Δελτίο της Ελληνικής Γεωλογικής Εταιρίας, Τομ. XXXIV/3, 959-965, 2001
Πρακτικά 9ου Διεθνούς Συνεδρίου, Αθήνα, Σεπτέμβριος 2001

Bulletin of the Geological Society of Greece, Vol. XXXIV/3, 959-965, 2001
Proceedings of the 9th International Congress, Athens, September 2001

PETROGRAPHICAL, PETROCHEMICAL INVESTIGATION OF SANDIKLI VOLCANIC AND USABILITY OF THIS ROCKS AS TRASS, IN AFYON REGION (WESTERN ANATOLIA), TURKEY

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ABSTRACT

Investigated area and its surrounding district consist of volcanic rocks. The Sandúklú volcanic are mainly composed of lavas, tuffs and tuffits. Using to K-Ar age method, the age of Sandúklú Lavas have been dated and ranged from 14 ± 0.3-8.0 to ± 0.6 Ma (Ercan, 1986).On the basis of diagrams SiO_2-(K_2O+Na_2O), Log (Zr/TiO_2*0.0001)-SiO_2, Nb/Y-Log (Zr/TiO_2*0.0001) and TiO_2-Zr lavas are thrachyandesite, phonolitic tefrite, basaltic andesite, basaltic thrachy–nephelinite, andesite and dacite. Tuffs have been widely zeolitizated and dominant zeolite minerals are chabazite and phillipsite. Three phillipsite form were determined. These are potassium-sodium-aluminum-silicate hydrate, sodium-aluminum-silicate hydrate and potassium-calcium-silicate-silicate hydrate. The chemical and technological tests of zeolitic tuffs, altered lavas and tuffits were carried out and they are suitable to trass standards in cement industry.

KEY WORDS: Sandúklú volcanics, chabazite, phillipsite, trass.

1. INTRODUCTION

Sandúklú is situated in the western part of Central Anatolia in Turkey. Investigated area and its surrounding district consist of volcanic rocks (Figure 1, 2). The thracyandesitic, andesitic and phonolitic lavas, tuffs and tuffits are situated in the studied area. In the east part of Sandýklý lava forms are morphologically well preserved. The main part of volcanic area is underlain by the carbonates series of Mesozoic aged. The lacustrine sediments of Middle-Upper Miocene are alternating with the volcanic rocks (Figure 2). Volcanic rocks have been studied by many investigators, recently by Villari & Keller (1972), Baþarýr & Kun (1982),Keller(1983), Ercan (1986), Afþin (1991), Harut(1995),Özpýnar (1998) Aydar(1998), Özpýnar et. al.(1999 a,b) Özpýnar et al.(2001)

2.MEDHOD OF STUDY

Purpose of this paper is to report the results of detail study of volcanics in Sandúklú region. In this study, detailed mapping (1/25000 scale) of an area about 180 km^2 was firstly done. After this, microscopic and chemical

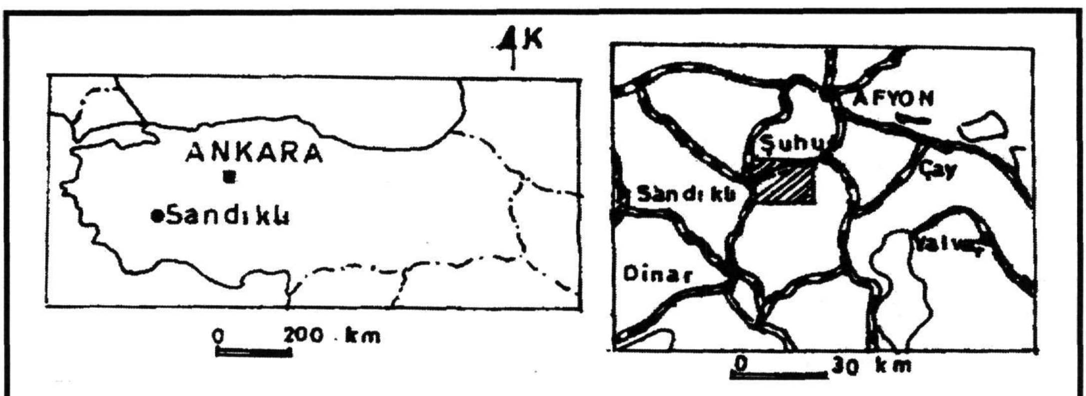

Figure 1. Location map of study area

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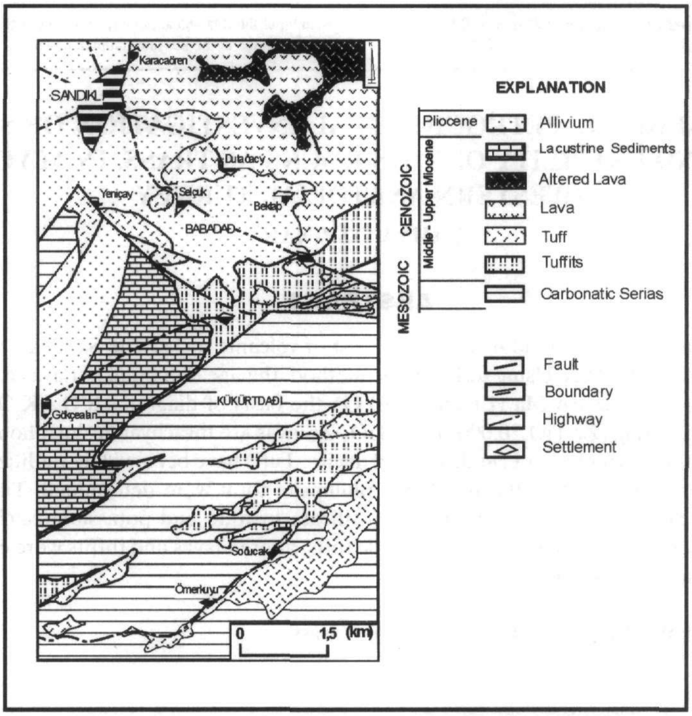


Figure 2. The simplified geological map of the study area

analyses studies were carried out. The zeolite minerals were qualitatively determined by XRD (33 sample), DTA (10 sample) and electron microscope (8 sample).The chemical analyses of the lavas (8 sample) were carried out by ICP-MS in Acme Analytical Laboratories Ltd., Canada (Table 1 and 2) . The chemical analyses of the altered lavas (2 sample), tuffs (11 sample) and tuffits (9 sample) were carried out by XRF in Denizli Cement factory (Table 3), Turkey. Puzzolanic activity and physico-mechanical tests(Table 4) have been made for the usage in different sectors of these zeolitic tuffs.

3. VOLCANICS

The Sandύklύ volcanic are mainly composed of red, gray and light brown lavas, crθme, milky brown and dark gray tuffs and white tuffits. Using to K-Ar age method, the age of Sandύklύ Lavas have been dated by Besang et al.(1977) and the ages obtained ranged from 14 ± 0.3- 8.0 to ± 0.6 Ma (Ercan, 1986).

3.1. Tuffs and Tuffits.

On the basis of $Na_2O+K_2O-SiO_2$ diagram, tuffs are alkaline and subalkaline in character(Figure 3). Tuffs are mainly composed of crθme, milky brown and dark gray tuffs. Tuffs are essentially vitritic and vitritic-crystal tuffs. In the tuffs the following properties were identified by optical microscope. They have various ratio pyroclast, extraclast, pyrogenetic and secondary minerals. In the tuffs, pyroclasts have microlitic and micro-porphyric texture. They contain albite, sanidine, honblende, augite and opaque minerals. Lithics (volcanic and non volcanic) are found in various sizes and amounts in tuffs. There is shapeless emptiness in glassy matrix which has intense zeolitization. Augite, hornblende and biotite were observed as a pyrogenetic minerals in this matrix. In the investigated area, crθme tuffs contain chabazite, milky brown tuffs contain chabazite and phillipsite and dark gray tuffs contain phillipsite.

In the north of Sandύklύ, the rhyolitic and ignimbrite volcanics are situated. In the study area, white color tuffits contain pumices and ύgnimbritic blocks which are found at the basement of the lacustrine sediments and/ or alternated with the lacustrine sediments.

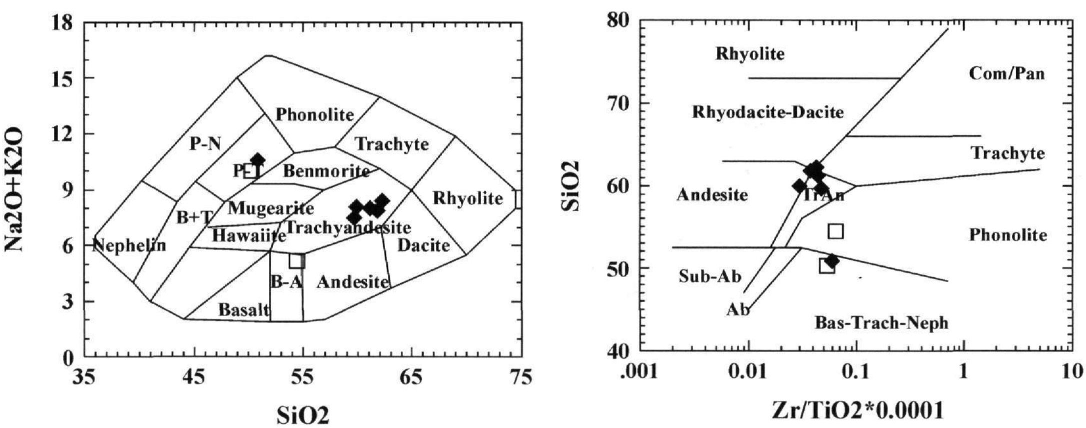
3.2. Lavas

The lavas are mainly of red, gray and light brown colour. In the Sandύklύ lava forms are morphologically well preserved. Their texture is essentially pilotaxitic, hyalopilitic, hyalo-porphyritic and micro-porphyritc. Groundmass essentially consists of plagioclase microlites in a glassy matrix. Sanidine, plagioclase (oligoclase), biotite, basaltic hornblende occur as phenocrysts. The sanidine phenocrysts have determined have very large sizes (3 cm to 5 cm). Apatite and zircon can be observed as accessory minerals. As secondary minerals illite, montmorillonite and calcite have been found.

Table 1. Major and trace element concentration of Sandůklů lavas (Samples:110,126,132, 141,200,S-14)) and tuffs (Samples:1,17).

Sample	1	17	110	126	132	141	200	S-14
%SiO_2	54.49	50.32	61.19	59.91	61.79	50.88	59.69	62.29
%Al_2O_3	16.49	17.49	14.87	16.11	14.68	17.14	14.60	14.54
%Fe_2O_3	3.55	5.40	4.93	5.56	5.50	7.07	5.15	4.80
% MgO	1.30	1.17	2.49	2.64	2.15	1.36	2.94	3.03
% CaO	4.12	3.24	4.53	4.48	3.97	6.19	4.35	3.95
% Na_2O	1.92	0.69	3.12	3.57	2.86	2.49	2.65	3.33
% K_2O	3.28	9.31	4.87	4.51	5.03	8.10	4.85	5.09
%TiO_2	0.65	0.97	1.04	1.09	0.92	1.29	1.10	0.99
% P_2O_5	0.30	0.19	0.66	0.53	0.63	0.21	0.77	0.59
% MnO	0.07	0.09	0.10	0.19	0.10	0.13	0.07	0.09
% Cr_2O_3	0.09	0.06	0.015	0.02	0.015	0.004	0.01	0.02
ppm Ba	3797	4421	1756	2000	1961	5832	1856	1687
ppm Ni	23	<20	29	<20	25	<20	25	35
ppm Sc	5	3	13	15	17	5	13	11
% LOI	13,3	10,3	1,8	1,5	2,0	3,8	3,4	0,8
% SUM	99.68	99.67	99.79	99.74	99.87	99.32	99.79	99.69

On the basis of SiO_2-(K_2O+Na_2O), Log (Zr/TiO_2*0.0001)-SiO_2, Nb/Y-Log (Zr/TiO_2*0.0001) and TiO_2-Zr, lavas are thrachyandesite, phonolitic tefrite, basaltic andesite, basaltic thrachy–nephelinite andesite and dacite (Figure 3). On the basis of AFM, FeO^T/MgO-FeO^T, lavas are calc-alkaline. On the basis of Na_2O+K_2O-SiO_2, lavas are alkaline and subalkaline in character. Chondrite REE contents of studying area were compared with Mid-Atlantic rift tholeyits and subduction related basalts and deeper mantle basalts. The volcanics of study area behave similar to deeper mantle related basalts and in view of chondrite normalized LREE contents indicate, 25-350 times enrichment, condrite normalized HREE contents are 20-25 times rich (Figure 4).



Lava specimens: ◆ , Tuff specimens: □

*Figure 3. Classification of volcanics according to their alkali(Na2O+K2O) and silica (SiO2) contents (Cox et.al, 1979) and silica(SiO2) and (Zr/TiO²*0.0001)contents(Winchester and Floyd,1977).*

Table 2. Trace and rare-earth element concentrations of Sandúklú lavas(Samples:110, 126, 132, 141, 200, S14)and tuffs(Samples: 1,17)

Sample ppm	1	17	110	126	132	141	200	S14
Co	9	9	16	18	20	17	17	17
Cs	79	29	11	8	20	88	13	11
Ga	20	19	20	20	23	22	22	21
Hf	10	15	13	9	11	21	15	12
Nb	57	41	45	40	32	52	47	43
Rb	167	393	180	161	292	1776	194	216
Sn	2	5	3	3	3	8	4	8
Sr	1954	1551	1208	1452	1020	3246	1320	1237
Ta	3	2	3	3	3	3	3	3
Th	47	43	29	45	53	54	34	40
Tl	0.5	0.9	0.3	0.4	0.4	0.2	0.5	0.4
U	8	12	9	17	24	11	12	16
V	61	132	92	114	127	216	11	81
W	6	3	6	4	7	4	8	5
Zr	419	517	457	327	343	774	520	419
Y	30	23	26	26	28	28	31	25
La	147	85	103	135	76	104	121	103
Ce	222	142	184	239	129	179	219	186
Pr	21	15	20	26	14	19	24	20
Nd	71	54	73	97	56	69	88	72
Sm	9	8	12	15	9	12	14	11
Eu	2.5	1.1	3.3	4.1	2.3	3.1	4.1	3.1
Gd	6.0	5.5	7.6	8.7	6.8	7.9	9.7	7.3
Tb	0.7	0.7	0.9	1.0	0.8	1.0	1.1	0.9
Dy	4.1	3.8	4.7	5.1	4.8	5.1	5.7	4.5
Ho	0.8	0.6	0.8	0.8	0.9	0.9	1.0	0.7
Er	2.7	2.2	2.5	2.5	3.0	2.8	2.9	2.3
Tm	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Yb	2.8	2.0	2.3	2.2	2.6	2.5	2.7	2.1
Lu	0.4	0.2	0.3	0.3	0.3	0.3	0.3	0.3

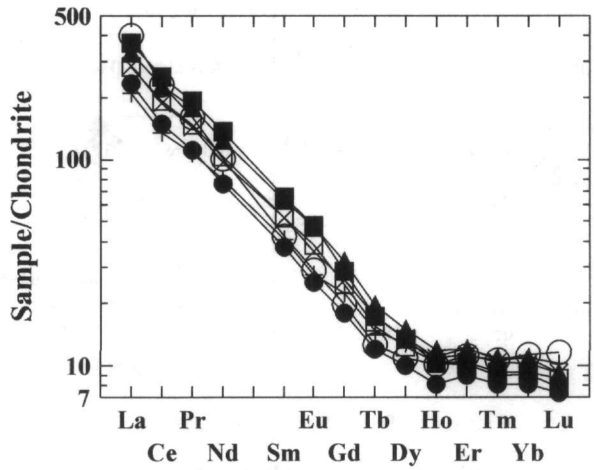


Figure 4. Condrite-normalized REE pattern of Sandúklú lavas.

3.3. Altered Lavas

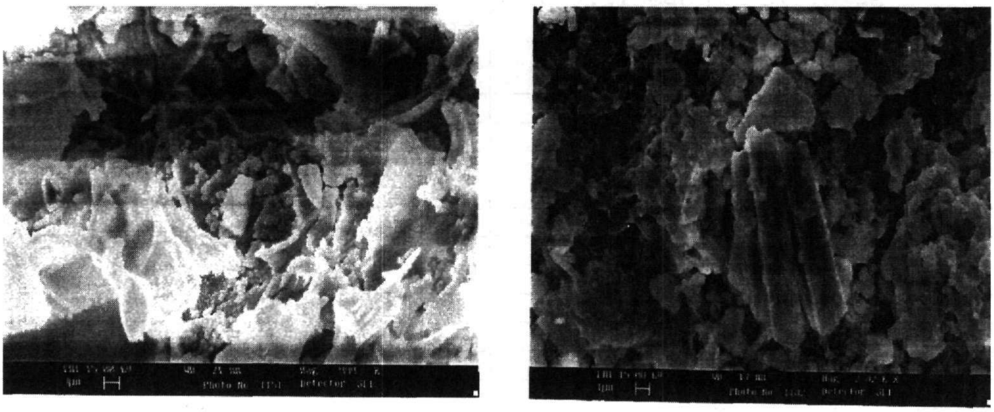
In some locations, the lavas have been extensively altered by hydrothermal solutions and formed to the clay (illite) and zeolite (chabazite) minerals. The zeolite formation of altered lavas is in small amount. In altered lavas, the following minerals were identified by optical microscope and X-ray diffractograms: sanidine, plagioclase (albite) basaltic hornblende, biotite, chlorite, illite, montmorillonite (in some specimens), calcite, opaque minerals and iron oxide.

3.4. Investigation of tuffs by electron microscope and x-ray diffraction Methods

Firstly, 22 natural zeolitic tuff specimens were investigated by X-ray diffraction method. After this, for the separation processes of zeolite from the zeolitic rock, heavy liquid (tetrabrom ethane) was used and than 8 purity of zeolite specimens were tested by X-ray diffraction method. Zeolite contents of tuffs were determined between 35-65 %. Zeolite contents of some tuff specimens are higher than %65. In investigated area, crθme tuffs contain chabazite and/or chabazite and phillipsite, milky brown tuffs contain phillipsite. These minerals were obtained under the electron microscope (Figure 5). According to x-ray diffractograms, three-phillipsite forms were determined. These are potassium–sodium–aluminum-silicate hydrate, sodium–aluminum-silicate hydrate and potassium-calcium–aluminum-silicate hydrate

4. THE USAGE AS A RAW MATERIAL OF TUFFS, TUFFITS AND ALTERED LAVAS IN CEMENT INDUSTRY

Trass plays an important role as a raw material in cement industry. The suitability of tuffs and tuffits for cement industry were carefully investigated. 2 altered lavas samples, 11 tuffs samples and 9 tuffits samples were tested. The chemical composition of tuffs and massive and homogenous tuffits are suitable to trass standards. The total amount of (SiO_2+Fe_2O_3+Al_2O_3) is between 73.34-81.80 % (accepted total amount is max. 70%, at Turkish standard, TS 26). However MgO is between 0.16 –2.4% (accepted amount is 5%), The amount of SO_3 is between 0.0-0.36 % (accepted amount is 3%). The results of physico-mechanical properties are suitable to trass standards. The specific densities of tuff and tuffits are between 2.3-2.86 gr/cm^3 The Blaine values(Specific area) are found between 4650-6130 cm^2/gr (accepted value is 3000 cm^2/gr), Table: 3,4.



a b

Figure 5. A) SEM image of chabazite, B) SEM image of phillipsite.

It is shown that the factor of decreasing Blaine value is abundance of lithic material ad minority glassy phase. The glassy phase, pumice content, the amount and size of intraclasts, and exraclasts, percentage of phenocrystal and present of alteration minerals in tuffs and tuffits which will be used as trass, play an important role in puzzolanic activity. The abundance zeolite minerals cause a decrease in specific density value but make increase of the Blaine value. The high amount of zeolite and glassy phase has been affected to the increasing of puzzolanic activity value. Because of the chemically homogenous composition, welded tuffs and/or composed tuffs and tuffits have high puzzolonic activity.

Table 3. Chemical analyses of altered lavas(S1, ST30), tuffs(S6, 21, 41, 43, 44, ST34, ZT3,4,5,6) and tuffits(S5,ST33, 36,39,ZT1,2, 8)

% Samp.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	SO_3	% LOI	SUM
S1	59.20	16.93	4.02	0.50	4.58	1.97	3.62	0.00	9.10	99.99
S30	60.08	15.75	4.30	1.78	3.66	3.70	4.29	0.00	5.28	99.28
S6	51.95	20.00	5.26	0.24	5.19	0,63	6,17	0.36	10.18	99.98
S21	49.91	16.91	5.60	1.19	5.21	3.95	5.67	0.28	10.80	99.19
S41	53.32	19.02	4.76	0.29	4.82	0.75	5.72	0.33	10.50	100.5
S43	51.95	20.00	5.26	0.23	5.19	0.63	6.17	0.36	10.20	99.97
S44	59.50	17.16	4.00	0.35	4.20	2.27	3.88	0.27	7.92	99.97
ST34	54.51	15.24	3.59	1.15	5.6	4.03	3.41	0.00	10.60	98.13
ZT3	54.54	16.38	3.60	1.93	7.88	4.06	3.74	0.00	6.20	98.53
ZT4	52.61	14.80	7.90	2.40	9.59	4.47	5.11	0.00	3.06	99.94
ZT5	52.19	14.61	7.49	2.26	9.44	5.41	3.34	0.00	4.16	98.87
ZT6	49.83	17.51	5.75	1.95	3.94	4.09	7.15	0.00	8.10	99.17
S5	54.72	17.36	4.38	1.95	6.11	4.10	4.65	0.00	4.90	98.17
S22	57.03	16.60	3.23	1.91	7.32	4,09	4,99	0.00	4.00	99,44
S42	55.33	21.16	9.31	0.16	3.26	2.32	7.18	0.00	5.47	98.21
S45	55.52	20.39	4.70	0.67	5.60	2.71	3.93	0.25	4.88	98.65
ST33	58.58	16.25	5.06	2.20	4.88	4.10	3.26	0.00	5.32	99.55
ST36	54.20	14.54	4.20	0.96	5.69	4.07	4.64	0.00	10.6	98.90
ST39	60.38	17.60	3.56	1.94	2.40	4.08	4.57	0.00	5.20	99.73
ZT1	52.62	16.46	3.30	1.98	7.13	4.08	5.01	0.00	5.90	96.02
ZT2	54.94	18.61	3.70	1.94	5.63	4.03	3.3	0.00	7.80	99.97
ZT8	55.94	16.3	3.64	1.91	5.18	4.05	3.76	0.00	8.45	99.23

Table 4. Specific density, specific area and puzzolonic activity values of altered lavas,tuffs and tuffits

Sample No.	Specific density gr/cm^3	Specific area cm^2/gr	Compression Strength 7. age days N/mm^2	Bending strength 7. age days N/mm^2
S1	2.33	6047	12.4	3.6
ST30	2.53	4878	2.5	0.9
S6	2.36	5589	11.9	3.7
S21	2.29	6130	10.6	3.4
S41	2.27	5518	10.3	3.0
S41	2.27	5518	10.3	3.0
S43	2.35	5184	12.8	3.70
S44	2.32	5490	12.2	3.80
ST34	2.35	5795	11.4	3.7
ST36	2.4	5369	115	3.5
ZT-3	2.38	5447	12.1	3.6
ZT-4	2.86	4605	3.4	1.2
ZT-5	2.82	5337	5.0	1.7
ZT-6	2.43	4811	10.0	3.2
S5	2.50	5112	13	4
S22	2.48	4804	14.5	3.7
S42	2.50	4890	12.80	3.70
S45	2.53	4951	11.5	3.60
ST33	2.53	4899	10.8	2.8
ST39	2.4	4650	13.2	3.8
ZT-1	2.6	4783	11.9	3.9
ZT-2	2.5	5399	14.8	3.7
ZT-8	2.38	5183	12.6	3.9

5. CONLUSIONS

In the investigated area, the volcanics of the alkaline and subalkaline character are mainly composed of red, gray and light brown lavas are crθme, milky brown and dark gray tuffs as well as white tuffits. The lavas were petrochemicaly identified as thrachyandesite, andesite, basaltic andesite and phonolitic tefrite.

The tuffs located in Sandúklú region have been widely zeolitizated and the dominant zeolite minerals are chabazite and phillipsite. According to x-ray diffractograms, three-phillipsite forms were determined. These are potassium-sodium-aluminum-silicate hydrate, sodium-silicate-silicate hydrate and potassium-calcium-silicate-silicate hydrate. Zeolite contents of tuffs firstly discovered in the area by the author are between 35-65 % and in some specimens higher than 65%.

In the north of Sandúklú, the rhyolitic and ignimbrite volcanics are situated. In the study area, white color tuffits contain pumices and úgnimbritic blocks, which are found at the basement of the lacustrine sediments and/ or alternated with the lacustrine sediments. This indicates that basin formations are pencontemporaneous with the development of explosive volcanic activity. In the later period following the ignimbritic explosive activity, thrachyandesitic lavas associated with blocks and ashes were erupted. In this period, the welded continental tuffs were formed. Because of the post volcanic hydrothermal activity, lavas were extensively altered. In this region, melts derived from the subduction of the African Plate along the Hellenitic Trench have caused the anatexis of the lower crust (Keller, 1983), and seem to be a reason for the crustal thinning. With the beginning of the anatexis process, the crust has begun thin and to extend (Aydar, 1998). The alluvial fan deposites, which occurred during the basin formation, contain pumices and ignimbritic blocks, which indicate the penecontemporeneous development of explosive volcanic activities (Aydar,1998). Asthenosferic diapirs were probably generated after the ignimbritic sequence(Harut,1995). The lamprophyric magma ascents from deep mantle has taken upper mantle fragments in to the body(the nodules) and interact with the crustal material in the magma chamber. They are found subvolcanic dept (Aydar,1998). As a result, volcanics of studied area cited as thrachyandesite, andesite, basaltic andesite, phonolite and basaltic thrachy–nephelinite.

According to the results of technological tests and chemical composition, the zeolitic tuffs, the altered lavas and the white tuffits are suitable to trass standards.

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