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PETROLOGICAL FEATURES OF THE METAMORPHICS OF THE YUKARIÇULHALI-BAŞÇATAK SEGMENT OF THE AKDAĞMADENİ MASSIF

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ABSTRACT.- The investigated area is within Akdağmadeni massif and is composed generally of metapelites, semimetapelites, metapsammites and metacarbonates as a metasedimentary sequence. These rock units, especially metapelites have mineral paragenesis suitable for petrological evaluation. Petrographic investigation of different schists and gneisses indicate that there are two different metamorphic zones The first one is typically characterized by the biotite+garnet (almandine) paragenesis and is called the I. zone metamorphism and the second is characterized by the sillimanite+kyanite paragenesis called the II. zone metamorphism. Petrogenetic evaluation was carried out by using the assemblages indicating a single-phase progressive dynamothermal-regional metamorphism.

INTRODUCTION

Akdağmadeni massif metamorphics including the investigation area is extended to Yozgat, Akdağmadeni, Sivas at the north, Çayıralan at the south and Hasbek at the west (Fig. 1). The investigation area which has a distance about 30 km. to Akdağmadeni is located at the center of the massif (Fig. 2).

Akdağmadeni metamorphics as a metasedimentary sequence lies in the northeastern part of the Middle Anatolian crystalline basement and is affected by a regional-dynamothermal metamorphism.

Dominant lithologies of this metasedimentary sequence consist essentially of metapelites, amphibolites, metapsammites, metacarbonates, all being intruded by granitoids.

Evaluation of petrologic results of the investigated area shows that there is an intense deformation divided into two zones of metamorphism, the division being based on paragenesis.

First investigation of the metamorphics was done by Pollak (1958), separating this sequence into three units. At the base, the "Basement Series" is composed of quartzite, marble, mica-gneiss; the medial part uncomformably overlying this unit was called the "Marble Series" and the upper" part consisting of mica-schists and mica-quartzite was named as the "Top Series". Vache (1962) continued the investigation of Pollak and according to him, the "Basement Series" was metamorphosed in meso-catazonal conditions and "the Middle and the Top Series" uncomformably overlying the Basement Series suffered an epizonal regional metamorphism.

Ketin (1959; after Ketin, 1983) prepared a 1:100 000 scale geological map of the area differentiating the metamorphics into two units which are composed of mica-schist, marble and calcschist.

Erkan (1975), based on the mineral associations of sillimanite+orthoclase and kyanite+staurolite, suggested that the prevailing pressure conditions in this area were higher than that of the Kırşehir region. Erkan (1980) also suggested that metamorphic rocks of the region can not be divisible into a top and a bottom series defending that it would not be plausible to have a lower grade metamorphism without having an imprint on the earlier high grade rocks. He determined that this region was affected by a high grade regional metamorphism.

The study of Dökmeci (1980) around Akdağmadeni includes description of metamorphic rock groups and a generalized columnar section. He defined all metamorphics as the Akdağ metamorphic group and distinguished two formations. The older

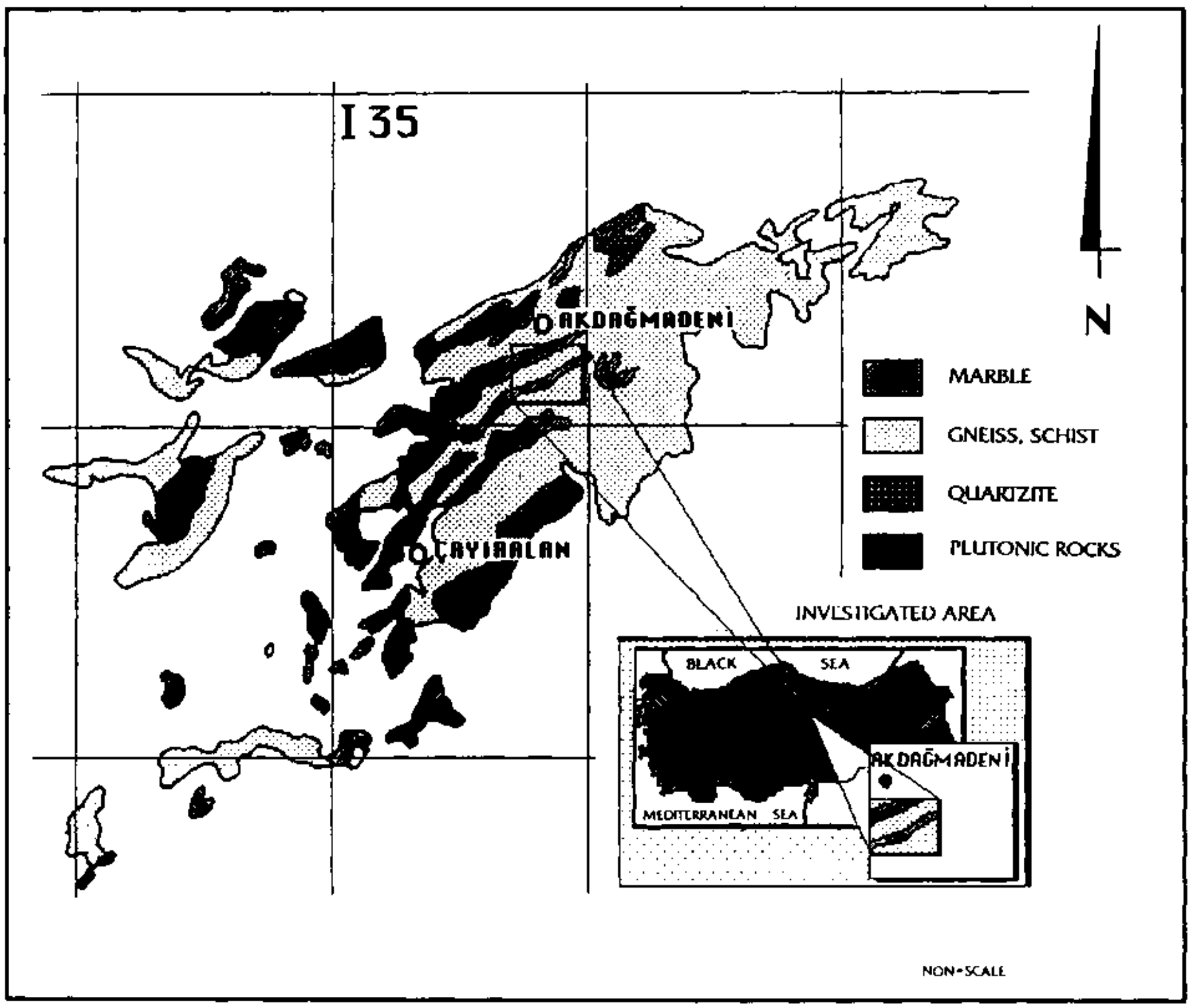

Fig. 1- Location of Akdağmadeni massif and the study area.

one, Köklüdere formation, is composed of gneisses and schists while the younger, Özerözü formation, comprise essentially of marbles. The authors observed that the metamorphic rocks were cut by granite, aplite-pegmatite and riolitic dykes.

Özcan et al. (1980) proposed a high temperature-medium pressure metamorphism which was described as an almandine-amphibolite facies metamorphism on the basis of the staurolite+kyanite+garnet and staurolite+sillimanite parageneses.

Tiilumen (1980) expressed that the metamorphic rocks were metamorphozed at temperatures of 500-600°C and a maximum pressure of 5 kb. He differantiated the regional metamorphic rocks into petrographic facies compatible with facies of metamorphism. Şahin (1991) described the metamorphic rocks as a metasedimentary sequence composed of mica-gneiss, calcsilicatic gneiss and muscovite-schists (metapelites) and marbles (metacarbonates) determining two metamorphic zones. The first zone is characterized by biotite+garnet paragenesis while the second by staurolite+kyanite and sillimanite+kyanite paragenesis. Tectonic elements (fault and folds) developed within the metamorphic units were investigated on a statistical basis, which yielded four sets of elements of folding.

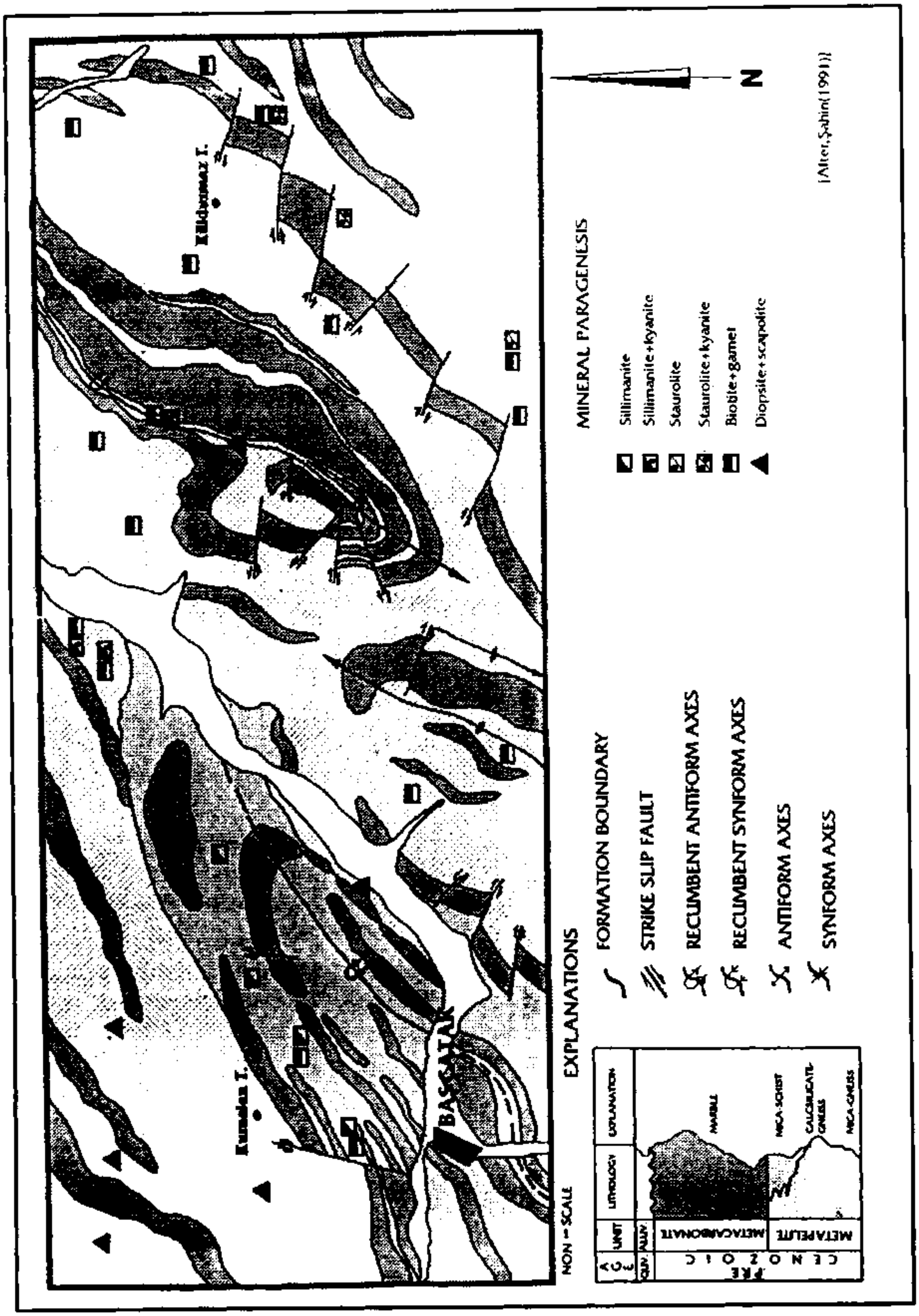

Fig. 2- Geological map of the study area [After, Şahin (1991)].

MINERAL ASSOCIATIONS AND ZONES OF METAMORPHISM

Typical mineral associations of the pelitic rocks of the area and physical conditions of metamorphism through a consideration are divided into two main groups.

Metapelites:

biotite+almandine

biotite+almandine+staurolite+kyanite

biotite+almandine+kyanite+sillimanite

Semi Metapelites:

diopside+scapolite+calcite+plagioclase+titanite

Biotite+garnet (almandine) association. - It seems that the "biotite+garnet" association represents the lowest grade of metamorphism of the area on consideration of physical conditions of metamorphism of the metapelites. It is noteworthy (Fig. 3) that biotite mineral appears first at temperatures above 400°C. Biotite existing in a very wide range of P/T condition does not yield information restricting the physical condition of metamorphism.

The zone where garnet appears was defined as the "garnet zone" by Winkler (1979). However, it is known that the first appearance of almandine in pelitic rocks is not indicative of P/T conditions. Almandine for which-stability fields have been determined by Hsu (1968), appears over 500°C as shown in Figure 4.

On evaluation of the above mentioned parameters together, we can suggest that biotite+garnet

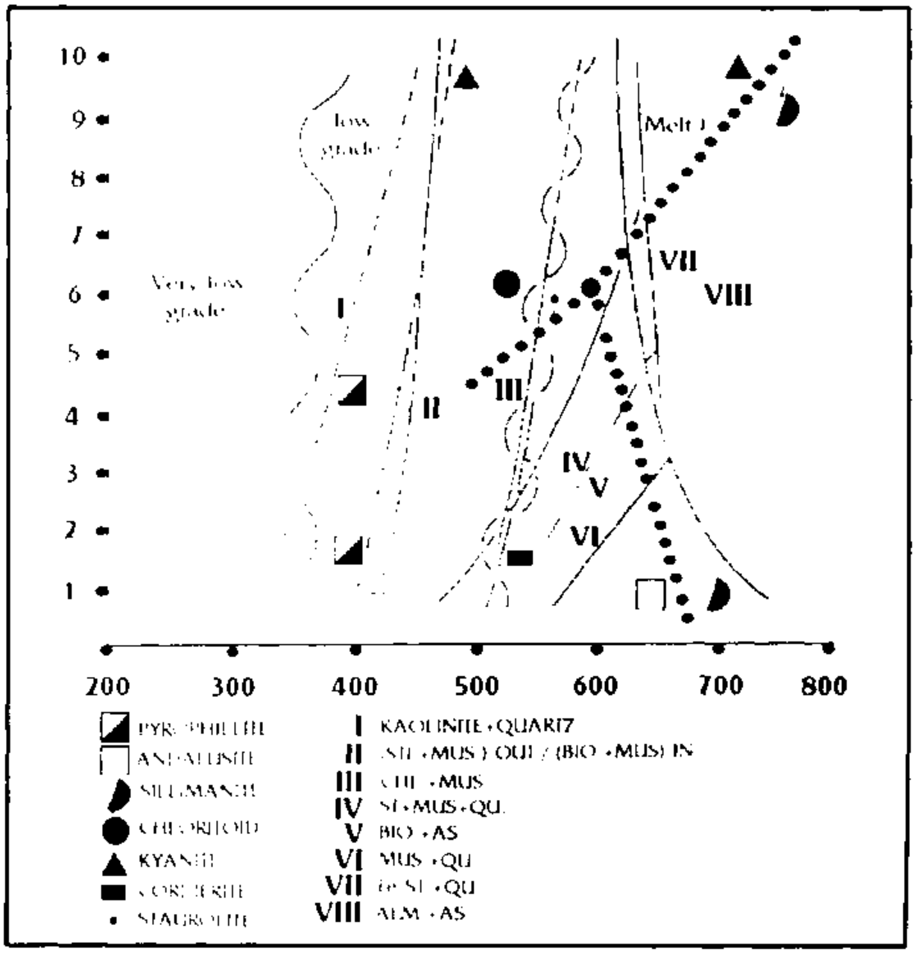

Fig. 3- Metamorphic reactions of pelitic rocks (Winkler, 1979).

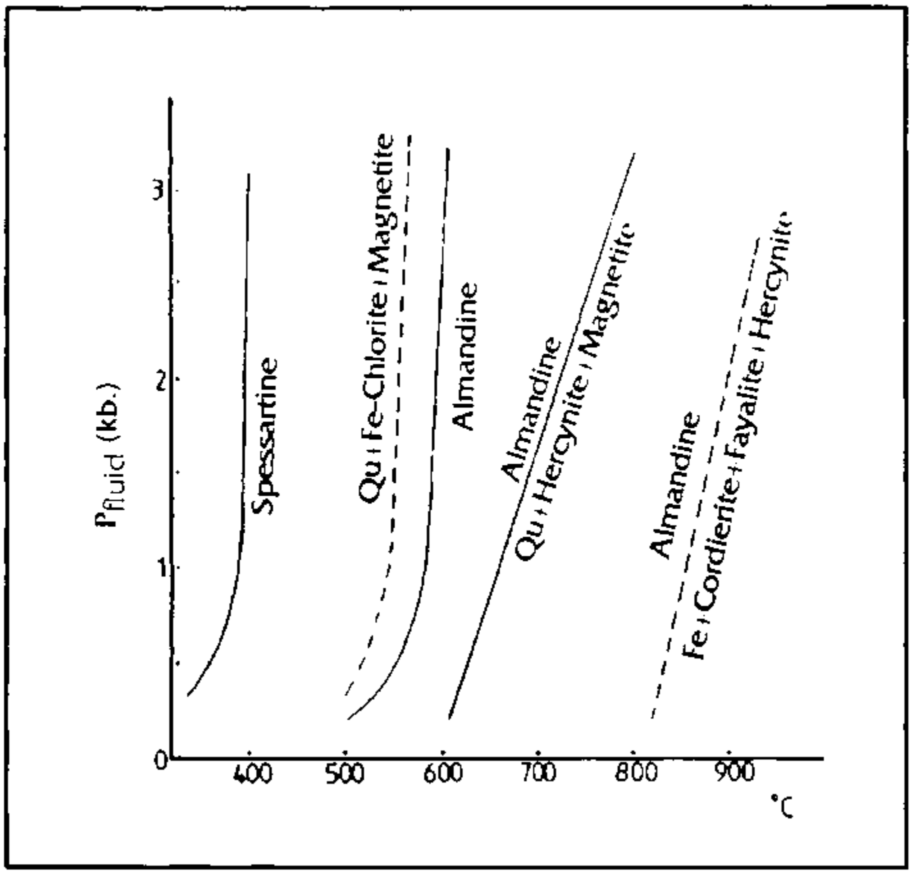

Fig. 4- Stability areas of almandine (Hsu, 1968).

association should correspond to the high-temperature range of the low-grade metamorphism. This association which was observed at the south-western part of the area is called as the I. zone of metamorphism. Mineral associations representing the lower limits of P/T conditions could not be determined. On the other hand the upper boundary is defined by the appearance of staurolite, kyanite and sillimanite which occur through progressive augmentation of P/T conditions. These minerals characterize the high grade zone of metamorphism.

Biotite+gamet (almandine) + staurolite + kyanite association. - The staurolite mineral observed in the eastern part of the area indicates the transition from low grade metamorphism to the medium. The medium grade zone was defined as the II. zone of metamorphism and was characterized by the biotite + almandine + staurolite + kyanite association in the metapelites of area.

According to Winkler (1979), the transition from the low grade to the medium grade is determined by appearance of staurolite and cordierite. The reactions of occurrence of these minerals have been evaluated as isoreaction-grads. It is noteworthy that instead of cordierite, staurolite appears within the metapelites of the area, with the implication that the physical conditions of the first appearance of staurolite need to be reconsidered.

It is shown in Figure 3 that the appearance of these minerals takes place at temperature greater than 500°C and at the same temperature range. But staurolite occurs at higher pressure ranges than cordierite, although one of the most important factors is the bulk chemical composition besides P/T conditions of occurrence of staurolite and cordierite. According to experimental studies, staurolite occurs with this reaction,

chloritoid+O_2 = staurolite+magnetite+quartz+H_2O

and P/T conditions are between 575°C temperature-10 kb. pressure and 545°C temperature-5 kb. pressure (Ganguly and Newton, 1969). In addition to experimental studies, staurolite can occur with chlorite+muscovite reaction if chloritoid absent is (Hoschek, 1969):

chlorite+muscovite = staurolite+biotite+quartz+H_2O

chlorite + muscovite + almandine = staurolite + biotite + quartz + H_2O

These reactions show that, staurolite occurs in metapelites of restricted chemical composition. Also Mg/(Mg+Fe) ratio is important. Winkler (1979) suggested that if this ratio is higher than 0.25, cordierite occurs instead of staurolite through the following reaction:

chlorite + muscovite + quartz = cordierite + biotite + Al_2SiO_5+H_2O

On consideration of the petrogenetic conditions of the occurrence of the biotite+garnet+staurolite+kyanite association and staurolite, in the II. zone of metamorphism in the investigated area, the medium-grade metamorphism was realized at temperatures greater than 550°C at 5.5-6 kbs. and the chemical composition had suitable [Mg/(Mg+Fe)] ratio for occurrence of staurolite.

Co-existence of cordierite+garnet paragenesis has been reported by Erkan and Tolluoğlu (1990) in the III. metamorphic zone in the northern part of Kırşehir. In the I. metamorphic zone of this region, chlorite+chloritoid paragenesis and high Mg content of chlorite have been determined. In the medium grade metamorphic zone of Kırşehir massif the existence of cordierite instead of staurolite indicates that the pressure in this region has been lower than that of the Akdağmadeni metamorphics and the Mg/(Mg+Fe) ratio is not suitable for the occurrence of staurolite.

Diopsite + scapolite + plagioclase + calcite + titanite association. _ The semi-metacarbonate lithologies or calcsilicate gneisses have the diopsite+scapolite+plagioclase+calcite+titanite paragenesis in the northwestern part of the study area. The same association was determined; by Erkan (1975) and Tolluoğlu (1986) in the calcsilicate rocks of the II. metamorphism zone in Kırşehir area. Existence of scapolite in this association is expected to occur in the high temperature part of the amphibolite fades of the regional metamorphism, suggesting higher temperature in the II. metamorphic zone of the area.

Kyanite-sillimanite mineral association. - Andalusite, kyanite and sillimanite minerals (Al_2SiO_5 polymorphs) yield important information for petrogenetic conditions. Experimental studies by Althaus (1967) to determine the stability fields of these minerals show that the P/T conditions of the triple point of the intersecting phase boundaries are P= 6.5 ± 0.5 kb., T= 595 ± 10°C. According to this study, with increase of temperature and pressure

andalusite - sillimanite

kyanite - sillimanite

transformation will be observed. The experimental works of various researchers indicated that kyanite = sillimanite transformation took place at 750°C temperature and 8.1 ±0.4 kb. pressure. Experimental studies of Richardson et al. (1968) showed that transformation was realized between 700-1500°C. Anderson and Kleppa (1969) investigated thermochemistry of kyanite = sillimanite equlibrium and pointed out kyanite = sillimanite transformation occured at 701°C at pressures lower than 12 kb. Evaluation of Figure 3 shows that kyanite = sillimanite transformation takes place at the P/T range of anatexis.

Sillimanite+kyanite association observed in the study area has not any features which are acceptable indicators of this transformation. Petrographic investigations showed that these minerals had not any indications of transformations. In addition to this, there are not any data for anatectic occurrence or indicator of anatexis in this area, implying that the temperature was lower than 700°C in the investigated rocks of the area. Nevertheless, for a general evaluation, conditions of occurrence of sillimanite and kyanite and of other minerals such as muscovite, biotite, quartz, almandine and plagioclase present with sillimanite and kyanite in the same rock must also be considered. Kyanite, the high pressure modification of Al_2SiO_5, appears at the high pressure range of low grade metamorphism by the following reaction:

pyrophillite = kyanite+3 quartz+1 H_2O

$Al_2Si_4O_{10}(OH)_2$ = Al_2SiO_5+3 SiO_2+H_2O

Pyrophillite loses its stability and enables occurrence of kyanite by this reaction. On the other hand, the other reaction by which kyanite occurs, is

staurolite+quartz = Al_2SiO_5+almandine+H_2O

This reaction occurs at about 700°C and in anatexis conditions (Fig. 3). As expressed before, non appearence of anatexis in the study area, presence of kyanite+staurolite association in the II. metamorphic zone and absence of staurolite = kyanite transformation in the investigated samples are datas implicit evidence showing that kyanite did not form through the staurolite+quartz reaction. In these samples, these minerals coexist.

First appearance of kyanite is with staurolite in the investigated area. The appearence of kyanite is thus, independent of transformations and the kyanite+staurolite association suggests that kyanite and staurolite crystallized from an appropriate bulk composition in the appropriate P/T range.

Two reactions had been investigated for occurrence of sillimanite, the high pressure modification of Al_2SiO_5.These are:

muscovite + quartz = sillimanite+orthoclase

staurolite + muscovite + quartz = biotite + Al_2SiO_5 + H_2O

Experimental studies showed that the high grade metamorphism was realized by muscovite and quartz reacting together to yield the sillimanite+othoclase association.

muscovite+quartz = K-feldspar+Al_2SiO_5+H_2O

For this reaction the equilibrium conditions are

PH_2O = 620°C for 2 kb.

PH_2O = 650°C for 3 kb.

PH_2O = 680°C for 4 kb. (Winkler, 1967).

On the basis of experimental work, it was stated that water pressure was effective on equilibrium temperature in the muscovite+quartz reaction and the temperature would augment by 30°C per 1 kb increase of pressure, so that the temperature would reach to 725°C at pressures of 5 kb. It was expressed that this temperature was the maximum stability temperature of muscovite+quartz assemblage, corresponding to begining of anatexis in gneisses. On the basis of these experimental data, and assuming a 30°C increase of temperature per 1 kb increase of pressure, a temperature of 740°C will be reached at a pressure of 6 kb. These physical conditions correspond to advanced stages of anatexis, which was not encountered in this study. The rocks in which kyanite+sillimanite co-exist, contain ample amounts of quartz in contact with muscovite, in addition to plagioclase having not been replaced by orthoclase, is suggestive that the temperatures are not high enough for the reaction:

muscovite+quartz = sillimanite+orthoclase

It is known that sillimanite can also form by the staurolite+muscovite+quartz reaction with increasing temperature (Hoschek, 1969):

staurolite + muscovite + quartz = Al_2SiO_5 + biotite + H_2O

Occurrence of biotite by this reaction associates it with biotites of earlier generations while formation of sillimanite is coeval with the second generation of biotite appearing through this reaction. The disappearance of staurolite implies that sillimanite forms through the staurolite+muscovite+quartz reaction. This impression is supported by occurence of biotite and fibrous sillimanite as clusters.

The kyanite+sillimanite association characterises high pressure/high temperatures in the II. metamorphic zone of the study area.

RESULTS

The petrographic and petrologic evaluation of collected samples shows that these rocks are of sedimentary origin. The following mineral paragenesis, found through this work, are indicative of facies changes ranging from the high temperature part of low grade to high grade temperature part of the medium grade:

biotite+garnet (almandine),

biotite+garnet(almandine)+staurolite+kyanite,

biotite+garnet(almandine)+kyanite+sillimanite,

diopsite+scapolite+plagioclase+titanite.

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