VOLCANIC ASH IN DIRT LAYERS FROM THE ALLAN HILLS BARE ICE AREA IN VICTORIA LAND, ANTARCTICA

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Abstract: Dirt layers were found in the Allan Hills bare ice area in Victoria Land, Antarctica. They contain volcanic ash consisting of abundant glass shards with subordinate crystal fragments of plagioclase, titanaugite, olivine, kaersutite, titanomagnetite, etc.

Tephra samples collected from each of 8 dirt layers are classified into three groups based on the petrography, morphology and major element chemistry. Moreover, the major element chemistry of the glass shards indicates that these tephras comprise two rock series: one is evolved basanitoid series toward nephelinite, and the other basanitoid-trachybasalt-trachyte series. Accordingly, these tephras may have been derived from at least two different volcanoes. If the tephra sources are restricted to two volcanoes, the transportation distance of the tephras estimated from their grain size is less than 1000 km. This estimation suggests that the tephra sources are restricted within Victoria Land. The tephras of basanitoid-trachybasalt-trachyte are similar in composition to some of the lavas of Quaternary volcanoes in Victoria Land. However, the tephras of the evolved basanitoid are different in composition from any Quaternary volcanic rocks hitherto reported from Antarctica. It will probably be confirmed in the future that some volcanoes in Victoria Land erupted such basanitoid ejecta.

1. Introduction

Dirt layers were found in the Allan Hills bare ice area in Victoria Land, Antarctica (Fig. 1). On the surface of the bare ice, which is widely distributed up-glacier from nunataks, a large number of meteorites have been collected (SHIRAISHI, 1979; YANAI, 1981). The dirt layers gently dip up-glacier and vary from a few centimeters to about 15 cm in thickness. During the two austral summers in 1978–79 and 1979–80, one and nine ice samples were collected, respectively, from the dirt layers in this area by the joint U.S.-Japan meteorite search team (NISHIO and ANNEXSTAD, 1980). The dirt materials in all of the ice samples are composed of volcanic ash. Therefore, these dirt layers are tephra layers preserved in ice sheets. Many tephra layers have been found from both the ice surface of glaciers and the ice cores in Antarctica (*e.g.* GOW, 1963; GOW and WILLIAMSON, 1971; KEYS *et al.*, 1977; KYLE and JEZEK, 1978; KING and WAGSTAFF, 1980; KYLE *et al.*, 1981, 1982).

In the Allan Hills bare ice area, only one tephra sample was collected in the 1978–

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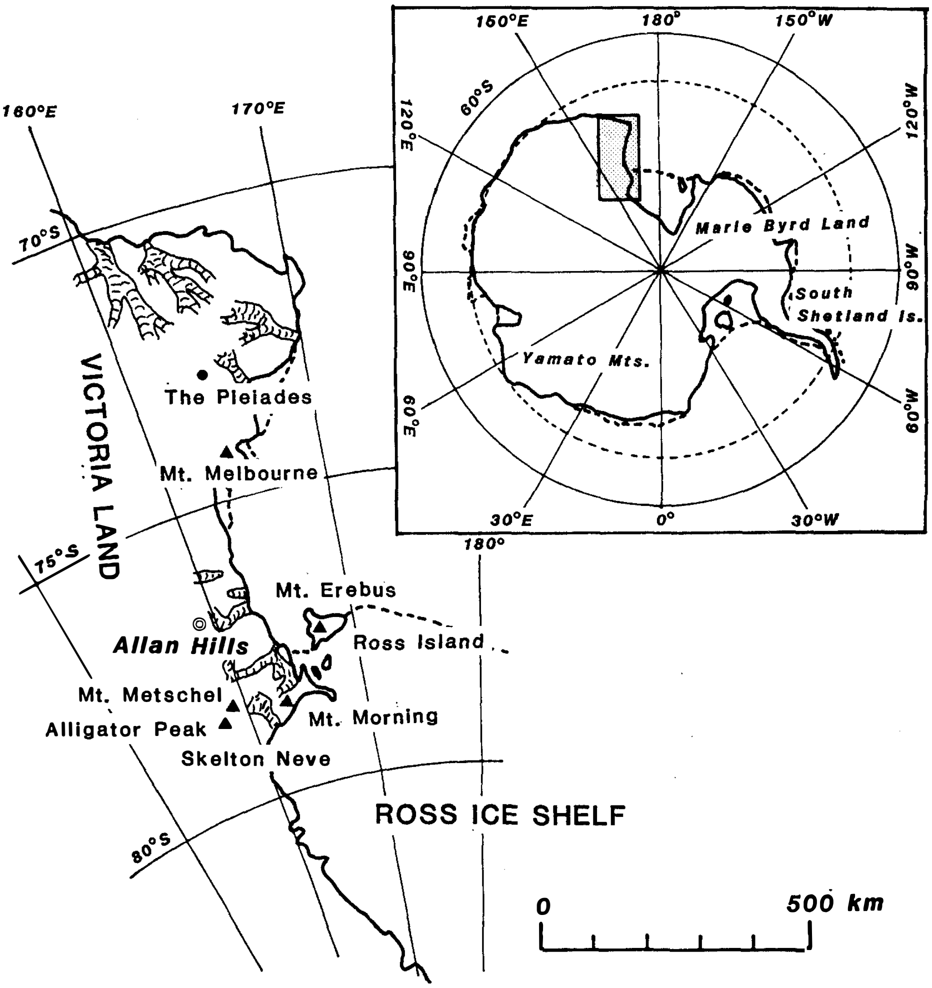

Fig. 1. Location map of the Allan Hills bare ice area and surrounding Quaternary volcanic provinces in Victoria Land, Antarctica.

79 summer and investigated petrographically and petrologically in comparison with the ash sample from the Yamato Mountains area by KATSUSHIMA *et al.* (1984). They described that the tephra collected from the Allan Hills area has a trachybasaltic composition, and suggested that its source may be some volcano of the McMurdo Volcanic Group. However, the mode of occurrence and distribution of the tephra layers in the Allan Hills have not been investigated.

In the 1979–80 summer, a field survey was made again in the Allan Hills area, where nine tephra layers were recognized, and from each of them tephra samples were collected. NISHIO *et al.* (1984) described the mode of occurrence of these tephra layers and discussed atmospheric transportation of the volcanic ash based on the grain size distribution of eight of the nine samples collected.

The present paper gives the petrography, morphology and major element chemistry of the same eight ash samples and discusses the character of the tephras. Moreover, their source areas are considered on the basis of their chemical features and grain size distributions.

2. Occurrence, Modal Composition and Petrography of Volcanic Ash

One sample was collected from each of the dirt layers. Their locations designated by ALH-1~ALH-9 are shown in Fig. 2 with the distribution of dirt layers. The samples used in this study are ALH-1 to -9 except for ALH-2. Stratigraphic relations are not always known for the eight dirt layers because of very limited outcrops. FIREMAN and NORRIS (1982) have determined the ^{14}C ages of the ice from this area and obtained the values of $2.5–12.3 \times 10^3$ years as shown in Fig. 2. They considered, however, that these values may be younger than the actual age due to the influence of the cosmic ray spallation of oxygen. On the other hand, NISHIO *et al.* (1982) estimated the age of the ice at approximately 2×10^4 years on the basis of fabric characteristics and grain size growth rate of depositional ice. Although any reliable age of the ice in this area has not yet been obtained, the tephra ages may date back to a few or several tens thousand years ago.

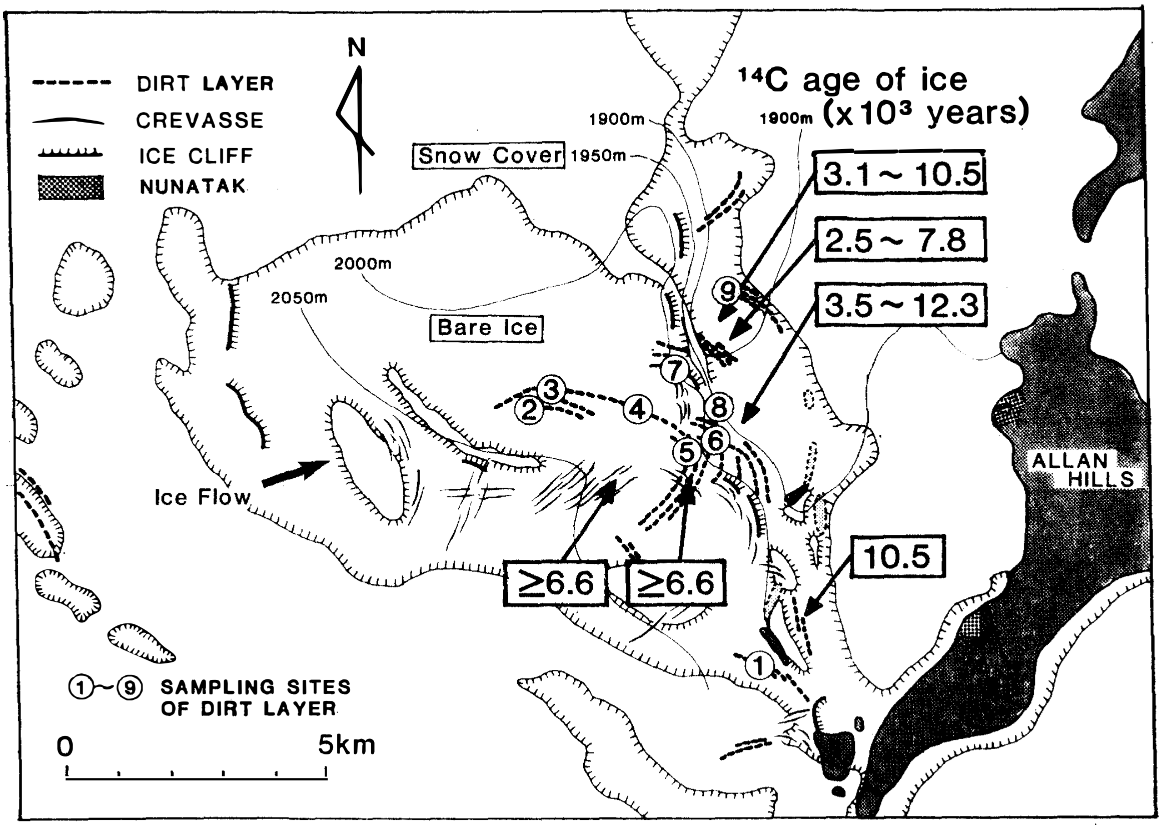

Fig. 2. Surface morphology and dirt layer distribution in the Allan Hills bare ice area. The open circles with numerals show the sample localities. The ^{14}C ages of ice (FIREMAN and NORRIS, 1982) are also indicated by arrows. The unit of age is 10^3 years.

After the collected ice samples were melted, the residual fragments were investigated using a polarization microscope and a scanning electron microscope. They are composed mainly of glass shards and subordinate amounts of crystal fragments. As described by NISHIO *et al.* (1984), their grain size distribution was determined on

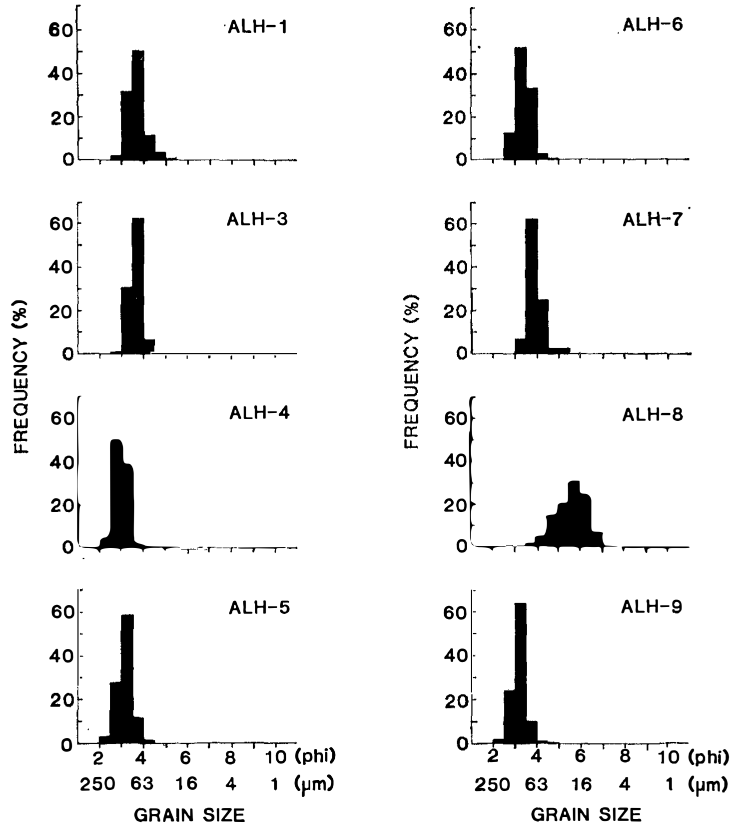

Fig. 3. Histograms of grain size distribution for the tephra samples measured on the scanning electron microscope (NISHIO et al., 1984). The percentage of particles of each grain size interval was computed assuming a circular cross section for the particles.

Table 1. Grain size of the volcanic ash in the dirt layers.

Sample No.	Grain size (µm) Mean	Maximum	Minimum
ALH-1	80	137	25
-3	80	131	47
-4	128	200	47
-5	112	210	54
-6	97	164	31
-7	69	123	18
-8	19	83	9
-9	109	189	36

the scanning electron microphotographs (Fig. 3). All of the tephras have a normal grain size distribution different from each other, and are well-sorted except sample ALH-8. Table 1 presents the mean, maximum and minimum diameters of the volcanic fragments in each sample. Based on the correlation diagram between grain size and atmospheric transportation obtained by NISHIO *et al.* (1984), it is suggested that samples ALH-4, -5, & -9 may have been transported for a distance of less than 1000 km, while ALH-1, -3, -6, & -7 less than 1500 km.

The modal analyses of the samples were carried out by counting more than one

Table 2. Modal compositions (%) of volcanic ash in dirt layers.

Sample No.	ALH-1	ALH-3	ALH-4	ALH-5	ALH-6	ALH-7	ALH-8	ALH-9
Glass shards	84.7	89.5	77.7	81.8	82.8	94.3	88.9	84.5
Type 1	34.4	23.6	1.5	5.2	5.3	53.9	75.6	34.7
Type 2	10.8	36.9	15.7	27.3	20.6	24.5	8.6	16.3
Type 3	39.4	28.9	58.4	48.4	55.9	16.0	4.7	33.3
Type 4	0.1	0.1	2.0	0.9	1.0	—	—	0.1
Crystal fragments	15.3	10.5	22.3	18.2	17.2	5.7	11.1	15.5
	(9.4)*	(8.1)	(14.7)	(12.5)	(11.8)	(4.6)	(5.7)	(9.5)
Feldspar	10.0	2.0	7.5	7.7	5.1	1.0	9.5	12.1
	(4.9)	(1.7)	(6.6)	(6.3)	(4.1)	(0.6)	(4.6)	(6.3)
Olivine	3.1	5.1	6.0	3.6	4.2	2.3	0.7	2.1
	(3.0)	(4.0)	(3.8)	(3.0)	(3.4)	(2.1)	(0.7)	(2.1)
Clinopyroxene	1.6	3.3	4.9	2.6	3.4	2.1	0.6	1.2
	(1.4)	(2.4)	(2.8)	(2.2)	(2.3)	(2.0)	(0.4)	(1.1)
Amphibole	—	—	3.4	2.7	2.0	—	0.2	—
			(1.1)	(0.5)	(0.5)			
Opaque mineral	0.3	0.1	0.6	0.6	2.2	0.2	0.1	0.1
	(0.1)	(0.1)	(0.4)	(0.5)	(1.6)	(0.1)		
Others	0.2	—	—	1.0	0.4	0.2	—	—

* Figures in parentheses indicate modal composition of crystal fragments with adherent glass.

thousand points each. The results are shown in Table 2. Glass shards are most dominant in all of the samples. They are classified into the following four types under the microscope:

type 1: colorless–pale brown sideromelane with a minor amount of crystallites and/or microlites,

type 2: pale brown–brown sideromelane with a large amount of crystallites and/or microlites,

type 3: dark brown–black opaque tachylite, and

type 4: orange–reddish or yellowish brown palagonite.

Crystal fragments occur with or without adherent glass. Those without adherent glass are generally scarcer and consist of the same kind of minerals as those with adherent glass. They consist of plagioclase, titanaugite, olivine, kaersutite, titanomagnetite, etc. Accidental materials derived from basement rocks have been scarcely observed in these samples. Their petrographical features are similar to those of the Allan ash which was described by KATSUSHIMA *et al.* (1984).

On the basis of the petrographical study these samples can be classified into three groups as follows:

(1) ALH-4, -5, & -6 include a large amount of tachylite, which may constitute more than half of the glass shards. They also characteristically include kaersutite and contain crystal fragments, especially mafic minerals, in greater amounts than other groups.

(2) ALH-1, -3, -7, & -9 contain variably the glass shards of types 1 to 3, and their crystal fragments are composed of plagioclase, olivine and titanaugite. Among them, ALH-1 and -9 are similar to each other in modal composition although they

are different in grain size. The two samples may be the lateral varieties of the same tephra.

(3) ALH-8 consists mostly of pale-colored sideromelanes without crystallites. Mafic minerals are scarce. Besides, a few colorless glass shards (trachytic) are also included. They are relatively fine-grained and flaky in shape.

Photomicrographs of the selected samples from each of the three groups are given in Fig. 4. This figure exhibits the distinctive characteristics of glass shards and crystal fragments of each group.

3. Morphological Features of Glass Shards

Figures 5–7 show selected scanning electron micrographs of the volcanic ash fragments from each of the above groups. In each figure, two of the three photographs are more enlarged to show morphological features of glass shards, which vary with groups as follows:

Samples ALH-4, -5, & -6 (group 1) are composed mainly of well-sorted equant glass fragments. They have hackly surfaces with subrounded edges and generally low vesicularity. Their vesicles are irregular-shaped and rough-walled (Fig. 5). ALH-1, -3, -7, & -9 (group 2) are composed mainly of well-sorted angular glass fragments. They have smooth surfaces with sharp edges. The vesicles are mainly spherical and rarely pod-like with very smooth walls (Fig. 6). ALH-8 (group 3) is composed of variable-sized glass shards with highly vesiculated bubble walls. They have spherical or elongated pipe-shaped vesicles with thin smooth walls (Fig. 7).

4. Major Element Chemistry of Glass Shards

Microprobe analyses of glass shards from each tephra were carried out using JEOL JCXA-733 at the National Institute of Polar Research with an acceleration voltage of 15 kV, a beam current of 0.013 μA and a beam diameter of 10 μm. Synthesized pure oxides and natural minerals were used for standards, with intensity data adjusted to BENCE and ALBEE's (1968) correction method. Moreover, the fused glass of the standard sample (JB-1) was also used for a cross check (Table 3).

Chemical compositions of glass shards in tephra may indicate the nature of the rock suite, because they correspond to the liquid compositions of the source magma at some stage of differentiation. Table 4 lists the average chemical compositions of the glass shards in each of the samples with standard deviation and CIPW norms. Analytical points range from 7 to 23. The average value is used as a representative composition of each sample in the following discussions.

As shown in Fig. 8, the average compositions of the glass shards plot in the alkaline field similarly to the volcanic rocks from Victoria Land and Marie Byrd Land in Antarctica. They can be divided into three groups on the basis of their chemistry. This division is consistent with the previous one by means of the petrographic and morphologic features of the volcanic ashes, as follows: ALH-4, -5, & -6 (group 1) are basanitoid with higher alkali and lower silica contents; ALH-1, -3, -7, & -9 (group 2) are basanitoid with lower alkali and higher silica; and ALH-8 (group 3) is trachybasalt

(a)
(b)
(c)

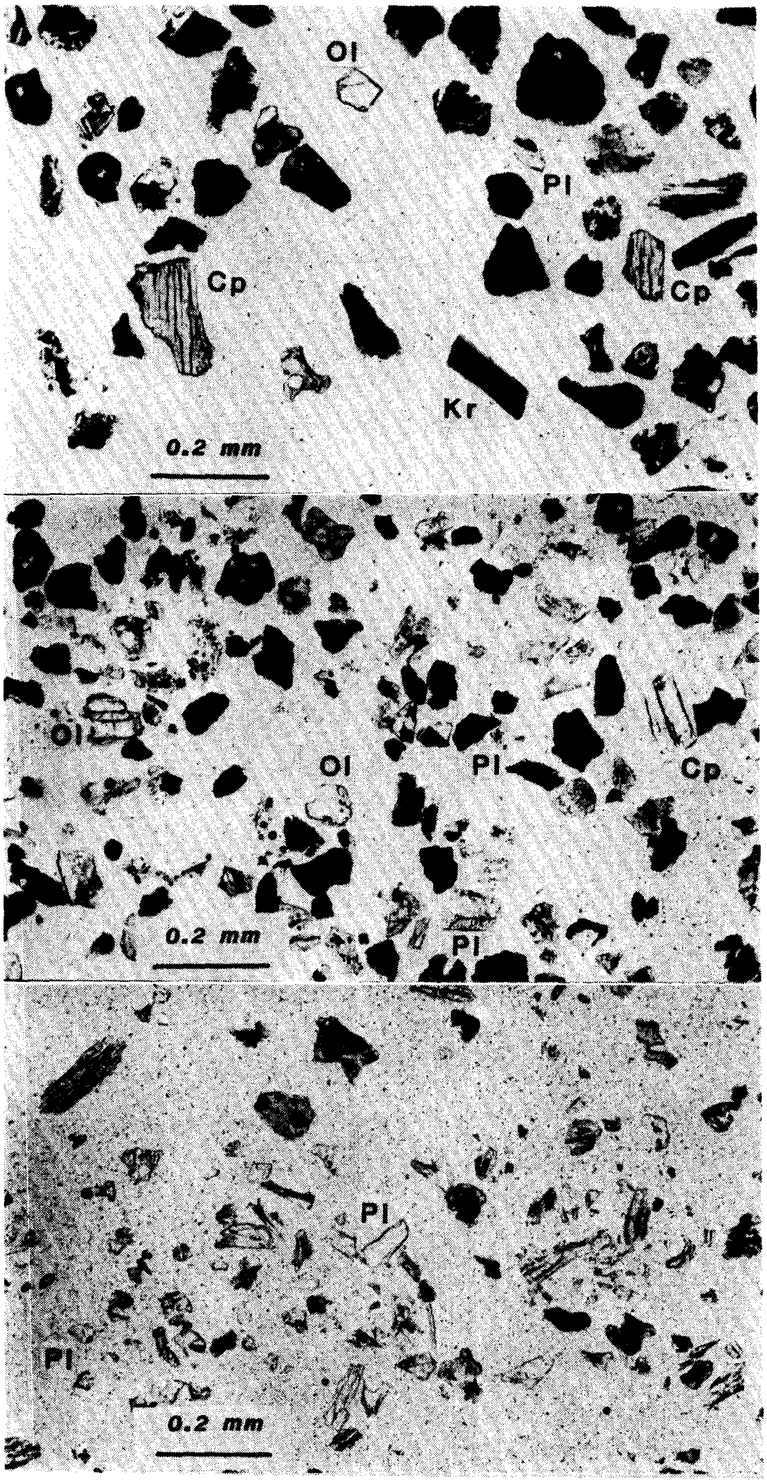

Fig. 4. Photomicrographs of the volcanic ash from each of the three groups. (a) ALH-4, consisting mainly of dark-colored tachylites with plagioclase laths and subordinate vesicular sideromelane and crystal fragments (Cp: titanaugite, Kr: kaersutite, Ol: olivine, and Pl: plagioclase). (b) ALH-1, consisting mainly of dark-colored tachylites and light-colored sideromelanes with gas bubbles and small amounts of crystals (Pl: plagioclase, Ol: olivine, Cp: titanaugite). (c) ALH-8, consisting of colorless to light-colored glass shards of various grain size with small amounts of plagioclase (Pl).

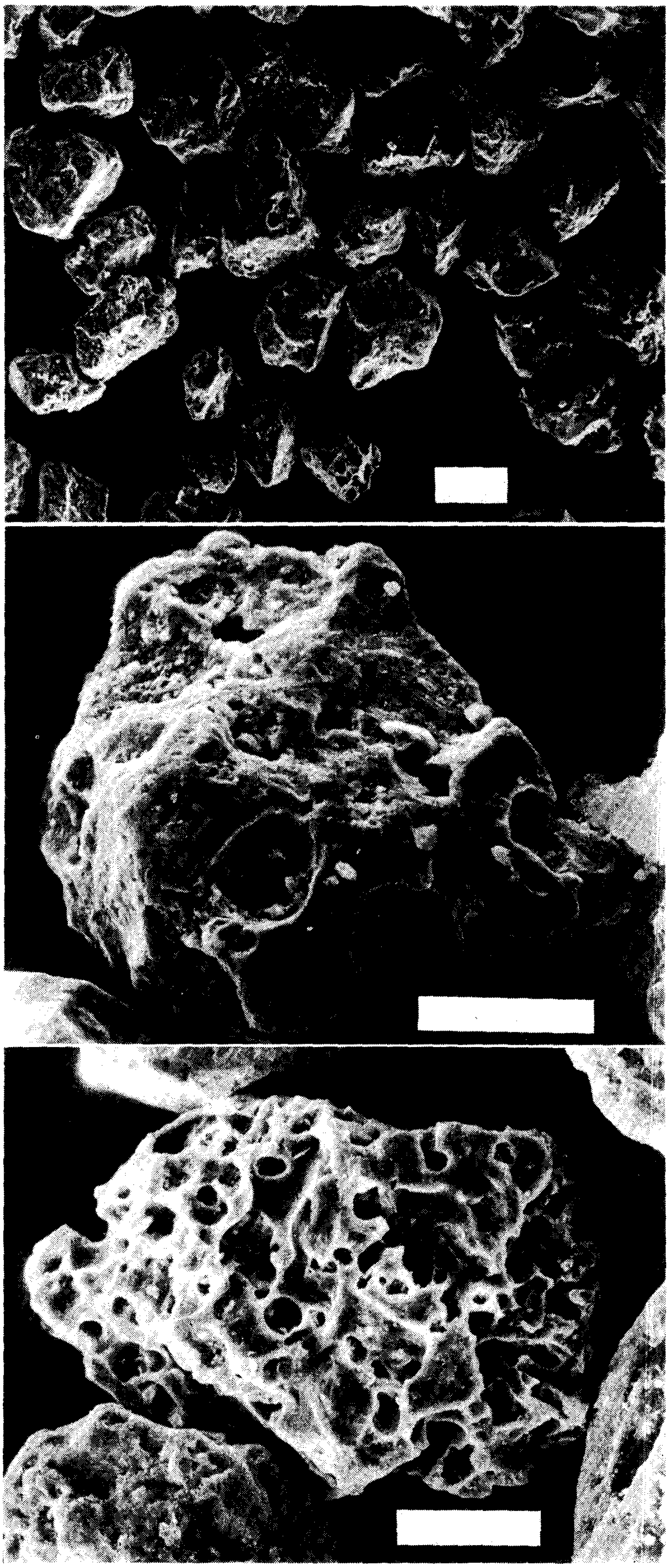

Fig. 5. Scanning electron microphotographs of sample ALH-4.

(a) Volcanic fragments (mainly glass shards). The scale is 100 μm.

(b) A glass shard with rough-walled vesicles. The scale is 50 μm.

(c) A glass shard with many irregular-shaped vesicles. The scale is 50 μm.

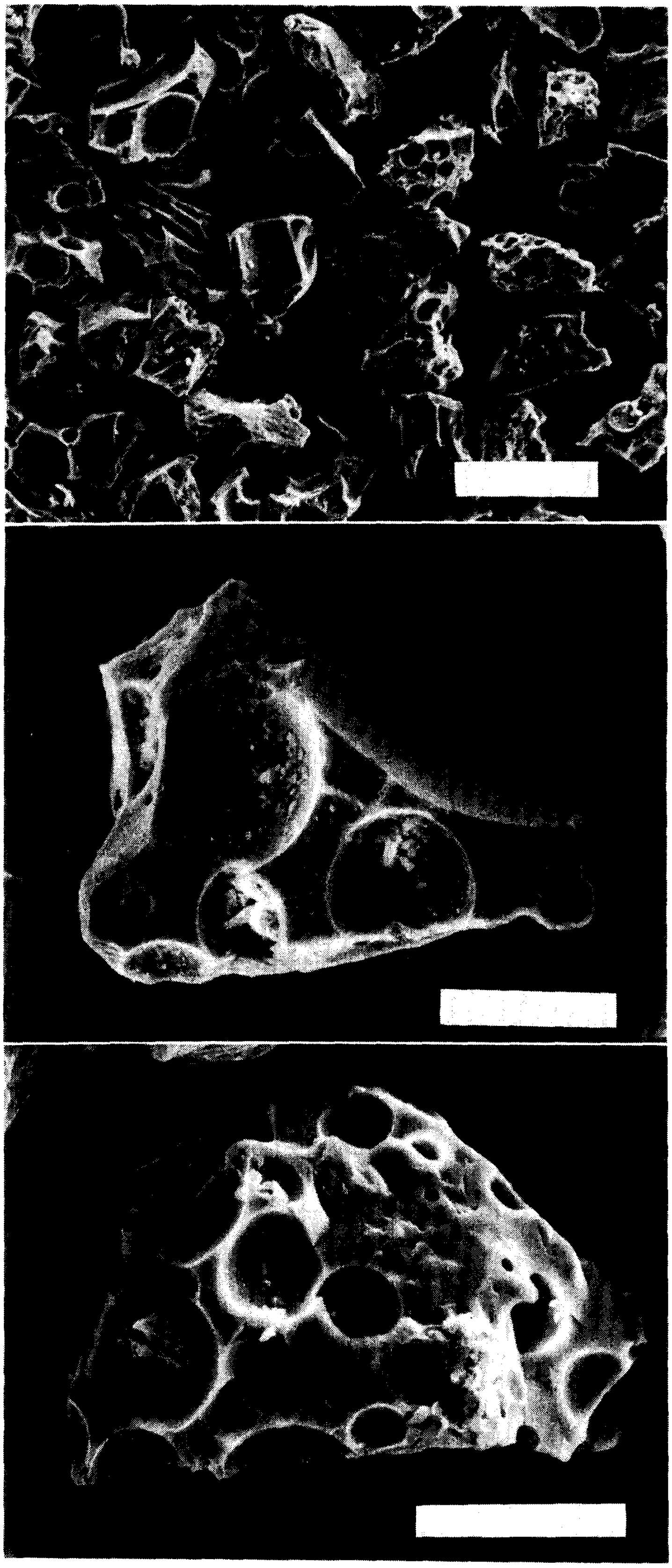

Fig. 6. Scanning electron microphotographs of samples ALH-7, -9, and -3.

(a) Volcanic fragments consisting mainly of glass shards (ALH-7). The scale is 100 μm.

(b) A glass shard with smooth vesicle wall (ALH-9). The scale is 50 μm.

(c) A glass shard with spherical vesicles (ALH-3). The scale is 50 μm.

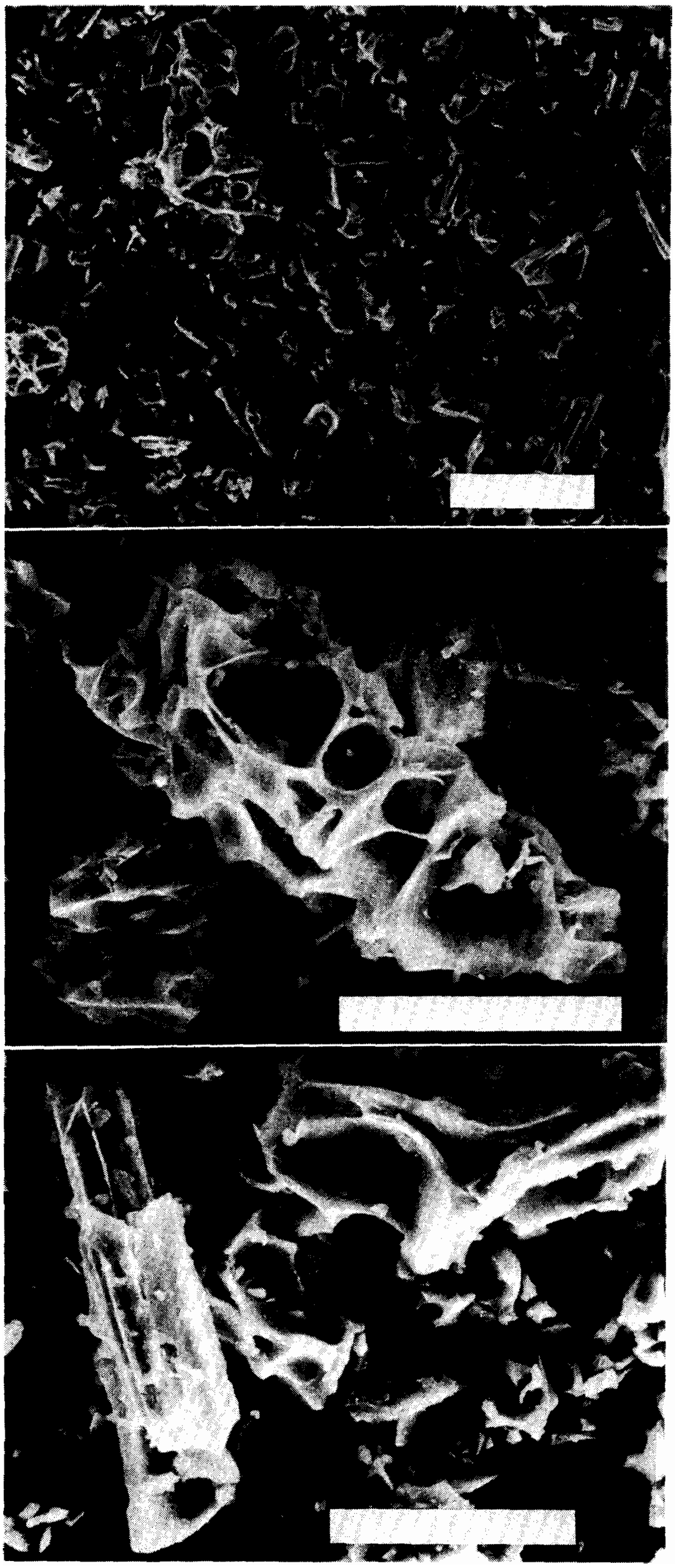

Fig. 7. Scanning electron microphotographs of sample ALH-8.

(a) Volcanic fragments (mostly glass shards). The scale is 100 μm.

(b) Highly vesicular glass shards. The scale is 50 μm.

(c) Two types of glass shards having spherical or elongated pipe-shaped vesicles. The scale is 50 μm.

Table 3. Precision of microprobe analysis.

	JB-1 (standard sample)	
	Recommended value**	Glass n=14 (σ)
SiO_2	53.33	53.80 (0.28)
TiO_2	1.37	1.37 (0.09)
Al_2O_3	14.85	14.78 (0.31)
Cr_2O_3	0.06	0.01 (0.01)
FeO*	8.28	8.14 (0.32)
MnO	0.15	0.16 (0.06)
MgO	7.91	8.10 (0.24)
CaO	9.44	9.10 (0.36)
Na_2O	2.86	2.90 (0.09)
K_2O	1.47	1.35 (0.11)
P_2O_5	0.27	0.27 (0.19)
NiO	—	0.05 (0.05)

* total iron as FeO. ** ANDO *et al.* (1974).
n: number of analyses. σ: standard deviation.

with relatively low alkali, and only has normative hypersthene. Although the analytical values are more or less dispersed especially in ALH-4, -5, & -6, none of the compositional fields of each group overlap each other.

The variation diagram of the major oxides *vs.* differentiation index (D.I. of THORNTON and TUTTLE, 1960) is shown in Fig. 9. The diagram includes two additional analyses of felsic glass shards (8′ and 8″ in Fig. 9) found in ALH-8, which are trachytic in composition and different from the averaged glass shards described before. The trachytic glass shards, however, are minor constituents of ALH-8. The group 2 glass shards (ALH-1, -3, -7, & -9) are clearly different from group 1 (ALH-4, -5, & -6) especially in SiO_2, TiO_2, P_2O_5 and alkali in the diagram. It is distinctly shown by ALH-1 and -6, which have the same D.I. The contrasting differentiation trends of the above two groups suggest that their source magmas are different from each other.

The analyses of two trachytic glass shards from ALH-8 together with the average ALH-8 plot on the extrapolated line of the variation trend for the group 2 glass shards (ALH-1, -3, -7, & -9). Therefore, the glass shard composition of ALH-8 and ALH-1, -3, -7, & -9 may represent a trend of basanitoid-trachybasalt-trachyte. On the other hand, the composition of ALH-4, -5, & -6 (group 1) represents an evolved basanitoid series toward nephelinite. Accordingly, the glass shards in the tephras of the present area are divided into the two rock series.

5. Discussion

5.1. Character of tephras

The volcanic ash samples in dirt layers from the Allan Hills bare ice area are well-sorted. They have individually different characteristic features in modal composition. The morphology and major element chemistry of their glass shards are also distinctive.

Table 4. Average chemical compositions of volcanic glass shards in dirt layers in the Allan Hills bare ice area.

Sp. No.	ALH-1 n=15 (σ)	ALH-3 n=16 (σ)	ALH-4 n=16 (σ)	ALH-5 n=23 (σ)	ALH-6 n=13 (σ)	ALH-7 n=11 (σ)	ALH-8† n=7 (σ)	ALH-9 n=22 (σ)
SiO_2	44.05 (0.43)	43.13 (0.61)	42.26 (1.33)	42.54 (2.05)	40.41 (1.38)	45.08 (0.57)	55.92 (0.84)	44.63 (0.60)
TiO_2	3.63 (0.11)	4.62 (0.35)	4.20 (0.74)	4.13 (0.71)	4.47 (0.48)	3.45 (0.21)	1.51 (0.18)	3.66 (0.16)
Al_2O_3	15.47 (0.16)	14.25 (0.45)	15.81 (1.58)	16.17 (1.37)	14.90 (0.51)	15.76 (0.46)	16.05 (0.47)	15.78 (0.47)
Cr_2O_3	0.01 (0.01)	0.01 (0.02)	0.01 (0.02)	0.02 (0.03)	0.02 (0.02)	0.01 (0.02)	0.02 (0.01)	0.00 (0.00)
FeO*	10.35 (0.36)	12.66 (0.66)	11.27 (1.69)	10.73 (1.75)	11.07 (1.20)	10.45 (0.76)	7.63 (0.69)	10.33 (0.51)
MnO	0.19 (0.05)	0.21 (0.05)	0.25 (0.06)	0.22 (0.07)	0.25 (0.04)	0.21 (0.05)	0.18 (0.05)	0.18 (0.05)
MgO	5.39 (0.22)	5.74 (0.45)	4.28 (0.53)	4.74 (0.80)	5.00 (0.52)	5.32 (0.39)	1.55 (0.24)	5.47 (0.36)
CaO	10.85 (0.36)	12.00 (0.54)	9.46 (1.59)	10.48 (1.50)	11.48 (1.29)	11.23 (0.58)	4.28 (0.44)	11.51 (0.55)
Na_2O	4.18 (0.15)	3.53 (0.33)	5.25 (0.96)	4.99 (0.83)	4.47 (0.65)	4.14 (0.27)	5.49 (0.36)	4.14 (0.24)
K_2O	1.51 (0.11)	1.15 (0.18)	2.42 (0.59)	2.20 (0.58)	2.23 (0.26)	1.57 (0.21)	3.43 (0.16)	1.50 (0.25)
P_2O_5	0.92 (0.33)	0.59 (0.34)	1.56 (0.47)	1.70 (0.65)	1.61 (0.43)	0.65 (0.21)	0.54 (0.22)	0.81 (0.32)
NiO	0.05 (0.05)	0.03 (0.02)	0.03 (0.03)	0.03 (0.04)	0.04 (0.04)	0.01 (0.02)	0.02 (0.03)	0.03 (0.04)
Total	96.60	97.92	96.80	97.95	95.95	97.88	96.62	98.04
				CIPW norm**				
or	8.92	6.80	14.30	13.00	13.18	9.28	20.27	8.86
ab	15.68	12.63	10.72	10.21	3.51	14.72	46.45	14.04
an	18.99	19.64	12.43	15.23	14.01	19.78	9.02	20.04
ne	10.67	9.34	18.26	17.34	18.59	11.00	—	11.37
di	23.31	29.20	19.81	20.78	26.21	25.66	7.32	25.66
hy	—	—	—	—	—	—	5.87	—
ol	6.08	5.39	5.44	5.53	4.03	5.44	0.66	5.34
mt	4.18	5.10	4.54	4.33	4.46	4.21	3.08	4.16
cm	0.01	0.01	0.01	0.03	0.03	0.01	0.03	0.00
il	6.91	8.79	7.99	7.86	8.51	6.56	2.87	6.96
ap	2.13	1.37	3.61	3.94	3.73	1.51	1.25	1.88
D.I.	35.3	28.8	43.3	40.6	35.3	35.0	66.7	34.3

* FeO = total Fe as FeO. ** for norm calculations, Fe_2O_3 standardized at 0.25 × FeO*. n: number of individual analyses. σ: standard deviation. D.I.: differentiation index. † Besides, two additional analyses of trachytic glass shards were obtained. They are not listed in this table but plotted in Fig. 9 (plots of 8′ and 8″).

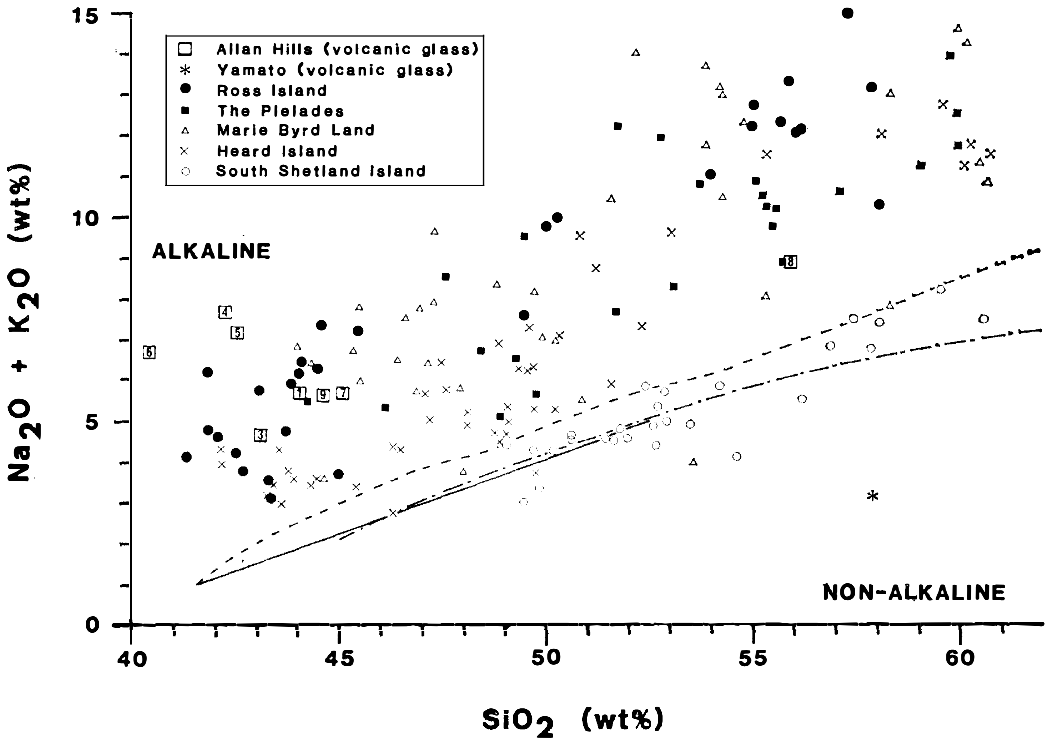

Fig. 8. Na_2O+K_2O vs. SiO_2 diagram of analyzed glass shards from the tephra layers in the Allan Hills bare ice area. The numerals with open square show the sample numbers (ALH-1-9). Shown for comparison are compositions of the Yamato ash (KATSUSHIMA et al., 1984) and the Cenozoic volcanic rocks from Ross Island (GOLDICH et al., 1975), The Pleiades (KYLE, 1982), Marie Byrd Land (GONZÁLEZ-FERRÁN and VERGARA, 1972), Heard Island (STEPHENSON, 1972), and the South Shetland Islands (GONZÁLEZ-FERRÁN and KATSUI, 1970; WEAVER et al., 1982). The boundaries between alkaline and non-alkaline fields are shown by solid (MACDONALD and KATSURA, 1964), chain (MIYASHIRO, 1978) and broken lines (GONZÁLEZ-FERRÁN, 1982).

Therefore, each of the dirt layers, except the layer of ALH-8, may represent a single fall unit of tephra which precipitated on the surface of the ice sheet.

Sample ALH-8 contains glass shards having various composition and wide grain size distribution, which suggests that the layer of ALH-8 consists of multiple fall units of tephras. However, these glass shards belong to the same rock series of trachybasalt-trachyte, suggesting that they may be the products of one cycle of eruption within a short period.

5.2. *Source of tephras*

The major element chemistry of the glass shards indicates that the present tephras comprise two rock series: evolved basanitoid series toward nephelinite (ALH-4, -5, & -6), and basanitoid-trachybasalt-trachyte series (ALH-1, -3, -7, -8, & -9). Therefore, the tephra sources are estimated to be two different volcanoes at least. On the other hand, the grain size analyses suggest that ALH-4, -5, & -9 may have been transported for a distance of less than 1000 km, and ALH-1, -3, -6, & -7 less than 1500 km. Accordingly, if all of the present tephras have been derived from only two volcanoes, the distance of atmospheric transportation of these tephras might be less than 1000

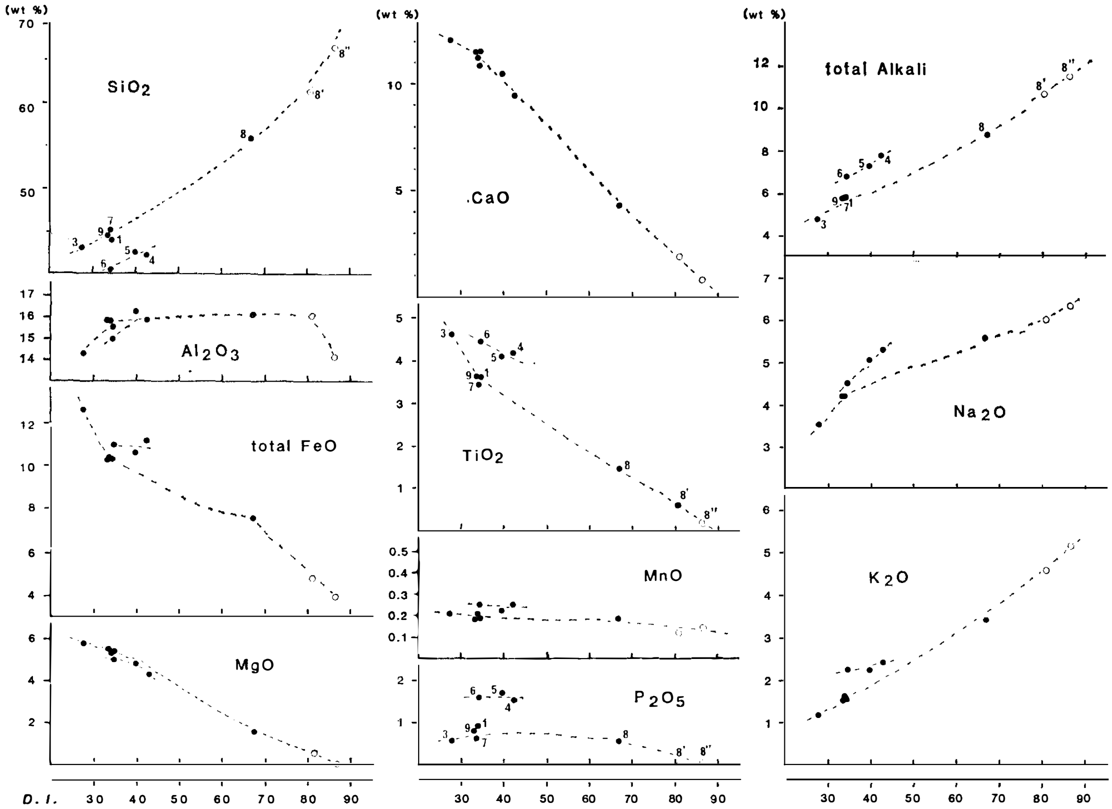

Fig. 9. Oxides variation diagram vs. differentiation index for the glass shards in the tephra layers in the Allan Hills bare ice area. Solid circle: averaged chemical composition. Plot of ALH-8 shows the average value excluding compositions of a few felsic glass shards. Open circle (8′ & 8″): felsic glass shards rarely included in ALH-8.

km. This estimation suggests that the source of the tephras is restricted within Victoria Land, where a number of Quaternary volcanic centers are distributed, especially in the McMurdo Sound region and around Mt. Melbourne.

Although it is uncertain whether the trachybasalt-trachyte glass shards of ALH-8 (group 3) are the evolved products from the basanitoid magma which supplied the basanitoid glass shards of ALH-1, -3, -7, & -9 (group 2), glass shards of both groups have a similar composition to some of the volcanic rocks from The Pleiades as shown in Fig. 8. Basanitoids having similar chemical features to the latter group occur also in other areas of Victoria Land. The tephras in the Skelton Névé and Kempe Glacier described by KEYS *et al.* (1977) also contain similar basanitoid glass shards though they have higher MgO contents. Their source has not yet been specified but may be considered to be Alligator Peak, a nearby volcano, because of their chemical similarity (PALAIS, personal communication). It is worthy of note, however, that the tephras in the Skelton Névé and Kempe Glacier have a very similar composition to those from the Allan Hills area, rather than to the rocks of Alligator Peak.

On the other hand, the basanitoids with the compositions similar to those of ALH-4, -5, & -6 (group 1) have not yet been reported from Antarctica. However, it will be confirmed in the future that some volcanoes in Victoria Land erupted such basanitoid ejecta. Further petrological investigations on the Quaternary volcanic rocks in Antarctica are necessary before the source volcanoes of the tephras in this area are specified.

6. Conclusion

1) Each of the dirt layers in the Allan Hills bare ice area represents a single fall unit of tephra which precipitated on the surface of the ice sheet.

2) Tephra samples from each of the eight tephra layers in this area have different characteristic features individually and are classified into three groups on the basis of their petrography, morphology and major element chemistry.

3) The major element chemistry of the glass shards indicates that these tephras comprise two rock series: one is evolved basanitoid series toward nephelinite, and the other basanitoid-trachybasalt-trachyte series.

4) On the basis of the grain size distributions and the chemical features of the tephras, their sources are estimated to be at least two different volcanoes within Victoria Land.

5) The tephras of basanitoid-trachybasalt-trachyte are similar in composition to some of the lavas of Quaternary volcanoes in Victoria Land. However, the tephras of the evolved basanitoid are different in composition from any Quarternary volcanic rocks hitherto reported from Antarctica. It will be confirmed in the future that some volcanoes in Victoria Land erupted such basanitoid ejecta.

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