Volcanic Eruptions Caused by Extreme Weather: The Role of Super Rainfall

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Express Letter

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Abstract

Volcanic eruptions are well known as sources of catastrophic damage and loss of life. In general, eruptions are understood to be caused by the movement of magma upward through the volcano, until it reaches the crater or a secondary vent where it is released explosively to the environment. In the case of steam (phreatic) eruptions, the exposure of water to the extreme heat injects significant amounts of energy into the system resulting in violent explosions and substantial destruction (Leonid et al. 1995)¹. Often, there is no warning on existing seismic monitoring networks of the impending eruption. However, we demonstrate a correlation between extreme rainfall and volcanic activity at Mt. Ontake in Japan and propose that phreatic eruptions are due to a movement of water rather than magma. This work demonstrates the importance of monitoring rainfall on volcanoes to prevent loss of human life in eruptions that may follow periods of excessive precipitation.

Background Of This Research

As volcanic eruptions have been known to directly impact human life, this topic has been extensively studied within the earth science community. Among the 111 active volcanoes in Japan, 50 have a “24-hour constant observation monitoring system” installed (Fig. 1).

In other words, an observation system consisting of heavy equipment is being put in place. The observation system that was in place during the eruption of Mount Ontake (as shown in Additional file 1) is a system that detects underground movement using a seismograph, as well as GPS and a remote camera.

An Automated Meteorological Data Acquisition System (AMeDAS; Japanese Meteorological Agency)² is also installed on the top of Mt. Ontake coincidentally, but these data are not available in the volcanic observation system. What does this mean?

It seems that people believe that this meteorological observation instrument should be thought of to observe the weather alone and that it is irrelevant for observing volcanic eruptions. In effect, this implies that rainfall is not considered a direct cause of eruptions.

However, when mountains that are not designated as active volcanoes (so-called unlabeled mountains) suddenly erupt, they often create victims. One recent example of this occurred on January 23, 2018, when steam erupted from Mt. Motoshirane, which had been used as a ski resort, killing one person, and injuring 11 people. Because these steam eruptions occurred suddenly and without any warning, they caused a human tragedy for holidaymakers. As human habitations exist near active volcanoes in Japan, it is inevitable that as soon as a volcano erupts, human lives, essential utilities, and daily routines will be negatively impacted.

In this paper, we attempted to analyze the September 27, 2014 phreatic (steam) eruption of Mount Ontake, which took the lives of 58 climbers and 5 missing and presumed dead, who were enjoying lunch

at the summit when it suddenly erupted without warning, becoming the worst volcanic disaster in recent years.

Reasons For The Study

In Japan, a country with significant volcanic activity, numerous experts and scholars are currently studying how to avoid damage caused by eruptions. We are concerned that it may be difficult to protect against damage in the future, as is currently the case.

Can damage from volcanic eruptions be prevented or mitigated?

Our paper starts from this question.

This paper reports a completely new approach regarding phreatic (steam) eruptions, which are one of three types of eruptions, with the other two being phreatomagmatic (magma steam) eruptions and magmatic (magma) eruptions. Phreatic eruptions can be generally explained as eruptions caused by underground magma that begins moving upward and encounters or approaches a pool of water. In contrast to the conventional view that “predicting phreatic eruptions is extremely difficult,” questions consistently crop up with regards to why eruptions can occur without any movement of magma.

Looking at Mount Ontake's volcanic activity over recorded history (Additional file 2), we see only phreatic eruptions. Although there are seismograph observations from after the eruptions because eruptions were sudden and without warning, there are no examples of predictions leading to forecasts.

If the magma is not moving, what might be an alternative cause of these eruptions?

In this paper, we hypothesize that water approaches stationary magma.

Results

Mount Ontake's rainfall observation device is called “AMeDAS”², which allows the Japanese Meteorological Agency to obtain daily records (Japanese Meteorological Agency). Looking at rainfall records from 1979 and 2014 (as shown in Table 1) we can discover some points in common. That is, there were torrential rains of 1,000 mm or more over the two months immediately preceding the eruptions, downpours of over 100 mm over the two consecutive days before the eruptions, and torrential rain of over 150 mm several days before the eruptions.

Table 1
The relationship between super rainfall and Phreatic Eruption of Mt.Ontake

2014 Phreatic Eruption of Mt. Ontake				1979 Phreatic Eruption of Mt. Ontake					
08/2014		09/2014		08/1979		09/1979		10/1979	
Precipitation				Precipitation					
Date	mm	Date	mm	Date	mm	Date	mm	Date	mm
1	0	1	21	1	0	1	14	1	91
2	0	2	0	2	0	2	12	2	0
3	23.5	3	1	3	1	3	3	3	28
4	29	4	42.5	4	10	4	65	4	28
5	21.5	5	59.5	5	0	5	2	5	0
6	22.5	6	9	6	35	6	0	6	6
7	0	7	6	7	66	7	14	7	33
8	20.5	8	0	8	1	8	0	8	5
9	9.5	9	0	9	0	9	0	9	0
10	185	10	0	10	0	10	0	10	0
11	29.5	11	8.5	11	0	11	0	11	0
12	39	12	0	12	25	12	0	12	0
13	0	13	0	13	0	13	1	13	0
14	34	14	0	14	0	14	6	14	0
15	85	15	0	15	0	15	69	15	0
16	146	16	0	16	0	16	0	16	0
17	102	17	0	17	6	17	2	17	0
18	11.5	18	0	18	31	18	3	18	21
19	6	19	0	19	0	19	8	19	187
20	0	20	0	20	30	20	0	20	3
21	0	21	0	21	152	21	1	21	0
22	2.5	22	0	22	67	22	33	22	0
23	18.5	23	0	23	16	23	7	23	0

2014 Phreatic Eruption of Mt. Ontake				1979 Phreatic Eruption of Mt. Ontake					
24	7	24	74.5	24	16	24	27	24	None
25	12.5	25	89.5	25	26	25	78	25	None
26	76	26	0	26	0	26	71	26	None
27	0	27	Phreatic Eruption	27	79	27	34	27	None
28	1.5	28		28	2	28	49	28	Phreatic Eruption
29	1.5	29		29	0	29	22	29	
30	9	30		30	0	30	19	30	
31	0			31	0			31	
Total (57 Days)			1,204.5	Total (81 Days)					1,505

Aug. 1979

https://www.data.jma.go.jp/obd/stats/etrn/view/daily_a1.php?prec_no=48&block_no=0416&year=1979&month=8&day=&view=

Sep. 1979

https://www.data.jma.go.jp/obd/stats/etrn/view/daily_a1.php?prec_no=48&block_no=0416&year=1979&month=09&day=&view=p1

Oct. 1979

https://www.data.jma.go.jp/obd/stats/etrn/view/daily_a1.php?prec_no=48&block_no=0416&year=1979&month=10&day=&view=p1

Aug. 2014

https://www.data.jma.go.jp/obd/stats/etrn/view/daily_a1.php?prec_no=48&block_no=0416&year=2014&month=08&day=&view=p1

Sep. 2014

https://www.data.jma.go.jp/obd/stats/etrn/view/daily_a1.php?prec_no=48&block_no=0416&year=2014&month=9&day=&view=

For both cases regarding Mt. Ontake, we must consider a common “extreme weather” relationship. In October 1979, Typhoon No. 20 (Typhoon Tip) traversed Japan, killing 110 people and flooding 47,943

buildings. Typhoon Tip set a record for the lowest observed pressure in observational history, even though its central atmospheric pressure had slightly increased from 870 hPa (mbar) while over Japan. Similarly, in August 2014, the long-term stationary weather fronts caused natural disasters such as landslides and rivers breaking their banks in various places. The observed volumes of torrential rain broke numerous historical records across the region, including the greatest quantity of precipitation over a 1-hour period, a 24-hour period, and a 72-hour period. Such extreme weather was of an intensity that has not been experienced previously.

Conclusions

1. Phreatic eruptions are caused by the movement of water, not magma.
 1. The phreatic eruption of Mt. Ontake was directly caused by a large amount of rainwater that accumulated over a period of two months due to torrential downpours. From the bowl-shaped caldera through the eruption path (the path connecting the crater to the magma chamber), it merged with a pool of groundwater and then collapsed, flowing quickly into the magma chamber, and encountering the magma. At 11:45, the seismograph responded to the reaction of the water reaching the magma, and up to 7 minutes later, at the time of the eruption at 11:52, the mass of water initiated a catastrophic explosion (Additional file 3).
 2. It appears that an abundance of rainfall just before the eruption added pressure to the head of water that was already in the crater. In the case of the October 28, 1979 eruption, there had been 208 mm of rainfall over the 18th and 19th of October, while for the September 27, 2014 eruption, 164 mm of rain had fallen during the 24th and 25th of September.
 3. This tremendous explosive power and its instantaneous nature are typical characteristics of phreatic eruptions.
 4. There was a time lag of several days between the downpours and the eruption of Mount Ontake, since it is over 3,000 m high, and the water required some time to reach the entrance of the magma chamber. The eruption path from the caldera to the magma chamber entrance varies depending on the condition of the material ejected from past eruptions. In the case of the 2014 eruption, it took two days.
2. To make predictions about future eruptions, it is necessary to install an AMeDAS rainfall observation device or rain gauge on all the volcanoes for monitoring purposes. And along with observing the movement of magma, we must additionally observe rainfall.

Closing Remarks

This paper's new finding focusses on the fact that climatic variation around the globe becomes more dynamic year by year, and exhibits behavior not predicted by current theory.

I hope that this concept will be widely shared across both Japan and the rest of the world, so that we can devise ways to minimize natural disasters.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

All data and materials of this manuscript are available on the website of Japanese Meteorological Agency.

<https://www.jma.go.jp/jma/index.html>

Competing interests

I declare that I have no competing interests.

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Authors' contributions

Not applicable

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Authors' information

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2. Automated Meteorological Data Acquisition System Japanese Meteorological Agency, (1974) <http://www.jma.go.jp/jma/kishou/known/amedas/kaisetsu.html>

Figures

Figure 1

50 volcanoes installed 24-hour observation monitoring system in Japan

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Additional1ObservationMt.Ontake20.7.15.docx](#)
- [Additional1ObservationMt.Ontake20.7.15.docx](#)
- [Additional2History.20.7.15.docx](#)
- [Additional2History.20.7.15.docx](#)
- [Fig2.png](#)
- [Fig2.png](#)