QUANTITATIVE ESTIMATION OF MORDENITE AND CLINOPTILOLITE IN SEDIMENTARY ROCKS (II)*

KAZUO TORII, MASAMI HOTTA and MAKOTO ASAKA

Government Industrial Research Institute, Tohoku, Sendai 983, Japan

Data regarding amounts of gas adsorbed, cation exchange capacity values and X-ray reflection peak intensities of mordenite and clinoptilolite from sedimentary zeolite rocks were compared with those of zeolite-content by the X-ray diffraction division method in order to simply know the zeolite-content.

Amounts of nitrogen and carbon dioxide adsorbed on mordenite-tuffs are fairly directly proportional to mordenite-content values as are those of carbon dioxide on clinoptilolite-tuffs to clinoptilolite-content values. The content values of mordenite and clinoptilolite in the specimens which contain both the above zeolite minerals, were successfully obtained at a time by a combination method of carbon dioxide adsorption and X-ray diffraction.

Cation exchange capacity values of mordenite-tuffs appears to be directly proportional to mordenite-content values. However those of clinoptilolite-tuffs are inadequate to estimate clinoptilolite-content values.

The relationships between X-ray reflection peak intensities of zeolite minerals and zeolite-content values can be expressed with a quadratic equation (1).

$$I = a \cdot x^2 + b \cdot x \quad (1)$$

where I is the X-ray reflection peak intensity, x is the zeolite-content value and, a and b are constants. The content values of mordenite and clinoptilolite in the specimens which contain both the above zeolite minerals, were easily calculated by the equation (1) using (202) plane for mordenite and (035) plane for clinoptilolite.

INTRODUCTION

Quantitative estimation of mordenite and clinoptilolite by the X-ray diffraction division method has been proposed by Torii, Hotta and Asaka (1979). The zeolite-content values of 57 specimens from Japan, U.S.A., Korea, New Zealand and South Africa by the above method were compared with the data of gas adsorption, cation exchange capacity (C.E.C.) and X-ray reflection peak intensity of zeolites. Simple estimation method of mordenite and clinoptilolite for gas adsorption method, C.E.C. method and X-ray reflection peak intensity method are discussed in this paper.

EXPERIMENTAL

Samples studied

The 57 samples studied, characterized by their numbers, and locations of occurrence, are: (1)–(19) Ōmori, Kamiyashi, Miyagi-chō, Miyagi pref., Japan; (20) Shirasawa, Miyagi-chō, Miyagi pref., Japan; (21) Oga, Akita pref., Japan; (22) Minase, Akita pref., Japan; (23)–(24) Itado, Akita pref., Japan; (25) Tenei, Fukushima pref., Japan; (26) Amagōchi, Nima, Shimane pref., Japan; (27) Arita, Saga pref., Japan; (28) Kampo, Kyongsangpuk Do, Korea; (29) Lovelock, Nevada, U.S.A.; (30) Whangape Habaun, Northland, New Zealand; (31) South Africa;

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(32)–(33), Naruui, Miyagi-chō, Miyagi pref., Japan; (34)–(35) Kawarago, Shiroishi, Miyagi pref., Japan; (36) Itaya, Yonezawa, Yamagata pref., Japan; (37) Tamayu, Shimane pref., Japan; (38) Iwami, Shimane pref., Japan; (39) Shizuma, Ōda, Shimane pref., Japan; (40) Tateyamazaki, Akita pref., Japan; (41) Yoichi, Hokkaidō, Japan; (42)–(43) Oshamanbe, Hokkaidō, Japan; (44) Haboro, Hokkaidō, Japan; (45) Sawaguchi, Ōe, Yamagata pref., Japan; (46)–(49) Futatsui, Akita pref., Japan; (50) Fukuroda, Ibaragi pref., Japan; (51) East Gate, Nevada, U.S.A.; (52) Jersey Valley, Nevada, U.S.A.; (53) Beaver Rim, Wyoming, U.S.A.; (54) Idaho, U.S.A.; (55) North Cape, New Zealand. The specimen (56) has been sold by the Anaconda Company. The specimen (57), Kunipia-F, is highly purified sodium montmorillonite from Kunimine Kōgyō Co., Ltd., and was used for reference.

X-ray diffraction process

(1) Estimation of zeolite by X-ray diffraction method

Content values of mordenite and clinoptilolite in sedimentary zeolite rocks were obtained by the X-ray diffraction division method reported by Torii, Hotta and Asaka (1979). This method consists of three different X-ray diffraction method in order to analyze the mineral composition of sedimentary zeolite rocks. Content values of mordenite, clinoptilolite, α -quartz, α -cristobalite, feldspar and mica were obtained by the so-called standard binary mixtures method. Content values of montmorillonite was estimated directly comparing the X-ray intensity of specimen with that of standard mineral. Content value of amorphous material was analyzed independently by the background intensity method.

(2) Measurements of peak intensities of zeolite minerals

Copper K α radiation (Ni-filtered) at 30 kV and 15 mA was used with 1°, 0.3 mm, 1° slits, 1°2 θ /min recording speed and 1 cm/min. chart speed. The peak intensities of mordenite (202) and clinoptilolite (132, 035) were measured to estimate the zeolite content.

Gas adsorption measurement

The powder samples, previously used in the X-ray diffraction process, were dehydrated at 400°C in the vacuum for 1 hour. After activation, equilibrium amounts adsorbed for nitrogen and carbon dioxide on the zeolite-bearing rocks at 25°C and 1 atm. were measured by the volumetric method.

C.E.C. measurement

The cation exchange capacities of zeolite-bearing rocks were obtained by the Shollenberger's method. About 200mg of specimen was fully saturated with NH $_4^+$ by treating with 100 ml of 1N-CH $_3$ COONH $_4$ solution for 4 hours. After washed with 80% C $_2$ H $_5$ OH solution, the exchanged NH $_4^+$ was extracted by treating with 100 ml of 10% KCl solution for 4 hours. The extracted NH $_4^+$ from the specimen was analyzed and regarded as C.E.C. value for the zeolite-bearing rock.

RESULT AND DISCUSSION

The values of zeolite-content, C.E.C. and equilibrium amounts adsorbed for the 56 specimens of sedimentary zeolite-bearing rocks from Japan, U.S.A., New Zealand, Korea and South Africa are shown in Table 1. Twenty-seven specimens contain mordenite only as zeolite, 14 specimens clinoptilolite only, and 15 specimens contain both zeolite minerals.

The values of zeolite-content by X-ray diffraction method were obtained by the X-ray diffraction division method. The

Table 1 Zeolite content, gas amounts adsorbed and cation exchange capacities for sedimentary zeolite-bearing rocks.

No	SPECIMENS	ZEOLITE-CONTENT (WT.%)				AMOUNT ADSORBED*		(ML/G)	C.E.C. (M.EQU.)
		X-RAY METHOD		CO ₂ METHOD		CO ₂ MEAS.	N ₂ CAL.**	MEAS.	
		MOR.	CLINO.	MOR.	CLINO.				
1	OMORI N-1	65.0	0	63.9		54.9		14.8	149
2	N-3	61.7	0	62.6		53.8		14.1	130
3	N-12	77.3	0	77.9		67.0		15.5	168
4	E-2	77.4	0	76.3		65.6		16.5	153
5	E-3	71.0	0	71.9		61.8		12.3	167
6	E-5	70.8	0	72.9		62.7		16.9	159
7	E-11	66.9	0	71.0		61.0		15.9	146
8	S-3	67.9	0	67.5		58.0		15.4	148
9	S-4	70.3	0	69.1		59.4			144
10	W-1	21.5	0	13.7		11.8		2.8	56
11	W-2	30.3	0	19.1		16.4		4.9	68
12	W-3	38.8	0	42.8		36.8		11.1	198
13	W-10	68.8	0	64.7		55.6		15.8	153
14	W-14	66.8	0	66.6		57.3		14.8	166
15	W-18	53.8	0	60.9		52.4		12.6	114
16	W-20	73.5	0	68.7		59.1		15.4	142
17	W-23	70.8	0	73.3		63.9		16.6	167
18	W-25	53.9	0	56.4		48.5		11.1	144
19	W-26	0	0	5.6		4.8		0	38
20	SHIRASAWA M	64.2	0	65.5		56.3			154
21	Oga	88.0	0	86.4		73.9		22.1	172
22	MINASE-15	61.7	0	62.0		53.3			
23	ITADO B-102***	82.0	0	82.0		70.5		18.9	161
24	B-3	65.6	6.8			65.3	61.6	15.6	160
25	TENEI	68.1	0	67.3		57.8		14.7	
26	AMAGUCHI	58.0	0	60.5		52.0		15.4	
27	ARITA	45.4	0	44.9		38.6			
28	KAMPO A	37.6	0	35.5		30.5			91
29	LOVELOCK	35.8	2.3			33.9	31.5	8.9	
30	WHANGAPE HABAUN	50.6	3.8			53.9	46.3	15.6	
31	SOUTH AFRICA	9.9	50.8			49.8	46.2		
32	NARUAI A	65.0	5.6			60.9	60.1	14.7	
33	B	46.6	7.8			38.3	45.8	10.5	
34	KAWARAGO S	60.9	3.1			57.9	54.7	14.3	
35	O	66.4	4.1			63.1	59.9		
36	ITAYA B	49.2	17.5			56.7	55.3		121
37	TAMAYU	23.9	49.6			55.4	56.6		
38	IWAMI	10.3	69.4			49.4	53.7		
39	SHIZUMA A	16.2	38.5			31.9	42.5		
40	TATEYAMAZAKI B	8.9	58.6			53.6	51.2		115
41	YOICHI	9.9	60.3			57.4	52.4		
42	OSHAMANBE A	0	65.1	79.7		52.5			
43	C	7.3	65.5			49.9	54.9		
44	HABORO	0	57.4	53.2		39.5			116
45	SAWAGUCHI	0	59.7	52.4		38.9			89
46	FUTATSUI FW-3	0	75.9	74.9		54.9			151
47	FW-5	0	73.5	75.4		55.9			159
48	FB-2	0	74.3	72.8		54.9			164
49	FG-4	0	72.9	67.9		59.4		15.5	165
50	FUKURODA	0	69.7	69.4		51.5			140
51	EAST GATE P-3***	0	95.9	95.0		79.5		22.9	162
52	JERSEY VALLEY	0	84.5	85.0		63.1			149
53	BEAVER RIM	0	82.3	81.9		69.8			185
54	IDAHO	0	61.9	61.9		45.9			143
55	NORTH CAPE	0	67.2	67.1		49.8			
56	ANACONDA 1010A	0	99.2	87.9		64.6			
57	KUNIPIA-F***	0	0			4.8			119

*: EQUILIBRIUM AMOUNTS ADSORBED AT 25°C AND 1 ATM. ON THE SPECIMENS DEHYDRATED AT 400°C FOR 1 HOUR.

** : CALCULATED CO₂ AMOUNTS ADSORBED FROM ZEOLITE-CONTENT VALUES BY X-RAY DIFFRACTION DIVISION METHOD ON THE ASSUMPTION THAT CO₂ AMOUNTS ADSORBED ON PURE MORDENITE AND PURE CLINOPTILOLITE AT 25°C AND 1 ATM. ARE 86.9 ML/G AND 74.2 ML/G RESPECTIVELY.

***: STANDARD SAMPLES.

detail mineral composition analyses of 30 of these specimens has already been reported by Torii, Hotta and Asaka (1979). The zeolite-content values by CO₂ method were

calculated from the carbon dioxide adsorption data assuming that the specimen Itado B-102 contains 82% of mordenite and the specimen East Gate P-3 95% of clinoptilolite.

lite.

The zeolite-content data by the X-ray diffraction method were compared with the data of gas adsorption and C.E.C. in order to confirm the accuracies of values.

Relation between zeolite-content by X-ray diffraction method and gas adsorption data

As shown in Fig. 1, nitrogen is adsorbed very rapidly on the mordenite specimen. Carbon dioxide adsorption on the mordenite-rock and the clinoptilolite-rock is also relatively rapid and the adsorption equilibrium is usually reached in 20 minutes, thus the measurement time is short.

When only mordenite is contained in the sedimentary rocks as zeolite, as shown in Fig. 2, the amounts adsorbed of nitrogen and carbon dioxide are linear functions of the mordenite-content by X-ray diffraction method in the specimens. Their relative standard error values are indicated in Table 2. As amounts adsorbed of carbon dioxide on the mordenite specimens are larger than those of nitrogen and the correlation coefficient between mordenite content and carbon dioxide amounts adsorbed is larger than that between mordenite content and nitrogen amounts adsorbed, the mordenite content values in the sedimentary rocks which contain only mordenite as zeolite mineral can be easily determined with high accuracy from the carbon dioxide adsorption data. The mordenite content values, calculated from the amounts of carbon dioxide adsorbed, on the assumption that the specimen Itado B-102 contain 82% of mordenite mineral, are shown in Table 1.

When specimens contain only clinoptilolite as zeolite mineral, the amount of carbon dioxide adsorbed is also a linear function of clinoptilolite content by X-ray diffraction method as shown in Fig. 3. A high correlation coefficient value and a low

Fig. 1 Kinetic data for nitrogen and carbon dioxide on zeolite-bearing rocks at 25°C and 1 atm.

Treating Temperature: 400°C for 1 hour.

Fig. 2 Relations between gas amount adsorbed and mordenite content in sedimentary rocks.

Treating temperature: 400°C for 1 hour.
Adsorption condition: 25°C, 1 atm.

relative standard error value for their relation are designated in Table 2. It is apparent that the clinoptilolite content values also can be estimated from the amounts of carbon dioxide adsorbed. The

Table 2 Basic statistics when regression: $y=ax$ is used for relations between physico-chemical properties and zeolite content.

PHYSICO-CHEMICAL PROPERTIES (Y)	ZEOLITE-CONTENT (X)	SLOPE (A)	R.S.E.	R	N
CO ₂ AMOUNT ADSORBED (ML/G)	MORDENITE (WT.%)	0.859	0.063	0.98	27
N ₂ AMOUNT ADSORBED (ML/G)	MORDENITE (WT.%)	0.224	0.109	0.96	22
CO ₂ AMOUNT ADSORBED (ML/G)	CLINOPTILOLITE (WT.%)	0.737	0.040	0.97	15
C.E.C. (M.EQUI./100G)	MORDENITE (WT.%)	2.185	0.112	0.96	23
C.E.C. (M.EQUI./100G)	CLINOPTILOLITE (WT.%)	1.998	0.136	0.68	11

R.S.E.: RELATIVE STANDARD ERROR, R: CORRELATION COEFFICIENT, N: NUMBER OF SAMPLES,
C.E.C.: CATION EXCHANGE CAPACITY.

Fig. 3 Relations between carbon dioxide amount adsorbed and clinoptilolite content by X-ray diffraction division method in sedimentary rocks.

Treating temperature: 400°C for 1 hour.
Adsorption condition: 25°C, 1 atm.

relationships between the two of zeolite content values by the X-ray diffraction division method and the carbon dioxide adsorption method for mordenite tuffs and clinoptilolite tuffs are shown in Fig. 4.

When specimens contain both mordenite and clinoptilolite, the content values of mordenite and clinoptilolite can not be estimated separately by the carbon dioxide adsorption data alone. We are however, able to assume indirectly whether the zeolite

content values by the X-ray diffraction method are correct or not. On the assumption that carbon dioxide amounts adsorbed on pure mordenite and pure clinoptilolite at 25°C and 1 atm. are 86.0 ml/g and 74.2 ml/g respectively, we may calculate the estimated values of carbon dioxide adsorbed on the specimens that contain the both zeolite minerals, from the zeolite content values by the X-ray diffraction method. If there is no or only a little difference between the two values of carbon dioxide amounts adsorbed of estimated and measured, it is obviously evaluated that the content values of mordenite and clinoptilolite by the X-ray diffraction division method are proper and vice versa. The data of calculated carbon dioxide adsorbed on the specimens which contain two kinds of zeolite minerals, are shown in Table 1.

On the other hand, we are able to estimate easily the content values of mordenite and clinoptilolite in the specimens by knowing the amounts of carbon dioxide adsorbed and the ratio of mordenite to clinoptilolite. The ratio of the above two zeolite minerals can be obtained from a calibration curve, using the peak intensities of mordenite (332) and clinoptilolite (035) as reported by Torii, Hotta and Asaka (1979). The results of the zeolite content values by the combination method of carbon dioxide adsorption data and X-ray diffrac-

Fig. 4 Relations between zeolite content by X-ray diffraction division method and carbon dioxide adsorption method in mordenite rocks and clinoptilolite rocks.

Table 3 Analytical results on specimens which contain mordenite and clinoptilolite.

SPECIMENS	ZEOLITE-CONTENT BY X-RAY DIFFRACTION DIVISION METHOD		ZEOLITE-CONTENT BY COMBINATION METHOD OF CO ₂ ADSORPTION AND X-RAY DIFFRACTION		ZEOLITE-CONTENT BY X-RAY INTENSITY METHOD	
	MOR.	CLINO.	MOR.	CLINO.	MOR.	CLINO.
ITADO B-3	65.6 WT.%	6.8 WT.%	69.7 WT.%	7.2 WT.%	55.9 WT.%	14.6 WT.%
LOVELOCK	35.8	2.3	37.4	2.4	36.9	10.8
WHANGAPE HABAUN	50.6	3.8	57.9	4.4	47.8	19.8
SOUTH AFRICA	9.9	50.8	8.7	44.9	9.4	52.1
NARUAI A	65.0	5.6	65.0	5.6	60.2	14.6
B	46.6	7.8	38.9	6.5	39.9	18.2
KAWARAGO S	60.9	3.1	64.5	3.3	62.6	8.8
O	66.2	4.1	69.7	4.3	63.3	10.8
ITAYA B	49.2	17.5	50.4	18.0	46.1	32.1
TAMAYU	23.0	49.6	22.5	48.5	21.7	54.3
IWAMI	10.3	60.4	9.5	55.6	10.2	63.2
SHIZUMA A	16.2	38.5	11.8	28.1	13.2	45.2
TATEYAMAZAKI B	8.9	58.6	9.3	61.4	7.1	58.6
YOICHI	9.0	60.3	9.9	65.9	9.4	68.7
OSHAMANBE C	7.3	65.5	6.5	58.5	6.7	62.8

MOR.: MORDENITE, CLINO.: CLINOPTILOLITE

tion data are shown in Table 3.

Relation between C.E.C. data and zeolite content by X-ray diffraction method

It is impossible to evaluate sedimentary rocks that contain above two kinds of zeolite minerals only by either the C.E.C. data or the gas adsorption data. When specimens contain only the zeolite mordenite, C.E.C. is linearly correlated with mordenite content estimated by the X-ray diffraction division method as shown in Fig. 5. Their

relative standard error value is almost the same as those for gas adsorption data, as shown in Table 2 if the regression: $y = a \cdot x$ is applied. However, as amorphous specimen (for example, Ōmori W-26) and/or montmorillonite specimen (for example, Kunipia-F) also indicate relatively high C.E.C. values, it is unreliable to estimate the mordenite content from C.E.C. values alone.

Fig. 6 shows the relation between C.E.C.

Fig. 5 Relations between cation exchange capacity and mordenite content by X-ray diffraction division method in sedimentary rocks.

Fig. 6 Relations between cation exchange capacity and clinoptilolite content by X-ray diffraction division method in sedimentary rocks.

and clinoptilolite content estimated by the X-ray method. As shown in Table 2, the coefficient correlation is not so good and it seems that the extent of dispersion is high compared with the mordenite data. Furthermore, extrapolated C.E.C. value at 100% clinoptilolite content is considerably smaller than the estimated value [282 m. equi./100 g for typical unit cell contents: $(\text{Na}_2, \text{K}_2)\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 7\text{SiO}_2 \cdot 6\text{H}_2\text{O}$]. These results may imply that all cations in the clinoptilolite are not completely exchanged by NH_4^+ . Compared with mordenite, clinoptilolite usually contains more potassium and it is assumed that potassium exchange by NH_4^+ will be difficult.

Relation between peak intensities of zeolite minerals and zeolite content by X-ray diffraction division method

Estimation of zeolite by the X-ray

diffraction division method has the advantage that all other minerals included in the specimens are simultaneously analyzed, although it takes much time and labour. On the other hand, we are unable to know the content of mordenite and clinoptilolite by the gas adsorption method or C.E.C. method, if the above specimens contain both zeolite minerals. Therefore we attempted to estimate the content values of both zeolite minerals simply by the peak intensities only.

To estimate mordenite content, the X-ray reflection peak of mordenite (202) was selected, because the intensity of X-ray reflection peak of clinoptilolite (051) is extremely weak even though the peak of mordenite (202) may be overlapped by that of clinoptilolite (051). The relation between peak intensity of mordenite (202) and

Fig. 7 Relations between X-ray reflection peak intensity and mordenite content by X-ray diffraction division method in sedimentary rocks.

X-ray diffraction condition: Cu(Ni); 30 kV-15 mA, slit; 1° -0.3 mm $^{-1}$.

○: Specimens containing mordenite.
△: Specimens containing both mordenite and clinoptilolite.

mordenite content is shown in Fig. 7. It seems that peak intensities of mordenite (202) can be expressed by a regression: $y = a.x^2 + b.x$, although a little dispersion is

Fig. 8 Relations between reflection peak intensities and clinoptilolite content by X-ray diffraction division method in sedimentary rocks.

X-ray diffraction condition: Cu(Ni); 30 kV-15 mA, slit; 1° -0.3 mm $^{-1}$.

□, ○: Specimens containing clinoptilolite.
△: Specimens containing both clinoptilolite and mordenite.

observed. The relative standard error values for two regression formula are indicated in Table 2 and Table 4. The zeolite content values by the X-ray peak

Table 4 Basic statistics when regression: $y = ax^2 + bx$ is used for relations between X-ray peak intensity and zeolite content.

X-RAY PEAK INTENSITY (Y)	ZEOLITE-CONTENT (X)	A	B	R.S.E.	R	N
(202) PLANE OF MORDENITE (CPS)	MORDENITE (WT.%)	0.0665	24.88	0.101	0.98	41
(132) PLANE OF CLINOPTILOLITE (CPS)	CLINOPTILOLITE (WT.%)	0.0601	18.55	0.103	0.87	14
(035) PLANE OF CLINOPTILOLITE (CPS)	CLINOPTILOLITE (WT.%)	0.0461	4.12	0.182	0.96	29

A, B: CONSTANTS, R.S.E.: RELATIVE STANDARD ERROR, R: CORRELATION COEFFICIENT BETWEEN VALUES OF MEASURED AND CALCULATED BY THE REGRESSION, N: NUMBER OF SAMPLES.

intensities in the specimens which contain both mordenite and clinoptilolite are shown in Table 3.

Fig. 8 indicates the relation between peak intensities of clinoptilolite (132) and (035), and clinoptilolite content. The content can easily be obtained by the peak of (132) plane if the specimens contain only the zeolite, clinoptilolite. When clinoptilolite is associated with mordenite in the specimens, the main peak of clinoptilolite (132) may be completely overlapped by

Fig. 9 Effects of Fe_2O_3 content in the specimens on peak intensity of mordenite (202) plane. X-ray diffraction condition: Cu (Ni); 30 kV-15 mA, slit; 1° -0.3 mm- 1° . Fe_2O_3 content: ○; <1.20 wt.%, △; 1.21 ~1.80 wt.%, □; 1.81 wt.% >.

that of mordenite (150). The peak of (035) plane was selected to estimate clinoptilolite content. In this case, the relative error is larger than that of (132) plane as shown in Table 4.

However, X-ray peak intensity is affected by coexistence elements, especially when it decreases because of the absorption effect of heavy elements. The effect of Fe_2O_3 contents in the specimens on the peak intensities of mordenite (202) is indicated in Fig. 9. If the specimens contain large amount of Fe_2O_3 , peak intensities of zeolite minerals appear to be weak and therefore the zeolite content values from the peak intensities appear to be low, and vice versa.

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堆積岩中のモルデンフッ石および斜プチロルフッ石の定量 (II)

鳥居 一雄・堀田 正己・浅賀 質

堆積岩中のモルデンフッ石および斜プチロルフッ石の含有量を簡単に知る方法を確立するため、ガス吸着量、陽イオン交換容量および上記ゼオライトのX線ピーク強度とX線回折按分法で得られたゼオライト含有量との

関係を検討した。

炭酸ガス吸着量を測定することにより、モルデンフッ石あるいは斜ブチロルフッ石を単独に含む堆積岩中のゼオライト含有量はかなり正確に求められた。陽イオン交換容量法ではモルデンフッ石含有量はうまく計算できたが、斜ブチロルフッ石含有量を推定するのは不適當であることが判明した。モルデンフッ石および斜ブチロルフッ石を同時に含む試料の場合は炭酸ガス吸着法およびX線回折法を組み合わせることにより、それぞれの含有量を求めることができた。またゼオライトのX線回折ピーク強度を用いることにより、その含有量を予測可能であったが、この場合は試料中の Fe_2O_3 含有量により影響を受けることがわかった。

欧 和 対 照 表

Ōmori, Kamiyashiki, Miyagi-chō, Miyagi pref.	宮城県宮城町上愛子大森
Shirasawa, Miyagi-chō, Miyagi pref.	宮城県宮城町白沢
Minase, Akita pref.	秋田県皆瀬
Itado, Akita pref.	秋田県板戸
Tenei, Fukushima pref.	福島県天栄
Amagōchi, Nima, Shimane pref.	島根県仁摩天河内
Arita, Saga pref.	佐賀県有田町
Naruai, Miyagi-chō, Miyagi pref.	宮城県宮城町鳴合
Kawarago, Shiroishi, Miyagi pref.	宮城県白石市川原子
Itaya, Yonezawa, Yamagata pref.	山形県米沢市板谷
Tamayū, Shimane pref.	島根県玉湯
Iwami, Shimane pref.	島根県石見
Shizuma, Ōda, Shimane pref.	島根県太田市静間
Yoichi, Hokkaidō	北海道余市
Oshamanbe, Hokkaidō	北海道長万部
Haboro, Hokkaidō	北海道羽幌
Tateyamazaki, Akita pref.	秋田県館山崎
Oga, Akita pref.	秋田県男鹿
Sawaguchi, Ōe, Yamagata pref.	山形県大江町沢口
Futatsui, Akita pref.	秋田県二ツ井
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