

THE INDEX MINERALS AND MINERAL ASSEMBLAGES DETERMINED IN METAMORPHITES OF EVCİLER-ÇATKÖY (ÇAYIRALAN-YOZGAT) SEGMENT OF AKDAĞMADENİ MASSIF

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ABSTRACT.- In the studied area, which is representing some part of metamorphic rocks of Akdağmadeni massif, some index minerals and mineral assemblages reflecting progressive regional dynamo-thermal metamorphism have been determined. In the metapelites belonging to the bottom levels of metamorphic rocks, the index minerals such as biotite, garnet, staurolite, kyanite, orthoclase and sillimanite and their assemblages have been determined; in the semi-pelitic rocks which take place above the metapelitic series we see index minerals such as plagioclase, calcite, diopside, hornblende, tremolite and their assemblages with the increasing carbonate in environment. In the metacarbonates that we see widely at the top most of metamorphic series, the mineral groups such as calcite, epidote, plagioclase, diopside and tremolite were found and they reflect metamorphism conditions. In the mineral assemblages originated from various amphibolites found almost in every lithology of metasedimentary sequence as intercalations and lenses, we see hornblende, plagioclase and garnet as index minerals. Looking at the experimental formation conditions of the mineral assemblages mentioned above, we could say that the metamorphic rocks of the studied area were formed under the progressive regional dynamo-thermal metamorphism conditions. It is pointed out by looking at the index minerals and mineral assemblages in metapelitic derivatives, metamorphism has occurred at 400-700 °C temperature and 3.5-6.5 kb pressure conditions progressively. The mineral assemblages found in semi-pelitic derivatives and metacarbonates also show a progressive metamorphism of 350-600 °C and medium-high grade. The mineral assemblage we see in the lithologies such as amphibolites reflects about 600 °C temperature and 6 kb pressure conditions.

INTRODUCTION

The metamorphic masses crapping out between Yozgat, Sivas, Kayseri, Niğde and Kırıkkale provinces in Central Anatolia are named as Central Anatolian massif (Ketin, 1983). The names central anatolian crystalline basement (Tolluoğlu, A.Ü. and Erkan, 1989) and Central Anatolian Complex (Erlar, A. and Bayhan, H., 1995) has also been used.

The Akdağmadeni massif (Fig. 1) is the largest of many independent metamorphic masses and located NE of the region. The massif is overlain by Mesozoic and Cenozoic units and is considered by many miners and geologists since 19th century because of its metallogenic potential. The mining and investigations, especially basic geologic investigations of ore deposits started towards the end of 1970's scientifically. The first observations founding these investigations were made by Pollak (1958) and Vache (1963). Investigators described the

metamorphic rock groups as quartzite, marble, micagneiss, mica schist, and mica quartzite. Pollak (1958) divided these rock groups into three series namely basement series, marble series and upper series. Vache (1963) explained that the basement rocks have been metamorphosed under mesokatazonal conditions and medium and upper series under epizonal conditions. But the later studies dealing metamorphism doesn't support this idea of Vache (1963).

Erkan (1980) depending on the field observations, mineral characteristics and the mineral assemblages found in very thick metasedimentary rocks such as calcsilicate gneiss, gneiss and amphibolite in east of Akdağmadeni, says that it is impossible to divide the regional metamorphic rocks of this region into upper and basement series. He also states it is not easy to say that, first a high-grade regional metamorphism and then a low-grade metamorphism were effective in the region. He re-

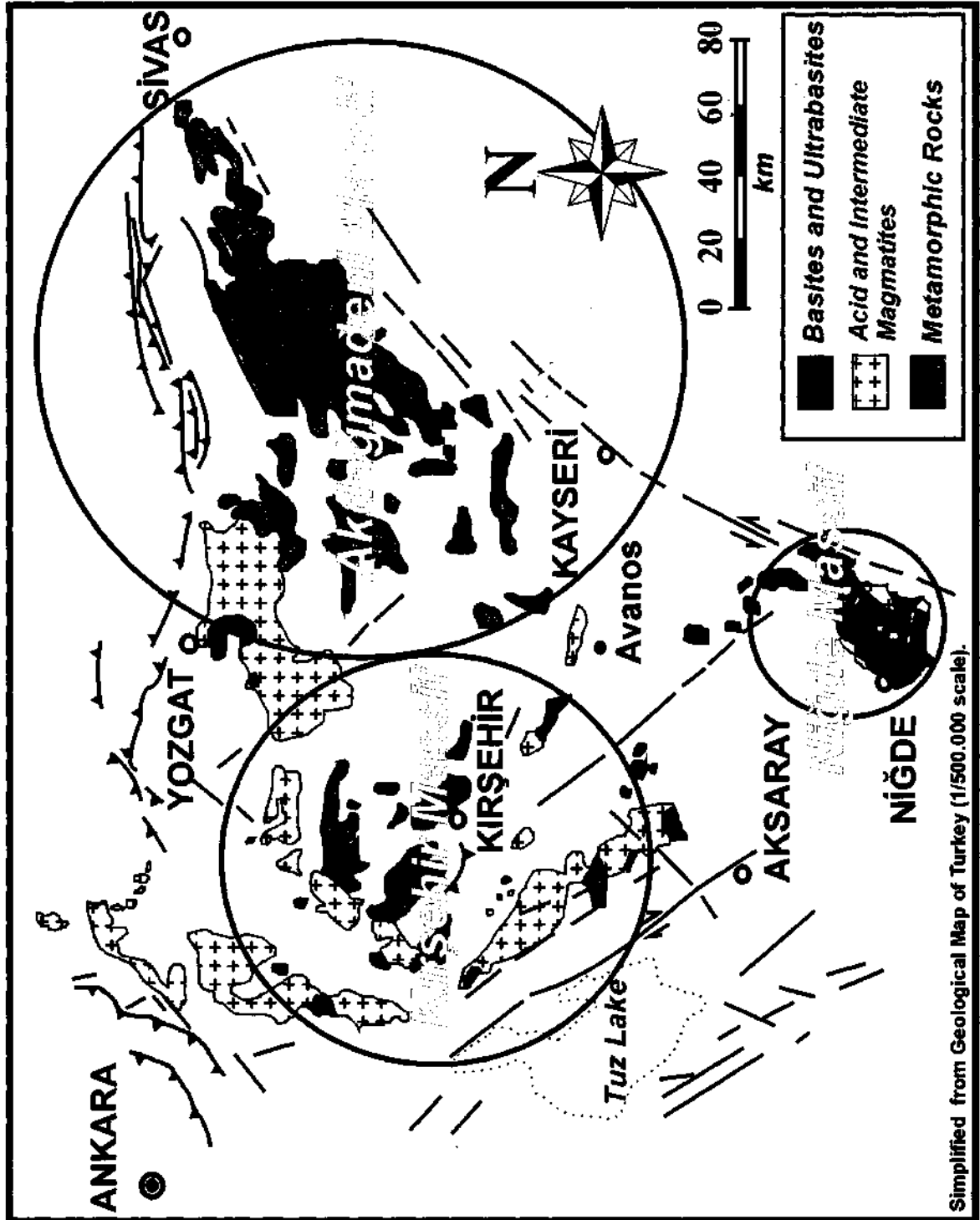


Fig. 1 - Metamorphic massifs of Central Anatolian crystalline complex.

cognized kyanite + staurolite and sillimanite + orthoclase paragenesis in the metamorphic rocks south of Akdağmadeni. However he says the mineral staurolite, which is very sensitive to change of temperature, and pressure conditions should change to chlorite-serisite aggregate or to chloritoid by a second low-grade metamorphism, but he couldn't observe any change in this mineral.

Özcan et al., (1980) carried out their studies in the northern part of central anatolian massif, between Akdağmadeni and Yıldızeli, and observed the sequence as augen gneiss, biotite-garnet gneiss, amphibolite, mica schist, marble, quartzite, calcsilicate marble and massif marble. They indicated staurolite + sillimanite + muscovite + biotite + garnet + quartz + tourmaline, kyanite + muscovite + quartz + sillimanite + biotite + oligoclase/andesine + quartz ± K-feldspar ± garnet ± muscovite, staurolite + kyanite + muscovite + biotite + labradorite + quartz, scapolite + diopside + hornblende + andesine + calcite (talc + phlogopite + orthoamphibolite + orthopyroxene + olivine + spinel in metaultramafites) mineral assemblages according to lithologic groups and metamorphic conditions (Özer and Göncüoğlu, 1982).

Dökmeci (1980) prepared a generalized lithostratigraphic section of the area around Akdağmadeni. The metamorphites named as Akdağ metamorphic group identified as Köklüdere formation (various gneiss and schist) and Özerözü formation (generally marbles).

Tülümen (1980) examined the petrographic and petrologic characteristics of metamorphic rocks, granites and scarns in his work in Akdağmadeni. Metamorphic rocks were differentiated to some facies according to their mineral paragenesis. These facies were established in a range from muscovite schist to almandine-biotite gneiss indicating rock names.

Sağıroğlu (1982) examined the metamorphic rocks and metamorphic conditions in his work dealing with lead-zinc deposits and their metasomatism near Akdağmadeni. He decided that the mafic metamorphites he defined as amphibolite and

amphibole gneiss according to their mineralogical compositions are magmatic origin.

Şahin (1991) in his work around Akdağmadeni-Başçatak, indicates that the metamorphites of sedimentary origin has been metamorphosed progressively under medium-high grade regional metamorphism conditions. It is revealed by some structural analyses that these rocks show superimposed fold geometry and undergone four different folding phases. In another work he stated that he didn't observe the interchange of sillimanite \leftrightarrow kyanite. He says this change only can be when the anatexis conditions are available therefore there were no temperature-pressure conditions for anatexis in the studied area (Şahin and Erkan, 1994).

Alpaslan (1993) studied the metamorphites around Yıldızeli, NE of Akdağmadeni massif. He named the metamorphites as Yıldızeli group and differentiated this group from bottom to top as Aşılık metamorphite containing metapelitic and migmatitic rocks, Fındıcak metamorphite containing calcsilicate and metapelitic rocks, Pelitlikaya quartzite Member containing quartzite and Kadıköy metacarbonate containing marbles. He claimed that the retrograde metamorphism has occurred during the uprising of Kırşehir block and he found the age of metamorphism as Santonian-Maestrichtian by K-Ar method.

After his studies at the east of Akdağmadeni Yılmaz et al., (1994) named the metamorphites as Akdağmadeni lithodem. They stated that this lithodem includes gneiss, amphibolite, schist, marble and quartzite and has been metamorphosed in high amphibolite facies.

The lithostratigraphic units of the studied area (Fig. 2), which is located between Çatköy and Evçiler villages, south of Akdağmadeni massif, are grouped bottom to top as metapelites, semi-metapelites, metacarbonates and metabasites (as lenses and intercalations in all these lithologic groups) (Şahin, 1999). The lithologies forming the mentioned lithostratigraphic units are mica-schist, mica-gneiss, sillimanite-mica-schist, garnet-staurolite-kyanite-mica-gneiss, quartz-muscovite-schist

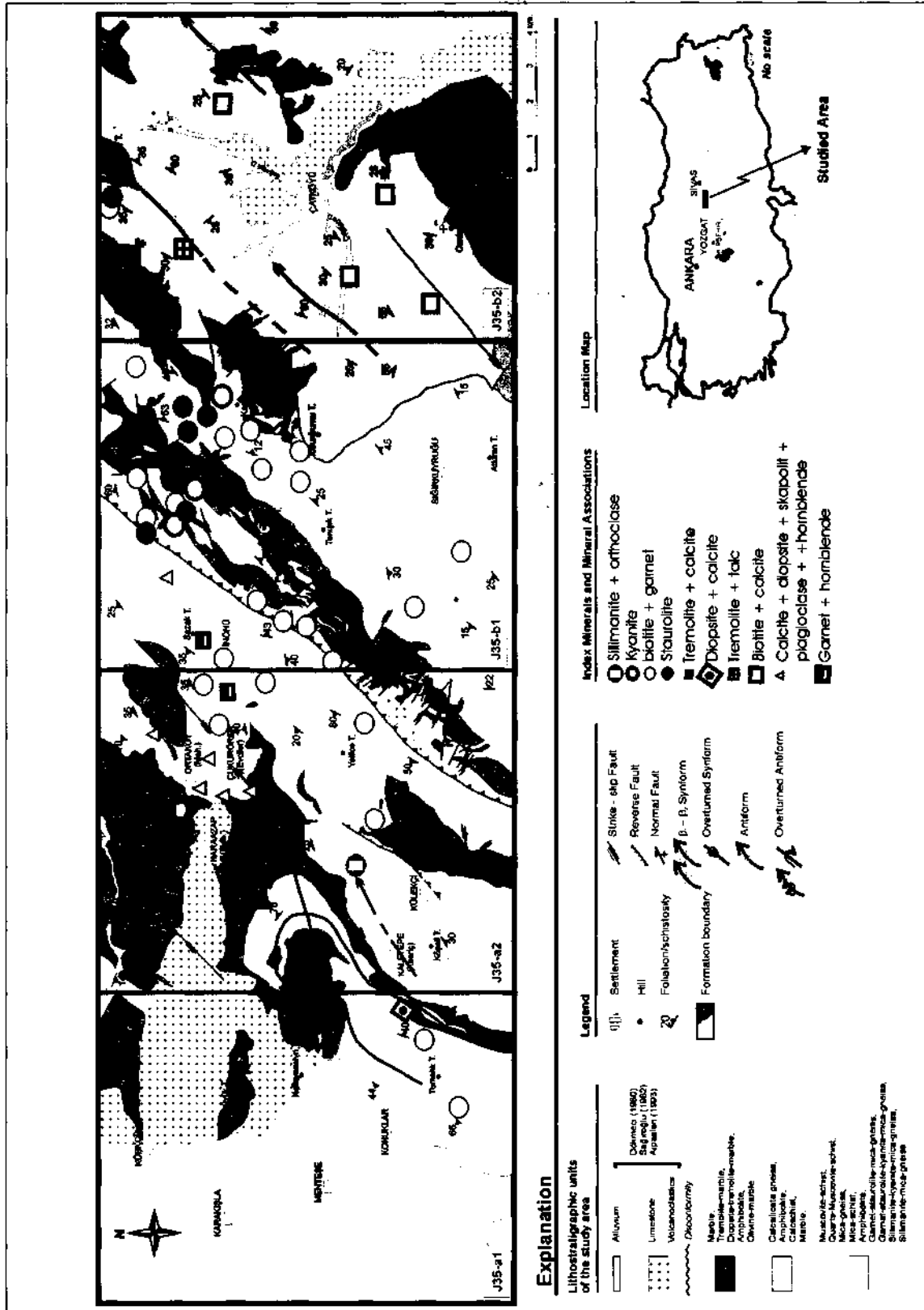


Fig. 2- Map of index minerals and mineral associations in Evçiler-Çatköy part of Akdağmadeni massif metamorphites.

forming metapelites, calcsilicate gneiss, calcschist forming semi-metapelites, epidote-marble, tremolite-diopside-marble, epidote-tremolite-marble, graphite-marble, monomineralic marbles forming metacarbonates and amphibolites forming metabasites (Şahin, 1999).

All of the investigations made on the metamorphic rocks of Akdağmadeni massif reveal that the metamorphites have a sedimentary origin with some basic intercalations. The bottom most units of this sequence of metasedimentary character consist of metapelites (various schist and gneisses). Semi-metapelites (calcsilicate-gneisses, calcschist and calcsilicate marbles), which formed by the increasing carbonate in environment, overlie this series (Fig. 3).

The upper most units consist of metacarbonates and in the border of passage from semi-metapelites to metacarbonates; sometimes a level, which is dominantly consisting quartzites of psammitic origin has been observed. The lithologies forming the metacarbonates of Akdağmadeni mas-

sif are marbles, tremolite-marbles, diopside-tremolite-marbles and olivine marbles.

INDEX MINERALS AND MINERAL ASSEMBLAGES

DEVELOPMENT AND ZONES OF METAMORPHISM

Some index minerals and mineral assemblages were determined in the metasedimentary units and in metabasites by some mineralogical and petrographic determinations. These are given in Table 1.

Some phase diagrams that obtained experimentally and literary are used to find the formation conditions and environments of index minerals and mineral paragenesis described in studied area and given in Table 1. The phase diagrams based on chemical composition and pressure (P) and temperature (T) parameters were interpreted for metamorphic derivatives of pelitic rocks, carbonates and basic rock groups severally.

Metapelites

When we consider the index minerals of

Table 1- "Index minerals and mineral assemblages of investigated area.

Unit	Lithology	Index Mineral	Mineral Association
Metapelite	Mica-gneiss Mica-schist	Kyanite Staurolite Garnet Biotite Muscovite Sillimanite	Biotite + muscovite Biotite + garnet Biotite + kyanite Biotite + staurolite Biotite + staurolite + kyanite Garnet + biotite + staurolite Garnet + biotite + staurolite + kyanite Sillimanite + biotite
Semi-metapelite Metacarbonate	Calcsilicatic gneiss Calcschist Marble	Calcite, diopside, scapolite, plagioclase, hornblende chlorite, tremolite, talc, biotite	Talc + tremolite + calcite Tremolite + calcite + quartz Plagioclase + calcite Diopside + calcite Plagioclase + calcite + diopside + scapolite + hornblende
Metabasite	Amphibolite	Plagioclase (andesine), hornblende (green), garnet, epidote	Plagioclase + hornblende + garnet + biotite + epidote

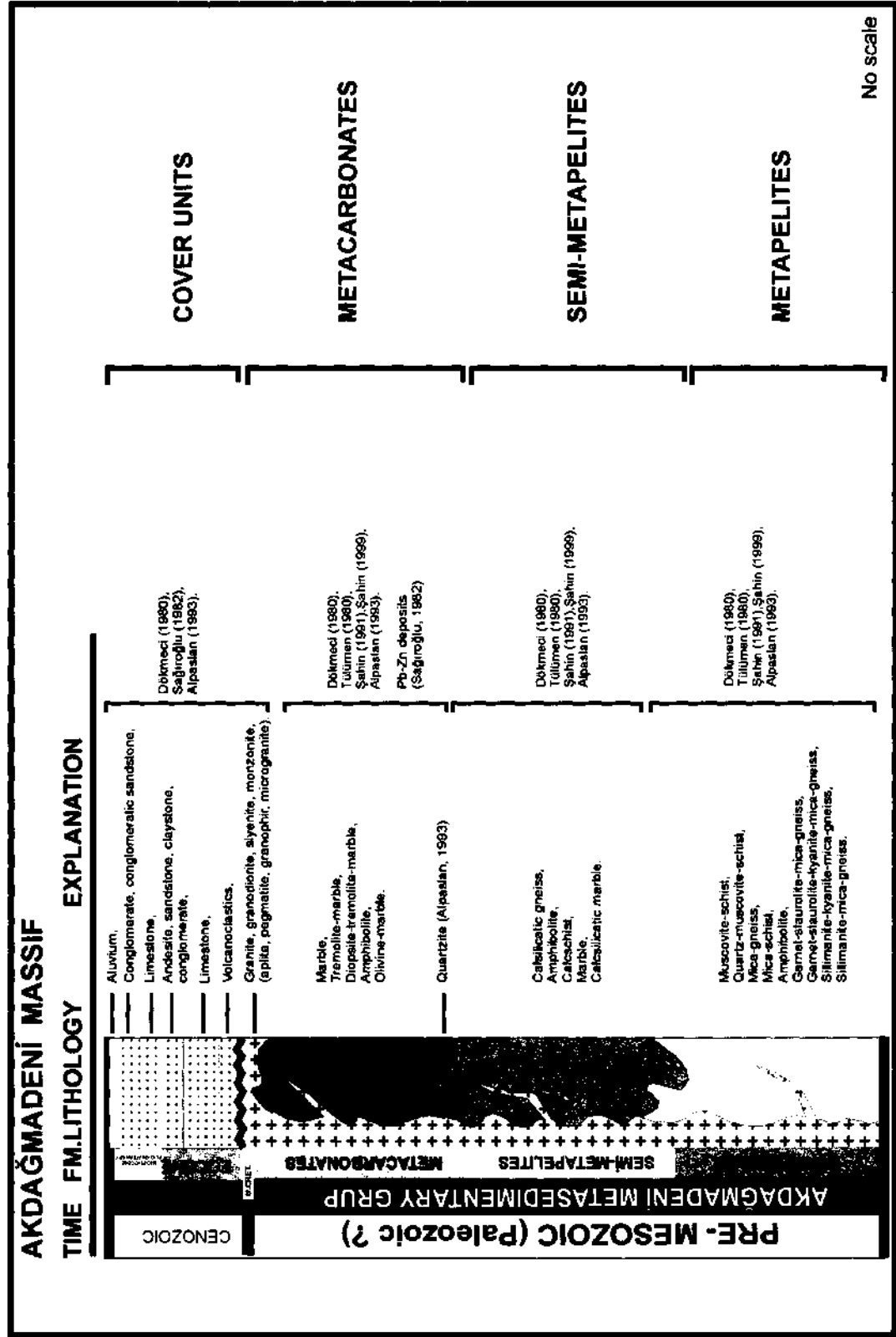


Fig. 3- Generalized lithostratigraphic section of Akdağmadeni massif (Şahin, 1999).

metapelites in the studied area; ASH system, based on SiO_2 , Al_2O_3 , H_2O and P-T parameters and giving formation conditions of kyanite and sillimanite which are the polymorphs of aluminum silicate; FASH system, reflecting formation conditions of staurolite and garnet (almandine) (FeO is added to parameters of chemical composition in this system); KNFASH system, in which the reactions involving mica taking place and in which K and Na of the chemical composition is interpreted and finally KFASH (AFM) system, in which the mineral assemblages appear dur-

ing progressive metamorphism in metapelitic rocks will be discussed on AFM projections.

Index mineral "kyanite" and ASH system.- When we consider the diagram (Fig. 4) called ASH system (Bucher and Frey, 1994) which shows the formation and inversion conditions of the minerals, that are polymorphs of aluminum silicates (andalusite, sillimanite and kyanite) as a function of temperature (T) and pressure (P), it has been seen that mineral kyanite is formed along "kyanite geotherm" at about 400 °C temperature and about 3.7

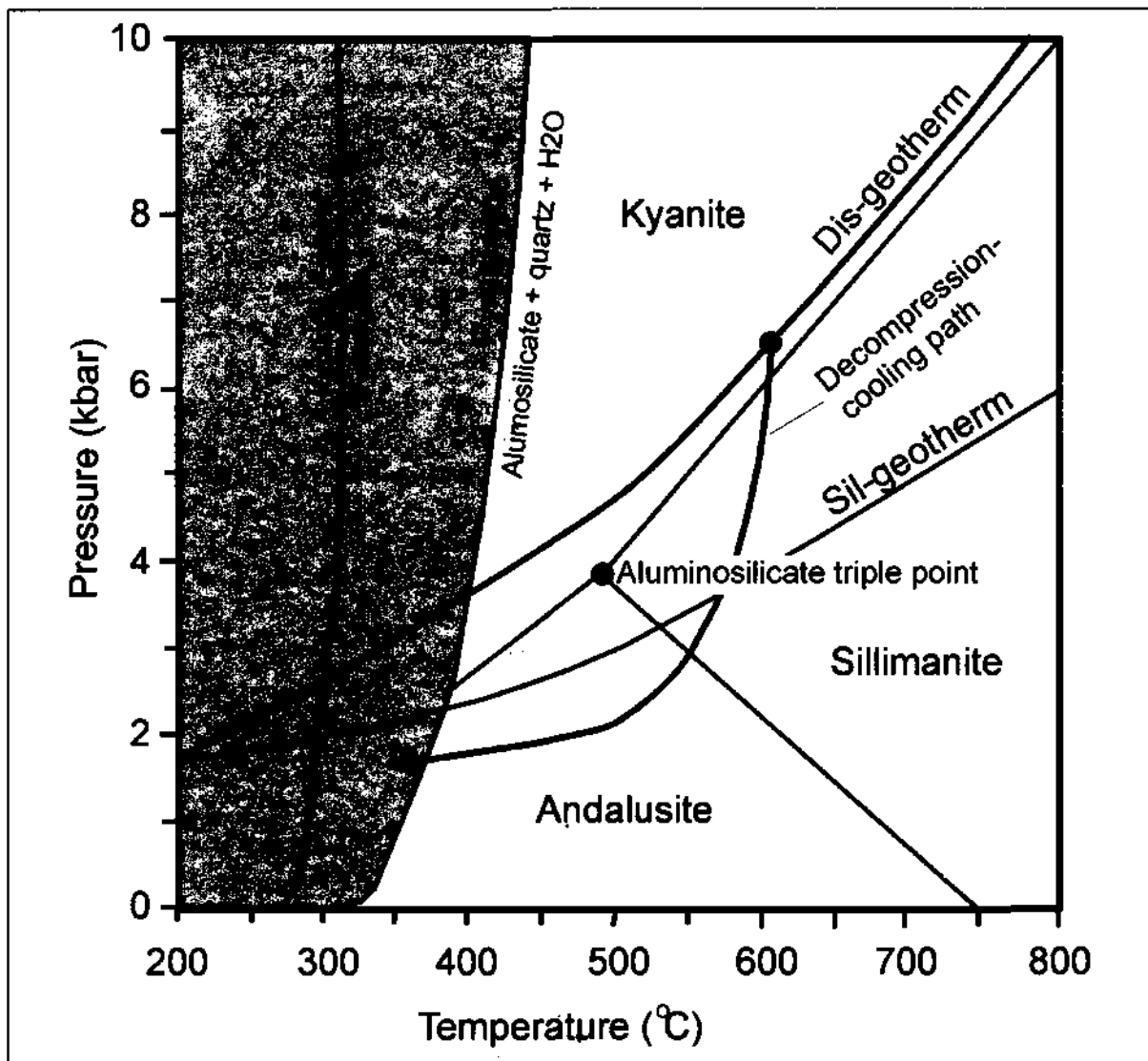


Fig. 4- Equilibria in the ASH system (Bucher and Frey, 1994).

Kb referring to this temperature after pyrophyllite.

In the samples taken from the studied area the mineral "kyanite" was identified in "biotite + kyanite", "biotite + staurolite + kyanite" and "garnet + biotite + staurolite + kyanite" assemblages. Therefore, the formation conditions and stability fields of the minerals biotite, garnet and staurolite that are forming assemblages together with kyanite should be examined on the related phase diagrams and finally the formation conditions and stability fields of the mineral assemblages should be explained. But when we look at the ASH diagram in figure 4 and the reactions (reaction 5) in ASH system (Table 2). It can be seen that the formation reaction of kyanite as "pyrophyllite=kyanite + 3 quartz + H₂O". Since we can't see the mineral pyrophyllite in the examined samples, the rocks that involving kyanite as diagnostic mineral and the other metapelites having similar compositions should be formed at conditions at least over the stability field of pyrophyllite.

Sillimanite that is another polymorph of aluminum silicate and formed in progressive metamorphism by the increasing temperature will be discussed after the minerals biotite, garnet and staurolite are examined.

Index minerals "staurolite+garnet" and FASH system.- The FASH system (Bucher and Frey, 1994) showing the formation conditions and stability fields of the minerals staurolite and garnet is eval-

uated by adding FeO component to ASH system.

When we look at the FASH system (Fig. 5) and "the reactions taking place in Table 3, we see that the mineral garnet (almandine) is formed at about 510 °C by the reaction (9) "chlorite + chloritoid + quartz". Staurolite is formed by the reaction (11) "chloritoid + kyanite" at the same temperature. The first appearance of the minerals staurolite and garnet (almandine) shows the transition from green schist facies (low pressure-low temperature) or from low-grade metamorphism to amphibolite facies (medium-high pressure, medium-temperature) or to medium grade metamorphism.

In the metapelites cropping out in the studied area, the minerals staurolite and garnet are found in "biotite + staurolite", "biotite + garnet", "biotite + staurolite + kyanite" and "biotite + garnet + staurolite + kyanite" assemblages. Therefore it will be reasonable to examine these two diagnostic minerals together with the other minerals that take place in mineral assemblages with them and than to come to a conclusion about the metamorphic conditions occurred.

Index minerals "biotite-muscovite" and KNFASH system.- The mica minerals that often found in metapelites of the investigated area biotite and muscovite. When we look at the phase diagram of KNFASH system (Fig. 6) which is formed by the addition of K and Na to FASH system and the reac-

Table 2- Reactions in the ASH system (Bucher and Frey, 1994).

Sillimanite (Sil), Kyanite (Ky), Andalusite (And)	Al ₂ SiO ₅
Quartz (Qtz)	SiO ₂
Pyrophyllite (Prl)	Al ₂ Si ₄ O ₁₀ (OH) ₂
Kaolinite (Kln)	Al ₂ Si ₄ O ₅ (OH) ₄
(1) And = Ky	
(2) And = Sil	
(3) Sil = Ky	
(4) Kln + 2 Qtz = Prl + H ₂ O	
(5) Prl = Ky + 3 Qtz + H ₂ O	
(6) Prl = And + 3Qtz + H ₂ O	

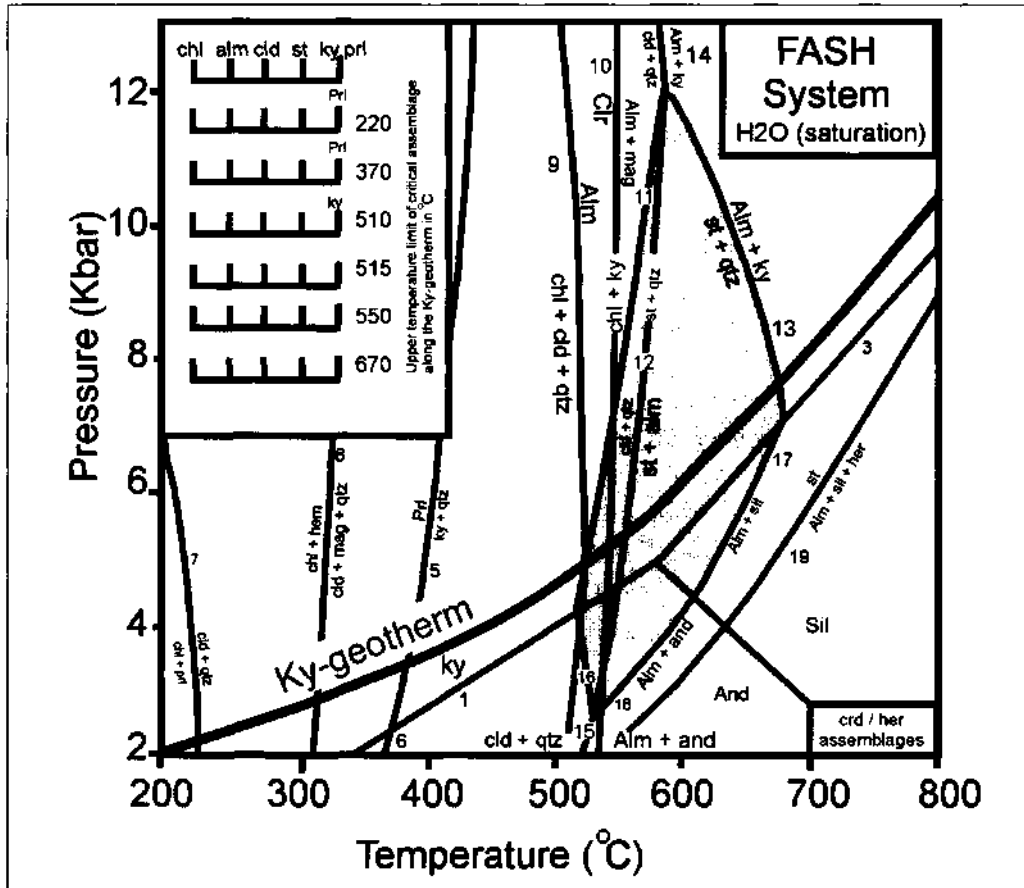


Fig. 5- Equilibria in the FASH system (Shaded field Coexistence of staurolite + quartz, Bucher and Frey, 1994).

tion (21) of Table 4, we see that "K-feldspar + chlorite" assemblage forms "biotite + muscovite" assemblage. Here it is stated that the mineral biotite can be seen green under microscope and the formation temperature is about 400 °C (Bucher and Frey, 1994). In the samples examined mineralogical and petrographical, "biotite (green) + muscovite" assemblage was observed very often. Since we couldn't see primary chlorite in examined metapelites, "biotite-muscovite" assemblage must represent the lowest metamorphism conditions of the metapelites of the studied area and it shows that they formed at about 400 °C temperature and 3-4 Kb pressure referring to the upper boundary of low grade metamorphism (green schist facies).

In the microscopic determination of "kyanite-mica-gneiss" sample taken near Kazıkgeçmez T. (J

35-b1), "biotite (green) + muscovite + kyanite" assemblage was found. The formation conditions of this assemblage reflects the intersection point of "biotite + muscovite" curve and "kyanite geotherm" in KNFASH system (Fig. 6). At this point which is the first point of the increase of temperature and pressure in the metamorphism effective in metapelites the temperature is about 410 °C and pressure is about 3.7Kb.

When we consider at the reaction (22) shown in Table 4, it has been seen that "biotite + garnet" assemblage is formed by the reaction "muscovite + chlorite + quartz". When we examine the phase diagram shown in figure 6, that this reaction is independent of pressure and occurred at about 520°C. The paragenesis mostly seen in the studied area is "biotite + garnet" assemblage (Fig. 2). When we

look at again to the previously examined FASH system (Fig. 5) and the reactions of this system (Table 3) it is observed that the minerals staurolite and garnet (almandine) assembling with biotite form "biotite + staurolite + garnet" paragenesis together with the biotite coming from the reaction (12) "chloritoid + quartz" at about 550 °C. The mineral chloritoid can't be observed in the studied area. This paragenesis observed NE of inonu village (J35-b1) is another data indicating the progressive character of metamorphism. The assemblage "staurolite + kyanite + biotite + garnet" observed in the same area refers to high temperature-high pressure range of medium grade metamorphism (amphibolite facies) and represents the disappearance temperature of staurolite (below 670°) and pressure conditions of about 5Kb.

The KNFASH system shown in figure 6 and the reaction (25) of the Table 4, indicate (with the presence of quartz) the upper most boundary of stability field of muscovite. Here "K-feldspar (orthoclase) + sillimanite" assemblage is formed by the reaction "muscovite + quartz". But aluminum silicate polymorph is accompanied by albite according to reaction (24). In the mineral assemblage formed by the reactions (24) and (25), aluminum silicate polymorph is accompanied by "K-feldspar + albite + quartz" assemblage. The "sillimanite + orthoclase + andesine + quartz" assemblage observed in sillimanite-mica gneiss sample taken from NE of Kaletepe Village shows the continuously increasing temperature. Here the completely disappearance of staurolite and the appearance of "sillimanite (or kyanite) + K-feldspar + andesine + quartz" assem-

Table 3- Reactions in the FASH system (Bucher and Frey, 1994).

Chlorite (Chl)	$\text{Fe}_5\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_8$
Chloritoid (Cld)	$\text{FeAl}_2\text{SiO}_6(\text{OH})_2$
Staurolit (St)	$\text{Fe}_4\text{Al}_{18}\text{Si}_{7.5}\text{O}_{44}(\text{OH})_4$
Almandine (Alm)	$\text{Fe}_3\text{Al}_2\text{Si}_3\text{O}_{12}$
Hercynite (Hc)	FeAl_2O_4
Magnetit (Mag)	FeFe_2O_4
Hematite (Hem)	Fe_2O_3
(7)	$\text{Chl} + 4 \text{Prl} = 5 \text{Cld} + 4\text{Qtz} + \text{H}_2\text{O}$
(8)	$\text{Chl} + 4\text{Hem} = \text{Cld} + 4\text{Mag} + 2 \text{Qtz} + 3\text{H}_2\text{O}$
(9)	$\text{Chl} + \text{Cld} + 2 \text{Qtz} = 2\text{Alm} + 5 \text{H}_2\text{O}$
(10)	$3\text{Chl} = 3\text{Alm} + 2 \text{Mag} + 12\text{H}_2\text{O} (+\text{QFM})$
(11)	$8 \text{Cld} + 10 \text{Ky} = 2\text{St} + 3 \text{Qtz} + 4 \text{H}_2\text{O}$
(12)	$23\text{Cld} + 7\text{Qtz} = 2\text{St} + 5 \text{Alm} + 19\text{H}_2\text{O}$
(13)	$75\text{St} + 312 \text{Qtz} = 100 \text{Alm} + 575 \text{Ky} + 150\text{H}_2\text{O}$
(14)	$3\text{Cld} + 2 \text{Qtz} = \text{Alm} + 2 \text{Ky} + 3 \text{H}_2\text{O}$
(15)	$3 \text{Cld} + 2 \text{Qtz} = \text{Alm} + 2 \text{And} + 3 \text{H}_2\text{O}$
(16)	$8\text{Cld} + 10\text{And} = 2\text{St} + 3 \text{Qtz} + 4 \text{H}_2\text{O}$
(17)	$75\text{St} + 312 \text{Qtz} = 100\text{Alm} + 575\text{Sil} + 150\text{H}_2\text{O}$
(18)	$75\text{St} + 312 \text{Qtz} = 100 \text{Alm} + 575\text{And} + 150\text{H}_2\text{O}$
	Decomposition of staurolite in qtz-free in rocks
(19)	$2\text{St} = \text{Alm} + 12\text{Sil} + 5\text{Hc} + 4\text{H}_2\text{O}$
(20)	$2\text{St} = \text{Alm} + 12\text{And} + 5\text{Hc} + 4\text{H}_2\text{O}$

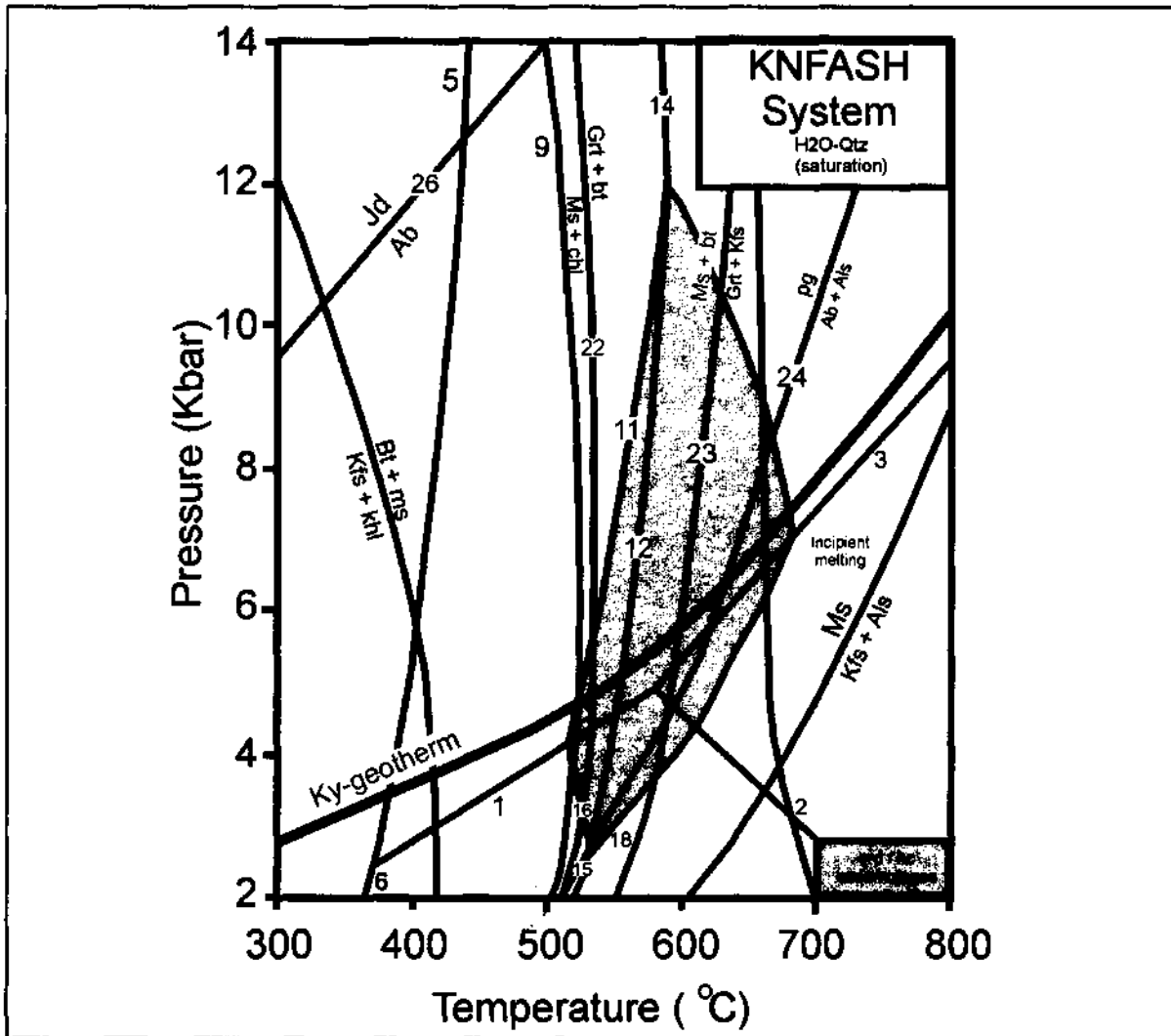


Fig. 6- Equilibrium in KNFASH system and mica reactions (Bucher and Frey, 1994).

blage show the high temperature metamorphism reaching to melting (above 700 °C).

According to the index minerals, mineral assemblages and phase diagrams mentioned above, it can be said that the related metamorphism conditions change by the physical and chemical parameters of environment with respect to time and space. It will be convenient to show the appearance and formation conditions of the diagnostic minerals and mineral assemblage in metapelites of the studied area on AFM diagrams according to their progressive formation order (Fig. 7).

The minerals and mineral assemblages observed in metapelites cropping out in the studies area and stating the progressive development of regional metamorphism in AFM diagrams of figure (7), follow the progressive formation order taking place in (Fig.8).

Semi-metapelites and metacarbonates

The index minerals taking place in the mineralogical composition of the marbles that considered as metacarbonates, calcsilicatic gneisses and calcschist and defined as semi-metapelites cropping out in the studied area will be discussed by

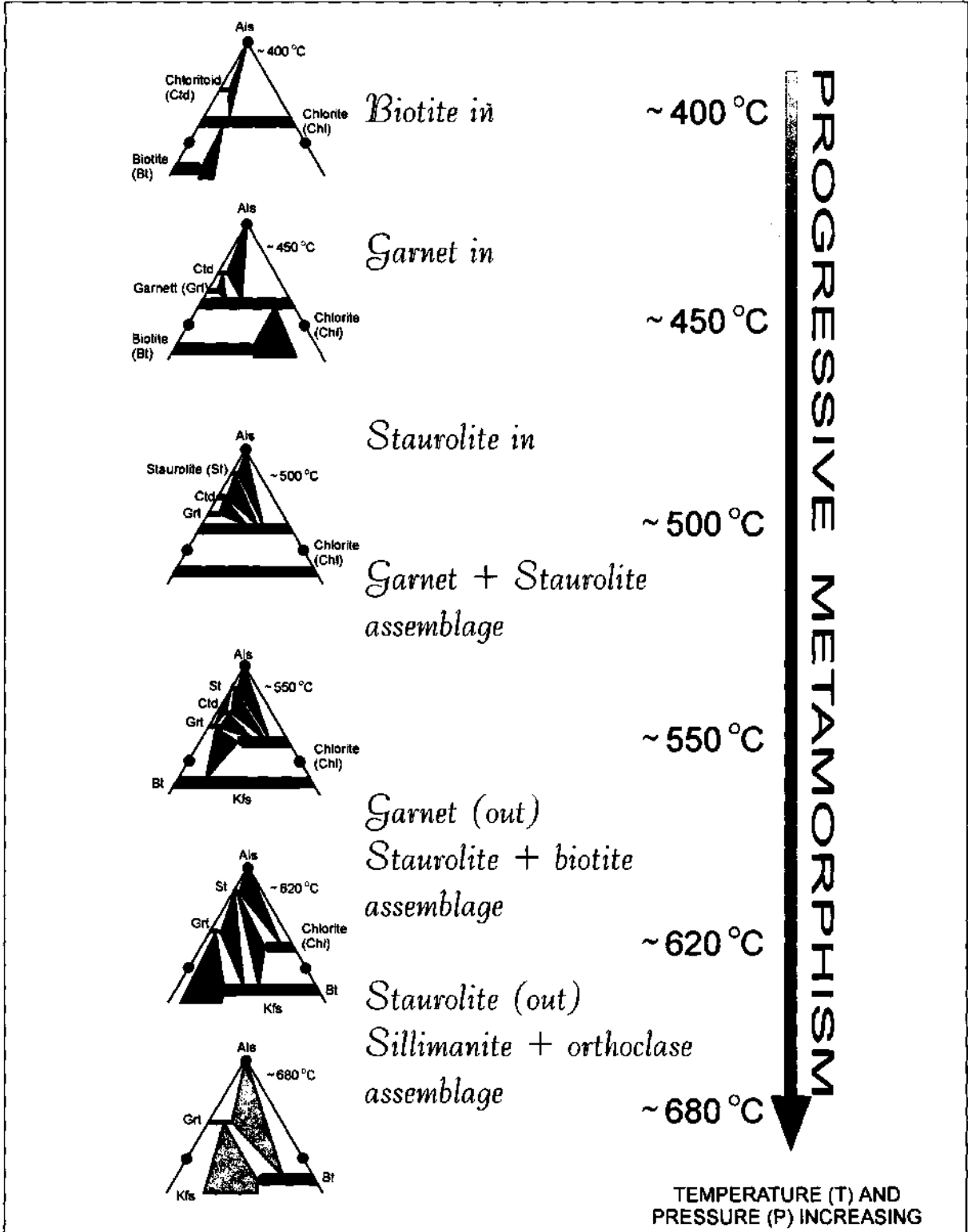


Fig. 7- Progressive metamorphism of metapelites in the investigated area (AFM diagrams, Bucher and Frey, 1994).

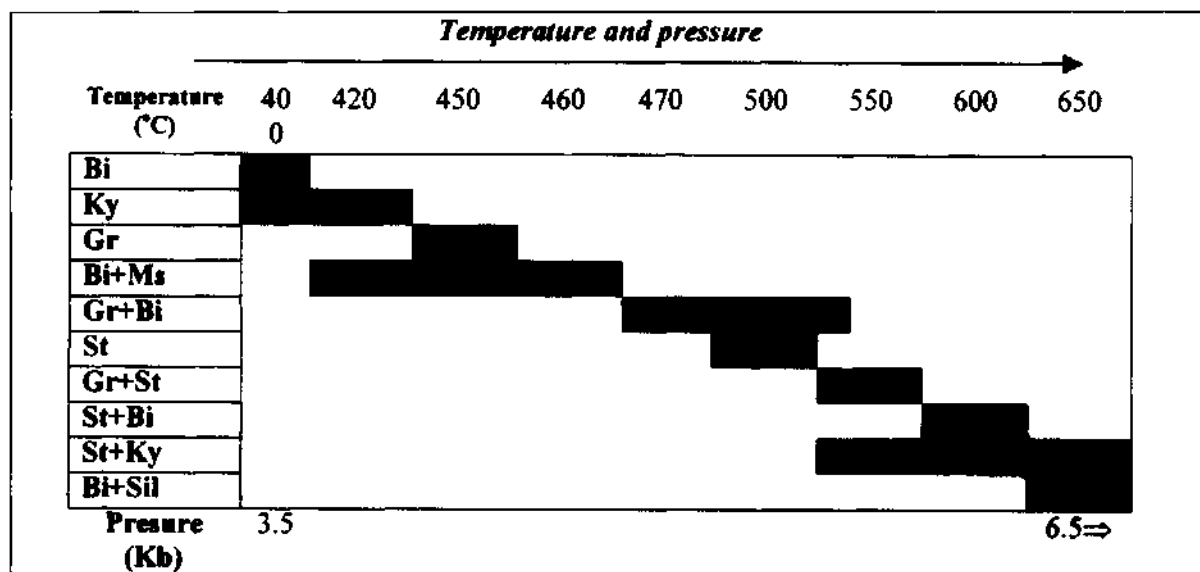


Fig. 8- Index minerals and mineral associations of metapelites in the investigated area.

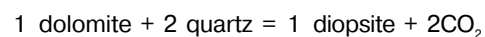
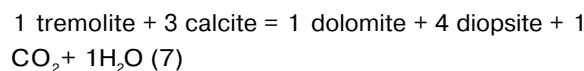
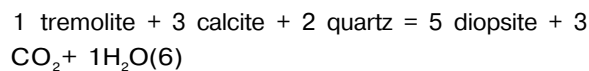
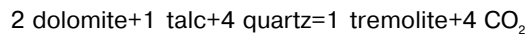
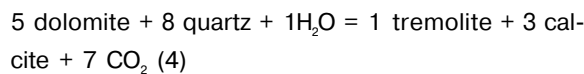
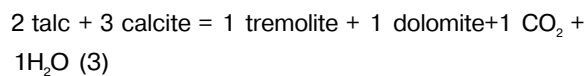
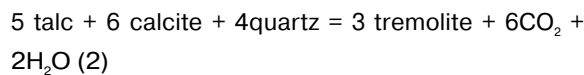
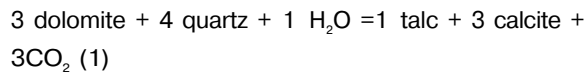
Table 4- Important reactions in the KNFASH system (Bucher and Frey, 1994).

Biotite (Bt)	$\text{KFe}_3\text{AlSi}_3\text{P}_{10}(\text{OH})_2$
Muscovite (Ms)	$\text{KAl}_3\text{Si}_3\text{O}_{10}(\text{OH})_2$
Paragonite (Pa)	$\text{NaAl}_3\text{Si}_3\text{O}_{10}(\text{OH})_2$
K-feldspar (Kfs)	KAISi_3O_8
Albite (Ab)	$\text{NaAlSi}_3\text{O}_8$
Jadeite (Jd)	$\text{NaAlSi}_2\text{O}_6$
Garnet (Grt)	
Aluminium silicate (Als)	
(21)	$3\text{Chl} + 8\text{Kfs} = 5\text{Bt} + 3\text{Ms} + 9\text{Qtz} + 4\text{H}_2\text{O}$
(22)	$\text{Ms} + 3\text{Chl} + 3\text{Qtz} = 4\text{Alm} + \text{Bt} + 12\text{H}_2\text{O}$
(23)	$\text{Ms} + \text{Bt} + 3\text{Qtz} = \text{Alm} + 2\text{Kfs} + 2\text{H}_2\text{O}$
(24)	$\text{Pa} + \text{Qtz} = \text{Ab} + \text{Als} + \text{H}_2\text{O}$
(25)	$\text{Ms} + \text{Qtz} = \text{Kfs} + \text{Als} + \text{H}_2\text{O}$
(26)	$\text{Jd} + \text{Qtz} = \text{Ab}$
	Discontinuous reaction in the KNFASH system
(27)	$\text{Ctd} = \text{St} + \text{Grt} + \text{Chl}$
(28)	$\text{Grt} + \text{Chl} = \text{St} + \text{Bt}$
(29)	$\text{St} + \text{Chl} = \text{Bt} + \text{Als}$
(30)	$\text{St} = \text{Grt} + \text{Bt} + \text{Als}$
(31)	$\text{St} + \text{Bt} = \text{Grt} + \text{Als}$
(32)	$\text{St} + \text{Chl} = \text{Als} + \text{Grt}$
(33)	$\text{Grt} + \text{Chl} = \text{Bt} + \text{Als}$

using the phase diagrams derived from experimental work and then will be studied petrologically.

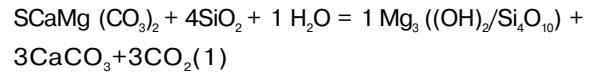
The diagnostic minerals observed in the calc-silicatic gneisses, calcschist and marbles of the studied area and forming the base of petrologic interpretation are calcite, plagioclase, diopside, scapolite, hornblende, chlorite, tremolite, talc and biotite and the assemblages of these minerals. These minerals are accompanied by quartz, titanite, apatite and epidote in many samples.

In this section first of all, the formation of talc, tremolite and diopside that are the index minerals of carbonate rocks of the studied area and having CaO-MgO-SiO₂ major components will be discussed. The resulting mineral parageneses also will be discussed. As a result of the experimental works carried by Turner (1968), Metz and Trommsdorff (1968); the below reactions involving quartz, dolomite, calcite talc and diopside were identified (Winkler, 1976).



When we consider the figure 7 which is first prepared by Metz and Trommsdorff (1968) and Later updated by Metz (1970) and Metz and Puhan (1970, 1971), it has been seen first that "talc+calcite" paragenesis appears over 400 °C temperature and low pressure conditions with the entrance of

dolomite and quartz to the reaction as below.



The investigation and observations done by Steck (1969), Puhan and Hoffer (1973) in Damara Belt, Africa and by Trommsdorff (1972) in Alps reveal that the first product of regional metamorphism is talc. The mineral talc is observed in calcschist derivatives and in "talc + tremolite + calcite" assemblage of semi-metapelitic derivatives taken from SE of Sıraalan hill (J35-b2).

The stability conditions of "talc + tremolite + calcite" assemblage which is represented by the reaction (2) of equilibrium diagram shown in (Fig. 9), change with respect to X_{CO₂} amount in fluid phase. But even if the amount of X_{CO₂} changes between 0.2 and 0.8 und Pf=1 Kbar and Pf=5 Kbar, the formation temperature of this assemblage remains between 490 °C and 600 °C. Since we don't know the total fluid phase pressure and the amount X_{CO₂} it could not be possible to give an exact value for the formation temperature of this mineral assemblage.

In addition to "tremolite+calcite+quartz" assemblage which occurred by the rising temperature in the tremolite-marbles of metacarbonates cropping out near Sıraalan hill (J35-b2) east of studied area, the presence of the diopside in the marbles indicates the rising of temperature up to 540 °C. Figure 9 shows that the formation of this paragenesis is also related to total fluid phase pressure and the amount of X_{CO₂}. The formation temperature of this reaction (6) giving diopside is higher than the formation temperature of reaction (2) giving talc. This situation shows that the stable mineral assemblage over 540 °C temperature is "diopside+tremolite+calcite+quartz". The presence of diopside in calcschists and absence of forsterite indicates that, the temperature can't be over 600°-700°C.

The "calcite+plagioclase" assemblage observed in the carbonated and semi-carbonated rocks of studied area also reflects the conditions of metamorphism. In the investigations carried out by Wenk

(1962) in Switzerland Alps. It is stated that the anorthite content of plagioclase taking place in "calcite + plagioclase" assemblage is increasing due to the increase in temperature increase during progressive metamorphism. The "calcite + plagioclase" assemblage found in the calcsilicatic gneiss and calcschist of the studied area represents medium grade metamorphism conditions. The typical mineral assemblage of calcsilicatic gneisses cropping out in Ortaköy, Çukurören and Sazak hill (J35-a2) is "plagioclase + diopside + scapolite + calcite + hornblende" (green). The presence of scapolite in this assemblage is interpreted as the indication of a medium-high grade metamorphism.

The minerals and mineral assemblages observed in carbonate and semi-carbonate lithologies show a progressive regional metamorphism as they are in the metapelitic derivatives. We observe the talc \rightarrow tremolite \rightarrow diopside sequence which is formed at 450°-600°C temperature and 4-5 Kbar pressure according to total fluid pressure (Pf) and amount of X_{CO_2} and we can't observe forsterite and wollastonite minerals. Therefore a medium-high grade metamorphism is expected.

Metabasites

The index minerals of the amphibolites, those are called metabasites and found in metapelitic

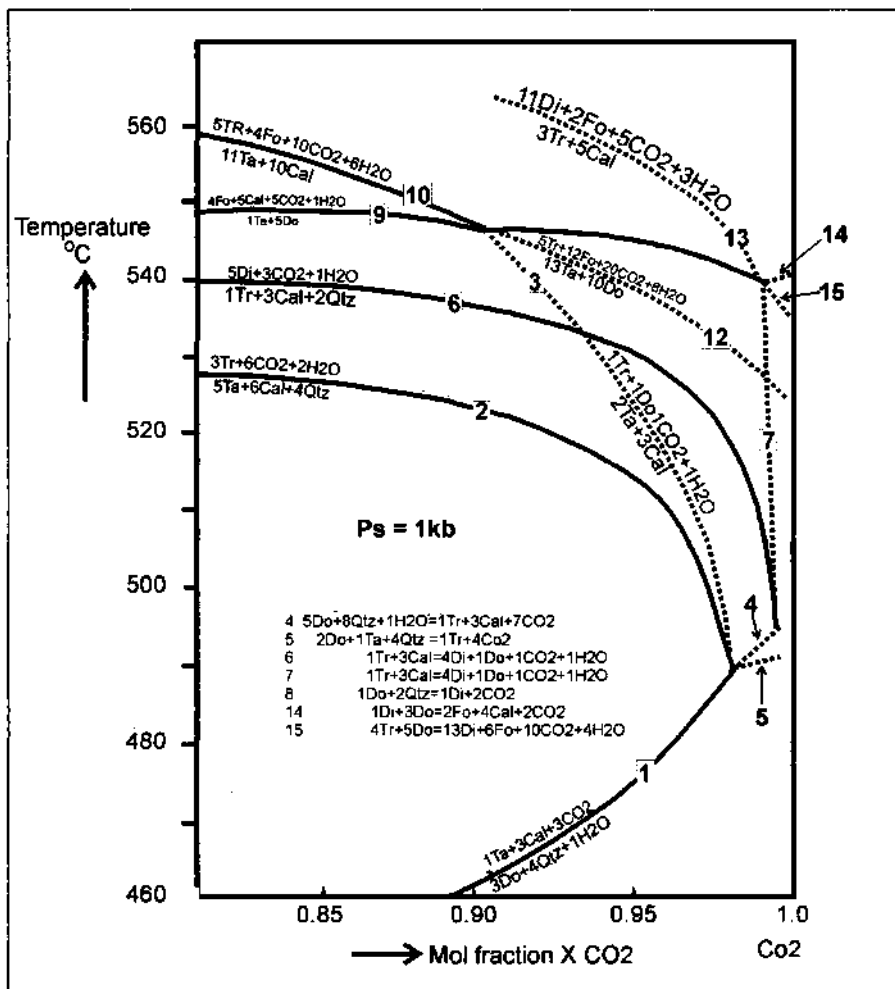


Fig. 9- Isobaric T-X_{CO2} diagram (Winkler, 1976)

units as lenses and intercalations, are plagioclase, hornblende, garnet and epidote. Apatite, titanite, quartz, biotite and opaque minerals sometimes accompany these minerals.

When we consider at their geological setting beside their mineralogical composition; it has been seen that they don't have a lithostratigraphic regularity like other metasedimentary units and they occur as irregular Lenses from a few meters to tens of meters in almost every lithological unit. In fact these findings show magmatic origin. The chemical analyses made by Sağıroğlu (1982) also show that the amphibolite group rocks of the massif are magmatic in origin. On his study the Niggli values has been evaluated and put on the diagrams prepared by Leake (1964). He stated that these values are in the field of "basic magmatic rocks" (Sağıroğlu, 1982).

The index minerals of the amphibolite samples

taken from the studied area those reflecting conditions of metamorphism are plagioclase (especially andesine in composition), green colored hornblende and accompanying garnet, biotite and epidote. They form the assemblage "plagioclase (andesine) + hornblende ± garnet ± biotite ± epidote. We can't see chlorite that normally accompanies "plagioclase + hornblende" assemblage at the starting conditions of amphibolite facies up to about 550°C temperature. We also can't see diopside that appears normally when it is reached to 650°C temperature and only garnet could be observed. When we consider at the above mentioned information above and the ACF diagram (Fig. 10) prepared by Bucher and Frey (1994), we can conclude that the amphibolites of the studied area are the products of a metamorphism taken place at about 600°C temperature and 6 Kb pressure.

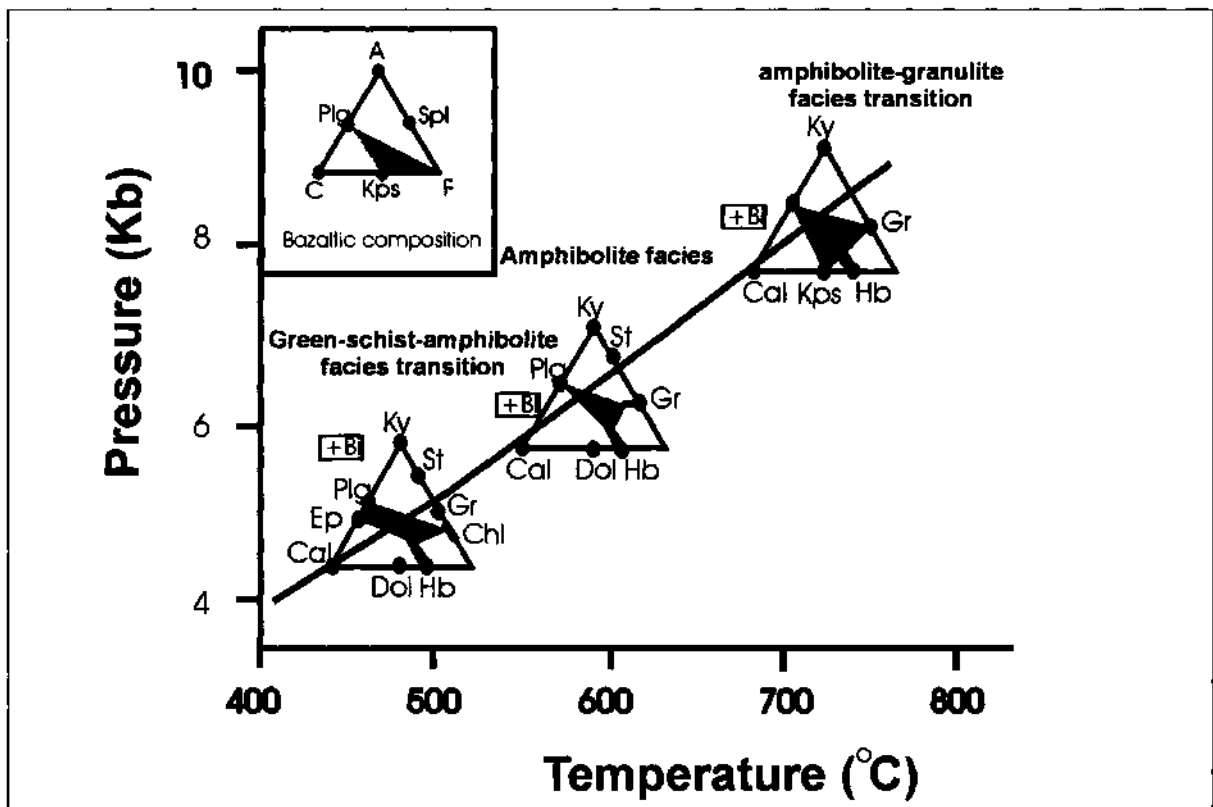


Fig. 10- Metamorphism of the mafic rocks (ACF diagram, Bucher and Frey, 1994).

CONCLUSION

When we consider the petrologic determinations of the mineral assemblages (Fig. 2) found in studied area, it is seen that the metamorphic rocks of the studied area have been metamorphosed progressively by a regional dynamo-thermal metamorphism. The minerals and mineral assemblages such as "biotite, garnet, kyanite, biotite + muscovite, biotite + garnet, staurolite, garnet + staurolite, biotite + staurolite, staurolite + kyanite, biotite + sillimanite" found in metapelitic derivatives show that metamorphism has taken place at 400°C-700° temperature and 3.5-6.5 Kb pressure conditions progressively. The "talc + tremolite + calcite, diopside + calcite + tremolite + quartz, plagioclase + quartz, plagioclase + diopside + scapolite + calcite + hornblende" assemblages found in semi-metapelitic derivatives and in metacarbonates also show a progressive metamorphism and represent a medium-high grade metamorphism at 350-600°C. The "plagioclase (andesine) + hornblende (green) ± garnet ± biotite ± epidote" assemblage found in lithologies like amphibolites reflect about 600 °C temperature and 6 Kbar pressure conditions. All the petrologic results obtained support each other regarding the type and character of metamorphism.

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PALEONTOLOGICAL (PLANKTIC FORAMINIFER-OSTRACOD) INVESTIGATION OF EOCENE SEQUENCE OF KARAMAN REGION

Ümit ŞAFAK*

ABSTRACT.- The microfauna of Eocene sequence outcropping around Karaman have been investigated. These planktic foraminifers and ostracods were systematically described; also *Acarinina bullbrooki* planktic foraminifer zone belonging to Lutetian has been determined and this zone was compared with other Eocene planktic foraminifer zones over the world indicating same level. In addition, ostracod species described were stratigraphically and paleogeographically compared with those of other basins.

OSTRACOD AND FORAMINIFER ASSEMBLAGES OF TERTIARY SEDIMENTS AT W. BAKIRKÖY (ISTANBUL)

Ümit ŞAFAK*, Niyazi AVŞAR* and Engin MERİÇ**

ABSTRACT.- The drilling samples taken from the western part of the Bakırköy Basin were investigated, and the microplaeontological data were evaluated. Pliocene, Late Miocene and Late Eocene aged sediments have been observed from top to bottom of drilling, at the results of the laboratory investigation. 14 genera and 25 species from the ostracods and 10 genera and 8 species of benthic foraminifera from the Pliocene sediments: 6 genera and 11 species of ostracods, 9 genera 9 species of benthic foraminifera from the Late Miocene deposits and 11 genera and 11 species of ostracods and 20 genera and 6 species of benthic foraminifera from the Late Eocene sediments were described. The microfauna of Pliocene sediments consists of *Cyprideis seminulum* (Reuss), *C. pannonica* (Mehes), *C. anatolica* Bassiouni, *C. torosa* (Jones), *C. tuberculata* (Mehes), *C. trituberculata* Kristic, *C. pontica* Kristic are rare, and characteristic for Pontic Basin. In addition, *Loxoconcha* sp., *Semicytherura* sp., *Xestoleberis margaritae* Mauller, *X. ventricosa* Mueller, *X. reymenti* Ruggieri, *X. communis* Mueller, *Darwinula stevensoni* (Brady&Robertson), *D. cylindrica* Straub, *Ilyocypris* cf., *bradyi* (Norman), *Candona* (*Candona*) *altoides* Petrovski, *C. (Candona) parallela pannonica* Zalanyi, *C. (Candona) decimal* Freels, *C. (Candona) Candida* (Müller), *C. (Candona) neglecta* Sars, *Heterocypris salina salina* (Brady), *Eucypris dulcifons* Diebel & Pietrzenuik are found in the sequence, and foraminifera consisting of *Siphonaperta aspera* (d'Orbigny), *Quinqueloculina seminula* (Linne), *Eponides concameratus* (Williamson), *Cibicidoides* sp., *Cibicides advenum* (d'Orbigny), *Asterigerina* sp., *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *Challengerella bradyi*, Billman, Hottinger & Oesterle, *Elphidium crispum* (Linne) are of Pliocene age. The following species were identified from the Upper Miocene; these are respectively *Cyprideis seminulum* (Reuss), *C. pannonica* (Mehes), *C. anatolica* Bassiouni, *C. torosa* (Jones), *C. pontica* Krstic, *Tyrrhenocythere triebeli* Krstic, *Xestoleberis ventricosa* Mueller, *X. reymenti* Ruggieri, *Ilyocypris* cf. *gibba* (Ramdohr), *Heterocypris salina salina* (Brady) from the ostracods species and *Quinqueloculina seminula* (Linne), *Q. cf. lamarkiana* d'Orbigny, *Quinqueloculina* sp. 1, *Quinqueloculina* sp. 2, *Cibicidoides* sp., *Eponides concameratus* (Williamson), *Lobatula* (Walker & Jacobs), *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *Porosonion subgranosum* (Egger), *Elphidium crispum* (Linne) from benthic foraminifera. Upper Eocene sediments contain following ostracods; *Cytherella triestina* Kollmann, *Bairdia subdeltoidea* (Muenster), *B. elongata* Lienenklaus, *B. cymbula* Deltel, *B. crebra* Deltel, *Bairdoppilata* cf. *gliberti* Keij, *Triebelina punctata* Deltel, *Schizocythere appendiculata appendiculata* Triebel, *S. tessellata tessellata* (Bosquet), *Eucythere* sp. 1, *Eucythere* sp. 2, *Thracella apostolescui* Sönmez, *Krithe rutoti* Keij, *Echinocythereis isabeanana* Oertli, *Leguminocythereis genappensis* Keij, *Nucleolina multicostata* (Deltel), *Pokornyella osnabrugensis* (Lienenklaus), *P. ventricosa* (Bosquet), *Hermanites paijenborchiana* Keij, *H. triebeli* Stchepinsky, *Quadracythere vermiculata* (Bosquet), *Q. hulüsü* Sönmez-Gökçen, *Cytheretta tenuistriata* (Reuss), *C. bartonica* Sönmez-Gökçen, *Xestoleberis sublobosa* (Bosquet), *X. muelleriana* Lienenklaus, *Uroleberis* sp., *Paracypris contracta* (Jones) Among the foraminifera *Halkyardia minima* (Liebus), *Sphaerogypsina globula* (Reuss), *Asterigerina rotula* (Kaufmann), *Chapmanina gassinensis* (Silvestri), *Nummulites fabianii* (Prever), *N. striatus* (Brugiere) are characteristic for this level. According to result of the drilling samples taken from the western part of the Bakırköy and Ataköy region, it is indicated that there were the restricted environments, and that salinity reduces depending on the shallowness in Late Miocene and shallow marine in Late Eocene in the region. In addition, it is observed that it changed to lagoonal and shallow marine in the Pliocene.

AN AUTOCHTHONOUS. RECENT LATERITIC OCCURRENCE IN THE EASTERN TAURUS BELT: BÜYÜKBELEN
(FARAŞA-YAHYALI) IRON OCCURRENCE

Şuayip KÜPELİ*, İsrail KAYABALI**, Mehmet ARSLAN*** and Hakan-'Aydin SAKA"

ABSTRACT.- In the study area, which is located 28 km southeast of the Yahyalı (Kayseri) village, are cropped out Upper Cretaceous aged pelagic sediments and ophiolitic rocks. These lithologies of the Bozkır unit are studied into the two main groups as Çavdaruşağı olistostrome and Pozantı-Faraşa peridotite nappe. Büyükbelen Laterites are composed of recent, autochthonous lateritic iron crust and red soils derived from pelagic carbonates intercalated with chert of the Upper Cretaceous aged Çavdaruşağı olistostrome. Above mentioned ores were formed by lateritization and partly karstification processes affected after Miocene. Lateritic iron ore is principally composed of goethite, hematite, ferrihydrite, quartz, illite, kaolinite, malahite, azurite and amorphous matter aggregates. Major oxide percentages of the laterites are, in average, 49.71 % Fe₂O₃, 3.12 % Al₂O₃, 30.75 % SiO₂ and 0.09 % CaO. Above mentioned lateritic ore was enriched in Fe, but was depleted in Si and Ca compared to the parent rock. Al component was also removed under poorly acidic-neutral weathering conditions. The red soils including average 4.05 % Fe₂O₃, 7.13 % Al₂O₃, 79.49 % SiO₂ and 1.73 % CaO are made up of quartz, montmorillonite, calcite, illite, opal-CT and amorphous matter. In electron microscopic investigation, it is observed that thin-fibrous goethite and euhedral hematite crystals in the laterite samples are authigenic, and transformations between these two minerals are common. The studied laterites are relatively rich in Cu, Cr, Co, Zn, Ba, Ni but poor in Ce, La, Th and Zr. On the other hand Cr, Cu and Mo concentrations are also high in the parent rock.

LATE MIOCENE ARTIODACTYLES (MAMMALIA) FROM YUKARISAZAK VILLAGE (KALE-DENİZLİ)

Vahdet TUNA****

Amongst the defined Artiodactyla specimen at Kapuşçabaşı locality. Yukarisazak village has been those that Helladotherium duvernoyi Gaudry, Protoryx carolinae Major, Tragoportax amalthea (Roth and Wagner) and Gazella deperdita (Gervais). These paleomammalian species has dated back as early as Late Miocene (Turolian) and implies presence of steppes covered by bush during that era.

AN EXAMPLE TO THE JASPEROIDAL-TYPE EPITHERMAL MINERALIZATION FROM THE WESTERN ANATOLIA:
DEĞİRMENCİLER ANTIMONY MINERALIZATION (SIMAV, KÜTAHYA)

Vedat OYGÜR***** and Ayhan ERLER*****

ABSTRACT.- Değirmenciler antimony mineralization consists of the stibnite-bearing quartz veins emplaced within the marble lenses of the biotite-gneisses which are at the bottom of the stratigraphical sequence of the Simav region. Quartz veins formed both as the replacement of and open-space filling in the limestone cut the schistosity of the host rock and crop out in accordance with it. Limestones were decalcified before the mineralization along the faults and later, transformed to jasperoid as a consequence of the replacement of calcite by silica. Intermediate and advanced argillic alterations consisting of the montmorillonite, smectite, dickite, quartz, opaline-CT and cristobalite developed on the wall rock. Halotrichite which represents the acid leaching zone of the hydrothermal alteration presents as well. Comb, cockade and banded textures as colloform and crustiform are widespread within the silicified rock. Hydrothermal breccias with black silica matrix and partly abundant pyrite are observed at the mineralized parts. Pyrite and graphite accompany the stibnite in the veins. In addition, galena, sphalerite, molybdenite, bismuthinite, gold and silver in lesser amounts are associated with the mineralized veins. Homogenization temperatures measured from the fluid inclusions of the quartz crystals vary 200 to 310° C and signify the deeper parts of an epithermal system. The association of stibnite and molybdenite in the veins points out that the hydrothermal solutions could have gained their metal content from the magmatic emanations. Therefore, it is suggested that the ore-bearing fluids has a genetical relationship with a buried granitoid stock which is represented by the dacite porphyries cropping out near the mineralization. However, graphite, rutile and anatase which are in the content of the vein show an addition to the hydrothermal solutions during their ascension as a leaching from the wall rocks.

PRECIOUS METALS AT SUMADIJA-KOPAONIK-RADAN-NOVA-BRDO ZONE. YUGOSLAVIA

Radule POPOVIC*

That part of the Serbia is characterized by the presence of numerous lead, zinc and at lesser amount copper beds and outcrops accompanying precious metals. Initiating by the Roman times, the mining activities at the area ranges its maximum level at Middle Ages previously and at twentieth century lately, The mentioned metallogenic belt usually is in accordance with the Vardar zone, the predominant tectonic unit and the lead-zinc beds and exposures picture a Avala, Kosmaj, Rudnik. Kotlenik. Tolisnica and Stanca (near Goc), Kopaonik (Sastavci, Kizevak, Plavkovo. Belo Brdo, Crnac. Koporac, Stari Trg and etc), Novo Brdo and Radan Mountains (Lece. Draznja, Tulare, Sijarinska Banja and others) lining up from north to south. Precious metals either go along with lead, zinc and copper and antimony, arsenite and quartz at a lesser degree or in lycvenites and diabase and dacite andesite at a lesser amount in the form of native as well. Mineralization patterns are veins, disseminated bodies and sometimes mesh.

PERIDODITIC XENOLITHS IN ALKALINE BASALTS ATTEKIRDAG REGION (THRACE)

Fahri ESENLİ"

In basaltic volcanics at Tekirdağ region (Thrace), peridotit(ic) xenoliths such as harzburgite and dunite thought as parts of upper mantle has been found. Petrographically, the basaltic lavas are olivine-basalts showing a primary paragenesis including mainly plagioclase, olivine, augite, magnetite and scarcely hypersthene as well the secondary minerals at important degrees locally. On the other hand, geochemically they correspond to the alkaline basalt, trachybasalt basanitic rock types. Peridotite xenolith-enclosing Hacıköy and Balabanlı and excluding Muratlı basalts also differ in both major and trace element contents. Including olivine (forsterite), enstatite, Cr-spinel and scarcely diopside, the peridotite xenoliths are typically protogranular and partly grading into porphyroclastic in fabric. Magmatic textures are well preserved. Displaying no foliation or lineation, those have coarse-to huge grain sizes. Bandings resembling twinning and deformation lamellas imply the mechanical effect and are characteristic for the olivines and pyroxenes. Whether, the presence of relations depicting partial melting of original mantle, between major elements of the peridotite xenoliths is a fact, the melting point is probably not high. They were unaffected by metasomatism and submit a somewhat consumed composition compared to primitive mantle.

Key words: Alkaline basalt, xenoliths, peridotite, Thrace-Turkey

GEOLOGY AND ORIGIN OF SOME CARBONATE-HOSTED HALLOYSITE DEPOSITS IN NW - ANATOLIA (TURKEY)

Ali UYGUN***

ABSTRACT.- Geology and origin of some halloysite deposits in the provinces Çanakkale and Balıkesir (NW-Anatolia-Turkey) are investigated in this study. The deposits of Taban, İlicaoba, Karasu-Kabakla, Şahbaz and Turplu are mostly located on the contacts of altered Neogene volcanics and Jurassic limestones. Pyrite, manganese, gibbsite and some alunite are the accessory mineralizations. Based on the geological position of the halloysites over the probably karstic topography of the limestones: the absence of halloysite in the volcanics and the correlation of the REE's with the carbonate rocks; the origin of the deposits are suggested to be originated by partial dissolution of the host rock limestones and formation of halloysite directly from Al and Si-rich acidic fluids.

PALAEOGEOGRAPHIC EVOLUTION OF SIVAS TERTIARY BASIN (W-SW SIVAS)

Zeki ATALAY*

ABSTRACT.- Sedimentological studies has been made at the west and the south west of Sivas (Figure 1) and investigated palaeogeographic evolution facies and environmental features of deposit rocks. A1 A2 A3 facies have been recognized at the middle Eocene aged Sahantepe member. A1 facies has deposited at the continental shelf; A2 A3 facies at swamp and coastal sabkha. B1 B2 B3 facies have been recognized at the Oligocene aged Küçükütüzhisar Formation. B facies in lagoon, B1 facies has deposited in barrier island. B2 B3 facies have deposited at continental sabkha and playa lake environment. At the Akören formation C1 C2 C3 C4 C5 C6 C7 facies have been recognized. C1 C2 facies at the meandering river and subenvironments. C3 C4 facies at the playa lake. C5 C6 facies meandering river and C7 facies has deposited at alluvial fan environments. Continental shelf deposits consists of claystone, siltstone and sandstone, has very well (Ta-Tb), (Ta-Tc) and (Ta) structures. These have been deposited by turbidite flows in shallow sea improved. At in the coastal sabkha environment have been deposited gypsum series and they are together with elastics. Meandering river deposits consist of channel fill, point bar and flood plain subfacies fining upward cycles. Playa lake and continental sabkha deposits consist of terrestrial elastics with interlayer gypsum and anhydrite; alluvial fan deposits consist of conglomerates and poorly sorted, pebbly sandstone with muddy matrix and show normal and reverse grading. In the studied area the marine regime has been the dominating agent up to of Eocene- then the marine influence has restrained but continental regime, as a result of this swamp and coastal sabkha environments have improved. During Oligocene period has become more effective. During this period continental sabkha, playa lake, meandering river and alluvial fan environments have been made. At the Sahantepe member palaeocurrent direction is towards from the NE to NW: at the Küçükütüzhisar Formation palaeocurrent directions are towards from the N to S and NW to SE and at the Akören formation palaeocurrent directions are towards from S to N, SW to NE. In Eocene period the formations (Bozbel Formation - Sahantepe Member) was supported by the ophiolites and metamorphic units, situated in the NE of the region and Oligocene period these formations (Küçükütüzhisar and Akören Formations) were supported by the ophiolites and metamorphic units and deep acidic and basic rock as well as volcanics situated in the SW and NW of the region. On the basis of these observations, it can clearly be indicated that the Sivas basin reflects a intraplate basin characteristics following the continent-continent collision.

GEOCHEMICAL CRITERIA FOR THE INVESTIGATION OF FACIES FEATURES OF PONTIAN BASINS IN EASTERN AZERBAIJAN

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ABSTRACT.- In this study, distributions and environmental conditions of the mollusc fauna which lived in the evolution of Pontian seas of Azerbaijan were investigated. The research of the environment conditions were based on the determination of geochemical relations which was between the organism and environment. Interpretation of the distribution differences of the Ba, Sr, Mg and Ca in the shell and deposits were indicated the salinity, temperature and paleofacies of the basin at the Ponsien age mentioned above. Detailed investigations indicated that, the reason of the widely appearances of in marine environments depended on the lithofacies properties of deposits, such that in the shallow marine facies deposits contain more barium. In any case the barium content of mollusc species belong to this facies are more than the other ones. Absolute temperatures of fauna and deposits formation environments were determined by Ca/Mg method during the development of the Ponsien seas. These are, in the early Ponsien age the temperature was 21-22° C, in the Middle Ponsien age the temperature was 20.6-21.5 C and in late Ponsien age the temperature was 21.5-22° C and it was determined that the temperatures were constant. In fact, it was proved that there is no balance between the Sr distribution of shell and deposits Sr amount in the deposits is less than the Sr amounts in the shells as a result, it is seen that the main parameter which controls the distribution of the Sr is the salinity rate of the environment. That is why, it is concrete that the lacustrine mollusc Sr amount is poor than the marine mollusc. Hence, Sr is an element which determines the salinity regime of the environment. It can be seen that, in the determination of the environment conditions of biogeochemical methods can also be used together with the other methods.

GEOLOGY OF DOĞANKUZU VE MORTAŞ BAUXITE DEPOSIT AND FEATURES OF SULFUROUS ZONES,
MID-TAURIDES, TURKEY

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Comprising a sulfurous zone made up of marcasite+pyrite+hematite+goethite+boehmite+diasporite+anatase+gypsum minerals at its base, Doğankuzu-Mortaş Bauxite ore bed locates at the discordance zone between Cenomanian and Santonian limestones of Cretaceous. Pisolithic ore bed, including locally calcareous conglomeratic lenticules sits on the sulfurous and lesser one-containing level and where the ore bed is thickening, that conglomeratic zones represent the paleodolines. Toward the upper parts the quality of ore increases and a massive blockage is seen. At uppermost part, a sulfuric zone, that of a few centimeters thick covers the ore and the pyrite-bearing clayey carbonates capping those, grades upward to the Santonian limestones. In these two ore beds, veins, bluish gray and green coloured, including marcasite and pyrite at 15 percent and thickening up to two meters, rich in diasporite, are seen and those are crackfills. These extend into neither underneath nor covering limestones. Petrographical and mineralogical findings show that, especially through internal diagenesis reductive processes were effective and an explanation for the formation of sulfurous zones is that the sulfates in the sea water penetrate into the bauxitic matter and being to the sulfides by the bacteria, synchronously to the deposition of Santonian carbonates.

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