Catalog Preparation of Tephras in Kyushu

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There are more than ten volcanoes, active and extinct, including three major ones, Aso, Kirishima, and Sakurajima, in Kyushu. A variety of tephras, i.e. volcanic ash, pumice, scoria, and pyroclastic flow deposit erupted from them, cover an area of 8800 km^2, which is approximately 20% of the whole area of Kyushu except Okinawa.[1] Especially in southern half of Kyushu, about 30% of total land area is covered with some kinds of tephras.

Properties of tephras are different with sources of eruption. Ejecta from Kuju or Unzen, for example, has andesitic composition with biotite and hornblende,[8] that from Aso, Sakurajima, and Kaimon is also andesitic but with augite,[8] and highly glassy volcanic ash from the Kikai caldera called Akahoya is rhyolitic.[6] On the other hand, although the composition of both ashes erupted from Sakurajima and Aso are augite-andesitic, the latter contains more heavy minerals and brown glasses with higher refractive indices. Accordingly, the latter contains more cations and the acidity is less than the former.[6] Furthermore, properties of deposits from the same source change with different stages of eruption as described on Sakurajima lavas[21]

Generally, tephras are to be considered not as soils but as parent materials of soils. In many cases, however, agriculture is performed directly on tephra layers because they form plowed horizons, and the properties of tephras affect on the agricultural techniques and productivities of the areas. Also, characteristics of tephras exert definite effects on pattern of weathering, and hence, on properties of soils derived from them: the chemical and physical peculiarities of tephras are strongly inherited by soils. Aomine[3] made a review on the distribution and limiting factors for agricultural productivity of pyroclastic soils in Kyushu.

For the reclamation of areas covered with various layers of tephras, therefore, the knowledges on distribution of tephras are especially important in predicting the properties of the soil which will become a plowed horizon after the reclamation.

Thus the identification of tephras and knowledges on their distribution and characteristics are indispensable for increasing agricultural productivity.

Problems related to tephra identification

Stratigraphic survey with the aid of some additional techniques such as primary mineral inspection has been the principal means for tephra identification. There are, however, about 200 volcanoes in Japan and more than 10 in Kyushu and numerous kinds of tephras from them exist complicatedly. It is probable that different tephras have similar features or the same tephra shows different appearances because of differences in grain size, environments of deposition, and/or the degree of weathering. Disturbance by erosion and translocation also causes more difficulties in identifying them. Exact identification by the routine method is thus rather difficult.

In Kyushu, stratigraphic survey of tephras has already been accomplished in fields of geology, tephrochronology, soil science, volcanology, etc. Description and C^{14} dating of individual tephras at certain sites have also been reported. Despite of these efforts, a number of tephra layers have not been well identified yet. The reason might be that the detailed description of the features of individual tephra layers had received much less attention as compared with the stratigraphic field survey. Machida[10] emphasized the importance of specification of features on each tephra from the standpoints of field survey, petrography, and chemistry. He proposed to sum up and compile the results into catalogs of tephras, which will facilitate the pursuit of tephras to a great extent. In the catalog preparation, studies on components or factors which are stable against disturbance or weathering can only provide a clue to identify a tephra among many layers.

Recently, the techniques to determine refractive indices of primary minerals has advanced, and those of hyperthenes and volcanic glasses in tephras have been revealed to be specific to each tephra.[9] Two wide-spread tephras were identified with the aid of this method.[9,11] Chemical and magnetophysical properties of ferromagnetic minerals involved in tephras have also been known to be specific to sources and eruption stages of host tephras. Chemical composition of ferromagnetic minerals has been studied and applied to identify a number of tephras.[7,18,20]

A method of tephra identification by thermomagnetic analysis of ferromagnetic minerals has been developed by Momose et al.[17] They carried out a series of the analyses on Plistocene pumice deposits and reported that each ferromagnetic minerals had a definite property peculiar to the pumice, which was confirmed also by Maenaka and Yokoyama.[13]

The present auther attempted to apply Momose et al.'s thermomagnetic method[17] for the identification of tephras in Kyushu, and the information so far obtained by the use of this method has proved to be highly helpful.[24,25] The method employed and the prepared catalogs of some of standard tephras in Kyushu will be presented below.

Method of thermomagnetic analysis for tephra identification

Advantages of using the thermomagnetic analysis for identification of tephras are: (1) ferromagnetic minerals are commonly involved in volcanic materials. (2) they are stable against weathering. (3) they can be easily separated with a hand magnet. (4) thermomagnetic analysis is a fairly sensitive method and a few milligrams of specimen are enough for one determination (5) magnetic properties can be revealed by a simple magnetic balance.

In ferromagnetic minerals, heating causes a gradual decrease of spontaneous magnetization, i.e. attractive force to a magnet, until the temperature reaches a certain critical temperature, which is called the Curie temperature (Tc). Above this temperature, the minerals lose all their spontaneous magnetization. The curve of the spontaneous magnetization vs. temperature as shown in Fig. 1 is called a thermomagnetic curve or a Js-T curve. Tc values and configurations of Js-T curves depend on the chemical composition of ferromagnetic minerals when the applied magnetic field is sufficiently high.

The structure of a vertical type magnetic balance is shown in Fig. 2. The temperature of the sample room changes after set program and the attractive force of the sample toward the magnet at every temperature is balanced to the rest position by a feed-back coil. The current of the coil for compensation is recorded against the corresponding temperature.

Distribution and description of several standard tephras in Kyushu

Several standard tephras whose sources and eruption ages are known are selected and their outer limit of distribution are shown in Fig. 3.[12,14]

Akahoya is highly glassy rhyolitic volcanic ash deposit with yellowish orange in color. It is known as one of wide-spread tephras in

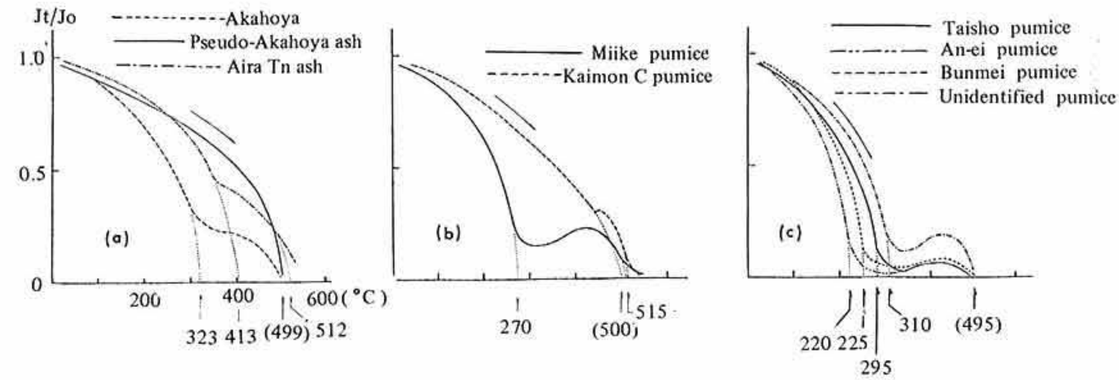

Fig. 1. Normalized *Js-T* curves of ferromagnetic minerals. (a) Glassy volcanic ashes, (b) Pumices from Kirishima and Kaimon, (c) Sakurajima pumices. *Jt* : spontaneous saturation magnetization intensity at determination temperatures, *Jo* : spontaneous saturation magnetization intensity at room temperature H=2500 œ and in vacuo (10^{-2} mmHg)

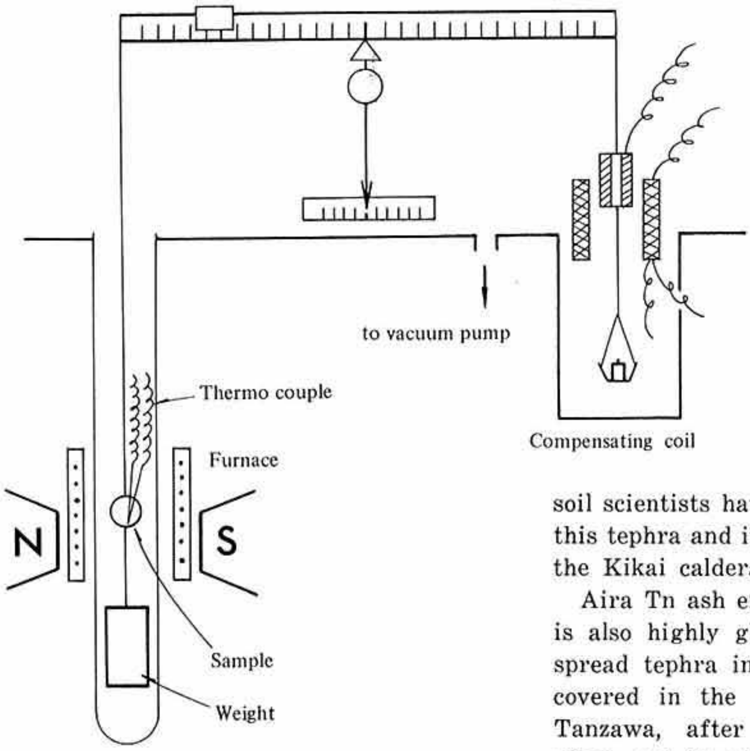

Fig. 2. Schematic diagram of a vertical type magnetic balance

Japan and have several local names, "Onji", "Imogo", etc. Many tephrochronologists and soil scientists have repeatedly discussed about this tephra and its source has been deduced as the Kikai caldera recently.[11, 19]

Aira Tn ash erupted from the Aira caldera is also highly glassy ash and is the widest-spread tephra in Japan. This was first discovered in the layers of Tokyo pumice at Tanzawa, after which the name Tn was given, and its origin was pursued to the Aira caldera by Machida and Arai.[9]

Pseudo-Akahoya ash has been considered as marginal facies of welded tuff of Aso[15], named Aso-4[23], and corresponds to Tosu[5] and Ube[16] loams. The appearance is very similar to Akahoya but this ash contains less volcanic glasses.

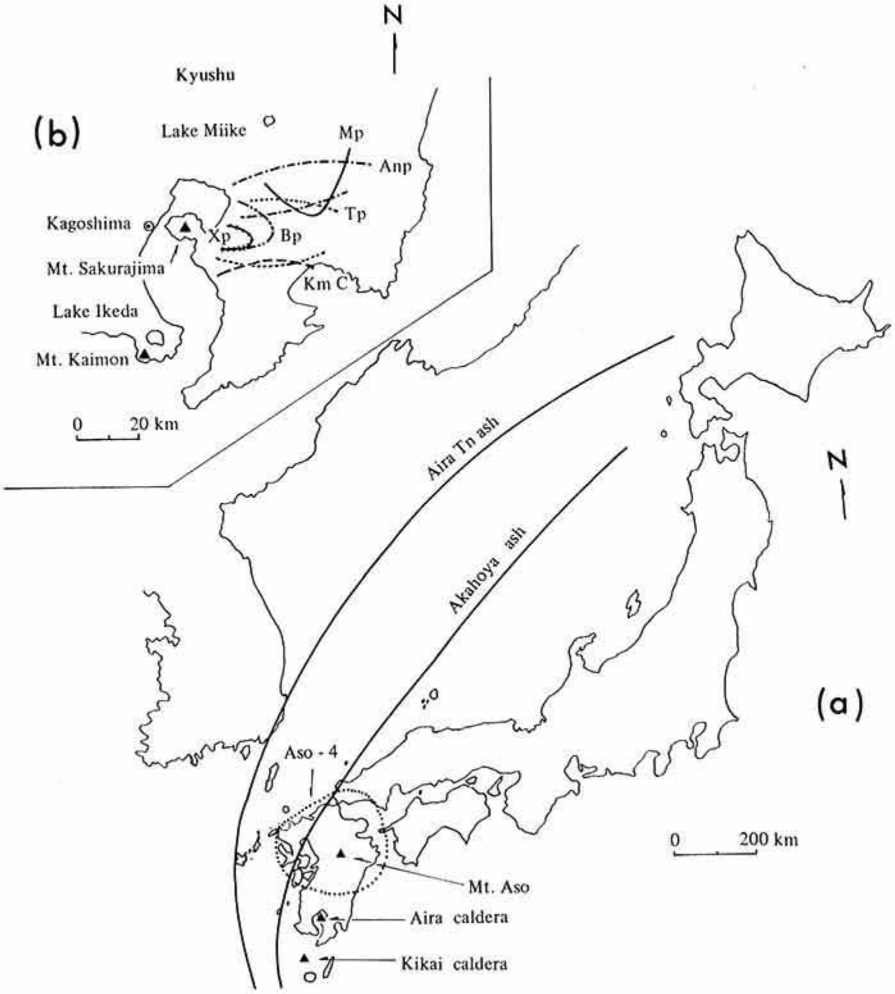

Fig. 3. Distribution of several tephras selected (a) Glassy volcanic ashes[13] (b) Pumices of Kirishima, Kaimon, and Sakurajima[15]
Mp : Miike pumice Km C : Kaimon C pumice Tp : Taisho pumice
Anp : An-ei pumice Bp : Bunmei pumice Xp : pumice of unknown old age in Holocene

Table 1. Catalog of several standard tephras in Kyushu

Tephra name	Source	Age	Curie temp. Tc(°C)	Lattice const. a(Å)	Fe/Fe+Ti (molar ratio)	No. of samples
Akahoya ash	Kikai caldera[11)19)]	$5\text{–}6\times10^3$y.B.P.[22)]	323 (498)	8.435	0.890	15
Aira Tn ash	Aira caldera[9)]	$21\text{–}22\times10^3$y. B. P.[10)]	413, 512	not determined		3
Pseudo-Akahoya ash	Aso[15)]	$30\text{–}40\times10^3$y.B. P.[10)]	499	not determined		7
Miike pumice	Miike, Kirishima[14)]	3×10^3y.B.P.[14)]	270, 507	8.446	0.872	8
Kaimon C pumice	Ikedako, Kaimon[14)]	4×10^3y.B.P.[10)]	502, 517	8.423	0.928	6
Taisho pumice	Sakurajima[14)]	1914 A.D.[14)]	295	8.432	0.885	5
An-ei pumice	Sakurajima[14)]	1778–1780 A.D.[14)]	220	8.453	0.853	8
Bunmei pumice	Sakurajima[14)]	1471–1476 A.D.[14)]	255	8.443	0.865	3
unidentified pumice	Sakurajima[14)]	unknown old age in Holocene[14)]	310 (495)	8.430	0.882	3

Miike and Kaimon C pumices are common standard pumices in southern Kyushu erupted from Lake Miike and Lake Ikeda, respectively. Miike pumice forms thick layers around Miyakonojo, a few killometers south of the source. Kaimon C, light yellowish brown pumice, is a pumice of hornblende-quartz andesitic composition and forms thick layers in southern part of the Ōsumi Peninsula.

Taisho, An-ei, Bunmei, and unidentified pumices are ejecta from Sakurajima. The names were given after the era names at the eruptions respectively. Taisho pumice is extremely fresh and hard two-pyroxene andesite pumice with light gray color. An-ei pumice is grayish yellow orange with slight stain but still fairly fresh and hard. The profile near the source consists of several fall units. Though it is still under discussion if the pumice was erupted during Bunmei eruption, Matsui and Wajima[14] considered that the certain pumice layers were the ejecta during Bunmei period. The term, Bunmei pumice, is used here after them. Unidentified pumice is slightly weathered and yellow in color and has been considered as ejecta at unknown old age in Holocene.

Catalog of several standard tephras in Kyushu

Js-T curves of ferromagnetic minerals extracted from tephras are illustrated in Fig. 1. Differences in thermomagnetic features among tephras can be seen clearly.

Table 1 is the catalog of these tephras. It includes source and age already reported by others, in addition to *Tc* values and a few other properties of ferromagnetic minerals.

The *Tc* values of titanomagnetite have been revealed to change almost linearly with Ti contents from high to low temperatures[2] so long as the oxidation degree is the same. The lattice constant, α(Å), is a length of an edge of cubic spinel crystals of titanomagnetite. It can be obtained by X-ray diffraction analysis and is known to correspond to Ti content and degree of oxidation of titanomagnetite.[2]

Tc values differ clearly among different tephras and differentiation among them can easily be made. Difference in *Tc* values also well corresponds to difference in values of the lattice constant and chemical compositions of ferromagnetic minerals.

Ferromagnetic minerals in pumices of different stages of Sakurajima show different properties indicating that characteristics of magma had changed with successive eruption stages. Similarity between ferromagnetic minerals of Taisho and unidentified pumices was, however, seen, which might indicate that magma properties were similar at the stages of these pumices. This is probable because SiO_2 content of Sakurajima lavas of different stages was reported to have changed gradually and periodically between 59 and 67%.[21]

Accumulation of catalogs on standard tephras as exemplified in Table 1, will make it possible to compare properties of unidentified tephras with the catalog and correlate them.

In Kyushu, tephra identification has not been promoted so systematically as in Hokkaido yet and numbers of tephras are still remained unidentified despite of many field surveys done till now. Comprehensive and systematic studies including petrographic, chemical, and magnetophysical investigations for catalog preparation are desired in this region.

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