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THE CATION EXCHANGE CAPACITY OF THE GREEK ZEOLITIC ROCKS

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Abstract

Forty two zeolitic rock samples, from the Prefectures of Evros, Rhodope, Samos and Cyclades, have been investigated for their cation exchange capacity (CEC, in meq/100g) and the mineralogical composition (wt.%), using the Ammonium Acetate Saturation method and Powder X-ray Diffraction method, respectively. HEU-type zeolite (heulandite-clinoptilolite) was found in Petrota area (43-89 wt.%, CEC 101-217), Samos island (34-91 wt.%, CEC 93-217), Pentalofos area (68-74 wt.%, CEC 124-202), Metaxades area (47-64 wt.%, CEC 119-140) and Thira island (33 wt.%, CEC 118). Mordenite was found in Samos island (64 wt.%, CEC 150), Polyegos island (61 wt.%, CEC 136), Thira island (56 wt.%, CEC 130), Milos island (45 wt.%, CEC 97), Kimolos island (30 wt.%, CEC 96) and Feres area (5 wt.%, CEC 22). Analcime was found in Samos island (27-71 wt.%, CEC 104-285) and Darmeni area (16 wt.%, CEC 62). Chabazite was found in Samos island (66 wt.%, CEC 243). HEU-type zeolite+mordenite were found in Feres area (45-74 wt.%, CEC 132-209), Samos island (81 wt.%, CEC 184), Thira island (72 wt.%, CEC 177), Polyegos island (66 wt.%, CEC 153) and Skaloma area (51-60 wt.%, CEC 126-143). HEU-type zeolite+phillipsite were found in Samos island (47 wt.%, CEC 170) and HEU-type zeolite+analcime were found in Samos island (55 wt.%, CEC 129). The CEC of the zeolitic rocks show positive correlations with the type of zeolite and the microporous minerals (zeolites+micas+clay minerals) content, mainly affected by the zeolites and to lesser extent by micas and clay minerals.

Key words: *Natural zeolites, Evros, Rhodope, Samos, Cyclades, tuffs.*

Περίληψη

Σαράντα δύο δείγματα ζεολιθοφόρων πετρωμάτων από περιοχές των Νομών Έβρου, Ροδόπης, Σάμου και Κυκλάδων μελετήθηκαν ως προς την ιοντοανταλλακτική τους ικανότητα (ΙΑΙ, meq/100g) και την ορυκτολογική τους σύσταση (% κ.β.) με τις μεθόδους του κορεσμού σε οξικό αμμώνιο και της περιθλασιμετρίας ακτίνων-Χ, αντίστοιχα. Ζεόλιθος τύπου-HEU (ευλανδίτης-κλινοπτιλόλιθος) βρέθηκε σε περιοχές των Πετρωτών (43-89 % κ.β., ΙΑΙ 101-217), της Σάμου (34-91 % κ.β., ΙΑΙ 93-217), του Πενταλόφου (68-74 % κ.β., ΙΑΙ 124-202), των Μεταξάδων (47-64 % κ.β., ΙΑΙ 119-140) και στη Σαντορίνη (33 % κ.β., ΙΑΙ 118). Μορντενίτης βρέθηκε στη Σάμο (64

% κ.β., IAI 150), στην Πολύαιγο (61 % κ.β., IAI 136), στη Σαντορίνη (56 % κ.β., IAI 130), στη Μήλο (45 % κ.β., IAI 97), στην Κίμωλο (30 % κ.β., IAI 96) και στις Φέρες (5 % κ.β., IAI 22). Ανάλκιμος βρέθηκε σε περιοχές της Σάμου (27-71 % κ.β., IAI 104-285) και στη Δαρμένη (16 % κ.β., IAI 62). Χαμπαζίτης βρέθηκε στη Σάμο (66 % κ.β., IAI 243). Ζεόλιθος τύπου-HEU+μορντενίτης βρέθηκαν σε περιοχές των Φερών (45-74 % κ.β., IAI 132-209), στη Σάμο (81 % κ.β., IAI 184), στη Σαντορίνη (72 % κ.β., IAI 177), στην Πολύαιγο (66 % κ.β., IAI 153) και στο Σκάλωμα (51-60 % κ.β., IAI 126-143). Ζεόλιθος τύπου-HEU+Φιλλιψίτης βρέθηκε στη Σάμο (47 % κ.β., IAI 170) και ζεόλιθος τύπου-HEU+ανάλκιμος βρέθηκε στη Σάμο (55 % κ.β., IAI 129). Η ιοντοανταλλακτική ικανότητα εμφανίζει θετική συσχέτιση με τον τύπο του περιεχόμενου ζεόλιθου, αλλά και τις περιεκτικότητες του συνόλου των μικροπορωδών ορυκτών (ζεόλιθοι+μαρμαρυγίες+αργιλικά ορυκτά), επηρεαζόμενη κυρίως από το ποσοστό των ζεόλιθων και σε μικρότερο βαθμό από αυτό των μαρμαρυγιών και των αργιλικών ορυκτών.

Λέξεις κλειδιά: *Φυσικοί ζεόλιθοι, Έβρος, Ροδόπη, Σάμος, Κυκλάδες, Τόφφοι.*

1. Introduction

Zeolite occurrences are widespread in Greece and HEU-type zeolites (Heulandite-Clinoptilolite) are the most common types (Kantiranis *et al.* 2006). Numerous industrial, agricultural and environmental applications have been proposed for the zeolitic rocks of Greece (eg., Kitsopoulos and Dunham 1994, 1996, Misaelides *et al.* 1994, 1995a, 1995b, Symeopoulos *et al.* 1996, Filippidis *et al.* 1997, 2006, Fragoulis *et al.* 1997, Haiduti 1997, Tserveni-Gousi *et al.* 1997, Sikalidis 1998, Yannakopoulos *et al.* 1998, 2000, Filippidis and Kassoli-Fournaraki 2000a, 2000b, 2002, Zorpas *et al.*, 2000a, 2000b, Marantos *et al.* 2001, Moirou *et al.* 2001, Vlessidis *et al.* 2001, Kyriakis *et al.* 2002, Papaioannou *et al.* 2002a, 2002b, Inglezakis and Grigoropoulou 2003, Inglezakis *et al.* 2003, Katranas *et al.* 2003, Krestou *et al.* 2003, Perraki *et al.* 2003, Papadopoulos *et al.* 2004, Deligiannis *et al.* 2005, Warchol *et al.* 2006). The cation exchange capacity of zeolitic rocks from Pentalofos area (Arvanitidis 1998, Stamatakis *et al.* 2001, Christidis *et al.* 2003, Perraki and Orfanoudaki 2004), Metaxades area (Marantos *et al.* 1989; Stamatakis *et al.* 2001), Dadia-Lefkimi area (Skarpelis *et al.* 1993), Feres area (Stamatakis *et al.* 2001), Polyegos and Thira islands (Kitsopoulos 1997b) has been reported, but without quantitative values for the zeolite or the microporous mineral percentage contained in the rocks.

In the present paper the cation exchange capacity is correlated to the zeolite percentage and type, contained in the Greek zeolitic rocks. In particular, 42 zeolitic samples have been collected from different locations in the Prefectures of Evros, Rhodope, Samos and Cyclades. Twenty five related values given by different authors (Marantos and Perdikatsis 1994, Marantos 2004, Kantiranis *et al.* 2004a, Filippidis, 2005, Filippidis and Kantiranis 2005, 2007, Filippidis *et al.* 2005) have been also used for the above mentioned correlations.

2. Materials and Methods

The geology, geochemistry, mineralogy and genesis of the Greek zeolitic rocks are presented and discussed by several authors, for Evros Prefecture (eg., Tsirambides *et al.*, 1989, 1993, Kirov *et al.* 1990, Tsolis-Katagas and Katagas 1990, Tsirambides 1991, Filippidis 1993, Koutles *et al.* 1995, Stamatakis *et al.* 1998, Hall *et al.* 2000, Kassoli-Fournaraki *et al.* 2000, Barbieri *et al.* 2001), for Rhodope Prefecture (Marantos *et al.* 1997, 2001), for Samos Prefecture (Stamatakis 1989a, 1989b, Pe-Piper and Tsolis-Katagas 1991, Hall and Stamatakis 1992) and for Cyclades Prefecture (Tsolis-Katagas and Katagas 1989, Hall *et al.* 1994, Stamatakis *et al.* 1996, Fragoulis *et al.* 1997, Kitsopoulos 1997a, Drakoulis *et al.* 2005).

The approximate location of the studied zeolitic samples are shown in Figure 1, while the precise location are given in Tables 1, 2, 3 and 4.

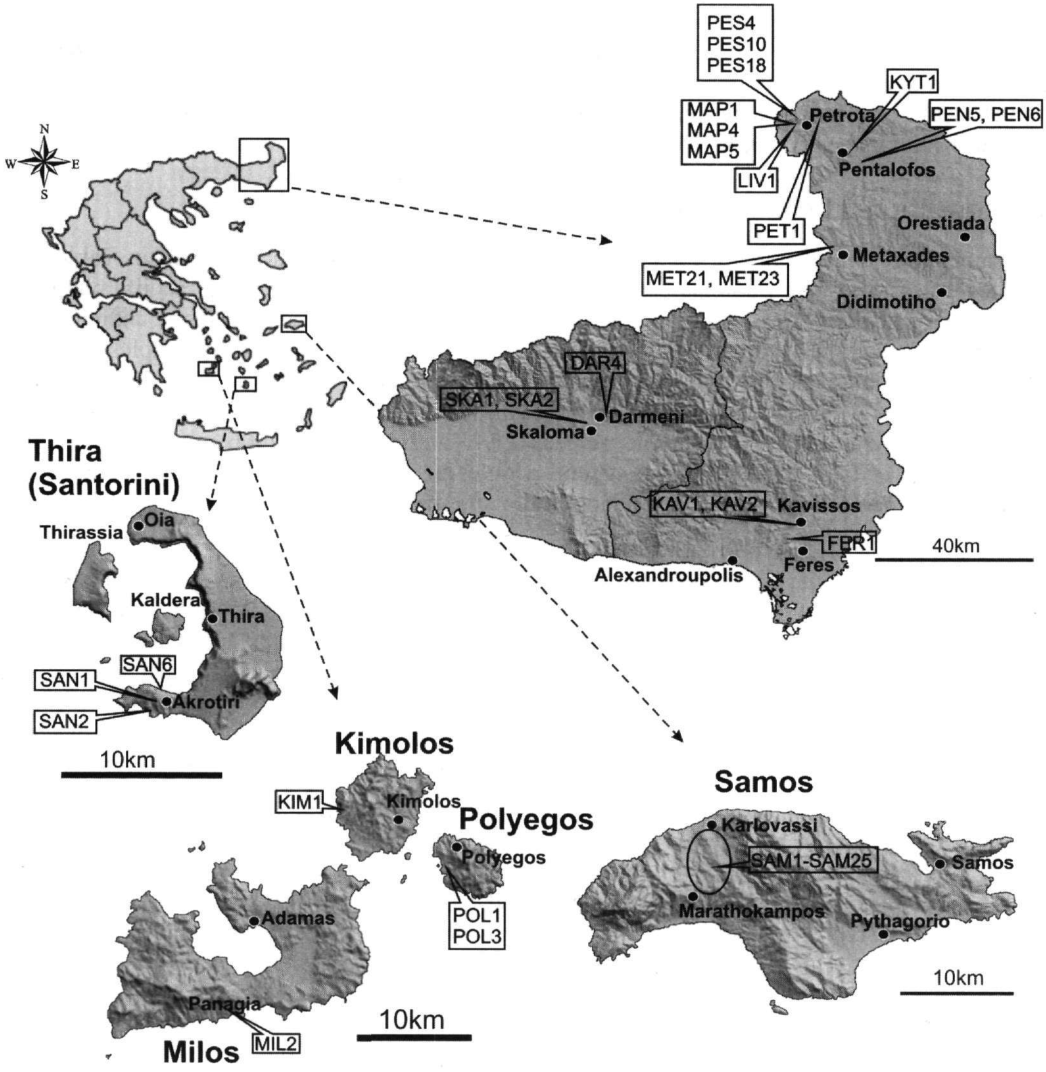

Figure 1 - Location of the studied Greek zeolitic rock samples

Each representative sample of the collected zeolitic tuffs was separated in two equal parts: the first, ground in grain-size <63 μm, was used for the investigation of the mineralogical composition, while the second, ground in grain-size <125 μm, was used in the experiments for the determination of their ammonium exchange capacity.

Mineralogical composition was determined using the X-Ray Powder Diffraction method (XRPD). XRPD was performed using a Philips PW 1710 diffractometer with Ni-filtered CuKα radiation. The samples were scanned over the 3-63° 2θ at a scanning speed of 1.2 °/min. Semi-quantitative estimates of the abundance of the mineral phases were derived from the XRPD data, using the intensity of certain reflections, the density and the mass absorption coefficient for CuKα radiation for the minerals present. Then results were corrected using standard mixtures of minerals (external standards) scanned under the same conditions. The semi-quantitative estimation of the percentage of total amorphous material was achieved by comparing the area of each broad background hump which represented the amorphous material in each sample with the analogous area of standard mixtures of minerals with different contents of natural amorphous material, scanned under the same conditions (Kantiranis *et al.* 2004b, Drakoulis *et al.* 2005).

The ammonium ion is most commonly used for CEC testing of materials and the results therefore are referred to as ammonium exchange capacity. The ammonium cation-exchange capacity of the studied zeolitic tuffs was determined according to the Ammonium Acetate Saturation (AMAS) method (Kantiranis *et al.* 2004a, Drakoulis *et al.* 2005).

3. Results and Discussion

The mineralogical composition of the studied zeolitic rock samples is presented in Tables 1-4. Zeolites, micas and clay minerals constitute the microporous minerals of the zeoliferous rocks. Five types of zeolites were identified: HEU-type, mordenite, analcime, phillipsite and chabazite. HEU-type (Heulandite-Clinoptilolite) was found in the majority of the studied samples (22 out of 42), while mordenite and analcime were found in fewer samples (6 and 4 out of 42, respectively). HEU-type+mordenite were found in 7 samples, while HEU-type+analcime, HEU-type+ phillipsite and chabazite were found in one sample, respectively. Kantiranis *et al.* (2006) studying the thermal characteristics of the Greek HEU-type natural zeolites in relation to their chemical composition, distinguished their HEU-type species (clinoptilolite, intermediate heulandite and heulandite).

The percentage in HEU-type zeolites varies widely between 18 wt.% and 91 wt.%, whereas the percentage of mordenite varies between 5 wt.% and 64 wt.%. Analcime varies between 16 wt.% and 71 wt.%. Phillipsite and chabazite were determined in percentages 29 wt.% and 66 wt.% , respectively. In addition, micas, clays, quartz, cristobalite, tridymite, feldspars, calcite and amphibole were also identified. Also, amorphous material was detected in 14 samples, ranging between 2 wt.% and 24 wt.%. Several researchers in their individual sampling of zeoliferous rocks from near-about the same locations and after a plethora of experimental techniques rendered similar or approximate or different results concerning the mineralogical composition and the CEC of the zeolitic rocks (Tables 1-4).

The CEC of the zeolitic rocks mainly depends on the type and content of the zeolite, as the most typical microporous minerals. A very good positive correlation is observed between CEC and the HEU-type zeolite content (Fig. 2). The same good correlation exists between the CEC and the mordenite, HEU-type + mordenite and analcime contents (Figs 3-5). A general positive correlation exists between CEC and the total zeolite content (Fig. 6). The differences in the CEC values observed in the different zeolitic rocks, depends mainly on their content but also on the type of zeolite. The ion exchange capacity is a function of the specific crystal structure of each zeolite species, and its framework and cationic composition. It should be noted, that the typical ion exchange capacity, calculated from the unit-cell formula for pure minerals, is higher: 454 meq/100g for analcime, 387 meq/100g for phillipsite, 381 meq/100g for chabazite, 291 meq/100g for heulandite, 254 meq/100g for clinoptilolite and 229 meq/100g for mordenite (Holmes 1994).

The CEC values are also affected to a lesser extent, by the other microporous minerals (micas + clays) contained in the zeolitic rocks. A positive correlation between the CEC and the total microporous minerals (zeolites + micas + clay minerals) is also observed (Fig. 7). The same is also observed between the CEC and total microporous minerals + amorphous material (Fig. 8), since amorphous material includes anionic charges that are responsible for the sorption ability of amorphous materials. It should be noted that the amorphous content ranges from 2 to 29 wt.% (Tables 1-4) and that the sorption ability of natural amorphous materials depends on their chemistry (Drakoulis *et al.* 2005).

Table 1 - Semi-quantitative mineralogical composition (wt.%) and cation exchange capacity (CEC, meq/100g) of Evros Prefecture zeolitic rocks.

Location	Sample	Microporous minerals					TMM	A	TMM + A	Non-microporous miner.					TNM	CEC	Ref
		H-C	Mo	ZT	Mi	Cl				Qz	Cr	Fs	Cc	AG			
From Petrota village									**PETROTA AREA**								
2.3 km W42N Paleochorafa	PES10	86	-	86	-	3	89	-	89	-	-	11	-	-	11	193	PP
	PES18	73	-	73	-	11	84	-	84	5	-	11	-	-	16	167	PP
	PES4	65	-	65	2	3	70	-	70	12	-	16	-	2	30	141	PP
3.2 km W4N Mavri Petra	MAP1	89	-	89	2	3	94	-	94	2	2	2	-	-	6	217	PP
	MAP5	81	-	81	3	3	87	-	87	2	2	7	-	2	13	181	PP
	MAP4	80	-	80	5	-	85	-	85	5	2	8	-	-	15	161	PP
1.5 km E8S Petrota location	PET1	63	-	63	-	3	66	-	66	7	-	27	-	-	34	132	PP
3.1 km W15S Livadakia	LIV1	43	-	43	11	7	61	-	61	14	-	23	-	2	39	101	PP
1.8 km N42W Paleochorafa-Kalamos		89	-	89	3		92	-	92	2	-	6	-	-	8	229	1
1.9 km W36N Paleochorafa		89	-	89	3		92	-	92	2	-	6	-	-	8	226	2
Not specified Petrota area		51	-	51	1	-	52	14	66	1	14	19	-	-	34	93	3
		27	-	27	5	-	32	5	37	9	8	42	-	4	63	63	3
From Pentalofos village									**PENTALOFOS AREA**								
1.5 km E31N Kyries Toumbes	KYT1*	74	-	74	10	4	88	7	95	-	-	5	-	-	5	202	PP
2.6 km E28S Tymbano	PEN6*	70	-	70	7	9	86	-	86	-	-	14	-	-	14	176	PP
	PEN5	68	-	68	11	7	86	-	86	4	2	8	-	-	14	124	PP
Not specified Pentalofos area		48	-	48	2	-	50	7	57	2	14	27	-	-	43	93	3
		32	-	32	5	-	37	2	39	10	10	41	-	-	61	79	3
1.3 km E30N Kyries Toumbes		77	-	77	8	5	90	6	96	-	-	4	-	-	4	208	4
2.8 km E27S Tymbano		73	-	73	6	6	85	-	85	-	-	15	-	-	15	184	4
From Metaxades village									**METAXADES AREA**								
2.7 km N41W Xerovouni	MET23*	64	-	64	9	7	80	-	80	5	5	10	-	-	20	140	PP
2 km N36W Gourounorema	MET21*	47	-	47	4	5	56	-	56	26	-	13	5	-	44	119	PP
2.6 km N45W Xerovouni		75	-	75	8	10	93	-	93	2	3	2	-	-	7	205	4
From Dadia village									**DADIA-LEFKIMI AREA**								
10.5 km S36W Synoro		53	-	53	2	2	57	-	57	-	36	7	-	-	43	135	4
15.4 km S12W Xephoto		51	-	51	2	3	56	-	56	-	39	5	-	-	44	130	4
From Feres village									**FERES AREA**								
3.4 km N9W Kavissos village	KAV1	48	26	74	2	12	88	-	88	10	-	2	-	-	12	209	PP
	KAV2	26	19	45	2	8	55	14	69	31	-	-	-	-	31	132	PP
2.9 km N38W Aspra Chomata	FER1	-	5	5	3	10	18	-	18	35	-	47	-	-	82	22	PP
3.4 km N9W Kavissos village		32	22	54	2	7	63	12	75	20	-	5	-	-	25	147	4
~6.2 km ~N23W Lakka		67	8	75	-	1	76	-	76	7	-	17	-	-	24	141	5
~4.6 km ~N13E Makrylofos		36	11	47	-	3	50	-	50	26	1	23	-	-	50	89	5
		27	8	35	-	9	44	26	70	15	-	15	-	-	30	70	5
~4.4 km ~W25N Kapsala		16	24	40	-	-	40	-	40	25	1	34	-	-	60	134	5
		23	12	35	-	-	35	29	64	20	-	16	-	-	36	112	5
~ 13.8 km ~W4N Aetochori		19	3	22	-	14	36	-	36	19	-	45	-	-	64	69	5

*: Industrial (> 500kg) samples, H-C: Heulandite-Clinoptilolite, Mo: Mordenite, ZT: Zeolite total, Mi: Micas, Cl: Clays, TMM: Total Microporous Minerals, A: Amorphous, Qz: Quartz, Cr: Cristobalite, Fs: Feldspars, Cc: Calcite, AG: Amphibole group, TNM: Total Non-Microporous minerals, PP: Present Paper, 1: Filippidis and Kantiranis (2007), 2: Filippidis (2005), 3: Marantos and Perdikatsis (1994), 4: Filippidis and Kantiranis (2005), 5: Marantos (2004)

Table 2 - Semi-quantitative mineralogical composition (wt.%) and cation exchange capacity (CEC, meq/100g) of Rhodope Prefecture zeolitic rocks.

Location	Sample	Microporous minerals						TMM	A	TMM + A	Non-microporous			TNM	CEC	Ref
		H-C	Mo	An	ZT	Mi	Cl				Qz	Cr	Fs			
From Skaloma village								**SKALOMA AREA**								
0.6 km N20W Avraam	SKA1	31	20	-	51	-	17	68	-	68	16	8	8	32	126	PP
	SKA2	23	37	-	60	-	2	62	16	78	7	-	15	22	143	PP
0.8 km N20W Avraam		27	33	-	60	-	2	62	16	78	7	-	15	22	151	4
From Darmeni village								**DARMENI AREA**								
0.8 km E25N Voukefalo	DAR4	-	-	16	16	-	3	19	14	33	54	-	13	67	62	PP
0.6 km E25N Voukefalo		-	-	18	18	-	5	23	15	38	49	-	13	62	98	4

H-C: Heulandite-Clinoptilolite, Mo: Mordenite, An: Analcime, ZT: Zeolite total, Mi: Micas, Cl: Clays, TMM: Total Microporous Minerals, A: Amorphous, Qz: Quartz, Cr: Cristobalite, Fs: Feldspars, TNM: Total Non-Microporous minerals, PP: Present Paper, 4: Filippidis and Kantiranis (2005)

Table 3 - Semi-quantitative mineralogical composition (wt.%) and cation exchange capacity (CEC, meq/100g) of Samos Prefecture zeolitic rocks.

Location	Sample	Microporous minerals								TMM	A	TMM + A	Non-microporous		TNM	CEC	Ref
		H-C	Mo	An	Ph	Ch	ZT	Mi	Cl				Qz	Fs			
From Marathokambos village										**KARLOVASSI - MARATHOKAMBOS AREA**							
5.3 km N25E	SAM22	91	-	-	-	-	91	4	-	95	-	95	-	5	5	213	PP
3.6 km E34N	SAM17	86	-	-	-	-	86	4	4	94	-	94	-	6	6	217	PP
2.1 km E32N	SAM21	73	-	-	-	-	73	12	4	89	-	89	4	7	11	187	PP
3.5 km E29N	SAM23	65	-	-	-	-	65	10	6	81	-	81	-	19	19	159	PP
2.9 km N2E	SAM24	57	-	-	-	-	57	14	6	77	-	77	-	23	23	143	PP
4.6 km E36N	SAM18	55	-	-	-	-	55	6	21	82	-	82	-	18	18	135	PP
4.6 km E38N	SAM19	34	-	-	-	-	34	24	4	62	8	70	-	30	30	112	PP
5.3 km N20E	SAM7	34	-	-	-	-	34	10	27	71	9	80	4	16	20	93	PP
2.0 km N45E	SAM1	60	21	-	-	-	81	4	9	94	-	94	3	3	6	184	PP
4.5 km E	SAM15	-	64	-	-	-	64	-	-	64	24	88	-	12	12	150	PP
6.6 km N15E	SAM4	-	-	71	-	-	71	5	2	78	10	88	4	8	12	285	PP
5.0 km N21E	SAM14	-	-	35	-	-	35	3	33	71	-	71	-	29	29	169	PP
5.3 km N20E	SAM6	-	-	27	-	-	27	10	27	64	7	71	5	24	29	104	PP
1.8 km E36N	SAM16	23	-	32	-	-	55	8	16	79	-	79	-	21	21	129	PP
5.7 km N29E	SAM20	18	-	-	29	-	47	2	44	93	-	93	-	7	7	170	PP
3.3 km N22E	SAM25	-	-	-	-	66	66	-	28	94	-	94	2	4	6	243	PP
2.1 km E32N		74	-	-	-	-	74	13	2	89	-	89	6	5	11	184	6
3.5 km E29N		57	-	-	-	-	57	10	2	69	-	69	3	28	31	149	6
4.6 km E36N		48	-	-	-	-	48	4	13	65	-	65	11	24	35	137	6
2.9 km N2E		47	-	-	-	-	47	12	3	62	-	62	3	35	38	133	6
6.4 km N14E		-	-	72	-	-	72	7	3	82	-	82	6	12	18	334	7

H-C: Heulandite-Clinoptilolite, Mo: Mordenite, An: Analcime, Ph: Phillipsite, Ch: Chabazite, ZT: Zeolite total, Mi: Micas, Cl: Clays, TMM: Total Microporous Minerals, A: Amorphous, Qz: Quartz, Fs: Feldspars, TNM: Total Non-Microporous minerals, PP: Present Paper, 6: Kantiranis et al. (2004a), 7: Filippidis et al. (2005).

Table 4 - Semi-quantitative mineralogical composition (wt.%) and cation exchange capacity (CEC, meq/100g) of Cyclades Prefecture zeolitic rocks.

Location	Sample	Microporous minerals					TMM	A	TMM + A	Non-microporous miner.				TNM	CEC	Ref
		H-C	Mo	ZT	Mi	Cl				Qz	Tr	Fs	AG			
From Kimolos village									**KIMOLOS ISLAND**							
4.0 km W5N	KIM1	-	30	30	15	-	45	-	45	-	-	55	-	55	96	PP
From Polyegos village									**POLYEGOS ISLAND**							
1.9 km S9W	POL1	22	44	66	-	5	71	-	71	5	-	24	-	29	153	PP
1.7 km S5W	POL3	-	61	61	-	-	61	22	83	5	6	6	-	17	136	PP
From Adamas village									**MILOS ISLAND**							
6.9 km S15W Panagia	MIL2	-	45	45	-	7	52	12	64	36	-		-	36	97	PP
From Akrotiri village									**THIRA (SANTORINI) ISLAND**							
0.8 km W	SAN1	33	-	33	-	14	47	4	51	-	-	42	7	49	118	PP
1.0 km W26S	SAN2	57	15	72	-	14	86	2	88	-	-	8	4	12	177	PP
0.8 km N34W	SAN6	-	56	56	-	4	60	11	71	5	-	13	11	29	130	PP

H-C: Heulandite-Clinoptilolite, Mo: Mordenite, ZT: Zeolite total, Mi: Micas, Cl: Clays, TMM: Total Microporous Minerals, A: Amorphous, Qz: Quartz, Tr: Tridymite, Fs: Feldspars, AG: Amphibole group, TNM: Total Non-Microporous minerals, PP: Present Paper.

4. Conclusions

The majority of the Greek zeolitic rock samples contain HEU-type (heulandite-clinoptilolite) zeolite (22 out of 42), while mordenite and analcime were found in fewer samples (6 and 4, respectively). HEU-type + mordenite were found in 7 samples, HEU-type + analcime, HEU-type + phillipsite and chabazite were found in one sample, respectively. The highest contents of HEU-type zeolite (70-91 wt.%) were mainly found in the areas of Petrota and Pentalofos (Evros Prefecture) and Karlovassi basin (Samos island), while the highest values of analcime content (71 wt.%) were found in the Samos island. The highest content (24 wt.%) of amorphous material was found in the mordenitic rocks of Samos island.

The cation exchange capacity (CEC) of zeolitic rocks reaches values up to 285 meq/100g for analcime-rich (71 wt.%) tuffs of Samos island, up to 243 meq/100g for chabazite-rich (66 wt.%) tuffs of Samos island, 217 meq/100g for HEU-type rich tuffs of Petrota area (89 wt.%) and Samos island (86 wt.%), 209 meq/100g for HEU-type (48wt.%) + mordenite (26 wt.%) rich tuffs of Feres area, 170 meq/100g for HEU-type (18 wt.%) + Phillipsite (29 wt.%) rich tuffs of Samos island, 150 meq/100g for mordenite-rich (64 wt.%) tuffs of Samos island, and 129 meq/100g for HEU-type (23 wt.%) + analcime (32 wt.%) rich tuffs of Samos island.

The CEC of the zeolitic rocks show positive correlations with the type and the content of zeolites and the microporous minerals (zeolites + micas + clay minerals) + amorphous material. The CEC is mainly affected by the zeolites and to a lesser extent by the other micrporous minerals (micas + clay minerals). The amorphous material may affect the CEC values, depending on their chemistry and despite the lack of crystallinity, the chemical structure of the amorphous materials includes anionic charges, and thus may result to some sorption ability.

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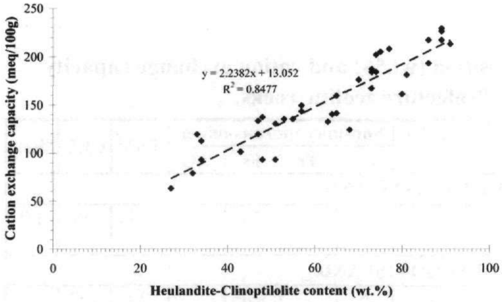

Figure 2 – CEC *vs* HEU-type zeolite content

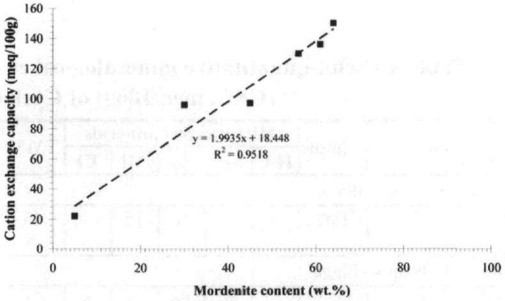

Figure 3 – CEC *vs* mordenite content

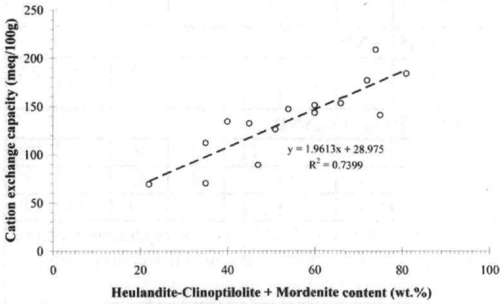

Figure 4 – CEC *vs* HEU-type + mordenite content

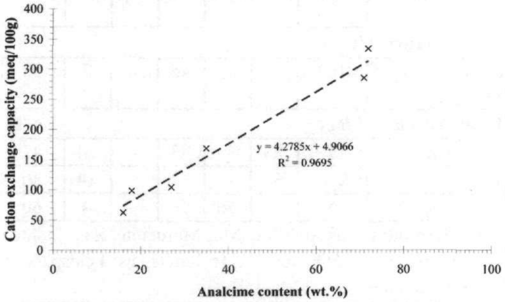

Figure 5 – CEC *vs* analcime content

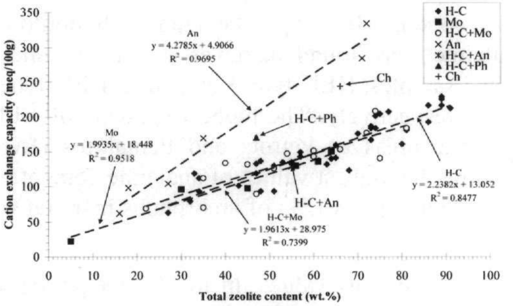

Figure 6 – CEC *vs* total zeolite content

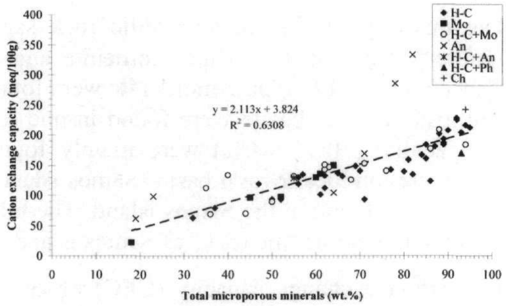

Figure 7 – CEC *vs* total micropor. minerals content (zeolites + micas + clay minerals)

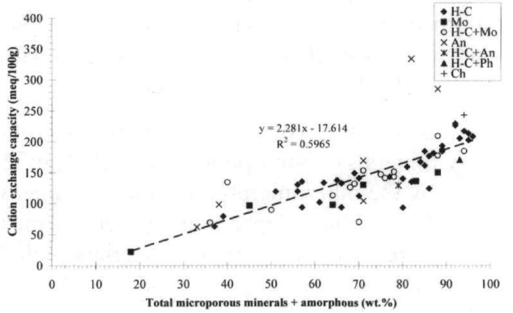

Figure 8 – CEC *vs* total microporous minerals content + amorphous material

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