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Geological characteristics of the boundary between Bolkardağı-Bozkır Units and the Ulukışla Basin and the structural evolution of the region, Central Taurides, Turkey

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Research Article

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ABSTRACT

The character of the boundary between the tectonic units in the Central Taurides and the Ulukışla Basin is controversial. The contact has been accepted as discordant or tectonic contact by different researchers. The deformation data of the units in the study area provide important information about the Mesozoic - Cenozoic period geological developments of the region. Regional compression in NW - SE direction has caused the development of fold, foliation and reverse fault type structures in the units in the study area. Similar structural deformations are observed in the rock units defined in the Ulukışla Basin as well. In this study, structural data were collected from the field in order to determine the deformation pattern and contact relations of the units in the region. Field data and structural analysis reveal that the contact between the Ulukışla Basin deposits and the Bolkardağı Unit in the study area is of 70° - 80° southeast dipping reverse fault character. These structural data in the region were interpreted as the product of a movement from southeast to northwest.

1. Introduction

Taurides extending from west to east along the southern boundary of Turkey, the western, central and eastern parts to be examined in three geographically. Accordingly, Kırkkavak Fault separates the Western Taurides and Central Taurides, while Ecemiş Fault separates the Central Taurides from the Eastern Taurides (Figure 1). The first division in the Taurides according to the definition of union was made by Özgül (1976).

The Central Taurides are the areas where the tectono - stratigraphy of the unions outcropping in the Taurides are best seen and followed. The Geyikdağı Unit is relatively autochthonous and located at the lowest part of the tectono - stratigraphy. While the Unit is overlain by Bozkır, Bolkardağı and Aladağ thrusts from the north, the Alanya and Antalya units thrust over the Geyikdağı Unit from the south (Figure 1).

The study area is located in the eastern part of the Central Taurides and includes the Bozkır, Bolkardağı and Aladağ units and the units forming the Ulukışla Basin (Figure 2). The Ulukışla Basin forms a contact with the lithologies of the Niğde Massif in the north. There are opinions that the basin sediments overlie the Niğde Massif unconformably or by tectonic contacts (Blumenthal, 1941, 1952; Whitney and Dilek, 1997; Gautier et al., 2002, Demircioğlu and Eren, 2000, 2003, 2017). The contact character of the basin with the tectonic units outcropping in the Taurides in the south is also controversial. In the discussions, the

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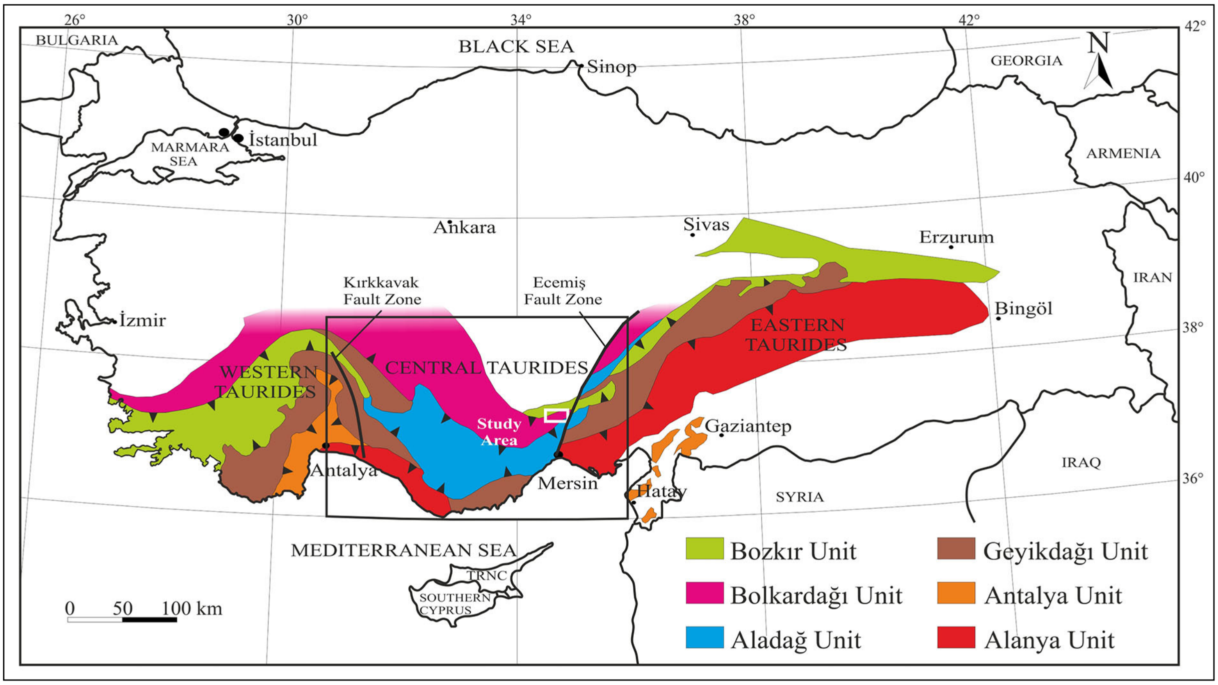

Figure 1- Map showing the general distribution of the Tauride belt and tectonic units along this belt (modified from Özgül, 1976).

character of the Ulukışla Basin's contact relationship with the units comes out. Some researchers argue that the Ulukışla Basin unconformably overlies the Bolkardağı Unit (Çevikbaş and Öztunalı, 1992; Dilek and Whitney, 1997; Clark and Robertson, 2002; Alan et al., 2007, 2011). However, the other researchers define the contact relationship tectonically (Blumenthal, 1956; Demirtaşlı et al., 1973, 1986; Ulu, 2002; Zorlu et al., 2011).

The apparent differences in opinions in studies indicating that the contact relationship between the two units is tectonic are also remarkable. Demirtaşlı et al. (1986) mapped the Bolkar Group formations corresponding to the Bolkardağı Unit as overlapping the Upper Cretaceous - lower - middle Eocene formations of the Ereğli - Ulukışla Basin along the Bolkar thrust. On the 1 / 500,000 scale geological map of the region prepared by MTA (Ulu, 2002), the contact relationship between the Bolkardağı Unit and the Ulukışla Basin is shown as thrust in some parts and as unconformable in other parts it is shown. Zorlu et al. (2011), on the other hand, showed the Bozkır Unit as thrusting over the Bolkardağı Unit, and the units belonging to the Ulukışla Basin as unconformable on the units in their maps.

However, according to Dilek et al. (1999*a*), Gautier et al. (2008), Sarıfakıoğlu et al. (2012) and Karaoğlan (2015), the boundary between the basin units and the units is tectonic contact represented by normal faulting. Gürer et al. (2016*a*, 2017) interpreted that the Ulukışla Basin thrusted over the Bolkardağı Unit and then the same fault plane worked as normal faulting. Seyitoğlu et al. (2017) stated that the basin units were deposited under the control of the İvriz Detachment Fault, and that the basin units were overlain by the Bolkardağı Unit in the following periods. Işık et al. (2018) showed that the primary contact of the Ulukışla Basin with the basement rocks (Bozkır, Bolkardağı units) in the Central Taurides had been significantly destroyed, and the lithologies of Bozkır and Bolkardağı Units in mapping areas thrusted over the Paleogene units of the basin with reverse/thrust faults from south to north after Middle Eocene.

Apart from reverse / thrust and normal fault contact relationship, the different fault characteristics are also included in the literature. According to Engin (2013), the Ulukışla Basin and the Bolkardağı Unit took to their current positions with a strike - slip fault. Similarly, Gürer et al. (2014) interprets the Ulukışla Basin as the continuation of the Sivas Basin and states that their current positions are associated with the strike - slip faulting. The contact relationship of the Ulukışla Basin with tectonic units outcropping in Taurides is important in terms of determining the

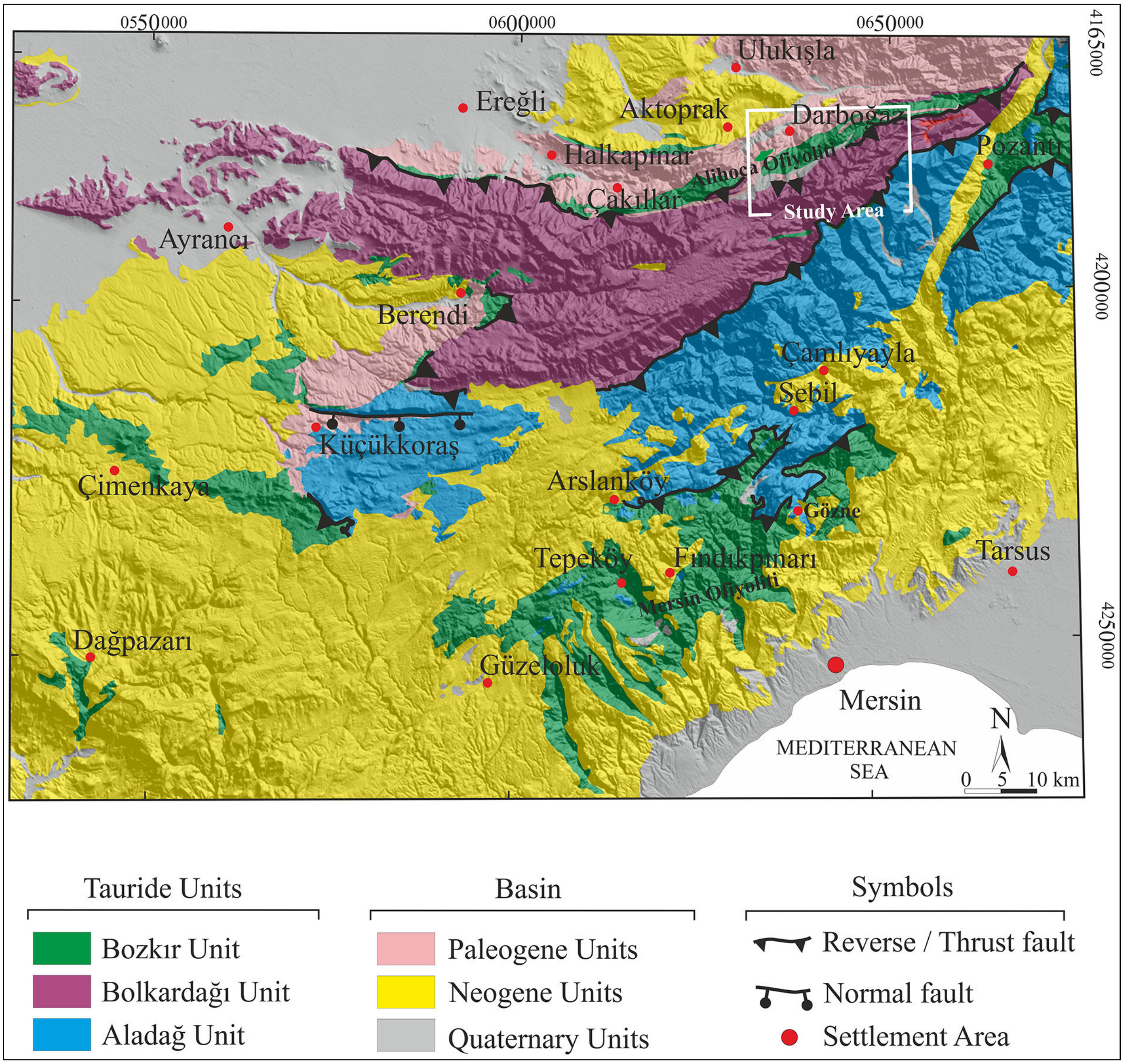

Figure 2- Geological map showing tectonic units and basin units outcropping in the eastern part of the Central Taurides (modified from Ulu, 2002).

geological development of both the Taurus orogenic belt and the Ulukışla Basin. The purpose of this study is to determine the contact relationship character of the Ulukışla Basin with the tectonic units cropping out in Taurides and to reveal the geological evolution of the study area.

2. Method

The eastern part of the Central Taurides (Figure 2), in which the study area is located, has been mapped for different purposes (Blumenthal, 1941, 1956; Özgül, 1971, 1976; Demirtaşlı et al., 1973, 1986, Alan et al., 2007, 2011). In this study 1/25.000 scale N33 - a1 and N33 - a2 sheets, in which the contact relationship of the Bolkardağı and Bozkır units and the Ulukışla Basin are evident, were selected as the study area (Figure 3). In this context, the rock units located in the study area were examined in order to reveal whether the basin contact relationship with the units was stratigraphic or tectonic, and if so, with what kind of faults the units came together. In the study area, the units forming the tectonic units outcropping in Taurides were determined and mapped as unit. The abbreviations were used to distinguish the mapped units (e.g., Kk: Kalkankaya formation).

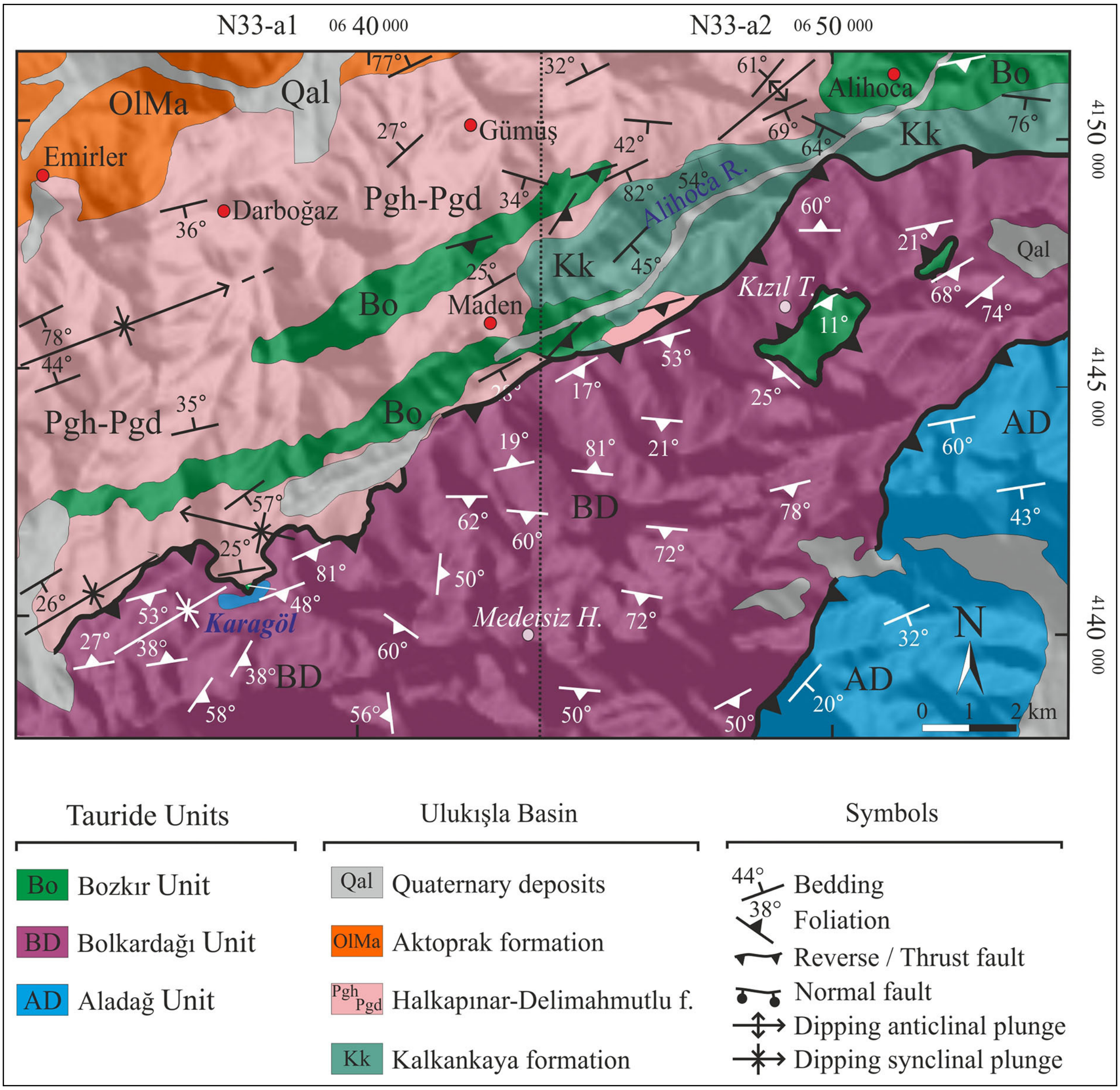

Figure 3- Geological map of the study area.

This abbreviation was also included in the text. The paleontological - petrographic samples were taken from all units representing the mapping area, the contact relationship of the units was examined, and all primary and secondary structural elements (bedding, foliation, fold, joint, fault) were determined. Total of 82 from the Bolkardağı Unit, 52 from the Bozkır Unit and 110 measurements from the Ulukışla Basin units (e.g. bedding, foliation, joint, reverse fault) were taken. The positions of these structural elements were evaluated in Stereonet v.11.2.2 (Allmendinger et al., 2013) and Win Tensor 5.9.0 software. The age, type of lithology, the formation environment and conditions of formations of rock units outcropping in the area were determined from thin section studies of samples taken for petrographic and paleontological purposes. By evaluating the field observations, structural measurements and sample analysis data together, the stratigraphy, deformation characteristic and geological evolution of the region were determined.

3. Regional Geology

The study area and its surroundings are located in the eastern part of the Central Taurides (Figure 2). The Ulukışla Basin is located in the northwest of the Bozkır and Bolkardağı units and in the south of the

Niğde Massif. The basin includes the units between the late Campanian - Quaternary age ranges. The basin is represented by carbonate, clastic and evaporitic lithologies. The fan delta, deep sea and lacustrine environment deposits overlying the shallow marine units at the basin floor reveal that the basin, which once was a shallow environment, gradually deepens then the basin depth decreases again over time and terrestrial environmental conditions prevail.

Tauride units, which limit the southern part of the basin, show arc geometry with an approximately east - west trending and southward bending. The Bozkır Unit is represented by oceanic crust rocks in the study area and its close vicinity, and it is defined as Alihoca Ophiolite and Ophiolitic Mélange, Kızıltepe Ophiolite, Pozantı - Karsantı Ophiolite, Mersin Ophiolite and Ophiolitic Mélange (Figure 2). The general acceptance is that these rocks began to overthrust the Tauride platform in the late Cretaceous. The Bolkardağı Unit, which is in contact with the basin sediments in the study area, includes Middle Devonian - Late Cretaceous units. The unit consists of rocks that has undergone metamorphism in greenschist and blueschist facies depending on the depth of burial. The widespread rock lithology of the study area is composed of marbles of which their primary sedimentation is Triassic. The contact relationship of the Bolkardağı Unit with the Bozkır Unit is tectonic. Similarly, it has a tectonic relationship with the Ulukışla Basin in the study area (Figure 3). Aladağ Unit consists of carbonates and clastics in the Late Devonian - Late Cretaceous age ranges (Figure 2). Mostly the Permian limestones crop out in the study area. The contact of this unit with other tectonic units (Bolkardağ, Bozkır) is tectonic. It is unconformably overlain by Miocene basin units in large areas outside the study area (Figure 2). Aladağ Unit has again unconformity contact with Oligocene and Miocene basin units along the Ecemiş Fault Zone.

4. Stratigraphy

The lithologies of Aladağ, Bolkardağı, Bozkır Units and the Ulukışla Basin constitute the rock units of the study area (Figures 3 and 4). Aladağ Unit is located in the southeastern part of the mapping area. In the northern and northwestern parts of the mapping area the rock units of Bolkardağı, Bozkır, Ulukışla Basins are located. The Bozkır Unit approximately strikes in NE - SW and outcrops in limited areas.

4.1. Aladağ Unit

The unit presents a sequence consisting of the late Permian recrystallized limestones and dolomite in the

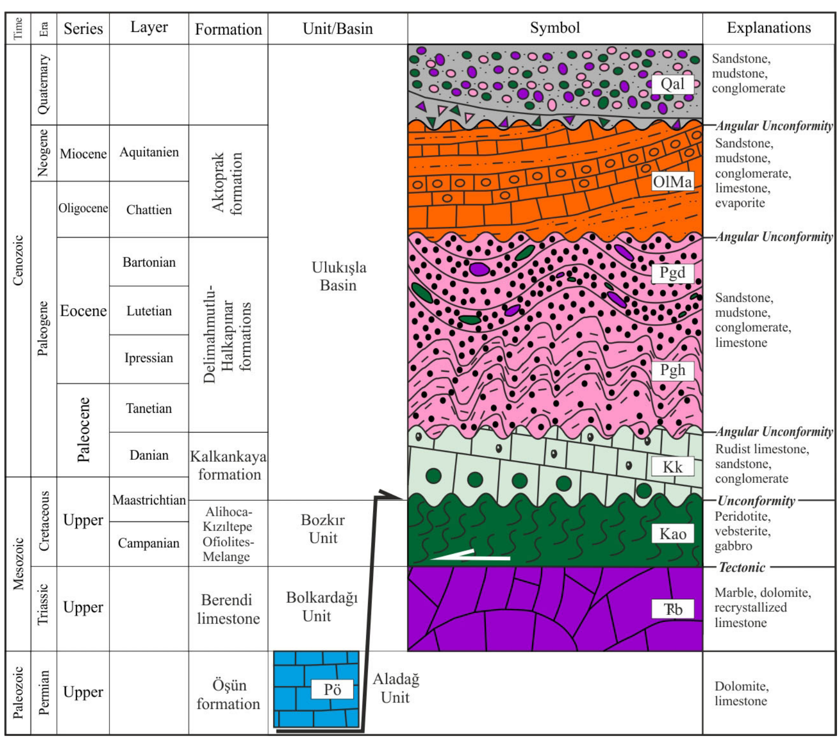

Figure 4- Stratigraphic section of the study area.

study area (Figure 5a). The weathering and fresh joint surfaces of limestones and dolomites are yellow, gray, smoky colored. The unit is occasionally thick - bedded and massive. Apart from folding, it has a broken structure in places. These limestones belonging to the Aladağ Unit have been described by Demirtaşlı et al. (1986) as the "Öşün formation" (Pö). The Aladağ Unit tectonically overlies the Bolkardağ Unit on the map. The upper contact of the unit is not visible in the study area. However, it is tectonically overlain by the ophiolite related Mersin Mélange of the Bozkır Unit between Arslanköy and Mersin in the south, outside the study area (Figure 2).

4.2. Bolkardağı Unit

Bolkardağı Unit located in the northeast of the Aladağ Unit in the study area has mostly marble and recrystallized limestone lithology (Figure 5b). In previous studies, this unit was named as the "Berendi Limestone" (Demirtaşlı, 1975) (TRb). Dolomite and calcschist constitute the other rock types of the Bolkardağı Unit within the mapping area. Metacarbonates are gray - white and widely folded. The foliation planes are prominent in calcschists and show different degrees of folding. Calcite and dolomite are commonly found as major minerals in thin section studies of these rocks (Figure 6a, b).

Although the granoblastic texture is typical, the orientation of the grains is clear. In some samples, the carbonate minerals are accompanied by glaucophane and chlorite minerals. The lithologies formed by plagioclase (albite), quartz, glaucophane, muscovite and chlorite minerals in samples taken from different levels of calcchists were defined as glaucophane schists. Some calcschists also contain fine glaucophane minerals in addition to the common calcite minerals. Hand sample and thin section studies indicate that the rocks forming the Bolkardağ Unit are affected by greenschist and blueschist facies metamorphisms. The metamorphism of the greenschist facies of the Unit has been emphasized by previous researchers (Özgül, 1976; Okay, 1985; Demirtaşlı et al., 1986; Çevikbaş, 1991; Whitney and Dilek; 1997; Okay and Tüysüz, 1999; Candan et al., 2005; Ulu, 2006; Robertson et al., 2009; Pourteau et al., 2010, 2013; Parlak et al., 2014; Van Hinsbergen et al., 2016). Kaaden (1966) and Çalapkulu (1980) stated that the unit contained rocks with glaucophane, while Göncüoğlu (2011) reported that some parts of the Kütahya - Bolkardağ belt has undergone metamorphism in the blueschist facies. Candan et al. (2005), Pourteau et al. (2010, 2014), Rimmelé et al. (2005), Parlak et al. (2014), Gürer et al. (2016*b*) stated that the Tauride microcontinent has undergone metamorphism under HP - LT conditions. Özgül (1976) stated that the youngest unit of the Bolkardağı Unit, which has undergone metamorphism, was of Paleocene age. Okay (1985), on the other hand, stated that the metamorphism of the Unit due to the ophiolitic thrust occurred in the latest Cretaceous period. Demirtaşlı et al. (1986) pointed out that the units in the Bolkardağı group showed a distinct metamorphism when moving towards the north and this situation was most evident in the increase of recrystallization in limestones and a decrease in the possibility of detecting fossils. According to Ulu (2006), the degree of metamorphism is more distinctive in the northern part and its age is Maastrichtian - Selandian.

4.3. Bozkır Unit

The Bozkır Unit is represented by the Alihoca Ophiolite, Ophiolitic Mélange and the Kızıltepe Ophiolite in the study area (Figure 5c, d). Ophiolite and mélange units in the region were named as the "Alihoca Ophiolite Massif" by Blumenthal (1956). These lithologies are found as NE - SW trending outcrops in the northern part of the mapping area (Figure 3). The Alihoca Ophiolite (Kao) consists of serpentinized peridotites, websterite, radiolarite, cumulate and isotropic gabbro.

Beneath this ophiolitic mass there is a mélange section. The Alihoca Ophiolite Mélange consists of blocky and red - brown clastic matrix. Blocky lithologies of mélange are ophiolite, recrystallized limestone, marble, dolomite and calcschist. The Kızıltepe Ophiolite (Kko) has limited outcrops in the study area. The lower parts of the unit, of which the upper parts are represented by serpentinized peridotites, are composed of rock assemblages dominated by the metamorphism. Thin section studies of hand samples taken from this section reveal that they have metagabbro, amphibolite and glaucophane albite schist lithology.

Plagioclase and glaucophane constitute the major mineral composition of some rocks (Figure 6c, d). The partial argillization and sericitization are evident in subhedral plagioclase phenocrysts. Glaucophane

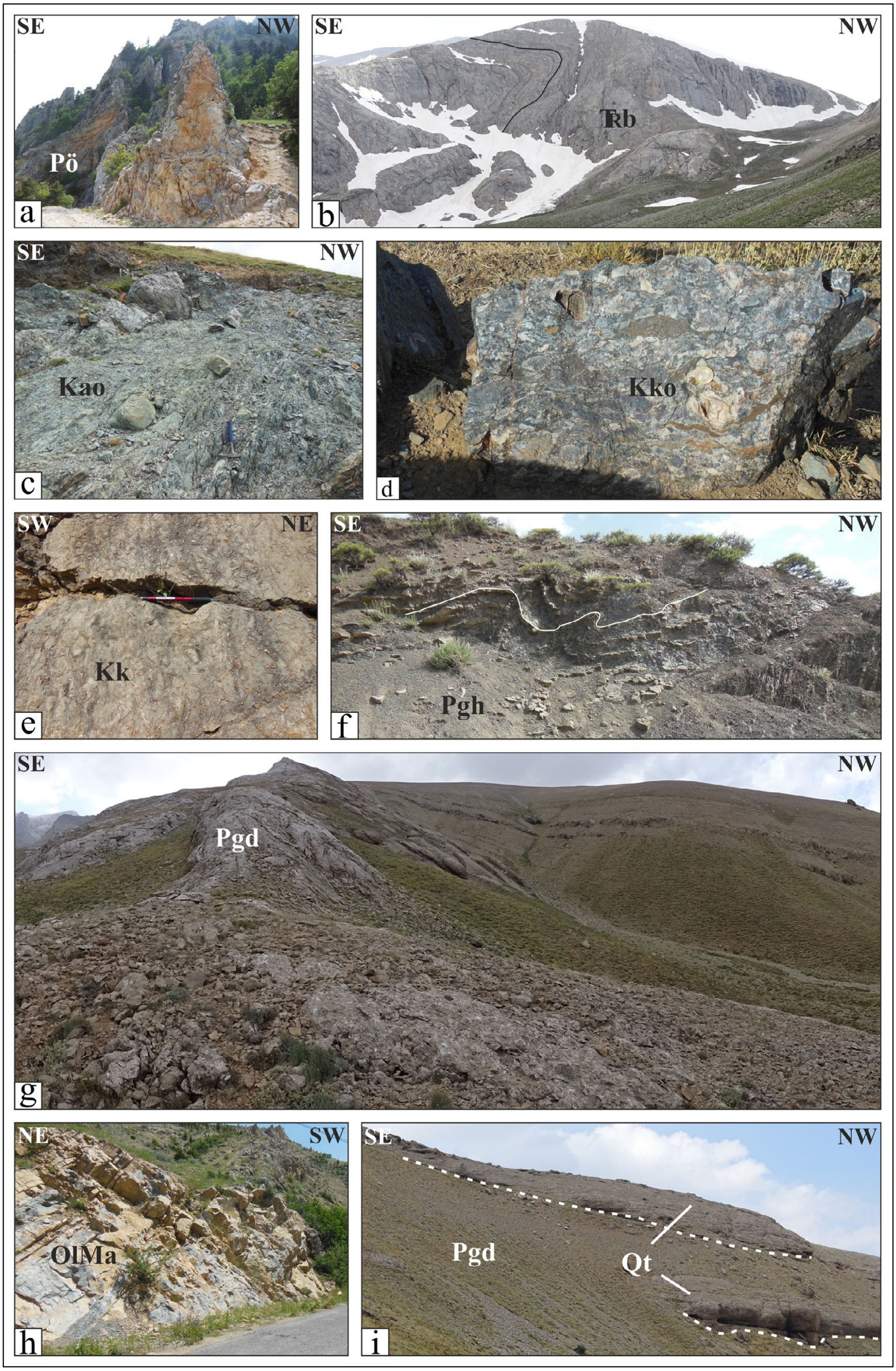

Figure 5- Field views of the units in the study area: a) Öşün formation limestones (Pö), b) Berendi limestone (TRb), c) Alihoca Ophiolite serpentinites (Kao), d) Kızıltepe Ophiolite metaperidotite (Kko), e) Kalkankaya formation limestones (Kk), f) Halkapınar formation sandstone-mudstone alternation (Pgh), g) Delimahmutlu formation calcarenites (Pgd), h) Aktoprak formation limestones (OlMa), i) Quaternary conglomerates (Qal).

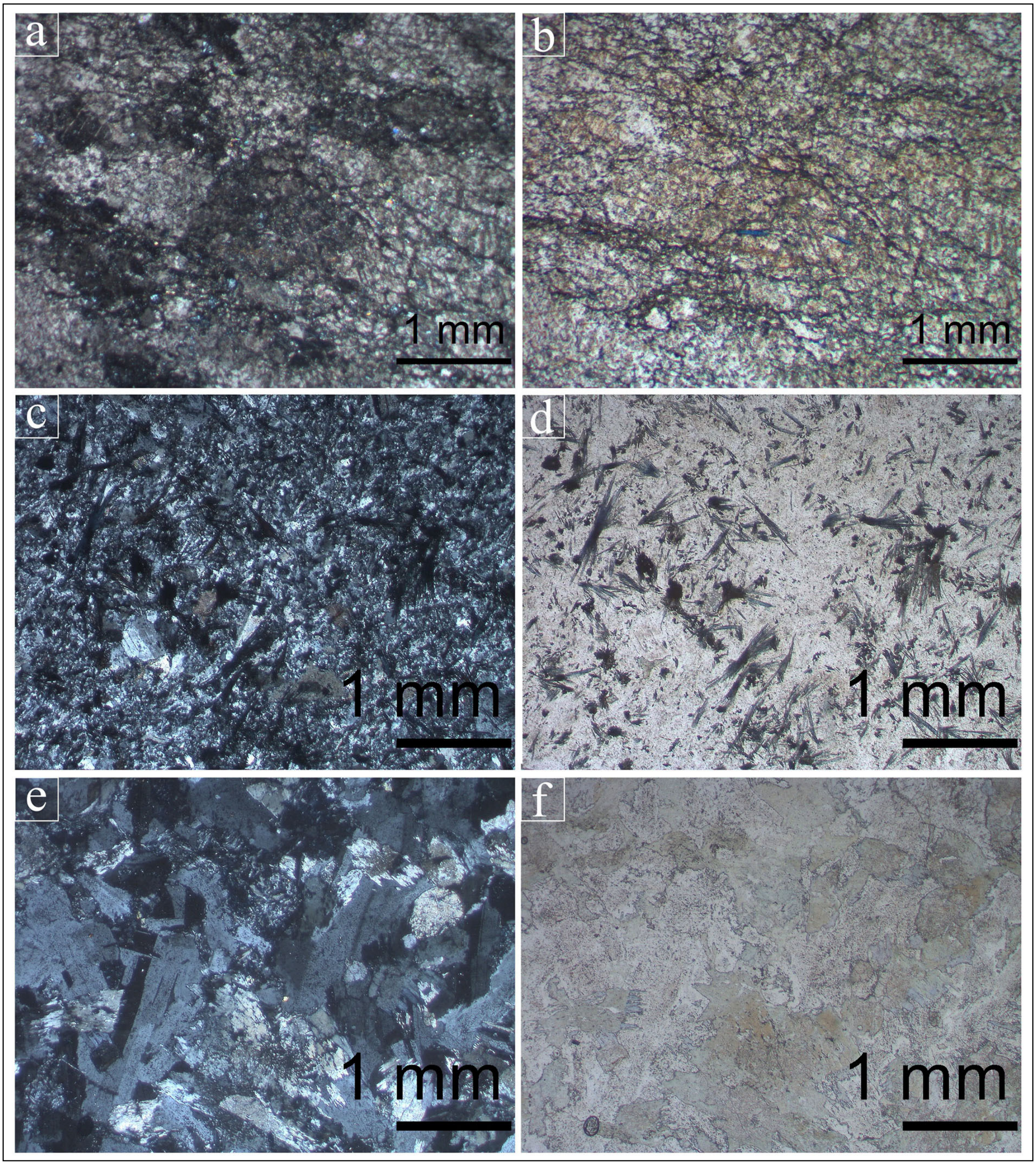

Figure 6- Microscopic views of the samples taken from the Bolkardağı Unit, which have undergone metamorphism in blueschist facies in the study area; a) cross nicols, b) parallel nicols; c, e) cross nicols and d, f) parallel nicols.

minerals, on the other hand, have acicular and thin rod - like grains; and it is distinctive with its typical bluish purple color. It is in disseminated grain and mineral clusters in the rock. This mineral composition is accompanied by local quartz. The plagioclase and clinopyroxene minerals constitute the major mineral composition of some rocks (Figure 6e, f). Plagioclases are subhedral grained that show local sericitization. The clinopyroxenes show full or partial uralitization. The clinopyroxene is seen as residue in areas where the alteration is weak. The actinolites are common minerals developed as a result of uralitization. These fringe - shaped minerals are accompanied by fine glaucophane and chlorite grains (Figure 6e, f).

Dilek and Whitney (1997) stated that the Kızıltepe Ophiolite was affected by metamorphism ranging from greenschist to blueschist facies.

4.4. Ulukışla Basin

In the northern part of the study area is the Ulukışla Basin, which is represented by Cenozoic units (Figures 2 and 3). The basin units defined on the basis of formation in previous studies show rejuvenation towards the northern part. The Kalkankaya formation (Kk), which is the oldest unit of the Ulukışla Basin, was first defined by Blumenthal (1956). The formation, which outcrops in the southern part of the basin, has outcrops trending approximately in E - W and NE - SW in the study area. The formation, whose dominant lithology is limestone, begins to deposit with red clastic (conglomerate, sandstone) rocks at the bottom then continues with limestones containing abundant rudist and loftusia fossils (Figure 5e) in upper parts. The formation also includes calcarenite levels in places. The formation is medium - thick bedded and has a thickness of approximately 100 m in the study area. Çevikbaş and Öztunalı (1992) dated the Kalkankaya formation as late Maastrichtian - early Paleocene. Its boundaries with the Bolkardağı Unit have a tectonical relationship within the mapping area (Figure 3). Its contact with the Bozkır Unit (Alihoca Ophiolite and Ophiolitic Mélange) is unconformable. Paleocene - Eocene Halkapınar (Pgh) and Delimahmutlu (Pgd) formations, which widely spread in the basin, unconformably overlie the Kalkankaya formation.

The Paleogene Halkapınar and Delimahmutlu formations have lateral and vertical relationships with each other. In this study, it was mapped together without discrimination. The formations were first defined by Demirtaşlı et al. (1973). Thin to medium thick bedded sandstone and mudstone constitute the main rock type of the Halkapınar formation (Figure 5f). Thick bedded limestones also accompany these units as interlayers. The formation with a thickness of 600 m in the study area is represented by the deep sea deposits. However, the thickness of the formation throughout the basin is 1,000 m (Demirtaşlı et al., 1984) or 2,000 m (Clark and Robertson, 2005) and shows different depositional environment characteristics from terrestrial to the deep sea environment (alluvial fan, fan delta, turbiditic sequence). According to Alan et al. (2007), the Halkapınar formation is Thanetian - Lutetian. The fossil assemblage (benthic foraminifera, algae and macro shell) of the samples collected within the scope of the study indicates that the formation is Thanetian. The Halkapınar formation does not have any contact with the Bolkardağ Unit within the study area; however, it unconformably overlies the Bozkır Units in limited areas. The primary boundary outside the study area was defined as a detachment fault (İvriz Detachment Fault) between the Halkapınar formation and Bolkardağı Unit in the western part (Seyitoğlu et al., 2017). In some other studies, the contact relationship between the Tauride units and Halkapınar formation is described as discordant (Demirtaşlı et al., 1986; Dilek and Whitney, 1997; Clark and Robertson, 2005; Gürer et al., 2016*a*). The Halkapınar formation in the study area transits into the Delimahmutlu formation at the top. The dominant lithology of the Delimahmutlu formation is constituted by conglomerate, sandstone and limestone (Figure 5g). The grains of the pebbles that form the basement levels are largely derived from the rocks of the Bolkardağ Unit. The pebble sizes are variable and sometimes in blocky size. They are badly sorted and rounded. The formation, which has a thickness of approximately 250 m, represents the fan delta depositional environment. It consists of rich macro fossil of which its certain levels are easily traced. Alan et al. (2007) determined the age of the formation as Lutetian - Bartonian (Middle - Late Eocene). The fossil assemblages (benthic foraminifera, algae) of the samples taken from the Delimahmutlu formation outcropping in the study area give the age of the formation as Late Ipressian (Early Eocene).

The Delimahmutlu formation is overlain by the Aktoprak formation, which is represented by terrestrial deposits. The Aktoprak formation crops out in a limited area in northwest part of the map. The formation was first defined by Demirtaşlı et al. (1973). The formation with evaporite, marl, lacustrine limestone lithology (Figure 5h) has a thickness of 450 m in the Ulukışla Basin. Blumenthal (1956) stated the age of the formation as Chattian - Aquitanian (Late Oligocene - Early Miocene). The Aktoprak formation has unconformable contact relationships with the upper and lower units in the mapping area. However, the formation presents a normal fault contact relationship in the western part with the underlying units (Seyitoğlu et al., 2017). Quaternary deposits are the youngest units in the mapping area. Quaternary sediments, which unconformably overlie the Unit rocks and basin units, represent colluviums, incised valley deposits and terraces (Figure 5i) on the foothills of high regions, and the fluvial deposits in areas where horizontal topography is dominant.

5. Structural Geology

The deformations in different densities are observed in the units outcropping in the study area and its close vicinity. The units, which form the Aladağ, Bolkardağı and Bozkır units, show folding in varying sizes (e.g. tight, closed, harmonic folds) and reverse faulting. The development of foliation almost parallel to the bedding and oblique foliation is also characteristic especially in the rocks forming the Bolkardağı Unit. The joint growth is common in these rocks. Foldings and faultings are observed in limited outcrops in units belonging to the Ulukışla Basin in the study area. Open folds are the common type of folds. The local tight folds are also common in Paleogene sequences of the basin. Reverse faults have also developed in areas close to the contacts of the basin with the unit rocks.

Structural measurements (bedding, foliation, fault, joint) obtained from the mapping area were grouped under three lithological groups. These are Bozkır and Bolkardağı units and the Ulukışla Basin.

5.1. Structures of the Bolkardağı Unit

The lithologies of the Bolkardağı Unit show folding varying from outcrop scale to megascopic scale. Demirtaşlı et al. (1986) assessed this structural feature of the Bolkar Unit as a large anticlinorium in the Bolkar Mountains and evaluated that the folds in the Ereğli - Ulukışla Basin and the folds in the Bolkar group were more or less parallel.

Our field observations reveal that the units forming the Bolkar Unit are mostly represented by asymmetric and overturned folds according to the axial planes and position of the fold limbs. Considering Fleuty (1964)'s fold classification, the angular relationship between the fold limbs indicate tight, narrow and open fold development of the Bolkardağı Unit lithologies. The bedding measurements obtained from sections where the stratification is significant reveal that the beds strike NE - SW and dip NW or SE. The analysis of these measurements determined the condition of the fold axis as N40°E, 14° (Figure 7a). The axis plane of the folding is determined as N50°W, 76°SW. The data obtained from the bedding measurements revealed that the folds in the Bolkardağı Unit cropping out in the study area are semi perpendicular to perpendicular axis planes and have low plunging fold axis as fold geometry. The folds in the foliation planes have also similar features. Analysis of the measurements obtained from these planes gives the condition of the fold axis as N74°E, 11° (Figure 7b), and the state of the axis plane as N14°W, 79° NE. Field observations show that the orientation of the folds is NW in direction.

There are reverse faults affecting the Bolkardağı Unit in the study area. Especially, the fault plane and slip plane developments are observed in places along the contacts of the unit with Paleogene units of the Ulukışla Basin. In some of these planes the shear lineation is evident. Figure 7c shows the distribution of measurements taken from reverse faults on the equal area net. The Froclich diagram shows that the faults are concentrated in the reverse fault zone (Figure 7d). The paleostress analyses of the planes in which the shear lineaments are characteristic reveal the position of the main paleostress axes (σ1, σ2, σ3) forming the faulting (Figure 7c). As can be seen in Table 1, the largest (σ1) and the intermediate main paleostress (σ2) axes forming the faults affecting the Bolkardağı Unit lithologies are close to horizontal, and the smallest main paleostress (σ3) axis is close to vertical. The ratios of R and R' obtained from the analysis are 0.89 and 2.50, respectively. When all the data are evaluated together, the reverse faulting affecting the Bolkardağı Unit points to the radial compressive tectonic regime (Table 1).

The Bolkardağı Unit offers metamorphism in addition to its prominent deformation. Our hand sample and microscopic examinations reveal that the rocks are affected by metamorphism in greenschist and blueschist facies. This metamorphism demonstrated by the Bolkardağı Unit in the Central Taurides has been evaluated in some studies. Accordingly, Ulu (2006) dated the greenschist metamorphism of the Bolkardağı Unit as Maastrichtian - Selandian (Upper Cretaceous - lower Paleocene). Robertson et al. (2009) stated that the unit was deep buried and underwent high pressure/low temperature metamorphism (blueschist). According to the researchers, the dating of this metamorphism is 80 my. However, Parlak et al. (2014) dated the high pressure/low temperature metamorphism as Turonian, which is much older.

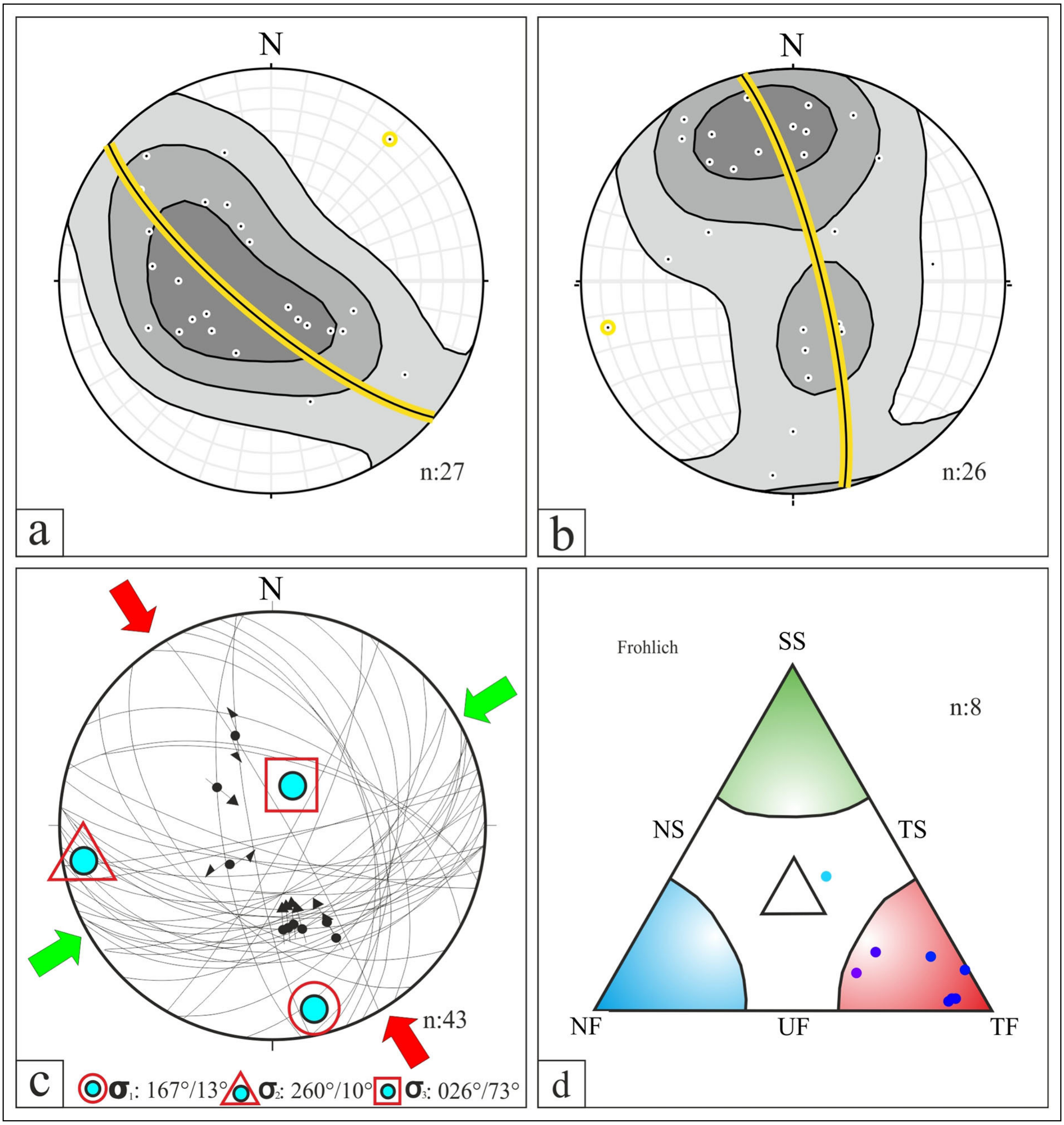

Figure 7- a) Point-contour diagram of the layer planes, b) point-contour diagram of the planes of foliations, c) diagram showing the reverse fault planes and compression directions, d) Froclich diagram showing the character of the faults (SF: Strike-slip fault, NF: Normal fault, RF: Reverse fault) of the Bolkardağı Unit in the study area.

Table 1- Table showing the results paleostress analysis of reverse faultings in the study area.

Area	Method	Fault Plain	σ_1	σ_2	σ_3	R Index	R' ndex	Misfit(α)	Tectonic Regime
Bolkardağı Unit	F5	43	167°/13°	260°/10°	023°/73°	0,89	2,50	6,2	Radial Compressive
Bozkır Unit	F5	20	173°/25°	290°/43°	063°/36°	0,64	1,36	14,6	Oblique Transpressive
Ulukışla Basin	F5	19	146°/21°	237°/04°	337°/68°	0,34	2,34	2,8	Pure Compressive

When we evaluate our findings and results of analysis together with the literature data, the Bolkardağı Unit should probably be located in the north of Tauride Platform and deeply buried due to the high pressure/low temperature metamorphism.

The thrust of the ophiolitic units representing the Bozkır Unit and the compression in regional scale caused the development of widely developed folds and reverse faults together. The character of the tectonic contact between the Bolkardağı Unit and the Ulukışla Basin reveals that, unlike its primary development, it has a reverse faulting character and that the faulting has developed due to the compression in NW - SE direction. The situation of reverse faults and dominant NW trend of folds do not support the previous north to south movement. On the contrary, it shows the existence of a development from south to north movement.

5.2. Deformation Structures of the Bozkır Unit

The lithologies belonging to the Alihoca Ophiolite, melange and Kızıltepe Ophiolite belonging to the Bozkır Unit are seen as folded in the study area, similar to the Bolkardağı Unit.

During our field studies, it was seen that folds on the foliation planes of the units that make up the Bozkır Unit revealed that the units were mostly represented by asymmetric and overturned folds according to the axial planes and position of fold limbs. The lithologies of the unit generally indicate the open fold developments.

The analysis of measurements obtained from the foliation planes gives the condition of fold axis as N84°E, 18°, and state of the axis plane as N6°W, 72°SW (Figure 8a). Field observations show that the orientation of the folds is NW.

There are observed reverse faults affecting the Bozkır Unit within the study area. In some parts of the reverse fault planes the slip lineaments are evident. Figure 8b shows the distribution of measurements taken from reverse faults on the equal area net. The Froclich diagram shows that the faults are concentrated in the reverse fault zone (Figure 8c). The paleostress analysis of the planes in which shear lineaments are characteristic reveal the position of the main paleostress axes (σ1, σ2, σ3) forming the faulting (Figure 8b). As can be seen in Table 1, the largest paleostress (σ1) axis that forms the faults affecting the Bozkır Unit lithologies is horizontal, and the smallest major paleostress (σ3) axis is close to the vertical. The ratios of R and R' obtained from the analysis are 0.64 and 1.36, respectively. When all the data are evaluated together, the reverse faulting affecting the Bozkır Unit points out an oblique transpressive tectonic regime (Table 1).

The analysis of measurements obtained from foliation planes seen in the Alihoca Ophiolite outcropping at the Karagöl location gives the condition of fold axis as N77°E, 7°, and the state of axis plane as N13°W, 83°SW (Figure 8d). The field observations show that the orientation of the folds is NW.

5.3. Deformation Structures of the Ulukışla Basin

Ulukışla Basin deposits are located at the northern boundary of Bolkardağı and Bozkır Units. The sequence in the basin includes Kalkankaya, Halkapınar, Delimahmutlu, Aktoprak Formations and Quaternary deposits. During our field studies, it was revealed that the units deposited in the Ulukışla Basin from basin deposits were mostly represented by asymmetric and overturned folds according to the position of the axial planes and fold limbs.

Considering Fleuty (1964)'s fold classification, the angular relations among the fold limbs indicate open fold development of the Ulukışla Basin units. The bedding measurements reveal that the beds strike NE - SW, dip NW or SE and strike NW - SE, and dip NE indicating two fold axes. Analysis of these measurements gives the position of the first fold axis as N63°D, 2°, the axis plane of the first folding that occurred was determined as N27°W, 88°NE, the state of the second axis as N13°W, 2°, and the axis plane as N77°E, 88°SW (Figure 9a). The data obtained from the bedding measurements reveal that the folds in the Ulukışla Basin units outcropping in the study area are semi perpendicular to perpendicular axis planes, low plunging fold axis as fold geometry.

The dominant orientation of the joints formed in the Ulukışla Basin units is N77°E (Figure 9b).

In the study area, there are reverse faults affecting the Ulukışla Basin deposits. In some parts of the reverse fault planes the slip lineaments are evident. Figure 9c shows the distribution of measurements taken from the reverse faults on the equal - area

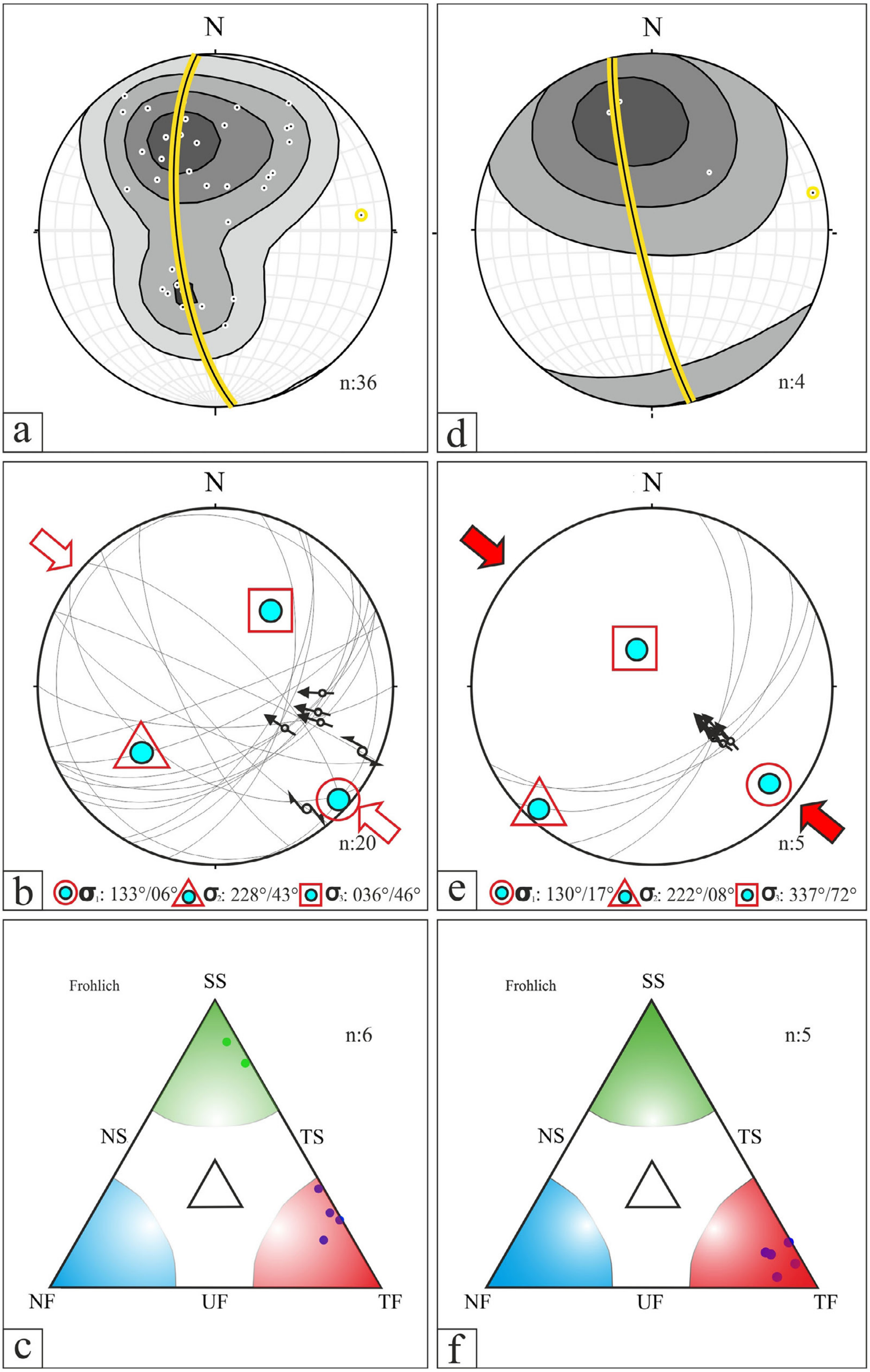

Figure 8- Point-contour diagram showing the reverse fault planes and compression directions and the Froclich diagram displaying the characteristics of the faults of units of the Bozkır Unit in the study area (a, b, c), and the ophiolites in the Karagöl location (d, e, f) (SF: Strike-slip fault, NF: Normal fault, RF: Reverse fault).

net. The Froclich diagram shows that the faults are concentrated in the reverse fault zone (Figure 9d). The paleostress analysis of the planes in which the shear lineaments are characteristic reveal the position of the main paleostress axes (σ1, σ2, σ3) forming the faulting (Figure 9c). As can be seen in Table 1, the largest (σ1) and intermediate main paleostress (σ2) axes forming the faults that affect the Ulukışla Basin lithologies are horizontal, and the smallest main paleostress (σ3) axis is close to the vertical. The ratios of R and R' obtained from the analysis are 0.34 and 2.34, respectively. When all the data are evaluated together, the reverse faulting that affect the Ulukışla Basin indicates a pure compressive tectonic regime (Table 1).

There are closed folds close to the border of Bolkardağı Unit (Figure 10c). The foliations were formed as dipping to the southeast. The reverse faults

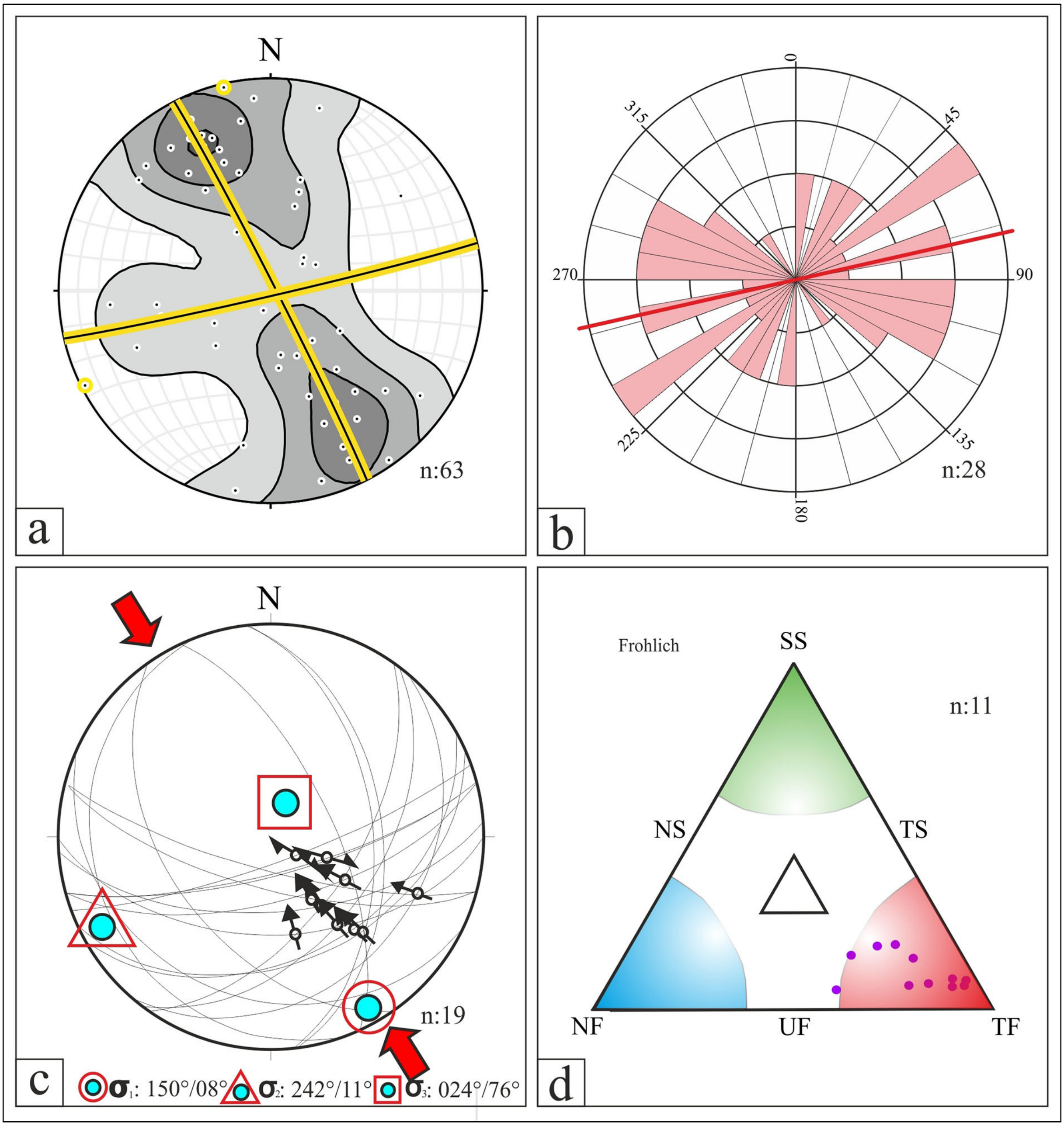

Figure 9- a) Point contour diagram of the bedding planes, b) rose diagram showing joint lineations, c) diagram showing the reverse fault planes and direction of compressions, d) Froclich diagram showing the characteristics of faults of units belonging to the Ulukışla Basin in the study area (SF: strike-slip , NF: Normal fault, RF: Reverse fault).

also dip accordingly to the southeast and the whole sequence is located in NW direction, indicating a thrust from SE to NW.

Demirtaşlı et al. (1986) state that the Bolkar group thrusts over the units of Ereğli - Ulukışla Basin from south to north along the Bolkar thrust. In east of the Horoz Village, they also state that the Bolkar group is thrusted over the Kalkankaya formation from south to north. The researchers claim that the Bolkar Group formations thrusted over the Upper Cretaceous - Paleocene sediments of the Ereğli - Ulukışla Basin along the Bolkar thrust in the late Paleocene - early Eocene from south to north. During the Oligocene and Miocene period, the Ereğli - Ulukışla Basin was completely closed, and the lacustrine limestones and marls (Kurtulmuş Tepe member of the Aktoprak formation) were deposited in local and small - scale lakes that replaced the retreated sea (Demirtaşlı et al., 1986).

Gürer et al. (2016*a*) stated that the Ulukışla Basin and Bolkardağı Unit were under a compression in NW - SE direction in their studies on deformation of the Ulukışla Basin. They claimed that due to this compression effect, the Ulukışla Basin thrusted towards the Bolkardağı Unit from northwest to southeast. Afterwards, they also stated that the Bolkardağı Unit back - thrusted the Ulukışla Basin which overlian it. They emphasized that due to this movement, the Cretaceous - Paleogene strata gained a subvertical slope and attributed this interpretation to Blumenthal (1956) and Demirtaşlı et al. (1973). Blumenthal (1956) and Demirtaşlı et al. (1973) stated that the Bolkardağı Unit thrusted over the Ulukışla Basin, but they did not make any comments on the fact that this thrust was a back thrust.

The contact of the Bolkardağı Unit with the Delimahmutlu formation just in the west of Karagöl is a reverse fault that moved from southeast to northwest. All of the folds and reverse faults in the internal structure of the Bolkardağı Unit also orient NW. Except for the Quaternary units, the Ulukışla Basin deposits also contain folds in NW direction.

Gürer et al. (2016*a*) indicate that there are southward orienting faults showing the movement from north to south on the slope in the north of Karagöl. The researchers who attribute the southward movement of the Ulukışla Basin to these faults state that this is the result of compression in NW - SE direction. However, these faults do not exist in the mentioned outcrop. The discontinuities shown as faults in the study are the boundary of Quaternary conglomerates (Figure 5i) and terraces deposited on the Delimahmutlu formation.

Since the discontinuity planes show movement from southeast to northwest, the thrust of the Bolkardağı Unit towards northwest over the Ulukışla Basin is a thrust but not a back thrust. That is, not the secondary but the primary movement of the unit is towards NW.

5.4. The Contact Relationship of the Central Taurides with the Ulukışla Basin

Numerous structural data on the boundaries of Bozkır, Bolkardağı units and the Ulukışla Basin were collected and analyzed in the study area and its vicinity. When structural analysis and field data were evaluated together, it was determined that the Bolkardağı Unit overthrust the Alihoca Ophiolite and melange with tectonic contacts along the boundary with Bozkır Unit.

As continental parts, which contain tectonic units outcropping in the Taurides, plunged under the Anatolian microcontinent towards the north, it was considered that the oceanic plate settled on top of these units and remained in this position. As stated in previous studies, the Bolkardağı Unit is in the form of a northward - overturned asymmetric anticline (Blumenthal, 1956). In addition, the unit is heavily folded in itself. Özgül (1976) showed the Bozkır Unit as overlying the other units in his studies in the Taurides, and following studies. Dilek and Whitney (1997) stated that the Kızıltepe Ophiolite overthrusts the Bolkardağı Unit in their studies in the region. In this study carried out in the region, it was seen that the Alihoca and Kızıltepe Ophiolites were found as clips not above the Bolkardağı Unit, but below the unit as a tectonic contact. The data regarding this contact relationship are explained in detail in the structural geology section. The ophiolites overthrusts the Bolkardağı Unit at the time of the closure of the ocean are below the Bolkardağı Unit today, after the closure of ocean. In the maps of studies carried out in the Ulukışla Basin (Clark and Robertson, 2002; Demirtaşlı et al., 1986; Robertson et al., 2009; Alan et

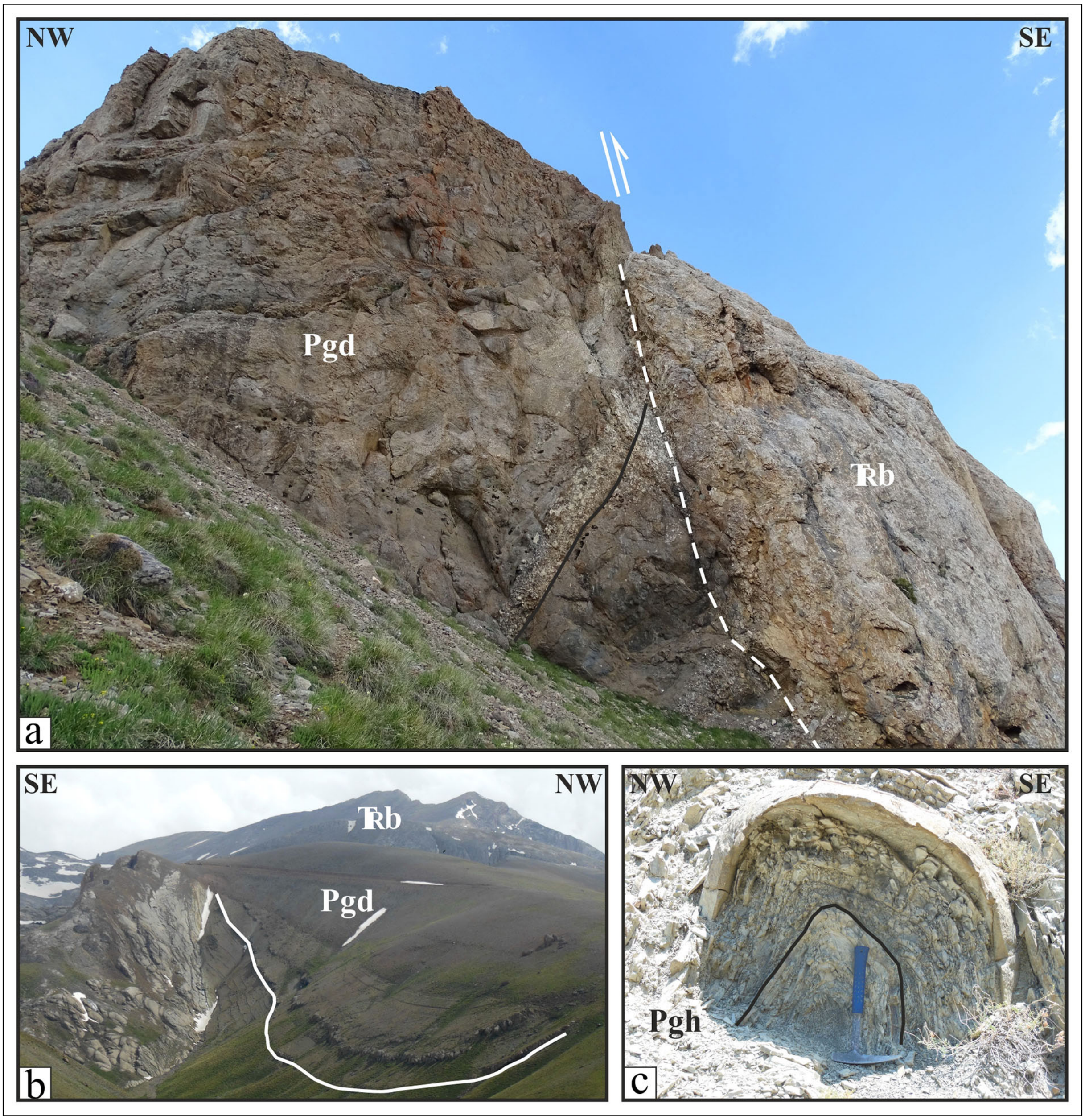

Figure 10- Deformations formed in units in the study area: a) unconformity and reverse fault inclined between the Delimahmutlu formation and Berendi limestone, b) megascopic syncline in the Delimahmutlu formation, c) narrow folds in the Delimahmutlu formation.

al., 2011), the Bolkardağı unit thrusts over it towards the northwest within itself.

Alihoca ophiolite and mélange belonging to the Bozkır Unit overlies the Ulukışla Basin units with a thrust towards the northwest. The units within the Ulukışla Basin are also seen as folded in accordance with this direction.

Gürer et al. (2016*a*), on the other hand, state that the ophiolites shifted backward, (ie. towards the north) after overthrusting the Bolkardağı Unit. However, the ophiolites are thrusted by the Bolkardağı Unit towards the northwest. Zorlu et al. (2011) evaluated the Late Cretaceous - late Paleocene period as the extensional phase and the late Paleocene - early Eocene period as the compressional phase in their studies on the geological evolution of Ulukışla Basin.

The Karagöl location in the south of Darboğaz Village is a location where the contact relationship of Bolkardağı Unit marbles, Alihoca Ophiolite and the Ulukışla Basin deposits can be clearly seen.

The reverse fault plane in northeast of the Karagöl locality, which cuts the Late Triassic marbles and pushes them onto the ophiolitic slice, strikes N89°E and dips 40°SE. The reverse fault in marbles on the western edge of Çiniligöl also strikes N55°W and dips 53°SW. Another reverse fault plane located between the Karagöl and Çiniligöl strikes N55°E and dips 58°SE. Bolkardağı marbles meet the basal conglomerates of the Delimahmutlu formation with a reverse fault plane which strikes N25°E and dips 75°SE just in north of Karagöl.

Another reverse fault, which cuts the marbles in Karagöl, strikes N73°W and dips 80°SW. The main vector of the polar points of the reverse faults cutting the unit is 349.4°/34.4°. The main strike of the reverse fault planes is N79.4°E and the dip direction is 55.6°SE. The reverse fault plane cutting the northern slope of Bolkar Mountains located in the west of Karagöl strikes N60°E and dips 77°SE. The fold axis plane of the megascopic scale recumbent anticline on the hanging block of this fault plane is also N60°E in direction, dips 34°SE. These reverse faults in and around Karagöl caused the unit to propagate, to be folded and get shorten from southeast to northwest.

The foliation found in marbles in contact with the Delimahmutlu formation in the north of Karagöl, on the other hand, strikes N55°E and dips 58°SE. These planes also show that the sequence remain under the effect of stress from southeast to northwest.

The conglomerates at the bottom of the Delimahmutlu formation, which face with marbles of the Bolkardağı Unit close to vertical strikes N35°E and dips 75°NW (Figure 10a). The bedding of the sandstone layers forming the deltaic sequence towards the top of the sequence turns to N75°W/78°NE. One of the reasons for this change in the direction of the beds is the thrust of Bolkardağı Unit over the Paleogene sequence while the deposition continues and the sequence to be folded during the "fault propagation deformation" process. The other reason is that the Paleogene sequence to consist of fan delta deposits and the charging channels to change direction to fill different depositional areas during the formation of these deposits.

Quaternary pebbles in the study area have a distinctive unconformable contact relationship with underlying delta deposits. The incised valley deposits with distinctive contact, which contain the pebbles of all units in the region were deposited in the Delimahmutlu formation. Due to the rapid uplift of the region, the section, which was a depositional area for the Delimahmutlu formation a while ago then turned into an erosional area. During this erosion, the incised valleys were formed in the formation and the pebbles, which fed by the lithologies in the source area formed the incised valley sediments, were deposited. The bottom contact of the incised valley deposits is eroded due to the sudden uplift and has a ditinctive unconformable contact. Gürer et al (2016*a*), who worked around Karagöl, stated that there was a fault at the contact between the Delimahmutlu formation and the overlying Quaternary incised valley deposits. They stated that the incised valley deposits thrusted over the Delimahmutlu formation deposits dipping towards north and moving from north to south.

At the aforementioned point, there is no deformation structure in the Quaternary deposits that can be formed by compression. There are no reverse faults thrusting from north to south within or in the north of delta deposits of the Late Ipressian Delimahmutlu formation.

The Delimahmutlu formation unconformably overlies the Bolkardağı Unit and the Alihoca Ophiolite with its basal conglomerate. The Bolkardağı Unit was subjected to NW - oriented folds due to the NW - SE compression effective in the region and propagated to the northwest by NE - SW trending and SE dipping reverse faults. Due to this propagation, the contact of the Delimahmutlu formation with the unit was inclined towards the northwest and became steep, and the sequence was folded to form a syncline in megascopic scale (Figure 10b). In all units, except for the Quaternary incised valley deposits and terraces in this location, NW - SE trending fold axis planes (Figure 10c) and reverse faults subjected to NW - SE compression were formed. These reverse faults have moved all the units in the region in NW direction. When structural data in the whole study area are examined together, it is seen that they are conformable with the data around Karagöl.

The units in the whole study area was deformed due to NW - SE compression in a way to contain NE - SW striking, NW orienting, SE dipping layer and discontinuity planes. In other words, the allochthonous rocks and basin deposits in the region was thrusted from southeast to northwest.

6. Geological Evolution

Stratigraphic, paleontological, structural and petrographical data were obtained through field and laboratory studies carried out in and around the study area. There are many previous studies on Bozkır and Bolkardağı Units and the Ulukışla Basin (Blumenthal, 1956; Demirtaşlı et al., 1984, 1986; Clark and Robertson, 2002, 2005). In these studies, especially the stratigraphic, sedimentological and metamorphic features in some units have been revealed in different details. In order to interpret data obtained together with the findings of previous study for the study area and its immediate surroundings the following geological evolution was proposed (Figure 11).

6.1. Late Cretaceous Period

6.1.1. Turonian Period (Subduction)

Before Turonian period, the Inner Tauride Ocean has existed between the Anatolia and the Tauride Mountains (Çalapkulu, 1978; Şengör and Yılmaz, 1981; Oktay, 1982; Demirtaşlı et al., 1984; Özgül, 1984; Okay, 1985; Şengör, 1987; Şengör et al., 1988; Dilek and Moores, 1990; Koçyiğit, 1990; Robertson et al., 1996; Dilek and Whitney, 1997; Whitney and Dilek, 1997; Görür et al., 1998; Dilek et al., 1999b; Okay and Tüysüz, 1999; Robertson, 2000; Kadıoğlu et al., 2003, 2006; Rimmele, 2003; Garfunkel, 2004; Parlak and Robertson, 2004; Dilek, 2006; Parlak et al., 2006; Işık et al., 2008; Mackintosh and Robertson, 2009; Gans et al., 2009; Kadıoğlu and Dilek, 2009; Robertson and Parlak, 2009; Pourteau et al., 2010; Pourteau, 2011; Koç et al., 2012; Jolivet et al., 2013; Warren et al., 2013; Esirtgen, 2014).

In the subduction zone formed in this ocean, the subduction processes started in the Turonian period (Okay et al., 2001). Studies related to the beginning of subduction are generally the studies related to petrography, mapping and dating of ophiolites. In these studies, it is stated that the Bozkır Unit, which contains ophiolites, overlain the Tauride platform from north to south as the ocean has begun to subduct northward during the closure process. This ocean, in some studies (Göncüoğlu, 1986; Göncüoğlu et al., 1992, 1997; Alan et al., 2007) is referred to as the northern branch of Neotethys (İzmir - Ankara - Erzincan Ocean) and in some studies (Özgül, 1976; Şengör et al., 1980; Şengör and Yılmaz, 1981; Koçyiğit, 1983; Demirtaşlı et al., 1984; Görür et al., 1984; Robertson and Dixon, 1984; Okay, 1985; Dilek and Moores, 1990; Dilek and Tekeli, 1992; Parlak et al., 1996; Robertson, 1998; Pourteau et al., 2010) as the Inner Tauride Ocean. In studies related to the basic units in the Tauride Mountains, it is stated that Bolkardağı and Aladağ Units also overlain the Geyikdağı Unit from north to south (Özgül, 1976; Ulu, 2006; Alan et al., 2007).

The subduction in the Neotethys Ocean started in the Turonian period 92 - 90 Ma years ago (Dilek and Whitney, 1997). The oceanic plate during this subduction process started to overlie the carbonate platform forming the Taurides (Figure 11a). Kızıltepe Ophiolite, Alihoca Ophiolite and melange, which are parts of this plate, are found as tectonic clips on the Bolkar Mountains according to this study. Dilek et al. (1999*a*), who emphasized that the Alihoca's ophiolite was very close to trench, states that the ages obtained from basement metamorphics or plagiogranites related to the time of formation of ophiolites range from 89 - 94 Ma (Dilek et al., 1999*a*; Parlak and Delaloye, 1999; Önen and Hall, 2000; Çelik et al., 2006, 2011; Van Hinsbergen et al., 2016). Robertson et al. (2009) stated that the subduction in the Inner Tauride Ocean had occurred between 95 - 85 ma, (Cenomanian - Santonian) in their studies investigating the ophiolites and mélange related to the northern boundary of the Tauride - Anatolide continent. Sarıfakıoğlu et al. (2012) stated that subduction in the Inner Tauride Ocean started in the Late Cretaceous, and that the Central Anatolian Crystalline Complex collided with the Tauride platform in Eocene.

6.1.2. Coniacian - Campanian Period (Metamorphism)

Towards the end of the Mesozoic period, the Bolkar platform and oceanic plate have subducted below the overlying oceanic plate due to the oceanic subduction and undergone regional metamorphism (Figure 11b). There are various studies about the stratigraphic position and the age of settlement of the Alihoca Ophiolite and melange, which was emplaced on the Bolkardağı Unit after subduction and metamorphism. Çevikbaş (1991), in his study in the Ulukışla - Çamardı Basin, stated that the Bolkar group had been subjected to metamorphism before

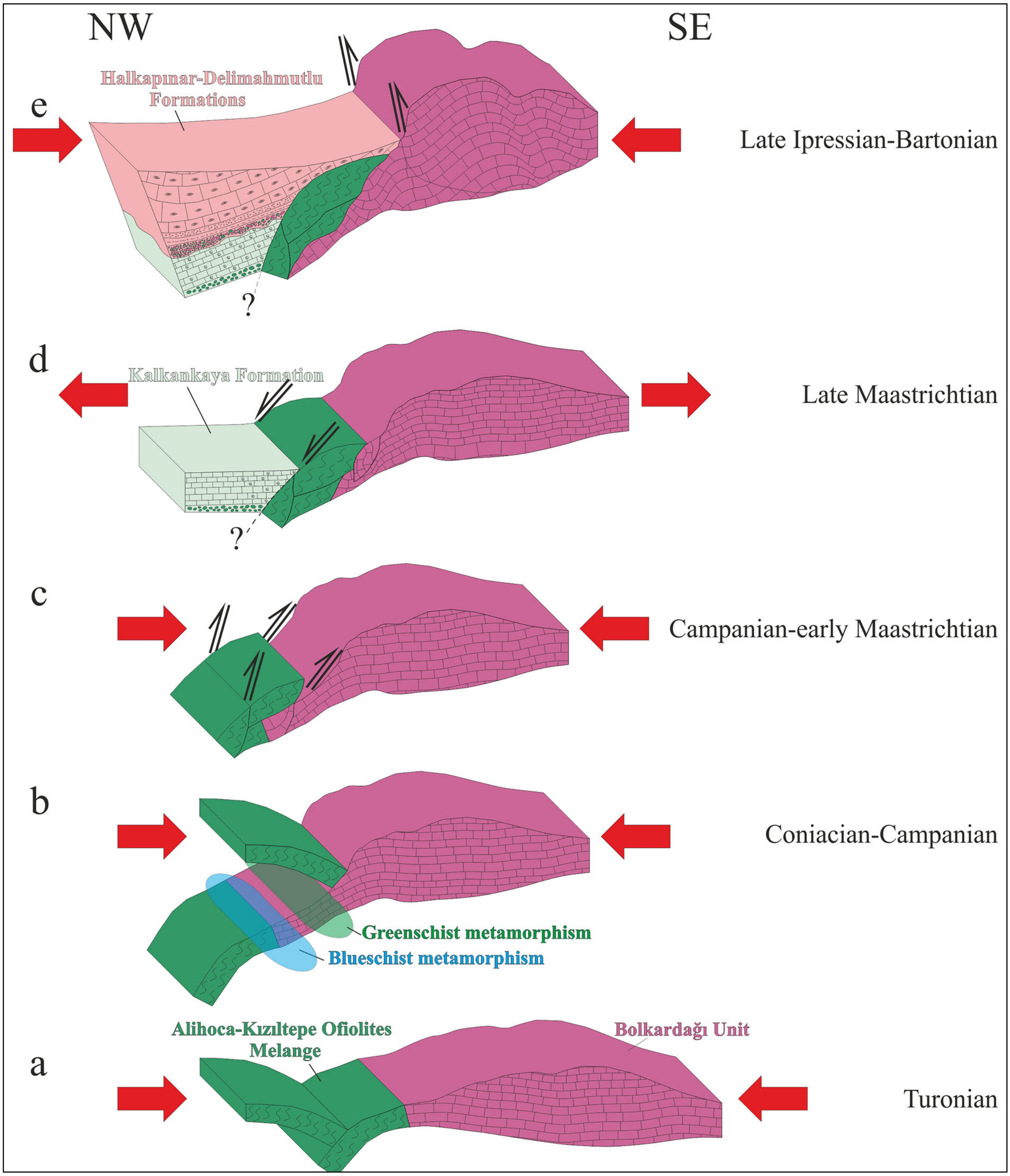

Figure 11- Tectonic development of the Bozkır Unit, Bolkardağı Unit and the Ulukışla Basin deposits over time.

the late Maastrichtian, and the Alihoca Ophiolitic Complex and Madenköy Ophiolite Melange probably had exhumed during this period, and interpreted the terrestrialization as the beginning of collision of the Bolkardağı Unit with the Niğde continental crusts. In their work on the exhumation of Niğde complex, Whitney and Dilek (1997) stated that the basement unit and ophiolites in the Bolkar Mountains region contained lithologies in the blueschist facies. They emphasized that this situation indicates the subduction of the northern edge of the Taurus carbonate platform partially beneath the Central Anatolian Crystalline Complex. The northern part of the Anatolide - Tauride continent has undergone HP - LT metamorphism according to the studies of Candan et al. (2005) and Pourteau et al. (2010, 2013). In the studies of Okay and Tüysüz (1999), Ulu (2006) and Van Hinsbergen et al. (2016), it was stated that there occured low grade metamorphism in the Taurus Mountains and the age of metamorphism became younger as moving from north to south. The sediments of the Bolkardağı Unit have been subjected to HP - LT metamorphism in many places. This metamorphism is described by Candan et al. (2005) and Pourteau et al. (2010, 2014) as 6 - 9 kbar and ~350°C, and by Rimmelé et al. (2005) as 13 - 14 kbar, and ~400°C. In his work on the metamorphism of the Bolkardağı Unit, Parlak et al. (2014) stated that during the collision of the submerged trench and the passive margin, the Taurus microcontinent had been deeply submerged and metamorphism under HP - LT conditions and these rocks had been exposed in the Maastrichtian. Gürer et al. (2016*b*) stated that the Taurus passive continental margin had propagated towards the subduction zone in the north in Cretaceous - Paleocene period at the latest and had been subjected to HP - LT metamorphism.

During the subduction process, Bolkardağı Unit and Alihoca Ophiolite has undergone metamorphism in greenschist and blueschist facies due to the different metamorphism conditions. The metamorphism of the Bolkardağı Unit is a regional metamorphism that occurred approximately 80 my ago in subduction processes (Robertson et al., 2009). While the northernmost parts of the Bolkardağı Unit submerged very deep with ophiolites and exposed to HP - LT conditions, the southern parts was subjected to metamorphism in the greenschist facies. The Bolkardağı Unit, which was risen later, had been overlain by the Alihoca Ophiolite.

During the field studies, the lithologies showing different metamorphic facies were determined in thin section studies of mineralogical - petrographic samples taken from Bozkır and Bolkardağı units. Considering the results of the petrographic examination, the carbonates in the Bolkardağı Unit and the ophiolitic rocks belonging to the Bozkır Unit have undergone metamorphism under varying depth and temperature conditions from greenschist to blueschist facies.

At the basement of the region there is a sequence belonging to the Bolkardağı Unit representing the northernmost end of the Tauride platform. This basement has submerged under the northern oceanic lithosphere together with ophiolites related to the subduction in the Inner Tauride Ocean and undergone different degrees of metamorphism in the greenschist - blueschist facies. Considering these data, the age of metamorphism of the Bolkardağı Unit must be Coniacian - Campanian, the time interval after the subduction in Turonian but before the early Maastrichtian when it turned into a land.

6.1.3. Campanian - early Maastrichtian Period (Exhumation - Ophiolite Obduction)

The submerged lithosphere during the closure process of the Inner Tauride Ocean has been ruptured between 76 - 67 Ma, (Parlak et al., 2013*a*). The Bolkardağı Unit and ophiolites, which had been undergone metamorphism due to the subduction, was exhumed rapidly after rupture. Therefore, the micrites with globotruncana unconformably overly all the units in the Bolkardağı Unit sequence (Özgül, 1997). After this exhumation, the Alihoca Ophiolite - melange and Kızıltepe Ophiolite have overlain the Bolkardağı Unit due to the continuation of the closure process (Figure 11c).

There are many opinions about ophiolite obduction. The Bolkar group had been exposed before the late Maastrichtian by Çevikbaş (1991) and in the early Maastrichtian by Çevikbaş and Öztunalı (1992). According to Özgül (1997), the Bozkır Unit overlain the Bolkardağı Unit in the late Senonian. Dilek et al. (1999*b*) stated in their studies in the Tauride Mountains that the ophiolites in the Paleocene had overlain the carbonate platform during the closure process in the Inner Taurus Ocean. Jaffey and Robertson (2005) mentioned that ophiolitic rocks settled southward on the Bolkar platform in the Late Cretaceous period. Robertson et al. (2009) admit that this settlement of the melange occurred in the Santonian - Maastrichtian period 85 - 65 ma ago.

The metamorphism of the unit took place in the Coniacian - Campanian period. The basement age of the Kalkankaya formation, which is the first unit to be deposited on ophiolites in the study area, is the late Maastrichtian. The formation is underlain by ophiolites and metamorphics belonging to the Bolkardağı Unit.

Before the deposition of the unit, the ophiolites have overlain and settled on the Bolkardağı Unit.

Considering this stratigraphic data, the Bolkardağı Unit must have been exposed in Campanian - early Maastrichtian period and overlain by ophiolites.

6.1.4. Late Maastrichtian Period (Deposition)

After the settlement of the Alihoca Ophiolite on the Bolkardağı Unit, Seyitoğlu et al. (2017) mentioned in his works in the region, that there was material inflow from Bolkardağı and Bozkır units to the basin with the activity of the main fault. The first unit deposited in the basin is the Kalkankaya formation defined by Blumenthal (1956). Before the deposition of the formation, the region was a continent in the early Maastrichtian (Çevikbaş and Öztunalı, 1992). The Kalkankaya formation, which forms the previous deposits of the Ulukışla Basin, overlies the Bolkardağı marbles and the Alihoca Ophiolite with an angular unconformity. The deposition of formation starts with red colored, mostly ophiolitic pebbles at the bottom. Limestones in the upper parts contain abundant loftusia and rudist.

The Kalkankaya formation, which contains the oldest sediments of the Ulukışla Basin, is of late Maastrichtian - early Paleocene age (Çevikbaş and Öztunalı, 1992).

Gürer et al. (2014), in their studies on the Ulukışla Basin, stated that the sediments had been deposited in the basin between the Central Anatolian Crystalline Complex and the Taurides during the Late Cretaceous - Paleocene period due to the activity of E - W trending listric faults. Gürer et al. (2016*a*), in their study on the deformation of the Ulukışla Basin, also emphasized that the basin had been subjected to N - S and E - W extensions up to 56 my, during latest Cretaceous - Paleocene period. They stated that the N - S directing extensions in Campanian - Maastrichtian were E - W in Paleocene. Seyitoğlu et al. (2017) defined the İvriz fault on the border of the Ulukışla Basin and the Bolkar group. They stated that this fault was a high angle detachment fault in the Late Cretaceous - Paleocene, but later transformed into a low angle normal fault and played an important role in the exhumation of the Central Anatolian Crystalline Complex.

Following the metamorphism, the Bolkardağı Unit was overthrusted by ophiolites, uplifted relative to the basin and formed a feeding area for the basin. During the Late Maastrichtian - early Paleocene period, the limestones of the Kalkankaya formation have been deposited in the depositional area located to the north of the Bolkardağı Unit and the Alihoca Ophiolite (Figure 11d). The Maastrichtian age was dated from the determination of samples taken from the Kalkankaya formation in the study area for paleontological purposes. Paleontological data show that the formation was deposited in Maastrichtian and that the basin had a shallow sea and transitional environment.

6.2. Early - Middle Eocene Period

6.2.1. Late Ipressian - Bartonian Period (Deposition and Compression)

Demirtaşlı et al. (1984) noted that the Bolkar thrust affected the Eocene deposits in the Ulukışla Basin and formed narrow - closed folds in their studies on the geology of the Bolkar Mountains. Since the Oligocene deposits unconformably overlie the boundary they accept the age of thrust as Eocene for the Bolkar Mountains. Dilek et al. (1999*b*) stated that the ophiolites shifted northward over the Bolkar Mountains in Eocene, and that the Bolkar Mountains rose vertically in the Oligo - Miocene relative to the Ulukışla Basin. Alan et al. (2007) stated that the nappe movements had continued during the Late Cretaceous - Eocene period in their work on the main units in the Central Taurides. Robertson et al. (2009) mentioned that the continental collision and crustal thickening phases occurred in the approaching phase between Lutetian and Bartonian. Engin (2013), in his study on the tectonic evolution of the Ulukışla Basin, mentioned that the opening in the region should have started in the middle Eocene after the continental collision and detachment of submerged plate. Gürer et al. (2014), stated that the Ulukışla Basin deposits were folded due to N - S compression in the post - Paleocene. Gürer et al. (2014) also emphasized that the Tauride fault - fold belt was south oriented and accepted a tectonic line cutting the Tauride belt as a back thrust. The researchers stated that this thrust propagated northward compressing the region. In their studies on the Ulukışla Basin, Gürer et al. (2016*a*) stated that there had been a short period of tectonic stagnation after the Late Cretaceous - Paleocene stress, and N - S orienting compression forming the fold structure of Bolkar Mountains between 49 - 20 Ma had also affected the Ulukışla Basin. They stated that Eocene sequence in the Karagöl region was affected by a south orienting thrust. Gürer et al. (2017) argue that in the Ulukışla Basin normal faults with strikes of E - W due to N - S compression since Lutetian were formed, and the region was folded.

The effects of compression in the region are seen as folding, development of reverse faults and vertical uplift. On the northern border of the Bolkardağı Unit, several folds and reverse faults are observed in the Ulukışla Basin deposits. The axes of the folds are asymmetrical and overturned. The angle between the fold limbs is mostly narrow and sometimes folds are seen as in closed fold geometry.

When folding caused by the compression of the region could not compensate the amount of compression, ESE - WNW trending SE dipping and N - NW oriented reverse faults developed in all units in the region and at the contacts of the units. The Bolkardağı Unit in this period overthrusted the overlying Alihoca Ophiolite with NW trending SE dipping reverse faults. Regional uplift also occurred as a result of folding and faulting. This uplift shows itself with the entrance of materials varying from blocks in few decimeters to silt - clay size into the Ulukışla Basin. During Thanetian - Lutetian period, the Halkapınar and Delimahmutlu Formations have been formed by the material entrance into the basin from Bolkardağı and the Bozkır Unit, which is the source area (Figure 11e). The Halkapınar formation located in the near west of the study area is the first product of this deposition. The fact that the thickness of the formation is between 1.000 - 2.000 m, contains deep sea sediments and debris flow deposits show that the basin deepens with the periodic activity of faults and that the continuous sedimentation takes place according to the source area. The deep sea sediments of the Halkapınar formation are seen below the conglomerates of the Delimahmutlu formation. The facies of the Halkapınar formation represents all the environments ranging from basin margin to the deep sea. The unit is Thanetian - Lutetian in age (Alan et al., 2007).

The thrust of the Bolkardağı Unit over the basin and the uplift caused the basin margin to rise and the deposition of the Delimahmutlu formation consisting of abundant nummulitic fan delta deposits in a shallow marine environment. In studies carried out in the region, Alan et al. (2007) state that the Delimahmutlu formation is Lutetian - Bartonian in age. During the studies, the late Ipressian age was obtained from the benthic foraminifera in samples taken from the contact of Bolkardağı marbles of the Delimahmutlu formation, and the middle Eocene age was taken from the areas at 800 m north of the same sequence at elevation of 100 m lower of the sequence.

Delimahmutlu formation was unconformably deposited on the Bolkardağı Unit marbles. The unit, which overlies the marbles with conglomerates, was inclined and folded with the effect of compression and vertical uplift. Both the structural and sedimantological data such as debris flows and brecciated levels in deltaic sequence show that the region continues to compress and the Bolkardağı Unit continues to rise, thrusts over the basin and deforms the units, and that the fault propagation folds develop. It is accepted that all the structural elements in the Bolkardağı Unit in the Central Taurides from north to south are south oriented in accordance with the ophiolite obduction. However, it was observed that the orientation of the structural elements in all units in the region were towards NW in field studies. In other words, the units contain structural elements that show movement from southeast to northwest, but not from north to south.

Gürer et al. (2016*a*) interpreted the faults at the contact of the Bolkardağı Unit and the Ulukışla Basin as folded or reversed normal faults. However, the faults at this contact are reverse faults. The orientation of fold axes within the Bolkardağı Unit and Ulukışla Basin deposits is towards NW and NE. The foliation planes strike ENE - WSW and dip SE. The faults in the region are of reverse fault character. The fault planes mostly strike NE - SW and dip SE.

All these structural elements clearly show that the region was thrusted from southeast to northwest in NW direction on planes striking NE - SW, dipping SE as a result of compression in NW - SE direction.

In the Early - Middle Eocene period, the Halkapınar and Delimahmutlu formation were unconformably deposited on the Bolkardağı Unit in the depositional area in the north of the Bolkardağı Unit. During the deposition of the Delimahmutlu formation, the unit was affected by regional tectonics and deformed together with the Halkapınar formation. These deformation products are seen as bending, folding and reverse faulting in the units. Işık et al. (2014), in their studies on the Savcılı fault zone, stated that faulting occurred at approximately 40 my and 23 my by Rb - Sr analysis, and the region had been compressed during this period. This compression to be observed in the area in the same period also supports this study.

7. Results

By evaluating stratigraphic, petrographic and structural data in this study, the following results were obtained:

1. In the study area, the oceanic lithosphere and the northern part of the Tauride belt have been subducted into different depths during the sub - oceanic subduction processes. The ophiolites belonging to the pre Campanian Bozkır Unit and the Bolkardağı Unit have undergone metamorphism in the greenschist and blueschist facies.

2. The ophiolites belonging to the Bozkır Unit have overthrust the Bolkardağı Unit during the Campanian - early Maastrichtian period.

3. The extensional regime effective in the region in the Late Maastrichtian - Bartonian period have enabled the Ulukışla Basin units to be deposited unconformably on the basin units in shallow and gradually deepening environments.

4. Starting from the Late Ipressian, the region began to be recompressed; the basement and basin units have been subjected to deformation. The structures developed in connection with this event revealed that the Bolkardağı Unit overthrusted the Alihoca Ophiolite / Mélange representing the Bozkır Unit, Kızıltepe Ophiolite and Ulukışla Basin deposits with reverse / thrust faults from southeast to northwest.

5. The initial unconformable contact between the Ulukışla Basin deposits and the Bolkardağı Unit was thrusted over the Ulukışla Basin of the Bolkardağı Unit, and then it turned into a 70° - 80° reverse fault in the study area. This structural development in the region was interpreted as the product of a movement from southeast to northwest.

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