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GEOLOGICAL CHARACTERISTICS OF BOLKARDAGI BAUXITE DEPOSITS, THE TAURUS MOUNTAIN, AYRANCI, TURKEY

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Keywords
Diaspore,
Bauxite,
Bolkardağı,
Torosdağı,
Ayrancı.

Abstract

The aim of this study is to determine the stratigraphic position of the bauxite deposits in the Ayrancı region, where the most important bauxite mineralization of the Bolkardağı region is located. In this context, the age of bauxite will be determined by determining the erosion surface associated with stratigraphic features during the formation of bauxite and the age of bauxite according to its side rocks. In the region, there are Permian-Cretaceous aged rocks belonging to the Bolkardağı Union, one of the main tectonic units forming the Central Taurus Mountains. Miocene units overlying these rocks are been surfaced in the study area. Miocene aged Mazı and Divlek Formations uncomfortably cover Karamanoglu ophiolite and older units. Bauxite deposits are clearly been seen in the Upper Permian aged Dedeköy Formation. According to the field studies, the bauxites were been formed in the Late Triassic - Early Jurassic interval, on the Upper Permian aged carbonate rocks and Lower Triassic aged shale - sandstone - limestone units and then deposited in caves and dolines within the carbonate rocks. The fact that bauxites are located above dolomites and below, within and above limestones are thought to be due to the different behavior of carbonate rocks.

BOLKARDAĞI BOKSİT ÇÖKELLERİ'NİN JEOLOJİK KARAKTERİSTİKLERİ, TOROS DAĞLARI, AYRANCI, TÜRKİYE

Anahtar Kelimeler
Diyaspor,
Boksit,
Bolkardağı,
Torosdağı,
Ayrancı.

Öz

Bu çalışmanın amacı, Bolkardağı bölgesinin en önemli boksit cevherleşmesinin bulunduğu Ayrancı yöresindeki boksit yataklarının stratigrafik konumunu belirlemektir. Bu kapsamda boksitin oluşumu sırasında stratigrafik özelliklerle ilişkili aşınım yüzeyi ve yan kayaçlarına göre boksitin yaşı belirlenecektir. Bölgede Orta Torosları oluşturan ana tektonik birimlerden biri olan Bolkardağı Birliğine ait Permiyen-Kretase yaşlı kayaçlar bulunmaktadır. Bu kayaçları örten Miyosen birimleri çalışma alanında yüzeylenmektedir. Karamanoğlu ofiyoliti ve daha yaşlı birimler Miyosen yaşlı Mazı ve Divlek Formasyonları tarafından uyumsuz olarak örtülmektedir. Boksit yatakları Üst Permiyen yaşlı Dedeköy Formasyonu'nda açıkça görülmektedir. Saha çalışmalarına göre, boksitler Geç Triyas - Erken Jura aralığında, Üst Permiyen yaşlı karbonat kayaları ve Alt Triyas yaşlı şeyl - kumtaşı - kireçtaşı birimleri üzerinde oluşmuş ve daha sonra karbonat kayaları içindeki mağara ve dolinlerde çökelmiştir. Boksitlerin dolomitlerin üzerinde ve altında, kireçtaşlarının içinde ve üzerinde yer almasının karbonat kayaçlarının farklı davranışlarından kaynaklandığı düşünülmektedir.

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Highlights

- The age of the bauxite can be determined according to the erosion surface and subordinate rocks associated with the stratigraphic features during the formation of the bauxite.
- In the study area, Permian-Cretaceous rocks belonging to the Bolkardagi Union, one of the main tectonic units forming the Central Taurus Mountains, and Miocene units overlying these rocks are surfaced. Karamanoglu ophiolite and older units are unconformably overlain by Miocene aged units. Bauxite deposits are observed in Upper Permian aged units.
- Bauxite was formed during the Late Triassic - Early Jurassic period and then deposited in caves and dolines within carbonate rocks.

Purpose and Scope

The aim of this study is to determine the age of bauxite by determining the geologic, stratigraphic and tectonic characteristics of bauxite surfaced in Ayrancı region of Bolkar Mountains.

Design/methodology/approach

In order to achieve the aim of the study, the geology and tectonic features of the region were investigated by utilizing previous studies. Then, detailed field studies were carried out in the study area and laboratory studies were carried out on the samples taken. All information was brought together and a conclusion was reached.

Findings

The geological features of the study area and the geological levels of bauxite ore were determined.

Research limitations/implications

The information obtained from the study area can be compared with other regions.

Practical implications

With this study, the formation of bauxite, geological and tectonic features have been clarified. Important data have been obtained in the search for new bauxite areas.

Social Implications

Economically, important data were obtained for the exploration of new bauxite fields. Scientific contribution to the geology of the region.

Originality

The data obtained for the geological properties of bauxite in this study conducted within the scope of the project are original and new information.

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1. Introduction

The area is located 15 km southeast of the Ayrancı district (Karaman) and covers an area of about 300 km^2 (Fig. 1). The Bolkardağı deposit is one of the largest bauxite deposits in Turkey, comprising a significant share of the world's bauxite reserves. Except for a few prospecting studies, there has been no detailed investigation on the stratigraphic setting and origin of these deposits. Based on 1/25000, scale geological maps made by previous workers (Blumenthal, 1956; Demirtaşlı et al., 1973; Selim and Demirtaşlı, 1984; Pampal, 1987; Murat and Temur, 1995), formation borders and tectonic structures were determined in the field. Since the paleontology, petrography and stratigraphy of younger units are outside the scope of the present work, most of the findings described in previous studies were accepted. Considering the age of host rocks, erosional characteristics of the area and the degree of metamorphism of surroundings rocks, the stratigraphic setting of bauxites is discussed.

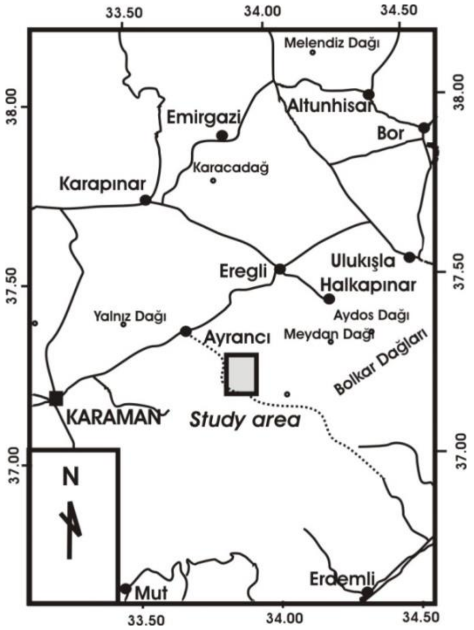

Figure 1 Location map of the study area.

Bolkar Mountain, one of the most important peaks in the central Taurides, is in the territories of Konya, Karaman, Mersin, Adana and Niğde cities. The NE–SW extending Bolkar Mountain, covering an area of about 9000 km^2, is 60 km wide and 150 km long. In this respect, the stratigraphical sequence comprising the Bolkar Mountain displays some differences within its own and neighboring basins. The mountain is been surrounded by the Ulukışla basin in the northwest, Ereğli-Ayrancı basin in the west, the Mut basin to the south, Adana basin to the east and southeast, and Niğde massive to the north. The first study on stratigraphy and tectonic evolution of the Bolkar Mountain was been carried out by Blumenthal (1956), who states that the Bolkardağı Mass forms an E–W extending anticline in which Horoz granite is emplaced. Thereafter, the geology of the Bolkar Mountain was studied by Demirtaşlı et al. (1973), Şişman and Şenocak (1982); Selim and Demirtaşlı (1984); Demirtaşlı et al. (1983, 1986) and the lithostratigraphic units described by several formations. Bolkar Mountain consists of Permian - Upper Cretaceous carbonates, which have undergone different degrees of metamorphism, and siliciclastic and volcanic alternations, which show deformation in the elevated carbonate platform (Demirtaşlı et al., 1973; Demirtaşlı et al., 1986). Demirtaşlı et al. (1983) divided the Bolkardağı unit into 3 formations, from bottom to top, as Upper Permian aged Dedeköy Formation, Upper Triassic aged Saraycık Formation and Jurassic-Cretaceous aged Berendi limestone. Şişman and Şenocak (1981) investigated the gold and silver-containing Pb-Zn deposits in Bolkardağ and its region. They divided the Bolkardağ mineralization into Bolkardağ I field Pb-Zn-Au-Ag mineralization and Bolkardağ II field mineralization.

Özgül (1971, 1976), who first described the rock units in the central Taurides, called the Devonian–Paleocene formations as the Bolkardağı Unit. Özgül indicates that the Bolkardağı Unit forms the cover of the Menderes massif and possibly the Kırşehir massif and mostly includes metamorphites with green schist facies. The oldest fossil-containing unit of the Unit is Devonian schists and marbles (Özgül, 1971). The Carboniferous is been represented by schist, quartzite and limestone, the Permian consists of recrystallized limestone with quartzite. Triassic includes shale, quartzite, limestone and dolostone, and in metamorphic regions, it includes chlorite and sericite schists. Liassic starts with base conglomerate. Jurassic and Cretaceous includes carbonate rocks. Upper Cretaceous (Cenomanian - Turonian) contains rudist limestone, Maastrichtian is represented by pelagic limestone. Maastrichtian and/or Paleocene aged the rocks at olistostrome facies constitute the uppermost unit of the the Unit (Özgül, 1976). Rock units of the Bolkardağı Unit of allochthonous character are been exposed at different regions of the central Taurides. Pampal (1987, 1988), who studied the stratigraphy of the western sector of the Bolkar Mountain, states that Karamanoğlu Ophiolite was thrust over the Bolkardağı Unit in the late Cretaceous. Using microtectonic analyses, İşgüden (1970) determined the relationship between folding and mineralization.

The aim of this study is to determine the geological and especially stratigraphic characteristics of Bolkardağı bauxites, one of the most important bauxite formations in different regions of the Taurus Mountains. Stratigraphic features and tectonic processes of bauxite mineralization surfaced in Ayrancı region of Bolkar Mountains were determined. Within the scope of the study, the geological, stratigraphic and tectonic features during the formation and formation of bauxite were determined, the erosion surface was explained and the age of the bauxite was determined by explaining the side rock properties.

2. Literature Survey

The first studies on the Bolkardağı bauxites were been carried out by Wippern (1961) and Boroviczeny (1962). Different scientists have shown interest in the region (Nicolas and Özlu 1976; Özlu 1977; Karadağ et al., 2003; Temur et al., 2003; Yalçın et al., 2005; Karadağ et al., 2006; Yalcin and Ilhan 2008; Karadağ et al., 2009; Zedef and Doyen 2009; Kansun et al., 2010; Yalcin et al., 2010; Yalçın et al., 2012; Hanilçi 2013; Yalçın and Ilhan 2013; Köse et al., 2021; Şimşek et al.; 2021; Atakoğlu et al., 2021; Atakoğlu and Yalçın 2021a; Atakoğlu and Yalçın 2021b). These researchers claimed that the diasporitic bauxites were formed on a discordance surface between Permian (?) aged dolomite- dolomitic limestone-limestone and Mesozoic aged sericite chlorite schist-phyllite-limestone and, subsequently, filled the karstic voids and cavities of the basement rock. Hanilçi (2013) stated that Bolkardag bauxites are of lateritic and karstic types in large numbers within the Bolkardag Unit. He states that gradual transition from protolite to saprolite and finally bauxite is been observed in lateritic type deposits, and states that karstic type deposits are composed of diasporite, hematite, pyrophyllite, chlorite, chamosite and anatase. Yalçın and Ilhan (2013) state that Küçükkoras diasporic bauxite deposits are composed of three types of ores in NW-SE direction during the Upper Cretaceous period. These are lenses, karst fillings (sinkhole fillings) and veins. These researchers say that the bauxite in this region was been formed because of the limestone turning into terra rossa and later of the terra rossa turning into bauxite. Atakoğlu and Yalçın (2021a) stated that Sütleğen bauxites (Kaş, Antalya) were been formed in an acidic environment and that bauxites were enriched with rare earth elements in these acidic conditions. Atakoğlu and Yalçın (2021b) revealed that Sütleğen bauxites undergo moderate and strong laterization because of deferruginization in the environment and are been divided into four groups as lateritic, ferritic, kaolintic and bauxite. Şimşek et al. (2021) state that most of the polies in the Taurus Karst Belt are located in the Isparta Angle in the Western and Central Taurus Mountains, and 65% of these poljes do not exceed 10 km^2. The researcher say that these macrokarstic shapes have increased circularity index values up to 28 and elongation ratio values up to nine because of hydrological and tectonic controls.

3. Material and Method

A literature review was been conducted on the study area and its immediate surroundings. After the preliminary information, field studies were been carried out. The data obtained were been drawn with computer drawing programs. Thin sections were been made from the samples taken from the rocks and microscope examinations were made.

4. Result and Discussion

4.1 Stratigraphy

Permian–Cretaceous rock units of the Bolkardağı Unit (Özgül, 1976) and Miocene cover units are been exposed in the study area (Figs. 2 and 3). In the Bozkır-Akseki region, the Devonian Hocalar Formation (Özgül, 1997; Temur et al., 2005), consisting of marble, sandstone and schist is not observed in the Bolkardağı. The sequence in the study area begins with the Upper Permian Dedeköy Formation (Fig. 4). Lower and upper levels of this formation are been dominated by dolostone and limestone, respectively. It is conformably overlies by the Lower Triassic Saraycık Formation, consisting of schist, phyllite, metasandstone and marble alternation. Vein rocks (Kasır Diabase) intercut the Saraycık formation with a maximum diameter of 50–60 m. These dykes were been probably intruded in the Middle Triassic. The Upper Triassic carbonate rocks (upper marbles), forming a thick sequence at northern part of Bolkar Mountains, are observed in the western and southern sections of the region. In the study area, the Saraycık Formation and other older units are unconformably set above the Jurassic–Cretaceous Berendi Formation. The Upper Cretaceous Karamanoğlu Ophiolite is been thrust over the Berendi Formation, observed as a thick carbonate sequence.

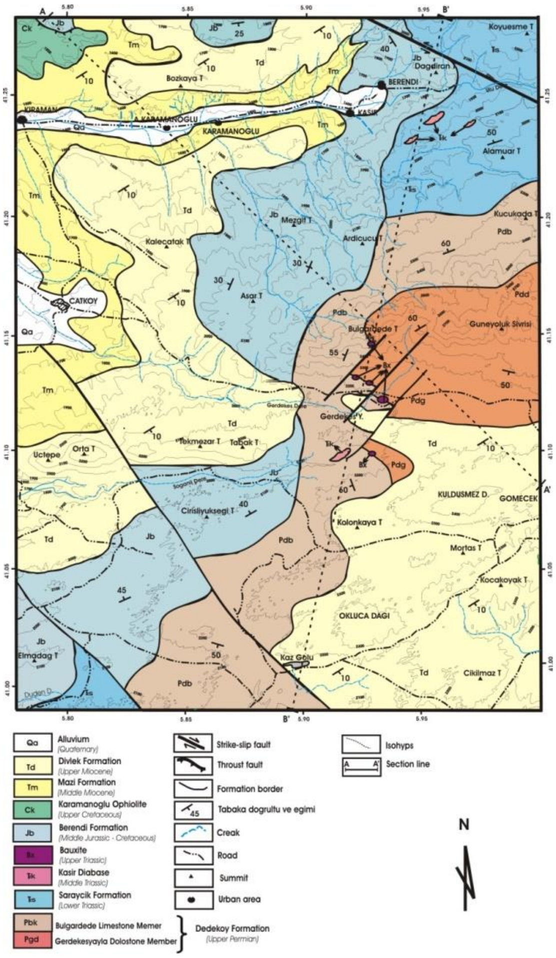

Figure 2 Geological map of the study area.

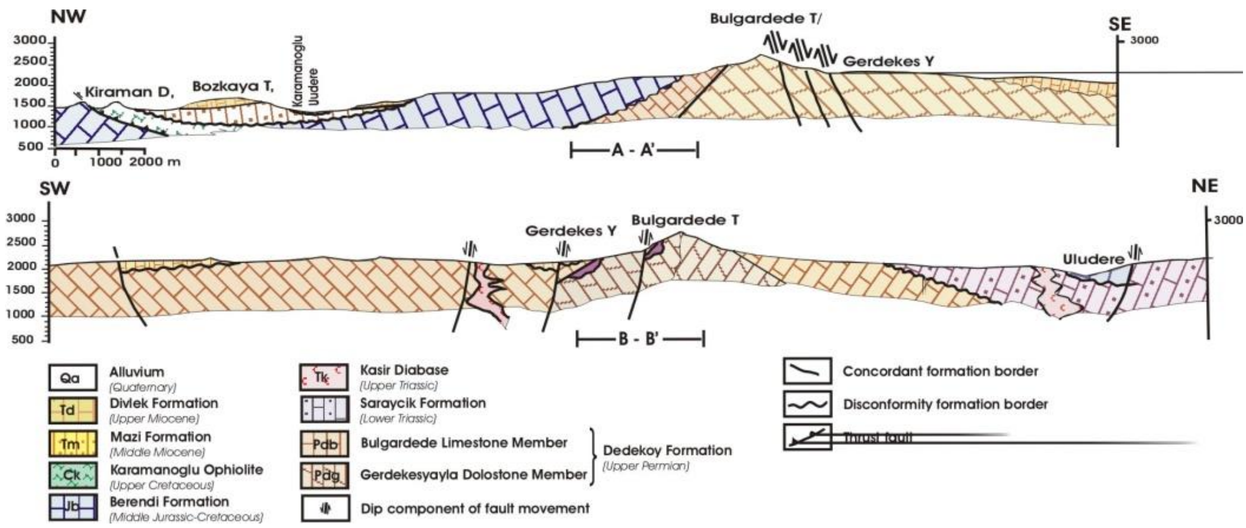

Figure 3. Geological sections of the study area.

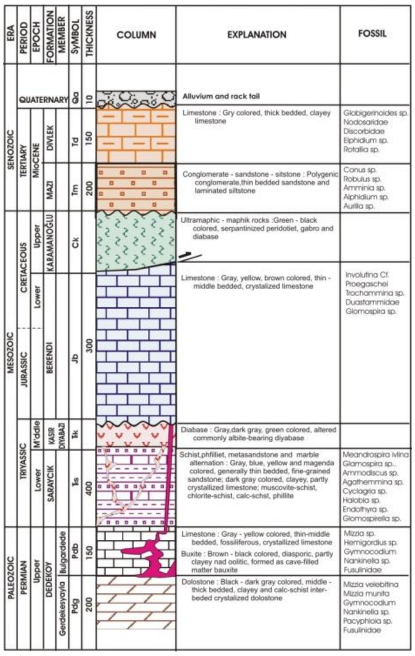

Figure 4. Stratigraphical section for rocks exposed in the study area.

At a northern part of the Bolkar Mountains, there is a thick sequence consisting of a sandstone–shale–limestone alternation developed in Paleocene volcano-sedimentary rocks and Eocene turbidite facies, but it is not been observed in the western and southern part of Bolkardağı. In the western part of the study area, Miocene Mazı and Divlek formations are unconformably set above the ophiolites. Of these two concordant formations, the Mazı Formation is composed of conglomerate and sandstone, while the Divlek Formation is of clayey limestone. Bauxite deposits in the region are found within the Upper Permian Dedeköy formation, between the Gerdekesyayla Dolostone and Bulgardede Limestone members, and also in the limestone. Geological setting and metamorphism degree of these diasporitic bauxites reveal that they were formed during the Late Triassic–Early Jurassic (?) within the Upper Permian carbonate rocks and above the Lower Triassic shale–sandstone–limestone alternation and then transported into the doline and caves of carbonate rocks.

4.1.1. Dedeköy Formation (Pd)

The lower levels of this formation are composed of black, crystalline, medium-to-thick bedded, local schist-alternated dolostones, while the upper sections are of gray/beige-colored, thin-to-medium bedded, crystalline limestones. The name of the formation comes from Dedeköy to the east of Ereğli (Demirtaşlı et al., 1983). Dolostone and limestones of the Dedeköy Formation are divided into two distinct levels by means of color and appearance, which can be detected as dolomitic interlayers. The bauxite deposits are always above the dolomitic level and at the basement, within or above the limestone (Yalçın et al., 2005). In this respect, dolostone and limestone levels of the formation were been differentiated as members, namely the Gerdekesyayla Dolostone Member and the Bulgardede Limestone Member.

4.1.1.1. Gerdekesyayla Dolostone Member (Pdg)

In general, this member consists of gray/black-colored, medium-to-thick bedded, dolomitic marbles. Because of the varying clayey material content, the unit changes to marl and schists over short distances. The bedding is disturbed and exposures are blocky in appearance (Fig. 5a), and lamination is very common. Gray, blue and locally green schists alternate with dolostones. The schists are composed of chlorite-schist, albite-schist and quartz-schist, or in some cases, chalk-schist. In addition, they also contain epidote, muscovite and lesser amounts of opaque minerals. XRD analyses indicate that carbonates are generally composed of dolomite and rarely calcite, and contain quartz and less calcite (Figs. 5d and 6).

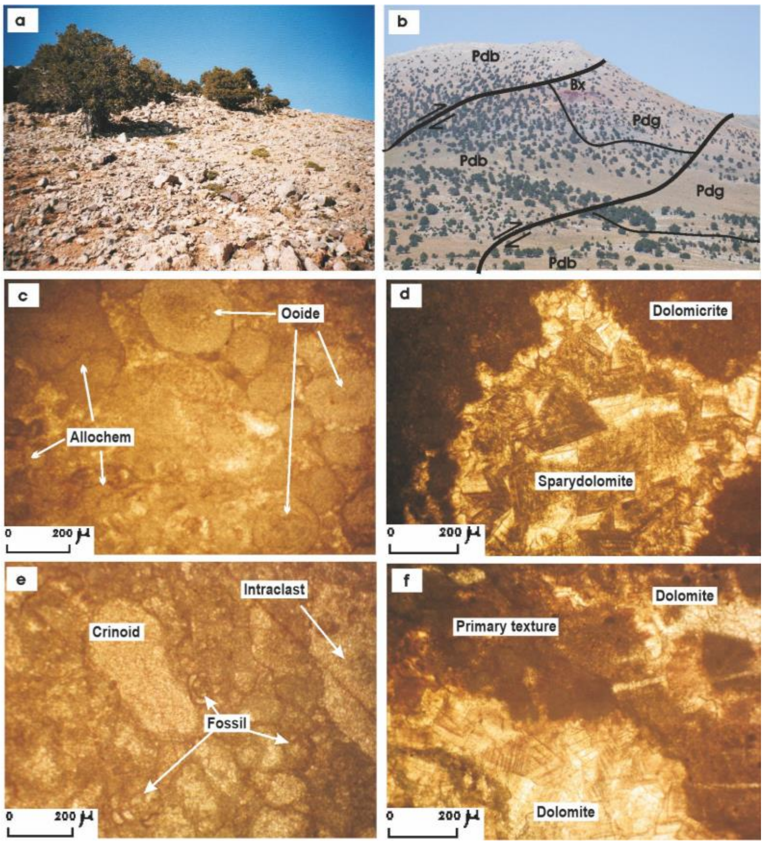

Figure 5. Field and thin section views of the Dedeköy Formation: **(a)** Dark-gray, black colored, peculiar bedded dolostones of the Gerdekesyayla Dolostone Member, SW of Gerdekes Plateau; **(b)** Discordant and faulty contact at the southern slope of Bulgardede Hill between dark-gray, black colored Gerdekesyayla Dolostone Member (Pdb) and Bulgardeade Limestone Member (Pdb), consisting of gray marbles and bauxite deposits (Bx) developed on the contact line; **(c)** Sparydolomite filling the voids of dolomicrites (painted with alizarine red, //N); **(d)** Ooide and allochems preserved in the dolostone (painted with alizarine red, //N); **(e)** Crinoid, intraclast and fossil shells preserved in the dolostone (painted with alizarine red, //N); **(f)** Partly preserved primary texture in dolostone and completely dolomitized parts (//N).

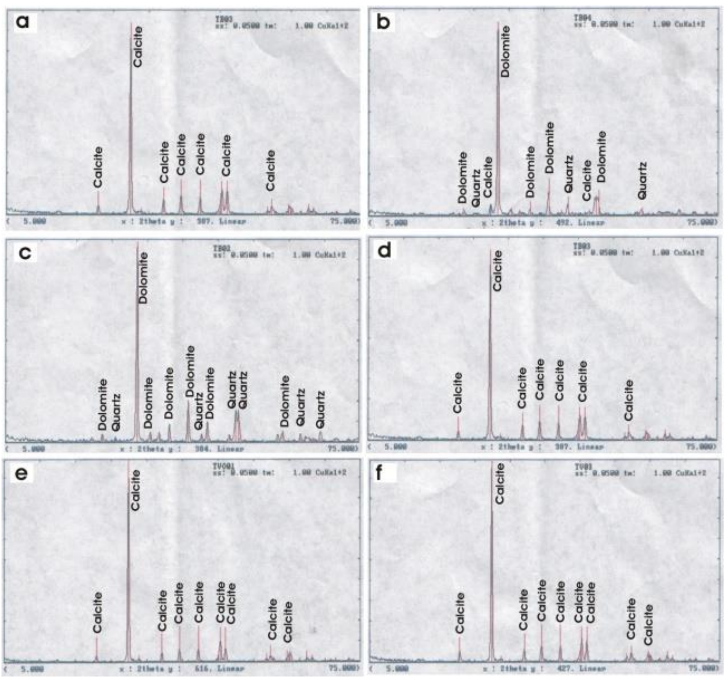

Figure 6. XRD diffractograms for the Dedeköy Formation, **(a)** Gerdekesyayla Dolostone Member: calcite; **(b)** Gerdekesyayla Dolostone Member: dolomite, calcite and quartz; **(c)** Gerdekesyayla Dolostone Member: dolomite and quartz; **(d)** Gerdekesyayla Dolostone Member: calcite; **(e** and **f)** Bulgardede Limestone Member: calcite.

Dolostone has generally been fractured and filled with white calcite bands. Karstic structures are rarely or never developed. Primary texture in the dolostone is partly preserved. In some cases, rhombohedral dolomite crystals fill the wedge-shaped dolomicrites (Fig. 5c). Some components, such as intraclast, fossil, pellet, ooide and allochems, are partly preserved and dolomitized (Fig. 5d and e). The most common allochem types are echinoid and crinoid fragments. In some parts, the primary texture is partly (Fig. 5f) or completely damaged, and dirty and clear dolomite crystals are randomly scattered. As a result, non-mimetic dolomite crystals are been formed.

The dolostone basements, which are widely exposed at eastern parts of the Gerdekes Plateau, are not been observed approximately the study area. In the Hadim-Bozkır-Akseki region, the Hocalar Formation (Özgül 1997; Temur et al., 2005), consisting of Devonian marble, metasandstone and schists, is found at the bottom of the Bolkardağı Unit. The Bulgardede Limestone Member of the same formation conformably overlies it. The younger bauxites (Fig. 5b), developed along the contact of these two units, are found as fills in karstic spaces of older units. Since its basement is not seen, the thickness of Gerdekesyayla Dolostone Member could not be determined. However, visible thickness is more than 200 m. Selim and Demirtaşlı (1984) proposed a thickness of 600 m for the formation around Büyükdede village (Ereğli, Konya), which is the typical site of the unit. In the Horoz village (Ulukışla, Niğde), the thickness of the Lower Marbles unit, which is a continuation of the same formation, is given as 1000 m by Şişman and Şenocak (1982) and 200–250 m by Temur (1989).

On the basis of Mizzia velebitina Schub, Mizzia munita, Gymnocodium sp., Nankinella sp., Pacyphloia sp. and Fuzulinidae fossil assemblages (Demirtaşlı et al.. 1973; Selim and Demirtaşlı, 1984; Sevgil, 1984), the age of the member is suggested as Upper Permian – this age was adopted in the present study.

Due to metamorphism, primary texture of the units was largely been damaged. Considering its general features, it can be assumed that the unit was deposited in a shallow carbonate platform where terrestrial material input was high. Dolomitization probably took place following diagenesis via Mg-rich solutions derived from clays and/or Kasır Diabase.

4.1.1.2. Bulgardede Limestone Member (Pdb)

The unit is generally composed of gray/beige-colored, thin-to-medium bedded, locally laminated crystalline limestones (marble). Dolomitization is rarely been developed, while limestone is mostly fractured. Several karstic structures, such as rillenkarren, channel, cut and fill, are been developed on the surface. Recrystallization greatly damaged the primary texture of the rock. XRD data indicate that rock is completely composed of calcite (Fig. 7a). In areas where primary features are partly preserved, rock is been observed as biosparite (Fig. 7b) or as calc-schist (Fig. 7c) or chlorite-schist if the clay ratio is increased. In fault and crushed parts, clays, filling the spaces between the dolostone breccias, give rise to the development of a mylonitic texture (Fig. 7d).

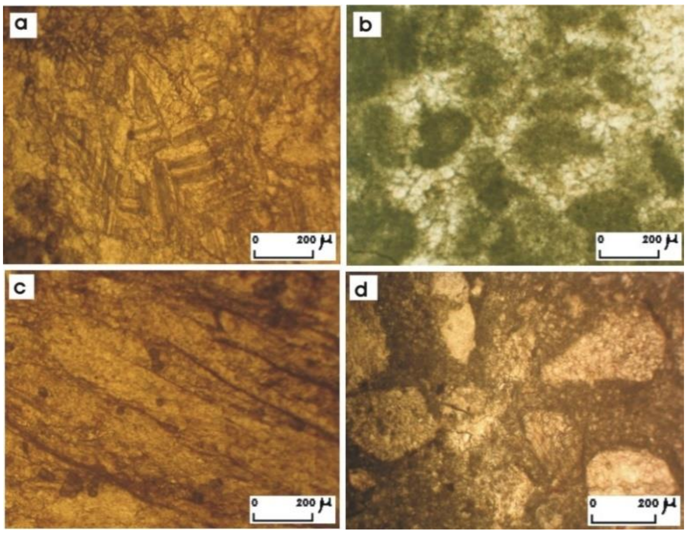

Figure 7. Thin section views for the Bulgardede Limestone Member: **(a)** Sugar textured, coarse crystalline marble (painted with alizarine red, //N); **(b)** Biosparite preserved among the marbles (//N); **(c)** Calkschist developed between the limestone beds due to increasing clay ratio (//N); **(d)** Mylonitic marble (painted with alizarine red, //N).

Limestone, exposed around the Kaz Lake to the south of the study area, extends to the Gerdekes Plateau, Bulgardede and Küçükada Hills. The Gerdekesyayla Doloston Member of the same formation is found at the base of the unit. Bauxites developed along the contact between these two units are younger and found in karstic voids of older units. Limestone is unconformably been overlain by the Saraycık formation. The Kasır Diabase veins cut the dolostone and schist.

On the basis of field observations and geologic sections, thickness of limestone is more than 150 m. Since previous workers did not differentiate the units in members, there are no data on unit thickness. Considering the fossil assemblage of Mizzia velebitina Schub, Mizzia munita, Gymnocodium sp., Nankinella sp., Pacyphloia sp. and Fuzulinidae found by Demirtaşlı et al. (1973), Selim and Demirtaşlı (1984) and Sevgil (1984) and also Mizzia sp., Hemigordius sp. and Stafella sp. determined in the present study, the unit age is accepted as upper Permian. This date is also consistent with the stratigraphic setting of the unit.

Due to metamorphism, primary structure and texture of the unit have largely damaged. Considering its general features, the unit was been deposited in a carbonate platform deeper than Gerdekesyayla Dolostone Member.

4.1.2. Saraycık Formation (TRs)

The formation is been composed of phyllite, slate, metasandstone and marble alternations. It was been first differentiated by Blumenthal (1956) and called the Gerdekes formation. Demirtaşlı et al. (1973), Selim and Demirtaşlı (1984) and Demirtaşlı et al. (1983, 1986) have also used the same name. However, in those studies, limestone at the top of the unit was included in the same formation or evaluated together with the formation. Selim and Demirtaşlı (1984) stated that the typical site of the formation is 4 km west of the Bulgardede Hill (Gerdekes Plateau), where the Triassic units are not exposed. In another work including some part of the study area, Pampal (1987) described the unit in detail and called it the Saraycık Formation – this name is also used in the present study.

Schist, phyllite, slate, metasandstone and marble, comprising the Saraycık Formation, alternate with each other in varying thicknesses from the bottom to the top of the formation. These units generally display gradual lateral and vertical transitions. Therefore, it is very difficult to map the general stratigraphic sequence. However, pelitic levels dominate the upper parts of the formation and thickness of carbonates increased upward. This is been more pronounced around the Körkuyu Plateau to the NE of the area. A 30–40 m limestone–dolomitic limestone level is been always found at the top of the formation.

Schist and phyllite that are generally beige, gray, red and brown colored and colors are changeable over short distances, depending on mineral types. This lithology has a distinct foliation and is been irregularly folded. The unit that underwent a green-schist metamorphism is composed of chalk-schist, sericite-chlorite schist, quartz-albite-schist and phyllite, while, mineralogical, it is composed of calcite, chlorite, sericite, muscovite, tremolite, quartz, albite, leucoxene and opaque minerals. Considering the mineralogical composition of these rocks, they are been believed to be composed primarily of pelitic material of mudstone, siltstone and claystone. Other slate characteristics are gray-black color, thin-to-medium bedded, foliated and oily brilliant. Among them, there are white-gray colored quartzite lenses and bands of a maximum thickness of 1 m. As the grain size increases, slates gradually change to metasandstone and schists.

Gray colored metasandstone is thin (1–5 m), alternating with schist and slates, and is cemented with a clayey material. More than 60% of grains are composed of quartz, relict carbonate and other rock fragments. The unit is been fine grained, well sorted and grains are well rounded. Quartz generally shows a wavy extinction. Plagioclase, chlorite, muscovite, biotite and calcite are been found in the matrix. The continuity of the unit can be traced for a few hundred meters. Metasandstone is been believed to be composed primarily of litarenite and calkarenite.

Carbonate rocks within the formation are always clayey and the clay ratio is 10–20%. Nodular limestone is been observed in pelitic parts in the transition to schist. Dark gray, thick-bedded parts are generally dolomitic in character. Limestone is yellowish to brownish colored and contains abundant fossils. Chert nodules are very common. Intrasparite, biosparite and intrapelsparite are very distinct, if crystallization is weakly developed.

Total thickness of units in the formation is been reported as 700 m by Demirtaşlı et al. (1973), 750 m by Selim and Demirtaşlı (1984), 600 m by Pampal (1987) and 200–250 m by Temur (1989). Since the top of the formation is unconformable and foldings are very common, the thickness is unclear. Based on geological sections, thickness is been estimated as 500 m. The Saraycık formation, covering a small area, is exposed in the SW and NE parts of the region.

The Saraycık Formation conformably covers the Permian carbonates and is easily distinguished with its abundant pelitic rocks. The limestone of the Jurassic–Cretaceous Berendi Formation unconformably overlies it (Fig. 4). Middle Triassic diabase dykes cuts the units of this formation. In addition, bauxite in the region were formed under terrestrial conditions during the Late Triassic–Early Jurassic (?) and was transported into the carbonate rocks under the sequence, filling the karstic spaces.

Based on fossil assemblage of Meandrospira ivlina, Glomospira sp., Ammodiscus sp., Agathemmina sp., Cyclagria sp., Trochammina sp., Endothyra sp., Glomospirella sp., Halobia superbu MOSSİSOVİCS, Halobia sydriaca, Halobia sp., Miyophoria micrasitica determined by Demirtaşlı et al. (1973), Selim and Demirtaşlı (1984) and Pampal

(1988), the age of formation is Lower–Middle Triassic. According to Selim and Demirtaşlı (1984), formation units were been deposited in a marine shelf close to the carbonate platform. Çalapkulu (1980) describes the unit as the southwest continuation of the Bolkardağı schists, which are exposed approximately Horoz village to the NE of the Bolkar Mountain. The degree of metamorphism decreases from northeast to southwest. Around the Yüğlük Mountain, southeast of Karaman, gray oolitic limestones of the Lower–Middle Triassic Kurucan Formation are exposed (Bilgiç and Gökten, 2005) and these units are been thought to be southern continuation of the Saraycık formation.

4.1.3. Kasır Diabase (TRk)

The vein rocks, composed of albite-diabase, were been first described by Selim and Demirtaşlı (1984), but they were not named. The magmatic rock is been exposed around Berendi and, since this name was used for another formation, these rocks were named as Kasır Diabase. Diabase in dark gray, black and greenish colors is been extremely altered. Considering its petrographic features, they show ophitic and subophitic texture. Its mineralogical composition is albite, pyroxene and altered mafic minerals (Fig. 8). Schistosity structure and mineral orientations are very common. Sericitization, chloritization silicification, epidotization and calcite formation are been frequently observed.

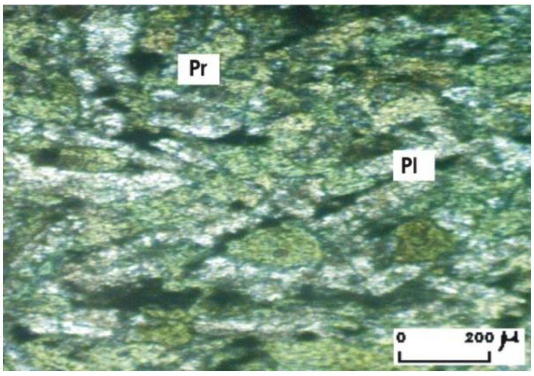

Figure 8. Distribution of pyroxene (Pr) and plagioclase (Pl) grains in the Kasır Diabase (XN).

In the study area, diabase has a limited distribution. Areas comprised of diabase are southwest of Berendi, Gerdekes Plateau. Since veins of the Kasır Diabase cut the carbonate rocks of the Upper Permian Dedeköy Formation and schist, slate and metasandstones of the Lower Triassic Saraycık formation, the age of diabase might be Middle Triassic or younger. Their relationship to other units in the area could not be determined. Dolostone and limestone of the Middle–Upper Triassic Elmadağ Formation and turbiditic sandstone and limestone of the Düden Formation were been exposed around the Yüğlük Mountain, southwest of Karaman, 80 km south of the area (Bilgiç and Gökten, 2005). This may indicate that Bolkardağı in the eastern end of the area were uplifted during the Late Triassic, while deposition at the south was been continued in carbonate and turbiditic facies. The Kasır Diabase might have developed as the first magmatic products of the ocean, which was been opened at the western Bolkar Mountain.

4.1.4. Berendi Formation (Jb)

This formation is generally composed of gray-, yellow-, beige-colored, thick bedded and well crystallized limestone. The carbonate rocks in the region were first named as the Berendi Formation by Demirtaşlı et al. (1973) and the same name was also used by Selim and Demirtaşlı (1984) and Demirtaşlı et al. (1983; 1986). However, some of the Upper Triassic carbonates were included in the Saraycık Formation by some workers (Pampal 1988, Murat 1992, Murat and Temur 1995). Limestone, comprising the thickest part of the formation and exposed on the Medetsiz, Aydos and Meydan peaks of the Bolkar Mountain, were determined to be in the Jurassic–Cretaceous age. In this respect, the name of the Berendi Formation was been used by these workers for Jurassic–Cretaceous carbonate rocks and this name was also adopted in the present study.

Carbonate rocks of the Berendi Formation that comprise a thick sequence at the Bolkar Mountain are generally unique in appearance. However, color, layer thickness, clay content, dolomitization and degree of metamorphism may change from the bottom to the top and from southwest to northeast. In general, limestone of the Berendi Formation is gray colored (Fig. 9a) and thick (40–100 cm) bedded. As the clay content increases, it can be observed in yellow, beige and cream colors, and layer thickness may be less than 20 cm in some places (Fig. 9b). Chert bands, parallel to bedding are very common. Bedding is generally regular and distinct. Intense fractures are been filled with white calcite of 1–2 mm thickness. The limestone is compact, resistant and fragile. Lower levels are composed of marble and their primary structural–textural characteristics are almost disturbed. Upper level is made of sparite, biosparite, pelsparite, packed biosparite (Fig. 9c) or packed pelsparite (Fig. 9d). Black-colored bituminous layers are also been observed locally. Clay content of marl–chalk schist levels is up to 20%.

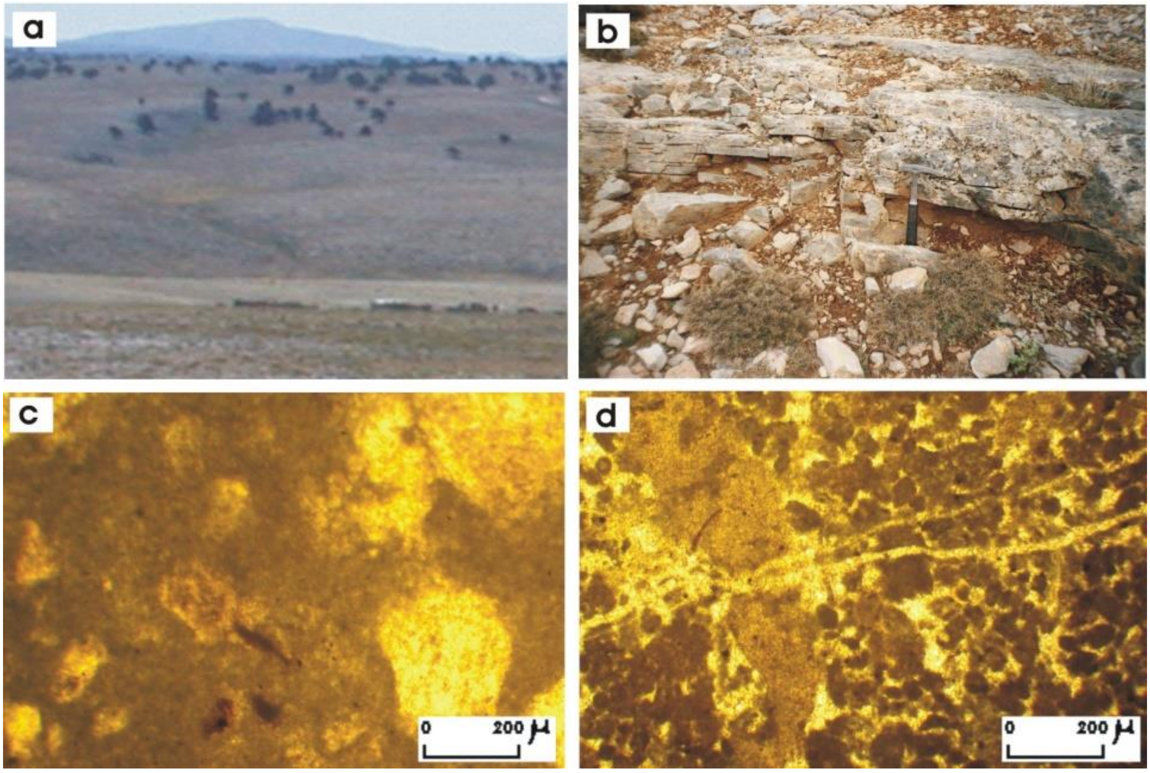

Figure 9. Field and thin section views for the Berendi Formation. **(a)** View of gray limestones of the Berendi Formation, SW of the Gerdekes Plateau; **(b)** thin-bedded, clayey limestone (south of Elemadağ) of the Berendi Formation; **(c)** packed biosparite (//N); **(d)** packed pelsparite (//N).

Based on results of mineral counts on 10 thin sections from the thick-bedded limestone of the formation, 0–5% of the rock is composed of calcite, 2–5% is dolomite and 2–5% is quartz. In general, sugar texture is dominant and the length of calcite crystals does not exceed one (1) mm. Sericite and opaque minerals are rarely observed. According to Demirtaşlı et al. (1973), there is a thick dolostone level, particularly at the bottom part of the formation. In places of high clay content, rock contains 30% muscovite, sericite and quartz.

Thickness of formation is been given as 500 m by Demirtaşlı et al. (1973), 700 m by Pampal (1987) and 1500 m by Çalapkulu (1980) and Temur (1989). A 250–300 m bottom layer of the unit is been exposed in the study area. Limestone of the Berendi Formation is set above the Lower Triassic Saraycık Formation and other older units with an angular unconformity. It is been overlain by the Karamanoğlu Ophiolite (Fig. 10a) and it is also unconformably covered with Tertiary Mazı and Divlek formations.

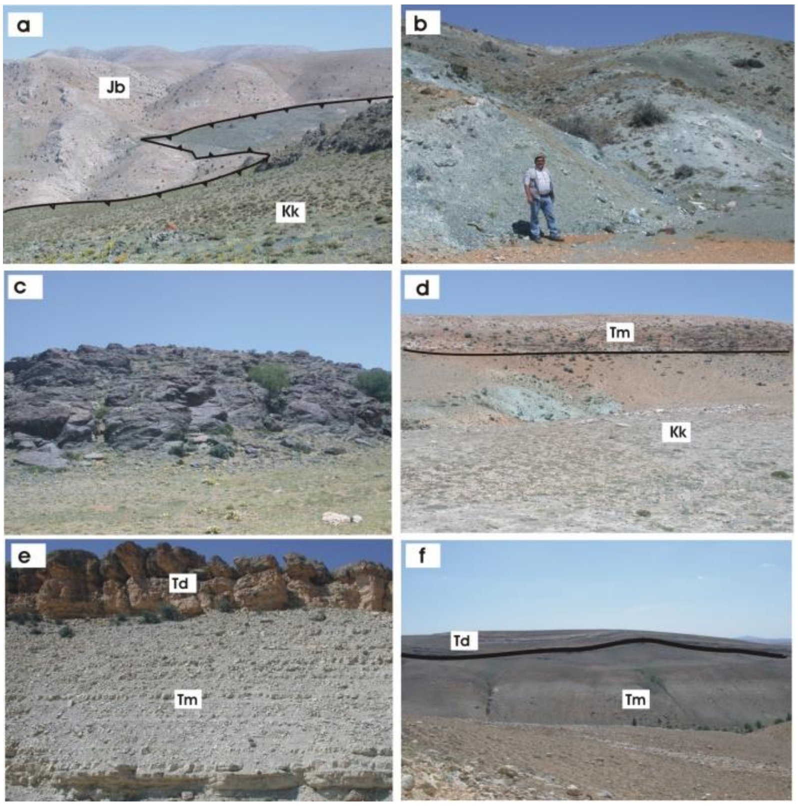

Figure 10. Views of contact relations between the Berendi, Mazı, Divlek formations and Karamanoğlu Ophiolite. **(a)** Upper Cretaceous Karamanoğlu Ophiolite (Ck) thrusting over the Jurassic–Cretaceous Berendi Formation (Jb). **(b)** Serpentinized ultrabasic rocks of the Karamanoğlu Ophiolite. **(c)** Dark green-black colored diabase and gabbros from the Karamanoğlu Ophiolite. **(d)** Detrital sedimentary rocks of the Middle Miocene Mazı Formation (Tm) that unconformably cover the serpantinites of the Karamanoğlu Ophiolite (Ck). **(e and f)** Concordant contact relations between Miocene Mazı (Tm) and Divlek (Td) formations and low-angle folding structure.

The Berendi formation, exposed along a line from southwest to northeast in the area, comprises Elmadağ, Cirisliyükseği Hill, Asar Hill, Ardıçucu Hill, Mezgit Hill and Berendi. Based on Involutina Cf., Praegaschei, Trochammina sp., Duastammidae, Glomospira sp. fossil assemblages determined by Demirtaşlı et al. (1973), the age of the Berendi Formation is Middle Jurassic–Cretaceous and formation was deposited in a shallow, stable carbonate platform.

4.1.5. Karamanoğlu Ophiolite (Ck)

The unit is composed of green-colored, grained ultrabasic and basic rocks. Demirtaşlı et al. (1973) included the unit in the Alihoca Ophiolite at northern Bolkar Mountain. Pampal (1987) renamed the formation as Karamanoğlu Ophiolithic Mélange. However, since ophiolites exposed in the area do not show a mélange character, the unit was been named Karamanoğlu Ophiolite.

It is composed mainly of serpantinite, diabase, gabbro, pyroxenite and peridotite. Peridotite is green-, brown-, black-colored and it is always serpantinized (Fig. 10b). Peridotite is made of dunite and changes to harzburgite over short distances. Dunite is red-brown colored and is been coated with iron, depending on alteration. Pyroxenite is commonly serpantinized and chloritized. Clinopyroxenes are mostly in augite composition. Uralitization occurs in places where pyroxenes are been changed to amphiboles. In serpantinized area, the unit is dark green-olive green in color. Coarse pyroxene grains are been easily identified by the naked eye. In general, olivine is composed of pyroxene. Hornblende and opaque minerals are also been found. Gabbro are blackish green colored (Fig. 10c), containing coarse hornblende grains. Hornblende is locally chloritized. Diabase is composed of plagioclase, clinopyroxene and hornblende, as well as abundant epidote. In diabase, the spaces between phenocrystals are been filled with serpentine and iron oxides.

Depending on alteration, kaolinization, talcization, chloritization, serpentinization and asbestos formation are very common within the Karamaoğlu Ophiolite. Talcization at the north of Kıraman gave rise to exploration of talc occurrences and deposits in this area (Murat and Temur, 1995). Perfect chrysotile asbestos occurrences of 10 cm in length are been found within the serpentinite fractures. Olivines, observed particularly in peridotites, are extremely altered and serpentinized. Diabase dykes cut the other units. Their fresh surfaces are dark green-black colored and the alteration surfaces are brown.

The Karamanoğlu Ophiolite is been exposed over a narrow part in northeastern section of the area. It is been thrust over the Middle Jurassic–Cretaceous Berendi Formation. It is been unconformably overlain by the Miocene Mazı Formation (Fig. 10d). The Karamanoğlu Ophiolite is the southern continuation of the so-called Alihoca Ophiolite unit (Demirtaşlı et al., 1973; Çalapkulu, 1980; Temur, 1991; Baş and Temur, 1991), exposed around Pozantı, north of the Bolkar Mountain. Demirtaşlı et al. (1983) found Late Campanian fossils in limestone blocks within the ophiolites around Berendi. Therefore, ophiolites have emplaced following Campanian. Emplacement age of ophiolites is given as Upper Cretaceous–Lower Paleocene by Pampal (1987) and as Campanian by Murat (1992). In this study, emplacement age of ophiolites is been accepted as Late Cretaceous (Maastrichtian). Ophiolitic complex, known as the Eğriçayır Mélange, exposed around the Yüğlük Mountain, southeast of Karaman, was been also reported to have an emplacement age of Upper Maastrichtian (Bilgiç and Gökten, 2005).

4.1.6. Mazı Formation (Tm)

It is composed of conglomerate, sandstone, siltstone and mudstone. The same unit was been named and described as the Ortaköy Formation, around Mut, by Sezer (1970), the Derinçay Formation by Gedik et al. (1979), the Kıraman Formation by Pampal (1987) and the Mazı Formation by Murat (1992). In this study, the name, Mazı Formation, was been used due to its suitability to the lithology.

There is a regular grading from bottom to top of the formation and the unit starts with conglomerate at the bottom and gradually changes to sandstone, siltstone and mudstone to the top. The conglomerate grains are composed mostly of limestone and ophiolite fragments of the older formations. It is generally coarse-grained, angular and poorly sorted. The conglomerate level is red colored. Grains are been bounded with carbonaceous and clayey cement. The sandstone level is gray–beige in color, thin medium bedded and in transition to conglomerate. The siltstone and mudstone levels are brown-, pink-, and yellow-colored, thin bedded and laminated. They have soft and fragile in structure.

Thickness of the Mazı Formation is been given as 400 m by Demirtaşlı et al. (1973) and Pampal (1987) and 150 m by Murat (1992). Formation attains a thickness of 200 m around Çatköy. It is been exposed around the Çatköy, Kıraman and Karamanoğlu villages in the western part of the study area. Units of the Mazı Formation, starting with a basement conglomerate, cover the Upper Cretaceous Karamanoğlu Ophiolite and other older units with an angular unconformity. Formation is been conformably overlain by clayey limestones of the Upper Miocene Divlek Formation (Fig. 10e, f). On the basis of Conus sp., Flabellipecten solarium LAMARCK, Cylypeaster altus KLEIN, Robulus sp., Ammonia sp., Alphidium sp., Aurilla sp., Cancris auriculus FICHTEL, Helicosphaera kumptneri, Cocolithus pelagcus, Globigerinidae, Discorbidae, Textularidae fossil assemblages determined in detrital sediments of the formation (Pampal, 1987 and Özdoğan, 2004), the age of the unit is Middle Miocene.

Units of the Mazı Formation were been deposited in a bowl-shaped marine basin during the Middle Miocene. By a deepening and filling of marginal parts of the basin with conglomerates, sandstones and siltstones were been deposited, which gradually changed to clayey limestone with increasing carbonate accumulation. According to Köksoy (2004), conglomerates mostly reflect fluvial conditions and gradually change to an open marine environment.

4.1.7. Divlek Formation (Td)

The Divlek Formation is composed of gray-beige colored, thick-bedded, oolitic limestones. The name of the formation was been given by Murat (1992) after the village, northwest of the area.

The limestone of the formation is gray/yellow/beige colored and the color tone changes over short vertical and horizontal distances. Bedding is generally thick (70–100 cm) and massive in appearance. In some places, thin-bedded clayey limestone and marl levels are been observed. Oolites are very distinctive and common. Limestone is generally soft and fragile. It contains vast amounts of macro algae, foraminiferans, gastropods, lamellibranches and coral fossils. Limestone is of oolite-biomicrite, pelmicrite and biosparite character. Oolites comprise more than 20% of the rock and they been also contain 1–2% quartz fragments (Pampal, 1987).

Limestone of the Divlek Formation is conformably set above the Mazı Formation (Fig. 10e, f). The limestone, which is the youngest unit of the area, is been overlain by Quaternary alluvium.

Thickness of formation is been given as 600–800 m by Selim and Demirtaşlı (1984), 50 m by Pampal (1987) and 100 m by Murat (1992). Since there are numerous lenticular inclusions in limestones, thickness change over short distances. Thickness was been calculated as 150 m from the topographic position around Kırman where the unit is well exposed. The Divlek Formation covers large areas around Çatköy, Kıraman, Karamanoğlu, Berendi, the eastern part of the Gerdekes Plateau, Küldüşmez, Gömecek and Okluca Mountain (Fig. 2).

On the basis of Globigerine paebollidae, Globigerinoides sp., Globirotalia, Globigerinoita, Nodosaridae, Discorbidae, Orbulina universa, Amphistegina sp., Meterostegina sp., Elphidium sp., Lithotamnium sp., Flabellipecten fagicus, Ostrea creasisima, Clyseaster sp., Spirolina sp., Archias sp., Rotallia sp., Cymbeloporetta sp. and Catapysdyrax fossils obtained from limestones, the age of formation is been accepted as Upper Miocene (Selim and Demirtaşlı, 1984; Pampal, 1987; Köksoy, 2004; Özdoğan, 2004).

Oolitic and clayey limestone of the Divlek Formation might have deposited on a shallow and high-energy sea floor where coarse-grained materials cannot transported. The fossiliferous limestone is of reef character (Gedik et al., 1979). According to Köksoy (2004) – open marine environment at the beginning changed to a shallow marine facies over time. The Divlek Formation can been lithologically and chronologically correlated with the Mut Formation (Sezer, 1970; Gedik et al., 1979) and the Karaisalı Formation (Schmit, 1961; Pampal, 1988), which is widely exposed within the southern part of the study area.

4.2. Tectonic Structures

Units exposed in the study area are located on the central Taurid Belt and included the Bolkardağı Unit, which is one of the tectonic units described by Özgül (1976). The Bolkar Mountain is a SW–NE extending mountain chain with a width of 60 km and length of 150 km. It corresponds to a major anticline that developed in the same direction (Blumenthal, 1956). The study area is located at the western edge of the northwest wing of this anticline. The anticline was been folded during the Early Paleocene–Middle Eocene (Çalapkulu, 1980; Temur 1989). Based on this structure, Paleozoic and Mesozoic units in the study area are supposed to strike to NE–SW and dip to the NW. However, these orientations have been largely disturbed due to local foldings.

There are two main discordant surfaces in the study area. One of them is been found at the basement of the Jurassic–Cretaceous Berendi Formation and reflects the Late Triassic terrestrial period. Paleozoic and Triassic units that formed prior to this transgression are generally in a NE–SW direction and dip to the NW at 50–60°. The second discordance is at the basement of the Miocene units. The Berendi Formation limestone that was been deposited between the two discordances is also in a NE–SW direction and dips to the NW at 50–60°. The Miocene units above the second discordance are in a NE-SW direction and dip to the SE at 10–15°.

There is a major thrust fold in the area. This fault, probably from the Maastrihtian age, gave rise to overriding of mafic-ultramafic rocks of the Karamanoğlu Ophiolite on the Bolkardağı Units. There are also several strike-slip faults that was been developed in parallel to the general tectonic orientation in the region. Although some of them have already been mapped (Fig. 2), there are still unmapped faults of similar trend.

4.3. Metamorphism

Dolostone and limestone of the Upper Permian Dedeköy formation, sandstone, shale and carbonates of the Lower Triassic Saraycık Formation and Late Triassic bauxites were been metamorphosed into green schist facies, and changed to schist, phyllite, slate, metasandstone, marble and diasporite. The limestone of the Jurassic–Cretaceous Berendi Formation reflects a metamorphism degree, decreasing from bottom to the top. The Upper Cretaceous Karamanoğlu Ophiolites above these units show low-degree metamorphism. Because of this metamorphism, foliation structures developed in serpentinites and these rocks became serpentine-schist. In this respect, the age of metamorphism could be Cretaceous–Paleocene.

By the Early Cretaceous, metamorphism was advancing in the units buried under the thick Mesozoic sediments and, due to compression by the Late Cretaceous; these units were been thrust by the ophiolites, resulting in folding. Thus, with the thickening and compression of the crust in the Paleocene, metamorphism in underlying units advanced to green schist facies. Since burial and folding processes were more effective in north and eastern parts of the Bolkar Mountains, the degree of metamorphism increased and S-type Horoz Granodiorite that was intruded during the Late Paleocene–Early Eocene (Çalapkulu, 1980; Temur 1989).

4.4. Geological Development

Metasediments of the Devonian Hocalar Formation, not exposed in the study but in a wide zone between Seydişehir (Konya) and Akseki (Antalya), is the oldest lithology of the Bolkardağı Units (Özçelik, 1984; Özgül 1997; Temur et al., 2005). Özçelik (1984) mentions that units of the Hocalar Formation were deposited in a neritic environment and Özgül (1997) states that the unit was deposited in a low-energy shelf environment under the wave base, where terrestrial material input is high and patch reefs developed (Fig. 11a). With the initiation of uplift activities in the basin where the Bolkardağı Unit was deposited, terrestrial conditions prevailed and during the Carboniferous–Early Permian period, erosion–transportation processes were dominant (Fig. 11b).

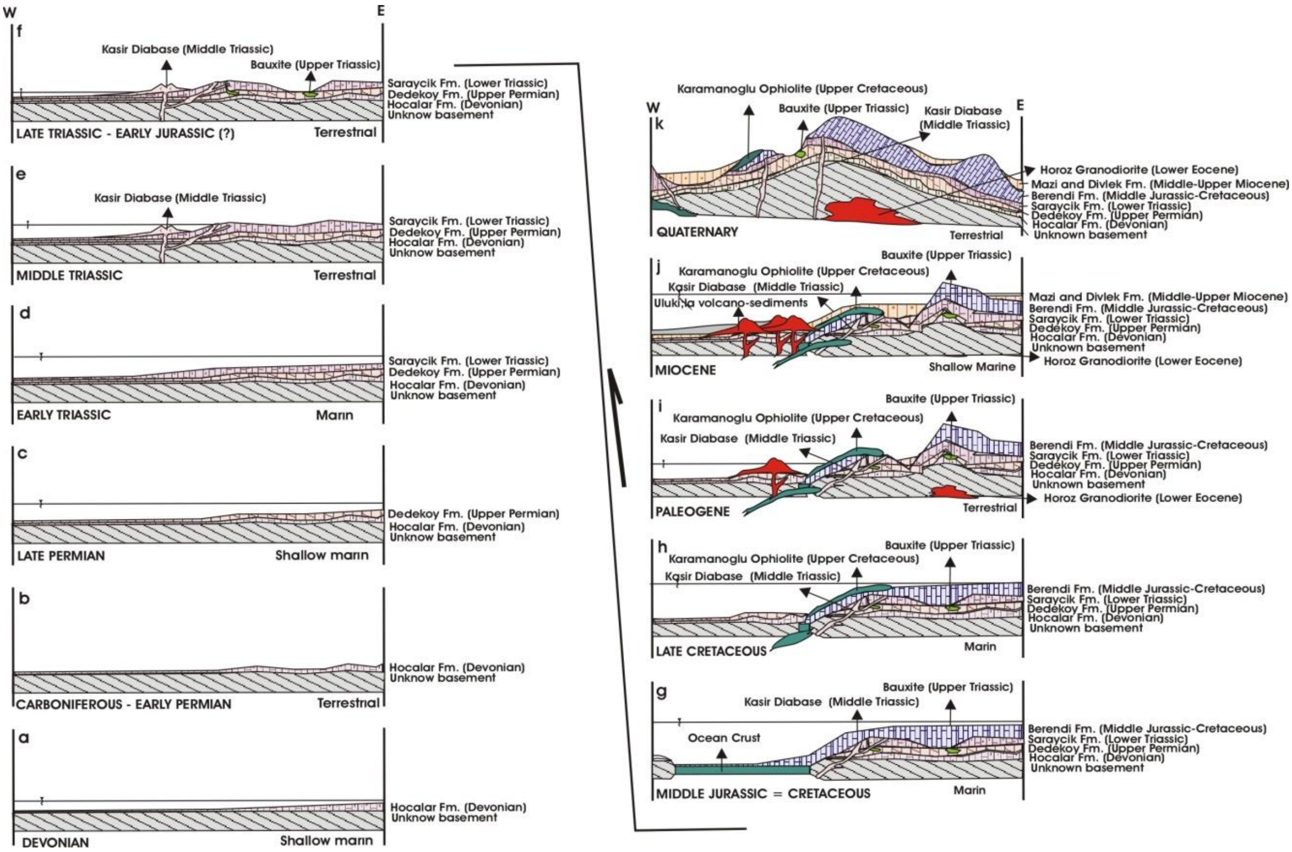

Figure 11. Schematic sections showing the geologic evolution scenario of the Bolkar Mountains.

With the Late Permian transgression, carbonate rocks of the Dedeköy Formation were been deposited (Fig. 11c). Dolostone at the base that comprise the Dedeköy Formation (Gerdekesyayla Dolostone Member) belongs to a shallow carbonate platform, while limestone (Bulgardede Limestone Member) belongs to a deeper one. As in the study area, Permian–Triassic contact is also concordant in other parts of the Bolkardağı Unit (İşgüden, 1970; Demirtaşlı et al., 1973; Çalapkulu, 1980; Pampal, 1987; Temur, 1989). According to Selim and Demirtaşlı (1984), sandstone, siltstone and carbonate of the Lower Triassic Saraycık Formation overlying the Dedeköy Formation were been deposited in a marine shelf close to the carbonate platform (Fig. 11d). The first magmatic products (Kasır Diabase) of the oceanic crust that started to form in Middle Triassic were uplifted and intercut Lower Triassic and other older units (Fig. 11e). This oceanic crust corresponds to the northern Taurid depression that opened in the Early Triassic and closed in the Paleocene–Early Eocene (Poisson, 1986). Meanwhile, with a second folding, the units inclined 10–20°. Thus, terrestrial conditions prevailed and chemical alteration, erosion and transportation processes started. With the erosion initiated in Late Triassic, Upper Permian units were exposed and karstified. At the same time, vein rocks of the Kasır Dibase, together with pelitic rocks of the Lower Triassic Saraycık formation, and terra rossa soils, resulting from alteration of carbonates, filled the karstic spaces and transformed to bauxite (Fig. 11f).

By the Early Jurassic, the oceanic crust was been developed and the Tethys Ocean was opened. In addition, the basin in which the Bolkardağı Unit was been deposited was covered with water after a new transgression. Thick carbonate sequence of the Berendi Formation was been deposited in a shallow and stable carbonate platform, which lasted until the Late Cretaceous (Fig. 11g). Oceanic crust at the base of Tethys, which started to close due to NW–SE compressional forces during the Late Cretaceous, was broken and pushed over the Bolkardağı Unit (Fig. 11h). In areas where limestone of the Berendi Formation is been found above the rocks of the oceanic crust, limestone is observed as olistoliths in a complex appearance (Pampal, 1987; Baş and Temur, 1992; Murat and Temur 1995). By thrusting of the rocks of the oceanic crust over the Bolkardağı Unit in the Late Cretaceeous (Maastrihtian), the Karamanoğlu and Alihoca Ophiolites were been emplaced at the south and north, respectively (Demirtaşlı et al., 1973; Pampal, 1988; Temur and Baş, 1991; Murat, 1992).

Due to compressional forces operating until the Early Eocene, units were folded and, as a result of folding of the Berendi Formation units by as much as 40–50°, the Bolkardağı Anticline was formed (Blumenthal, 1956).

Due to piling of 700-m thick carbonate of the Berendi Formation and intense thickening of the crust by folding, units were been subjected to metamorphism and lost their primary structure, texture and mineralogical composition. The gradual increase in degree of metamorphism with depth resulted in significant effects on rocks of varying ages. In addition, metamorphism was more intense in the northern and eastern parts of the Bolkar Mountain, where fold-wings are steeper and crustal thickening is higher. In the east, metamorphism in the core of the Bolkardağı Anticline was at anatexis level and probably resulted in partial melting of rocks of the Devonian Hocalar Formation and other older units. Thus, the magma of granitoid composition (Horoz Granodiorite) intruded into the Paleozoic and Mesozoic units (Fig. 11i). In the Ulukışla basin, north of the Bolkar Mountain, a syenitic-type magma developed by the partial melting of the subducted oceanic crust, and trachyte, andesite, basalt and dacite-type volcanic rocks were deposited, together with sedimentary rocks, forming the Paleocene–Eocene volcano-sedimentary rocks (Fig. 11j) (Baş and Temur 1992). These rocks of typical island arc volcanism are not observable at the south and eastern sections of the Bolkar Mountain.

By a new transgression at the beginning of the Neogene, the Middle Miocene Mazı formation, which consists of conglomerate, sandstone, siltstone and mudstone, was been deposited in marginal parts of the bowl-like marine basin (Fig. 11j). On the shallow and wavy sea floor within the same basin, in places where coarse-grained material is not observed, oolitic clayey limestone of the Divlek Formation of partly reef character were deposited (Gedik et al., 1979). According to Köksoy (2004), the offshore environment, which was dominant at the beginning, changed to shallow facies over time. Due to the NW–SE trend in the compressional regime developed in the Late Miocene, units were been folded and a regression occurred (Fig. 11k). Because of alteration and transportation processes continuously operating in terrestrial conditions, the Bolkar Mountains gained their present topographic shape. Common karstification in carbonate rocks, thick terrace sediments in deep valleys and alluvium in riverbeds are the results of later geological processes.

5. Conclusion

Based on geological studies conducted around the Bolkardağı diasporitic bauxite deposits, the following results were obtained. The sequence in the study area starts with the Upper Permian Dedeköy Formation. Dolostone at the lower levels and limestones at the upper levels represent the Dedeköy Formation, which comprises the country rocks of bauxites. Considering the degree of dolomitization, it is been divided into two parts: the Gerdekesyayla Dolostone Member and the Bulgardede Limestone Member.

The Dedeköy Formation is been conformably overlain by the Lower Triassic Saraycık Formation, which is composed of schist, phyllite, metasandstone and marble alternation. Vein rocks of diabase composition (Kasır Diabase) with a few meters in diameter divide all these units.

Bauxite deposits in the region are been found within the Upper Permian Dedeköy Formation and between the Gerdekesyayla Dolostone and Bulgardede Limestone members and limestone. Topographic positions, wall rock relations and metamorphism degree of the diasporitic bauxites indicate that they were developed during the Late Triassic–Early Jurassic (?) above the Upper Permian carbonate rocks and Lower Triassic shale–sandstone–limestone interbedding and then transported into the doline and caves of carbonate rocks. The fact that bauxites are been found above the dolostone, as well as within and at the base of limestones, indicates that these low carbonate rocks responded differently to karstification.

The Saraycık Formation and other older units are been unconformably overlain by the Jurassic–Cretaceous Berendi formation. The Karamanoğlu Ophiolite is been thrust over the Berendi Formation, which is observed as a thick carbonate sequence. This ophiolite was been emplaced during the Late Cretaceous. Miocene Mazı and Divlek formations are unconformably set above the ophiolites. The Mazı formation is been characterized by conglomerate and sandstone, while the Divlek Formation is represented by clayey limestone.

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Conflict of Interest

No conflict of interest was declared by the authors.

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