) in Q-A-P-F diagram (Streckeisen, 1967) of these tuffs are considered, these are "rhyodacite" and "dacite". When these tuffs are examined in the classification diagram *according to percentage distribution of grains in pyroclastic rocks* of Le Maitre (2005), they are named as "lapillistone" and "ash tuff" (Figure 13-a). Tuffs are seen as "vitric tuff" in *glass-crystals-lithic fragments diagram* (Pettijohn et al., 1987) (Figure 13-b). When the analysis results (Kansun and Üçgün, 2019) and the mineralogical compositions in Q-A-P-F diagram (Streckeisen, 1967) of the lavas are considered, these lavas are "dacite" and "rhyodacite" (Table 2).

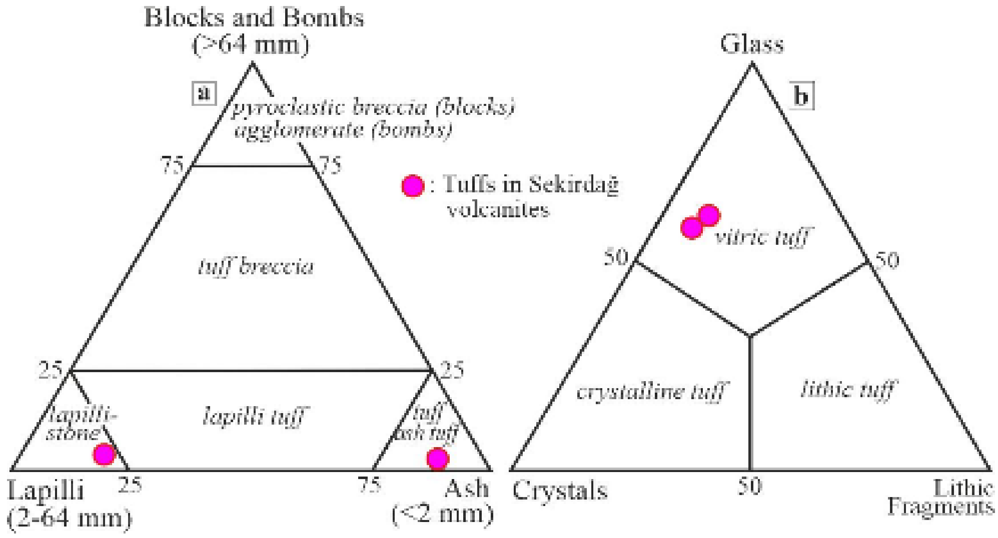

Figure 13. The classification diagrams according to percentage distribution of grains (a) and according to composition of glass-crystals-lithic fragments (b) for the tuffs belonging to Sekirdağ volcanites. Diagram a was gotten from Le Maitre (2005), and Diagram b was gotten from Pettijohn et al. (1987)

The quartzs observed in tuffs and lavas are xenomorphic (Figure 14-a). Plagioclases, which are generally sub-idiomorphic, show typically polysynthetic twins and zoned structures (Figures 14-c and d). The plagioclases in dacitic-rhyodacitic lavas are in oligoclase ($Ab_{75}An_{25}$, $Ab_{78}An_{22}$) and andesine ($Ab_{66}An_{34}$, $Ab_{52}An_{48}$) compositions. Sanidines which are other felsic mineral show typical prismatic form, karlsbad twin and low angle oblique extinction. The biotites in these rocks are brown colored and platy-shaped. The amphiboles are brown colored and show oblique extinction at low angle and prismatic shape (Figures 14-c and d). These amphiboles are in hornblende composition. Amphiboles and biotites which are observed in especially tuffs and in rarely lavas are commonly opacited and oxidized (Figure 14-b). Volcanic rock fragments rock fragments form in tuffs (Figure 14-c).

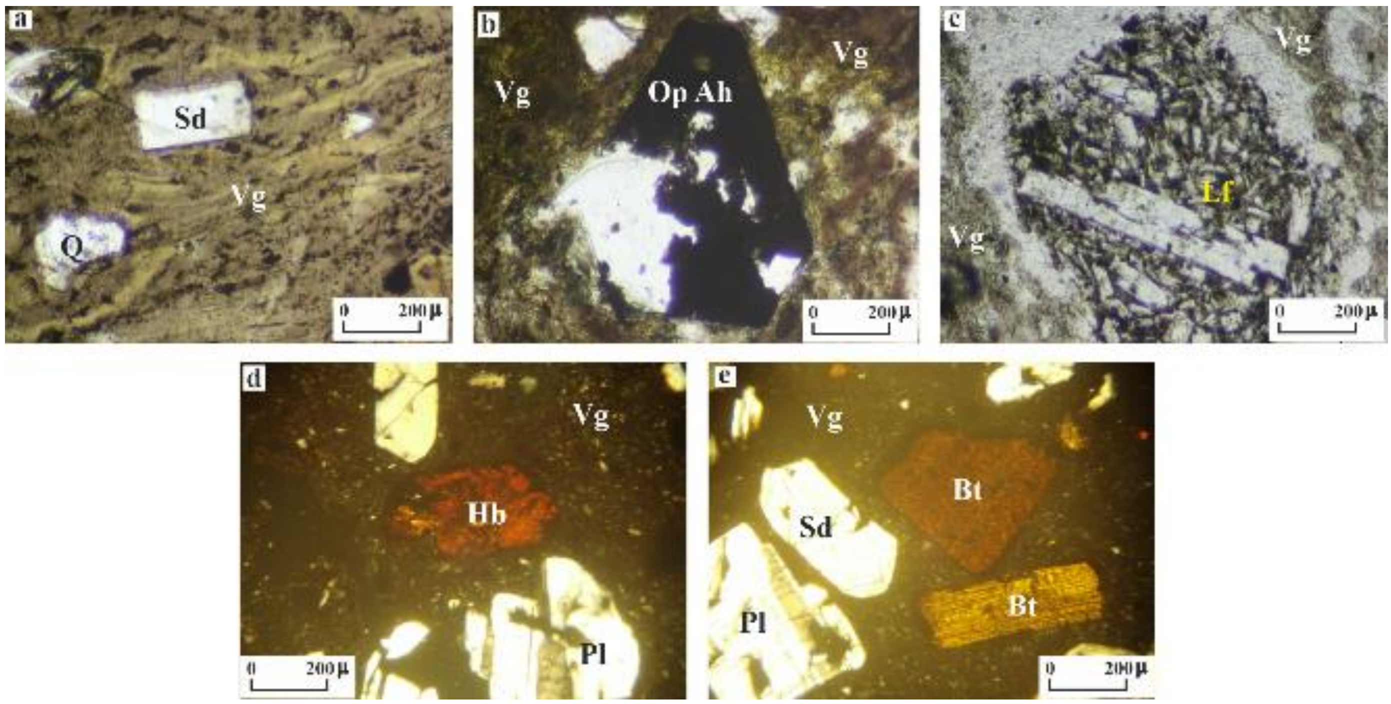

Figure 14. The tuffs (a, b and c) and dacites (d and e) belonging to Sekirdağ volcanites. Q: Quartz, Sd: Sanidine, Vg: Volcanic glass, Op Ah: Opacitated amphibole, Lf: Litic fragment, Pl: Plagioclase, Hb: Hornblende, Bt: Biotite. a, b and c: / Nicol, d and e: // Nicol

Sekirdağ volcanites show a thickness of 100-200 m in the study area. Sekirdağ volcanites stratigraphically show lateral - vertical transition with Taşbasamaklar member belonging to Alibonca formation. It is overlain by alkaline basalts belonging to Solhan volcanites (Figure 3).

The age of the unit was found as 11.2 ± 1.5 Ma according to the age determinations made from the agglomerates belonging to Sekirdağ volcanites in Eleşkirt-Horasan vicinity (Ercan et al., 1990). Therefore, the age of Sekirdağ volcanites is Upper Miocene.

3.1.4. Solhan Volcanites

The unit is mainly composed of alkali basalts. These basalts are called as Solhan volcanites by Yılmaz et al. (1987a) according to the their typical outcrops in Solhan (Bingöl) region. The unit is seen in the vicinity of Korkuluk Hill and in the northern part of the Ulukent Village in the central and southwestern parts of the study area (Figure 2).

The unit consists of alkali basalts, which are dark gray-black colored and brown alteration colored and show columnar blocks and occasional gas voids. These basaltic lavas were generally formed by cleft eruption and flowed as plateau lavas. They usually show a massive structure in macro samples. These basalts shows a porous structure at the levels where pores which are formed due to gas outlets are more. They are generally fine grained. Plagioclase phenocrysts are sometimes observed as slats in these basalts. Therefore, the basalts show aphanitic porphyritic texture. In some outcrops of alkaline basalts in the study area, columnar block structures are quite characteristic.

Alkali basalts belonging to Solhan volcanites contain *quartz, olivine, clinopyroxene (diopside/augite), apatite, opaque mineral* in phenocrystal phase and *plagioclase microliths* in matrix phase. The components, percentage values of the components and rock names of these components of the alkali basalts are shown in Table 3.

Table 3. The components, percent values and rock names of two samples taken from Solhan volcanites

			The Ratio of Component (%)	
			L14-18	**L14-19**
The Name of Component	**Phenocryst**	Plagioclase	5	3
		Olivine	7	5
		Clinopyroxene (Diopside/Augite)	4	8
		Apatite	1	-
		Opaque mineral	1	1
	Matrix	Plagioclase microlites	82	82
The Name of Rock			*Olivine basalt*	*Pyroxene basalt*

The basalts belonging to Solhan volcanites are fine grained. The matrix which is formed from plagioclase microlites is commonly observed in basalts (Figure 15). Phenocrystalline phase of these rocks is less than 20%. Plagioclase, olivine and clinoproxen form phenocrystal phase. Plagioclases show generally long prismatic shape, polysynthetic - karlsbad twin and distinct zoned structure. These plagioclases are in andesine ($Ab_{55}An_{45}$, $Ab_{52}An_{48}$) and labrador ($Ab_{37}An_{63}$, $Ab_{40}An_{60}$) compositions. Olivines show characteristically prismatic – sub-idiomorpic shapes, colorless-very pale green colors, cracked structures and flat extinctions (Figure 15-a). Clinopyroxenes generally have long-short prismatic shape and oblique extinction at 42° - 44° angle. It are thought that these pyroxenes, which are very pale green colored, are in diopside/augite composition. The olivines and pyroxenes are observed both in phenocrystalline phase and in matrix phase in basalts (Figure 15-b). These basalts whose matrix are composed of only microliths show holocrystalline porphyritic texture. In some basalts, the microlites extend in one direction and give these rocks a trachytic texture. The porous structure was also found in basalts. Some pores are filled with secondary carbonate minerals. In the study area, the rocks belonging to Solhan volcanites were named as olivine basalt "and pyroxene basalt" according to their mineralogical composition (Table 3). According to chemical analysis values (Kansun and Üçgün, 2019), these rocks are in "alkaline basalt" composition.

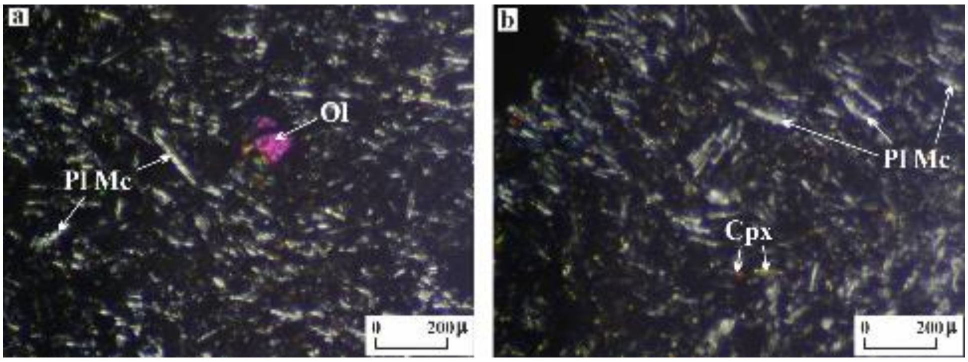

Figure 15. The views of alkali basalts belonging to Solhan volcanites. Pl Mc: Plagioclase microlites, Ol: Olivine, Cpx: Clinopyroxen, // Nicol

Solhan volcanites show a visible thickness of 40 m in the study area. Solhan volcanites stratigraphically overlie Alibonca formation and Sekirdağ volcanites from the bottom. They are covered by Tazekent trachyandesite member belonging to Hamur volcanites (Figure 3). Solhan volcanites cover Sekirdağ volcanites in vicinities of Korkuluk Hill and northwest of Ulukent Village in the study area. They is covered by Dalören ignimbrite member belonging to Hamur volcanites in northwest of Ulukent Village (Figure

2). In the study area, Solhan volcanites cover Upper Miocene clastic, carbonated and pyrolastic-volcanic rocks. Akay and Türkecan (1990) and Türkecan et al. (1992b) sayed that the age of the unit was 4.3 ± 0.8 Ma, 4.4 ± 1.3 Ma and 6.0 ± 0.6 Ma according to the radiometric age analysis which are made from Solhan volcanites in Solhan (Muş) vicinity. Therefore, the age of Solhan volcanites is Lower Pliocene.

3.1.5. Hamur Volcanites

Hamur volcanites were named by Türkecan et al. (1992a) and Türkecan et al. (1992b). Hamur volcanites were investigated by dividing into two members as Tazekent trachyandesite member and Dalören ignimbirite member from bottom to top in the study area (Figure 3).

3.1.5.1. Tazekent Trachyandesite Member

The unit is composed of trachyandesites. These trachyandesites are named as Tazekent trachyandesite members due to their outcrops in south of Tazekent Village where they are typically observed. The unit is observed in Keçikıran Hill vicinity in south of Tazekent Village (Figure 2).

Trachyandesites are gray-dark gray-brownish colored (Figure 16). They are observed as lava flows and domes in the study area. The sizes sanidine and plagioclase phenocrysts in the rocks reach up to 1 cm. These rocks are characterized by their hard structures, fine grains and massive appearances. The gas gaps are rarely seen in trachyandesites observed at the upper levels of the member.

Figure 16. The trachyandesites belonging to Tazekent trachyandesite member observed in the vicinity of Tazekent Village

The trachyandesites include *plagioclase, sanidine, amphibole (hornblende), clinopyroxene (diopside/augite), apatite, opaque mineral* in phenocrystalline phase and *plagioclase and sanidine microliths* in matrix phase. The components, percentage values of the components and rock names of trachyandesites are shown in Table 4.

Table 4. The components, percent values and rock names of three samples taken from the tazekent trachyandesite member

			The Ratio of Component (%)		
			L17-22	**L17-23**	**L-17-24**
The Name of Component	**Phenocryst**	Plagioclase	6	7	6
		Sanidine	5	4	5
		Amphibole (Hornblende)	3	2	4
		Clinopyroxene (Diopside/Augite)	4	4	4
		Apatite	-	1	1
		Opaque mineral	2	1	1
	Matrix	Plagioclase and Sanidine microlites	80	81	79
The Name of Rock			Trachy-andesite	Trachy-andesite	Trachy-andesite

The trachyandesites are fine grained and contain small amounts of phenocrysts. The matrix phase in these rocks is around 80%. The matrix phase of these rocks consists of plagioclase and sanidine microliths (Figure 17). Plagioclases in phenocrystalline phase are mostly zoned, twinning and long prismatic (Figure 17-a). Plagioclases are in composition of oligoclase ($Ab_{73}An_{27}$) and andezine ($Ab_{58}An_{42}$, $Ab_{62}An_{38}$). Sanidines show a very pronounced karlsbad twin and a prismatic shape (Figure 17-b). The mafic minerals in the rocks are generally small amounts in matrix phase. Amphiboles from these mafic minerals show brown color and long prismatic shape. Amphiboles are probably in hornblende composition. Clinopyroxenes, which are colorless-very pale green colored, show prismatic shape and oblique extinction between 43º - 47º. Clinopyroxenes are probably in diopside/augite composition according to these properties. Oxidation and carbonation are observed in trachyandesites. Carbonation is observed in plagioclases and amphiboles in matrix and phenocrystalline phase. Oxidation is observed in mafic minerals. The trachyandesites show holocrystalline porphyritic texture (Figure 17). Some trachyandesite samples also show trachytic texture. The rocks belonging to tazekent trachyandesite member are in “trachyandesite” composition both according to their chemical analysis values (Kansun and Üçgün, 2019) and according to their mineralogical compositions (Table 4).

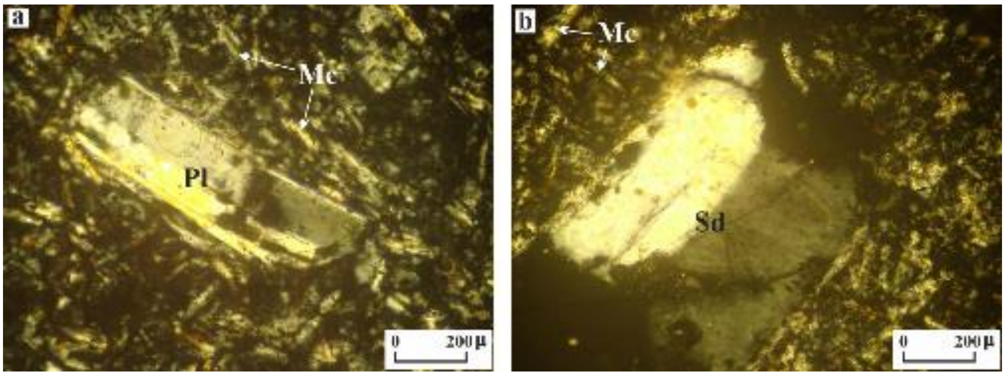

Figure 17. Trachyandesites belonging to Tazekent trachyandesite member. Pl: Plagioclase, Sd: Sanidin, Mc: Plagioclas and Sanidin microlites, // Nicol

Tazekent trachyandesite member has an apparent thickness of approximately 30 m in the study area. This unit, which is observed stratigraphically on Sekirdağ volcanites (Figure 3), cuts out Sekirdağ volcanites in the study area (Figure 2). The unit is covered by Dalören ignimbrite member belonging to Hamur volcanites. Innocenti et al. (1980) sayed that the age of lavas belonging to Hamur volcanites was 5.6 ± 0.3 Ma and 5.1 ± 0.2 Ma. Therefore, the age of Tazekent trachyandesite member is Lower Pliocene.

3.1.5.2. Dalören Ignimbrite Member

The unit contains ignimbrites. These ignimbrites are observed in Yukarı Dalören Village and Mağara Hill vicinities, north of Günbuldu Village, west of Dibekli Village and northwest of Taşbasamak Village in the sudy area (Figures 2 and 18).

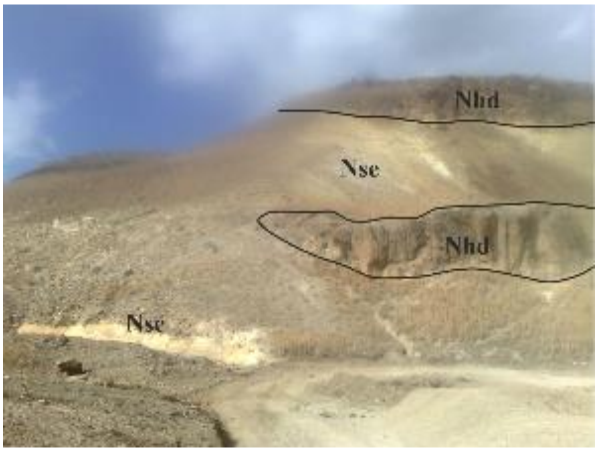

Figure 18. The view from the ignimbrites belonging to Dalören ignimbirite member (Nhd) and the tuffs belonging to Sekirdağ volcanites (Nse) observed southwest of Dibekli Village

The ignimbrites are brown-black colored, and show fiamme structure. These ignimbrites show lateral-vertical transition with trachyandesitic lavas which are gray-brown colored and contain rarely gas gaps. The ignimbrites consist of grains of ash and lapilli size. Fiamme structures in the ignimbrites are dark brown-black colored and lenticular. Pumice fragments form fiamme structures. In the study area, ignimbrites flowed over a large area. The upper surfaces of the ignimbrites are plateau-shaped and the lower surfaces of these conform to the morphology. Plagioclase, sanidine, hornblende and proxene phenocrysts are observed in some ignimbrite samples. They have porphyritic texture.

When we look at the thin section samples of ignimbirites, plagioclase (5%), hornblende (4%), clinopyroxen (4%), sanidine (2%), pumice fragments (8%), litic fragments (7%) and matrix which contain volcanic glass (70%) are observed (Figure 19). The rock fragments are composed of volcanic, pyroclastic and metamorphic rock fragments. Very prominent flowing texture is observed in these rocks. The ignimbrites have vitrophyric porphyritic texture. Plagioclases in the ignimbrites show zoned structure, albite twinning and long prismatic shape. Sanidines are characterized by karlsbad twin and oblique extinction at low angle. The hornblendes show prismatic shape and brown color. Clinopyroxenes show prismatic shape and colorless-very pale green color. Pumice parts are observed as generally ellipsoidal grains extending in one direction (Figure 19). The ignimbrites have the andesite/trachyandesite composition according to their mineralogical compositions.

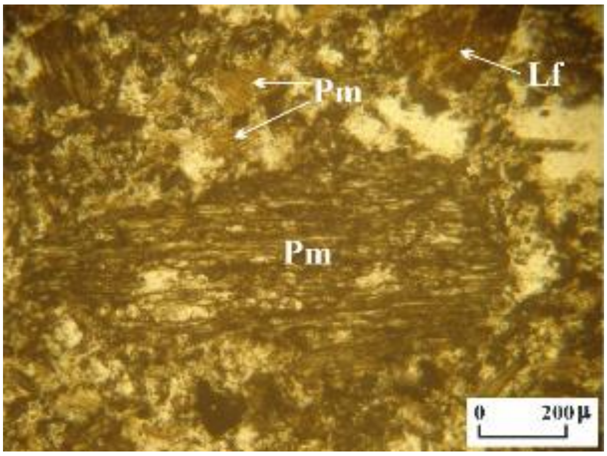

Figure 19. Pumice parts (Pm) and litic fragment (Lf) observed in ignimbirite belonging to Dalören ignimbirite member, / Nicol

Dalören ignimbirit member shows the visible thickness of approximately 20 m in the study area. Dalören ignimbirit member stratigraphically covers Tazekent trachyandesite member belonging to Hamur volcanites from the bottom and is overlain unconformably by Kale pyroclastics at the top (Figure 3). Dalören ignimbirite member is observed on Boyalan conglomerate member belonging to Alibonca formation, Sekirdağ volcanites and Solhan volcanites in the study area (Figures 2 and 18). Innocenti et al. (1980) determined that the age of ignimbrites belonging to Hamur volcanites was 5.2±0.2 Ma. Accordingly, the age of Dalören ignimbirit member is Lower Pliocene.

3.1.6. Kale Pyroclastics

The pyroclatics consist of lapilli tuff, ash, volcanic bomb, basaltic slag and agglomerate in alkaline basalt composition. These lithologies were named as Kale pyroclastics, referring to Kale Hill where typically was observed in the east of the study area. This unit was named as "pyroclastics" by Aydoğan (2000) which studied in the investigation area and as "Tutak volcanites" by Sümengen (2009b) which studied in Patnos (Ağrı) - Malazgirt (Muş) and Bulanık (Muş) vicinities. Sümengen (2009b) specified that Upper Pliocene – Pleistocene aged Tutak volcanites are composed of basalt, hawaiite and benmorite lavas which contained sometimes slag. In this study, seperation of the pyroklastics and basalts, which were lithologies which Sümengen (2009a) was named as "Tutak volcanites" was done. The pyroklastics were named as "Kale pyroclastics", and basaltic lavas were named as "Tutak volcanites". Kale pyroclastics are observed in Kale Hill and its vicinity in the east of the study area (Figure 2).

The unit is composed of dark gray - brownish colored lapilli tuff, ash, volcanic bomb, slag and agglomerate in alkaline basalt composition (Figure 20). Lapilli tuffs are easily dispersed and have porphyritic texture. Plagioclase and pyroxene phenocrysts in the these tuffs are sometimes prominent. The fine grained section of lapilli tuffs forms from the matrix. Volcanic bombs are in basaltic composition. They are very hard structured and have a diameter of up to 20 cm. The slags are black colored and very light and have plenty pore and a irregular surface. The slags are composed of pyrolastic grains at lapilli and block sizes.

Figure 20. Kale pyroclastic observed in Kale Hill vicinity

The tuffs belonging to Kale pyroclastics include *plagioclase, clinopyroxene (diopside/augite), olivine, opaque mineral* in phenocrystalline phase, *volcanic glass* in matrix phase and also *litic fragments*. *The agglomerates* belonging to Kale pyroclastics include *plagioclase*, *olivine, clinopyroxene (diopside/augite), orthopyroxene (enstatite), apatite, opaque mineral* in phenocrystalline phase, *volcanic glass* in matrix phase and also *litic fragments*. Tuffs and agglomerates show vitrophyric porphyritic texture. The components, grain sizes and classifications of tuffs and agglomerates belonging to Kale pyroclastics are shown in Table 5.

Table 5. The components, percent values, grain sizes and classifications of two tuffs and one agglomerate samples belonging to Kale pyroclastics

<table>
<tr><th colspan="3"></th><th colspan="3">Sample Number</th></tr>
<tr><th colspan="3"></th><th>L24-31</th><th>L24-32</th><th>L25-34</th></tr>
<tr><td rowspan="8">The Name of Component</td><td rowspan="6">Phenocryst</td><td>Plagioclase</td><td>% 8</td><td>% 7</td><td>% 7</td></tr>
<tr><td>Olivine</td><td>% 3</td><td>% 5</td><td>% 4</td></tr>
<tr><td>Clinopyroxene (Diopside/Augite)</td><td>% 4</td><td>% 3</td><td>% 5</td></tr>
<tr><td>Orthopyroxene (Enstatite)</td><td>-</td><td>-</td><td>%3</td></tr>
<tr><td>Apatit</td><td>-</td><td>-</td><td>% 1</td></tr>
<tr><td>Opaque mineral</td><td>% 1</td><td>% 1</td><td>% 1</td></tr>
<tr><td>Matrix</td><td>Volcanic glass</td><td>% 74</td><td>% 76</td><td>% 17</td></tr>
<tr><td></td><td>Litic fragments</td><td>% 10</td><td>% 8</td><td>% 62</td></tr>
<tr><td colspan="2">Grain Size (in macro sample)</td><td>Size (mm)</td><td>mostly 2-64 mm</td><td>mostly 2-64 mm</td><td>mostly > 64 mm</td></tr>
<tr><td colspan="2" rowspan="3">Distribution of percentage of grains (in macro sample)</td><td>< 2 mm</td><td>% 32</td><td>% 28</td><td>% 3</td></tr>
<tr><td>2 – 64 mm</td><td>% 65</td><td>% 70</td><td>% 20</td></tr>
<tr><td>> 64 mm</td><td>% 3</td><td>% 2</td><td>% 77</td></tr>
<tr><td colspan="2" rowspan="4">Classification</td><td>According to Grain Size</td><td>Lapillistone</td><td>Lapillistone</td><td>Agglomerate</td></tr>
<tr><td>According to Composition and Grain Size</td><td>Basaltic tuff</td><td>Basaltic tuff</td><td>Basaltic agglomerate</td></tr>
<tr><td>According to Percentage Distribution of Grains</td><td>Lapilli tuff</td><td>Lapilli tuff</td><td>Agglomerate</td></tr>
<tr><td>According to Glass-Crystals-Litic Fragments Composition</td><td>Vitric tuff</td><td>Vitric tuff</td><td>-</td></tr>
</table>

The grain sizes of the tuff samples belonging to Kale pyroclastics are mostly between 2-64 mm (Table 5). Thus, tuffs are defined as “lapillistone” when they are evaluated in *grain size classification diagram of pyroclasts* of Schmid (1981). The grain size of agglomerate which has been examined is mostly > 64 mm. Furthermore, the litic fragments in this agglomerate have rounded shapes. Therefore, the rock was named as “agglomerate” when it is evaluated in *grain size classification diagram of pyroclasts* of Schmid (1981). When the mineralogical compositions of these tuffs and this agglomerate (Table 2) are evaluated in Q-A-P-F diagram (Streckeisen, 1967), it is seen that these are in “basalt” composition. When these tuffs are evaluated in the classification diagram according to *percentage distribution of grains in pyroclastic rocks* of Le Maitre (2005), they are named as “lapilli tuff”. When the agglomerate is evaluated in the classification diagram according to *percentage distribution of grains in pyroclastic rocks* of Le Maitre (2005), it is defined as “aglomerate” (Figure 21-a). The tuffs are seen in “vitric tuff” area in *glass-crystals-lithic fragments diagram* of Pettijohn et al. (1987) (Figure 21-b).

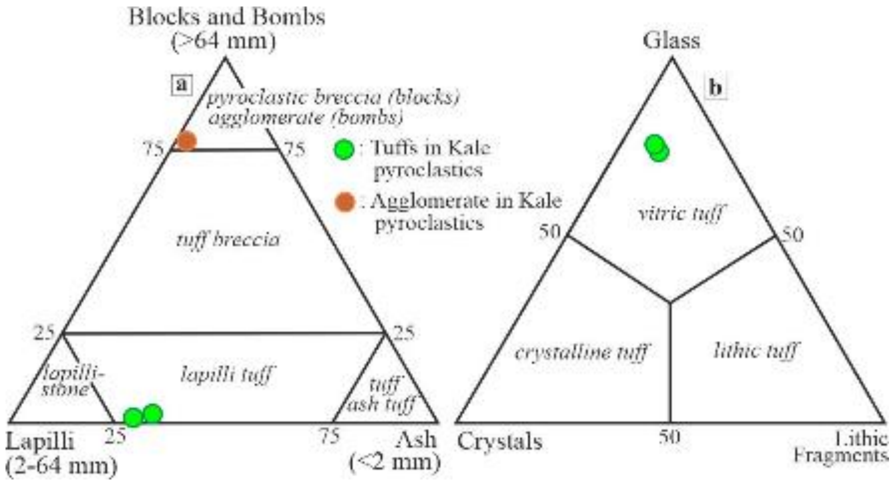

Figure 21. The classification diagrams according to percentage distribution of grains for tuffs and agglomerate belonging to Kale pyroclastics (a) and according to glass-crystals-lithic fragments compositions for tuffs belonging to Kale pyroclastics (b). Diagram a was gotten from Le Maitre (2005), and Diagram b was gotten from Pettijohn et al. (1987)

Kale pyroclastics show a visible thickness of approximately 30-100 m in the study area. The pyroclastics stratigraphically are unconformably located on Dalören ignimbirite member belonging to Hamur volcanites. They are covered by Tutak volcanites from the top (Figure 3). Kale pyroclastics are unconformably observed on Boyalan and Kuşburnu pyroclastic members belonging to Alibonca formation in the study area (Figure 2).

Türkecan et al. (1992a) determined that the age of the Tutak volcanites, which consisted of pyroclastic and lavas and which were observed in Tutak (Van) vicinity, was Upper Pliocene - Pleistocene. In addition, Sanver (1968), which studied Hamur (Ağrı) vicinity, and Innocenti et al. (1980), which studied Patnos (Ağrı), specified that the age of the basaltic lavas observed together with these pyroclastics was Upper Pliocene – Pleistocene according to the radiometric age determinations. Therefore, the age of the Kale pyroclastics is Upper Pliocene - Pleistocene.

3.1.7. Tutak Volcanites

They consist of alkaline basalts which show columnar structure and flow structure. Türkecan et al. (1992a), which studied in Tutak (Van) vicinity, were named as “Tutak volcanites” to the lithologies which consisted of basalt, hawaiite and mugearite. Later, Sümengen (2009a and 2009b) , which studied in Patnos (Ağrı) - Malazgirt (Muş) and Bulanık (Muş) vicinities, were defined as “Tutak volcanites” to the rocks which consisted of basalt, hawaiite and benmorite lavas which contained slag. The seperation of pyroclastics and basalts, which were named as “Tutak volcanites” by Sümengen (2009a ve 2009b), was done in this study. In the study, the pyroclastics were named as “Kale pyroclastics”, and the basaltic lavas were named as “Tutak volcanites” adhering to the first nomenclature of Türkecan et al. (1992a). Tutak volcanites are located in the vicinities of Değirmen Ridge and Harabe Ridge in the northeast of the study area (Figure 2).

Tutak volcanites are composed of gray-black-reddish colored alkaline basalts, and these basalts show column structure (Figure 22). Also, they is observed as lava flows in the study area. The basalts is generally fine grained and porous. Plagioclase, olivine and pyroxene phenocrysts rarely distinguish in macro samples. The fine grained sections of these rocks are formed from matrix. The basalts show aphanitic porphyritic texture.

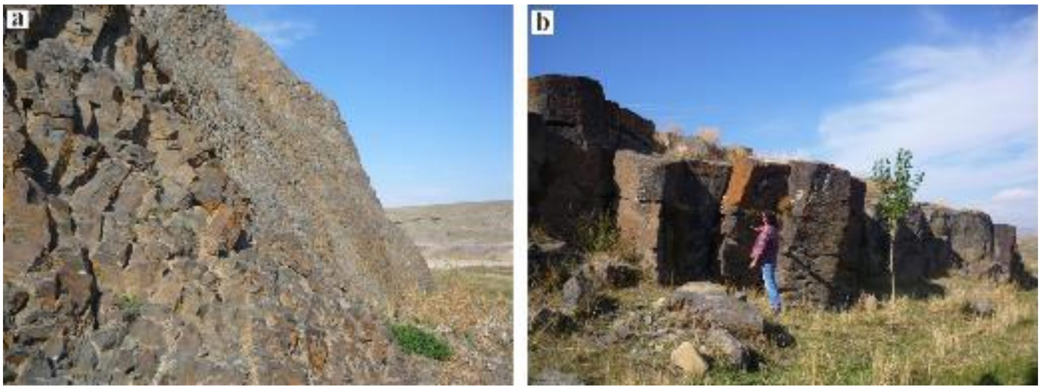

Figure 22. Alkaline basalts belonging to Tutak volcanites (a) and column structure in these basalts (b) observed in Kezo Dere vicinity in east of Değirmen Ridge

Alkaline basalts include *plagioclase, olivine, clinoproxene (diopside/augite), orthoproxene (enstatite), apatite, opaque mineral* in phenocrystal phase and *plagioclase microliths* in matrix. The components of alkaline basalts, percentage values of the components and rock names are shown in Table 6.

Table 6. The components, percent values and rock names of four samples taken from Tutak volcanites

			The Ratio of Component (%)			
			L2-1	**L8-12**	**L9-13**	**L22-29**
The Name of Component	**Phenocryst**	Plagioclase	4	6	6	7
		Olivine	14	13	10	11
		Clinopyroxene (Diopside/Augite)	8	5	6	10
		Orthopyroxene (Enstatite)	-	2	3	4
		Apatite	1	1	-	-
		Opaque mineral	2	1	1	2
	Matrix	Plagioclase microlites	71	72	74	66
The Name of Rock			Olivine basalt	Olivine basalt	Olivine basalt	Olivine basalt

Basalts are fine grained and phenocrystals in these are small amount. The matrix formed by plagioclase microlites is commonly observed in the basalts (Figure 23). The phenocrystals rarely observed in basalts are plagioclase, olivine and proxen. Plagioclases, characterized by their prismatic form, show polysynthetic - karlsbad twins and mostly zoned structure. Plagioclases are in andesine ($Ab_{59}An_{41}$, $Ab_{62}An_{38}$) and labrador ($Ab_{48}An_{52}$, $Ab_{43}An_{57}$) compositions according to the extinction angle determination of these. Olivines observed in the basalts are mostly observed as small size crystals (Figure 23-a). Olivines are prismatic shaped, sometimes cracked and colorless-very pale green colored. Clinopyroxenes are observed as prismatic and sub-idiomorphic crystals. They show angled extinction between 45º - 47º. It is thought that the colorless - very pale green colored clinopyroxenes are in “diopside/augite” composition. Orthopyroxenes are typical with flat extinction, whitish pale green colors and prismatic shapes (Figure 23-b). Orthopyroxenes are probably in “enstatite” composition according to these properties. The pyroxenes observed in the basalts are mostly observed as small size crystals (Figure 23-d). The basalts have holocrystalline porphyritic and trachytic textures.

The rocks belonging to Tutak volcanites according to chemical analysis values (Kansun and Üçgün, 2019) are in “alkaline basalt” composition. In the Q-A-P-F diagram (Streckeisen, 1967), these rocks were named as “olivine basalt” according to their mineralogical compositions (Table 6).

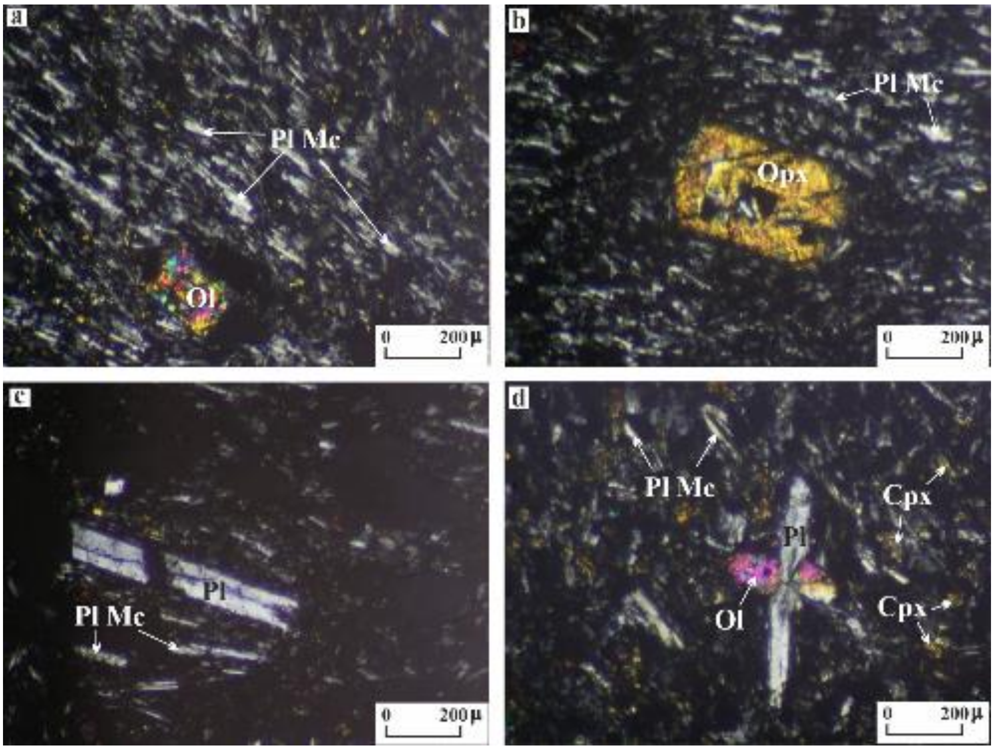

Figure 23. Olivine basalts belonging to Tutak volcanites. Pl: Plagioclase, Ol: Olivine, Cpx: Clinopyroxene, Opx: Orthopyroxene, Pl Mc: Plagioclase microlites, // Nicol

Tutak volcanites show a visible thickness of approximately 40 m in the study area. They cover stratigraphically Kale pyroclastics from the bottom, and are unconformably overlain by Travertine and Alluvium from the top (Figure 3). Tutak volcanites are unconformably observed on Boyalan and Kuşburnu pyroclastic members belonging to Alibonca formation to northeast of the study area (Figure 2).

Sanver (1968) determined that the age of basaltic lavas, which were located in Hamur (Ağrı) vicinity, were 1.07 ± 0.12 Ma. Innocenti et al. (1980) sayed that the age of basaltic lavas belonging to Tutak volcanites, which are observed in northeast of Karabulak Village (Patnos-Ağrı), was 2.0 ± 0.1 Ma and that the age of basaltic lavas belonging to Tutak volcanites, which are observed in Gülkoru (Malazgirt-Muş) vicinity, was 3.9 ± 0.4 Ma. Therefore, the age of Tutak volcanites is Upper Pliocene - Pleistocene.

3.1.8. Travertine

Travertines is carbonated rocks, which are deposited by carbonated spring waters and show sometimes bedding. Travertines are observed the vicinities of Köprü Thermal Spring, Yılanlı Thermal Spring, Davut Thermal Spring, Tazekent Thermal Spring, Hocayurdu Hill, Ali Hill and Ulukent Village in the study area (Figures 2 and 24). They have a visible thickness of about 30 m. The age of the travertines is Holocene (Quaternary).

Figure 24. Travertines observed in Köprü Thermal Spring vicinity

3.2. Discussion

The aim of this study is to determine the stratigraphic and petrographic properties of the units which are commonly made of volcanic - pyroclastic rocks and outcrops in the region including Diyadin geothermal field. Keskin (1998) and Pasvanoğlu (2013) stated that the Upper Miocene aged lithologies consisted of pyroclastics, lavas, ignimbrites and lacustrine sediments in the region. On the other hand, carbonated-clastic rocks and trachyandesitic tuffs-agglomerates (Alibonca formation) and dacitic-rhyodacitic tuffs-agglomerates-lavas (Sekirdağ volcanites) are Upper Miocene aged in the study area. The ignimbrites belonging to Hamur volcanites are Lower Pliocene aged and cover unconformably to Upper Miocene lithologies.

Pasvanoğlu (2013) stated that glassy textured basalts and andesitic-dacitic tuffs were deposited on Upper Miocene aged lacustrine limestones. In this study, it was found that dacitic-rhyodacitic tuffs and agglomerates were deposited by lateral-vertical transitions on the lacustrine limestones forming the Taşbasamak limestone member and that these units were cut by the Lower Pliocene aged alkaline basaltic lavas (Solhan volcanites). Pasvanoğlu (2013) stated that the lavas, which are stratigraphically related to pper Miocene aged ignimbrites, are in andesite composition. This researcher also sayed that the basalts overlying these are covered by pyroclastics which consisted of volcanic bombs, lapilli and volcanic ash. In contrast, these lavas that Pasvanoğlu (2013) specified are in trachyandesite composition and are Lower Pliocene aged. The Pyroclastics (Kale proklastics), which are composed of, lapilli tuff, ash, volcanic bomb, slag and agglomerate in alkaline basalt composition, are covered by alkaline basaltic lavas (Tutak volcanites) in the region.

4. Conclusions

Paleozoic and Cenozoic aged lithologies take part in the study area. Paleozoic aged Batıbeyli metamorphites are observed at the base of the study area. Batıbeyli metamorphites are composed of crystallized limestones containing calcschist interlevels. The Upper Miocene aged Alibonca formation is unconformably observed on these metamorphites. Alibonca formation consists of conglomerates (Boyalan conglomerate member) at the base, on these, of tuffs and agglomerates in trachyandesitic composition (Kuşburnu pyroclastic member). The sandy limestone-marl-dolomite-dolomitic limestone-lacustrine limestone-limestone which contain chert interlevels are observed at upper levels of Alibonca formation. Upper Miocene aged Sekirdağ volcanites are observed with lateral-vertical transition on Alibonca formation. These volcanites consist of dacitic - rhyodacitic tuffs, agglomerates and lavas. Towards up, Lower Pliocene aged Solhan volcanites, which are composed of alkaline basaltic lavas, are observed. Solhan volcanites are covered by Upper Pliocene aged Hamur volcanites. Hamur volcanites are composed of trachyandesites (Tazekent trachyandesite member) at the base and ignimbrites (Dalören ignimbrite member) covering these trachyandesites. Towards up, Upper Pliocene-Pleistocene aged Kale pyroclastics consisting of lapilli tuff, ash, volcanic bomb, slag and agglomerate and being in alkaline basalt composition are observed. Kale pyroclastics are covered by Upper Pliocene-Pleistocene aged Tutak volcanites, which show columnar block structure and flow structure and are in alkaline basalt composition. At the top, travertine and alluvium are found.

Calcite + dolomite ± quartz ± muscovite mineral paragenesis is observed in metacarbonates belonging to Batıbeyli metamorphites. The calcschists, which are seen as interlevels among these metacarbonates, contain *calcite + chlorite (ripidolite-picnochlorite) + muscovite ± quartz ± opaque mineral*. The tuffs belonging to Kuşburnu pyroclastic member include *quartz, plagioclase, sanidine, clinopyroxene (diopside/augite), biotite, amphibole (hornblende), sphene, opaque mineral* in phenocrystalline phase, *volcanic glass* in matrix phase and also *lithic fragments*. These tuffs have been named as *lapillistone and ash tuf* "according to grain size", as *trachyandesitic tuff* "according to composition and grain size", as *lapillistone, ash tuff and lapilli tuff* "according to percentage distribution of grains" and as *vitric tuff* "according to glass-crystals-lithic fragments compositions".

The *tuffs* belonging to Sekirdağ volcanites contain *quartz, plagioclase, sanidine, biotite, amphibole (hornblende), opaque mineral* in phenocrystalline phase, *volcanic glass* in matrix phase and also *litic fragments*. The *dacitic and rhyodacitic lavas* belonging to these volcanites contain *quartz, plagioclase, sanidine, biotite, amphibole (hornblende), opaque mineral* in phenocrystalline phase and *plagioclase microliths* and *volcanic glass* in matrix phase. The tuffs of Sekirdağ volcanites have been named as *lapillistone* and *ash* *tuf* "according to grain size", as *rhyodacitic tuff* and *dacitic tuff* "according to composition and grain size", as *lapillistone* and *ash tuff* "according to percentage distribution of grains" and as *vitric tuff* "according to glass-crystals-lithic fragments components".

Alkaline basalts belonging to Solhan volcanites contain *quartz, olivine, clinoproxene (diopside/augite), apatite, opaque mineral* in phenocrystalline phase and *plagioclase microliths* in matrix phase. The *trachyandesites* belonging to tazekent trachyandesite member (Hamur volcanites) contain *plagioclase, sanidine, amphibole (hornblende), clinopyroxene (diopside/augite), apatite, opaque mineral* in phenocrystalline phase and *plagioclase and sanidine microlithes* in matrix phase. *Plagioclase, hornblende, clinopyroxene, sanidine, pumice fragments, litic fragments and volcanic glass* are observed in the *ignimbrites* belonging to Dalören ignimbrite member (Hamur volcanites).

The *tuffs* belonging to Kale pyroclastics contain *plagioclase, clinopyroxene (diopside/augite), olivine, opaque mineral* in phenocrystalline phase*, volcanic glass* in matrix phase and also *litic fragments*. The *agglomerates* belonging to Kale pyroclastics include *plagioclase, olivine, clinopyroxene (diopside/augite), orthopyroxene (enstatite), apatite, opaque mineral* in phenocrystalline phase, *volcanic glass* in matrix phase and also *lithic fragments*. These tuffs have been named as *lapillistone* "according to grain size", as *basaltic tuff* "according to composition and grain size", as *lapilli tuff* "according to percentage distribution of grains" and as *vitric tuff* "according to glass-crystals-lithic fragments compositions". The agglomerate in *basaltic agglomerate* composition "according to composition and grain size". The *alkaline basalts* belonging to Tutak volcanites contain *plagioclase, olivine, clinopyroxene (diopside/augite), orthopyroxene (enstatite), apatite, opaque mineral* in phenocrystalline phase and *plagioclase microliths* in matrix phase.

5. Acknowledge

This study was prepared by using the project numbered 10201138 supported by Selçuk University Scientific Research Projects Coordination Unit.

References

Açlan, M., & Turgut, İ. K. (2017). Şekerbulak (Diyadin-Ağrı) dolaylarında yüzeyleyen volkanik kayaçların mineralojik-petrografik ve jeokimyasal özellikleri. *Çukurova Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi*, 32(4), pp. 163-174.

Akay, E., & Türkecan, A. (1990). *Muş Tersiyer havzasının stratigrafisi, yapısal jeolojisi, bazı jeomorfolojik özellikleri ve volkanolojisi* (Report No:8973). MTA, Ankara, Turkey.

Alpman, N. (1974). *Doğu Anadolu'da Sıcak Suların Envanteri*. MTA Enstitüsü, Ankara, Turkey.

Aydoğan, B. M. (2000). *Diyadin (Ağrı) jeotermal suların hidrojeolojik ve hidrojeokimyasal incelenmesi* [Unpublished master's thesis]. Çukurova University, Adana, Turkey, 103 p.

Bilgin, A. (1984). Serçeme (Erzurum) deresi ve dolayındaki volkanitlerin jeokimyası. *Türkiye Jeoloji Kurultayı Bült.*, 5, pp. 41-50.

Bilgin, A. (1987). Serçeme (Erzurum) volkanitlerinin mineralojisi, petrografisi. *A. Ü. Isparta Müh. Fak. Derg.*, 3, pp. 47-59.

Buket, E. (1989). Petrology and major element geochemistry of Tertiary and Quaternary volcanics from Varto region, Eastern, Turkey. *Metu Journal of Pure and Applied Sciences*, 22 (3), pp. 69-89.

Burçak, M., Yıldırım, T., & Yücel, M. (1997). *Ağrı - Diyadin Çermik Sahası Jeotermal-Jeofizik Etüt Raporu*. MTA, Ankara, Turkey, 12 p.

Çakır, Y. (1994). *Ağrı, Diyadin ve Iğdır dolayının Jeoloji Etüdü* (Report No:9988). MTA, Ankara, Turkey.

Çolakoğlu, A. R., Oruç, M., Arehart, G. B., & Poulson, S. (2011). Geology and isotope geochemistry (C−O−S) of the Diyadin gold deposit, Eastern Turkey: A newly-discovered Carlin-like deposit. *Ore Geology Reviews*, 40, pp. 27-40.

Dunham, R. J. (1962). Classification of carbonate rocks according to depositional texture. *AAPG*, 1, pp. 108-121.

Eltez, M., Doğan, M. A., Durukan, M., & Hepbaşlı, A. (2001). Diyadin integrated geothermal application. *Proceedings, Twenty-Sixth Workshop on Geothermal Reservoir Engineering Stanford University*, Stanford, California, SPG-TR-168.

Ercan, T., Fujitani, T., Matsuda, J. L., Notsu, K., Tokel, S., & Ui, T. (1990). Doğu ve Güneydoğu Anadolu Neojen-Kuvaterner volkanitlerine ilişkin yeni jeokimyasal, radyometrik ve izotopik verilerin yorumu. *MTA Derg.*, 110, pp. 143-164.

Ercan, T., & Asutay, H. I. (1993). Malatya-Elazığ-Tunceli-Bingöl-Diyarbakır dolaylarındaki Neojen-Kuvatemer yaşlı volkanitlerin petrolojisi. *AÜFF Jeoloji Böl. Suat Erk Sempozyumu Bildiriler Kitabı*, pp. 291-302.

Ercan, T., Ölmez, E., & Yıldırım, T. (1994). Tendürek (Doğu Anadolu) Jeotermal Alanı'nın (Diyadin, Zilan, Çaldıran) Volkanolojisi ve Jeotermal Enerji Olanakları. *Türkiye Jeoloji Kurultayı Bülteni*, 9, pp. 48-55.

Erişen, B., Akkuş, İ., Uygur, N., & Koçak, A. (1996). *Türkiye Jeotermal Envanteri*, MTA, Ankara, 480 p.

Eşder, T. (1997). *Diyadin (Ağrı) jeotermal alanında 23.07.1997-24.07.1997 tarihinde yapılan prospeksiyon çalışmasına ilişkin rapor*. REMAR, İzmir, 25 p.

Folk, R. L. (1962). Spectral subdivision of limestone types, in Ham W. E. (ed.), class-fication of carbonate rocks., *A.A.D.G. Memoir*, 1, pp. 62-84.

Güleç, N., Hilton, D. R., & Mutlu, H. (2002). Helium isotope variations in Turkey: relationship to tectonics, volcanism and recent seismic activities. *Chem. Geol.*, 187, pp. 129–142.

Güner, Y., & Şaroğlu, F. (1987). Doğu Anadolu'da Kuvaterner volkanizması ve jeotermal enerji açısından önemi. *Türkiye 7. Petrol Kong. Bildiriler Kitabı*, pp. 371-383.

Innocenti, F., Mazzuoli, R., Pasquare, G., Serri, G., & Villari, L. (1980). Geology of the volcanic area north of Lake Van (Turkey). *Geologische Rundschau*, 69 (1), pp. 292-323.

Innocenti, F., Manetti, P., Mazzuoli, R., Pasquare, G., & Villari, L. (1981). *Anatolia and northwestern Iran*, *Andésites: Orogenic andésites and related rocks* (R.S. Thorpe Ed.). Wiley, Newyork, N.Y., pp. 327-349.

Innocenti, F., Mazzuoli, R., Pasquare, G., Radicati, F., & Villari, L. (1982). Tertiary and Quaternary volcanism of the Erzurum-Kars area (Eastern Turkey): Geochronological Data and Geodynamic Evolution. *Jour. Volcan., Geoth. Res.*, 13, pp. 223-240.

Irrlitz, W. (1972). Lithostratigraphie und tektonische Entwicklung des Neogens in ordostanatolien. *Beih. Geol. Jb.* 120, pp. 1-111.

İlker, S. (1966). *Erzurum-Muş bölgesinde Karaköse-J48a4 ve J48d1 paftalarının 1:25000 ölçekli detay petrol etüdü hakkında rapor* (Report No:4177). MTA Enstitüsü, Ankara, Turkey.

Kansun, G. & Üçgün, F. (2019). *Davut-Tazekent köyleri (Diyadin-Ağrı) civarındaki volkanitlerin petrografi-jeokimyası ve Diyadin jeotermal sahasının özellikleri* (Number: 10201138). Selçuk University Scientific Research Projects, Konya, Turkey.

Keskin, B. (1998). *Ağrı- Diyadin jeotermal alanı jeolojik etüd raporu ve jeotermal potansiyeli*. MTA Raporu, Ankara, Turkey, 16 p.

Kıral, K., & Çağlayan, A. (1980). *Kağızman (Kars-Ağrı-Taşlıçay) dolayının jeolojisi* (Report No:6785). MTA Enstitüsü, Ankara, Turkey.

Koçyiğit, A., Yılmaz, A., Adamia, S., % Kuloshvili, S. (2001). Neotectonics of east Anatolian Plateau (Turkey) and Lesser Caucasus: implication for transition from thrusting to strike-slip faulting. *Geodynamica Acta*, 14, pp. 1-19.

Lambert, I., Holland, J. G., & Owen, P. F. (1974). Chemical petrology of a isuite calc-alkaline lavas from mount Ararat, Turkey. *Jour. Ged.*, 82, pp. 419-438.

Le Maitre, R. W. (2005). *Igneous Rocks: A Classification and Glossary of Terms: Recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks* (2nd Ed.). Cambridge University Press.

Mutlu, H., Aydın, H., & Kazancı, A. (2013). Diyadin (Ağrı) jeotermal sahasına yönelik jeokimyasal ve izotopik bulgular. *11. Ulusal Tesisat Müh. Kong.,* İzmir, pp. 47-67.

Pasvanoğlu, S., & Chandrasekharam, D. (2011). Hydrogeochemical and Isotopic study Of Thermal and Mineralized Waters from The Nevşehir (Kozakli) Area, Central Turkey. *J. Volcanol*, 202, pp. 241-250.

Pasvanoğlu, S. (2013). Hydrogeochemistry of thermal and mineralized waters in the Diyadin (Ağri) Area, Eastern Turkey. *Applied Geochemistry*, 38, pp. 70-81.

Pearce, J. A., Bender, J. F., de Long, S. E., Kidd, W. S. F., Low, F. J., Güner, Y., Şaroğlu, F., Yılmaz, Y., Moofbath, S., & Mitchell, J. G. (1990). Genesis of collision volcanism in Eastern Anatolia, Turkey. *Jour. Volcan. Geoth. Res.*, 44, pp. 189-229.

Pettijohn, F. J., Potter, P. E., & Siever, R. (1987). *Sand and Sandstone*. Springer Verlag, New York, N.Y. 553 p.

Sanver, M. (1968). A paleomagnetic study of Ouaternary volcanic rocks from Turkey. *Phys. Earth Planet Interiors*, 1, pp. 403-421.

Schmid, R. (1981). Descriptive nomenclature and classification of pyroclastic deposits and fragments: Recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks. *Geology, The Geological Society of America*, Boulder, 9, pp. 41-43.

Streckeisen, A. (1967). Classification and nomenclature of igneous rocks. *Nues Jarbuch fur Mineralogie Abhandlungen*, 107, pp. 144-240.

Sümengen, M. (2009a). *Ağrı-İ48 paftası, MTA Genel Müdürlüğü 1:100000 Ölçekli Türkiye Jeoloji Haritaları* (Report No:110). MTA, Ankara, Turkey, 19 p.

Sümengen, M. (2009b). *Ağrı-J49 paftası, MTA Genel Müdürlüğü 1:100000 Ölçekli Türkiye Jeoloji Haritaları* (Report No:112). MTA, Ankara, Turkey, 18 p.

Şaroğlu, F., Güner, Y., Kidd, W. S. F., & Şengör, C. (1980). Neotectonics of Eastern Turkey:New evidence for crustal shortening and thickening in a collisional zone. *EOS, Trans. Am. Geophys*, Union 61, 17, 360.

Şengör, C., & Kidd, W. S. F. (1979). Post-collisional tectonics of the Turkish-Iranian plateau and a comparison with Tibet. *Tectonophysics*, 55, pp. 361-376.

Şengör, C., & Yılmaz, Y. (1981). Tethyan evolution of Turkey; A plate tectonic approach. *Tectonophysics*, 75, pp. 181-241.

Şimşek, Ş. (1997). *Geochemical potential in Northwestern Turkey*. In: Schindler C, Pfister M (Eds), *Active Tectonics of Northwestern Anatolia (The Marmara Poly-Project)*, Zurich, 111–123.

Türkecan, A., Dönmez, M., Özgür, B., Mutlu, G., Sevin, D., & Bulut, V. (1992a). *Patnos-Tutak-Hamur (Ağrı) yöresinin jeolojisi ve volkanik kayaçların petrolojisi* (Report No:9434). MTA Enstitüsü, Ankara, Turkey.

Türkecan, A., Dönmez, M., Sevin, D., Özgür, B., & Mutlu, G. (1992b). Perakalen volkanizma ve Doğu Anadolu'daki örnekleri. *Türkiye Jeolojisi Kurultayı Bülteni*, pp. 108-115.

Winkler, H. G. F. (1979). *Petrogenesis of metamorphic rocks* (5th ed.). Springer-Verlag, New York-Berlin, p. 348.

Yılmaz, Y., Şaroğlu, R., & Güner, Y. (1987a). Initation of die neonıagmatism in East Anatolia. *Tectonophysics*, 134, pp. 177-199.

Yılmaz, Y., Şaroğlu, R., & Güner, Y. (1987b). Doğu Anadolu'da Solhan (Muş) volkanitlerinin petrojenetik incelenmesi. *Hacettepe Yerbilimleri*, 14, pp. 133-163.