Magma-Tectonic Interactions – Static Stress Triggering

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Penn State
Outline

Stress Triggering

- Dynamic, Quasi-Static & Static

Earthquake-Eruption Triggering Examples

- Vesuvius-Apennines
- Mt. Fuji & Nankai

Earthquake-Earthquake Triggering
Static vs Dynamic Triggering

- **Dynamic triggering**
  - $1/r^2 - 1/r$ (body & surface waves)
  - Time lag = min. to hours
  - $r < 1200$ km
  - Magmatic processes: advective overpressure, rectified diffusion

- **Quasi-Static triggering**
  - $1/r^2 - 1/r$
  - Time lag = years to centuries
  - Dependant on effective viscosity of lower crust & upper mantle
Static vs Dynamic Triggering

- **Static triggering**
  - $1/r^3$
  - Time lag = months to years
  - Limited to a few fault lengths

- **Volcanism**
  - Normal stress change – ‘unclamping’
  - Compressional stress – ‘squeeze’ magma chamber

- **Stresses – Low!**
  - Smaller than Earth tides (0.001 MPa)
Figure 3. Schematic illustration of the response of a hypothetical Vesuvius magmatic system to a southern Apennine normal-faulting earthquake for (a) a buried dike in which at least one fissure or feeder conduit strikes NE and (b) a buried spherical magma chamber with a NE striking fissure.

Nostro et al. (1998) JGR
Vesuvius and Apennines

Nostro et al. (1998) JGR
Vesuvius and Apennines

Nostro et al. (1998) JGR
1707 Hoei Earthquake and Mt. Fuji Eruption
- $M_w$ 8.7 earthquake followed 49 days later by VEI 5 eruption
- Investigate stress trigger; 1703 Genroku $M_w$ 8.2 & Mt. Fuji
- Magma mixing – andesitic & dacitic magmas; basaltic magmas later

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Mt. Fuji

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Mt. Fuji Eruptive History & Nankai Seismicity

<table>
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1703 Genroku & 1707 Hoei

1707 $M_w$ 8.7 Hoei and 1703 $M_w$ 8.2 Genroku earthquakes

Chesley et al. (2012) GRL
1703 $M_w$ 8.2 Genroku

Chesley et al. (2012) GRL

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1707 $M_w$ 8.7 Hoei

Chesley et al. (2012) GRL

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1707 Hoei Eruption and Mt. Fuji Eruption
- M_w 8.7 earthquake followed 49 days later by VEI 5 eruption
- Unclamping of dike at ~10 - 20 km depth
- Magma mixing – andesitic & dacitic magmas; basaltic magmas later

Chesley et al. (2012) GRL
Mt. Fuji
Mt. Fuji

Map of Tephra Thickness from 1707 Fuji Eruption


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1960 $M_w$ 9.5 Valdivia, Chile

Chesley et al. (2012) GRL

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Lara et al. (2004)
P. Hill (2013)

Lara et al. (2004)
Nicaragua Fore-Arc Motion

- Upper plate seismicity indicates northwest directed fore arc sliver transport
  - Central Costa Rica to Guatemala
- Diffuse deformation in CCRDB
- Shallow (<20 km) & located within 20 km of arc
- Focal mechanisms are consistent w/ NE or NW trending fault planes
- $M_s < 6.5$
- Elongated damage zones & focal mechanisms NW to NE
- Cluster & Migrate along strike
- Historically have caused greater damage and loss of life (e.g., 23/12/72 M6.2 Managua)
Earthquake - Earthquake

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Earthquake - Earthquake

08/1951 – 08/1951

Right-Lateral

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Earthquake - Earthquake

08/1951 – 04/1955

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Earthquake - Earthquake

04/04/1955 – 04/30/1955

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Earthquake - Earthquake

08/1999 – 07/2000

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Journey to the Center of the Earth: Thrinukagiggar, Iceland

http://youtu.be/Ganz9CJvCf0