Phreatomagmatic Volcanic Hazard in Rift Edge in Coastal Regions of Volcanic Islands

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Miyakejima Volcanic Island - Geology

Tsukui et al., 2005
Lahar deposit: ~12 ka C14
Miyakejima Volcanic Island – summit growth

Pre-9th Century

9th Century

1085 AD

1154 AD

Phreatomagmatic flank

- Early evolution: formation of Kuwanokidaira caldera (~10 ka)
- Near-complete infill of Kuwanokidaira caldera and formation of summit cones
- Growth of central volcano in Hatchodaira (post ~2.5 ka) caldera
Evolution of the multiple caldera complexes

Kuwanokidaira caldera (K): at least 10 ka

Hatchodaira caldera (H): 2.5 ka

Pre-2000 AD morphology (Geshi 2009)
Post-2000 AD morphology (Geshi 2009)

Oyama caldera: 2000 AD
Miyakejima – modern fissure eruptions

1469 AD

1535 AD

1595 AD

1643 AD

1712 AD

1763 AD

1811 AD

1835 AD
Miyakejima – role of phreatomagmatism

1874 AD

1940 AD

1962 AD

1983 AD

2000 AD

4 October, 1983

Nippana tuff ring

Shinmyoike maar

By Osamu Ooshima
Role of phreatomagmatism

Mt Oyama – Intra-caldera compound volcanic volcano

Suona crater (pre-9th century)

9 July 2000 (S. Nakada)
1.0 X 0.8 km with 0.2 km depth

4 June 2001 (T. Kaneko)
1.6 km across with 0.5 km depth
Suona crater: pre-9\textsuperscript{th} century chain of craters.
- Initial eruption took place in the flank of the island (about half way to the summit).
- Initial eruptions were magmatic explosive eruptions leaving behind scoriaceous, spatter-dominated successions.
- Eruption progressed along a fissure toward the centre of the edifice.
- Eruption gradually switch to more explosive phreatomagmatic style leaving behind a pyroclastic sequence composed of less vesicular, more angular and chilled pyroclast-dominated units.
- In higher position, phreatomagmatism is more prominent eruption style along fissures.
Flank fissure toward summit

Initial magmatic explosive deposits: lava spatter

Older crater

Younger Suona crater
Flank fissure toward summit
Flank fissure toward summit

Higher in section, more abundant cauliflower lapilli and bomb in fine ash matrix
Flank fissure toward summit

Suona – medial-to-distal sections
Flank fissure toward coast - 1983 event

Shinmyoike maar

Nippana tuff cone

Nippana tuff cone
Nippana tuff cone

Flank fissure toward coast - 1983 event
Flank fissure toward coast - 1983 event
Flank fissure toward coastal plains – common case?! 

Pre-9th Century maar deposits
Caldera infill: evidences for phreatomagmatism

Kuwanokidaria vs Hatchodaria calderas

Phreatomagmatic phase of Hatchodaira caldera formation

Confined aquifers in strato-volcanic setting

Phreatomagmatic explosive eruptions
Other Pacific Islands

Ambrym

Ambae

2005 AD

1913 AD
Conclusion
**Historic Eruption Styles**

**Historical Activity**

<table>
<thead>
<tr>
<th>Year</th>
<th>Phenomenon</th>
<th>Activity Sequence</th>
<th>Damages, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>832 (Tencho 9)</td>
<td>Moderate: Phreatomagmatic eruption</td>
<td>June 23. Air-fall pyroclastic material. The eruption occurred on the northern slope crater chain. Magma eruption volume = 0.007 km³ DRE. VEI 3</td>
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<tr>
<td>850 (Kasho 3)</td>
<td>Large: Magmatic eruption</td>
<td>October 7. Lava flow → air-fall pyroclastic material. The eruption occurred in the Hachodara caldera and at the Miekii mire. Magma eruption volume = 0.082 km³ DRE. VEI 4</td>
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</tr>
<tr>
<td>886 - 1154</td>
<td>Moderate: Magmatic eruption</td>
<td>November. Air-fall pyroclastic material and lava flow. The eruption occurred at the central crater (Oyama) and the northeastern foot of the volcano (eruption fissures from Hinayama Pass to near Shitori shrine). Magma eruption volume = 0.055 km³ DRE. VEI 3</td>
<td></td>
</tr>
<tr>
<td>1085 (Otoku 2)</td>
<td>Moderate: Magmatic eruption</td>
<td>December 24. Air-fall pyroclastic material and lava flow. The eruption occurred on the western slope (from the water reservoir area near the west of the Kawanakajima caldera). Magma eruption volume = 0.002 km³ DRE. VEI 3</td>
<td></td>
</tr>
<tr>
<td>1154 (Kyri 6)</td>
<td>Moderate: Magmatic eruption</td>
<td>March. Air-fall pyroclastic material and lava flow. The eruption occurred between the summit and the southeastern volcano foot. Fissure eruption. Magma eruption volume = 0.003 km³ DRE. VEI 3</td>
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<tr>
<td>1468 (Sumi 1)</td>
<td>Moderate: Magmatic eruption</td>
<td>November 22. Air-fall pyroclastic material and lava flow. The eruption occurred at the southeastern volcano foot. Fissure eruption. Magma eruption volume = 0.002 km³ DRE. VEI 3</td>
<td></td>
</tr>
<tr>
<td>1535 (Tenbu 4)</td>
<td>Moderate: Magmatic eruption</td>
<td>Approximately 3 weeks from March 31. Air-fall pyroclastic material and lava flow. The eruption occurred on the western slope (from the Koshiki scoria cone to the Kawanakajima eruption fissure). A fall-earthquake at 1600 on March 31, and an eruption at 2000, ejecting lava which flowed approximately 3 km to the sea. The entire village of Ako (which was located in a different location from the present Ako) was buried or burned down. The former Tsubota was downwind, so a large amount of volcanic ash and incandescent lapilli fell buried houses and fields. No injuries or fatalities resulted. The eruption lasted approximately 3 weeks. Magma eruption volume = 0.012 km³ DRE. VEI 3</td>
<td></td>
</tr>
<tr>
<td>1643 (Kan'ei 20)</td>
<td>Moderate: Magmatic eruption</td>
<td>Approximately 2 weeks, starting February 4. Air-fall pyroclastic material and lava flow. The eruption occurred at the south-southeastern volcano foot. Fissure eruption. Fissure eruptions occurred from approximately 1800 on Feb. 4. Lava erupted on the volcano slope (7) was observed at approximately 2000: Lava discharged from the Kawanakajima reached the sea (Nippana?). Muddy water buried many houses and caused livestock damage at Ako. The sound of the eruption could be heard at Kamakura. The eruption began with an eruption of approximately 2 weeks, and ceased in the following year. Magma eruption volume = 0.003 km³ DRE. VEI 3</td>
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<tr>
<td>1712 (Shōhō 1)</td>
<td>Moderate: Magmatic eruption</td>
<td>The eruption began on August 17. Air-fall pyroclastic material and lava flow. The eruption occurred at the south-southwestern volcano foot. Fissure eruption. Eruptions occurred frequently from approximately 1800 on Aug. 17. Lava erupted on the volcano slope (7) was observed at approximately 2000: Lava discharged from the Kawanakajima reached the sea (Nippana?). Muddy water buried many houses and caused livestock damage at Ako. The sound of the eruption could be heard at Kamakura. The eruption began with an eruption of approximately 2 weeks, and ceased in the following year. Magma eruption volume = 0.003 km³ DRE. VEI 3</td>
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<td>1763 to 1769 (Horeki 13 to Meiw 6)</td>
<td>Large: Magmatic eruption</td>
<td>The eruption occurred at the south-southwestern volcano foot. Fissure eruption. Eruptions began at night at the summit of Oyama, with rumbling and earthquakes the following day. During this time, an eruption occurred at Usagi, Ako. Volcanic blocks and ash fell in both Ako and Tsuobata. A deep crater formed in Usagi, retaining water (Shinmyoko Pond?). Volcanic activity continued until 1769 (Meiw 6). Magma eruption volume = 0.066 km³ DRE. VEI 4</td>
<td></td>
</tr>
<tr>
<td>1811 (Bunii 6)</td>
<td>Moderate: Magmatic eruption</td>
<td>Approximately 1 week, beginning on January 27. Air-fall pyroclastic material and lava flow. The eruption occurred between the summit and the east-northeastern volcano foot. Fissure eruption. The eruption began at night near the summit and moved to the northeastern slope. The eruption waxed at approximately 0600 on Jan. 27, but earthquake swarms lasted until February 1. Two open cracks were formed on the northeastern foot of the volcano (flow of lava is unclear). Magma eruption volume = 0.002 km³ DRE. VEI 3</td>
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</table>
### Historic Eruption Styles

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<td>1835</td>
<td>Moderate Magmatic eruption</td>
<td>10 days, starting on November 10. Air-fall pyroclastic material and lava flow. The eruption occurred on the western slope (inside the Kusawanokataki caldera). Rambling was frequent and an eruption occurred near Kusaji, on the western slope. Volcanic blocks and lava flow. The eruption calmed on the middle of the eruption. Even after the eruption ended, earthquake swarms occurred, and landslides and fissures in both Iga and Ako. A hot spring appeared in Ako as a result of the eruption. Magna eruption volume = 0.0001 kDRE.</td>
</tr>
<tr>
<td>1974</td>
<td>Moderate Magmatic eruption</td>
<td>Approximately 2 weeks, beginning on July 3. Air-fall pyroclastic material → lava flow. The eruption occurred on the northern slope. Occasional earthquakes began at approximately 08:00 on July 3. At roughly noon, an eruption occurred in the mountains to the south of Kamakura. Lava flowed to the north reaching Togo and creating 5,000 m² of new land on the coast. 45 houses were buried by lava. The eruption and rambling ended 4 days later, but activity continued for approximately 2 weeks. 1 person was killed. Total ejecta: 7 x 10⁶ m³. Magna eruption volume = 0.015 kDRE.</td>
</tr>
<tr>
<td>1900</td>
<td>Earthquake</td>
<td>November. Houses were damaged in Miyakejima, Mikurajima, and Kozushima, and many aftershocks occurred (the largest being M6).</td>
</tr>
<tr>
<td>1935</td>
<td>Earthquake</td>
<td>From August 27 to mid-September earthquake swarms occurred (maximum magnitude of M5.1).</td>
</tr>
<tr>
<td>1940</td>
<td>Moderate Magmatic eruption</td>
<td>July 12. Air-fall pyroclastic material and lava flow. The eruption occurred at the northeastern slope fissure and summit crater. It began from the pyroclastic cone near Akaibiko and from the northeastern volcano slope. Earthquakes occurred for several days before the eruption. Divers heard rumbling underwater in Akaibiko Bay for 2 or 3 days before the eruption. On July 12 at 09:30 an eruption from the northeastern slope began. Lava flowed down and covered villages on the island, reaching Akaibiko. The eruption on the slope was mostly over by July 13. A summit eruption began on the morning of July 14, producing a large amount of volcanic ash and pyroclastic material. This eruption ended by approximately August 8. The eruption killed 11 people, injured 20, killed 30 cattle, destroyed or burned down 24 houses, and caused extensive additional damage. Total ejecta: 1 x 10⁷ m³. Magna eruption volume = 0.012 kDRE.</td>
</tr>
<tr>
<td>1943</td>
<td>Earthquake</td>
<td>Earthquake swarms between December 9 and 31 (maximum magnitude of M5.3).</td>
</tr>
<tr>
<td>1953</td>
<td>Earthquake</td>
<td>From August 24, 1953, a hot spring anomaly was noted on Yonama. Saplings wilted and died on the slopes, and the sea temperature rose.</td>
</tr>
<tr>
<td>1956</td>
<td>Earthquake</td>
<td>April 14-31 and 1962: April 10-19. Volcanic activity was observed on Yonama. Saplings wilted and died on the slopes, and the sea temperature rose.</td>
</tr>
<tr>
<td>1959</td>
<td>Earthquake</td>
<td>Earthquake swarms from late April to early August (maximum magnitude of M5.4).</td>
</tr>
<tr>
<td>1962</td>
<td>Moderate Magmatic eruption</td>
<td>After earthquake swarms in May (which continued intermittently until September), an eruption occurred after 22:00 on August 24 at an elevation of between 200 m and 400 m on the northeast slope (near the site of the 1960 eruption). Fissure eruption, lava fountain. Lava flowed from many craters into the sea. The eruption ended in 30 hours, but many felt earthquakes occurred from the middle of the eruption, with the number of earthquakes affecting local villages surpassing 2,000 by August 30. Children were evacuated from the island, and island residents were extremely anxious about the situation, but the number gradually tapered off by the end of the year. The hypocenters were not in the same area as the eruptions, but instead were in the northwest of the island. The largest earthquake had a magnitude of M5.9 (August 26). 5 houses were burned down, and roads, mountainous areas, and agricultural land were damaged. The Samukawa caldera (measuring a cone formed in the thirteenth year of the Showa Era, 19624D) was formed. Total ejecta: 7 x 10⁶ m³ (approximately 20 million tons). Magna eruption volume = 0.007 kDRE.</td>
</tr>
<tr>
<td>1963</td>
<td>Fumarole</td>
<td>A new fumarolic area appeared near the summit of Yonama.</td>
</tr>
<tr>
<td>1974</td>
<td>Earthquake</td>
<td>From June 27 to 30 (maximum magnitude of M6.1).</td>
</tr>
<tr>
<td>1982</td>
<td>Earthquake</td>
<td>December 13 to January 13, 1983. Earthquake swarms general 20 km to approximately 20 km at sea, to the southeast, maximum magnitude of M6.4.</td>
</tr>
<tr>
<td>1983</td>
<td>Moderate Magmatic eruption</td>
<td>October 3 to 4. Air-fall pyroclastic material, lava flow, pyroclastic surge. The eruption occurred on the south-southwestern volcano foot eruption fissure.</td>
</tr>
<tr>
<td>1990</td>
<td>Moderate Magmatic eruption</td>
<td>From August 27 to mid-September earthquake swarms occurred (maximum magnitude of M5.1).</td>
</tr>
<tr>
<td>1992</td>
<td>Moderate Magmatic eruption</td>
<td>From June. Air-fall pyroclastic material, lava flow, pyroclastic surge. The eruptions occurred on the summit caldera, and in the sea approximately 1 km west of Miya.</td>
</tr>
<tr>
<td>1996</td>
<td>Moderate Magmatic eruption</td>
<td>From August 24, 1996, a hot spring anomaly was noted on Yonama. Saplings wilted and died on the slopes, and the sea temperature rose.</td>
</tr>
<tr>
<td>2000</td>
<td>Earthquake</td>
<td>From August 24, 2000, a hot spring anomaly was noted on Yonama. Saplings wilted and died on the slopes, and the sea temperature rose.</td>
</tr>
<tr>
<td>2004</td>
<td>Earthquake</td>
<td>From August 24, 2004, a hot spring anomaly was noted on Yonama. Saplings wilted and died on the slopes, and the sea temperature rose.</td>
</tr>
<tr>
<td>2006</td>
<td>Moderate Magmatic eruption</td>
<td>From August 24, 2006, a hot spring anomaly was noted on Yonama. Saplings wilted and died on the slopes, and the sea temperature rose.</td>
</tr>
<tr>
<td>2008</td>
<td>Earthquake</td>
<td>From August 24, 2008, a hot spring anomaly was noted on Yonama. Saplings wilted and died on the slopes, and the sea temperature rose.</td>
</tr>
<tr>
<td>2010</td>
<td>Earthquake</td>
<td>From August 24, 2010, a hot spring anomaly was noted on Yonama. Saplings wilted and died on the slopes, and the sea temperature rose.</td>
</tr>
</tbody>
</table>

*Reference documents have been appended with reference to the Active Volcano Database of Japan, AIST (Kudo and, 2006) for volcanic periods, areas of activity, eruption types, and eruption events.*