CHEMICAL COMPOSITION AND FISSION-TRACK AGE OF SOME MUONG NONG-TYPE TEKTITES

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***Abstract*:** Six Muong Nong-type tektites from Laos and Thailand and one indochinite from Viet Nam were studied petrologically, and their fission-track age was determined. Under the microscope the tektites have conspicuous flow structures, formed by alternating bands of glass of slightly different refractive index. In one sample B, pale brown parts are present sporadically in the colorless matrix, and both of them show some difference in chemical composition. Major elements were determined by a Hitachi scanning electron probe microanalyzer. It is remarkable that there is a wide range in chemical composition of Muong Nong-type tektites, ranging from 71 to 82% SiO_2, which almost covers the whole range of tektites in general.

For determination of water content, a finely powdered sample was melted in a high-frequency induction furnace in vacuum, and evolved water was converted to hydrogen. Water content was determined by measuring the volume of the hydrogen, and the isotopic composition of the hydrogen was determined by a mass spectrometer MAT 250. H_2O content ranges from 0.08 to 0.10%, and δD from -56.4 to -79.2‰. These values preclude the possibility that the water was derived from the lunar rocks, but may support the terrestrial origin of these tektites.

Fission-track age dating gives values from 0.65 to 0.70 Ma, which agree with the ages obtained by other workers using fission-track and other methods on the indochinites in general.

1. Introduction

Normal indochinites have characteristic splash forms, such as pear, dumbbell, tear drop, flask, etc. and also have sculptured surfaces, whereas Muong Nong-type tektites are commonly irregular in shape, and have a ragged surface. Generally they are larger than normal indochinites and weigh sometimes more than 1 kg. Sometimes Muong Nong-type tektites have well-developed banded structure, slightly similar to terrestrial welded tuffs. It is generally regarded that Muong Nong-type tektites may be more primitive than indochinites. Therefore in order to elucidate the origin of tektites some Muong Nong-type tektites were petrologically studied and their fission-track age was determined.

2. Samples Studied

The samples studied except for G were provided by Mr. Darryl S. FUTRELL of California, and comprise the following:

A. Muong Nong-type tektite from Thailand.

B. Muong Nong-type tektite from Laos. This has well-developed laminar structure.

C. Muong Nong-type tektite from Laos. Covered partly by lateritic soil.

D. Muong Nong-type tektite from Laos. Laminar structure is observed.

E. Muong Nong-type tektite from Laos. Laminar structure and bubbles are observed on the surface, which is partly covered by lateritic soil.

F. Muong Nong-type tektite from Laos. Laminar structure is visible and is partly covered with lateritic soil.

G. Normal indochinite from Viet Nam, studied for comparison. Tear drop shaped, and is covered with pitted surface.

3. Microscopic Observation

All the samples are fairly homogeneous, and lack any microlites which are common in obsidian. Flow structure is more or less developed, and is formed by alternating bands of glass of slightly different refractive index, arranged either in parallel bands or contorted swirls as shown in Figs. 1A and 1E. They sometimes show anomalous strain birefringence under the crossed nicols. Complete absence of microlites is noteworthy, since they are always present in terrestrial obsidian.

In sample B, pale brown bands or irregular shaped patches are present in the nearly colorless and more or less homogeneous matrix, as shown in Figs. 1B, 1C and 1D. Sometimes these darker parts are parallel to the banding or cut by the banding irregularly. As shown later, there is a slight difference in chemical composition between the darker parts and the colorless matrix.

Although some workers (O'KEEFE and ADLER, 1966) considered these banded tektites as some kinds of welded tuffs, the structure is quite different from the terrestrial welded tuffs, which usually have many elongate Y-shaped glassy shards.

4. Chemical Composition

Major-element analysis was made by a Hitachi scanning electron probe micro-analyzer, Model X-560S, using an energy-dispersive analytical system. Analysis was made on several spots, widely separated from each other in the section. In general the composition was found to be similar, as shown in samples A and C (Tables 1 and 2).

In the sample B, however, the pale brown parts and nearly colorless matrix mentioned above have slightly different composition, as shown in Table 3. The difference

Table 1. Chemical composition of tektite A.

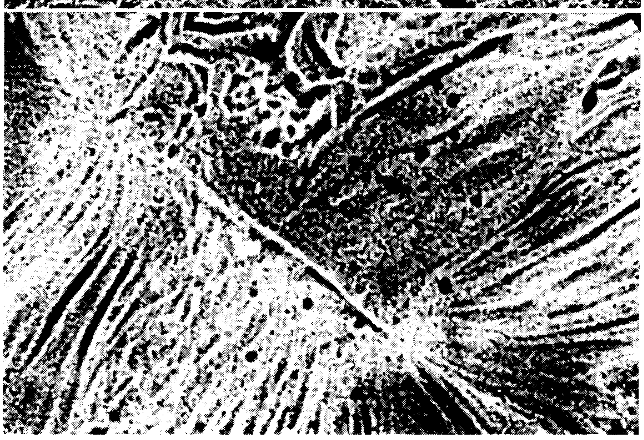
	1	2	3	4	Average
SiO_2	71.61	71.52	72.16	71.33	71.66
TiO_2	0.79	0.92	0.85	0.85	0.85
Al_2O_3	13.64	14.13	13.80	14.44	14.00
FeO*	4.62	4.56	4.45	4.55	4.55
MnO	0.00	0.09	0.00	0.00	0.02
MgO	2.44	2.58	2.45	2.52	2.50
CaO	2.66	2.61	2.70	2.90	2.72
Na_2O	1.18	1.01	1.31	1.17	1.17
K_2O	2.61	2.69	2.59	2.65	2.64
Total	99.56	100.11	100.32	100.42	100.11

Table 2. Chemical composition of tektite C.

	1	2	3	4	5	6	Average
SiO_2	71.41	72.12	72.91	72.72	71.93	71.97	72.18
TiO_2	0.79	0.76	0.73	0.75	0.74	0.77	0.76
Al_2O_3	13.09	13.18	13.13	13.55	13.40	13.74	13.35
FeO*	4.53	4.30	4.41	4.25	4.48	4.63	4.43
MnO	0.06	0.06	0.05	0.06	0.06	0.07	0.06
MgO	2.48	2.24	2.27	2.33	2.48	2.34	2.36
CaO	2.78	2.88	2.96	2.71	2.72	2.98	2.84
Na_2O	1.47	1.38	1.56	1.58	1.73	1.58	1.55
K_2O	2.57	2.56	2.56	2.65	2.57	2.61	2.59
Total	99.19	99.48	100.57	100.60	100.12	100.70	100.12

FeO*: Total iron as FeO.

A



B

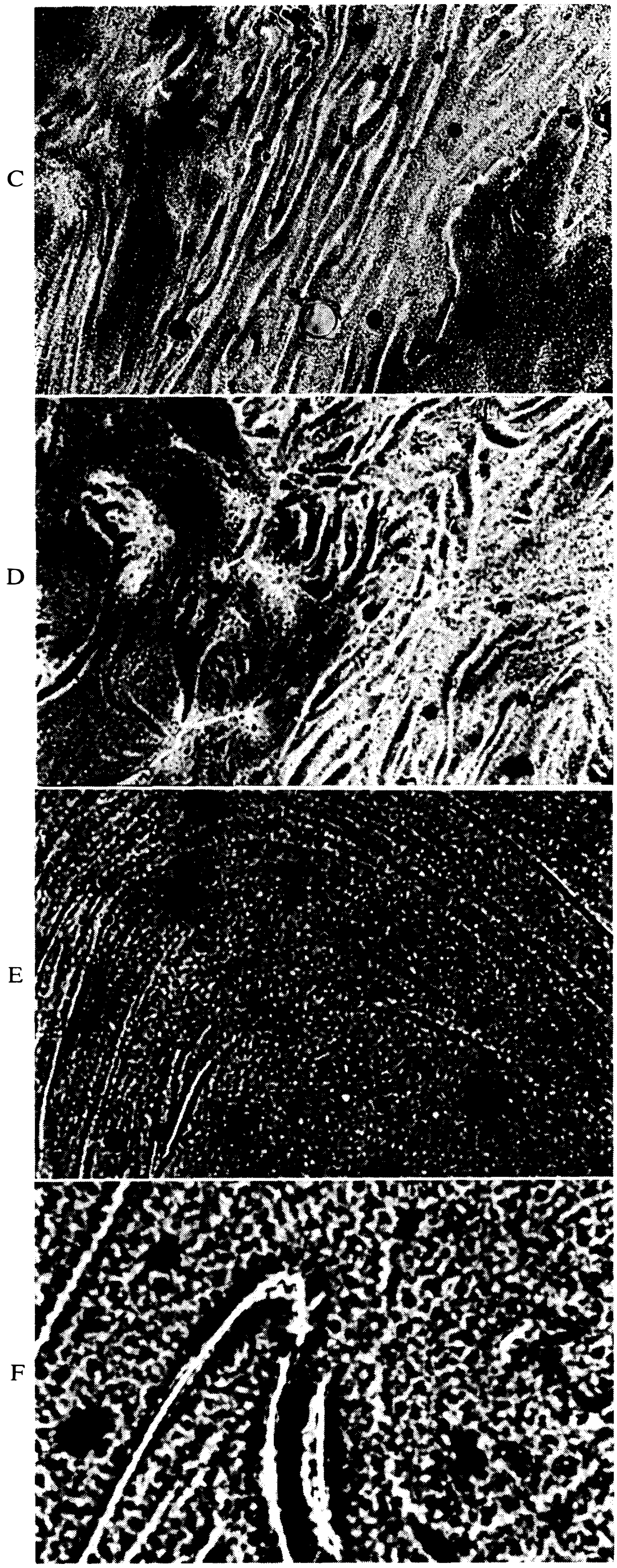


Fig. 1. *Photomicrographs of Muong Nong-type tektites and an indochinite. Width of all figures is 0.7 mm.*

A. Tektite A. Fine flow structure is well-developed. Several vesicules are present.

B. Tektite B. Conspicuous development of radiating bands in various directions. Dark parts represent pale brown patches.

C. Tektite B. Nearly parallel bands. Vesicules are present. Note that the brown patches are roughly parallel to the banding.

D. Tektite B. Note that the brown patches are cut through by many complicated lenticules.

E. Tektite C. Fine curved laminar structure in a homogeneous matrix.

F. Tektite G. Only few lenticules are present in a homogeneous matrix.

Table 3. Chemical composition of tektite B.

	1	3	5	7	Average
SiO_2	82.18	81.26	81.02	81.18	81.41
TiO_2	0.69	0.70	0.66	0.66	0.68
Al_2O_3	9.69	9.42	9.47	8.87	9.36
FeO*	3.59	3.26	3.47	3.18	3.38
MnO	0.00	0.10	0.00	0.05	0.04
MgO	1.62	1.68	1.68	1.40	1.60
CaO	1.01	0.94	0.97	0.98	0.98
Na_2O	0.67	0.51	0.49	0.56	0.56
K_2O	2.20	2.19	2.11	2.15	2.16
Total	101.65	100.07	99.86	99.04	100.17
	2	4	6	Average	Overall average
SiO_2	80.44	79.76	77.97	79.39	80.40
TiO_2	0.73	0.73	0.76	0.74	0.71
Al_2O_3	10.34	10.77	11.34	10.82	10.09
FeO*	3.67	3.30	3.73	3.57	3.48
MnO	0.09	0.06	0.12	0.09	0.07
MgO	1.68	1.83	1.64	1.72	1.66
CaO	0.86	1.22	1.00	1.03	1.00
Na_2O	0.64	0.70	0.53	0.62	0.59
K_2O	2.29	2.32	2.35	2.32	2.24
Total	100.74	100.69	99.44	100.30	100.17

1, 3, 5 and 7: Pale brown-colored patches. Average is given as B_P in Fig. 2.
2, 4 and 6: Colorless matrix. Average is given as B_M in Fig. 2.

Table 4. Chemical composition of tektites.

	A	B	C	D	E	F	G
SiO_2	71.66	80.40	72.18	71.65	74.21	82.13	74.40
TiO_2	0.85	0.71	0.76	0.72	0.66	0.51	0.73
Al_2O_3	14.00	10.09	13.35	13.75	12.45	9.09	13.41
FeO*	4.55	3.48	4.43	4.51	4.30	3.08	4.38
MnO	0.02	0.07	0.06	0.06	0.01	0.03	0.05
MgO	2.50	1.66	2.36	2.32	2.28	1.23	2.15
CaO	2.72	1.00	2.84	2.70	2.13	0.99	1.99
Na_2O	1.17	0.59	1.55	1.49	1.21	0.89	1.15
K_2O	2.64	2.24	2.59	2.69	2.60	2.30	2.43
Total	100.11	100.17	100.12	99.89	99.85	100.25	100.69

reaches 2.0% in SiO_2 and 1.4% in Al_2O_3. However, the total FeO content is almost the same, and the reason for the difference in color is not clear. Overall average composition of B is used in Tables 4 and 5. A normal indochinite was also analyzed for comparison.

It is remarkable that there is a wide range in chemical composition of these Muong Nong-type tektites, from 71 to 82% SiO_2. This range covers almost the whole range in composition observed in all kinds of tektites. In spite of their similar appearance and limited localities, this wide difference in composition is quite noteworthy.

Table 5. Comparison of chemical composition of tektites and various rocks.

	Tektite			Terrest. granite	Lunar granite	Shale + quartz**
	A	B	F			
SiO_2	71.66	80.40	82.13	74.22	76.2	73.24
TiO_2	0.85	0.71	0.51	0.20	0.5	0.54
Al_2O_3	14.00	10.09	9.09	13.61	11.6	12.79
FeO*	4.55	3.48	3.08	1.83	2.6	5.04
MnO	0.02	0.07	0.03	0.05	0.0	0.08
MgO	2.50	1.66	1.23	0.27	0.3	2.62
CaO	2.72	1.00	0.99	0.71	1.8	2.57
Na_2O	1.17	0.59	0.89	3.48	0.4	1.08
K_2O	2.64	2.24	2.30	5.06	6.6	2.69
P_2O_5	0.00	0.00	0.00	0.14	0.0	0.12
Total	100.11	100.17	100.25	99.57	100.0	100.77

** After TAYLOR (1962).

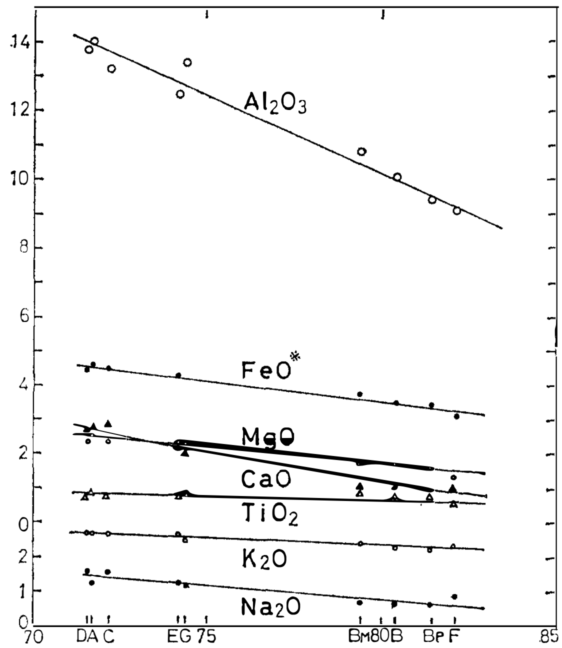


Fig. 2. Variation diagrams for the six analyzed Muong Nong-type tektites and an indochinite.

The variation diagrams of these tektites are given in Fig. 2. In igneous rocks some constituents increase with increasing SiO_2 content, and variation may be curvilinear. Exactly the opposite is true in the Muong Nong-type tektites. The constituents always decrease with increasing SiO_2 content, and the variation is represented by almost straight lines. These characteristics may support that these tektites represent the results of mixing of shaly rocks with highly siliceous material, rather than the results of differentiation from a magma. The wide range probably indicates the inhomogeneity in the resulted mixture.

When compared with the variation diagrams for indochinites (BARNES, 1964), SiO_2 content covers nearly the same range, and the lines for Al_2O_3 and K_2O are almost identical with his lines. Those for CaO and MgO are higher, however, and those for Na_2O and total FeO are slightly lower than his lines. BARNES reported that, contrary to Muong Nong-type tektites, normal indochinites are very similar, showing less than 3% SiO_2 range. Sample G also falls within this range.

The average composition of these tektites is compared with that of the terrestrial and lunar granites, and also a mixture of shale and quartz given by TAYLOR (1962). It is noted that some Muong Nong-type tektites are close to the last in composition, whereas they are much different from both the terrestrial and lunar granites.

5. Water Content and D/H Ratio

Determination of water content in the tektites was performed by the dehydration technique using high-frequency induction heating. A finely powdered sample was melted in a high-frequency induction furnace in vacuum. The evolved water was passed over hot uranium metal (700°C), and was converted to molecular hydrogen. H_2O content was determined by measuring the volume of the hydrogen. Then the isotopic composition of hydrogen was measured by a mass spectrometer, MAT 250.

D/H ratio is presented by the following expression:

$$\delta D(‰)=\frac{(D/H)_{sample}-(D/H)_{SMOW}}{(D/H)_{SMOW}}\times 1000.$$

During our experiment it was noticed that the H_2O content determined increased with decreasing grain size of the analyzed sample, and a maximum value was obtained in the finest grains. We do not believe that atmospheric moisture is a serious contaminant in these samples. This is supported by the observation that water was not evolved below *ca.* 300°C. This may rule out adsorbed water. Therefore the H_2O contents of the finest grains are given in Table 6. We suspect that the water may be very tightly combined with the structure of tektite glass.

FRIEDMAN (1958) showed that water in tektites is at the level of 0.01% or less, which is smaller by one order than our results, although the δD of the present tektites are in the same range of his values. These values are also similar to δD of natural obsidians, which are $-45\sim-50$‰ (FRIEDMAN and SMITH, 1958).

Table 6. H_2O and δD content of tektite.

Tektite		SiO_2	H_2O wt%	δD ‰
Muong Nong-type	A	71.66	0.104	−59.3
	B	80.40	0.085	−69.3
	C	72.00	0.084	−59.4
	D	71.65	0.106	−56.4
	E	74.21	0.086	−71.4
	F	82.13	0.075	−69.4
	G	74.40	0.102	−79.2

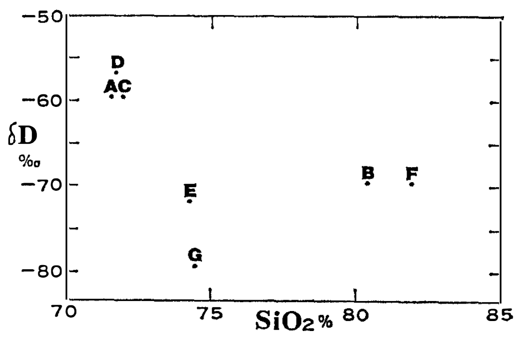


Fig. 3. Relation between δD (‰) and SiO_2 content of Muong Nong-type tektites and an indochinite.

FRIEDMAN *et al.* (1970) reported that water from a lunar breccia is 150~455 ppm and δD is $-580\sim-870$‰. It is apparent that δD in the Muong Nong-type tektites is much different from that of the lunar breccia. To the contrary it is rather similar to δD of common terrestrial rocks or clays.

Therefore, these experimental data favor their being originally terrestrial, and rule out the possibility of lunar origin of these tektites.

It was shown in some granitic rocks that δD of hornblende or biotite decreases with increasing SiO_2 content of the host rock (KURODA *et al.*, 1974). In the case of these tektites no such definite relation is observed when δD values are plotted against the SiO_2 content of the tektites (Fig. 3).

6. Fission-Track Age

For fission-track age dating two thin slices were made of one sample. After etching one slice by HF 46% solution, the spontaneous fission tracks were measured. Then the other slice was exposed to thermal neutrons together with a standard glass of known uranium content, and the induced tracks were counted. The uranium content of the tektite can be obtained by comparison with the standard glass. Thus, when spontaneous track density ρ_s and induced track density ρ_i are measured, the fission-track age A can be calculated from the following equation:

$$A=6.00\times10^{-8}\frac{\rho_s}{\rho_i}\phi,$$

where ϕ represents thermal neutron per unit.

Table 7. Fission-track age data of tektite.

	ρ_s Spon. fiss.-track dens. $\times10^2$/cm^2	ρ_i Induced fiss.-track dens. $\times10^4$/cm^2	ϕ Neutron fluence $\times10^{15}$ n/cm^2	Age 10^6 year	U wt ppm
A	3.49	8.71	2.81	0.68	1.6
B	3.68	5.84	1.73	0.65	1.7
C	3.97	9.25	2.71	0.70	1.7
D	3.50	8.48	2.69	0.67	1.6
E	3.59	5.55	1.74	0.68	1.6
F	3.47	6.10	1.91	0.65	1.6
G	3.38	7.97	2.63	0.67	1.6

The results are given in Table 7. Average uranium content is 1.6 ppm. The average fission-track ages are about 0.67 Ma for both Muong Nong-type tektites and the indochinite.

FLEISCHER *et al.* (1969) reported the fission-track ages of Muong Nong-type tektites from Thailand to be 0.78 and 0.45 Ma, and GENTNER *et al.* (1969) determined the fission-track ages of Muong Nong-type tektites from Laos to be 0.61~0.71 Ma and 0.66~0.74 Ma. Recently NISHIMURA (1981) determined the fission-track age of a tektite obtained from the base of the Kabu Formation in central Java to be 0.67 Ma. Thus the present results are in good agreement with these reported fission-track ages as well as K-Ar ages of the tektites from the Southeastern Asian strewn-field determined by GENTNER and ZÄHRINGER (1960) and MCDOUGALL and LOVERING (1969).

7. Summary and Conclusions

Flow structure composed of fine banded layers of lenticules is well-developed in all the Muong Nong-type tektites. Microlites are completely absent. Chemical composition covers a wide range in the Muong Nong-type tektites, almost corresponding to the whole range of all kinds of tektites.

H_2O content ranges from 0.084 to 0.106%, and δD from -56.4 to $-71.4‰$. These values favor the tektites being terrestrial in origin. Fission-track ages are $0.65 \sim 0.70$ Ma.

From these observations it is concluded that these Muong Nong-type tektites were formed by fusion of mixtures of shaly rocks with highly siliceous material, probably sandstone or chert.

Acknowledgments

We are greatly indebted to Mr. D. S. FUTRELL for the valuable samples of the Muong Nong-type tektites, and to Prof. K. AOKI and Dr. H. FUJIMAKI of Tohoku University for their help in the EPMA analysis. Thanks are also due to the staffs of the Institute for Atomic Energy, Rikkyo University for the operation of the reactor and to the Rikkyo Reactor Committee of University of Tokyo for financial support.

References

BARNES, V. E. (1964): Variation of petrographic and chemical characteristics of indochinite tektites within their strewn-field. Geochim. Cosmochim. Acta, **28**, 893–913.

FLEISCHER, R. L., PRICE, P. B., VIERTL, J. R. M. and WOOD, R. T. (1969): Age of Darwin glass, Macedon glass, and Far Eastern tektites. Geochim. Cosmochim. Acta, **33**, 1017–1074.

FRIEDMAN, I. (1958): The water, deuterium, gas and uranium content of tektites. Geochim. Cosmochim. Acta, **14**, 316–322.

FRIEDMAN, I. and SMITH, R. L. (1958): The deuterium content of water in some volcanic glasses. Geochim. Cosmochim. Acta, **15**, 218–228.

FRIEDMAN, I., O'NEIL, J. R., ADAMI, L. H., GLEASON, J. D. and HARDCASTLE, K. (1970): Water, hydrogen, deuterium, carbon, carbon-13, and oxygen-18 content of selected lunar material. Science, **167**, 538–540.

GENTNER, W. and ZÄHRINGER, J. (1960): Das Kalium-Argon Alter von Tektiten. Z. Naturforsch., **15a**, 93–102.

GENTNER, W., STORZER, D. and WAGNER, G. A. (1969): New fission-track ages of tektites and related glasses. Geochim. Cosmochim. Acta, **33**, 1075–1081.

KURODA, Y., SUZUOKI, T., MATSUO, S. and KANISAWA, S. (1974): D/H fractionation of coexisting biotite and hornblende in some granitic rock masses. Ganseki Kôbutsu Kôshô Gakkaishi (J. Jap. Assoc. Mineral. Petrol. Econ. Geol.), **69**, 95–102.

MCDOUGALL, I. and LOVERING, J. F. (1969): Apparent K-Ar dates on cores, and excess Ar in flanges of australites. Geochim. Cosmochim. Acta, **33**, 1057–1070.

NISHIMURA, S. (1981): On the fission-track dating of tuffs and volcanic ashes. Nucl. Tracks, **5**, 157–167.

O'KEEFE, J. A. and ADLER, I. (1966): Lunar structures as deduced from Muong Nong tektites. Proc. Lunar Sci. Conf., 92–101.

TAYLOR, S. R. (1962): The chemical composition of australites. Geochim. Cosmochim. Acta, **26**, 685–722.

(*Received May 31, 1982*)