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LEVYNE FROM DŌZEN (OKI ISLANDS), JAPAN

TOKIKO TIBA AND SATOSHI MATSUBARA

Department of Geology, National Science Museum, Tokyo, Japan

ABSTRACT

Levyne, chabazite and other zeolites occur in amygdules of a Pliocene trachybasalt lava near Kuniga, Nishi-no-shima, Dōzen (Oki Islands). Levyne forms aggregates of thick tabular crystals with or without thomsonite and cowlesite. Wet-chemical analyses yielded the empirical formulae $(Na_2)_{0.16}(K_2)_{0.04}Ca_{0.96}Al_{2.27}Si_{3.72}O_{12}\cdot 5.8H_2O$ (Z=9) for levyne; and $(Na_2)_{0.11}(K_2)_{0.08}Ca_{0.82}Fe^{3+}_{0.01}Al_{2.14}Si_{3.88}O_{12}\cdot 6.3H_2O$ (Z=6) for chabazite. The levyne has n_ω 1.497, n_ϵ 1.494, hexagonal parameters a 13.338, c 23.004Å, specific gravity 2.04.

SOMMAIRE

La lévyne, la chabasie et autres zéolites se présentent en amydales dans une lave trachybasaltique pliocène près de Kuniga, Nishi-no-shima, Dōzen (Îles Oki). La lévyne se rencontre sous forme d'agrégats de cristaux tabulaires épais avec ou sans thomsonite et cowlesite. A l'analyse chimique par voie humide, les compositions sont: $(Na_2)_{0.16}(K_2)_{0.04}Ca_{0.96}Al_{2.27}Si_{3.72}O_{12}\cdot 5.8H_2O$ (Z=9) pour la lévyne et $(Na_2)_{0.11}(K_2)_{0.08}Ca_{0.82}Fe^{3+}_{0.01}Al_{2.14}Si_{3.88}O_{12}\cdot 6.3H_2O$ (Z=6) pour la chabasie. La lévyne a pour indices: ω 1.497, ϵ 1.494; en axes hexagonaux: a 13.338, c 23.004Å; D(mes.) 2.04.

(Traduit par la Rédaction)

INTRODUCTION

Levyne is a rather rare zeolite in Japan and elsewhere and only four localities are known in Japan (Shimazu & Mizota 1972; Mizota *et al.* 1974; Shibuya & Kuwano 1975). None of these localities has yielded material for a wet-chemical analysis, mainly because of the presence of intergrown zeolites such as erionite and offretite. However, levyne crystals in amygdules, with no other intergrown zeolites, in a trachybasalt near Kuniga, Nishi-no-shima, Dōzen (Oki Islands), permitted a complete wet-chemical analysis to be made. Analyses were also made on the associated chabazite and the host rock in order to determine the chemical environment in which there was preferential formation of these two compositionally similar zeolites. From the comparative study of the chemical compositions of known levynes, a combination of three substitution couples has been derived to account for the compositional variation of this mineral.

OCCURRENCE

Host rock

An amygdaloidal, zeolite-bearing trachybasalt flow crops out at a road-cut about 750 m northwest of Kuniga tunnel, Nishi-no-shima, Dōzen, Oki Islands (Fig. 1). Dōzen (Oki Islands) is a part of remnants of a Pliocene volcano composed of somma, caldera, and a central cone (Tiba 1975). The lava pile of the somma reaches 350 m in maximum thickness, though individual lavas are usually 1-2 m thick or less. The trachybasalt lava which is the host of the amygdules is 5 m thick and is in the lower part of the somma lava pile.

The trachybasalt contains abundant megascopic plagioclase phenocrysts in a dark grey, dense matrix and has cavities and amygdules of various sizes and shapes. Plagioclase occurs as euhedral prismatic or tabular crystals, generally 1 to 2 mm and occasionally up to 5 mm in size, which are polysynthetically twinned and which are distinctly zoned in their outer part. Clinopyroxene grains are short prismatic, average about 0.6 mm long, and are rarely twinned. Euhedral olivine has been entirely replaced by aggregates of pale straw-yellow or light green fibres rimmed by magnetite ribbons. Magnetite occurs as euhedral grains 0.2-0.4 mm across. The fine-grained, dense groundmass consists mainly of plagioclase laths, euhedral to subhedral clinopyroxene grains, irregular-shaped magnetite granules, and ilmenite spicules with subordinate hematite.

Chemical analysis and CIPW norms of the trachybasalt are given in Table 1. The rock has a high TiO_2 content and high $Fe_2O_3/(Fe_2O_3+FeO)$ and $K_2O/(Na_2O+K_2O)$ ratios. The rock is a member of moderately potassic lineage (alkali olivine basalt – trachybasalt – tristanite – K-rich trachyte defined by Coombs & Wilkinson (1969). The small amount of normative quartz is interpreted to be the result of alteration of olivine.

Amygdules

The amygdules are generally oval and 1 to 10 cm across (Figs. 2). Some horizontally flattened, irregular-shaped amygdules exceed 10 cm in length and show a roughly parallel arrangement. Amygdules stained by a light yellow substance are common. Several associations of amygdale minerals have been recognized; their decreasing frequency of appearance is: (1) chlorite+thomsonite+chabazite; (2) chlorite+levyne; (3) chlorite+thomsonite+chabazite; (4) chlorite+calcite; (5)chlorite+thomsonite+chabazite+calcite; (6) chlorite+cowlesite+levyne; (7) chlorite+calcite+phillipsite+chabazite; (8) chlorite+thomsonite+levyne; (9) chlorite+cowlesite.

Levyne

The levyne from Dōzen occurs either as a monomineralic phase in amygdules, or in association with cowlesite or thomsonite only. The levyne is present as transparent, thick tabular hexagonal crystals (Fig. 3) up to 8 mm in diameter and 1 mm thick. The crystals occur on a thin film composed of aggregates of fibrous dark green chlorite which rims the amygdules. Some levyne is found as isolated crystals, but most of the tabular crystals form boxworks which completely fill the amygdules (Fig. 2). Much of the levyne is associated with cowlesite or thomsonite, and in these cases the levyne crystals are present sporadically on white minute cowlesite scales which grew inward on the chlorite film or on mammillary aggregates of thomsonite. Both cowlesite and thomsonite are always older than levyne. Levyne is never in direct contact with chabazite, phillipsite or calcite. Scanning electron microscope and X-ray powder-diffraction studies show that other zeolites are not associated with levyne crystals. Thus, the Dōzen occurrence differs from those at Beech Creek (Sheppard *et al.* 1974; White 1975), Sardinia (Passaglia & Galli 1974), Deccan traps (Chatterjee 1971) and Kawajiri (Mizota *et al.* 1974), all of which have erionite or offretite intergrown with levyne. The occurrence of levyne without associated chabazite in this case also distinguishes Dōzen levyne from those from County Antrim (Walker 1951, 1960a), Iceland (Walker 1960b) and Sardinia (Passaglia & Galli 1974).

Table 1. Chemical analysis and CIPW norms of zeolite-bearing trachybasalt (NSM-M20523)

	wt%	CIPW norms		wt%
SiO_2	47.44	Q		0.44
TiO_2	2.87	or		17.14
Al_2O_3	17.22	ab		23.59
Fe_2O_3	4.59	an		25.89
FeO	4.96	di	wo	6.04
MnO	0.16		en	4.83
MgO	3.34		fs	0.51
CaO	8.88	hy	en	3.48
Na_2O	2.79		fs	0.37
K_2O	2.90	mt		6.64
H_2O+	2.46	il		5.44
H_2O-	1.76	ap		0.94
P_2O_5	0.39	cc		0.41
CO_2	0.18			
total	99.94			

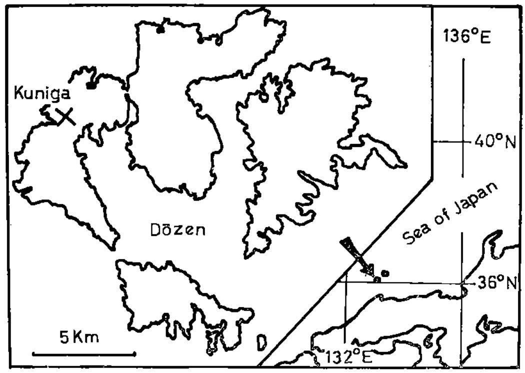

FIG. 1. The locality of zeolite-bearing trachybasalt.

FIG. 2. Thin section of levyne. Crossed polars. Scale bar is 1 mm.


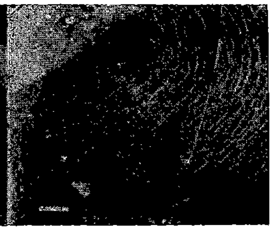

FIG. 3. (left). Scanning electron micrograph of a thick tabular levyne crystal on cowlesite. Scale bar is 0.1 mm.

FIG. 4. (right). Scanning electron micrograph showing growth lines on (0001) of a levyne crystal. Scale bar is 3 μm.

Properties

The levyne is colorless and transparent with a vitreous lustre. The surface of the crystals is rarely coated with a light yellow filmy material. Cleavage is lacking and hardness is about 5.5. Growth lines are observed on (0001) (Fig. 4). Specific gravity measured by pycnometer is 2.04.

Table 2. Chemical analyses of levyne and chabazite

	wt% 1	wt% 2		atomic ratios on O=12 1	atomic ratios on O=12 2
SiO_2	43.88	45.38	Si	3.7153	3.8824
Al_2O_3	22.73	21.21	Al	2.2682	2.1386
Fe_2O_3	-	0.22	Fe^{3+}	-	0.0144
CaO	10.57	8.91	Ca	0.9591	0.8160
Na_2O	2.01	1.32	Na	0.3297	0.2190
K_2O	0.80	1.45	K	0.0865	0.1583
H_2O+	14.87	15.36			
H_2O-	5.67	6.60			
total	100.53	100.45			

1. Levyne from zeolite-bearing trachybasalt (NSM-M20523).
2. Chabazite from zeolite-bearing trachybasalt (NSM-M20523).

Table 3. Atomic ratios of levynes (on an anhydrous basis of O=12)

	Si	Al	Ca+Mg	Na+K	H_2O	Si/Al	$Ca+Na_2+K_2$
1	4.11	1.86	0.79	0.39	5.38	2.21	0.99
2	4.00	2.00	1.00		6.00	2.00	
3	3.98	2.03	0.83	0.30	5.66	1.96	0.99
4	3.94	2.04	0.70	0.71	4.62	1.93	1.06
5	3.90	2.10	0.91	0.29	5.50	1.85	1.06
6	3.89	2.11	1.00		6.00	1.84	
7	3.86	2.13	0.98		6.23	1.81	1.10
8	3.84	2.16	0.96		4.92	1.78	1.08
9	3.78	2.22	1.00		6.00	1.70	
10	3.71	2.27	0.96	0.41	5.80	1.64	1.17
11	3.69	2.32	0.96	0.39	4.81	1.59	1.16

1, 3 and 5; levynes from Sardinia (Passaglia & Galli 1974).
2, 6 and 9; levynes assuming NaSi⇌CaAl substitution.
4; levyne from Siberian traps (Feoktistov et al. 1971).
7 and 8; levynes from Colorado (Feoktistov et al. 1971).
10; levyne from Dōzen (present study).
11; levyne from Iceland (Feoktistov et al. 1971).

The levyne is uniaxial negative with $n\omega$ 1.497 and $n\varepsilon$ 1.494 (both ±0.002). Penetration twins are commonly observed in thin sections. All the diffraction peaks of the Dōzen levyne are satisfactorily indexed in terms of a unit cell with 13.338, c 23.004Å, space group $R\bar{3}m$.

X-ray powder patterns of levynes and chabazites from several amygdules were checked prior to the preparation of material for chemical analyses. No significant variations were observed. Chemical analyses of hand-picked levyne and chabazite, with purity confirmed by microscopy and X-ray diffractometer studies are given in Table 2. Their SiO_2 contents are rather low, whereas Al_2O_3 contents are high. Levyne has a H_2O deficiency and chabazite has excess H_2O compared with their theoretical formulas.

Although the mole ratio $Al_2O_3/(CaO+Na_2O+K_2O)$ for any zeolite (devoid of Fe_2O_3 and TiO_2) should be unity, this ratio for the levyne and chabazite is 0.97 and 1.07, respectively. The Si/Al ratio for levyne is 1.64 and for chabazite, 1.80. The (Na+K) / (Ca+Na+K) ratios for levyne and chabazite are 0.30 and 0.32, respectively. The levyne is more aluminous and calcic and less potassic than the associated chabazite.

DISCUSSION

Atomic ratios calculated on an anhydrous basis of O=12 (or Si+Al=6) obtained from the known reliable analyses of levynes are given in Table 3. As can be seen in the table, the Si/Al ratios ranges from 2.21 to 1.59. Assuming three substitution couples: CaAl⇌NaSi, Ca⇌2Na, and Na⇌K, the sum of Ca, Na_2 and K_2 must range from 0.99 to 1.17 in accordance with the variation of Si/Al ratio stated above. Levyne analyses

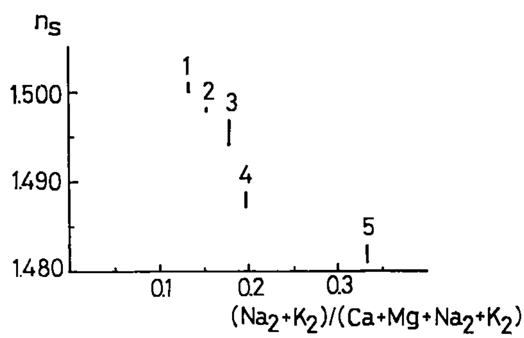

FIG. 5. Refractive indices versus $(Na_2+K_2)/(Ca+Na_2+K_2)$ in levynes. 1, 2 and 4: levynes from Sardinia (Passaglia & Galli 1974). 3: levyne from Dōzen. 5: levyne from Siberian traps (Feoktistov *et al.* 1971).

conform fairly well with this assumption. On the other hand, if only two substitution couples, CaAl⇌NaSi and Na⇌K, are allowed (Feoktistov *et al.* 1971), the sum of Ca+Mg+Na+K must be 1 on the anhydrous basis of O=12, independent of Si/Al variation. However, significant deviations from the sum of 1 are present, especially in levynes with high alkali contents. Thus, compositional variation of levyne is explained better by the combination of the three substitution couples mentioned above. The H_2O content is highly variable from 4.62 to 5.80 and considerably lower than the theoretical value 6 in all cases. It is not known whether such H_2O deficiencies are structural or result from inadequate sample preparation. From the data available, the ideal formula of levyne may be expressed as $(Ca,Na_2)Al_2Si_4O_{12}\cdot 6H_2O$ (with Na < Ca). Levynes in silica-poor rocks such as olivine basalt from Iceland and trachybasalt from Dōzen have low Si/Al ratios, but the ratio is high in levynes in silica-rich rocks such as andesite from Sardinia.

Figure 5 gives the relationship between refractive indices and $(Na_2+K_2)/(Ca+Na_2+K_2)$ ratios in levynes. The substitution of Na_2 or K_2 for Ca lowers the refractive indices of the mineral.

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REFERENCES

CHATTERJEE, A. C. (1971): Levyne in the Deccan traps. *Mineral. Mag.* 38, 527-528.

COOMBS, D. S. & WILKINSON, J. F. G. (1969): Lineages and fractionation trends in undersaturated volcanic rocks from the East Otago volcanic Province (New Zealand) and related rocks. *J. Petrology* 10, 440-501.

FEOKTISTOV, V. P., USHCHEPOVSKAYA, Z. V., KASHAEV, A. A. & LAKHNO, T. A. (1971): On finding of levyne in the traps of the Siberian platform. *Mem. All-Union Mineral. Soc.* 100, 745-748. (In Russ.).

MIZOTA, T., SHIBUYA, G., SHIMAZU, M. & TAKESHITA, Y. (1974): Mineralogical studies on levyne and erionite from Japan. *Mem. Geol. Soc. Japan* 11, 283-290.

PASSAGLIA, E. & GALLI, E. (1974): Levynes and erionites from Sardinia, Italy. *Contr. Mineral Petrology* 43, 253-259.

SHEPPARD, R. A., GUDE, A. J., 3rd & DESBOROUGH, G. A. (1974): Levyne-offretite intergrowths from basalt near Beech Creek, Grant County, Oregon. *Amer. Mineral.* 59, 837-842.

SHIBUYA, G. & KUWANO, N. (1975): Amygdale minerals of basalt from Keya, Fukuoka Prefecture, with special reference to the occurrence of levyne. *Chigaku Kenkyu.* 26, 327-336. (In Japanese).

SHIMAZU, M. & MIZOTA, T. (1972): Levyne and erionite from Chojabaru, Iki Island, Nagasaki Prefecture, Japan. *J. Japan. Assoc. Mineral. Petrology Econ. Geol.* 67, 418-424.

TIBA, T. (1975): Geology of Dōzen, Oki Islands, *Bull. Nat. Sci. Mus. Ser. C (Geol.)* 1, 137-145. (In Japanese, Eng. abstr.).

WALKER, G. P. L. (1951): The amygdale minerals in the Tertiary lavas of Ireland. I. The distribution of chabazite habits and zeolites in the Garron plateau area, County Antrim. *Mineral. Mag* 29, 773-791.

——— (1960a): The amygdale minerals in the Tertiary lavas of Ireland. III. Regional distribution. *Mineral. Mag.* 32, 502-527.

——— (1960b): Zeolite zones and dike distribution in relation to the structure of the basalts of eastern Iceland. *J. Geol.* 68, 515-528.

WHITE, JR., J. S. (1975): Levyne-offretite from Beech Creek, Oregon. *Mineral. Record* 6, 171-173.

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