

Erionite in Welded Tuff from Ashio, Tochigi Prefecture, Japan

By

Satoshi MATSUBARA, Tokiko TIBA and Akira KATO

Department of Geology, National Science Museum, Tokyo 160, Japan

Introduction

Recent finds of erionite in Japan have provided useful informations about the mode of occurrence as well as its associated minerals including clay minerals besides zeolites. It occurs in basalts at Maze, Niigata Prefecture (SHIMAZU and KAWAKAMI, 1967; HARADA *et al.*, 1967), Kawajiri, Yamaguchi Prefecture (SHIMAZU and MIZOTA, 1972; MIZOTA *et al.*, 1974), and Chichijima, Tokyo (NISHIDO *et al.*, 1976), in basaltic tuff breccia at Chojabaru, Nagasaki Prefecture (SHIMAZU and MIZOTA, 1972; MIZOTA *et al.*, 1974), in altered pitchstone at Narushima, Nagasaki Prefecture (MUCHI *et al.*, 1972), and in acidic tuff breccia at Iwayaguchi, Niigata Prefecture (SHIMAZU and YOSHIDA, 1969).

Erionite here described is found in welded tuff and similar to the mode of occurrence at Narushima and Iwayaguchi, and considered to be a product under higher vapour pressure condition that prevailed after the formation of glassy parts due to partial welding of accumulated hot ash. Since the welded tuff has an unaltered appearance, the present find informs the importance of careful mineralogical survey of welded tuff even if it has a fresh appearance.

The authors sincerely thank for Dr. Yasuji SAITO, Department of Geology, National Science Museum, for his help to observe erionite under the electron microscope. Also they are very much indebted to Mr. Hideaki KUSAKA, who aided the authors' field work and collection of studied materials.

Occurrence

The erionite locality is an outcrop of a welded tuff very probably overlying older sedimentary rocks belonging to Awano Group (WATANABE, ed., 1957), which is one of the principal basement-forming constituents of the Ashio Mountainland. The welded tuff is a member of Neogene pyroclastic and volcanic rocks developed in the northern part of this mountainland and they are considered to be responsible for the mineralization of subvolcanic ore deposits of the Ashio mine (NAKAMURA, 1970) located about 5 km NNW of the locality near Kasuo Pass (Fig. 1).

In the outcrop erionite occurs in two different modes of occurrence. One is the invisible but qualitatively important constituent of a light ochre siltstone-looking compact lense-formed parts less than 5 cm thick and 50 cm long with rather sharp

boundaries to the country rock. In the exposure are a few lenses. The other is in microscopical cavities developed in glassy parts of the country rock with a very fresh appearance. The compact material shows partial heterogeneity due to dark grey lithic fragments.

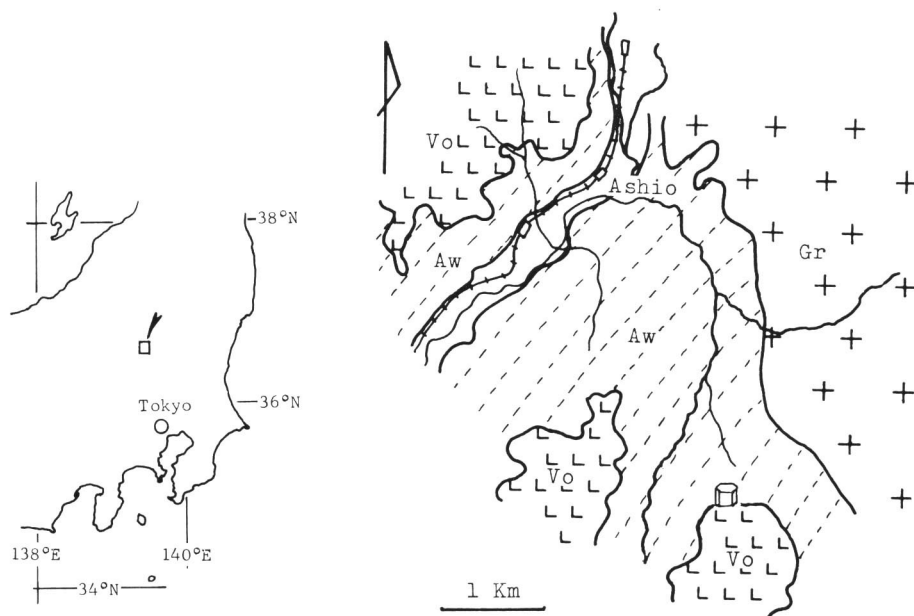


Fig. 1. Geologic sketch map of the adjacent area of erionite locality (hexagonal prism). After WATANABE, *ed.* (1957) with minor correction by the authors. Aw: Rocks of Awano Group, Gr: Granite, Vo: Acidic volcanics.

Under the microscope, the compact part includes abundant pumice and less abundant lithic fragments embedded in a matrix composed of glass shards. The lithic fragments are seemingly sandstone hornfels composed of plagioclase, alkali feldspar and opaque mineral with secondary sericite. Erionite is found as aggregates of minute acicular crystals which are developed on corroded surfaces of glass shards. Under the electron microscope are observed aggregates of striated prisms developed in drusy parts (Fig. 2). Mean refractive index measured by the immersion method as $n=1.48$, which is lower than that of adjoining glass. Anhedral quartz grains less than 0.2 mm across are occasionally found. They include minute dusts and accompany clay mineral on their grain surfaces. Grains of alkali feldspar are also anhedral and less than 0.6 mm across. Partial alteration to sericite is also common. Besides them, X-ray powder study of some portions of compact part informed the presence of minor phillipsite and clinoptilolite.

The country rock of the lense-formed compact part is made up of angular, often

flattened pumice less than 20 mm long, angular dark grey looser matrix. Since a rough parallel texture composed of pumice and lithic fragments is apparently observed in the exposure surface, this rock is considered to be a welded tuff.

Microscopically the rock consists of abundant glass shards, sporadic plagioclase, quartz, biotite, lithic fragments, and interstitial montmorillonite. The glass shards are clear and have irregularly curved outlines. Its surface is more or less replaced by montmorillonite. Plagioclase occurs as fragments or fine laths. Quartz is found as discrete fragments only. Biotite flakes are small in amount and is pleochroic from pale brown to dark green. Lithic fragments are biotite-quartz-plagioclase hornfels. Interstitial montmorillonite forms aggregates of very minute tabular crystals with light yellowish brown colour. In this rock erionite is found in microscopic cavities developed along the pumiceous glassy parts, and is less frequent than in the former occurrence.

The microscopical appearances of two rocks are similar in each irrespective of the macroscopic differences especially in colour. This suggests that the light ochre compact rock was derived from the welded tuff probably due to more remarkable concentration of vapour that favoured the more abundant formation of erionite.

The presence of erionite and montmorillonite in these rocks suggests the prevalence of higher vapour pressure condition after the formation of welding texture, which is well preserved, though partially replaced by these minerals. The present find informs the necessity of detailed mineralogical survey of welded tuffs even if it has an unaltered appearance.

X-ray Powder Study

X-ray powder pattern of a part of compact part was obtained by the diffractometer method using Ni-filtered Cu radiation (Table 1). The unique detected contaminating material is montmorillonite which gives its strongest peak with $d=15.5 \text{ \AA}$ only and this is removed in the table. The unit cell constants of erionite calculated due to indexing are $a_0=13.328(8)$, $c_0=15.108(8) \text{ \AA}$ respectively. They are somewhat larger than those of erionites hitherto reported (WISE and TSCHERNICH, 1976), although the larger value of a_0 suggestive of lower SiO_2 content is conformable with the result of chemical analysis of the erionite-bearing compact rock examined by X-ray powder study.

The appearance of some diffractions like $d=5.400$, 4.203 and $3.297 \text{ \AA}$ indexed as (201), (121) and (123) respectively warrants the existence of erionite as a dominant phase in the examined material. Offretite has a very similar X-ray powder pattern (SHEPPARD and GUDE, 1969) but lacks the above diffractions on account of its halved c_0 dimension as compared with that of erionite. Thus the absence of offretite in the studied material cannot be ruled out.

Chemical Analyses of Erionite-bearing Rocks

Since the separation of pure erionite was unsuccessful due to its fine grain size and

Table 1. X-ray powder data for erionites from California and Kasuo Pass, Ashio

1							2						
d	I	d	I	Qobs.	Qcalc.	hkl	d	I	d	I	Qobs.	Qcalc.	hkl
11.41	100	11.59	50	0.0074	0.0075	100	2.496	20	2.517	40	0.1578	0.1576	410
9.07	12					101					0.1577		006
7.51	8	7.622	10	0.0172	0.0175	002	2.480	17					224
6.61	75	6.681	25	0.0224	0.0225	110			2.498	25	0.1603	0.1601	322
6.28	6					102	2.200	11	2.220	15	0.2029	0.2027	330
5.72	16	5.779	25	0.0299	0.0300	200	2.113	6	2.129	6	0.2206	0.2202	332
5.34	14	5.400	23	0.0343	0.0344	201	2.079	5	2.095	10	0.2278	0.2277	422
4.595	8					103	1.982	4	1.994	10	0.2515	0.2502	512
4.551	12	4.595	60	0.0474	0.0475	202			1.967	5	0.2585	0.2578	504
4.322	67	4.369	70	0.0524	0.0525	120			1.932	8	0.2679	0.2671	415
4.156	25	4.203	25	0.0566	0.0569	121					0.2672		127
3.813	35	3.840	50	0.0678	0.0676	300	1.882	6					430
3.746	65	3.779	95	0.0700	0.0700	122			1.886	12	0.2811	0.2803	424
3.570	25	3.590	60	0.0776	0.0776	104					0.2804		008
3.402	4					302					0.2822		431
3.303	40	3.331	30	0.0901	0.0901	220	1.834	8					520
3.276	26	3.297	13	0.0920	0.0919	123			1.816	5	0.3032	0.3028	514
3.271	25			0.0926		114			1.780	20	0.3156	0.3153	416
		3.160	30	0.1001	0.1001	204			1.760	5	0.3228	0.3228	610
3.106	12					311			1.714	8	0.3404	0.3403	612
2.923	10					312			1.697	5	0.3472	0.3480	308
2.910	10					105			1.666	25	0.3603	0.3603	440
2.860	60	2.882	70	0.1204	0.1201	400			1.594	15	0.3936	0.3929	614
2.839	50	2.854	100	0.1228	0.1226	124			1.569	5	0.4062	0.4072	533
2.812	52					401							
2.686	15					304							
2.680	12	2.696	28	0.1376	0.1376	402							
2.673	8					205							
a ₀	13.214(2)	a ₀	13.328(8)										
c ₀	15.041(4)	c ₀	15.108(8)										

1. Erionite. Tecopa, Inyo County, California. After Sheppard and Gude, 3d (1969). CuK α radiation, diffractometer method.
2. Erionite. Kasuo Pass, Tochigi Prefecture, Japan. Cu/Ni radiation. Diffractometer method.

finely admixed state with glass and montmorillonite, two wet chemical bulk analyses of erionite-bearing rocks were made by the second author (Table 2). The results show the difference in grade of alteration irrespective of their microscopical similarity. The former is more altered than the latter seeing from its higher H₂O content. Low SiO₂ and high Al₂O₃ contents are obviously due to dominance of erionite and montmorillonite to the latter. The alteration led to the formation of parts of advanced stage of

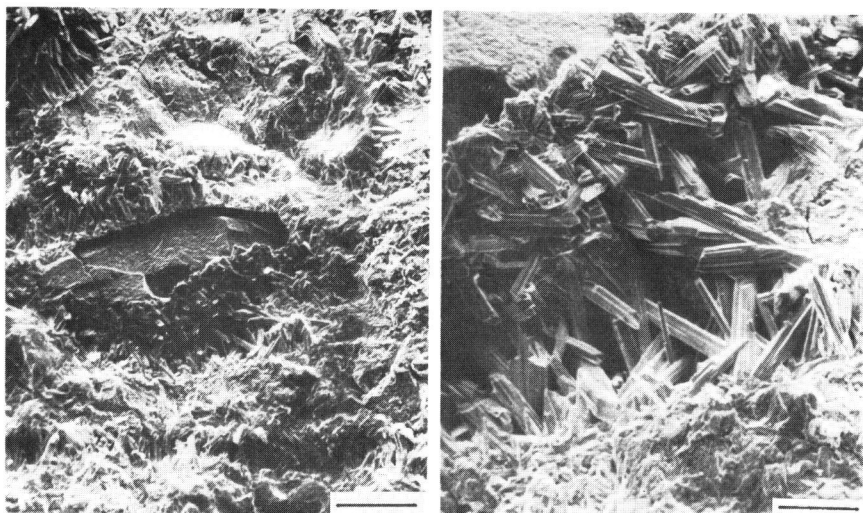


Fig. 2. Scanning electron micrographs of erionite-rich part in the compact siltstone-like rock (left, bar 50 μ) and aggregate of erionite prisms (right, bar 15 μ).

Table 2. Chemical analyses of erionite-bearing welded tuff and erionite-rich compact lense in welded tuff.

	1	2	norm of 1	
SiO ₂	65.53	50.93	Q	32.42
TiO ₂	0.24	0.27	or	22.43
Al ₂ O ₃	14.77	18.17	ab	21.76
Fe ₂ O ₃	1.57	2.70	an	6.31
FeO	0.71	n.d.	C	4.12
MnO	0.05	n.d.	en	1.52
MgO	0.61	0.42	mt	1.76
CaO	1.27	4.81	il	0.46
Na ₂ O	2.57	0.41	hm	0.35
K ₂ O	3.80	3.34	total	91.13
H ₂ O+	5.50	11.80		
H ₂ O-	3.67	7.50		
total	100.29	100.35		

1. Erionite-bearing welded tuff.

2. Erionite-rich compact lense (NSM-M21743) in 1.

alteration with sharp boundaries to less altered, which has no significant difference in mineralogical constituents from the altered one. That is, a notable concentration of alteration products in certain parts of welded tuff with sharp boundaries, which will be geochemically implicative seeing from the difference in the degree of concentration of alteration products.

References

- HARADA, K., S. IWAMOTO & K. KIHARA, 1967. Erionite, phillipsite, gonnardite in the amygdales of altered basalt from Maze, Niigata Prefecture, Japan. *Am. Mineral.*, **52**: 1785–1794.
- MIZOTA, T., G. SHIBUYA, M. SHIMAZU & Y. TAKESHITA, 1974. Mineralogical studies on levyne and erionite from Japan. *Mem. Geol. Soc. Japan*, **11**, 283–290.
- MUCHI, M., H. YAMAMOTO & M. TEJIMA, 1972. Erionite from Narushima, Nagasaki Prefecture. *Abstr. 79th Annual Meeting of Geol. Soc. Japan*, 289 (In Japanese.).
- NAKAMURA, T., 1970. Mineral zoning and characteristic minerals in the polymetallic veins of the Ashio Copper Mine in Volcanism and Ore Genesis, 231–246. University of Tokyo Press.
- NISHIDO, H., N. MIURA & R. OTSUKA, 1976. Apophyllite from Chichijima, Ogasawara. *Abstr. Annual Meeting of Miner. Soc. Japan*, 126. (In Japanese.).
- SHEPPARD, R. A. & A. J. GUDE, 3d, 1969. Chemical composition and physical properties of the related zeolites offretite and erionite. *Am. Mineral.*, **54**: 875–886.
- SHIMAZU, M. & T. KAWAKAMI, 1967. Erionite from Maze, Niigata Prefecture. *Jour. Japan Assoc. Miner. Petr. Econ. Geol.*, **57**: 68–71. (In Japanese.).
- SHIMAZU, M. & T. MIZOTA, 1972. Levyne and erionite from Chojabaru, Iki Island, Nagasaki Prefecture, Japan. *Jour. Japan Assoc. Miner. Petr. Econ. Geol.*, **67**: 418–424.
- SHIMAZU, M. & S. YOSHIDA, 1969. Occurrence of erionite from Iwayaguchi district, Osado area, Niigata Prefecture. *Jour. Geol. Soc. Japan*, **75**: 389–390. (In Japanese.).
- WATANABE, T. ed., 1957. Geological map of Ashio Mountainland and the explanatory text. Tochigi Prefecture Office. (In Japanese.)
- WISE, W. S. & R. W. TSCHERNICH, 1976. The chemical composition and origin of the zeolites offretite, erionite, and levyne. *Am. Mineral.*, **61**: 853–863.