Phosphorus Status of Some Andosols in Japan

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The belt around the Pacific Ocean is called the Circum-Pacific Volcanic Zone, or "Fire Ring," because of the existence of numerous active volcanoes. Japan is at the northwestern part of the ring. The Japan Islands Arc holds only one-thousandth of the earch surface, and sends out 7×10^{23} erg per year, or one-sixth of energy due to volcanic activity of the earth. Volcanic ejecta are spread throughout Japan. The ejecta alter to form Andosols, which occupy one-fourth of our arable land. Accordingly researches for Andosols are very important.

Distribution of Andosols in Japan

Andosols are mainly spread over Hokkaido, Tohoku, Kanto, Kyushu, and part of Chugoku District, as shown in Fig. 1. Their classification and distribution are set out in Table 1. According to humus content and thickness of humus horizons, they are divided into five subgroups, i.e., Thick High Humic, Thick Humic, High Humic, Humic, and Light-colored. The Light-colored Andosols include immatured ones, truncated ones, and exceedingly matured ones, all of which may be intergrades to other soil groups.

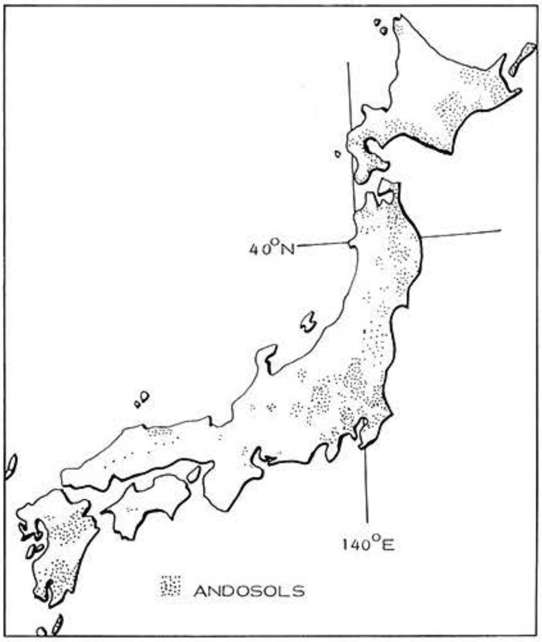

Fig. 1. Distribution of Andosols in Japan

Table 1. Distribution of Andosols in Japan

Soils	Total area	% of arable land
	ha	%
Andosols (Andepts)	954, 279	18. 8
Wet Andosols (Aquic Andepts)	348, 820	6. 9
Gleyed Andosols (Andaquepts)	52, 610	1. 0
Total arable land	5, 084, 065	100. 0

Distribution pattern of tephra* as parent materials of Andosols

Volcanoes eject pyroclastics usually upto the stratosphere at the altitude between 12,000 and 18,000 m at the time of eruption. The pyroclastics extend by the westerly jet stream in the mid-latitude of the northern hemisphere. The isopachs, or thickness contour lines of tephra layers are commonly ellipses with major axes extending to the east of craters. Some examples in Hokkaido are shown in Fig. 2.

The tephra thin away from their eruption

* The term, "tephra," has been widely used since S. Thorarinsson proposed it as a collective term for all pyroclastics transported from the crater through the air, including both air-fall and flow pyroclastic materials. It originally means ashes in Greek.

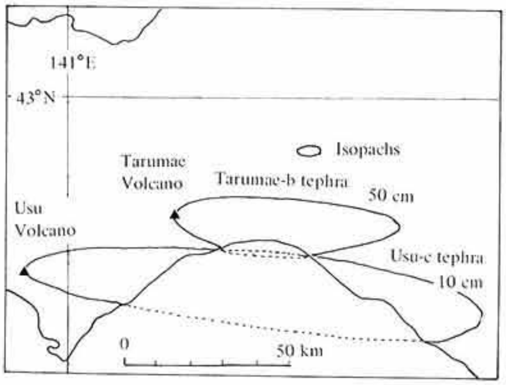

Fig. 2. Distributions of some tephra in Hokkido

sources. Organic matter accumulates during the intervals between eruptions. Fig. 3 shows a schema of tephra stratigraphy. Andosols, extending wide to Kanto Plain in the central Japan, show that the stratigraphy above-mentioned is not only a schema but an actual form (Fig. 4).

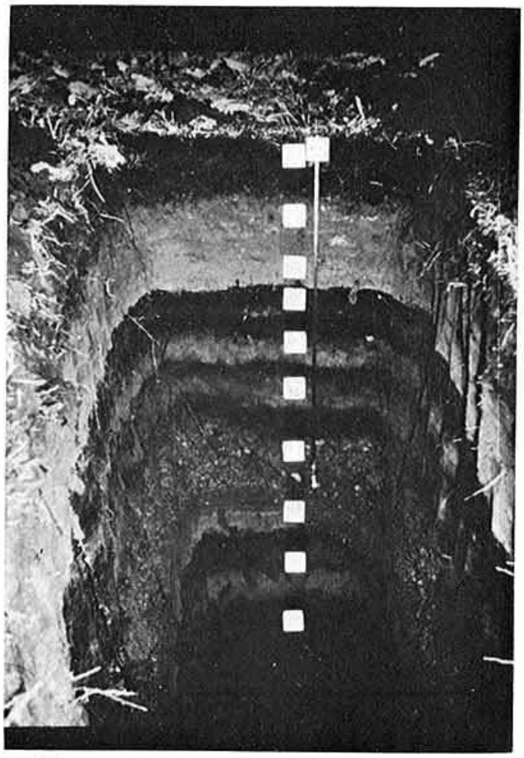

Plate 1. A profile of Andosol derived from tephra of Mt. Mashu

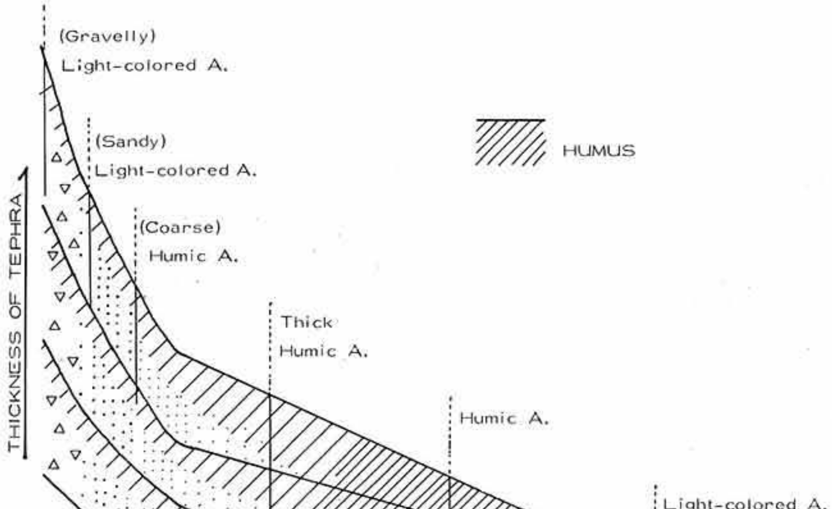

Fig. 3. Schema of distribution of Andosol

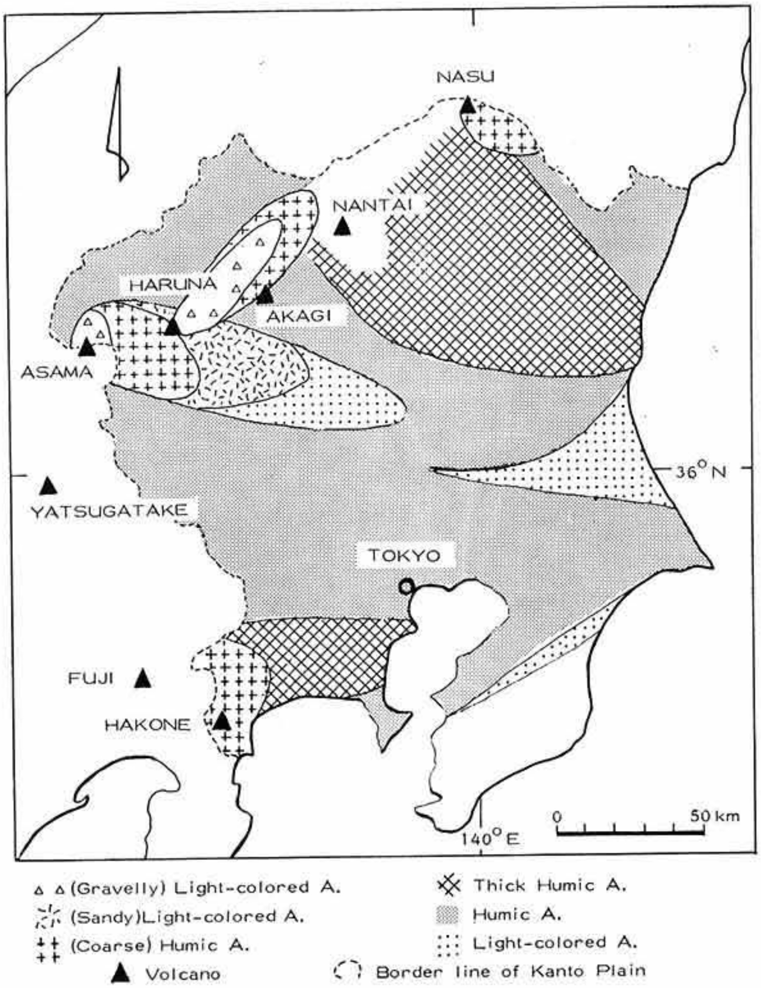

Fig. 4. Distribution pattern of Andosols in Kanto Plain in central part of Japan

Genesis of Andosols

Weathering of tephra is so rapid that differentiation of horizon occurs at an early stage, as —(A)/C—A/C—A/(B)/C—A/B/C. Accumulation of humus, allophanic clay, moisture retention, and phosphate fixation capacity increase simultaneously with weathering. At the latest stage of Andosol development decline the phosphate fixation capacity and humus accumulation.

However, rejuvenation of soil by tephra addition is usual and is a very important fact for soil formation in volacanic zone (Plate 1). Andosols, including buried ones, show wide variations in the properties according to their ages after deposition. They cannot be defined only with such a diagnostic subsurface horizon as Argillic or Spodic horizon.

Fertility of Andosols

Farmers in Japan had regarded Gray and Brown Lowland Soils as the most productive and Andosol as one of the lowest-productive until the nineteenth century, although farmers in other countries might not always have regarded Andosols infertile.

Since commercial phosphate ferilizers applied to Andosols at the beginning of the twentieth century, agricultural production from Andosols has markedly increased in Japan. The most important problem in fertility of Andosols has been considered to be phosphate supply. Many workers have studied phosphorus for higher crop production to find its available form, its determination, and physico-chemical equilibrium between soil and phosphorus, especially fixation of phosphorus by Andosols. However, few workers seem to have dealt with the fate of phosphorus in connection with soil genesis.

Consumption of large amount of phosphorus compounds is giving impact at present to the environment in some cases in Japan. For the solution of these problems investigations are necessary in relation to the behavior of phosphorus in ecosystem.

Phosphorus in Andosols

1) Phosphorus in ecosystem

In addition to native phosphorus derived from parent materials, soils receive phosphorus from aerosols, plant remains, animal wastes, manures and fertilizers. On the other hand, soils lose phosphorus in solution in ground water, erosion, crop production and so on.

Behavior of phosphorus under natural conditions may be investigated by choosing appropriate sites for study. Effect of manures and fertilizers may be removed in uncultivated soils, and the influence of erosion may be neglected at flat sites. Andosols may lose few amount of phosphorus for solution in water because of their high capacities of phosphorus fixation.

2) Phosphate fixation

Phosphate fixation is also called phosphate absorption, sorption or retention.

For the determination of phosphate sorption, a method by ammonium phosphate, 2.5% $(NH_4)_2HPO_4$ at pH=7.0, has long been used in Japan. Phosphate sorption of Andosols by the method are usually higher than 1,500 mg P_2O_5/100 g soil.

Figure 5 shows a comparison of the traditional method with Blakemore's method which

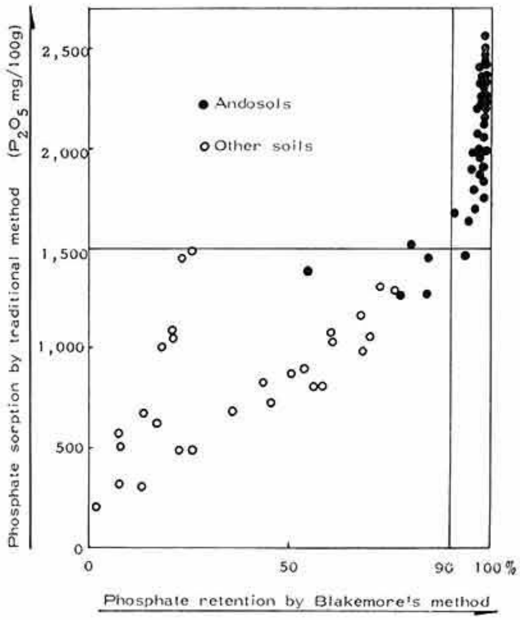

Fig. 5. Phosphate sorption of Andosols (A comparison of the traditional method of Japan with Blakemore's method)

was proposed of late. Phosphate retentions of Andosols by his method are mostly over 90%.

Status of phosphorus

1) Well-drained Andosols

Soil phosphorus is divided at first into three fractions; HCl-soluble inorganic phosphorus (IP), HCl-soluble organic phosphorus (OP), and hardly-soluble phosphorus (HP).**

The upper part of Fig. 6 shows an example of Light-colored Andosol corresponding to Typic Vitrandept of the U.S. System, well-drained and derived from basaltic tephra of Mt. Fuji. The surface layer was deposited in 1707 A.D., and the third layer in 1910 B.P.*** Total phosphorus (TP) contents of the soils are relatively high, some of which are more than 2,000 ppm P. TP contents are higher in humic horizons than in low-humic ones. HP is contrastive to TP. OP contents are dominantly high in A horizons and low in C horizons.

** HP=TP−(OP+IP)

*** B.P.=years before 1950 A.D., determined by radiocarbon dating.

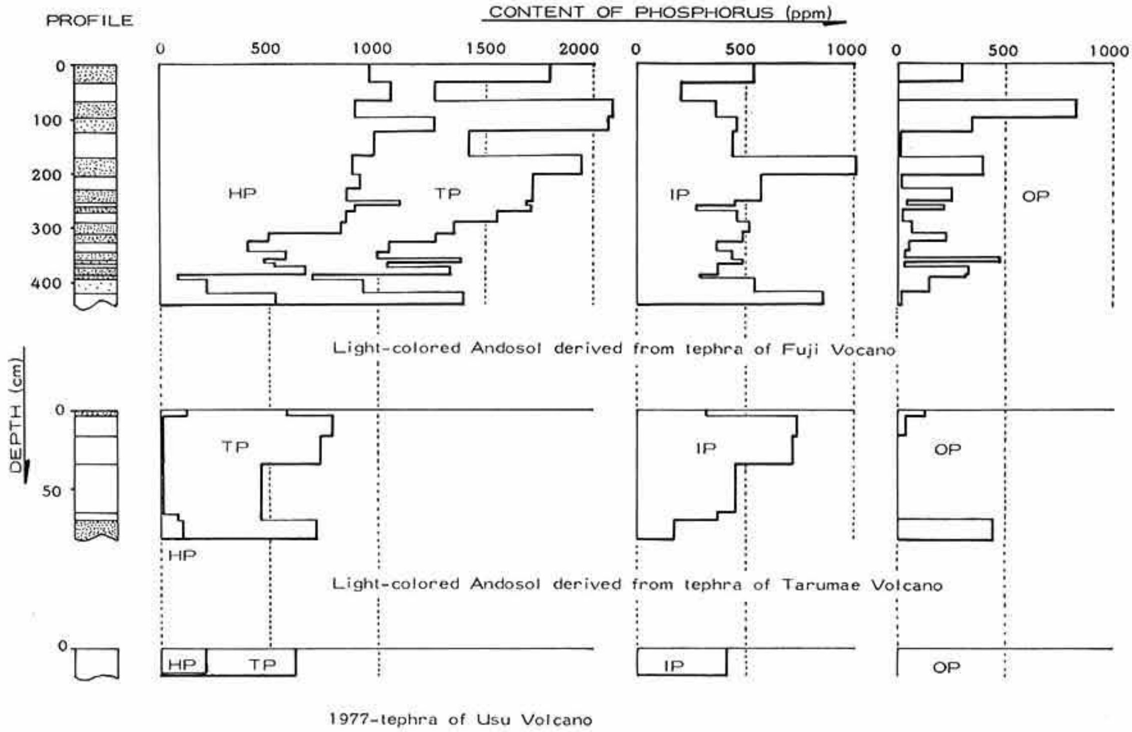

Fig. 6. Phosphorus distributions in well-drained Andosols

In the lower part of Fig. 6 are examples of Light-colored Andosol, well-drained and derived from andesitic tephra of Mt. Tarumae, and dacitic ones of Mt. Usu (Typic Vitrandept). The surface layer, so-called Tarumae-a tephra, was deposited in 1739 A.D. The second layer, so-called Tarumae-c tephra, is estimated to have deposited in 1,100—1,640 B.P. by radiocarbon dating. Usu tephra were sampled on the next day of eruption in 1977. Tarumae tephra have lower contents of TP than Fuji tephra and higher than Usu tephra. In general, the higher the contents of silicon in tephra is, the lower is the contents of TP. OP content of Usu tephra is zero. Tarumae tephra have markedly high OP in A hiorzons, especially in buried IIA horizon. The accumulation of OP seems to be pararell to the periods of weathering at the earth surface, i.e., appreciable amount of phosphorus seems to be retained in the organic fraction during the intervals between eruptions.

2) *Andosols under different water regime*

Poorly-drained Andosols have higher accumulation of organic matter than well-drained ones. Soils derived from the same tephra should have different distribution of phosphorus under different water regime. Phosphorus distributions were examined in a sequence of Andosols from the same tephra with different drainage, or a *hydrocatena*.

As shown in Fig. 7, TP contents are higher in poorly-drained soils than in well-drained ones. IP shows limited variation in each soil profile, and between profiles of different drainage. On the contrary, OP contents are extremely high in poorly-drained soils. The higher values of TP are related to the accumulation of OP.

In Table 2 is set out the results of subdivision of IP, comparing Light-colored Andosol (Typic Dystrandept) with Thick High Humic Wet Andosol (Aquic Dystrandept) sampled at Hokkaido. The specimen A represents the A horizon of Tarumae-b tephra deposited in 1667 A.D., and the IIA represents buried A horizon

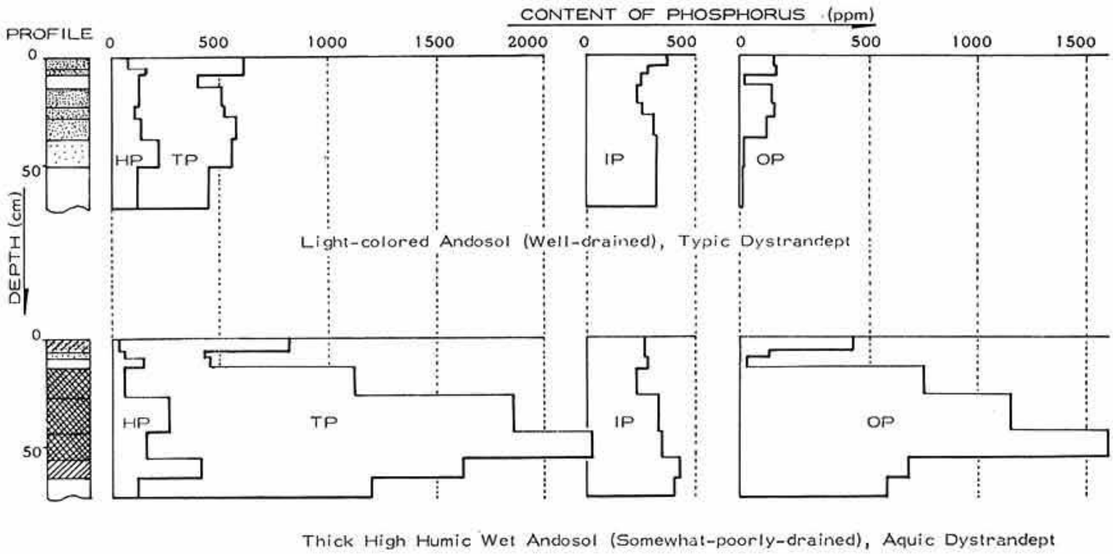

Fig. 7. Phosphorus distributions in Andosols with different drainage

Table 2. Subdivision of inorganic phosphorus in two Andosols

Sample	*M*/2 NH_4Cl	*M*/2 NH_4F	*N*/10 NaOH	(DCB)* *N*-NaOH	*N*/2 HCl	*N* HCl	Residual Org.	Residual Inorg.
				ppm P				
Light-colored Andosol (Well drained)								
A	31	76	33	11	110	5	34	58
C	1	1	2	5	128	4	3	22
IIA	1	56	13	14	20	4	36	68
Thick High Humic Wet Andosol (Somewhat poorly drained)								
A	22	90	45	8	108	3	55	91
C	1	6	2	6	141	4	6	21
IIA	1	53	49	15	31	3	68	70

* Dithionite-Citrate-Bicarbonate treatment

of Tarumae-c tephra. The period of soil development of the IIA is about 1,000 years longer than that of the A.

Small amount of easily-soluble P extracted by NH_4Cl can be found in surface A, but very few of them in buried IIA. The Ca-bound P extracted by HCl is high in the least weathered C, and low in IIA. The Al-bound P extracted by NH_4F and the Fe-bound P extracted by NaOH increase at an early stage of weathering and, then, gradually decline with time. The occluded P extracted by dithionite-citrate-bicarbonate and subsequent NaOH treatment gradually increase with increasing degree of soil development.

Organic phosphorus as a marker of Andosol age

Organic phosphorus in Andosols accumulates proportionally with increasing time upto about 8,000 B.P. Consequently, it is quite reasonable to postulate that in case when tephra are younger than 8,000 B.P., and have had no influence of erosion and heavy application of organic matter, their age can be estimated from the following equation, based on organic phos-

Table 3. Tephra ages estimated by the proposed equation

Tephra	Soil	Land use	Tephra age estimated by	
			Organic P	Radiocarbon
			y.B.P.	
Fuji	Light-colored A.	Deciduous forest	1,700	1,910±110
Tarumae-d	Light-colored A.	Deciduous forest	3,000	3,580±100
	Hight-Humic Wet A.	Deciduous forest	3,200	3,580±100
Daisen	Thick High Humic A.	Coniferous forest	2,760	2,490~3,200
	Thick High Humic A.	Vegetable field	3,060	2,490~3,200

phorus accumulation *in situ* of standard tephra of given age.

$$\frac{\sum_{i=1}^{c} b_i d_i p_i}{T} = \frac{\sum_{i=1}^{x} b_i d_i p_i}{y}$$

Therefore,

$$y = \frac{T}{\sum_{i=1}^{c} b_i d_i p_i} \sum_{i=1}^{x} b_i d_i p_i$$

where, y=unknown age of any tephra; T=given age of standard tephra; b=soil bulk density of each horizon; d=thickness of each horison; p=soil organic phosphorus content of each horizon; c=cth horizon (horizon No. of the standard tephra. The surface horizon counts 1st); x=xth horizon (horizon No. of tephra of unknown age); bdp is organic phosphorus accumulation per unit area of any horizon, and (the sum of bdp)/T is the accumulation rate of organic phosphorus per year *in situ*.

Some results obtained by above-mentioned procedure are set out in Table 3.

Phosphorus is an important element in soil fertility. Although large amount of consumption of phosphorus causes some environmental problems, its resources are poor in Japan. Phosphorus should be applied according to soil properties.

There is no epilogue in research on long-term behavior of phosphorus. The conversion rates of various forms of phosphorus might largely vary in other countries under the climate different from Japan.

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