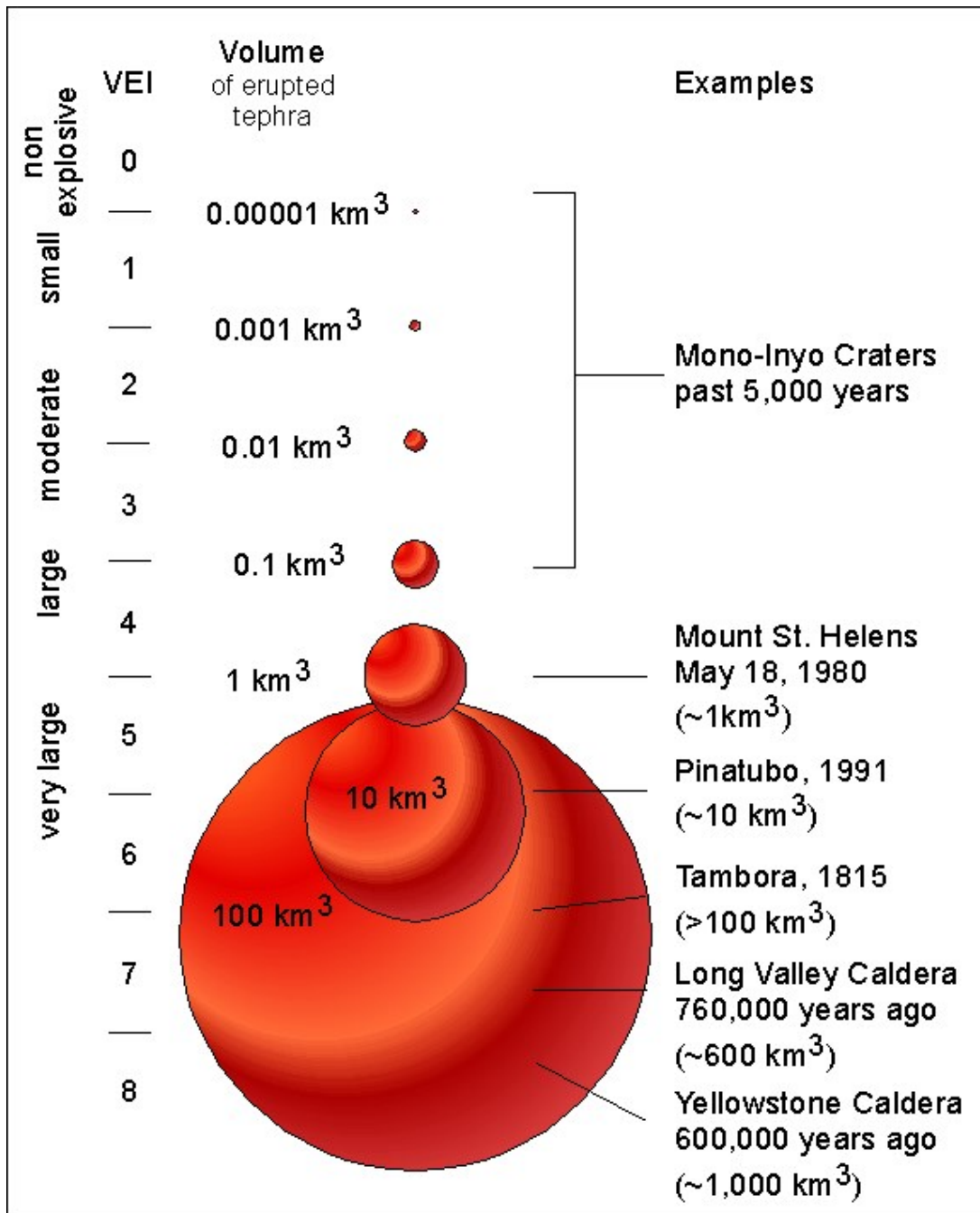


# Is there a link between explosive volcanism and the Earth's climate?

Susanne M. Straub (Lamont)  
Maureen 'Mo' Raymo (Lamont)  
Richard Arculus (ANU, Australia)  
Arturo Gomez-Tuena (UNAM, Mexico)

*Anatahan eruption 2003*





# VEI - Volcanic Explosivity Index

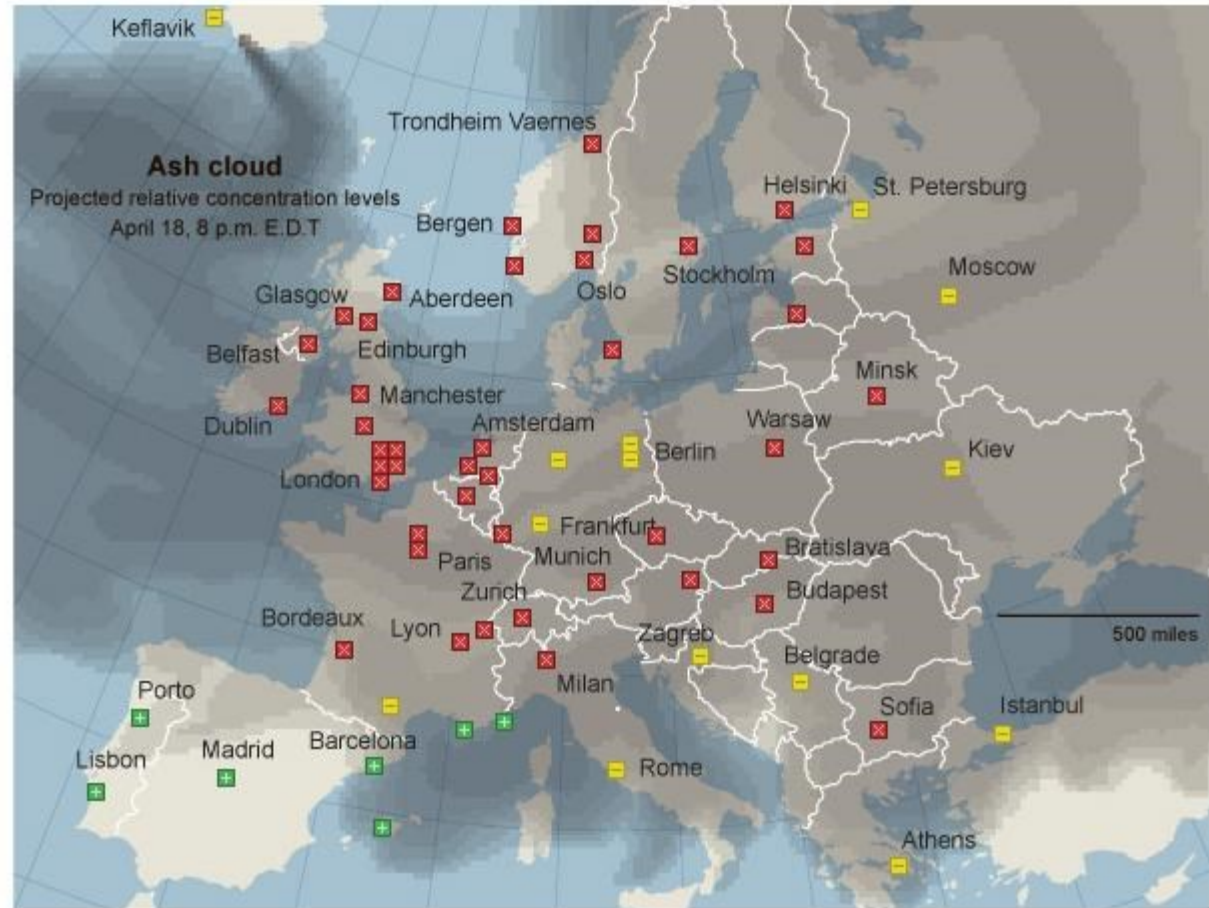
tephra =  
volcaniclastics =  
'broken volcanic  
rock'



# Eyjafjallajökull 2010

VEI 4

Key: ✖ All flights canceled ■ Some flights operating + Open; only flights to or from affected areas canceled

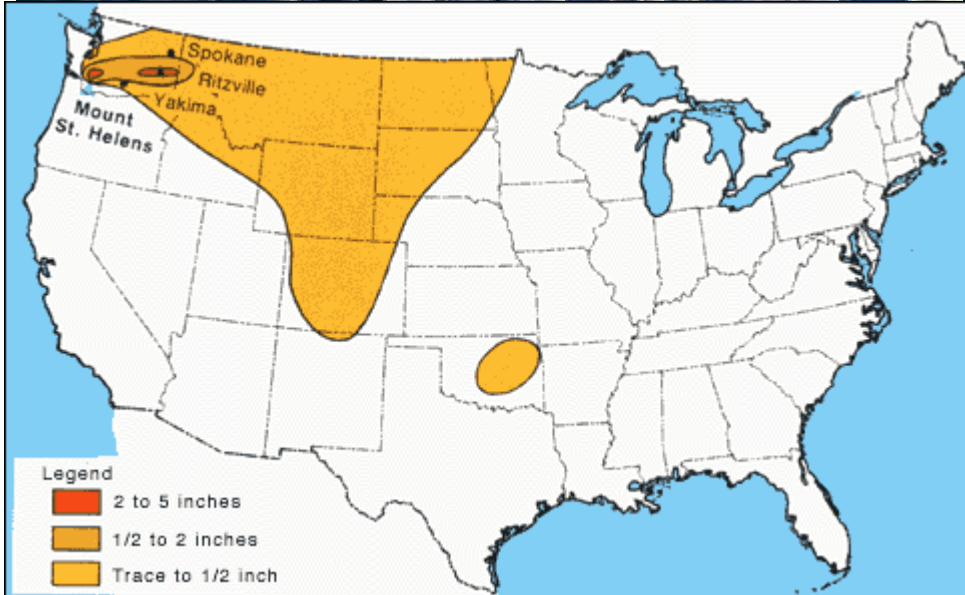


- 48% (ca. 100,000) of global flights cancelled;
- 10 million stranded passengers;
- 1.5-2.5 billion Euros lost for airlines.

Source: Japan, Rasmussen, Science, National Environmental Research Institute, at Aarhus University, Denmark

# Mt St. Helens, 18 May 1980

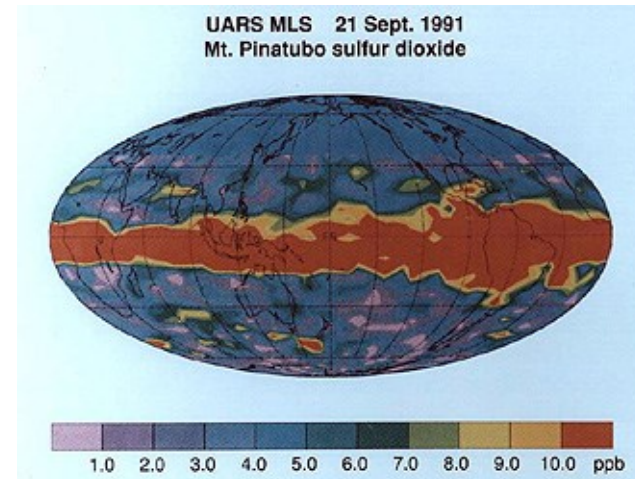
VEI 4 ~ 5



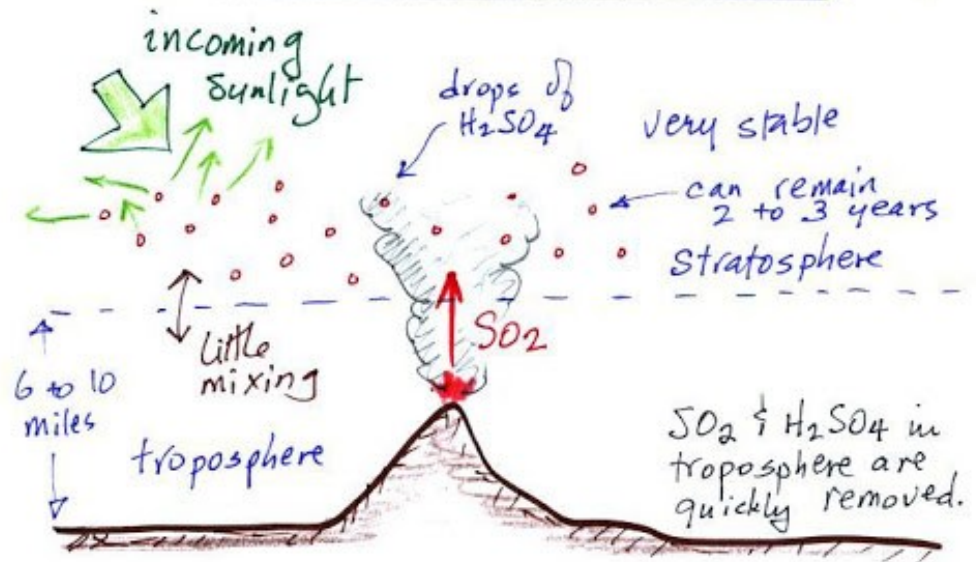
- 57 people died;
- thousands of animals killed;
- 200 homes and 200 miles of road and railway destroyed;
- estimated 860 US\$ damage.

# Mt Pinatubo 1991

VEI 6



In June 1991 Mt. Pinatubo (Philippines)

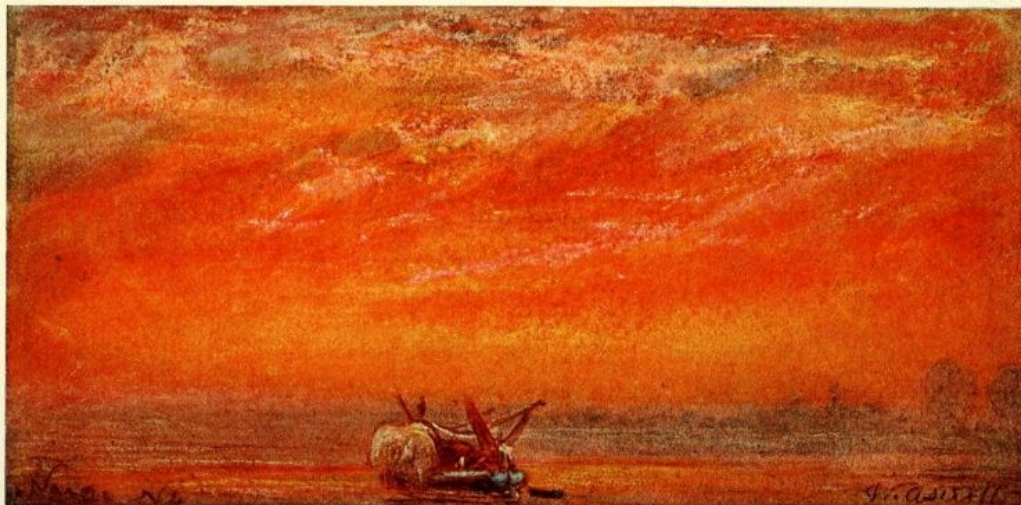
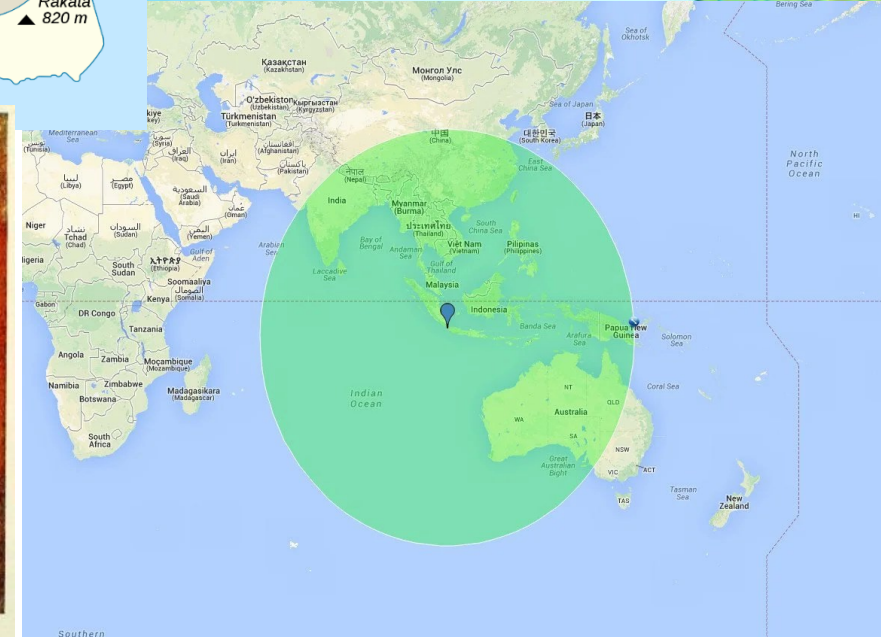


- second-largest eruption of the 20<sup>th</sup> century;
- sulfuric aerosol, dust injection caused 10 % reduction of sunlight reaching Earth's surface;
- decrease of 0.7 F globally;
- caused accelerated ozone destruction in atmosphere;

# Krakatoa 1883

VEI 6

- a 42 m high tsunami killed 36,000 people on surrounding shores;
- sonic bang heard up to 3000 mi away;
- global temperature drop by 0.7 F
- global 'optical effects: beautiful sunsets for years.



AN ENGLISH SUNSET TINGED BY KRAKATOA.

(From a Drawing made at Chelsea at 4.40 p.m. on Nov. 26th, 1883, by Mr. W. Ascroft.)

# Tambora 1815

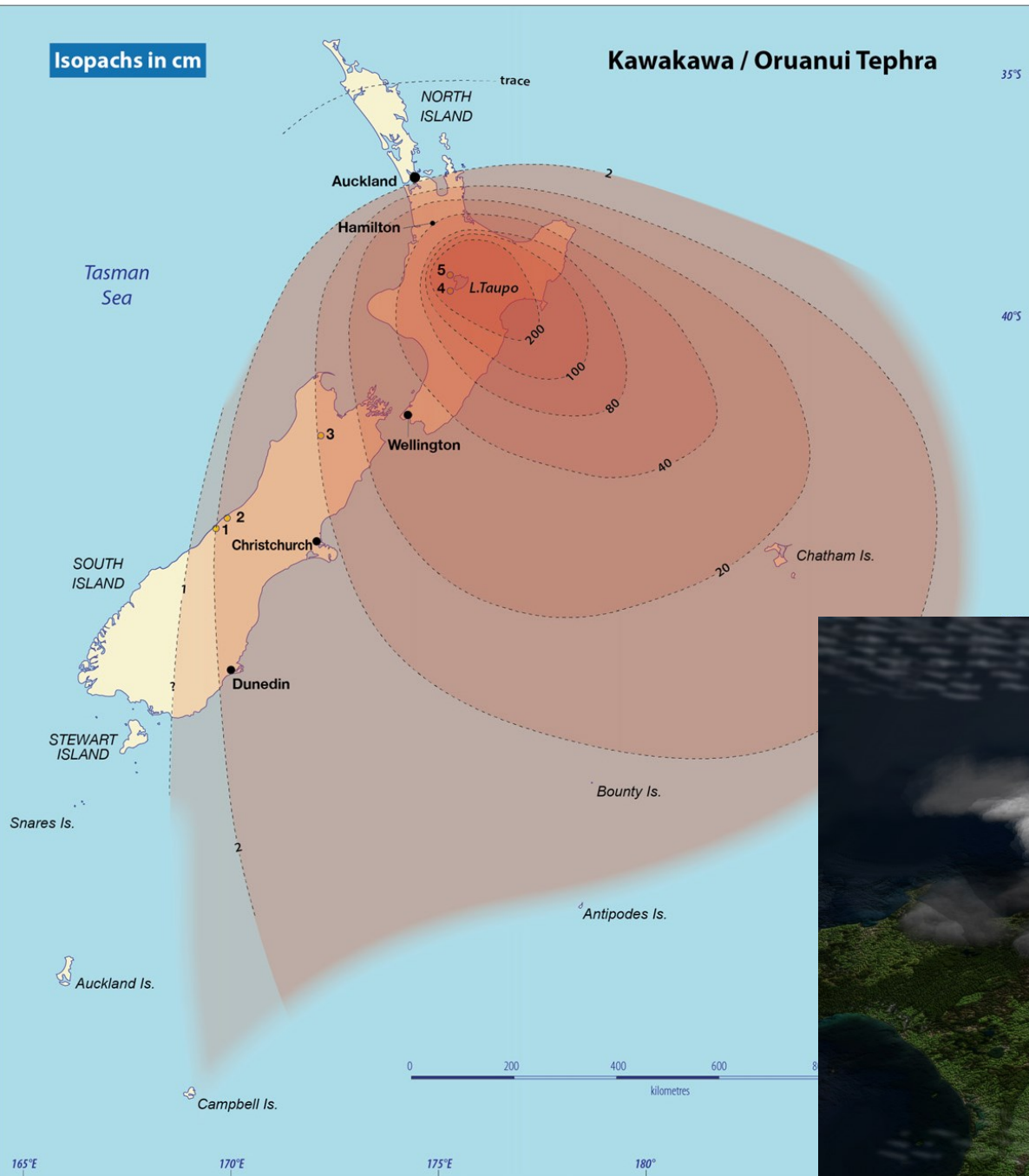
VEI 7

- most powerful volcanic eruption in recorded human history in April 1815;
- global cooling by 0.95 F;
- 1816 “Year Without Summer” (snow and frost in June in New England);
- failed crops and famine in three summers afterwards worldwide;
- diseases spread;
- direct and indirect human death toll into >100,000.



Isopachs in cm

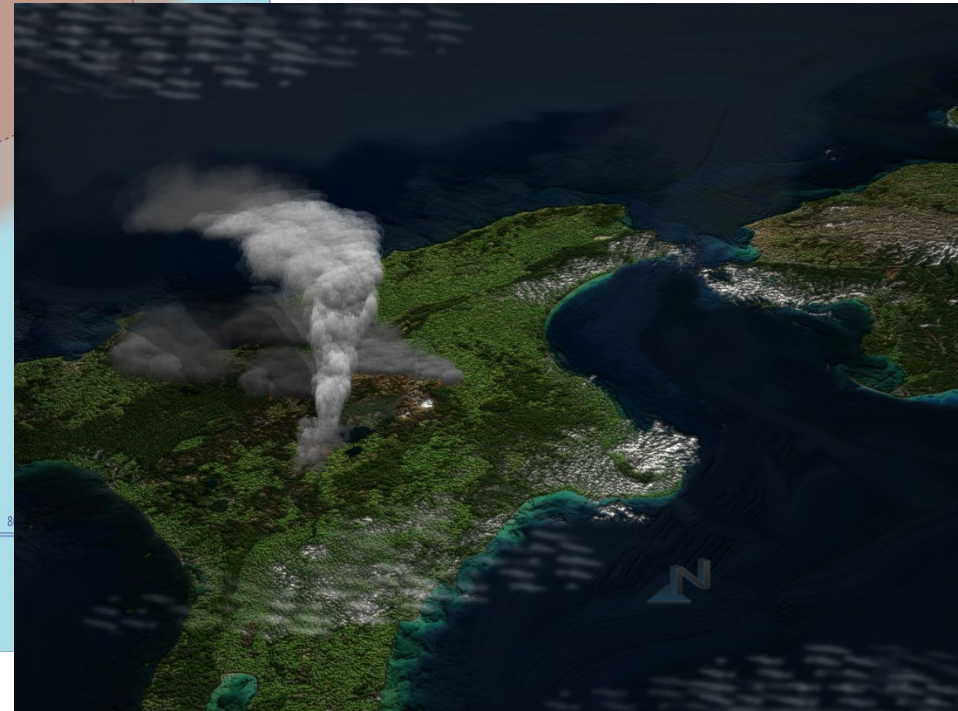
Kawakawa / Oruanui Tephra



# Oruanui event

VEI 7

- 26,500 yrs;
- 18 cm thick ash on Chatham;
- covered much of North Island with 200 m thick ash flow.





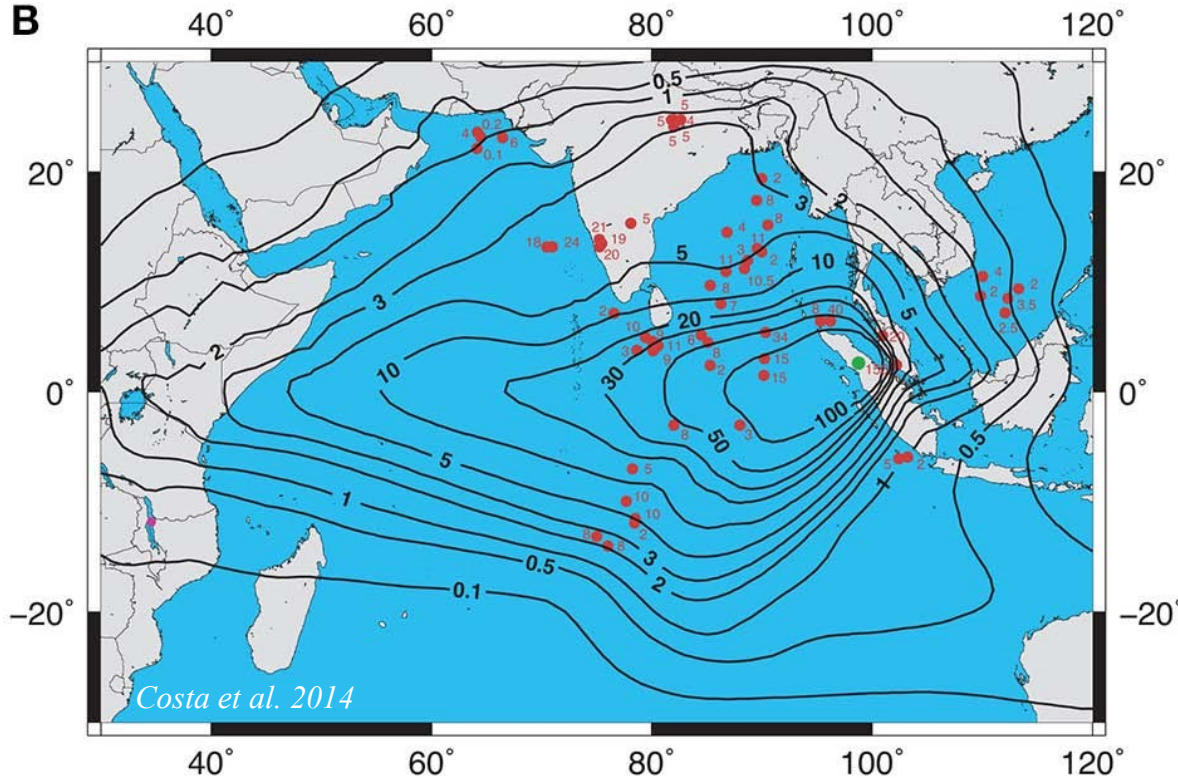
# Toba Caldera

VEI 8

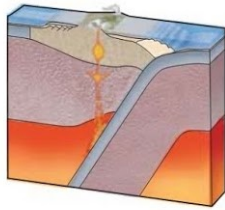
- 75,000 yrs;
- one of the largest known super-eruptions
- global ecological disaster?
- 10 years of global volcanic winter?;
- 1000 yrs global cooling?;



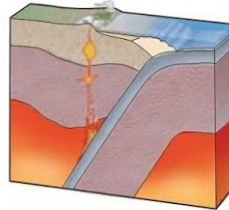
B



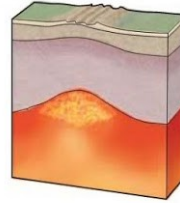
# Subduction-related volcanoes



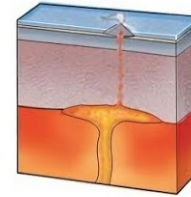
Ⓘ = Island arc



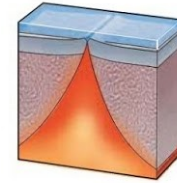
Ⓒ = Continental arc



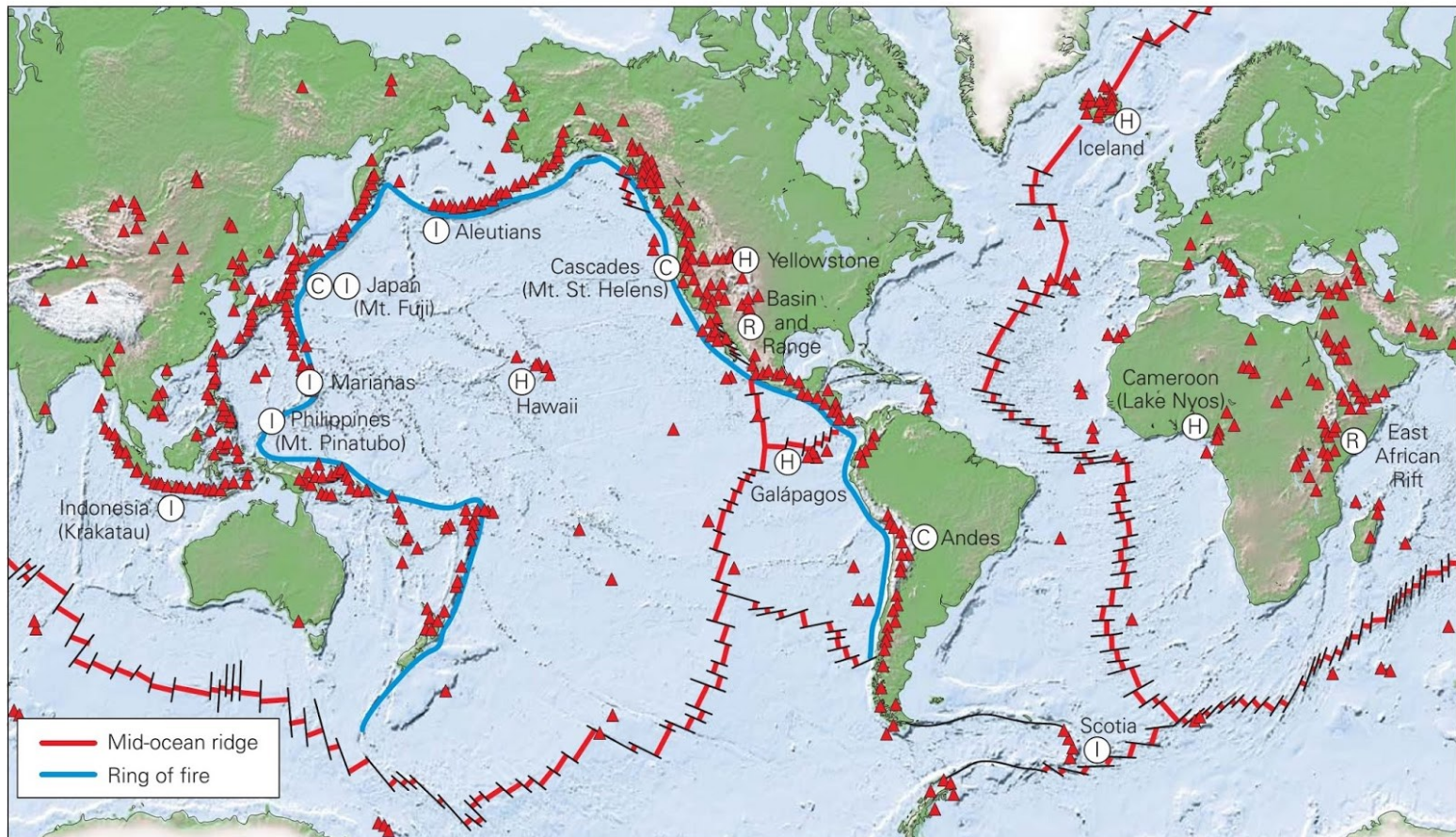
Ⓓ = Rift



Ⓗ = Hot spot



Ⓜ = Mid-ocean ridge



# Are these explosive eruption a climate player?

- meaning: does their activity influences, or is influenced, by longterm climate evolution;
- For example: can volcanic eruption force global glaciation?
- Or is their effect on climate short-term?
- How do explosive eruptions affect climate?
  - cooling through atmosphere loading by aerosol and sulfur?
  - Warming by addition of CO<sub>2</sub>?
- Does the number of volcanic eruption matter?
- Does the timing of volcanic eruption matter?

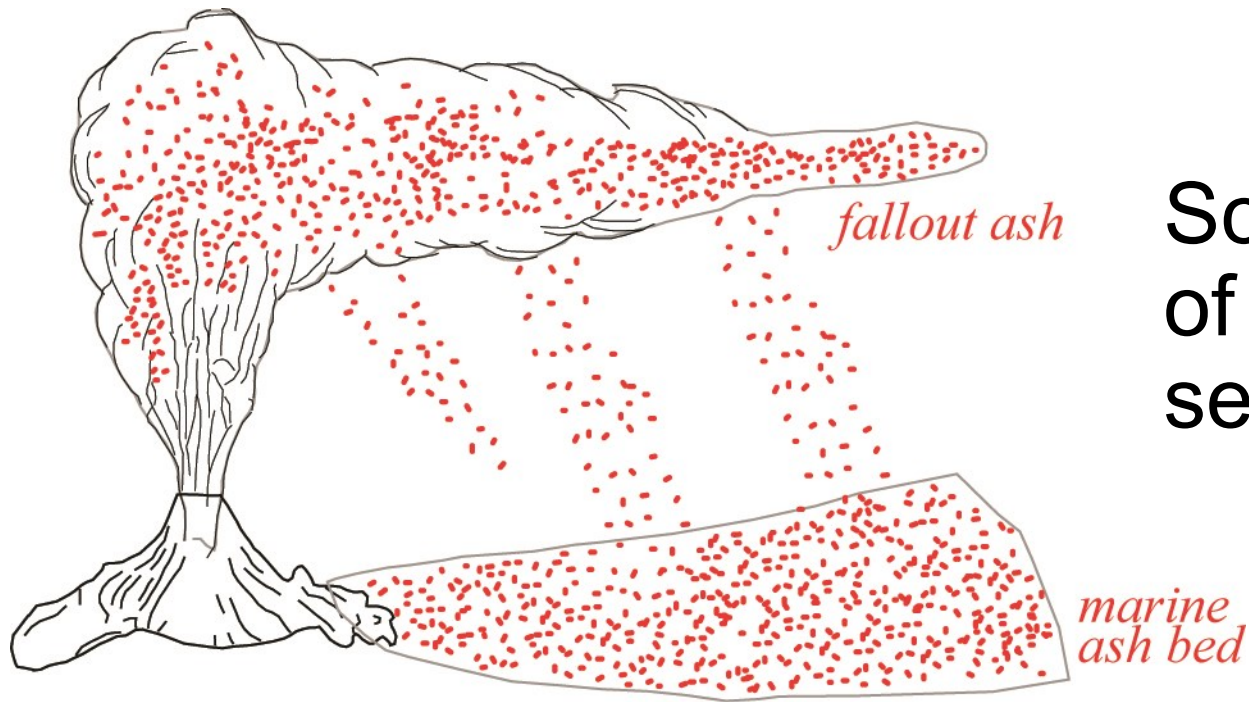
**How do we know and how can we investigate these links?**

# We need a geological record through time!



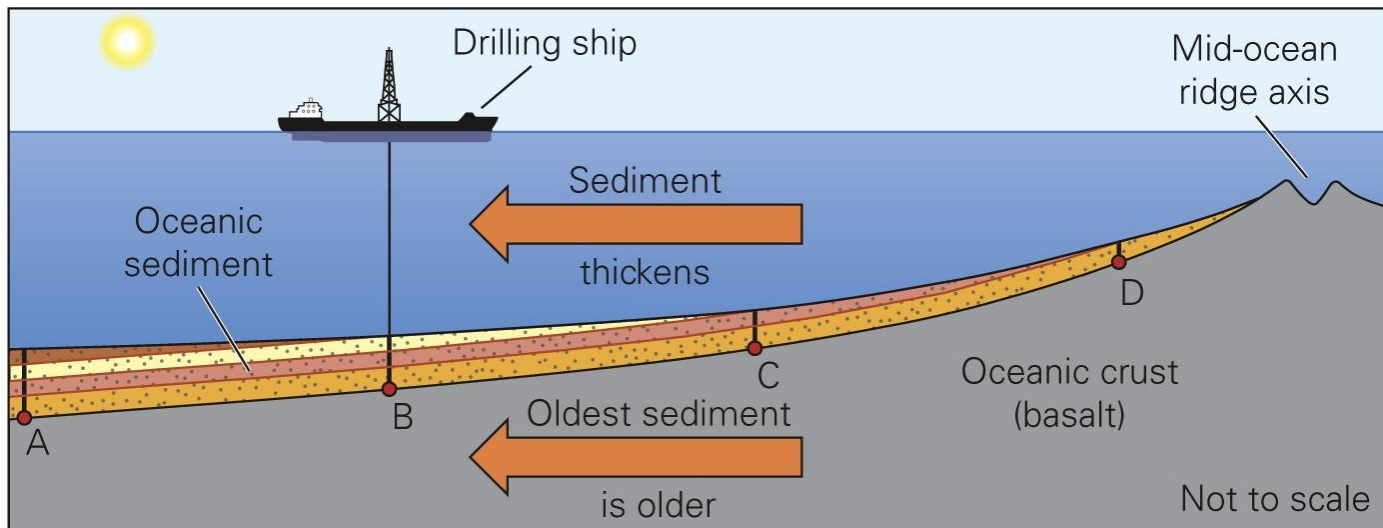
Which does not exist on land due to rapid erosion!



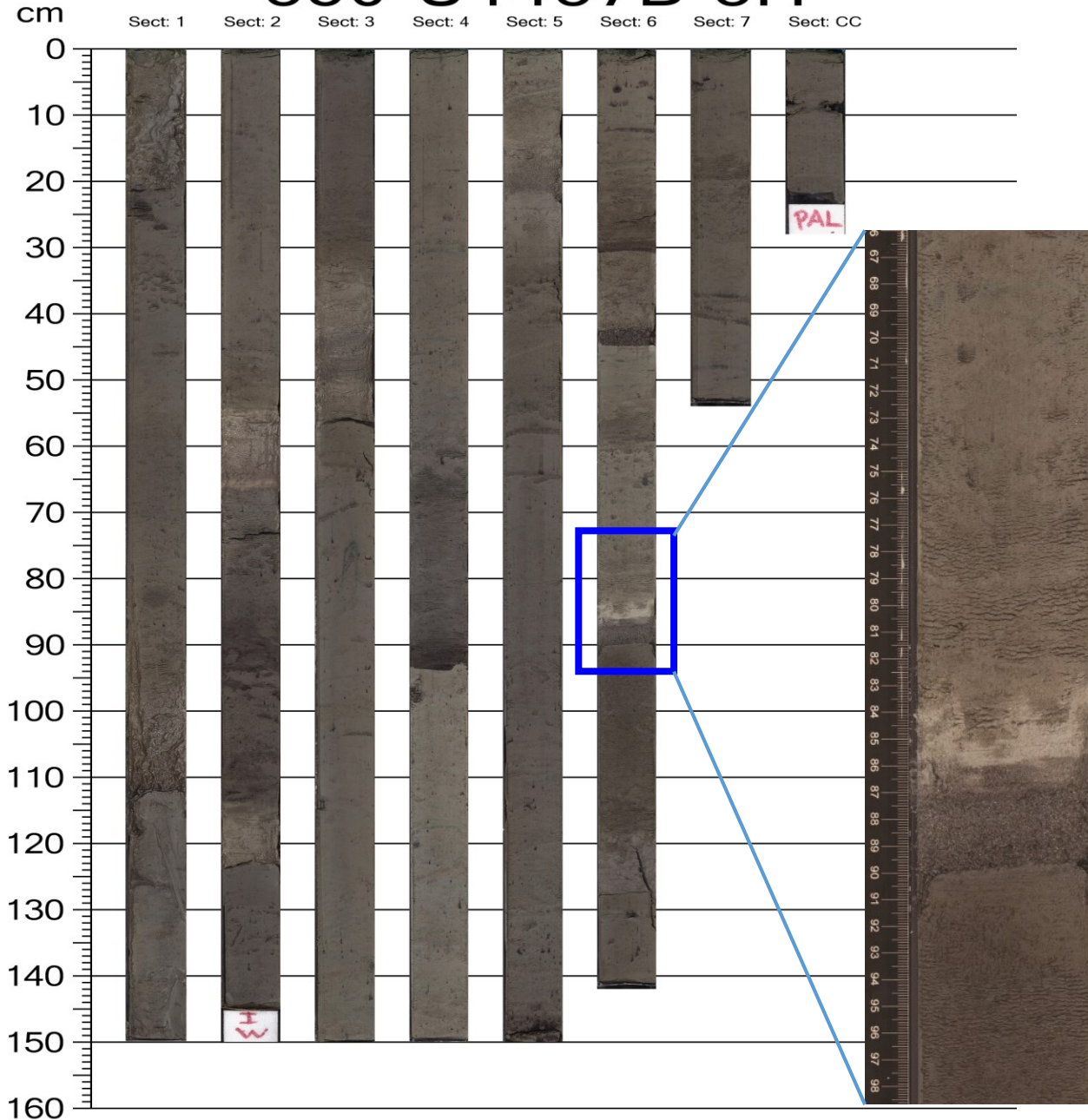


# Scientific drilling of deep-sea sediments

*modified from Sigurdsson and Carey 1980*



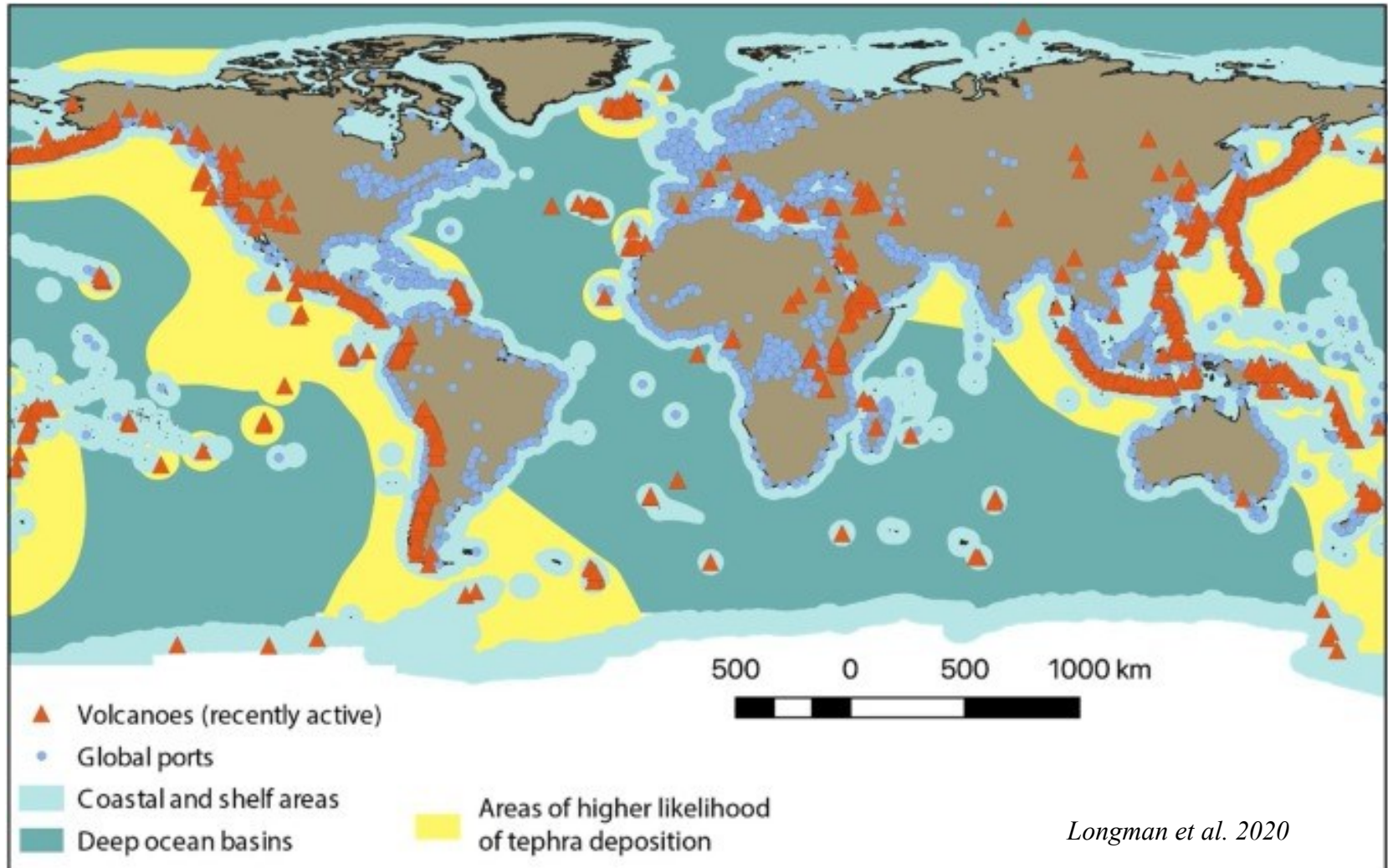
# 350-U1437B-3H



## Marine ash layers

- cm-thick;
- dark and light-colored;
- mirror instantaneous volcanic events;
- widespread;
- datable;
- time-precise;
- time-series.

# Discovery of abundant ash layers



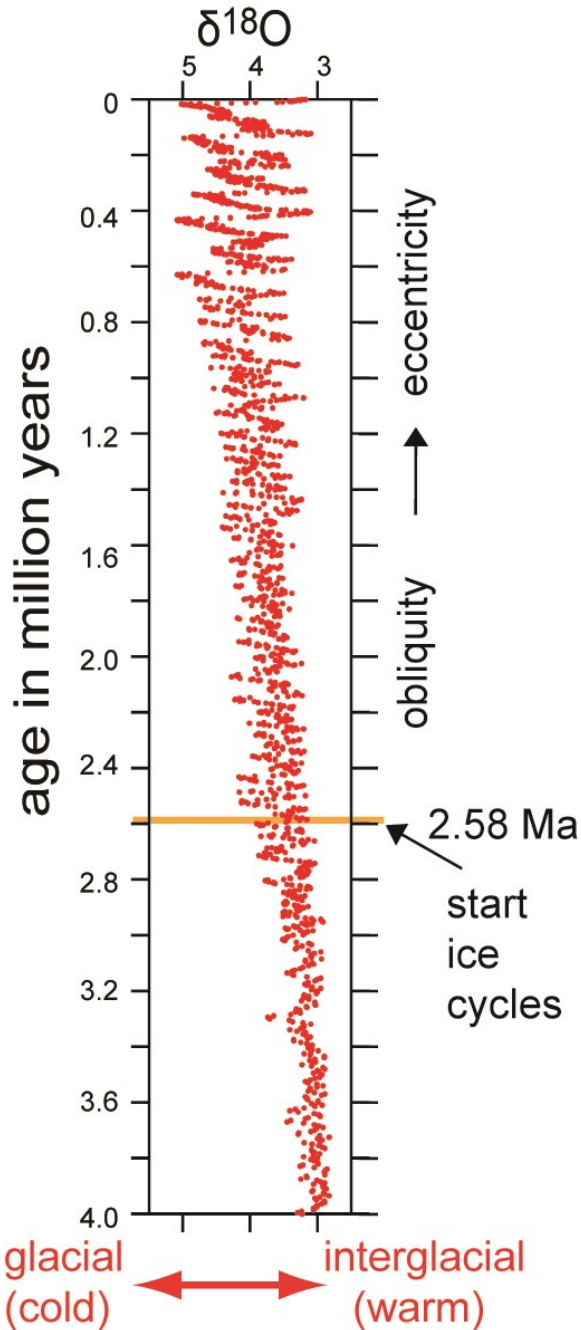
# How does this relate to climate?

Here I need to open a 'side box' and explain the climate signals during the last few million years of Earth' history.

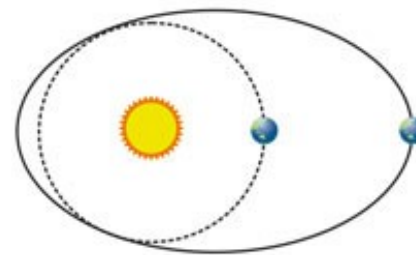


# Ice cycle signal in the marine sediments

$\delta^{18}\text{O}$  signal is forced by the waxing and waning of the ice sheets during the last 2.58 million years

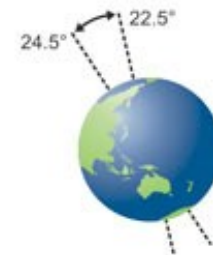


## Milankovitch Cycles



Eccentricity

100,000 yrs



Obliquity

41,000 yrs



Precession

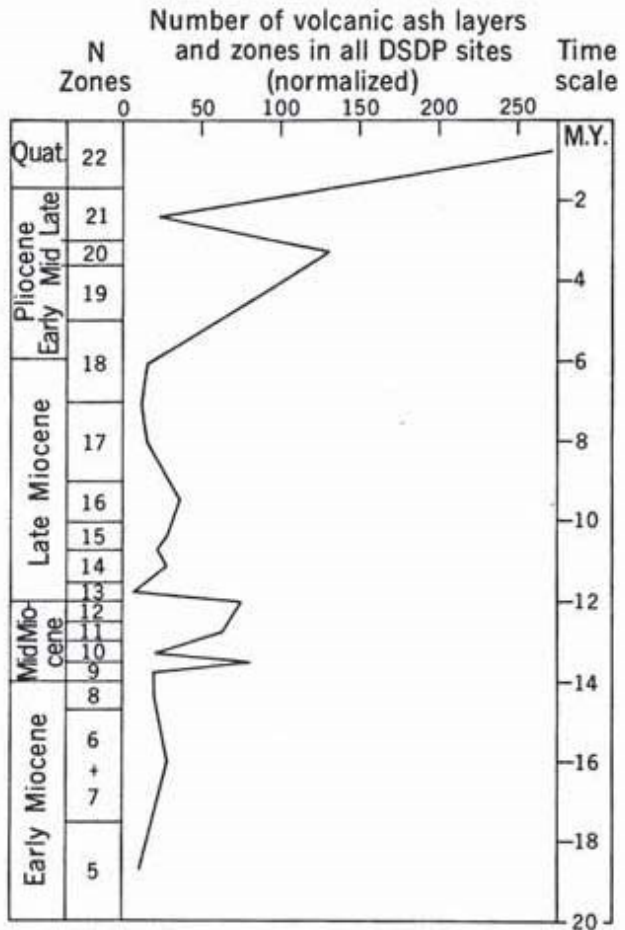
26,000 yrs

Do the ash beds also show such  
'orbital' cyclicities?

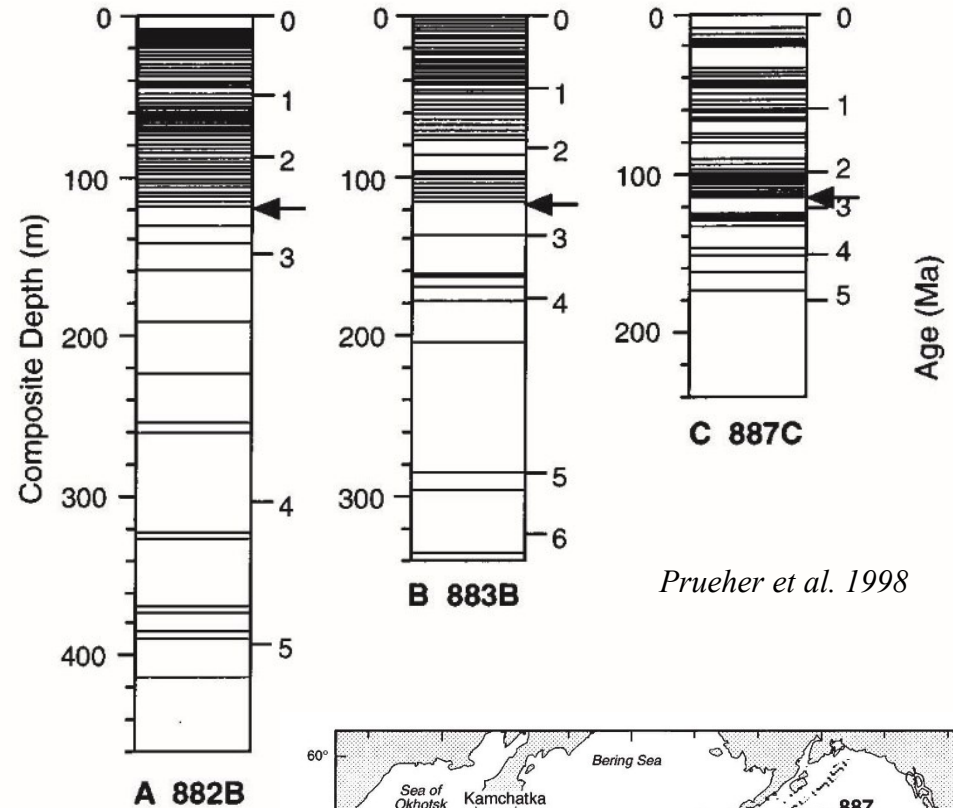
If yes, then a causal link to climate evolution seems  
very likely.

Right now, we have two observations:

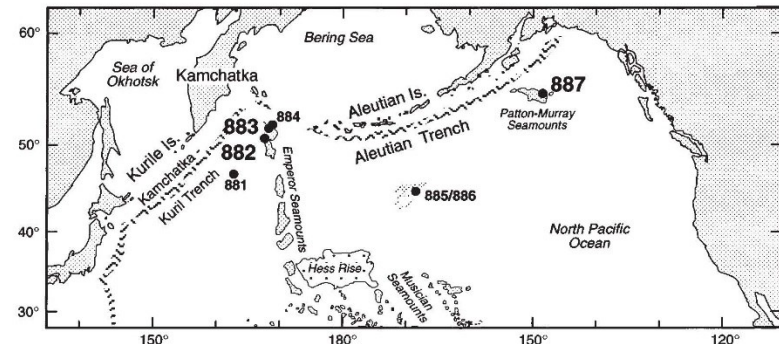
# 1. Increase in ash bed frequency at 2.58 Ma



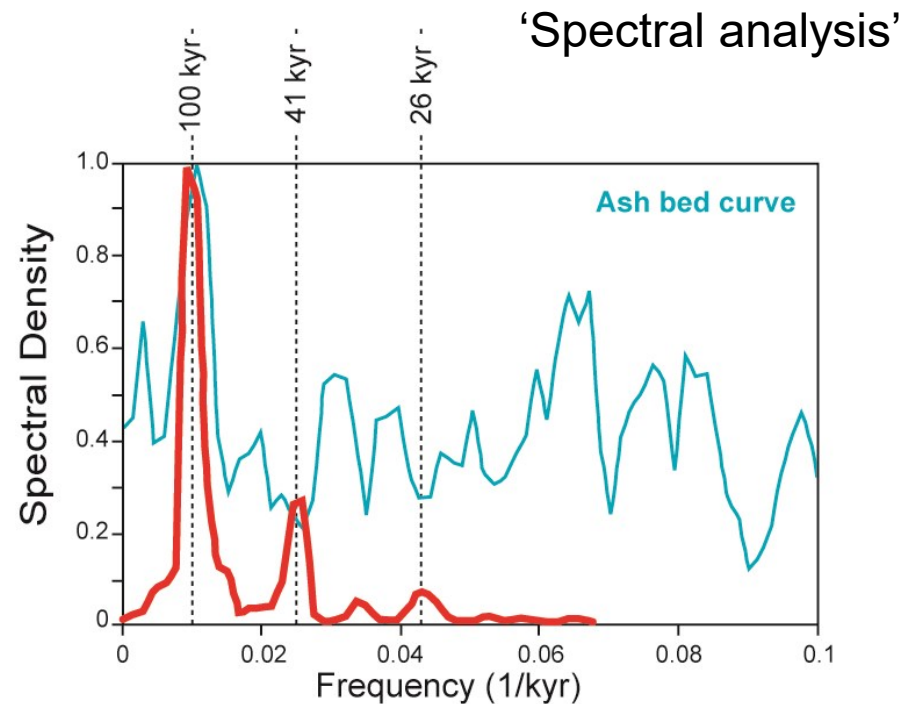
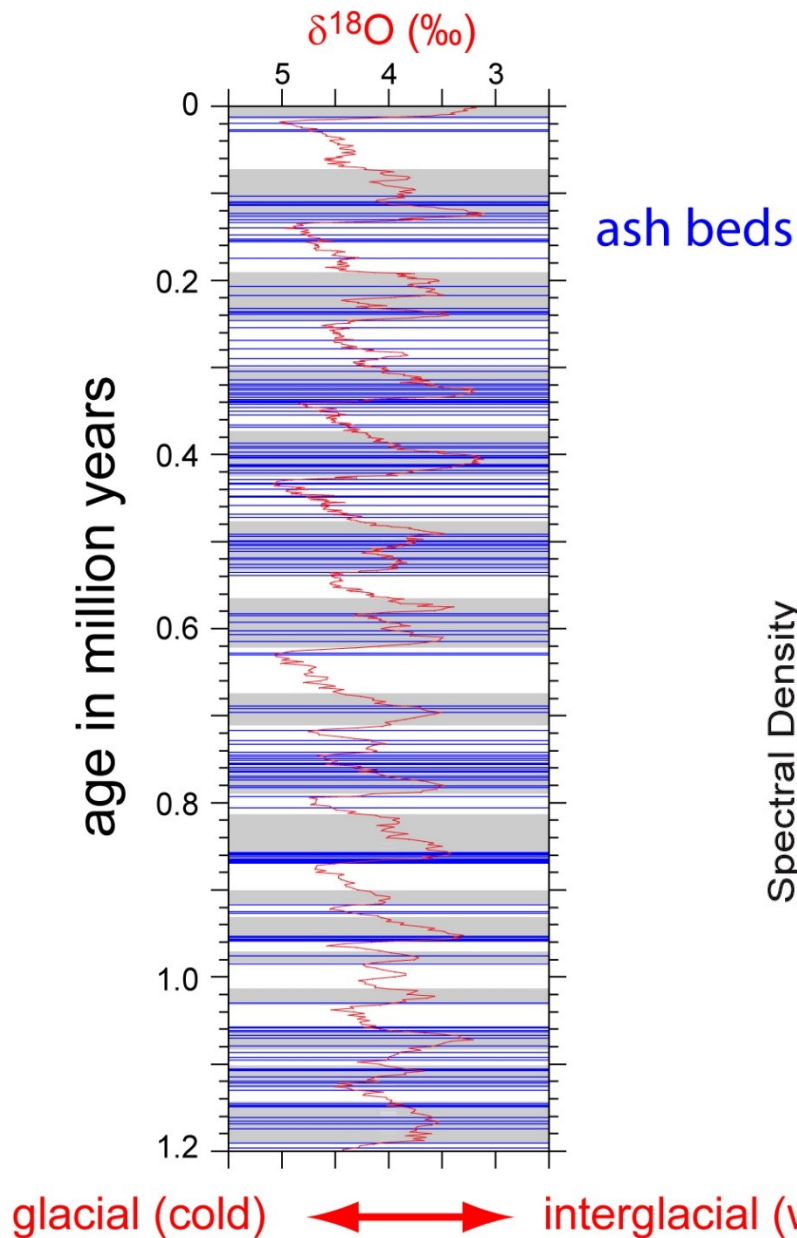
Kennett & Thunell 1975



Prueher et al. 1998



## 2. Ash bed cyclicality during the ice cycles in drill hole IODP 1437B

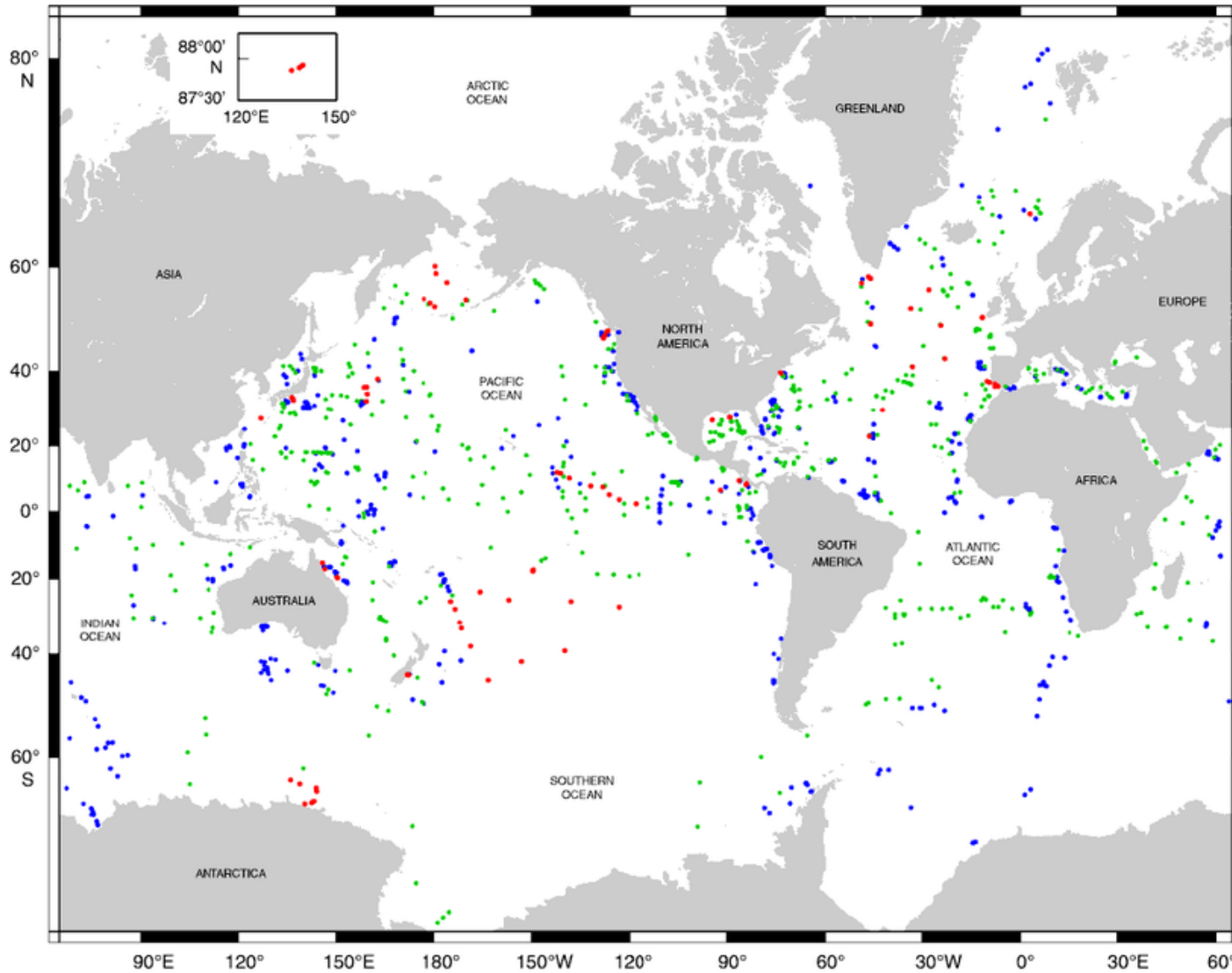


# These are intriguing observations

**Now:** We need **more cores with ash bed series** to test whether such ash bed cyclicities are a local or are indeed global phenomenon as the sediment signals.

- Cores that reach back to 2.58 Ma and older;
- Cores from high latitudes vs. low latitudes;
- Core from different arcs with different crustal basements.

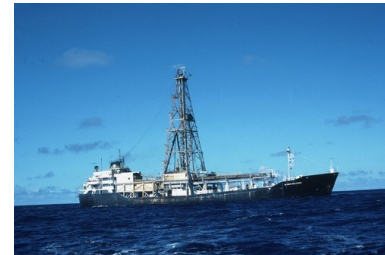
# Drill holes drilled in ocean floor



DSDP Legs 1–96 (●), ODP Legs 100–210 (●), IODP Expeditions 301–339 (●)

*since 1968*

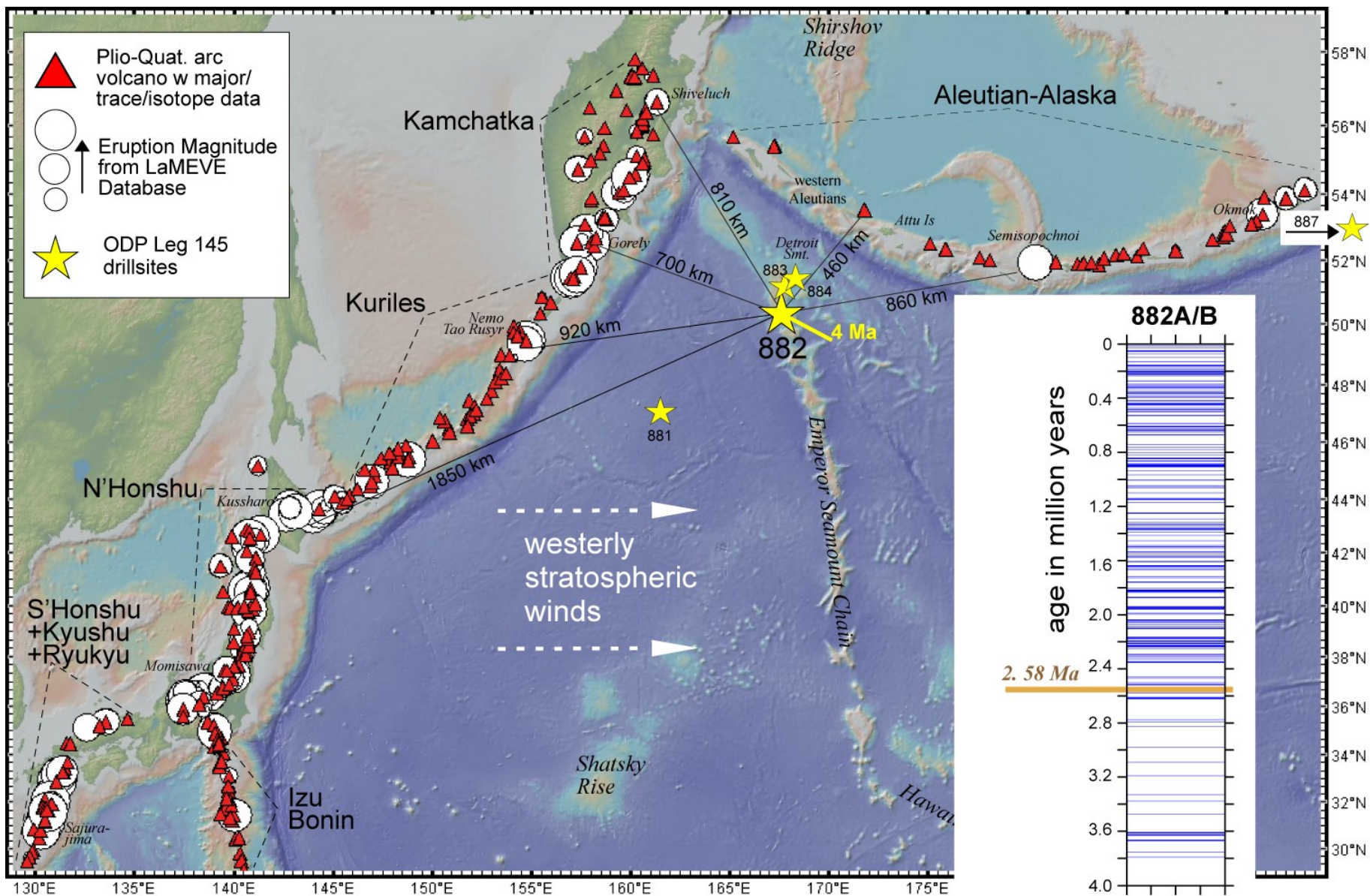
DSDP  
ODP  
IODP



*current expedition: X391C*

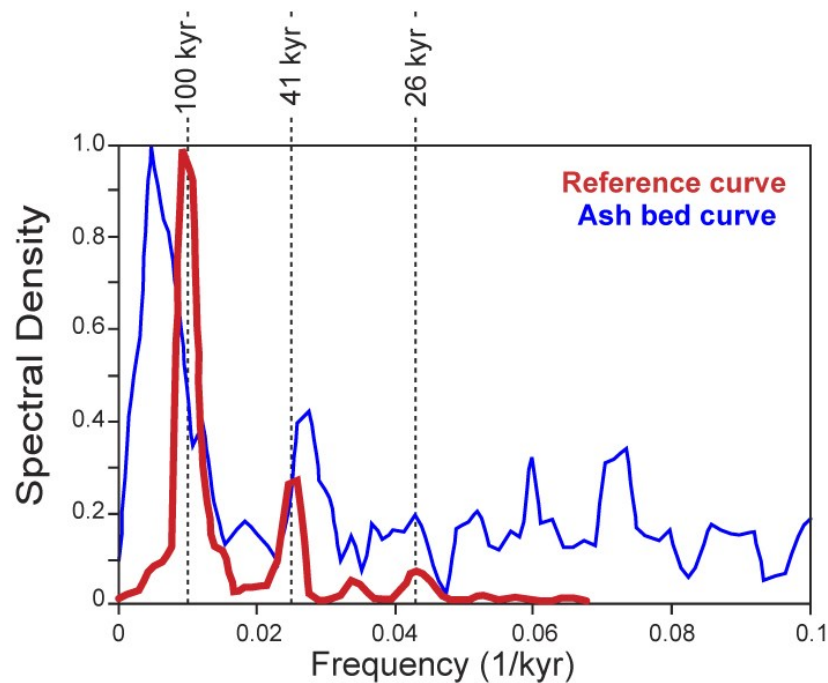
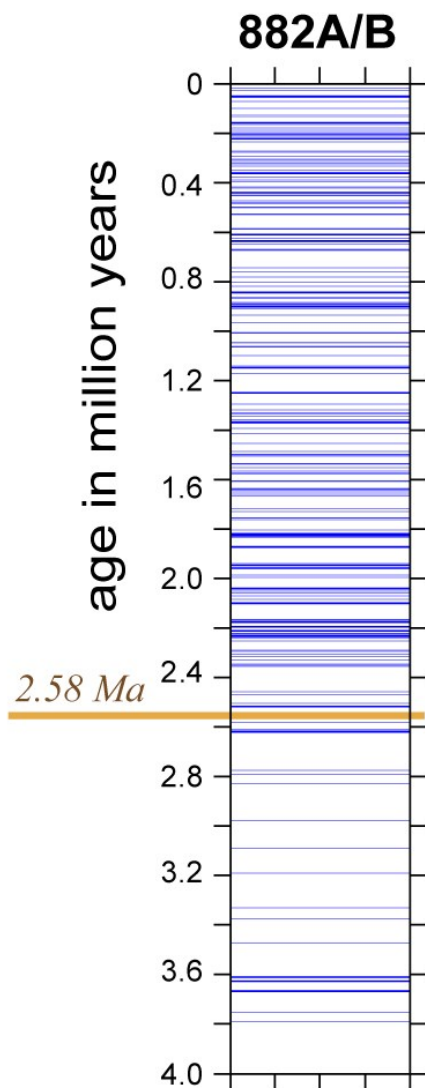
# A 'good' drill site: multiple criteria

- Continuous recovery of undisturbed core (technically possible since about 15 years);
- Datable with a resolution suitable to resolved ice cycles;
- Higher background sedimentation rate, but not too high;
- Need to have regular ash input.





# Current 882 ash bed cyclicity problem



- re-do with new and better age model now available;
- using re-description of ash bed series.

# Three possible results:

- Volcanism is unrelated to climate; existing volcanic cyclicities are controlled by other mechanisms (which ones?).
- Volcanism drives glaciation by
  - 'atmospheric loading': pump volcanic dust and aerosols into the atmosphere and deflect sunlight
  - fertilize the oceans and causing biological bloom, which lowers CO<sub>2</sub> in the ocean/atmosphere.
- Glaciation drives volcanism.



882A,  
Core 11-1

*ash bed,  
19 cm thick  
VEI ~ 7*

*dropstone  
(from  
iceberg)*

# Resources



**About volcanic eruption:**  
Mount St. Helens 40 years later  
44 min documentary  
released in 2020

**About scientific ocean drilling:**

<https://iodp.tamu.edu/>

<https://usoceandiscovery.org>

(lots on Outreach & Education)



882A,  
Core 11-1

*ash bed,  
19 cm thick  
VEI ~ 7*

*dropstone  
(from  
iceberg)*