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Potential Impact of a Major Future Summer Eruption of Changbai Mountains

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Abstract: *Volcanic activities are always accompanied by local and global impacts. A major eruption of a volcano can claim lives, seriously damage local economies, and cause global environmental issues. This article mainly studies the impact of a potential major eruption Changbai Mountain by examining past eruption histories and referring to eruptions of volcanoes in similar latitudes. By considering the geographical, cultural, and economical aspects of nearby regions, this article aims to undercover the worst-case scenario so that in case of a such an event in the future, geologists, policy makers, and those who are involved in the situation would provide some idea of what are in stake.*

Keywords: *Changbai Mountain, volcanic eruption, volcanic ash, demographics, economic losses, ecological impact*

1. Introduction

1.1 Volcanic hazards

Volcanic eruptions have been observed and recorded in human history for thousands of years. During an eruptive event, geological hazards of different types could occur, and human society's physical health, economic wellbeing, and mental health could be serious affected. Some of the common hazards of volcanic eruption included: pyroclastic flow, ash fall, lava flow, earthquake, toxic gas, landslide, lahar, etc [1]. These hazards can cause tremendous impact on human society. Eruption of volcanoes can be followed by a range of consequences such as health hazard, economic loss, agricultural loss and many environmental hazards. In order to mitigate the influence, predicting the volcanic activities is essential.

1.2 Current prediction methods and limitations

To start with, general principles of volcano seismology can be useful in making predictions. Seismic activities like earthquakes and tremors are highly related to eruption of volcanoes. As eruption is led by an increased pressure inside the magma chamber that pushes overlying layer upwards. As a result, increased abnormal seismic activities can be detected before eruptive activities.

The other commonly used tool is to monitor geoelectric potential changes and magnetic field changes. These signals can be used to predict the eruption of volcanoes. To illustrate, on Izu Island, Japan, significant anomalous changes took place in the ultra-low frequency before the seismic activity and were successfully detected [2].

Gas emission also indicates volcanic activities as eruption of volcanoes is accompanied by gas emission [3]. Before the 1991 eruption of Mt. Pinatubo, abnormality in gas emission provided geologists vital clue about the upcoming eruption, and this method has proved to be quite useful [4]. Before an eruptive event, magma dissolved with gas ascends from the magma chamber, and pressure drops during the ascending. Dissolvability decreases as pressure drops, and therefore, abnormal gas emission can be detected before the eruption. Thus, by monitoring the changes in gas emission, predictions can be made. Additionally, infra-sound detection is playing increasingly important role in detecting, locating, characterizing, and quantifying eruptive events [5]. Volcanologists use the aforementioned methods to assess and monitor potential eruption events and provide decision makers with information for evacuation or sheltering.

However, limitations exist for these methods. Firstly, recorded cases of eruptions are rare, so it is hard to establish fixed patterns. Thus, the predictions can be biased and not reliable enough. Secondly, some of the volcanoes locate in remote areas, no sufficient equipment and personnel are stationed to

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monitor and predict the eruption. In this case predictions and interactions may not be taken on time due to the lack of resources. Thirdly, some volcanoes might give little information and makes it difficult to observe and predict the volcanic activities. Finally, as volcanoes are different, signals of eruption, especially from volcanoes with phreatic eruption type, can be hard to detect.

2. Geographical and Geological Background of Changbai Mountain

2.1 Regional Geography

ChangBai Mountain is a dormant volcano standing in between Jilin Province, China and North Korea (Figure 1). It locates in an area that is famous for food production and was once the most important industrial center of China. The base of Changbai Mountain is quite populated with main cities nearby. Baishan, a prefecture-level city with 0.91 million population [6], is just 130 kilometers from the Heaven Lake (Figure 2), the caldera lake formed after a previous eruption; Tonghua, another prefecture-level city with 1.53 million population [7], is 175 km away; Shenyang, the capital of Liaoning Province with a population of 9.15 million [8], is only 370 km away; finally, Anshan, an important industry city that produces steel has a population of 3.31 million [9], is 420 km to the southwest of the Heaven Lake. Changbai Mountain has advanced tourism facilities such as ski resorts at its west slope attracting more than a million visitors annually (Figure 3) [10]. For its excellent ecological environment and fertile fields, the pharmaceutical industry and agriculture is very thriving among the regions nearby. Rice farming are agaric and ginseng cultivating are staples of the region.

2.2 Eruption history

Eruption history of Changbai Mountain has been studied by scholars from China and all over the globe. Earliest eruptive event can be dated back to around 22.6 million years and lasted for more than 10 million years. The most powerful eruption took place in 946 CE and was classified as a VEI-6 event. These cases can be used to predict the extent of influence caused by eruption. The following table 1 summarizes the eruption history of Changbai Mountain.

Table 1: Eruption History of Changbai Mountain

Eruptive episode	Age	Eruptive product	Description
Pre-shield stage	22.6-10.4 Ma	Basic	Non-explosive
Shield forming stage	5.02-1.05 Ma (Tianchi)	Basic, basic to neutral	Non-explosive
	4.77-1.86Ma (Wangtian'e)	Basic, basic to neutral	Non-explosive
	1.22-1.18Ma (Namphothe)	Basic, basic to neutral	Non-explosive
	5.50-1.11Ma (Tuen River)	Basic, basic to neutral	Non-explosive
Post-shield stage	1.17-0.05Ma	Basic, basic to neutral	Mild explosive
Cone-construction stage	1.37-0.01Ma (Tianchi)	Neutral, neutral to felsic	Mild explosive to explosive
	3.14-2.12Ma (Wangtian'e)	Felsic, felsic to neutral	Mild-exclusive to explosive
	1.79-0.70Ma (Namphothe)	Felsic, felsic to neutral	Mild explosive
Caldera-forming stage	0.01Ma to 946 CE (Tianchi)	Felsic	Explosive
Post-caldera	1403/1668/1703/1903CE (Tianchi)	Felsic	Non-explosive, Mild explosive, Explosive

*Table adapted from Zhang et. al. 2018 [11].

3. Methodology

For this reason, we only consider the impact of the eruption on the Chinese economy for the time being.

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In order to estimate the impact and making prevention properly, we previous eruption data as reference and consider the 946 CE eruption to be the worst-case scenario for a potential future eruption.

The 1980 eruption of Mt. St. Helens will also be a reference because Changbai mountain has a similar latitude as St. Helens. Latitudes of a volcano would affect how the volcanic ash would travel in the atmosphere after the eruption. Generally speaking, ashes sent to sky from volcanic eruption at low latitude would impact both hemisphere whereas eruptions from a super volcano in mid-latitude such as Yellowstone would only affect one hemisphere [12]. Mt. St. Helens (46.1914° N, 122.1956° W) and Changbai Mountain (41.7450° N, 127.9656° E) are comparable in terms of latitude, meaning that the global impact will be relatively similar for the two volcanoes. In 1890, St. Helens erupted lasted for 8 hours, lava flow affected and area within 10 km of the vent and tephra flow caused influence within 600km [13]. As for the scale of the eruption, Mt. St. Helens recorded 5 in the Volcanic Explosive Index (VEI), it is considered a very large eruption even though it has barely passed the threshold [14]. We can use the eruption of St. Helens as reference to predict the environmental impact of eruption of Changbai mountain with the expectation that Changbai Mountain Eruption could be even greater than that of Mt. St. Helens.

Data from Mt. Pinatubo is also used because just like Changbai Mountain, Mt. Pinatubo locates in a populous area, and before the 1991 eruption, evacuations were issued prior to the eruption, saving hundreds of thousands lives. With Pinatubo eruption also a VEI 6 very large eruption, we believe the evacuation effort would be similar.

In order to evaluate the hazards to agriculture, economy, health problems and environment, Statistic data of population and agricultural acreage published by local government are collected and estimated for a sum.

4. Results

4.1 Cost Associated with Evacuation

After an eruptive event is predicted, government would typically issue evacuations to ensure minimum damage to life and properties. Days before the Mt. Pinatubo eruption, residents within 30 km distance from the Pinatubo summit totaling more than 58,000 were evacuated [15]. A similar evacuation effort can be expected, indicating that towns in the vicinity of the mountain will have to be evacuated. According to the Seventh National Census of China, as of Nov. 1, 2020, there were 61,146 people in Changbai Mountain Special Protection and Development District [16]. All these people would have to be evacuated. The total number of evacuatees would be comparable to that of Mt. Pinatubo. The cost associated with caring for the evacuatees were about $93 million dollars for Mt. Pinatubo eruption in 1991, an equivalent of $208 million dollars nowadays.

4.2 Direct Economic Losses Due to Operation Shut Down

As residents need to be evacuated, the cities will not continue operating. Shut down in business and industry will lead to huge loss. Damaged infrastructures such as buildings and roads will have to be rebuilt, tephra will cover the streets and need to be cleaned. The resorts nearby might be ruined by the earthquakes and eruption and the airport at the base of Changbai Mountain will be damaged. Millions or even more would be needed to rebuild homes and infrastructures.

4.3 Biological Impacts

Eruption of volcanoes is usually accompanied by a spread of tephra, animals in the mountains, aquatic organisms in the lakes and plants are likely to be affected by the falling tephra since these ash particles are extremely dense. Those small particles can cause many terrestrial animals to suffocate, and seriously affect water quality and therefore harm aquatic lives. Some endangered species living in the region such as Manchurian tigers and spotted deer could be in an even more perilous situation than they are already in now.

4.4 Environmental

Toxic gases such as SO_2 and acid aerosols produced from the eruption can be quite harmful. For example, SO_2 is a factor of acid rain which can do harm to the environment, the emission of SO_2 will

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increase the possibility of acid rain to occur. Additionally, gases can also cause health problems such as respiratory morbidity [17]. If Changbai mountain erupts the health of residents in nearby regions will be threatened, buildings and fields will be corroded by the acid rain at the same time. An estimation of affected area is projected in figure 4 based on reports of Mt. St. Helens Eruption. Even though tephra from Mt. St. Helens reached locations more than 600 km from the summit, the impact was minimal at those farther places. We expect people living in towns as far away as Anshan, 370km away could be affected and mask mandate might be needed.

4.5 Agricultural

If the eruption takes place before harvest, the crops in fields will be damaged so agriculture will be hampered in the year. As Jilin province is famous for crops like rice and blueberries, eruption will reduce the output of these crops, shortage may take place. According to statistics, Baishan has 1,420,000 hectares of farmland [18]. Tonghua has 4,500,000 hectares of farmland [19]. Thus, when eruption takes place, it hazards about 5.9 million hectares of farmland which harms the agriculture severely.

4.6 Mental health

Mental problems may also be led by the eruption. A study shows that the eruption of St. Helens led to a significant morbidity for psychiatric disorders [20]. Also, chronic exposure to H_2S in geothermal areas can lead to respiratory diseases and nervous system. For north-east region of China, as industry has seriously slumped during the recent decades, unemployment and low-income is a big problem confidents towards life of residents is quite low. If the volcano erupts, work and life will be hindered cost of living might increase. Thus, it will be more possible for residents to get anxious or even some mental problems.

5. Discussion

Eruption of Changbai Mountain will have serious effects in quite a wide range of regions. It is necessary to monitor volcanic activities in the region. There are many other factors that we have not taken into the consideration such as extreme weather. Part of the reason why the 1991 Pinatubo eruption caused so much damage was because the rainfall brought by Typhoon Yunya triggered further lahar disasters [21]. Precipitations or sandstorms can both add to the damage. Meanwhile, there is forest on ChangBai Mountain, forest fire could be caused.

In our study, we did not consider the impact an eruptive event would have on North Korea. It is highly likely that evacuation is also needed. The damage could be much higher than we approximated. All the data we used is only previous cases and comparable volcano, so the study can only be qualitative but not quantitative. With the global climate change and extreme weathers, the reality might be even harsher.

6. Conclusion

In this article, we examined the eruption history and overall geography of Changbai Mountain. We further analyzed the potential economic losses the eruption would bring, the environmental and ecological impact, and the psychological impact it would have on local people. We conclude that a major eruption from the sleeping giant could have significant impact on local people both financially and mentally, and it would also harm local agriculture and industry. We believe close monitoring and tastings are necessary for Changbai Mountain, and prompt decision-making is essential if an eruption does take place.

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