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62. *Identification of Tephra by Means of Ferromagnetic Minerals in Pumice.*

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Summary

For the purpose of tephrochronology (volcanic ash chronology), we conducted a series of thermomagnetic studies on ferromagnetic minerals of pumice grains from pumice-fall layers embedded within the Pleistocene tephra (volcanic ash) deposits.

The results hitherto obtained well indicate:

(1) Thermomagnetic property of ferromagnetic minerals separated from six pumice layers which are expressed, from older to younger, by the symbols Pm-I′, Pm-I, Pm-II, Pm-II′, Pm-III, and Pm-IV (the last one is otherwise expressed as Sc-I, because it would better be called scoria) within the Shinshu Loam (tephra) formation, leads to a conclusion that the relation between the Curie temperature and the lattice constant of ferromagnetic minerals in pumices is comparable to the corresponding relation in respect to the minerals in volcanic rocks.

(2) Ferromagnetic minerals from pumice layers within the Kanto Loam section at Kajiyama in Yokohama were studied. Thermomagnetic analysis justified our former expectation that the Pm-I could be recognized within this section which is ca. 200 km apart from the source volcano.

(3) It has thus been confirmed that pumice grains from each pumice layer has a definite Curie temperature pertinent to their ferromagnetic minerals in various grain-size fractions. Thermomagnetic examination would, accordingly, be helpful for identification of pumices.

1. Introduction

It is a tough problem to make a stratigraphic zonation of tephra deposit, unless we find, within a tephra deposit, any visible or marked key horizon indicated, for instance, by such coarser materials as pumices or scoriae. Pleistocene air-borne tephra which usually are more or less weathered are identified often by their mode of occurrence and lithological appearance, sometimes by their mechanical and mineralogical compositions and by refractive indices of some constituent minerals.[1]

But the difficulty of these methods comes from the fact that in Japan so many pumices and scoriae with a similar kind of mineral assemblage often prohibit our exact identification, and that according to the mode of deposition, some unstable minerals are weathered to varying degree, obscuring the primary mineral composition of pumices and scoriae. Glass shards and glass component of pumices are readily weathered, as known even in the latest Pleistocence ash, of which glass component has often altered wholly to allophane. Studying some samples from North Kanto and Shinshu districts, F. Arai (unpublished) recently read a paper on the efficiency of refractive indices of hypersthene for the identification of pumices and scoriae. This method of identification is expected to apply to various samples. The Older Loam in Shinshu which probably predates the Riss-Würm interglacial stage, is intensively weathered and contains exclusively much ferromagnetic minerals accompanied by a little amount of other kinds of mafic minerals.

Heavy mineral assemblage of tephra has been widely surveyed but sometimes discrimination is quite impossible owing to the similarity in mineral composition. In heavy mineral analysis, it is very difficult to identify less amount of pumices from a remote source, which is embedded within some other thicker tephra deposit supplied from nearer sources. These are the reasons why we devised, for correlation purpose, a plan concerning magnetic property of ferromagnetics which are said to be fairly stable against weathering.

Our experiments have proved that ferromagnetics in pumices show their own thermomagnetic characteristics pertinent to each pumice layer. In many cases, the Curie temperature (T_c) and the feature of thermomagnetic curve (J-T curve: mode of change in magnetization with temperature) of a sample satisfactorily provide a diagnostic criterion to recognize, thereby to discriminate itself from others. Information from this sort of study which Akimoto and others already[2][3][4][5][6] conducted on

1) R.E. WILCOX, *Quaternary of the United States* (Princeton, 1965), 807.
2) S. UYEDA, *Jap. Journ. Geophys.*, **2** (1958), 1.
3) S. AKIMOTO, T. KATSURA and M. YOSHIDA, *Journ. Geomag. Geoele.*, **9** (1957), 165.
4) S. AKIMOTO and T. KATSURA, *ibid.*, **10** (1959), 69.
5) T. NAGATA, *Rock Magnetism* (Tokyo, 1961), pp. 75-125.
6) M. OZIMA and E.E. LARSON, *Journ. Geomag. Geoele.*, **19** (1967), 177.

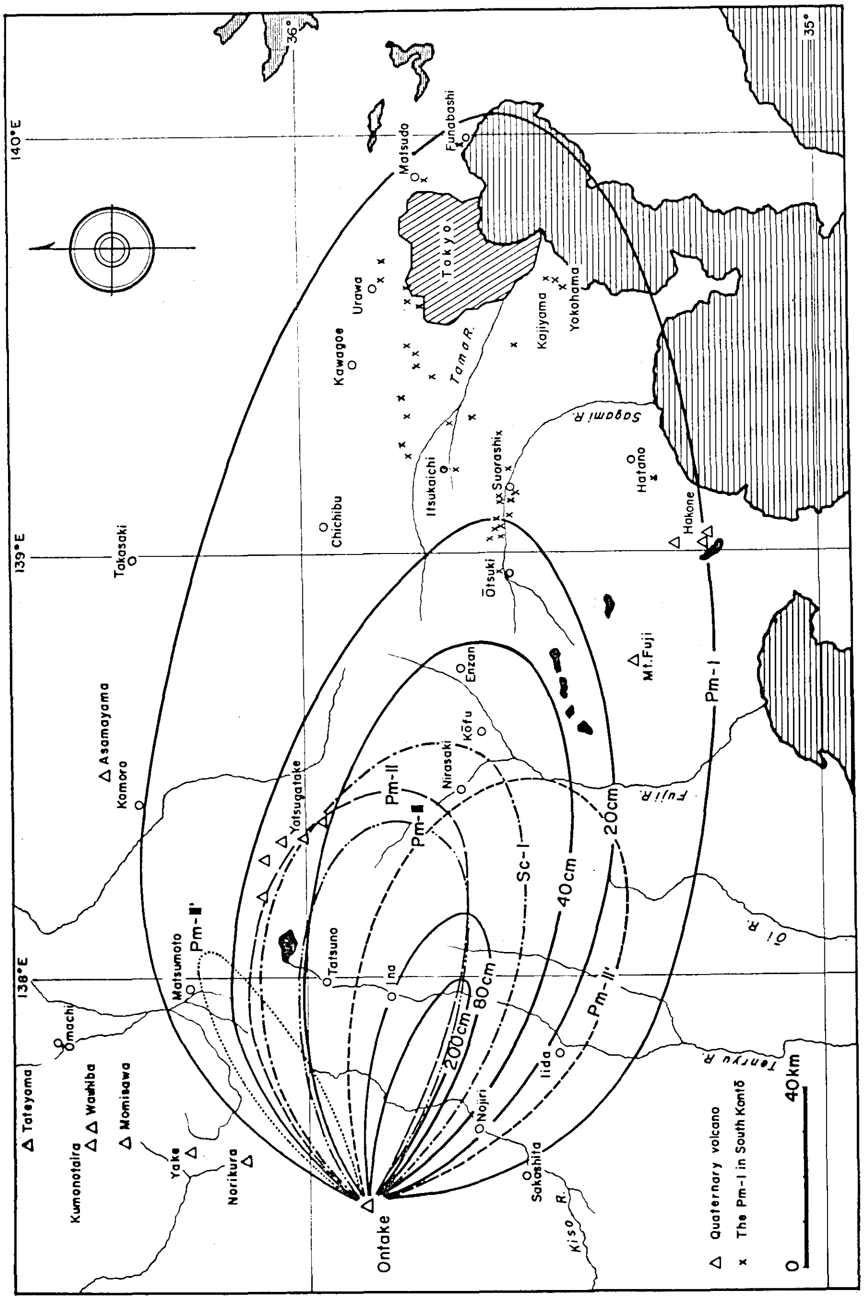


Fig. 1. Distribution of pumice-fall deposits originated from Ontake volcano. Solid line: Isopach map for the Pm-I. Dotted and broken lines: Outer limit of visible distribution of other pumice layers. ×denotes the location of our finding of the Pm-I in South Kanto.

some pumice-flow deposits and volcanic rocks, have benefited us in carrying out our study of air-borne pumices.

2. Basic Experiments

(1) *Pumice at the Type Section of Shinshu Loam*

The Pleistocene tephra erupted from Ontake volcano in central Japan carry, in popular usage, the name "Shinshu Loam" (tephra) which is classified into three time-straightigraphic units, *i.e.* the Younger, the Middle and the Older units. The Middle tephra unit with intercalation of four or five pumice layers, is unconformably overlain by the Younger tephra unit of which the basal part embeds a marked reddish brown scoria layer (Sc-I or Pm-IV). In Fig. 1, besides the isopach map of the Pm-I, outer limit of visible distribution of other pumice and scoria deposits are illustrated.

Outer limits of these deposits would be modified in future study. Heavy mineral composition of these pumices are put in Table 1.[7] As for the radiometric ages, two woods associated with the Pm-IV (Sc-I) are dated by radiocarbon at about 27,000 Y.B.P.[8] and the Pm-III is

Table I. Heavy mineral composition (percentage in number) of purified pumices and scoriae from Shinshu Loam at type locality (in grain-size fraction 1/8−1/16 mm) *H/T percentage of heavy mineral in total weight, reproduced from Kobayashi and Shimizu, 1966.

	Sample	H/T*	biot.	hornb.	aug.	hyp.	mag.	others	Tc(C°)
(1)	Sc-II (Pm-V)	61.0	−	3.0	13.5	65.2	18.2	−	
(2)	Sc-I (Pm-IV)	28.7	−	−	14.7	53.1	32.2	−	240
(3)	Pm-III	14.0	−	3.2	3.2	56.2	37.3	−	400
(4)	Pm-II′	16.5	−	2.1	−	22.2	75.7	−	60,400(−)
(5)	Pm-II	21.0	−	6.4	−	77.5	15.6	(Z)0.5	425
(6)	Pm-I	5.9	+	38.2	5.6	9.7	37.4	2.5+ (Z)6.7	450-460
(7)	Pm-I′	9.0	+	21.4	4.3	5.6	59.0	8.5+ (Z)1.3	460,555

(1) From Loc. Yochi-II, west of Ina.
(2)-(7) From type locality at Ina Tobu Junior High School. Z. denotes "zircon"

7) K. KOBAYASHI and H. SHIMIZU, *Journ. Fac. Sci., Shinshu Univ.*, **1** (1966), 97.
8) K. KIGOSHI and K. ENDO, *Radiocarbon*, **5** (1963), 109.

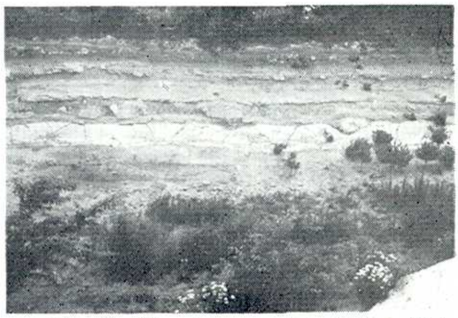


Fig. 2. The type section of the Middle Loam unit of Shinshu Loam exposed at the Ina Tobu Junior High School (see also Fig. 12.).

dated by radiocarbon at 35,700±1,400 Y.B.P. and additionally by Ionium at 37,600±5,500 Th^{230} Y.[9]

The middle stratigraphic unit of the Shinshu Loam is well exposed at the type locality of the Tobu Junior High School, east of the town of Ina, South Shinshu.[10] At type locality (Fig. 2), within the middle Loam are embedded, from older to younger, five pumice layers Pm-I′, Pm-I, Pm-II, Pm-II′, Pm-III, followed by a scoria layer of the younger Loam, which is expressed the "Sc-1", otherwise the "Pm-IV". Thermomagnetic curves of ferromagnetics contained in these pumice layers are shown in Fig. 3. (a, b, c, d, e, f). For this measurement, pumice grains, were purified to remove contaminants, and carefully pulverized by fingers not to split mineral grains. Minerals, after repeated cleaning in water, were desiccated at a low temperature between 30° and 40°C to prevent oxidation. Ferromagnetics magnetically separated from mineral grains were sieved, so that mineral grains in the fraction $\phi=0.13-0.25$ mm might be used. Finally the samples were measured in vacuum of about 10^{-3} mm Hg. The T_{cs} of the samples from pumice layers of the Shinshu Loam are measured as discussed in the following.

In Fig. 3. (a, b, c, d, e, f), except for two instances of the Pm-I′ (Fig. 3a) and the Pm-II′ (Fig. 3d), most J-T curves demonstrate that the samples are simply demagnetized with increase in temperature, and their J-T curves are of Néel's Q type.

(i) There seems to be a general tendency that gradual decrease of the T_c occurs with respect to pumice layers in ascending order.

(ii) J-T curve of the Pm-III (Fig. 2e) was provided by Kazuo Kobayashi who made a measurement for us.

(iii) It has been observed that with decrease in T_c the lattice constant increases from 8.406 Å of the Pm-I to 8.432 Å of the Pm-IV (Sc-I).

(iv) Table 2 shows the relation between T_c and the lattice constant of the pumices. The relation between the T_c and the lattice constant proves to accord approximately with the corresponding relation

9) K. KIGOSHI, *Science*, **156** (1967), 937.

10) K. KOBAYASHI and H. SHIMIZU, *Journ. Fac. Lib. Arts. Sci., Shinshu Univ.*, **15** (1965), 37.

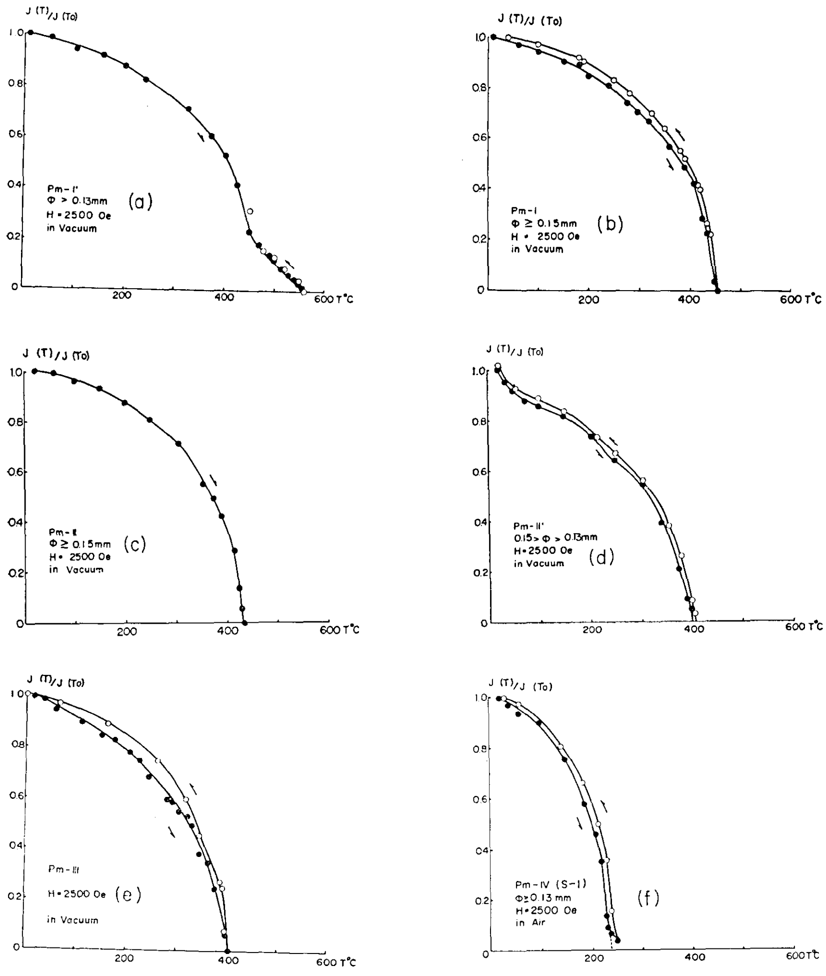


Fig. 3 ($a\sim f$). *J-T* curves pertinent to six pumice and scoria layers including the Pm-I', Pm-I, Pm-II, Pm-II', Pm-III, and Pm-IV (Sc-I) at the type locality, South Shinshu.

in cubic ferromagnetic minerals in volcanic rocks.[11)12)13)]

(v) As for the Pm-IV the relation shown in Table 2, however, seems to deviate from the known linear relationship between T_c and lattice constant of titanomagnetite.[14)] The apparent discordance between the T_c and the lattice constant of Pm-IV may possibly be attributed to the fact that; (a) the sample may possibly consist of ferromagnetic

11) T. NAGATA, *loc. cit.*, 88—89, Fig. 3-10, 11, 5).
12) S. AKIMOTO and T. KATSURA, *loc. cit.*, 4).
13) T. NAGATA, *Proc. Benedum Earth Magnetism Symposium*, (1962), 69.
14) T. NAGATA, *ibid.*, 13).

Table 2. Relation between the T_c and the lattice constant of ferromagnetic minerals of pumices in Shinshu Loam at type locality

Pumice	Curie temperature	Lattice constant
Pm-I′	460°C, 555°C	8.405 Å
Pm-I	450°C−460°C	8.406 Å
Pm-II	425°C	8.408 Å
Pm-II′	60°C, 400°(−)C	——
Pm-III	400°C	8.415 Å
Pm-IV	240°C	8.432 Å

grains having different T_{cs}. (b) obtained lattice constant of the sample denotes an average, whereas the obtained T_c marks the highest one. We expect that the problem will amply be solved by our future application of thermomagnetic separation to the sample.[15]

Since it is accepted that the T_c of the cubic ferromagnetic minerals in volcanic rocks systematically changes with their chemical composition, *e.g.* Fe_2TiO_4 content and the degree of oxidation, the T_c and the feature of *J–T* curve may well be used for identification of ferromagnetic minerals in pumice and scoria.

Fig. 4. The 3 m thick exposure of the Pm-I at the Komagane Higashi Junior High School 4 km south of the town of Akaho.

(2) *Thermomagnetic Property of the Pm-I′*

J–T curve of the Pm-I′ has two different T_{cs} at 460°C and 555°C (Fig. 3a). The demagnetization, however, progressed from 460° to 555°C and this portion of *J–T* curve can be reversibly traced through both processes of heating and cooling. These facts imply that *J-T* curve of the Pm-I′ may not be affected by

15) S. Akimoto and T. Katsura, *loc. cit.*, 4).

oxidation, but the sample may have two T_{cs}. Thermomagnetic property of the Pm-I′ as well as that of the Pm-II′ provides an example which besides the T_c, the J-T curve is to be usable for pumice identification.

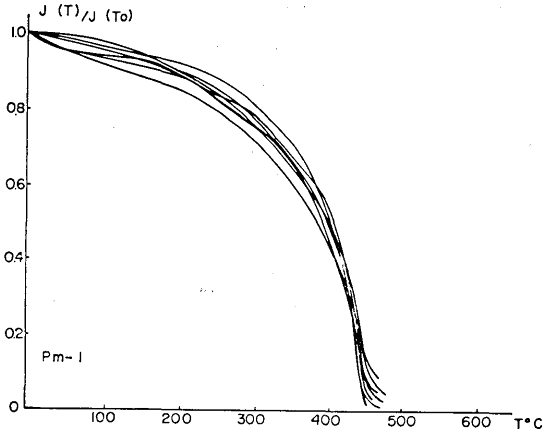


Fig. 5. *J-T* curves (heating curves only) pumices from various horizons of the Pm-I layer, showing a coincidence in the mode of demagnetization. (Samples from Komagane Higashi Junior High School).

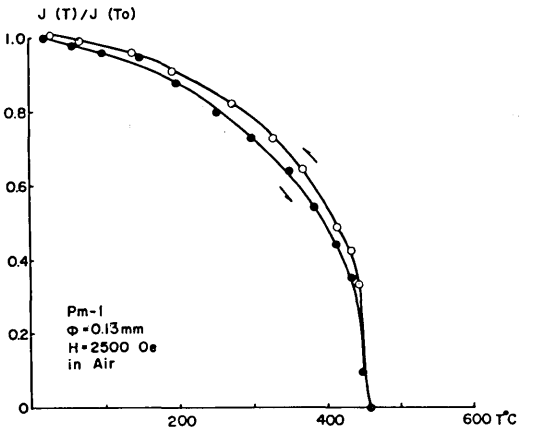


Fig. 6. *J-T* curve of a sample treated in the saturation magnetization field Hex=2500 Oe. This sample was already used for measurement and put in Fig. 5.

(3) *Thermomagnetic Property of the Pm-I*

a) *J-T* curve of the Pm-I at Komagane Higashi Junior High School.

A typical 3 m thick section of the Pm-I is exposed beside the playground of the Komagane Higashi Junior High School (Fig. 4). For the purpose of examining whether or not pumice grains from any parts of the whole section of the Pm-I with a considerable thickness could have the specified thermomagnetic property, ferromagnetic minerals of pumices from several horizons were measured (Fig. 5). Since all the *J-T* curves proved to be reversible through heating and cooling processes, only those of the heating process are put in this figure. The weakness of the applied magnetic field in this experiment, is responsible for the somewhat rounded feature revealed in these curves. One set of curves obtained at Hex=2,500 Oe (Fig.6) well demonstrates that the curves satisfactorily accord with those of the Pm-I from type locality at the Ina Tobu Junior High School. Somewhat scattered distribution of the demagnetizing points

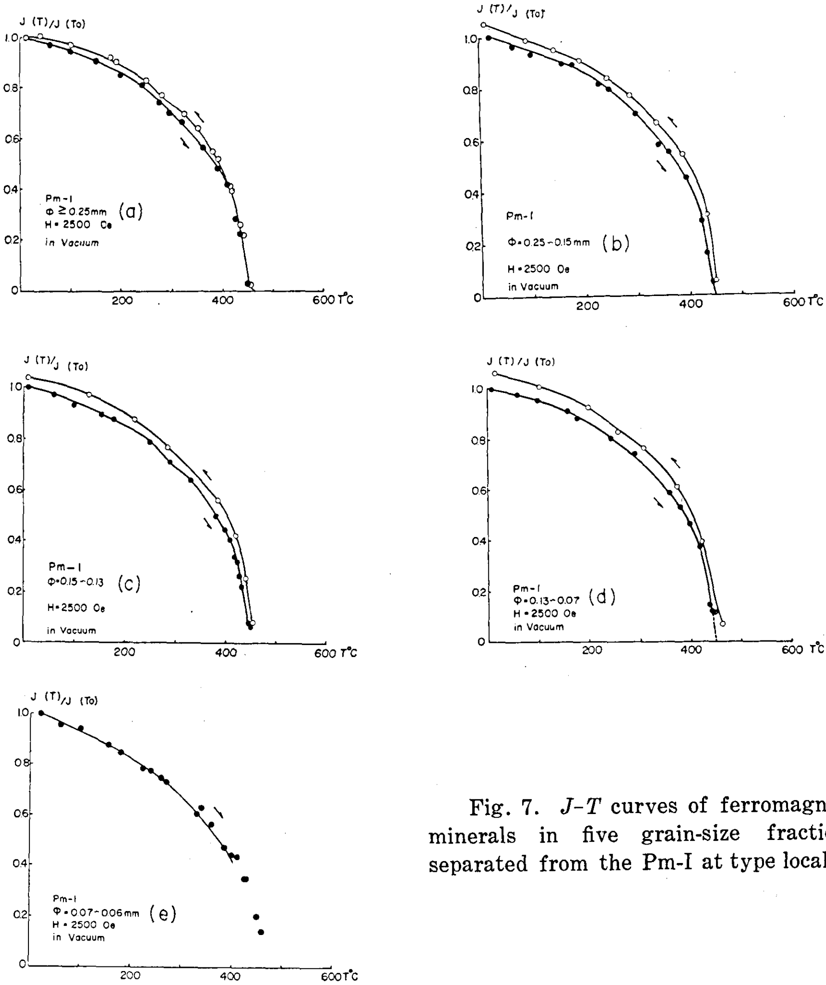


Fig. 7. *J*-*T* curves of ferromagnetic minerals in five grain-size fractions, separated from the Pm-I at type locality.

in Fig. 5 is due to the fact that rather smaller grains in the fraction $\phi \leqq 0.13$ mm were used and the samples were forced to have been heated in an unsatisfactory vacuum. Of all curves, the portions with high gradient, point to 450°C, implying that all pumice grains from the Pm-I have a T_c with a narrow range 450°C to 460°C.

b) *J*-*T* curves of ferromagnetic mineral grains in various grain-size fractions.

The relation between grain-size and Ti-content of ferromagnetics in tephra was discussed by R. Aoyagi and I. Iwasaki[16] in terms of

16) R. Aoyagi and I. Iwasaki, *Quat. Res.*, **6** (1967), 44.

ferromagnetic minerals contained within finer volcanic ash. To examine whether or not the difference in grain-size of ferromagnetic minerals in pumice may have a relationship to the pertinent T_c, ferromagnetic grains extracted from the Pm-I at type locality, were sieved into the following five grain-size fractions, *i.e.* $\phi \geqq 0.25$ mm, 0.25−0.15 mm, 0.15−0.13 mm, 0.13−0.07 mm, and 0.07−0.06 mm. The measurement was practiced in vacuo of 10^{-3} mm Hg (Fig. 7 a, b, c, d and e).

In this figure, it is observable from the feature of cooling process curves, oxidation has progressed to higher degrees with decrease in grain-size. From the heating process curve, with decrease in grain-size, the pertinent T_c seems to fall to a point more apart from 450°C. The mineral grains with the diameter $\phi = 0.07-0.06$ mm were oxidized below 450°C, hence it is undesirable to make a heat treatment on fine-grained sample whose grain-size does not exceed 0.07 mm.

In conclusion, four of five *J-T* curves thus obtained apparently indicate the T_c being between 450°C and 460°C. However, the sample in smaller grain-size from 0.07 to 0.06 mm is readily oxidized during heating process, there may possibly be a suspicion that in reality the pertinent T_c might be a little lower than 450°C. This sample should need a re-examination in the higher vacuum condition.

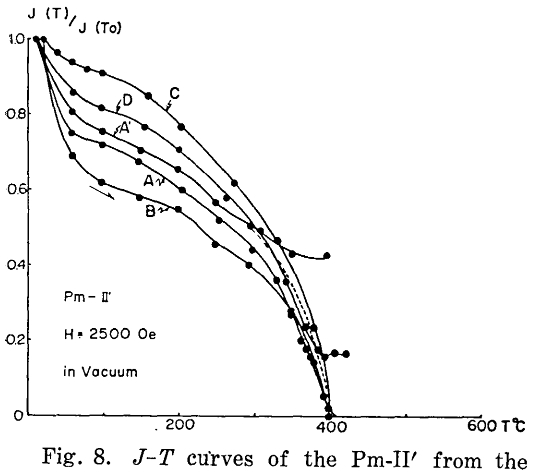


Fig. 8. *J-T* curves of the Pm-II′ from the Ina Tobu Junior High School. Curves A and B: for the grain-size $\phi \geqq 0.25$ mm. Curve A′: for the much smaller-grained minerals produced, by pulverization, from the mineral grains with diameters $\phi \geqq 0.25$ mm. The samples A and B were taken from different positions of the same layer. Curve C: for the same sample as that which yielded the Curve A, but the grain-size is nearly 0.06 mm across. Curve D: for the sample of the Pm-II′ from another locality (Loc. Kashima I-1).

(4) *Thermomagnetic Property of the Pm-II′*

The *J-T* curve seems to consist of two phases, as indicated by a dent in the low temperature part of both heating and cooling curves (Fig. 3d). The higher one of the two T_{cs} of the Pm-II′, which is at ca. 400°(−)C is nearly the same as that of the Pm-III, hence both samples are indistinctive from each other, if based only upon the T_c (Fig. 2d). Fig. 8 shows some examples of heating curve of the Pm-II′ taken from several localities including the type locality. In Fig. 8, the curves A and B obtained from two samples from different positions of the same layer, show the results with respect to the mineral grains larger than 0.25 mm across, and both heating curves characteristically have a dent in their respective curve, suggesting the presence of one of the T_{cs} being at about 60°C. Even with repeated measurements, this feature in the *J–T* curves of the samples A and B was unchanged. The substance having a low T_c is likely to be attributable to the ilmenite-hematite series minerals.

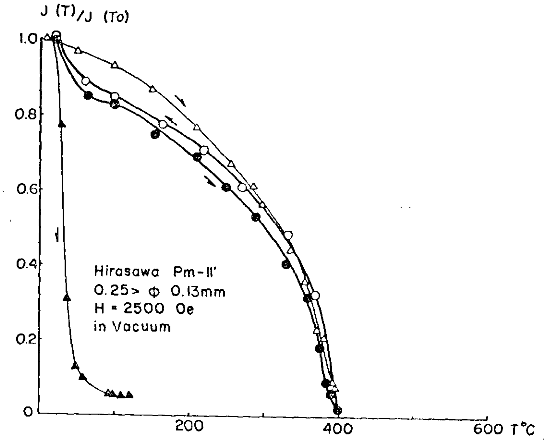


Fig. 9. Three kinds of *J–T* curve, showing that ferromagnetic grains of the Pm-II′ consist of two components having different T_{cs} respectively at 60°C and 400°C.

After the mineral grains ($\phi \geqq 0.25$ mm) of the sample A were pulverized into much smaller grains, ferromagnetic minerals thus extracted by a magnet yielded a result (curve A′) as indicated in Fig. 8. The general feature of the curve A′ is essentially the same as that of the curve A, but the dent of the curve seems to have become weaker. During heating, the material was oxidized above 300°C owing to the fineness of grain-size, but had the oxidation not taken place, demagnetization would have progressed along the broken line to the final point approximately at 400°(−)C. Curve C indicates the result from the sample A, whose natural grain-size was used in the fraction nearly 0.06 mm.

From these results, it was expected that some sort of mineral which has a lower T_c in the ilmenite-hematite series, increased in amount with increase in grain-size of the sample. In Fig. 9 are put one set of *J–T* curves (indicated by solid and open circles) of the ferromagnetic grains of the Pm-II′, of which the grain-size ranges between 0.25 and 0.13 mm. In this figure, are also put *J–T* curves (indicated by solid and open triangles) of the two groups of ferromagnetic grains into which the same sample from Hirasawa was fractionated by magnetic separation at 100°C. The result of measurement shows that the Pm-II′ contains two different kinds of ferromagnetic minerals; one has a T_c at 400°(−)C, the other amounting to 22.8% in weight has a lower T_c at 60°C. The latter grains, which appeared as hexagonal platy crystals under the microscope, were identified by the X-ray analysis to be the ilmenite-hematite series minerals.

In Fig. 8, is also indicated curve D with a similar dent at ca. 60°C in the curve obtained from a rather isolated locality (Kashima I-1, Nojiri) on the Kiso river.

It follows in conclusion that identification of the Pm-II′ may thus be possibly based on the feature of the J-T curve, and especially the identification is easier when grain-size of the Pm-II′ is larger than some 0.06 mm in diameter.

3. Thermomagnetic Property of the Pm-I in South Kanto

The pumice-fall deposit Pm-I is traced over a considerably longer distance, into the Kanto district. Kobayashi[17] first gave an account of the existence of the Pm-I within the section at Kajiyama (in his paper of 1965, Loc. Kamisueyoshi-III on p. 384), and later the Pm-I bed with a maximum thickness of 15 cm has been revealed by recent excavation (Fig. 10). It occupies the middle part of the Shimosueyoshi Loam. The identification of the Pm-I was formerly based mainly on its distinguished heavy mineral composition.[18,19]

Fig. 10. The Pm-I (above) well exposed at the cliff east of Kajiyama near Shimosueyoshi in Yokohama. At the level from 60 to 100 cm below the Pm-I are indicated two layers of the "Oyako pumice" (OyP and OyP′).

In the Kanto district more than 200 km from the source, the Pm-I layer is usually very thin and often vague in appearance, being embedded within the tephra section consisting of the volcanic material mainly supplied from Hakone and Fuji volcanoes.

17) K. KOBAYASHI, *Spec. Paper Geol. Soc. Amer.* **84** (1965), 367.

18) K. KOBAYASHI and H. SHIMIZU, *loc. cit.*, 10).

19) K. KOBAYASHI, H. SHIMIZU, K. KITAZAWA and T. KOBAYASHI, *Journ. Geol. Soc. Japan*, **73** (1967), 291.

The Pm-I that already were identified by mineral composition have thermomagnetically been surveyed. At Kajiyama the Pm-I with its higher T_c, exhibits a marked contrast with those of other pumices in the section (Fig. 12). Samples of the Pm-I at remote localities from their source volcano were measured. Among these localities, Suarashi and two localities near Uenohara (Ue-108 f, Ue-57 g) are respectively on the Sagami and Katsura rivers. The exposure at Shirako is located on the northwestern outskirt of the City of Tokyo and is at the edge of the Musashino upland. And the exposure at Shimo-fujisawa is about 20 km northeast of Itsukaichi and is at the edge of the Kaneko upland. The results obtained are shown in Fig. 11. Measurement was made on all samples in vacuo, in the external magnetic field of Hex = 2500 Oe. In this figure, only the heating curves are put in order to prevent complexity. The continuous solid line indicates the J-T curve of the Pm-I from its type locality in South Shinshu. As seen in the figure, although some samples show an oxidation having taken place, most curves prove that demagnetizing points should be at 450°C.

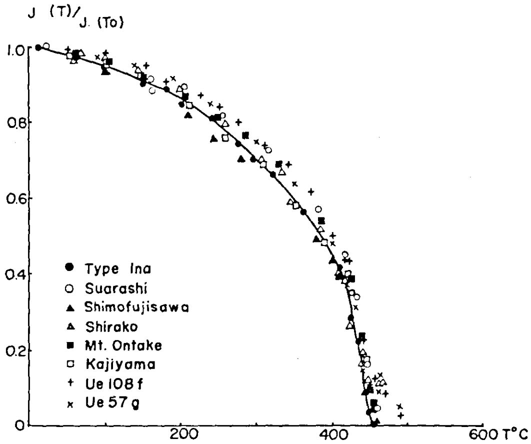


Fig. 11. The similar modes of demagnetization of the ferromagnetic minerals of the Pm-I from many localities mainly in South Kanto.

4. Thermomagnetic Property of Pumices in Shimosueyoshi and Musashino Loams

At the exposure of Kajiyama, the aeolian Shimosueyoshi Loam conformably covers the Shimosueyoshi formation, and is overlain by the Musashino Loam. Ten or more pumice layers from these Loam units were thermomagnetically studied. In Fig. 12 are shown stratigraphic positions of these pumices and T_{cs} of their ferromagnetic minerals, along with those of pumices in Shinshu Loam.

(i) The so-called "Sanshoku aisu" (Three-coloured ice cream) pumice consists of several variegated seams (e, p, n, k, and f) some of which

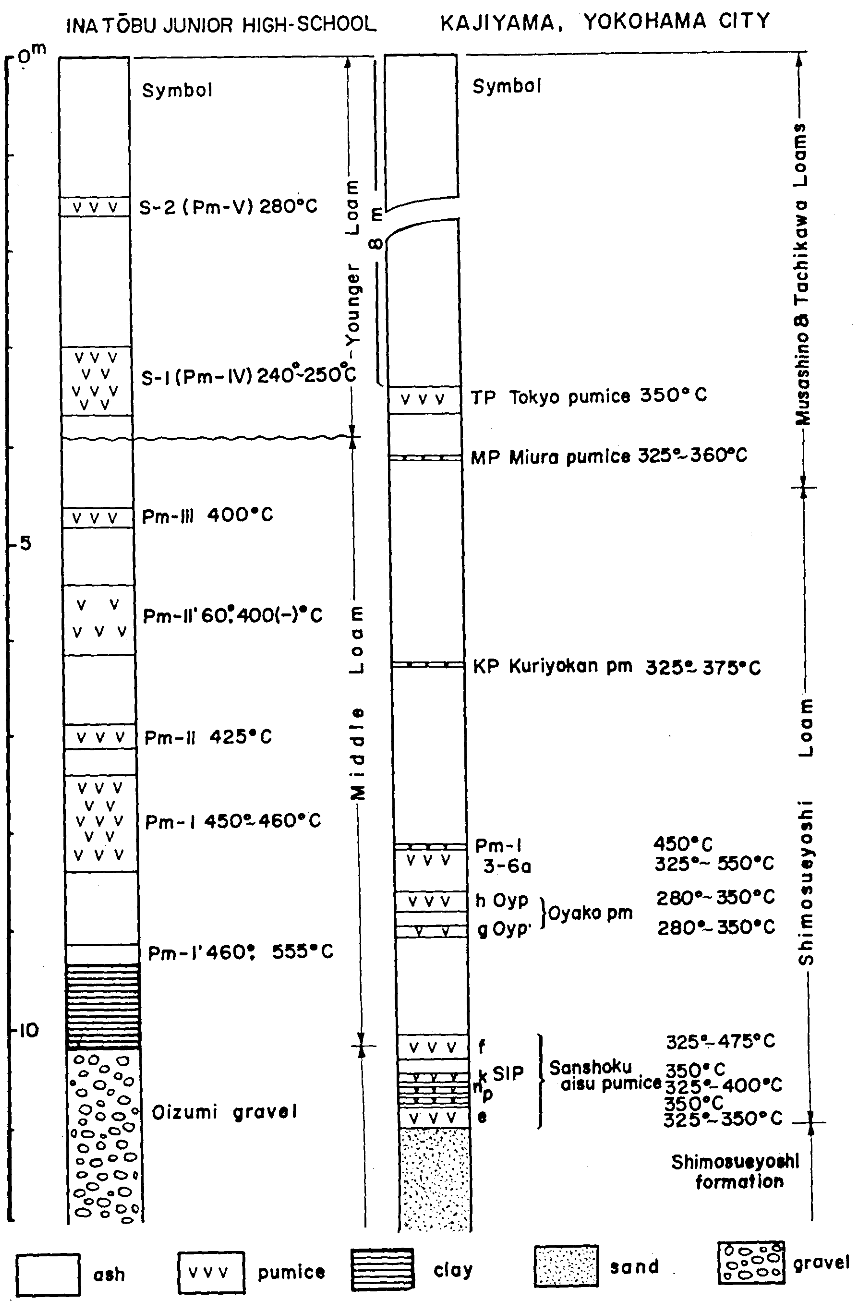
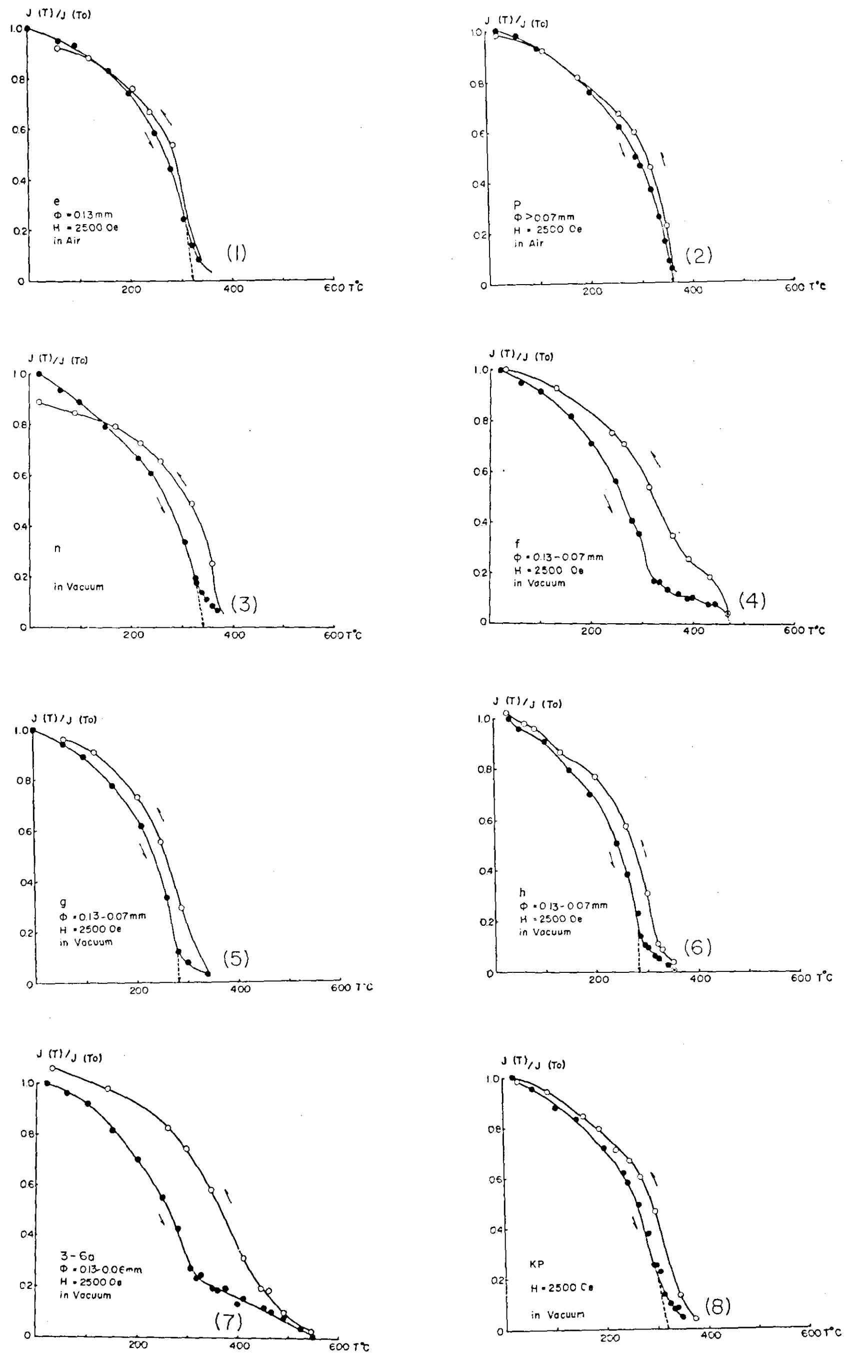


Fig. 12. Stratigraphic positions of pumices of Shinshu and Kanto Loams and pertinent Curie temperatures.


J (T)/J (To)
e
Φ = 0.13 mm
H = 2500 Oe
in Air
(1)
P
Φ > 0.07 mm
H = 2500 Oe
in Air
(2)
n
in Vacuum
(3)
f
Φ = 0.13-0.07 mm
H = 2500 Oe
in Vacuum
(4)
g
Φ = 0.13-0.07 mm
H = 2500 Oe
in Vacuum
(5)
h
Φ = 0.13-0.07 mm
H = 2500 Oe
in Vacuum
(6)
3-6a
Φ = 0.13-0.06 mm
H = 2500 Oe
in Vacuum
(7)
KP
H = 2500 Oe
in Vacuum
(8)
0
0.2
0.4
0.6
0.8
1.0
200
400
600 T°C

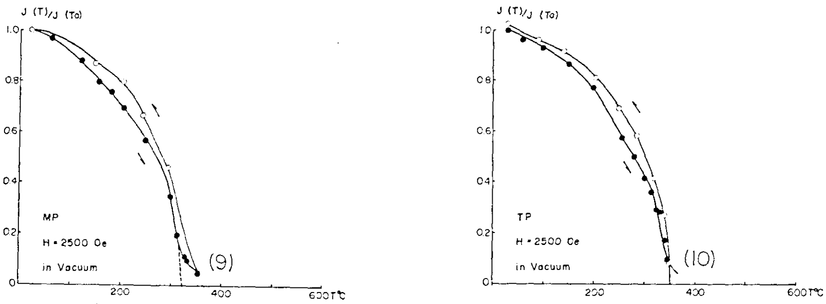


Fig. 13. (1~10) J-T curves of ferromagnetic minerals of pumices within the section of Kanto Loam east of Kajiyama, Yokohama City. See also Fig. 12.

were studied. The pumice lies nearly at the top horizon of the water-laid sediments which were deposited during the so-called "Shimosueyoshi transgression".

(ii) The so-called "Oyako" (meaning parent and child) pumice consists of thick (h: Oyp) and thin (g: Oyp′) pumice layers about 15 cm apart from each other.

(iii) Immediately below the Pm-I and above the "Oyako" pumice (Oyp and Oyp′) is sometimes recognized a faint indication of pumice seam (3-6a) which was collected by Kobayashi in 1964 from an exposure near Hosenji temple in Shimosueyoshi.

(iv) The upper part of the Shimosueyoshi Loam is marked by a zone of scattered pumices which are named "Kuriyokan" (KP: Meaning chestnut bearing jelly of beans).

(v) Above these pumices are two pumice layers called "Miura pumice" (MP), and "Tokyo pumice" (TP), of which the latter is notable for its wide distribution and its characteristic appearance.

J-T curves of these pumices from an exposure of Kajiyama are also in Fig. 10 for the Pm-I in this exposure. Ferromagnetic grains ranging in rather smaller size from 0.13 to 0.06 mm were used, consequently many samples were oxidized in the course of heating. Although some samples which were subjected to an intensive oxidation do not always afford satisfactory values, the T_c are inferred by extrapolating the themomagnetic curve along the broken line to the abscissa. Hence these pumices are judged to have relatively low T_c between 350° to 280°C. Among these, the p and the TP in Fig. 13. (2, 10) have a maximum T_c of 350°C. J-T curve of the Pm-I (Fig. 11) gave ground for the reliability of identification of this pumice by means of heavy mineral analysis. As seen in Fig. 12, the T_c of the Pm-I in a section of Kajiyama is uniquely higher than the other pumices of Kanto Loam.

Conclusion

Ferromagnetic minerals extracted from various pumice grains at different horizons of an apparently single pumice layer indicated a good coincidence in the feature of J–T curve and in the value of T_c. Ferromagnetic minerals extracted from the geologically same layer, which is, however, located at different places, proved also a uniformity in both characters mentioned above. The Pm-I shows an apparent coincidence of thermomagnetic character, despite varying grain-size of ferromagnetic minerals used in our experiment.

These facts may be due to:

(1) Ferromagnetic grains from a single pumice layer are pretty uniform in the chemical composition.

(2) After the solidification of ferromagnetic minerals in pumice, they may have sufferred little alteration seemingly regardless of difference in sedimentary environment.

(3) Nagata, Akimoto and Uyeda[20][21] reported that an ensemble of ferromagnetic minerals separated from a piece of volcanic rock by the usual magnetic method generally consists of a large number of grains of different chemical composition, having different T_{cs}. As for pumices, we have treated, an ensemble of various kinds of ferromagnetic grains which are contained in a lump of pumice and having different T_{cs}, may have a definite ratio in assemblage.

Our experiments hitherto carried out indicate that the thermomagnetic character of ferromagnetic minerals in pumices and scoriae sensitively reflects their chemical composition which is characteristic of each pumice and scoria layer. Accordingly the thermomagnetic analysis may be more effective for the identification of pumice and scoria than heavy mineral analysis and possibly other known methods of identification. The relatively stable nature of these opaque minerals also favours the application of this method to variably weathered samples. This method which concerns opaque minerals in solid solution series is comparable with the optical analysis in which refraction indices of non-opaque minerals, *i.e.* plagioclase, amphibole, pyroxene groups etc., reflect their respective chemical composition.

20) T. Nagata, S. Akimoto and S. Uyeda, *Journ. Geomag. Geoele.*, **5** (1953), 168.
21) S. Akimoto and T. Katsura, *loc. cit.*, 4)

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62. 軽石中の強磁性鉱物によるテフラの同定

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テフラ（降下火山砕屑物）の同定を目的として，その中の軽石中の強磁性鉱物の磁気的性質に注目し熱磁気測定を行つた．

この実験に使用した試料は御岳火山起源の中期および新期ローム層中の6枚の軽石層と関東地方の下末吉・武蔵野ローム層中の12枚の軽石層中の軽石中のものである．

(1) 御岳火山起原の軽石中の強磁性鉱物のキュリー温度は下位軽石層（Pm-I′）から上位軽石層（Sc-1）にむかつて大局的に低下し，それぞれ相違した．

(2) 各地に分布する御岳火山起原の中期および新期ロームにぞくする各軽石層は産地如何にかかわらずよく一致した．

(3) 下末吉・武蔵野ローム層中の軽石中の強磁性鉱物のキュリー温度は，Pm-I 軽石層を除き280°—350°C にあつて，御岳火山起原の後者の 450°C とは顕著な差違を示した．

以上の事実にもとづきテフラの同定に際し軽石中の強磁性鉱物のキュリー温度及び熱磁気曲線のタイプに注目することは，従来の諸方法の限界を拡張する可能性が大きい．