CATACLYSMIC ERUPTIONS

The really big ones!

This figure compares the size of some recent, well-known eruptions. Note how small the eruptions of Mount St. Helens and even Vesuvius are compared to Katmai, Krakatau, Tambora and Mount Mazama.
Within the very recent geological past, there have been extremely violent explosive eruptions several orders of magnitude greater in size than any historical eruptions:

<table>
<thead>
<tr>
<th>Location</th>
<th>Date</th>
<th>Volume Km³</th>
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<tbody>
<tr>
<td>Mount St Helens</td>
<td>1980</td>
<td>2</td>
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<td>Pinatubo</td>
<td>1991</td>
<td>8</td>
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<td>Krakatoa</td>
<td>1883</td>
<td>18</td>
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<td>Santorinini</td>
<td>1628 BC</td>
<td>39</td>
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<td>Crater Lake</td>
<td>6845 BP</td>
<td>75</td>
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<tr>
<td>Long Valley</td>
<td>700,000 BP</td>
<td>500</td>
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<td>Yellowstone</td>
<td>2 million BP</td>
<td>2500</td>
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These volcanoes have erupted vast volumes of rhyolite - dacite ash and pyroclastic flows. Some are still potentially active and could very well erupt again (Yellowstone, Long Valley, Rabaul, Pozzuoli).
There are two basic types:

I. Volcanoes that have completely blown themselves apart, leaving a huge crater in their place.

- Crater Lake, Oregon, 75 km³
- Santorini, Mediterranean, 39 km³
- Krakatau, Indonesia, 18 km³
Crater Lake, Oregon (6,845 B.P.)

**Stage One**

- Plinian eruption
- Pyroclastic flows
- Extensive ash deposits
- Single vent

**Stage Two**

- Caldera collapse
- Pyroclastic flows blasted out radially
- Collapsing volcano leaves large caldera.
Crater Lake from the air. Diameter about 6 miles.

Crater Lake with Wizard Island
Map showing the aerial extent of Crater Lake ash fall, which blanketed all of the Pacific Northwest and extended into Canada.
II. Huge elliptical depressions (calderas) above a very large magma reservoir.

Long Valley, USA

Yellowstone, USA

Rabaul, Papua, New Guinea

Pozzuoli, Italy
Long Valley, California

Caldera (15 x 30 km) formed some 760,000 years ago, following massive outpouring about 500 km3 of ash and pyroclastic flows.

Most recent volcanic activity (rhyolite flows and domes) was about 250-600 years ago.

Seismic, activity and 25 cm uplift of the resurgent dome, caused anxiety in the 1980’s.
Views of the huge depression of the Long Valley Caldera

Rhyolite flows and domes constitute the most recent eruptions about 250 -600 years ago.
Schematic cross-section beneath Long Valley Caldera. Note the huge inferred magma chamber. The caldera, initially 2-3,000 ft deep was filled by pyroclastic flows and lava flows. The xx’s mark the location of 1983 seismicity.
Distribution of ash from Yellowstone, Long Valley and Valles calderas

- Yellowstone
- Long Valley
- Valles
Toba Caldera – about 100 km long and 30 km across, with resurgent dome forming Samosir Island.

Long eruptive history since 1.2 m.yrs ago, with the last cataclysmic event 2800 km³ at about 74 ka.

Cause of 1000 yr cold period seen in Greenland ice cores? Bottleneck in human evolution?
Bottleneck in human evolution attributed to Toba eruption

Figure 4. The Volcanic Winter/Weak Garden of Eden model proposed in this paper. Population subdivision due to dispersal within African and to other continents during the early Late Pleistocene is followed by bottlenecks caused by volcanic winter, resulting from the eruption of Toba, 71 ka. The bottleneck may have lasted either 1000 years, during the hyper-cold stadial period between Dansgaard-Oeschlger events 19 and 20, or 10 ka, during oxygen isotope stage 4. Population bottlenecks and releases are both synchronous. More individuals survived in Africa because tropical refugia were largest there, resulting in greater genetic diversity in Africa.
Can this type of eruption occur today?

- All of these eruptions have occurred within the last 2 million years.
- Some, within the last 10,000 years.
- There is no reason to believe that they can’t happen again.
- In fact, there have been three examples of “caldera unrest” in the 1980’s (Long Valley, Rabaul, Pozzuoli).
- The problem is we have no idea what to anticipate.
This is what the USGS think would happen if (when?) Yellowstone does it again.

Fantastic BBC movie “Supervolcano”
Rabaul is located on a sunken caldera (filled with sea water) that is ringed by active volcanoes.
In 1971, the center of the caldera began to uplift (a potential sign of a forthcoming volcanic eruption).

By 1984 the uplift was at 5-10 cms/month, reaching a whopping maximum of 164 cms! This was accompanied by increasing seismic activity.
The seismic activity accompanied the uplift, but increased dramatically between Sept. 1983 to July 1985, reaching a maximum rate of 13,000 quakes/month in April, 1984. Then everything settled down, with an eruption occurring in 1994.
This caldera formed with a giant eruption about 35 thousand years ago. Between 1982 and 1984 the caldera started to uplift, accompanied by earthquake swarms. The map shows a maximum uplift of 150 cms.
What happened at Pozzuoli?
What might happen?

As with Rabaul and Long Valley, the activity died down in 1986. But, what if there was an eruption, similar in size to the one that formed the caldera?

- Total destruction of an area of 120 km radius by pyroclastic flows and surges (red circle)
- Extensive ash fall (10 - 100 cms) over much of eastern Europe (purple area).
FLOOD BASALTS or LARGE IGNEOUS PROVINCES (LIP) (Armageddon Volcanoes?)

“Civilization lives by geological consent, subject to change without notice.”
Will Durant, 1946
There are both continental (yellow) and oceanic (orange) flood basalt provinces. They are characterized by:
- Huge volumes
- Thick piles of flows
- Relatively short duration (< 3 Ma)
- All are old (> 16 Ma)
- Closest historical eruption is the Laki eruption, Iceland (1783)
Many Flood Basalts are associated with continental break-up and the formation of volcanic continental margins.
The Laki Eruption, Iceland (1783 -1784)

- Duration – 9 months (June – February)
- Volume - 14.7 km³
- No direct fatalities but several farms destroyed
- 50 percent of cattle died
- 75 percent sheep
- 24 percent of entire Iceland population died of starvation and illness
Effects on Europe and North America

- Drop in winter temperature of 1 – 3 °C
- Volcanic haze (VOG) blanketed much of Europe and northern N. America.
- 40% higher mortality rate than expected in England in both summer and winter.
The Geological Time Scale
(Breaks between Periods and Epochs based on major changes in fauna and flora (extinctions))

<table>
<thead>
<tr>
<th>EON</th>
<th>ERA</th>
<th>PERIOD</th>
<th>EPOCH</th>
<th>Approximate Age in Millions of Years Before Present</th>
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Origin of earth: 4.500

Approximate age of Earth: 4.500 years

Approximate age of Life: 3.500 years

Approximate age of the Solar System: 4.600 years
Are Flood Basalts Responsible for Mass Extinctions?
Is the Mantle a Serial Killer?
What is the Kill Mechanism?
Amazing correlation between the time of major extinctions and the ages of flood basalts. Only one known impact event (Chicxulub) at end of Cretaceous.
Correlations, although suggestive, are not proof. Timing is Critical

Problems
- Need to know precise age and duration of extinctions.
- Need to know precisely when and for how long flood basalts were erupted.

Dating
- Early K/Ar dating indicated eruptions over 40-50 Myr.
- Modern $^{40}\text{Ar}/^{39}\text{Ar}$ dating narrows this down to under 2 Myr for 80 – 90 % of the eruptive event.
- New Pb dating of zircon narrows this down further to less than 1 Myr.
The end of Permian extinction (90% of all marine species and largest loss of floral and faunal diversity in earth’s history) occurred about 250 Myr ago.

Early K/Ar dating of the Siberian Traps gave ages from 235 – 220 Myr.

Conclusion – no connection.

Subsequent 40Ar/39Ar dating increased and refined the ages for the Traps to 250 +/- 1.6 Myr.

Smoking Gun!

New (2013) very precise zircon dating shows the following:-

1) Age of end of Permian extinction (Meishan, China) between 251.94 and 251.88 Myr (in other words the extinction occurred in less than 100 thousand years!).

2) The beginning of the eruption occurred at 252.28 Myr (that is, before the extinction event).

Cause and Effect!