

AN INTRODUCTION TO CALDERAS

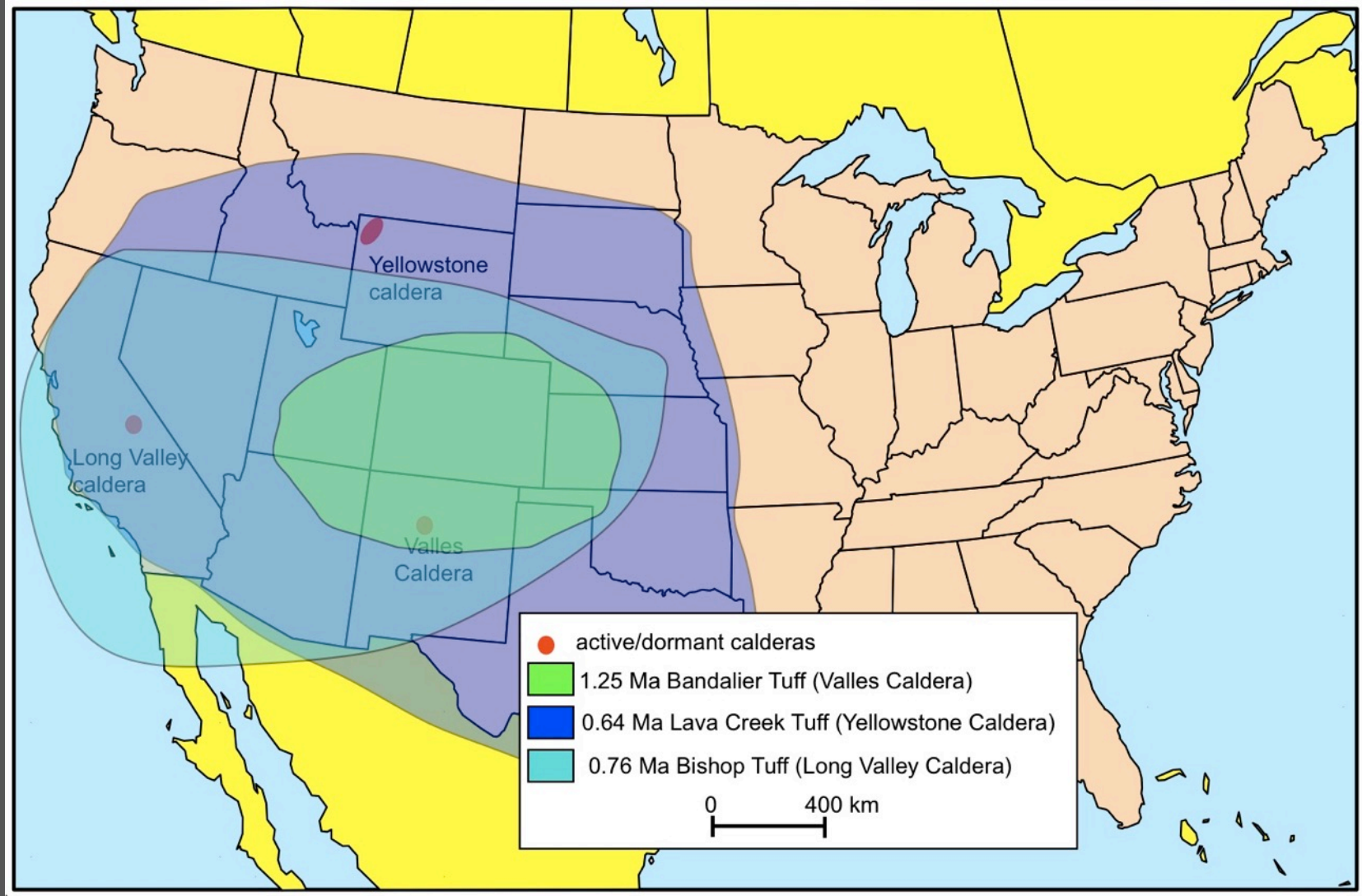
Matthew Zimmerer – matthew.zimmerer@nmt.edu - Bureau 329



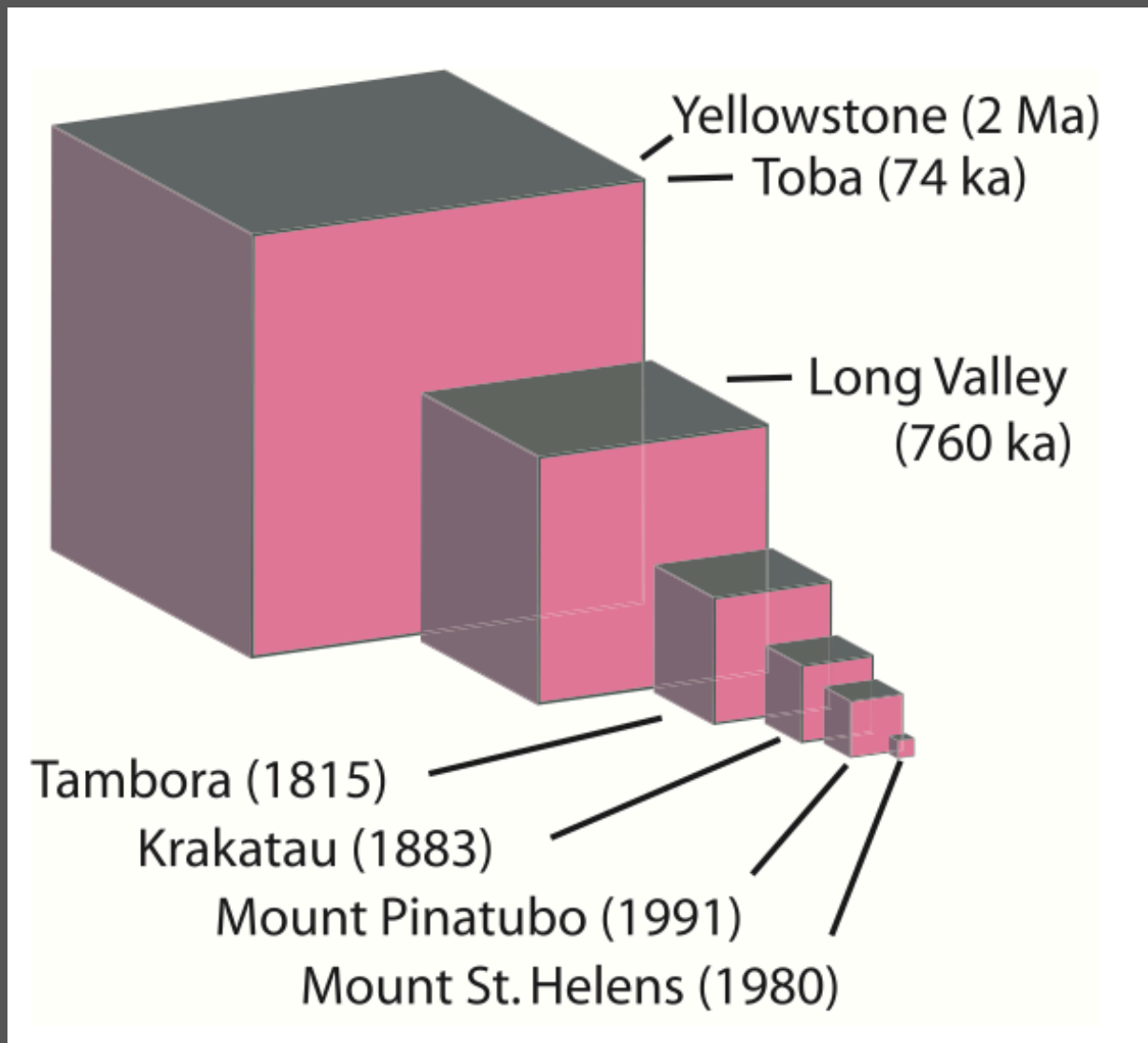
Objectives

- 1) Why are calderas important to study?
- 2) Describe the 3 stages of caldera evolution?
- 3) Describe the geomorphic and structural characteristics of calderas?
- 4) How are calderas identified in the geologic record?

Caldera hazards



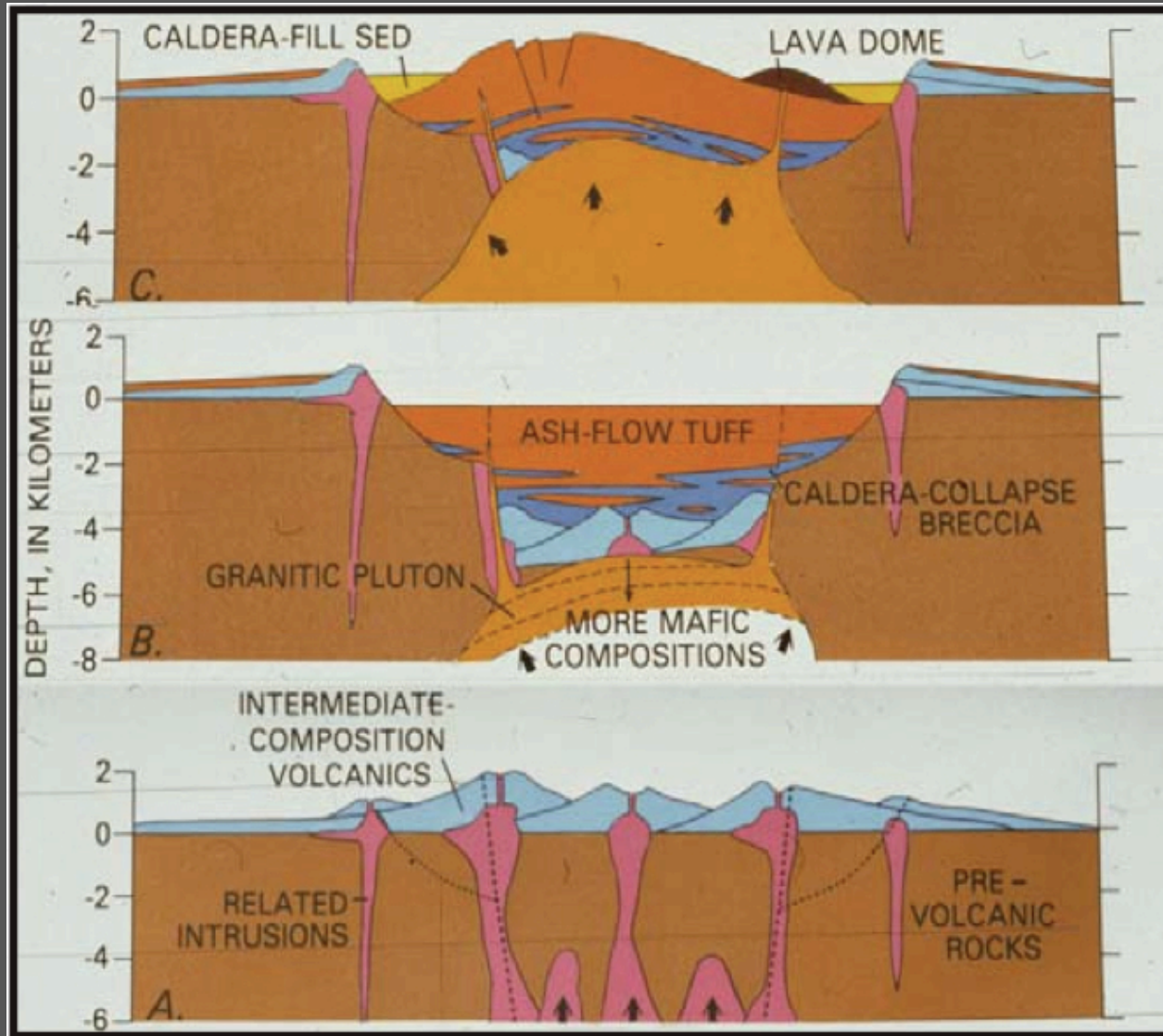
Modified from Goff, 2010



Geothermal Energy and Ore Deposits

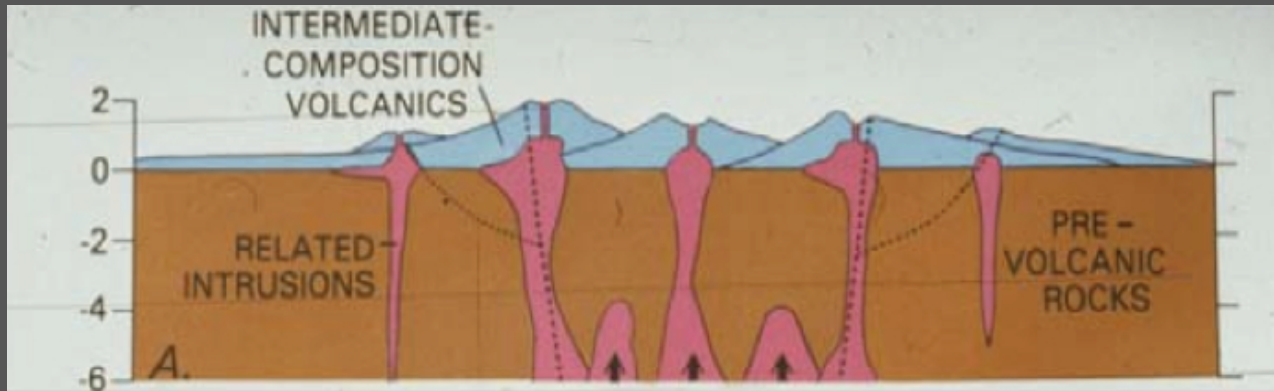


Caldera 101

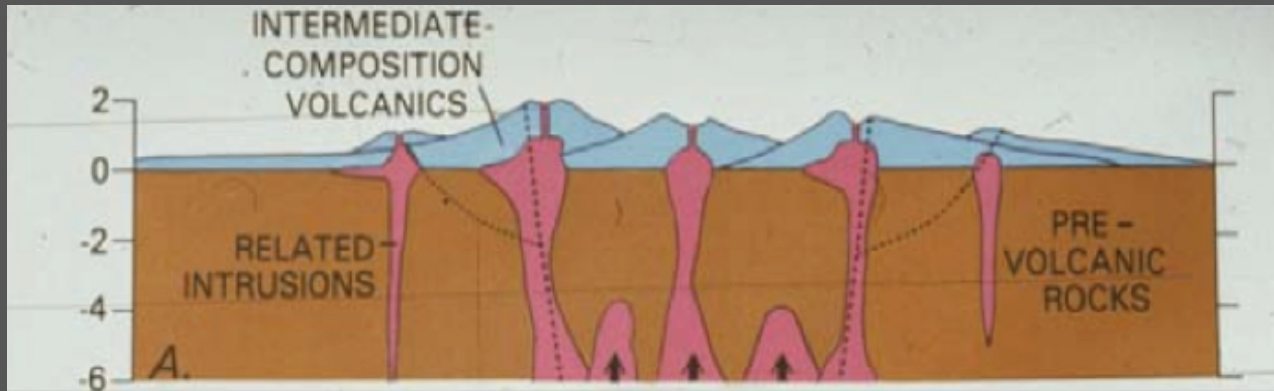


Lipman et al., 1978

Precaldera Volcanism (waxing magmatism)



Precaldera Volcanism (waxing magmatism)



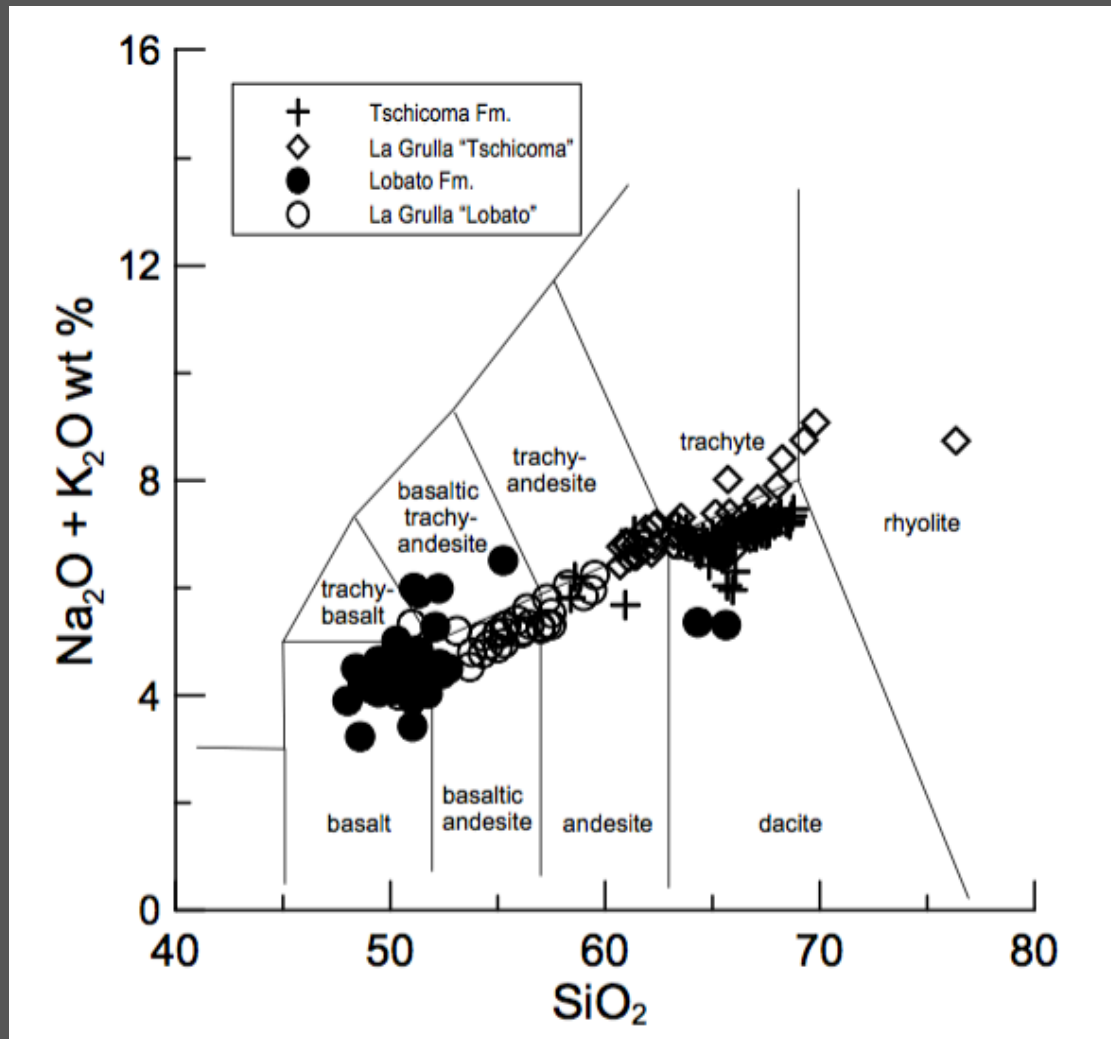
1) Numerous eruptions

2) Duration is 10^4 to greater than 10^6 yrs

3) Compositionally diverse

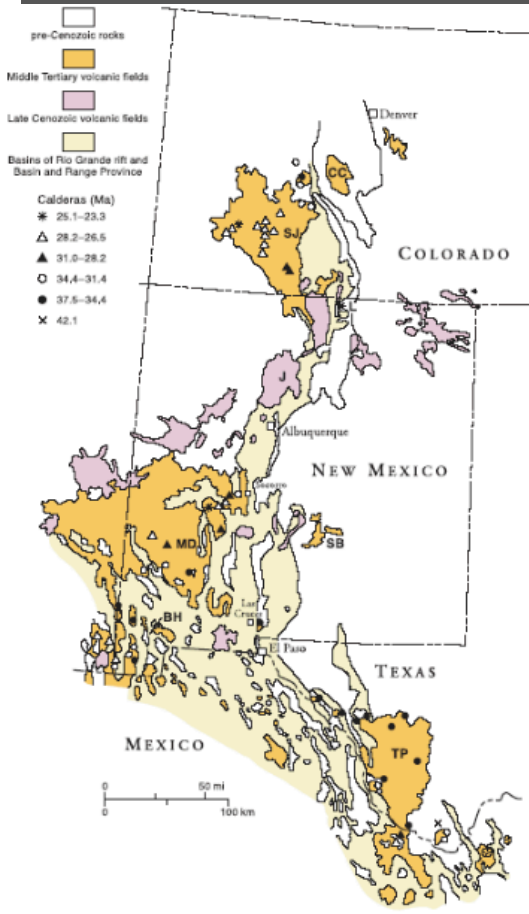
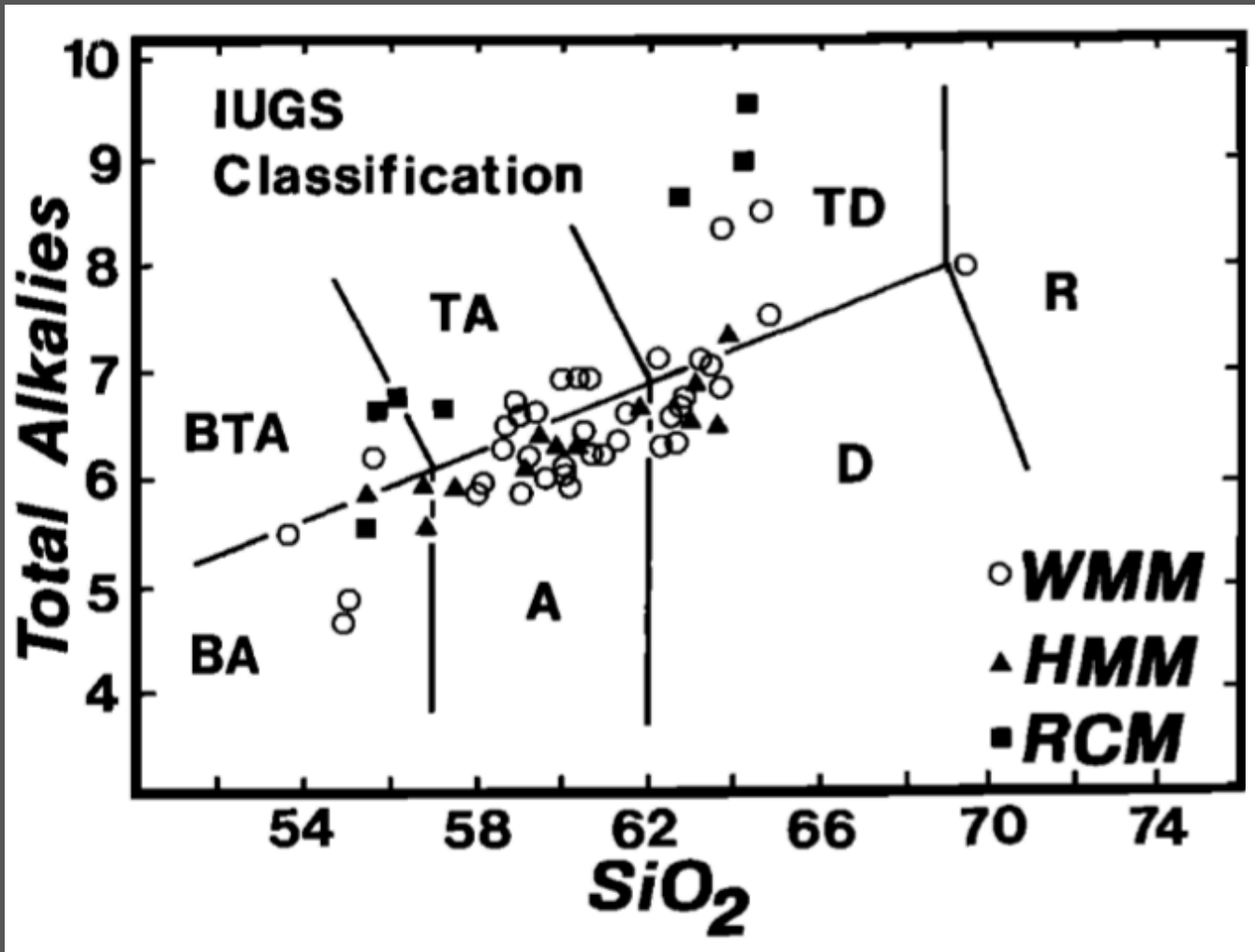
(rhyolite to basalt; dominantly andesite and dacite)

Precaldera Volcanism (waxing magmatism)



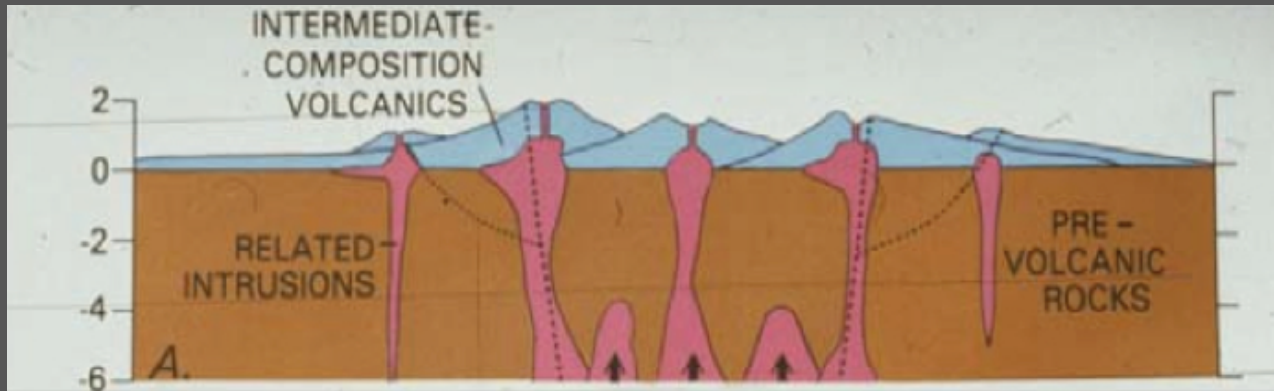
Precaldera geochemistry from Valles caldera

Precaldera Volcanism (waxing magmatism)



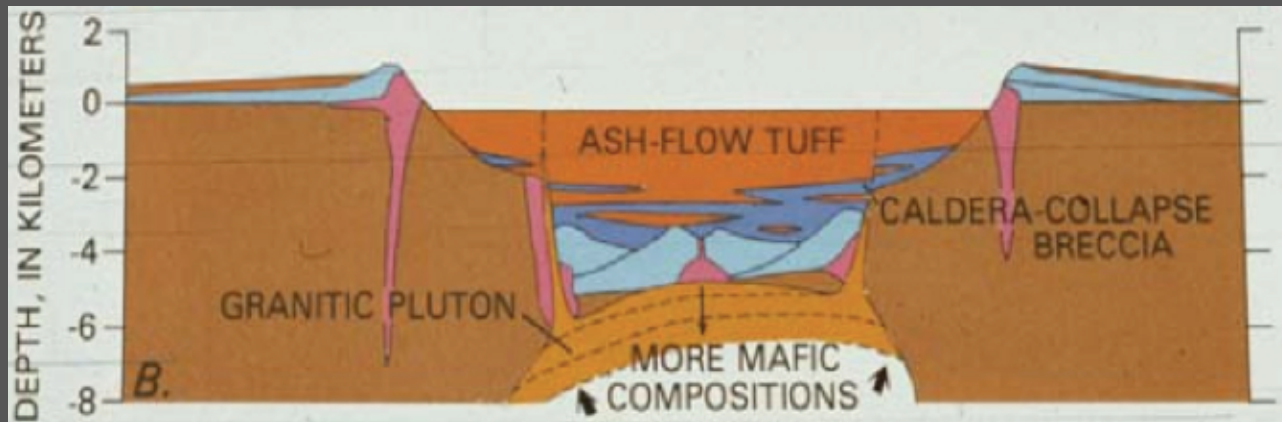
Precaldera geochemistry from San Juan VF

Precaldera Volcanism



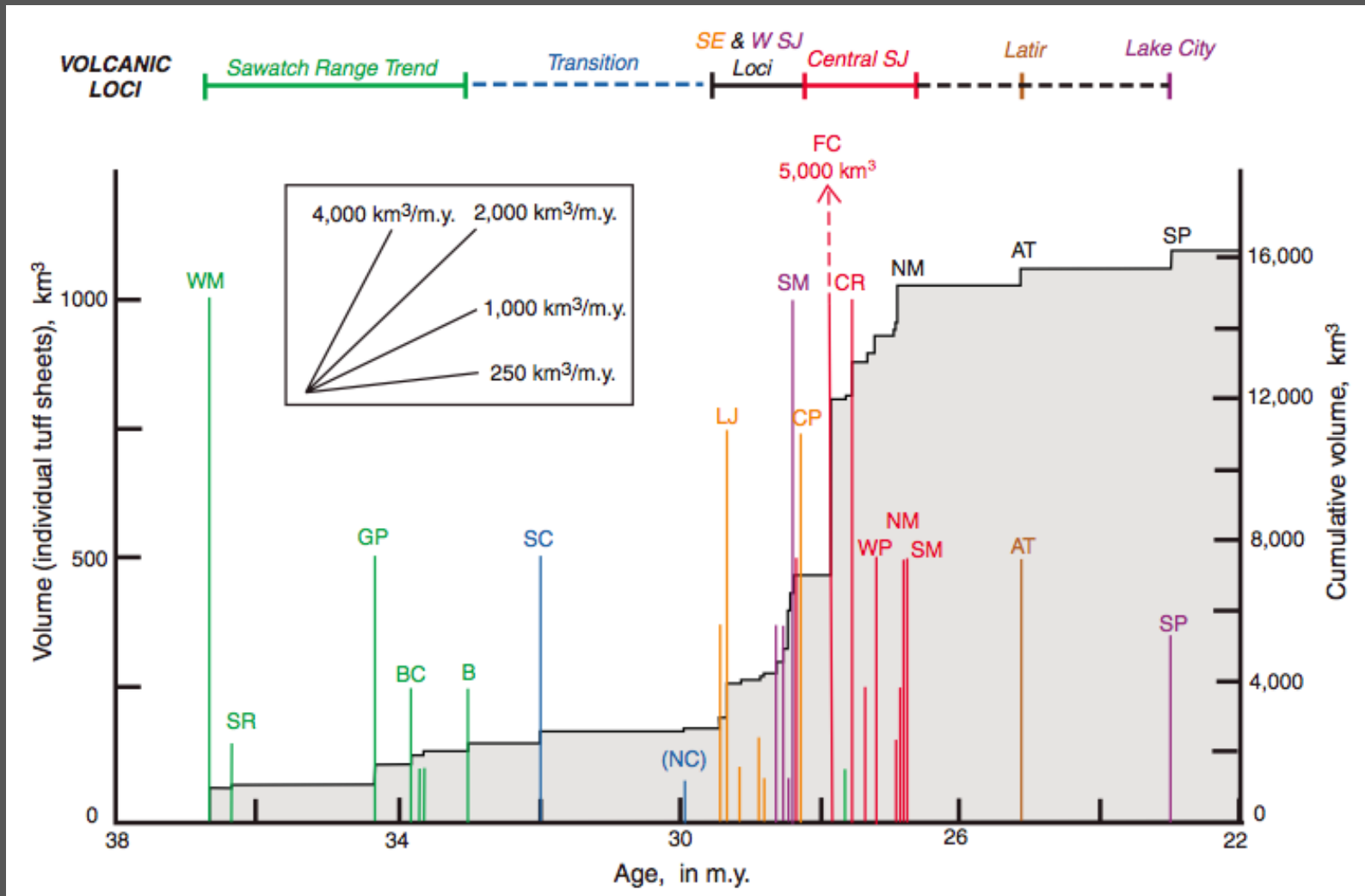
Tengger
Caldera

Caldera Formation – peak magmatic output



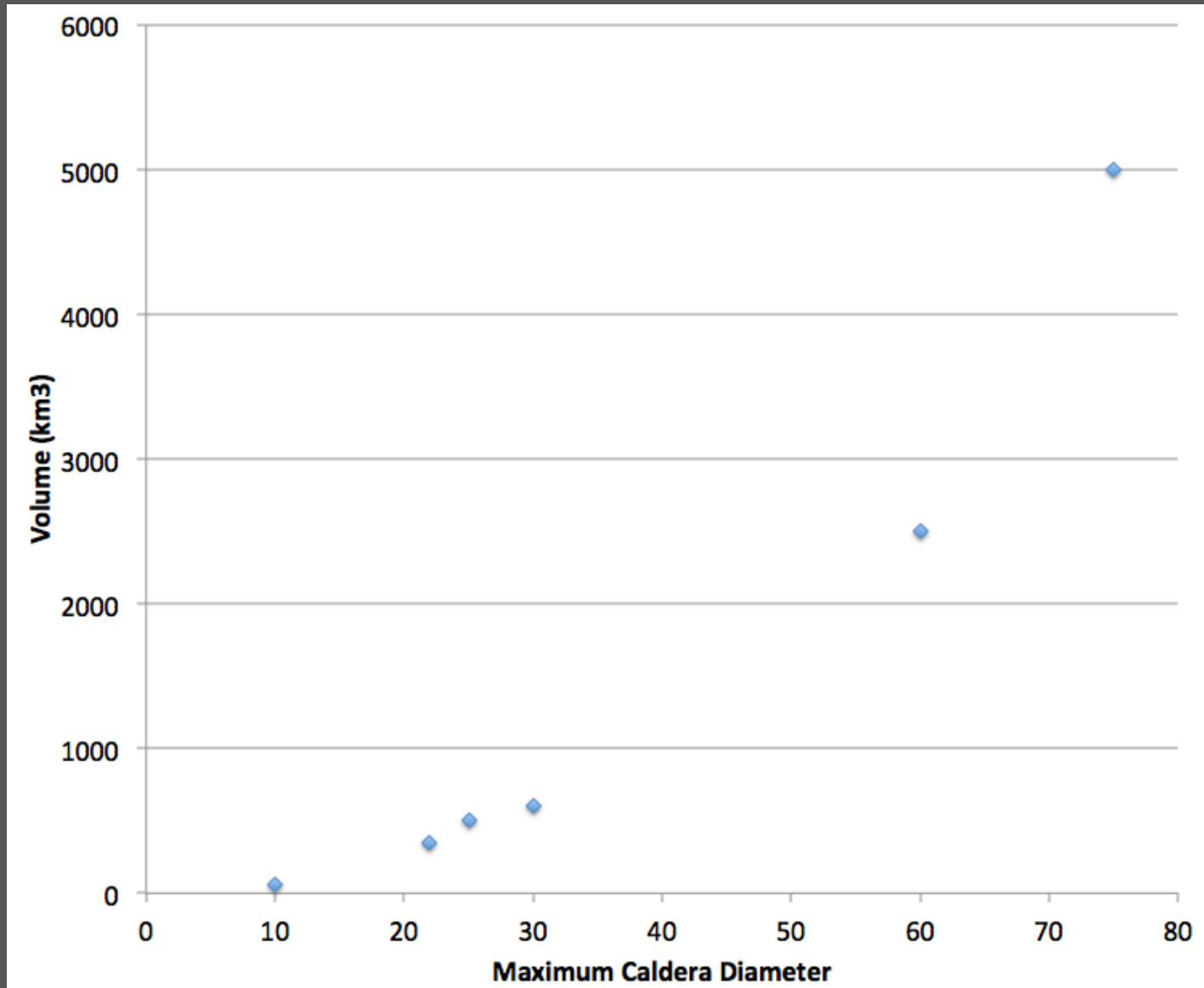
- 1) Eruptive duration – days to months (maybe yrs?)
- 2) 10s km³ to 1000s km³
- 3) Rhyolite to Dacite (zoned vs. monotonous)

Volume of caldera forming ignimbrite

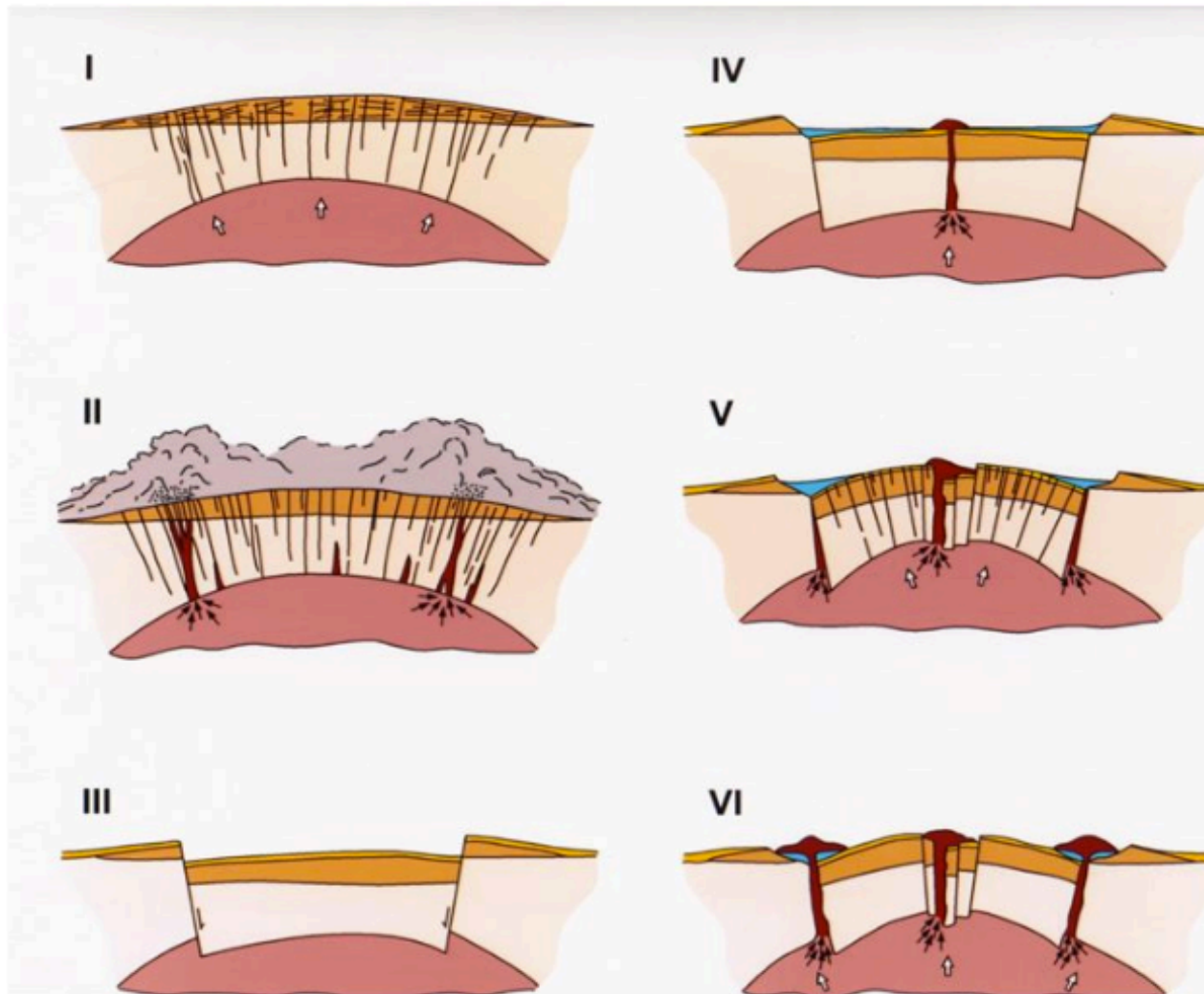


Volume range from 10s to 1000s of km^3

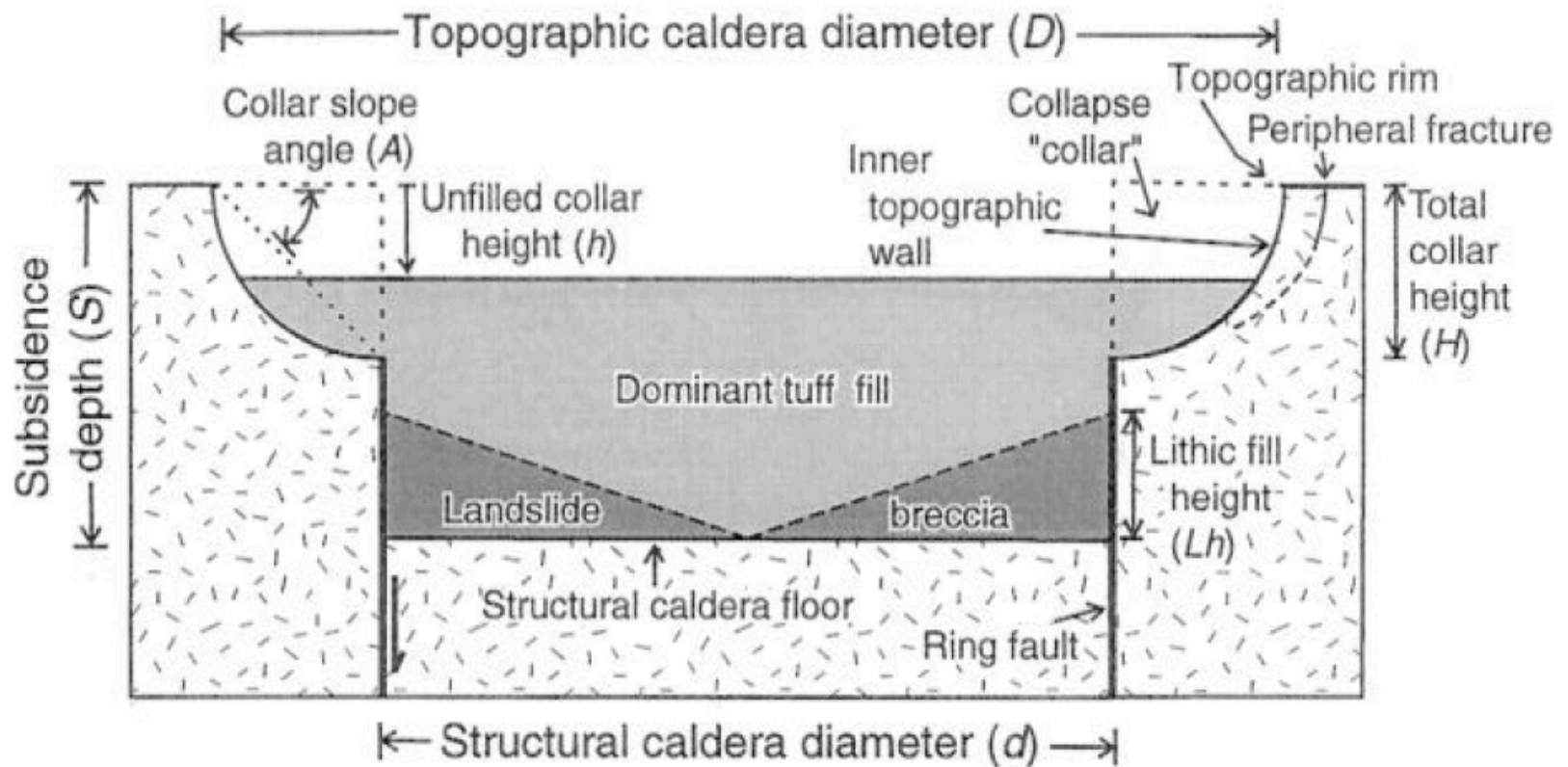
Volume erupted vs. Caldera diameter



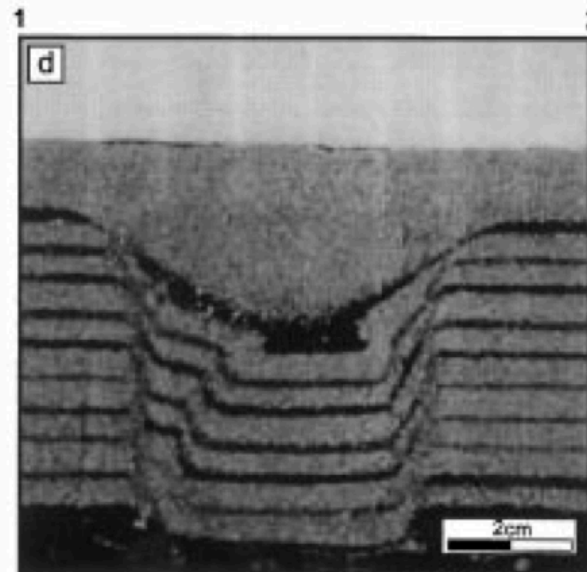
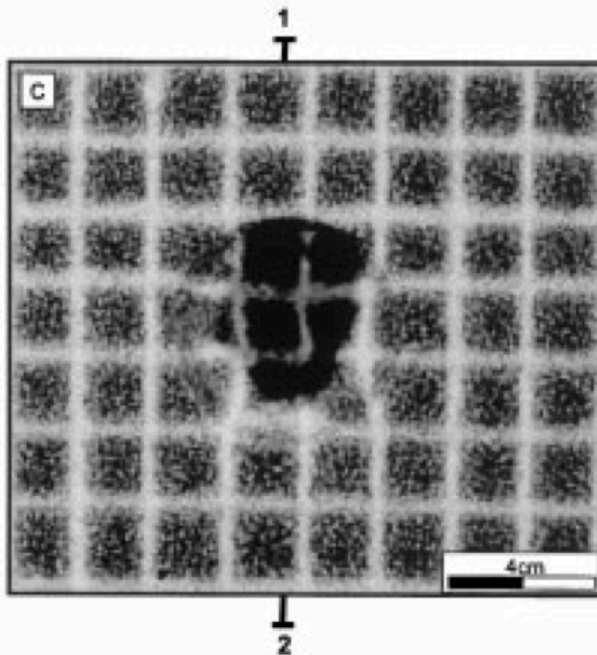
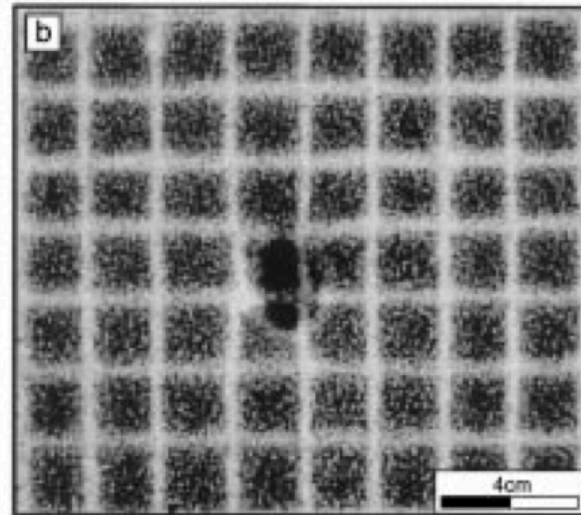
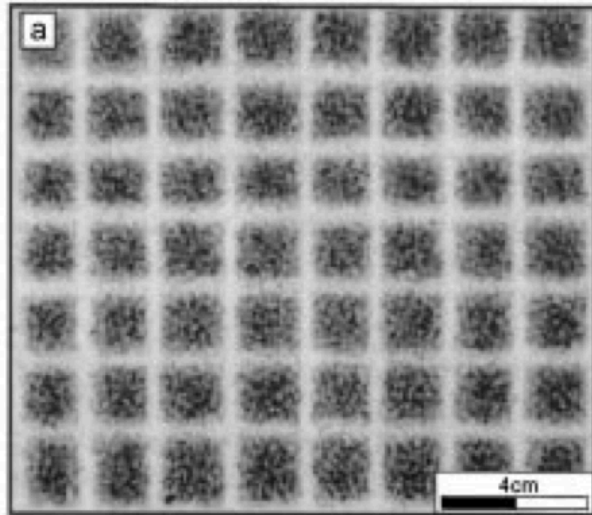
Smith and Bailey's caldera cycle



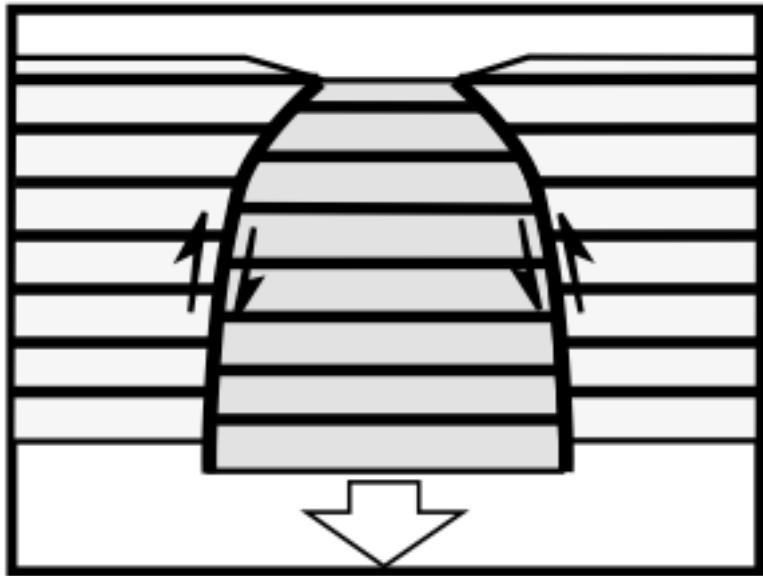
Caldera geometry



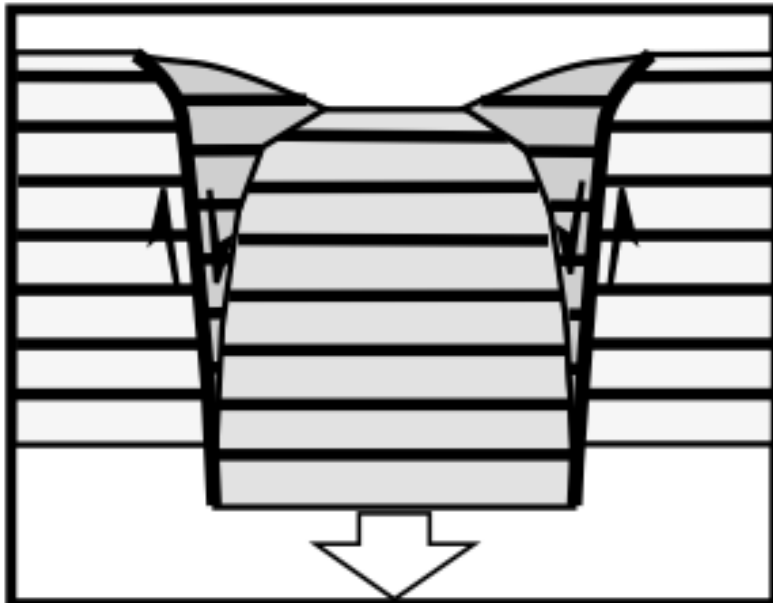
Ring Faults



Ring Faults

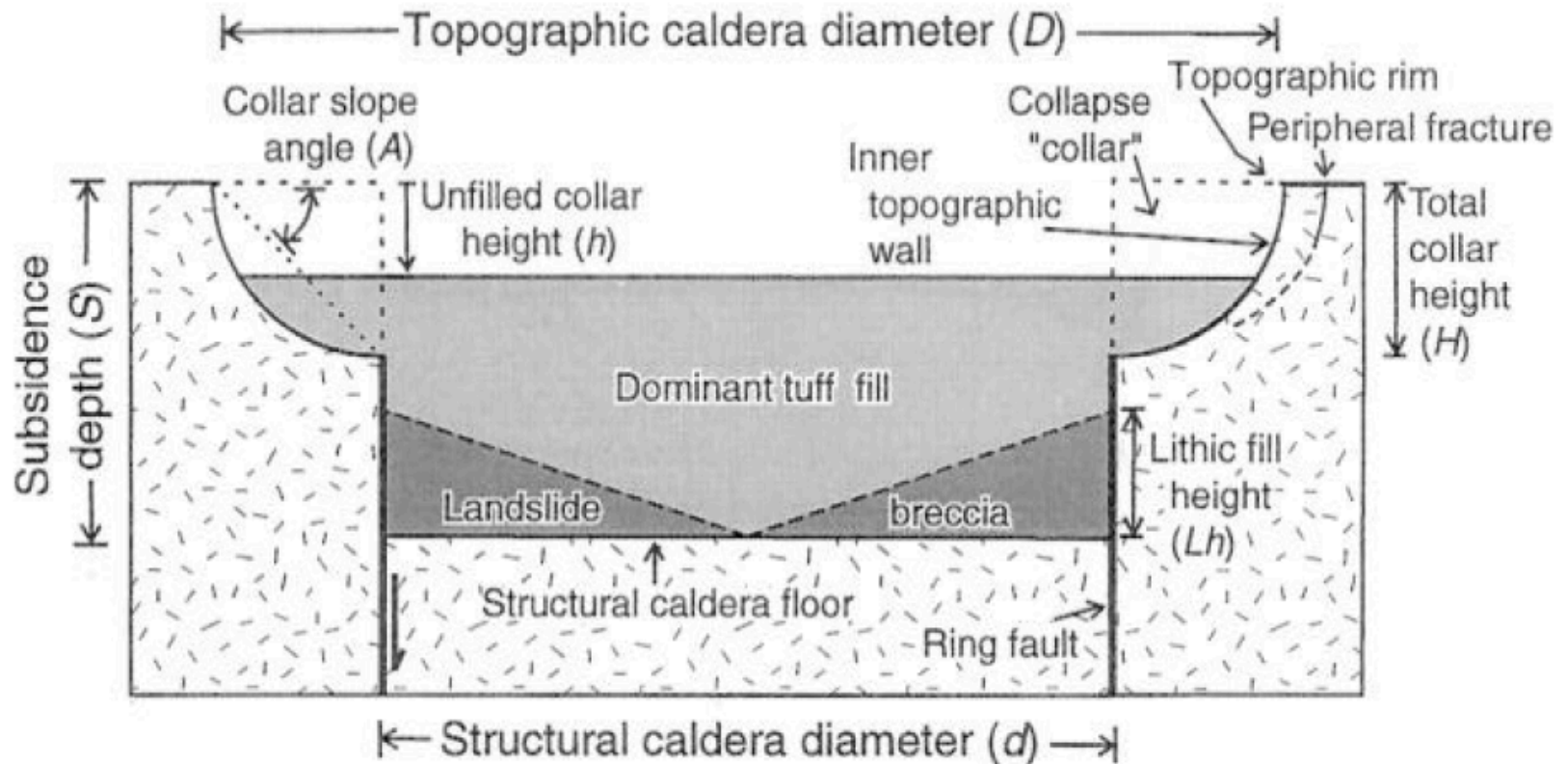


Early Stage – Reverse Faults



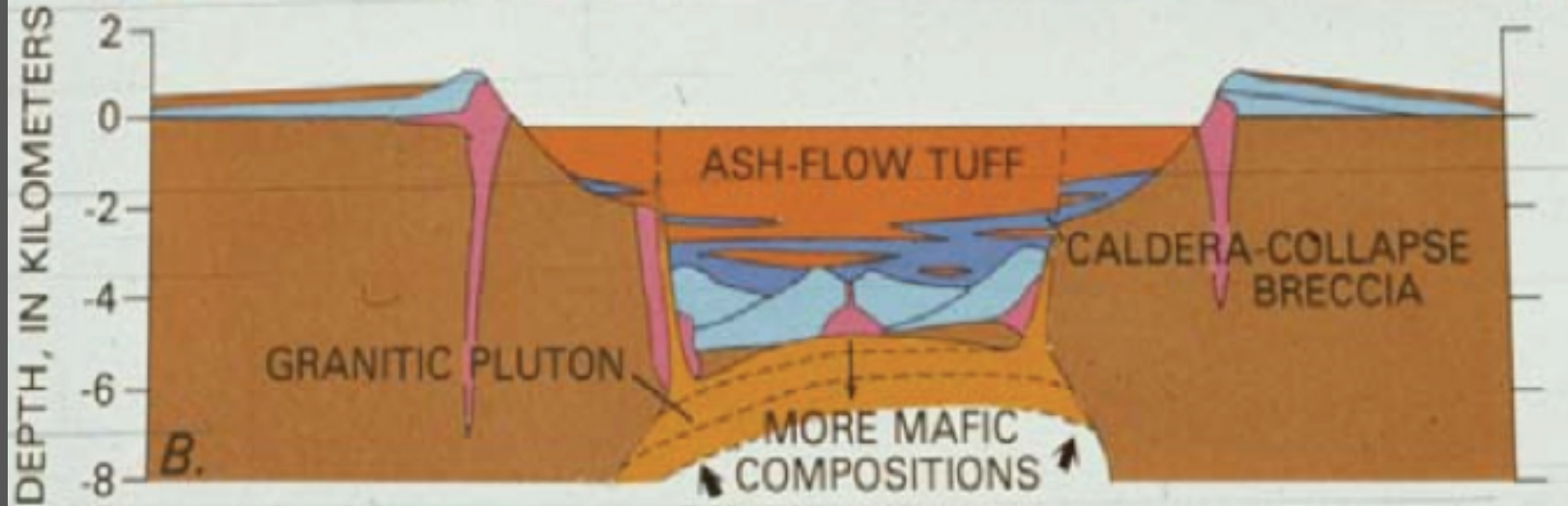
Late Stage – Normal Faults

Caldera geometry

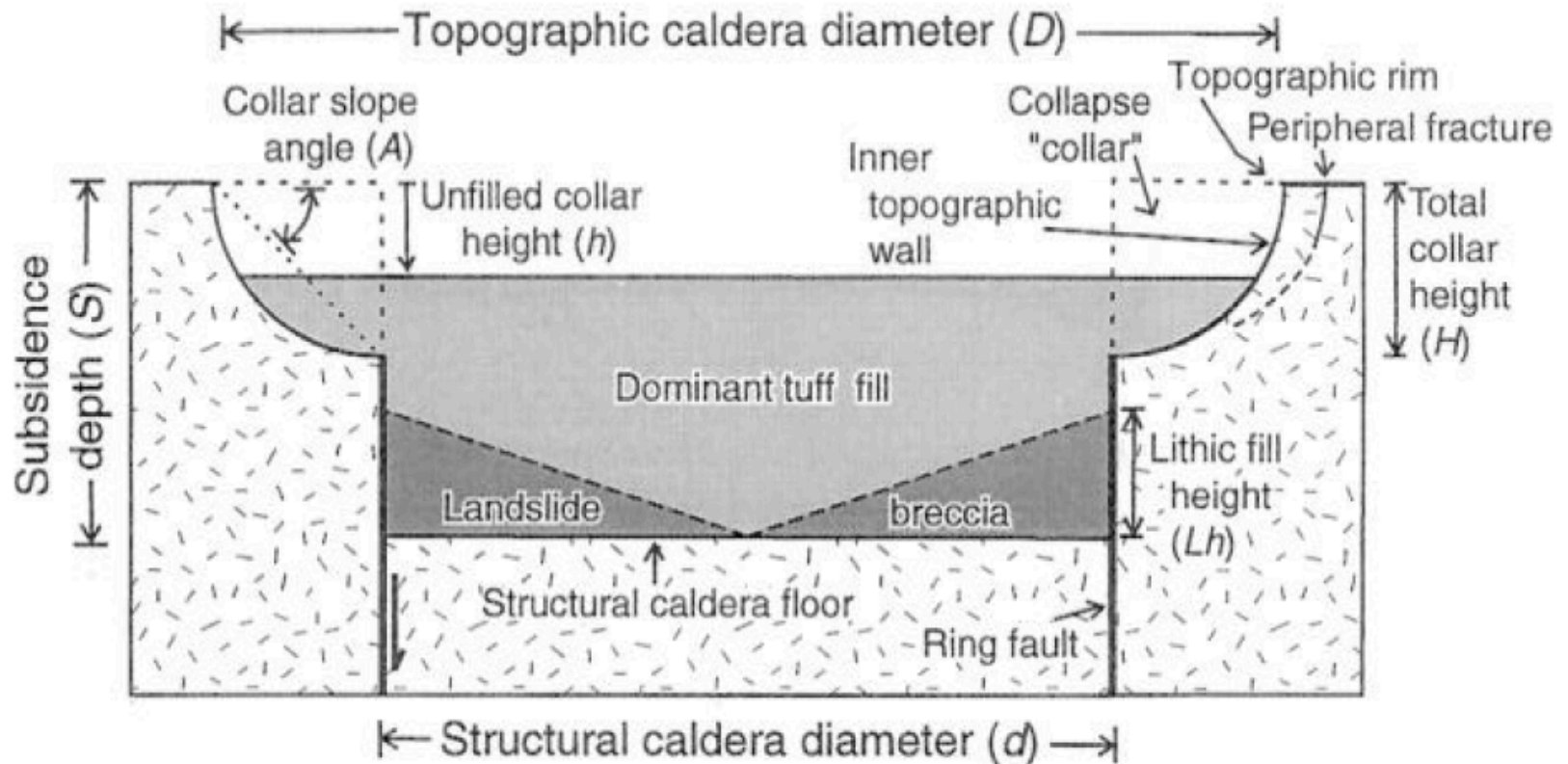


Diameter of Topographic rim > Diameter of structural margin



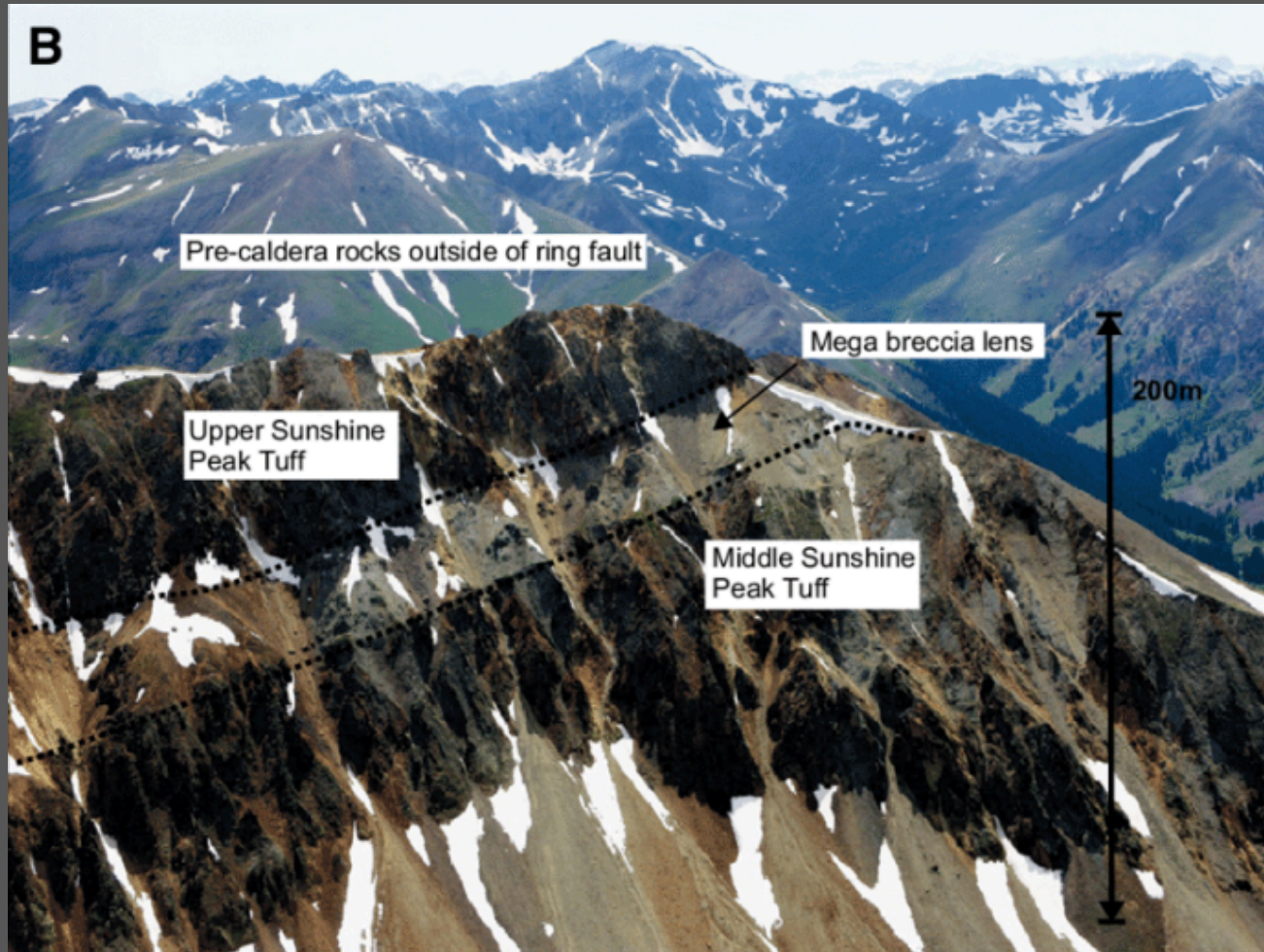


Caldera geometry

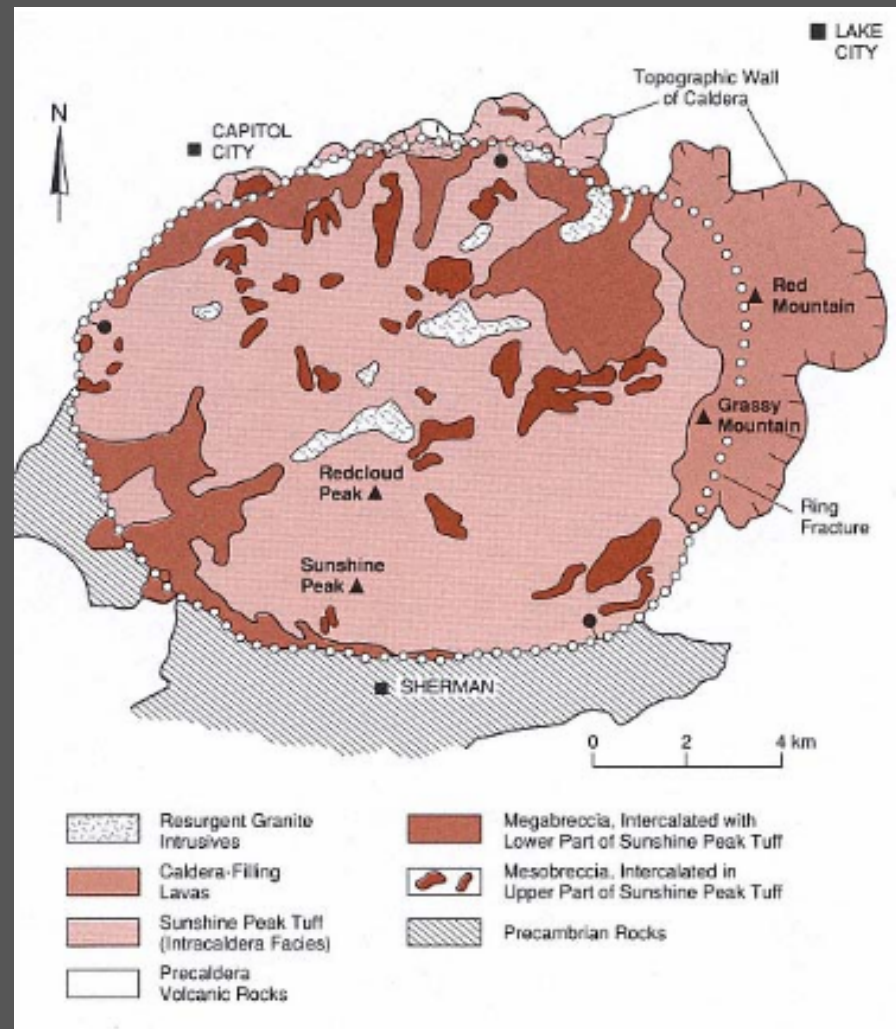


Diameter of Topographic rim > Diameter of structural margin

Caldera collapse breccias —Megabreccia (> 1 m)—



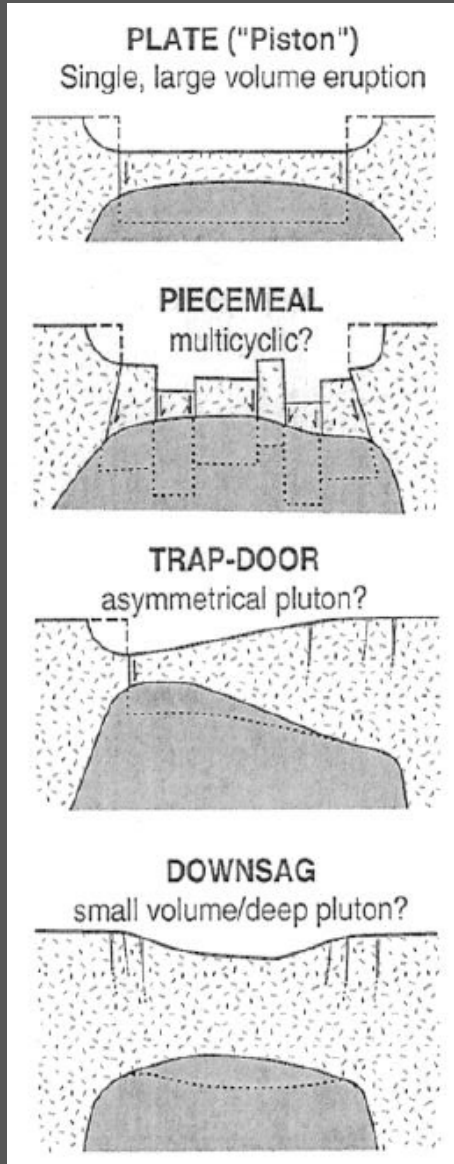
Caldera collapse breccias —Megabreccia (> 1 m)—



Caldera collapse breccias — Mesobreccia (< 1 m) —



Collapse Styles



Different collapse styles a function of:

1) Roof geometry of caldera-forming magma chamber

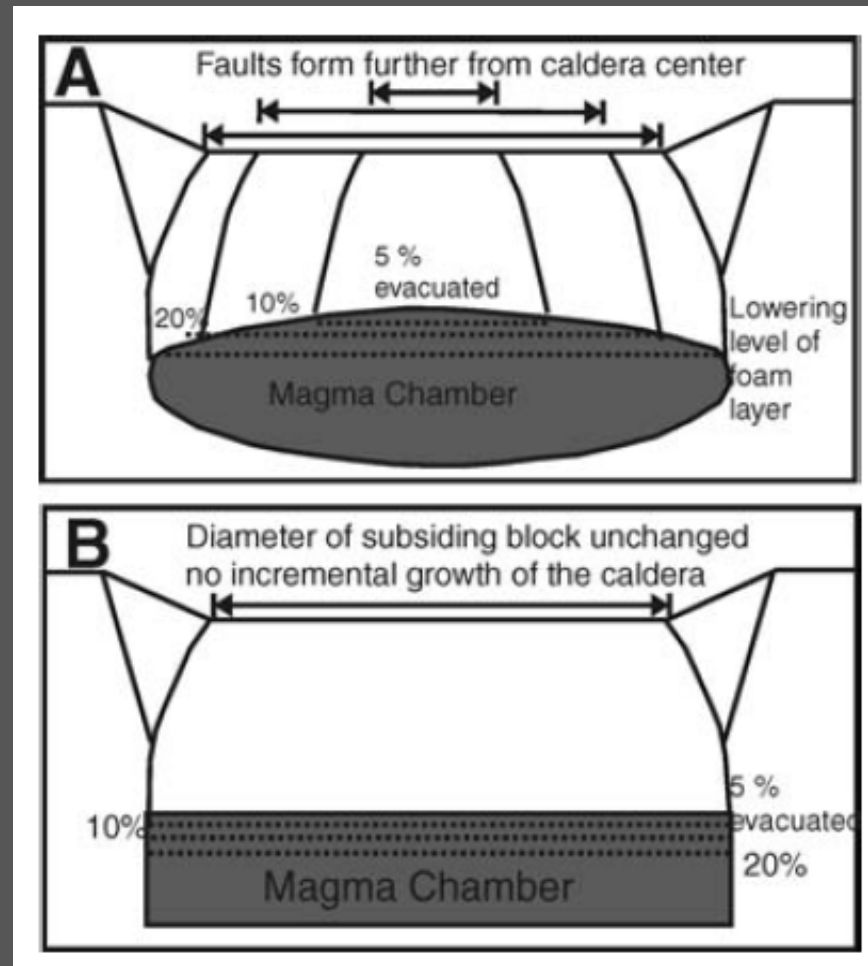
2) Depth of magma chamber

3) Timing of collapse during caldera-forming eruption

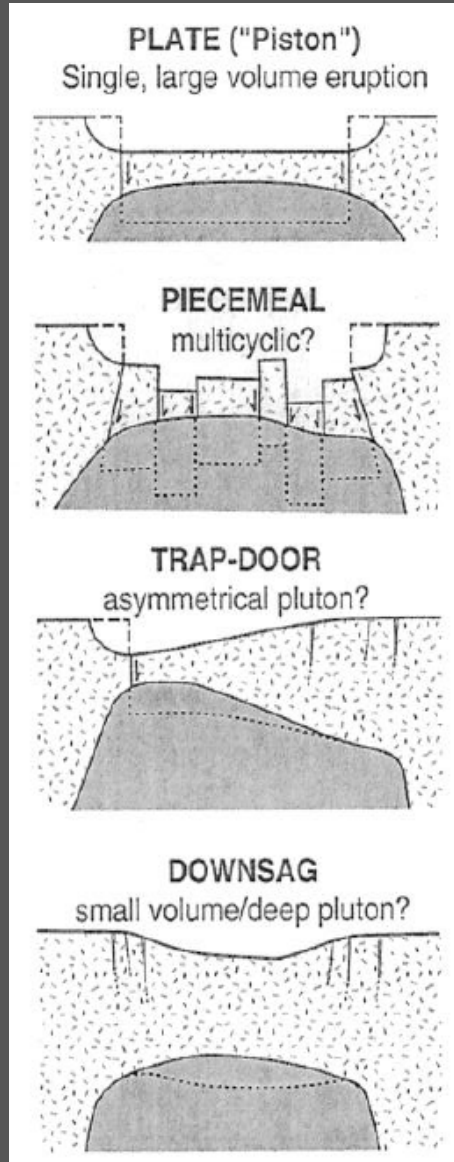
4) Number of caldera cycles

5) Tectonics and Lithologic controls

Influence of chamber shape



Collapse Styles



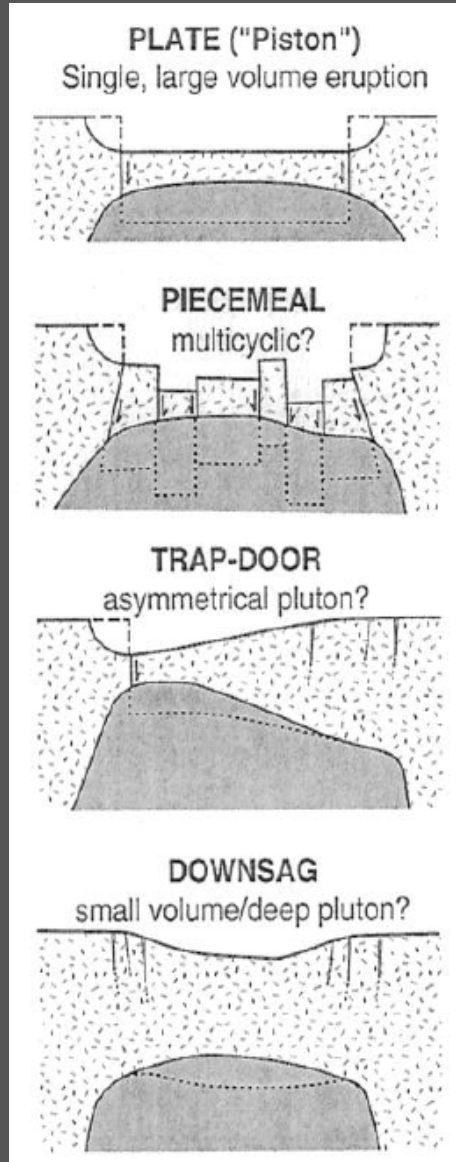
Plate

1) Oversimplified

2) A single, ring fault

3) Near uniform thickness of intracaldera tuff

Collapse Styles



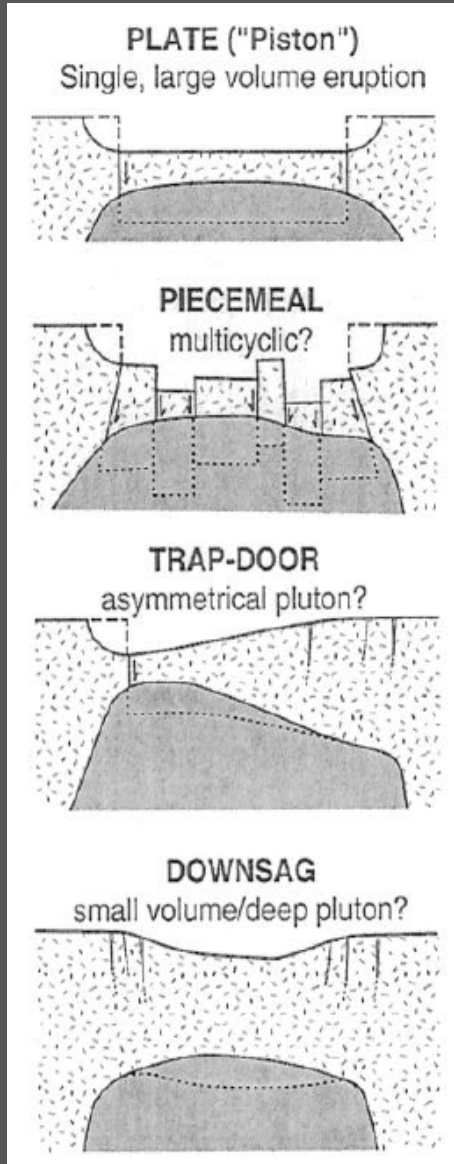
Piecemeal

1) Most realistic?

2) Multiple structural faults with variable Offsets

3) Dramatic lateral variation in fill thickness

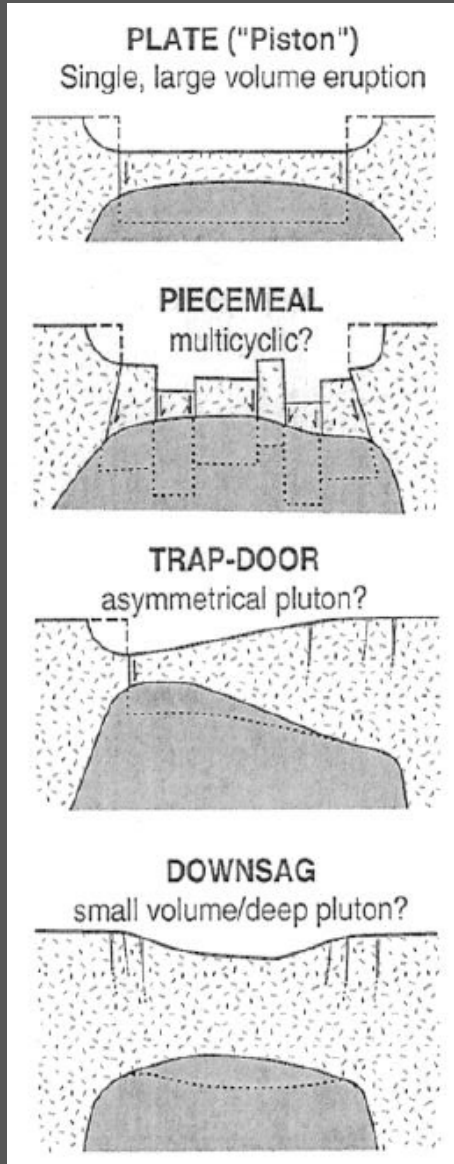
Collapse Styles



Trap-door

- 1) Somewhat rare
- 2) Incomplete formation of ring fault
- 3) Wedge-shaped geometry of intracaldera fill

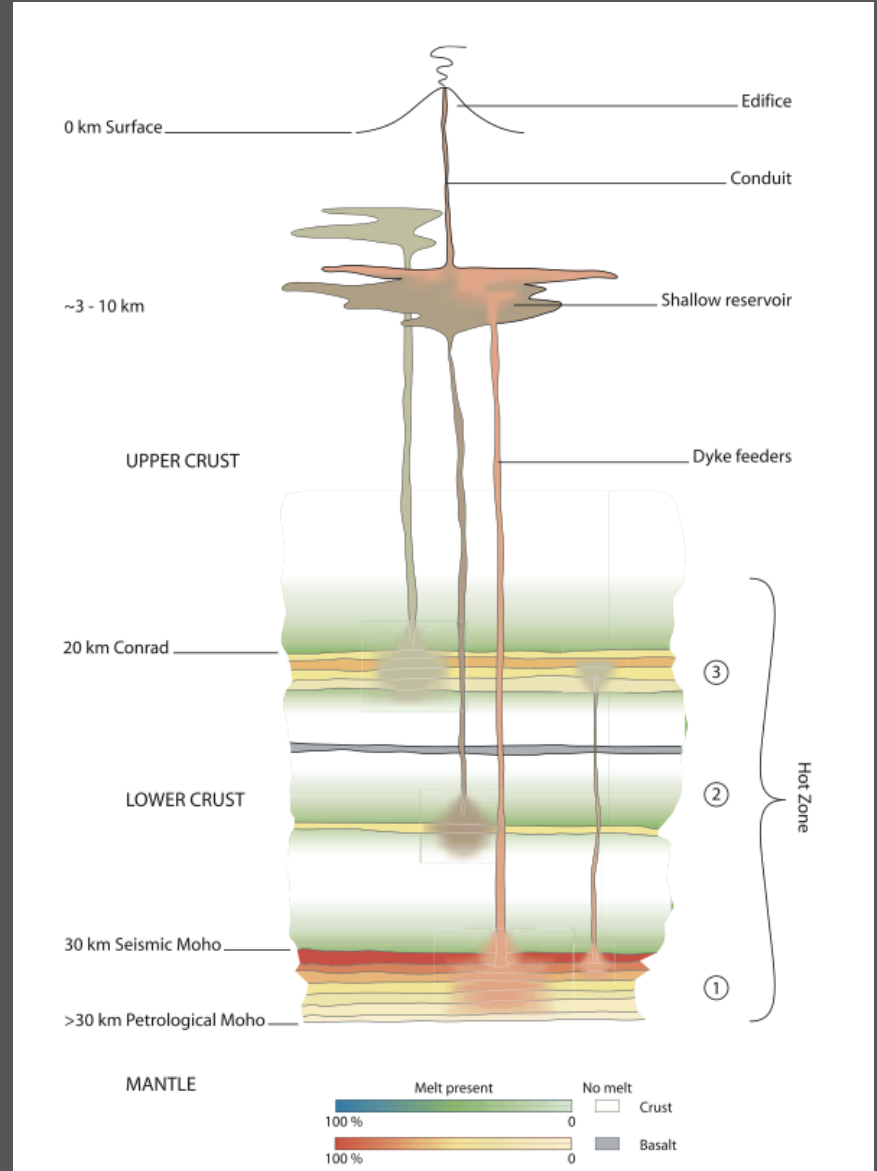
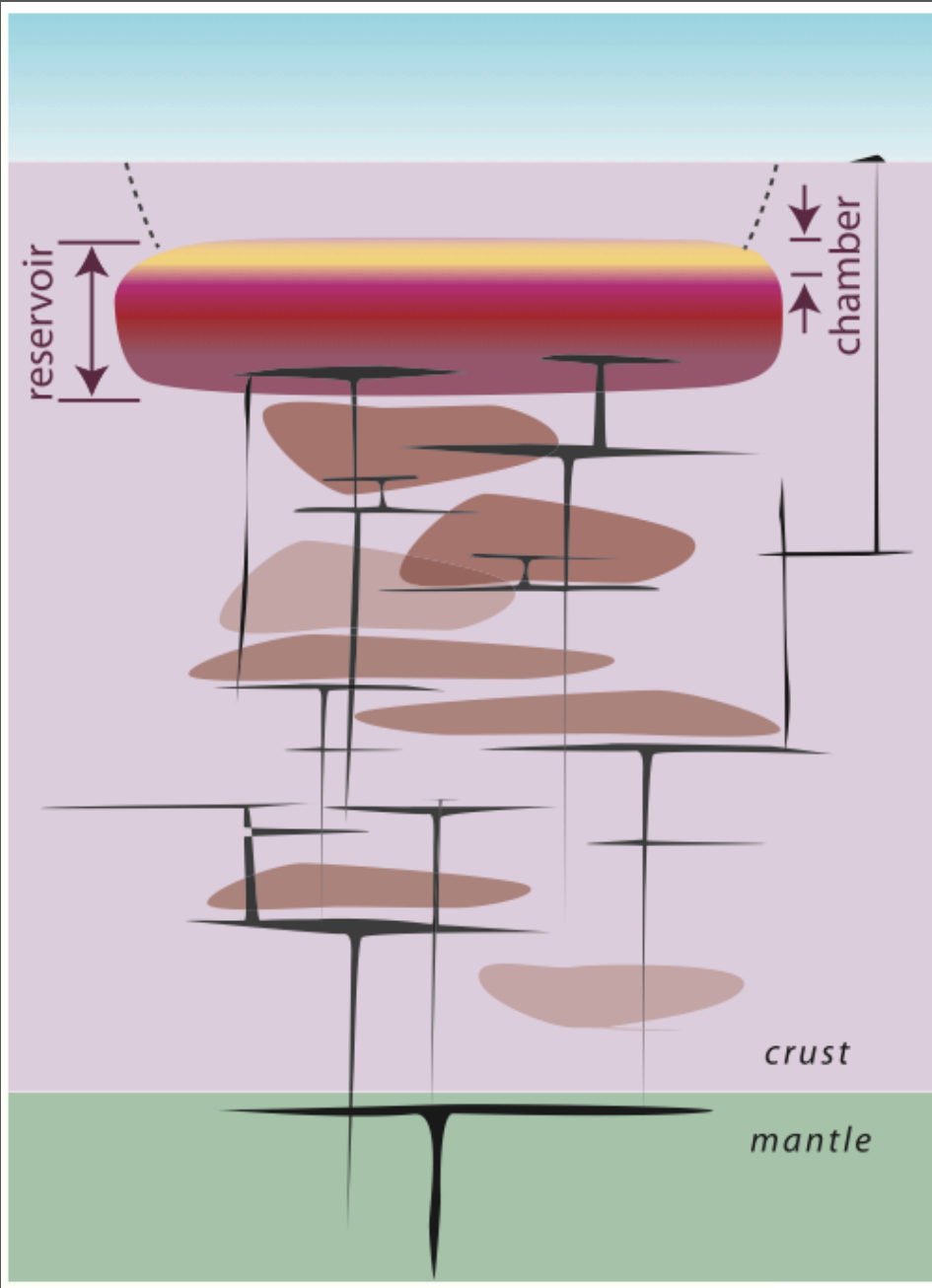
Collapse Styles



Downsag

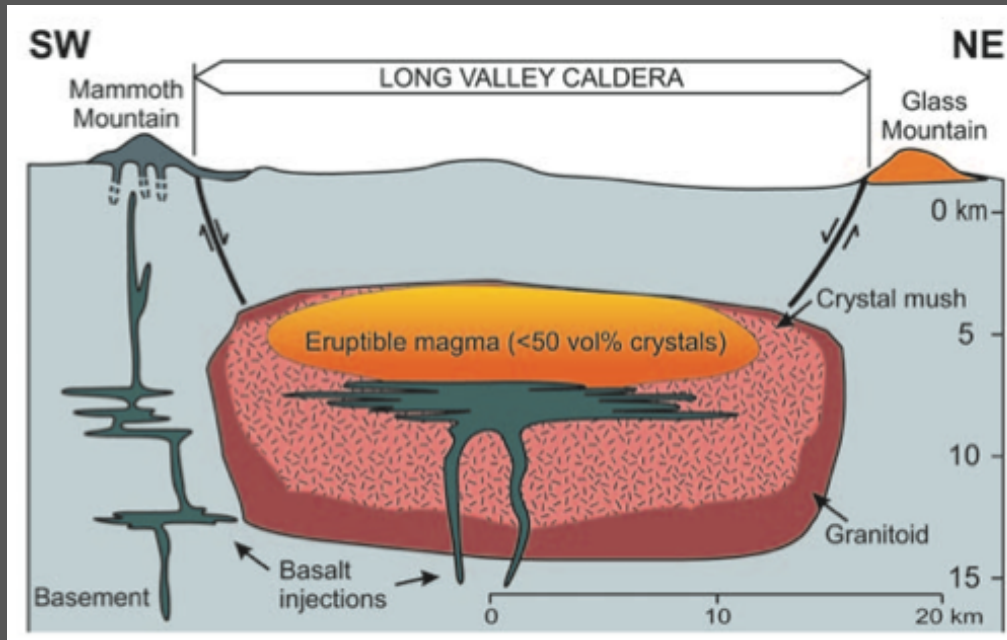
- 1) Somewhat rare for large eruptions;
More common in smaller summit
calderas
- 2) Ring faults do not intersect surface
- 3) Lens-shaped geometry of intracaldera
fill

Magmatic plumbing Beneath calderas...

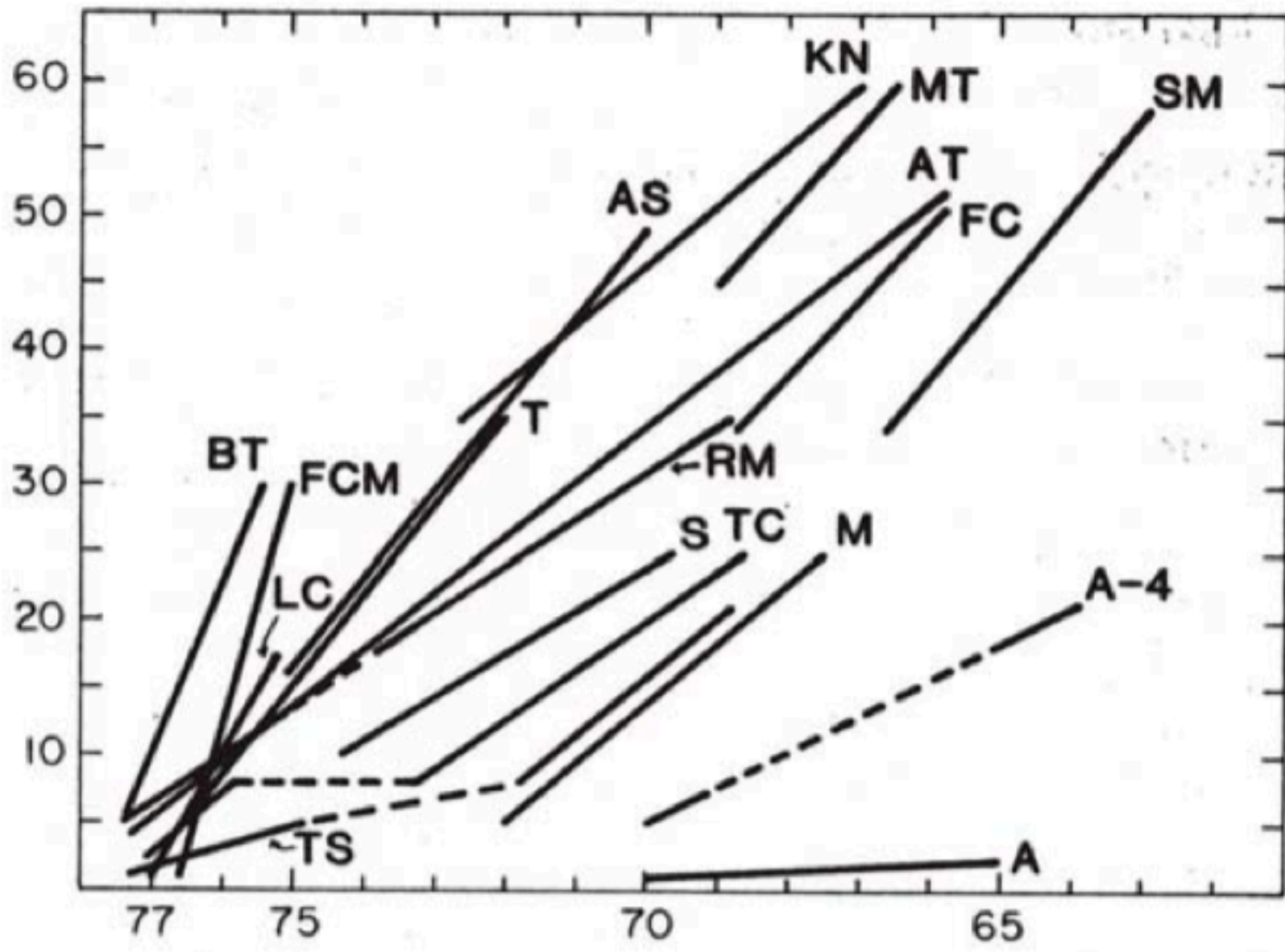


Magmatic plumbing Beneath calderas...

Not a simple, completely
molten magma body



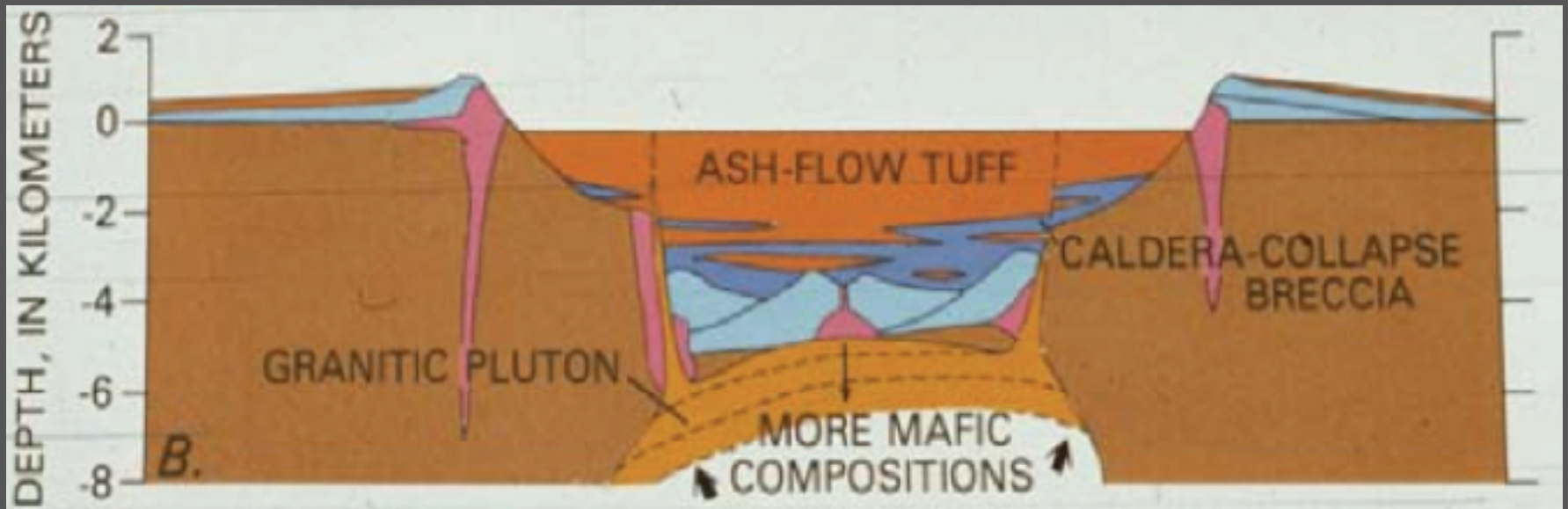
VOLUME % PHENOCRYSTS



Wt. % SiO₂

A

Intracaldera Tuff vs. Outflow Tuff



Intracaldera Tuff vs. Outflow Tuff

1-5 km thick deposit



> 1 km of Intracaldera Tuff w/ no base exposed

Intracaldera Tuff vs. Outflow Tuff



> 1 km intracaldera tuff with no base exposed

Intracaldera Tuff vs. **Outflow Tuff**



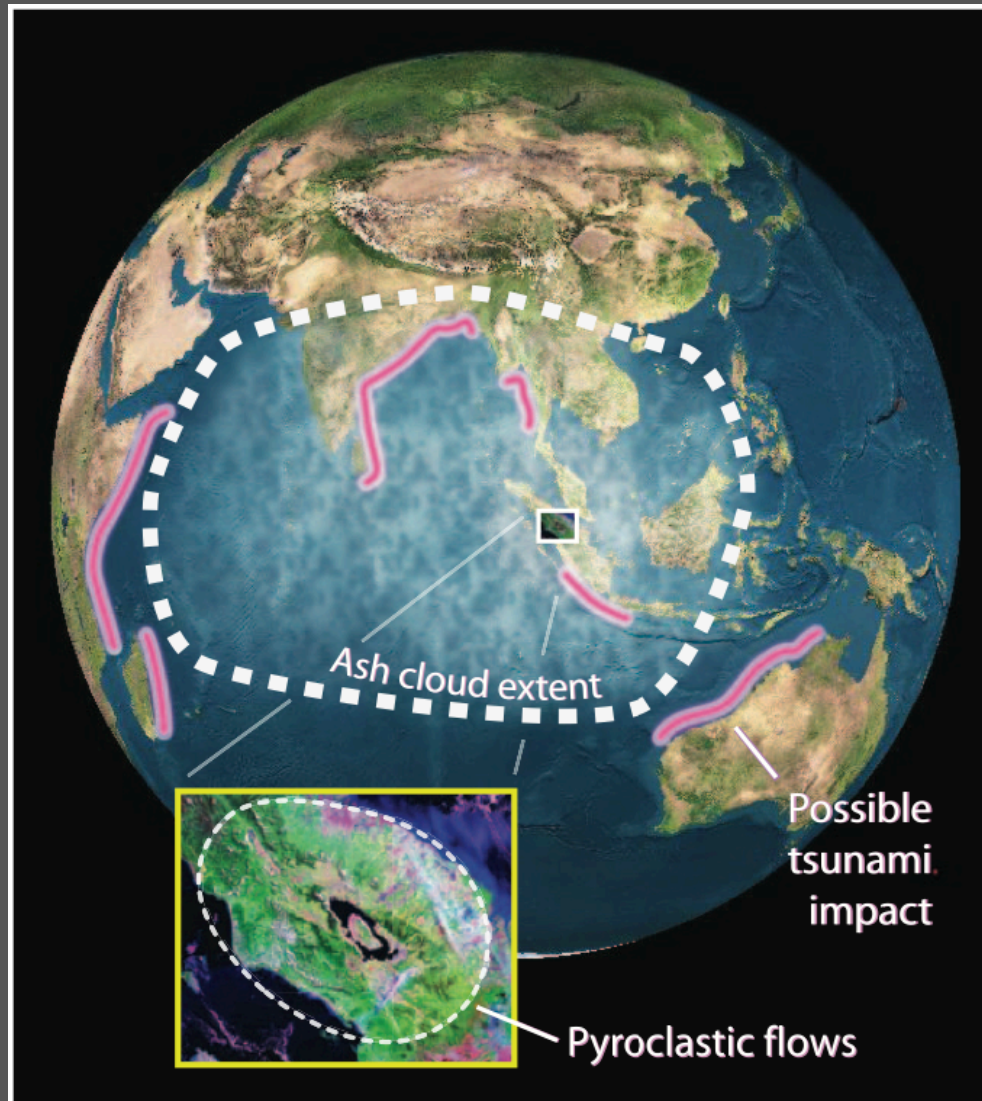
Proximal Outflow Deposit

Intracaldera Tuff vs. Outflow Tuff



Ignimbrite Sheet

Outflow Tuff vs. Ash-Fall deposits



Toba Caldera
75 ka

Postcaldera Volcanism

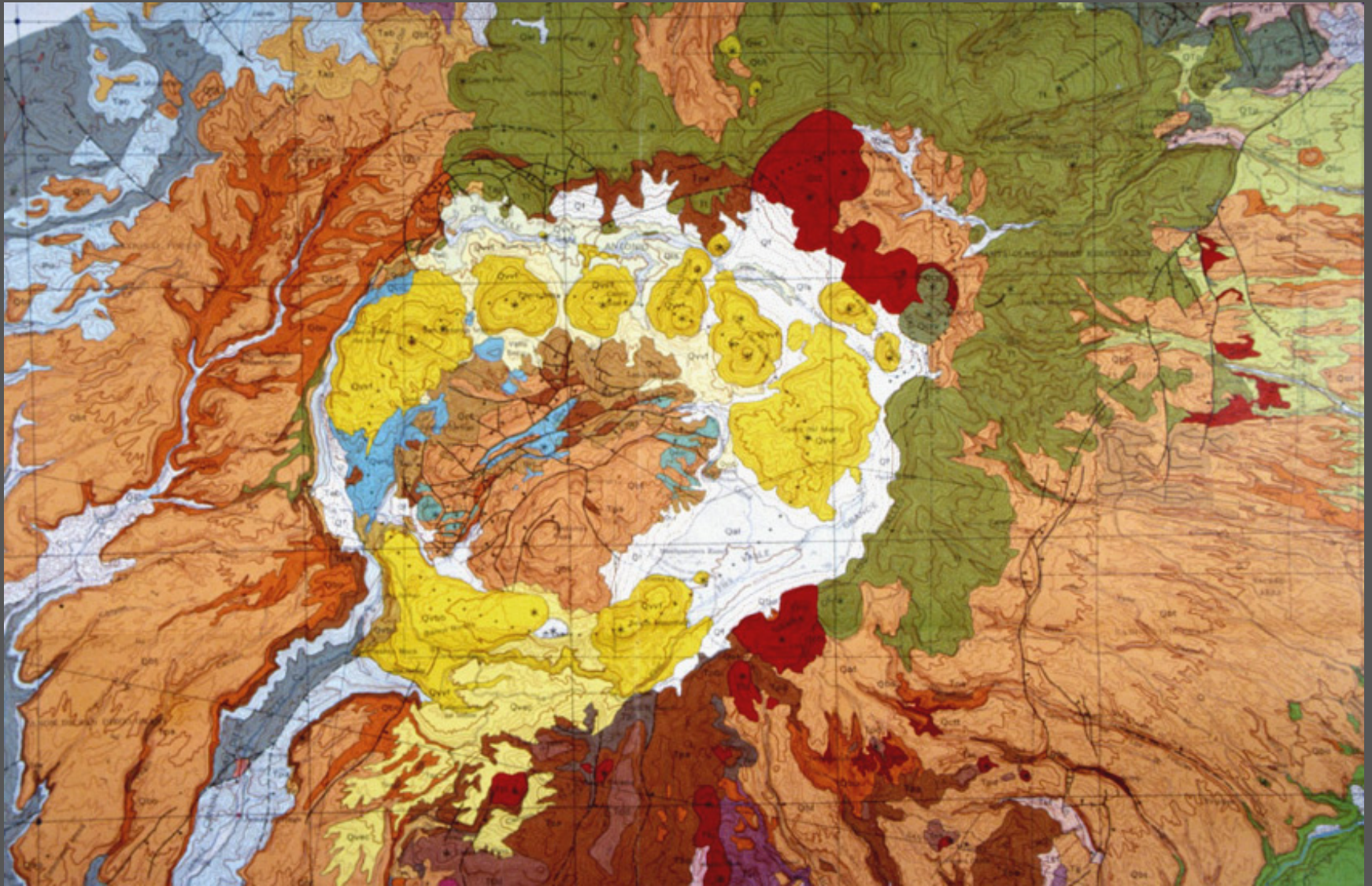


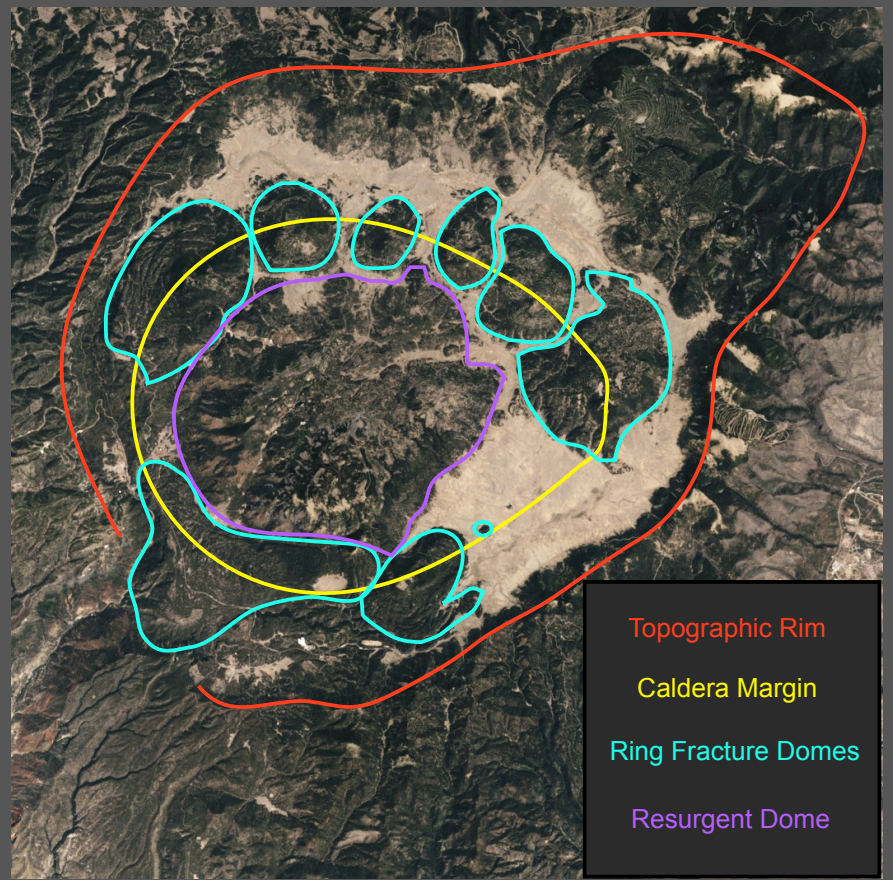
Postcaldera Volcanism (waning magmatism)



- 1) Numerous eruptions, compositionally diverse, during extended period (10^4 to $> 10^6$ yrs)
- 2) Caldera lake
- 3) Formation of resurgent dome
- 4) Extensive mineralization
- 5) Large volume of magma emplaced as plutons/intrusion

Valles – circular moat rhyolite pattern





Topographic Rim

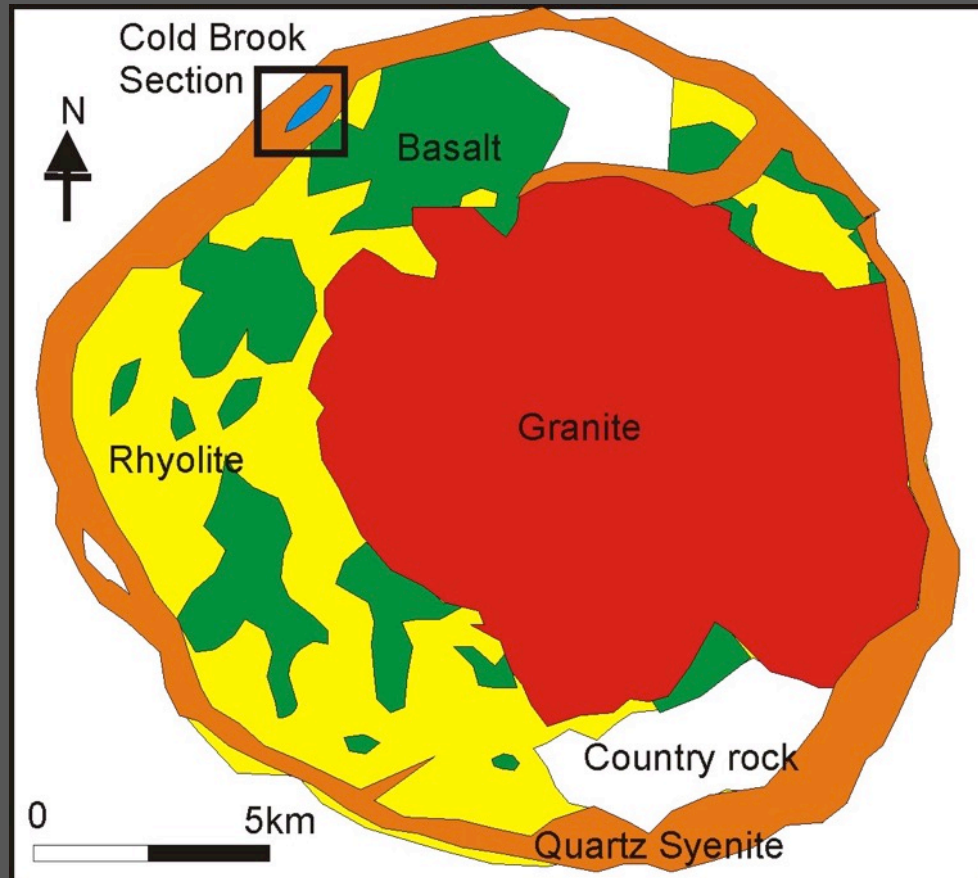
Caldera Margin

Ring Fracture Domes

Resurgent Dome



Ossipee ring complex



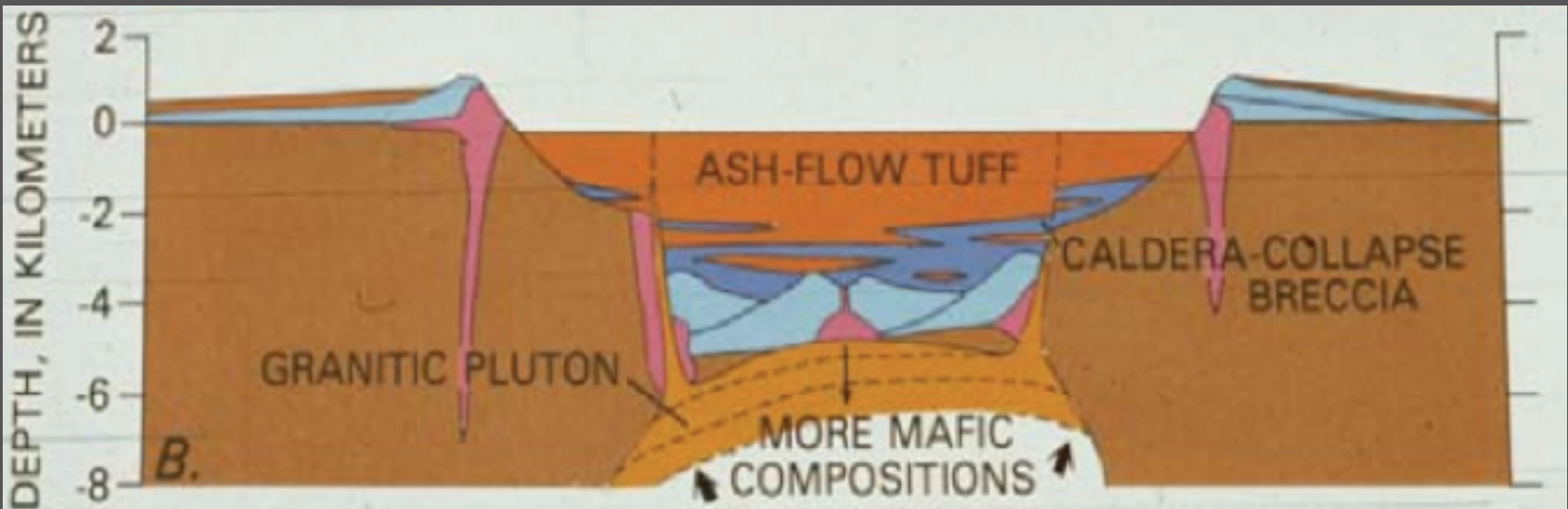
Caldera Lakes



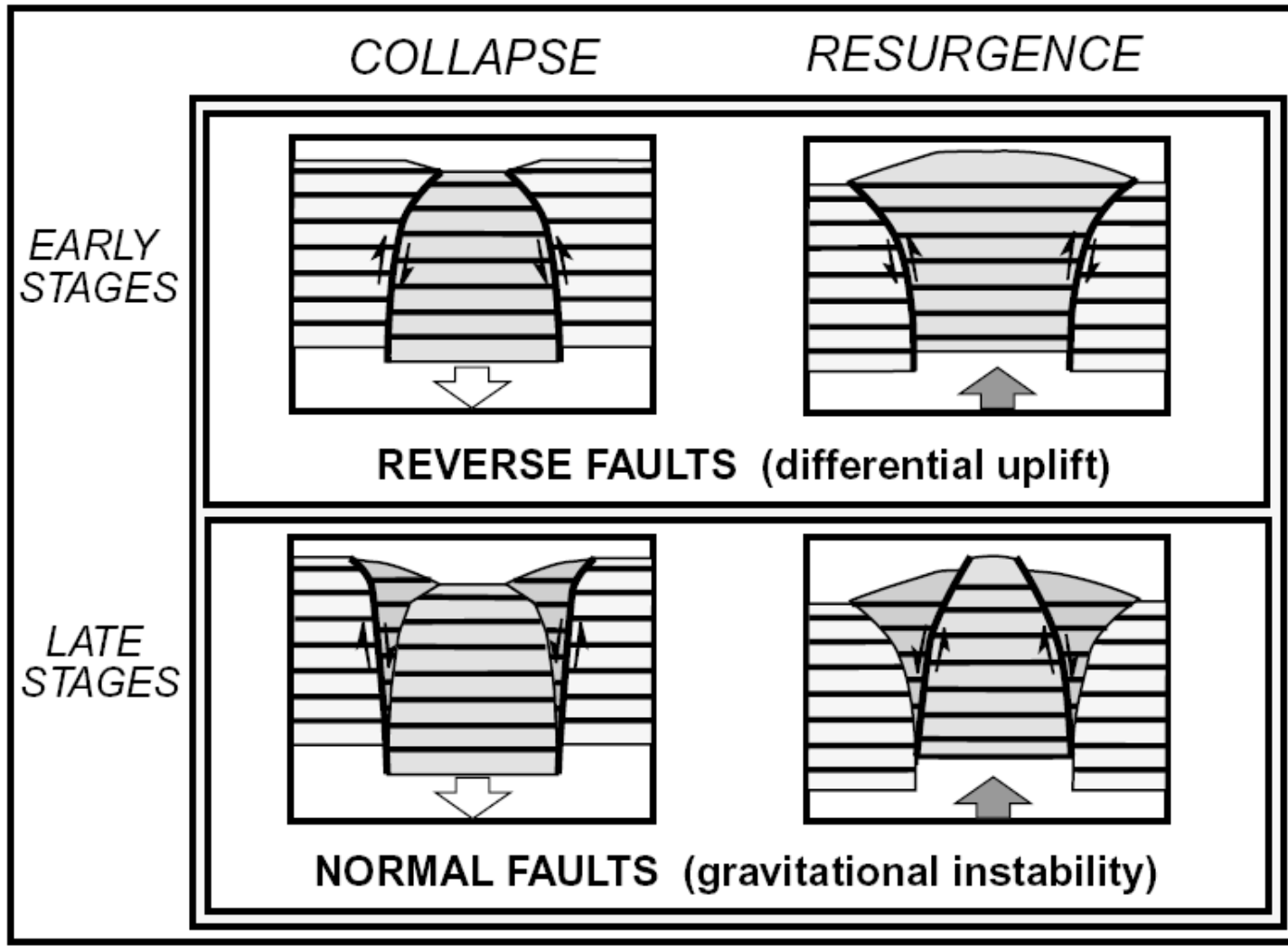
Caldera Lakes



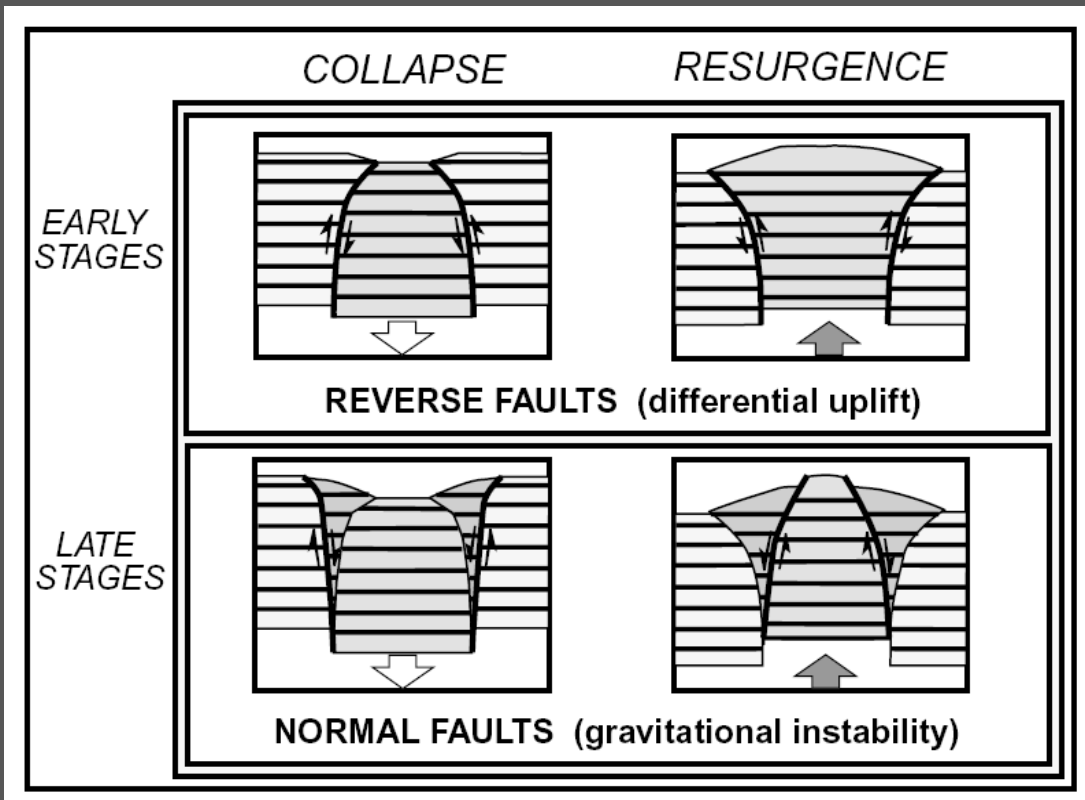
Resurgent domes



Faulting during collapse and resurgence

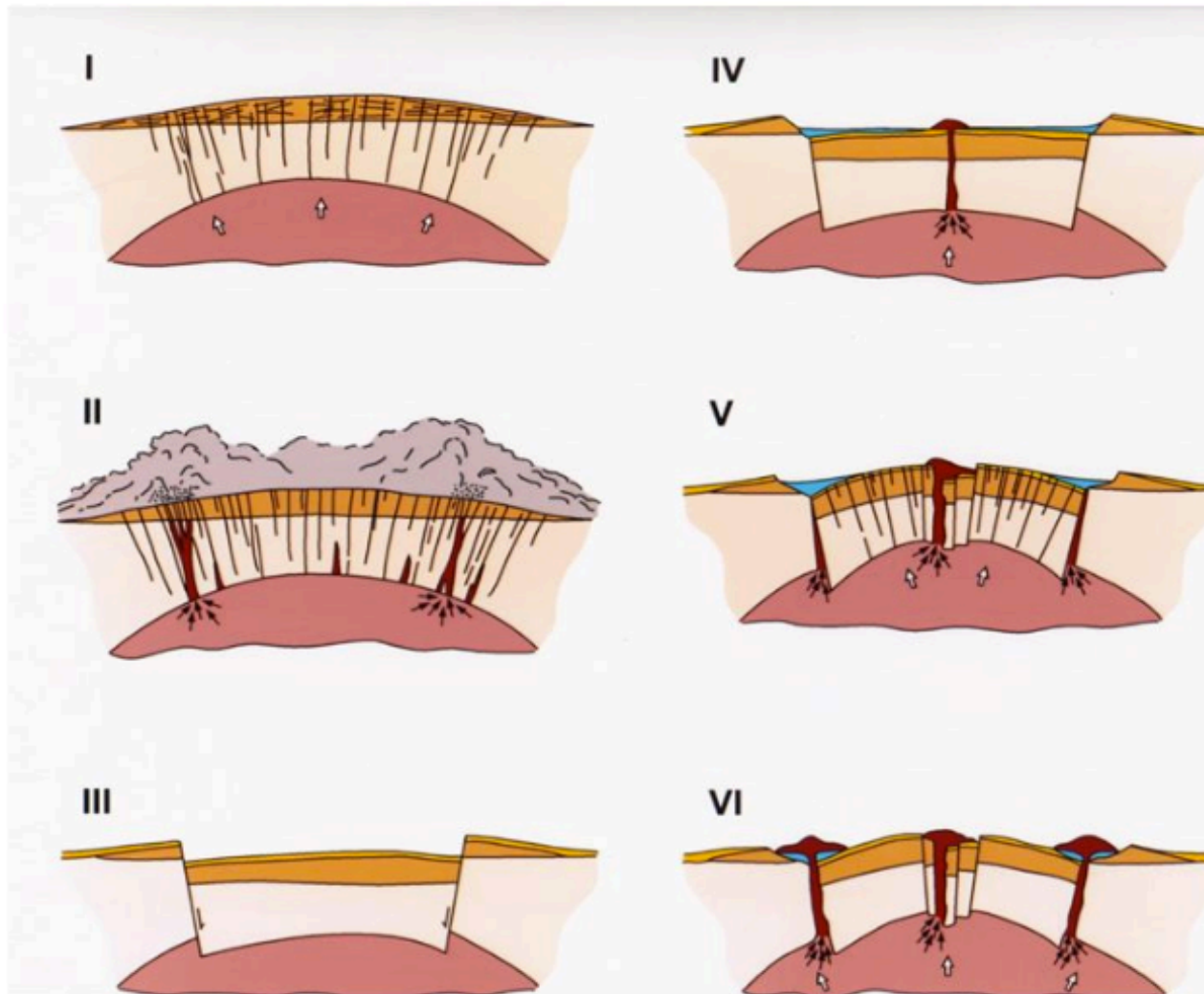


Resurgent domes



26.9 Ma Creede Caldera
SW Colorado

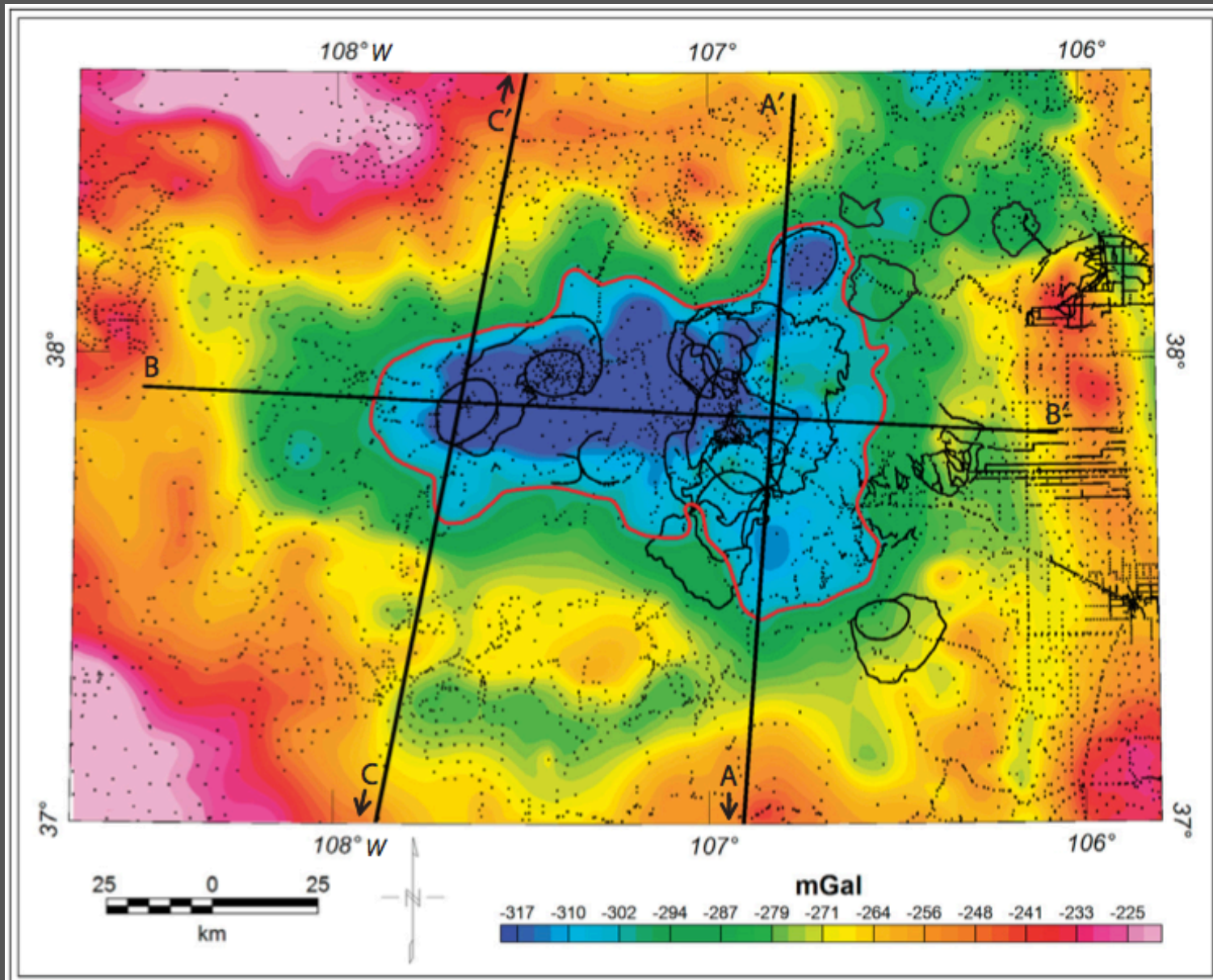
Smith and Bailey's caldera cycle



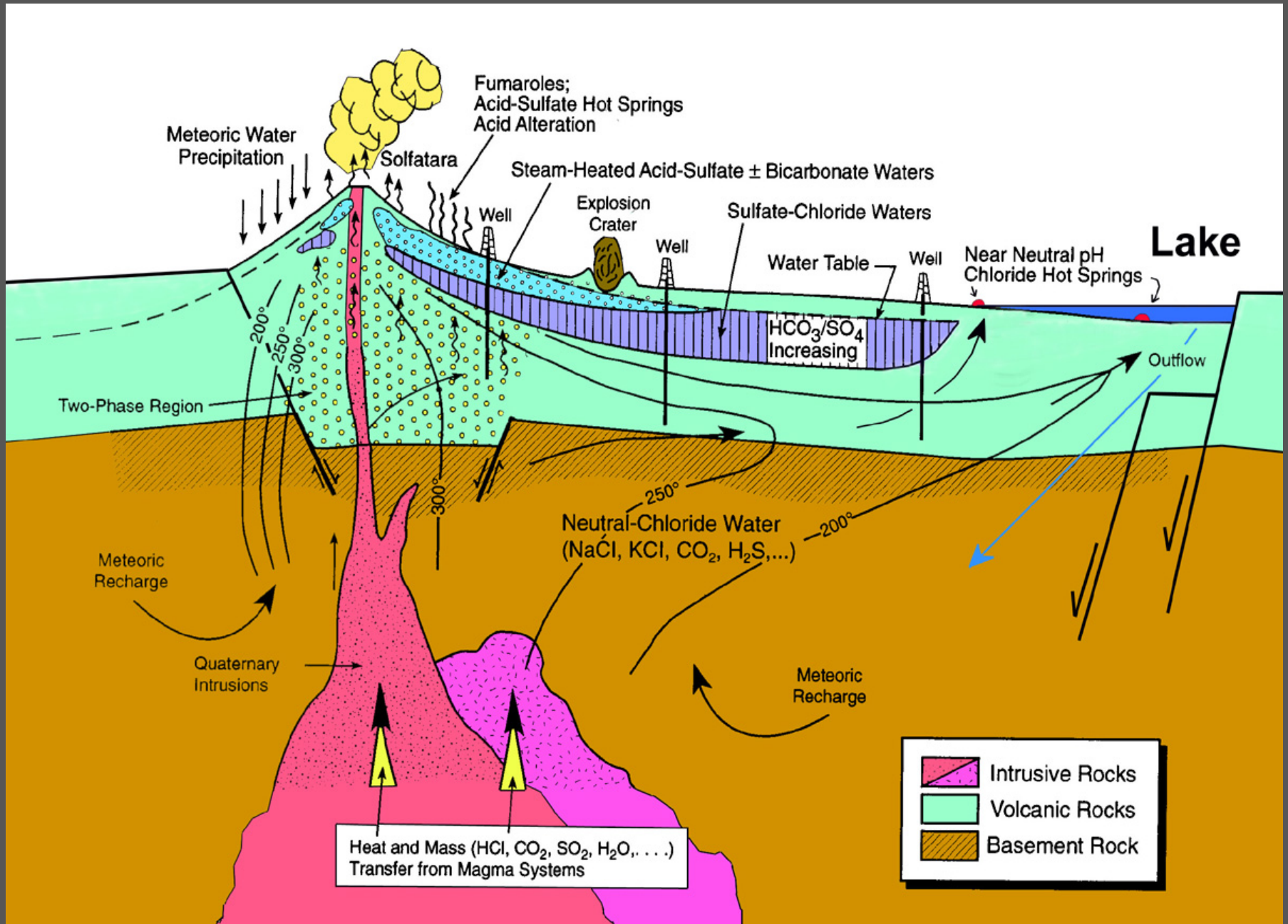
Bouguer Gravity Anomaly

- The difference between the expected value of gravity at a given location (taking into account factors such as latitude, longitude, altitude, and the rotation of the Earth) and its actual value.

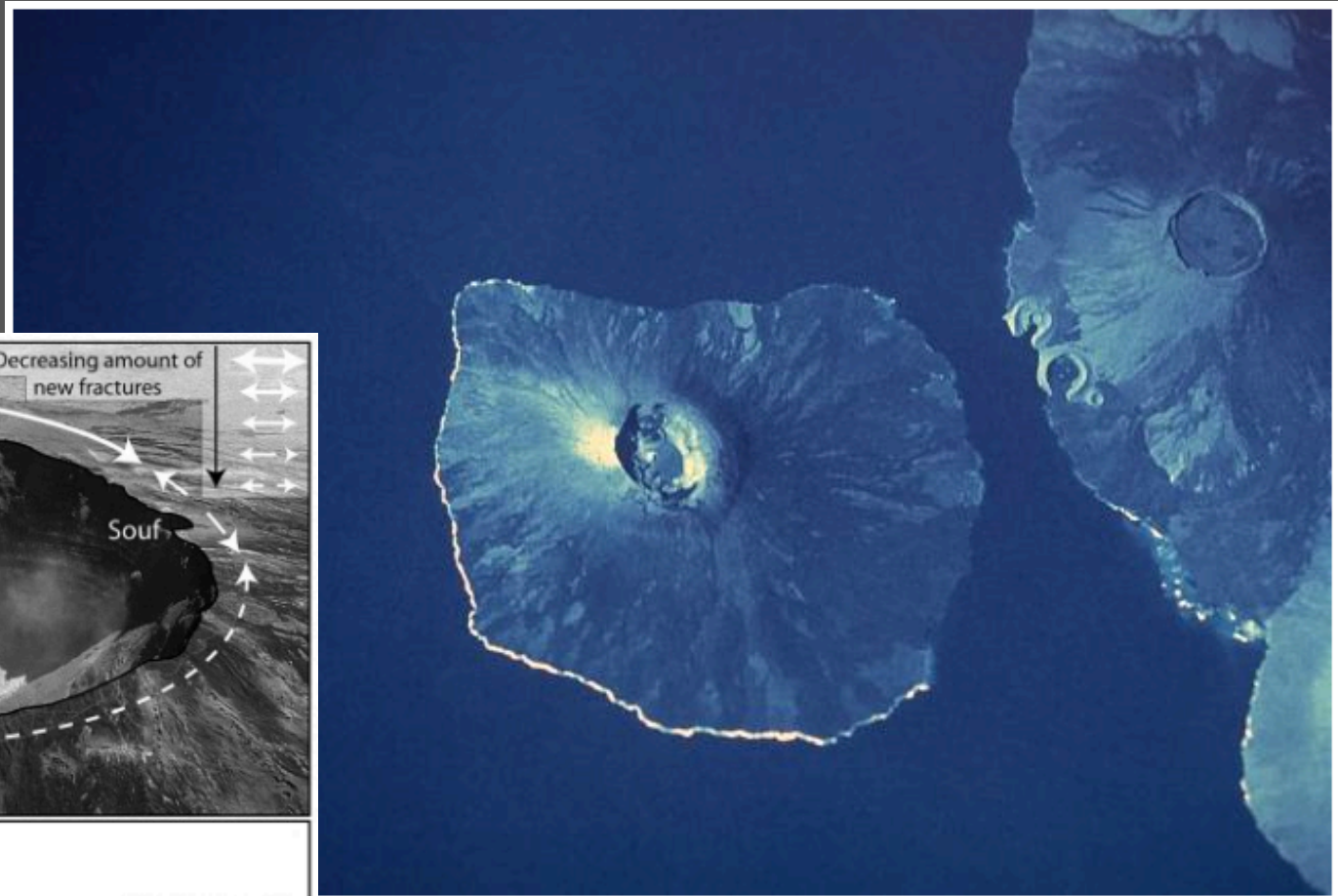
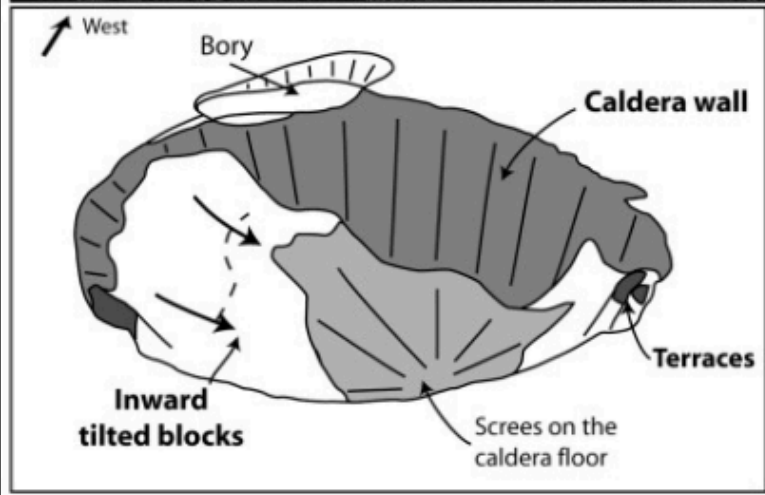
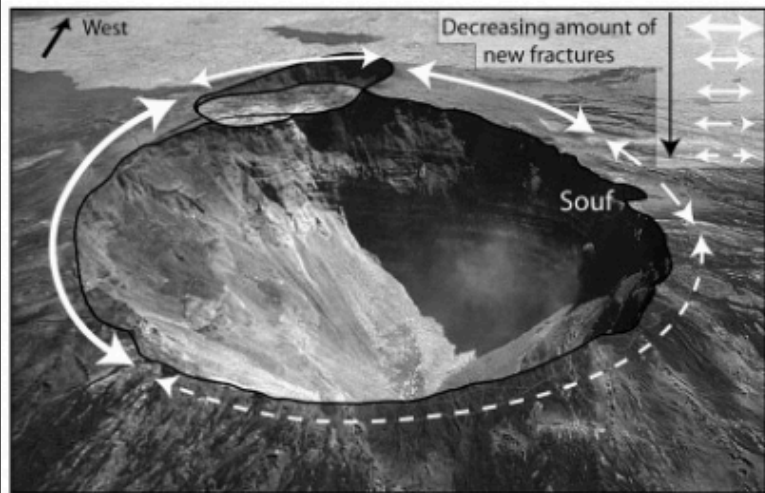
Postcaldera intrusions



Drenth
Et al. 2011)



Basaltic Calderas

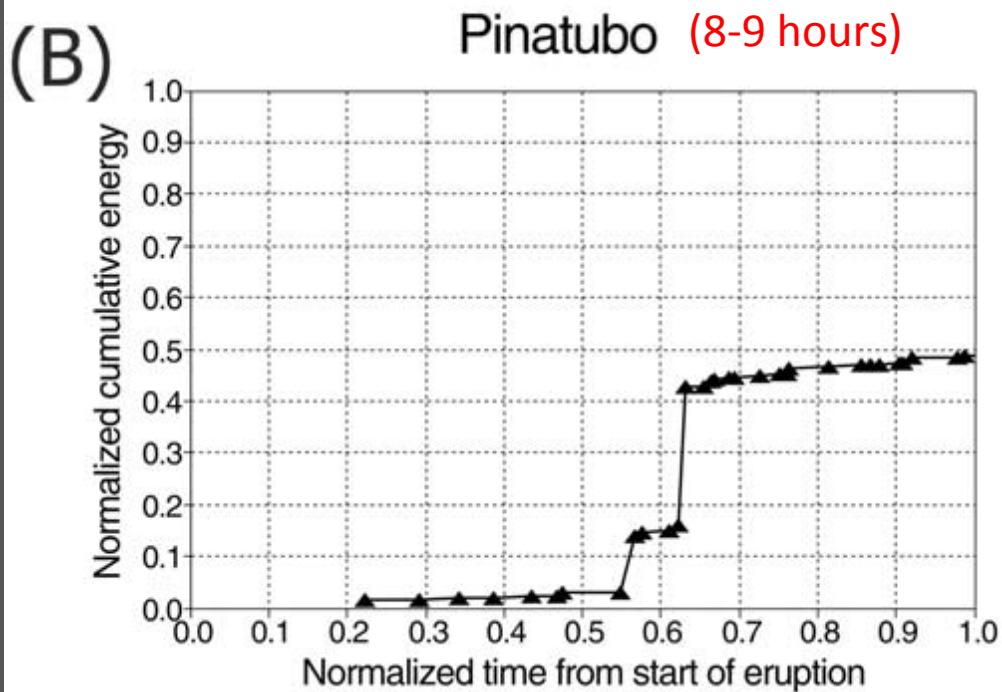
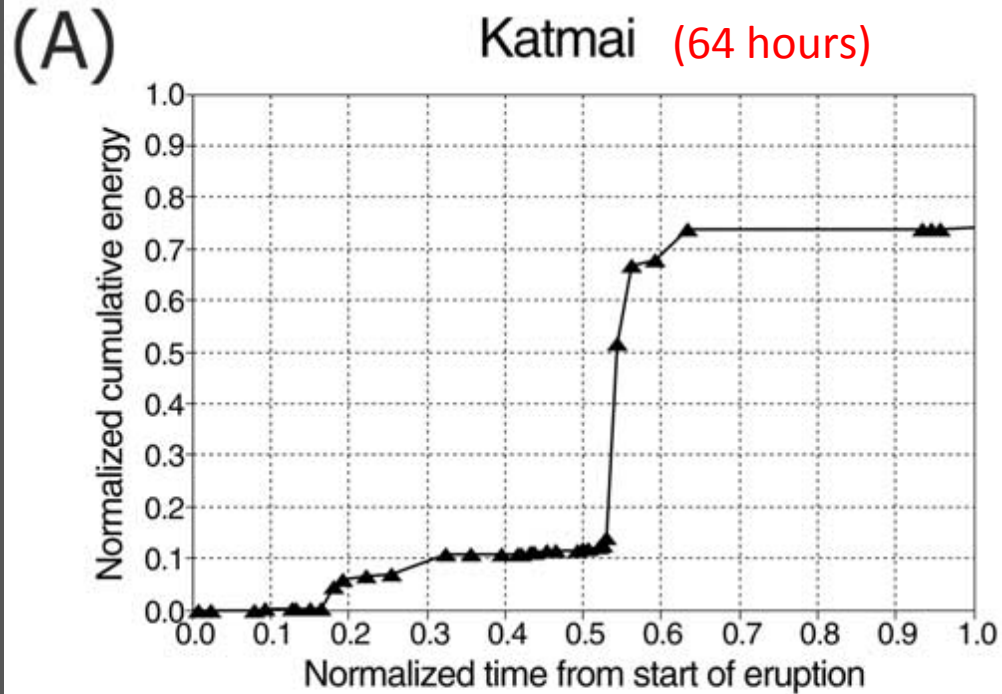


Fernadina Caldera

Piton de la Fournaise
(Michon et la., 2007)

Katmai 1912, Pinatubo 1991

Silicic magma



Basaltic magma

Fernandina 1968

