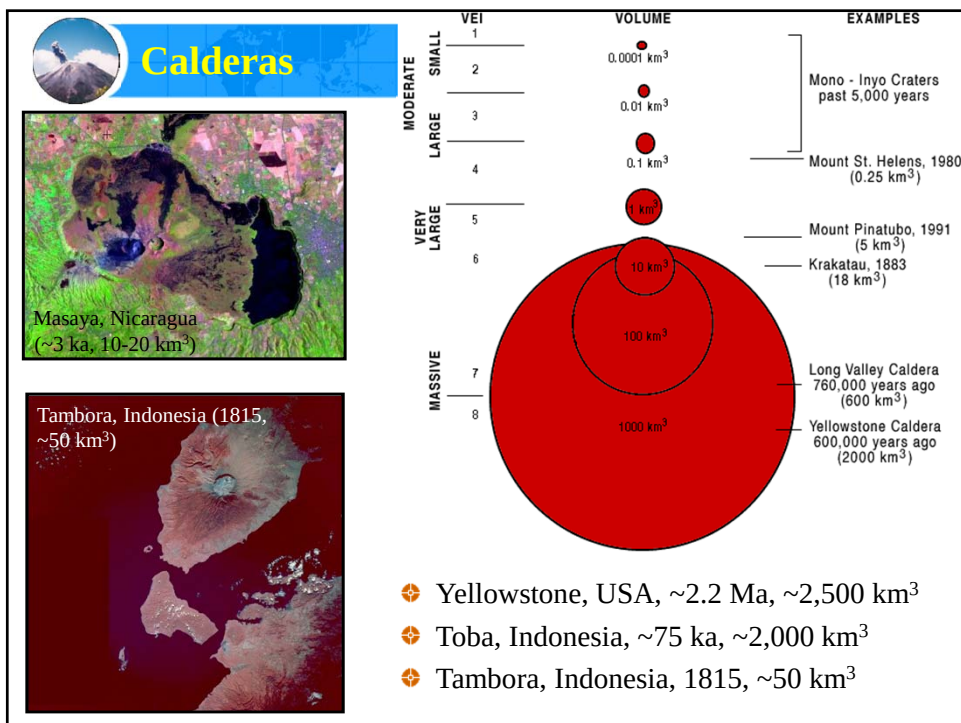


EASC 421 - Volcanology



Calderas





2 basic types

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Mazama-type

- ✦ Volcanoes that have completely blown themselves apart & then collapsed, leaving a huge crater in their place.

✦ Crater Lake, Oregon	75 km ³
✦ Santorini, Greece	39 km ³
✦ Krakatau, Indonesia	20 km ³



Santorini, Greece
(1650 BC)



Krakatau, Indonesia (1883)



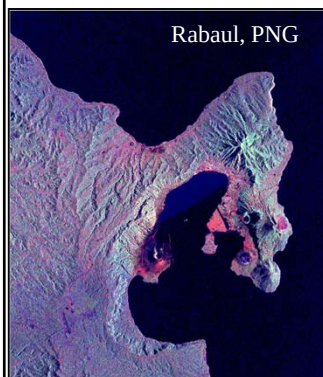
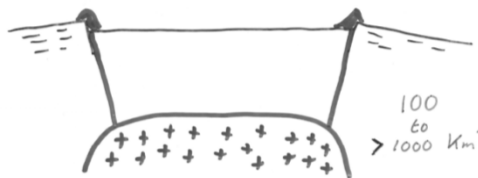
2 basic types

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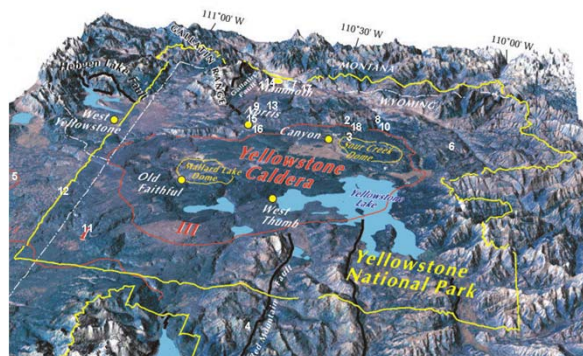
Valles-type

- ✦ Huge elliptical depressions (calderas) above a very large magma reservoir

✦ Long Valley, USA
✦ Yellowstone, USA
✦ Rabaul, Papua, New Guinea
✦ Campi Flegrei, Italy



Rabaul, PNG





Terminology & Definitions

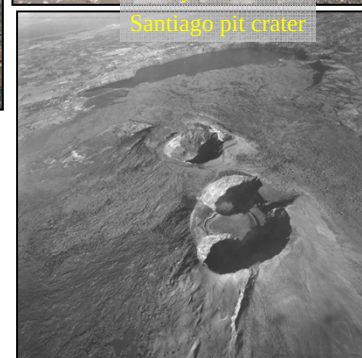
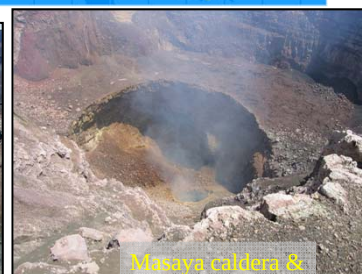
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- ✦ **Caldera:** A large (>1 km?) circular-elliptical depression formed by loss of support and roof subsidence following magma eruption and/or its drainage at depth
- ✦ **Ring-fault:** caldera margin fault along which main subsidence took place
- ✦ **Ring-fracture:** arcuate/ring fracture, commonly parallel to caldera ring-faults
- ✦ **Resurgence:** uplift (tumescence) of caldera floor by rising magma, etc.
- ✦ **Downsagging:** down warping of surface strata to form a caldera without ring-fault
- ✦ **Syncaldera:** “at same time” as caldera collapse
- ✦ **Postcaldera:** following caldera collapse
- ✦ **Nested:** term used to refer to overlapping of two or more calderas at same volcano
- ✦ **Cauldron:** term usually refers to deeply eroded calderas where collapsed “roof” can be observed. Cauldron blocks may be present



Calderas and pit craters

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- ✦ term “pit crater” is rather loosely used
- ✦ most cases refers to “mini-caldera” (<1 km across?) formed by drainage of magma
- ✦ should only be used when evidence of subsidence of floor, otherwise use “crater”



The basics

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- ✦ Common at most large-volume volcano (shield or stratovolcano) of mafic, intermediate or felsic composition
- ✦ Most mafic (& some intermediate) calderas form by drainage of magma at depth or phreatomagmatic explosions
 - ✦ Mafic to intermediate calderas <10 km diam.
- ✦ Most felsic calderas associated with **large-volume** pyroclastic eruptions (ignimbrites)
 - ✦ Felsic calderas up to 75 km diam.
- ✦ Diameter correlates with eruption volume
- ✦ Can collapse incrementally or in a single event
- ✦ Margins can be faulted and/or downsagged
- ✦ Postcaldera effusive vents along caldera margin faults (or parallel faults) common
- ✦ Complex plumbing => eruption & collapse may occur in different areas
- ✦ Simultaneous collapse of adjacent volcanoes has been documented

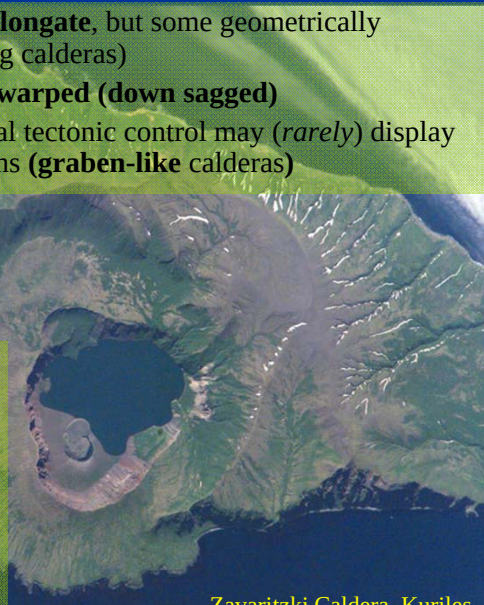


Caldera margins

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- ✦ Most calderas **roughly circular** or **elongate**, but some geometrically complex (esp. in areas of overlapping calderas)
- ✦ Caldera margins -> **ring-faulted** or **warped (down sagged)**
- ✦ Calderas in areas with strong regional tectonic control may (*rarely*) display **linear (or polygonal)** faulted margins (**graben-like calderas**)

- ✦ Ring-faults typically **dip steeply** at surface
- ✦ Single calderas can display **both** types of margin
- ✦ Some calderas display “**trapdoor**” (i.e., faulted on one side & sagged on opposite side) subsidence

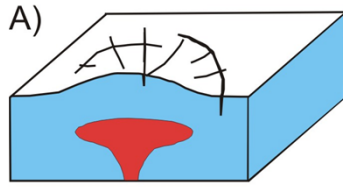


Zavaritzki Caldera, Kuriles

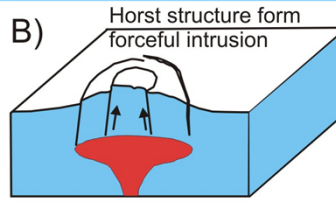


Stage 1 Chamber intrusion Tumescence ?

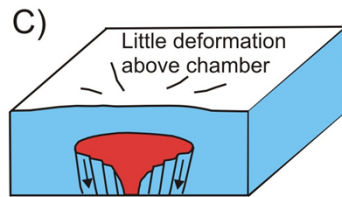
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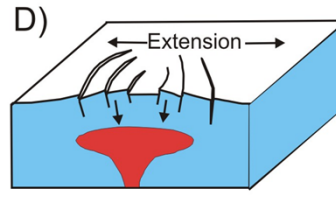
A) Radial and concentric fractures no fault displacement



B) Horst structure form forceful intrusion
Some displacement along faults



C) Little deformation above chamber
Chamber floor depression below chamber



D) Extension
Rifting with curvi-linear normal faults

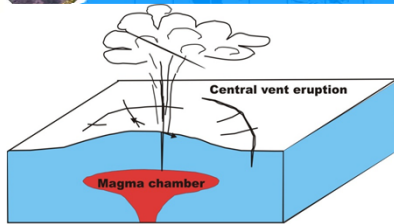


Emplacement of shallow sill-like magma chamber

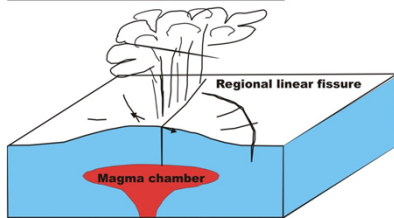


Stage 2 Plinian overpressure ephase

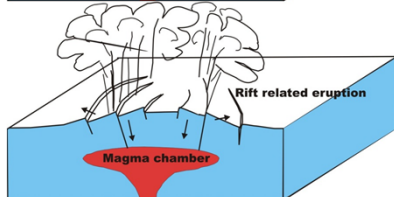
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Central vent eruption



Regional linear fissure



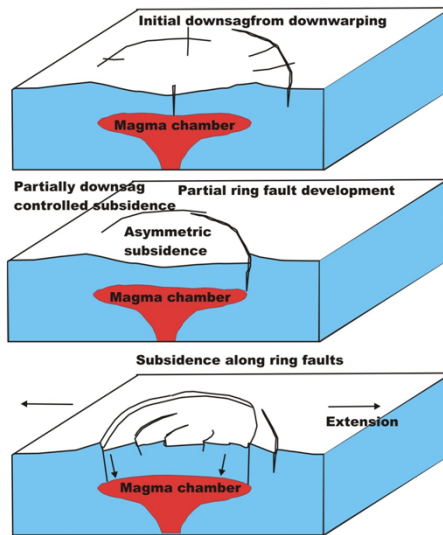
Rift related eruption

- ✦ Initial eruption
 - ▣ related to overpressure
- ✦ Plinian column - fall deposits
- ✦ During eruption
 - ▣ depressurisation and vesiculation in magma chamber
- ✦ Magma chamber becomes foamy unable to support the roof



Stage 3. Onset of subsidence

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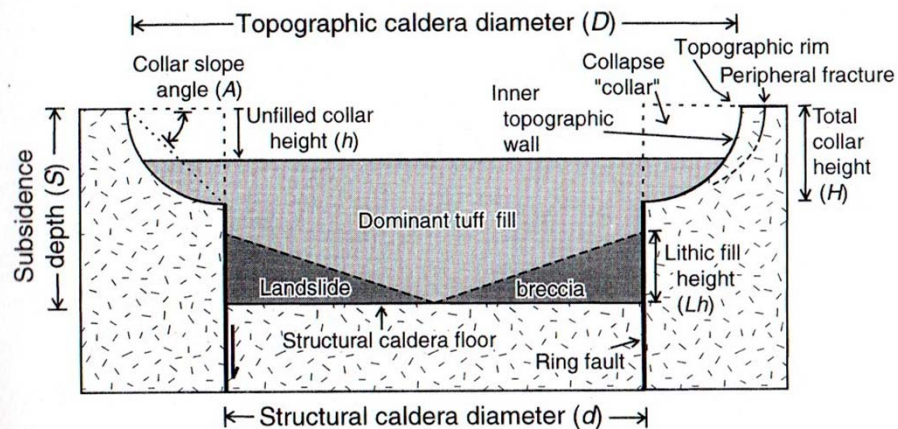


- ✦ Subsidence downsagging
 - ✦ Associated with pyroclastic flow eruption
- ✦ Viscous deformation?
 - ✦ Hot around magma chamber
- ✦ Development of ring fault- lithic distribution-unzipping!
- ✦ Trapdoor subsidence
- ✦ Downsag



Subsidence mechanisms

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- ✦ Simplest (and earliest ideas) involved piston-like (or plate-like) collapse of roof following eruption of voluminous pyroclastics
- ✦ Now know that collapse is in many cases considerably more complex than this

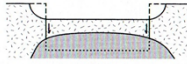


Subsidence models

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“Valles-type”

PLATE (“Piston”)
Single, large volume eruption

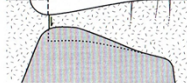


“Krakatoan-type”

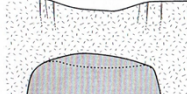
PIECEMEAL
multicyclic?



TRAP-DOOR
asymmetrical pluton?



Downsag
small volume/deep pluton?



FUNNEL
small / deep pluton?

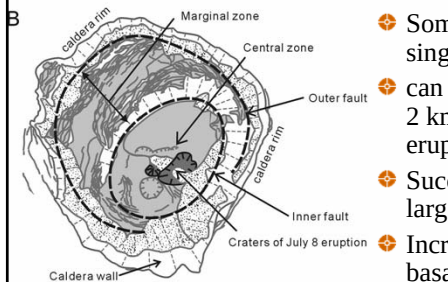
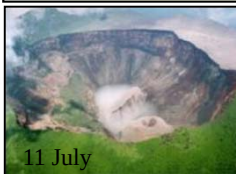
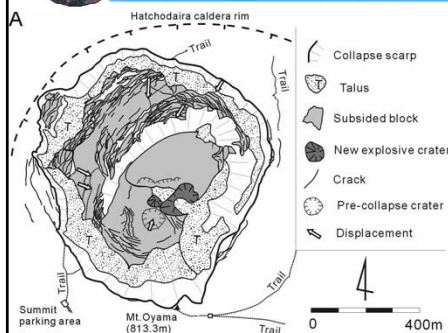


- ✦ Most caldera collapses probably involve >1 process
- ✦ All mechanisms could be incremental or single events
- ✦ All syncaldera eruptives could be associated with some (or dominant) drainage of magma at depth
- ✦ In most(?) cases roof subsidence considered as extension of stoping to the near surface
- ✦ Many small (< few km) calderas probably formed by funnel-like mechanism
- ✦ Could also add “chaotic collapse” to these mechanisms

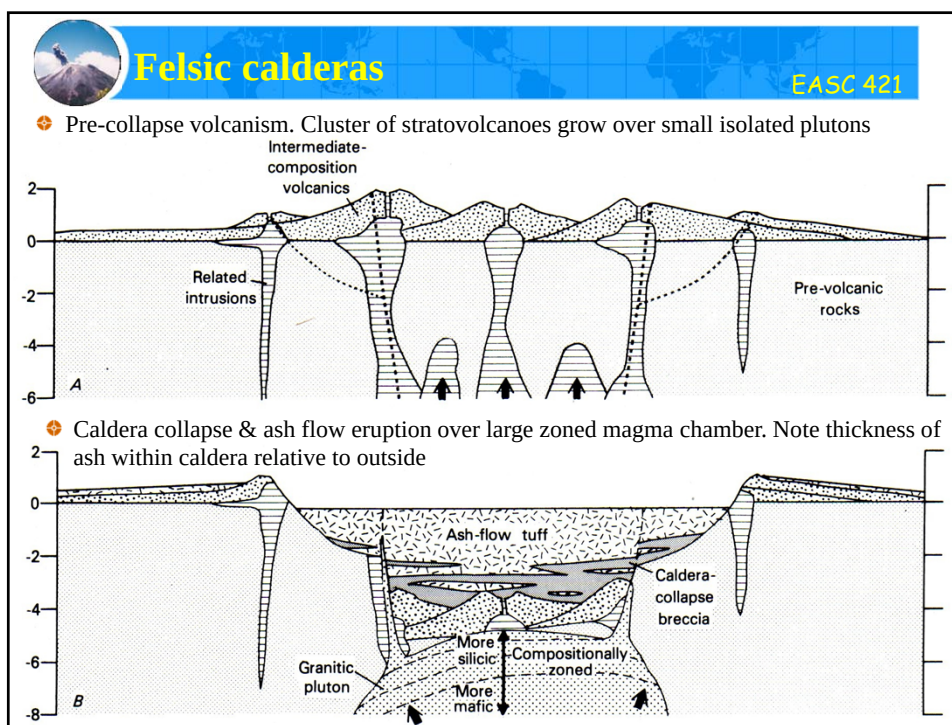
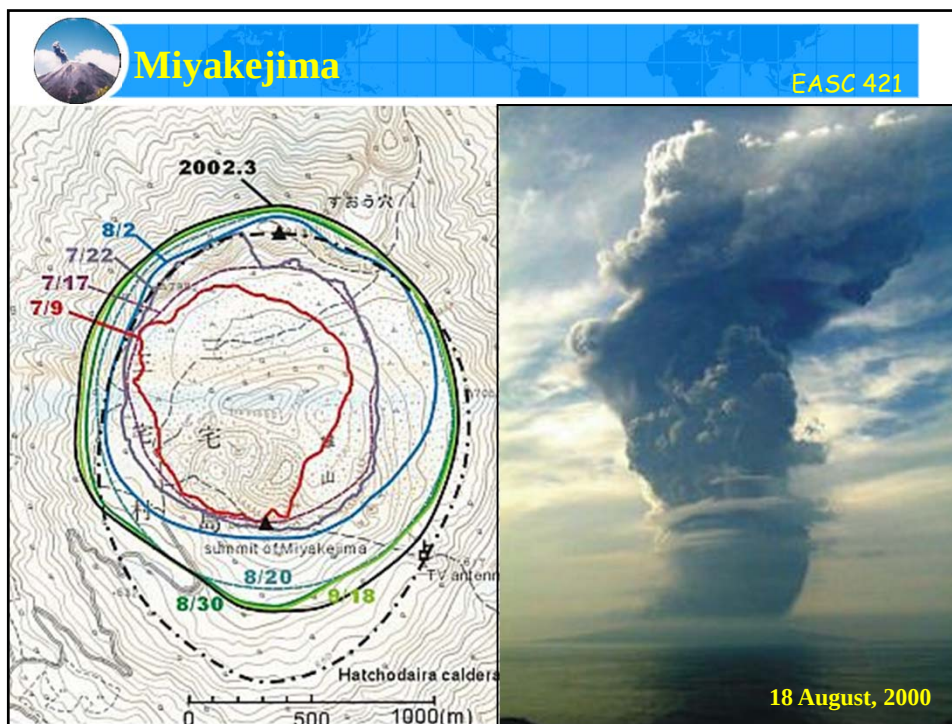


Incremental collapse

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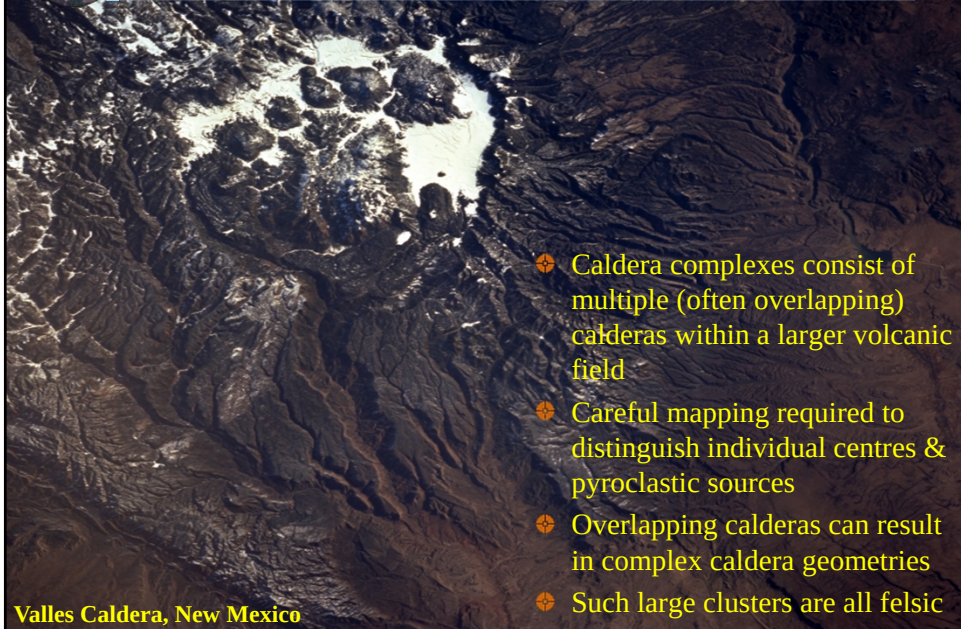
- ✦ Some calderas collapse incrementally not during a single event
- ✦ can be generated by even small vol. eruptions (e.g., 2 km diam. caldera at Pinatubo from 4-5 km³ eruption)
- ✦ Successive small volume eruptions can build up larger calderas (e.g., Katmai, 1912)
- ✦ Incremental collapse probably more common in basaltic calderas (e.g., Kilauea)





Caldera complexes

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- ✦ Caldera complexes consist of multiple (often overlapping) calderas within a larger volcanic field
- ✦ Careful mapping required to distinguish individual centres & pyroclastic sources
- ✦ Overlapping calderas can result in complex caldera geometries
- ✦ Such large clusters are all felsic

Valles Caldera, New Mexico



Basaltic calderas

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- ✦ Majority of mafic calderas form by drainage of magma at depth
- ✦ Most have no or very little associated syncaldera material
- ✦ Some mafic calderas may involve eruption of voluminous of lava flows



Erta Ale, Ethiopian Rift



Intra-caldera fill

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- ✦ Intra-caldera fill can be very complex (particularly its geometry),
 - ✦ typically includes PF deposits (very coarse poorly sorted lag deposits) associated with subsidence, coarse fallout, slide blocks & other collapse “megabreccias” from country rock
 - ✦ later postcaldera facies: lacustrine facies, fluvial facies, domes, lava flows etc.
- ✦ Interbedded ignimbrite lag and caldera wall slide breccias is a common intra-caldera fill



Comagmatic lag breccias



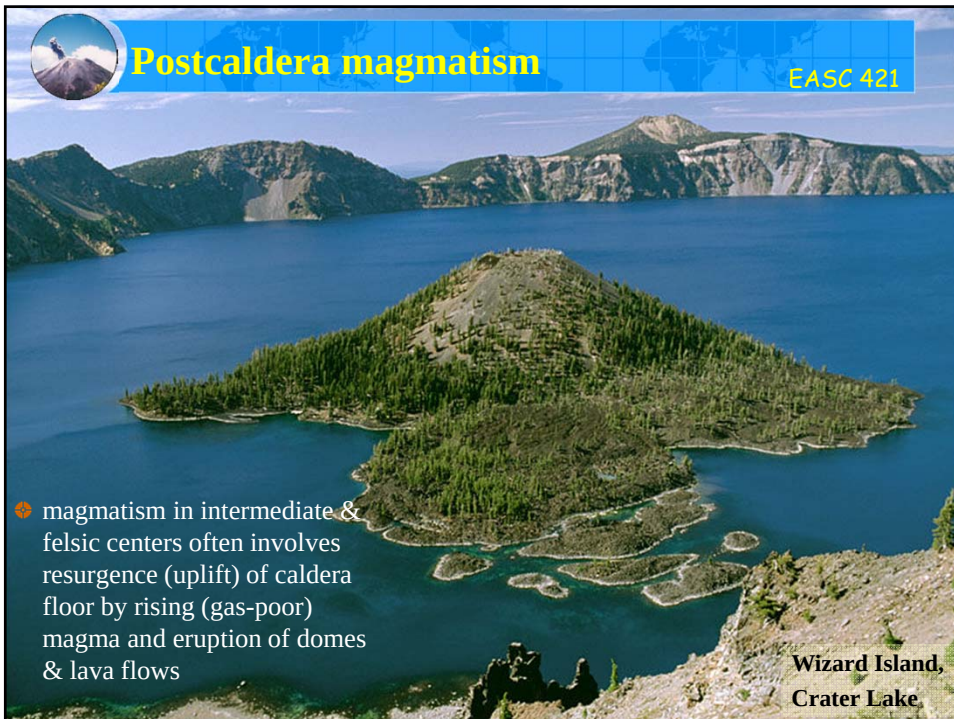
ignimbrites



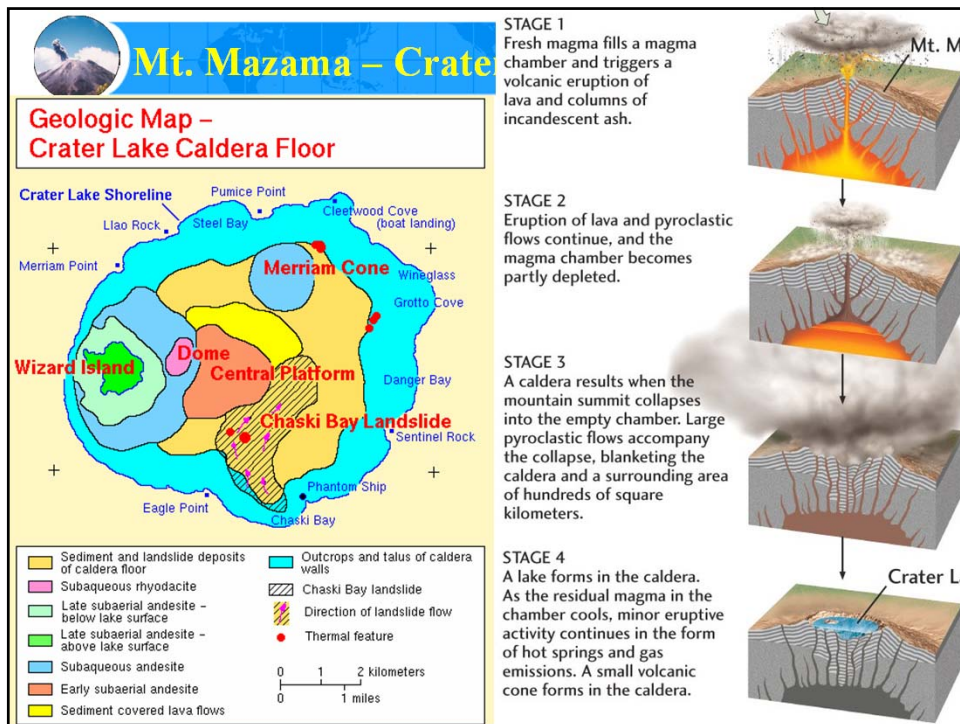
Postcaldera magmatism

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- ✦ magmatism in intermediate & felsic centers often involves resurgence (uplift) of caldera floor by rising (gas-poor) magma and eruption of domes & lava flows



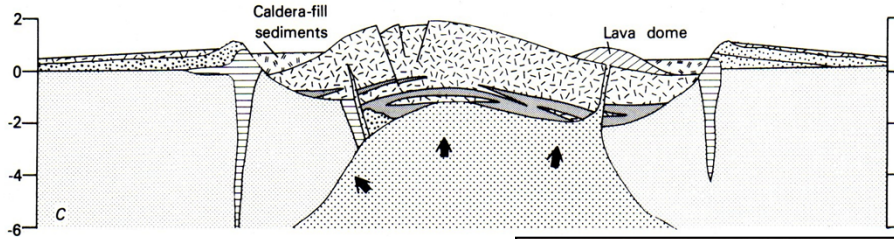
Wizard Island,
Crater Lake





Caldera resurgence

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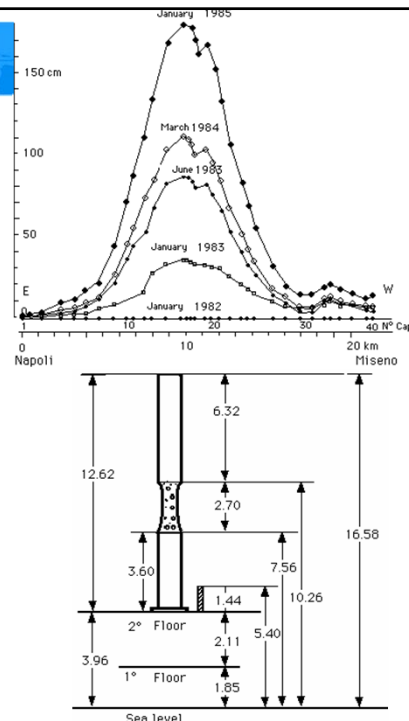


- ✦ Caldera resurgence due to postcaldera rise of large magma body
- ✦ Domed uplift of caldera floor accompanied by eruptions (often low-volume effusive or mildly explosive)
- ✦ Uplifted faulted blocks (sometime on ring faults) may occur
- ✦ **Toba lake** 900 m a.s.l. -> 500 m of uplift

■ multiple episodes of subsidence



Caldera resurgence





Caldera margins: post-collapse modification EASC 421



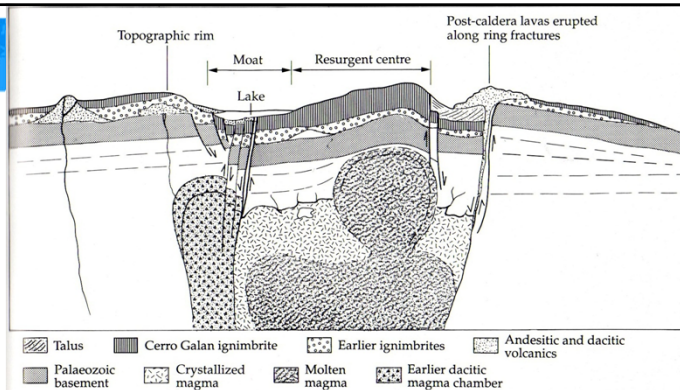
Masaya caldera

- ✦ Original collapse geometry modified by mass wasting of caldera scarp, postcaldera vents & intrusions along ring-fault
- ✦ Mass wasting may give rise to scalloping of walls and a collar of deposits
- ✦ In absence of obvious slideblocks or mass wasting deposits on caldera floor distinguishing primary collapse morphology from later modification can be difficult



Facies

- ✦ Sometimes very difficult or even impossible!



- ✦ **Precaldera:** truncated by caldera ring fault or warped by downsagging
- ✦ **Syncaldera:** commonly large-volume pyroclastic deposits, laterally equivalent flank (“outflow” facies) & intracaldera facies.
 - ✦ Syncaldera facies in caldera margin areas may be disturbed, downfaulted or drape across margin, depending on relative timing of collapse and eruption
 - ✦ (Low-volume) syncaldera facies associated with incremental collapse can be especially difficult to recognise as syncaldera in origin!
- ✦ **Postcaldera:** drapes caldera margins & syncaldera facies, intrudes/erupts along caldera bounding faults or on caldera floor



Long Valley, California

EASC 421

- Caldera (15 x 30 km) formed ~760,000 years ago, following massive outpouring about 600 km³ of ash & pyroclastic flows (Bishop Tuff).
- Most recent volcanic activity (rhyolite flows & domes) was ~250-600 years ago.
- Recent seismic activity & 25 cm uplift of resurgent dome, caused anxiety in the 1980's.



Long Valley, California

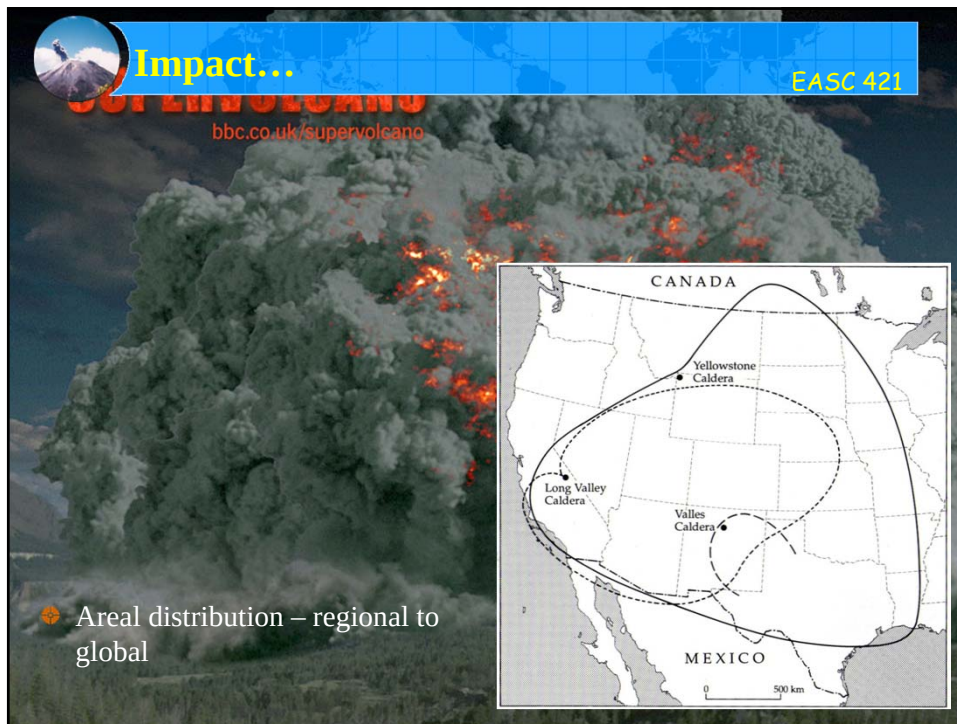
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Views of Long Valley Caldera



Obsidian flows & lava domes



SUPERVOLCANO bbc.co.uk/supervolcano

- ✦ All of these eruptions have occurred within the last 2 million years.
- ✦ Some, within the last 10,000 years.
- ✦ No reason to believe that they won't happen again.
- ✦ have been 3 examples of “caldera unrest” in the 1980's (Long Valley, Rabaul, Campi Flegrei)
- ✦ **Problem:** no idea what to anticipate

Can this type of eruption occur today?