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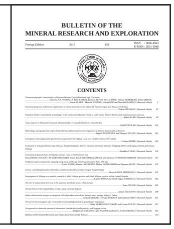
BULLETIN OF THE
MINERAL RESEARCH AND EXPLORATION
CONTENTS

Tectonostratigraphic characteristics of the area between Çayeli (Rize) and İspir (Erzurum)

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Research Article

Keywords:
Eastern pontides, Maçka tectonic slice, Taşköprü tectonic slice, tectono-stratigraphy, magmatism.

ABSTRACT

The study area is located in the Eastern Pontides between Rize, Çayeli, Arhavi, İspir and İkizdere. In this area, Maçka Tectonic Slice (MTS) and Taşköprü Tectonic Slice (TTS) are exposed. MTS is composed from old to young; Late Jurassic-Early Cretaceous limestone (Berdiga fm.); Turonian-Santonian conglomerate, sandstone, micritic limestone, siltstone, marl, basaltic, basaltic-andesitic lava, pyroclastites (Çatak fm.); Santonian rhyolitic, dacitic lava, pyroclastites, sandstone, clayey limestone (Kızılkaya fm.); late Santonian-Campanian basaltic, andesitic lava, pyroclastites, sandstone, clayey limestone (Cağlayan fm.); Campanian-Mastrihtian rhyolitic, dacitic lava, pyroclastites, sandstone, clayey limestone (Çayırbağ fm.);late Maastrichtian-Danian sandstone, claystone, tuff, marl, clayey limestone (Cankurtaran fm.). Sedimentary, volcanosedimentary units in the Late Paleocene-Quaternary range (Erenler, Kaplıca, Melyat, Pazar, Hamidiye formations, and Handüzü, Çağırankaya volcanites) unconformably overlies the MTS. In the study area, Turonian-Maastrichtian basaltic andesitic lavaş, pyroclastites and sandstone, micritic limestone, claystone units (Yağmurdere fm.) belonging to TTS are observed, and Early-Middle Eocene sedimentary and volcanosedimentary units (Yedigöze, Çoruh formations) unconformably overlies the TTS. According to Ar/Ar dating, Çayırbağ formation was determined as 83.2 ± 1.0 Ma, Melyat formation as 47.8 ± 1.6 Ma, and Handüzü volcanics as 4.25 ± 0.55 Ma for andesite level and as 3.93 ± 0.46 Ma for dacite level. The MTS was intruded by Cretaceous-Paleocene Kaçkar granitoid I, Eocene Kaçkar granitoid II, Late Eocene Ardeşen gabbro, while the TTS was intruded by Cretaceous-Paleocene Kaçkar granitoid-I, Late Eocene Güllübağ monzonite.

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1. Introduction

The study area is located in the Eastern Pontides and covers an area of approximately 4200 km^2 between the east and south of Rize, Çayeli, Arhavi, İspir and İkizdere (Figure 1). Geologically, the Black Sea mountain range were first described by the Hamilton (1842) as Pontides. The Eastern Pontides were divided by different researchers as; north zone, middle zone and south zone (Gattinger, 1956); north zone and south zone (Bektaş et al., 1995), Hopa-Borçka, Artvin-Yusufeli (Arni, 1939; Bektaş et al.,

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1987; Güven, 1993; Kurt et al., 2006) and Olur-Tortum zone (Konak et al., 2001). According to these definitions the study area is located in north zon, in Pontide autochthonous of Akeniz (1988), and in Hopa-Borçka zone of Konak et al. (1991, 2001). Yılmaz et al. (1997) stated that Eastern Pontides are part of the southern part of the Trans-Caucasus, and represented by the Adjara-Trialeti unit in the north and the Artvin-Bollisi unit in the south. They also expressed that the Late Cretaceous arc and back-arc deposits of Pontide and Trans-Caucasus are stratigraphically similar. For the first time, data from different studies have been compiled by Güven (1998), and 1/100.000 scaled geological map of a part of the Easrtern Pontides have been derived. This map has been the basis for many of the subsequent studies. The Eastern Pontides have been attracted by many earth scientists (Çağatay and Boyle, 1977; Çağatay, 1993; Gökçe and Spiro, 2000; Arni, 1939; Şengör et al., 1981; Gedik et al., 1992; Okay and Şahintürk, 1997*a, b*; Yılmaz et al., 1997; Boztuğ et al., 2001; Eyüboğlu et al., 2014) due to both geodynamic evolution of the region and contained Kuroko-type VMS (volcanogenic massive sulpide) deposits (e.g., Lahanos, Çayeli and Murgul Cu-Zn deposits). Today, both the Kuroko-type deposits occurred associated with the Late Cretaceous dacitic-ryolitic volcanism, and the porphyry, skarn and epithermal type deposits associated with the magmatic intrusions of different age range between the Late Cretaceous and Eocene, attracts by many scientists and the mining industry.

There are different opinions about the geodynamic evolution of the Pontide belt. Subduction polarity of Eastern Pontides suggested as; to northward from the Paleozoic to the Eocene (e.g. Dewey et al., 1973; Eyüboğlu et al., 2007), to northward from the Paleozoic to end of the Eocene (e.g. Adamia et al., 1977; Ustaömer and Robertson, 1996), and to soutward from the Paleozoic to the Middle Jurassic, and then to northward from the Late Cretaceous to end of the Eocene (Şengör and Yılmaz 1981; Okay and Şahintürk, 1997*b*). It is stated that the first transgression on the Paleozoic basement in the Eastern Pontides started in Liassic (e.g. Okay and Şahintürk, 1997*a*; Ustaömer and Robertson, 2010), and the collision between the Pontides and the Anatolid-Taurides occurred during the Paleocene-Early Eocene period (e.g. Ustaömer and Robertson, 1996; Okay and Şahintürk, 1997*a, b*). While some researchers separated the Eastern Pontides into nappe structures (Akdeniz et al., 1994; Akdeniz, 1988; Konak et al., 1991-2001), others separated into tectonic slices (Duygu et al., 2013; Uğuz et al., 2011). Uğuz et al. (2011) suggested that these tectonic slices have moved from north to south. Some of these tectonic slices are defined by Duygu et. al. (2013) as Maçka and Taşköprü tectonic slices.

Magmatic activities of different composition have occurred in different age ranges in Eastern Pontides. From these magmatites; the medium potassium calc-alkaline Early Cretaceous granitoids (Çamlıkaya) represent the early arc, the medium to high potassium calc-alkaline Late Cretaceous-Early Paleocene granitoids (Sırtyayla and Morselavat) represent the mature arc, the Paleocene leucogranite (Asniyar) represent the collision period, the high potassium calc-alkaline microgranites (Ayder and Samistal) represent the post collision, the low alkaline monzonite (Güllübağ), quartz monzodiorite (Halkalıtaş) ranging from medium potassium to low tholeiite, the low potassium tholeiitic gabbro (Ardeşen) and the diabase (İsina) represent the Late Eocene extensional period (Boztuğ et al., 2001). In addition, Kovenko (1943), İğdır (1971) and Gedik et al. (1992) stated that the Late Cretaceous volcanism in the Eastern Pontides is acidic and basic in character.

Important Kuroko-type Cu-Zn deposits in Turkey (e.g. Murgul, Çayeli, Kutlular, Lahanos, Kanköy) is located in Eastern Pontides in the Santonian aged Kızılkaya formation, and the Çayeli Cu-Zn deposit is located in study area. The study area has an important potential for such mineralizations, but the Campanian-Maastrichtian aged Çayırbağ formation containing similar lithologies to the Kızılkaya formation in which the mineralization is found is confused along the Eastern Pontides. For the exploration and development of the mineralization potential of the region, it is necessary to well construct the stratigraphic sequence correctly, to make detailed geological maps and to construct the geodynamic evolution of the region in the direction of the data. In this study; (i) for the first time, 1 / 25.000 scaled detail basic geological maps of the region were made in accordance with the stratigraphic relations and standards; (ii) the paleontological and radiometric ages obtained and then the lithostratigraphic and chronostratigraphic units were re-assessed and comments on the stratigraphy of the region were made; (iii) and lithological and volcanic features of the Taçköprü tectonic slices and their relationship with each other have been examined in a regional sense and the tectonostratigraphic location of the region has been tried to be explained.

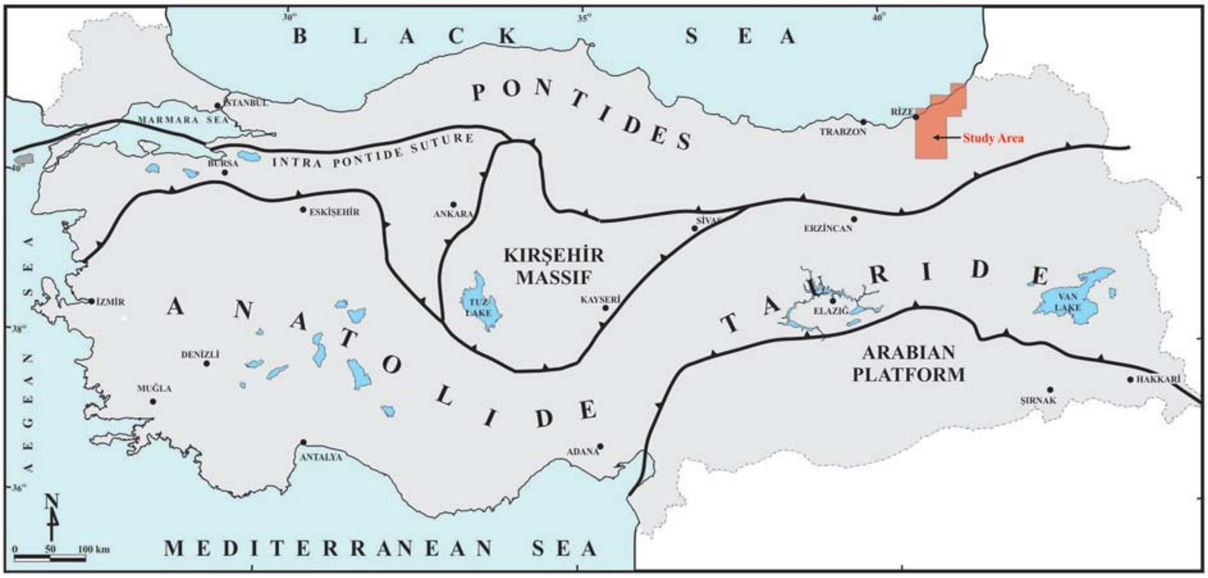

Figure 1- Location map of the study area (Tectonic map simplified from Okay and Tüysüz, 1999; Robertson and Ustaömer, 2009).

2. Methods

Samples were taken in order to make paleontological determinations, petrographic study, and geochronological age determination by taking into consideration relations between upper and lower lithological contact, during mapping.

Thin sections were prepared in the General Directorate of Mineral Research and Exploration (MTA) laboratories from the samples taken for the purpose of petrographic studies and paleontological identification, and rock and texture were defined in polarizing microscope, and age determination was made by the expert paleontologists of the MTA. During these petrographic studies, less altered samples were determined which could be suitable for geochronological age determination. Geochemical analyzes were carried out, and then samples with low loss of ignition (LOI) content were selected for radiometric dating. Thus, for the radiometric age determination, dacite and andesite samples belonging to Handüzü volcanites, one dacite sample belonging to Çayırbağ formation and one basalt sample belonging to Melyat formation were selected. Age determinations of these samples have done geochronology laboratory of Actlabs (Canada) using the method ^{40}Ar / ^{39}Ar (Table 1). The samples wrapped in Al foil was loaded in evacuated and sealed quartz vial with K and Ca salts and packets of LP-6 biotite interspersed with the samples to be used as a flux monitor. The sample was irradiated in the nuclear reactor for 48 hours. The flux monitors were placed between every two samples, thereby allowing precise determination of the flux gradients within the tube. After the flux monitors were run, J values were then calculated for each sample, using the measured flux gradient. LP-6 biotite has an assumed age of 128.1 Ma. The neutron gradient deed not exceeded 0.5% on sample size. The Ar isotope composition was measured in a Micromass 5400 static mass spectrometer. 1200ºC blank of 40Ar did not exceed n*10-10 cc STP.

3. Stratigraphy and Tectonic

Within the study area; the sedimentary, plutonic and volcanic rocks in ages ranging from Late Jurassic-Early Cretaceous to Quaternary are observed. The units within specified age range were mapped by defining them in different tectonic slices (Figure 2a, b). In this study, considering the stratigraphy formed by Güven (1993, 1998) and the tectonic slices defined by Duygu and others (2013) in the vicinity of Maçka district in west of the study area, the units located in the study area were assessed in an order and tried to be explained by correlation. These slices of which their contact relationships are not observed in the study area but well observed in the near west of the study area, separate from each other with a thrust plane extending towards the area. This thrust line follows the Varda village north (Güneyce-Rize), and Polut mountain (Trabzon), and extends from from the north of the Zigana passageway to the study area (Duygu et al.,

Table 1- Within the scope of this study, radiometric age determinations of volcanic rocks with $^{40}Ar/^{39}Ar$ method (See Figure 2b for sample locations).

Sample ID / Separated Mineral	Rock Type	Formation Name	IIA (My) ±1s	TFA ±1 s	WMPA (My)±1s	Ca/K	Comments
HD1 groundmass	Dacite	Çayırbağ Formation	—	80.2±0.9	**83.2±1.0**	0.37-1.15	Three steps plateau
HD2 Amph+Px	Basalt	Melyat Formation	40.0±4.0	50.0±1.4	**47.8±1.6**	3.73-24.79	Three steps plateau
VB1 whole rock	Dacite	Handüzü Formation	10.29±1.76	5.48±0.39	**3.93±0.46**	15.10-52.99	Two steps low temperature intermediate plateau
VB2 whole rock	Andesite	Handüzü Formation	4.08±0.51	4.28±0.39	**4.25±0.55**	1.54-4.91	Four steps plateau

Explanation:
±1 s = Estimated uncertainty (1 sigma); **IIA** = Inverse Isochrone age **TFA** = Total fusion age;
WMPA = Weighted mean plateau age; **Ca/K =** Apparent Ca / K ratios;

2013). The thrust line between these slices, which are described under the name of Maçka and Taşköprü tectonic slices (Figure 2a), is not clearly seen on the field due to the uplift and erosional processes of the Kaçkar granitoid I. The type locality of the Taşköprü tectonic slice, which is observed under the Maçka tectonic slice, is the Taşköprü valley outside the study area in the Yağmurdere district, Gümüşhane province (Duygu et al., 2013). While the volcanic activity is less intense in Taşköprü tectonic slice than Maçka tectonic slice, the sedimentary rocks are more intense.

The Kızılkaya formation, which hosts Kuroko-type Cu-Zn deposits in the Eastern Pontides is in the Maçka tectonic slice. The absence of this formation in the Taşköprü tectonic slice has provide an important guide in distinguishing and to correlation of these tectonic slices. The units of the Maçka tectonic slice, which are well observed along the road route from the Akarsu village (Maçka) to the shore in west of the study area, give wide outcrops in the northern and central parts of the study area. Also in this study, the Kaçkar granitoid I, the Kaçkar granitoid II, the Güllübağ monzonite and the Ardeşen gabbro were explained under separate titles.

3.1. Maçka Tectonic Slice

In the study area, the slice in Late Jurassic-Early Cretaceous to late Maastrichtian-Danian time interval, is unconformably overlain by the Thanetian-Middle Eocene and Early-Middle Eocene units (Figure 3). The Maçka tectonic slice can be correlated with the Karabulduk tectonic slice of Uğuz et al. (2011).

3.1.1. Berdiga Formation (JKb)

The unit consisting mainly of neritic carbonates was named by Pelin (1977) around the Berdiga Mountains of Alucra village, Giresun. The unit give outcrops in limited areas in the study area. It is possible to see the outcrops of the limestones belonging to the Berdiga formation between Çatak formation and Kaçkar granitoid I in the west of Ortayayla (G45 b3), north of Ortayay and near Gölyayla (G45 d1, d2) (Figure 2b).

The formation is represented by gray, beigeish gray, middle-layered, locally cherty, abundant macro fossiliferous limestones deposited in shallow and shelf environments in the study area (Figure 4). The unit, which unconformably overlies the Liassic-Dogger Hamurkesen formation outside of the study area, is intruded by the Kaçkar granitoid I. The upper contact of the unit is unconformable with the Çatak formation (Figure 3). The apparent thickness of the unit, which is observed in limited outcrops in the study area, is between 50 and100 m. However, it is known from previous studies that the thickness of the unit in outside of the study area is varying between 100 and 300 meters.

There was not obtained fossil assemblage that give detailed age from the samples collected from the unit which has limited outcrops in the study area. But, the Early Cretaceous age was obtained from the fossil determination (Table 2) of a sample collected in the formation. According to the research carried out by Uğuz et al. (2011) in the near west of the study area the foraminiferous fossil assemblage of the Late Jurassic-Early Cretaceous age was obtained. The Late Jurassic-Early Cretaceous age was obtained from the

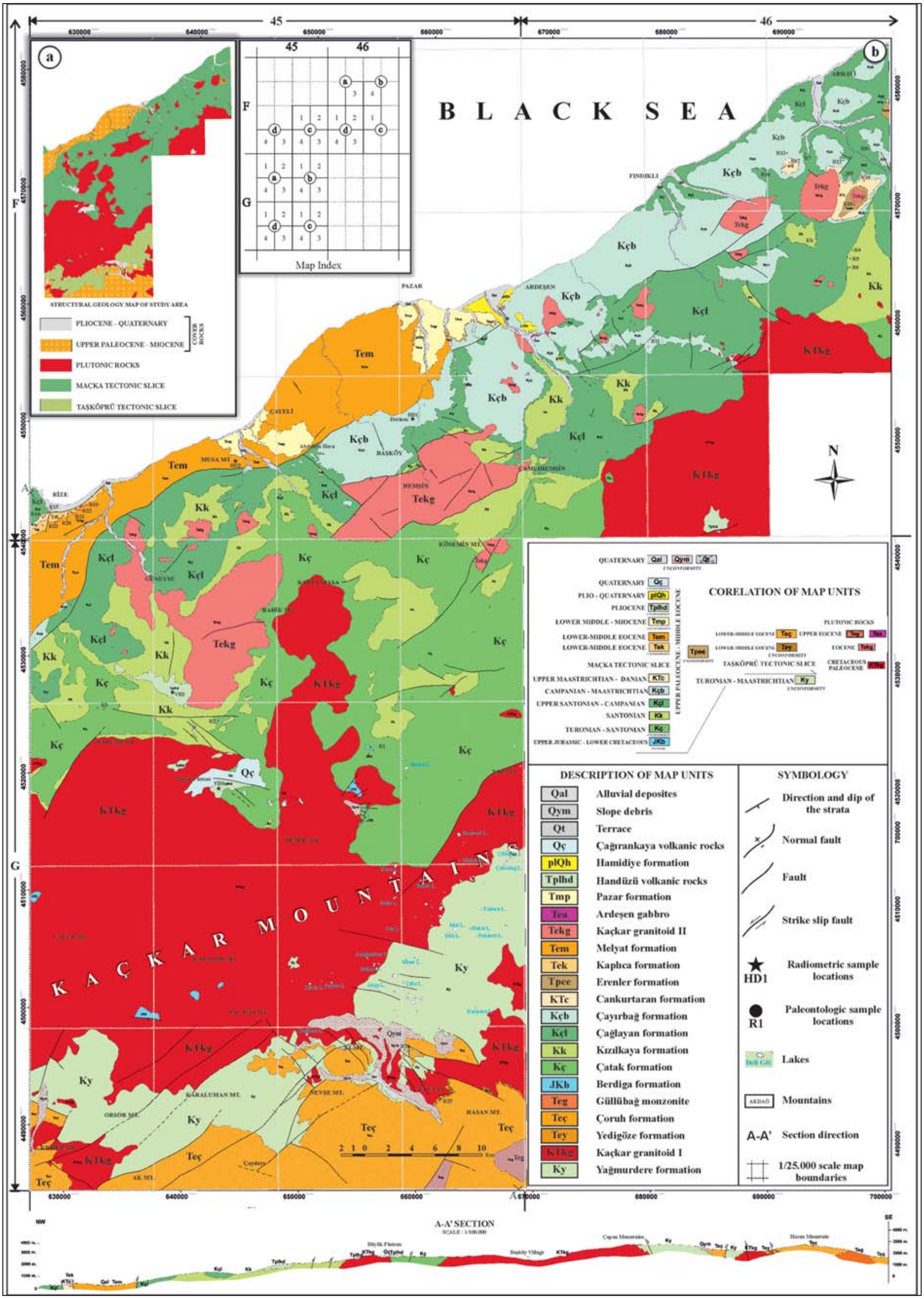

Figure 2- (a) Structural geology and (b) detail geological map and the cross section of the study area (vertical scale in the cross section exaggerated).

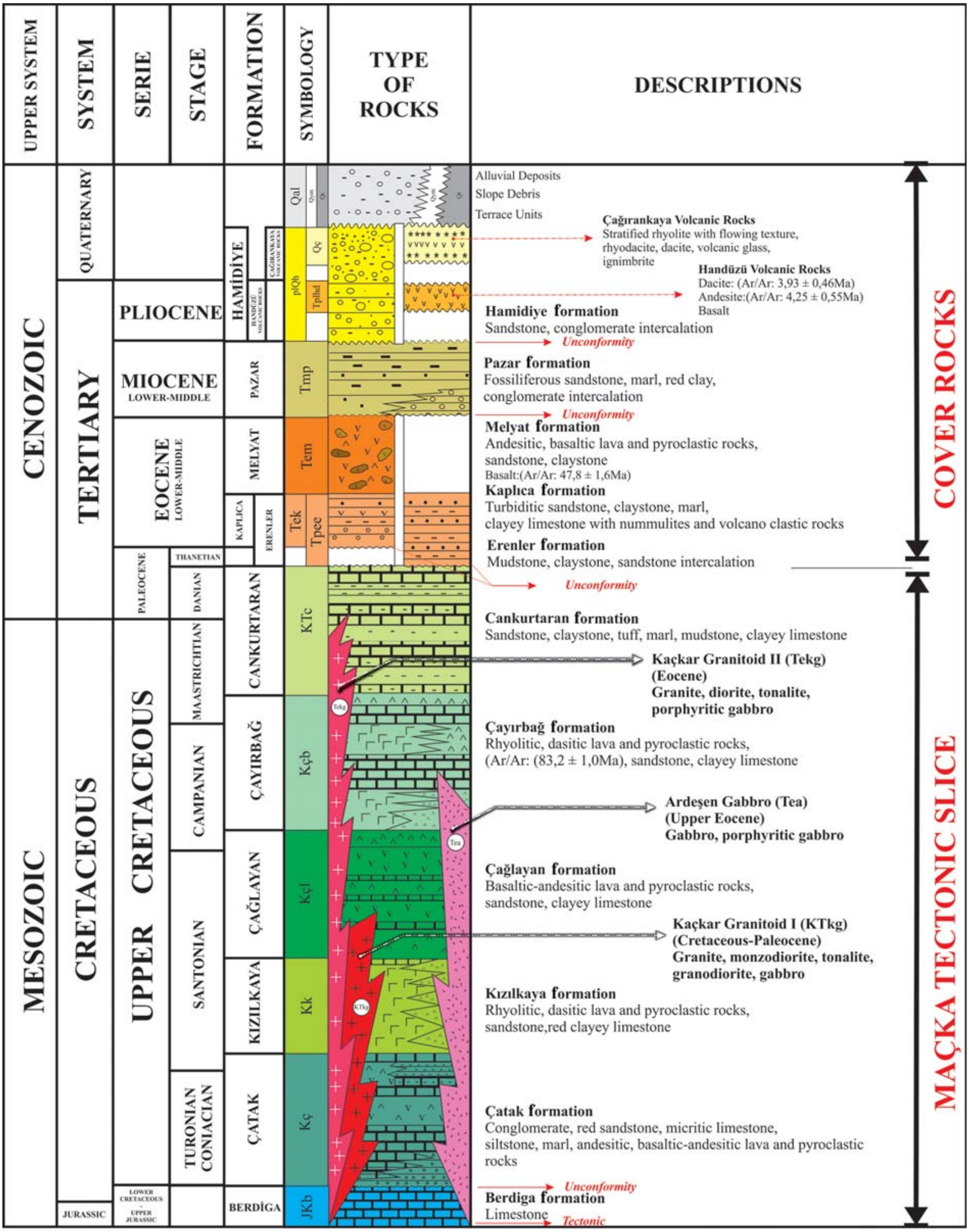

Figure 3- The generalized stratigraphic columnar section of the Maçka tectonic slice and its cover units.

Table 2- Fossil findings obtained from the units belonging to Maçka tectonic slice (Coordinates are UTM ED 1950).

Formation Name	Sample ID on Map (Figure 2b)	Sample Location	Age	Fossils
Berdiga	R1	Y: 655150 X: 4522750	Early Cretaceous	*Vercorsella* sp.
Çatak	R2	Y: 643100 X:4524900	Turonian	*Helvetoglobotruncana* cf. *helvetica* (Bolli), *Marginotruncana pseudolinneiana* Pessagno, *Whiteinella* sp., *Praeglobotruncana gibba* Klaus
	R3	Y: 633224 X: 4525850	Turonian – Santonian	*Macroglobigerinelloides* sp, *Heterohelix* sp., *Marginotruncana coronata (*Bolli), *Marginotruncana pseudolinneiana* Pessagno, *Globigerinelloides* sp.,
Kızılkaya	R6	Y: 696960 X: 4567330	Turonian – Santonian	*Marginotruncana coronata* (Bolli), *Marginotruncana pseudolinneiana* Pessagno, *Heterohelix* sp.
	R5	Y: 696905 X: 4567330	Coniasian–Santonian	*Dicarinella* cf. *concavata* (Brotzen), *Dicarinella asymetrica* (Sigal), *Marginotruncana asymetrica* Pessagno, *Macroglobigerinelloides* sp., *Heterohelix* sp.
	R4	Y: 696985 X: 4567362	Santonian	*Dicarinella asymetrica* (Sigal), *Marginotruncana* sp., *Macroglobigerinelloides* sp., *Heterohelix* sp.,
Çağlayan	R7	Y: 692100 X: 4573425	Santonian	*Dicarinella asymetrica* (Sigal), *Marginotruncana pseudolinneiana* Pessagno, *Marginotruncana coronata* (Bolli), *Heterohelix* sp., *Macroglobigerinelloides* sp., Globigerinellodidae
	R9	Y: 695420 X: 4572870	Late Santonian	*Spirillina* sp., *Dicarinella concavata* (Brotzen), *Dicarinella asymetrica* (Sigal), *Marginotruncana pseudolinneiana* Pessagno, *Marginotruncana coronata* (Bolli), *Inoceranus* sp.
	R10	Y: 688000 X: 4572500	Campanian	*Globotruncana linneiana* (d'Orbigny), *Globotruncanita* cf. *stuartiformis* (Dalbiez), *Globotruncanita* cf. *elevata* (Brotzen), *Rosita fornicata* Plummer, Heterohelixidae
	R8	Y: 698253 X: 4573842	Campanian–Maastrichtian	*Globotruncanita stuartiformis* (Dalbiez), *Globotruncana linneiana* (d'Orbigny), *Globotruncanita* sp., *Globigerinelloides* sp., *Heterohelix* sp. and radyolarya fosilleri
Çayırbağ	R11	Y: 680150 X: 4557775	Campanian–Maastrichtian	**Nannoplankton***: Arkhangelskiella cymbiformis* Vekshina, *Quadrum gothicum* (Deflandre), *Prediscosphaera cretacea* (Arkhangelsky), *Cretarhabdus crenulatus* Bramlette ve Martini, *Ceratolithoides aculeus* (Stradner), *Calculites obscurus* (Deflandre), *Micula decussata* Vekshina, *Lucianorhabus cayeuxii* Deflandre, *Watznaueria barnesae* (Black), *Reinhardtites levis* Prins and Sissingh, *Arkhangelskiella* sp.
	R12	Y: 696512 X: 4571728	Campanian–Maastrichtian	*Globotruncana arca* (Cushman), *Globotruncana linneiana* (d'Orbigny), *Globotruncana* cf. *bulloides* Vogler, *Globotruncana hilli* Pessagno, *Globotruncana* cf. *aegyptiaca* Nakkady, *Globotruncana ventricosa* White, *Globotruncanita angulata* (Tilev), *Globotruncanita stuartiformis* (Dalbiez), *Globotruncanita* cf. *conica* (White), *Contusotruncana* cf. *walfishensis* (Todd) and *Globotruncana* sp.
	R13	Y: 690066 X: 4573000	Campanian–Maastrichtian	*Globotruncana linneiana* (d'Orbigny), *Globotruncana cf. ventricosa* White, Globigerinidae
Cankurtaran	R14	Y: 626300 X: 4541150	Campanian–Maastrichtian	*Globotruncana arca* (Cushman), *Globotruncana linneiana* (d'Orbigny), *Globotruncana* cf. *linneiana* (d'Orbigny), *Globotruncana lapparenti* (Brotzen), *Globotruncana orientalis* El-Naggar, *Globotruncana mariei* Banner and Blow, *Globotruncana falsostuarti Sigal, Globotruncana* sp., *Contusotruncana fornicata* (Plummer), *Contusotruncana* cf. *walfishensis* (Todd), *Contusotruncana* cf. *potelliformis* (Gandolfi), *Pseudotextularia nutalli* (Voorwijk), *Heterohelix* sp., *Rugoglobigerina pennyi* Brönnimann, *Kuglerina rotundata* (Brönnimann)
	R16	Y: 696512 X: 4571728	Campanian–Maastrichtian	*Globotruncana bulloides* Vogler, *Globotruncanita stuartiformis* (Dalbiez), *Macroglobigerinelloides* sp., *Heterohelix* sp., Globigerinidae
	R15	Y: 626300 X: 4541150	Campanian–Maastrichtian	**Nannoplankton***: Arkhangelskiella cymbiformis* Vekshina, *Reinhardtites levis* Prins ve Sissingh, *Ceratolithoides aculeus* (Stradner), *Aspidolithus parcus parcus* (Stradner), *Lucianorhabus cayeuxii* Deflandre, *Calculites obscurus* (Deflandre), *Eiffellithus turriseiffelii* (Deflandre), *Micula decussata* Vekshina, *Micula concava* (Stradner), *Quadrum gothicum* (Deflandre), *Quadrum gartneri* Prins and Perch-Nielsen, *Microrhabdulus decoratus* Deflandre, *Glaukolithus compactus* (Bukry), *Prediscosphaera cretacea* (Arkhangelsky), *Stradneria crenulata* Bromlette and Martini, *Cribrosphaerella ehrenbergii* (Arkhangelsky), *Lithraphidites carniolensis carniolensis* Deflandre, *Watznaueria barnesae* (Black)
	R17	Y: 690145 X: 4573529	Maastrichtian	*Gansserina gansseri* (Bolli), *Globotruncanita* cf. *stuartiformis* (Dalbiez), *Globotruncana linneiana* (d'Orbigny), *Globotruncana* sp., *Heterohelix* sp., *Macroglobigerinelloides* sp., Globigerinidae, *Globotruncana arca* (Cushman)

Figure 4- View of gastropods and lamellibranch fossils in limestones of the Berdiga formation, reflecting the shallow marine deposition environments (East of Semköhot yayla, G45 b4).

similar units in Bayburt, Gümüşhane and Trabzon vicinities (Keskin et al.,1991; Korkmaz, 1993; Gürsoy et al., 1993; Güven, 1993-1998; Akdeniz et al., 1994; Okay and Şahintürk, 1997; Kurt et al., 2006)

Considering the lithologies and fossil content of the formation in the study area, it is understood that the formation is deposited in shallow marine environment and show shelf character. The Berdiga formation can be correlated with Sarıçiçek formation (Akdeniz et al., 1994) defined in Bayburt nappe in southern zone, and Hozbirikyayla formation (Ağar, 1977; Keskin et al., 1991) defined in around Bayburt.

3.1.2. Çatak Formation (Kç)

The type locality of the unit consisting of sandstone, siltstone, marl, shale and limestone and basalt, andesitic lava and pyroclastics is the Çatak village, located in south of the Maçka district, and was first named by Güven (1993). It is possible to see the rocks of the formation on the northern slopes of the Kaçkar Mountains, parallel to the ridges (Figure 2b).

Outside the study area, in the vicinity of Maçka, the unit begins to deposit with claret-red sandstones and conglomerates then continues upward with the alternation of grayish siltstone, marl, claystone, clayey limestone intercalating with greenish basaltic, andesitic lavas (Figure 5). In the study area, there are observed greenish, purple colored, spilitic, pillow type basaltic lavas (Figure 5) and medium layered greenish gray and purple colored, silicified, partly cherty micritic limestones alternating with pyroclastics. The andesitic intercalations are also observed in this section which is widely composed of volcanic rocks. There are peperitizations in lava layers occasionally. In the upper levels of the formation there are red to purple colored, fine to medium layered micritic limestones.

The Çatak formation unconformably overlies the Berdiga formation in south of the Kuyuculu Valley (G45 b4). At the same time, there is observed a crosscutting relationship with the Kaçkar granitoid I which its upper boundary is conformably overlain by the Kızılkaya formation (Figure 3). Outside the study area, the apparent thickness of the formation is defined as 1100 m in its type section (Maçka district) (Güven, 1998). However, the apparent thickness of the formation varies from 600 to 700 m in the study area.

The age of the formation was given as Turonian - Santonian from the fossil determinations of the samples collected from the micritic limestones in the formation (Table 2). Together with its faunal characteristics, the existence of turbiditic-pelagic sediments intercalating with volcanites indicates that the formation might have been deposited in slope-basin conditions in which the basic volcanism have accompanied to the sedimentary deposit. The Çatak formation can be correlated with the basic I series of Çekiç et al. (1984).

3.1.3. Kızılkaya Formation (Kk)

The unit, which is generally composed of rhyolite, dacites and pyroclastic rocks and clayey limestones, was first named by Güven (1993) as the Kızılkaya formation. It is possible to see the formation in the

Figure 5- View of pillow basaltic lavas within the Çatak formation (north of Kaptanpaşa, eastward view, G45b1).

form of outcrops, which are difficult to follow laterally, especially due to facial changes in the study area. The outcrops are observed in Yeşildere (G45 a1), Çamlıca (G45 a2), Kantarlı (G45 b1), Meydanköy (G45 b3), Madenköy (F45 c4, d3), Çamlıhemşin and the Fırtına River (F45 d4; figure 2b).

The formation mainly consists of rhyolitic and dacitic lavas and clayey limestones, and also the interlayers of purple sandstone (Figure 6). Dacitic lavas have yellowish beige, grayish green, pinkish colored (columnar) cooling surfaces. The unit, which has very coarse quartz grains, has evident feldspars and porphyritic texture. The alteration is very common in dacites. In these mostly yellowish brown altered areas, beige to white colored unaltered dacites are passed. The dacites are rich in pyrites and there are also observed argillization, chloritization and hematization in them. The rhyolites are mostly grayish white in color. Quartz grains in macroscopic scale are less distinct than dacite and are mainly observed in the form of silica, and they have less propagation than dacites. Ignimbrites are distinctive with their light green color and massive appearance. Pumice grains are dominant in ignimbrites in the form of accretion up to 20 m. Greenish gray, purple micritic limestone and pinkish quartz sandstone layers are also observed in ignimbrites. Since the Kuroko-type Cu-Zn deposits in the Eastern Pontides (Çayeli, Murgul, Lahanos and Kutlular) are located within this formation, the Kızılkaya formation is especially important for such deposits. Particularly the massive section of the Kuroko-type Cu-Zn deposits located in this formation are observed above ignimbrite levels and below micritic limestones and sandstones.

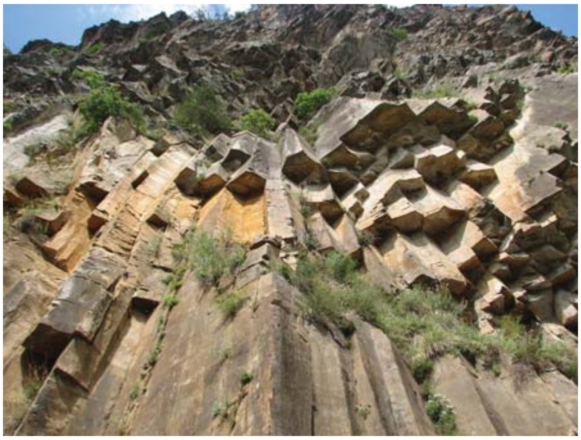

Figure 6- View of columnar dacites of the Kızılkaya formation (outside the study area, in north of the Maçka district, westward view, G43 a4).

The Kızılkaya formation conformably overlies the Turonian-Santonian Çatak formation and underlies the Late Santonian-Campanian Çağlayan formation (Figure 3). The thickness of the formation in the study area is variable, and appeartent thickness ranges between 300 and 400 meters.

In the fossil determination of the samples collected from purple micritic limestones in the formation, the Santonian age, the Coniacian - Santonian age and the Turonian - Santonian ages were obtained. The Santonian age was given to the Kızılkaya formation by taking into consideration the fossil assemblages (Table 2) of the unit, and the relationship of the upper and lower contact units.

Faunal and lithological characteristics of the Kızılkaya formation showed that the formation is deposited in pelagic and turbiditic environments in slope conditions, and acidic volcanism accompanied. The formation can be correlated with the lower level where asidic volcanism is effective in Esiroğlu formation of Uğuz (2011), with the first dacitic series of Schultze-Westrum (1960), with the Kaleciktepe dacitic member of the Tepeköy formation of Pelin (1977) and with the Makenet formation of Özsayar et al. (1982).

3.1.4. Çağlayan Formation (Kçl)

The unit, which overlies the acidic volcanism and is generally formed by the alternation of basalt-andesitic lava, pyroclastics, sandstone, marl and clayey limestone, was named as the Çağlayan formation by Güven (1993). It extends in the study area in east-west and northeast-southwest directions on slopes of the the Kaçkar Mountains by the sea. It is possible to see the outcrops of the formation in Güneysu, Dumankaya, Muradiye (G45 a1), Bulutlu, İslahiye (G45 a2), Yenihisar, Gürgenli and Büyükköy vicinity (F45 d3), Pazar-Hemşin road, (F45 c2, c3) Çamlıhemşin, Topluca district (F46 d4), the vicinity of the Tunca village (F46 d1, d2), south of Arhavi valley interior and the Arılı village (F46 b4; Figure 2b).

The unit consists of sandstone, marl, greenish gray and claret red limestone layers in alternating with basaltic, andesitic lava and pyroclastics. The lavas belonging to the unit bearing peperitic layers are green to dark gray, very hard and fractured. While pillow structures are seen in basaltic lavas, the prismatic (columnar) cooling surfaces are very rarely observed. Tuff and breccia are well bedded and consist of limestone and lava fragments. Among these basic volcanic rocks, greenish, grayish, burgundy marl, sandstone and micritic limestone layers are seen. Agglomerates, volcano cemented spilites are basaltic and andesitic in composition and fine to medium bedded. There are occasionally observed slip-settlement structures within the unit.

The formation conformably overlies the Santonian Kızılkaya formation at the bottom and underlies the Campanian-Maastrichtian Çayırbağ formation at the top (Figure 3). Between Rize provincial center and the Çayeli district, it is seen tectonically in contact with Eocene units.

The Santonian, Kampanian- Maastrichtian, late Santonian and Campanian ages were obtained in the fossil determinations (Table 2) of the samples taken from the formation. Considering the fossil assemblages, age ranges and the upper and lower contact relationships, the age of the Çağlayan formation was given as the late Santonian-Campanian in this study.

The faunal and lithological features observed in the Çağlayan formation and the slip-settlement structures indicate that the unit may have been deposited under slope conditions where the basic volcanism is effective. The apparent thickness varies between 600 and 700 m in the study area. The Çağlayan formation can be correlated with the section in which the basic volcanism of the Esiroğlu formation is effective of Uğuz et al. (2011), the upper basic series of Schultze-Westrum (1960) and the basic II series of Çekiç et al. (1984).

3.1.5. Çayırbağ Formation (Kçb)

The unit, which is the last phase of the acidic volcano character of the Late Cretaceous period and is named by Güven (1993). It outcrops along the road cut of Pazar-Hemşin where the stone quarries are located (F45 b3), in the Aşıklar and Erenler villages (F45 b4), in the vicinity of Babadağ (F45 b3) and between Ardeşen and Arhavi nearly in NE-SW direction, along the low topography near the sea in the study area (Figure 2b).

The formation mainly consists of rhyolite, dacite, pyroclastics, sandstones and limestones, which constitutes the phases of acidic volcanism products (Figure 7). The rhyolites and dacites are mostly grayish-green and pink-colored and have

Figure 7- View from ignimbrites (green) and micritic limestones (brown) in the Çayırbağ formation (Rize city, west of Hurmalık village, İyidere-İkizdere road, northeast view, G44 b2).

prismatic (columnar) cooling surfaces in occasion. The alteration is widespread and white, beige and pinkish colored argillized products are encountered. In dacites and rhyolites, quartz grains and feldspars are visible and have porphyritic texture. Unlike the Kızılkaya formation, which has the similar features, there are not observed much pyrites in dacites and rhyolites belonging to the Çayırbağ formation. In the Çayırbağ formation, the light green ignimbrites are dominant and distinctive in pyroclastics and they exhibit a thickness of 15-20 m Greenish gray and burgundy, fine-to-medium bedded micritic limestones can be seen in ignimbrites. These lithologies can be seen especially on ridges of the Derinsu village and in the north of Ardeşen-Tunca village.

The formation conformably overlies the Çağlayan formation and underlies the Cankurtaran formation (Figure 3). In the study, the Early-Middle Eocene Kaplıca formation (without the Cankurtaran formation) unconformably overlies the Çayırbağ formation along the Hemşin road in south of the Pazar district.

The Campanian - Maastrichtian age was obtained in the fossil determinations of the samples collected from the formation (Table 2). Furthermore, radiometric age determinations (^{40}Ar / ^{39}Ar) of dacites (HD1, F45c3, 659500; 4552000) taken from the Çayırbağ formation in the study area were obtained as 83.2 ± 1.0 Ma (Figure 8a). Taking into account the ages and upper and lower contact relations of the unit, the Campanian - Maastrichtian age was given to the Çayırbağ formation.

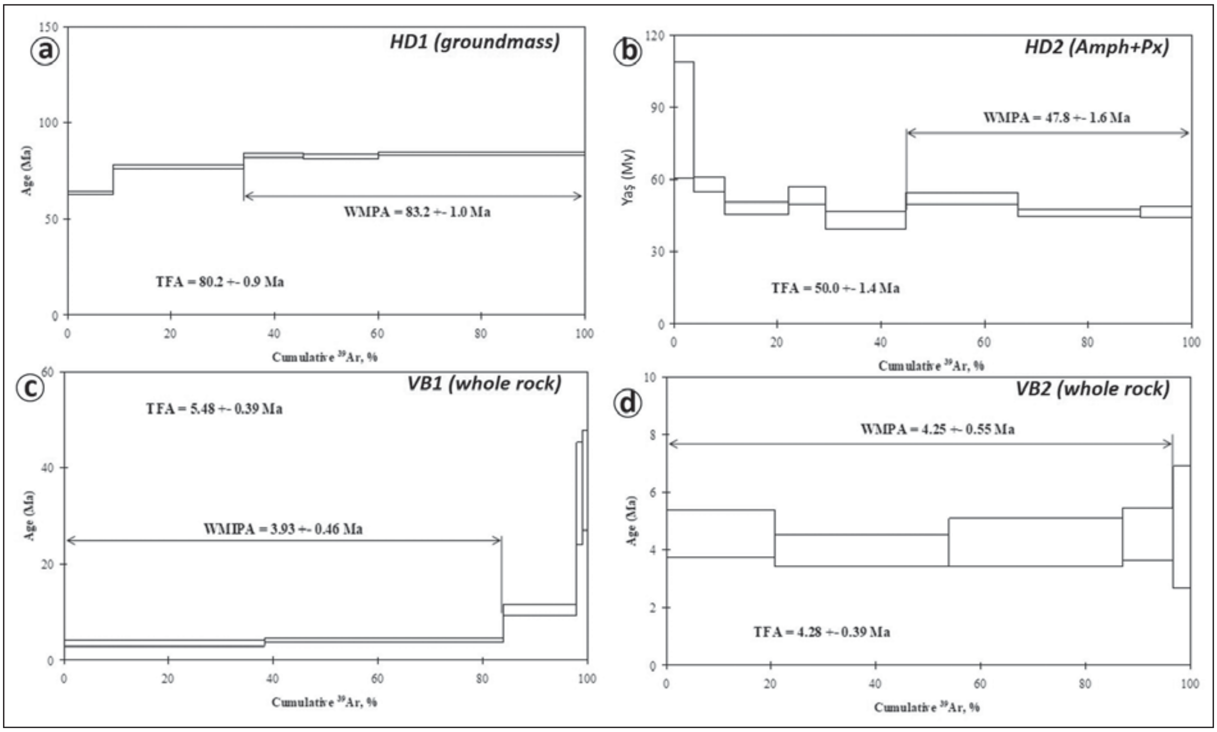

Figure 8- Ar-Ar plateau age for; (a) dacite of Çayırbağ formation, (b) basalt of Melyat formation, (c) dacite and (d) andesite of Handüzü formation.

The Çayırbağ formation was deposited in marine environment accompanied by the acidic volcanism. The deposition of micritic limestone occurred when the volcanism was inactive. The appearent thickness of this formation is between 150 and 200 m. The Çayırbağ formation can be correlated with the upper sections of the units investigated by Uğuz et al. (2011) below the Esiroğlu formation, the Tirebolu formation of Güven (1993) where the trachyandesitic lavas are dominant and the rock units introduced in the Eastern Pontides as second-phase dacitic series, the hematitic series defined by Kahraman et al. (1987) and with the dacitic lava and pyroclastics of mineralized sections defined by Güner et al. (1983).

3.1.6. Cankurtaran Formation (KTc)

The formation, which is mainly composed of sandstone, claystone and clayey limestone, was named as the Cankurtaran formation by Yılmaz et al. (1997). The Cankurtaran formation has small outcrops in the study area. It is possible to see the limited outcrops of the formation along the Kalkandere side road of Rize (F45 d4) and between the Derbent village and Başköy west (F46 b4) to the south of Arhavi.

The lower parts of the formation are mostly of clastic units. The succession begins with yellowish beige and greenish-colored, fine-to-medium bedded sandstone and claystone alternations and passes into marl, mudstone and carbonate levels in the upper layers (Figure 9). The upper levels of the formation are in the form of beige and burgundy colored, thin to medium bedded micritic limestones, with much fractures and micro faunas. The mudstones are also observed in the limestones in intermediate levels. Outside the study area, the presence of tuff, volcanic sandstone, agglomerate levels in the Cankurtaran formation is mentioned (Terlemez, 1986; F46 b3). The

Figure 9- View from the micritic limestones and sandstone layers in the upper levels of the Cankurtaran formation (southwest of the Rize provincial center, eastward view F45 d4).

folds in layers of the formation, slip-settlement and bottom structures are also seen.

The apparent thickness of the formation in the study area varies between 150 and 200 m. The thickness exceeds 250 m along the Hopa-Borçka road, in outside of study area. The Cankurtaran formation conformably overlies the Çayırbağ formation (Figure 3). However, the formation is unconformably overlain by the Erenler formation, which is the cover rock of the Maçka tectonic slice to the east of the study area, and by the Kaplıca formation to the near south of Rize.

The Campanian - Maastrichtian and Maastrichtian ages were obtained in the fossil determination of the samples collected from the Cankurtaran formation (Table 2). Kandemir et al. (2014) obtained Campanian-early Selandian age range from the formation to the east of the study area. In addition, Yılmaz et al. (1997) found Danian age at the upper levels of the formation in around the Hopa. According to data of previous studies, fossil contents and the gradational transition between the formation and the Çayırbağ formation at the bottom, and the unconformable contact with the Late Paleocene-Middle Eocene Erenler formation at the above, the age of the Cankurtaran formation should be late Maastrichtian-Danian.

The lithological and faunal characteristics of the Cankurtaran formation and its slip-and-settlement structures suggest that the unit may have been deposited under slope-basin conditions where the marine volcanism is effective. The environment is under the effect of the magmatic arc activity (Yılmaz et al., 1997). The Cankurtaran formation can be correlated with the Akveren formation (Badgley, 1959), Mescitli formation (Güven, 1993), one section of the Bakırköy formation (Güven, 1993), Fatsa formation (Terlemez and Yılmaz, 1980), Rize formation (Gedik and Korkmaz, 1987) and the Katila formation of Adamia et al. (1992).

3.2. Cover Units on the Maçka Tectonic Slice

The cover units, which unconformably overlie the Maçka tectonic slice are; the Late Paleocene-Middle Eocene Erenler Formation, the Early-Middle Eocene Kaplıca and Melyat formations, the Early-Middle Miocene Pazar formation, the Pliocene Handüzü volcanics, the Plio-Quaternary Hamidiye formation and the Quaternary Çağırankaya volcanics (Figure 3).

3.2.1. Erenler Formation (Tpee)

The sedimentary rocks, which are generally formed by the alternation of mudstone, claystone and sandstone in the east of the study area, Hopa and Borçka, were named as the Erenler formation by Yılmaz et al. (1997). The unit is observed in the vicinty of Aşağışahinler village in the southeast of Arhavi County in F46 b3 sheet and the Çatak Tepe (hill) in the southwest of Arılı in limited outcrops (Figure 2b). The large outcrops are located in the Hopa-Borçka region in east of the study area.

The unit is composed of greenish gray, brownish white, thin to medium bedded clastic rocks in turbiditic character such as mudstone, claystone and sandstone. It is possible to see the depositional traces like flute marks and canal structures in sandstones.

The formation unconformably overlies the Çağlayan, Çayırbağ and Cankurtaran formations in the study area (Figure 3). It is known that the unit, which its upper contact cannot be observed in the study area is transitional with the Middle Eocene Kabaköy formation in Hopa-Borçka region (Yılmaz et al., 1997). The apparent thickness of the unit, which has limited outcrops in the study area, is around 100-150 m. However, this thickness can vary between 500-750 m in east of the Hopa district (Yılmaz et al., 1997).

The Early Eocene age was obtained in the fossil determination of the samples collected from the Erenler formation (Table 3). However, Yılmaz et al. (1997) found that the formation was Middle Eocene in age, while Kandemir et al. (2014) found the Late Paleocene-Middle Eocene age for the same formation in east of the study area. Considering previous studies and fossil contents, the Late Paleocene-Middle Eocene age was given to the formation.

Faunal and lithological features indicate that the formation was deposited in a shallow marine and semi-pelagic environment. The sedimentary structures observed in the unit such as flute marks represent the semi-pelagic environment. The formation can be correlated with Erenler and Kaplıca formations (Gedik and Korkmaz, 1987), the lower levels of the Tonya formation (Kurt et al., 2006), one part of the Fındıkbeli formation (Pelin, 1977), Sarp formation (Adamia et al., 1992) and Yedigöze formation (Akdeniz et al., 1994).

Table 3- Fossil findings of the cover units on the Maçka tectonic slice (Cooridantes are UTM ED 1950).

Formation Name	Sample ID on Map (Figure 2b)	Sample Location	Age	Fossils
Erenler	R18	Y: 695484 X: 4569834	Early Eocene	**Nannoplankton**: *Coccolithus crassus* Bramlette and Sullivan, *Ericsonia obruta* Perch-Nielsen, *Fasciculithus tympaniformis* Hay and Mohler, *Sphenolithus radians* Deflandre, *Sphenolithus anarrhopus* Bukry and Bramlette, *Neochiastozygus perfectus* Perch-Nielsen
Kaplıca	R19	Y: 630393 X: 4542704	Ypresian	**Nannoplankton**: *Coccolithus crassus* Bramlette and Sullivan, *Ericsonia obruta* Perch-Nielsen, *Fasciculithus tympaniformis* Hay and Mohler, *Sphenolithus radians* Deflandre, *Sphenolithus anarrhopus* Bukry and Bramlette, *Neochiastozygus perfectus* Perch-Nielsen
	R20	Y: 630396 X: 4542692	Late Ypresian –Early Lutetian	**Nannoplankton**: *Discoaster sublodoensis* Bramlette and Sullivan, *Reticulofenestra dictyoda* (Deflandre), *Discoaster kuepperi* Stradner, *Sphenolithus radians* Deflandre, *Tribrachiatus orthostylus* Shamrai, *Coccolithus crassus* Bramlette and Sullivan, *Calcidiscus protoannulus* (Gartner), *Rhabdosphaera truncata* Bramlette and Sullivan, *Rhabdosphaera tenuis* Bramlette and Sullivan, *Chiasmolithus grandis* (Bramlette and Riedel), *Blackites spinosus* (Deflandre and Fert), *Discoaster lodoensis* Bramlette Riedel, *Rhabdosphaera morionum* (Deflandre), *Lophodolithus nascens* Bramlette and Sullivan, *Neochiastozygus perfectus* Perch-Nielsen, *Pontosphaera multipora* (Kamptner), *Coronocyclus prionion* (Deflandre and Fert), *Imperiaster obscurus* (Martini), *Zygrhablithus bijugatus* (Deflandre), *Toweius? gammation* (Bramlette and Sullivan)
	R21	Y: 630486 X: 4542750	Late Ypresian	*Reticulofenestra dictyoda* (Deflandre), *Coccolithus crassus* Bramlette and Sullivan, *Tribrachiatus orthostylus* Shamrai, *Discoaster binodosus* Martini, *Sphenolithus radians* Deflandre
	R22	Y: 630409 X: 4542652	Ypresian–Lutetian	*Subbotina linaperta* (Finlay), *Subbotina* cf. *triangularis* (White), *Subbotina* sp.,*Acarinina* sp., *Globanomalina* sp., *Morozovella* cf. *subbotinae* (Morozova), *Morozovella* cf. *aragonensis* (Nuttall), *Acarinina* cf. *angulosa* (Bolli), *Acarinina* cf. *primitiva* (Finlay)
	R23	Y: 630000 X: 4542250	Middle Eocene	*Pseudohastigerina micra* (Cole), *Acarinina* cf. *bulbrooki* (Bolli), *Globigerinatheka* sp., *Acarinina* sp., *Morozovella* sp., *Globigerina* sp., *Hantkenina* sp., *Turborotalia* sp., Textularidae, *Nummulites* sp., *Truncorotaloides* sp.

3.2.2. Kaplıca Formation (Tek)

The unit, which consists of Early-Middle Eocene claystone, mudstone, sandstone, clayey limestone and volcanoclastic rocks in the northern part of the Kaçkar Mountains in the study area, was named as the Kaplıca formation by Gedik and Korkmaz (1987). The formation was distinguished and investigated only near the Rize provincial center in the study area.

Figure 10- View of dense sandstone layers observed at the bottom of the Kaplıca formation (Rize province, Kaplıca district, to southeasterly view, F45 d4).

The unit begins to deposit with alternation of sandstone, claystone and limestone, and continues upward in the form of mudstone and clayey limestone interlayers. It then passes in to the Melyat formation with alternating claystone and volcanoclastics in upper layers (Figure 10). The sandstones at the bottom are yellowish beige colored, medium to thick bedded with thicknesses sometimes reaching up to one meter, hard and fragile. Sandstones have greenish-gray colored claystones. The limestones located in intermediate levels are beige-colored, medium bedded and rarely outcrop. The upper levels of the formation consist of greenish, brownish and burgundy colored, thin bedded volcanoclastic, claystone, sandstone and mudstone. The Eocene aged volcanics are more alkaline than the Cretaceous volcanics. However, they sometimes show calc-alkaline characteristics (Gedik et al., 1992).

The Kaplıca formation unconformably overlies the Cankurtaran formation (Figure 3). It is both vertically and laterally transitional with the overlying Early-Middle Eocene Melyat formation. The apparent thickness of the unit varies between 250-300 m.

The fossil determinations of the samples collected from the Kaplıca formation yielded Ypresian, late Ypresian-early Lütetian, late Ypresian and Middle Eocene ages (Table 3), and the age of the formation was given as Early-Middle Eocene. The lithological characteristics and fossil contents of the Kaplıca formation indicate that it was deposited in a shallow marine environment. The formation can be correlated with the Foldere formation of Korkmaz (1993), the lower levels of Tonya formation of Kurt et al. (2006), the Erenler formation of Yılmaz et al. (1997) and with one section of the Fındıkbeli formation of Pelin (1977).

3.2.3. Melyat Formation (Tem)

The unit, which is generally composed of andesitic and basaltic lavas, pyroclastic rocks and sandstone and claystone, was named as the Melyat formation by Gedik and Korkmaz (1987). The formation extends along the slopes facing the seaside in NE-SW directions between Rize city center and the Pazar district in the study area.

The dominant lithology of the formation is andesite, basaltic lavas, tuffs and agglomerates. Rarely, it is possible to find clastics between the volcanic levels. Basaltic and andesitic lavas often show a color change ranging from a som, grayish smoked to a brownish purple. In basalts, there is sometimes observed an alteration from inside towards outside. It is possible to see yellowish, gray altered areas in the outcrops in south of the Çayeli County. Basaltic lavas rarely show columnar and sometimes pillow structures. The clastic layers between the lavas are composed of grayish sandstone, claystone and shales. The apparent thickness of the formation in the study area is between 600 and 700 m.

The formation is laterally and vertically transitional with the Early-Middle Eocene Kaplıca formation at the bottom and unconformably overlain by the Pazar formation (Figure 3). It unconformably overlies the Campanian-Maastrichtian Çayırbağ formation among the Aşıklar, Derinsu, Suçatı and Sivrihisar (F45 c3, c4) villages in south of Çayeli and Pazar districts, and has a fault contact relationship with the Late Santonian-Campanian Çağlayan formation among Pazarköy, Yenihisar and Musadağı villages in Rize province center and south of the Çayeli district (F45 d3, d4).

Paleontological data was not taken from the formation. Radiometric age determinations by Ar/Ar method from andesites in the lower levels of the formation gave the age of 47.8 ± 1.6 Ma (Figure 8b) (HD2, F45 d3, 946000; 4545000). Barbieri et al. (1985) and Akıncı et al. (1991) performed radiometric determination by K/Ar method in seven samples between Trabzon-Arhavi and obtained 45.2 to 54.3 My age. In addition, the Melyat formation is both laterally and vertically transitional with the underlying Early-Middle Eocene Kaplıca formation. Therefore this formation was given the same age.

Aydınçakır and Şen (2013) stated that the similar aged volcanics developed under the post-collisional extensional tectonic regime in their investigation in the vicinity of Borçka to the east of the study area. Considering also the environmental characteristics of the Kaplıca formation, which is transitional both in lateral and vertical directions, it can be said that the formation was formed in the shallow marine conditions. The Melyat formation can be correlated with the Yeşilce formation of Terlemez and Yılmaz (1980) around Ordu, upper part of of the Fındıkbeli formation of Pelin (1977), the Kabaköy formation of Güven 1993) and upper part of the Tonya formation of Kurt et al. (2006).

3.2.4. Pazar Formation (Tmp)

The unit is composed of the intercalations of sandstone, marl, conglomerate and claystone and was named as the Pazar formation by Gedik and Korkmaz (1987). The unit, which has very limited exposures in the study area, is observed only around Çayeli (F45 d3) and Pazar (F45 c1, c2) districts.

The formation begins with the deposition of conglomerate at the bottom then continues upward with sandstone, sandy limestone, marl and claystone (Figure 11). The conglomerates are poorly sorted and mainly of volcanic origin. The claystones are thin bedded and reddish. Sandstone layers are beige, grayish, thin bedded, much macrofossilliferous. Gastropod and lamellibranch shells are widely observed.

The apparent thickness of the formation ranges between 50 and 100 m, and the formation was

Figure 11- View from macrofossilliferous sandstone layers in the Pazar formation (Rize province, Çayeli county, road of Abdullahhoca village, F45 c4).

deposited in shallow marine environment. The formation unconformably overlies the Early-Middle Eocene Melyat formation and unconformably underlies the Plio-Quaternary Hamidiye formation (Figure 3). No fossil assemblage was obtained from the samples in the formation. Abundant quantities of gastropods and lamellibranch shells are observed in the sandstones. However, Özsayar (1980) determined from this formation the microfossil of Elphidium reginum which gave the Early-Middle Miocene age. Due to previous studies and stratigraphic location of the formation the age of the unit was given as Early-Middle Miocene. The Pazar formation can be correlated with the Sarıkum formation defined in the vicinity of Sinop (Sinan, 1959) and the Sinop formation (Gedik and Korkmaz, 1984).

3.2.5. Hamidiye Formation (plQh)

Pliocene units composed of the alternations of conglomerate and sandstone were named as the Hamidiye formation by Gedik and Korkmaz (1987). The unit has very limited exposures in the study area and is well observed along the Ardeşen - Çamlıhemşin crossroad.

The unit, which mainly consists of the alternation of pebbles and sandstones, are thick and cross-bedded in places. Layers have lateral transitions with each other and form lenses. The beds are nearly horizontal. Pebbles are well rounded and well sorted in the formation, which is observed in grayish white color range. Most of the gravels were derived from the underlying volcanic rocks and exhibit well gradation. Conglomerate and sandstone layers forming the formation show lateral transitions in them.

The Hamidiye formation unconformably overlies Pazar, Melyat and Çayırbağ formations in the study area and overlain by the Quaternary forms (Figure 3). The Ardeşen-Çamlıhemşin road cut is a good type section for the formation and its apparent thickness ranges between 40-50 m. The Hamidiye formation must have been deposited in a continental environment characterized by the flood plain.

No fossils for the age determination were found in the formation. Considering the stratigraphic location, the age of the formation was estimated as the Plio-Quaternary. The formation is not widely observed in the region. However, it can be correlated with the units around the Trabzon Airport studied by Uğuz et al. (2011) outside the study area.

3.2.6. Handüzü Volcanics (Tplhd)

These volcanics are composed of basalt, andesite and dacites and were named in this study the first time. The basalt and andesite defined within the Çağırankaya formation in previous studies (Güven, 1993) and crosscutting dacites were investigated as the Handüzü volcanics in this study and the age ranges were re-assessed.

It is understood from the studies of Ağar (1977) that the unit of which its exposures are observed in the Han yayla (valley) (G45 a2), Kafkuma yayla and the south of Büyük yayla had also distributions around Trabzon.

In the lowermost part of the volcanics, the basalts, andesites and rarely observed crosscutting dacites are seen (Figure 12). In the Han valley, the pinkish red and occasionally grayish basalt and andesitic sections with flow structures are present. Whereas the domal type, grayish dacitic sections are observed in the southern part other valley. The apparent thickness of the Handüzü volcanics is about 150-200 m.

The Handüzü volcanics show characteristics varying from basic to acidic, and are considered to have been exposed through cracks and fractures. This volcanics are above the Çatak formation and the Kaçkar granitoid I and there was not observed any unit in the upper contact. The radiometric dating of dacites from volcanics was estimated as 3.93 ± 0.46 My (VB1, G45 a3, 643650; 4519250) and 4,25 ± 0,55 My (VB2, G45 a2, 638750,4527250) based on the Ar/Ar method (Figure 8c, d) and the age of Handüzü volcanics was

Figure 12- View from dacites in the Handüzü volcanics (Rize province, İkizdere county, southeast of Büyükyayla, southward view G45 a3).

Figure 13- View from obsidians within the Çağırankaya volcanics (Rize province, İkizdere county, southwest of Büyükyayla, G45 a3).

evaluated as Pliocene. This unit can be correlated with the Çağırankaya formation of Güven (1993).

3.2.7. Çağırankaya Volcanics (Qç)

The volcanics composed of rhyolite, rhyodacite, dacite, obsidian and ignimbrites were redefined in this study and investigated under the name of Çağırankaya volcanics. Güven (1993) in his study defined the unit under the name of Çağırankaya volcanics including also the basic volcanics (Handüzü volcanics) located in the lower part. The Çağırankaya volcanics give outcrops throught the fracture and crack systems around the Büyük yayla (G45 a3; figure 2b).

The Çağırankaya volcanics are of an acidic volcanic product and consist of rhyolite, rhyodacite, dacite, ignimbrite and obsidian (Figure 13). Rhyolite and dacites are in banded flowing structure. The obsidians, which are seen as hillocks, alternate with rhyolites in places. Rhyolites and dacites are whitish gray and obsidians are black, brownish red, red, black banded and somewhat mottled, and exhibit columnar and brecciated views. The apparent thickness of the Çağırankaya volcanics is about 75-100 m, and overlie the Çatak formation, Handüzü volcanics and the Kaçkar granitoid I.

There was not detected any age from the volcanics. However, Hanedan (2008) performed the radiometric dating to obsidians in the Çağırankaya volcanics by using Ar/Ar method and determined their ages as ranging between 1.7 My and 2 My and gave the Quaternary age to the unit. The age of the Çağırankaya volcanics was evaluated as Quaternary also in this study. The Çağırankaya volcanics can be correlated with the Çağırankaya formation of Güven (1993) and the Büyükyayla obsidian of Hanedan (2008).

3.3. Taşköprü Tectonic Slice

The Turonian - Maastrichtian Yağmurdere formation section consisting of the basic volcanic and clastic-carbonate interlayers outside the study area of the slice, which is formed by the clastic, carbonate and volcanogenic rocks between Paleocene-Maastrichtian age intervals, is observed (Figure 14). This formation is unconformably overlain by the Early-Middle Eocene Yedigöze and Çoruh formations. The Kaçkar granitoid I and the Yağmurdere formation are in contact with each other. The Güllübağ monzonite is in contact with the Early-Middle Eocene units, which are the cover rocks of the Taşköprü tectonic slice, and is in Late Eocene age (Figure 14). It is possible to correlate the Taşköprü tectonic slice with the Kadırga tectonic slice of Uğuz et al. (2011).

3.3.1. Yağmurdere Formation (Ky)

The Turonian-Maastrichtian unit, which consists of basalt, andesite, lava, pyroclastics, micritic limestone, sandstone and claystone, was named as the Yağmurdere formation by Duygu et al. (2013). It is possible to see the widespread exposures of the formation on the southern slopes of the Kaçkar Mountains, on the Ovit mountain section of the İkizdere-İspir road (G45 c4),

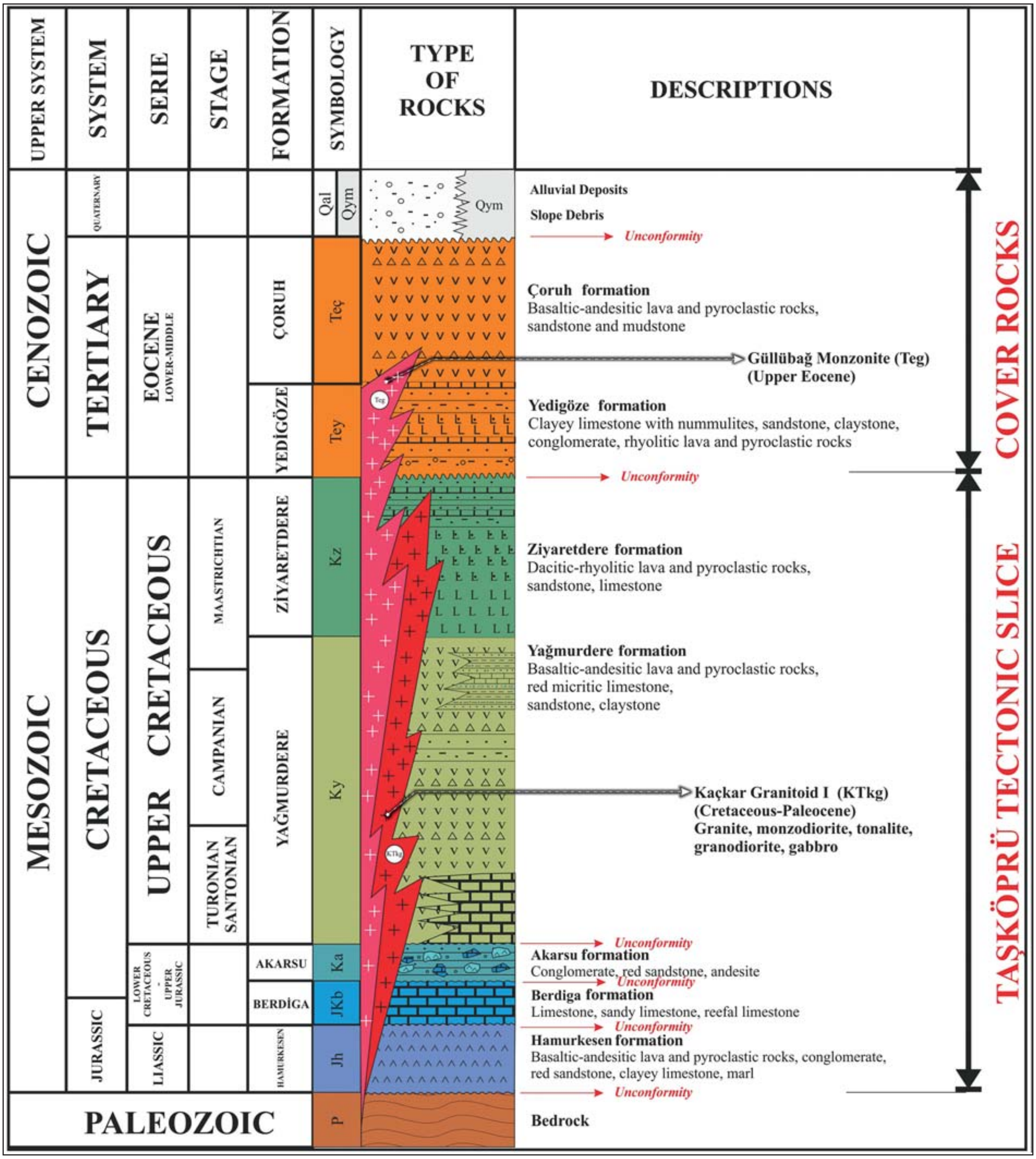

Figure 14- Generalized stratigraphic section of the Taşköprü tectonic slice and cover rocks (Duygu et al., 2013).

in the vicinity of the Orso Mountain (G45 d4) and the Karaduman Mountain, between the Büyükdere village and the Abros Yayla (valley) (G45 d3), between the Moryayla village (G45 c3) and the Tetos Mountain (G45 c2).

With the sedimentary deposits generally formed by basalt, andesite, pyroclastic, limestone, sandstone and claystone in the formation and the alternating basalts in places are grayish black and green colored and have pillow structures in occasion. Andesites are grayish-green, hard, brittle and massive in appearance. Pyroclastic rocks are grayish, greenish, very thick and massive. These volcanic levels consist of grayish, green and burgundy sandstone, claystone and micritic limestone layers. The micritic limestones are burgundy and thin to medium bedded, whereas the sandstone and claystones are thin bedded. The topography, in which basalt and andesitic lavas are present, is in the form of steep cliffs.

The formation unconformably overlies the Akarsu formation outside the study area. It has crosscutting relationship with the Kaçkar granitoid I in the area. The formation is unconformably overlain by the Early-Middle Eocene Yedigöze and Çoruh formations, which are laterally and vertically transitional with each other (Figure 14). The apparent thickness of the formation in the study area is between 750 and 800 m around the Büyükdere village.

The age of Yağmurdere formation determined as Turonian-Maastrichtian according to fossil determination (Table 3) of the samples taken from the near north of the Ulutaş village. Uğuz et al. (2011) obtained the Cenomanian age from the units that can be correlated with this formation in the investigation carried out to the west of the study area. Duygu et al. (2013) made detailed paleontological studies from widespread carbonates in the western part of the same unit. The authors' found ages as Turonian-Santonian in samples collected from the Karameşe locality (G43 c2) in east of the Çatak valley; as Campanian-Maastrichtian in samples taken from the upper levels of the unit in the vicinity of the Aytaş village (Table 4) . Depending on all these data, they suggested the age of the Yağmurdere formation as ranging between Turonian-Maastrichtian. Considering the stratigraphic position and the data given above, the age of the unit was suggested as Turonian-Maastrichtian.

The existence of turbiditic and pelagic sediments intercalating with volcanic rocks and faunal assemblage indicate that the formation may have been deposited in slope environments where the basic volcanism is effective. The Yağmurdere formation can be correlated with the Çatak and Çağlayan formations of Güven (1993) and the Esiroğlu and Ayeserdere formations of Uğuz and others (2011).

3.4. The Cover Units on the Taşköprü Tectonic Slice

3.4.1. Yedigöze Formation (Tey)

The unit mainly consists of limestone, sandstone, claystone, conglomerate, rhyolitic lava and pyroclastic rocks and is defined by Akdeniz et al. (1994) as the Yedigöze formation. The units belonging to the formation can be seen around Moryayla, Ulutaş villages and Vank valley (G45 c3) in the study area (Figure 2b).

The unit is represented with conglomerate at the bottom then passes into yellowish beige, greenish-brown, fine to medium bedded limestone, sandstone and claystone alternation (Figures 15 and 16). Among these marine facies; white, whitish green rhyolites and

Table 4- Fossil findings both of the units belonging to Taşköprü tectonic slice and its cover units ([1] and [2] taken from Duygu et al., 2013; [3] Uğuz et al., 2011, Coordiantes are UTM ED 1950).

Formation Name	Sample ID on Map (Figure 2b)	Sample Location	Age	Fossils
Yağmurdere	R24	Y: 659000 X: 4496700	Turonian-Maastrichtian	Globotruncanidae, *Globigerinelloides* sp.
		[1]Çatak plateau, Karameşe avenue	Turonian–Santonian	*Marginotruncana coronata* Bolli, *Marginotruncana renzi* (Gandolfi), *Marginotruncana pseudollinneiana* Pessegno, *Marginotruncana* sp., *Dicerinella* sp.
		[2]Aytaş village	Campanian–Maastrichtian?	*Globutruncana arca* (Cushman), *Globutruncana* cf. *linneiana* (d'Orbigny), *Globutruncana bulloides* Vogler, *Stomiosphaera sphaerica* (Kaufmann), *Marginotruncana* sp., *Globigerinelloides* sp., *Heterohelix* sp
Yedigöze	R25	Y: 662650 X: 4493500	Middle Eocene (probably Bartonian)	Globotruncanidae, *Globigerinelloides* sp.
		[3]Yazlık village (Aydıntepe-Bayburt)	Early Eocene	*Discocyclina* sp., *Asterocyclina* sp., *Nummulites* sp., *Lockhartia* sp., *Sphaerogypsina* sp., *Rotalia* sp., Gypsinidae, Rotaliidae, Textularidae, Miliolidae, Algae, Bryozoa

ignimbrites are observed. These levels continue in the lateral direction as clastic carbonate facies. Very large nummulites are encountered in the nodular limestones on conglomerates. The apparent thickness of the formation in the study area is between 100 and 150 m.

The Yedigöze formation unconformably overlies the Kaçkar granitoid I and Yağmurdere formation in the study area. It is both laterally and vertically transitional with the overlying same aged Çoruh formation (Figure 14). The lower layers of the Çoruh formation are distinguished from the Yedigöze formation with purple andesites and clastic alternations.

The Middle Eocene (Bartonian ?) age was obtained from fossil determination of samples taken in the study area, and Early Eocene age was obtained from fossil determination of the samples (Table 4) taken by Uğuz et al. (2011) from westward extension of the Yedigöze formation in outside of the study area (Yazlık village, Aydıntepe county, Bayburt province), Thus the Yedigöze formation was aged as the Early-Middle Eocene.

The formation should have been deposited in a shallow marine environment ranging from the terrestrial environment, where red conglomerates are deposited, to the tidal environment where the energy occasionally falls and rises. The Yedigöze formation can be correlated with the Eocene volcanic flysch of Yalçınlar (1952) and the Nişantaşı member of Yazyurdu formation of Keskin et al. (1989).

Figure 15- View from conglomerates observed at the bottom of the Yedigöze formation (Erzurum province, İspir county, east of the Ulutaş village, G45 c3).

Figure 16- View of the nummulitic limestones belonging to the Yedigöze formation (Erzurum province, İspir county, east of the Ulutaş village, G45 c3).

3.4.2. Çoruh Formation (Teç)

The unit, which its lower layers are composed of the alternation of clastic and basalt, and lower layers are composed of basalt, andesite and pyroclastic rocks, was described by Akdeniz et al. (1994) as the Çoruh formation. The formation widely outcrops in the southern part of the study area, along the eastern and western lines on the southern slopes of the Kaçkar Mountains and in the vicinity of the Kemer Mountain, Akdağ (G45 d4), Taşlıyayla, Güneydere (G45 c3), Kızıldağ (G45 c4, d3), Soğuksu (G45 c4), Özlüce, Çayırözü and Kaynakbaşı villages (Figure 2b; G45 c3).

The grayish green, purple and sometimes pinkish gray colored unit begins to deposit at the bottom with clastics then transitionally passes into grayish purple and pink andesitic lavas with pyroclastics in the upper layers (Figure 17). Lava fragments are commonly observed in pyroclastics. The succession continues upward in the form of purple basalt, andesite, tuff, agglomerate and red mudstone. Sandstones are dirty white to gray in color and thin to medium bedded. Lavas are dominant at the topmost layers of the succession. Basalts are red to smoke colored, gas-filled with pillow structures occasionally. Andesites are in the form of blue layers between gray, bluish-gray, purple clastics and pyroclastics. Tuffs are in the form of whitish gray, purple colored, disintegrated crystal and lithic. In the alteration zones where the vein or semi-plutonic rocks intrude in the form of dikes along cracks and fractures, a considerable amount of pyrite is encountered and these areas are important in terms of mineralization.

Figure 17- View from lavas and pyroclastics located in the Çoruh formation which show alternation with clastics (Erzurum province, Pazaryolu county, west of the Çaydere village, southward view G45 d3).

In the study area, it is both laterally and vertically transitional with the same aged Yedigöze formation under the Çoruh formation (Figure 14). Besides, it unconformably overlies the Kaçkar granitoid I without having the Yedigöze formation in lateral direction. The Late Eocene Güllübağ monzonite in south of Özlüce and Yukarı (Upper) Fındıklı villages in G45c3 sheet (Figure 2b) cuts the Çoruh formation.

The fossil content could not be detected in the Çoruh formation. However, the age of the formation was considered to be Early-Middle Eocene as the stratigraphic position and the age of the Yedigöze formation is Early-Middle Eocene.

The apparent thickness of the Çoruh formation is more than 1000 m, and is the last phase products of the arc volcanism corresponding to the calc-alkaline and alkaline subduction zone (Tokel, 1973). The formation can be correlated with the Yazyurdu formation of Keskin et al. (1989) and the Kabaköy formation defined by Güven (1993) which covers the Early-Mid Early Eocene volcanic units in the study area.

3.5. Plutonic Rocks

3.5.1. Kaçkar Granitoid I (KTkg)

Granitoids, which cut a part of the Late Cretaceous units and are transgressively covered by the Early-Middle Eocene units, are called as the Kaçkar granitoid I by Güven (1998). It is possible to see the widespread outcrops of the Kaçkar granitoid I (G45 a3, a4, b4, c1, c2 and d series) on Kaçkar Mountains extending in SW-NE directions from the south of the İkizdere District in the study area. The exposures belonging to these granitoids are well observed along the road that runs from İkizdere district (Rize) to İspir district (Figure 2b; Erzurum).

The Kaçkar granitoid I is observed as greenish, greyish beige and pink colored, compact, in massive structure and arenized in most places. In general, the Kaçkar granitoid I consist of granite, granodiorite, diorite, tonalite and monzonite. The granitoids consisting of granite and monzonite are beige to pink colored, and have large visible orthoclase grains. Alkaline feldspar granites are mostly light greenish and grayish in color. It is possible to encounter the enclaves in the rocks of the Kaçkar granitoid I. The gabbro is greenish-gray in color and macroscopically has granular texture.

Lithologies belonging to the Cretaceous-Paleocene Kaçkar granitoid I, one section of the Late Jurassic-Early Cretaceous, the Late Cretaceous sedimentary and volcanic rocks (Berdiga and Çatak formations) have cross cutting relationship. It is unconformably overlain by the Early-Middle Eocene units in the upper contact (Figure 3). It outcrops as magmatic complex on large areas along the ascension of Kaçkar Mountains.

The Campanian age with 80.7 My by Taner (1977), the Late Cretaceous and Paleocene age by Boztuğ et al. (2001, 2006), the Campanian age with 79 My by Karslı et al. (2010*a*) (Harşit pluton) in similar units and the Campanian age with 80 my by Evcimen et al. (2013) were taken from the areas corresponding to the Kaçkar granitoid I. Therefore; when field observations of the Kaçkar granitoid I and the radiometric age data was considered, the Cretaceous-Paleocene age was given to the Kaçkar granitoid.

The rocks of the Kaçkar granitoid I are the; I-type granitoids formed by the northward subduction of the oceanic crust of Neotethys beneath the Pontide continent (Gedik et al., 1992, Yılmaz and Boztuğ, 1996, Okan and Şahintürk, 1997; Okay and Tüysüz, 1997; Boztuğ et al., 2006; Karslı et al., 2007, 2010*a*, 2010*b*).The units of the Kaçkar granitoid I can be correlated with the Harşit pluton located at east of the study area (Karslı et al., 2010*a*), the Kaçkar batholith (Altınlı, 1970), Ayder, Ortaköy, Kaptanpaşa plutons

(Gedik et al., 1992), one part of the Composite Kaçkar batholith (Boztuğ et al., 2001, 2006) and the Rize granite (Çoğulu, 1970).

3.5.2. Kaçkar Granitoyid II (Tekg)

The Eocene intrusive rocks in the Kaçkar Mountains were described by Güven (1998) as the Kaçkar granitoid II. The granitoids observed in the vicinity of Güneysu, Hemşin, Ardeşen, Fındıklı districts, which are composed of tonalite, granite, diorite, granodiorite, gabbro and gabroporphyry were investigated under the name of Kaçkar granitoid II in this study too. The units belonging to the Kaçkar granitoid II outcrop mostly at lower elevations on the north-facing slopes of Kaçkar Mountains (Figure 2b). The gabbro in south of the Kurtuluş village (F46 d1), the granite on the road of Ardeşen-Çamlıhemşin and in Hemşin, and the gabbro porphyries on the road to Derinsu and Erenler villages from the Pazar district (F45 c4) in the Çayırbağ formation are well observed in small outcrops (Figure 2b) which cannot be mapped. Granodiorite and diorite are well observed in south of Fındıklı and Arhavi districts (F46 c1, d2) and in the near south of Güngören, Taşköprü and Söğütözü districts (Figure 2b).

When looking at the nomenclatures and mineral associations of rocks of the Kaçkar granitoid II, there is not observed much difference than the Kaçkar granitoid I. The rocks in the petrographic descriptions of the Kaçkar granitoid II are granite, tonalite, diorite, gabbro and gabbro porphyry (Figure 18). The enclaves are also seen in all these rocks. The surface colors are mostly blackish in gabbroic rocks, greenish gray in granites, and greenish gray and black in diorites, and they have very hard and compact appearance. The fractured structure is well developed in gabbroic rocks.

Figure 18- View from the gabbro porphyry belonging to the Kaçkar granitoid II intruded in the rocks of the Campanian-Maastrichtian Çayırbağ formation (Rize province, Pazar county, north of Derinsu village, northward view, F45 c3).

The Kaçkar granitoid II has generally crosscutting relationship with the Late Cretaceous units. The porphyritic units of granitoid is intruded the Ipresian levels of the Erenler formation only in one locality (southwest of the Arılı village). The intrusions in south of Ardeşen, Fındıklı and Arhavi in units of the Kaçkar granitoid II are observed in the form of crosscutting relationship with Çağlayan, Çayırbağ and Cankurtaran formations (Figure 3).

The units of the Kaçkar granitoid II have crosscutting relationship with the Late Santonian, Campanian, Maastrichtian, Danian and Ipresian units in different areas. According to the radiometric dating for the samples taken from the gabbro porphyries intruded into the Çayırbağ formation the Ipresian age (50,5±0,8 My) was detected using the Ar/Ar method. In addition, Boztuğ et al. (2001, 2006) reported that the units belonging to the Kaçkar granitoid II were of the Eocene age. Evcimen et al. (2013) obtained 43,81 My age based on radiometric dating from the sample they collected in these units. The age of the unit was given as the Eocene by Keskin (2013) and younger than Eocene by Kahraman et al. (1987).

Both the data regarding the age and boundary relationships and the interpretations for the geodynamic evolution show that the units of the Kaçkar granitoid II indicate the continuous plutonism from Early Eocene to the beginning of Late Eocene. The rocks of the Kaçkar granitoid II form the post collisional products (Okay and Tüysüz, 1999, Topuz and others 2005, 2011, Karslı et al., 2007, 2010*a*, 2010*b*, 2011). These granitoids can be correlated with Asniyor leucogranite, Ayder granitoid and the Samistal microgranite of Boztuğ et al. (2001, 2006), the Tertiary granitoid of Evcimen et al. (2013) which they investigated under the name of the Kaçkar batholith and with one section of the Harşit pluton of Karslı et al. (2010*a*).

3.5.3. Güllübağ Monzonite (Teg)

Monzonites located in the north of İspir district (Erzurum) towrads the south of the Kaçkar Mountains were defined by Boztuğ et al. (2001, 2006) under the name of Güllübağ monzonite. It is possible to observe the outcrops in the south of Özlüce and Yukarı Fındıklı villages (G45 c3) in the study area (Figure 2b).

Güllübağ monzonites are magmatic rocks which intruded into the Early-Middle Eocene rocks (Figure 14) in the form of stocks and dykes (Boztuğ et al., 2001, 2006). It is grayish pink, massive and somewhat altered and arenitized. It is composed of plagioclase, orthoclase, amphibole, augite and biotite and is typical with its porphyritic texture.

The Güllübağ monzonite is observed in the form of stocks and dykes in the study area. It has crosscutting relationship with the Early-Middle Eocene lithologies (Boztuğ et al., 2001, 2006). There was not observed any unit overlying this intrusion in the study area.

Boztuğ et al. (2001, 2006) detected that these units were of Late Eocene in age by using the radiometric dating. The Güllübağ monzonite was accepted as Late Eocene in this study. The Güllübağ monzonite expresses the opening environment which formed due to the gravitational collapse of the thickening crust after collision in the Late Eocene (Boztuğ et al., 2001, 2006).

The Güllübağ monzonite has been investigated in many studies under the name of Kaçkar batholith. In terms of indicating that it corresponds to the opening in geodynamic evolution (Boztuğ et al., 2001, 2006) it was deemed appropriate to introduce this monzonite with a different name than Kaçkar granitoids in this study.

3.5.4. Ardeşen Gabbro (Tea)

The greenish black Late Eocene gabbro, which outcrops in a narrow area to the south of the Ardeşen district in the study area, was defined by Boztuğ et al. (2001, 2006) as the Ardeşen gabbro. Ardeşen gabbro is greenish black, occasionally fractured and massive in appearance and intruded into the Campanian-Maastrichtian Çayırbağ formation (Figure 3) in the form of stocks and veins. Based on radiometric dating the age of the Ardeşen gabbro was determined by Boztuğ et al. (2001, 2006) as the Late Eocene. The Ardeşen gabbro was intruded due to the gravitational collapses of the thickening crust during the collision in the Late Eocene (Boztuğ et al., 2001, 2006).

3.6. Quaternary Units

Quaternary units observed in the study area are mainly alluvial, terrace and slope debris. Terraces (Qt) are often observed in suspended river beds. The slope debris (Qym) develops on the hill slopes of intensive faults which developed by the effect of tectonism in the study area and steep slopes. The alluvial (Qal) is formed along river beds formed by the rivers flowing to the black Sea.

4. Geodynamic Evolution

There are different opinions about the subduction in the Eastern Pontides where the study area is located. A group of researchers suggested that the lithosphere belonging to Paleotethys subducted northward beneath the Pontides starting from Paleozoic to Eocene (Adamia et al., 1977; Tokel, 1981; Ustaömer and Robertson, 1996; Rice et al., 2009; Dilek et al., 2010). There have also been reports on the formation of the Eastern Pontide magmatic arc by the northern subduction of the northern branch of Neotethys beneath the Sakarya continent in Cretaceous (Şengör and Yılmaz, 1981; Okay, 1989; Okay and Şahintürk, 1997; Yılmaz et al., 1997; 2003, Şengör et al., 2003). According to another view, the lithosphere belonging to Paleotethys has been subducted from north to south under the Eastern Pontides in Paleozoic-Eocene interval (Dewey et al., 1973; Bektaş et al., 1999; Eyüboğlu et al., 2007). The most commonly accepted opinion with controversy is that the northern branch of Neotethys subducted northward benath the Eastern Pontides through Cretaceous period and formed the arc magmatism in Late Cretaceous.

The basement of the Eastern Pontides, which is also included in the study area, is formed by the Devonian-Early Carboniferous Pulur metamorphic rocks and Carboniferous Gümüşhane granodiorites. The Pulur metamorphic rocks are unconformably overlain by the Late Carboniferous-Early Permian clastic carbonate deposits. The presence of Liassic deposits and the absence of Triassic deposits with a transgression after the Early Permian caused this period to be interpreted as terrestrial. The presence of transgression in Liassic is expressed by the opening of the northern branch of Neotethys and accordingly; the clastic and carbonated sediments have been deposited in the environment deepening starting from Liassic (Görür et al., 1983; Şengör and Yılmaz, 1981; 1983; Yılmaz, 1995; Bektaş et al., 1987). However, the presence of the Late Triassic age determined based on the fossils collected from the İzmir-Ankara-Erzincan Zone, which is considered to have been opened in Liassic as the northern branch of Neotethys (Uğuz et al., 1999; Tekin et al., 2002), the presence of the Middle-Late Triassic volcanic seamounts in OIB (Oceanic Island Basalts) character and the Late Permian metamorphism in basic rocks belonging to the oceanic crust of the Ankara mélange (Sarıfakıoğlu et al., 2011; 2014) in basal rocks of the oceanic crust within the Ankara melange have made all these claims contradictory.

In this study, geodnamic evolution model of the region comprising between the Turonian and Middle Eocene range is presented (Figure 19). This model was depicted by evaluating of the data both obtained at this study and at literature. The environment to become continental in the Early Cretaceous then the subduction of the Neotethys oceanic lithosphere beneath the Pontide have initiated a new transgression and caused the deposition of a Turonian-Maastrichtian volcanic succession (Figure 19a). The late Maastrichtian-Danian Cankurtaran formation in the study area was formed in an environment where the activity of the arc volcanism had continued and the back arc basin had begun to develop (Figure 19b). The Yağmurdere formation belonging to the Taşköprü tectonic slice should be the product of the environment where the arc volcanism has been partially effective relatively in the character of axial sediments in the arc and the southern face of the arc volcanism (Figures18 b, c). The lack of volcanic activity in southern areas outside the study area reinforces this idea. The continent to continent collision has occurred starting from the Late Paleocene by the depletion of the Mesozoic ocean during Cretaceous. In the close southern parts of the study area the Danian depositions should have probably been subjected to pre Early Eocene erosion while the Danian deposition has been detected in the study area and the close vicinity of the back arc region. The pebbles of the outcropping granitoid rocks (Kaçkar granitoid I) are observed at the bottom of the Early-Middle Eocene units. The age of the Maçka tectonic slice range until Danian before Eocene. The first pre Eocene age is the Maastrichtian obtained from the Taşköprü tectonic slice which is observed below the thrust contact outside the study area. The absence of Paleocene can be explained by the fact that while the sedimentation was continued in Danian in the Maçka tectonic slice before the thrust, at that time the area where the Taşköprü tectonic slice is located is in the land. After Danian, the Maçka tectonic slice should probably have thrusted on the Taşköprü tectonic slice during the pre-Late Paleocene period (Figure 19c). The disappearance of these traces and being erased by the overlying Kaçkar granitoid I in the study area, the observation of the gravels of these granitoids at the bottom of the Early-Middle Eocene can be explained in such a way that the units of the Kaçkar granitoid I outcropped and was eroded probably in late Thanethian period.

By the exposure of units of the Kaçkar granitoid I in the study area, the Kaçkar Mountains separated the region as the form of ridge in pre Early-Middle Eocene as north, south and east. Thus, Erenler in the east, Kaplıca and Melyat in the north, and Yedigöze and Çoruh formations in the south were deposited (Figure 19 d). It is possible to see the continental deposits in the same period in the near south of the Kaçkar mountains highs while the marine deposits are observed in the north in Miocene. During Pliocene and Quaternary periods, the Handüzü and Çağırankaya volcanoes were formed under the control of the E - W extending joint and fracture systems. The lithologies of the Plio-Quaternary units and their appearance as coarse pebbles in the region indicate that the uplift continued in this time.

5. Conclusions

The results of this study covering the area of approximately 4200 km^2 between the east and south of Rize, Çayeli, Arhavi, İspir and İkizdere in Eastern Black Sea Region are presented below.

1. In the study area, the first detailed stratigraphy compatible geological mapping was made for 1/25000 scaled 29 sheets (F45 c1, c2, c3, c4, d3, d4, G45 a1, a2, a3, a4, b1, b2, b3, b4, c1, c2, c3, d2, d3, d4, F46 a3, b4, c1, d1, d2, d3, d4).

2. The Kızılkaya formation, which includes Kuroko-type Cu deposits commonly observed in Eastern Pontides, is confused with Çayırbağ formation containing similar lithologies. This confusion is removed by (i) a clear definition of the stratigraphic location of the Çağlayan formation consisting of volcanosedimentary deposits dominated by basic volcanics between both formations and (ii) re-evaluation the age of Çayırbağ formation as Kampanian - Maastrichtian according to 83.2 ± 1.0 My (Ar / Ar method) radiometric age obtained first time at this study and fossil descriptions.

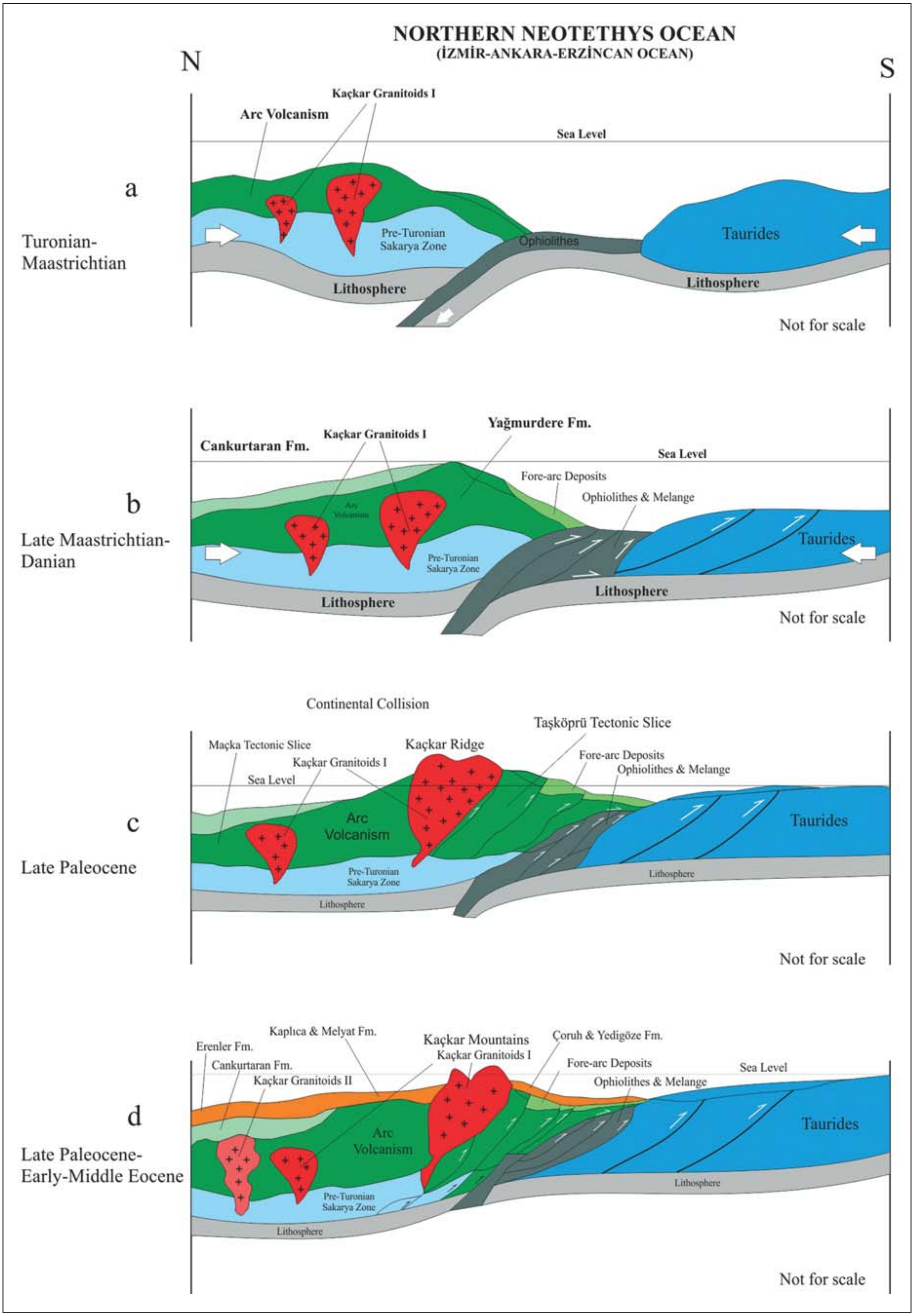

Figure 19- Model sections showing the regional tectonic evolution of the Eastern Pontides between Late Cretaceous and Early-Middle Eocene.

3. Within the scope of this study, it was observed that the products of arc volcanism in the Maçka tectonic slice were more dominant than the Taşköprü tectonic slice. The contact relation of both tectonic slice which is stated as tectonic in outside of study area in Çankaya village (Araklı-Trabzon) by Duygu et al., (2013) disappeared with the rise of Kaçkar granitoid I in Late Paleocene.

4. The extend of the granitoid rocks which are defined in restricted area by Boztuğ et al. (2001, 2006) named as (i) Cretaceous-Paleocene aged Kaçkar granitoid I product of arc magmatism, (ii) Eocene aged Kaçkar granitoid II product of collision, and (iii) Late Eocene aged Güllübağ monzonit and Ardeşen gabbro product of extentional were mapped for the first time in the study area.

5. It has been determined that the deposition of the Cankurtaran formation, which has been reported to have deposited in back-arc basin in Campanian to the east of the study area (Kandemir et al., 2014), have started in Maastrichtian.

6. It has been determined that the Early-Middle Eocene deposits in and around the study area were developed in three different areas. With the beginning of the continent to continent collision in the Late Paleocene, the units of Kaçkar granitoid I were uplifted in this part of the Eastern Pontides and formed a ridge dipping eastward (Hopa-Borçka) in NE-SW direction. The Eocene sediments should be deposited in the form of two branches in different area in the Eocene sea, most likely started to move in Late Paleocene from east to west. Late Paleocene and Eocene sediments were formed by showing small differences between each others, and these units were defined in the study area as Kaplıca, Melyat, Çoruh,Yedigöze and Erenler formations.

7. The ages of the units belonging to between Late Cretaceous and Eocene were re-assessed on the basis of detailed paleontological data. In addition, it was determined by radiometric datings (^{40}Ar / ^{39}Ar) that the age of Çayırbağ formation is Campanian (83.2 ± 1.0 Ma), the age of Melyat formation is Lutetian (47.8 ± 1.6 Ma) and the age of Handüzü volcanics are Pliocene (andesite, 55 Ma; dacite, for example, 3.93 ± 0.46 Ma).

8. According to ages obtained from the arc volcanism and clastic and carbonates of Late Cretaceous, its concluded that the volcanic products of (i) first basic stage are located in the Çatak formation, (ii) first asidic stage are located in the Kızılkaya formation, (iii) second basic stage are located in the Çağlayan formation, and (iv) second asidic stage are located in the Çayırbağ formation. Especially, determination of the stratigraphic relations of these Late Cretaceous volcanic rocks will also contribute to the exploration of Kuroko-type deposits in the region.

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