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VOLCANIC DISASTERS IN THE JAPANESE MAIN ISLANDS AND NEW ZEALAND

by

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(with 2 text-figures)

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Abstract

A number of disastrous volcanic eruptions in the Japanese Main islands, including all those recorded eruptions which have caused great loss of life, have been studied, and in most cases the volcanoes have been visited. It appears that lahars (mud-flows) and tsunamis, either caused by lahars or avalanches entering the sea, or by submarine faulting, have been the main cause of loss of life.

A comparison has been made with volcanic disasters in New Zealand, a country with a much shorter period of recorded history, and there too the lahar is the main cause of loss of life.

Mention is made of two present potential hazards in Japan, and attention is drawn to the need for multiple methods of surveillance and prediction of eruptions.

Introduction

During Quaternary time, considerable volcanic activity has occurred in Japan. Yagi and Katsui (1965) estimated about 180 volcanoes have been active. In historic time, 46 have erupted and 12 show solfataric activity.

The Japanese Islands are associated with complex island arc systems. The Kurile Arc to the north continues south-west into eastern Hokkaido; the western volcanoes of Hokkaido form part of another arc extending south through Honshu. Near Mount Fuji is the northern part of the Mariana Arc which extends to the southwest; while another chain of volcanoes stretch southwest through Kyushu and the Ryukyu Islands.

As the Pacific Plate moves west beneath the Japanese Islands, the resulting subduction zones underlie them, deepening to the west. In Honshu, the eastern Nasu volcanic zone contains volcanoes distinctly less alkaline than those of the western Chokai Zone (Yagi and Katsui, 1965).

Japan is a heavily populated country, with a present population in excess of 112,000,000. The population density is greatest around the coasts, especially in

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Honshu and Kyushu, but also to some extent in Hokkaido. Because of this population distribution, it could be expected that the worst volcanic distasters of historic times have occurred in coastal areas. The period of recorded history in Japan is long (in excess of 1300 years), in contrast with the short period of recorded history in New Zealand (about 140 years). Therefore, so much can be learned of historic volcanic activity in Japan, especially concerning events of the last 400 years, which are relatively fully recorded.

Eruptions of historic times in Japan have not included very large rhyolitic tephra eruptions comparable to those of Taupo (130 AD) or even Kaharoa (1020 AD) in New Zealand. However, numerous calderas with associated large tephra and welded tuff deposits attest to the fact that great pumice and ignimbrite eruptions have occurred in the past, at invervals the frequency of which is uncertain. They may be expected in the future, as they may be in New Zealand at probably shorter intervals than in Japan.

By far the greatest losses of life in historic times in Japan have been due to two causes; mud flows (lahars) and volcano-induced tusnamis. Historic events are well described by Kuno (1962) and by other writers. Many accounts are in Japanese, but most are included in Part XI of the Catalogue of Active Volcanoes of the World, and so may be studied in this summary by those who, like the present writer, lack the ability to read the Japanese language. It is clear that in virtually every case, premonitory signs have occurred, and evacuation of population would have minimized casualties. However, most disasters occurred before the development of the modern science of volcanology, and warning signs were either ignored or not heeded sufficiently. Some of the most serious Japanese volcanic disasters are considered here as a series of 'case-studies'. In the first three case-studies, tsunamis play an important role, though in two of the three studies, the tsunamis were caused by lahars or avalanches. In the second group, lahars are not accompanied by tsunamis; the volcanoes are inland. Mention is made of what the present writer considers are two current potential hazards in Japan, and comparisons are made with New Zealand disasters.

Case-Study I. Unzen, 1791–92.

The Unzen volcano is a large complex structure, about 15 km from north to south, 12 km from west to east. It is situated on the west coast of Kyushu (Fig. 1). Volcanic rocks overlie Pliocene sediments, and consist of basalt lava and tephra; higher in the sequence andesitic lava occurs. Above this basement rise three distinct volcanic structures; Kinugase to the south, Kusembu to the north and Hugen to the east (see Kuno,1962, p. 40 for map). These volcanoes

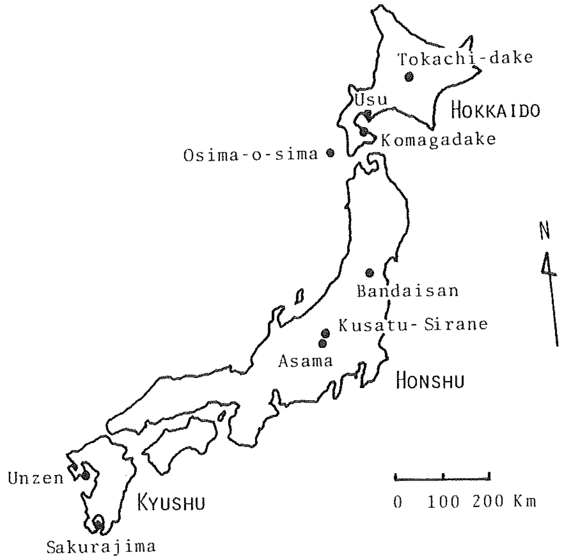

Fig. 1 Japanese Main Islands, indicating localities of volcanoes included in studies.

are composed of andesitic and dacitic rocks and all have lava domes in their central portions.

Hugen-dake, 1360 m, the highest and youngest of the three Unzen centres, is relatively undissected. Although its most recent lava is referred to as andesite (Kuno, 1962, p. 45) silica is over 66%, so it is probably dacitic.

A minor lava eruption from Hugen took place in 1657, and at other times fine tephra was emitted. The eruption which caused the worst volcanic disaster in Japan's recorded history took place early in 1792. This eruption had begun in 1791, when from November 13 earthquakes and some avalanching occurred. A small crater exists on the central lava dome of Hugen, and on 10 February, 1792, rock fragments were ejected from the vicinity of this crater. The summit eruption ceased before the end of February; and on March 1 lava was erupted from a vent 1 km north of the summit. The lava was small in volume, (0.11 km^3) and travelled a distance of 3 km, terminating as a steep fronted coulee. Further landslides occurred on March 5.

The town of Shimabara is situated on the coast of the Sea of Ariake, 7 km northeast of the summit of Hugen-dake, but only 3 km from Mayeyama, a dacite dome forming part of the Hugen complex and rising to a height of over 800 meters. Shimabara suffered earthquakes on April 21. One month later, on May 21, the great catastrophe occurred when the eastern part of the Mayeyama dome collapsed. An avalanche of rock and mud, almost 0.5 km^3 in volume flowed over Shimabara, killing 10,000 persons. It continued into the almost enclosed waters of the Ariake Sea, initiating a tsunami 10 metres in height which swept the opposite coasts and killed a further 4,300.

Triggering of the Mayeyama collapse may have been due to earthquakes or phreatic explosion, though Ota (1973) suggests receeding tide. Katayama (1973) who has examined contemporary accounts, found that following the collapse, a large volume of hot water poured from the shattered remains of Mayeyama; hence lubrication of the debris by water appears certain to have occurred, and the 'avalanche' may be termed a lahar. The writer has examined the debris, which resembles closely lahar debris on white Island and elsewhere in New Zealand, and considers the flow responsible for the Shimabara catastrophe to have probably been a lahar.

Case-Study 2. Komagadake, 1640

Komaga-dake is located on the east side of the Oshima Peninsula of southwestern Hokkaido. It lies at the southwestern portal of the entrance to Uchiura Bay (Volcano Bay), its summit reaching a height of 1140 m. It is a strato-volcano, consisting of andesitic lava and tephra including pumice flows. At the summit is a large elliptical crater, containing two smaller craters.

Evidence of former lahars is prominent at the southern foot of the volcano (Ishikawa, in Kuno, 1962). Pumice and other tephra, andesitic in composition and at times very hot, have been erupted on frequent occasions. Some loss of life resulted from a pumice flow eruption in 1929, and hot pumice burned out the village of Honbetsu, 12 km east of the crater, in 1856.

The most disastrous eruption was that of 1640. This was a major tephra eruption, some of which fell as far south as Niigata in Honshu, 600 km southwest. Although tephra accumulated to a depth of 2 metres at the foot of the volcano, serious loss of life (700 persons) resulted from a tsunami sweeping the coasts east of the volcano. This tsunami was caused by an avalanche from the volcano entering the sea (Katsui, 1975). The present writer considers the avalanche may have been a lahar.

Case-Study 3. Osima-o-sima, 1741

The island volcano of Osima-o-sima is uninhabited, and is situated 60 km offshore from the western coast of Oshima Peninsula, southwestern Hokkaido. It is 4 km by 3.5 km; its highest point is 714 m above sea level.

Early basaltic and andesitic eruptions formed a large cone. Summit subsidence resulted in a caldera within which andesite and basalt were erupted to form a second strato-volcano. Another caldera resulted from further subsidence, and a central cone formed within it. Flank eruptions on some occasions resulted in extrusion of lava into the sea.

In 1741 very strong tephra eruptions occurred, probably with accompanying lava flows. These were sufficiently intense to cause darkness in daytime (in the month of August). Fine tephra fell on villages 80 km distant. On August 23 a tsunami swept the coast of Oshima Peninsula, killing 1467 persons and destroying many houses. The northern coast of Honshu also felt the effects of the tsunami, 8 persons and 82 houses being destroyed at a distance of over 100 km from the volcano. Imamura (1947) considered the tsunami was caused by a submarine dislocation associated directly or indirectly with the eruption.

Comments on Case-Studies 1, 2 and 3

The three eruptions described above all caused many deaths by tsunami generation, although in the catastrophe of Unzen, greater damage to life was caused by the lahar which then generated the tsunami. In the cases of Unzen and Osima-o-sima vigorous and spectacular volcanic activity had preceded the fatal events. Evidence for Komagadake in 1640 is not clear. In 1640 very few Japanese lived in Hokkaido, and written records are brief. In all cases, presumably the danger of sea-wave generation was not understood, and coastal dwellers were not alert to the possibility of danger from such a source.

In the special case of Unzen, the destruction of Shimabara by lahar emphasizes the danger of a town being sited close below a high volcanic edifice, especially during eruptions accompanied by earthquakes.

New Zealand has most to learn from case-study 3, the Osima-o-sima eruption, because of the similarity of this volcano to White Island, in the Bay of Plenty. Both are of comparable size, though White Island is smaller; both have at times erupted dacitic or andesitic products, though White Island is more acidic. Both are a comparable distance offshore from a low-lying, populated coast, though today the population of Oshima Peninsula is very much greater than it was in Ainu times. Many geologists have drawn attention to the obvious danger to persons in the Bay of Plenty area, New Zealand, in the event of a Krakatoan eruption of White Island. However, in the case of Osima-o-sima, the eruption of 1741 was not Krakatoan. From the descriptions available, it appears to have been similar to but much more intense then the 1968 tephra eruption of White Island (Clark, 1970). The possibility of tsunami generation from submarine faulting following or accompanying a severe tephra eruption of White Island should not be ignored.

Case-Study 4. Asama, 1783

Asama is a large (2560 m) composite volcano, situated in central Honshu about 140 km northwest of Tokyo. As with many Japanese volcanoes, Asama itself is a young andesite cone rising within the remains of an older volcanic complex.

Following an eruption in 685 AD, a period of dormancy ensued until 1108, since when eruptions have been frequent. Some loss of life occurred during eruptions in 1596, 1721 and 1803 but the greatest catastrophe was that of 1783. The eruption of that year began on May 9 with minor explosions. A major eruption began on July 26, and pumice was erupted in considerable quantity. On August 4 a pyroclastic flow covered 19 km^2 on the northern slopes; on the next day a large nuée ardente moved rapidly down the same slope, becoming a lahar which reached the Agatuma River, over 12 km distant from the summit crater. Its debris mingled with the river water, producing an even greater lahar, with resulting flood which killed 1300 persons. The eruption terminated with a lava flow which followed immediately after the nuée (Aramaki, 1956).

Case-Study 5. Bandai-san, 1888.

The Bandai volcano is situated in central Honshu (Fig. 1). It reaches a height of 1,818 m; a caldera, of about 2 km diameter, opens to the north, and was formed in the 1888 eruption. Formerly a northern peak, Kobandai, existed on the site of the caldera.

Lahars had been produced at various periods in the past from Bandai-san (806, 1808). The catastrophic event of 1888 was preceded by earthquakes and explosions thought to have been phreatic. More than 15 explosions occurred at Kobandai and this part of the cone collapsed. A lahar developed from the collapsed material, and over 1 km^3 of water saturated rubble moved rapidly down the northern slopes, for a distance of about 10 km. A number of villages were buried, and more than 460 persons killed. The Nagara River was blocked and a number of large lakes formed.

Case-Study 6. Tokachi-dake, 1926.

Tokachi-dake is situated in central Hokkaido; its summit is 2,077 m above sea level. It consists of a group of centres, sited along a northeast – southwest line; further northeast along this lineament lie the Daisetsu group of volcanoes. A number of craters are present in the Tokachi summit area. An explosion crater formed in the lower part of the central cone in 1887 while higher in the cone a small crater developed two years later.

From the end of 1925 tephra was erupted from the summit, volcanic tremors and audible rumbling were noted. An explosion from a new crater on the western flank of the cone occurred on May 24, 1926. Melted snow produced a lahar which destroyed a nearby small spa hotel. Four hours later, at 1618 hours, the northwest part of the cone collapsed, causing a hot avalanche which, with melted snow developed into a rapidly moving lahar. It reached the town of Kami-Furano 20 km west of the cone in only 20 minutes. 144 people were killed and over 5,000 houses destroyed.

A further eruption occurred in 1962, and 5 sulphur workers were killed. However, this eruption took place in June, after winter snows had melted, and no lahar resulted. After this eruption, a volcano observatory was constructed nearby, by the Japan Meteorological Agency.

Case-Study 7. Kusatu-Sirane, 1932

This andesite volcano is situated immediately north of Asama in Honshu. On its eastern side are three craters, all with lakes; Mizugama, Yugama and Karagama. Historic eruptions have all been phreatic explosions, most from the wall of Yugama. In 1932, eruption of water from Yugama produced a mudflow which killed two persons mining sulphur near the crater.

This case-study is included not because it ranks as a major disastrous eruption, but because today Kusatu-Sirane represents a much greater hazard than previously. Due to growth of the tourist industry in Japan, and new roads, about 2 million persons visit the crater lakes of Kusatu-Sirane each year (D. Shimozuru, pers. comm.). Even a small crater lake eruption today could cause great loss of life.

Comments on case Studies 4, 5, 6 and 7

Loss of life and property in all four of the eruptions described resulted from mud-flows. In the eruptions of Asama, Tokachi and Kusatu-sirane, the source of the water in the lahars was mainly, though not entirely, secondary; the Agatuma River in the case of Asama, snow in Tokachi, and crater-lake water at Kusatu-sirane.

The Bandai event, however, has some resemblance to the Shimabara lahar at Unzen; the Kobandai portion of the Bandai volcano collapsed and a lahar formed in a manner which appears remarkably similar to the Mayeyama collapse 90 years earlier.

Two other Volcanoes dangerous to the Japanese Main Islands

Usu, in southwestern Hokkaido, is situated on the southern margin of the Toya caldera. Initially a strato-volcano, later eruptions have consisted of formation of lava domes, some notable in historic times. In 1822, a nuée ardente overwhelmed the old village of Abuta, causing 103 casualties. At the end of 1943, further activity commenced in the area, culminating in 1944 and 1945 with the extrusion of another dacite dome, Siowa-Sinzan. Adequate warnings were given, and no casualties occurred.

Sakurajima, in Kagoshima Bay, southern Kyushu, lies near the southern margin of the Aira Caldera. It is an andesite volcano, reaching a height of 1118 metres, and is composite, consisting of three strato-cones coalescing. The currently active crater on Minami is in the southern-most of the three, and at the time of writing is emitting considerable fine tephra. A substantial amount of andesite lava, over 1.56 km^3 in volume, was erupted from flank fissures on the southern cone in 1914 and some casualties occurred. The lava emission was accompanied and followed by appreciable crustal deformation. A smaller lava eruption occurred in 1946.

In earlier years, it is noteworthy that submarine eruptions in Kagoshima Bay near Sakurajima caused tsunamis, presumably small, from 1779 to 1882.

When visiting this volcano, the writer was impressed by the steepness and possibly unstable nature of some of its higher slopes. Should partial collapse of some of the higher parts of the cone occur, especially under wet conditions, avalanches or lahars could reach Kagoshima Bay by several routes. Two examples of such routes may be noted, one immediately north of the Kyoto University Volcano Observatory, another directly south from Minami-dake. Such lahars, if large, could cause dangerous tsunamis in Kagoshima Bay. The situation appears to be in some respects analagous with that at Unzen prior to the partial collapse of Mayeyama.

Comparison of Japanese and New Zealand Volcanic Hazards

Japanese historical accounts extend back nearly 1500 years, and verbal information probably covers a substantial earlier period. But New Zealand was uninhabited until about 900 AD, and its written history extends back only about 140 years.

By far the greatest volcanic event in either country in the last 2000 years was the hot pumice eruption from the Taupo area (Fig. 2), which occurred about 131 AD. Over 25 km^3 of pumice was erupted, burning forest over much of the centre of the North Island. Drainage from Lake Taupo was blocked for a time, and great flooding occurred. However, this eruption cannot be termed catastrophic, as there were no inhabitants to be affected.

Another lesser but still very large volcanic event was the rhyolitic eruption which produced the Kaharoa tephra, about 1020 AD, from the Tarawera centre. This eruption almost certainly affected early Maori inhabitants of the Rotorua region (R. Parker, pers. comm.). However, these were probably few in number, and while the event appears to be remembered in Maori legend, it does not appear as a major catastrophe.

No acidic pumice eruption of magnitude comparable with that of Taupo or even Kaharoa has occurred in Japan within the last 2000 years. Such an eruption would have been a very great calamity. It is possible such eruptions will occur in the future in both countries. The tephra record in both Japan and New Zealand make this highly likely.

In historic times, New Zealand has suffered three principal volcanic disasters. The first, the basaltic eruption of Tarawera, 1886, resulted in the deaths of many of the inhabitants of the Maori village of Te Wairoa, and elsewhere in the vicinity. Most if not all of the casualties were caused by burial of the area in a rain of mud, mostly thrown from Lake Rotomahana. A later (1917) steam explosion in this area, at Frying-pan Flat, also caused some casualties.

A mudflow at White Island, in September 1914, caused the deaths of all 11 men mining sulphur on the Island at that time. They were buried by a lahar caused by collapse of part of the western wall of the crater, within which their living quarters were situated. The rubble blocked the steam vents, became saturated with hot water, and flowed south on a very gentle slope to cover almost the entire floor of the crater with up to 10 meters thickness of rock,

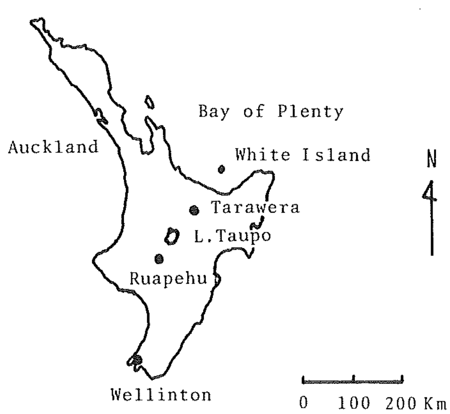

Fig. 2 North Island of New Zealand, showing localities of volcanoes mentioned in text.

mud and hot water. Newspaper reports at the time of the disaster describe attempts made by investigating parties to dig through the mud to find any traces of the victims, but these were unsuccessful because of the hot water which permeated the mud.

In 1953 a lahar from Ruapehu Crater Lake flooded the Wangaehu River and destroyed the railway bridge at Tangiwai just before an express train reached it. Most of the train crashed into the river, causing the deaths of 151 persons. In this case the lahar was the result of sudden clearance of a natural ice tunnel drain from the crater lake, which had been blocked since the volcano erupted in 1945.

Tsunamis may have occurred prior to the period of recorded history in New Zealand, but if so we have no knowledge of them. But certainly lahars have caused serious loss of life in both New Zealand and Japan. A reasonable conclusion to draw from the study of Japanese volcanic disasters is that mudflows and tsunamis are serious potential hazards in both countries and may cause heavy casualties at long distances from the volcanoes which produce them. Andesitic or dacitic tephra and nuée ardente eruptions are a lesser but real danger; rhyolitic tephra eruptions, though fortunately infrequent, could be extremely destructive.

Mitigation of Volcanic Disaster in Japan and New Zealand

This topic is a vast one, and the only aspect considered briefly in this paper is warning of impending dangerous activity. In Japan many volcano observatories exist. The Japan Meteorological Agency maintains numerous observatories, on most dangerous volcanoes, and several universities also maintain well equipped observatories. Seismic and tilt observations are the most usual means of monitoring behaviour, but many other methods of surveillance are also used. At Shimabara, ground water level, temperature and conductivity are constantly recorded at the Observatory of Kyushu University, and seismic equipment is about to be installed at that observatory. Some chemical work on gases and temperature measurement by various means is also proceeding on various volcanoes. A comprehensive list is beyond the scope of this paper.

In New Zealand, an observatory on Ruapehu is currently being upgraded, and it is hoped to install a seismometer with telemetry to the mainland on White Island later this year (1976) to supplement observations taken on regular visits made to the island by a team of vulcanologists. In addition, seismic and other observations are made in the Taupo volcanic zone by scientists of N.Z. Dept. of Scientific and Industrial Research, and of New Zealand Universities.

In both countries the risk of further eruptions producing hot pumice has been mentioned, and clearly vulcanologists should monitor carefully any unusual activity, especially in the vicinity of an existing caldera.

However, the lesson of recent volcanic history is clear. Lahars have taken heavy toll of life in the past, and can be expected to do so in the future unless adequate warning can be given. Neall (1976) has given a comprehensive list of lahars and their causes, although in his paper the Shimabara catastrophe is not recognised as due to lahar.

Whenever possible, crater lakes such as shose of Kusatu-Sirane should be monitored chemically, and temperature changes noted. Ground water level changes, and changes in fumarole and hot spring activity may also indicate water saturation. The subject is extremely large, but the great dangers to life and property of lahars, especially when they may generate tsunamis, are clear.

Conclusion

Attention is drawn to two passages from the Final Report of the UNESCO regional seminar on surveillance and prediction of volcanic activity in the Western Pacific (1975). On p. 13 of this report the statement appears "Needless to say, quantitative prediction of eruptions cannot succeed only from a single type of observation. Combination of observations of various kinds of physical and chemical parameters and the suitable interpretation of their data leads to prediction of eruptions and mitigation of volcanic disasters." on p. 26, the following recommendation appears:—

"Be it resolved that in the interest of public safety and for increase of scientific knowledge, active volcanoes should, where feasible, always be monitored by establishment of appropriately equipped and suitably staffed volcano observatories."

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