



# The Stratigraphic and Petrographic Characteristics of Metamorphites of Alanya Unit, and the Porphyroblast - Foliation Relationships in Sugözü Complex (Middle Nappe), Anamur-Mersin-Turkey\*

Gürsel Kansun<sup>1†</sup>, Kerim Koçak<sup>2</sup>, Ahmad Omid Afzali<sup>3</sup>, Alican Öztürk<sup>4</sup>, Arif Delikan<sup>5</sup>, Selma Delikan<sup>6</sup>, Fuat Işık<sup>7</sup>

<sup>1</sup> Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geology Engineering, Konya, Turkey (ORCID: 0000-0002-4581-6076)

<sup>2</sup> Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geology Engineering, Konya, Turkey

<sup>3</sup> Afghanistan Academy of Sciences, Department of Geosciences, Kabul, Afghanistan

<sup>4</sup> Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geology Engineering, Konya, Turkey

<sup>5</sup> Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geology Engineering, Konya, Turkey

<sup>6</sup> Enerya Konya Gas Distribution Anonymous Company, Konya, Turkey

<sup>7</sup> Konya Governorate, Administration and Audit Directorate, Konya, Turkey

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## Abstract

The study area is located in the southern part of the Central Taurus in Anamur (Mersin) vicinity. The Alanya Unit consisting of completely metamorphites consists of threeimbricate metamorphic nappes. Lower-Middle Cambrian aged the Mahmutlar group (lower nappe) is composed of widespread mica schists containing crystallized limestone, cherty dolomite, quartzite interlevels and greenschist lenses. Precambrian aged Sugözü complex (middle nappe) contains kyanite-sillimanite-staurolite mica schists and widespread garnet-mica schists, which contain greenschist-amphibolite-amphibol schist bands-lenses and metagabro-metadiabase dykes-interlevels. In the middle nappe, Cambrian and Permian blocks belonging to Alanya Unit are observed. The Yumrudağ group (upper nappe) begins with Lower-Middle Cambrian aged mica schists containing cherty dolomite, crystallized limestone, quartzite interlevels and greenschist lenses. Higher up with an unconformity pass into the Upper Permian aged alternation of quartz schist - calc schist - crystallized limestone - phyllite and thick bituminous crystallized limestone containing greenschist lenses. Barite, copper and galenite formations take place in upper nappe lithologies (Ağzıkara formation). Upper Paleocene - Middle Eocene aged Kötekler formation unconformably overlies the Alanya Unit.

Alanya Unit has been subjected to multi-stage deformations in connection with intense tectonic movements. Especially, *biotite* (brown, green) + *muscovite* + *garnet* (prop-*almandine-grossular*) + *quartz* ± *chlorite* (*ripidolite-picnochlore*, *pennin-clinoclone*) ± *kyanite* ± *staurolite* ± *sillimanite* + *plagioclase* (*albite-oligoclase-andesine*) ± *epidote* ± *zoisite/clinozoisite* ± *orthoclase* + *tourmaline* (green, brown) ± *graphite* ± *sphene* ± *rutile* ± *apatite* mineral paragenesis are observed in metapelitic and metasemipelitic rocks belonging to Sugözü complex (middle nappe). Amphibolites and amphibole schists of this complex contain *hornblende* (*tchermacite*, *ferro-tchermacite*, *magnesian-hornblende* and *edenite*) + *garnet* + *plagioclase* (*albite-oligoclase-andesine*) ± *relic clinopyroxene* (*augite-pigeonite*) + *chlorite* (*ripidolite*, *clinoclone*) ± *orthoclase* ± *epidote* ± *zoisite/clinozoisite* ± *biotite* (green, brown) ± *actinolite* ± *muscovite* ± *quartz* ± *calcite* ± *sphene* ± *apatite* ± *rutile* mineral assemblage. *Hornblende* (*tchermacite*, *ferro-tchermacite*) ± *plagioclase* (*albite-oligoclase-andesine*) + *relic clinopyroxene* (*augite*) ± *garnet* + *quartz* + *chlorite* (*ripidolite*, *pennin-clinoclone*) ±

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

*actinolite* ± *zoisite/clinozoisite* ± *epidote* ± *calcite* ± *sphene* ± *apatite* is observed in metagabbros and metadiabases. The greenschists are characterized by *tremolite* + *actinolite* + *chlorite* (*ripidolite-picnochlorite*) + *plagioclase* (*albite*) ± *garnet* + *zoisite / clinozoisite* + *epidote* ± *quartz* ± *microcline* ± *relic clinopyroxene* (*augite*) ± *calcite* + *sphene* ± *apatite* mineral assemblage. Especially when the index minerals, different mineral paragenesis and deformation-metamorphism relations within the Sugözü complex take into account, it has been seen that Alanya unity underwent three phases of metamorphism which follow one another.

**Keywords:** Anamur (Mersin), Alanya Unit, Stratigraphy-petrography, High temperature - middle pressure metamorphism, Deformation - metamorphism relationship

# Alanya Birliđi Metamorfitlerinin Stratigrafik ve Petrografik Karakteristikleri ve Sugözü Karışığında (Orta Nap) Porfiroblast - Foliasyon İlişkileri, Anamur-Mersin-Türkiye

## Öz

Çalışma alanı Orta Toroslar'ın güney kesiminde Anamur (Mersin) civarında yer alır. Çalışma alanında tabanda tamamen metamorfitlerden oluşan Alanya Birliđi gözlenir. Alanya Birliđi üst üste duran üç metamorfik naptan ibarettir. Mahmutlar grubu (alt nap), Alt-Orta Kambriyen yaşlı kristalize kireçtaşı, çörtlü dolomit, kuvarsit ara seviyeleri ve yeşilşist mercekleri içeren yaygın mika şistlerden oluşur. Prekambriyen yaşlı Sugözü karışığı (orta nap) yeşilşist-amfibolit-amfibolşist bantları-mercekleri ve metagabro-metadiyabaz dayk-ara düzeyleri içeren distenli-sillimanitli-stavrolitli mika şistleri ve yaygın granatlı mika şistleri içerir. Birim içerisinde Alanya birliđine ait Kambriyen ve Permian yaşlı bloklar gözlenir. Yumruadağ grubu (üst nap), altta Alt-Orta Kambriyen yaşlı çörtlü dolomit, kristalize kireçtaşı, kuvarsit ara seviyeleri ve yeşilşist mercekleri içeren mika şistlerle başlar. Üste doğru uyumsuzlukla, yeşilşist mercekleri içeren Üst Permian yaşlı kuvarşist-kalkşist-kristalize kireçtaşı-fillit araldanması ve kalın bitümlü kristalize kireçtaşları gözlenir. Üst nap litolojileri (Ağzıkara formasyonu) içerisinde barit, bakır ve galenit oluşumları yer alır. Çalışma alanında Üst Paleosen – Orta Eosen yaşlı Kötekler formasyonu Alanya Birliđi'ni uyumsuzlukla örter.

Alanya Birliđi yoğun tektonik hareketlerle ilişkili olarak çok evreli deformasyonlara maruz kalmıştır. Özellikle orta napı oluşturan Sugözü karışığı içerisinde metapelitik ve metasemipelitik kayalarda *biyotit* (*kahve, yeşil*) + *muskovit* + *granat* (*prop-almandin-grossular*) + *kuvars* ± *klorit* (*ripidolit-piknoklorit, pennin-klinoklor*) ± *disten* ± *stavrolit* ± *sillimanit* + *plajioklas* (*albit-oligoklas-andezin*) ± *epidot* ± *zoisit/klinozoisit* ± *ortoklas* + *turmalin* (*yeşil, kahve*) ± *grafit* ± *sfen* ± *rutil* ± *apatit* mineral parajenezi yer alır. Bu karışığa ait amfibolitler ve amfibol şistler *hornblend* (*çermakit, ferro-çermakit, magnesio-hornblend ve edenit*) + *granat* + *plajioklas* (*albit-oligoklas-andezin*) ± *relikt klinoproksen* (*ojit-pijeonit*) + *klorit* (*ripidolit, klinoklor*) ± *ortoklas* ± *epidot* ± *zoisit/klinozoisit* ± *biyotit* (*yeşil, kahve*) ± *aktinolit* ± *muskovit* ± *kuvars* ± *kalsit* ± *sfen* ± *apatit* ± *rutil* mineral topluluğu içerir. Metagabrolar ve metadiyabazlarda *hornblend* (*çermakit, ferro-çermakit*) + *plajioklas* (*albit-oligoklas-andezin*) + *relikt klinoproksen* (*ojit*) ± *granat* + *kuvars* + *klorit* (*ripidolit, pennin-klinoklor*) ± *aktinolit* ± *zoisit/klinozoisit* ± *epidot* ± *kalsit* ± *sfen* ± *apatit* gözlenir. Yeşilşistler *tremolit* + *aktinolit* + *klorit* (*ripidolit-piknoklorit*) + *plajioklas* (*albit*) ± *granat* + *zoisit/klinozoisit* + *epidot* ± *kuvars* ± *mikroclin* ± *klinoproksen* (*ojit*) (*relikt*) ± *kalsit* + *sfen* ± *apatit* mineral topluluğu ile belirgindir. Özellikle Sugözü karışığı içerisindeki indeks mineraller, farklı mineral parajenezleri ve deformasyon-metamorfizma ilişkileri gözönüne alındığında Alanya Birliđi'nin birbirini takip eden üç evreli metamorfizmaya uğradığı görülür.

**Anahtar Kelimeler:** Anamur (Mersin), Alanya Birliđi, Stratigrafi-petrografi, Yüksek sıcaklık - yüksek basınç metamorfizması, Deformasyon-metamorfizma ilişkisi

## 1. Introduction

The study area is located in the north-northeast of Anamur district of Mersin city (Figure 1). Alanya Unit observed in the study area is one of the Middle Taurus tectonic units. The Alanya Unit is distinguished from the other tectonic units in the Middle Taurus belt by its metamorphism characteristics at high pressure – lower temperature in Alanya region and its metamorphism characteristics at middle pressure – high temperature in Anamur region. In this study, it has been aimed that the stratigraphic and petrographic characteristics of the metamorphic series of the Alanya Unit and the porphyroblast - foliation relationships which observed in Sugözü Complex (middle nappe) which outcrops in the region are investigated.

Alanya Unit is located in the Taurides Main Tectonic Unit (Ketin, 1966) and the Anatolid-Tauride Block (Okay and Tüysüz, 1999) (Figure 1-a). The Taurides Main Tectonic Union is observed as Western Taurides, Central Taurides and Eastern Taurides extending from west to east in the southern part of Turkey. Alanya Unit is the metamorphic belt which is located in south of the Central Taurides which are bounded by the Ecemiş fault and the Kırkkavak fault (Figure 1-a).

Blumenthal (1951) divided the metamorphites, which were named “Alanya Massif” in Alanya region, to two unites as “schisteous section” at the base and “overburden limestone” at the top. Peyronnet (1965 and 1971) distinguished three stratigraphic series in the

Alanya Massif in his work in the Alanya region. These are “schisteous series” (Upper Carboniferous), “carbonated series” (Permo-Triassic) and “Neogene”.

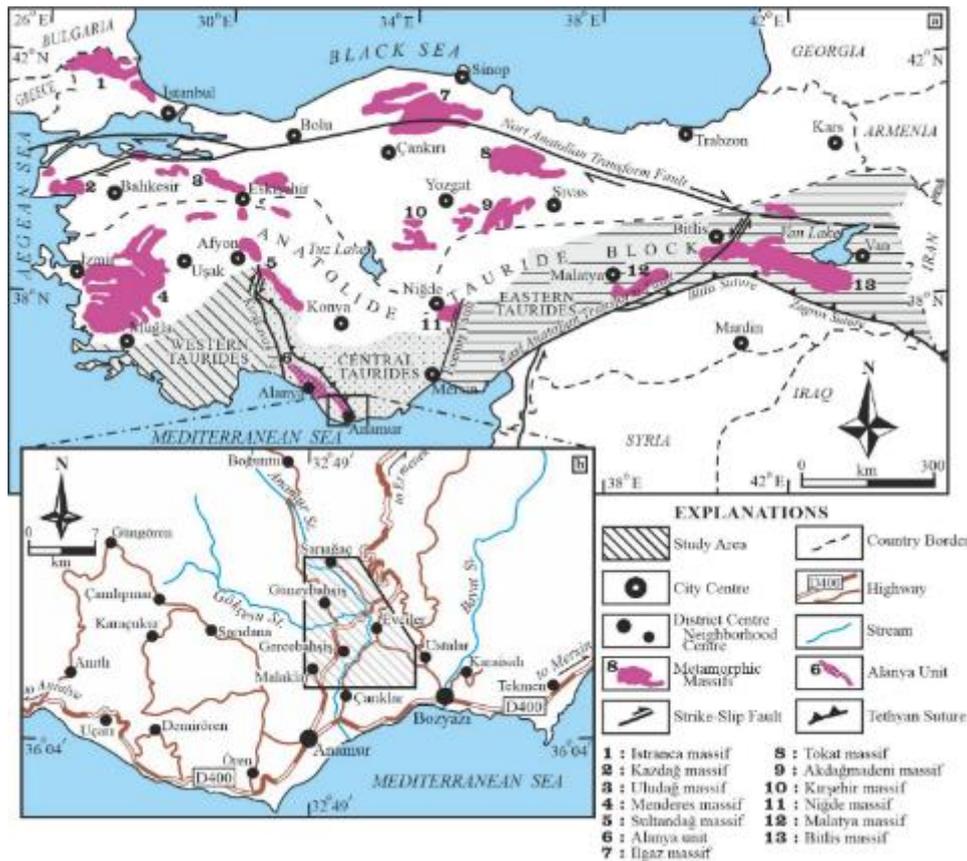


Figure 1. a) The general tectonic features of Turkey, the main parts and the dispersions of Taurus, and metamorphic massifs in Turkey (modified from Okay and Tüysüz (1999), Özgül (1984), Atalay (1987) and Şahin (2002)), b) The location map of the study area

Özgül and Arpat (1973) stated that the Alanya metamorphites (Alanya Unit) were tectonically located on the rock assemblage (Antalya Unit), which showed more or less similar age was not metamorphic, and that both unites covered tectonically to the Geyikdağı Unit at north. Ricau et al. (1974) said that Alanya and Antalya units were initially located in the north of the Taurus-Anatolian platform and that the both reached today's position in the south by crossing the platform with the Eo-Oligocene phase. Şengül et al. (1978) specified that the Alanya Massif was the stratigraphic and structural basis of Western Taurides and that these Massif was covered by the Upper Triassic aged clastic rocks as transgressive. Okay and Özgül (1982) specified that the Sugözü nappe underwent metamorphism in the blueschist / eclogite facies ( $13,5 \pm 1,5$  kb,  $510 \pm 15$  °C) at a depth of 45 km within the Alanya Unit and that the Mahmutlar nappe underwent metamorphism in the greenschist-amphibolite facies ( $7,5 \pm 0,5$  kb,  $484 \pm 23$  °C) at a depth of 25 km.

Özgül (1984), in his study between Alanya-Gazipaşa, stated that Alanya Unit consisted of three imbricate metamorphic nappes. This researcher said that Mahmutlar formation, which formed the lower nappe, was represented by Permian-probably Upper Permian aged meta-clastic and metacarbonates and that Yumruadağ group, which formed the upper nappe, was represented by Upper Permian-Lower Triassic aged meta-clastic and metacarbonates. This researcher stated that Sugözü formation, which formed the middle nappe, was composed of garnet-mica schists containing eclogite, amphibolite and glaucophanite bands-lenses. Okay (1986) said that the Alanya Massif was composed of three superimposed nappes. The researcher stated that the Mahmutlar nappe formed by metamorphism of a heterogeneous series which consisted of sandstone, dolomite, shale and limestone were observed at the bottom and that the Sugözü nappe consisting of garnet-mica schist and sparse metabasite bands and lenses were observed in middle levels these Massif and that the Yumruadağ nappe being formed with metamorphism of a thin shale unite and thick Permian carbonates taken part in the top.

Öztürk et al. (1995) specified that Cambrian and Ordovician aged “Payallar unite” taken part in the base of Alanya nappe and that Upper Triassic and / or Upper Cretaceous aged and flysch characterized “Chaotic series” was tectonically observed on Payallar unite. The researchers said that Çukuryurt unite deposited in various ages and lithologies from the Cambrian to the Cretaceous was tectonically observed at the top. Işık and Tekeli (1995) indicate that Alanya metamorphites outcropping around Anamur contained the metapelites, metabasites, marble and quartzites and that these rocks were affected by a Barrovian type metamorphism reaching up to amphibolite facies at high temperature.

Kansun (2000), in his study in Alanya-Demirtaş-Bucak-Kızılcıtaş vicinities, specified that Alanya Unit consists of three imbricate metamorphic nappes. The researcher said that Mahmutlar group (lower nappe) was composed of Cambrian aged chloritoid schist and widespread mica schists containing crystallized limestone, cherty dolomite, quartzite interlevels and greenschist

lenses at the base and that this group was composed of Upper (?) Permian aged metasandstone, phyllite, quartzite and crystallized limestone at upper levels. Kansun (2000) stated that Late Cretaceous-Paleocene (?) settlement aged Sugözü complex (middle nappe) composed of garnet-mica schists containing greenschist, amphibolite, glaucophanite, eclogite bands-lenses and metagabro levels and that Cambrian, Permian and Triassic aged blocks were observed within the complex. The researcher specified that Yumrudağ group (upper nappe) started with Cambrian aged mica schists containing cherty dolomite, crystallized limestone, quartzite interlevels and greenschist lenses at the bottom and higher up that Upper Permian aged containing greenschist lenses, indicates that alternation quartz schist - chloritoid schist - calcschist - crystallized limestone - phyllite and thick bituminous crystallized limestone were unconformably observed. The researcher said that Lower Triassic aged calcschists starting with a bauxite level at the bottom unconformably taken part in these units and that Middle (?) - Upper Triassic dolomites, which contain also bauxite lenses at the bottom, formed the highest level of Yumrudağ group.

Turan (2007), in his study in Bozyazı (Mersin) vicinity, specified that Late Cretaceous aged Sugözü nappe taken part in the lower part of the metamorphites belonging to Alanya Unit and that Yumrudağ nappe was observed the upper metamorphic slice in the Bozyazı (Mersin) region. The researcher suggested that these metamorphic nappes were unconformably covered by Late Paleocene-Eocene aged flyschoids.

Çetinkaplan (2018), in his study in Anamur vicinity, stated that Precambrian aged metaclastics (Sarıağaç unite), which was cut by basic and acidic metamagmatics in the region and underwent metamorphism under the conditions of upper amphibolite facies, constituted the paraohtonic base. The researcher suggested that the Kapıdağ nappe, which underwent medium pressure metamorphism at Barrov type under greenschist facies conditions, covered the Sarıağaç unite with a tectonic contact. Çetinkaplan (2018) said that the Kapıdağ nappe, which forms a regular and thick sequence, started with a possible infracambrian aged group consisting of alternation of dolomite, marble, muscovite-quartz schist and chlorite schist at the base and that low-grade metamorphics consisting of quartzites, metacarbonates and schists, which were derived from Cambro-Oordovician aged Hüdai, Çaltepe and Seydişehir formations, were observed on these unites.

## **2. Material and Method**

In the field studies, detailed geological map of the study area was prepared by using the Alanya - P 29-c1 and Alanya - P 29-c2 numbered topographic maps at 1/25000 scale (Figure 2). In addition, it was made use of the geological map prepared by Kansun et al. (2018) and Deli (2011). The stratigraphic cross section of the region was created by taking into account the bottom-top relationships of the lithologies in the study area (Figure 3). The lithologies outcropping in the study area were identified and 295 rock samples were taken for petrographic studies. Thin sections were made from 210 rocks at Konya Technical University, Faculty of Engineering and Natural Sciences, Department of Geological Engineering. These thin sections were investigated to determine to mineralogical compositions, texture - structure properties, mineral paragenesis, index minerals and metamorphism - deformation relations with polarizing microscope. In particular, the definitions of some index minerals in the Sugözü complex were supported by microprobe analyzes (Kansun et al., 2018), which were made in the laboratories of the Middle East Technical University.

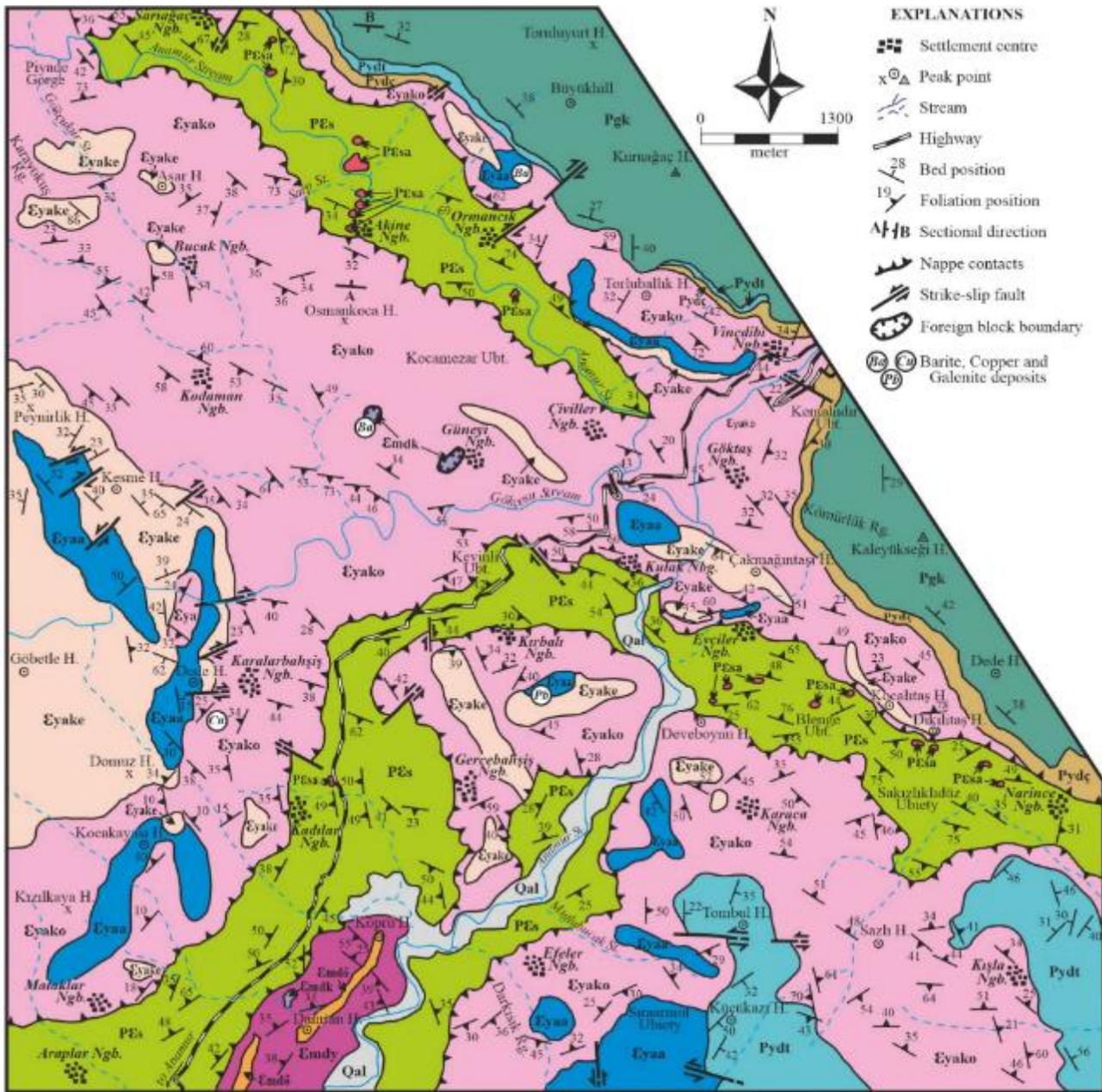
The classification of metamorphic rocks have been made by considering mineralogical compositions, texture-structure properties and sometimes characteristics of origin. "Phyllite", "quartzite" and "mica schist" were determined in "the classification diagrams of metamorphic rocks at low and high temperature" of Winkler (1979). The massive structured metamorphic rocks, which are rich with regard to carbonate minerals, were named as "crystallized limestone", "dolomitic limestone" and "dolomite". The rocks containing calcite minerals more than 90% were named as "crystallized limestone". The rocks containing dolomite minerals more than 90% were named as "dolomite". The rocks containing 50-90% calcite mineral and 10-50% dolomite mineral were named as "dolomitic limestone". The separation of calcite and dolomite minerals in these rocks was made with the help of their optical properties at the polarizing microscope and with the test of the alizerine applied to these rocks. It was observed that the rocks, which were classified as "metagabro" and "metadiabase", underwent to metamorphism and that they protected the origin rock textures. These rocks was named as "gabro" and "diabase" by considering the mineralogical composition and texture-structure properties, and the prefix "meta", which showed that they underwent metamorphism, was placed at the beginning of these naming.

## **3. Results and Discussion**

### **3.1. Stratigraphy and Petrography**

The metamorphic rocks observed between Manavgat-Alanya-Anamur in south of the Middle Taurides were named as first "Alanya Massif" and later "Alanya-Anamur Massif" in the Alanya region by Blumenthal (1951 and 1963). It was understood that these metamorphites hadn't an old basic characteristic with both their age and their structural location, and this group consisting of metamorphites was named as "Alanya Unit" by Özgül (1976) according to Alanya District where it is best observed.

Alanya Unit consists of threeimbricate metamorphic nappes. These, from the bottom to the top, are Lower-Middle Cambrian aged Mahmutlar group (lower nappe), Precambrian aged Sugözü complex (middle nappe) and Lower-Middle Cambrian and Upper Permian aged Yumrudağ group (upper nappe) (Figure 3). The base of Alanya unit could not be observed in the study area. On the other hand, the Alanya Unit tectonically overlies the Antalya Unit in the vicinities of Gündoğdu, Köprülü and Demirtaş (Antalya) and in the west and southwest of the study area (Özgül, 1984). Alanya Unit is unconformably overlain by Upper Paleocene - Middle Eocene aged Kötekler formation in the study area (Figure 3). The lithologies belonging to the Aladağ Unit are observed by tectonic contact over the Alanya Unit and Kötekler formation in about 2 km northeast of the study area (Özgül, 1984; Turan, 2007).



ALANYA UNIT

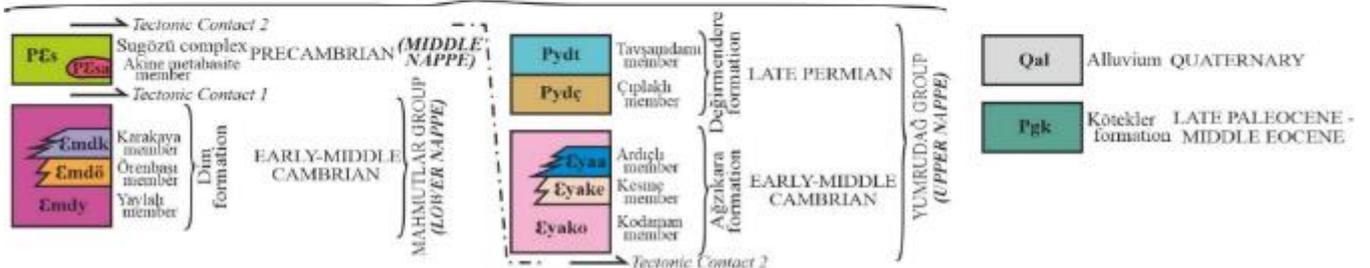


Figure 2. Geological map of the study area

3.1.1. Mahmutlar Group (Lower Nappe)

The metamorphites observed at the base of the Alanya Unit were initially named as Permian aged “Mahmutlar formation” by Okay and Özgül (1982). Kansun (2000) stated that these metamorphites consisted of two formations shown different ages, and he was named as the Mahmutlar group to these lithologies. The Mahmutlar group is observed in places where the topography is lower

according to Sugözü complex (middle nappe) and Yumruadağ group (upper nappe). Mahmutlar group is represented by Dim formation in the study area (Figures 2 and 3).

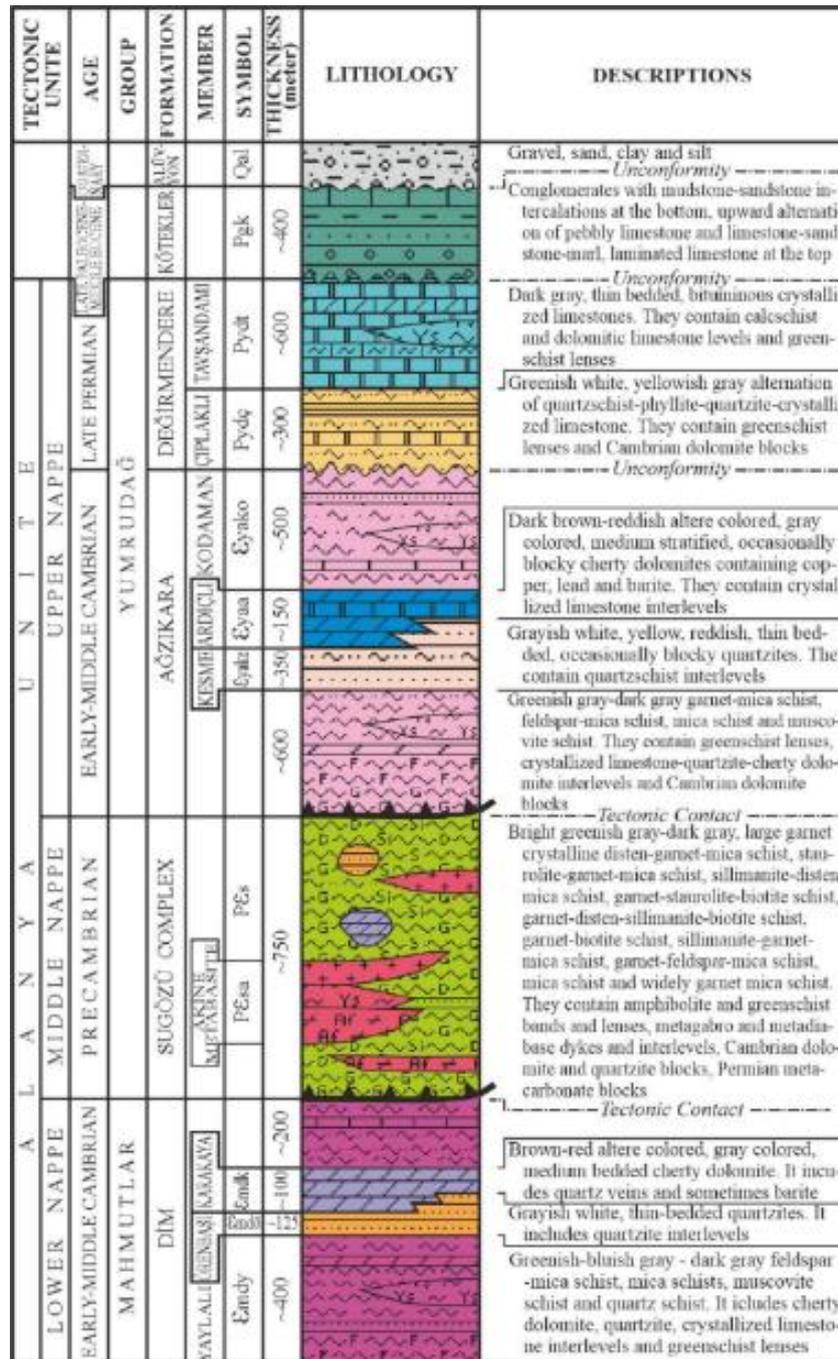


Figure 3. The tectono-stratigraphic cross section of the study area

### 3.1.1.1. Dim Formation

It is a lithostratigraphic unit composed of mainly cherty dolomite, quartzite, crystallized limestone interlevels, greenschist lenses and muscovite schist, quartz schist and widespread mica schists. It was named as Dim formation by Kansun (2000), referring to the Dim River area in Alanya, where it was typically observed. The formation is divided into three members by considering its lithological characteristics and mappable dimensions. These are Örenbaşı member consisting of quartzites, Karakaya member consisting of cherty dolomites and Yaylalı member consisting of extensively metapelitic rocks (Figures 2 and 3).

#### 3.1.1.1.1. Yaylalı Member

It is composed of quartz schist, muscovite schist and extensively mica schists containing cherty dolomite, quartzite, crystallized limestone interlevels and greenschist lenses. It was named as Yaylalı member by Kansun (1993), referring to Yaylalı Neighborhood

(Alanya) where it typical was observed. Yaylalı member observes in the western parts of the Anamur Stream in south of the study area (Figure 2).

Yaylalı member is commonly composed of greenish-yellowish gray, dark gray colored mica schists (Figure 4). Feldspar-mica schists emerge especially at the base levels of the member. Muscovite schists and quartz schists are sometimes seen in the member. The metapelitic schists, which are rich in chlorite, show green color. The folded structures are sometimes observed in these pelitic schists. Mica schists generally show not densely curved structure in the study area. On the other hand, the densely folded structures and the small-scaled faults are dominant in mica schists observed especially in the boundaries where Sugözü complex overlies tectonically Mahmutlar group. Especially in the mica schists in these zones, the amount of chlorite increases, the rocks are green color due to large amounts of chlorite, the grain size is smaller in the rocks, and the thickness of the foliation levels is thinner in the rocks. Abundantly milk-white colored secondary quartz veins has filled the cracks of these mica schists. The effects of dislocation metamorphism are observed in very narrow areas in some mica schists observed in the thrust zones. The rocks turned to mylonite schists in these zones.



Figure 4. a) Mica schists belonging to Yaylalı member shown in the west of Damran Hill, b) Dolomite interlevels in mica schists observed in south of Köprü Hill

The cherty dolomite, quartzite and crystallized limestones are observed as lenses and interlevels in metapelitic schists. These show sometimes alternate of with schists. The cherty dolomites, which are observed as thin levels, are dark gray colored, brown alteration colored, and show 5-20 cm layer thickness and sometimes blocky structure. These dolomites show thicknesses up to 2 meters in mica schists (Figure 4-b). The quartzite interlevels are gray - white colored, pink-red alteration colored and thin bedded. Layer thicknesses of these quartzites reach up to 30-40 cm. The gray colored crystallized limestone interlevels are thin-medium bedded. The isoclinal oblique folds are observe typically in these metacarbonates, whose thicks reache sometimes up to 1 m in schists.

There are yellowish green - green colored and foliated greenschists at sizes that can not be mapped in very narrow areas within Yaylalı member. These metabasic rocks are in the form of bands and lenses developed parallel to the foliations within the metapelitic schists. The albite-chlorite schists and epidote-actinolite schists form the greenschists.

**Metapelitic schists** belonging to Yaylalı member show porphyroblastic and granolepidoblastic textures. *Biotite (brown) + muscovite + quartz + chlorite (pennin-grocoyite and ripidolite) + plagioclase ± microcline ± epidote ± tourmaline (brown) ± apatite* are observed in these rocks. Albite-chlorite schists and epidote-actinolite schists (greenschist) show porphyroblastic, granolepidoblastic, granonematoblastic and nematoblastic textures. The mineralogical composition in the **greenschists** is *chlorite (ripidolite-picnochlorite) + actinolite (bluish green, green) + plagioclase (albite) + epidote ± zoisite / clinozoisite ± quartz ± calcite ± tremolite ± muscovite ± biotite (green) + sphene ± apatite*.

The **biotites** in the mica schists are brown - reddish brownish colored (Figure 5). The biotites are sometimes have been converted to chlorite from their crystal edges and cleavages. Two different recrystallization planes are observed from time to time in mica schists, in which increase muscovite content. These are primary foliation planes ( $S_1$ ) that develop with early stage deformations, and are secondary foliation planes ( $S_2$ ) been formed with progressive deformations. The primary foliations have been folded again over time, and muscovite, sometimes chlorite (ripidolite-picnochlorite turned to from biotite) and biotite (green) recrystallizations have been developed in the axial planes of the secondary folds. The new foliation planes ( $S_2$ ) belonging to late stage deformations cut the previous foliations at an angle. This structure is called as monoclinial kink bands (Etheridge and Hopps, 1974). Since muscovites are easily foldable minerals, the kink band formation is typical in rocks where muscovites are dense. The muscovites, chlorites and biotites show symmetrical creasing folds (kink band) by depending repetitive and advanced deformations in mica schists.

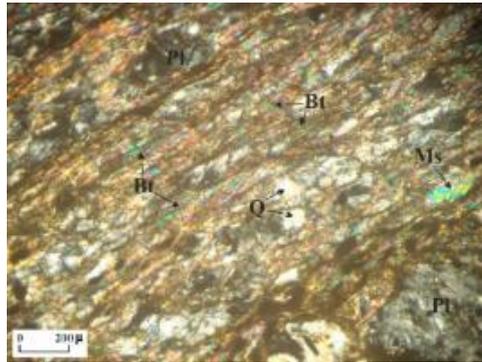


Figure 5. The view from the micaschist belonging to the Yaylali member. Ms: Muscovite, Bt: Biotite, Pl: Plagioclase, Q: Quartz, // Nicol

**Chlorites** have formed with retrograde metamorphism from biotites in metapelitic schists. These chlorites in these rocks are green colored and probably in ripidolite composition. Chlorites, which are observed primary in some micaschists, are pale green colored and probably in pennin-grocoite composition from Mg-chlorites. Chlorites are the major component of chlorite schists. The green colored chlorites in these rocks are in probably ripidolite-pinochlorite composition from Mg-Fe chlorites. **Plagioclases** generally are in porphyroblast view, and contain abundant inclusions (Figures 5 and 6). The quartzs, muscovites and opaque minerals form the inclusions. According to extinction angle determinations, plagioclases are albite ( $Ab_{94}An_{06}$ ,  $Ab_{96}An_{04}$ ), oligoclase ( $Ab_{82}An_{18}$ ), andezine ( $Ab_{67}An_{33}$ ) in metapelitic schists, and are albite ( $Ab_{92}An_{08}$ ,  $Ab_{96}An_{04}$ ) in greenschists. **Actinolites**, which are green-bluish green colored and prismatic-fibrous shaped, form the major component of the greenschists (Figure 6). **Tremolites** observed in a small amount in greenschists are prismatic shape and colorless-very pale green colored.

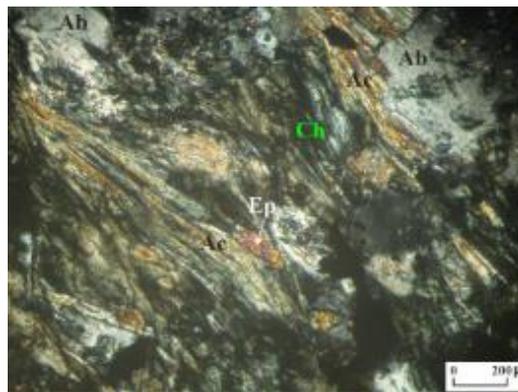


Figure 6. The view from the epidote-actinolite schist belonging to Yaylali member. Ac: Actinolite, Ep: Epidote, Ch: Chlorite, Ab: Albite, // Nicol

The minerals and their percentage values in the five samples belonging to metapelitic schists and greenschists are given in Table 1.

Table 1. Components, percentage values of components and rock names of five samples belonging to metapelitic schists and greenschists observed in Yaylali member

The Name of Mineral	The Name of Rock				
	Mica schist	Feldspar-mica schist	Muscovite schist	Albite-chlorite schist	Epidote-actinolite schist
Biotite	15	17	-	1	2
Muscovite	35	31	45	2	-
Quartz	30	23	35	3	2
Chlorite (from biotite)	15	12	-	-	-
Plagioclase	3	12	4	18	7
Chlorite	-	3	12	57	13
Actinolite	-	-	-	5	42
Zosite/Clinzoisite	-	-	-	3	8
Calcite	-	-	-	-	2
Tremolite	-	-	-	-	3
Microkline	1	-	2	-	-
Epidote	-	1	-	9	18
Sphene	-	-	-	1	2
Tourmaline	1	-	1	-	-
Apatite	-	1	1	1	1
<b>TOTAL</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

The visible thickness of Yaylalı member, which forms a large part of the Dim formation, is approximately 600 m. The base of Yaylalı member could not be observed in the study area. The metapelitic rocks constituting the dominant lithology of Yaylalı member show lateral and vertical transitions with metaclastics and metacarbonates belonging to Örenbaşı member and Karakaya member (Figure 3). Yaylalı member is tectonically covered by Sugözü complex in the east of Araplar Neighborhood in the south of the study area (Figure 2).

According to Kansun (2000), Yaylalı member offers features that can be correlated with metapelitic schist levels of Precambrian (?) and Upper Cambrian - Ordovician aged Payallar unite, which defined in the northeast of the Payallar by Öztürk et al. (1995), and with Cambro-Ordovician aged Gevinde formation, which defined in Demirtaş-Gazipaşa (Antalya) vicinities by Erbay (1998). Kansun (2000) specified that the metapelites belonging to Yaylalı member of Dim formation in Alanya region show lateral-vertical transition with quartzites and cherty dolomites, which were Lower and Middle Cambrian aged according to Öztürk et al. (1995) and Erbay (1998), and that the metapelites belonging to Yaylalı member contained the quartzites (Örenbaşı member) and the cherty dolomites (Karakaya member) as the interlevels. Therefore, Kansun (2000) said that the age of Yaylalı member was Lower-Middle Cambrian.

Also, Yaylalı member show features that can be correlated with "Pre-Ordovician" aged the base levels of the Tülüce complex Caran (1999) within Menderes Massif, which observed between Uşak-Banaz-Sivaslı (Kansun, 2000).

### **3.1.1.1.2. Örenbaşı Member**

It is composed of quartzites containing quartz schist interlevels. It was named by Kansun (2000), referring to Örenbaşı Ubiety (Alanya) where it was best observed. Örenbaşı member is observed as the thin level at Damran Hill and Köprü Hill in the south of the study area (Figures 2 and 7).

Örenbaşı member is composed of pink-red surface colored and grayish white breakage colored quartzites (Figure 7). Muscovite-quartz schists are observed as interlevels in places where phyllosilicate minerals are increased within the member. Quartzites are thin bedded and mostly massive. The thicknesses of bed of quartzites is between 5-30 cm. Abundant fractured structures are observed in quartzites.



*Figure 7. Quartzites belonging to Örenbaşı member observed in the south of Köprü Hill*

Quartzites and quartz schists observed in the member show granoblastic and granolepidoblastic textures. These rocks have mineral paragenesis of *quartz* ± *muscovite* ± *epidote* ± *microcline* ± *chlorite* ± *biotite* (brown) ± *plagioclase* (albite) ± *tourmaline* (green) ± *apatite*. Muscovite-quartz schists come into the open at the result of that of the micas and chlorites increase in in the rocks and that the rock show the foliated structure.

Örenbaşı member, which is observed within Dim formation in the study area, presents an apparent thickness of approximately 125 m. Quartzites are observed as thin levels at dimensions which sometimes can be mapped and sometimes can be not mapped, within metapelitic schists belonging to Dim formation. Örenbaşı member generally show vertical transitions with metapelitic schists belonging to Yaylalı member from the bottom, and show lateral-vertical transitions with cherty dolomites belonging to Karakaya member from the top (Figure 3).

Öztürk et al. (1995) said that the quartzites observed in the bottom levels of "Payallar unite", which defined in the bottom levels of Alanya Unit in the northeast of Payallar were Lower Cambrian aged. Erbay (1998) stated that the quartzites, which observed at the base of the Alanya Unit, taken part in as concordant under Middle Cambrian aged cherty dolomites containing trilobite, and that the quartzites were Lower Cambrian aged (Kansun, 2000). The quartzites belonging to Örenbaşı member in the study area are observed as concordant under cherty dolomites (Figure 3). Therefore, Örenbaşı member is Lower Cambrian aged.

The quartzites belonging to Örenbaşı member show features that can be correlated with Lower Cambrian aged Hüdai quartzite (Özgül et al., 1991) in Homa-Akdağ and Sultandağları, with Lower Cambrian aged Kocaosman formation (Şenel, 1992) in the Karacahisar dome and with Lower Cambrian aged Hacıisaklı formation (Demirtaşlı, 1987) in Silifke vicinity (Kansun, 2000).

### **3.1.1.1.3. Karakaya Member**

It is composed of cherty dolomites. These dolomites were named as Karakaya member referring to Karakaya Ridge in the northern part of Alanya, where they observed typically, by Kansun (2000). In addition, these cherty dolomites are observed as

interlevels within the schists belonging to Dim formation (Figure 4-b). It is seen at the very narrow area in the northwest of Damran Hill (Figure 2).

Karakaya member is composed of reddish brown-red surface colored and gray-dark gray breakage colored dolomites. These dolomites are very hard structured, medium bedded and sometimes at blocky appearance (Figure 8). The thicknesses of stratum of them varies between 10-25 cm. The chert levels, which developed parallel to stratification, are observed in dolomites. The cherts are in dark gray - blackish colors, and the thicknesses of the chert levels are 1-3 cm. Sometimes, the cherty dolomites are typical with their blocky appearances. The diameters of these blocks reach up to 3 meters. The cleft and crack systems developed in different directions are observed in the cherty dolomites. These cleft and crack systems are filled with milk white colored quartz (Figure 8).

Dolomites contain *dolomite* + *calcite* ± *quartz* ± *chlorite* (*pennin-clinoclone*) as mineralogical composition. The amount of dolomite mineral in these metacarbonates is more than 90% (Figure 9). Chlorites observed in minor amounts in metacarbonates are pale green colored and are possibly in Mg-chlorite composition.

The dolomites belonging to Karakaya member have the visible thickness of approximately 100 m in places, where the thickest outcrops are observed (Figure 3). These dolomites show lateral and vertical transition with metapelitic schists belonging to Yaylalı member. They show lateral and vertical transition with quartzites belonging to Örenbaşı member in many locations, where they are observed, in Dim formation (Figure 3).



Figure 8. The blocked dolomites containing milky white colored quartz veins belonging to Karakaya member in northwest of Damran Hill

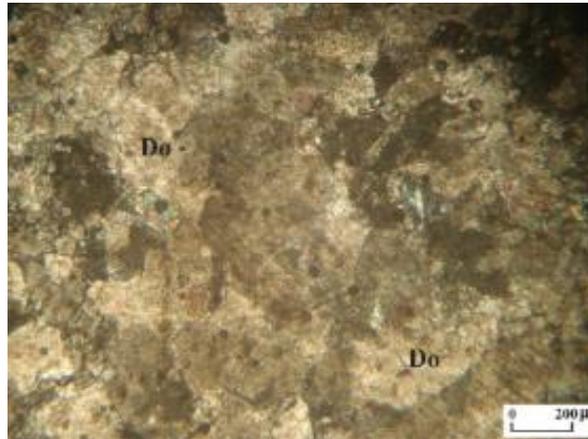


Figure 9. The dolomites belonging to Karakaya member. Do: Dolomite, // Nicol

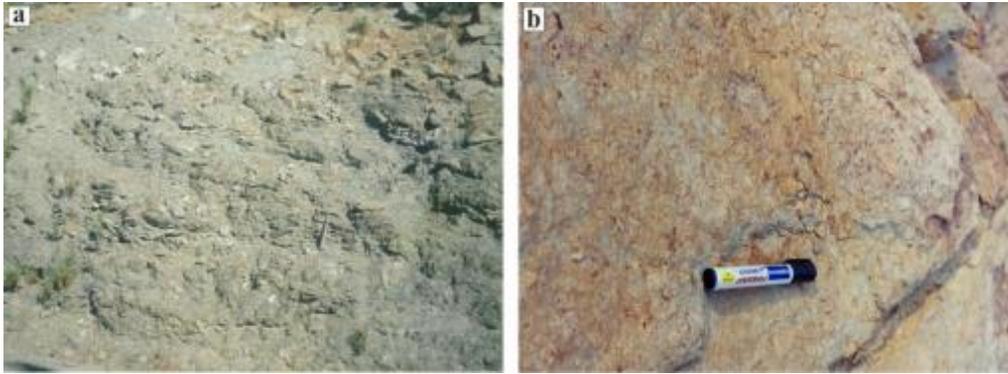
Erbay (1998) stated that the thick-bedded dolomites, which contain the chert nodules and barite veins and which are called as Çaltepe formation at the bottom levels of Alanya Unit in Demirtaş-Gazipaşa (Antalya) vicinities, contain trilobite fossils and that are Middle Cambrian aged. Reference Öztürk et al. (1995) said that the dolomites, which contain the chert nodules and barite veins and which observed in Payallar unite defined as the bottom levels of Alanya Unit in the northeast of Payallar, are Middle Cambrian aged. Kansun (2000) claimed that the chert dolomites observed at the bottom levels of Alanya Unit in Alanya region are Middle Cambrian aged. In the study area, the dolomites belonging to the Karakaya member, which show very similar features with the lithologies and the boundary relations, which were defined by Erbay (1998), Öztürk et al. (1995) and Kansun (2000) should be Middle Cambrian aged.

The dolomites belonging to Karakaya member have similar lithological features with Middle Cambrian aged Çaltepe limestone (Monod, 1977) observed in Homa-Akdağ (Özgül et al., 1991), Sultandağları (Öztürk et al., 1981) and Karacahisar dome (Şenel, 1992), and with Middle Cambrian aged Ovacıkışıklı formation (Demirtaşlı, 1987) observed in Silifke vicinity (Kansun, 2000).

### **3.1.2. Sugözü Complex (Middle Nappe)**

It is composed of mica schists with kyanite-sillimanite-staurolite and extensively granat-mica schists. In these metapelitic schists, it is observed sometimes quartzite and quartzschist interlevels, amphibolite - amphibole schist - greenschist bands and lenses, metagabbro - metadiabase dykes and interlevels, Cambrian aged dolomite – quartzite blocks and Upper Permian aged metacarbonate blocks belonging to Alanya Unit. This unit was first described as the Sugözü formation by Okay and Özgül (1982). Kansun (2000) specified that the intense metabasite interlevels - metagabbro blocks - metacarbonate levels together with metasediments and also Cambrian - Permian - Triassic blocks at various ages and lithologies belonging to Alanya Unit were observed in the unite. Therefore, Kansun (2000) was named as Sugözü complex the litologies, which are composed of many different rocks and lost their primary relations. In this study, the intense metabasite interlevels and metagabbro - metadiabase blocks together with metasediments and Cambrian - Permian aged the rock blocks at different ages and lithologies belonging to Alanya Unit have been observed in the unite. Therefore, these lithologies have been named as Sugözü complex in this study. In the study area, Sugözü complex according to Mahmutlar group is observed in areas where topography is higher. Whereas, Sugözü complex according to Yumrudağ group where topography is lower. Sugözü complex are seen in the vicinities of Araplar Neighborhood, Kadılar Neighborhood, Evciler Neighborhood, Narince Neighborhood, Sariağaç Neighborhood, Akine Neighborhood and Ormancık Neighborhood in the study area (Figure 2).

Sugözü complex is commonly composed of mica schists with garnet (Figure 10-a). In the complex, also sillimanite-garnet-mica schist, staurolite-garnet-mica schist, garnet-feldspar-mica schist, sillimanite-kyanite-mica schist, kyanite-garnet-mica schist, garnet-staurolite-biotite schist, garnet-biotite schist and garnet-kyanite-sillimanite-biotite schist are observed (Figure 10-b). These metapelitic rocks do not have a regular sequence, and can be observed at all levels of the complex. The bands and lenses of amphibolite-amphibole schist- greenschist, dykes and interlevels of metagabbro - metadiabase are observed in Sugözü complex (Figures 3 and 11). The metapelitic and metabasic rocks of the Sugözü complex are characterized by garnet porphyroblasts, bright greenish colors due to retrograde metamorphism and generally thick foliation structures. For this reason, the Sugözü complex is easily distinguished from the lithologies of the Mahmutlar and Yumrudağ groups within the Alanya Unit. Garnet porphyroblasts are generally brown and sometimes green colored, and diameters of these porphyroblasts reach up to 5-6 mm in places (Figure 10-a). These garnet porphyroblasts observed in Sugözü complex are used to determine the boundaries in the field. Because, these garnet porphyroblasts have been not observed in both the lithologies of Mahmutlar group forming the lower nappe and the lithologies of Yumrudağ group forming the upper nappe. In metapelitic rocks belonging to Sugözü complex in places near the thrust boundaries at the bottom and top levels of the Sugözü complex, the garnets disappear due to the retrograde metamorphism that occurs probably simultaneously or later with the thrust, the garnets disappear and turn to completely chlorite, biotite and epidote.



*Figure 10. a) The sillimanite-kyanite-micaschists belonging to Sugözü complex observed in the vicinity of Blende Ubiety, b) Brown colored garnet porphyroblasts observed in mica schists with garnet belonging to Sugözü complex, the south of Evciler Neighborhood*

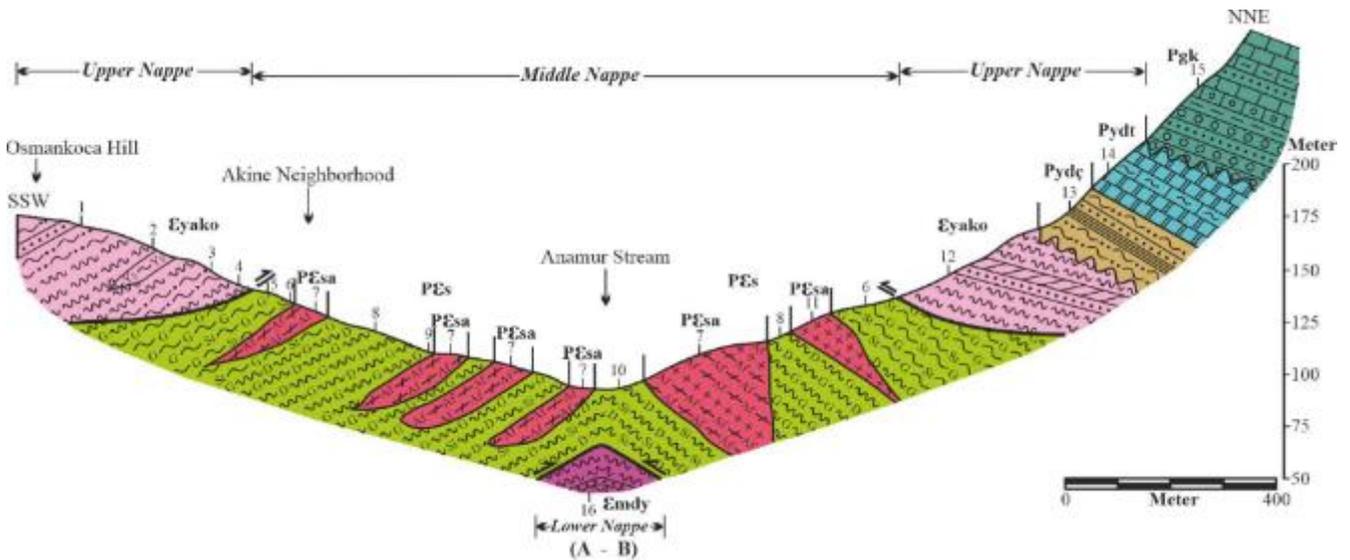


Figure 11. Geological section of the outcrops belonging to Sugözü complex (Pes, Pesa), Yumruadağ group (eyako, Pydç, Pydt) and Kötekler formation (Pgk) along Osmankoca Hill - Akine Neighborhood - Anamur Stream line (A-B). The geological cross-section which is along A-B is shown in the geological map given in Figure 2. 1) Yellowish white colored quartz schist level which contain with quartzite interlevels, 2) Greenish gray colored mica schist level which contain greenschist lenses, 3) Gray colored quartz-muscovite schist level, 4) Grayish green colored mica schist level which contain widespread chlorite, 5) Bright green - dark gray colored garnet-biotite schist level which contain large garnet crystals, 6) Shiny greenish gray colored garnet-staurolite-biotite schist level which contain prominent garnet crystals and thick schistosity structures, 7) Green - blackish green colored garnet - amphibolite level which show mass structure and sometimes weak schistosity structure compatible with foliation of metapelitic rocks, which observe lenticular and which contain coarse garnet crystals, 8) Bright green-gray colored kyanite-garnet-mica schist level which contain garnet porphyroblasts, 9) Bright greenish gray colored garnet-mica schist level which contain common coarse grained mica and garnet crystals, 10) Bright green-gray colored sillimanite-dysten-mica schist level which contain coarse feldspar crystals, 11) Green - black colored metagabbro level which show massive structure and sometimes weak schistosity structure and which contain coarse hornblende crystals, 12) Greenish-whitish gray colored micaschist level which contain quartzite and cherty dolomite interlevels, chlorite is commonly observed at the bottom, 13) Greenish white - yellowish gray colored muscovite-quartz schist level which contain alternation of phyllite – quartzite, 14) Dark gray colored, thin-bedded, partly bituminous crystallized limestone level which contain calcschist interlevels, 15) Burgundy-gray-pinkish colored conglomerate, pebbly limestone, alternation of limestone-sandstone-marl which contain mudstone-sandstone interlevels, 16) Mica schists belonging to Dim formation (emdy) in Mahmutlar group (probable)

The micaschists in the Sugözü complex are yellowish gray, dark gray in color and appear bright green due to retrograde metamorphism. They constitute the dominant lithology of Sugözü complex. The garnet minerals at large and small sizes are found varying proportions in the rocks. Micas are in the form of large crystals in some mica schists.

The symmetrical, asymmetrical, overturned folds and finer foliations have intensely developed especially in the boundary boundaries belonging to Alanya Unit and sometimes in the micaschists in the complex, depending on both the nappes and the progressive deformations. The micaschists rarely contain quartzite - quartzschist interlevels and milky white colored quartz veins that develop parallel to schistosity.

The greenschist, amphibolite and amphibole schist bands-lenses and metagabbro - metadiabase dykes and interlevels are extensively observed in the Sugözü complex (Figure 12). These metabasites are brownish green, blackish green, greenish black in color, and have blocky appearance and sometimes weak schist structure. These bands and lenses have a length of 5-80 m and a width of 2-50 m. Some metabasites are smaller in sizes.



Figure 12. The garnet-mica schists (Msc) belonging to Sugözü complex, and the garnet-amphibole schist (Amp) lens observed within the garnet-mica schists. The northeast of Kirbali Neighborhood

Metabasites are generally in dimensions, which can not be mapped. The ones, which can be mapped, have been shown on the geological map by being exaggerated (Figure 2). The Cambrian aged cherty dolomite and quartzite blocks and Upper Permian aged crystallized limestone blocks belonging to Alanya Unit were sometimes observed within the Sugözü complex. These blocks are the pieces that Sugözü complex gets them into by tearing off from different aged unites of the Alanya Unit.

The metapelitic and metasepilitic rocks belonging to Sugözü complex show porphyroblastic, lepidoblastic and granolepidoblastic textures. The biotite (brown, green) + muscovite + garnet (prop-almadine-grossular) + quartz ± chlorite (ripidolite-picnochlorite, pennin-clinocllore) ± kyanite ± staurolite ± sillimanite + plagioclase (albite-oligoclase-andesine) ± epidote ± zoisite / clinozoisite ± orthoclase + tourmaline (green, brown) ± graphite ± sphene ± rutile ± apatite mineral assemblage are observed in these metapelitic and metasepilitic rocks.

**Biotites** are reddish brown, brown and green in color in pelitic schists. The brown colored biotites are parallel to the foliation planes S<sub>1</sub> and S<sub>2</sub> (Figures 13-a and b). Green colored biotites, which are rarely observed in mica schists, are parallel to S<sub>3</sub> foliation plane. The brown colored biotites are observed as large porphyroblasts in garnet-biotite schists. This biotites have transformed into sillimanite and kyanite by progressive metamorphism and have transformed into partially or completely chlorite (ripidolite) by retrograde metamorphism in the mica schists and biotite schists (Figure 13-b).

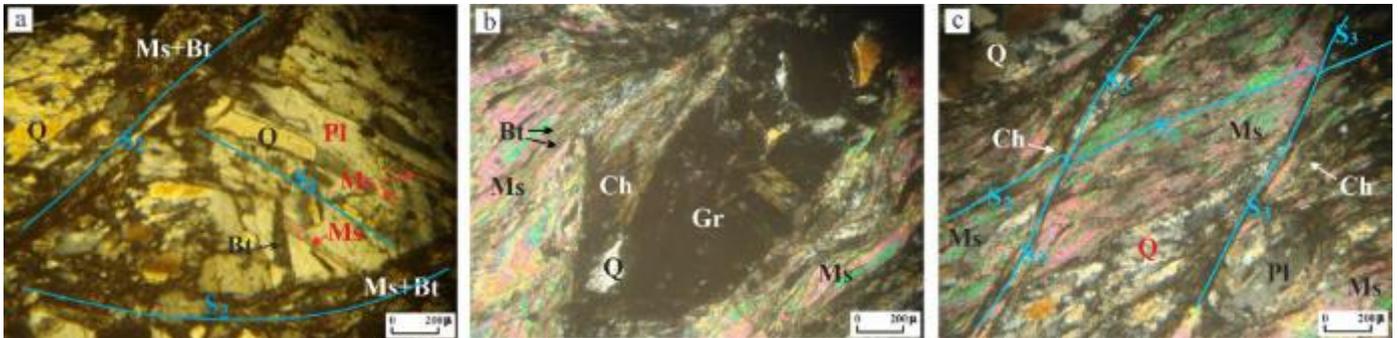


Figure 13. a) S<sub>1</sub> foliation consisting of muscovites (Ms) and biotites (Bt) in plagioclase (Pl) porphyroblast and S<sub>2</sub> foliation consisting of muscovites and biotites surrounding this plagioclase in garnet-mica schist belonging to Sugözü complex, b) Muscovites and biotites forming S<sub>2</sub> foliation in garnet-mica schist belonging to Sugözü complex, c) S<sub>2</sub> foliation consisting of muscovites and biotites, which turn to chlorites, and S<sub>3</sub> foliation developed in the fold axis planes of S<sub>2</sub> in garnet-feldspar-mica schist belonging to Sugözü complex. Ch: Chlorites consisting of biotite, Q: Quartz, // Nicol

The **muscovites** observe in foliation planes S<sub>1</sub>, S<sub>2</sub> and S<sub>3</sub> (Figure 13). They are observed as porphyroblasts in kyanite-garnet-mica schists. These porphyroblasts have crystallized as pre-tectonic according to the S<sub>2</sub> foliation planes of the rock. Especially, the king-band structures have developed in S<sub>2</sub> foliation planes in muscovite-rich mica schists. Muscovites have sometimes transformed into sillimanite and kyanite by progressive metamorphism.

**Garnet** crystals formed in two different phases are observed in metapelitic rocks. The first phase garnets are colorless - pale brownish yellow in colors. These are seen as xenoblastic – sub-idioblastic and prismatic crystals. These garnets contain sometimes very abundant and are observed as very large porphyroblasts. These first phase garnets have surrounded by the S<sub>2</sub> foliation, which muscovite, brown colored biotite and occasionally long prismatic kyanite forms, in metapelitic rocks. Therefore, these are pre-tectonic according to the F<sub>2</sub> deformation phase. In addition, some garnets have surrounded by elongated chlorites in pressure shadow at the direction of foliation in garnet-feldspar-mica schists (Figure 14-a). This feature shows that these garnets are again pre-tectonic. In the garnet porphyroblasts, the quartz, staurolite, zoisite, muscovite and brown colored biotite inclusions, which form the S<sub>1</sub> foliation, form the snowball structure and helisitic texture (Figures 14-b and c). The snowball structure shows that these garnets crystallize

simultaneously with the F<sub>1</sub> deformation phase (syntectonic). Helisitic texture shows that the crystallization continues after the F<sub>1</sub> deformation phase (post-tectonic). That these garnets sometimes cut S<sub>2</sub> foliation (F<sub>2</sub> deformation phase) and are idioblastic specified that the growth of these garnets continues after the F<sub>2</sub> deformation phase. That staurolite and zoisite inclusions in first phase garnets indicates high pressure areas. These garnets have transformed into chlorite (ripidolite) and sometimes biotite + chlorite + epidote with retrograde metamorphism.

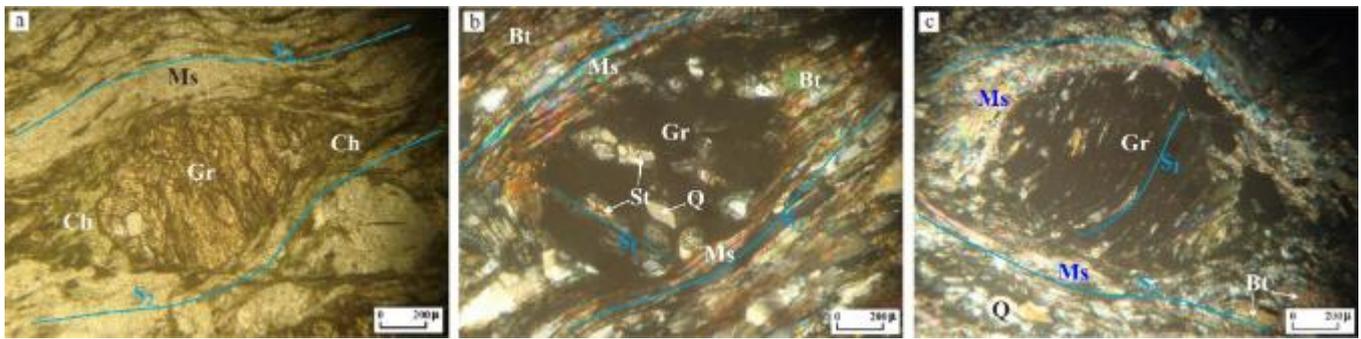


Figure 14. a) In garnet-feldspar-mica schist, the pre-tectonic garnet (Gr) porphyroblast surrounded with chlorites (Ch) extended in a direction in the direction of foliation and in pressure shade, and muscovites (Ms) forming S<sub>2</sub> foliations, b) Pre-tectonic garnet porphyroblasts surrounded by S<sub>2</sub> foliation consisting of muscovite and biotite in staurolite-garnet-mica schist. In the garnet porphyroblast, staurolite (St) and quartz (Q) inclusions extended in one direction which form S<sub>1</sub> foliation form the helisitic texture, c) In the garnet-feldspar-mica schist, quartz and muscovite inclusions which form the S<sub>1</sub> foliation and present the folded s-structure in garnet porphyroblast shown helisitic texture. Garnet porphyroblasts are post-tectonic according to S<sub>1</sub> foliation, and pre-tectonic according to S<sub>2</sub> foliation consisting of muscovite and biotite that surrounds itself. a) / Nicol, b and c) // Nicol

The second phase garnets observed in metapelitic rocks are colorless-pale yellow colored and hexagonal-octagonal shaped. These garnets are generally porphyroblasts, whereas they are observed as smaller idiomorphic octagonal and sub-idioblastic crystals in some garnet-feldspar-mica schists (Figure 15). The quartz and muscovite inclusions forming to the S<sub>1</sub> foliation plane in these garnets show a linear and sometimes slightly folded elongation. This gave the garnet a helisitic texture. Therefore, these garnets are post-tectonic according to the F<sub>1</sub> deformation phase. These garnets have been sometimes surrounded by the S<sub>2</sub> foliation forming of muscovite, brown colored biotite, long prismatic kyanite and sillimanite, also they have cut mostly this foliation. Moreover, sometimes hexagonal shapes have been preserved in these garnets. Therefore, the second phase garnets began to crystallize before the F<sub>2</sub> deformation phase, and they continued to grow after this phase. Like the first phase garnets, these garnets have converted to chlorite (ripidolite) by retrograde metamorphism. Ca (grossular) content from the center to the edge decreases in the garnets observed in Staurolite-garnet-mica schists, whereas Mg (prop) and Fe (almandine) content increases (Kansun et al., 2018). Therefore, there is the decreasing pressure in the environment.

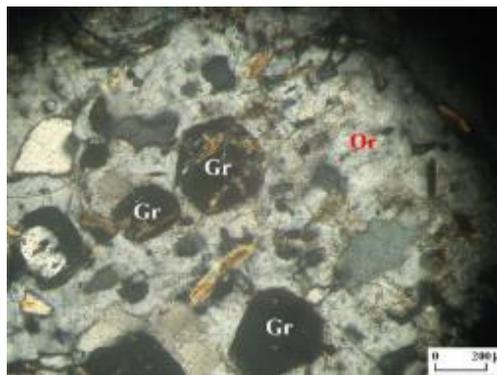


Figure 15. The idiomorphic-hexagonal garnets (Gr) within orthoclase (Or) porphyroblast at garnet-feldspar-mica schist, // Nicol

**Feldspars** is observed as plagioclase and orthoclase in metapelitic rocks. **Plagioclases** show sometimes twinning. Deformation twins are observed in some plagioclases. This shows the effect of increasing deformation in the environment. The inclusions of quartz, muscovite, biotite, garnet, sphene, rutile and opaque mineral are common in plagioclase, which are generally observed as porphyroblasts in metapelitic rocks (Figures 13-a, 16-a and 16-b). In some plagioclase porphyroblasts, quartz, muscovite, biotite, sphene and rutile inclusions, which form S<sub>1</sub> foliation, show the folded S-structure. These plagioclases shown helisitic texture developed as post-tectonic according to the F<sub>1</sub> deformation phase (Figure 16-b). Again, these plagioclase porphyroblasts have been generally surrounded by S<sub>2</sub> foliation. Therefore, these plagioclases are also pre-tectonic according to the F<sub>2</sub> deformation phase (Figures 13-a and 16-a). That these plagioclases occasionally cut the S<sub>2</sub> foliation (F<sub>2</sub> deformation phase) indicates that the growth of these plagioclases continues after the F<sub>2</sub> deformation phase (Figure 16-b). These plagioclases show oligoclase (Ab<sub>75</sub>An<sub>25</sub>, Ab<sub>77</sub>An<sub>23</sub>) and andesine (Ab<sub>60</sub>An<sub>40</sub>, Ab<sub>62</sub>An<sub>38</sub>) compositions according to extinction angle determinations. Some plagioclase porphyroblasts observed in metapelitic schists intersect the S<sub>2</sub> foliation plane. Therefore, they show post-tectonic characteristics according to the F<sub>2</sub> deformation

phase. The xenomorphic and scattered garnet grains are shown in some of these plagioclase porphyroblasts. This particular indicates that these plagioclases were formed from the garnets. These plagioclases, which are thought to be the last product of metamorphism, have to albite ( $Ab_{93}An_{07}$ ,  $Ab_{94}An_{06}$ ) composition according to extinction angle determinations. Some plagioclases have converted to sericite by retrograde metamorphism.

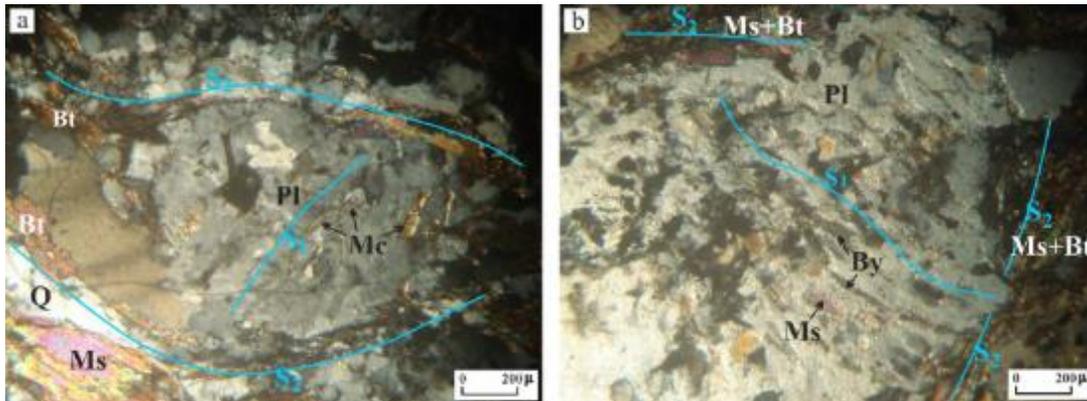


Figure 16. a), The plagioclase porphyroblast, which is pre-tectonic according to the  $S_2$  foliation and are surrounded by  $S_2$  foliation which is formed of muscovite (Ms) and biotite (Bt) in garnet-feldspar-mica schist. The mica (Mc) inclusions, which extend in one direction and are formed the  $S_1$  foliation in the plagioclase porphyroblast, show that the plagioclase porphyroblast is post-tectonic according to  $S_1$  foliation, b) Helicitic textured plagioclase porphyroblast containing muscovite and biotite inclusions, which form  $S_1$  foliation and show a folded s-structure, in the kyanite-garnet-mica schist. This porphyroblast partially interrupts the  $S_2$  foliation formed by muscovite+biotite. Q: Quartz, // Nicol

**Orthoclases** are typical of sub-idiomorph-xenomorph crystals, abundant inclusions and sometimes karlsbad twins (Figure 17). These inclusions are composed of quartz, muscovite, biotite and garnet (Figure 15). Orthoclases are observed together with sillimanite in almost all pelitic schists.

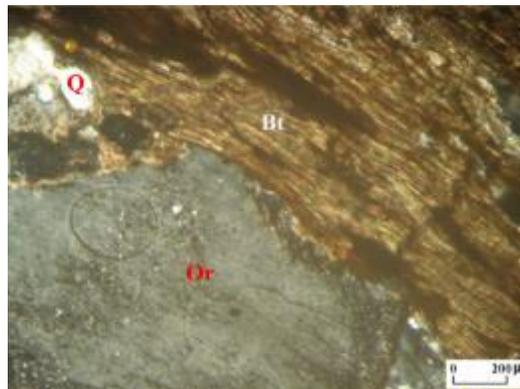


Figure 17. Orthoclase (Or), biotite (Bt) and quartz (Q) in sillimanite-kyanite-mica schist, // Nicol

**Staurolites** are distinct yellow colored and prismatic shaped and contain sometimes quartz inclusions in metapelitic rocks (Figure 18). In metapelitic schists, their proportions reach up to 15%. They are seen generally as porphyroblasts. Staurolite porphyroblasts have been surrounded by  $S_2$  foliation. Therefore, these are pre-tectonic according to the  $F_2$  deformation phase (Figure 18-a). That the staurolite porphyroblasts sometimes grow by interrupting  $S_2$  foliation indicates that they grow as post-tectonic therewithal according to the  $F_2$  deformation phase (Figure 18-b).

In particular, the presence of staurolite together with kyanite and sillimanite (Figures 18-c and d); indicates that the staurolites are still preserved despite the increasing temperature in the environment (progressive metamorphism). Staurolite inclusions are sometimes observed in garnet porphyroblasts which are formed at the second metamorphism phase. This indicates that garnet replaces staurolite as a result of advancing reactions (increasing temperature). As a result, the staurolites were formed in the first metamorphism phase in the Alanya Unit, and they were transformed into kyanite and / or sillimanite and garnet as a result of the increase in temperature. Some staurolite crystals have been transformed into chlorite from their edges. This transformation indicates to the retrograde metamorphism at the environment.

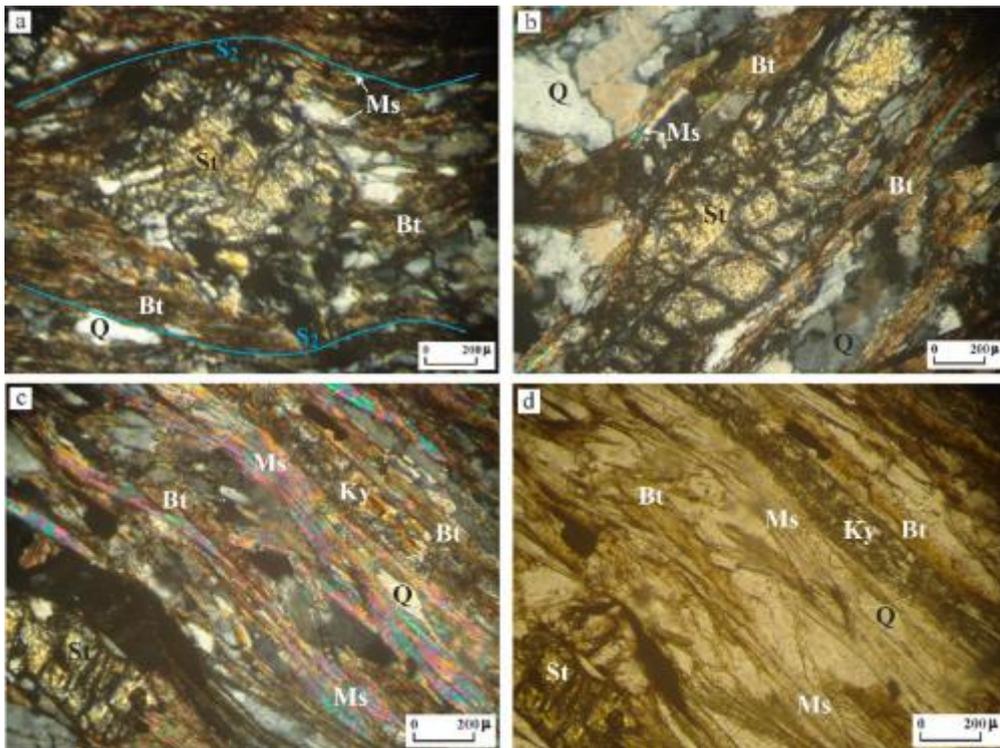


Figure 18. a) The staurolite (St) porphyroblast observed as pre-tectonic according to  $S_2$  foliation which is formed from muscovite (Ms) and biotite (Bt) in staurolite-garnet-mica schist, b) The staurolite porphyroblast observed as post-tectonic according to  $S_2$  foliation which is formed from muscovite and biotite in staurolite-garnet-mica schist, c and d) The staurolite porphyroblast,  $S_2$  foliation which is formed from muscovite and biotite, the kyanite (Ky) porphyroblast which is observed as parallel to this foliation and is formed from biotite and / or muscovite in staurolite-garnet-mica schist. Q: Quartz, a, b and c) // Nicol, d) / Nicol

**Kyanite** is generally seen as sub-idioblastic and prismatic crystals in metapelitic rocks. It shows cleavages which are perpendicular to each other and oblique extinction at low angle (Figure 19). Kyanite porphyroblasts observed in mica schists and biotite schists have been sometimes surrounded by  $S_2$  foliation (Figure 19). Therefore, they are pre-tectonic according to the  $F_2$  deformation stage. In contrast, they are seen generally as long prismatic crystals observed as parallel to muscovites and biotites that form  $S_2$  foliation (Figure 20). In some mica schists, the kyanites have rarely continued to grow by cutting this foliation. Therefore, the formation of the kyanites started before the  $F_2$  deformation phase and continued to its formation in this phase. The kyanites in the metapelitic rocks have consisted with advancing reactions from muscovite, biotite and sometimes staurolite (Figures 18-c and d). Some kyanite porphyroblasts have been transformed into fibrous sillimanites from their crystal edges. This indicates the progressive metamorphism at environment (increasing temperature). The kyanite and sillimanite coexist in some metapelitic rocks, such as sillimanite-kyanite-mica schists.

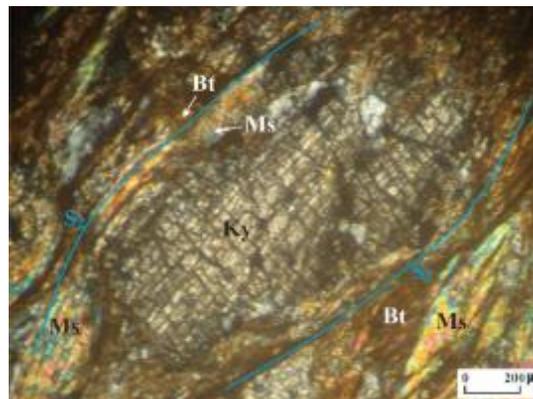


Figure 19. Pre-tectonic kyanite (Ky) porphyroblasts surrounded by  $S_2$  foliation which consist of muscovite (Ms) and biotite (Bt) in sillimanite-kyanite-mica schist

Some kyanites observed in sillimanite-kyanite-mica schists have been partially or completely transformed into muscovite from their crystal edges and their cleavages (Figures 20-c and d). These muscovites are cut to  $S_2$  foliation in metapelitic rocks (Figure 20-d).

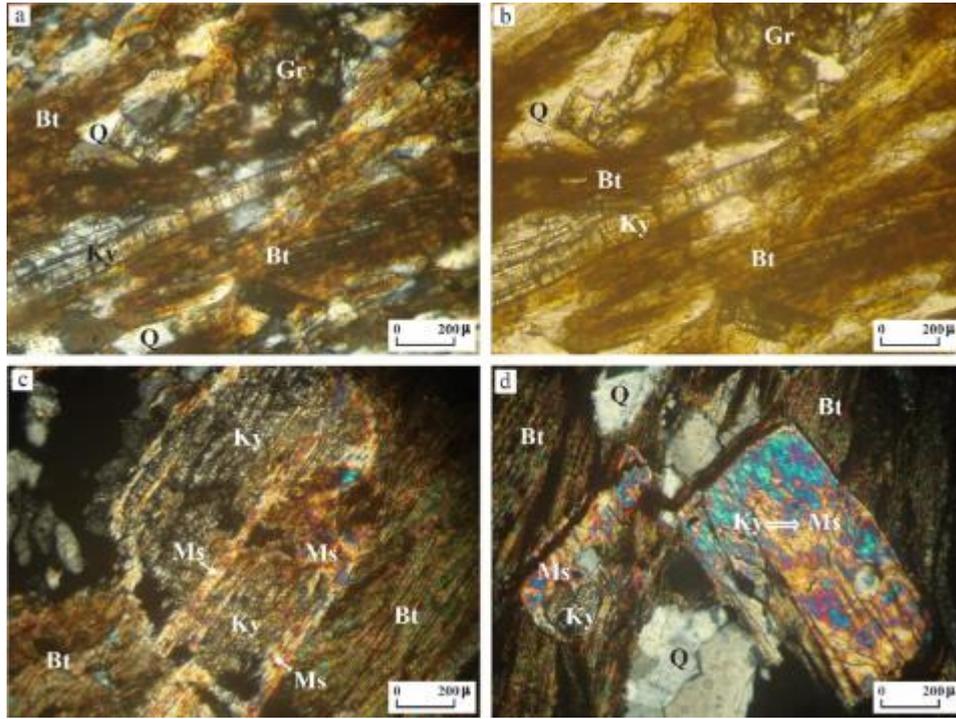


Figure 20. a and b) Long prismatic kyanite (Ky) porphyroblast as observed parallel to  $S_2$  foliation in garnet-kyanite-sillimanite-biotite schist, c) Kyanite porphyroblast, which was transformed into muscovite (Ms) from its crystal edges and its cleavages in sillimanite-kyanite-mica schist, d) Kyanite porphyroblasts, which were transformed into muscovites in sillimanite-kyanite-mica schist. Bt: Biotite, Gr: Garnet, Q: Quartz. a, c and d) // Nicol, b) / Nicol

**Sillimanite** shows fibrous shape and flat extinction (Figure 21). The sillimanite crystals in the metapelitic rocks consisted of mica, kyanite and possibly staurolite with advancing reactions. The fibrous sillimanite crystals are parallel to  $S_2$  foliation which consist of muscovites and brown colored biotites in these rocks (Figure 21). The sillimanites is observed together with orthoclases in metapelitic schists.

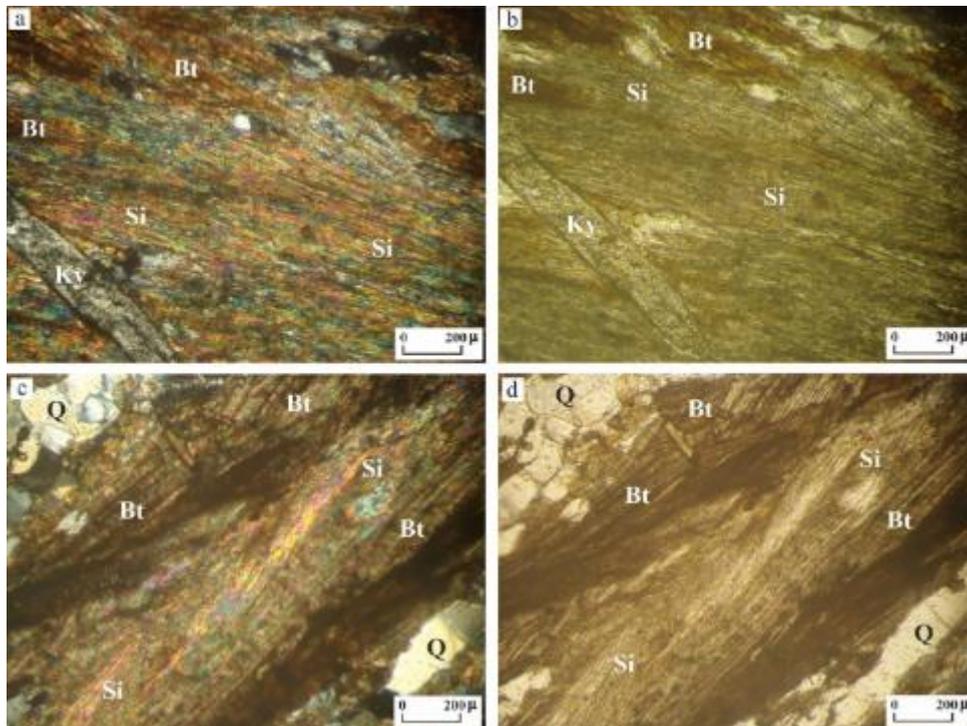


Figure 21. a and b) Fibrous sillimanite (Si) crystals, which consist of biotite (Bt), in garnet-kyanite-sillimanite-biotite schist, c and d) Sillimanite, biotite and quartz (Q) crystals in sillimanite-kyanite-mica schist. Ky: Kyanite. a and c) // Nicol, b and d) / Nicol

The minerals and their percentage values determined in the metapelitic schists belonging to Sugözü complex are given in Table 2.

Table 2. The Components, percentage values and rock names of seven samples belonging to mica schists and biotite schists observed in Sugözü complex

The Name of Mineral	The Name of Rock						
	Garnet-mica schist	Garnet-feldspar-mica schist	Staurolite-garnet-mica schist	Kyanite-garnet-mica schist	Sillimanite-kyanite-mica schist	Garnet-staurolite-biotite schist	Garnet-kyanite-sillimanite-biotite schist
Quartz	22	16	12	17	20	26	17
Muscovite	28	13	13	11	10	-	-
Biotite	14	31	27	30	30	40	35
Garnet	15	10	12	14	3	7	7
Kyanite	-	2	2	10	17	-	10
Staurolite	-	3	10	-	2	15	3
Sillimanite	-	3	6	4	7	-	15
Plagioclase	2	9	2	2	3	3	2
Orthoclase	-	6	4	4	3	-	3
Epidote	1	-	1	2	-	-	1
Zoisite/Clinzoisite	-	2	1	-	-	2	-
Chlorite	15	3	9	3	2	3	5
Graphite	1	-	-	1	-	-	-
Tourmaline	-	1	1	-	1	1	1
Rutile	-	1	-	1	-	1	-
Apatite	1	-	-	-	1	1	-
Sphene	1	1	-	1	1	1	1
<b>TOTAL</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Sugözü complex (middle nappe) tectonically covers the Mahmutlar group (lower nappe) at southwest of the study area (Figure 2). In this region, the blocks of Cambrian aged cherty dolomites belonging to the Mahmutlar group are abundant observed in the Sugözü complex, especially in places near the Sugözü complex - Mahmutlar group border. Sugözü complex must have taken these blocks into itself during the thrust. In the study area, the metamorphism at the greenschist facies, which developed in the last phase and affected the whole of the Alanya Unit (Özgül, 1984; Kansun et al., 2018), erased the contacts of the nappe. On the other hand, there is the significant difference between the Sugözü complex and the Mahmutlar group in terms of the metamorphism conditions. While the Sugözü complex had the metamorphism characteristics at high temperature reaching the upper amphibolite facies conditions, the Mahmutlar group below this complex underwent to the metamorphism at lower temperatures and lower pressures (Kansun et al., 2017; Kansun et al., 2018). All these features indicate that there is no the stratigraphic relationship between the Sugözü complex and the Mahmutlar group, and that the Sugözü complex covers tectonically the Mahmutlar group.

Sugözü complex is tectonically overlain by Yumrudağ group (upper nappe) at large section of the study area (Figure 2). As at the transition of Sugözü complex - Mahmutlar group, the schistosity planes, which are one another compatible, are observed in metapelitic rocks at the transition of Sugözü complex - Yumrudağ group. On the other hand, some features observed both at the transitions of lower nappe - middle nappe and at the transitions middle nappe - upper nappe point out that these contacts are the tectonic contacts. These features are densely folded - overturned folds in the metapelitic rocks, the reduction grain sizes in metapelitic rocks, the reduction of thickness of schistosity planes in metapelitic rocks, formation of cataclastic rocks, such as mylonite and mylonite schist, the widely chlorite formation as a result of retrograde reactions in metabasic and metapelitic rocks. The one another concordant schistosity observed along the contacts of both Sugözü complex - Mahmutlar group and Sugözü complex - Yumrudağ group came up as a result of a retrograde metamorphism simultaneously or subsequently with the nappe emplacements.

Since the Sugözü complex is limited to the tectonic contact from the top and the bottom, the stratigraphic thickness of Sugözü complex is variable. It shows a thickness of 750 m in the vicinity of Akine Neighborhood and Kadılar Neighborhood (Figure 2), where the thickest outcrops occur.

Dim formation belonging to Mahmutlar group (lower nappe) and Ağzıkara formation belonging to Yumrudağ group (upper nappe) show great similarities in the study area. The both formations are composed of micaschists containing quartzite, cherty dolomite, crystallized limestone interlevés and greenschist bands-lenses. The metamorphism characteristics of both formations showing Lower-Middle Cambrian age are similar. Likewise, both in the Mahmutlar group (Kansun, 2000) and in the Yumrudağ group, the Upper Permian aged lithologies, which are composed of metapelitic-metasepic-metacarbonate rocks as the fine level at the bottom and thick metacarbonates including greenschist interlevels at the top, are unconformably observed above the Upper-Middle Cambrian aged lithologies. These Upper Permian lithologies are observed as Degirmendere formation belonging to Yumrudağ group in the study area and as Sindebeleni formation belonging to Mahmutlar group in Alanya region (Kansun, 2000) outside of the study area. These similarities observed both as the lithological and as metamorphism conditions at the both lower nappe and upper nappe in Alanya Unit show that they were in the same stratigraphic level before the nappe emplacement and that the similar levels covered each other along the tectonic lines as a result of the nappe emplacement with the ruptures at the stratigraphic sequence in Alanya unit. Initially, the metapelitic and metabasic rocks belonging to Sugözü complex, which form the middle nappe within Alanya Unit, underwent the metamorphism at higher temperatures and higher pressures than the metapelitic and metapsammitic rocks, which form the lower and upper nappes (Kansun, 2000; Kansun et al., 2017; Kansun et al., 2018). The fact that this initial metamorphism

observed in Sugözü complex in the study area occurs in the Upper amphibolite facies (Kansun et al., 2017; Kansun et al., 2018) indicates that the Sugözü complex as primitive was formed in deeper parts of the crust compared to the lower and upper nappe lithologies. The initial metamorphisms in lower and upper nappe came true at the maximum greenschist facies conditions (Kansun et al., 2017; Kansun et al., 2018). Therefore, all these features indicate that Sugözü complex are located at the bottom of Mahmutlar group and Yumruadağ group before the nappe emplacement and that the nappe emplacement in the Alanya Unit is formed as a result of the ruptures at the stratigraphic sequence. Eventually, the lithologies within the Alanya Unit covered each other along the tectonic lines. As a result, at the primitive position before the nappe emplacements in the Alanya Unit, the sedimentation age of the Sugözü complex, which took place under of the Lower-Middle Cambrian aged lithologies, should be Precambrian.

Çetinkaplan (2018), in his study around Anamur, described the metaclastics, which underwent at high temperature and were cut by basic and acidic metamagmatics, as Sariağaç unite at the base of Alanya Unit. This unit corresponds to the middle nappe lithologies within the Alanya Unit. Çetinkaplan (2018) sayed that the age of the acidic metamagmatics, which cut the metaclastics in this unit, was  $550.2 \pm 8.2$  Ma and that the primitive age of Sariağaç unit might be Precambrian.

Since Sugözü complex is an allochthonous mass in the study area, the settlement age of the complex is important for illuminating the geology of the study area.

The Cambrian and Upper Permian aged metacarbonate and quartzite blocks belonging to Alanya Unit are observed in the Sugözü complex in the study area. These blocks must have settled in the Sugözü complex during the nappe emplacements in the Alanya unit and the settlement of the complex. Jurassic aged lithologies were not observed both in the study area and in Alanya Unit shown at Alanya region (Kansun, 2000).

The Sugözü complex shows great similarities with the Upper Cretaceous aged “Chaotic series”, which was defined between Demirtaş-Gazipaşa (Erbay, 1998) and around Payallar (Öztürk et al., 1995). In particular, Erbay (1998) states that the unit containing widely serpentinite has the melange character.

Upper Senonian-Lower Tertiary (?) aged the mixed with ophiolite consisting of serpentinite, basic metavolcanite, glaucophane schist and metaclastic rocks is observed along the lower contact of Alanya Unit between the border of Alanya and Antalya Units at Gündoğmuş region (Antalya) (Şengül et al., 1978; Özgül, 1984). Özgül (1984) sayed that the oceanic crust developed before the Senonian in the region and that the part belonging to this crust covered Antalya Unit together with Alanya Unit as the dagger of complex with ophiolite, which show high pressure metamorphism, as a result of the closing, that started in the Senonian. This researcher stated that this thrust occurred during the end of Senonian - Pre-Lutetian. The fact that Alanya Unit covered Antalya Unit also caused the nappe emplacements within the Alanya Unit (Kansun et al., 2017).

Sugözü complex contains widely metabasite interlevels together with metapelitic-metasemipelitic-metapsammitic rocks in the study area. Also, Sugözü complex contains serpentinites between Demirtaş-Gazipaşa (Erbay, 1998). Therefore, Sugözü complex show the ophiolitic character.

The fact that the metamorphism developed at the Upper Paleocene-Lower Eocene aged greenschist facies, which affected the whole Alanya Unit and developed at the last metamorphism phase (Kansun, 2000), obliterated nappe contacts shows that the age of the greenschist metamorphism is synchronous or younger with the nappe emplacements in Alanya Unit.

According to the above informations, the settlement age of the Sugözü complex (middle nappe) should be Upper Cretaceous-Paleocene (?).

### **3.1.2.1. Akine Metabasite Member**

It consists of amphibolite, amphibole schist, greenschist, metagabbro and metadiabase. It is generally observed at dimensions, which can not is mapped, as thin levels in metapelitic and metapsammitic rocks belonging to Sugözü complex. In contrast, some metabasites observed as relatively thick levels have been shown on the geological map. The metagabros observed in Sugözü complex belonging to Alanya Unit in the east of the Alanya were called as “Yalçı metagabbro” by (Kansun, 2000). This researcher identified the other metabasites (eclogite, glaucophanite, amphibolite and greenschist) in Sugözü complex as interlevels in garnet-mica schists, and he showed them at the geological map because the metabasites had small dimensions. These metabasites are widely and typically observed especially at Akine Neighborhood vicinity at the north of the study area (Figures 2 and 11). Therefore, these metabasites were named as Akine metabasite member. Also, the metabasites are widely shown between the Evciler and Narince Neighborhoods at the southeast of the study area (Figure 2).

The Akine metabasite member consists of amphibolite, amphibol schist and greenschist as bands and lenses and metagabbro and metadiabase as dykes and interlevels within metapelitic rocks belonging to Sugözü complex (Figures 3 and 11). All these metabasic rocks show green, blackish green and grayish green colors and very hard structure (Figure 22). These metabasites, which sometimes have a blocky appearance, show generally massive and sometimes weak foliation structures. In particular, the lengths of bands and lenses of amphibolites with dykes and interlevels of metagabbros and metadiabases are in the range of 5-80 m. The widths of them are in the range of 2-50 m. Some of them are smaller in sizes.

Amphibolites, amphibole schists and greenschists are seen as compatible interlevels with the foliation of mica schists and biotite schists belonging to the Sugözü complex. Metagabros and metadiabases are sometimes compatible with the foliations of schists, and cut sometimes the these foliations (Figure 22-c). Especially, brown garnet crystals are quite prominent in garnet-amphibolites (Figure 22-d). In addition, large hornblende porphyroblasts are observed in some metabasic rocks.

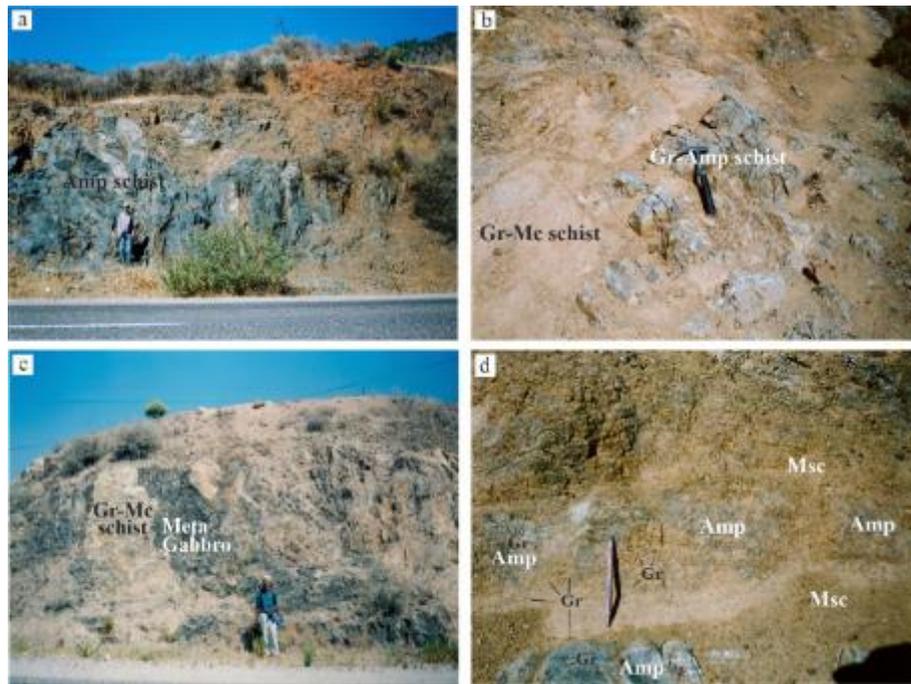


Figure 22. a) The view of the amphibole schists belonging to Akine metabasite member at the northeast of Kadilar Neighborhood, b) The garnet-amphibole schists, which are observed as interlevels in garnet-mica schists at the north of Narince Neighborhood, c) The metagabbro dykes (dark areas) observed in garnet-mica schists, d) Brown colored garnet porphyroblasts (Gr) in garnet-mica schists (Msc) and in garnet-amphibole schists (Amp) interlevels observed in within these mica schists at north of Narince Neighborhood

The **amphibolites** and **amphibole schists** in the Sugözü complex contain hornblende (tschermacite, ferro-tchermacite, magnesio-hornblende and edenite) + garnet + plagioclase (albite-oligoclase-andesine) ± relic clinopyroxene (augite-pigeonite) + chlorite (ripidolite, clinochlore) ± orthoclase ± epidote ± zoisite / clinozoisite ± biotite (green, brown) ± actinolite ± muscovite ± quartz ± calcite ± sphene ± apatite ± rutile. These metabasic rocks show porphyroblastic and nematoblastic textures.

**Amphiboles** are commonly composed of tchermacite, ferro-tchermacite, magnesio-hornblende, sometimes edenite and a small amount of actinolite (Figure 23).

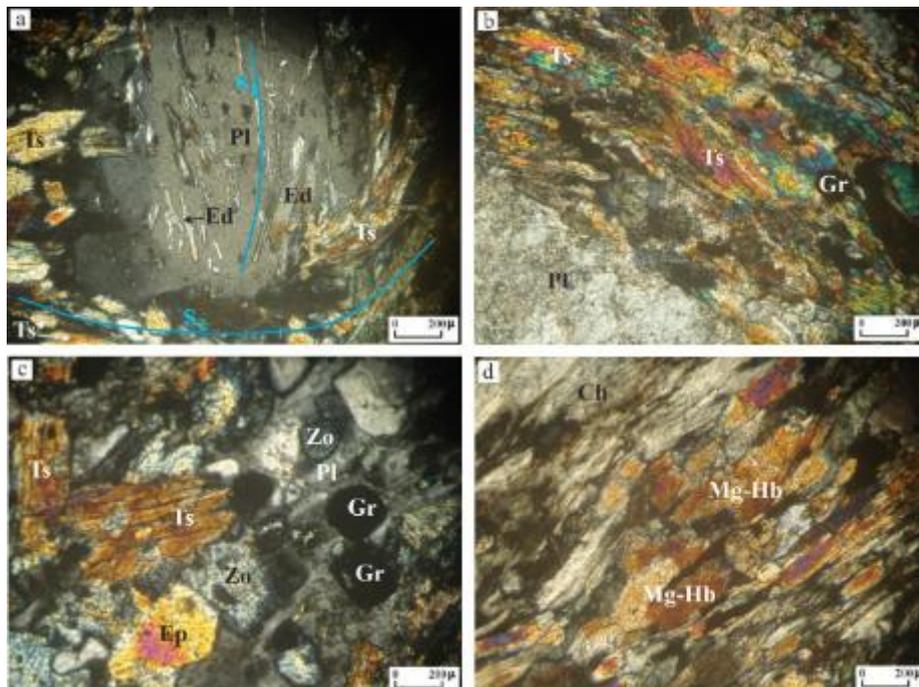


Figure 23. a) The plagioclase (Pl) porphyroblast, edenite (Ed) and tschermacite (Ts) in amphibole schist belonging to Akine metabasite member, b) The tschermacite, garnet (Gr), and plagioclase porphyroblast which turned into sericite in garnet-amphibole schist, c) The tschermacite, garnet, plagioclase, epidote (Ep) and zoisite (Zo) in garnet-amphibolite, d) The magnesio-hornblende (Mg-Hb) and chlorite (Ch) in amphibole schist. // Nicol

**Edenites** show prismatic shape, green-dark green colors and oblique extinction between  $20^{\circ}$  -  $24^{\circ}$ . The plagioclase porphyroblasts contain edenite inclusions, which elongate in a direction and form  $S_1$  foliation, in some amphibole schist samples (Figure 23-a). These inclusions are incompatible with  $S_2$  foliation which consist of tschermacites surrounding the plagioclase porphyroblast. Other amphiboles observed commonly in amphibolite and amphibole schists are **tschermacite** and **ferro-tschermacite** (Figures 23-a, b and c). They show generally long prismatic shapes. The tschermacites show brownish green color, and the ferro-tschermacites show green-dark green colors. The tschermacites showing oblique extinction between  $15^{\circ}$  -  $22^{\circ}$  are sometimes observed as porphyroblasts in metabasites. The garnet, epidote, quartz, plagioclase, zoisite and relic clinopyroxen inclusions are observed in these porphyroblasts. The tschermacites are seen as long prismatic crystals, which are parallel to  $S_2$  foliation, especially in amphibole schists (Figure 23-b). The tschermacites have been transformed into chlorite and actinolite from the crystal edges with the retrograde reactions.

The **magnesio-hornblendes** show prismatic shape, oblique extinction between  $16^{\circ}$  -  $22^{\circ}$  and distinctly green color. These are particularly observed in amphibole schists that are relatively rich in chlorite (Figure 23-d). Magnesio-hornblendes are seen as prismatic crystals elongated in one direction in amphibole schists, and they form together with tchermacites form the  $S_2$  foliation of the rock (Figure 23-d). Magnesio-hornblendes probably have consisted of garnets.

The magnesio-hornblende (green colored) and the tschermacite (brownish green colored) minerals, which form  $S_2$  foliation of the amphibole schists, indicate the regular increase in temperature developing at the amphibolite facies in the environment. The fibrous **actinolites** observed in very small amounts in the metabasites have consisted of garnet and tschermacite with the retrograde reactions.

**Garnets** are generally observed as sub-idioblastic and hexagonal-octagonal porphyroblasts (Figures 23-c and 24-a). They are sometimes seen as smaller idiomorphic crystals in plagioclase porphyroblasts (Figure 24-b). Garnets are characterized by their colorless-pale yellow colors and their isotropic features in the metabasites. Garnet porphyroblasts containing quartz, tschermacite and actinolite inclusions are surrounded by  $S_2$  foliation which consist of tschermacites. In addition, the garnets, which are observed as parallel to  $S_2$  foliation which consist of chermacites and form budinaj structure, are seen. Therefore, these garnet porphyroblasts are before the formation of tchermacites, and these garnets are pre-tectonic according to the  $F_2$  deformation phase.

Some garnet porphyroblasts, which are idiomorphic – sub-idiomorphic, have cut tschermacites, ferro-tschermacites and magnesio-hornblendes, which form  $S_2$  foliation. This shows that the formation of the garnets continues after tschermacite and magnesio-hornblendes and that the garnets are post-tectonic according to the  $F_2$  deformation phase. These garnets, which are the product of the first phase metamorphism and develop at high pressures (Kansun et al., 2018), have been transformed into sometimes ferro-tschermacite from the crystal edges due to possibly the decrease in pressure. Garnets have partly or completely transformed into chlorite, epidote and actinolite in amphibolite and amphibole schists. This indicates the retrograde metamorphism, which occur at low temperature, at environment. In the garnets observed in garnet-amphibolites, Ca (grossular) content decreases from the center to the edge, and Mg (prop) and Fe (almandine) contents increases from the center to the edge (Kansun et al., 2018). This indicates the decreasing pressure in the environment.

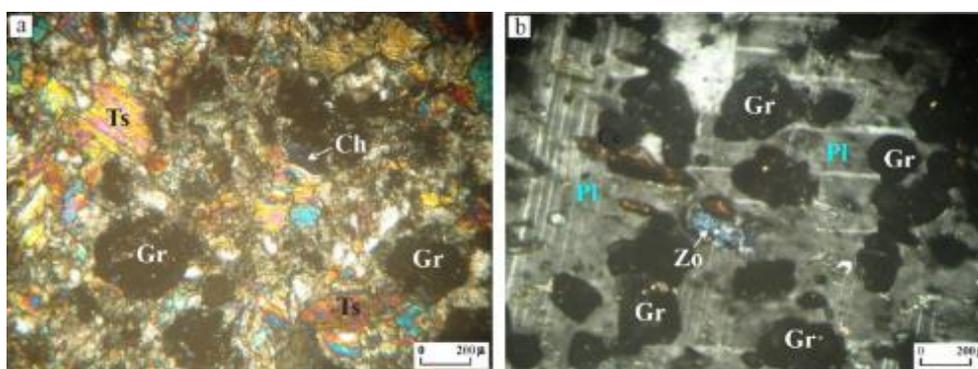


Figure 24. a) The garnet-amphibolite belonging to Sugözü complex, Ts: Tschermacite, Gr: Garnet, b) Garnet and zoisite (Zo) observed in plagioclase (Pl) porphyroblast in garnet-amphibolite. // Nicol

**Feldspars** are observed as plagioclase and orthoclase in amphibolite and amphibole schists (Figures 23-a, b, c and 24-d). **Plagioclases**, which are generally seen as porphyroblasts, are sub-idioblastic-prismatic, and the twinning is prominent some of them (Figures 23-c and 24-d). The hornblende (mostly edenite), garnet, clinopyroxen (relic), epidote, quartz and tourmaline inclusions are observed in plagioclase porphyroblasts (Figures 23-a and 24-d). The edenite inclusions, which elongate in a direction and show sometimes folded structure, in these plagioclase porphyroblasts surrounded by the  $S_2$  foliation plane, which formed by tschermacites, form the  $S_1$  foliation plane of the rock (Figure 23-a). Therefore, these plagioclases showing helicitic texture have crystallized as post-tectonic according to  $F_1$  deformation phase and as pre-tectonic according to  $F_2$  deformation phase. According to extinction angle determinations, the plagioclases in amphibolites and amphibole schists are albite ( $Ab_{92}An_{08}$ ), oligoclase ( $Ab_{75}An_{25}$ ,  $Ab_{76}An_{24}$ ) and andezin ( $Ab_{62}An_{38}$ ,  $Ab_{64}An_{36}$ ). Plagioclase porphyroblasts observed in amphibol schists show the increase at anorthite content from the center to the edge (Kansun et al., 2018). This indicates an increasing temperature in the environment. **Orthoclases** are generally xenomorphic crystals and show abundant inclusions. The orthoclases and plagioclases were sometimes transformed into sericite with retrograde metamorphism (Figure 23-b).

**Metagabbros** and **metadiabases** belonging to Sugözü complex show blastoporphic and blastoophytic textures in micro samples. The schistosity structure, which is formed as a result that hornblendes elongate in one direction is seen in particularly some

metagabbros. Mineral paragenesis in **metagabbros** are *hornblende (tschermacite, ferro-tschermacite) + plagioclase (albite-oligoclase-andesine) + relic clinopyroxene (augite) ± garnet + quartz + chlorite (pennin-clinoclare) ± actinolite ± zoisite/clinozoisite ± epidote ± sphene ± apatite*. *Hornblende (tschermacite, ferro-tschermacite) + plagioclase (albite-oligoclase) + chlorite (ripidolite) + quartz + relic clinopyroxene (augite) ± epidote ± zoisite / clinozoisite ± calcite ± sphene ± apatite* are observed in **metadiabases**.

**Amphibole**; The amphibole crystals in metagabbros and metadiabases are tschermacite, ferro-tschermacite and actinolite. **Tschermacite** and **ferro-tschermacite** porphyroblasts are observed in the fine-grained phase composed of relic augites in particularly metagabbros (Figure 25-a). These tschermacites were formed by progressive reactions from augites. The augite relics are sometimes observed in these tschermacite and ferro-tschermacite porphyroblasts (Figures 25-a and b). The ferro-tschermacites which transformed from garnet are seen at the edge zones of some garnet porphyroblasts in metagabbros. This show that garnets turn to ferro-tschermacites depending on the increased temperature in the environment. The tschermacites and ferro-tschermacites have caused the schistosity at these rocks by extending in a direction in some metagabbros and metadiabases. The fibrous **actinolites** have formed with retrograde reactions from garnets in particularly metagabbros. In addition, some tschermacites have turned to chlorite with retrograde metamorphism from their crystal edges in metadiabases (Figure 25-f).

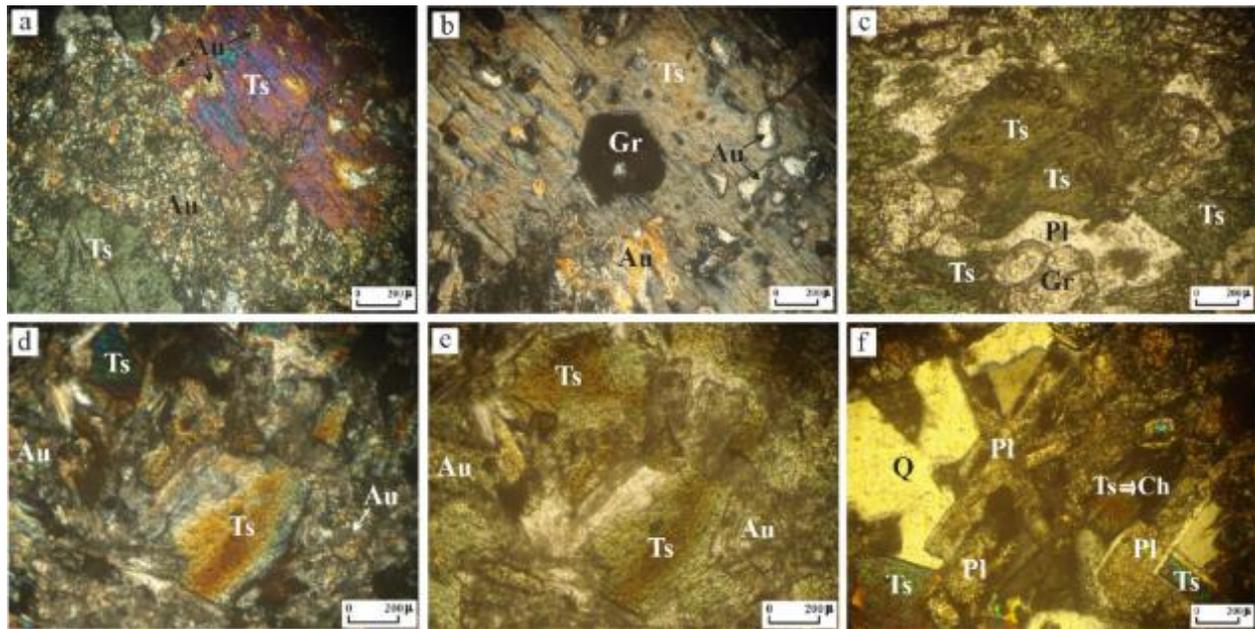


Figure 25. a) The tschermacite (Ts) porphyroblasts in the fine-grained phase consisting of augite (Au) in metagabbro belonging to the Akine metabasite member, b) Relic augites observed in chermacite porphyroblast in metagabbro, Gr: Garnet, c) Greenish brown tschermacite, garnet and plagioclase (Pl) in metagabbro, d and e) Greenish brown tschermacite and augite in metadiabases, f) Plagioclase lathas which turned to sericite, tschermacite, quartz (Q), and tschermacite which turned to chlorite from their edges (Ts ⇒ Ch) in metadiabase. a, b, d and f) // Nicol, c and e) / Nicol

**Plagioclases** are observed as big crystals together with garnets and tschermacites in the fine-grained phase composed of relic augites in particularly metagabbros (Figure 26-a). These plagioclase porphyroblasts contain generally abundant inclusions. The inclusions consist of mostly augite relics (Figure 26-a). Plagioclases are generally observed as porphyroblasts in metagabbros. Plagioclases observed in metadiabases are in the shape of long prismatic lathas (Figures 25-f and 26-b). Plagioclases are in albite (Ab<sub>93</sub>An<sub>07</sub>), oligoclase (Ab<sub>74</sub>An<sub>26</sub>) and andesine (Ab<sub>63</sub>An<sub>37</sub>) compositions in metagabbro and metadiabases. It is seen sericite formations as a result of retrograde reactions in these plagioclases (Figures 25-f and 26-b).

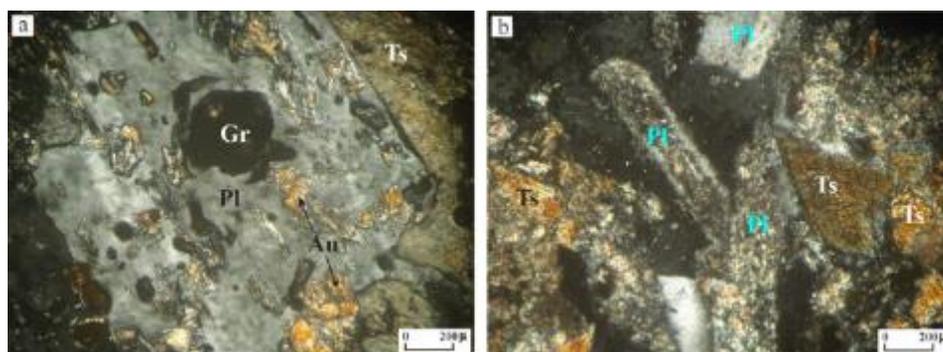


Figure 26. a) In metagabbro, garnet (Gr) in plagioclase (Pl) porphyroblast, and relic augites (Au). Ts: Tschermacite, b) In metadiabase, plagioclase (Pl) lathas which turned to sericite, and tschermacites. // Nicol

**Garnets** are observed as sometimes porphyroblasts and as sometimes crystals at smaller sizes in porphyroblasts of plagioclase and tschermacite in metagabbros (Figures 25-b and c, 26-a). The garnets observed in the metagabbros were formed by progressive reactions from the augites (Figure 27). These garnets have transformed into ferro-tschermacites from their crystal edges depending on decreasing pressure and increased temperature in the environment (Figure 27). In addition, some garnets have transformed into the epidote.

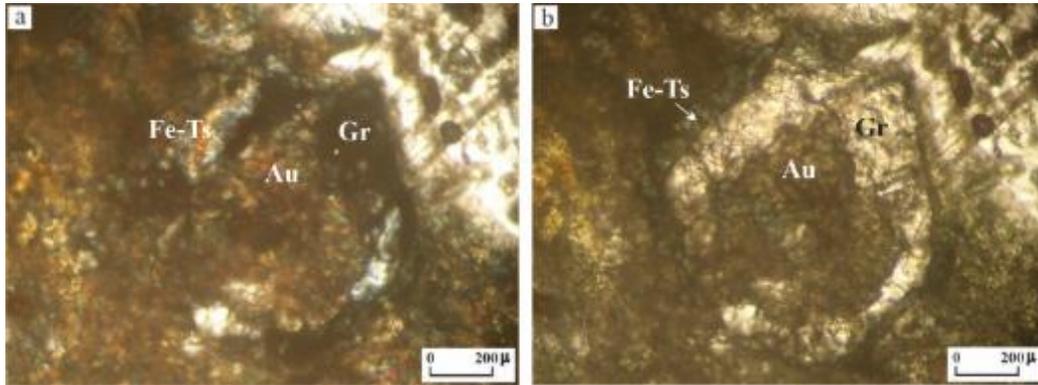


Figure 27. The Augite (Au)  $\Rightarrow$  Garnet (Gr)  $\Rightarrow$  Ferro-tschermacite (Fe-Ts) reaction in metagabbro. a) // Nicol, b) / Nicol

**Relic Clinopyroxene (Augite)** is seen up to 25% in especially metagabbro. The augites observed as relics of magmatic rocks before the metamorphism are generally found as the fine-grained phase in metagabbros (Figure 25-a). These augites, which protect from metamorphism and alteration, show a prismatic shape, cleavage which are perpendicular to each other, very pale green color, and oblique extinction between approximately 40°-45° (Figure 28). The majority of these relic augites have transformed into tschermacite, ferro-tschermacite, garnet and chlorite with advancing reactions in metagabbros and metadiabases (Figure 27).

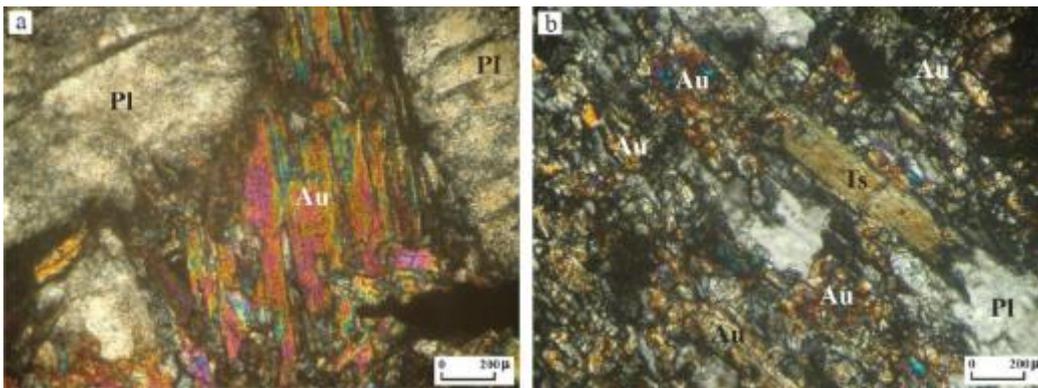


Figure 28. a) In metagabbro belonging to Akine metabasite member; augite (Au) relic, and plagioclases (Pl) that turn into sericite, b) Metagabbro showing schistosity with the effect of metamorphism. Ts: Tschermacite. // Nicol

The **greenschists** observed in the Akine metabasite member are consist of “zoisite - tremolite schist”, “chlorite - tremolite schist” and “garnet - chlorite - tremolite schist” (Figure 29). The metabasic rocks show granonematoblastic, nematoblastic and porphyroblastic textures. The mineralogical composition in the greenschists is tremolite + actinolite + chlorite (ripidolite-pinochlorite) + plagioclase (albite)  $\pm$  garnet + zoisite / clinozoisite + epidote  $\pm$  quartz  $\pm$  microcline  $\pm$  biotite (green)  $\pm$  clinopyroxene (augite) (relic)  $\pm$  calcite + sphene  $\pm$  apatite.

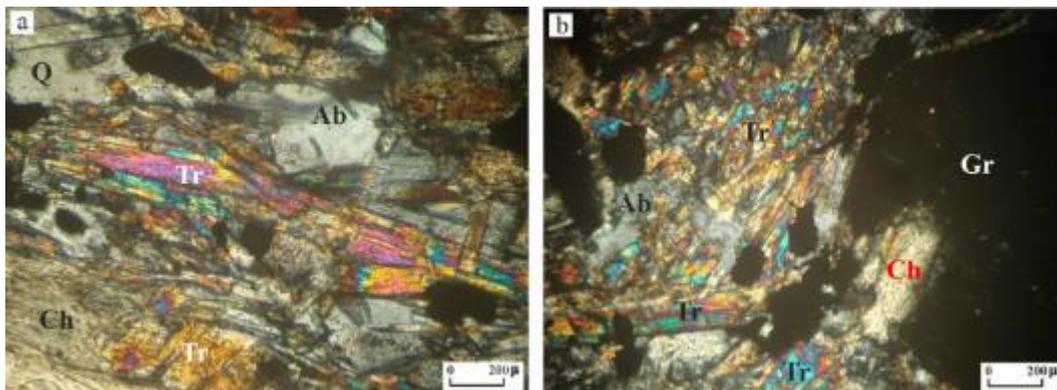


Figure 29. a) Tremolite (Tr), chlorite (Ch) and albite (Ab) in garnet-chlorite-tremolite schist belonging to Akine metabasite member, b) Garnet (Gr) porphyroblast, tremolite, albite and chlorite garnet in garnet-chlorite-tremolite schist. // Nicol

**Tremolites** and **actinolites** show fibrous and prismatic shapes in greenschists (Figure 29). Actinolites are green colored, while tremolites are colorless or very pale green colored. Particularly, tremolites observed in garnet-chlorite-tremolite schists have formed with prograde reactions from augites. **Chlorites** are in Mg-Fe chlorite (ripidolite-picnochlorite) composition (Figure 29-a), and they forms the major component of chlorite schists. **Garnets** are seen as porphyroblast in especially garnet-chlorite-tremolite schists (Figure 29-b). In the garnet porphyroblasts of garnet-chlorite-tremolite schists, Ca (grossular) content decreases from the center towards the edge, whereas Mg (prop) and Fe (almandine) contents increase from the center towards the edge (Kansun et al., 2018). Therefore, there is a decreasing pressure in the environment. These garnet porphyroblasts have transformed into chlorite with retrograde metamorphism from their edges. **Feldspars** are observed as plagioclase and microcline in greenschists. Plagioclases are mostly seen as porphyroblasts, and they contain abundant inclusion. Plagioclases are in albite (Ab<sub>92</sub>An<sub>08</sub>, Ab<sub>94</sub>An<sub>06</sub>) composition in greenschists.

The minerals and percentage values determined in amphibol schist, amphibolite, metagabbro, metadiabase and greenschist belonging to Akine metabasite member are shown in Table 3.

Table 3. The components, percentage values and rock names of ten samples belonging to amphibol schist, amphibolite, metagabbro, metadiabase and greenschist observed in Akine metabasite member

The Name of Mineral	The Name of Rock									
	Amphibole schist	Garnet-amphibolite	Garnet-amphibolite	Meta gabbro	Meta gabbro	Meta gabbro	Meta diabase	Zoisite-tremolite schist	Chlorite-tremolite schist	Garnet-chlorite-tremolite schist
Tschermakite and Ferrous-tschermakite	16	33	32	34	41	48	33	-	-	-
Magnesio-hornblende	20	4	5	-	-	-	-	-	-	-
Edenite	3	4	2	-	-	-	-	-	-	-
Plagioclase	13	11	17	18	17	14	25	17	16	15
Clinopyroxene (Augite) (relic)	-	-	-	21	25	19	7	1	-	3
Clinopyroxene (Augite-Pigeonite) (relic)	-	2	-	-	-	-	-	-	-	-
Garnet	-	16	15	14	-	6	-	-	-	15
Quartz	4	4	3	3	2	3	8	-	4	3
Chlorite	27	11	9	1	4	4	15	5	27	18
Epidote	5	3	4	4	4	2	5	5	3	1
Zoisite/Clinozoisite	4	-	4	3	2	1	3	23	2	5
Actinolite	2	4	3	-	2	2	-	3	3	-
Tremolite	-	-	-	-	-	-	-	43	38	36
Biotite (brown)	2	1	-	-	-	-	-	-	-	-
Biotite (green)	-	-	3	-	-	-	-	-	-	2
Muscovite	1	1	-	-	-	-	-	-	-	-
Orthoclase	-	2	-	-	-	-	-	-	-	-
Microcline	-	-	-	-	-	-	-	1	-	1
Calcite	-	-	-	-	-	-	2	-	4	-
Rutile	1	1	-	-	-	-	-	-	-	-
Sphene	1	2	2	1	2	1	1	1	2	1
Apatite	1	1	1	1	1	-	1	1	1	-
<b>TOTAL</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

The metabasic rocks belonging to Akine metabasite member are mostly compatible with Precambrian aged metapelitic-metasemipelitic schists belonging to Sugözü complex in the study area. Amphibolites, amphibol schists and greenschists are observed as the interlevels which are compatible with the foliation of mica schists and biotite schists belonging to Sugözü complex. Amphibol schists and greenschists show the foliation. Whereas, metagabbros and metadiabases are sometimes compatible with the foliation of these schists and sometimes interrupt this foliation.

Çetinkaplan (2018), in his study at Anamur region, stated that Precambrian aged metaclastics (Sarıağaç unit), which corresponds to the middle nappe (Sugözü complex) of Alanya Unit, were cut by basic and acidic (550.2 ± 8.2 Ma) metamagmatites. The acidic metamagmatites have been not observed in Sugözü complex in the study area. On the other hand, metagabbros and metadiabases which are basic metamagmatites cut metapelitic and metasemipelitic rocks at some levels within Sugözü complex.

Özgül (1984) mentioned from the formation of an oceanic crust that continues its development throughout the Dogger-Lower Maestrichtian at Alanya region. Kansun (2000) specified that the metagabbros observed in Sugözü complex at Alanya region taken place in the form of blocks within the Sugözü complex with a relatively ophiolitic character and that Sugözü complex was settled the region along the Upper Cretaceous-Paleocene (?) depending on subduction events and the nappe emplacements. Thus, this researcher suggested that these metagabbros might be related to the formation of the Dogger-Lower Maestrichtian aged oceanic crust mentioned by (Özgül, 1984).

### 3.1.3. Yumruadağ Group (Upper Nappe)

The metamorphic imbricate which consisted of metapelites, metapsammities and metacarbonates observed at the upper levels of Alanya Unit was named as Yumruadağ group consisting of Upper Permian and Lower Triassic aged lithologies by Okay and Özgül (1982). Yumruadağ group is observed in areas where topography is higher than Mahmutlar group and Sugözü complex belonging to Alanya unit in the study area. Yumruadağ group was examined by dividing into two formations as Ağzıkara formation at the bottom and Değirmendere formation at the top in this study.

#### 3.1.3.1. Ağzıkara Formation

It is composed of mica schists and muscovite schists including quartzite, cherty dolomite, crystallized limestone interlevels and greenschist bands-lenses. These lithologies were named as Ağzıkara formation by Kansun (2000), referring to the vicinity of Ağzıkara Neighborhood (Alanya-Antalya), where they were typically observed. The formation is divided into three members by taking into account its lithological characteristics and its dimensions that can be mapped. These are Kesme member which consist of quartzites, Ardıçlı member which consist of cherty dolomites and Kodaman member which consist of metapelitic rocks (Figures 2 and 3).

Ağzıkara formation belonging to Yumruadağ group (upper nappe) show great similarities with the Lower-Middle Cambrian aged Dim formation belonging to Mahmutlar group (lower nappe) in the study area. The both formations consist of mica schists containing quartzite - cherty dolomite - crystallized limestone interlevels and greenschist bands-lenses. The metamorphism characteristics and ages of both formations are similar. These similarities observed at both their lithological properties and their metamorphism conditions in Ağzıkara formation belonging to upper nappe and Dim formation belonging to lower nappe indicate that they were at the same stratigraphic level before the nappe emplacements. Later, the breakings occurred the stratigraphic imbricate belonging to Alanya Unit. Thus, the similar levels in Alanya Unit covered each other along the tectonic lines as a result of the nappe emplacements.

##### 3.1.3.1.1. Kodaman Member

The member consists of feldspar-mica schist, mica schist and muscovite schists containing quartzite - cherty dolomite - crystallized limestone interlevels and greenschist bands-lenses (Figure 3). These lithologies are typically observed at Kodaman Neighborhood vicinity in the study area. Also, they are seen at Bucak Neighborhood, Kodaman Neighborhood, Güneyi Neighborhood, Gökteş Neighborhood, Kulak Neighborhood, Karalarbahşiş Neighborhood, Karaca Neighborhood, Gercebahşiş Neighborhood, Kızılkaya Hill, Sazlı Hill and Efeler Neighborhood vicinities (Figure 2).

The lithologies belonging to Kodaman member are characteristic with greenish gray, dark gray colors. The member is commonly made up of mica schists. Garnet-mica schists and feldspar-mica schists are observed as a fine level in the lower levels of the member. In addition, muscovite schists take place in the member. Micaschists are thin-medium grained and have generally thick schistosity (Figure 30-a). Large feldspar porphyroblasts are sometimes seen in feldspar-mica schists observed in the lower levels of the Kodaman member. Garnets in garnet-mica schists observed at these levels are seen as small size crystals at micro studies. The mica schists observed in places near the thrust boundary at the lower levels of the member show very often folded structures due to the thrust. The chlorites are intensely seen in these mica schists, and the mica schists show green color. The secondary quartz veins that develop parallel to foliation and reach a thickness of ~ 30 cm take place intensely in these mica schists. Also, kink-band structures, symmetrical - asymmetrical - overturned folds and z-folds developed in these mica schists due to intense deformations (Figure 30-b). Especially, the isoclinal oblique folds are quite prominent in quartz schists.

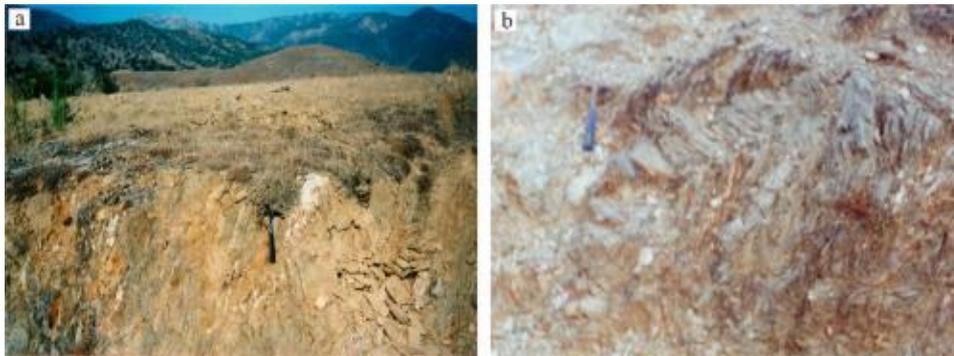


Figure 30. a) Mica schists and secondary quartz interlevels (white colored levels) belonging to Kodaman member, the west of Güneyi Neighborhood, b) Mica schists showing the frequent folded z-structure belonging to Kodaman member around Gökteş Neighborhood

The mica schists belonging to the Kodaman member are distinguished with some features of them from the mica schists belonging to Sugözü complex in macro samples. These features in mica schists belonging to the Kodaman member are that they not contain garnet porphyroblasts and amphibolite-metagabro-metadiabase bands-lenses and that contain cherty dolomite-quartzite interlevels.

The quartzites observed as interlevels in mica schists are gray-white-reddish in color, thin-bedded and sometimes in blocky appearance (Figure 31-a). These quartzites, which show an easily dispersible feature, show transition to sometimes quartz schists. The cherty dolomites observed as interlevels in mica schists are red-yellow altere colored, dark gray colored and medium-thick bedded

(Figure 31-b). These dolomites, which are quite hard structure, contain extensively chert interlevels. Milk-white quartz veins, which have 2-4 cm thickness, are observed in the dolomites. The *chalcopyrite + pyrite + bornite + malachite + azurite + hematite* paragenesis, which settle at vein-shaped in fractures and cracks, is observed in cherty dolomites at the southwest of Karalarbahşiş Neighborhood in the study area (Figures 2 and 31-c).



Figure 31. Parasitic fold in quartzite interlevels in mica schists at the east of Çiviler Neighborhood, b) Thick bedded cherty dolomite (Dol) interlevels in mica schists (Msc), the northwest of Kevinli Ubiety, c) Malachite (Ma) formations (green colored levels) observed in vein-shaped in cherty dolomites, the southwest of Karalarbahşiş Neighborhood

The crystallized limestone interlevels in the metapelitic schists are dark gray-gray colored, fine grained and thin-medium bedded. The crystallized limestones are observed as very thin levels in Kodaman member. The gray-brownish black colored chert levels, which are maximum 3 cm in thickness are seen in some crystallized limestones. These cherty crystallized limestones are coarse-grained. The graphite levels are sometimes observed in schists belonging to Kodaman member. The graphite schists show wide spread in especially the north of Bucak Neighborhood. The bands and lenses of greenschist, which are parallel to the schistosity of metapelitic rocks, take place within Kodaman member. The greenschists are yellowish green - green colored and show schistosity structure. Since the greenschists show dimensions that can not be mapped, their borders have been not shown in the geological map.

Kodaman member includes the brown alteration colored and Cambrian aged cherty dolomite blocks belonging to Mahmutlar group. These blocks must have settled within Kodaman member belonging to Ağzıkara formation at result that Yumruadağ group overlies Sugözü complex and Mahmutlar group. The mica schists belonging to Kodaman member have encircled of these dolomite blocks like the onion skin. These dolomite blocks are extensively seen in the member. Most of these blocks were not shown on the geology map because they are too small dimensions. The cherty dolomite blocks observed at the west of only Güneyi Neighborhood have been shown on the geological map (Figure 2).

Metapelitic rocks within the Kodaman member show porphyroblastic, granolepidoblastic and lepidoblastic textures. Greenschists in this member consist of chlorite-albite-actinolite schist and albite-chlorite schist. The greenschists show porphyroblastic, lepidoblastic, nematoblastic and occasionally fibroblastic textures. The mineralogical composition in **metapelitic rocks** consist of *muscovite + biotite (brown, green) + quartz ± chlorite (ripidolite) ± plagioclase (albite-oligoclase) ± garnet ± microcline ± graphite ± epidote ± calcite ± apatite ± sphen ± tourmaline (green)*. The **greenschists** include *chlorite (ripidolite-picnochlorite) ± actinolite + plagioclase (albite) + epidote + zoisite / clinozoisite ± calcite ± tremolite ± quartz ± muscovite ± clinopyroxene (relict) + sphene ± tourmaline ± apatite* mineral paragenesis.

**Micas** consist of muscovite and biotite in metapelitic schists (Figure 32). Biotites are mostly brown and sometimes green colored. The brown colored biotites observed in mica schists, which are present at regions near the thrust boundary, have almost completely transformed into chlorite (ripidolite) depending on retrograde metamorphism. The muscovites forms the major component of muscovite schist. Sometimes two different recrystallization planes are observed in mica schists and muscovite schists, like in the metapelitic rocks of Mahmutlar group and Sugözü complex. These are S<sub>1</sub> foliation planes, which formed with first phase deformations, and S<sub>2</sub> foliation planes, which formed with progressive deformations. S<sub>1</sub> foliation planes have been acquired kink-band structures as a result of deformations, and later, mucovite + biotite recrystallizations, which were formed S<sub>2</sub> foliation planes, have developed.

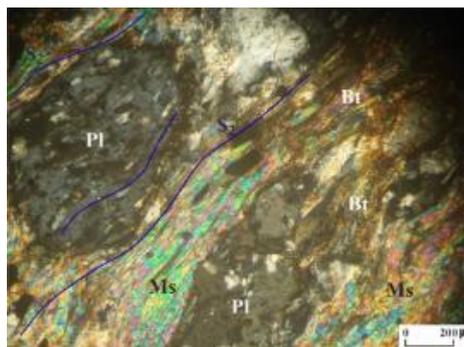


Figure 32. Muscovite (Ms), biotite (Bt), helicitic textured plagioclase (Pl) porphyroblast in feldspar-mica schist belonging to Kodaman member, // Nicol

**Feldspars** consist of plagioclase and microcline. **Plagioclases** are mostly inclusions and are observed as porphyroblasts in metapelitic schists and greenschists (Figure 32). The quartz, muscovite, graphite, epidote, zoisite / clinozoisite, sphene and opaque mineral form the inclusions. Some plagioclase porphyroblasts have surrounded by S<sub>2</sub> foliation planes, which consist of biotite and muscovite, in metapelitic schists. Therefore, the plagioclase porphyroblasts are pre-tectonic according to F<sub>2</sub> deformation phase. The inclusions, which have folded S-structure, within these plagioclase porphyroblasts show helicitic texture (Figure 32). Therefore, plagioclase porphyroblasts are therewithal post-tectonic according to F<sub>2</sub> deformation phase. Plagioclases in metapelitic schists are albite (Ab<sub>95</sub>An<sub>05</sub>) and oligoclase (Ab<sub>69</sub>An<sub>31</sub>). Plagioclases in greenschists are in albite (Ab<sub>93</sub>An<sub>07</sub>, Ab<sub>97</sub>An<sub>03</sub>) composition.

**Chlorite**; Two types of chlorite are seen in metapelitic rocks. Chlorites with green color are probably in “ripidolite” composition. These chlorites were formed from biotites as a result of retrograde metamorphism. The ripidolites are common within mica schists observed at regions near the border of particularly Ağzıkara formation - Sugözü complex. The primary chlorites observed in metapelitic rocks are pale green colored, and they are in possibly pennin-clinochlore (Mg-chlorite) composition. Chlorites observed within greenschists, are green-dark green colored, and they have probably ripidolite-picnochlorite (Mg-Fe chlorite) composition (Figure 33). **Garnet** take part in minor quantities within mica schists observed at the base of Kodaman member. These garnets are seen as sub-idioblastic and small crystals. They have been almost completely transformed into chlorite + quartz with retrograde metamorphism. **Actinolites** and **tremolites** observed within greenschists show prismatic and sometimes fibrous shapes (Figure 33).

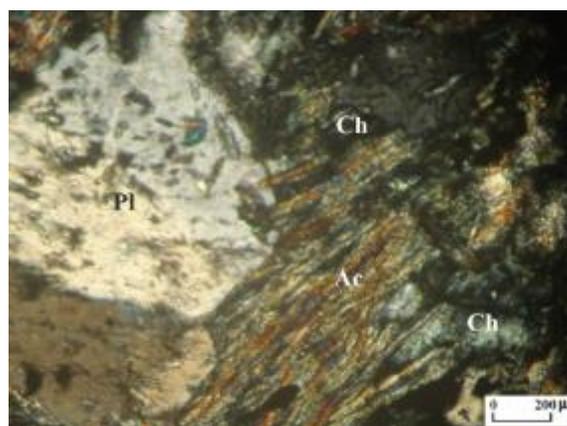


Figure 33. Actinolite (Ac), chlorite (Ch) and plagioclase (albite) (Pl) within chlorite-albite-actinolite schist belonging to Kodaman member, // Nicol

The components and percentage values observed in metapelitic schists and greenschists belonging to Kodaman member are given in Table 4.

Table 4. The components, percentage values of components and rock names of six samples belonging to metapelitic schists and greenschists observed in Kodaman member

The Name of Mineral	The Name of Rock					
	Mica schist	Feldspar-mica schist	Garnet-mica schist	Muscovite schist	Albite-chlorite schist	Chlorite-albite-actinolite schist
Muscovite	25	30	22	46	4	-
Biotite	20	14	28	-	-	-
Quartz	35	15	20	25	5	3
Chlorite	10	14	15	18	56	14
Actinolite	-	-	-	-	-	42
Plagioclase	4	20	6	4	27	22
Garnet	-	-	3	-	-	-
Microkline	2	-	1	2	-	-
Epidote	2	2	1	-	3	5
Zoisite/Clinozoisite	-	-	-	-	3	4
Clinopyroxene (relic)	-	-	-	-	-	5
Tremolite	-	-	-	-	-	2
Calcite	-	1	1	2	-	1
Graphite	1	-	-	1	-	-
Apatite	1	1	1	-	-	1
Sphene	-	2	1	1	1	1
Tourmaline	-	1	1	1	1	-
<b>TOTAL</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Kodaman member is located over the Sugözü complex with the tectonic contact. It is overlain unconformably by Değirmendere formation (Figures 2 and 3). It shows the visible thickness of approximately 1100 m at place where their thickest outcrops are seen.

Kodaman member shows the features which can be correlated with the Cambrian-Ordovician aged lithologies belonging to Çukuryurt unite described by Öztürk et al. (1995) in the western parts of Akdağ and with the Lower-Middle Cambrian aged Ağzıkara formation described by Kansun (1993) in Alanya region. Çukuryurt unite according to Öztürk et al. (1995) begins Lower Cambrian aged quartzites, which are yellowish red colored, and higher up passes Middle Cambrian aged cherty dolomite, which are red-brown colored, and Upper Cambrian-Ordovician aged pelitic schists.

In the study area, Kodaman member of Ağzıkara formation belonging to Yumruadağ group (upper nappe) shows great similarities with Lower-Middle Cambrian aged Yaylalı member of Dim formation belonging to Mahmutlar group (lower nappe). The both members consist of mica schists and muscovite schists containing greenschist lenses and crystallized limestone - quartzite - cherty dolomite interlevels. The both members initially underwent metamorphism under same metamorphism conditions before the nappe emplacements at Alanya Unit (Kansun, 2000; Kansun et al., 1997). These similarities show that they were in the same stratigraphic level before the nappe emplacements and that the similar levels covered each other along the tectonic lines as a result of the nappe emplacement with the ruptures at the stratigraphic sequence in Alanya unit. According to these datas, the age of Kodaman member is considered to be Lower-Middle Cambrian.

### 3.1.3.1.2. Kesme Member

It consist of commonly quartzites. It is typically observed at Kesme Hill vicinity in the study area. Also, the member are seen at Göbetle Hill, Çakmağıntaş Hill, Kocalıtaş Hill, the south of Kırbalı Neighborhood, the west of Karaca Neighborhood and Bucak Neighborhood vicinity in the study area (Figure 2).

Kesme member commonly contains quartzite (Figure 34-a). The mica-quartz schists take place as interlevels in these quartzites. The quartzites are grayish white-yellow-reddish colored and thin bedded. They have the blocky view. The quartzites are abundantly cracked. Parallel and cross lamination is seen within quartzites.

Quartzites and quartz schists show granoblastic and granolepidoblastic textures. The mineralogical composition of these rocks is quartz + muscovite + plagioclase ± epidote ± zoisite / clinzoisite ± microcline ± chlorite (ripidolite) ± biotite (brown) ± sericite ± sphene ± apatite (Figure 34-b and c). With retrograde metamorphism in some quartzite and quartz schist samples, biotites turned to chlorite, and plagioclases turned to sericite (Figure 34-c).

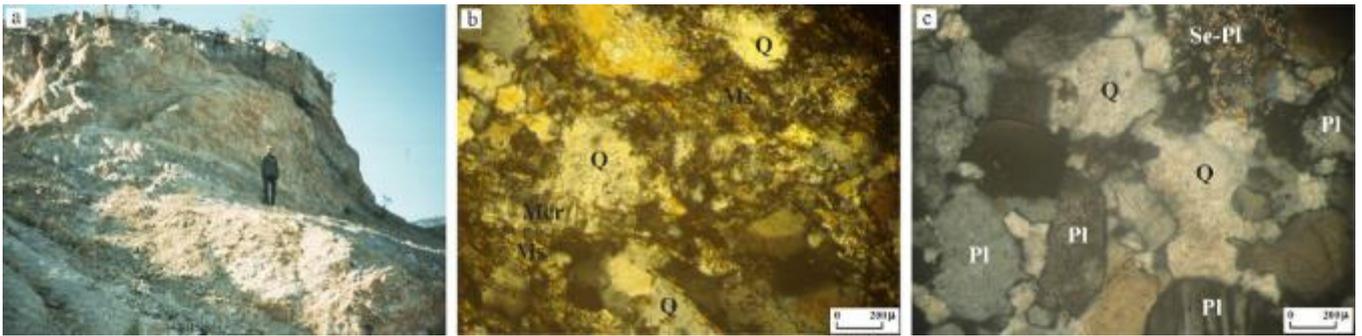


Figure 34. a) Quartzites belonging to Kesme member observed in the east of Güneyi neighborhood, b) Quartz (Q), muscovite (Ms) and microcline (Mcr) in mica-quartz schist, c) Plagioclase transforming into sericite (Se-Pl), quartz and plagioclase in feldspar-quartzite, // Nicol

Kesme member shows a visible thickness of approximately 350 m in the western parts of the study area, where the thickest outcrops of the member are observed. The quartzites belonging to Kesme member show vertical transition with metapelitic rocks belonging to Kodaman member from the bottom in the Ağzıkara formation, and these quartzites laterally and vertically transitive with Ardıçlı member consisting of cherty dolomites from the top (Figure 3).

Öztürk et al. (1995) defined the “Payallar unite” at the base levels of Alanya Unit in the northeast of Payallar, which is located west of the study area. The researchers indicated that quartzites observed at the base levels of Payallar unite were Lower Cambrian aged. Erbay (1998) stated that quartzites were found as compatible under the Middle Cambrian aged cherty dolomites containing trilobite at the lower levels of Alanya Unit and that these quartzites were Lower Cambrian aged. In the study area, the quartzites belonging to Keskin member are observed as compatible under cherty dolomites (Figure 3). Kansun (2000) stated that Ağzıkara formation, which was located in the upper Nappe of Alanya Unit in the Alanya region, consisted of metapelitic rocks containing quartzite - cherty dolomite interlevels and that the age of the formation was Lower-Middle Cambrian. The age the quartzites belonging to Kesme member are Lower Cambrian aged according to all these datas.

### 3.1.3.1.3. Ardıçlı Member

It is composed of cherty dolomites containing crystallized limestone interlevels. It has been named as Ardıçlı member, referring to the vicinity of Ardıçlı Ubiety, where it is typically observed. Also, Ardıçlı member are observed at the north of Ormancık Neighborhood, at west and southeast of Kesme Hill, at the north of Kulak Neighborhood, at the south of Kırbalı Neighborhood, at the west of Karaca Neighborhood, at the vicinities of Efeler Neighborhood and Sıraarmut Ubiety in the study area (Figure 2).

Ardıçlı member is commonly composed of dolomites. The dolomites are dark brown-reddish altere colored, gray colored and medium-thick bedded (Figure 35). They have a blocky appearance. These dolomites, which show sometimes brecciated structures, are generally fine grained. The chert interlevels, which are yellowish gray colored and show 2-3 cm thick, are observed in dolomites. Dolomites contain crack systems advanced in different directions. These cracks have been generally filled with milk white colored secondary quartzs. In the study area, almost everywhere, where Ardıçlı member is observed, quartzites are observed at the base of cherty dolomites within Ağzıkara formation. The cherty dolomites sometimes contain crystallized limestone levels, which are gray colored and thin bedded. Galenite formations in cherty dolomites the south of Kırbalı Neighborhood and barite formations in chert dolomites to the north of Ormancık Neighborhood are observed (Figure 2).



*Figure 35. The cherty dolomites belonging to Ardıçlı member observed the northwest of Kesme Hill*

The dolomites contain *dolomite + calcite ± quartz*. The ratio of dolomite crystals, which are typical with romboeder appearances within micro samples, is more than 90% in all dolomite samples. On the other hand, the ratio of calcite minerals in crystallized limestones is more than 90%.

Dolomites belonging to Ardıçlı member have a visible thickness of approximately 150 m. The dolomites of the Ardıçlı member show lateral-vertical transitions with mostly quartzites belonging to Kesme member from the base. They show vertical transition with metapelitic rocks belonging to Kodaman member from the top (Figure 3). Also, these dolomites are observed as interlevels at dimensions, which can not be mapped, in metapelitic rocks within Ağzıkara formation.

Erbay (1998) stated that Çaltepe formation, which was defined at the lower levels of Alanya Unit at his study, was composed of thick bedded dolomites, which contain chert nodules and barite veins and are brown-red alteration colored and gray colored. This researcher sayed that these dolomites contained trilobite fossils and that they were Middle Cambrian aged. Öztürk et al. (1995) defined Payallar unite at lower levels of Alanya Unit at the northeast of Payallar (Antalya). The researcher specified that Payallar unite consisted of Middle Cambrian aged dolomites, which contain chert nodules and barite veins and are brown-red surface colored. Kansun (2000) argued that the metapelitic rocks in the Ağzıkara formation observed in the upper nappe of Alanya Unit at Alanya (Antalya) region show lateral - vertical transition with cherty dolomites and quartzites and that the age of the cherty dolomites were Middle Cambrian. Therefore, cherty dolomites belonging to Ardıçlı member, which show very similar characteristics to the lithologies and boundary relations defined by these researchers in the study area, are Middle Cambrian aged.

### **3.1.3.2. Değirmendere Formation**

It is composed of alternation of quartz schist – phyllite – quartzite - crystallized limestone containing greenschist lenses at the bottom. Higher up, bituminous crystallized limestones containing calcschist - dolomitic limestone interlevels and greenschist lenses are observed. These lithologies were named as “Cebireis formation” by Okay and Özgül (1982), as “Upper Permian level of Çukuryurt unite” at the west of Akdağ by Öztürk et al. (1995), as “Topraktepe formation” and “Karatepe formation” by Erbay (1998). Kansun (2000) were named this imbricate, which consist of metapelitic rocks at the base and thick metacarbonates at the top, as Değirmendere formation at Alanya (Antalya) region. Değirmendere formation was examined by seperating to two members in the study. These are Çıplaklı member consisting of generally metapelitic rocks with lower temperature, and Tavşandamı member consisting of metacarbonates above it (Figures 2 and 3).

#### **3.1.3.2.1. Çıplaklı Member**

It consists of alternation of quartz schist – phyllite - quartzite - crystallized limestone containing greenschist lenses. It was named as Çıplaklı member belonging to Değirmendere formation at Alanya region by Kansun (2000). The member is observed as a narrow strip in the western and northern parts of the study area (Figure 2).

Çıplaklı member consists of alternation of quartz schist, phyllite, quartzite and crystallized limestone. The dominant lithology of Çıplaklı member is composed of quartz schists. The quartz schists are yellow-gray colored and show foliation. The quartzschists contain massive structured quartzite interlevels. The quartzit schists and quartzites show abundant cracked structure and are fragile. Phyllites are yellowish gray-greenish colored and show alternation with quartz schists at some levels in the member. Phyllites show very often folded structure. Crystallized limestones are gray colored, abundantly cracked and thin bedded. *Mizzia sp.* is observed at levels, where the bitumen rate increases, in crystallized limestones. The greenschist bands-lenses, which are parallel to foliation and

bedding, take place between metapelitic rocks and metacarbonates in Çıplaklı member. The greenschists that show evident foliation consist of chlorite schists. The Cambrian aged cherty dolomite blocks belonging to Mahmutlar group are observed in Çıplaklı member. These blocks must have settled within Çıplaklı member as a result that Yumruadağ group overlies Sugözü complex and Mahmutlar group.

**Quartz schists, quartzites and phyllites** show porphyroblastic, granolepidoblastic and granoblastic textures. The dominant mineralogical composition of these rocks is *quartz + muscovite + sericite ± biotite (green) ± chlorite (ripidolite-pinochlorite) ± epidote ± plagioclase (albite) ± calcite ± tourmaline (green)* (Figure 36). **Greenschists** show porphyroblastic and lepidoblastic textures. Greenschists include *chlorite (ripidolite-pinochlorite) + plagioclase (albite) + epidote + zoisite / clinozoisite ± actinolite ± calcite ± muscovite ± quartz + sphene* as mineralogical composition.

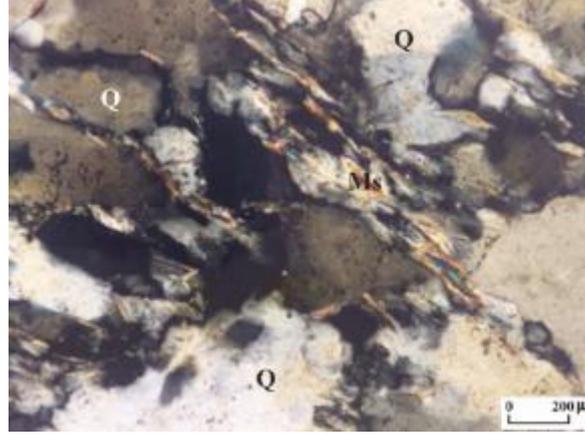


Figure 36. Quartz (Q) and muscovite (Ms) in muscovite-quartz schist belonging to Çıplaklı member, // Nicol

The components and percentage values in quartz schist, quartzite, phyllite and chlorite schist belonging to Çıplaklı member are given in Table 5.

Table 5. The Components, percentage values of components and rock names of four samples belonging to quartz schist, quartzite, phyllite and chlorite schist observed in Çıplaklı member

The Name of Mineral	The Name of Rock			
	Muscovite-quartz schist	Quartzite	Albite-phyllite	Zoisite-chlorite schist
Quartz	81	88	12	3
Muscovite	11	3	3	2
Plagioclase (Albite)	3	4	7	8
Chlorite	2	2	4	62
Biotite (green)	-	1	-	-
Epidote	1	1	-	4
Zoisite / Clinozoisite	-	-	-	13
Sericite	-	-	71	-
Actinolite	-	-	-	4
Calcite	1	-	3	2
Tourmaline (green)	1	1	-	-
Sphene	-	-	-	2
<b>TOTAL</b>	100	100	100	100

Çıplaklı member unconformably overlies Ağzıkara formation belonging to the lower nappe. It is observed with a tectonic contact on Sugözü complex which forms the middle nappe at Narince Neighborhood vicinity. Çıplaklı member is unconformably overlain by Upper Paleocene - Middle Eocene aged Kötekler formation at the west of the study area. It is overlain as compatible by the metacarbonates of Tavşandamı member belonging to Değirmendere formation at the north of Göktaş Neighborhood (Figures 2 and 3). Çıplaklı member observed as a thin strip at the northeast of the study area has a visible thickness of approximately 650 m.

*Mizzia sp.* are observed at crystallized limestone levels in Çıplaklı member. Accordingly, the age of Çıplaklı member is Upper Permian. Çıplaklı member shows features that can be correlated with "Upper Permian aged Topraktepe formation" observed between Demirtaş-Gazipaşa (Erbay, 1998) and "lower levels of Upper Permian belonging to Çukuryurt unite" observed at Alara Stream - Kargı Stream - Akdağ vicinities (Öztürk et al., 1995).

### 3.1.3.2.2. Tavşandamı Member

It consists of common crystallized limestones with calcschist and dolomitic limestone interlevels and greenschist lenses. These lithologies are named as Tavşandamı member within Değirmendere formation according to Tavşandamı Neighborhood vicinity (Alanya), where was typically observed, by Kansun (2000). Tavşandamı member are seen at Tombul Hill, Küçükazı Hill, Kışla Neighborhood vicinity and northwest of the study area (Figure 2).

The crystallized limestones are dark gray colored and thin bedded (Figure 37). These metacarbonates show sometimes laminated - banded structures. Also, the lapia structures, which show karstic melt gaps, are prominent in the metacarbonates. The crystallized limestones, which are mostly large grained and occasionally fine grained, show plenty of fractured structures. Bituminous levels are seen sometimes in crystallized limestones. Macro-fossil remains are observed at levels where the bitumen rate increases. The overturned and oblique isoclinal folds and Z-folds are seen in the crystallized limestones. The folds have developed as a result of the intense deformations and the polymetamorphism occurring in Alanya Unit. Tavşandamı member includes dolomitic limestone - calcschist interlevels and greenschist lenses. Greenschists consist of actinolite schists.

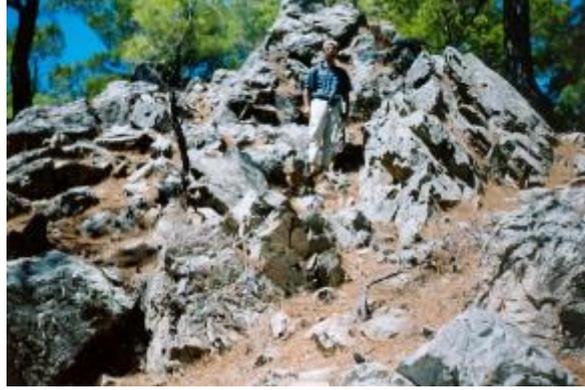


Figure 37. The crystallized limestones belonging to Tavşandamı member observed on the western slopes of Tombul Hill

**Crystallized limestones** and **dolomitic limestones** show granoblastic and mosaic textures. *Calcite + dolomite ± muscovite ± quartz* mineral paragenesis was observed in these metacarbonates. The **calcschists** contain *calcite + muscovite + chlorite (ripidolite) ± quartz ± epidote* mineral assemblage. The calcschists are granolepidoblastic textured. The **greenschists** are characteristic with porphyroblastic and granonematoblastic textures. *Actinolite + chlorite (ripidolite-picnochlorite) + plagioclase (albite) ± calcite ± muscovite ± epidote ± zoisite / clinozoisite + sphene* are observed in greenschists.

The metacarbonates belonging to Tavşandamı member are unconformably observed on the metapelitic and metacarbonate rocks belonging to Ağzikara formation at the south of the study area. On the other hand, it takes place as compatible over metapelitic-metapsammitic-metacarbonate rocks (Çıplaklı member) belonging to Değirmendere formation at the north of Göktaş Neighborhood. Tavşandamı member is unconformably overlain by the Upper Paleocene - Middle Eocene aged Kötekler formation (Figure 2). Tavşandamı member has a visible thickness of approximately 600 m.

*Mizzia Sp.* from alga is observed at bituminous crystallized limestone levels belonging to Tavşandamı member. In addition, *Fusulinidae*, which is one from the foraminifera, take part in metacarbonates within the member. In metacarbonate levels belonging to Tavşandamı member, Özgül (1984) determined *Bellerophon Sp.*, and Erbay (1998) determined *Pachyphloia Sp.*, *Permocalculus Sp.* and *Stylidophylloides Sp.* fossils. Therefore, the age of Tavşandamı member is Upper Permian. Tavşandamı member shows features that can be correlated with Upper Permian aged Karatepe formation observed between Demirtaş-Gazipaşa (Erbay, 1998) and with the upper levels of the Upper Permian belonging to Çukuryurt unit observed at Alara Stream – Kargı Stream – Akdağ vicinities (Öztürk et al., 1995).

## 3.2. Discussion

Işık and Tekeli (1995), at his study in the Anamur vicinity, stated that Alanya Unit consists of schist, amphibolite, greenschist, phyllite, quartzite and marble from bottom to top. The researchers said that the Alanya Unit was subjected to metamorphism reaching up to amphibolite facies at high temperatures. In fact, the Alanya Unit consists of metapelitic, metasemipelitic, metapsammitic, metacarbonate and metabasic rocks. On the other hand, in the study area, Alanya Unit consists of three different nappes which are observed with tectonic contact on each other. In addition, three phased metamorphisms reaching up to the upper amphibolite facies conditions were identified within Alanya Unit.

Çetinkaplan (2018) showed Alanya Unit in the form of two separate tectonic slices (Sarıağaç unit and Kapıdağ nappe) in his study around Anamur. In this study, Sarıağaç unit corresponds to Sugözü complex and Kapıdağ nappe corresponds to Yumrudağ group. On the other hand, Alanya Unit consists of three nappe cleavages in the study area. In the study area, Mahmutlar group is located as a separate nappe under the Sugözü complex, which corresponds to the Sarıağaç unit called by Çetinkaplan (2018). Çetinkaplan (2018) stated that Sarıağaç unit underwent the metamorphism in the upper amphibolite facies. On the other hand, three different metamorphism phases have been determined in the Sugözü complex corresponding to Sarıağaç unit in the study. Sugözü

complex initially underwent progressive metamorphism in amphibolite facies and upper amphibolite facies conditions. Later, this complex underwent a retrograde metamorphism at greenschist facies.

Çetinkaplan (2018) stated that there were acidic metamagmatites that cut the metapelitic rocks in Sariağaç unit. The researcher says that the age of crystallization of these acidic metamagmatites consisting of quartz and plagioclases was  $550.2 \pm 8.2$  Ma. In this study, acidic metamagmatites which cut the metapelitic rocks were not observed in the Sugözü complex which corresponds to the Sariağaç unit and in other parts of the Alanya Unit. On the other hand, the quartzites interlevels are extensively found in the metapelitic rocks of Mahmutlar group and especially Yumrudağ group of Alanya Unit. In addition, quartzite-quartzschist interlevels are sometimes observed in metapelitic rocks belonging to Sugözü complex. These quartzites are always compatible with the schizozites of metapelitic rocks in Alanya Unit. Particularly, feldspar-quartzites are observed at quartzite levels (Kesme member) within the Ağzıkara formation of Yumrudağ group. These feldspar-quartzites contain 12-15% feldspar (plagioclase + microcline) and 85-88% quartz. These feldspar-quartzites are observed especially in the eastern parts of Kesme Hill and are compatible with the schizozites of metapelitic schists belonging to Kodaman member of Ağzıkara formation. In the study area, the ages of Örenbaşı member (Dim formation) belonging to Mahmutlar group and Kesme member (Ağzıkara formation) belonging to Yumrudağ group consisting of quartzites were determined as Lower Cambrian. This age is partially compatible with  $550.2 \pm 8.2$  Ma age specified by Çetinkaplan (2018).

#### 4. Conclusions

Precambrian and Paleozoic aged Alanya Unit consisting of completely metamorphic rocks take places at the base of the study area. The Upper Paleocene - Middle Eocene aged Kötekler formation unconformably overlies the Alanya Unit. The Alanya unit consists of three separate nappe slices, which take place with tectonic contacts one above the other. These are Lower-Middle Cambrian aged Mahmutlar group (lower nappe), Precambrian aged Sugözü complex (middle nappe) and Lower-Middle Cambrian and Upper Permian aged Yumrudağ group (upper nappe).

The Mahmutlar group (lower nappe) is composed of muscovite schist, quartz schist and extensively mica schist containing cherty dolomite – quartzite - crystallized limestone interlevels and greenschist lenses (Dim formation). Sugözü complex (middle nappe), which is evident large garnet crystals, consist of mica schists with kyanite-sillimanite-staurolite and extensively garnet-mica schists. The semipelitic quartzite - quartz schist interlevels, amphibolite - amphibole schist - greenschist bands and lenses, metagabro - metadiabase dykes and interlevels and Cambrian aged dolomite – quartzite blocks and Upper Permian aged metacarbonate blocks belonging to Alanya unit are observed in these pelitic schists. Yumrudağ group (upper nappe) begins with mica schist and muscovite schists containing quartzite - cherty dolomite - crystallized limestone interlevels and greenschist bands - lenses (Ağzıkara formation) at the bottom. The alternation of quartz schist – phyllite – quartzite - crystallized limestone containing greenschist lenses and bituminous crystallized limestones containing calcschist - dolomitic limestone interlevels and greenschist lenses (Degirmendere formation) are observed in the upper levels of Yumrudağ group. The Cambrian aged cherty dolomite blocks belonging to Mahmutlar group (lower nappe) are seen in the Yumrudağ group. The formations barite, copper and galenite take place in upper nappe lithologies (Ağzıkara formation).

The three-phased metamorphism, which follow one another, is observed within Alanya Unit, which is subjected to multi-phased deformations as associated with intense tectonic movements. The datas of the polymetamorphism are particularly evident in Sugözü complex, which forms the middle nappe of Alanya unit. *Biotite (brown, green) + muscovite + garnet (prop-almandine-grossular) + quartz ± chlorite (ripidolite-picnochlorite, pennin-clinocllore) ± kyanite ± staurolite ± sillimanite + plagioclase (albite-oligoclase-andesin) ± epidote ± zoisite / clinozoisite ± orthoclase + tourmaline (green, brown) ± graphite ± sphene ± rutile ± apatite* mineral assemblage are observed in metapelitic and metapelitic rocks belonging to Sugözü complex. Amphibolites and amphibole schists belonging to this complex contain *hornblende (tschermacite, ferro-tschermacite, magnesio-hornblende, edenite) + garnet + plagioclase (albite-oligoclase-andesine) ± relic clinopyroxene (augite-pigeonite) + chlorite (ripidolite, clinocllore) ± orthoclase ± epidote ± zoisite / clinozoisite ± biotite (green, brown) ± actinolite ± muscovite ± quartz ± calcite ± sphene ± apatite ± rutile. Hornblende (tschermacite, ferro-tschermacite) + plagioclase (albite-oligoclase-andesine) + relic clinopyroxene (augite) ± garnet + quartz + chlorite (ripidolite, pennin-clinocllore) ± actinolite ± zoisite / clinozoisite ± epidote ± calcite ± sphene ± apatite* mineral assemblage are seen in metagabros and metadiabases. The greenschists contain *tremolite + actinolite + chlorite (ripidolite-picnochlorite) + plagioclase (albite) ± garnet + zoisite / clinozoisite + epidote ± quartz ± microcline ± clinopyroxene (augite) (relic) ± calcite + sphene ± apatite* mineral paragenesis.

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