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CONTENTS

PHYSICOCHEMICAL PROPERTIES AND USES OF KARACAÖREN AREA (NEVŞEHİR) DIATOMITE

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Research Article

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ABSTRACT

In this study, physicochemical properties and the area of use of diatomites that occur in association with Central Anatolian volcanism in the Karacaören region (Ürgüp country, Nevşehir) are investigated. In the investigated area two stratigraphic sections were measured, one is in Quaternary lake units (K1) and another section is in the lacustrine sediments of Bayramhacılı member within Ürgüp formation of late Miocene-Pliocene age (K2). In order to specify physicochemical properties and the area of use of diatomites, various analyses were carried out at the Laboratories of General Directorate of Mineral Research and Exploration including loss on ignition (at 1050 °C), XRD, amount of acid and water-insoluble matter, thermal conductivity (in the range of 101; 150 °C and ± 10 °C), XRF, pH, total porosity, specific gravity, specific surface area, pore volume, pore size, whiteness, particle size and SEM analysis. The evaluation of the analyses results showed that the studied diatomites have a commercial value and can be used directly in percolator, as filler and structuring agents and in silicate manufacturing. In addition, once processed, they can also be used as mild abrasive and cleaner in production of isolation material.

1. Introduction

The study area comprising 1/25000-scaled Kayseri K33-c3 and K33-d3 quadrangles is on the Ürgüp-Karain road in Karacaören area in Ürgüp town of Nevşehir city (Figure 1). Previous studies in and around the study area generally focused on volcanism (Beekman, 1963, 1966; Sassano, 1964; Pasquere, 1968; Ayrancı, 1970; Innocenti et al., 1975; Batum, 1978; Özkuzey and Önemli, 1977; Yıldırım and Özgür, 1981; Ekingen, 1982; Güner and Emre, 1983; Yıldırım, 1984; Ercan et al., 1990; Ercan and Yıldırım, 1988; Pasquare et al., 1988; Schumacher et al., 1990, 1992; Aydar, 1992; Göncüoğlu and Toprak, 1992; Temel, 1992; Bigazzi et al., 1997; Aydar et al., 1998; Gevrek et al., 1994 *a, b*; Toprak, 1996; Duritt et al., 1995; Temel et al., 1998 *a*; Le Pennec et al., 2005; Gürel et al., 2007). 1/25000-scaled geological maps of Hasandağ and Melendiz Dağı regions, Niğde-Nevşehir-Kırşehir-Kayseri regions and Niğde-Aksaray-Derinkuyu regions are made by Beekman (1966), Atabey et al. (1987, 1988) and Ayhan et al. (1988), respectively. Schumacher and Schumacher (1996), Dhont et al. (1998), Froger et al. (1998), Koçyiğit and Beyhan (1998), Kürkçüoğlu et al. (1998), Temel et al. (1998 *b*), Toprak (1998) and Dönmez et al. (2003) studied mineralogy, geochemistry and structural and Petrographic characteristics of Cappadocian Volcanic Province (CVP) while Göz et al. (2014) investigated geology, mineralogy and geochemistry of Miocene-Pliocene lacustrine occurrences within this province. Viereck-Gotte and Gürel (2003), Gürel et al. (2008), Kadir et al. (2006) and Gürel and Kadir (2006) studied paleosol, caliche and clay occurrences within ignimbrites in the study area. Yavuz-Işık and Toprak (2010) investigated palinostratigraphy and vegetation characteristics of Neogene terrestrial deposits alternating with Cappadocian ignimbrites. There is limited number of studies on diatomites in the area. Kayalı et al. (2005) and Gürel and Kadir (2008) studied spectroscopic characteristics of clays and diatomites in Central Anatolia. Diatom assemblage

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and paleoenvironment properties of diatomites in the Çiftlik Basin (Niğde) region are studied by Yıldız and Gürel (2005) and diatom assemblage and lithofacies characteristics of diatomites in the Ihlara-Selime region are investigated by Gürel and Yıldız (2006).

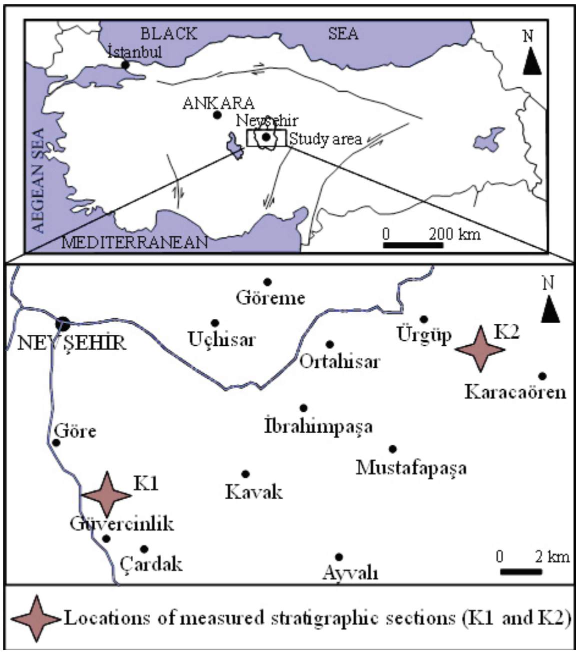

Figure 1- Location map of study area with measured stratigraphic section sites.

Physicochemical properties and the area of use of diatomite levels within late Miocene-Quaternary volcanogenic units exposing in the study area are first discussed in this study in detail. The Cappadocian Volcanic Province (CVP) is one of diatomite-rich regions in Turkey. In this respect, determining the physicochemical properties and the area of use of diatomites of Karacaören region within CVP is important to contribute to science and industry.

2. Material and Method

In the study area, 2 stratigraphic sections were measured; one is in Quaternary lacustrine deposits (K1) (thickness 9 m) and another is in lacustrine deposits of Bayramhacılı member of Miocene Ürgüp formation (K2) (thickness 50 m). A total of 12 diatomite samples were collected along both sections and were photographed in the field (Figures 2-5). Scanning electron microscope (SEM) (FEI Quanta 400 MK2 model) photographs of diatomite assemblage of a diatome-rich sample (sample K2-5) were taken at laboratories of General Directorate of Mineral Research and Exploration in Ankara (Figure 6). To determine physicochemical properties and the area of use of diatomites, samples collected from the field were subjected to several analyses at laboratories of General Directorate of Mineral Research and Exploration (MTA) including X-ray diffractometry (XRD) analysis (Cu X-ray tube Bruker D8 Advanced XRD device), loss on ignition (at 1050°C), thermal conductivity analysis (using Unitherm Model 2022

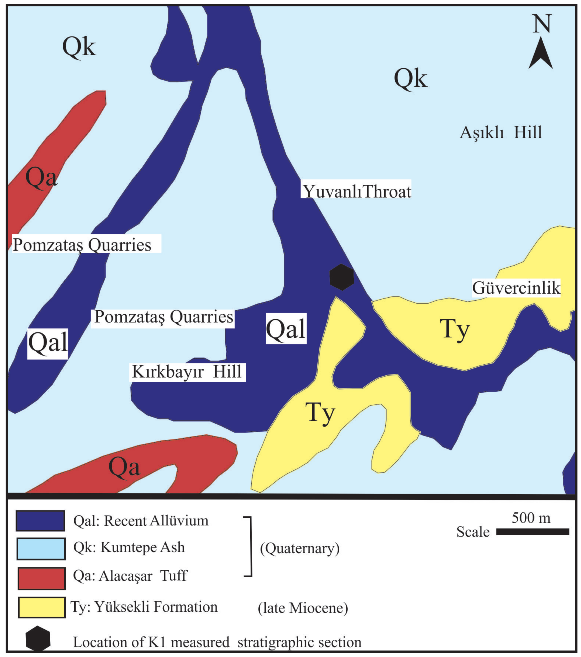

Figure 2- Location of K1 measured stratigraphic section and geology map (complied from Pasquare, 1968; MTA, 1989).

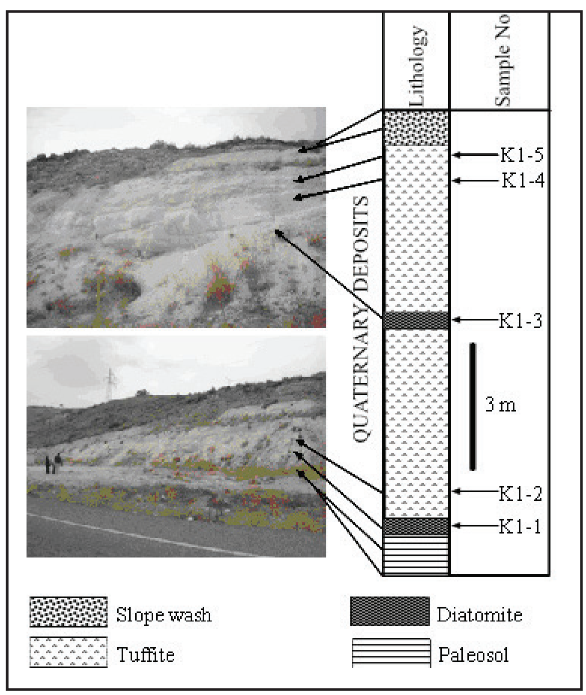

Figure 3- K1 measured stratigraphic section.

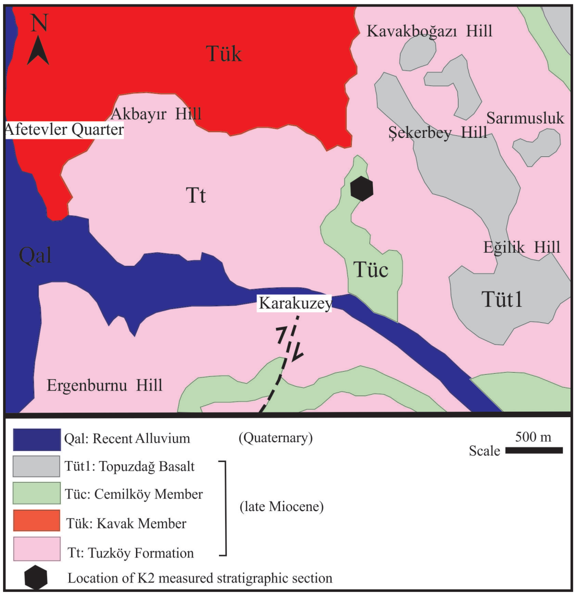

Figure 4- Location of K2 measured stratigraphic section and geology map (complied from Pasquare, 1968; MTA, 1989).

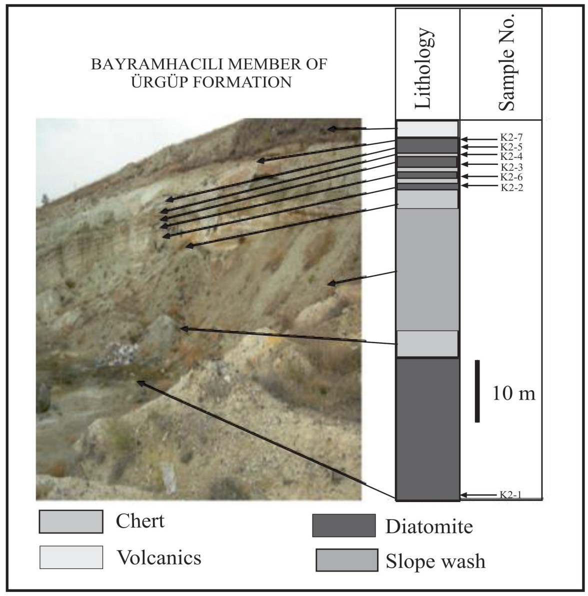

Figure 5- K2 measured stratigraphic section geology map (complied from Pasquare, 1968; MTA, 1989).

Thermal Conductivity Instrument 101; at 150°C and ±10°C), X-ray fluorescence spectrometer (XRF) analysis (samples were dried at 105°C and analysis was made with Thermo ARL brand XRF device equipped with UQ program), pH analysis (pH analysis of 10% solution of samples was made with wet method), amount of acid and water-insoluble matter (chemical analysis was made drying samples at 105°C), total porosity and density (since samples fall apart during absorption, porosity tests were not performed by water absorption method but their apparent density was determined with mercury-method), whiteness analysis (using Minolta Chroma Meter CR 300 device), specific surface area, pore volume, pore size analysis (with Nova Station B device) and grain size analysis (with wet method on Malvern Mastersizer 2000 device) (Tables 1–5). Results obtained were compared to those from standardized analysis of diatomites in Turkey and various parts of the world and the area of use of diatomites was assessed.

3. Regional Geology and Stratigraphy

The study area is located in the Cappadocian Volcanic Province (CVP). The CVP is a NE-SW extending province with length of 250–300 km and width of 60 km lying about 1400-1500 m above the sea level (Aydar et al., 2012). CVP is a calc-alkaline volcanic terrain which was formed as a result of collision between Eurasia and Africa-Arabian plates (Batum, 1978). The study area was undergone a complex neotectonic deformation during late Miocene-Pliocene and consequently several faults and within plate basins were formed and the region witnessed intense volcanism (Dirik, 2001). The Cappadocian Volcanic Province is bordered by Central Anatolian Fault Zone at east, Tuz Gölü Fault Zone at west and Orta Kızılırmak Fault Zone to the north. Derinkuyu Fault and Niğde Fault Zone are at the south. CVP is grouped into three rock units comprised by volcanic complexes corresponding to main eruption centers, volcaniclastic rocks and cinder cone areas. A total of 19 volcanic centers were determined. The highest ones are Erciyes Mountain (3917 m) and Hasandağ (3268 m) (Ekingen, 1982). Based on paleontological, palynological and radiometric age data, tectonic depression area at north of CVP was filled during late Miocene-Quaternary time by lacustrine and fluvial sediments that are intercalated with volcanic units. Volcano-sedimentary rocks in the region unconformably overlie the Paleozoic-Cretaceous basement rocks of Niğde massif at south and Kırşehir massif at north (Schumacher et al., 1990; Toprak, 1996). These deposits in the Ürgüp basin are described by Pasquaré (1968) and Viereck-Goette et al. (2010) as Ürgüp formation. This stratigraphic level corresponds to Messinian salinity crisis that took place in the late Miocene. The deposits of Ürgüp formation which are interlayered with lacustrine and fluvial sediments are widely distributed within CVP and host several ignimbrite, andesitic and basaltic lava levels.

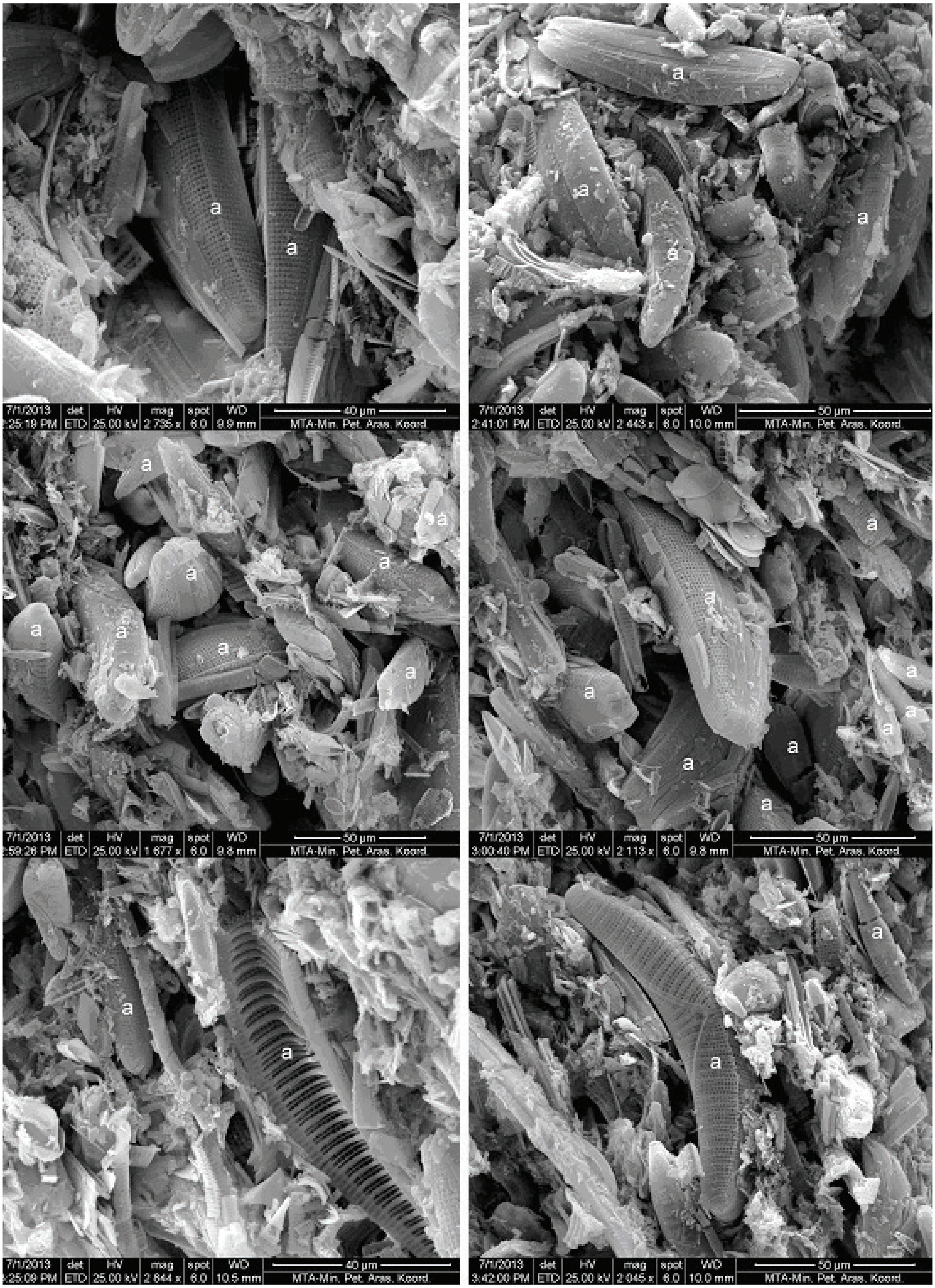

Figure. 6- Scanning electron microscope (SEM) images of samle K2–5 from K2 measured section, (a) bulk pennate diatome forms.

Table 1- Results of XRD analysis of the studied samples.

Sample No.	Analysis Results
K1-1	1- Smectite 2- Feldspar 3- Opal-CT 4- Opal A
K2-1	1- Smectite 2-Feldspar 3- Opal- CT. 4-Quartz (trace) 5- Opal A
K2-4	1- Smectite 2-Feldspar 3- Opal- CT.
K2-7	1- Smectite 2- Opal- CT.

They are namely Kavak, Zelve, Sarımaden Tepe (or Sofular), Cemilköy, Tahar, Gördeles, Kızılkaya and İncesu ignimbrites, Topuzdağ and Çataltepe basalts and Bayramhacılı and Kışladağ members. Radiometric age data indicate that these rocks are of late Miocene-Pliocene age (Besang et al., 1977). The Bayramhacılı member is composed of lacustrine and fluvial sediments consisting of conglomerate, sandstone, limestone, marl and diatomite. The Kışladağ member is composed of lacustrine limestone and diatomite. Lacustrine limestone contains ostracode and gastropod fossils. Kavak, Zelve and Sarımaden Tepe ignimbrites are generally white-gray while Cemilköy ignimbrite is dull gray colored. The pinkish colored Tahar ignimbrite, dull gray colored Gördeles ignimbrite and red-pinkish colored Kızılkaya ignimbrite are have a wide distribution and show columnar joint structures (Le Pennec et al., 1994). The Ürgüp formation is overlain by Quaternary alluvium. The age ignimbrite series within the formation is found as 1 to 9 Ma ($^{40}Ar/^{39}Ar$ plagioclase and U-Pb zircon dating methods) (Aydar et al., 2012).

Table 2 – Results of thermal conductivitiy analysis.

	At Temperature of ± 10 °C		At Temperature of 101; 150 °C	
Sample No.	Average Sample Temperature (°C)	Thermal Conductivity Value (W/mK)	Average Sample Temperature (°C)	Thermal Conductivity Value (W/mK)
K1-1	- 4,63	0,891	101,08	0,193
	2,10	0,785	126,28	0,198
	11,81	0,738	151,53	0,221
K2-1	- 5,79	0,984	101,04	0,223
	1,71	0,860	126,21	0,220
	11,42	0,790	151,36	0,225
K2-4	- 6,20	0,590	100,90	0,164
	1,17	0,503	126,08	0,155
	11,00	0,452	151,09	0,140
K2-7	- 5,42	0,742	100,90	0,136
	1,31	0,595	125,99	0,137
	10,98	0,484	151,05	0,134

Table 3- Total porosity, whiteness, acid and water-insoluble matter contents of diatomite samples from studied area.

Sample No.	Total Porosity (%)	Results of Whiteness Analysis				Acid-Insoluble Matter Content (%)	Water-Insoluble Matter Content (%)
		L	a	b	Y		
K1-1	69,40	84,29	+0,94	+6,66	64,63		
K2-1	64,89	92,62	+0,62	+4,29	82,29		
K2-4	76,90	87,14	+0,22	+15,04	70,30		
K2-7	76,56	83,93	+1,60	+11,97	63,94		
K2-5						90,20	98,85

Table 4 – Results of specific surface area, pore volume and pore size analysis.

Methods	Sample No.			
Specific Surface Area	**K1-1**	**K2-1**	**K2-4**	**K2-7**
Multiple Point BET	2,027 e^{+02} m^2/g	4,315 e^{+01} m^2/g	1,678 e^{+01} m^2/g	1,558 e^{+01} m^2/g
Cumulative Absorption Specific Surface BJH	1,200 e^{+02} m^2/g	3,337 e^{+01} m^2/g	1,938 e^{+01} m^2/g	1,956 e^{+01} m^2/g
Cumulative Desorption Specific Surface BJH	1,985 e^{+01} m^2/g	4, 485 e^{+01} m^2/g	2,574 e^{+01} m^2/g	2,600 e^{+01} m^2/g
Cumulative Absorption Specific Surface DH	1,217 e^{+01} m^2/g	3,387 e^{+01} m^2/g	1,967 e^{+01} m^2/g	1,985 e^{+01} m^2/g
Cumulative Desorption Specific Surface DH	2,011 e^{+01} m^2/g	4,550 e^{+01} m^2/g	2,610 e^{+01} m^2/g	2,638 e^{+01} m^2/g
Pore Volume				
Cumulative Absorbtion Pore Volume BJH		8,124 e^{-02} cc/g	4,626 e^{-02} cc/g	4,334 e^{-02} cc/g
Cumulative Desorbtion Pore Volume BJH	3,190 e^{-01} cc/g	7,245 e^{-02} cc/g	4,133 e^{-02} cc/g	3,747 e^{-02} cc/g
Cumulative Absorbsion Pore Volume DH	2,865 e^{-01} cc/g	7,916 e^{-02} cc/g	4,508 e^{-02} cc/g	4,225 e^{-02} cc/g
Cumulative Desorption Pore Volume DH	3,109 e^{-01} cc/g	7,064 e^{-02} cc/g	2,029 e^{-01} cc/g	3,654 e^{-02} cc/g
Pore Diameter				
Absorbtion Pore Diameter BJH	3,125 e^{+}01 A	3,141 e^{+}01 A	3,141 e^{+}01 A	4,038 e^{+}01 A
Desorption Pore Diameter BJH	3,703 e^{+}01 A	3,671 e^{+}01 A	3,716 e^{+}01 A	3,687 e^{+}01 A
Absorbsion Pore Diameter DH	3,125 e^{+}01 A	3,141 e^{+}01 A	3,141 e^{+}01 A	4,038 e^{+}01 A
Desorption Pore Diameter DH	3,703 e^{+}01 A	3,671 e^{+}01 A	3,716 e^{+}01 A	3,687 e^{+}01 A

Table 5- Standardized compositions of various diatomites used in different areas and comparison of XRF, loss on ignition, grain size, density and pH analyses on samples 1) Spain, raw, 2) France, calcined, beer filtration, 3) Italy, raw, light construction material, 4) W. Germany, fertilizer carrier, 5) W. Germany, calcined, beer filtration, 6) W. Germany, calcined and fill material, 7) W. Germany, fitler matter, 8) Brazil, insulation matter, 9) USA, calcined filtration diatomite, 10) Basalt-Nevada (modified from Uygun, 2001).

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**KARACAÖREN**			
											K1-1	**K2-1**	**K2-4**	**K2-7**
%SiO_2	86,6	89,9	88,6	69,7	82,9	92,1	94,4	86	88,4	83,13	68,3	84,2	88,9	87,1
% TiO_2	0,1	0,6	0,2	0,4	0,1	0,2	0,1	0,7	0,2		0,4	0,1	< 0,1	< 0,1
% Fe_2O_3	0,4	2,2	8,3	3,1	10,1	0,6	4	1,4	1,5	2,00	4,6	1,1	1,8	3,3
% Al_2O_3	0,9	3,9	1,7	4,9	1,8	2,6	2,3	9,4	4,1	4,60	11,5	3,8	0,7	0,9
% CaO	5,2	0,8	0,6	0,4	2,5	0,1	0,2	0,1	0,6	2,50	2,4	1,6	1,1	1,1
% MgO	0,6	0,2	0,1	0,1	0,4	0,1	0,2	0,4	0,8	0,64	2,7	0,8	0,3	0,3
% Na_2O	0,2				1,1	0,9	3,2		2,9	1,60	1	0,6	0,1	0,3
% K_2O	0,1	0,2	0,3	1,2	0,3	0,3	0,6	0,2	0,7	0,44	0,7	0.3	< 0,1	< 0,1
% P_2O_5	0,2	0,3	0,1		0,1	0,1	0,1		0,2	4,92	0,1	0,6	0,5	0,4
% V_2O_5 + TiO_2										0,23				
% SiO_3											0,20	0,35	0,10	0,08
% SrO											0,03	0,02	< 0,01	< 0,01
% BaO											0,03	< 0,01	< 0,01	< 0,01
% ZrO_2											0,02	< 0,01	< 0,01	< 0,01
% V_2O_5											0,02	0,03	0,01	0,03
% ZnO											0,01	< 0,01	< 0,01	< 0,04
% CuO											0,01	< 0,01	< 0,01	< 0,01
% MnO											0,2	< 0,1	0,1	< 0,1
Loss on Ignition % (at 850°C)	5,5	0,7	0,5	19,1	0,5	3	5,9	2	0,3	5,30	7,65(1050 °C)	6,20(1050 °C)	6,20(1050 °C)	6,10(1050 °C)
Average Grain Size (μ)	3,4	2,7	2,4	4,7	4,5	1,2	6,8	2,7	14,7		550	15	15	20
Grain Smaller than 20 μ (%)	3,7	0,8	1,6	23,4	6,8	2,7	20	4,6	31,8		<1	< 5,5	< 7,5	<7
Wet Density (g/cm^3)	4,17	2,44	2,44	3,00	2,17	2,50	2,50	2,08	2,44		2,43	2,26	2,29	2,30
Filtration Rate (ml/min)	12	52	30	18	70	10	190	50	740					
pH	8,3						8,5		8,8		8,65	9	8,7	9,85
Quartz (%)				18										

Table 6- Comparison of analyses values of various commercially used diatomites in Turkey with those of studied diatomites 1) Turkey – Kayseri, 2) Kayseri-Kırka, 3) Aydın-Dedeler, 4) Ürgüp, 5) Denizli-Sarayköy, 6) Kütahya-Alayunt, 7) Balıkesir-Balya, 8) Niğde-Belisırma, 9) Afyon-İncehisar, 10) Afyon-Tınaztepe, 11) Ankara-Kızılcahamam, 12) Çankırı-Çerkeş (modified from Sarıiz and Nuhoğlu. 1992; Aruntaş et al., 1998; Bozkurt, 1999; Nuhoğlu and Elmas, 1999; Bentli, 2001; 8 th Five-Year Development Plan, 2001; Uygun.2001).

	1	2	3	4	5	6	7	8	9	10	11	12	KARACAÖREN			
													K1-1	K2-1	K2-4	K2-7
% SiO_2	90,2	90,0	89,6	88,7	85,0	84,42	79,5	72,1	81,86	84,15	88,62	83,25	68,3	84,2	88,9	87,1
% TiO_2	0,1	0,2	0,01	0,06	0,01	0,05		0,2					0,4	0,1	< 0,1	< 0,1
% Fe_2O_3	0,8	1,1	14	3,38	2,8	1,55	3,24	4,4	1,87	3,36	0,57	1,20	4,6	1,1	1,8	3,3
% Al_2O_3	3,3	2,9	21	1,11	5,0	5,02	6,14	13,1	3,91	4,50	3,30	5,50	11,5	3,8	0,7	0,9
% CaO	0,6	0,7	0,01	1,35	0,01	0,96	12	0,9	0,86	1,07	0,74	1,30	2,4	1,6	1,1	1,1
% MgO	0,3	0,5	12	0,38	1,6	0,74	1,19	3,7	0,15	1,03	0,80	1,90	2,7	0,8	0,3	0,3
% Na_2O		0,6	0,06	0,28	0,13	0,62		17		0,47	0,77	0,95	1	0,6	0,1	0,3
% K_2O	0,1	0,2	0,15	0,32	0,4	0,60		0,1		0,44	0,71	1,30	0,7	0.3	< 0,1	< 0,1
% P_2O_5			0,01	0,42	0,01			1,7					0,1	0,6	0,5	0,4
% V_2O_5 + TiO_2								1,9								
% SiO_3													0,20	0,35	0,10	0,08
% SrO													0,03	0,02	< 0,01	< 0,01
% BaO													0,03	< 0,01	< 0,01	< 0,01
% ZrO_2													0,02	< 0,01	< 0,01	< 0,01
% V_2O_5													0,02	0,03	0,01	0,03
% ZnO													0,01	< 0,01	< 0,01	< 0,04
% CuO													0,01	< 0,01	< 0,01	< 0,01
% MnO													0,2	< 0,1	0,1	< 0,1
Loss on Ignition % (at 850 °C)	4,2	4,6	5,5	2,7	5,25	6,09	8,35	4,2	11,31	4,92	4,24	5,54	7,65(1050 °C)	6,20(1050 °C)	6,20(1050 °C)	6,10(1050 °C)
Average Grain Size (μ)	3,3					10					145	90	550	15	15	20
Grain Smaller than 20 μ (%)	2,7												<1	< 5,5	< 7,5	<7
Wet Density (g/cm^3)	2,94					1,9 2,4					1,95	1,90	2,43	2,26	2,29	2,30
Filtration Rate (ml/min)	48															
pH		8,0									7,87	7,28	8,65	9	8,7	9,85
Color						White					White	White	White	White	White	White

Stratigraphic units in the study area, from bottom to the top, are composed of late Miocene Tuzköy formation (Tt), Yüksekli formation (Ty) and Kavak member (Tük), Cemilköy member (Tüc), Topuzdağ basalt (Tüt1), Quaternary Alacaşar tuff (Qa), Kumtepe Ash (Qk) and recent alluvium deposits (Qal) within the Ürgüp formation (Bayramhacılı member) (Figure 7).

Tuzköy Formation (Tt): It was named by Atabey et al. (1988). It consists of yellow colored, thin bedded, bioturbated siltstone, laminated silicified claystone, thin bedded and laminated sandstone and tuff alternation. Limestone and claystone host gypsum crystals. The unit has thickness of 100 m It is unconformable with underlying Kızılöz formation. Based on *Cyprideis* sp., *Chara, Ilyocyris* cf. *gibba* (Ranbohr) fossils in marl samples and stratigraphic relations, the age of Tuzköy formation is late Miocene.

Yüksekli Formation (Ty): It was named by Aydın (1984). It consists of whitish-gray colored, medium-fine grained, trough cross bedded sandstone, pebbly sand, tuffite, siltstone, claystone and coarse sandstone and conglomerate. Pebbles show sorting and orientation. The unit that represents a lacustrine environment has thickness of 200 m and is concordant with underlying Tuzköy formation.

Bayramhacılı Member of Ürgüp Formation (Tü): It was named by Pasquare (1968). This member is found at the base of Ürgüp formation. It consists of lacustrine and fluvial sediments that are made up by conglomerate, limestone, clay, marl, volcanic ash,

Table 7- Comparison of physicochemical properties of diatomites in the study area with standardized compositions of diatomites commercially used in various industrial sectors (modified from Özbey and Atamer,1987; Açıkalın, 1991; Aruntaş et al., 1998; Bentli, 2001).

	COMMERCIAL	DIATOMITES USED IN SUGAR PLANTS IN TURKEY	FILTER		FILL			ABRASIVE AUTOMOBILE POLISH	REGULATORY FERTILIZER	KARACAÖREN			
			WINE	SUGAR	PAPER	PAINT	PLASTIC			K1-1	K2-1	K2-4	K2-7
%SiO_2	>85,0	87,3								68,3	84,2	88,9	87,1
% TiO_2										0,4	0,1	< 0,1	< 0,1
% Fe_2O_3	<1,5	1,95								4,6	1,1	1,8	3,3
% Al_2O_3	<5,0	3,23								11,5	3,8	0,7	0,9
% CaO	<1,0	1,09								2,4	1,6	1,1	1,1
% MgO	<0,5	0,45								2,7	0,8	0,3	0,3
% Na_2O	<1,0	0,47								1	0,6	0,1	0,3
% K_2O	<1,0	0,44								0,7	0.3	< 0,1	< 0,1
% P_2O_5										0,1	0,6	0,5	0,4
% SiO_3										0,20	0,35	0,10	0,08
% SrO										0,03	0,02	< 0,01	< 0,01
% BaO										0,03	< 0,01	< 0,01	< 0,01
% ZrO_2										0,02	< 0,01	< 0,01	< 0,01
% V_2O_5										0,02	0,03	0,01	0,03
% ZnO										0,01	< 0,01	< 0,01	< 0,04
% CuO										0,01	< 0,01	< 0,01	< 0,01
% MnO										0,2	< 0,1	0,1	< 0,1
Loss on Ignition % (at 850°C)	< 6,0	4,43								7,65(1050 °C)	6,20(1050 °C)	6,20(1050 °C)	6,10(1050 °C)
Average Grain Size (µ)			2,5	22		6,8	5,1	5,5		550	15	15	20
Grain Smaller than 20 µ (%)										<1	< 5,5	< 7,5	<7
Wed Density (g/cm^3)			2,3	2,0	2,4	2,2	2,8	2,4	1,7	2,43	2,26	2,29	2,30
Water Absorption(%)	>280 >180												
pH		4,49	7,0	10	7,0	10	7,0	9,4	7,0	8,65	9	8,7	9,85
Moinsture (%)	<15												
	White	Dirty White	Pink	White	Grey	White	Pink	White	Yellowish	White	White	White	White

siltstone and diatomite and volcanic material-bearing sandy and fine grained deposits interbedded with epiclastic, lateritic and sandy soils (Pasquare, 1968; Le Pennec et al., 1994).

Kavak Member (Tük): It was named by Pasquare (1968). The member has ignimbritic character and contains light brown, whitish homogeneous ignimbrite and pumice. In the Kavak member, white-dirty white colored, glassy tuff-bearing angular pumice ash levels are also observed. The member with thickness of 100 m represents the first ignimbrite occurrence in the Ürgüp region. It is transitional to Tuzköy formation.

Cemilköy Member (Tüc): It was named by Pasquare (1968). According to Pasquare (1968), the member is pure white colored, pumice-bearing a volcano-sedimentary unit with a lithic character. It locally contains ophiolitic rock and basaltic lava pebbles. The unit with thickness of 80 m is conformable with underlying Kavak and Sarımaden Hill members. In the member following fossils were determined: *Hipparion gracile* de Christol, *Samotherium majori* Bohlin, *antilope* sp., *gazella* sp. and *Hipparion meditarreneum* Hansel, *Rhinoceras* sp. (Şenyürek, 1953, İzbırak and Yalçınlar, 1951).

Topuzdağ Basalt (Tüt1): Volcanites of basic composition exposing at west of Tekkedağ are named by Dönmez et al. (2003) as Topuzdağ Volcanite. The same rock unit is called as Topuzdağ basalt by Atabey (1989). The main eruption center is at northeast of Ürgüp. It is composed of dark black-gray colored, banded, platy altered lava and pyroclastics of basic composition having little or no phenocrystal (Dönmez et al., 2003). It is described as pyroxene andesite.

Alacaşar Tuff (Qa): It is exposed in the area between Nevşehir, Alacaşar, Gülşehir and Çat. It is widely distributed in Alacaşar village, Baçlın, Çat and Sulusaray counties and at south of Gülşehir. It is composed of pink colored, obsidian-rich, glassy and pumice-bearing tuffs interbedded with gray ash deposits (Atabey, 1989). Brecciated tuff and sand

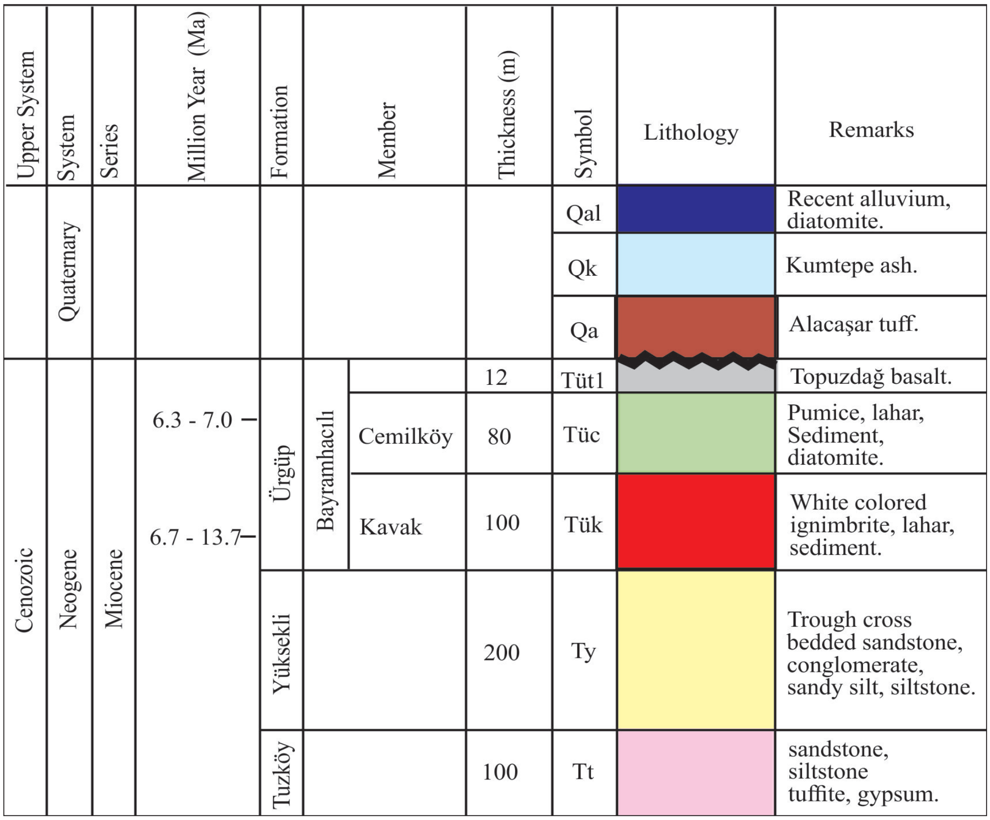

Figure 7- Generalized stratigraphic section of the study area (complied from Pasquare, 1968; MTA, 1989; Lepetit et al., 2014), No scale.

interlayers are locally observed. Boğazköy obsidian, Taşkesik hill, Villa hill and Tepeköy rhyolites are covered by the Alaşar tuff (Dönmez et al., 2003).

Kumtepe Ash (Qk): It is composed of pumice-rich glassy ashes. Fragmented pumice, obsidian, vitrophyre, plagioclase crystals and (oligoclase and andesine) and hornblende are observed within the vitrified cement. Based on vertebrate fossils such as *Sus* sp., *Antilope* sp., *Cervus* sp., *Equus* sp. within clays at Hanyerininbaşı hill, the age of Kumtepe ash is accepted as Holocene (Ozansoy, 1964).

Recent Alluvium (Qal): Recent alluviums in the study area are composed of pebble, sand and soils distributed along the Kızılırmak River.

4. Results

4.1. Stratigraphic Sections Measured in the Study Area

In the study area two stratigraphic sections were measured; one is in Quaternary lacustrine sediments (K1) and another is in lacustrine sediments of Bayramhacılı member of Miocene aged Ürgüp formation (K2) (Figures 2–5).

K1 measured stratigraphic section: In 1/25.000 scaled Kayseri K33-d3 quadrangle, K1 section has start coordinates of longitude: 0651683, latitude: 4269138, elevation: 1311 m and end coordinates of longitude: 0651645, latitude: 426917, elevation: 1320 m. The thickness of section is 9 m and 5 samples were collected (Figures 2 and 3). The section starts at the bottom with a light brown paleosol level. Towards the upper part of section, following units are observed: 50 cm-thickened white colored diatomite level, 4.5 m-thickened light gray tuffites and 30 cm-thickened white diatomite level. The second diatomite level is overlain by a gray colored tuffite level of 3.7 m thickness and a slope wash comprises the uppermost part of section (Figure 3).

K2 measured stratigraphic section: In 1/25.000 scaled Kayseri K33-d3 quadrangle, K2 section has start coordinates of longitude: 0670278, latitude: 4278081, elevation: 1175 m and end coordinates of longitude: 0670351, latitude: 4278360, elevation: 1233 m. The thickness of section is 58 m and 7 samples were collected (Figures 4 and 5). The K2 section starts at the bottom with a white diatomite level of 23 m thickness. It is overlain by light brown chert level of 4 m thickness and slope wash of 10 m thickness. It is covered with another light brown chert level of 4 m thickness and 4 different white diatomite levels of about 1 m alternating with cherts (Figure 5). Diatomites at both locations are light and soft and easily fall apart within hand.

4.2. Results of Analysis for Samples Collected From the Study Area

In order to determine physicochemical properties and the area of use of diatomites in the study area, XRD analysis was carried out on samples collected from the field. Results indicate that smectite is the main clay mineral in both sections (K1 and K2) and feldspar and opal are the secondary phases. A sample from K2 section (sample K2-1) contains little quartz (Table 1). It is known that smectite is an authigenic mineral occurring in alkali environments (Gürel and Kadir, 2006). This might show that diatomites in the area were formed in an alkali environment.

As a result of thermal conductivity analysis, samples from both sections (K1 and K2) are found to have thermal conductivity values in the range from 0.452 to 0.984 W/mK at ±10°C and from 0.134 to 0.225 W/mK at 150°C. It is noticeable that conductivity values of samples are decreased as temperature is increased (Table 2).

It was determined that samples have extremely high porosity values between 64.89 and 76.90%, whiteness between 63.93 and 82.29%, acid-insoluble matter of 94.20% and water-insoluble matter of 98.85% showing that they behave as inert chemical reactions. Diatomites may be white, light yellow, beige and gray in color while organic matter-rich ones are green, brown and black in color (Cummins, 1960; Uygun, 1976; Brady and Clauser, 1991). Studied diatomites are white colored and therefore it can be said that they do not contain any organic matter and may be nearly pure (Table 3).

As a result of specific surface area, pore volume and pore size analyses, cumulative absorption specific surface area of studied diatomites is found to change from 1200 e^{+2} m^2/g to 3,387 e^{+2} m^2/g, cumulative desorption specific surface area value is between 1.985 e^{+1} m^2/g and 4.485 e^{+1} m^2/g, cumulative absorption pore volume values change from 2.865 e^{+1} cc/g to 8.124 e^{-02} cc/g, cumulative desorption pore volume values are between 2.029 e^{-01} cc/g and 7.245 e^{-02} cc/g, absorption pore diameter value is between 3.125 e^{+} 01 Å and 4.038 e^{+} 01 Å and desorption pore diameter value ranges from 3.671 e^{+} 01 Å to 3.716 e^{+} 01 Å. These findings indicate that samples have high porosity (Table 4).

As a result of XRF, loss on ignition, grain size, density and pH analyses, diatomite samples are determined to have following range of chemical compositions: SiO_2: 68.3-88.9%, TiO_2: < 0.1-0.4%, Fe_2O_3: 1.1- 4.6%, Al_2O_3: 0.7-11.5%, CaO: 1.1-2.4%, MgO: 0.3-2.7%, Na_2O: 0.1-1%, K_2O: < 0.1-0.7%, P_2O_5: 0.1-0.6%, SiO_3: 0.03-0.35%, SrO: < 0.01-0.03%, BaO: < 0.01-0.03%, ZrO_2: < 0.01-0.02%, V_2O_5: 0.01-0.03%, ZrO_2: 0.3-2.7%, ZnO: < 0.01-0.01%, CuO: <0.01-0.01% and MnO: < 0.1-0.2%. Loss on ignition values of samples are between 6.10 and 7.65% at 1050 °C, grain size values of samples from K1 section are 0.4-3000 μ with an average of 550 μ and those of samples from K2 section are 0.4-100 μ with an average of 15-20 μ. Regarding average grain size, grain size of samples from K2 section are under sand size while samples from K1 section contain sand-size material. Density of samples from both sections is between 2.26 and 2.43 g/cm^3 and pH values are between 8.65 and 9.85 showing that samples reflect a basic environment (Table 5).

Assessment of scanning electron microscope images of diatomite assemblage in a sample from K1 section (sample no K2-5) reveals that diatomite samples in the study area are generally composed of coarse, elongate and pennate diatom forms (mostly species of *Epithemia*) (Figure 6).

5. Results and Discussion

The diatomite which is used in various sectors such as toothpaste, newspaper, automobile tire, coffee cup, headache tablet and wall paint, is one of important raw materials required by modern technology. The areas of use of diatomites are 1) filtration material, 2) fill material, 3) construction material, 4) absorbent, 5) carrier, 6) catalyst and catalyst carrier, 7) silicate production, 8) mild abrasive and cleaner and 9) isolation material. In industry diatomite is mostly used for filtration material (58%), fill material (19%), isolation material (4%) and various purposes (19%) (Uygun, 2001).

Regarding their physicochemical properties, commercialized diatomites should meet the following composition spectrum (Özbey and Atamer, 1987; Aruntaş et al., 1998): SiO_2: > 85%, Fe_2O_3: < 1.5%, Al_2O_3: < 5.0%, CaO: < 1,0%, MgO: < 0.5%, Na_2O: < 1.0%, K_2O: < 1.0%, loss on ignition value (at 850°C): < 6.0%, water absorption: > 180 to > 280%, moisture content: < 15% and their color is to be white (Table 7). In the study area diatomites at K2 location have following compositions: SiO_2: 84.2-88.9%, Fe_2O_3: 0.1-1.6%, Al_2O_3: 1.1-1.8%, MgO: 0.3-0.8%, Na_2O: 0.1-1.6%, K_2O: < 0.1-0.3% and loss on ignition value (at 1050°C): 6.1-6.2% and they have white color. These characteristics are conformable with standardized physicochemical properties of commercial raw diatomites. Only CaO value is slightly higher (0.1-2.4%) which can be reduced by processing (Tables 5-7). Standardized analysis values of studied diatomites and diatomites that are used commercially in various fields are given in table 5 for comparison. Commercially used diatomites are represented by the following compositions: SiO_2: 83.13-94.0%, TiO_2: 0.1-0.7%, Fe_2O_3: 0.4-10.1%, Al_2O_3: 0.9-9.4%, CaO: 0.1-5.2%, MgO: 0.1-0.8%, Na_2O: 0.2-1.60%, K_2O: 0.1-0.7%, P_2O_5: 0.1-4.92%, loss on ignition value (at 850°C) between 0.3-19.1%, the average grain size of 1.2-14.7 µ, wet density value of 2.08-4.17 g/cm^3, rate of filtration of 10-740 ml/min and pH value of 8.3-8.8. In table 6 commercially used diatomites in Turkey are compared to those from study area. Commercially used diatomites have the following compositions: SiO_2: 72.1-90.2%, TiO_2: 0.01-0.2%, Fe_2O_3: 0.20-14%, Al_2O_3: 1.1-13.1%, CaO: 0.01-12%, MgO: 0.15-12%, Na_2O: 0.06-17%, K_2O: 0.1-0.71%, P_2O_5: 0.01-1.7%, loss on ignition value (at 850°C) between 2.7-11.31%, the average grain size of 3.3-145 µ, wet density value of 1.9-2.94 g/cm^3, rate of filtration of 48 ml/min and pH value of 7.28-8.0. Diatomites in the study area are represented by SiO_2 contents of 68.3% (at location of K1 section) and 84.2-88.9% (at location of K2), TiO_2 contents of < 0.1-0.4%, Fe_2O_3 contents of 1.1-4.6%, Al_2O_3 contents of 0.7-3.8% (at location of K2 section) and 11.5% (at location of K1 section), CaO contents of 0.1-2.4%, MgO contents of 0.3-0.8% (at location of K2 section) and 2.7% (at location of K1 section), Na_2O contents of 0.1-1.0%, K_2O contents of < 0.1-0.7%, P_2O_5 contents of 0.1-0.6%, loss on ignition values of 6.10-7.65%, average grain sizes of 15-20 µ (at location of K2 section) and 550 µ (at location of K1 section), wet density values of 2.26-2.43 g/cm^3, pH values of 8.65-9.85. These values indicate that, except for grain size, diatomites particularly at K2 section are similar to those of other commercial diatomites in the world. Diatomites in the K2 location can be used commercially if their grain size is minimized. It was found that analysis values of diatomites at both locations (K1 and K2) are consistent with those of various commercial diatomites in Turkey and that diatomites only in the K2 location could be used commercially if their grain size is minimized (Tables 5 and 6).

Based on results of analysis conducted on studied diatomites, their areas of use can be categorized as follows:

As filtration material: Due to its high porosity, resistance to chemical effects and purity, filtration is the most common area of use of diatomite (Köktürk, 1997). Diatomite increases rate and efficiency of filtration because of its porous structure and providing wide filtration surface and absorbing oil and some microorganisms. Diatomite is utilized for purification of liquids that contain suspended undesirable materials such as raw sugar syrup (glucose), beer, whisky, wine, fruit juice, metallic and vegetable oil, pharmacy products, polluted waters, dry cleaning solvents, industrial wastes, chemical materials and varnish. In order for diatomite to be used in filtration, it has to contain minimum 84% SiO_2 (Bozkurt, 1999). In percolators pure, elongate and coarse diatom species are desired (Uygun, 2001).

Diatomites in the study area are characteristic with their high porosity (porosity: 64.89–76.90%, pore volume: 2.865e-01cc/g – 8.124e-01cc/g; pore size: 3.125e-01–4.038e-01 Å), resistance to chemical effects (amount of acid-insoluble matter: 94.20%, amount of water-insoluble matter: 98.85%), purity (with their white color and whiteness values of 63.94-82.29%), SiO_2 values up to 88.9% (particularly samples from K2 section) and pure, elongate and coarse diatom species (especially *Epithemia* species) and therefore, they are suitable to be used in percolators (Tables 3, 4, 5, 7) (Figure 6). For wine filtering process, diatomites with pink color, grain size of 2.5 µ, wet density of 2.3 g/cm^3 and pH value of 7.0 are used while for sugar filtering process, diatomites with white color, grain size of 22 µ, wet density of 2.0 g/cm^3 and pH value of 10 are utilized (Açıkalın, 1991) (Table 7). In addition, sugars that are processed at sugar plants in Turkey are in white color and have the following compositions: 87.3% SiO_2, 1.95% Fe_2O_3, 3.23% Al_2O_3, 1.09% CaO, 0.45% MgO, 0.47% Na_2O and 0.44% K_2O with loss on ignition of 4.43% (at 850 °C) and pH of 4.49-10 (Bentli, 2001) (Table 7). Diatomite samples from K2 section with their white color, grain size of 15-20 µ, wet density of 2.26–2.30 g/cm^3, pH value of 9.85 – 9.0 and composition of 84.2-88.9% SiO_2, 1.1-3.3% Fe_2O_3, 0.7-3.8% Al_2O_3, 1.1-1.6% CaO, 0.3-0.8% MgO, 0.1-0.6% and Na_2O, <0.1-0.3% K_2O are similar to diatomites used in sugar filtering process but differ from these diatomites with their loss on ignition (at 1050°C) which ranges from to 6.10 to 6.20% (Tables 3,5,6,7).

As fill material: Diatomite is used for production of paper, plastic, match, paint, pesticides, polish, toothpaste, cleaning supplies, some chemical materials and improving and increasing the performance of products of drug and cosmetic industries. For diatomites to be used as fill material purity, fine grained texture, high porosity, lightness, and resistence to chemicals, ability to insulate sound and heat and high absorptance and minimum 80% SiO_2 are required. In paint sector, diatomite with grain size of 200–300 µ is added to paint in an amount of 2–3%. Moreover, it is shown in table 7 that diatomites used in paper industry are required to have wet density of 2.4 g/cm^3, pH value of 7.0 and gray color while those used in paint industry are required to have an average grain size of 6.8 µ, wet density of 2.2 g/cm^3, pH value of 10 and white color and finally diatomites used in plastic industry are required to have an average grain size of 5.1 µ, wet density of 2.8 g/cm^3, pH value of 7.0 and pink color (Diatomite Inventory of Turkey, 1968; Bentli, 2001; Açıkalın, 1991; DPT, 2001; Uygun, 2001). Diatomites in the study area, particularly samples from K2 section, are represented by high whiteness character (63,94–82,29%), grain size of 15-20 µ, high porosity (porosity: 64.89–76.90%, pore volume: 2.865e-01 cc/g – 8.124e-01 cc/g, pore size: 3.125e-01 – 4. 038e-01 Å) and low density (2.26–2.43 g/cm^3), high resistance to chemicals (amount of acid-insoluble matter: 94.20%, amount of water-insoluble matter: 98.85%), high ability to insulate heat (thermal conductivity values at ±10 ˚C are between 0.452 and 0.984 W/mK, 101; thermal conductivity values at 150 °C are 0.134-0.225 W/mK), high absorptance character (since samples are easily fall apart in water, their absorptance property could not be determined experimentally. However, their high porosity and low density may be indicative of their high absorptance character) and high SiO_2 contents (84.2-88.9%) and therefore, they may be used as fill material (Tables 2, 3, 5, 6, 7). Results of analyses of the studied diatomites indicate that particularly those from K2 section may be suitable to be used in paint industry if coarse grains within them are removed (Table 7).

As construction material: In the construction industry diatomite is used as admixture for cement, mortar and bentonite-bearing light bricks. It is shown that 3% diatomite addition to concrete increases compressive strength 20% and tensile strength 10%. In this industry low-quality diatomites may also be utilized (MTA, 1968; DPT, 2001; Uygun, 2001). Diatomites in the study area can be used as construction material if required. In addition, diatomite is used as mineral admixture in Portland-cement concretes if $SiO_2+Al_2O_3+Fe_2O_3$ total is at least 70% and loss on ignition is maximum 10% (Aruntaş et al., 1998). $SiO_2+Al_2O_3+Fe_2O_3$ total of studied diatomites 70.1-105% and loss on ignition (at 1050 °C) is 6.10-7.65% and therefore diatomites at both locations may be used as mineral admixture in Portland-cement concretes (Tables 5-7).

As carrier: Diatomite may also be utilized to carry nitrogen-bearing fertilizers. Under dry climate conditions, diatomite can absorb even little amount of moisture in the air thus providing fertilizer is easily blended with the soil. In addition, grinded diatomite may be directly used as fertilizer in silica-deficient soils (MTA 1968; DPT, 2001; Uygun, 2001). Diatomites which are preferred as regulator in fertilizer industry 1.7 g/cm^3 wet density and pH of 7.0 are required. Because studied diatomites have wet densities of 2.26-2.43 g/cm^3 and pH values between 8.65 and 9.85, they are not suitable to be used as carrier (Tables 5-7).

In silicate production: Diatomite is utilized in production of ceramic, glazer and ultramarine and various glass materials (MTA 1968; DPT, 2001; Uygun, 2001). Diatomites in the study area, particularly those in the area of K2 section, have high SiO_2 contents (84.2–88.9%) and therefore can be used for silicate production (Tables 5-7).

As mild abrasive and cleaner: Diatomite is used as mild abrasive and cleaner in laundry detergent, stain absorber and automobile polisher (MTA, 1968; DPT, 2001; Uygun, 2001). Diatomites used as abrasive in automobile polishers are white colored and have an average grain size of 5.5 μ, wet density of 2.4 g/cm^3 and pH value of 9.4 (Açıkalın, 1991). Because diatomites in the study area are white colored and represented by wet density of 2.26-2.43 g/cm^3 and pH values of 8.65-9.85, they are suitable to be used as mild abrasive and cleaner. However regarding grain size they are not suitable and therefore grain size is required to be minimized (Tables 3, 5-7).

As isolation material: Due to its high porosity, diatomites are good insulators for heat and sound. They are used in walls and flooring by injecting asbestos-mixed plates into lime or cement. Diatomite coating in vapor and gas pipes and diatomite bricks in outer wall of blast furnace prevent heat loss. In addition, it is also used for production of firebrick as isolation material (Uygun, 2001). In order for diatomite to be used as isolation material it should contain minimum 94% SiO_2 (Bentli, 2001).

Considering low thermal conductivity values (thermal conductivity values at ±10 °C are 0.452-0.984 W/mK, 101; thermal conductivity values at 150ºC are 0.134-0.225 W/mK), high porosity values (porosity: 64.89–76.90%, pore volume: 2.865e-01–8.124e-01 cc/g, pore size: 3.125e-01–4.038e-01 Å) and low density values (2.26–2.43 g/cm^3), diatomites in the study area can be used as isolation material. However, diatomites at both locations with SiO_2 contents of 68.3-88.9% are needed to be enriched to be used for isolation (Tables 2-5).

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