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Metamict zircon and Structural Characters: Pütürge Metamorphite Example

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Abstract

Mineralogical studies (rock named, zircon separate), geochemical analysis(LA-ICPMS) and cathodoluminescence (CL) image were applied to samples of the Pütürge metamorphites representing different facies such as amphibolites and greenschiste. Pütürge metamorphites are made up of pelite/semi-pelite, psammite, metagranite gneisse, schist, amphibolite, marble and quartzite type rocks. Mineral paragenesis, the transformation of the garnet mineral advancing on the kyanite-almandine-muscovite and staurolite-almandine sub-facies of the amphibolite facies of the massive to chlorite and biotite minerals along with the transformation of the kyanite mineral to muscovite mineral show that the massive has undergone two retrograde metamorphisms on the greenschist facies. The exhumation process of the metamorphites is seen as the cause of the retrograde metamorphism.

The cathodoluminescence images of zircon minerals show a zoning that indicates a metamorphic growth where partial radiation damage in the shape of oscillatory zoning and porous structure also occurs pointing out the magmatic root. A zircon type with different textural and chemical components which might be called partially metamictte has developed. The luminescence feature in partially radiated zircon particles rich in radiogenetic minerals is rather high in comparison with other zircon particles. High temperature during the metamorphism of the massive and the ratio of the radiogenetic elements like U and Th in the mineral are effective in the textural and chemical difference between the core and rims of zircons.

Keywords: Metamictisation, Radiation damage, Zircon, Metamorphic rocks, Pütürge

Metamikt Zirkonlar ve Yapısal Özellikleri: Pütürge Metamorfiti Örneği

Özet

Pütürge metamorfitlerinde mineralojik (kayaç adlandırılması, zirkon ayrımı), jeokimyasal (LA-ICPMS) ve Kathödölüminesans (CL) incelemeleri Pütürge metamorfitlerinin amfibolit ve yeşilşist fasiyesi gibi farklı fasiyesleirn özelliğini yansıtacak örneklerden alınmıştır. Pütürge metamorfitleri, pelit/semi-pelit, pisamit, metagranit, gnays, şist, amfibolit, mermer ve kuvarsitten oluşur. Mineral parajenezleri, masifin amfibolit fasiyesinin disten-almandin-muskovit ve stavrolit-almandin alt fasiyeslerinde ilerleyen, granat mineralinin klorit ve biyotit minerallerine dönüşümleri ve disten mineralinin muskovit mineralinine dönüşümü gibi özelliklerden yeşilşist fasiyesinde gerileyen türden iki metamorfizma geçirmiş olduğunu göstermektedir. Gerileyen metamorfizmaya metamorfitlerin yükselme süreci sebep olarak görülmektedir.

Zirkon minerallerinin kathödölüminesans görüntülerinde, magmatik kökeni işaret eden ilksel (oscilatory) zonlanma ve gözenekli yapı şeklinde, kısmen radyasyon hasarının da geliştiği büyüme zonlanması görülür. Dokusal ve kimyasal bileşimleri farklı olan, kısmen metamikt diyebileceğimiz zirkon değişimi gelişmiştir. Radyojenetik kapantı minerallerince zengin metamikt zirkon tanelerinde, luminesans özellik diğer zirkon tanelerine nazaran yüksektir. Zirkonda, çekirdek ve kenar kısımları arasındaki dokusal ve kimyasal farklılığa, masifin metamorfizması sırasındaki yüksek sıcaklık ve U, Th gibi radyojenetik elementlerin mineral içerisindeki oranı etkili olmuştur.

Anahtar Kelimeler: Metamiktizasyon, Radyasyon hasarı, Zirkon, Metamorfik kayaçlar, Pütürge

1. Introduction

Zircon ($ZrSiO_4$) is stable mineral for all P-T conditions such as crustal and upper mantle. This mineral is remarkably resistant against dissolution or chemical alteration over geological environments. Zircon generally incorporates differ from Hf, light REE (LREE) and non-formul elements like Ca, Al, Fe and Mn [11,7,8,6]. Minerals containing U and Th commonly occur in amorphous state although they were formed as crystalline. These phases are called metamict minerals and indicate groups of oxides, phosphates and silicates. Metamictization of minerals is a result of two counteracting processes such as radiation damage accumulation and radiation damage annealing [9]. Geisler et al.[7] suggested loss of U and Th from zircon during low temperature leaching experiments, whereas Mathieu et al.[14] concluded that U enriched rim of it was caused by an incorporation of U together with LREE [10]. In this paper, we investigate the distribution of radiation damage in zircon chrystalline and physical properties of zircon. Then, we demonstrate how image specific internal textures.

2. Materials and Methods

2.1. Sampling

The samples used in this study were collected from orthogneisse and greniticgneisse into the Pütürge metamorphite which is located within the Southeastern Anatolia thrust belt on the Eastern Taurus Orogenic Belt and Arap platform is a metamorphic massive that had developed as a result of the closure and collision of the Eurasia and Arab plates starting from the upper Cretaceous [1] (Figure 1).

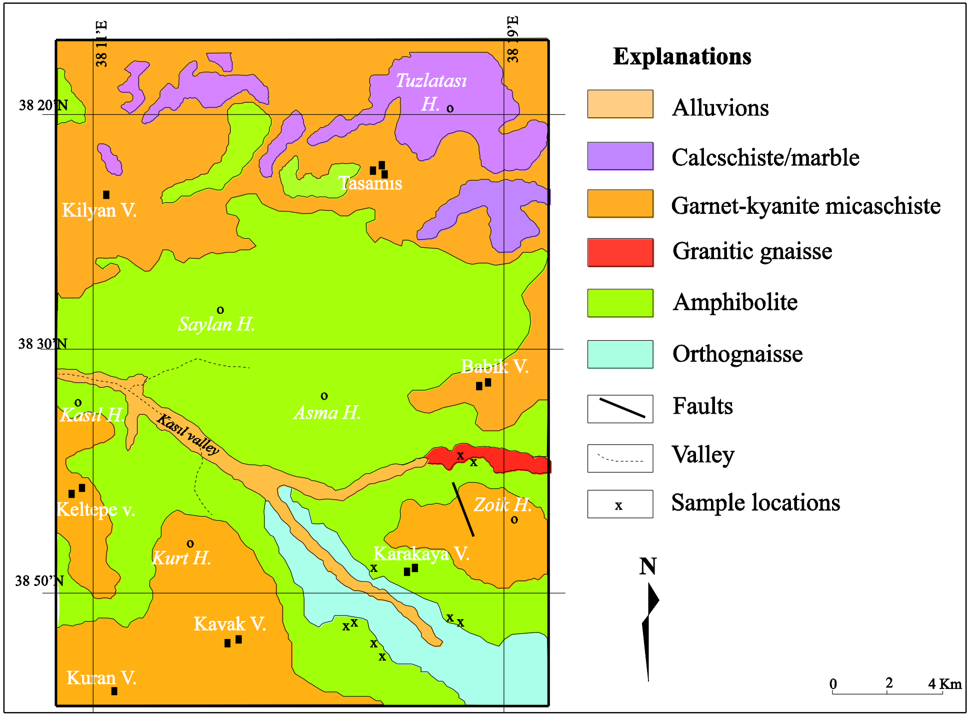

Figure 1. Geological map of the study area [2]

The rocks consist of pelite, semi-pelite, psammite, schist, metagranite, gneisse, amphibolite, marble and quartzite. The orthogneisse and granitic gneisse have highly zircon minerals. In this rocks as a primary minerals were quartz, feldpar, biotite, muscovite and opac minerals like apatite, sphene [2] (Figure 2).

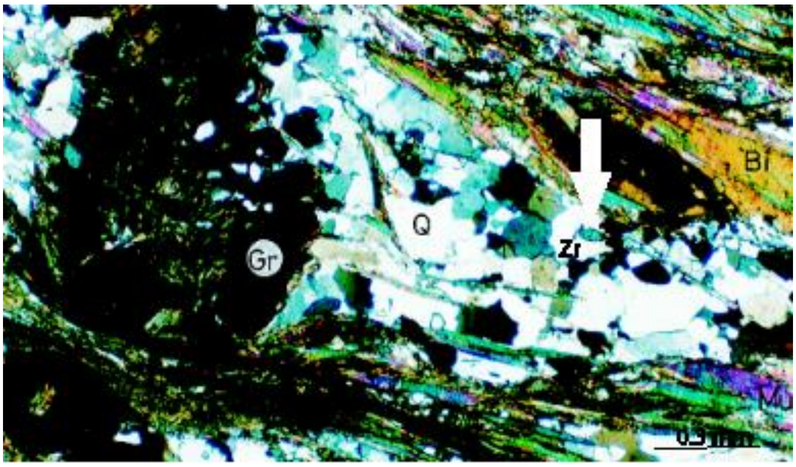

Figure 2. Prismatic zircon crystal inside the orthogneiss of the Pütürge metamorphites

2.2. Digestion procedure for the samples

Examples have been taken from all the rocks in the examination area for petrographical and geochemical examination and thin sections have been prepared in the geology lab of Firat University. Total amount of major oxides and minor elements have been found by the method of ICP-MS (Inductively Paired Plasma Mass Spectrometry), and lithium metaborate /tetraborate ($LiBO_2$) fusion and dilute nitric acid digestion methods are used in the examples of 0.2 g and maked in ACTLAB (Canada).

An Cathodoluminescence analyzer (CL) was used for CL-images of zircons. Zircons seperated from augengneiss via heavy fluids that their size varies from a few milimeters to centimeter with colors of gray-gray or sometimes dark Brown. Cathodoluminescence images of the zircons (108 grain) were taken before in-situ LA-ICP-MS dating in Geological department of the Hacettepe University (Ankara) to characterize zircons to be dated. The CL images were produced by a Zeiss Evo-50 SEM equipped with cathode-luminescence and EDS detectors. For mineral pre-separation, rock samples pulverized from zircon rich augen-gneisse are first separated into 2 samples with sieve diameters of 63-125mm and125-250mm; they are enriched first on a wet shaking table and afterwards with tetrabromethane and diodemethane and magnetic heavy minerals were removed via a magnetic separator. In the last stage, the sample was passed through Clerici solution, separated into 5 dimensional fractions and hand separated under a binocular until 100 % purity is obtained.

An ICPMS analyses was used for quantitative analysis of major elements and REE concentrations in the samples and maked in ACTLAB (Canada).

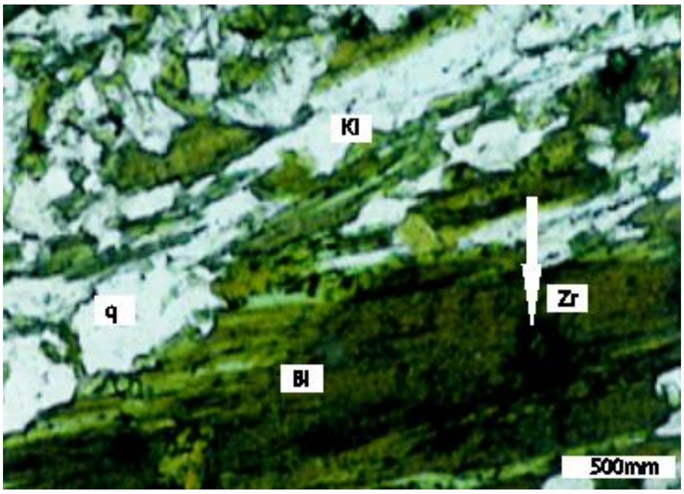

Figure 3. Metamict zircon particle inside the biotite mineral in biotite schists [5]

2.3. Structure and chemical characteristic

The zircon in metamorphites was observed cavities between particles or inside porphyroblasts with inclusions (Figure 2,3). Radiated zircons which also indicates high temperature conditions is also enclosed inside biotite mineral (Figure 3). Radiation damage can cause loss of Pb, high containing U and Th or melts that help to recrystallization [24,17,18]. But, H_2O as a melt is thought to have strong effect on radiation and annealing of zircon. Water lowers the temperature and increases the rate of recrystalization of it. So, we say that H_2O rate is low because of we have samples with high radiation damage. Radiation damaged zircon may change CL intensity [17]. İn our study, the cores show a modified relict primary growth or patchy zoning (Figure 4).İn CL images some, zircons show a porous texture with Th-U mineral microinclusions such as thorite and coffinite (Figure 5).

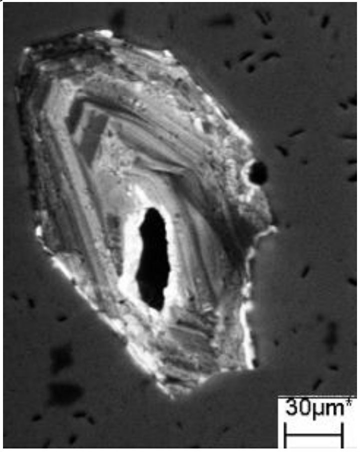

Figure 4. Primary growth and patch zoning in core

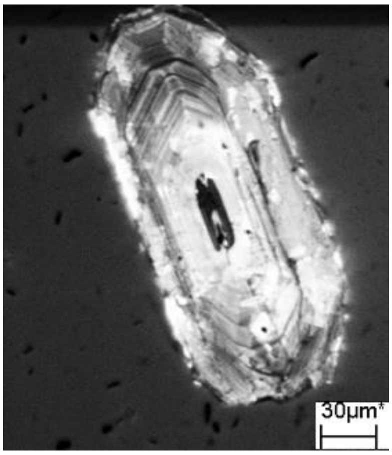

Figure 5. Porous texture with Th-U mineral microinclusions in zircon

Weak luminescent core is the product of prograde dehydration reactons during regional metamorphism [11,12,15]. Temperature, fluid or melts that help recrystallization may affect the extent of the damage. The formation of zircons with different textural properties from the same root rock at the same temperature conditions was interpreted as the diversity of the variables that cause radiation. Textures of zircons visibled by Cathodoluminescence (CL) which are characterized by irregularly curved rose like in core of zircon (Figure 6A), homogeneously luminescent or inclusion rich (Figure 6B), porous domain (Figure 6C). Zircon grains from orthogneisse are round to slightly subhedral.They are relatively ranging from 100 to 300µm. Most grains are colorless-brown and they are composed of CL weak.

Zircon grains from granitic gneisse are relatively 300 µm are colorless or light brown. Grains are euhedral or subhedral and have internal zones. Generally this grains shows luminescent core and oscillatory growth zoned rim (Figure 7).They comprises low-luminescent core or highly luminescent core and surrounded by a low luminescent rim or highly luminescent rim. In some particles intensive luminescence where zoning is not well preserved is especially striking and an almost homogeneous structure is observed. The formation of this texture can be explained by primary growth alteration [23, 10]. Pore dimension may vary in zircons with porous structure. Different pore dimension is related to the distribution in enclosed elements.

Trace elements were analyzed zircon grains in the orthogneisse (Table 1) [2]. In this table, metamict zircons have high REE, Yb, Hf, Th, ve U. The reason fort his, zircons which are large ionic radius not enter to cristal structure. Elements can go in it by fluids through fractures. Th and U are fairly high. The dark luminescent core shows a big variation in the rare earth elements (REE) with Lu_N/Gd_N ranging from 7.5 to 5.3, Th/U ratios 3.03-4.61. The matt luminescent core show a big variation in trace element concentrations including the REE with Lu_N/Gd_N ranging from 8 to 24 and Th/U ratios 0.2-1.7. These property have negative Eu and positive Ce anomalies. Zircon with brown color are rich in REE. Zircon with white color is poor in REE. The internal structure of analysed zircons and crystalline-amorphous transformation in zircons have recently been described that low degree of radiation damage occurs isolated islands that amorphous areas within crystalline matrix. At this instance, diffusion of grain through the structure at temperature is controlled by volume diffusion through crystalline domains [21, 22]. Recrystallization of amorphous zircon reduces the molar volume of the reacted spaces, creating strain and producing a porous structure at the nanoscale. The change of crystallites is cause nanoporosity and reactions. Furthermore, the concentrations of Ca, Al, Fe in the altered areas not compatible with the zircon structure and are thus dissolve in the amorphous remnants inside the reacted areas [7,20,17]. Radiation damaged zircon loses differently amounts of Zr, Hf, Si, U, Th, REE to fluid and cations in zircon grains are soluble [24]. The element difference due to the approaching of the fluid to the crystal lattice or due to enclosure minerals affects luminescence property [25,10]. Porous and patch core types are seen in both rock samples. According to Xi-sheng Xu [5] and Pan [19], this porous structure and cracks that represent the first stage of radiation damage speed upto metamicttization process.

3. Results

Pütürge metamorphites went through metamorphism right after ophiolite settlement in the region and that this event might be prior to Arabia-Eurasia collision and the closure of the southern branch of Neotetis [8]. In addition, it is also highly probable that metamorphism took place first during Upper Cretaceous-Santonian. It has been determined that a Barrovian type regional metamorphism has been effective in the massive from green schist to upper amphibolite facies. Traces of regressive metamorphism indicate that rocks have been affected from regressive metamorphism during the surfacing of the Pütürge metamorphites as a result of newer events. The exhumation period of these metamorphites make up the regressive metamorphism of these metamorphites.

Cathodoluminescence (CL) examinations of the zircons in the gneisse has led to the conclusion that it is made up of core and rim zones; that the core is rich in uranium and that the emission from the core causes volumetric expansion in zircon particles along with radial cracks. The porous texture and cracks comprise the first stage of radiation damage and have caused partial metamictization. Loss of lead in zircon signify that the fluids approaching the crystal lattice can be effective in the radiation damage processes [12,3,4,16] and that they change Th/U ratio. Th/U high ratio is signature radiation effect. Textural difference in the core and rim of zircons are seen as causes of chemical difference, mineral reactions and radiation damage in both enclosure and prismatic zircon crystals.

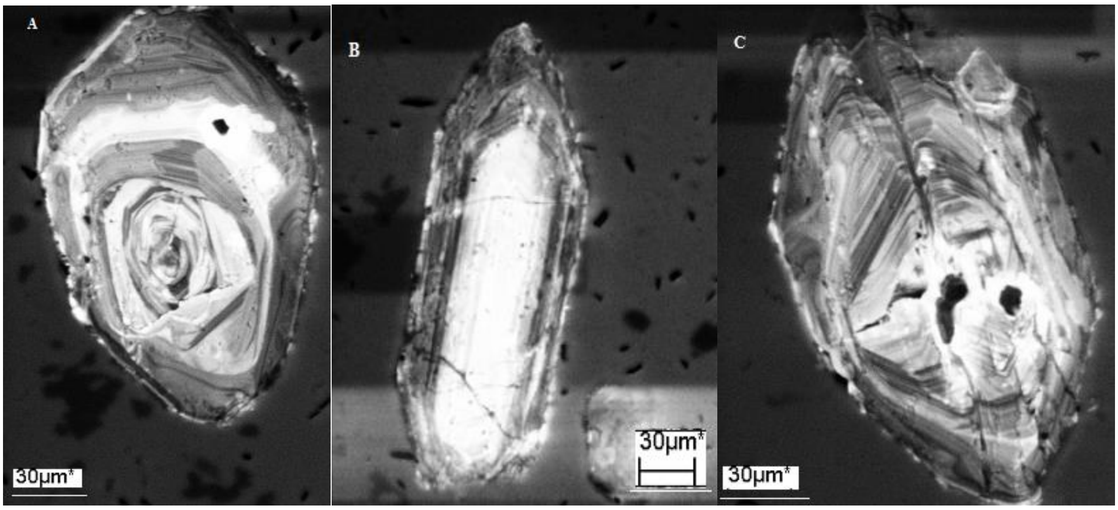

Figure 6. (A) Rose image in core of zircon, (B) Homogeneous luminescent characteristic, (C) Primary zoned at rim and core with porous in zircon

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