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Data and Notes　資料

Distribution manner of plants along fumarole groups in Eastern Hokkaido, Japan

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The present study was conducted in two fumarole areas in eastern part of Hokkaido, northern Japan, to address a lack of knowledge about volcanic gas action that constrains the progress of succession. The number of species increased in proportion to the distance from fumaroles to adjacent forest zones. Indicator species were extracted using TWINSPAN. The indicator species were different between two topographically different study sites. This finding suggests that the sulfuric acid concentration in the soil varies depending not only on the distance from fumaroles but also on the elevation and this affects the plant distribution.

Keywords
Teshikaga, fumarole, sulfuric acid, vegetation, TWINSPAN

1 Introduction

Japan is located in the circum-Pacific volcanic zone and has 86 active volcanoes, which corresponds to 8% of all volcanoes on the Earth[1]. Eruptive activities have detrimental impacts on vegetation growth around active volcanoes. On volcanic, hillside slopes covered with less plant, the ground surface movement intensifies and sometimes causes barren-like conditions[2]. However, rich natural vegetation can be found on outskirts of active volcanoes. This suggests that the eruptive activities repeatedly disturb surrounding vegetation and invasion of plants there[3]. In general, plant communities on volcanic barrens do not reach their climax stage even under natural conditions. As a result, several seral stages may co-occur through the succession[4].

In areas with fumaroles, volcanic gas continuously affects the plant community[5]. Naito et al.[6] confirmed frequent absence of *Fagus crenata* within a 500 m radius of a group of sulfur fumaroles. They also found that the vegetation shifts from a bare ground, to *Carex angustisquama* community, to *Miscanthus sinensis*–*Cladonia theiophila* community, to bushes, to *Pinus parviflora* var. *pentaphylla* forest, and to *Fagus crenata* forest concentrically around groups of fumaroles.

In this study, we selected two volcanic areas with many fumaroles in Teshikaga, eastern Hokkaido, as the study sites in order to clarify the plant distribution by taking particular note of differences between around the fumaroles and inside the forests.

2 Methods

2•1 Study area

The study was conducted in two fumarole sites (Site A called the second Mt. Iwo, and Site B called Bokke in Ainu language) located in Teshikaga, eastern Hokkaido (144° 13' – 144° 36' and 43° 23' – 43° 42'). The mean annual air temperature in Teshikaga was 6.0°C in 2014, although large annual ranges, 32.8°C in August and -18.3°C in February[1], were recorded. Almost all areas of Teshikaga are designated as the Akan–Mashu National Park. The area is based on three calderas, Akan, Kussharo, and Mashu, created by volcanic activities in the Chishima volcanic zone, and the above two sites are situated in a special protection area for the rich primitive landscape[7].

Site A is a rugged stand of approximately 6,800 m^2 in

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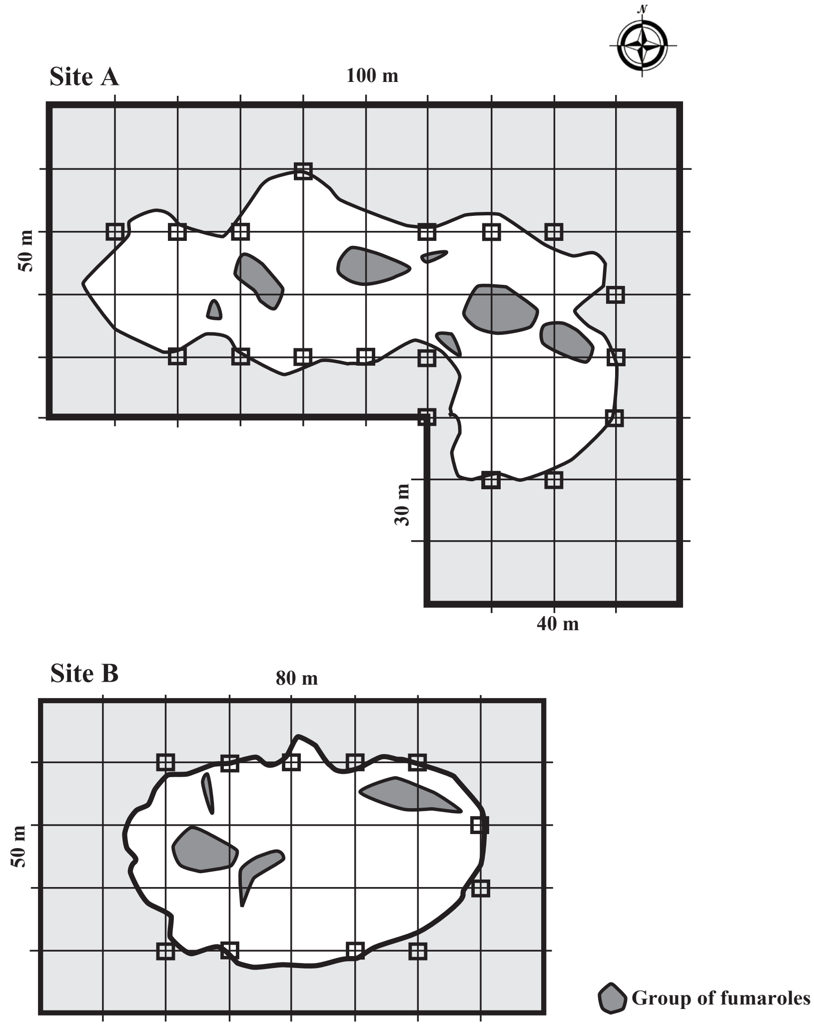

Fig. 1 Maps of Sites A and B.

Light gray and white areas show forest and herbaceous zones. A 2-m wide area inside and outside a forest edge was defined as the margin zone. A grid of 10 m x 10 m squares was established in both sites and 2 m x 2 m study plots were created on intersections of the gridlines. Small squares in the maps indicate the study plots in the margin zones.

area at ca 180–200 m a.s.l., of which approximately 2,200 m^2 is a non-vegetated area. Site B is a muddy volcano and a shallow basin-like lowland located approximately 400 m west of Site A. This site is located at ca 160–170 m a.s.l., and extends over an area of approximately 4,000 m^2, of which approximately 1,700 m^2 is a non-vegetated area spreading in a concave part lower than the adjacent forest. The number of fumaroles is 80 in Site A and 60 in Site B at most (Fig. 1). Several fumaroles form a group and seven groups of fumaroles were observed in both sites. The largest fumarole group consists of approximately 40 fumaroles and the smallest one has three fumaroles.

2•2 Study method

The ground around the fumarole groups is mostly bare and is covered with a few herbaceous plants in some quarters of both sites. The bare ground and the herbaceous plant-covered ground were recognized as herbaceous zones. A clear margin can be observed where groups of fumaroles and a forest zone meet. Therefore, we defined a 2 m-wide area both inside and outside a forest edge as a margin zone. Then, each site was divided into three zones: forest, margin, and herbaceous zones. In order to create a vegetation map, we identified the tree species compositions in both sites. In order to determine the dominances (cover, %) of understory species (tree seedlings and saplings smaller than 1 m,

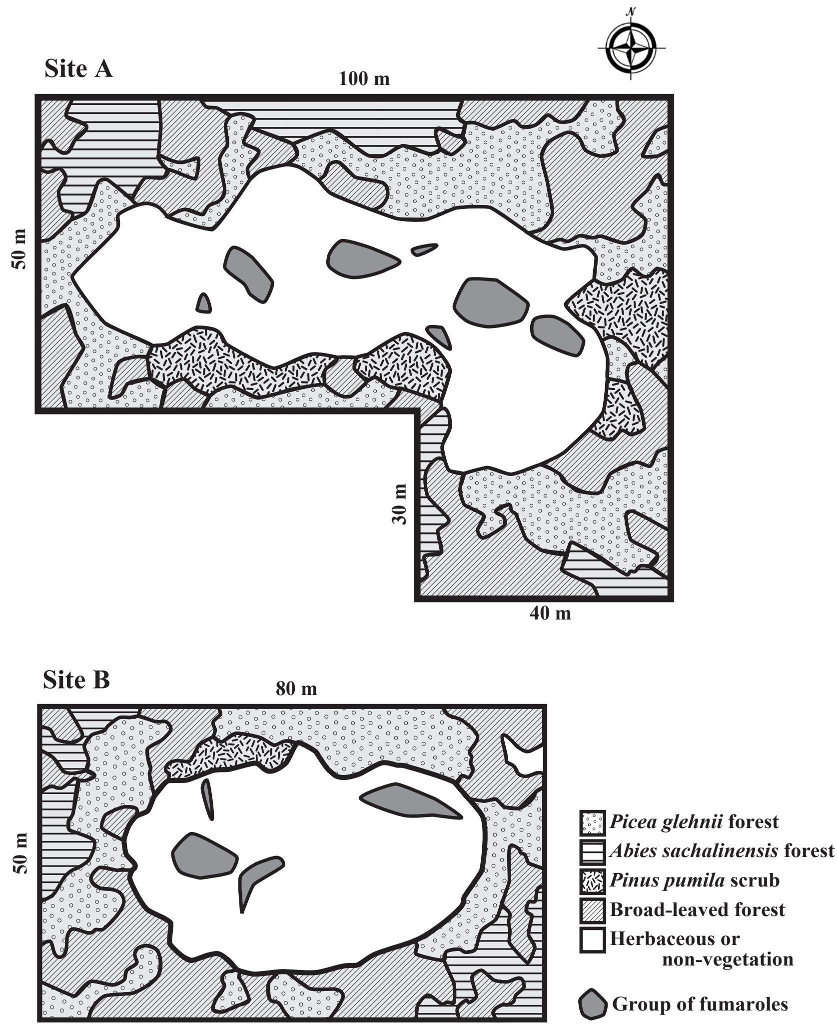

Fig. 2 Vegetation maps of Sites A and B.
Forest zones were classified into four types according to predominant tree species. *Betula platyphylla*, *Quercus crispula*, and *Acer* spp. were dominant in broad-leaved forests.

herbs, ferns, bryophytes, and lichens) composition, we established a grid of 10-m squares in both sites and created 2-m quadrats at intersections of gridlines as study plots. The number of study plots was 49 in the forest, 18 in the margin, and 12 in the herbaceous zones in Site A, and 32 in the forest, 11 in the margin, and 11 in the herbaceous zones in Site B (Fig. 1).

Species observed in this study were identified with reference to Satake et al.[8] for tree species, Satake et al.[9] for herbaceous, Iwatsuki[10] for ferns, Iwatsuki[11] for bryophytes, and Yoshimura[12] for lichens.

Indicator species were extracted for each zone of both sites using TWINSPAN (Two-Way INdicator SPecies ANalysis, PC-ORD version 6.0, mjm SOFTWARE) to clarify the difference in plant distribution pattern between the study sites.

3 Results

Fig. 2 shows the vegetation maps of Sites A and B.

The forest types classified by constituent tree species were roughly the same in both sites. *Picea glehnii* forest, *Abies sachalinensis* forest, *Pinus pumila* scrub and broad-leaved forest, which were mainly comprised of *Betula platyphylla*, *Quercus crispula*, and *Acer* spp., were recognized. On the forest floor, seedlings of broad-leaved species such as *Betula platyphylla* and *Quercus crispula* were scattered among those of *Picea glehnii* and *Pinus pumila*. *Pinus pumila* was distributed locally in the forest zone and observed in southern and eastern areas of Site A, but in just part

Table 1 Cover (%) of understory species in three vegetation zones of Sites A and B.

*	Species name	Site A Herbaceous (n=7)	Site A Margin (n=18)	Site A Forest (n=49)	Site B Herbaceous (n=11)	Site B Margin (n=11)	Site B Forest (n=32)
f	*Pteridium aquilinum* var. *latiuculum*	16.7	12.2	23.9	20.7	29.3	37.9
h	*Sasa nipponica*	16.5	14.0	12.2	3.0	15.3	25.5
h	*Miscanthus sinensis*	5.0	13.0	1.0	19.8	8.7	3.8
h	*Leersia oryzoides*	7.3	2.1	1.1	6.0	16.5	2.3
b	*Polytrichum commune*	—	13.2	4.6	20.0	25.5	3.8
b	*Dicranum hamulsum*	8.0	7.4	5.4	—	5.0	3.8
h	*Carex lanceolata*	—	1.0	11.3	10.0	5.0	1.0
l	Cladoniaceae sp.	7.5	3.3	3.2	—	3.3	1.0
h	*Fimbristylis dichotoma*	1.0	1.0	1.0	—	9.0	1.0
h	*Maianthemum dilatatum*	—	5.0	2.2	1.0	1.0	2.2
l	Physciaceae sp.	—	2.8	2.7	—	3.6	4.4
b	*Brachythecium glareosum*	1.0	3.4	5.3	—	—	1.0
h	*Mosla japonica* var. *thymolifera*	—	—	1.0	1.0	3.5	4.0
h	*Carex dissitiflora*	—	50.0	1.0	3.5	—	—
b	*Bazzania trilobata*	—	7.3	7.4	—	—	11.8
b	*Hypnum plumaeforme*	—	5.3	16.9	—	—	1.0
b	*Dicranum flagellare*	—	4.7	11.3	—	—	1.0
b	*Dicranum nipponense*	—	1.0	3.7	—	—	9.0
b	*Dicranella heteromalla*	—	4.5	3.0	—	—	2.3
b	*Pohlia elongata*	—	1.0	1.0	—	—	—
h	*Senecio cannabifolius*	—	—	3.0	—	—	—
h	*Oxalis acetosella*	—	—	2.7	—	—	—
b	*Jungermannia pyriflora*	—	—	1.0	—	—	—
b	*Thuidium recognitum* var. *delicatulur*	—	—	1.0	—	—	—
Tree seedlings							
	Rhus trichocarpa	8.0	4.4	2.4	—	1.0	1.7
	Picea glehnii	—	5.0	2.4	—	—	21.4
	Acer mono	—	1.0	1.0	—	—	5.0
	Betula platyphylla	—	—	—	3.0	1.0	1.0
	Pinus pumila	1.0	1.0	1.0	—	—	—
	Magnolia obovata	—	1.0	1.0	—	—	1.0
	Abies sachalinensis	—	—	2.3	—	—	1.4
	Quercus crispula	—	1.0	1.7	—	—	—
	Acer amoenum var. *matsumurae*	—	1.0	1.0	—	—	—
	Rhododendron brachycarpum	—	—	10.0	—	—	—
	Total number of species	10	26	33	10	14	24
	Shannon-Wiener index (H^*)	0.30	0.44	0.39	0.18	0.20	0.29

*f: ferns, h: herbaceous, b: bryophytes, l: lichens

Table 2 Indicator species (+) extracted by TWINSPAN in three vegetation zones of Sites A and B.

Species name	Site A Herbaceous	Site A Margin	Site A Forest	Site B Herbaceous	Site B Margin	Site B Forest
Hypnum plumaeforme	-	-	+	-	-	-
Carex lanceolata	-	-	+	-	-	-
Senecio cannabifolius	-	-	+	-	-	-
Acer amoenum var. *matsumurae*	-	-	+	-	-	-
Bazzania trilobata	-	-	+	-	-	+
Picea glehnii	-	-	+	-	-	+
Abies sachalinensis	-	-	+	-	-	+
Sasa nipponica	-	-	-	-	-	+
Fimbristylis dichotoma	-	-	-	-	-	+
Acer mono	-	-	-	-	-	+
Miscanthus sinensis	-	+	-	+	-	-
Dicranella heteromalla	-	+	-	-	-	-
Rhus trichocarpa	-	+	-	-	-	-
Leersia oryzoides	+	-	-	-	+	-
Carex dissitiflora	-	-	-	+	-	-

of northern area of Site B. Few standing trees of *Abies sachalinensis* were found in the margin zone; they grew mainly in the forest zone.

Table 1 shows the understory species composition and cover (%) in Sites A and B.

The species compositions observed in both sites were highly similar as it is the case in tree species. The number of species in the forest zone was two to three times higher than that in the herbaceous zone in Sites A and B. Graminoid species were abundant in all zones and dicotyledonous plants excluding *Mosla japonica* var. *thymolifera* were found only in the forest zone. Almost all bryophyte species were found in the margin and forest zones, although *Polytrichum commune*, *Dicranum hamulosum*, and *Brachythecium glareosum* were also found in the herbaceous zone. In Site B, Shannon–Wiener index indicated that the forest zone had the highest value (0.29), followed by the margin zone and then the herbaceous zone. On the other hand, the margin zone has a higher value (0.44) than the forest zone in Site A. The indices were overall higher in Site A than in Site B.

Table 2 shows indicator species extracted by TWINSPAN in the three zones of Sites A and B.

Indicator species in each category extracted by TWINSPAN were *Hypnum plumaeforme*, *Bazzaania trilobata*, *Carex lanceolata*, *Senecio cannabifolius*, and tree seedlings (*Picea glehnii*, *Abies sachalinensis*, and *Acer amoenum* var. *matsumurae*) in the forest zone, *Miscanthus sinensis*, *Dicranella heteromalla*, and *Rhus trichocarpa* seedlings in the margin zone, and *Leersia oryzoides* in the herbaceous zone in Site A. In Site B, *Sasa nipponica*, *Bazzania trilobata*, *Fimbristylis dichotoma*, and tree seedlings (*Abies sachalinensis*, *Picea glehnii*, and *Acer mono*) in the forest zone, *Leersia oryzoides* in the margin zone, and *Miscanthus sinensis* and *Carex dissitiflora* in the herbaceous zone were recognized as indicator species. Indicator species common to both sites were *Picea glehnii*, *Abies sachalinensis*, *Miscanthus sinensis*, *Leersia oryzoides*, and *Bazzania trilobata*, although *M. sinensis* and *L. oryzoides* were indicators for different zones of the two sites.

4 Discussion

Miscanthus sinensis, *Acer mono*, *Quercus crispula*, *Betula platyphylla*, *Picea glehnii*, and *Abies sachalinensis* were found in the two fumarole sites of this study (Table 1). These species were listed in the report of vegetation survey in Kussharo caldera[13]. Particularly, *Fimbristylis dichotoma* was a typical indicator plant of the fumarole vegetation related to geothermal activities in Hokkaido[13].

The number of species increased toward the forest zone (Table 1). Intolerant species to volcanic activities can survive only in forests. It is suggested that plants grow according to the influence of environmental gradients, because dicotyledonous plants except for *Mosla japonica* var. *thymolifera* were observed only in the forest zones and many bryophytes were not found in the herbaceous zones (Table 1).

On the other hand, *Picea glehnii*, *Betula platyphylla*, and *Quercus crispula*, which are predominant species of the climax stage in Akan–Mashu National Park[13], were also found in the margin zones (Figs. 1 and 2). Moreover, the Shannon–Wiener index of the margin zone in Site A was the highest among all zones. These results show that pioneer species are not necessarily species that grow in the margin zone affected by volcanic products. It is suggested that species invading into volcanic barrens vary depending not only on disturbance impacts but also on surrounding vegetation conditions[3].

In general, the progress of community succession in a disturbed area is faster in the marginal zone than in the center of disturbance. However, the results of TWINSPAN showed that the indicator species of the three zones were different between the two study sites. This indicates that the evident relationship between the distance from a seeds supply location and the number of seedlings is not always precise[14, 15]. Therefore, it is presumed that there is high correlation with variable vegetation types resulting from different soil substrates, topographic features, and biological interactions[16].

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東部北海道における
噴気孔群沿いの植物の分布様式

南 佳典[1]・野口侑璃奈[1]・吉川朋子[1]

火山活動は，植生に対する自然攪乱の一つである．火山地帯において火山活動が植生に対しておよぼす影響に関する研究は数多くなされてきた．植生に対する火山ガスの影響は地域ごとにさまざまである．本研究では，火山ガスの影響が遷移の進行を制限するということにおける知見を検討するため，北海道東部にある噴気孔群２箇所を調査地とした．その結果，次のようなことが見いだされた．出現種数は森林部に向けて噴気孔から離れるに従い増加した．下層植生の種組成から TWINSPAN を用いて表徴種を抽出したところ，２箇所の調査区で異なる表徴種が確認された．この結果は，各立地における土壌中の硫酸濃度が噴気孔からの距離のみならず比高によっても異なり，それらが植物の分布に影響していることを示唆している．

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