

A PROPOSAL FOR THE SOURCE VENT OF THE RISHIRI-WANKONOSAWA TEPHRA (RS-WN), THE LATE PLEISTOCENE MARKER TEPHRA IN NORTHERN HOKKAIDO

Hideki MIURA*

Abstract Rishiri-Wankonosawa tephra (Rs-Wn) is one of the late Pleistocene marker tephtras in northern Hokkaido. This tephtra was previously considered to have been supplied from the central part of Rishiri island volcano. Detailed mapping of thickness and grain-size of this tephtra, however, shows that the source vent lies not on the island but at the crater-like depression submerged 90m below sea-level about 5.5km off the southeastern coast of the island. Radiocarbon age determinations and stratigraphical features of this tephtra associated with distal marker tephtra and periglacial phenomena indicate that the eruption took place during the maximum stage of the Last Glaciation. The lithofacies of this tephtra with no phreatomagmatic component suggest that the eruption possibly occurred on land at the low stand of sea-level.

Key words: Rishiri-Wankonosawa tephtra formation, Rishiri-Hotoku tephtra formation, submerged source vent, maximum stage of the Last Glaciation, eruption age

1. Introduction

Several air-fall tephtra layers supplied from Rishiri volcano occur in Sarobetsu and Tonbetsu plains, northernmost Hokkaido (Fig.1). Sarobetsu Research Group *et al.* (1966) and Junenchi Research Group (1967) classified younger tephtra layers into two groups: the lower "Wankonosawa pumiceous deposits" which consist of pumice, scoria, clay and sand layers, and the upper "Hotoku volcanic ash" consist of black ash and loam deposits.

There still remain several problems on these tephtras: 1) the volcano-stratigraphical definition of each tephtra is not so clear, 2) the strict location of source vent for each tephtras is not clear, 3) reliable data for the eruption age is not given. This paper aims to give fundamental data and discusses to clarify these problems.

* National Institute of Polar Research.

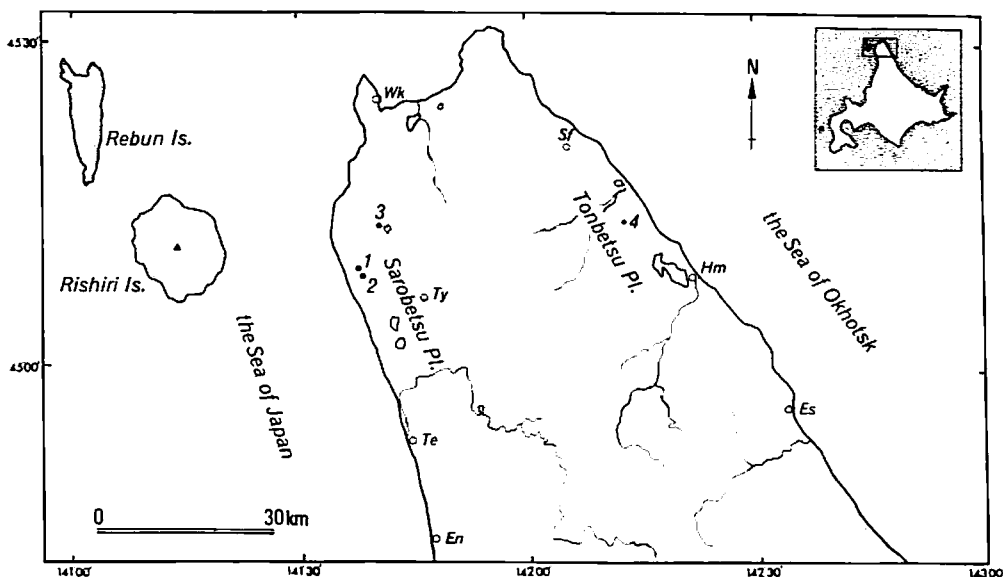


Fig. 1 Index map

Loc. 1: Hotoku in Hotoku hills (Type section in the present paper), Loc. 2: Hotoku (Tomioka and Otowa, 1973), Loc. 3: Kabuto-numa (Yanagida and Shimizu, 1993 and Fig. 6 in the present paper), Loc. 4: Asajino (Fig. 6 in the present paper) En: Enbetsu, Te: Teshio, Ty: Toyotomi, Wk: Wakkanai, Sf: Sarufutsu, Hm: Hamatonbetsu, Es: Esashi

2. Stratigraphy of Rishiri Tephra Layers

As the tephra layers previously defined in this area (Sarobetsu Research Group *et al.*, 1966; Junenchi Research Group, 1967) do not seem to represent a single tephra layer but tephra group and include non-volcanic products, some revisions will be needed for the volcano-stratigraphical studies. Basically a single tephra layer should be identified by the recognition of volcanic products of one single eruptive episode and each layer can be classified by soils or unconformities.

Figure 2 shows a synthesized columnar section of the tephra layers occurring in northern Hokkaido. The stratigraphy of Rishiri tephra layer is described with each single tephra layer and facies, *i.e.* color, granulometric classification and maximum pumice size (MP), maximum lithic size (ML), maximum scoria size (MS). In practice, MP, ML and MS are taken as the average maximum diameter of the largest three fragments of each type seen at each exposure (Walker, 1980).

The type section is located in Hotoku hills, Sarobetsu plain (Fig. 1; Loc. 1) where a whole section of upper part of Rishiri tephra is exposed:

	0- 46 cm	black humus soil
	46-101 cm	brown soil
Rs-Ho	101-149 cm	thinly bedded black ash with lithic fragments; ML 5mm (upper part)

	149-217 cm	red and black scoria. lapilli with lithic fragments; MS 20mm, ML 4mm (middle part)
	217-299 cm	thinly bedded black ash with accretionary lapilli (lower part)
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	299-303 cm	pinkish soil
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Rs-Wn	303-313 cm	black ash (unit 5)
	313-316 cm	yellow vesiculated pumice; MP 5mm (unit 4)
	316-358 cm	normally graded blue and banded pumice with lithic fragments; fine grained at the top; MP 47mm, ML 13mm (unit 3)
	358-413 cm	reversely graded white and blue pumice with lithic fragments; MP 47mm, ML 6mm (unit 2)
	413-416 cm	black ash (unit 1)
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	416-451 cm	brown soil

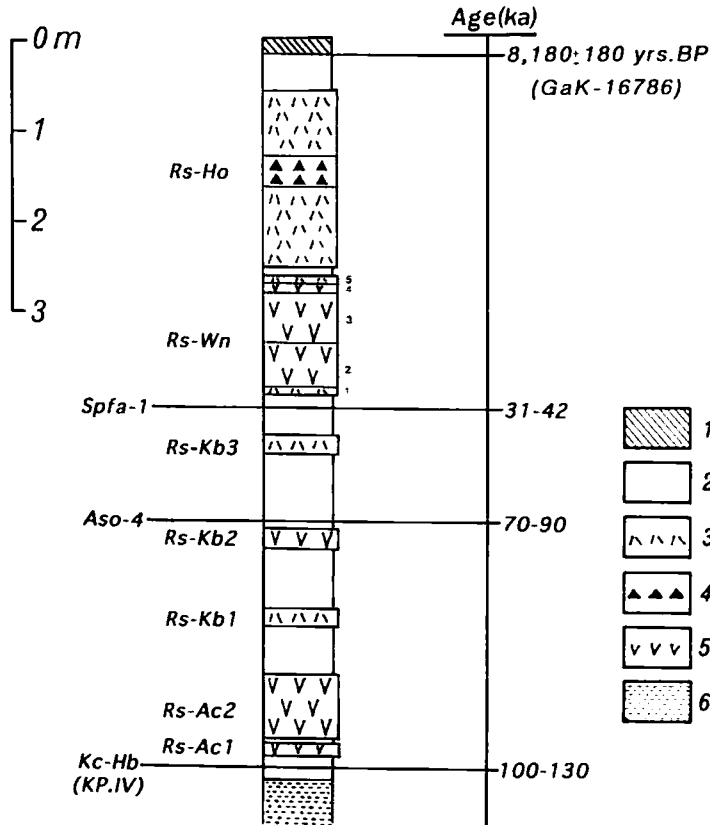


Fig. 2 Synthesized stratigraphic column of tephra erupted from Rishiri volcano in northern Hokkaido

1: humus soil, 2: brown soil, 3: volcanic ash, 4: scoria, 5: pumice, 6: marine sand

The author newly proposes the *Rishiri-Hotoku tephra formation (Rs-Ho)* for the upper black ash and scoria layers (101-299cm), and the *Rishiri-Wankonosawa tephra formation (Rs-Wn)* for the lower pumiceous tephra formation (303-416cm): because both tephtras are separated by the pinkish soil (299-303cm). Since this pinkish soil is very thin, both eruptions occurred probably in short interval of time. In addition, the *Rishiri-Kabutonuma 1, 2, 3 tephra formations (Rs-Kb1, Kb2, Kb3)* and the *Rishiri-Achiaru 1, 2 tephra formations (Rs-Ac1, Ac2)* are recognized below the Rs-Wn tephtra in this section (Miura, 1994; Fig. 2). The present paper deals with upper two tephtra layers: Rs-Ho and Rs-Wn.

Table 1 shows characteristics and petrographical properties of these tephtras. The Rs-Ho tephtra is composed of three parts: lower black fine ash with accretionary lapilli, middle scoria lapilli and upper thinly bedded black ash. This tephtra formation is rich in olivine as phenocrysts.

The Rs-Wn tephtra comprises five fall-units 1-5. The eruption started with ejection of black ash (unit 1) followed by coarse-grained banded pumice with lithic fragments (unit 2 and 3). And the yellow vesiculated pumice (unit 4) and black ash (unit 5) followed its eruption. The Rs-Wn tephtra has the characteristic assemblage of

Table 1 Characteristics of the Rishiri-Hotoku and the Rishiri-Wankonosawa tephtras and related widespread tephtras in northern Hokkaido

(1)	(2)	(3)	(4)	(5)	(6)		(7)	(8)	(9)	(10)	(11)		(12)
Tephtra	Loc	Type	Color	Th cm	MP mm	ML mm	So	Ve	Phe	Lf	Mineral composition mafic minerals / volcanic glass		SV
Rs-Ho (Upper)	1	afa, B	gy, br	48	f	5	w	—	m	r	ol, opx, cpx		Rs
Rs-Ho (Middle)	1	sfa, B	or, bk, rd	68	20	4	p	p	m	r	cpx, ol		Rs
Rs-Ho (Lower)	1	afa, B	gr, bk	82	f	—	w	—	r	p	ol, opx, cpx		Rs
Rs-Wn (5)	1	afa, B	bk	3	f	—	w	—	m	p	ol, cpx, opx		Rs
Rs-Wn (4)	1	pfa, D	yl	10	5	—	m	w	m	p	opx, cpx		Rs
Rs-Wn (3)	1	pfa, D	bl	42	47	13	m	p	m	m	ho, opx	pm	Rs
Rs-Wn (2)	1	pfa, D	wh/bl	55	47	6	m	m	p	r	ho, opx	pm	Rs
Rs-Wn (1)	1	sfa, B	bk	3	f	—	w	p	m	r	ol, opx, ho		Rs
Spfa-1	4	afa, D	wh	tr	vf	—	—	—	—	—	—	bw (n:1.500-1.503)	Sk
Aso-4	3	afa, D	gy	2	vf	—	w	—	—	—	—	bw (n:1.508-1.510)	As

(2) Locality is shown in Fig. 1 (3) pfa: pumice fall, afa: ash fall, sfa: scoria fall, D: dacite, B: basalt (4) wh: white, yl: yellow, br: brown, or: orange, gy: gray, rd: red, bl: blue, bk: black, pk: pink (5) Thickness (6) MP: the average maximum diameter of the largest three pumice fragments at exposure, ML: the average maximum diameter of the largest three lithic fragments at exposure, f: fine, vf: very fine (7) So: Sorting, w: well, m: intermediate, p: poor (8) Vesiculation, w: well, m: intermediate, p: poor (9) Phe: Phenocryst abundance, r: rich, m: intermediate, p: poor (10) Lf: Lithic fragment abundance, r: rich, m: intermediate, p: poor (11) ol: olivine, opx: orthopyroxene, cpx: clinopyroxene, ho: hornblende, bi: biotite, mg: magnetite, qt: quartz, bw: bubble-walltype of glass shard, pm: pumice type of glass shard, n: refractive index of volcanic glass shard (12) SV: Source volcano, Rs: Rishiri Volcano, As: Aso Volcano, Sk: Shikotsu Volcano

phenocrysts in each fall unit as shown in Table 1.

3. Source Vent of the Rs-Wn Tephra

Sarobetsu Research Group *et al.* (1966) and Junenchi Research Group (1967) showed the isopach of the lowest part of "Wankonosawa pumiceous deposits" and the distribution map of "Hotoku volcanic ash". This lowest part of "Wankonosawa pumiceous deposits" probably corresponds to the fall-units 1 to 3 of the Rs-Wn tephra in the present paper. The dispersal axis of this "Wankonosawa pumiceous deposits" lies in East-West direction on land area, while the axis of this tephra bends abruptly toward the central part of Rishiri island with no evidence. Then the distribution map with no isopach of "Hotoku volcanic ash", which consist of loam deposits (weathered volcanic ash soil), shows that it occurs extensively in northern Hokkaido.

On the basis of this isopach and dispersal axis, Kobayashi (1987) presumed that the source vent of "Rishiri-Wankonosawa pumiceous deposits" is "Maoyani crater" (marked M in Fig. 3) on the southern slope about 600m a.s.l. of Rishiri volcano. He identified a fine pumiceous ash as "Rishiri-Wankonosawa pumiceous deposits" to the south of "Maoyani crater", but described no petrographic nature of this ash. It seems curious that the pumice size close to this area is finer than that in remote area, and that the plinian deposit can not be recognized on land of Rishiri island. Therefore the "Maoyani crater" is probably not the source vent of this tephra.

Figures 4 (1) ~ (6) show the isopach maps of fall-units 1, 2, 3 and total thickness of Rs-Wn and isograde maps of fall-units 2, 3. The dispersal axis of the Rs-Wn tephra lies in the East-West direction from Wankonosawa (Fig. 1. Loc. 1) in Hotoku hills to Asajino (Fig. 1. Loc. 4) in Tonbetsu plain. This line seems to extend to the area off the southern coast of Rishiri island. The submarine topography around this area edited by Marine Safety Agency (1991) shows that a submerged depression lies off about 5.5km SSE of Oniwaki in Rishiri island (marked solid star in Fig. 3). This depression has a crater-like shape with a diameter of about 5km. The areal variation of the thickness and the grain size of pumice fall deposits suggest that this submerged depression is possibly the source vent of Rs-Wn. In addition, the location of this depression is accord with the prominent direction (NNE-SSW) of dikes, flank cones and maars of Rishiri volcano (Nakamura, 1969) (Fig. 3). The bottom of this depression is possibly flat and below sea-level about 90m in depth. The submarine structural chart (Marine Safety Agency, 1991), however, shows that the surface materials in and around this depression are composed of mud and sand.

Figures 5 (1) ~ (3) show the isopachs of Rs-Ho. The Rs-Ho tephra occurred only around Sarobetsu plain. These maps suggest that this tephra formation is possibly derived from southern parasitic cone(s) or unknown submerged source vent(s) of Rishiri volcano. Rs-Ho itself has not yet been identified on Rishiri island.

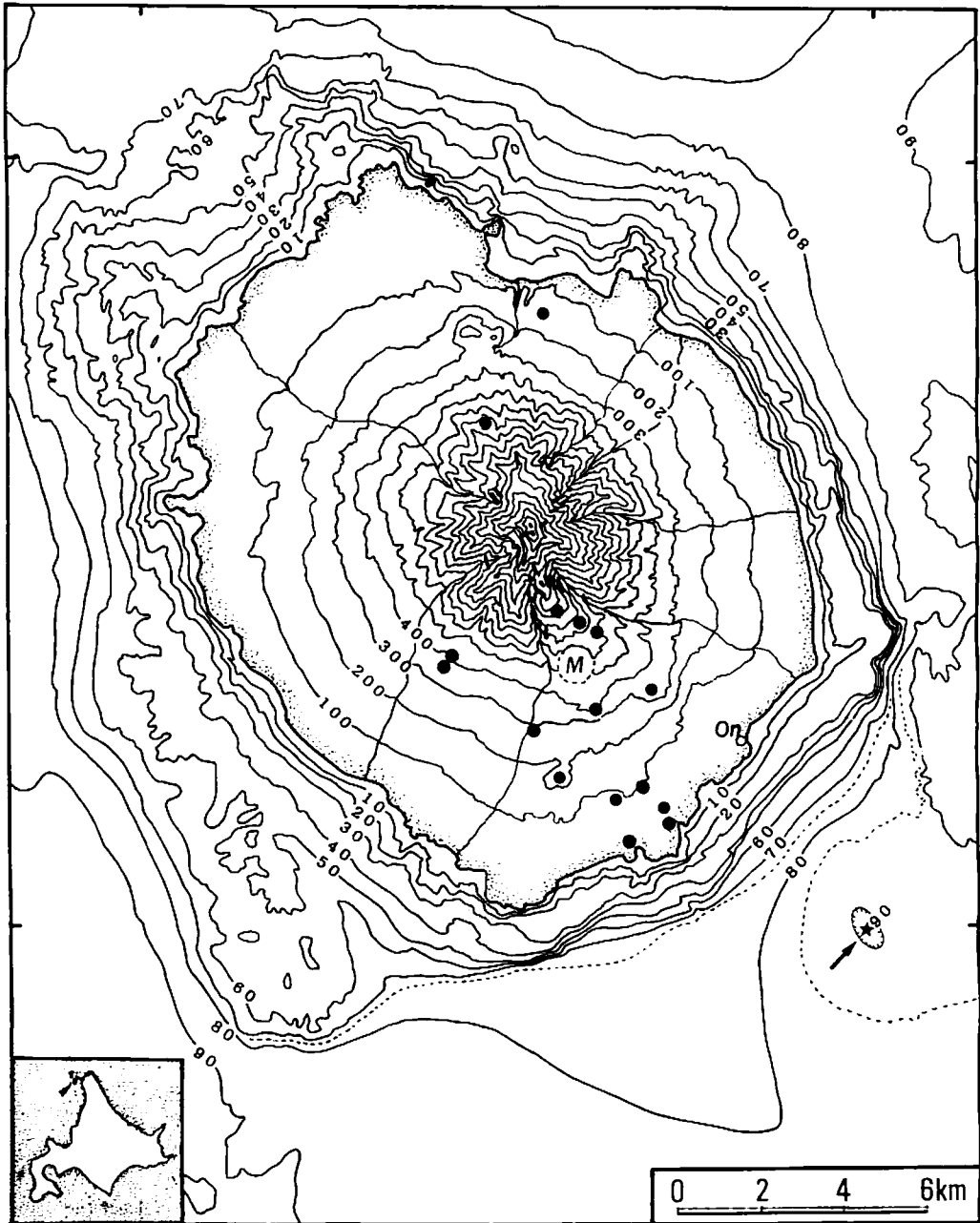


Fig. 3 The distribution of flank cones and dikes in Rishiri island and the possible source vent of Rs-Wn
 On: Oniwaki;
 M: "Maoyani crater"(after Kobayashi, 1987)
 Solid circle shows flank cone and thick line shows dike.
 Solid star shows the proposed source vent of Rs-Wn

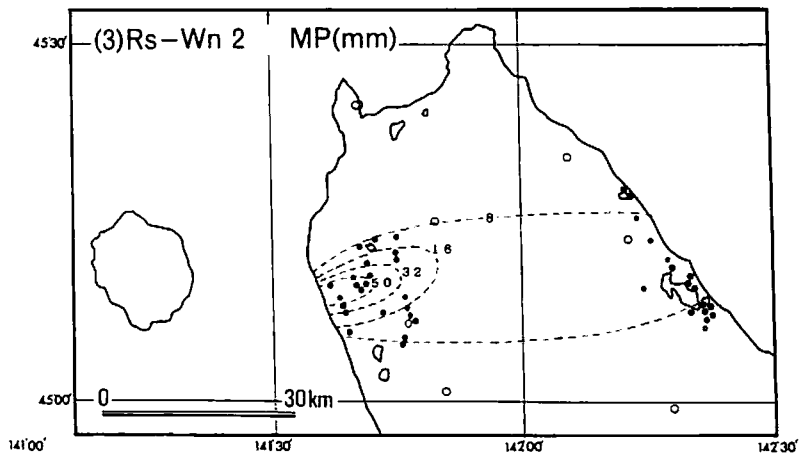
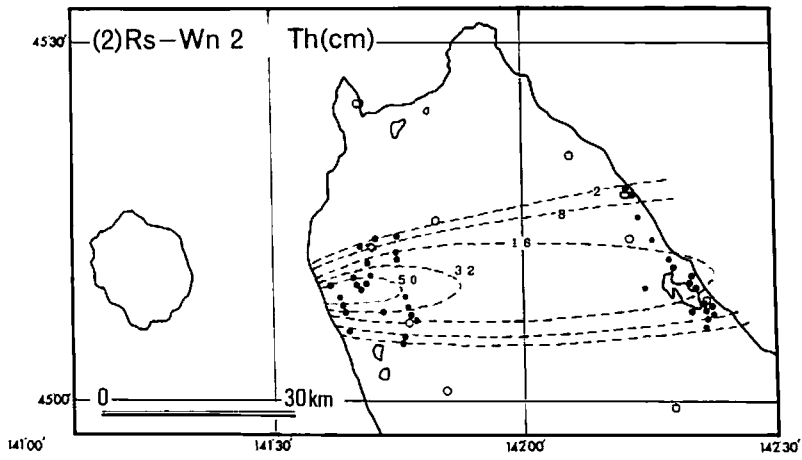
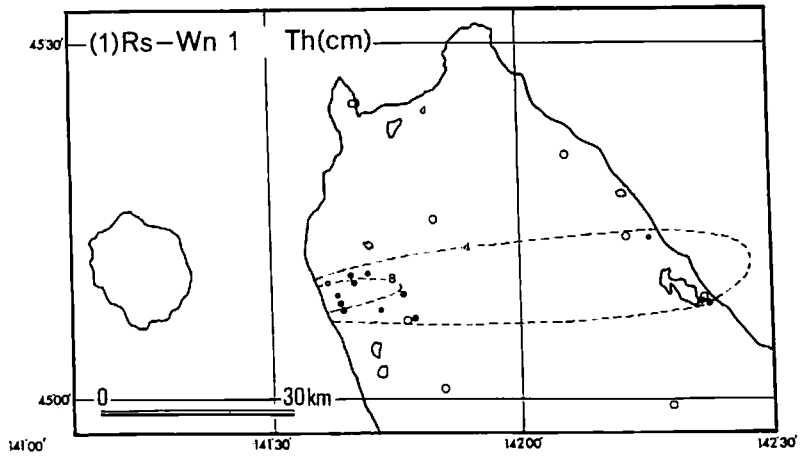
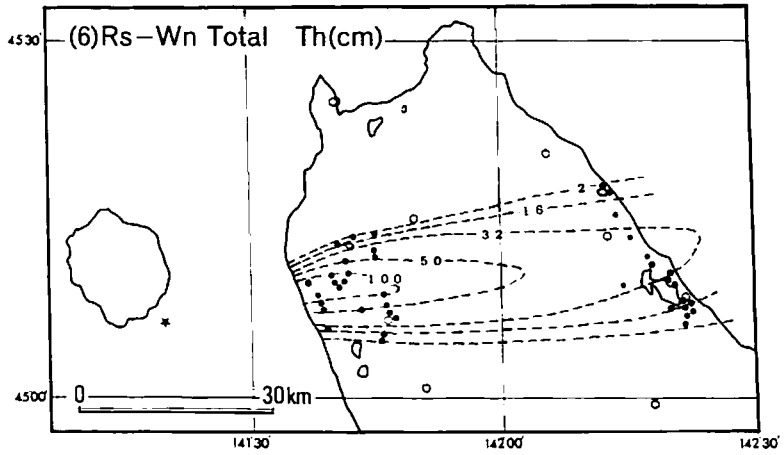
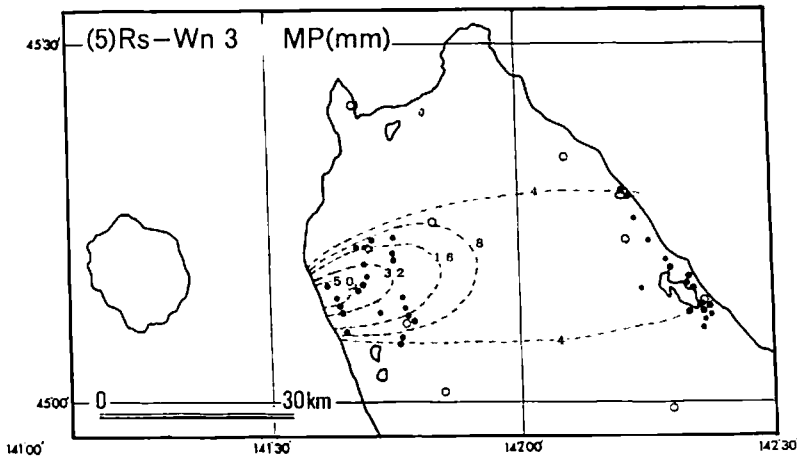
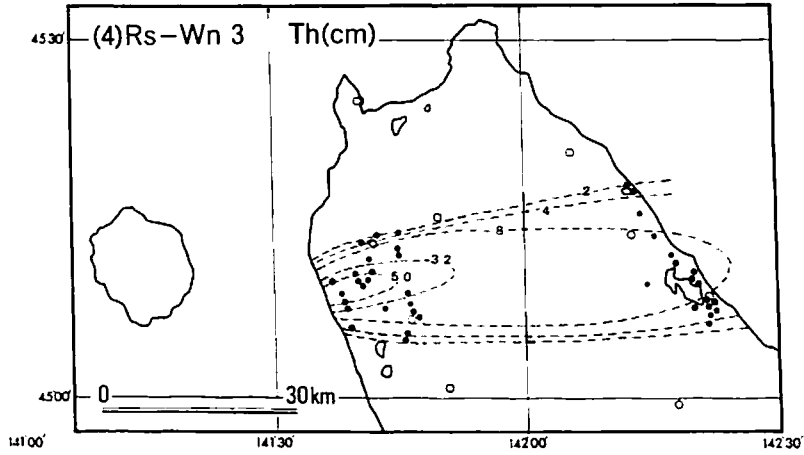


Fig. 4 Isopach and isopleth maps of the Rishiri-Wankonosawa tephra (Rs-Wn)



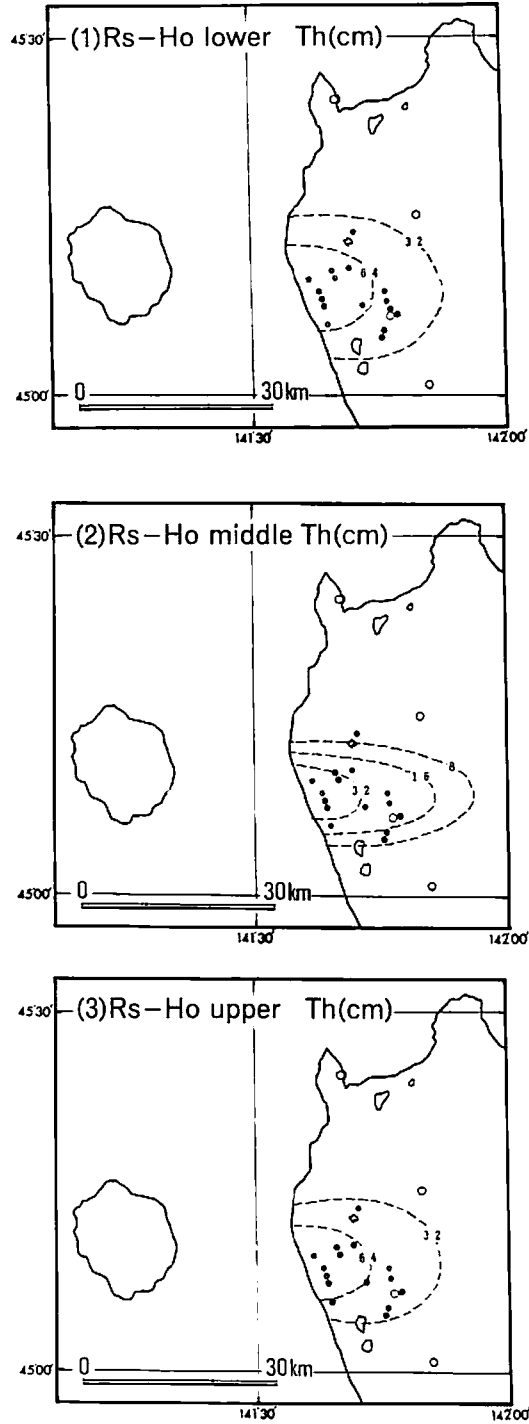


Fig. 5 Isopach maps of the Rishiri-Hotoku tephra (Rs-Ho)

4. Eruption Age

Previous works

The eruption age of "Rishiri-Hotoku ash" was previously estimated to be early Holocene and that of "Rishiri-Wankonosawa pumiceous deposits" late Pleistocene (Sarobetsu Research Group *et al.*, 1966) without any conclusive evidences.

Sasaki *et al.* (1971) first reported the radiocarbon ages of $5,240 \pm 100$ years BP (GaK-3338) for humic acid below "Hotoku volcanic ash", and $3,570 \pm 120$ years BP (GaK-3339) from humic acid over "Wankonosawa pumiceous deposits", and $14,800 \pm 1,000$ years BP (GaK-3340) from peat below "Wankonosawa pumiceous deposits". They did not describe the sampling horizon and localities in detail.

Afterwards Tomioka and Otowa (1973) exchanged the age of $3,570 \pm 120$ years BP (GaK-3338) of "Wankonosawa pumiceous deposits" for the age of $5,240 \pm 100$ years BP (GaK-3339) of "Hotoku volcanic ash", because they considered that Sasaki *et al.* (1971) had mistaken the sample of GaK-3338 for the sample of GaK-3339. Tomioka and Otowa described the sample of humic acid (GaK-3338) taken from the humic layer 73-91cm below "Hotoku volcanic ash".

There seems to lie a problem in identification of these tephras, because humic layer exists intercalating in dune sand over Rs-Ho there. Moreover this sampling depth is too shallow for the Rs-Ho horizon. Sasaki *et al.* (1971) and Tomioka and Otowa (1973) probably include the dune sand in the "Hotoku volcanic ash", and accordingly the age of $3,570 \pm 120$ years BP (GaK-3338) is far younger than the eruption age of Rs-Ho.

In addition, Tomioka and Otowa (1973) described the sampling site for dating of "Wankonosawa pumiceous deposits" as follows:

- (1) humic acid in humus over the "Wankonosawa pumiceous deposits" in Hotoku hills ($5,240 \pm 100$ years BP: GaK-3339)
- (2) peat with *Oxycoccus*, *Sphagnum* and wood, intercalated with diluvial clay corresponding to the lower part of weathered "Wankonosawa pumiceous deposits" in upland near Kabuto-numa ($14,800 \pm 1,000$ years BP: GaK-3340)

They obtained the sample of GaK-3339 from the layer 50-73cm in depth at the section (1). However, Rs-Wn in the present paper never occurs in such shallow depth in Hotoku hills (Fig 1, Loc. 2). They did not describe the columnar section (2) in detail. Even if this diluvial clay is derived from weathered pumice of Rs-Wn, the existence of diluvial clay intercalating in peat indicates that this clay is not primary Rs-Wn. Therefore these radiocarbon ages (GaK-3339, 3340) do not show the eruption age of Rs-Wn.

Yanagida and Shimizu (1992) reported two radiocarbon ages of $>48,800$ years BP (I-16345) and $>48,800$ years BP (I-16346) for organic silt above and below "Wankonosawa pumiceous deposits" respectively from the section in Kabuto-numa, Sarobetsu plain (Fig. 1, Loc. 3).

In this section, Rs-Wn with thickness of 27cm is recognized 140cm above the peat (Fig. 1, Loc. 3; Fig. 6). The author found a vitric ash 2cm in thickness in the upper-

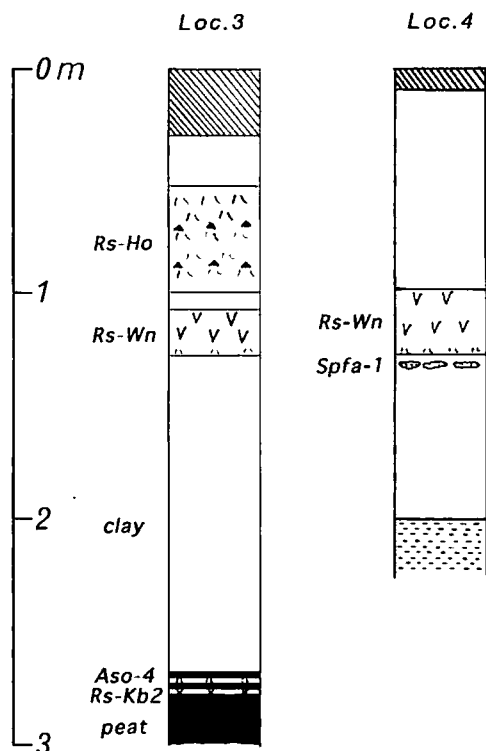


Fig. 6 Columnar section of tephra near the Kabuto-numa (Loc. 3) and in Asajino (Loc. 4) The locations are shown in Fig. 1 and the legend in Fig. 2.

most part of this peat, that probably corresponds to the organic silt horizon reported by Yanagida and Shimizu (1992). The refractive index of this volcanic glass of bubble-wall type ranges between 1.508 and 1.510 (Table 1). Therefore this vitric ash should be identified with the Aso-4 tephra (*ca.*70-90 ka: Machida and Arai, 1992). Accordingly, both radiocarbon ages (I-16345, 16346: Yanagida and Shimizu, 1992) came from below Rs-Wn.

Estimation of the eruption age

As discussed above, the "Hotoku volcanic ash" and the "Wankonosawa pumiceous deposits" in previous works are not strictly identical with Rs-Ho and Rs-Wn defined in the present paper. Therefore the estimated eruption age of Rishiri tephras must be re-examined.

Although no reliable radiometric ages of Rs-Wn and Rs-Ho have been obtained yet, lines of evidence suggest that the eruption of Rs-Wn and Rs-Ho can be estimated to take place during the maximum stage of the Last Glaciation (oxygen isotope stage 2) based on several evidences: (1) The Rs-Wn tephra is above the distal Shikotsu pumice fall-1 (Spfa-1) (*ca.* 31-35ka: Machida and Arai, 1992; *ca.* 42ka: Yanagida, 1994) in Tonbetsu plain (Fig. 1, Loc. 4: Fig. 6: Table 1). (2) The radiocarbon age determined on the acid

insoluble-humus fraction (boiling with 1N-HCl for 60 min.) from the lowest part of humus soil above the Rs-Ho tephra is $8,180 \pm 180$ years BP (GaK-16786) (Fig. 2). (3) It is likely that the eruption of Rs-Wn occurred on land in the low sea-level stages of the Last Glaciation, because the estimated source vent of the Rs-Wn tephra lies 90m below present sea-level, and this tephra has no phreatoplinian component. Also the soil between Rs-Wn and Rs-Ho is separated by very thin soil, indicating a relatively short hiatus between two eruptions. (4) Many kinds of fossil periglacial phenomena are found in Rs-Ho and Rs-Wn. In particular, the periglacial wedge (thermal frost cracking), estimated to have formed during the maximum stage of the Last Glaciation in eastern Hokkaido (Miura and Hirakawa, in press), occurs after the eruption of Rs-Ho.

5. Conclusion

Rishiri-Hotoku (Rs-Ho) and Rishiri-Wankonosawa (Rs-Wn) tephra formations are strictly defined by the recognition of volcanic products of one single eruptive episode. The isopach and isograde maps of Rs-Wn show that the source vent lies at the crater-like depression submerged 90m below sea-level about 5.5km off the southeastern coast of Rishiri island. This tephra has no phreatomagmatic component, suggesting that the eruption possibly occurred on land at the low stand of sea-level. Radiocarbon age determinations and stratigraphical features of this tephra associated with distal marker tephra (Spfa-1) and periglacial phenomena (in particular, thermal frost cracking) indicate that the Rs-Wn possibly erupted during the maximum stage of the Last Glaciation (oxygen isotope stage 2) after the eruption of Spfa-1.

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He wishes to dedicate this paper to Professor Hiroshi Kadomura in commemoration of his retirement from Tokyo Metropolitan University.

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