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UPPER CRETACEOUS-TERTIARY GEOLOGY/STRATIGRAPHY OF PERTEK AND ITS VICINITY (TUNCELİ, TURKEY)

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Research Article

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ABSTRACT

The basement units of the study area are Paleozoic-Mesozoic Keban metamorphics and Late Cretaceous Elazığ magmatics. As a result of tectonic events caused by final collision in Middle Maastrichtian, all these basement units were juxtaposed, uplifted, eroded and acted as a source area for the Maastrichtian-Paleogene basins. Upper Cretaceous-Paleogene deposits were systematically sampled in order to determine their ages and lithologies. Due to new age findings and stratigraphical positions the marine units were identified as; Harami, Seske and Kırkgeçit formations. Late Oligocene-Early Miocene Alibonca formation and Pliocene Karabakır formation are the other units of the study area. Maastrichtian-Thanetian Harami formation is formed by grainstone intercalated with sandstone at the bottom and white limestone at the top. Early Lutetian Seske formation consists of conglomerate at the bottom and much nummulitic, carbonate cemented sandstone with ophiolitic fragments at the top. Kırkgeçit formation consists of sandstone-siltstone-limestone intercalation, and it is early Bartonian-early Chattian. Late Chattian-middle Burdigalian Alibonca formation consists of conglomerate at the bottom, reefal limestone in the middle and clayey limestone intercalated with algal limestone at the top. Pliocene Karabakır formation is formed by conglomerate-mudstone and locally by intercalations of pyroclastics and lavas. Pertek Andesite and Basalt Members are both vertically and laterally transitional with sedimentary lithologies of the Karabakır formation. There is no data to date the lithology; however, it was assumed that it had been Pliocene in age according to the lithostratigraphical succession. In the study area, macrotectonic events were experienced in Late Cretaceous, Early Eocene, middle-late Lutetian, Middle?-Late Miocene and in the Latest Pliocene. During the last tectonic phase, the Anatolian plate bounded by the East Anatolian Fault (EAF) in E-SE began to move westward, and the right lateral strike slip Pertek Fault activated in the study area.

1.Introduction

This study was initiated in order to prepare Elazığ K42 sheet in 1/100.000 scale. Although; c-d sheets in 1/25.000 scale consisting the southern part of K42 sheet have been studied by Herece et al. (1992), a-b sheets forming the northern part have not been studied at all. To prepare the geological maps and define the geological units of the non-investigated areas, short term field studies were carried out in the region. Within scope of the study; first 1/35 000 scale aerial photos of the region were investigated in the office; discriminated geological units were transferred on to map then checked on the field. In the study; Keban metamorphics and Elazığ magmatics, which are the basement units of the region and the unconformably overlying Tertiary units were distinguished. In order to determine the rock types of Elazığ magmatics and stratigraphical relationships and ages in Tertiary units, the basin deposits were collected from bottom to top in systematically. Rock types in the Elazığ magmatics were distinguished based on petrographical descriptions. The age intervals of the formations were determined following the paleontological studies, and the units were defined based on formational nomenclature in the region and their surrounding (Figures 1 and 2).

Preliminary studies were carried out in the region which were started in 1940’s and the regional geology and stratigraphy in wide areas were investigated (Ketin, 1946; Tolun, 1955; Altınlı, 1966). Later on; the allochthonous units cropping out along the belt, Yüksekova complex (Perinçek, 1979), Keban metamorphics (Özgül, 1976; Kipman, 1976, 1981; Yazgan, 1981, 1983, 1984; Özgül and Turşucu, 1984) and Baskil magmatics (Asutay, 1988) have been studied in the following years. The sedimentary outcrops around Pertek, Yüksekova complex (Bingöl, 1984) and Cretaceous volcanics and ophiolitic rocks

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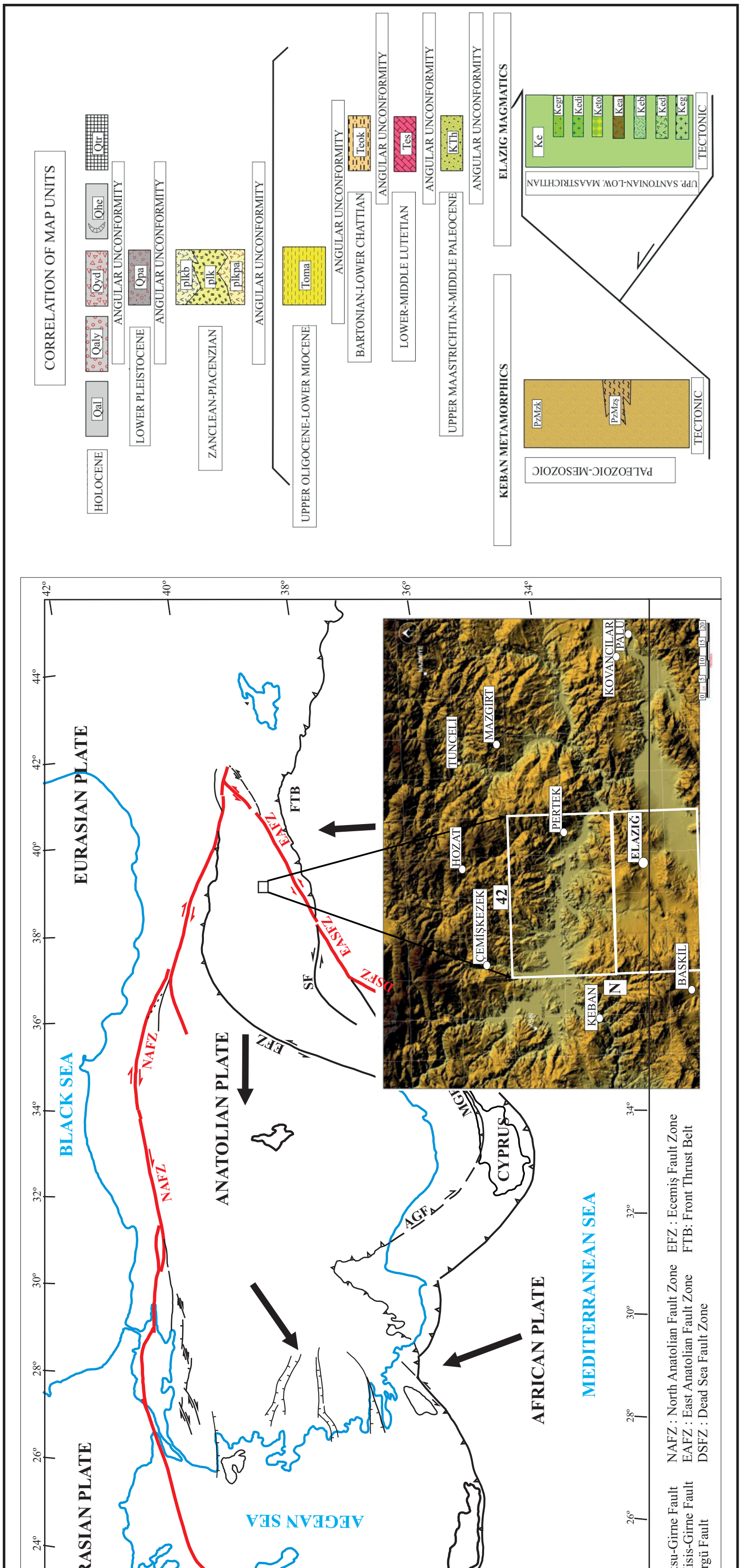


Figure 1- Location of the study area and the explanation of distinguished geological units (Herece, 2016).

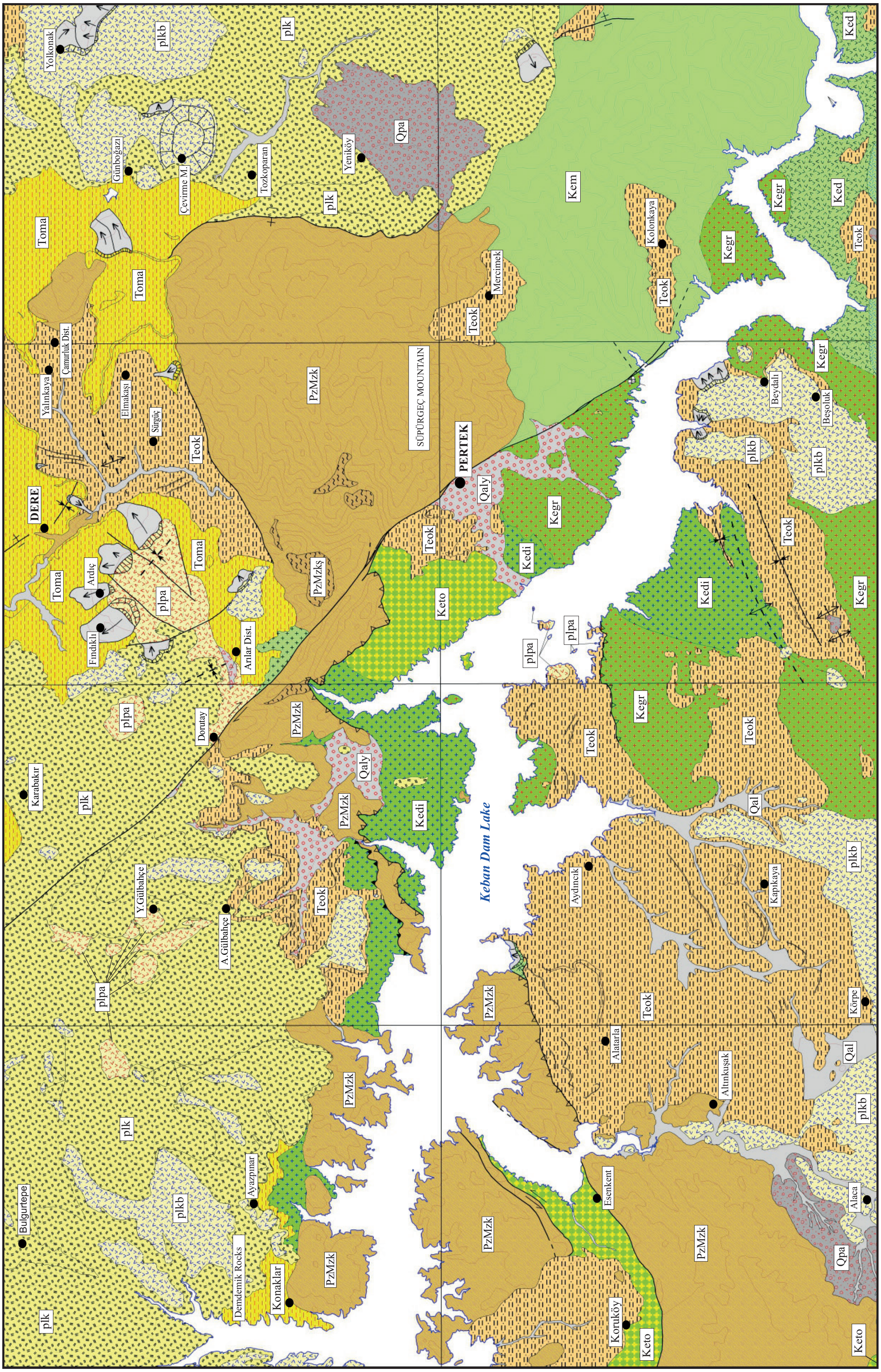


Figure 2- Geological map of the study area (modified from Herece, 2016).

around Elazığ were studied (Hempton and Savcı, 1982; Hempton, 1984, 1985). Besides; the fossils of a section within the Kırkgeçit formation in local areas in west of Pertek were described based on species (Avşar, 1991, 1996).

2. The Stratigraphy Of The Region In Pre-Late Maastrichtian

Keban metamorphics and Elazığ magmatics cropping out around Pertek which are the basements units of the region. Harami, Seske and Kırkgeçit formations are Late Cretaceous-Tertiary in age. Adilcevaz formation is Late Oligocene-Early Miocene and the Karabakır formation and its members are Pliocene.

2.1. Keban Metamorphics (PzMzk)

Keban metamorphics are generally composed of schist and marble. It outcrops in north of the Keban Dam Lake between Konaklar-Tuzbaşı districts, around Eğer Tepe in south of the dam lake, the east of Kolbaşı district, the north of Esenkent and in west of Altınkuşak (Figure 3a).

The unit was first named by Kipman (1976), Özgül (1976), Perinçek (1979) and Erdoğan (1982), and the same nomenclature was used in other studies (Özgül and Turşucu, 1984). The exposures of metamorphics in Pertek and its surround were shown as one unit since the rock type discrimination had not been studied before. The outcrops of the unit in different places are similar in character and formed dominantly from grayish, white marbles and seldom amphibolite schists. The unit was defined as basic amphibolites in sections which can be distinguished by its dark color in the outcropped areas and in section which displays schistose structure. Amphibolites are composed of nematoblastic textured hornblende, plagioclase, quartz, sphene and opaque minerals (Herece, 2016).

Keban metamorphics overlie Late Cretaceous Elazığ magmatics with reverse fault at the bottom and is unconformably overlain by Maastrichtian deposits on top.

There is not age data within study area; however, Özgül (1976) obtained Permian-Triassic age from the bottom of the unit. Özgül and Turşucu (1984), detected ages ranging from Permian and Upper Triassic to Cretaceous from recrystallized limestones which are in the form of two layers. Kipman (1976) detected Permo-Carboniferous ages based on fossils described in samples in schists beneath marbles. Yılmaz et al. (1993) detected Campanian age from the topmost part of the metamorphics. According to these age data, the marbles were deposited as limestone between Permian to Cretaceous, then metamorphosed in greenschist facies between Campanian-early Maastrichtian.

2.2. Elazığ Magmatics (Kem)

Elazığ magmatics, which have extensive spreads along the belt, were defined as Yüksekova complex (Perinçek, 1979), İspendere-Kömürhan ophiolites (Yazgan, 1983, 1984; Poyraz, 1988), Elazığ complex (Hempton and Savcı, 1982), Elazığ igniyıs complex (Hempton, 1984, 1985), four units belonging to Yüksekova complex (Bingöl, 1984), Elazığ magmatics (Turan et al., 1995; Beyarslan and Bingöl, 1996; 2000)

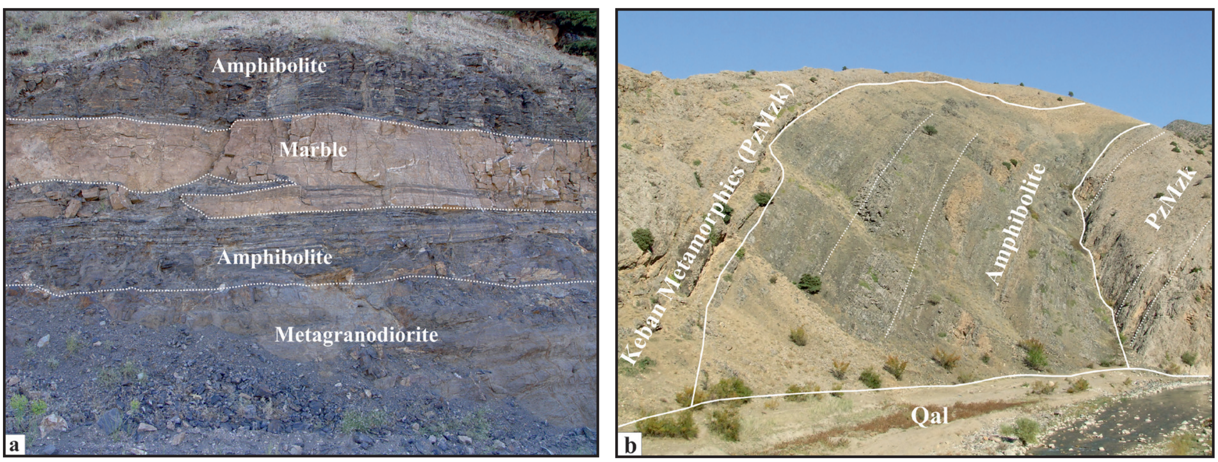


Figure 3- Views of amphibolites, which are distinctive with their dark colors and schistose structures, observed in limited area within Keban metamorphics; a) K42 a2, 21285-07968, looking south and b) K42 a2, 21630-07400, looking northwest.

and Elazığ-Baskil magmatic complex (Robertson et al., 2007). Elazığ magmatics cropping out in Elazığ surround are formed by ophiolitic succession which developed in the intra-oceanic supra subduction zone and by the overlying ensimatic island arc units. The ophiolites present a successive deposit and consist of gabbro, diabase, basalt and andesitic volcanics-tuff and agglomerates from bottom to top. Diabase unit, which outcrop in limited locality in the study area, is observed with basalt units, arc volcanics (andesite, andesitic volcano-clastics, tuff and agglomerate), and with intrusive diorite, monzodiorite, tonalite, granite and granodiorites of the widespread ensimatic island arc.

2.2.1. Diabase (Ked)

The unit outcrops around Sarıbük village in south of the Keban Dam Lake and observed as widespread and massive masses. It has sheeted dykes parallel to each other at 500 meters east of the Kilise Tepe at 1 km SW of Yeşildere outside the study area. Diabases have sometimes ophitic and intersertal textures of which plagioclase microliths have formed. Generally; chloritization, carbonation and epidotization are observed and it consists of sphene as accessory mineral.

The lower contact of the unit is not observed in the study area, and it is transitional with the underlying gabbro outside the study area (Hempton, 1985; Herece et al., 1992). However; it is transitional with the basalt unit cropping out in limited area in its upper contact. There is not any radiometric data for the unit. It is Late Senonian according to the pelagic fauna detected in the overlying basalts (Herece et al., 1992). It is a unit of the supra subduction zone ophiolite which developed on the intra-oceanic subduction zone.

2.2.2 Basalt (Keb)

The unit is composed of basalt and it crops out in a limited area in east of Sarıbük village at the south of the Keban Dam Lake. The unit was named as Basalt Unit based on lithological name within scope of this study. The unit is composed of maroon like green lavas at 4 km's northwest of the Osmanağa village in southwest outside the study area. Rarely, it consists of pelagic limestone interlayers and is intruded by small gabbro intrusives and diabase dykes. It has been much disintegrated in occasion, and flow and pillow structures are deteriorated. However; pillow structures along the road from Barge stream in south of the Karodağ to the Yeşildere village are widespread and distinctive outside the study area, and flow directions can also be seen by flow structures in places. The pillow structures were cut by dasitic and andesitic dykes in this area. Basalts are amygdoidal in texture and pores are filled by mineral. It has rare, red and fossilliferous limestone interlayers (Herece et al., 1992). Basaltic pillow lavas, lava flows and diabase dykes, rhyolitic and andesitic pyroclastic intercalations in few amounts comprise andesitic dykes, lava flows and gabbro and diorite stocks (Hempton, 1985).

Basalt unit is generally observed as tectonically associated with diabase unit. However; it is transitional with diabase in the lower boundary and andesitic volcanics in the upper boundary outside the study area (Herece, 1992). There is not any thickness data in the studied area. The unit thickness is 1000 m around Karodağ in southeast and outside the study area (Herece et al., 1992) and 375 m around Hazar Lake (Hempton, 1985). There is also not any radiometric age data for the unit, and it is unconformably overlain by the late Maastrichtian Harami Formation (Herece et al., 1992). The unit is Santonian-early Campanian based on *Marginotruncana coronata* Bolli, *Globotruncana carinata* Dalbiez and *Globotruncana linneiana* (d'Orbigny) fauna in samples collected from pelagic limestones blocks, which has been formed with basalts and of which their primary location failed by the flow, outside the study area (Herece et al., 1992).

Samples collected from the blocks in lavas (Herece et al., 1992), *Globotruncanita* cf. *stuarti* (de Lapparent) and *Globotruncanita stuartiformis* (Dalbiez) fauna are also early Maastrichtian. The basalts are Senonian "late Senonian" according to these age data, and these are the part of ophiolites forming in the intra-oceanic supra subduction zone.

2.2.3. Andesitic Volcanics (Kea)

Andesitic volcanics, though have limited spread in the study area, crop out over wide areas in south of the study area. The unit generally consists of lithologies of andesite, andesitic agglomerate and tuffite, and rarely consists of pelagic limestone intercalations. The whole succession is green to pale green in color. However; the fresh and decayed colors of andesitic rocks are white. Agglomerates are moderately sorted and well cemented. The succession consists of laterally lensoidal pyroclastic layers. Occasionally; diabase and dacitic dyke intrusions and rare pelagic intercalations take place within the unit (Figure 4).

Andesitic volcanics are transitional with the underlying basalts of the Elazığ magmatics at its lower contact (Herece et al., 1992); however, it is unconformably overlain by the late Maastrichtian Harami Formation at its upper contact. Its thickness is unknown since the measured stratigraphical section could not be taken in the unit. Nevertheless; in south and outside the study area it is approximately 1800 m thick (Herece et al., 1992). There is no age data for the unit in the investigated area; however, its age outside the study area was detected as early Maastrichtian (Herece et al., 1992). The presence of clayey limestone intercalations and blocks requires indicates that they have been deposited in open marine environment.

2.2.4. Ensimatic Island Arc Rocks

The rocks of the ensimatic island arc together with Intra Oceanic Supra Subduction ophiolites outcrop within the study area. Ophiolites and the overlying andesitic volcanics were distinguished; however, the rocks of widespread ensimatic island arc were named based on the petrographical descriptions of samples collected from the area. These rocks are generally beige, pink or pale and occasionally have lineation and fracture system. Rock types in exposures covering wide areas were distinguished as Tonalite (Keto), Diorite (Kedi) and Granite-Granodiorite (Kegr) (Herece, 2016).

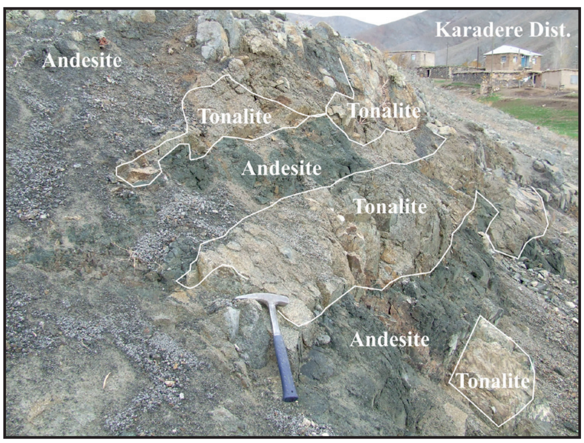


Figure 4- Views of intrusive tonalite dykes with the andesites of Elazığ magmatics on the road cut of the auto road in west of the Karadere District (K42 b1, 2407-03847, looking NNE).

Tonalite (Keto) : It is an intrusive rock in andesites, which outcrops on the road cut in west of the Karadere district in NW of Pertek (Figure 4). The andesite has hypidiomorphic texture (pilotaxitic texture) and consists of plagioclase, hornblende, quartz, biotite and opaque minerals. The groundmass consists of plagioclase, hornblende, very few biotite microliths, amorphous quartz grains and opaque minerals. However; tonalite has hypidiomorphic holocrystalline granular texture and consists of plagioclase, quartz, orthoclase, hornblende, biotite, apatite and opaque minerals. Chloritization, argillization, calcification in plagioclases; chloritization and argillization in the orthoclases; chloritization in biotites are widespread (Herece, 2016).

Towards west, it is formed by NE-SW extending Eğer Tepe metamorphics in south of Koruköy; however, the NW looking slope of the hill is formed by intrusive rocks. In the cut of water canal, which vertically crosscut the hill, Keban metamorphics and Elazığ magmatics are tectonically and intrusively associated with each other (Figure 5a-b). Elazığ magmatics consist of tonalite and granodiorite; however, the latter intrusives are basalt and diabase (Figure 6a-b). These dyke intrusions consist of enclave fragments detached from previously formed magmatics. Tonalite is holocrystalline granular textured, and consists of plagioclase, quartz, hornblende, biotite, zircon, apatite and opaque minerals. Granodiorite has holocrystalline granular texture and consists of plagioclase, quartz, orthoclase, hornblende, biotite, zircon and opaque minerals. Some plagioclases consist of quartz, alkaline feldspar, hornblende and chloritized biotite inclusions. Minerals are; clinopyroxene, biotite and serpentinized olivine as the secondary mineral around epidote at the center as phenocrystals; and clinopyroxene, secondary carbonate, secondary chlorite minerals among plagioclase microliths in the groundmass. Intrusive basalt has hypocrystalline porphyritic texture and the groundmass is intergranular textured. Intrusive diabase porphyry is holocrystalline porphyritic and intergranular textured. Minerals are; clinopyroxene, plagioclase, quartz, and plagioclase with secondary rod like calcite phenocrystals, quartz and opaque minerals, and they are observed within intergranular textured groundmass which consists of secondary chlorite and secondary calcite.

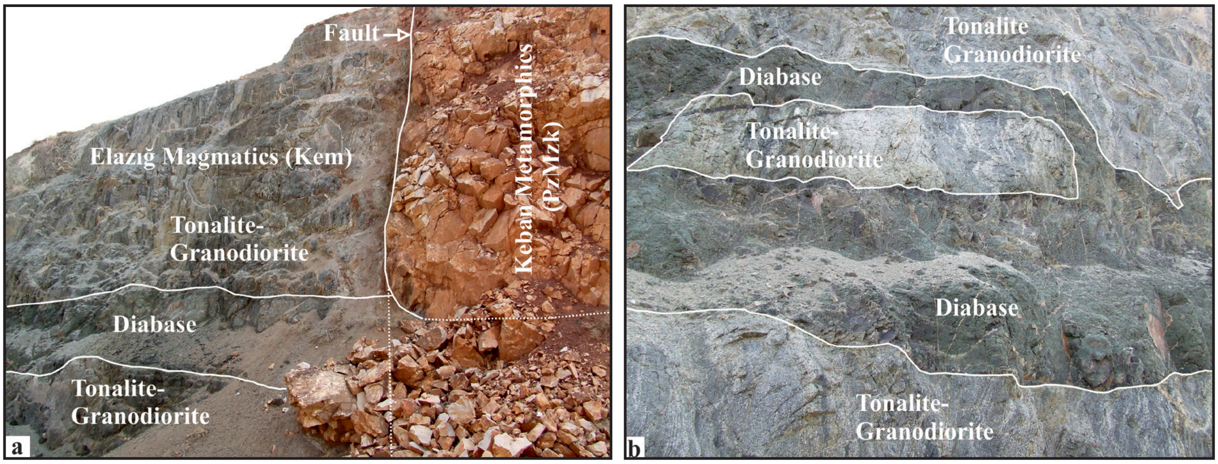


Figure 5- a) Views of Elazığ magmatics tectonically associated with Keban metamorphics in the cut excavated in water canal, in SW of Koruköy (K42 a4, 00300-96025, looking east), b) views of tonalites cut by diabase dykes in Elazığ magmatics (K42 a4, 00300-96025, looking east).

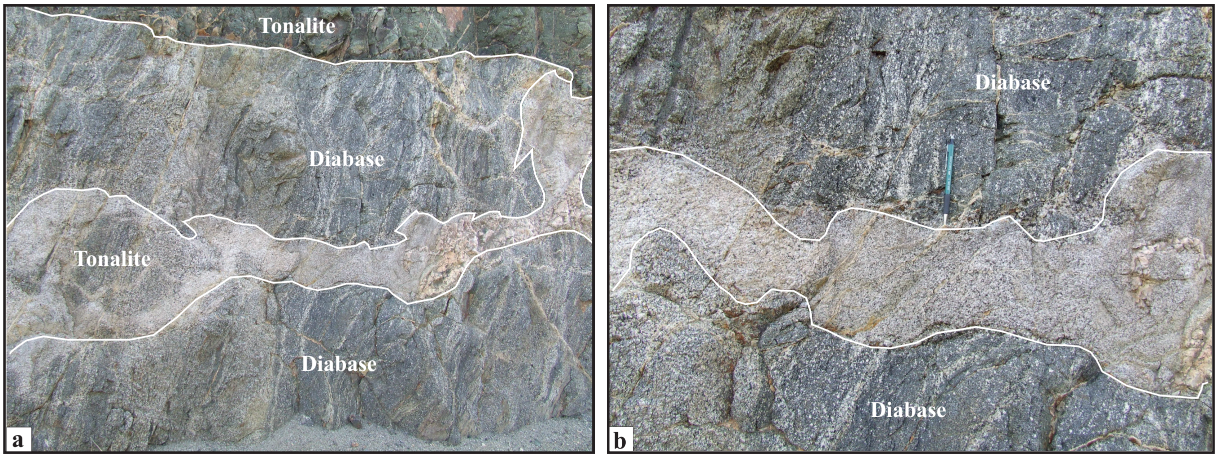


Figure 6- General views of diabases and intrusive tonalites in Elazığ magmatis in the cut excavated in the water canal in SW of Koruköy (K42 a4, 00300-96025, looking east).

On the other hand, norite and gabbronorite were identified in magmatic rocks exposing in the area towards the north of Pertek Fault (Herece, 2016). Norite is holocrystalline in texture and consists of plagioclase, orthopyroxene and opaque minerals. Plagioclases have polysynthetic twinning and rarely observed opaque minerals are in the form of fine grains. Gabbronorite is holocrystalline textured and consists of medium-fine grained plagioclase, orthopyroxene, clinopyroxene and opaque minerals.

Diorite (Kedi): It is the tectonically associated rock type beneath Keban metamorphics in northeast of the Hasır district. Diorite is holocrystalline and poikilitic textured and is formed by plagioclase, amphibole (hornblende) and opaque minerals. Plagioclase minerals are partly sericitized and argillized, and amphiboles are carbonated.

Magmatic rocks cropping out in south of the Hasır district are quartized diorite, microdiorite and metadiorite (Herece, 2016). Quartz diorite is granular textured and consists of plagioclase, amphibole, quartz and zircon minerals. Argillization and sericitization are widespread in plagioclase minerals. Diorite and alkaline feldspar granite are the other intrusive related rocks in the same region. Diorite is holocrystalline granular textured, and it consists of plagioclase, orthoclase, quartz, hornblende, clinopyroxene and opaque minerals.

Granite (Kegr): These are holocrystalline granular textured magmatics and located in Hodinik Mountain in south of Pertek (Herece, 2016). Granite is holocrystalline textured and consists of orthoclase, quartz, hornblende, augite, biotite, titanite, apatite, zircon and opaque minerals. There are observed argillization, sericitization and chloritization in plagioclases, and sericitization and argillization in orthoclases. Basic and intrusive rocks, along with road cuts towards Edincik district in southwest of Pertek, are metagabbro and granites, respectively (Figure 8). Metagabbro is holocrystalline textured and consists of plagioclase, augite, hornblende, tremolite-actinolite, opaque minerals and uralitic hornblende minerals. However; the granophyre is holocrystalline in texture and consists of plagioclase, quartz, alkaline feldspar, biotite, zircon and opaque minerals. There are observed argillization and sericitization in plagioclases and alkaline feldspars.

Ultrabasic rocks and intrusive dykes are remarkable along the road cut at 2.6 km southeast of the Kolbaşı district along the auto road heading westward from Pertek. The dominant rock types observed on the cut are metagabbro, metagranitoid and moreover granite in intrusive dykes (Figure 7). Metagabbro is blastoporphyritic in texture and consists of plagioclase, orthoclase, hornblende, clinopyroxene, biotite, titanite, spinal and opaque minerals. Plagioclases are chloritized, sericitized, carbonated, epidotized and argillized; and orthoclases are chloritized, sericitized and argillized. It has probably been altered from pyroxene mineral in octagonal minerals which area completely infilled by amphibole. Most of the minerals resembling to that have been medium carbonated, chloritized and the edges have been altered into amphibole. In some of these minerals the residual pyroxene and fully chloritized biotite residuals are observed.

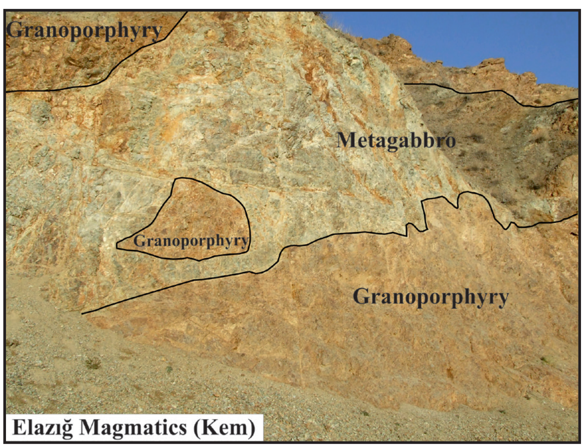


Figure 7- General views of granoporphyries, which are located with metagabbro in Elazığ magmatics and form wide alteration zone, along the road cut of the auto road in NW of the Edincik district (K42 b3, 31882-96900, looking north).

The intrusive gabbro of Elazığ magmatic was cut by granodiorites along Pertek-Hozat auto road (Figure 8), and the microdiorites were cut by diabase rocks along Elazığ-Pertek auto road (Figure 9a-b). In southern areas of the Keban Dam Lake, monzodiorite outcrops at the west of Çolaklı district; and granite, altered syenite/altered monzonite and metabasic rocks crop out in the south of Tilağası district.

There is not any age data in the area investigated for magmatic, and late Maastrichtian Harami formation unconformably overlies the unit. Santonian-early Campanian age was detected from pelagic limestones in which basalts are located, and early Maastrichtian age was taken from pelagic limestone blocks located in lavas (Herece, 1992). These data indicate that the age of magmatics could more probably be late Senonian.

On the other hand, Late Senonian basalts and Early Maastrichtian andesitic volcanics are cut by granitoid intrusions or by the youngest intrusives, and are unconformably overlain by the late Maastrichtian Harami formation. If the youngest granitoids cutting andesitic volcanics have developed with andesites then their ages should be early Maastrichtian or even younger.

3. The Upper And Post Maastrichtian Stratigraphy Of The Region

Late Cretaceous-Tertiary units are formed by Harami formation, Seske formation, Kırkgeçit formation, Alibonca formation, Karabakır formation and its Pertek andesite member and basalt member.

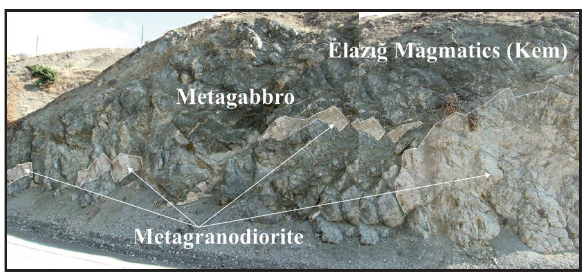


Figure 8- Intrusive views of metagabbros with metagranitoids in SE of the Kolbaşı district on Pertek-Hozat auto road cut (K42 a2, 21492-06625, looking north).

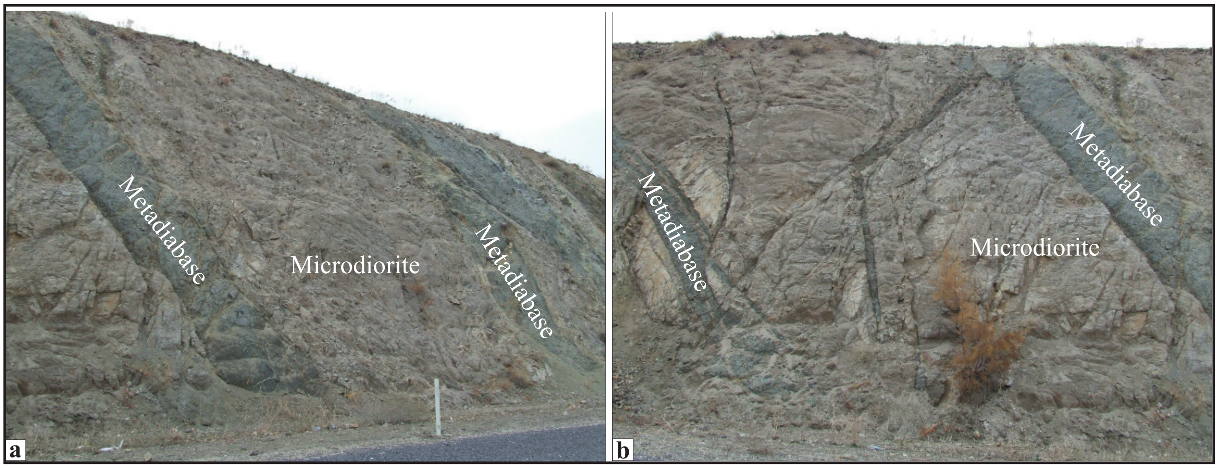


Figure 9- a-b. Views of microdiorites and intrusive metadiabases on Elazığ-Pertek road cut (K42 a3, 17608-95485, looking east).

3.1. Upper Late Cretaceous – Paleogene Units

3.1.1. Harami Formation (KTh)

The unit was first named by Perinçek (1979) and Erdoğan (1982), and the same nomenclature was used in other studies carried out in the region. The formation outcrops at high elevations of the ridges located on the southern boundary of the Kurbankapan village (Figure 10).

The unit at the bottom consists of reddish, pale brown basal conglomerate intercalating with carbonate cemented, angular, pebbly sandstone and algal fragmented grainstone (Figure 11a-b). The succession continues with white, thick to very thick bedded limestones towards upper layers.

The unit unconformably overlies Elazığ magmatic and unconformably overlain by Seske and Kırkgeçit formations. The thickness of the formation is not

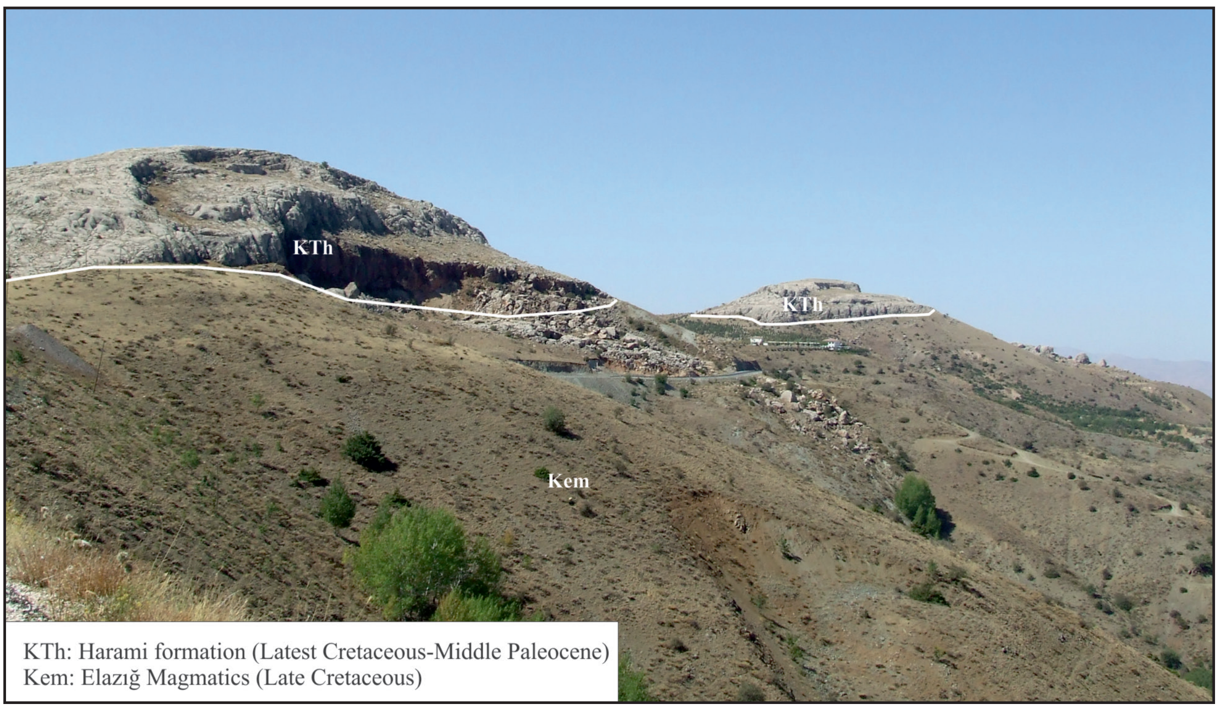


Figure 10- General view of the Harami formation which unconformably overlies the Elazığ magmatics (K42 b4-c1; 27365-87915, looking south).

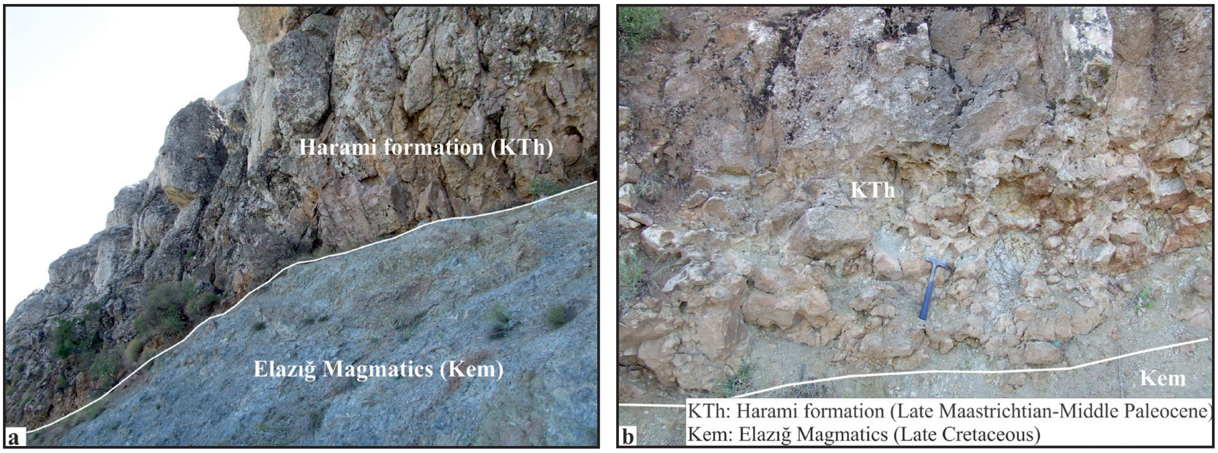


Figure 11- a) The unconformable relationship of the Harami formation with Elazığ magmatics, b) close up view of 2 m thick conglomerate which forms the bottom (K42 b4-c1; 27365-87915, looking south).

known in the study area; however, the measured stratigraphical sections taken from the unit in the near south of the area were estimated about 60 m (Herece et al., 1992).

In samples collected from the bottom of the unit on road cuts in south of the Kurbankapan district, the late Maastrichtian age was obtained by benthic foraminifers; *Siderolites calcitrapoides* Lamarck, *Sirtina orbitoidiformis* Bronnimann and Wirtz, *Hellenocyclina beotica* Reichel, *Siderolites* spp. and *Omphalocyclus* sp. (Herece, 2016).

In samples collected from the southern part of the study area (Herece et. al., 1992), the Selandian age was obtained according to the fauna such as; *Cuvillierina sireli* İnan or *Pseudocuvillierina sireli* (İnan), *Miscellanea* sp., *Sistanites* sp. for the upper part of the succession. According to these data the Harami Formation is late Maastrichtian-Late Paleocene (Selandian) and it was deposited in shallow shelf environment.

3.1.2. Seske Formation (Tes)

Seske formation was first named by Erdoğan (1975) in the vicinity of Seske village of Adıyaman. It consists of bioclastic packstone and algal grainstone in the bottom, and angular pebbly conglomerate and clastic sandstone in the top. The unit, which was first named by Herece (2016) around Pertek, was observed in the southern part of the ferry pier at south of Keban Dam Lake (Figure 12). This outcrop, which was formerly beneath the water, emerged as a result of 20 m decrease in water level in the dam lake.

The unit does not have wide outcrops to nomenclature for a new formation. Eastern and western extensions of the succession observed in the limited area remain below the dam lake. However, it was defined in order to detect that the formation is present in this region. The extension of the formation at east is formed by the medium bedded sandy limestone-limestone alternation. In the western extension, the conglomerate made up of angular pebbles derived from ophiolites at the bottom grades into many nummulitic sandstones with much ophiolitic clastics (Figure 13a-b). The unit unconformably overlies Elazığ metamorphics at the bottom at ferry pier; however, the upper contact is paraconformably overlain by the Kırkgeçit Formation (Herece, 2016). Approximately; 10-15 m thick section of the unit could be observed in the outcrop at the southern edge of the Pertek ferry pier. Since the lateral extension of the succession remains below the dam lake, its thickness is unknown.

In samples collected from the lower part of the succession exposing in the area (Herece, 2016) the late Kuvizian age was detected by *Nummulites manfredi* Schaub (spp) fauna. However; *Nummulites messinae* Schaub (spp), *Gyroidinella* sp. (n.sp?), *Neorotalia* sp., Belemnitidae fauna gave early Lutetian age in samples collected from the upper part of the succession (Herece, 2016).

On the other hand, *Nummulites messinae* Schaub (spp.), *Fabiania cassis* Oppenheim, *Gyroidinella* sp. (n.sp?, grain forms available), *Discocyclina* sp., *Praefabiania?* sp. and Belemnitide form (plenty) fauna assemblage described in the sample collected

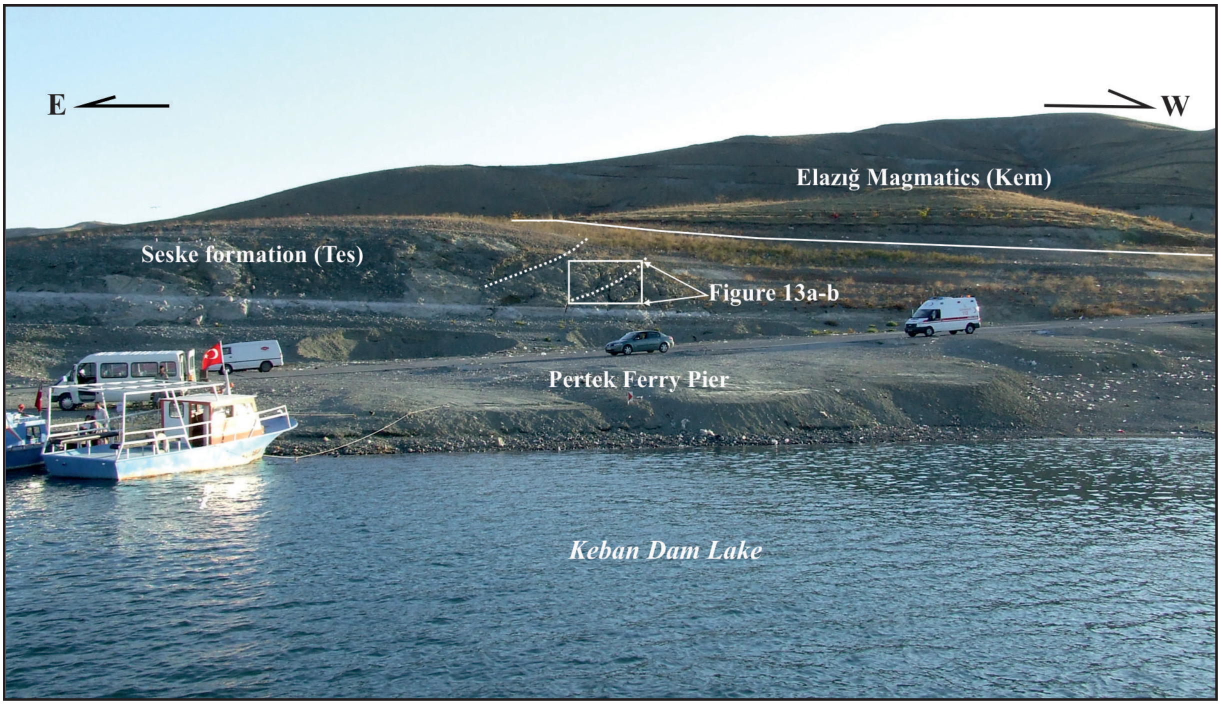


Figure 12- General view of the Seske formation on the southern edge of the Pertek ferry pier (K42 b4; 23820-98025, looking SSW).

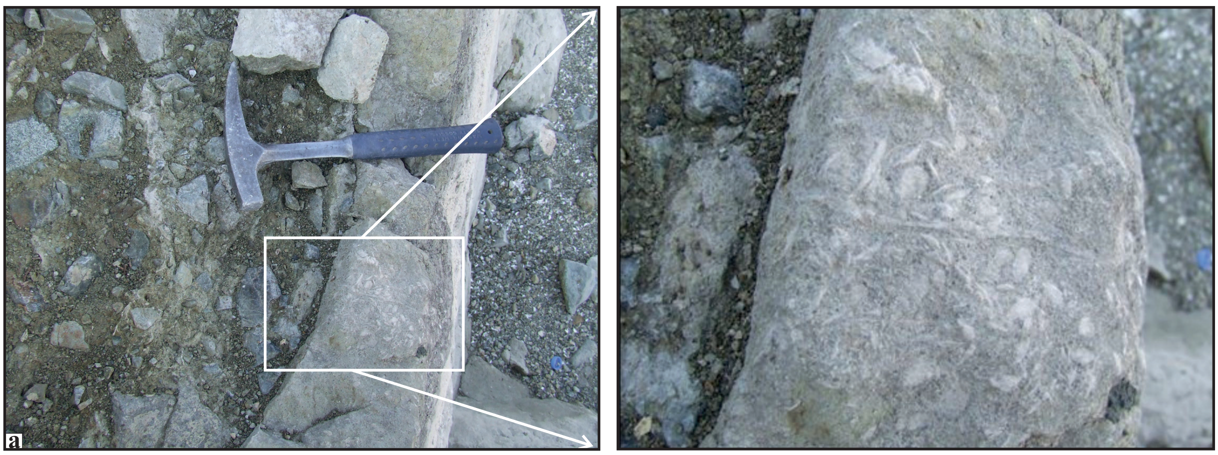


Figure 13- a-b. The close up view of much nummulitic grainstone overlying the coarse conglomerate in the lower part closer to the bottom of the Seske Formation on the southern edge of the Pertek ferry pier (K42 b4; 23820-98025, looking SW).

from algal and bryozoan fragmented grainstone, which is located below the Kırkgeçit formation around Tilağası district, give upper early Lutetian-early middle Lutetian age.

According to these data, the age of the formation cropping out in areas around Pertek ranges from late Kuvizian to early middle Lutetian. In exposures outside the study area, Yazgan (1984) investigated the Seske formation together with Harami formation under the name of Upper Paleocene-Lower Eocene limestones. Turan and Bingöl (1991) and Türkmen et al. (2001) defined the Seske formation as Late Paleocene-Early Eocene. The unit was deposited in fore reef environment.

3.1.3. Kırkgeçit Formation (Teok)

The formation, which consists of the alternation of basal conglomerate, sandstone, siltstone and limestone, crops out in wide areas from north to south. The unit, which is formed by sedimentary deposits in similar characteristics, is observed as separate outcrops as a result of effective tectonical events in the region after sedimentation.

The unit which was first named by Perinçek (1979) was defined under the same name. The outcrops of the Kırkgeçit Formation are observed in near west of Pertek, between the Cevizlik Tepe (hill) and Taht Tepe (hill), in west of Pertek, between Aşağı Gülbahçe and Karşıyaka District, in near east of Pertek, around Mercimek village, in SE of Pertek, between Kabasakal District- Kolonkaya, in south of Pertek, between Karacalar District – Kabakçılar District, in SW of Pertek, between Altınkuşak and Tilağası District.

The formation, which outcropped in 6 different areas, was mapped for the first time and successions were systematically sampled from bottom to top in order to determine rock type characteristics and ages of each exposure.

Kırkgeçit Formation outcropping between Cevizlik Tepe and Taht Tepe: The formation generally trends in NW-SE direction. The bottom of the basin is located in the west of Soğukpınar district and begins with the alternation of fine and coarse grained grainstone. Grainstone is grayish-pale brown, medium-thick bedded, flaky and with conglomerate-pebblestone intercalations. First; the sedimentary deposit is laterally transitional with pale green claystones, then continues as pale yellowish, brown, fine to medium bedded limestone with plenty of *Gypsina*, and algal and spar cemented boundstone and algal fragmented grainstone in upper layers. However; the uppermost part of the succession is formed by reddish-brown, medium to thick bedded, medium to fine textured boundstone with highly porous algae and bryozoans (Figure 14).

The age of the unit was determined according to fauna described in samples collected systematically from bottom to top at the outcrop in the west of Pertek (Herece, 2016).

In samples collected from the grainstone with much *Gypsina* in the section at the bottom of the unit, boundstone with algea and *gypsina*, grainstone with algae fragments and clastic packstone-grainstone (Herece, 2016); *Nummulites ptukhiani* Kacharava, *Chapmanina gassinensis* (Silvestri) (spp), *Fabiania cassis* (Oppenheim) (spp), *Schlosserina asterites (*Gümbel), *Gypsina mastalensis* Bursh, Praecalcarina tohmaensis Alan *Alveolina* gr. *fusiformis* Sowerby, *Nummulites* cf. *dufrenoyi* d'Archiac and Haime, *Penarchaias* sp., *Borelis?* sp., *Eoannularia* sp., *Heterostegina* sp., *Discocyclina* sp., *Peneroplis* sp. and *Opertorbitolites* sp. benthic foraminiferal assemblage was detected which gives Bartonian age.

In samples collected from clastic packstone-grainstone in the succession gives Latest Bartonian according to *Borelis wonderschmitti* (Schweighauser), *Chapmanina gassinensis* (Silvestri) / n.sp?, *Planorbulina bronnimanni* Bignot and Decrouez, *Schlosserina asterites* (Gumbel) and *Borelis* sp./n. sp?, fauna (Herece, 2016).

In samples collected from clayey limestones located on the grainstone (Herece, 2016*a*); Late Bartonian-Lower Early Priabonian age was given detecting *Silvestriella tetraedra* (Gumbel), *Chapmanina gassinensis* (Silvestri), *Halkyardia minima* (Liebus), *Planorbulina bronnimanni* Bignot and Decrouez, *Fabiania cassis* (Oppenheim), *Nummulites* gr. *ptukhiani* Kacharava and Miliolidae fauna (Figure 14).

In samples collected from packstone located on the grainstone in the middle part of the succession (Herece, 2016), *Nummulites fabiani* (Prever), *Nummulites striatus* (Bruguiere), *Nummulites incrassatus* De La Harpe, *Nummulites boullei* De La Harpe and *Silvestriella tetraedra* (Gumbel) fauna was determined, and the early Priabonian age was given (Figure 14).

In samples collected from the boundstone close to the upper part of the unit (Herece, 2016); the early Rupelian age was given by *Halkyardia minima* (Liebus) (spp), *Halkyardia* cf. *maxima* Cimerman, *Nummulites* gr. *vascus* Joly and Leymerie, fA), *Nummulites* spp. (with flat radiated mesh), *Amphistegina* spp., *Planorbulina* sp. and Miliolidae (plenty) benthic foraminiferal assemblage (Figure 14).

In samples collected from the algal and bryozoan fragmented grainstone in the uppermost part of the succession (Herece, 2016); late Rupelian-early Chattian age was given with benthic foraminifers of *Nummulites vascus* Joly and Lymerie, *Borelis merici* Sirel and Gündüz, *Bullalveolina bulloides* (d'Orbigny) (spp), *Borelis* spp., *Halkyardia* sp., *Archaias?* sp., *Heterostegina* sp. and *Peneroplis* sp. (Figure 14).

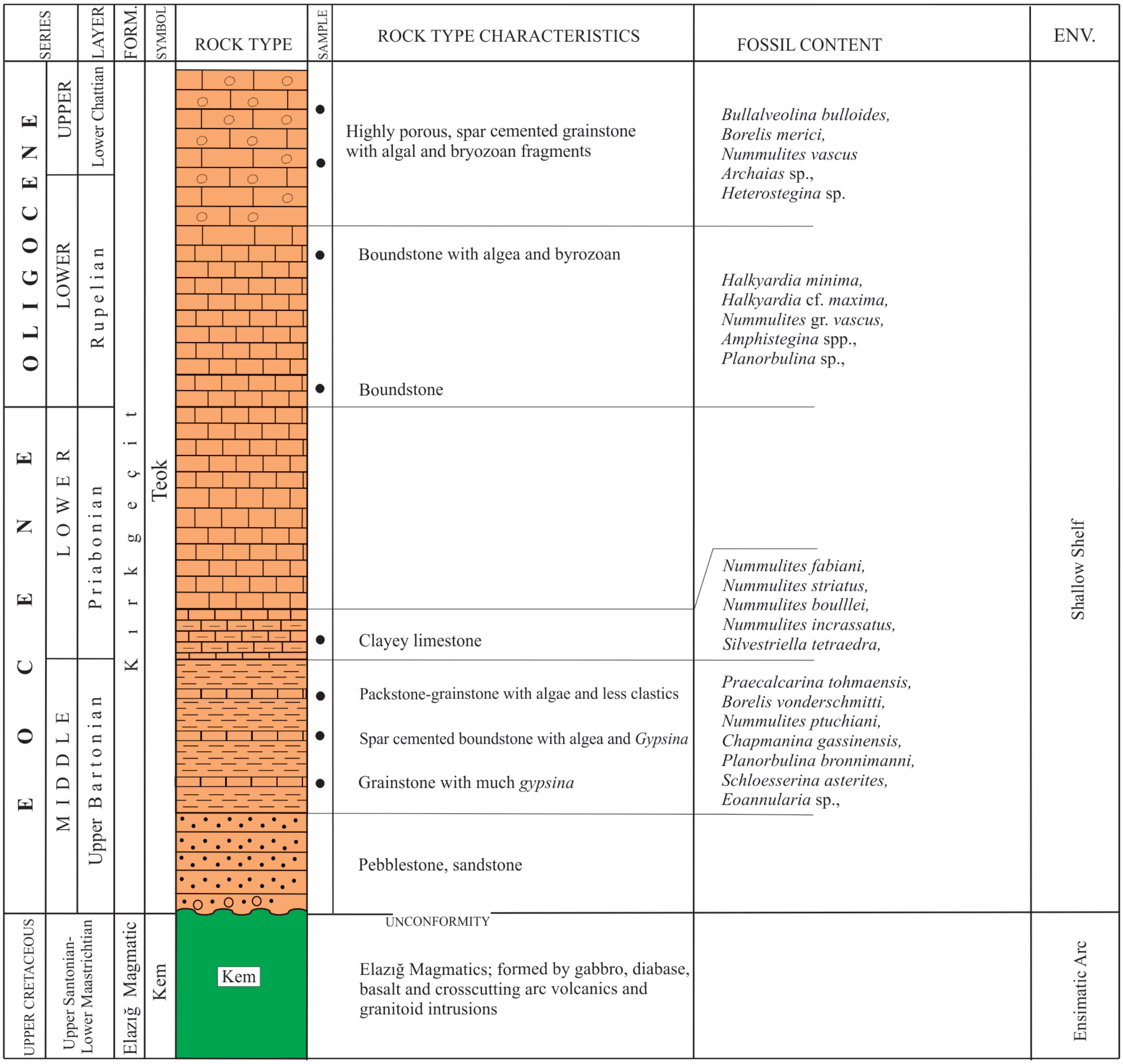


Figure 14- The columnar section showing the rock type characteristics and locations of the samples collected from the succession of the Kırkgeçit formation outcropping between Cevizlik Tepe and Taht Tepe in west of Pertek (Herece, 2016).

According to these data, the age of the Kırkgeçit formation outcropping between Cevizlik Tepe and Taht Tepe in west of Pertek continuously ranges from late Bartonian to early Chattian. The whole succession can clearly be observed in this region (Herece, 2016).

The lower contact of the unit is unconformable with the underlying Elazığ magmatics in this area; however, the upper contact is unconformably overlain by younger units.

Both benthic and planktonic foraminifers are observed within the succession forming the formation. Therefore; the depositional environment of the unit is wide reefal flat which is in contact with the fore reef and back reef. The exact thickness of the unit is not known since the measured stratigraphical section could not be performed, but it is approximately assumed to be 250 meters according to topographical data.

Kırkgeçit Formation between Aşağı Gülbahçe and Karşıyaka Districts: The deposit begins with basal conglomerate at the bottom then grades into sandstones in upper layers. Most of the conglomerates originate from well-rounded Keban metamorphics and seldom from ophiolites which do not show any sorting-grading. The deposit is formed by much miliolitic grainstone with algal fragments, widespread limestone and by the alternation of algal fragmented grainstone with plenty of *Gypsina*, claystone, silty grainstone, grainstone-boundstone (Figure 15).

In samples collected from algae fragmented and much miliolitic grainstone overlying the basal conglomerate cropping out between Aşağı Gülbahçe and Karşıyaka Districts in the west of Pertek (Herece, 2016*a*) the age of the unit was given as late Bartonian according to; *Malatyna drobneae* Sirel and Acar, *Halkyardia minima* (Liebus), *Peneroplis dusenbory* Henson, *Fabiania cassis* (Oppenheim), *Gyroidinella magna* Le Calvez, *Medocia blayensis* Parvati, *Austrotrillina* cf. *eocenica* Hottinger, *Haymanella* cf. *huberi* (Henson) (spp), *Penarchaias* cf. *glynnjonesi* (Henson) (spp), *Alveolina (Alveolina)* gr. *fusiformis* Sowerby, *Borelis* sp./n.sp?, *Nummulites* spp., *Discocyclina* spp., *Schlosserina* sp., *Rhabdorites* sp., *Orbitolites* sp. benthic assemblage (Figure 15).

In samples collected from the upper continuation of the grainstone (Herece, 2016), *Chapmanina gassinensis* (Silvestri), *Praecalcarina tohmaensis* Alan *Asterigerina rotula* (Kaufmann), *Halkyardia minima* (Liebus), *Alveolina* (Alveolina) gr. *fusiformis* Sowerby), *Nummulites* sp., *Schlosserina* sp. and Miliolidae fossil assemblage was detected which give the upper late Bartonian age (Figure 15).

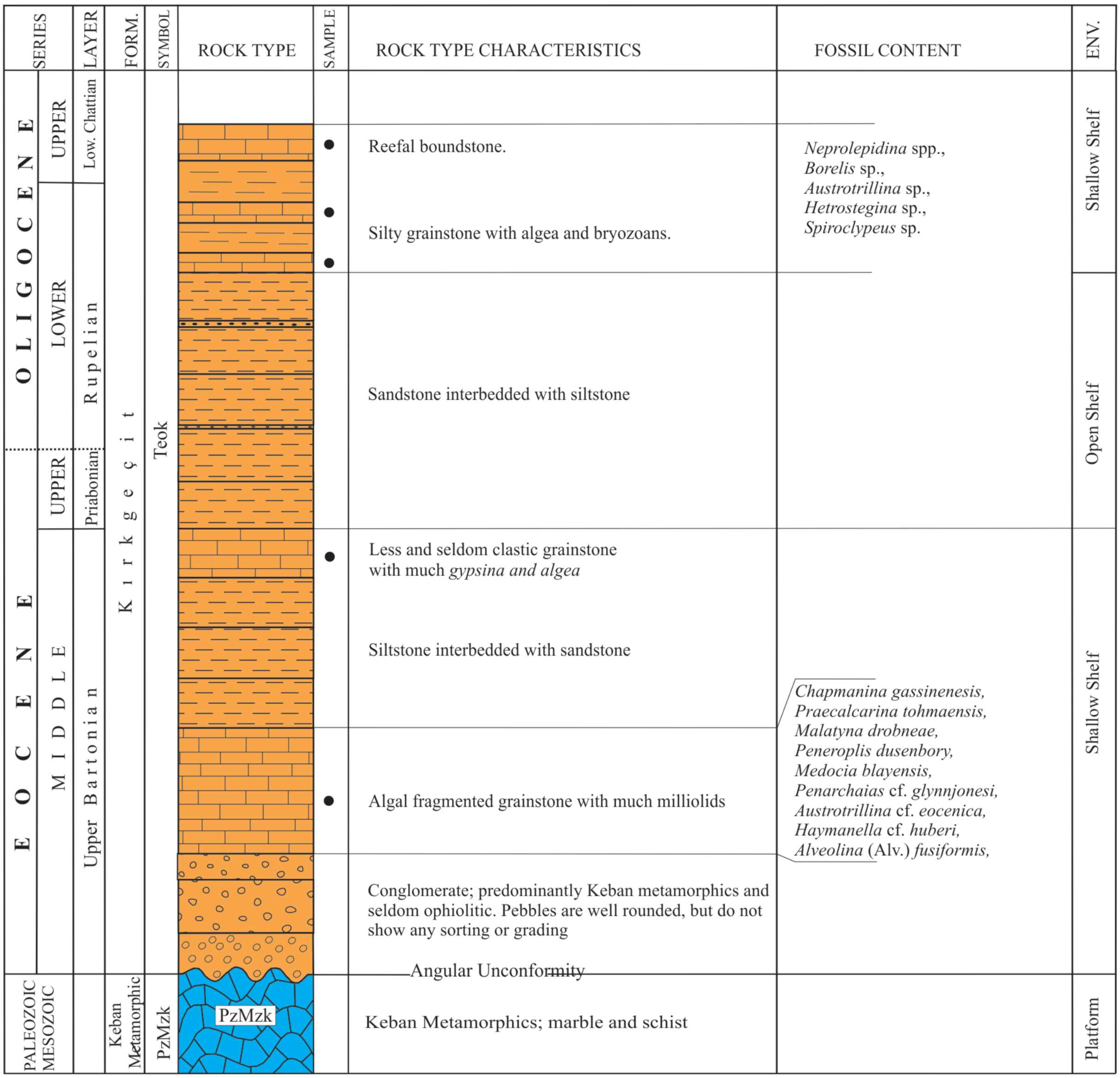


Figure 15- Generalized stratigraphical section showing the lithological characteristics, sample locations and fossil content of the Kırkgeçit formation outcropping between A. Gülbahçe village and the north of Karşıyaka District (Herece, 2016).

Samples collected from the upper part of the succession (Herece, 216) belong to late Rupelian-early Chattian with *Nephrolepidina* spp., *Borelis* sp./n. sp?, *Austrotrillina* sp., *Pararotalia* spp., *Neorotalia* spp. and Miliolidae fauna. According to these data, the age of the formation ranges from late Bartonian-early Chattian (Figure 15).

The lower contact of the unit is unconformable with Keban Metamorphics; however, the upper contact is unconformably overlain by younger deposits. The thickness is not known as the measured stratigraphical section could not be performed for the formation. The unit was deposited in shelf environment.

Kırkgeçit Formation outcropping around Mercimek village: The unit begins to deposit with pebblestone and coarse sandstone at the bottom. Then it grades into much algal detritic limestone with bryozoan fragments, highly porous boundstone with coarse algal fragments and claystone intercalating with laterally lensoidal limestone (Figure 16). The bottom and lower contact relationship of the formation is not distinctive because of the overlying unstable basement unit. However; lithologies near the bottom are grayish pale yellow and consist of medium bedded much algal and bryozoan detritic limestones and coarse algal fragmented boundstones on coarse sandstone (Figure 16).

According to the samples collected from much algal and bryozoan fragmented detritic limestone located at the bottom of the formation (Herece, 2016*a*); the basement age of the basin was detected as the late Bartonian according to *Halkyardia minima* (Liebus), *Chapmanina gassinensis* (Silvestri) (spp), *Schlosserina asterites* (Gumbel), *Gyroidinella magna* Le Calvez (fB), *Alveolina* (Alv) sp. and *Discocyclina* sp. fauna (Figure 16). As sufficient sampling could not be carried out in Late Oligocene-Oligocene transitional-conformable deposits because of special conditions of the region, the fossil-fauna assemblage could not detected.

The unit unconformably overlies Elazığ magmatics (Figure 17a-b), and it is unconformably overlain by younger units. Its thickness is not known as the measured stratigraphical section could not be done. It was deposited in open shelf environment.

Kırkgeçit formation between Kabasakal District and Kolonkaya Village: The sedimentary deposit

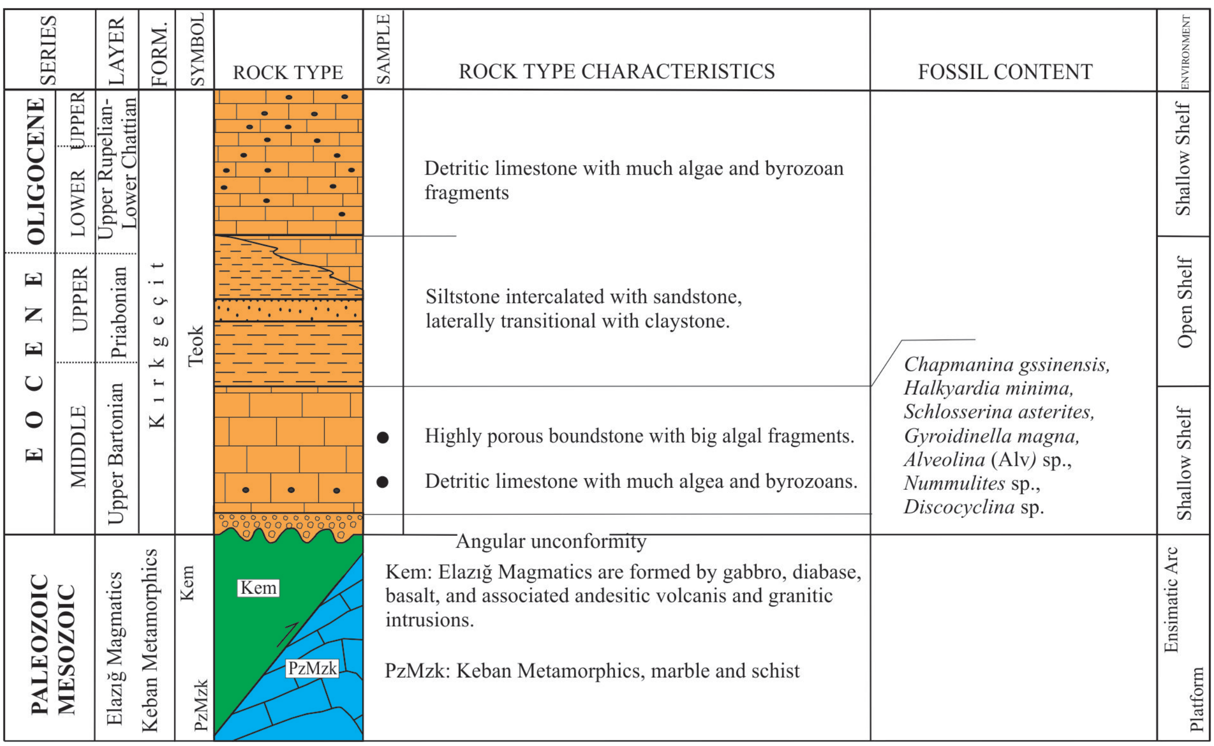


Figure 16- The columnar section showing the lithological characteristics of the Kırkgeçit formation outcropping in the vicinity of Mercimek village and lower sampled part of the unit (Herece, 2016).

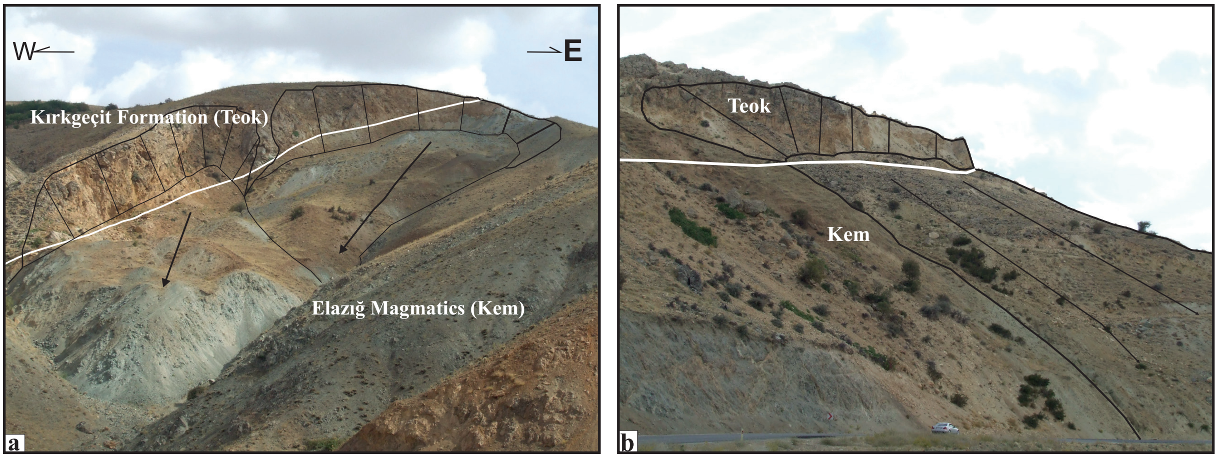


Figure 17- a-b. The bottom contact relationship of the Kırkgeçit formation outcropping i the vicinity of Mercimek village and the view of widespread landslides developed near the bottom of Elazığ magmatics (Kem) (K42 b3, 33100-00850, looking NNE).

in this region begins with basal conglomerate and coarse sandstone on the northern edge of the basin. Sandstones are fine-medium bedded, fine grained and clastic textured. Grains are medium-poorly rounded, well sorted and carbonate-cemented. Sandstones continue with algal, reefal, clastic wackestone, packstone and claystone intercalated with laterally lensoidal limestone. The uppermost part of the succession consists of fine-medium grained, much algal and bryozoan fragmented, well-compacted sandstones with angular pebbles and much gypsinides.

In samples collected from wackestone-packstone overlying the basal conglomerate in the unit which outcrops between Kabasakal district and Kolankaya village in the southeast of Pertek (Herece, 2016); *Chapmanina gassinensis* (Silvestry), *Fabiania cassis* (Oppenheim), *Gyroidinella magna* Le Calvez (spp), *Planorbulina* cf. *bronnimanni* Bignot and Decrouez, *Halkyardia* cf. *minima* (Liebus), *Nummulites* cf. *incrassatus* De La Harpe, *Nummulites* gr. *boullei* De La Harpe, *Nummulites* gr. *biedai* Schaub, *Nummulites* gr. *biaritzensis* d'Archiac and Haime, *Nummulites* gr.*striatus* (Bruguiere), *Alveolina* (Alveolina) sp. (fusiform type) and Microcodium? fauna assemblage was determined which gives the Upper Late Bartonian as the basement age of the unit (Figure 18). The formation unconformably overlies Elazığ magmatic, and is unconformably overlain by the Quaternary alluvial deposits. The unit was deposited in open shelf- shelf front environment.

Kırkgeçit Formation between Karacalar and Kabakçılar Districts: The bottom of the formation is observed in the near north of the Kabakçılar district (Figure 18). The lowermost part of the unit in this area begins with fine grained, intraclastic, steeply dipping sandstone and grades into medium bedded much fossilliferous limestone consisting of 5-8 cm thick sandy limestone interlayers (Figure 19a-b). Sandstone is badly sorted, angular, fine to medium grained, with metamorphic and volcanic pebbles. This bottom succession presents approximately 4 m thickness and grades into laterally lensoidal, algal fragmented, very few clastic grainstone, and grainstone-claystone alternation in upward direction. This part of the outcropping succession is formed by limestones intercalating with packstone-wackestone.

The age of the unit is early Bartonian according to *Halkyardia minima* (Liebus), *Nummulites biaritzensis* d'Archiac and Haime, *Nummulites* cf. *discorbinus* (Schlotheim), *Nummulites* cf. *beamonti* d'Archiac and Haime, *Nummulites* cf. *perforatus* (De Montfort), *Linderina* spp., *Neorotalia* sp. (spinal form), *Pararptalia* sp. (abdomen and ridge much pillared), *Schlosserina* sp. and Rotalidae fauna in samples collected from the fine grained sandstone located at the bottom of the unit near the Kabakçılar district.

Samples were collected from rare clastic grainstone overlying the pebbly packstone, from laterally lensoidal, NE-SW trending, fine grained clastic limestone and from fine-grained sandstone located in the southern part of the road heading to Kabakçılar district in 300 m SSW of the Kurtoğlu district (Herece, 2016). According to these collections; *Austrotrillina eocenica* Hottinger,

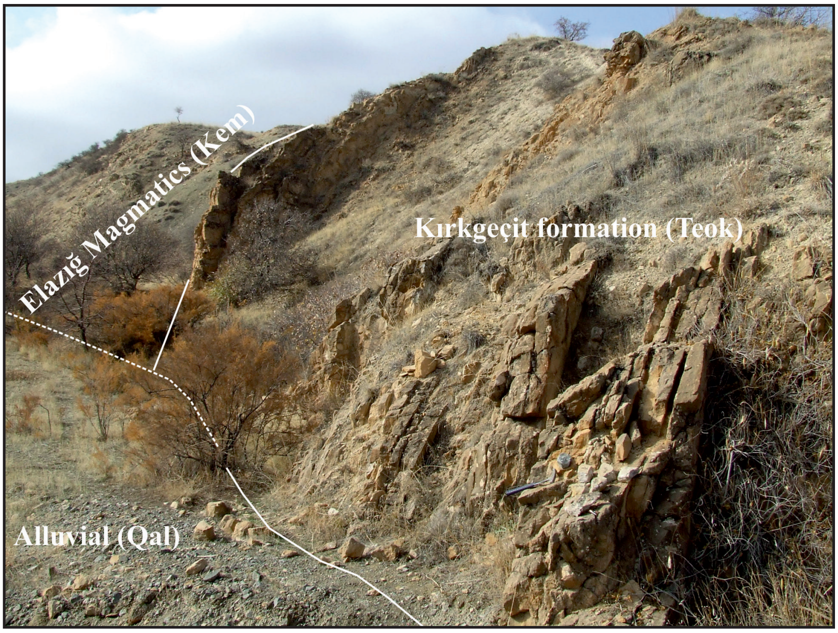


Figure 18- General view of the Kırkgeçit formation which unconformably overlies the Elazığ magmatics between Kabakçılar district and Kolankaya village (K42 b4, 26528-93459, looking NW).

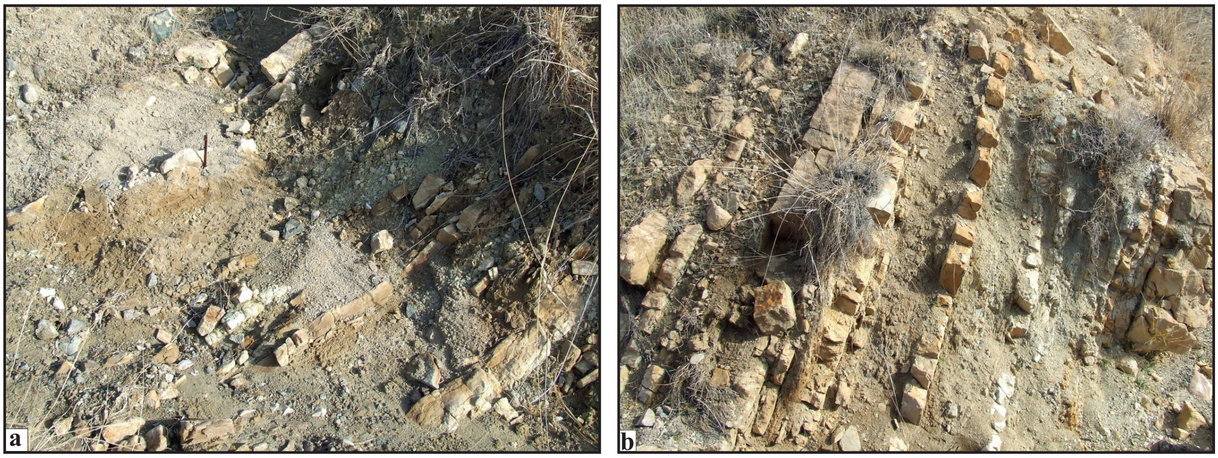


Figure 19- a) Fine grained sandstone, sandstone intercalated with limestone forming the basement of the Kırkgeçit formation in NW of the Kabakçılar district, and b) the overlying limestone-sandstone alternation (K42 b4, 26534-93450).

Chapmanina gassinensis (Silvestri), *Praecalcarina tohmaensis* Alan, *Gypsina mastalensis* Bursh, *Schlosserina asterites* (Gumbel), *Nummulites* cf. *dufrenoyi* d'Archiac and Haime or *Nummulites* cf. *lyelli* d'Archiac and Haime, *Alveolina (Alveolina)* gr. *fusiformis* Sowerby (badly preserved), *Borelis* sp., *Maslinella?* sp. and *Linderina* sp. fauna were described which give the late Bartonian age.

According to nannoplankton samples collected from claystones in the upper part of the sedimentary deposit (Herece, 2016) such as; *Helicosphaera compacta* Bramlette and Wilcoxon, *Cyclicargolithus floridanus* (Roth and Hay), *Dictyococcites bisectus* (Hay, Mohler and Wade), *Reticulofenestra reticulata* (Gartner and Smith), *Discoaster saipanensis* Bramlette and Riedel the Late Eocene (Priabonian) age was given.

According to these data, the depositional conditions began in early Bartonian in the Kırkgeçit basin outcropping between Karacalar and Kabakçılar districts in SE of Pertek and continued in Priabonian (Figure 20). However; the late Rupelian?-early Chattian deposits, which should be located in the upper part of the succession, could not be observed

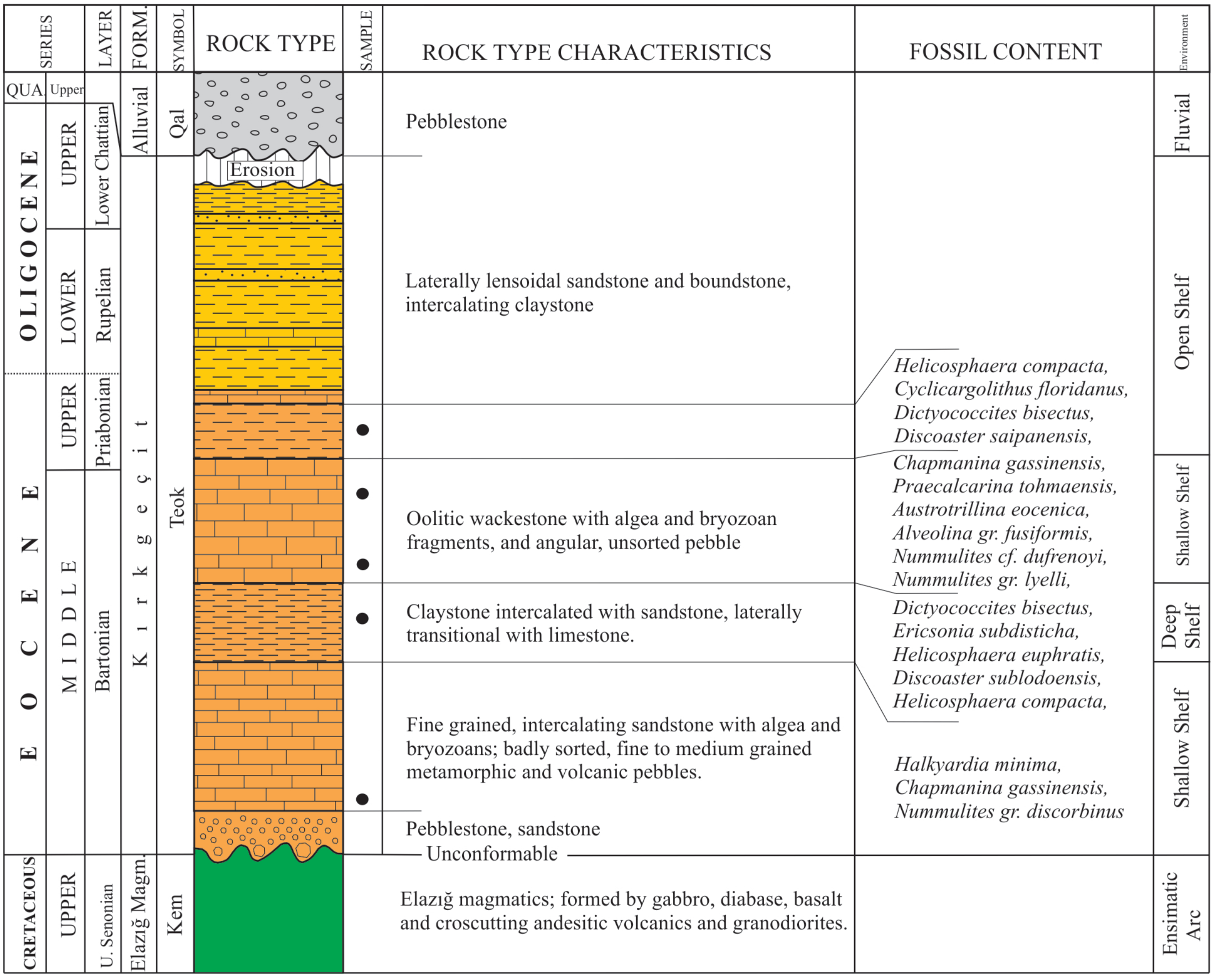


Figure 20- Generalized stratigraphical section showing the lithological characteristics of the Kırkgeçit formation outcropping between Karacalar and Kabakçılar districts and the locations of collected samples.

probably because of insufficient sampling. The formation unconformably overlies Elazığ magmatic and unconformably overlain by Pliocene volcanics. The unit was deposited in open shelf environment.

Kırkgeçit formation between Altınkuşak-Tilağası Districts: The formation outcrops in a wide area between Alatarla district at north and Körpe district at the south. The basin extends in NE-SW directions and presents a successive deposit which gives a type section from SE to NW. The deposit is distinctively traced along the section in NNW-SSE directions in the western part of the basin and in the area between the Körpe District and Keban Dam Lake.

The bottom of the unit is observed in west of Çömlek village and in southeast of the Körpe District. It begins with fine grained sandstone and algal and bryozoan grainstones then grades into sandy limestone and limestone in west of the Çömlek village. The lowermost section of the unit, which can be observed in the vicinity of the Körpe village, begins with algal and bryozoan grainstones and fine grained intraclastic sandstones, then grades into flysch facies in upper layers. Sandstones are poorly sorted, angular, fine to medium grained, metamorphic and pebbly. Flysch consists of 80% claystone and 20% sandstone. Claystones are grayish green, fine and laminated, and the sandstone is fine to medium bedded and consists of rare macro fossil and much small nummulites. The deposit grades into laterally lensoidal, thick bedded-massif limestone and coarse grained, thick bedded sandstone, sandstone-claystone alternation. Reddish, pale brown conglomerate, which formed as result of shoaling of ENE-WSW trending basin, comprises intercalated mudstone-sandstone interlayers. Afterwards; the deposit ends with algal, bryozoan fragmented grainstone, algal, bryozoan and reefal boundstone and algal fragmented, rare clastic grainstone (Figure 21).

The observable lowermost part of the formation in the east of Körpe district consists of grayish-dirty white colored, medium to thick bedded grainstone and is overlain by Pliocene volcanics. Grainstones are overlain by claystone intercalating with ~25 m thick sandstone. It is then overlain by thick bedded boundstone with occasional massive grainstone which form Cankurtaran Tepe and Kaplıkaya Tepe extending from the Körpe district to Kaplıkaya. The grayish-dirty yellow, medium to thick bedded, fine textured, blocky disintegrated grainstone among Yukarıdirektepe, Aşağıdirek and Çakılburnu hills in NE of the Ebil district; and grayish-pale brown, fine to medium bedded grainstone outcropping in Kale Tepe (hill) in north of Çatalharman are located in the lower part of the succession. The middle and the upper part of the deposit cropping out in the area extending from Alatarla to North are formed by the grainstones consisting of boundstone interlayers (Figure 21).

According to samples collected from the basal conglomerate, which unconformably overlies magmatics and the lowermost part of the sandstone in the vicinity of Ebil district, in the west of Çömlek district and in the Körpe district (Herece, 2016); the late Bartonian age was taken from *Penarchaias glynnjonesi* (Henson), *Chapmanina gassinensis* (Silvestri), *Praecalcarina tohmaensis* Alan, *Gypsina mastalensis* Bursh (fA), *Planorbulina bronnimanni* Bignot and Decrouez, *Fabiania cassis* (Oppenheim), *Halkyardia minima* (Liebus) (spp), *Asterigerina rotula* (Kaufmann), *Malatyna* cf. *vicensis* Sirel and Acar, *Medocia* cf. *blayensis* Parvati, *Alveolina (Alveolina)* gr. *fusiformis* Sowerby, *Nummulites* gr. *lyelli* d'Archiac and Haime, *Nummulites* gr. *perforatus* (De Montfort), *Nummulites* sp. (*Nummulites* gr. *ptukhiani* Kacharava), *Schlosserina* spp., *Haymanella* sp., *Eoannularia* sp. (piece), *Malatyna* sp. (n.sp?) and *Linderina* sp. (coarse form, axial section) fauna assemblage (Figure 21).

From the algal grainstone collected in northeast of the Çatalharman village (Herece, 2016a); *Planorbulina bronnimanni* Bignot and Decrouez, *Halkyardia minima* (Liebus), *Nummulites* cf. *fabianii* (Prever), *Gypsina* cf. *mastalensis* Bursh, *Peneroplis spp*. fauna was detected which gives the late Bartonian?-early Priabonian age (Figure 21).

In samples collected from grainstone in the vicinity of the Çakıl district and the north of Alatarla village (Herece, 2016a); the Priabonian age was given with *Nummulites fabianii* (Prever) (spp), *Chapmanina gassinensis* (Silvestri) (spp, n.sp?), *Penarchaias glynnjonesi* (Henson), *Silvestriella tetraedra* (Gumbel), *Eoannularia eocenica* Cole and Bermudez, *Halkyardia minima* (Liebus), *Schlosserina asterites* (Gumbel), *Planorbulina bronnimanni* Bignot and Decrouez, *Fabiania cassis* (Oppenheim), *Nummulites* cf. *striatus* (Bruguiere), *Peneroplis* spp., *Praebullalveolina*? sp., *Borelis?* sp.

Due to samples were taken from the grainstone in the upper part of the section (Herece, 2016); the Rupelian age was given with *Planorbulina bronnimanni* Bignot and Decrouez, *Halkyardia* cf. *maxima* Cimerman, *Nummulites* cf. *fichteli* Michelotti, fA), *Nummulites* gr. *vascus* Joly and Leymerie, (fA), *Peneroplis* spp. fauna.

According to samples taken from spar cemented boundstone and grainstone around Alatarla (Herece, 2016); *Nummulites vascus* Joly and Leymerie, *Borelis inflata* Adams (spp) (small, bulky and ovoid forms), *Borelis merici* Sirel and Gündüz, *Halkyardia minima* (Liebus), *Nummulites* cf. *fichteli* Michelotti, *Victoriella* cf. *conoidea* (Rutten), *Borelis* cf. *pygmaea* Hanzawa, *Amphistegina* spp., *Heterostegina* spp. (X=3), *Eulepidina* sp., *Schlosserina* sp. *Bullalveolina?* sp. faunal assemblage were detected which give the late Rupelian-early Chattian age.

According to all these data, the depositional conditions began in Bartonian and continued until late Rupelian?-early Chattian in the Kırkgeçit formation.

The formation unconformably overlies Keban metamorphics and Elazığ magmatic, but are overlain by younger units with angular unconformity. The outcrops in the Pertek fortress and its northern side are intruded by volcanic necks where andesitic volcanics erupt. Whereas; the outcrops located between Altınkuşak and Aydıncık districts are overlain by reverse fault striking from north to south by Keban metamorphics along its northern boundary. Since SW extension of the unit was covered by the Pliocene volcanics in the east of Körpe district, the lower contact can not be observed.

Thickness of the unit is not known as the measured stratigraphical section could not be done, but based on

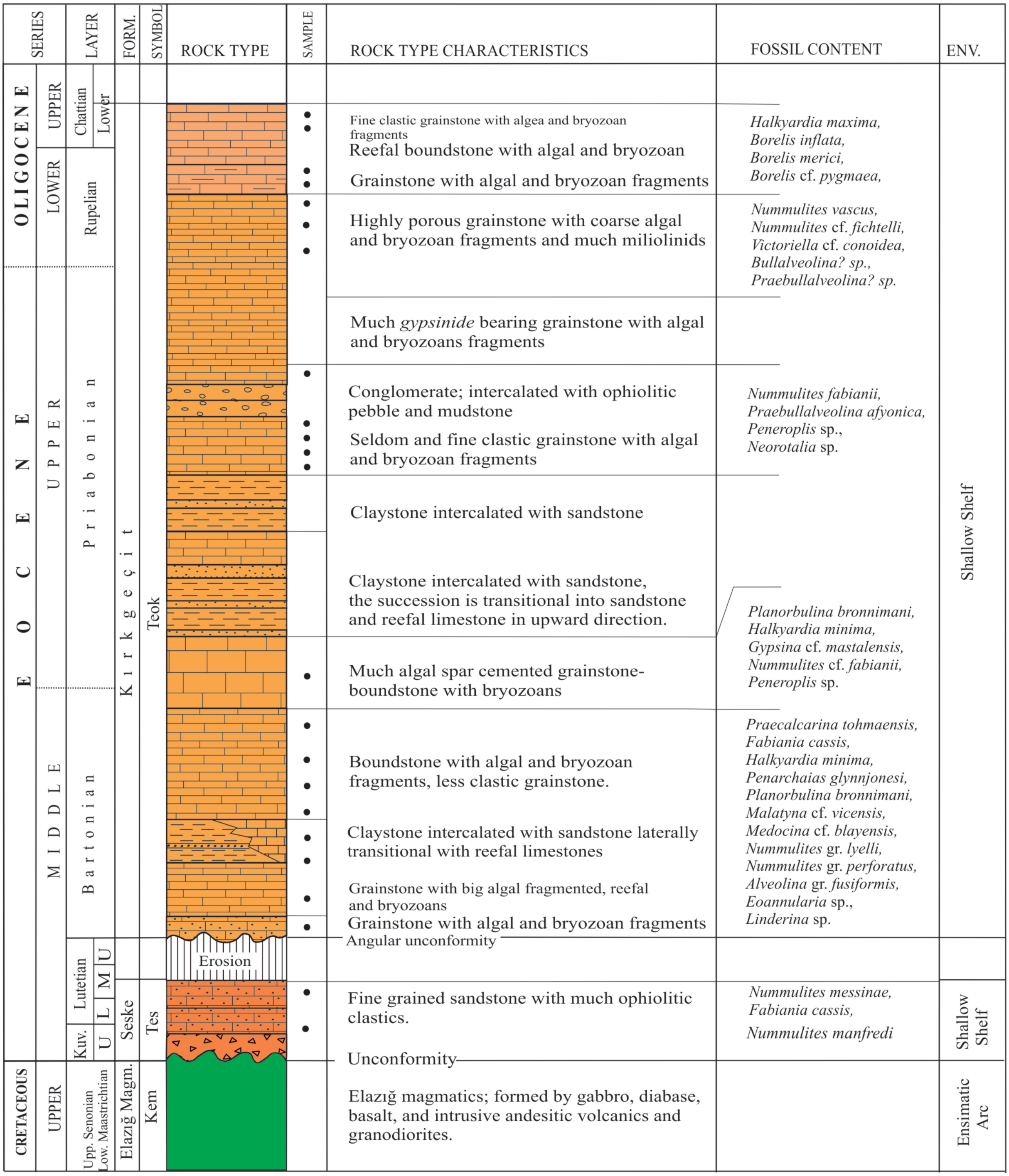


Figure 21- Generalized stratigraphical section showing the lithological characteristics of the Kırkgeçit formation outcropping between Altınkuşak-Tilağası districts and the locations of collected samples.

areal distribution of the basin, the thicknesses which can vary from region to region should mostly occur in the outcrop between Altınkuşak-Tilağası districts. The unit was deposited in fore reef and open shelf environment.

3.2. Upper Paleogene-Neogene Units

Late Oligocene-Neogene deposits widely cropping out in north of the Keban Dam Lake are represented by Alibonca formation, Karabakır formation and by the Pertek andesite and Basalt member.

3.2.1. Alibonca Formation (Toma)

The unit, which consists of conglomerate, sandstone, boundstone and claystone, extends towards Dere town through Dağarcık district by enlarging through Ayazpınar in the northern edge of the Keban Dam Lake and Arılar, Çukurbağ, Kaballı districts in NNW of Pertek and towards Çamurluk district at east.

The unit, defined first by Soyutürk (1973) in the vicinity of Alibonca village of the Muş city was defined under the same nomenclature also in studies around Elazığ and Malatya. The formation is the lateral equivalent of the Adilcevaz formation around Van Lake which was named by Demirtaşlı and Pisoni (1965).

The outcrops of the unit are observed in two different areas separated by the Pertek fault. The SW outcrop of the Pertek fault is between Ayazpınar and Çukurca villages (Figure 22). It begins to deposit with basal conglomerate (Figure 23a), continues with medium to thick bedded boundstone (Figure 23b) and ends with clayey limestone in the area. In the outcrop, which is located nearly at 930-950 m elevations, 4 meter thick boundstone makes distinctive moldings and is observed 3 km long in the lateral direction. Pale green, clayey limestone in the upper part of the sedimentary deposit, which unconformably overlies

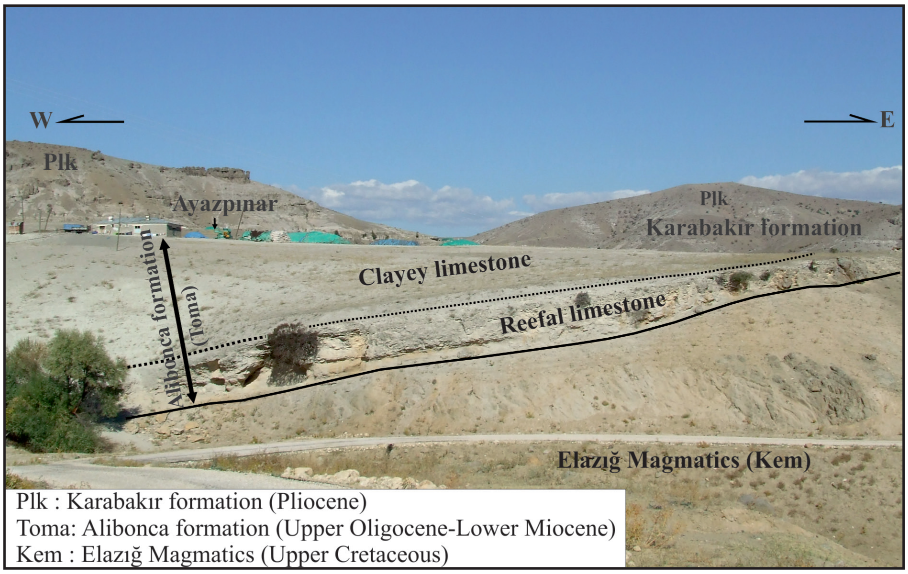


Figure 22- General view of the Alibonca formation exposing in the vicinity of Ayazpınar (K42 a1, 05168-08397, looking north).

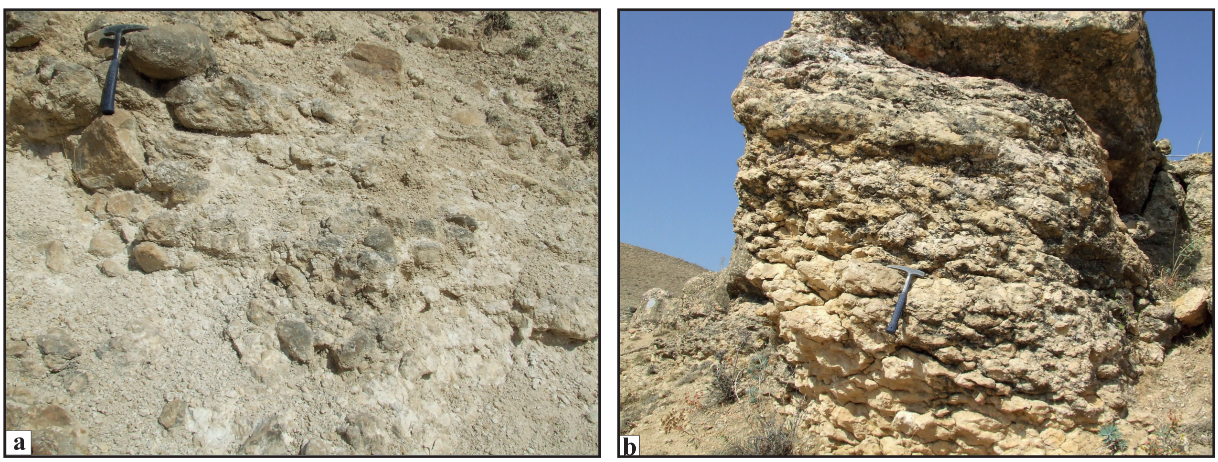


Figure 23- General views of the pebbly conglomerate derived from Elazığ magmatics, which is located at the bottom of the outcropping unit between Ayazpınar and Çukurca villages, and the overlying boundstone (K42 a1, 05087-08320, looking north).

the Elazığ magmatics, is paraconformably overlain by Pliocene volcanogenic sediments.

The exposures in the N-NE side of the Pertek fault are wider and spread on larger areas. The sedimentary deposit here is narrower in the west but widens eastward and its thickness increases. The exposures in the westernmost side are in the vicinity of Arılar, Çukurbağ and Kaballı districts in north of Sağman. The unit in these exposures begins with conglomerate-sandstone and ends with algal and bryozoan boundstone, grainstone-boundstone and clayey limestones (Figures 24 and 25). Conglomerate is thick bedded, loose-medium compacted, mostly derived from Keban platform, Elazığ magmatics and less from Kırkgeçit formation pebbles. The dominant rock type of the outcropping sedimentary deposit is boundstone, and it forms steep and thick moldings in the lateral direction on topography. It is also interlayered with clayey limestone in its western extension. The upper part of the succession consists of grayish-pale green clayey limestones, and it is interlayered with laterally lensoidal sandstone and limestone.

It extends first northward from the Dağarcık district then westward and eastward. The eastern extension of this outcrop is cut by N-S trending Değirmen Stream which was excavated at a depth of 250 m It is subhorizontally deposited in the outcrop in the west of Değirmen stream and consists of 40-50 m thick boundstone and the overlying clayey limestone (Figure 26a-b). The outcrops located on the eastern side of the Değirmen stream have the same lithological characteristics (Figure 27a-b); however, the clayey limestones are more widespread.

The unit unconformably overlies Elazığ magmatics and Keban metamorphics. It also unconformably overlies magmatics with 60 cm thick, loose compacted, rapid deposited, angular, pebbly conglomerates derived from Elazığ magmatics in the eastern slope of the Kara Tepe (hill) looking towards Tandır stream in the south of the Arılar district (Figures 28 and 29). The unit again unconformably overlies Keban metamorphics on the western part of the Dere town (Figures 30 and 31a-b). There is an angular unconformity on Keban metamorphics in the east of the Söğütlütepe district. However; it is unconformably overlain by younger sediments (Figure 32). Since the measured section could not be carried out its thickness is not known, but is considered to be more than 100 meters changes through in lateral direction.

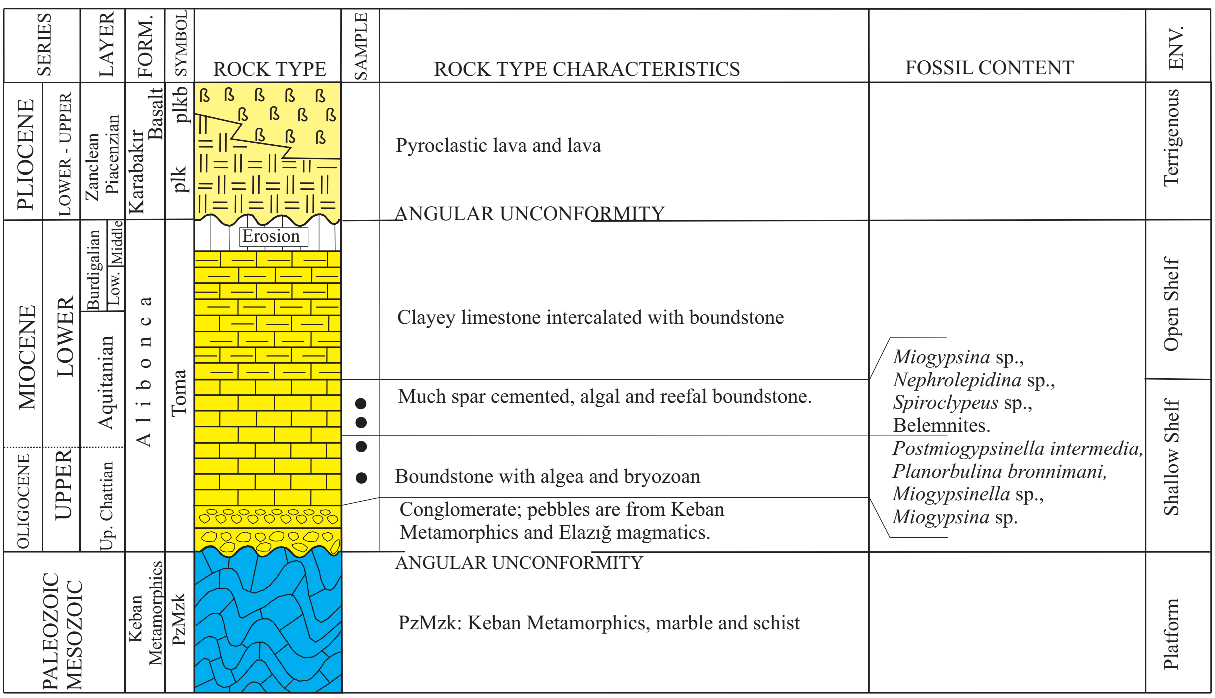


Figure 24- Generalized stratigraphical section showing the lithological characteristics of the Alibonca formation on the eastern edge of Uygun Tepe (hill), south of the Kaballı district and the sampled section (Herece, 2016).

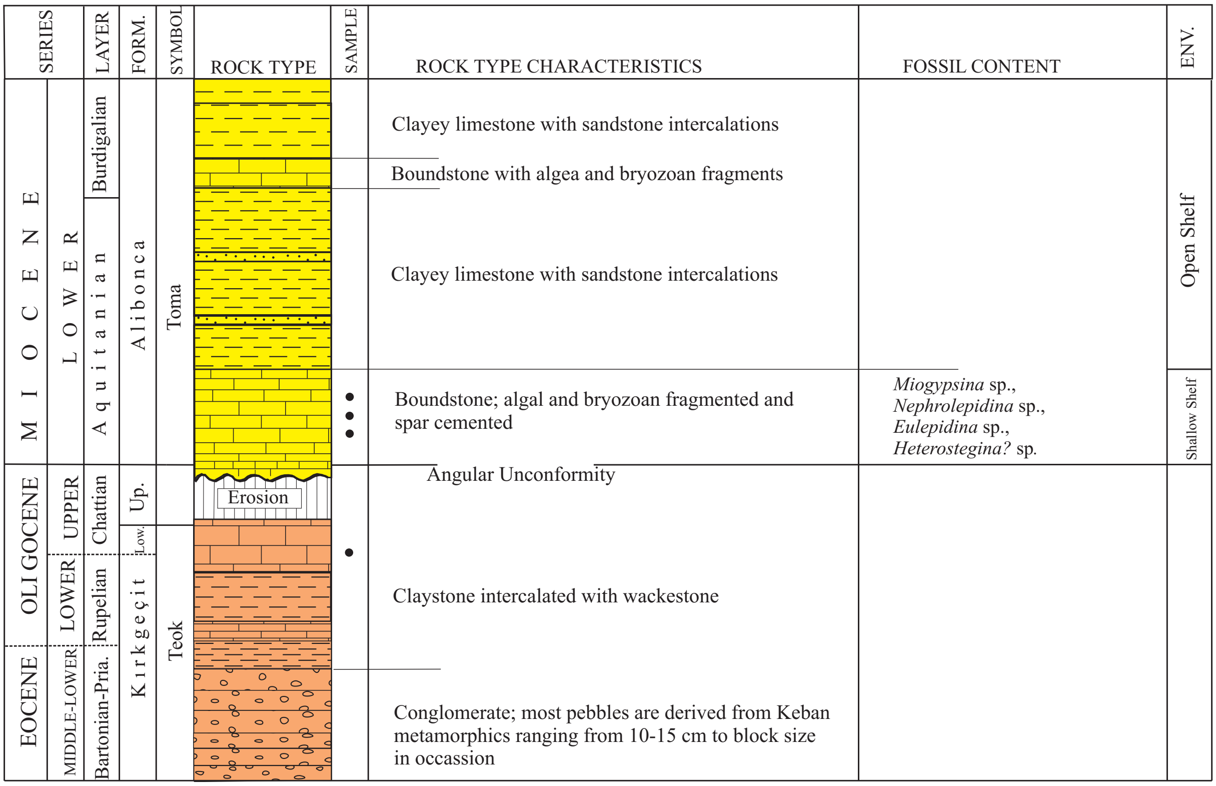


Figure 25- The generalized stratigraphical section showing the lithological characteristics of the Alibonca gormation cropping out in 1 km south of the Dağarcık district, the north of Sağman village, and sampled section of the succession (K42 b1, 25700-09500) (modified from Herece, 2016).

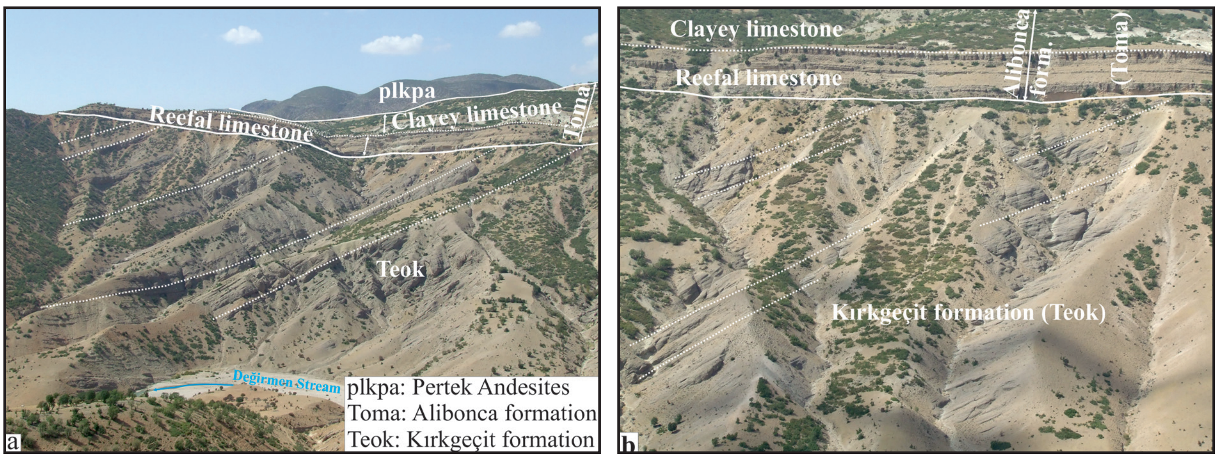


Figure 26- a-b. Horizontally deposited lithologies of the Alibonca formation extending northeastward from Sağman and the general views of the Kırkgeçit formation overlain by the angular unconformity (K42 b1, 27800-08900, looking NW).

The age of the Alibonca formation was determined by benthic, planktonic fauna and nannoplankton descriptions carried out in several samples collected at different elevations of the exposures in different areas (Herece, 2016).

The unit spreads over the wide region from east to west and the lithologies of the succession thickens with lateral facies changes. Therefore; a type location representing the whole unit could not be found. On the other hand, the western exposures of the boundstone forming the bottom of the formation are a few meters thick; however, this thickness reaches 50 meters towards east and forms steep cuts. Samplings in reefal limestones were carried out at different levels, which can be traced and reached in

Figure 27- a-b. General views of; a) the outcrop on the Kazıkbaba ridge in southeast of the Karabulut district (K42 b1, 32.500-14.400, looking west), south of the Yalınkaya village of the Alibonca formation, and b) the angular unconformities on the Kırkgeçit formation (K42 b1, 31.200-15.400, looking NW).

Figure 28- The general view of the lower contact relationship of the Alibonca formation which unconformably overlies the Elazığ magmatics (K42 b1, 22660-08663, looking WNW).

Figure 29- The general view of the basal conglomerate located at the bottom of the Alibonca formation and originated from angular, coarse ophiolitic pebbles, which unconformably overlies Elazığ magmatics in south of the Arılar district (K42 b1, 22660-08663, looking west).

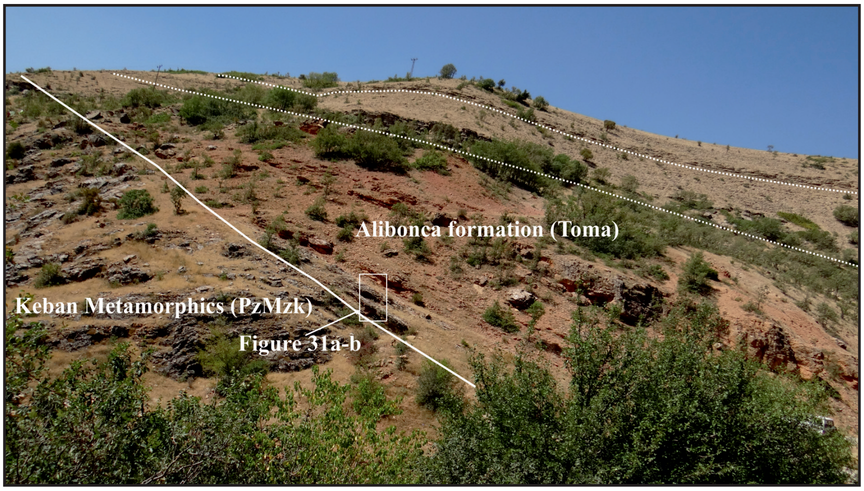


Figure 30- The general view of the Alibonca formation, which unconformably overlies the Keban metamorphics, and its lower contact relationship (K42 b1, 26425-15897, looking NW).

Figure 31- a-b. General views of the ~2 m thick basal conglomerates from pebbles of the Keban metamorphics at the bottom of the Alibonca formation (K42 b1, 26425-15897).

Figure 32- The contact relationship between the basalt member of the Alibonca and Karabakır formations in NE of the Ekşiler district (K42 b1, looking SSW).

the lateral direction, and the age data obtained were given below (Figures 33 and 34).

Samples taken from the first levels corresponding to the bottom of the unit in Dağarcık and Akmezra districts in Pertek NW and Çevirme district in the south of Tunceli city; *Postmiogypsinella intermedia* Sirel and Gedik, *Nephrolepidina morgani* Lemoine & Douville, *Planorbulina brönnimanni* Bignot and Decrouez, *Miogypsinella* cf. *complenata* (Schlumberger) foraminiferal assemblage was described which are late Chattian in age.

According to samplings made from bottom to top in reefal limestones, which are located at the lower part of the succession, from 1 km south of the Dağarcık district in NW of Pertek and from the Çamurluk district in the NW of the Günboğazı village (Figure 33); Early Miocene (early Aquitanian) age was taken from *Planobulina bronnimanni?* Bignot and Decrouez (piece), *Miogypsina* spp. (1, 2, 3), *Miogypsinoides* sp., *Nephrolepidina* sp., *Eulepidina* sp. and *Spiroclypeus* sp. fossil assemblage.

Boundstones are laterally transitional into clayey limestones in their upward and eastward extending exposures. Clayey limestone samples consisting the upper part of the succession in NW of the Dere town are Early Miocene (late Aquitanian-Burdigalian) with *Globoquadrina dehiscens* (Chapman, Parr and Collins), *Paragloborotalia semivera* (Hornibrook), *Globigerinoides trilobus* (Reuss) planktonic foraminifers. Samples collected from the north of Yalıkaya village at 5 km east of the Dere town are early Miocene (Burdigalian) with *Sphenolithus heteromorphus* Deflandre, *Cyclicargolithus abisectus* (Müller) nannoplanktons; and the samples collected from the boundstone in the vicinity of Günboğaz are Early Miocene (Burdigalian) with *Nephrolepidina tournoueri* Lemoine and Douville, *Miolepidocyclina* sp., *Miogypsina* spp. and *Eulepidina* sp. benthic fauna.

On the other hand, the levels forming the upper part of the clayey limestone deposit are observed around Karaveli. In several samples collected on these levels; *Globigerinoides trilobus* (Reuss), *Globigerinoides quadrilobatus* (d'Orbigny), *Catapsydrax dissimilis* (Cushman and Bermudez), *Globigerinoides sacculifer* (Brady), *Globoturborotalita euapertura* (Jenkins), *Globigerinoides altiaperturus* Bolli, *Globoquadrina venezuelana* (Hedberg), *Neogloboquadrina continuosa* (Blow), *Globigerina praebulloides occlusa* Blow and Banner, *Globigerinella obesa* (Bolli), *Globoquadrina* cf. *dehiscens* (Chapman, Parr and Collins), *Globigerinella* cf. *praesiphonifera* (Blow) and *Globigerinoides* cf. *quadrilobatus* (d'Orbigny) planktonic fauna gave Early Miocene (early-middle

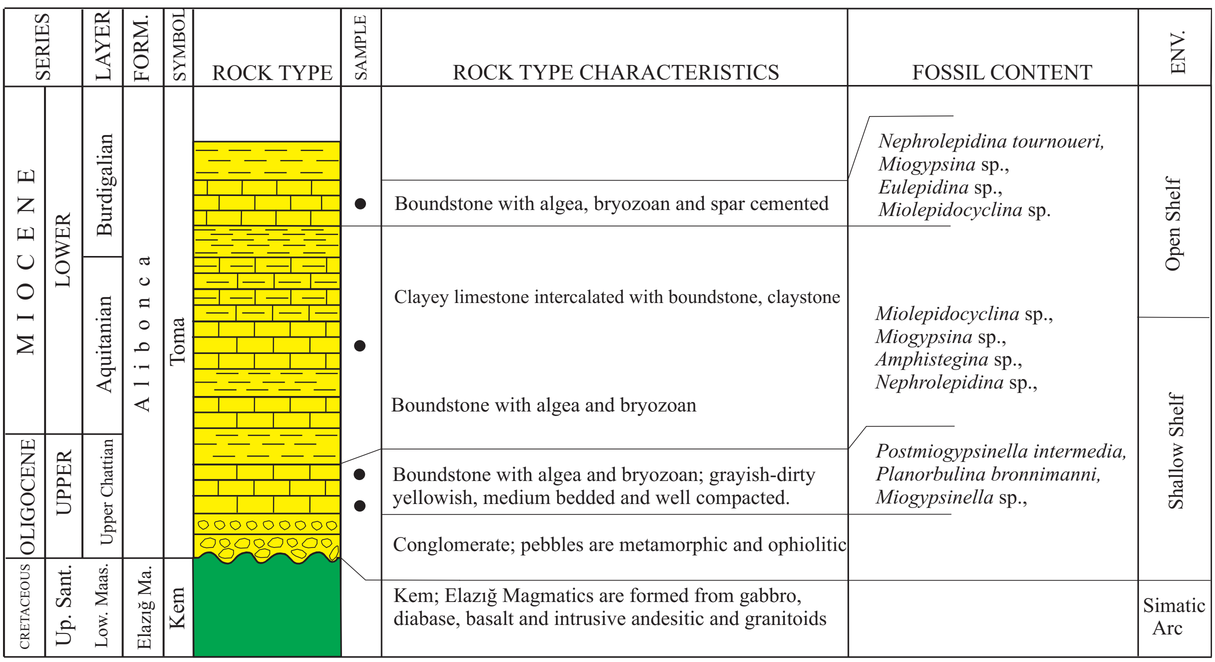


Figure 33- Stratigraphical section showing the rock type characteristics and sampled sections of the Alibonca formation in the vicinity of the Çamurluk district (K42 b1-b2).

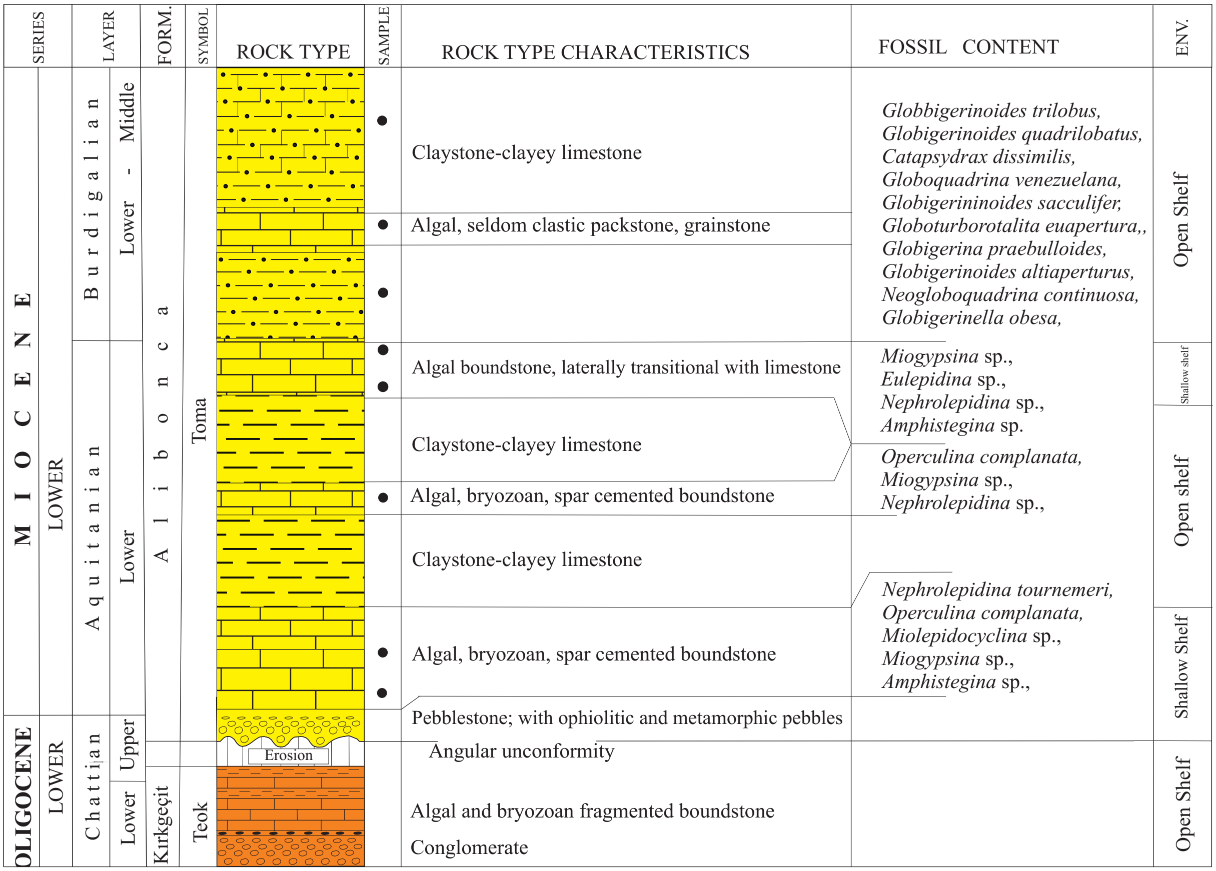


Figure 34- The generalized stratigraphical section showing the lithological characteristics, sampled sections of the succession and ages of the deposits of the Alibonca formation outcropping in north of Pertek.

Burdigalian) age. According to all these data the Alibonca formation is Late Oligocene-Early Miocene (late Chattian-middle Burdigalian) (Figure 34).

Conglomerate and sandstone located at the bottom of the succession were deposited in fluvial-shallow marine environment, the reefal limestone, clayey limestone and claystone were deposited in fore reef and open shelf conditions.

3.2.2. Karabakır Formation (plk)

Karabakır formation is outcropping in the region consists of volcanoclastics, pyroclastics, epiclastics, lava flows and lacustrine limestones, which are both laterally and vertically transitional, and fluvial deposits. Andesitic volcanic rocks, which have large exposures around Pertek within unit, and andesitic volcanics were named as the Pertek Andesite member and Basalt Member, respectively (Herece, 2016).

Pyroclastics cropping out in the vicinity of Aşağı Gülbahçe begins with coarse grained tuffs, continues with andesitic tuffs; afterwards, they present a deposit in the form of nearly 12 m thick lapillistones and pyroclastic breccia. Thicknesses of pyroclastic breccias increase towards Y. Gülbahçe village in the north. In poorly sorted breccias; the material forming the breccia is mostly andesitic and few basaltic in origin. In north of A. Gülbahçe village, reddish lapillistones outcropping in limited areas present distinctive structures as fairy chimneys in topography (Figure 35a-b). Reddish color is most probably because of ferric content in cement material (Figure 36a-b). Dominant pebbles in subhorizontally deposited lapillistone are andesitic and in minor amount basaltic in origin.

Volcanoclastics exposing in large areas present different characteristics based on depositional environment and on distances to volcanic centers. The lower part of the deposit crops out as tuff-ignimbrite alternation on the southwest end of the Demdemik rocks in northeast of the Konaklar district (Figure 37a-b). Tuffs are grayish white and ignimbrites are grayish-pale brown and massive. In the eastward lateral continuation

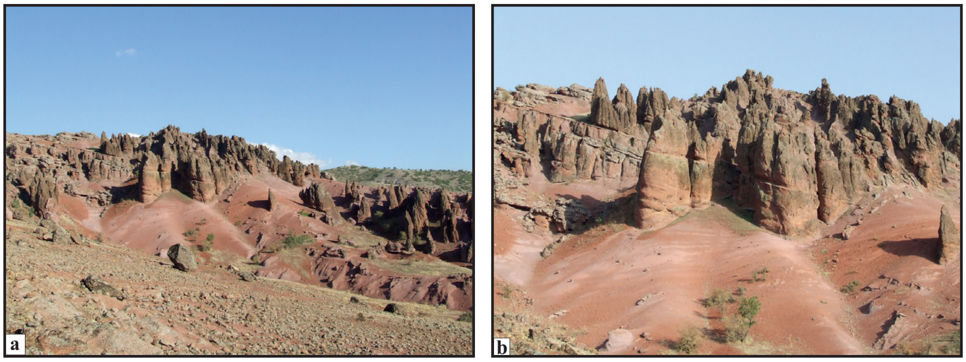


Figure 35- Views of lapillistones in N-NE of Aşağı Gülbahçe resembling to fairy chimneys on topography (K42 a2, 14750-09500, looking ENE).

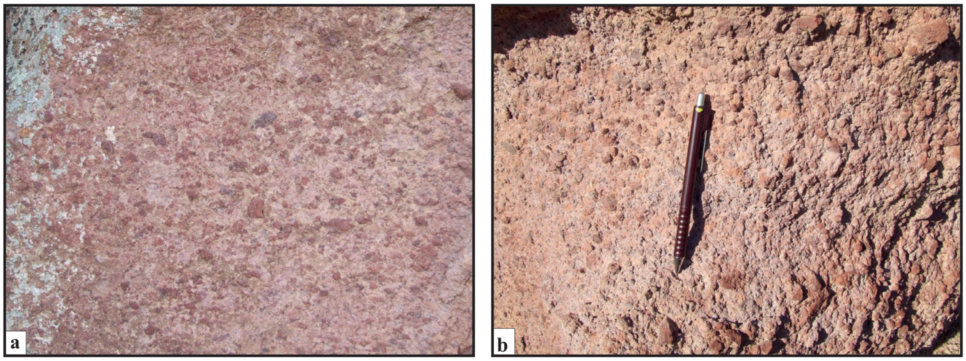


Figure 36- Close up views of the lapillistones cropping out in N-NE of Aşağı Gülbahçe (K42 a2, 14750-09500).

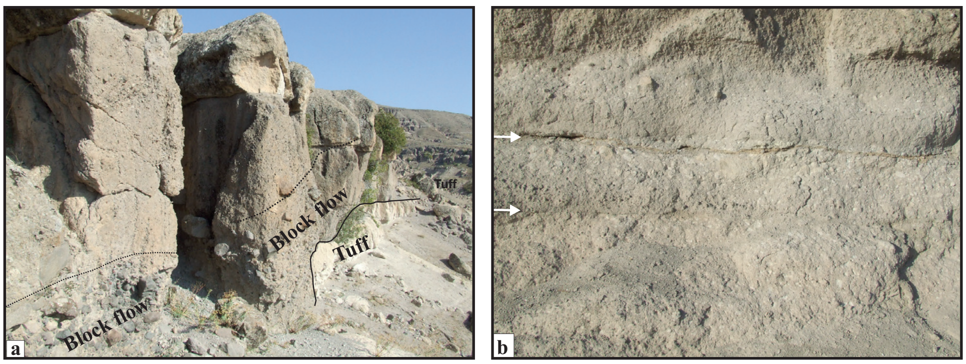


Figure 37- a) Views of ash and block flows during eruptions in SW end of Demdemik rocks, the NE of Konaklar, and b) eruptive volcanic products transported into the depositional environment (arrows indicate the sedimentary deposits of the basin).

of the same deposit, the debris flow and blocks from north to south during volcanic eruptions are observed on tuffs (Figure 38a-b). Similarly; eruptive volcanic products and pumice accretions in lapilli type on 3-6 cm thick mudstone bands are observed (Figures 39a-b and 40a-b). There is also observed the presence of lacustrine environment in the close vicinity of volcanic centers during volcanic activity.

Epiclastics are represented by agglomerate, sandstone, claystone and lacustrine limestones. Agglomerates are poorly sorted and angular pebbly in various sizes (Figure 41a-b). Most pebbles are andesitic and in few amounts basaltic origin. Sandstone interlayers deposited as alternating with agglomerate were formed by sub-horizontal, coarse grained sand accretion in ophiolitic and metamorphic origin. The groundmass among grains are formed by clay size material. Claystone interlayers are greenish brown with capillary caliche and loose textured.

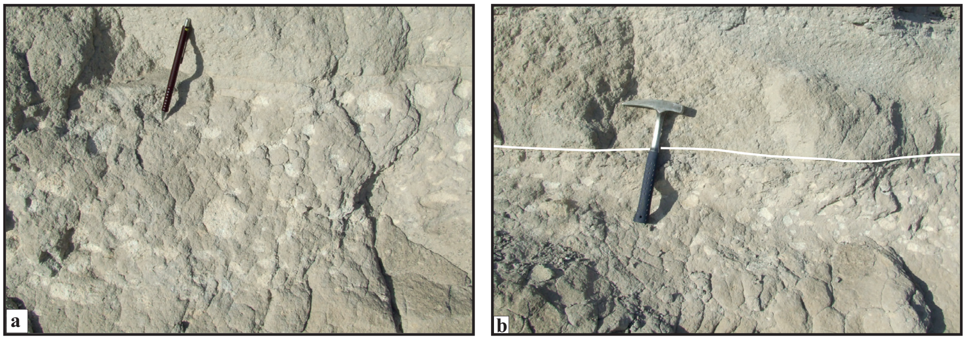


Figure 38- a-b. Volcanic products transported into the lacustrine environment during eruption (in tuff and lapilli sizes) (K42 a1, looking north).

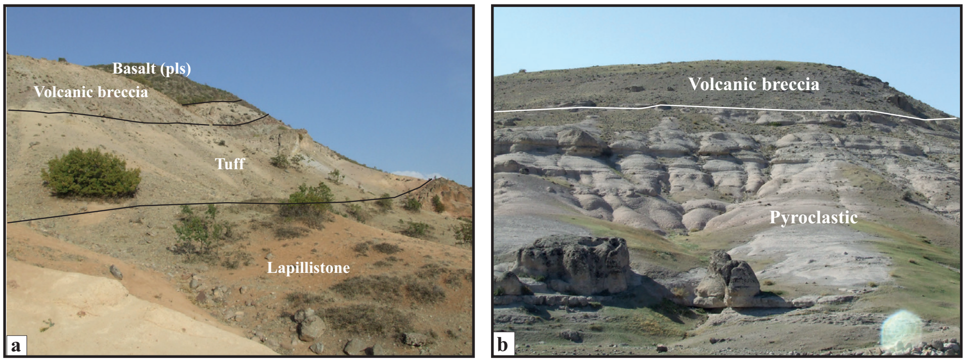


Figure 39- Views of; a) lapillistone and the overlying tuff, volcanic breccia and basaltic lava flows in Aşağı Gülbahçe NW (K42 a2), and b) volcanic breccias located on pyroclastics in the lower part of the succession in 1 km NE of Konaklar (K42 a1).

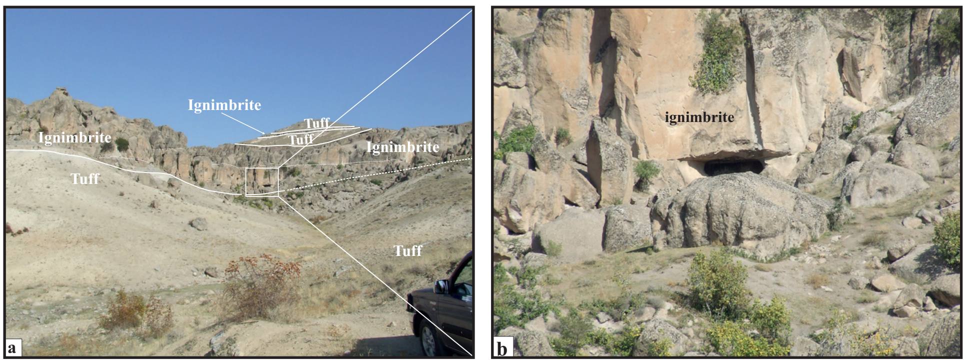


Figure 40- a-b. Views of tuff-ignimbrite alternation in the southwest end of Demdemik Rocks in NE of Konaklar (K42 a1, looking north).

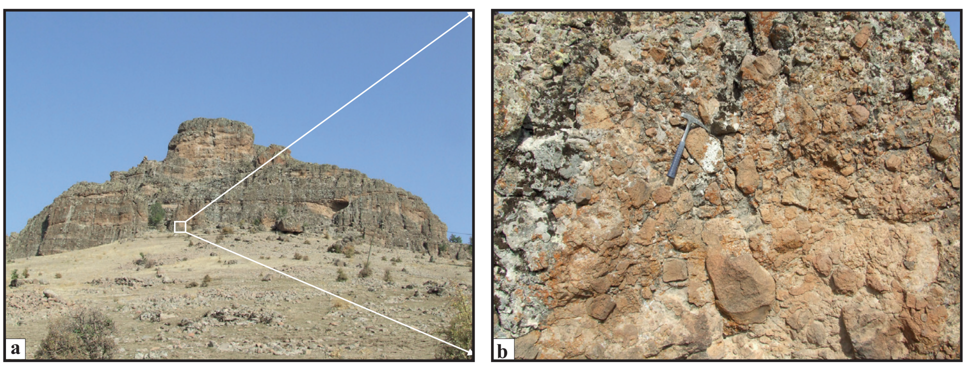


Figure 41- a) Massive agglomerates which have wide spread and outcrop in north of Yukarı Gülbahçe, and b) the close up views from agglomerates (K42 a2).

Undistinguished epiclastics are also observed within the study area. These are represented by conglomerate (agglomerate), sandstone, mudstone and lacustrine deposits. Coarse layered, massive agglomerate is badly sorted and matrix supported. Pebbles are of variable size, and blocks in 1 m size are encountered. Pebbles are generally angular, and most of them are andesite and the remaining is basalt.

Karabakır formation is stratigraphically deposited below the basalt member in 2 km northwest of the Günboğazı village. In the locality, the eastern part of the study area, the thickness of deposit becomes thinner compared to outcrops in west, and basalt exposures become widespread. The deposit of the formation cropping out along the road cut consists of the alternation of loose compacted, cross bedded, channel filled, coarse sandstone-pebblestone and conglomerate (Figure 42a), and it covers the rounded pebbles of the Alibonca formation (Figure 42b). The outcrops in east of the Tozkoparan village are located on the eastern slopes of the Karaçalı hills. The outcrop here consists of the alternation of grayish milky white, loose compacted, coarse sandstone and reddish bordeaux claystone.

Karabakır formation, which is located below the basalt in the near south of the study area along the cuts of Pertek-Elazığ road, is channel filled mudstone which is not thick (Figure 47a), and it comprises rounded, coarse pebbles of the basement units with Alibonca formation (Figure 47b).

The Karabakır formation has unconformable lower contact relationship with the underlying older units, but the upper contact is unconformably overlain by Quaternary deposits.

There was not made any fossil dating in the Karabakır formation. However; in the middle part of the lacustrine deposit, which consists of the Çaybağı basin located between Elazığ and Palu in near south of the study area without volcanics Micro Mammals Fauna (MMF) was determined as; *Promimomys moldavicus*, *Apodemus* cf. *dominans* and Castoridae gen. et. sp. indet. (big form) and the Early Pliocene age (MN-14) was detected representing 5.3-4.2 my interval. Similarly; *Mimomys occitanus*, *Occitanomys brailloni*, *Apodemus* sp. (cf. *dominans?*), Cricetidae gen. et sp. indet MMF fauna was detected from the Sürsürü district in south of Elazığ gives Early Pliocene (MN-15) which represents 4.2-3.4 my age interval (Herece et al., 1992). In Muş and its surrounding, the Late Pliocene-Early Pleistocene (MN-17) representing 2.6-1.95 my age interval was obtained from the lateral equivalence of the similar deposits (Akay et al., 1989).

On the other hand, the basalt, which outcrops in large areas in east and outside the study area and named as Solhan volcanics, were radiometrically dated. These radiometric ages were taken as; 4.4±1.08my and 6.0±1.0my (Pearce et al., 1990), in Karakoçan surround as; 4.1±0.32my (Sanver, 1968) and in Muş surrounding as; 4.4±1.3my and 6.0±0.6my (Türkecan, 1991). The ages corresponding to upper Late Miocene-lower Early Pliocene most probably match with the lower age boundary of volcanics, and the lower age limit of the volcanics may drop down to upper Late Miocene (Messinian).

According to these data, the volcanism in the Karabakır formation began in the upper Late Miocene and the depositional conditions have continued until Late Pliocene as transitionally in horizontal-vertical directions with the active volcanism and depositional

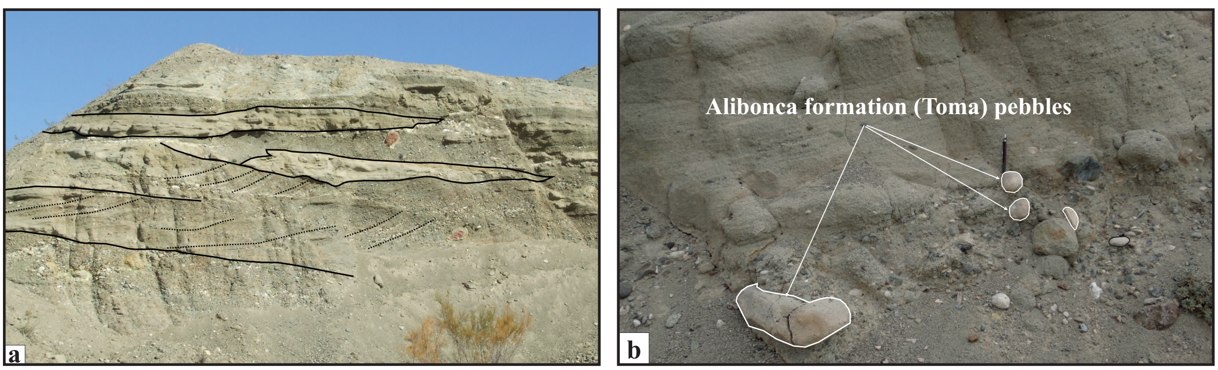


Figure 42- a) Coarse sandstone-conglomerate alternation forming the bottom of the Karabakır formation (K42 b2, 37384-14207), and b) lime pebbles of the Alibonca formation within conglomerate (K42 b2, 37384-14207).

environments of the unit are fluvial, fluvial-lake and lake environments in which the volcanism is active.

Pertek Andesite Member (plkpa): It consists of andesitic volcanics and was first defined and named by Herece (2016a). The exposures of andesitic volcanics around Pertek are located in south and north of the Keban Dam Lake. Type locality is observed on Karataş Tepe (hill) in the south of the dam lake and in Pertek fortress in Dam Lake (Figure 43a-b). The exposures in north of the Keban Dam Lake are observed in north of Yukarı Gülbahçe village and as volcanic neck (Figure 44a) in Kale Tepe and as large dyke in east (Figure 44b). The outcrop of andesites in Pertek NW are the Büyük Tepe located among the Çıkıntı district in south, Ardıç village in north and Söğütlütepe in east, Eşikmeydanı Tepe and other elevated areas. Most of the unit in this area is massive and sustainable to eroding and weathering.

Andesitic volcanics were sampled in the field and collected samples were petrographically described (Herece, 2016). Samples collected from the northern slope of the Büyük Tepe in the Fındıklı district of Pertek were defined as hornblende andesite. Andesite is microlithic porphyric and occasionally glassy, microlithic porphyric in texture and consists of plagioclase, amphibole (hornblende), biotite and opaque minerals. The groundmass of the rocks is formed by volcanic glass, plagioclase, amphibole, biotite microliths and rare opaque minerals.

The outcrop in the south of Pertek-Söğütlü Tepe was defined as andesite porphyry. The rock is glassy microlitic porphyritic in texture and consists of plagioclase, amphibole and biotite minerals. The groundmass is amphibole opacitized with plagioclase microliths. Another andesite sample is microlitic porphyritic in texture and contains plagioclase,

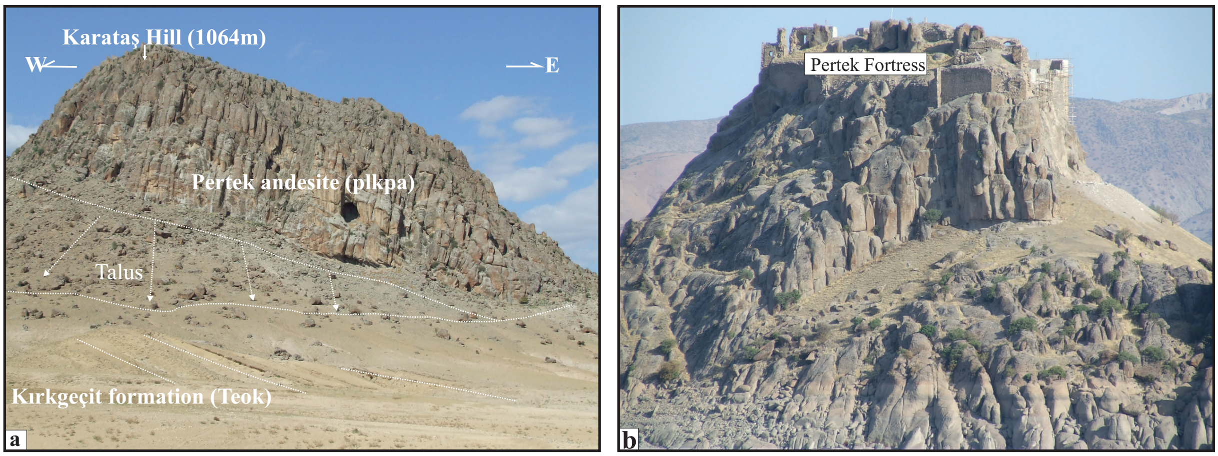


Figure 43- Views of volcanic chimneys formed by outcropping Pertek andesites a) in Karataş Tepe in Pertek SW (K42 b4, 22000-99000) and b) in Pertek fortress (K42 b4, 23500-99500).

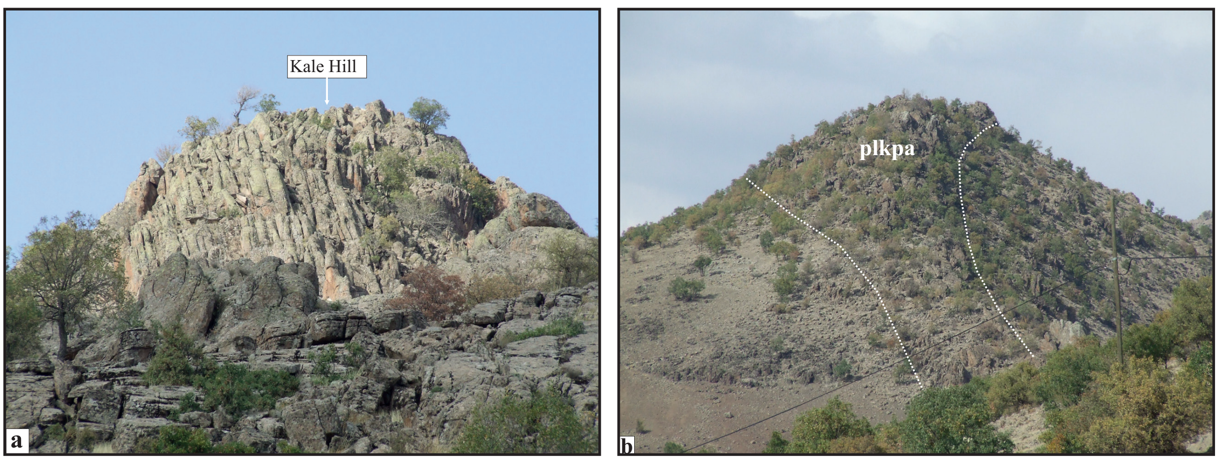


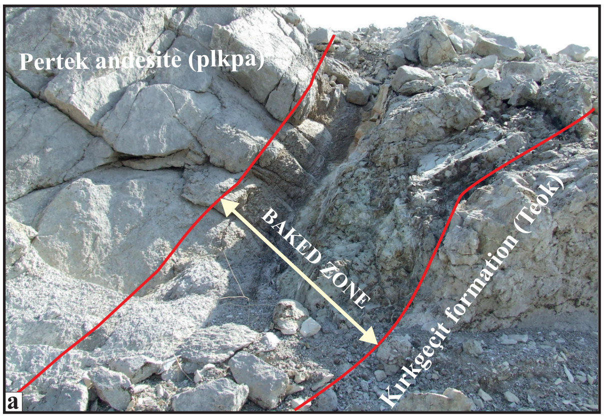
Figure 44- a-b. General views of the Pertek andesites outcropping in Kale Tepe and its east side in north of the Yukarı Gülbahçe village (K42 a2, 14075-12100, looking north).

pyroxene (clinopyroxene) and amphibole minerals. The groundmass is formed by plagioclase and tiny opaque minerals which are in radiated form with amphibole microliths.

The northeastern end of the Pertek fortress, as the location of volcanic neck, in south of Pertek was sampled (Figure 45b). All these samples were described as andesite. The rock consists of plagioclase, amphibole (hornblende), biotite, opaque mineral, apatite and zircon minerals, and the groundmass is formed by plagioclase and opaque minerals which are radiated with amphibole microliths. Sericitization and argillization are observed among the plagioclase microliths in the groundmass.

There is not any data on age and the formational period of Pertek andesites. Lower and upper age boundaries are hypothetically determined according to the contact and stratigraphical relationships of the rocks with respect to its surrounding.

Andesite outcrops in Pertek fortress and its close vicinity is intrusively associated with Kırkgeçit and Alibonca formations (Figure 45a-b). According to these stratigraphical relationships the andesitic volcanism is younger than Kırkgeçit and Alibonca formations. Besides; agglomerates in the volcanoclastic deposit of the Karabakır formation widely comprises andesitic pebbles (Figure 46a), and the andesitic volcanics in west of the Çıkıntı district in Pertek are also overlain by sub horizontally bedded tuff and basalts of the Pliocene Karabakır formation (Figure 46b). Also the lapillistone in lower part of the deposit forming the formation is much andesitic pebbly. Moreover; thin andesitic lava flows are observed also within pyroclastics. Pertek andesites are stratigraphically located in the lower part of the volcanic succession and in the upper part of the succession on the other side. Besides; they support volcanic products to volcanoclastics and pyroclastics located in upper part of the deposit, and the youngest ones of the volcanism cut Pliocene Karabakır formation as dykes.



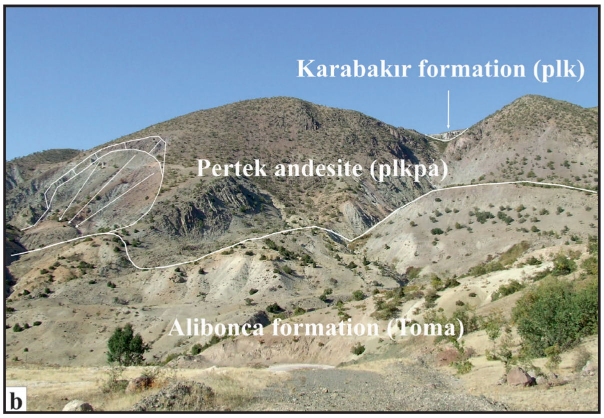


Figure 45- a) Baked zone between Pertek andesite and Kırkgeçit formation in NE end of Karataş Tepe on the southern boundary of the Keban Dam Lake (K42 b4) and b) the crosscut of the Alibonca formation in N-NE of the Çıkıntı District by Pertek andesites (K42 b2).

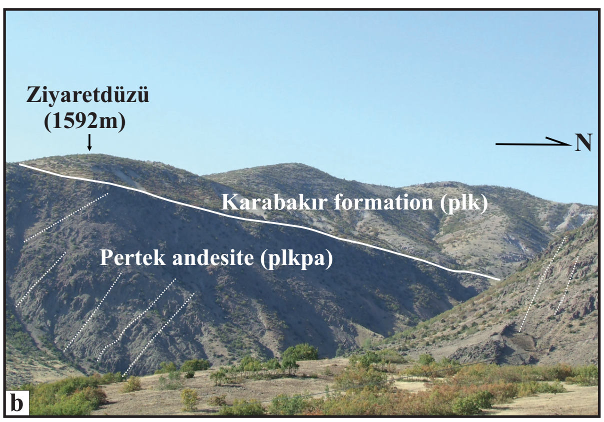


Figure 46- a) Views of andesitic volcanic pebbles in the agglomerates of the Karabakır formation and b) the coverage of the Karabakır formation of the Pertek andesites in 1 km west of the Çıkıntı District (K41 b1).

According to all these stratigraphical and contact relationships, the volcanism forming Pertek andesites should have begun in pre Pliocene, most probably in Late Miocene and continued its activity during Pliocene.

Basalt Member (plkb): Sub horizontally deposited basalts overlying the Karabakır formation are the dominant rock type in their eastward and westward extensions. Basalts, which have the first primary relationship with the Karabakır formation, were distinguished as the member and named based on the lithology (Herece, 2016). The locations of the volcanic centers were defined as basalt member in exposures which are not distinctive or in places outside the study area. Basalt outcrops located in north of the Keban Dam Lake are in the vicinity of the Çevirme District in east and Gülbahçe and Konaklar villages in west. The outcrops in south of the dam lake are observed between Alaca-Körpe and around Beydalı-Beşoluk.

Basalt exposures in north of the Keban Dam Lake and the eastern part of the mapping area are observed in the Çevirme district and its east. The outcrops in this locality originated from E-W trending volcanic crater with sizes of 1.7x2.5 km. Type localities of the unit are in the vicinities of Günboğazı, Yolkonak and Beydamı villages. The basalt that had flown from the Korucak Tepe (hill) located at an elevation of 1383 m in 2.25 km of the Bulgurtepe village to S-SW direction have reached the Demdemik rocks at 1020 m in 1.5 km NE of the Konaklar village. Volcanics in this area are between ~100-110 m thick according to topographical data.

Basalt outcrops in south of the Keban Dam Lake are located in east and west of the Körpe district in the west and between Beydalı-Beşoluk in east. The exposures around the Körpe district originates from the volcanic center in the south and outside the mapping area and continues northward. However; the volcanic centers of exposures in east are the hill with elevation of ~970 m in the south of Beşoluk village. Basalt that had flown northward starting from the center has formed Çakmaközü and Beydalı plains today. Basaltic flows in the area are ~40-50 m thick, and this thickness flows towards centers in south. Type localities of the unit are road cuts along Elazığ-Pertek highway (Figure 47a-b).

Samples collected from basaltic lava flows are glassy, microlitic porphyritic textured. The groundmass of the rock consists of plagioclase microliths and opaque minerals in radiated form. It contains plagioclase, pyroxene (augite), olivine and much olivine residuals with opaque minerals (Herece, 2016).

Basalt member is laterally transitional in vertical-horizontal directions with sedimentary lithologies of the Karabakır formation at its lower boundary; however, it is unconformably overlain by the Early Pliocene deposits.

There is not any radiometric dating performed for the Basalt member within the study area. However; the

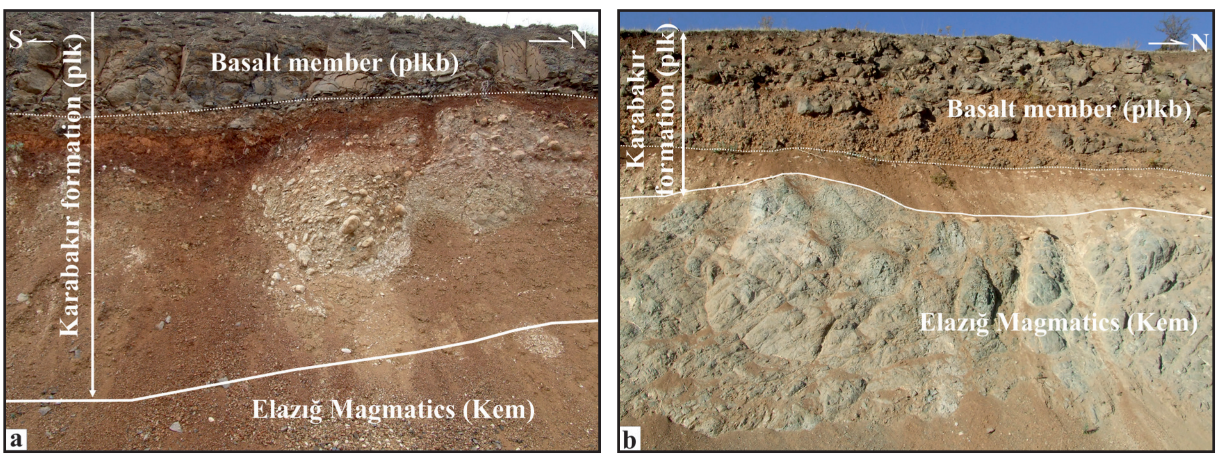


Figure 47- General views of; a) the basalt member of the Karabakır formation and the underlying mudstone and channel fill conglomerate in road cuts of the Pertek-Elazığ highway (K42 d2, 18223-88326, looking west), and b) lower contact relationships of the thin Karabakır formation and Basalt member (K42 a3, 17400-89925, looking west).

basalts outcropping in Elazığ NW were radiometrically dated, and 1.8±0.05my and 1.9±0.08my (Sekrek et al., 2008); 1.47±0.09my and 1.87±0.07my (Arger et al., 2000) were taken. These ages correspond to the Late Pliocene.

The depositional environment of volcanic and volcanoclastic rocks are fluvial and lacustrine that are horizontally-vertically transitional with volcanic center.

3.3. Palu Formation (Qpa)

The unit, which is rounded, grain supported pebble stocks, was first named by Herece et al. (1992). Type locality of the unit, which outcrops in Pertek NE and Alaca Village NW, are the road cuts of the Pertek-Tunceli highway in the south of Yeniköy. The unit consists of conglomerate and the overlying pale brown sandstone and thin mudstone layers. The formation has an angular unconformity with the underlying Karabakır formation and other older units.

There is not any age data but most probably it should be early Pleistocene. Mostly; they are alluvial fan deposits.

3.4. Quaternary (Qal)

Forms mapped as terraces, alluvial deposits, talus, alluvial fans have been formed as a result of river and stream activities in the region. The alluvial deposits, which formed by loosely compacted silt, clay and fine sand-intra block material, develop on river sides and rivers.

4. Structural Geology

4.1. Faults

The abvious faults in the region were observed. Significant faults are right lateral strike slip Pertek fault and left lateral strike slip Koruköy fault.

4.1.1. Pertek Fault

The fault restricts the Pertek settlement area from east (Bingöl, 1984; Aksoy, 1994), forms distinctive structures at the surface and can laterally be traced from SE to NW. SE extension of the fault remains beneath the Keban Dam Lake and NW extension of it can be traced until NW of Çağlarca town. Fault scarps, fault plains and slickensides preserved on plains indicate that movement along the fault zone is right lateral strike slip (Herece, 2014). According to fault scarps, plains formed and offsets in the drainage perpendicular to the fault zone, destructive earthquakes with magnitudes more than 7 (M≥7.0) could develop along the zone (Herece, 2014). However; the slip-rate to be low in the fault zone shows that the recurrence intervals of earthquakes could be quite long.

4.1.2. Koruköy Fault

This fault is formed by two distinctive segments on the eastern facing slopes of the Keban metamorphics in north of Koruköy. NE extensions of the faults are below the Keban Dam Lake, and SW extensions could not be traced due to agricultural activity. The eastern segment is between Keban metamorphics and Elazığ magmatics, and restricts magmatics from the west.

4.1.3. Esenkent Fault

The fault restricting Esenkent settlement area from east extends linearly toward NE, and its SW extension makes a smouth curve. The fault restricts Elazığ magmatics from the east and separates from Keban metamorphics. There was not found any data about the recent activity of the fault.

Faults have most probably developed as reverse faults on the NNW boundary of the Kırkgeçit formation outcropping in south of the Keban Dam Lake during NNW-SSE directed compression which ends the basin forming process in the Kırkgeçit formation. Keban metamorphics in north of Alatarla overlies Elazığ magmatics and Kırkgeçit formation with reverse fault. In addition; probable left lateral strike slip faults with the strike of N30°-40°E are observed located within Keban metamorphics and between Keban metamorphics and Elazığ magmatics in NE of Koruköy. There is observed another fault with similar strike located between Keban metamorphics and Elazığ magmatics in east of these faults. NE extensions of the fault systems in this area remain below the Keban Dam Lake; SW extensions on the other hand fall outside the study area and remain as a problem to be solved.

4.1.4. Folds

Folds with an axial strike of N65°E in the Kırkgeçit formation is observed in the vicinity of the Kabakçılar district. The convergence that has been effective in the region is N25°W in direction. The folding in this area has not affected basalts of the horizontally bedded Pliocene Karabakır formation. Besides; the Alibonca formation is horizontally bedded as well. Accordingly; the regional compression generating the folding should have occurred during early Chattian.

4.3. Mass Movements

Remarkable landslide areas are observed within the study area. The first of the landslides is along Pertek-Tunceli road, the south of the Mercimek village. The landslide here originates from heavily crushed zones developed in Elazığ magmatics and the hill slope (Figure 48a-b).

The second landslide is in the last section of Pliocene volcanics in south of the Keban Dam Lake (K42 b4). It is nearly 500 meters wide and occurs in the NE end of the Çakmaközü Plain and the NW end of the Beydali Plain (Figure 49a). Both landslides develop towards Keban Dam Lake. The reason that causes the landslide is lithologies which are not well compacted below thick basalts.

NW-SE extending ridge in Sorkun District in NW of Pertek is formed by Pliocene basalts. The presence of fault extending along the NE boundary of the ridge and loose lithologies of the Alibonca formation give rise to landslide (Figure 49b).

In 4 km NW of the Sorkun District, four different landslides 1 km width take place on the northern slope of the Eşikmeydanı hill that formed by andesitic volcanics (Figure 50a). Fındıklı (Figure 50b), Ardıç and Söğütlütepe villages (K42 b1) are located on

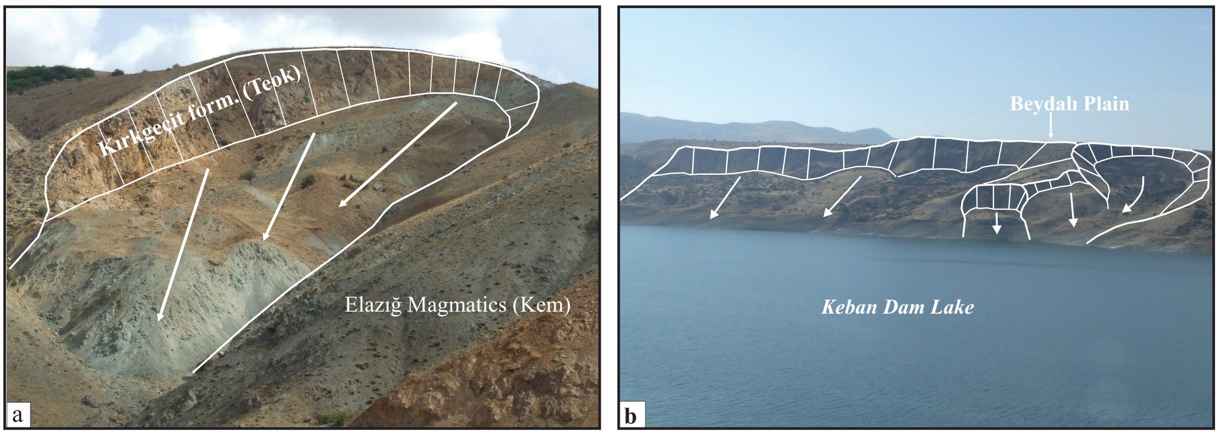


Figure 48- Views of; a) ophiolites of the Kırkgeçit formation and widespread landslides that have formed in the lower boundary around Mercimek village (K42 b3, looking NE), and b) the landslide that developed on NE slope of the Beydalı Plain in north of the Beydalı village (K42 b4, looking SW).

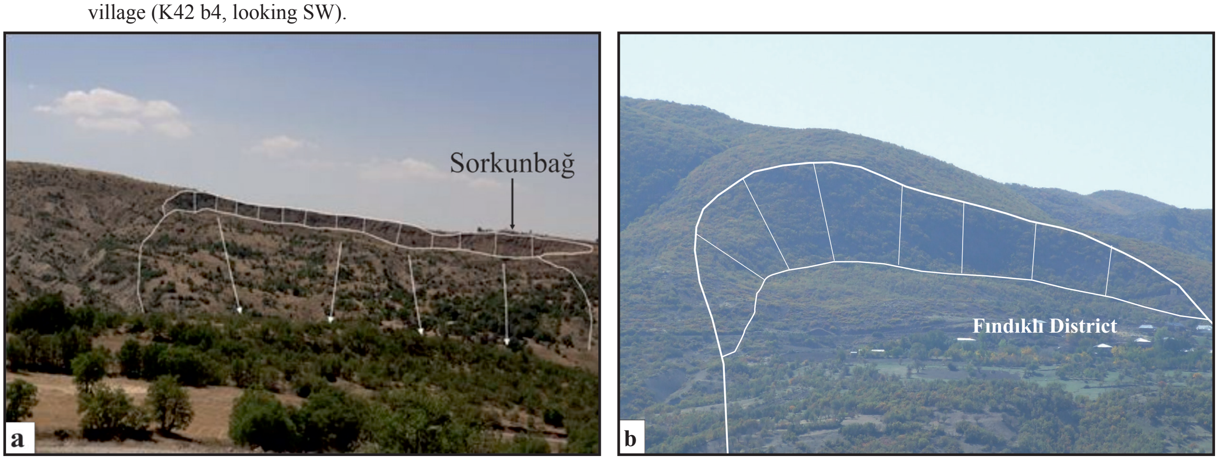


Figure 49- The general view of the landslide that developed; a) along a distinctive fault on NW boundary of Pliocene volcanics outcropping in near north of the Sorkunbağ village (K42 b1, Sorkunbağ district, looking south), and b) towards NW in Kengerlik locality located in NW slope of Eşikmeydanı Tepe (K42 b1, looking SE).

landslides that have developed from steeply sloping hills in the south towards north.

4.4. Deformation Phases

There have been some macrotectonic events during Maastrichtian, Lower Eocene, middle-upper Lutetian, Middle Oligocene, Middle-Late Miocene and Late Pliocene corresponding to periods in which the unconformities in sedimentary deposits had formed in the study area.

4.4.1. Macrotectonics during Maastrichtian Phase

Rifting of Neotethys ocean which separates the northern and southern continents that began during the Middle?-Late Triassic and continued during the Late Jurassic-Early Cretaceous to form the ophiolites. On the supra-subduction zone dipping north in the ocean that began during the Late Cretaceous, SSZ ophiolites and Elazığ magmatic and by the subduction of the oceanic crust beneath the Keban platform in the north, Baskil magmatics were formed.

Keban-Malatya metamorphics, Baskil and Elazığ magmatics that form the northern continent are being overlain by late Maastrichtian-Middle Paleocene Harami formation while the Pütürge metamorphics and Guleman ophiolites located in the south are being covered by late Maastrichtian-Middle Paleocene Simaki formation with angular unconformity.

All these basements units have been juxtaposed due to tectonic events as a result of the collision occurred in middle Maastrichtian; they have been uplifted and eroded and have formed source areas for the Paleogene basins that begin with late Maastrichtian deposits. In the study area there are no data to indicate subduction during Paleogene.

All these basements units have been juxtaposed due to tectonic events as a result of the collision occurred in middle Maastrichtian; they have been uplifted and eroded and have formed source areas for the Paleogene basins that begin with late Maastrichtian deposits.

4.4.2. Macrotectonics during Lower Eocene Phase

During Early Eocene, the region has been uplifted and depositional conditions in the Harami formation were terminated. The uplifted region has re-subsided and caused the formation of the Seske formation which has exposures in limited areas.

4.4.3. Macrotectonics during middle-upper Lutetian Phase

The second deformation affecting the region occurred in middle-late Lutetian. Distinctive deformations of this phase is observed in the south of Elazığ.

The tectonic line which is known as Uluova fault in the south of Elazığ begins in Palu and extends westward on Çaybağı, Mollakendi and south of Akçakale and juxtaposes different basement units of different ages and the Paleogene basins. In the area north of the Uluova fault Keban-Malatya platform, Elazığ magmatics and Andezitik volcanoclastics, and in the south of the fault Pütürge metamorphics and Guleman ophiolites are located. The basement units located in the north are unconformably being overlain by late Maastrichtian-Middle Paleocene Harami formation, late Cuvisien-middle Lutetien Seske formation and early Bartonian-early Chattian Kırkgeçit formation. The basement units on the south of the fault, on the other hand, are unconformably being overlain by late Maastrichtian-Paleocene Simaki formation, Paleocene-Early Eocene Gehroz formation and Lutetian Melefan and Karadere formations.

By N-S directing compression during Middle-late Lutetian, areas in south of the Uluova fault were uplifted and the depositional conditions terminated. Consequently, while block formations in Melefan formation were occurring, volcanic facies in Karadere formation developed. In the area to the north of the fault the Seske basin first uplifted and became terrestrial and the Kırkgeçit basin which began forming during the early Bartonian continued its development until early Chattian with a new angular unconformity.

4.4.4. Middle Oligocene Stage Macrotectonics

In this deformation period, the region uplifted and depositional conditions in the Kırkgeçit basin has ended. Although the deformation has occurred due to the compression of the region in NNW-SSE directions, the reason is not clearly known. Late Oligocene-Early Miocene Alibonca formation developed in the basin formation that has formed due to the termination of compression.

4.4.5. Macrotectonics During Middle?-Late Miocene Phase

Another deformation period that has been effective in the region occurred in Middle-Late Miocene and the region was uplifted; so the depositional conditions ended in the Alibonca formation. The deformation occurred due to the compression in N-S directions. It has most probably occurred by the northward movement of the African-Arabian plate (Herece, 2008). As a result of the decrease in N-S convergence velocity in this deformation period, the lacustrine deposits and widespread volcanic activity in local areas have occurred.

4.4.6. Macrotectonics During Uppermost Pliocene Phase

The most remarkable structure of this deformational period is the development of the EAF. Continental convergence rate which continued slower during the Pliocene has increased during the Latest Pliocene and the region was uplifted by compression. The most effective N-S convergence before the development of the EAF in the region has caused east-west trending compressive folds in the Çaybağı Pliocene basin located in the east of Elazığ; therefore, the basement in north of the basin has been uplifted and locally thrusted on Pliocene units.

Based on the activity of the EAF which began moving after this folding and deposition, Early Pleistocene deposits were developed. Due to this compression, the right lateral movement along the Pertek fault should have begun to gain activity. Aksoy (1994) investigated one segment of the fault around Pertek and stated that it had been right lateral strike slip fault with reverse fault component. The position of the fault within regional tectonism, its extension and activity was also asserted (Ozaner et al., 2010; Herece, 2014).

The 40 km section of the Pertek fault cropping out within study area was mapped for the first time based on field data. However; the extensions of the fault towards NW and SE have not adequately been investigated. The right lateral strike slip fault also covers the reverse slip component in few amounts. Besides; 6.0 km and 3.25 km offsets were detected in basement units and Pliocene deposits, respectively (Herece, 2014). The regional compression forming the fault is ~350°, and right-lateral offsets varying in between 75-975 meters have occurred in streams that are flowing perpendicular to the fault (Herece, 2014).

5. Discussion

Keban metamorphics and Elazığ magmatics are the basement units of the region. Keban metamorphics are generally observed as; marble, schist and amphibolites. They were deposited as limestone within interval of Permian-Cretaceous and metamorphosed in green schist facies during Campanian-early Maastrichtian.

Elazığ magmatics were formed by ensimatic island arc units developed on the ophiolitic deposit which formed in the intra-oceanic supra subduction zone. Ophiolites present a successive deposit and consist of gabbro, diabase, basalt and andesitic volcanics-tuff and agglomerates from bottom to top. Ensimatic island arc consists of intrusive diorite, monzodiorite, tonalite, granite and granodiorite and it is Late Cretaceous.

Keban platform was intruded by Baskil magmatics due to the northward subduction in Senonian. The intrusives of the Baskil magmatic also intruded into the tectonic contacts of metamorphics with ophiolites (Yazgan and Chessex, 1991). The bottom of metamorphics in and around the study area cannot be observed and they overlie Elazığ magmatics with reverse fault. The succession, which deposited under environmental conditions, are most probably the lateral equivalence of Malatya metamorphics.

Elazığ magmatics are the unit discussed in limited studies within the study area and defined under various names. The unit, which has a wide spread along a belt, have been defined as; Yüksekova complex (Perinçek, 1979), Elazığ complex (Hempton and Savcı 1982), Elazığ igniyıs complex (Hempton 1984, 1985), and as 4 units belonging to Yüksekova complex (Bingöl 1984). However; Turan et al. (1995) investigated Elazığ magmatics cropping out in this region under the name of "Elazığ magmatics" as they are in a successive internal structure.

There is not any radiometric age determination in Elazığ magmatics within study area. The unit is unconformably overlain by late Maastrichtian Harami formation. The basalt unit, which is on top of diabases located in the upper part of magmatics, is Late Senonian based on planktonic fossils as described in samples collected from pelagic limestones (Herece et al., 1992). On the other hand; the ophiolitic deposit, which is located below and in the western extension of Elazığ magmatics in the vicinity of Hazar Lake, was named as Kömürhan ophiolites (Yazgan, 1983; Poyraz, 1988). Kömürhan ophiolites consist of three tectonic slices (Yazgan 1983; Poyraz 1988; Yazgan and Chessex 1991; Beyarslan and Bingöl 1996; Beyarslan and Bingöl, 2000) and its upper tectonic slice is the basement unit of the Baskil arc unit (Yazgan an Chessex, 1991). The lower tectonic slice was dated as; 127±14my, 89.5±5my by K/Ar method. Besides; 85±3 my age was taken by means of biotite dating from leucodiorites, which formed by the partial melting of amphiboles; and 78.5±2.5 My age was taken from trondjhemitic granophyre by means of muscovite dating (Yazgan and Chessex, 1991).

Baskil magmatics, which cut Keban metamorphic, were as well dated by K/Ar method as; 76±2,5 My, 78,5±2,5 My; and from biotite, muscovites in granodioritic intrusives 75±2,5 My, 75,4±2,5 My ages were obtained. The ages taken are explained by the partial melting of the continental crust below the ophiolitic nappes due to ophiolitic obduction (Yazgan and Chessex, 1991).

Kömürhan ophiolite around Hazar Lake overlies Pütürge metamorphics by 40° northerly dipping reverse fault. However, it is underlain by Elazığ magmatics with a similarly dipping reverse fault (Robertson et al., 2007) and transitional with Elazığ magmatics in the west of Hazar Lake (Herece et al., 1992). On the other hand, both units are then unconformably overlain by late Maastrichtian Harami formation (Herece et. al., 1992).

It is stated that the depositional environment of Elazığ magmatics are products of arc-backarc (Hempton, 1985), arc-forearc (Yazgan and Chessex, 1991) of the ensimatic island arc, and the ensimatic island arc products of the supra subduction zone ophiolites due to intraoceanic subduction-obduction (Beyarslan and Bingöl 2000; Robertson, 2002).

Supra-subduction zone ophiolites and ensimatic island arc volcanics are unconformably overlain by late Maastrichtian-Selandian Harami formation. On the other hand, it is asserted that there is not any unconformity between Harami formation and Elazığ magmatics in studies carried out by Aksoy et al. (1999). It is also emphasized that the depositional conditions in the Harami formation began in late Campanian and continued in Maastrichtian as well in which the arc magmatism had stopped. In studies carried out by Herece et al. (1992) and Herece (2008) in the same region, the Harami formation was sampled, and the forms with Campanian?-Maastrichtian age and the late Maastrichtian fauna were determined. Therefore; there is significant unconformity between the Harami formation and Elazığ magmatic.

6. Results

Following results were reached when available age data had been assessed for the geodynamical evolution of the region (Figures 50 and 51). The preliminary breaks in the ocean before the collision began in Cenomanian-Turonian (Yazgan and Chessex, 1991; Robertson et. al., 2007). The first subduction has started in the ocean and supra subduction zone ophiolites have developed with the subduction (İspendere, Kömürhan and Guleman). While Kömürhan ophiolites developed as oceanic crust on the supra subduction zone (Turan et al., 1995; Beyarslan and Bingöl, 1996; Bingöl and Beyarslan, 1996; Beyarslan and Bingöl, 2000), the gabbro, diabase, basalt and andesitic volcanics developed in the upper part (Herece et al., 1992). The basalts, which consists of the upper part of the Kömürhan ophiolites, are late Senonian according to pelagic fauna described in samples (Santonian-early Maastrichtian) and early Maastrichtian in andesitic volcanics (Herece et al., 1992).

Another subduction has occurred along the southern edge of the Keban platform and Baskil arc magmatics cutting the platform have formed. Baskil magmatics, which outcrop in 25 km NW outside the map area, are represented by depth, vein and surface rocks (Asutay, 1988). Magmatics show development with plutonic rocks compound, which is represented by gabbros in early stages of the magmatism, and with monzodiorite, quartz monzodiorite, quartz diorite, tonalite, granodiorite, quartz monzodiorite, quartz monzonite compound in latter stages (Yazgan and Asutay, 1981). Basic and acidic vein rocks, which frequently cut granitoids and syenite porphyries, are significant compounds of the Baskil magmatics. Baskil magmatics end generally with andesitic, basaltic volcanic rocks represented by lava flow, pillow lava and tuffs. They are Santonian-Campanian (85-76 my) according to radiometric dating (Yazgan and Chessex, 1991) and they are the lateral equivalences of 85 my Elazığ magmatic with these characteristics (Yu-Chin et al., 2015).

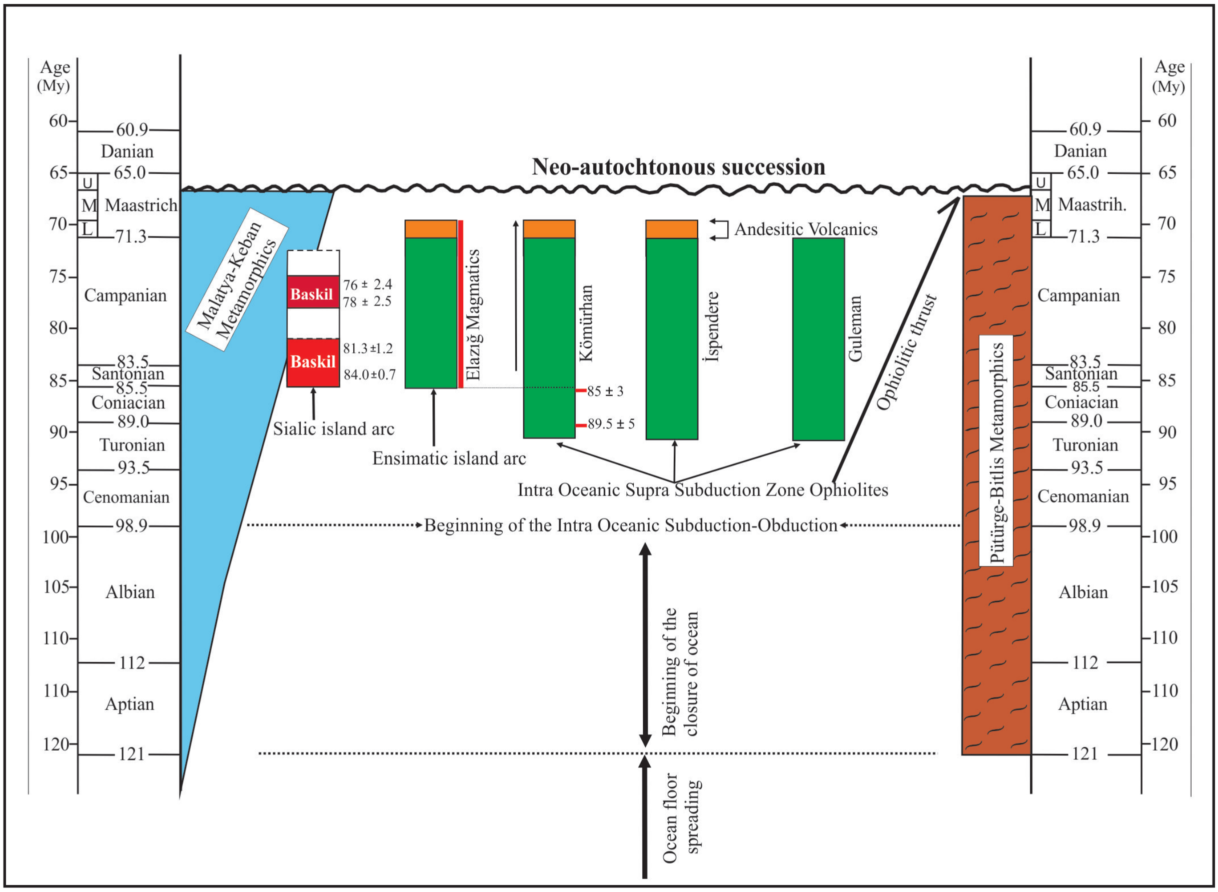


Figure 50- Relationships of the ophiolitic rocks outcropping in Elazığ and the vicinity of Pertek with basement rocks and dating within units (Yazgan and Chessex, 1991; Herece et al., 1992; Robertson et al., 2007).

Baskil magmatics are 75 my and 86 my according to isotopic age determination by K/Ar method. These calc-alkaline magmatics, which are defined as I type granitoid, cut Keban platform and affect them as the contact metamorphism (Asutay, 1988). The contact metamorphic zone is represented by easily breaking, sugar textured marbles. In contacts of marbles, which are formed by calcite and dolomite, especially with magmatic rocks the mineral assemblages reflecting the conditions of pyroxene-hornfels facies metamorphism such as; olivine, garnet, spinal and magnetite were encountered (Asutay, 1988).

Elazığ and Baskil magmatics are similar in age and rock type, and they are the lateral equivalences of each other. Baskil arc magmatics were formed in Coniacian-Santonian-Campanian, the ophiolite obduction in Campanian, and the arc-continent collision in late Campanian-early Maastrichtian (Yazgan and Chessex, 1991) and the last emplacement of ophiolites occurred in middle Maastrichtian. All basement units in the region are unconformably overlain by late Maastrichtian Harami formation. The stratigraphical relationships between the basement units and Paleogene deposits indicate that the final collision ended in the middle Maastrichtian.

On the other hand, the location and the time of the subduction zone during the closure of the ocean is still in debate. In preliminary suggested models, it was asserted that supra subduction zone ophiolites had occurred by the northern intra-oceanic subduction and Baskil granitoid had been formed by the extension of the subduction beneath the Keban platform (Hall, 1976; Aktaş and Robertson, 1984, 1990; Yılmaz et al., 1993; Robertson, 2000). In two subductional models, one of the subduction submerges beneath the Keban platform and forms Baskil magmatics, and the another subduction has occurred within the ocean and formed supra subduction zone ophiolites (İspendere, Guleman, Kömürhan) (Robertson, 2000). A third model is suggested as multi staged subduction (Robertson et al., 2007; Parlak et al., 2009). Another problem to be solved is the beginning period of the

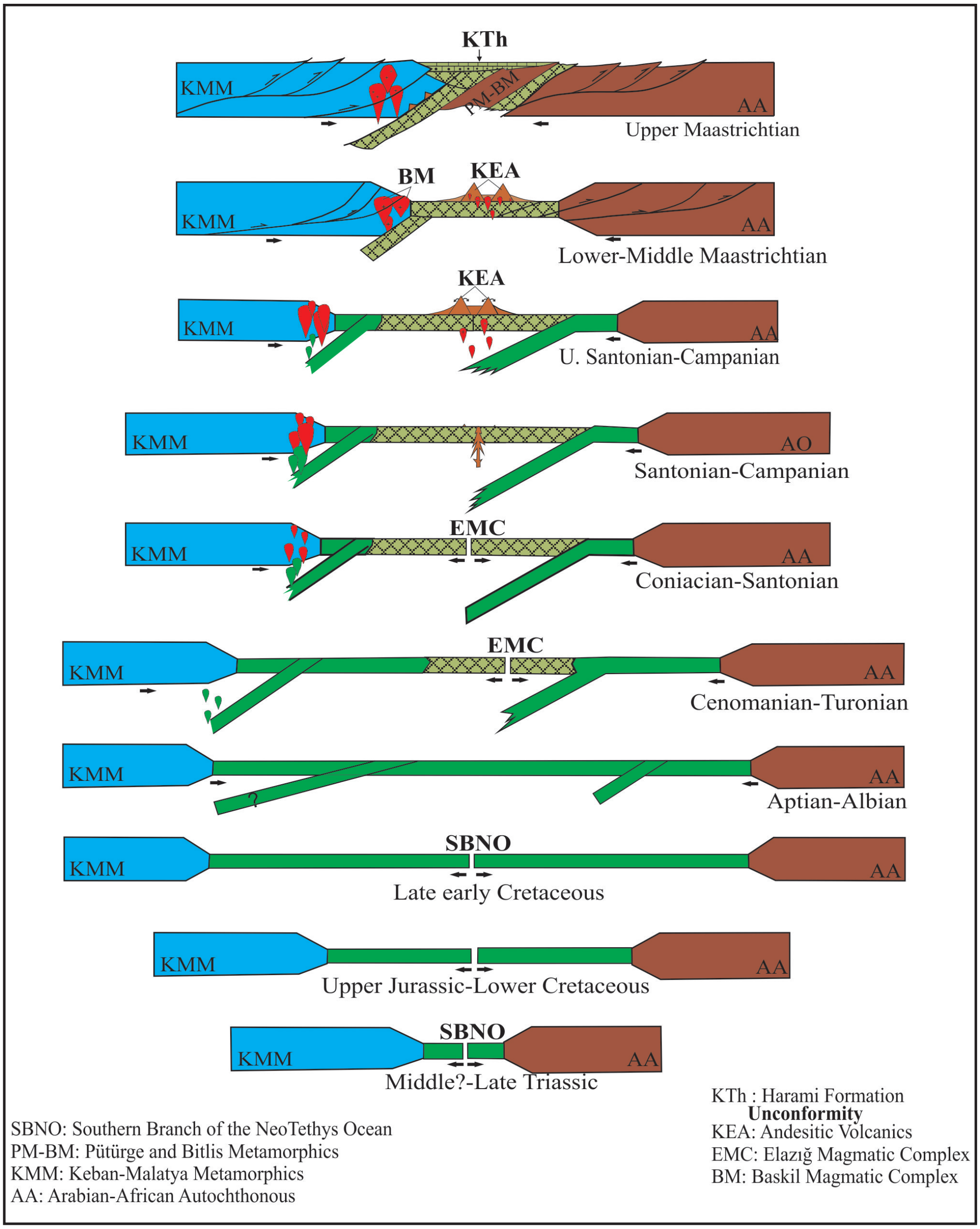


Figure 51- Hypothetically geological evolution model of basement models from Middle?-Late Triassic to late Maastrichtian (modified from Yazgan and Chessex, 1991; Bingöl and Beyarslan, 1996; Herece, 2008).

subduction and the formation ages of the supra subduction zone ophiolites.

Late Cretaceous-Paleogene marine deposits in the region were mapped and defined for the first time. Faunal assemblages collected from field were described based on species. Late Cretaceous-Paleogene deposits begin with late Maastrichtian-Selandian Harami formation. The unit, which begins with the deposition of basal conglomerate, is the first neo-autochtonous deposit unconformably overlying the Elazığ magmatics in post collision at the same time. The depositional conditions in the Harami formation ended with the regional uplift in Late Paleocene-Lower Eocene. Due to decreasing or diminishing in the regional compression affecting in the region, the Seske formation was deposited. Seske formation, which has not widespread exposure, was defined in the region for the first time and it is late Kuvizian- early middle Lutetian.

The nomenclature of formations and their ages carried out in previous studies and its close vicinity are given in Figure 52.

The effective tectonism in the region occurred in middle-upper Lutetian. In this time, the depositional conditions in Seske formation finished by regional uplifts, and the basin forming conditions of the Kırkgeçit formation, which had been deposited in the early Bartonian, occurred. Very thick and widespread deposits occurred in the Kırkgeçit formation in Early Bartonian-early Chattian. In mid Chattian, the Kırkgeçit formation was folded and outcropped at another deformation affecting in the region. This deformation phase terminated at the beginning of Upper Chattian, and the late Chattian-Burdigalian Alibonca formation was deposited. Typical deposits of this marine environment are reefal limestones and clayey limestones laterally transitional with them. In the deformation period, which was active in Middle-Upper Miocene, the depositional conditions of the formation finished. The extensive volcanism, which started at the end of Upper Miocene-Lower Pliocene, caused the development of andesitic at the beginning and pyroclastics that are transitional with lacustrine deposits and the basaltic volcanism.

In the last deformation period affected in the region, the Pertek fault formed in Late Pliocene was mapped. It was detected that the fault zone had been active and the offset values developed along the zone were given.

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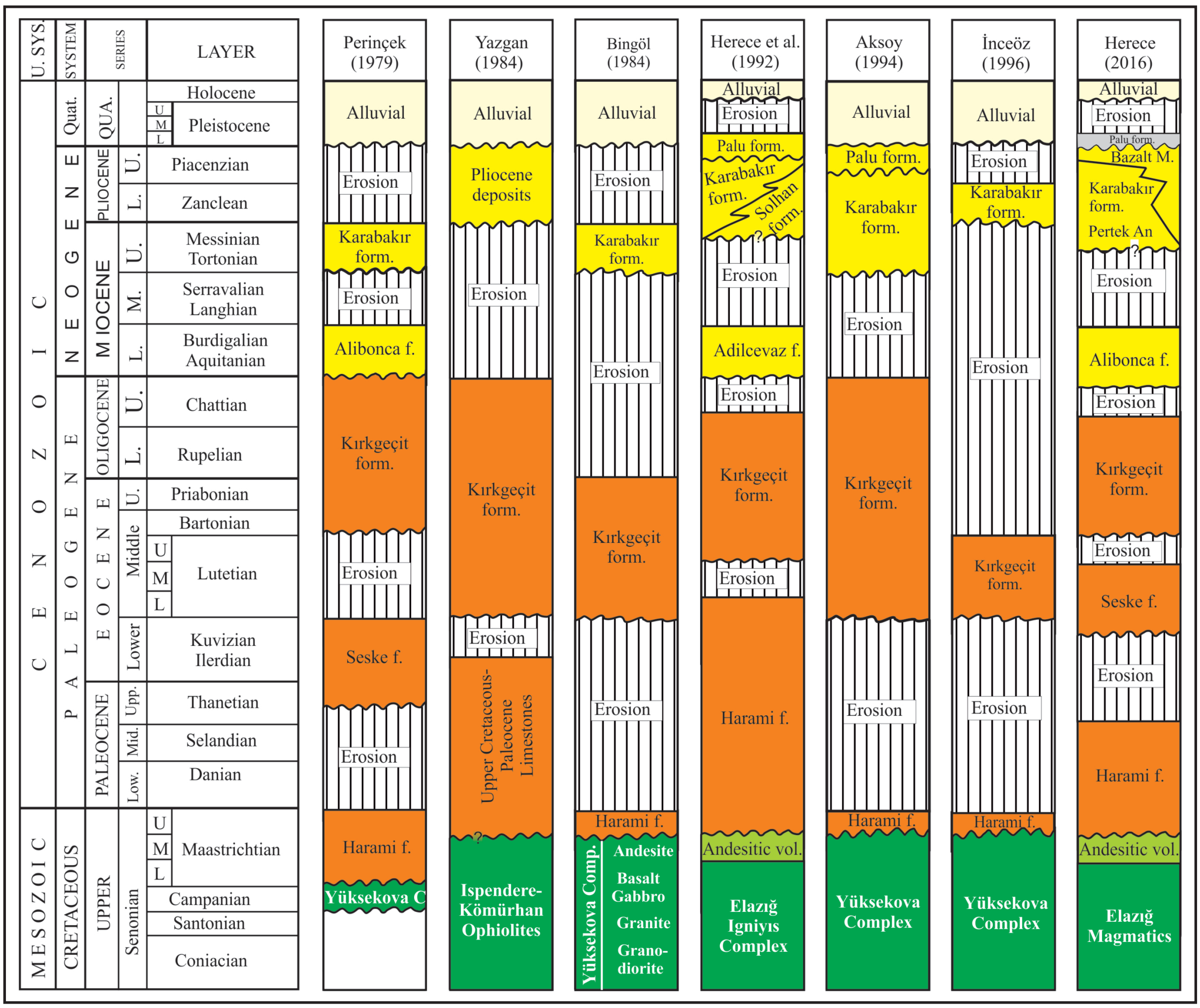

Figure 52- The nomenclature of formations made in the study area and its surrounding and their age correlations (Herece, 2016).

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