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Conference Paper

Disaster-prevention education in relation to infrequent large-scale volcanic eruptions for Japanese high school students: Developing teaching materials about the widespread Holocene volcanic ash of the Kikai-Akahoya eruption

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Abstract

Japan has 111 active volcanoes and is prone to volcanic disasters as well as earthquakes. However, education regarding volcanic disaster-prevention is not provided extensively at high schools. Therefore, the authors used the widespread volcanic ash that fell over a wide area of Honshu after the eruption of Kikai Caldera in Kagoshima Prefecture approximately 7,300 years ago, as teaching material for classes on volcanic disaster-prevention. The class comprised 95 second-year students in the Basic Earth Science class at a high school in the central area of Hyogo Prefecture, which is located in an area without active volcanoes. The students observed some pyroclastic materials in the first class and observed Kikai-Akahoya volcanic ash in the second class. After these observations, the students in the second class inferred the kind of volcanic disaster. At the end of the first class, 72% of students acknowledged the necessity of knowing the location of volcanoes and of inferring triggers to prevent volcanic disasters. At the end of the second class, more students were aware of the disaster caused by Kikai-Akahoya volcanic ash, where the wind caused volcanic ash to fall over a wide area in the future. In conclusion, we found that some students became aware of the dangers of volcanic disasters caused by wind-driven volcanic ash flow from active volcanoes.

Key words : volcanic disaster-prevention, wide-spread volcanic ash, Kikai-Akahoya volcanic ash, Jomon period, high school students

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Introduction

An active volcano in Japan is defined as a volcano that has erupted within 10,000 years and/or ongoing fumarolic activity. Recently, Japan has experienced volcanic disasters. For example, the eruption of the Unzen volcano during 1991–1995 generated pyroclastic flow due to dome collapse, and killed 43 people (Sugimoto and Nagai, 2009). Pyroclastic flow also had an impact on human society. On the other hand in October 2021, pumice drifted ashore on the islands of Okinawa and Kagoshima Prefectures, causing mass mortality of fish and disruption to the navigation of fishing boats and other vessels (Hydrographic and Oceanographic Department, Japan Coast Guard, 2021b). One of the characteristics of disasters caused by pumice drift from undersea volcanic eruptions is that, unlike volcanic disasters that occur on land in Japan, they take place infrequently. Even though infrequently, caldera eruptions that spread volcanic ash over large areas could take place great disasters.

Regarding the textbooks provided in high school, some Basic Earth Science textbooks contain descriptions of volcanic ash (Kimura et al., 2016; Morimoto et al., 2016; Ogawa et al., 2021). As a widespread volcanic ash is one of topics for further reference, there is no need to cover descriptions of it in class and it is introduced only at the discretion of the teacher. Furthermore, we want to teach about local volcanic disasters in Hyogo Prefecture, it is difficult to give examples because Hyogo Prefecture has no active volcanoes in the vicinity. In Kumamoto Prefecture, the example (Otsuka et al., 1990) of the Kikai-Akahoya volcanic ash (Machida and Arai, 1978; Fukusawa, 1995) that was distributed in the prefecture, was developed for junior high school students as a science teaching material for key bed or observing rock-forming minerals. However, no research had been conducted on volcanic disaster-prevention education using wide-area volcanic ash as a teaching material. In high school earth science textbooks, there are descriptions of the Kikai-Akahoya volcanic ash, but no descriptions of disasters caused by the Kikai Caldera eruption in the Jomon period, so it was necessary to develop a practical study. The authors used the Kikai-Akahoya volcanic ash (Koda and Sato, 2020) as a teaching material for volcanic disaster-prevention learning for high school students in Basic Earth Science, to inform them that volcanic ash-fall eruptions have historically occurred in various parts of Japan, and to teach them that eruptive activities of volcanoes located in distal areas can also lead to volcanic disaster risk. The authors investigated the actual situation in volcanology and volcanic disaster-prevention education on this theme. This paper details the additional discussion from the perspective of earth science education for overseas readers, based on a paper (Koda et al., 2022) for Japanese readers.

Volcanic disaster risk

Active volcanoes in Japan as at 2022

One hundred eleven active volcanoes are located on Japan, and 50 of these are the target of constant monitoring by the Japan Meteorological Agency. Based on the observational results, the Japan Meteorological Agency releases volcanic warnings (Japan Meteorological Agency).

Basic volcanology class in Japan

In Japan, under the school science curriculum, students study basic volcanology in elementary, junior high and high school. Basic Earth Science class in high school covers basic volcanology. The textbooks deal with the types of eruptions, types of magma and geomorphology, and pyroclastic tephra such as volcanic ash, pumice and scoria so that high school students will understand basic volcanology after the class.

Volcanic disaster risk in Hyogo Prefecture

The volcanoes distributed in Hyogo Prefecture during the Quaternary Period, and that are known, are summarised as follows in order of newest to oldest (Geological Survey of Japan, 2021) : the Kannabe volcanic group (active from about 740,000 to 20,000 years ago), the Kamisano and Mesaka volcanoes, the Mikata volcano group, the Takarayama volcano, the Oginosen volcano, the Genbudo volcano, the Sabo volcano, the Oya and Todoroki volcanoes and the Teragi volcano (about 3.13 million to 2.25 million years ago). Active volcanoes have not been identified in Hyogo Prefecture (Japan Meteorological Agency).

The Hyogo Prefecture Regional Disaster Prevention Plan contains countermeasure plans for wind and flood disasters and earthquake disasters (Hyogo Prefecture, 2021), but no plans for volcanic disasters. The only volcanic disaster risk assessment plan is the Kansai Disaster Prevention and Mitigation Plan, which lists volcanoes as an example of an alert situation in the emergency category. Thus, volcanic disaster risk in Hyogo Prefecture is not recognised as greater than meteorological or earthquake disasters. In fact, a survey of students in Osaka Prefecture University (currently known as Osaka Public University) on natural disasters found that earthquake disasters were the most threatening, followed by weather disasters, with volcanic disasters ranked third (6% of the total, Sato and Koda, 2021). The latest disaster education manual for teachers published by the Hyogo Prefectural Board of Education (Board of Education, Hyogo Prefecture, 2013), discusses only earthquake and flood disasters. The reason why the board of education does not deal with volcanic disasters in its supplementary reader on disaster education is probably because, as mentioned above, volcanic disasters are rarely covered in Hyogo Prefecture's regional disaster management plans.

Planning of the practical class

Practice school

This instructional practice was conducted with three classes (96 students) of the second-year Basic Earth Science class at X High School in central Hyogo Prefecture, which is in an area without active volcanoes (Fig.1). This was due to the need for education on volcanic disaster-prevention, even in areas without active volcanoes.

Actual situation of students

The students had learned about volcanoes approximately three months before the class but had not observed pyroclastic material samples at the time of the class. We surmise that the students might not have been familiar with the operation of the binocular stereo microscopes (hereafter microscopes) used for observation, and found that it was necessary to reinforce the instruction on the observation of the samples.

Concept of teaching materials

The students had already studied volcanic eruptions, but in this practice, we planned to

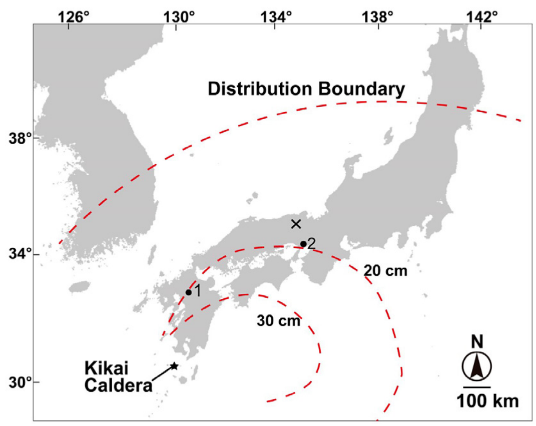

Fig. 1 Isopac map of the Kikai-Akahoya Volcanic Ash (after Machida and Arai, 2003)
1, 2: Sampling points, x: practice high school

organise their knowledge of volcanic eruption phenomena and eruptions to inform them that disaster-prevention measures are not effective in the same way because the rate of pyroclastic dispersion is different for each phenomenon.

Widespread volcanic ash, such as the Kikai-Akahoya volcanic ash, is described in some high school Basic Earth Science textbooks as one of the volcanic eruptions that was distributed over a wide area (Morimoto et al., 2016; Ogawa et al., 2021). The section in these textbooks covers the Aso-4 volcanic eruption about 90,000 years ago (Machida and Arai, 2003). However, we have not seen the eruption as a trigger of disaster because no human presence has been confirmed (Kimura et al., 2016). In contrast, the large-scale eruption of the Kikai Caldera about 7,300 years ago (Fukusawa, 1995) caused enormous disasters for the Jomon people in southern Kyushu (Machida, 1981; Kuwahata, 2002), yet this volcanic disaster is not mentioned in science textbooks. Therefore, in this practice, we decided to use as a teaching material the Kikai-Akahoya volcanic ash, of which examples are described in science textbooks.

Teaching guidelines and material

The first class

The title of this lesson was ʻVolcanic eruptions and disastersʼ, with the aim of having the students consider the relationship between volcanic eruptions and the bubbling of gases in magma. The aim was also for them to understand that the speed at which volcanic products move (lava flows, volcanic mudflows and pyroclastic flows) varies, and that specific disaster-prevention measures need to be considered for each phenomenon.

In the first class, we asked students to observe specimens of pyroclastic materials as a review of their volcano studies and to become familiar with the operation of the microscope. Different chemical compositions of magma result in different eruption styles and morphological characteristics of pyroclastic materials. To give students a comprehensive understanding of this relationship, the samples shown in Fig.2 were prepared.

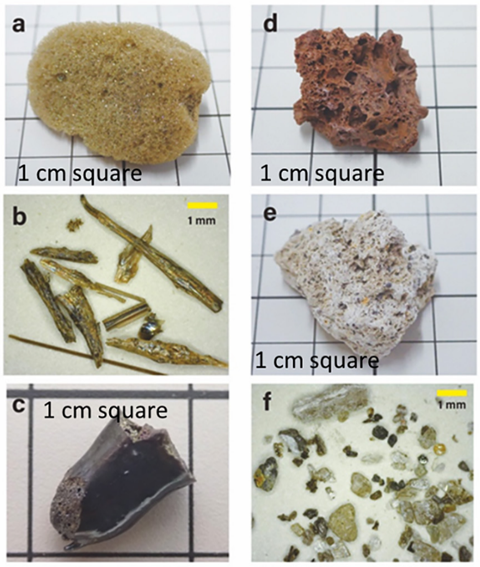

Fig. 2 Specimens of pyroclastic materials used in the first class (after Koda et al., 2022)
a: highly vesiculated pumice from Kilauea volcano
b: glass shards of scattered basaltic magma that have been stretched and solidified (Peleʼs hair)
c: glass shards with a rounded surface from basaltic magma eruption (Peleʼs tears)
d: scoria from the Kannabe volcano
e: pumice from the Sakurajima Taisho eruption
f: ash from the Aso-4 pyroclastic flow deposit

The second class

The title of this lesson was ʻVolcanic ash and volcanic disaster riskʼ. The aim was to consider what can be done to prevent disasters in the future, and to recognise that even in areas where there are no active volcanoes nearby, volcanic ash that falls over a wide area can cause disasters. In the Basic Earth Science class, students learn about triggers for volcanic disasters, and the fact that caldera eruptions are explosive, is associated with the viscosity of the magma. It is important for students to understand, as background, that the highly viscous magma that foams to form bubble-shaped volcanic glass which spreads over a wide area is not only related to the fine and light particles but also to the natural factors of the prevailing westerlies blowing overhead. In addition, the degree of damage to humans is related both to geographical distance and to the population density and lifestyle of the ash-fall area, and the fact that social factors have changed significantly between the Jomon period and the present day should be taken into consideration regarding future disaster countermeasures.

In the second class, the topic of volcanic disaster-prevention was incorporated into the lesson. First, the students observed under a microscope the Kikai-Akahoya volcanic ash obtained from two sampling points (Fig.1), and noticed that both were composed mainly of volcanic glasses. Then, the classes were designed to make the students predict the possible disasters that could occur as a result of such widespread volcanic ash fall, and to warn them of possible disasters.

The Kikai-Akahoya volcanic ash used in this practical class was Sample 1, collected around the Aso volcano (near Nishi Yuura, Aso City, Kumamoto Prefecture) in 2019, and Sample 2, collected at the Tarumi Hyuga site (Hyuga, Tarumi-ku, Kobe City, Hyogo Prefecture; Kobe City Board of Education and Kobe City Sports Education Corporation, 1992) in 1997, both of which consist mainly of colourless, transparent volcanic glasses (Fig.3).

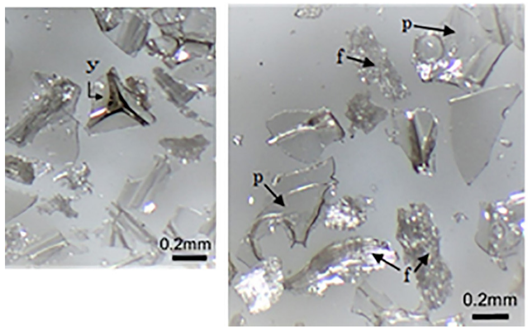

Fig. 3 Sample 2: Kikai-Akahoya volcanic ash used in the second class (after Koda and Sato, 2020)
y: bubble-type Y-shaped glass
p: bubble-type plate glass
f: pumice-type fibrous glass

Results of the teaching practice

Analysis of learning records in the first class

At the end of the instructional period, students wrote on their worksheets their answers to the following question: ‘How can I know if I am in danger when an eruption is likely?’ Fifty of the 78 students (64.1%) responded to this question. Table 1 shows the classification results for the content of the answers. The most common answers were to collect information on volcano disaster-prevention. Examples of specific answers are ‘Identify how far away from the mountain you are that is about to erupt’ and ‘Find out how far away the volcanic ejecta will fly’. Many students described the distance from the volcano and the expected range of damage. Based on their responses, we can assume that 72.0% of the students recognised that ‘information on the location of volcanoes and the prediction of phenomena that trigger disasters are necessary for volcanic disaster-prevention’ after this class. However, the idea that it is necessary to predict the type of eruption style for disaster-prevention, since the speed of pyroclastic movement varies depending on the phenomenon of volcanic eruption, was not found in the written comments.

Table 1 Responses on actions taken for volcanic disaster-prevention (N = 50)

contents	information	hazard map	others
Number of descriptors	36	6	15
Percentage (%)	72.0	12.0	30.0

Table 2 Responses to the impact of volcanic ash falling over a wide area of modern society (N = 64)

contents	electronics	agriculture	transportation	lifelines	health	others
Number of descriptors	27	24	16	10	8	23
Percentage (%)	42.2	37.5	25.0	15.6	12.5	35.9

Analysis of learning records in the second class

At the end of the instructional period, students wrote on a worksheet about the impact of volcanic disasters on modern society. We gave examples on this worksheet of 'lifelines (electricity and water supply), transportation (roads and railroads), crops (rice and vegetables), and climate (sunshine hours and weather)'. Sixty-four of the 95 students (67.4%) responded to this question. Table 2 shows the classification results for the content of the answers. Many of the students' responses were based on the examples provided on the worksheet, such as 'cars and transportation will stop' and 'water supply will become dirty'. However, five students described ecosystems, climate, and so on, which were not presented as examples on the worksheets. These are classified as 'others' in Table 2. We considered that these students were able to answer the questions based on their own thinking.

When asked what their disaster-prevention plan would be if the volcanic ash were to accumulate at a thickness of about 20 cm, about 40% students wrote on a worksheet about evacuating plans based on hazard maps. These students are likely unaware that ash fall from remote volcanoes is not shown on hazard maps.

Pre and post surveys

To identify differences in students' responses before and after the class, we conducted a pre survey at the beginning of the first class (22 September 2021) and a post survey one week after the second class (6 October), with both given in the classroom under teacher supervision. Response times of the two surveys were limited to five minutes, and they were collected immediately after completion.

In both the pre and the post survey, respondents were asked which of the following items are related to the occurrence of volcanic disasters to discover how they perceive triggers and factors that predispose them to volcanic disasters. The options included two items each for trigger (ejection of lava and pyroclastic materials in eruptions), natural factors affecting the movement of volcanic products (volcanic valley topography, wind), and social factors (presence of human habitation). The students were asked to select all items they considered relevant.

Discussion

Perception of factors before the practice class

The responses to the questions in the pre survey are shown in Table 3, and the answers indicate that approximately 90% of the students responded to the triggers ('a. eruption', 'b. magma and pyroclastic materials') and are correctly aware that eruptive phenomena can lead to volcanic disasters. Regarding natural triggers, the highest response rate was for 'd. wind', which relates to volcanic ash fall. In comparison, there is a significant difference (direct probability test, two-tailed; $p = 0.000$, $p < .05$) in the proportion of students responding to 'c. valley', which relates to lava flow, and the proportion of students who are more aware of this is lower than for ‘d. wind’.

Perception of factors after the practice class

The changes in students’ responses from pre to post questioning were analysed, as shown in Table 3, which indicates the status of responses on matters related to volcanic disasters. Comparing the number of respondents in the pre and post survey, the χ^2 test (5% level of significance) shows no significant differences except for ‘d’ and ‘f’. It can therefore be said that a higher proportion of students were aware of wind as a natural factor and the presence of human habitation away from the volcano as a social factor following the class. This suggests that more students were aware of disasters caused by widespread volcanic ash fall, where winds bring ash fall over a wide area.

Ejecta and eruptions

Based on the essays that the students wrote on the worksheet after the class, we will discuss the results in terms of this science class. Among the students who participated in the class, there were students who left the essays column blank. Therefore, 77 students wrote their essays in the first class, and 79 students wrote their essays in the second class. Table 4 shows the number of students who wrote comments related to the content of the Basic Earth Science course (with duplicate counts). Of the pyroclastic materials in Table 4 in the second class, 45 students described volcanic ash. Specific descriptions of the observations include the color and shape of the volcanic ash, and voids caused by air bubbles. Referring the relationship between pyroclastic materials and eruption is a description of the type of eruptions and the composition of magma can be inferred from the composition of the particles of pyroclastic materials.

Although it cannot necessarily be said that everyone's ideas were picked up, there was a significant difference in the number of descriptions of volcanoes and eruptions between the first and second classes (Fisher's exact probability test, two-tailed test: p = 0.0489* ($p<.05$)), indicating an increase after the second class. No significant differences were found for the other items. As for “specific description of observations”, it is possible that some students did not write about this in the comments section, since there is a space for this in the worksheet. Few students described the relationship between the ejecta and the eruption. This is something that the students have already learned before this class, but it is necessary to set up a learning activity to make the students think deeply about the connection between the observed volcanic ash and the composition of the volcano and magma that erupted it.

The two periods of the class were a developmental course of the Basic Earth Science. The authors believe that students gained a deeper understanding of volcanic eruptions and volcanic disaster-prevention by observing actual volcanic

Table 3 Responses on matters related to volcanic disasters (pre survey and post survey)
a, b: triggers, c, d: natural factors, e, f: social factors

	a	b	c	d	e	f	g
factor	eruption	magma pyroclastic materials	valley	wind	foothills houses	remote houses	others
classification	trigger		natural factor		social factor		
pre survey (n=93)	84	81	15	44	59	9	1
post survey (n=86)	79	75	19	58	58	18	1
p	0.797	1.000	0.344	0.010	0.638	0.039	1.000
result	n.s.	n.s.	n.s.	$p<.05$	n.s.	$p<.05$	n.s.

Table 4 Number of the comments related to the content of the Basic Earth Science course in the first and second class (with duplicate counts).

the content of the Basic Earth Science course	volcano eruption	pyroclastic materials	Specific description of the observation	the relationship between pyroclastic materials and eruption
The first class (N=77)	23	34	16	4
The second class (N=79)	38	48	13	3

materials while relating them to the nature of volcanic eruptions. The authors also believe that the observation of actual volcanic materials, while linking them with those morphology and properties of magma, provided a deeper understanding of volcanic eruptions and volcanic disaster-prevention. Because "I was surprised that we can tell what happened to the magma at the time of eruption just from the shape, structure, and other characteristics of volcanic ejecta." and "The size and viscosity of volcanic ash are completely different from volcano to volcano, so I thought that we need to consider countermeasures for each volcano." However, not many students wrote these in their comments. More data are needed to analyze this issue in detail in the future. Regarding the lesson design, the students generally gave a positive evaluation to the lecture and observation using the materials. On the other hand, there were some who said they wanted more time for observation and discussion, so the lesson content needs to be more carefully selected.

Conclusions

Regarding the first class, 72.0% of the students recognised after the class that information on the location of volcanoes and predictions of phenomena that trigger disasters is necessary for volcanic disaster-prevention. After the second class, it appeared that more students were aware of disasters caused by a widespread volcanic ash fall, where winds bring ash fall over a wide area. The authors believe that the observation of actual volcanic materials provided a deeper understanding of volcanic eruptions and volcanic disaster-prevention. However, the problem is that students do not realize that local hazard maps do not include volcanic disaster risks, and they remain short-sighted in their thinking that they only need to refer to hazard maps for disaster-prevention.

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