



Minamiite and Alunite Occurrences Formed From Volcanic Emanations, West-Southwest of Konya, Turkey

Konya'nın (Türkiye) Batı-Güneybatısında Volkanik Emanasyonların Etkisi ile Minomit ve Alunit Oluşumları

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Abstract

Aluminum sulfate minerals, kaolin and bentonitic clay deposits and zeolites occur within upper Miocene-Pliocene high-K andesitic-dacitic volcanic rocks and lacustrine sediments in the west southwest of Konya, Turkey. In the area, post-volcanic phenomena, such as solfatara activity, has already been continued.

The samples taken from the study area were mineralogically and chemically examined using XRD, SEM-EDS, XRF, AAS, DTA-TG and microprobe instruments. As a result of this investigation, it has been determined that alteration minerals formed by early-and/or post volcanic acid solutions reacted with the solutions were highly acidic in character, alunite and natroalunite were produced by the alteration of mainly dacitic volcanic rocks, while minamiite was formed by the alteration of andesitic volcanic rocks. However, acidic or weakly acidic solutions yielded kaolinite and/or halloysite and illite.

Alunite group minerals are K, Na and Ca sulfate with formula $(Ca, Na, K) Al_3(SO_4)_2(OH)_6$ and mainly form as hydrothermal minerals in the study area. Nearly pure minamiite and alunite have been found in a few samples. They are commonly associated with silica polymorphs, kaolinite and halloysite in various parts of the study area.

Stability relations of minerals in the advanced argillic alteration zone indicate alteration took place under acidic conditions in the near-surface environment. Mineralogical and textural evidence also suggests alteration occurred in steam-heated environment, rather in a supergene or magmatic hydrothermal origin.

Key Words : Alunite, halloysite, kaolinite, Konya, minamiite, Turkey.

Öz

Konya'nın (Türkiye) Batı-Güneybatısında ÜstMiyosen-Pliyosen yaşlı, yüksekK'lu andesitik-dasitik volkanik kayalar ve gölsel çökeller içerisinde alüminyum sülfat mineralleri, kaolin, bentonitik kil yatakları ve zeolitler oluşmuştur. Bölgede volkanizma sonrası işlevler, örneğin s olfatar evreye özgü faaliyetler, halen devam etmektedir.

İnceleme alanından alınan örnekler üzerinde XRD, SEM-EDS, XRF, AAS, DTA-TG ve mikroprobe analizleri yapılmıştır. Araştırma sonucunda alterasyon minerallerinin yüksek asidik karakterli çözeltilerin volkanik malzeme ile reaksiyonları sonucu oluştuğu belirlenmiştir. Alunit ve natroalunit çoğunlukla dasitik, minamit ise andesitik volkanik kayalardan türemiştir. Bunun yanında asidik veya zayıf asidik çözeltiler kaolinit ve/veya halloysit ve illitin oluşumunda rol oynamıştır.

Çalışma alanında hidrotermal olarak oluşan alunit grubu mineraller genelde K, Na ve Ca'lu olup, $(Ca, Na, K) Al_3(SO_4)_2(OH)_6$ şeklinde formüle edilmiştir. Hemen hemen saf minamit ve alunit birkaç örnekte tespit edilmiştir. İnceleme alanının çeşitli kesimlerinde bu mineraller çoğunlukla silika polimorfları, kaolinit ve halloysite birlikte gözlenmiştir. İlli t ve paragonit bazen alunit grubu minerallerle birlikte gözlenmesi yanında zeolit nadiren bulunmuştur.

Anahtar Sözcükler : Alunit, halloysit, kaolinit, Konya, minamit, Türkiye.

INTRODUCTION

Upper Miocene-Pliocene high-K andesitic-dacitic volcanic and volcano-sedimentary rocks are widespread at the western-southwestern part of Konya province in southern Central Anatolia (Figure 1). Volcanic rocks of varying composition erupted in the study area at different times. In the area, the reaction of warm, recent post-

volcanic acidic fluids with volcanic rocks yielded sulfate minerals, silica polymorphs, clay minerals and zeolite-group minerals (Çelik et al., 1997).

Alunite group mineral occurrences are locally found within clay deposits having hydrothermal origins. Recent acidic alteration caused by the reaction of sulphurous are also abundant in the study area.

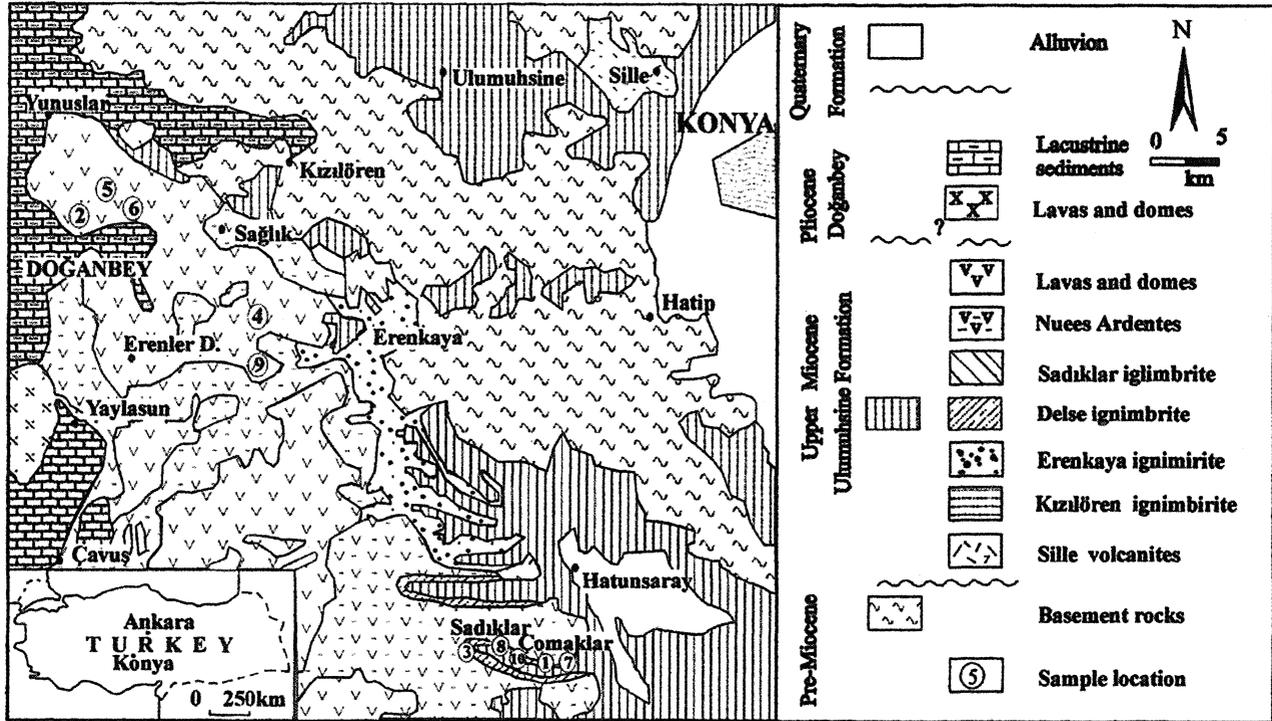


Figure 1: Simplified location and geologic map of investigation area.
 Şekil 1: İnceleme alanının basitleştirilmiş jeolojik ve yer bulduru haritası.

Alunite occurs as irregular veins (5-15 cm length and 1-5 cm wide) in fracture zones and occasionally as lenses 2-5 cm thick in altered volcanic rocks. Clay minerals (kaolinite and halloysite) also occur locally in association with sulfate minerals. In the study area, clay occurrences (kaolinite and bentonite) have economic in places and some of these were studied for this purpose (Sevgil, 1979, 1981; Suludere et al, 1986; Özgüner, 1987; Çelik et al, 1994, 1997). Real reserves of alunite occurrences have not been determined, but they have economic interest.

The general formula of the alunite group minerals is $MR_3(SO_4)_2(OH)_6$, where M is the large cation like K^+ , Na^+ , NH_4^+ , Pb^{2+} , and Ca^{2+} held in 12 fold coordination; R sites are occupied mainly by trivalent (Al, Fe) cations (Ossaka et al., 1982). In alunite $K > Na$, while $K < Na$ in

natroalunite, and $Ca > Na > K$ in minamiite. This study describes the assemblages of the secondary minerals, chemical properties and economic importance of alunite-group minerals and discusses their relationships to the type of parent material.

GEOLOGICAL SETTING

A pre-Miocene ophiolitic complex and metasedimentary rocks (quartzite, crystallized limestone) constitute the basement in the study area (Figure 1). Miocene-Pliocene volcanic rocks and lacustrine sedimentary rocks unconformably overlie these basement rocks. Volcanism, which began 11.9 million years ago (Keller et al., 1977), is represented by pyroclastic flow and fall deposits, lava flows and domes. The lithologies were divided into Uluhsine and Doğanbey formations (Çelik et al., 1994;

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1997). The Ulumuhsine formation comprises laterally and vertically interbedded volcanic rocks and lacustrine sediments. Nuee-ardentes were formed by the fracturing of these domes and high vapor pressure. The age of other young volcanics is 5.76 m.a. (Keller et al., 1977). In the study area, at least 14 separate eruptions were occurred from beginning of volcanism. So, products of different eruptions covered or mixed with each other. The Ulumuhsine formation, composed mainly of lacustrine sediments and in some places laterally and vertically interbedded volcanoclastics. The ages of this volcanics within the formation range from 3.35 to 3.32 million years (Keller et al., 1977). Lacustrine sedimentation, consisting of clayey units, is dominant away from or at the periphery of the volcanics. However, lacustrine sedimentation was interrupted by the volcanic input, causing intercalation of volcanics and lacustrine sediments (Figure 1).

MATERIALS AND METHODS

The mineralogical composition of samples was determined by means of a Philips PW 1140 X-ray powder diffractometer using graphite monochromated and Ni-filtered CuK α radiation at Hacettepe University, Turkey. Powder diffraction data were corrected using NaCl as an internal standard. IR spectra were obtained with a Mattson 1000 FTIR spectrometer, in range 400-4000 cm⁻¹ using KBr pellets (Russell and Fraser, 1994) at Selçuk University, Turkey. DTA-TG analyses were carried out with a Rigaku 2.22E2 type instrument by loading about 20 mg of the specimen heated in the range 20 to 900°C, at heating rate of 10°C/min, using $\text{OC-AL}_2\text{O}_3$ as a reference material, General Director of Mineral Research and Exploration, Turkey. SEM studies were done with a JEOL 840A SEM equipped with EDS using an accelerating voltage of 25kV at Middle East Technical University, Turkey. Analyses of major elements were performed by X-ray fluorescence spectrometry of volcanic rocks and atomic absorption spectrometry (AAS) of alunitic samples at Hacettepe University, Turkey, the percentages of the major elements were determined on fused glasses (prepared 0.75 g rock powder and 4.5g lithium tetraborate) (Brown, et al, 1973; Temel et al, 1998). The spectrometers were calibrated using international standards (USGS and GEOSTANDARDS). Loss-on-ignition (LOI) was calculated from weight loss after heating 2 g of sample at 1000°C for 2 hours. The usual wet analysis method was adopted for Al_2O_3 and SO_3 and LOI was

obtained from weight loss. A Beckman 1272 model spectrometer was used for K₂O and Na₂O. Ca and Al were determined by AAS using a Perkin Elmer 370 spectrometer. Point analyses of alunite-type minerals were carried out on a Cambridge Microscan 5 electron microprobe with an accelerating voltage of 20kV and a beam current 30pA at Glasgow University, UK. The method of Keller and Matlack (1990) was applied for pH measurements.

RESULTS

The alunite-group minerals occur as chalky-white, greasy, fine-grained fragments within highly altered andesitic and dacitic volcanic rocks. The samples consists of alunite, natroalunite, minamiite, silica minerals (quartz, cristobalite, opal-CT), amorphous silica (opal-A), and clay minerals (generally kaolinite and halloysite, rarely paragonite and illite).

In the study area, zeolite-group minerals (erionite, heulandite and stilbite) and smectite occurrences were also observed, but these samples do not contain any alunite-group minerals (Table 1).

Table 1: Probable parent rocks and mineral assemblages of whole-rock of representative samples (rare components are omitted).

Çizelge 1: Çalışmayı temsil eden kay aç örneklerinin mineral toplulukları ve muhtemel ana kayacı (nadir bileşenler dikkate alınmamıştır).

Sample No.	Mineral Composition	Probable parent rocks
1	Minamiite + paragonite	Andesite
2	Alunite+halloysite+opal-CT	Dacite-Andesite
3	Alunite+halloysite+opal-CT	Dacite-Andesite
4	Alunite+opal-CT	Dacite
5	Alunite+quartz	Andesite
6	Alunite+quartz+kaolinite	Dacite
7	Minamiite+quartz	Andesite
8	Minamiite+quartz+cristobalite	Andesite-Dacite
9	Quartz+kaolinite+natroalunite	Dacite
10	Alunite+halloysite	Dacite

Minamiite occurs as lenses or fracture fillings of varying thickness (1-20 cm) beneath the Detse ignimbrite

in the vicinity of Detse village. Minamiite formation pinches into ignimbrite layers towards the north. The true thickness and lateral extent of the occurrences could not be measured due to soil cover. Minamiite occurrences partly pass into alunite occurrences. In the field investigation, it is difficult to separate the two mineral occurrences. The occurrences pass into coal layers and lacustrine sediments vertically and laterally. The occurrence of minamiite is more restricted than that of alunite.

Alunite-bearing occurrences are located at 15-20 km to the SE of Yunuslar and north of Erenkaya and south of Sadıklar village (Figure 1). Alunite coexisting with kaolinite, halloysite and/or silica polymorphs occurs in irregular veins, thin layers or coatings on partially altered calc-alkaline andesitic-dacitic rock. In the Yunuslar area, alunite occurrences pass into kaolinite deposits. The kaolinite deposits are generally poor, with an economic importance. The upper parts of the deposits are mostly silicified and are light gray and grainy. Joint surfaces in the kaolins are yellow to rust-colored due to sulfur-and iron bearing-seepage. Post volcanic sulphurous solutions (H₂S) were active in the area.

In addition to chemical and microprobe analyses made from selected samples, alunite, natroalunite and minamiite diffraction lines were also detected. The d values and relative intensities for these minerals are in agreement with the alunite, natroalunite and minamiite patterns given by other authors (Ossaka et al., 1987; JCPDS, 1993, 34-79, 34-143, 14-136, 4-865) (Figure 2).

But nearly pure natroalunite samples were not encountered (Table 1). A series of strong-intensity infrared absorption bands of minamiite and alunite are also in good agreement with each other (between 600 and 700 cm⁻¹ and a weaker shoulder at 1230 cm⁻¹ for alunite are represented by a hydroxyl stretching band.

DTA-TG curves of alunite, natroalunite and minamiite are characterized by a strong and sharp endothermic peaks at 505.8°C, followed by weak exothermic peaks at 711.5°C and 721.7°C, and by endothermic peaks at 744.4°C. the TG curve shows a two step loss corresponding to the two endothermic peaks. The weight losses are 13.8% and 13.7% at the first endotherm and 18.7% and 17.0% at the second endotherm for alunite, and minamiite are 32.55 and 30.7% respectively which correspond to the emission of about of the total So. The first endotherm represents dehydroxylation whereas the second endotherm represents desulfation (Slansky, 1975;

Cho et al, 1994). A DTA-TG investigation was not conducted for natroalunite.

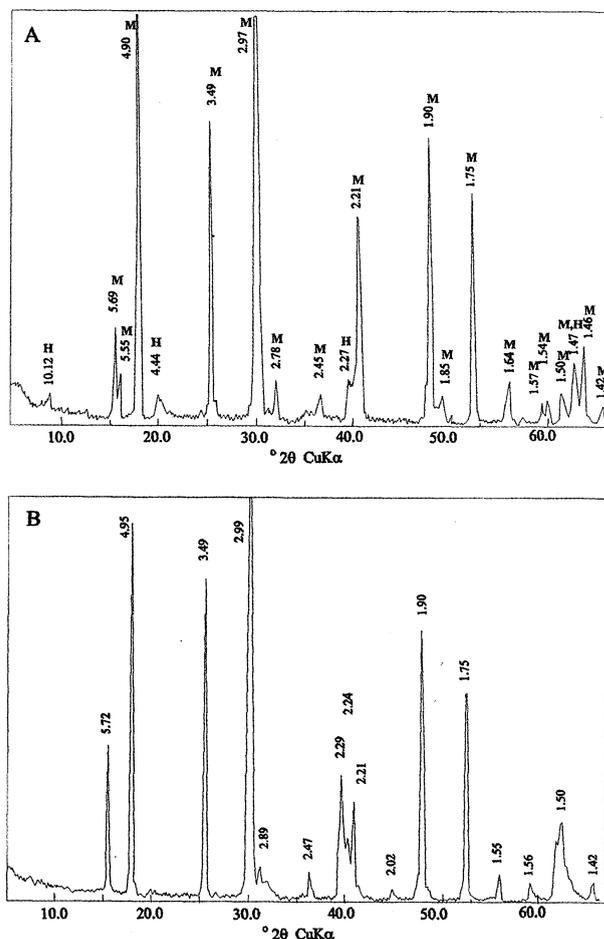


Figure 2: Selected X-ray diffraction profiles from the study area, A-minamiite, B-alunite.

Şekil 2: İnceleme alrından seçilmiş X-ışmlan difraksiyon profilleri, A-minamiite (H: halloysite, M: minamiite), B-Nearly pure alunite.

The pH values of nearly pure alunite-group minerals samples are generally between 3 and 4 pH values of other samples containing kaolinite, halloysite, and rarely illite along with alunite-group minerals are above 4 and generally between 6 and 7. The pH of sulphurous water is usually between 2.5 and 4.8 in east of Doğanbey village.

According to SEM studies, crystals of minamiite and alunite are coarsely crystalline, rhombohedral or pseudocubic, and loosely packed, while those of natroalunite are typically anhedral (Figures 4 and 5).

Acicular halloysite crystals occur as dense aggregates or as separate particles between alunite crystals (Figure 6). Wet chemical analyses were made on nearly pure samples. However, samples having 6.37-12 SiO₂ % may

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contain minor inclusions of silica polymorphs. The total Na₂O and K₂O contents of minamiite are low compared to these of alunite, and significant amounts of Pb, Zn and Cu present in alunitic samples.

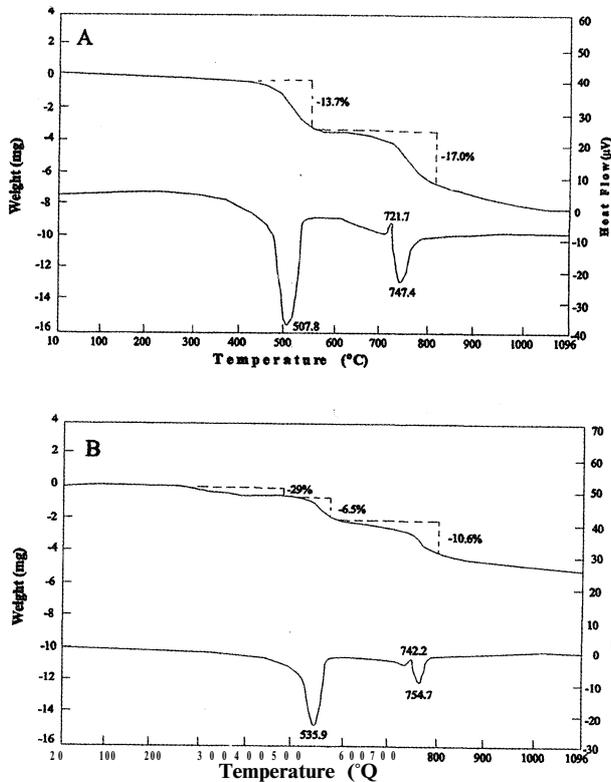


Figure 3: DTA-TG curves for A-minamiite and B-alunite.
Şekil 3: Minamiit (A) and alunit (B) in DTA-TG eğrileri.

In these samples, some black impurities can be observed with naked eye. The PbO contents are higher than

the others, ranging between 0.5-6.4%. But there are no black-ore deposits in the study area. Partly alunitic and natroalunitic minerals were found in some minamiitic samples during microprobe analyses. According to the microprobe analyses the Na₂O contents of natroalunites is 2.60%. These relations between the chemical compositions Ca²⁺-Na⁺-K⁺ of alunite, minamiite, natroalunite have been plotted on the ternary diagram proposed by (Ossaka et al, 1987) (Figure 7).

These element oxides plot in all fields. But most of analyses are seen at the borders of the three fields commonly along the minamiite-alunite and alunite-natroalunite ties.

Also, some of data plot within the field for alunite-group minerals. Most of minamiitic samples results are situated near the alunite-field margins. Most of alunites are rich in K and Na while the natroalunites are typically rich in K and Na. Minamiite is commonly rich in Ca and somewhat in Na (Figure 7, Table 2).

It is assumed that the relatively large K⁺ was situated in both the M(1) and M(2) sites of minamiite (Ossaka et al., 1982). The Na₂O contents of the analyzed samples vary from 0.78 to 5.17, representative alunite, sodian alunite or potassian minamiite compositions. The Al₂O₃ and SO₃ contents of alunite are similar to minamiite. The TiO₂, Fe₂O₃, and MgO contents of both minamiite and alunite are generally as low as 0.50 (Table 2). The chemical composition of the sulfur fluids are very rich in SO₃ (1027-2250mg/l) (Çelik et al, 1997).

Table 2: Major-element chemistry of whole-rock samples and minerals from the study area (wt%).

Çizelge 2: İnceleme alanındaki kayalık ve mineral örneklerinin ana element kimyası (% Ağırlık).

Sample	1	2	3	4	6	7	8	9	10	11	12	13
							n=18	n=16	n=18	n=8	n=7	
SiO ₂	7,00	8,18	6,37	8,02	8,41	---	---	---	59,89	66,47	59,000	65,44
Al ₂ O ₃	37,03	36,04	40,74	37,49	38,59	39,13	39,14	39,27	16,04	15,90	17,45	16,56
Fe ₂ O ₃	0,27	0,26	0,15	0,20	0,09	0,11	0,12	0,13	5,77	3,24	6,71	3,39
MgO	0,05	0,05	0,07	0,09	0,22	0,02	0,01	0,05	3,31	1,44	3,41	1,98
CaO	3,96	1,40	0,96	1,02	1,21	0,32	0,10	4,14	6,40	3,61	6,81	4,53
Na ₂ O	5,15	2,44	0,87	4,00	2,71	1,40	2,28	2,06	3,11	3,87	9,94	4,28
K ₂ O	1,40	5,70	6,76	4,90	4,80	6,25	4,29	1,12	3,20	3,32	1,42	1,93
TiO ₂	---	---	---	---	---	---	---	0,02	0,68	0,42	0,91	0,61
SO ₃	32,14	30,85	31,33	28,84	30,65	40,31	40,24	40,15	--	---	---	
LOI	44,9	44,19	43,97	43,93	42,90	---	---	---	1,38	1,71		
Total	99,91	98,26	99,96	99,65	98,93	87,54	86,18	86,94	99,78	99,99	99,65	100,0

Note: 1-6 represent minamiite, alunite and sodian alunite, 7-9 are alunite, natroalunite, and minamiite analyses done by electron microprobe at low accelerating voltage, 10-11 are andesite and dacite analyses, respectively (by wet chemical method); 12-13 calc alkaline andesite and dacite, respectively (Ewart, 1979), n= sample number, Fe₂O₃: total iron, LOI: loss in ignition.

The chemical formula of minamiite and alunite were calculated from an average 40 microprobe analyses. Neglecting the inclusions, the chemical formula of alunite, natroalunite and minamiite, respectively, were found to be as follows,

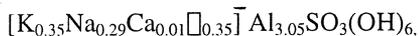
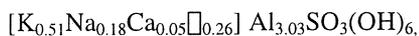


Figure 4: SEM photomicrograph of rhombohedral minamiite crystals.

Şekil 4: Rombohedral minamiit kristallerinin SEM fotoğrafları.

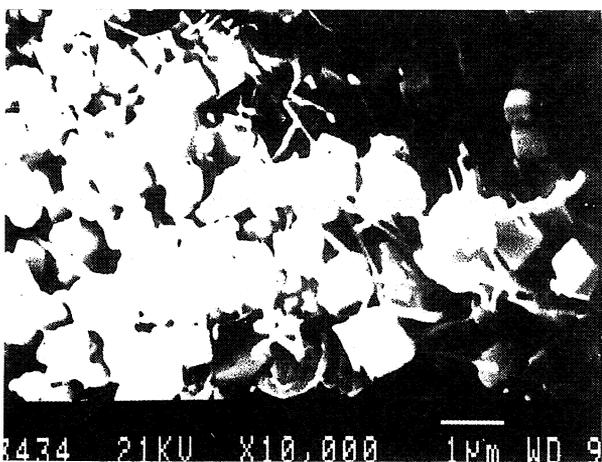


Figure 5: SEM photomicrograph of subidiomorphic alunite crystals with some acicular halloysite.

Şekil 5: Yan öz şekilli alunite kristalleri ile iğnemsı halloysit kristallerinin SEM fotoğrafları.

DISCUSSION

The study area is covered by Miocene-Pliocene volcanic rocks erupted from different volcanic centers.

Mostly high-K andesitic to high-K dacitic volcanic product and lacustrine sediments form a volcanosedimentary sequence. Reactions between postvolcanic fluids and volcanic rocks have resulted in the formation of alunite, clay, silica and, zeolite-group mineral occurrences.

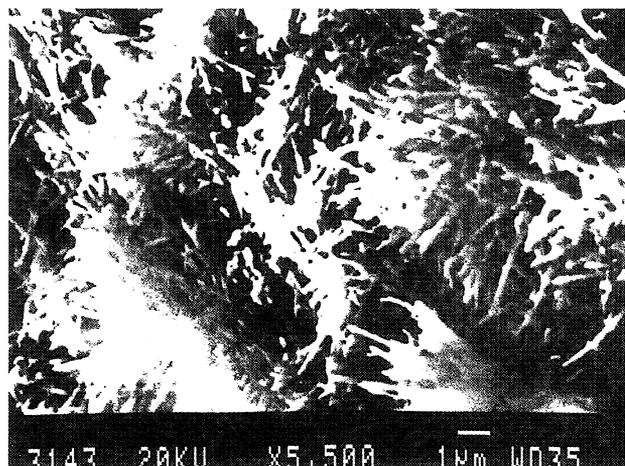


Figure 6: SEM photomicrograph of acicular halloysite crystals.

Şekil 6: İğnemsı halloysit kristallerinin SEM fotoğrafları.

Large quantities of low-pH solutions are required to produce acid sulfate alteration and requisite acid fluids can be generated by several mechanisms in supergene, steam-heated and magmatic hydrothermal environments (Rye et al, 1992). Supergene acid sulfate alteration is the result of weathering of sulfide-rich rocks and commonly results in a topographically controlled alteration blanket. In steam-heated environments, sulfuric acid is produced by oxidation, above the water table, of H₂S distilled off the underlying hydrothermal system (Schoen et al., 1974) and resultant alteration assemblage is similar to that produced in the supergene environments (Rye et al., 1992).

Magmatic hydrothermal acid sulfate systems are driven by magmatic heat and have a significant magmatic fluid component, with sulfuric acid being produced by disproportionation of magmatic SO₂ with decreasing temperature. Acid sulfate alteration in these systems is generally fracture-controlled and characterized by extreme base-leaching resulting in vuggy silica zones, replacement of feldspar phenocrysts by alunite and large amounts of pyrite in the assemblage and also native sulfur (Rye et al, 1992).

There are two main hydrothermal alteration mineral types distinguished by mineralogical composition, color and structural features situated several kilometers from

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each other. The first consists principally of alunite, kaolinite and silica polymorphs within hydrothermally altered dacitic lava and pyroclastics. The second consists of minamiite which occurs locally with alunite, paragonite and quartz and rarely with kaolinite in altered andesitic rocks. In this part of the area, recent post-volcanic acidic sulfur-rich solutions can be observed in the area. Mixing of minamiitic and alunitic samples is probably related to the restricted nature of minamiite occurrences (Okada et al., 1987) and to the many volcanic eruptions of very short time duration and of different characters.

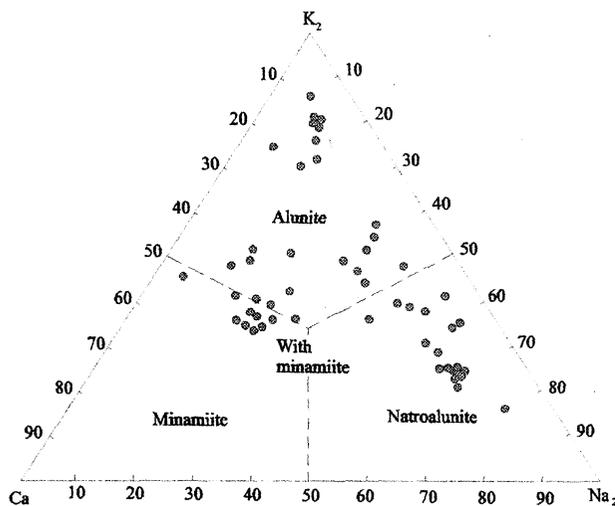


Figure 7: The relations between the chemical compositions of minamiite and alunite and natroalunite, mole % of $\text{Na}_2\text{O}-\text{K}_2\text{O}-\text{CaO}$ component were used (Ossaka et al., 1987).

Şekil 7: Minamit-alunit-natroalunitin kimyasal bileşimleri arasındaki ilişkiler, $\text{Na}_2\text{O}-\text{K}_2\text{O}-\text{CaO}$ in % mole içerikleri kullanılmıştır (Ossaka vd., 1987).

Alunite-group minerals may have been produced by the breakdown of feldspar in the rocks by sulfate solutions under generally acidic conditions. Reaction of strongly acidic solutions rich in SO_4^{2-} with latitic rocks produced almost pervasive alteration to opal -C/CT along the paths of high percolation, but with reaction of original structure (Wirsching et al., 1990) Alunite - group minerals, kaolinite and silica polymorphs have formed along the path of high percolation from andesitic to dacitic rocks. In other words, acidic to weakly acidic SO_4^{2-} rich fluids, which mainly contain aluminum, potassium and/or calcium besides silica and other elements, caused extensive alteration to alunite+opal or opal+minamiite+alunite in adjacent volcanic rocks. The original K-feldspar in the dacites and andesites were adequate to supply the potassium for alunite. The K_2O

and Na_2O contents of dacites in the area vary from 3.20 to 3.32 wt% and 3.11 to 3.87%, respectively (Table 2). While K_2O content of investigated volcanites is higher than calc-alkaline dacite and andesite, Na_2O is lower (Ewart, 1979). K_2O ions may be carried by hydrothermal solutions. The average CaO content of the andesitic rocks is 6.40% while 3.61% in dacites. The higher CaO contents of andesites may have led to the development of minamiite (Table 2).

It is common that certain of these minerals from acid volcanic rock precursor material in areas of intense volcanic fluids, where high H^+ and SO_4^{2-} concentrations occur (Hemly et al., 1969). Thus, these minerals are formed by the release of the K and Ca ions from feldspar according to the following reactions (Holler, 1967):

The original K-feldspar of the dacites was adequate to supply the potassium for alunite formation. However, the K_2O contents of the dacites in the area are restricted (2.9-3.35%wt), and the source of K is, therefore, not clear. The K^+ ion may be carried in part by hydrothermal solutions. By reactions with strongly acidic primary solutions rich in SO_4^{2-} in acidic to intermediate rocks, pervasive alteration to opal±cristobalite along high percolation zones occurred. The resulting strongly acidic solutions rich in aluminum, silicon and other elements, such as K, Ca, Na, Pb, Zn, Cu, etc., caused extensive alteration to opal + alunite in the adjacent rocks. After saturation with respect to alunite, alunite precipitated with silica minerals, then alunite was consumed and the pH of the solution increased, and kaolinite precipitated with or without alunite.

Hydrothermally altered plagioclase in andesites may yield Ca to form minamiite. Andesitic volcanites are richer in Ca^{2+} but poorer in K^+ relative compared to the dacitic volcanics. Minamiite formation requires an environment with high Ca^{2+} activity, but intermediate Na^+ and very low K^+ activity (Ossaka et al., 1982, 1987). Minamiite, rather than alunite was formed when andesitic volcanic rocks were invaded by hydrothermal solutions rich in Ca^{2+} and SO_4^{2-} . In the $\text{CaO}-\text{Na}_2\text{O}-\text{K}_2\text{O}-\text{Al}_2\text{O}_3-\text{SO}_3-\text{H}_2\text{O}$ system, precipitated alunite-type compounds show occupation trends such as like alunite > natroalunite > minamiite (Ossaka et al., 1987). So, formation of minamiite only proceeded after removal of Na^+ from the solution probably after precipitation of paragonite. In the study area, natroalunite formation is observed

and paragonite is found only rarely with minamiite in the some samples.

Sulfur isotope analyses could not be made in the study area, but the absence of secondary iron oxide and hydroxide minerals such as hematite, limonite, goetite, and the fracture-controlled morphology, and presence of abundant pyrite and native sulfur occurrences, suggest acid sulfate alteration in the region is not of supergene or magmatic hydrothermal origin. In addition to these determination, PbO, ZnO and CuO content (1-7%) were found in some alunite samples in microprobe analyses. There is no metallic mineralization in the region. These observation supports that alunite occurrences are related to steam-heated environments not a second enrichment from a black ore deposits. PbO, ZnO and CuO compounds may be carried by hydrothermal solutions from the depth. And also coarsely crystalline, loosely packed and euhedral and semieuhedral habits of alunite minerals reveal that they are in hypogene origin (Alpers and Brimhall, 1988; Bird et al. 1989).

Acid sulfate alteration produced by steam-heated waters may or may not overlie mineralization deposited at deeper levels in the system (Henley and Ellis, 1977 and Henley, 1985). The source for the hydrothermal system is unclear, but possibilities include the Erenler Dağı and other volcanics in the region.

CONCLUSIONS

It is concluded that acid sulfate alteration mineralizations have been determined of Upper Tertiary high-K calc-alkaline andesitic-dacitic rocks in the region south west of Konya occurred in a steam-heated environment, magmatic-steam components, rather than in a supergene or magmatic hydrothermal environment. The alteration assemblages, such as alunite, minamiite, natroalunite, kaolinite, halloysite, and paragonite, clearly indicates that large volumes of acidic fluids were generated at shallow depths and there is a good evidence that sulfur-rich solutions were venting to the paleosurface during the lifespan of the hydrothermal system. Alunite occurrences were observed mainly in altered dacitic volcanic rocks while minamiite occur in dacitic volcanic rocks. Whereas alunite is generally associated with halloysite or kaolinite, minamiite occurs principally with paragonite.

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