

**FIGURE 48.** Diagram of the Solitario as it appears today. See text and compare with figure 9.

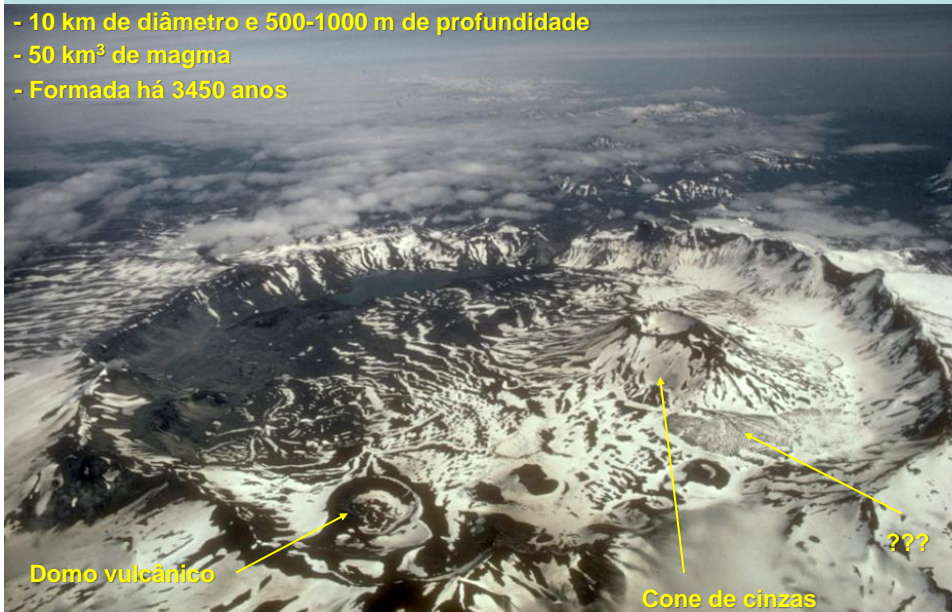
## Crater Lake (Oregon)



## Aniakchak Caldera Aleutian Range

Alasca (USA)

- 10 km de diâmetro e 500-1000 m de profundidade
- 50 km<sup>3</sup> de magma
- Formada há 3450 anos





**Caldeira Mauna Loa (Hawaii)**  
(3 x 5 km e 180 m de profundidade)



***Cauldrom***

- Caldeira vulcânica parcialmente erodida
- Exemplos: Tapajós (Pará), Yellowstone (WY, MT, ID)



**Cauldron Coatepeque (El Salvador)**



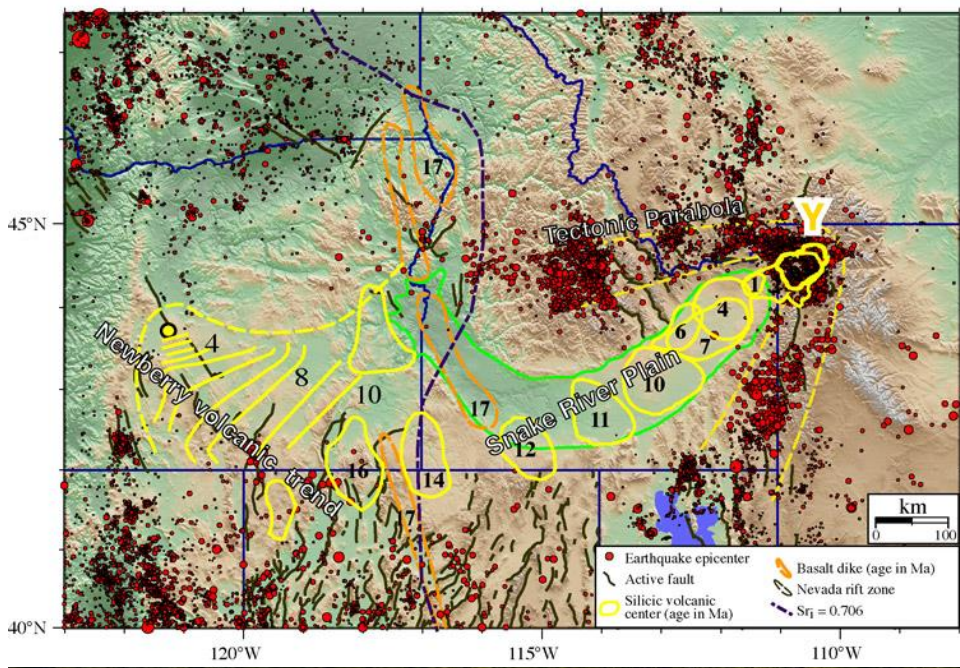
**Cauldron Ilopango (El Salvador)**

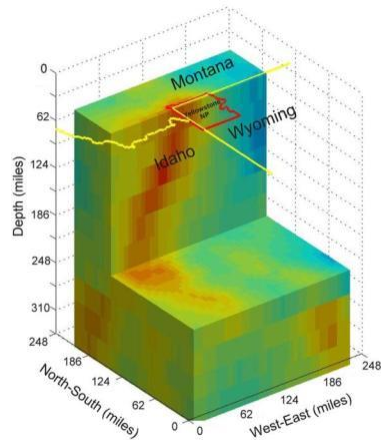
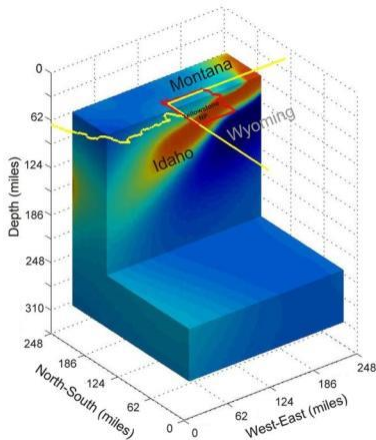
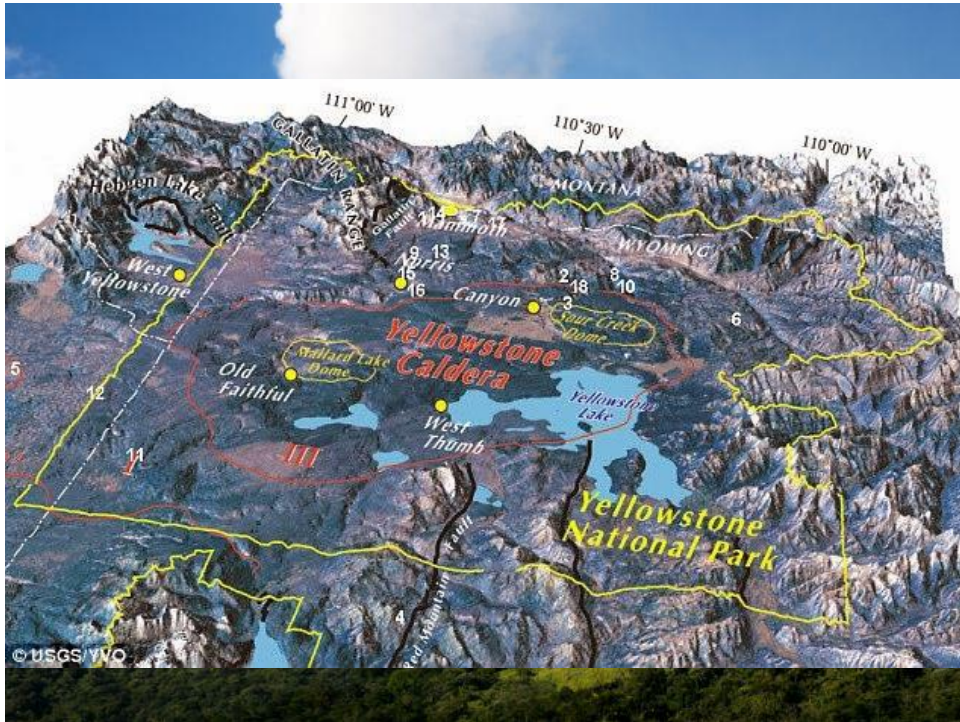


# Caldeiras Vulcânicas Aninhadas ou Complexos de Caldeiras

(*Nested Volcanic Calderas ou Caldera Complexes*)

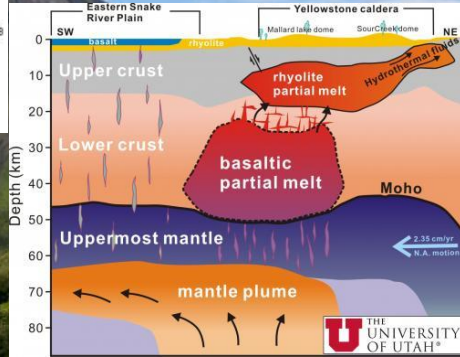
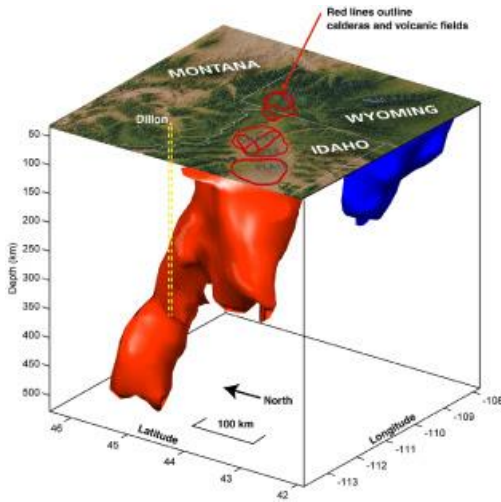
- Conjunto de caldeiras vulcânicas aninhadas ou parcialmente superpostas de diferentes idades  
→ Associações parcialmente preservadas
- Grandes caldeiras em alinhamentos são causadas por vulcanismo associado a *hot spots* continentais
- Exemplo: Yellowstone (WY, MT, ID)





This illustration compares two views of the volcanic plume that feeds the **supervolcano** at Yellowstone National Park. The "geoelectric" image on the left is a new one based on variations in electrical conductivity of rock and fluids underground. It shows the plume dipping about 40 degrees to the west, and the method can only "see" the plume to a depth of about 200 miles (320 km). The more conventional seismic image on the right was made using earthquake waves. The seismic image shows the volcanic plume dipping 60 degrees to the west-northwest and the plume reaches a depth of at least 410 miles (660 km) (this image doesn't go that deep). Together, the two images suggest then Yellowstone hotspot plume is bigger than had been thought based in the seismic image alone. Credit: University of Utah. Read more at: [http://www.redorbit.com/news/science/2030732/scientists\\_map\\_volcanic\\_plume\\_under\\_yellowstone/#Q5KopPHY4v22M00.99](http://www.redorbit.com/news/science/2030732/scientists_map_volcanic_plume_under_yellowstone/#Q5KopPHY4v22M00.99)





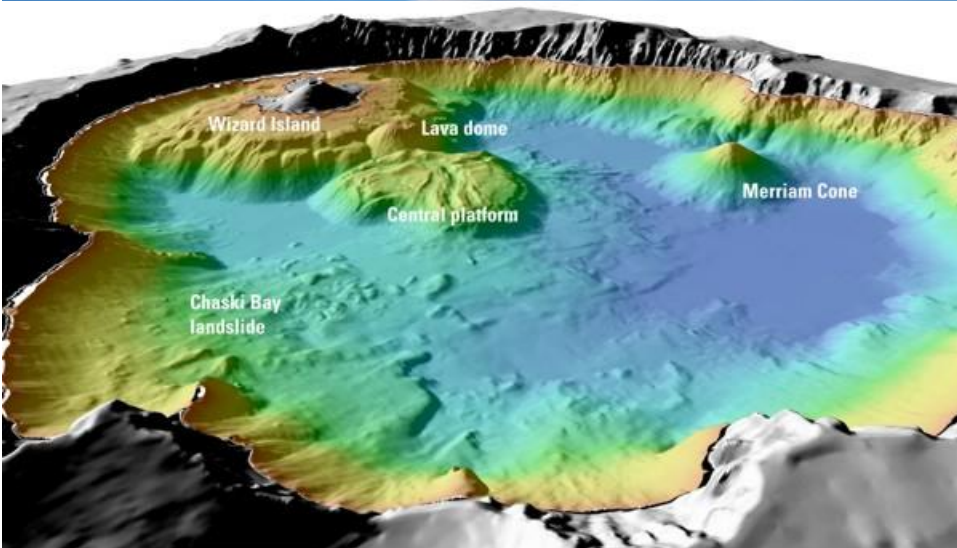
**Monte Mazama (Oregon), há 7.700 anos (pintura)**



## Monte Mazama atual



## Monte Mazama e Crater Lake Batimetria



# Krakatoa 11/08/1883

**Krakatau, Indonesia**

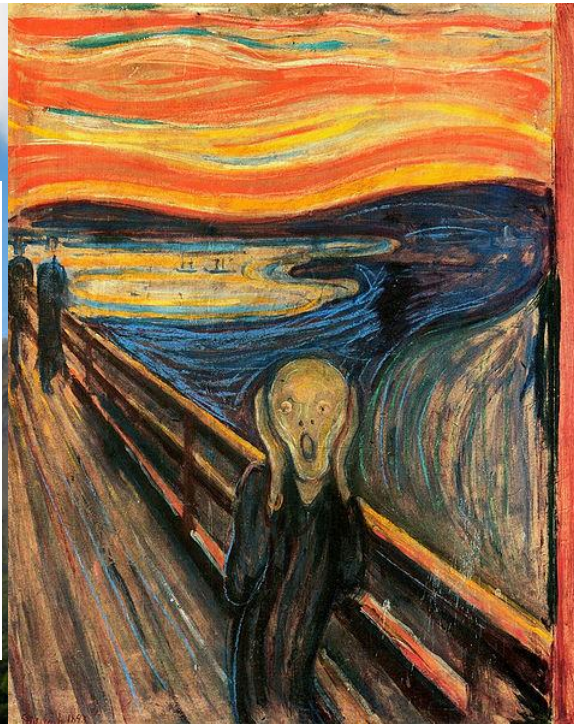
Verlaten Island, Perboewatan, Lang Island, Anak Krakatau, Danau, Rakata, Krakatau Island

Island before 26 August 1883

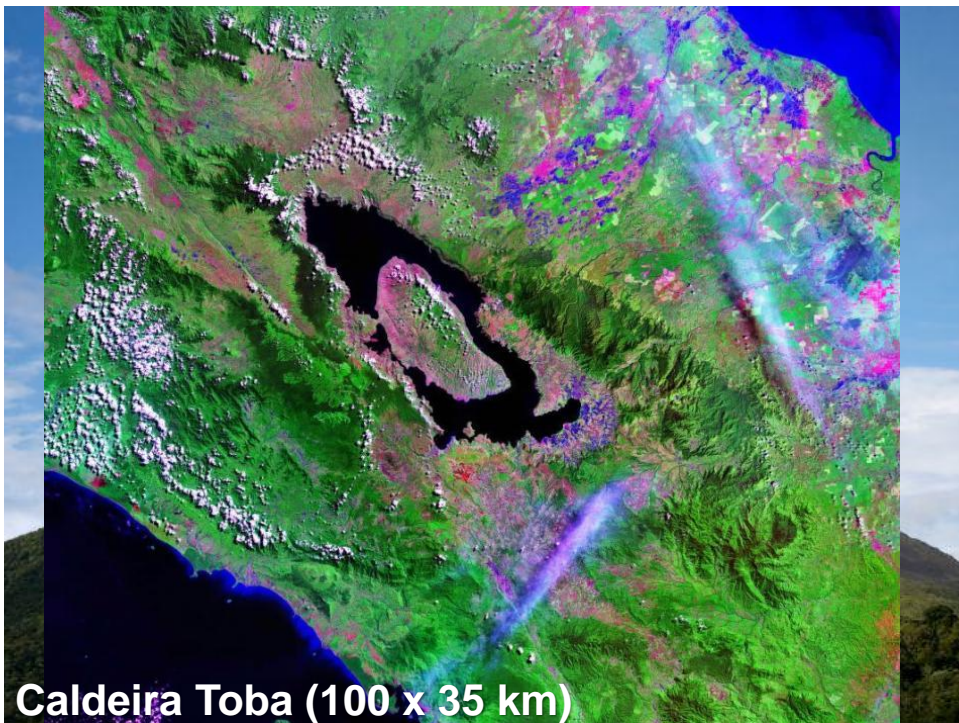
0 5 kilometers  
0 3 miles

**USGS** Topinka, USGS/ICVD, 1999, Modified from: Simkin and Fiske, 1983, Krakatau 1883, Smithsonian Inst.

**Edvard Munch (1863–1944)**

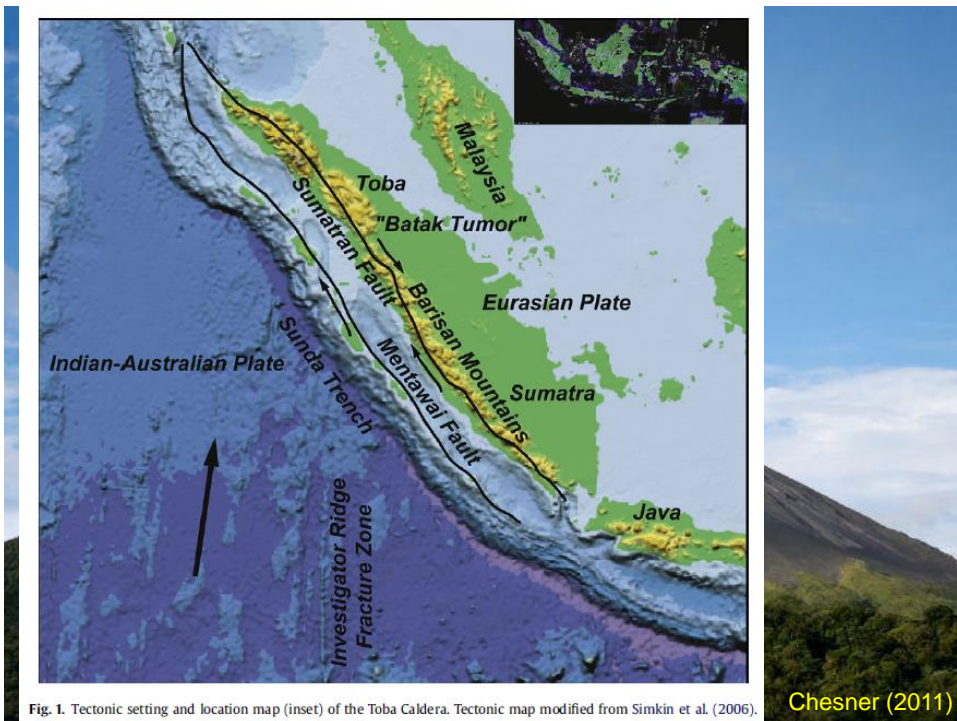


**Caldeira Tambora (Indonésia)**  
**Explodiu em abril de 1815 - “O ano sem verão”**



## Caldeira Toba, Indonésia

- 100 x 35 km e 500 m de profundidade
- 2500 a 3000 km<sup>3</sup> de rochas pulverizadas



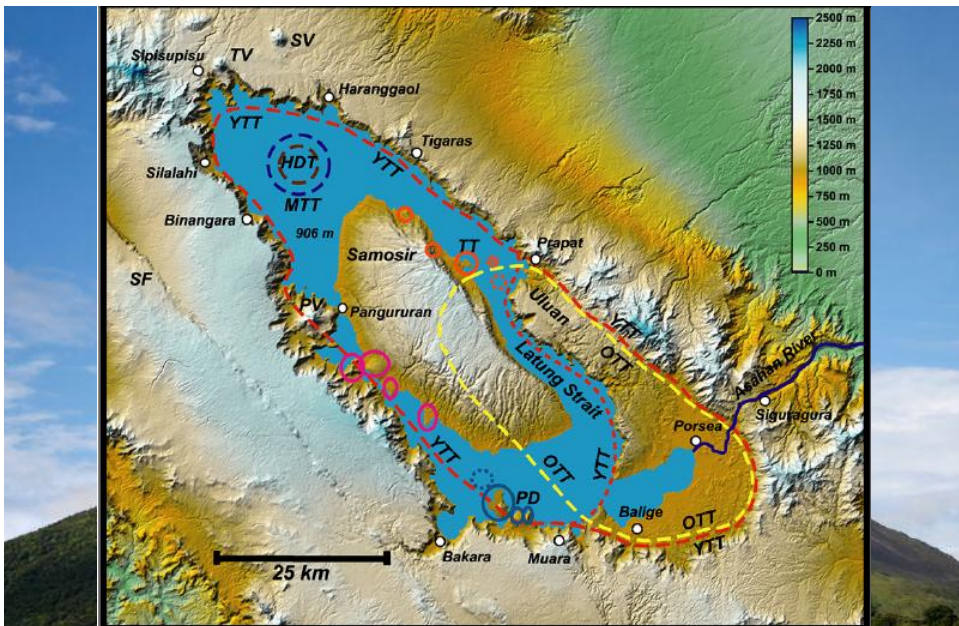


Fig. 2. Toba Caldera Complex location map plotted on base DEM image. Caldera locations indicated by dashed lines where HDT = brown, OTT = yellow, MTT = dark blue, and YTT = red. Inner YTT collapse fault is shown with short red dashes. Samosir lava domes are outlined by orange circles and Pardepur lava domes are light blue. Dotted orange and light blue circles are sub-lacustrine lava domes, identified by bathymetry, that belong to the Samosir and Pardepur lava dome groups respectively. Orange asterisk is possibly an area of sub-lacustrine hydrothermal activity associated with another Samosir lava dome. Pink ovals are areas of recent uplift that may be underlain by hypabyssal intrusions. Abbreviations are: PV = Pusikbukit volcano, PD = Pardepur lava domes, TT = Tuk-Tuk lava domes, TV = Tandukbenua volcano, SV = Singalag volcano, SF = Sumatran Fault. Towns are indicated in white (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

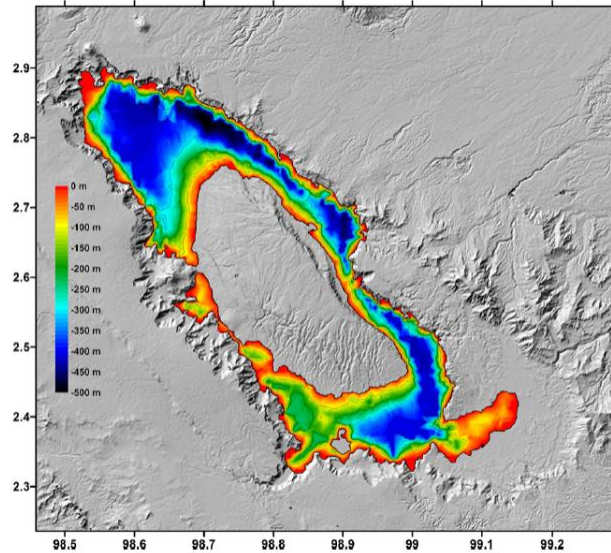


Fig. 6. Bathymetric map of Lake Toba. Depth is represented by isochromes; 100 m contour lines are plotted for reference. Data was gridded using the kriging method and map was generated using *Surfer*® from Golden Software.

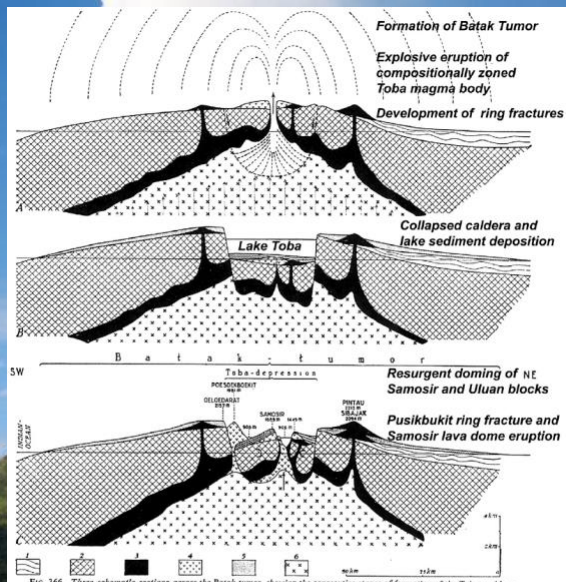
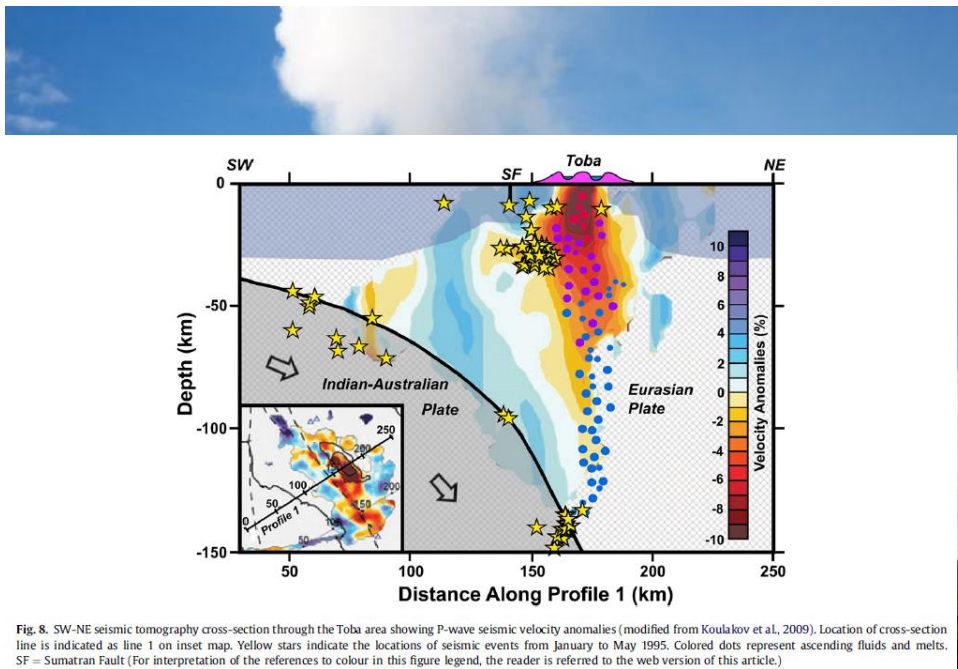
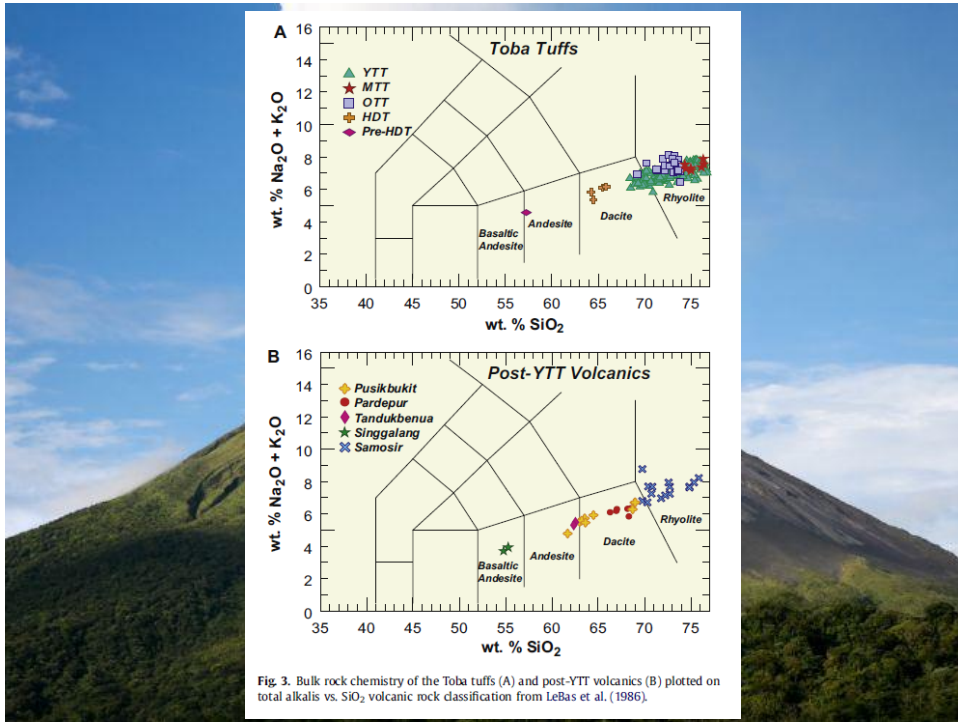


FIG. 366. Three schematic sections across the Batak tumor, showing the consecutive stages of formation of the Toba caldera. (From VAN BENNEKEN, 1939 a, Fig. 4, p. 138)

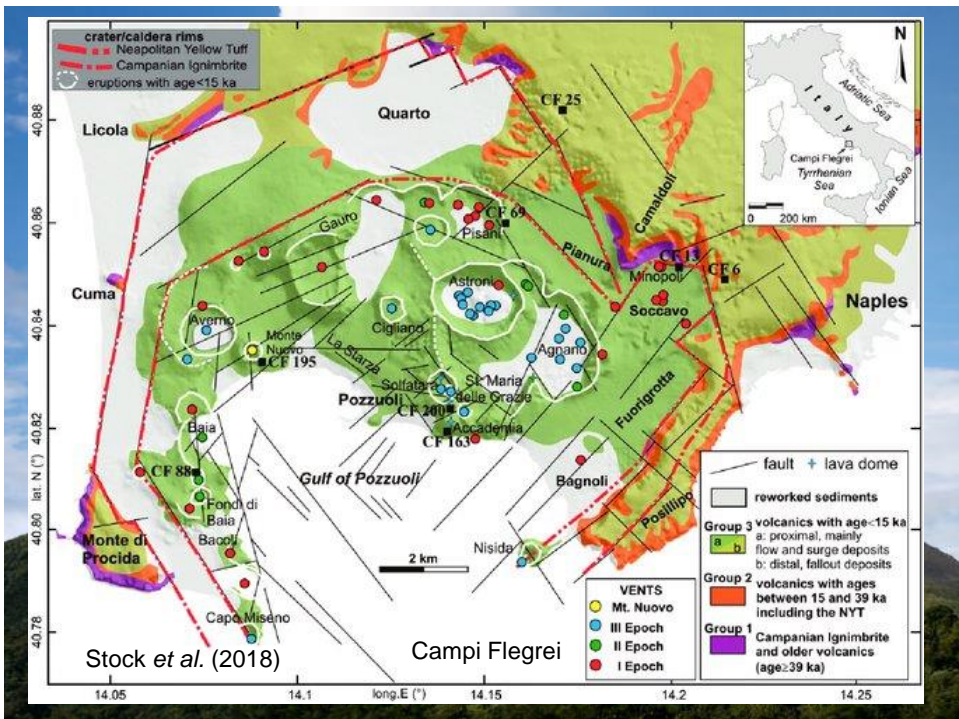
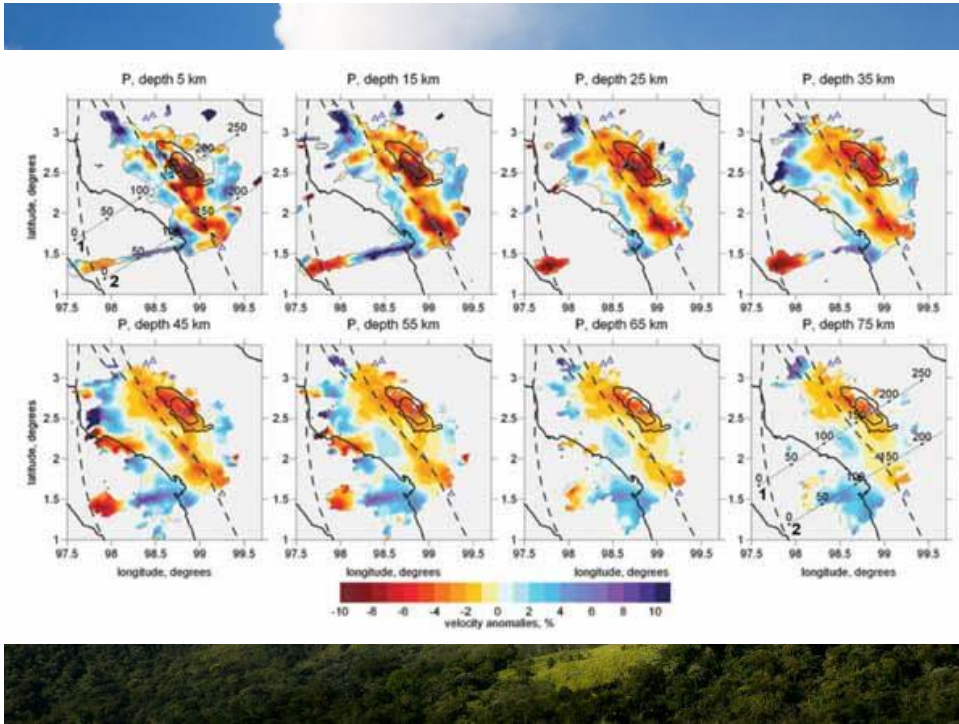
**Key:**  
 1. Neogene marine deposits of the Medan coast.  
 2. Pre-tertiary basement complex.  
 3. Basic-intermediary magmas and eruption products.  
 4. Welded rhyolite tuffs and breccias of Samosir and the Prapai-Porsea Peninsula ("Iginimbrites" according to WESTERVELD, 1967, who surmises that these massive  
 5. Acidic Toba tuffs.  
 6. Granitic Toba batholith.

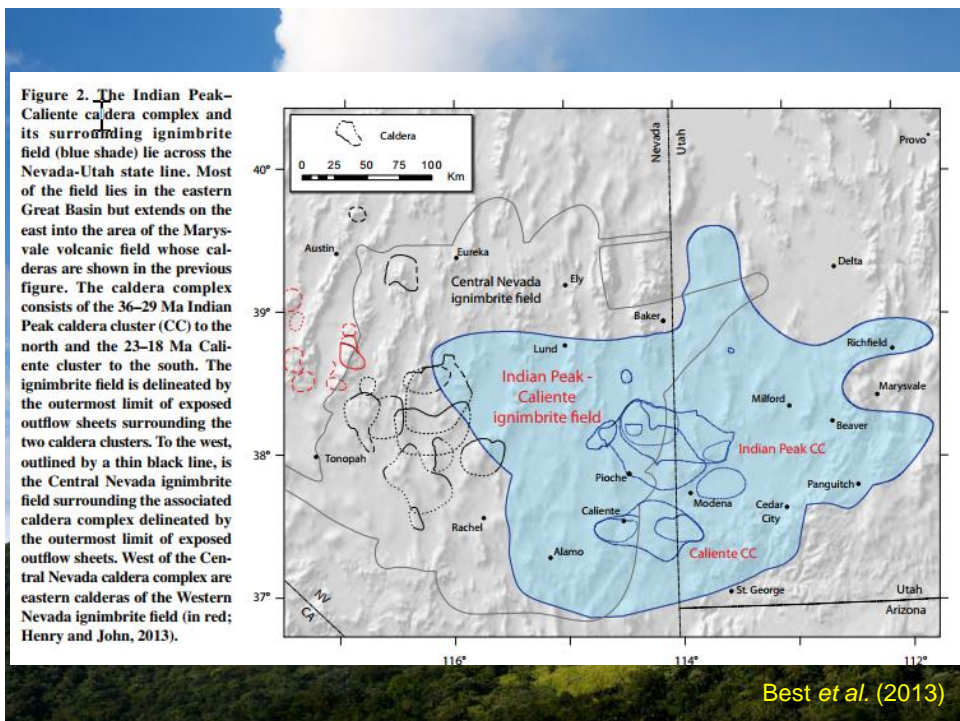
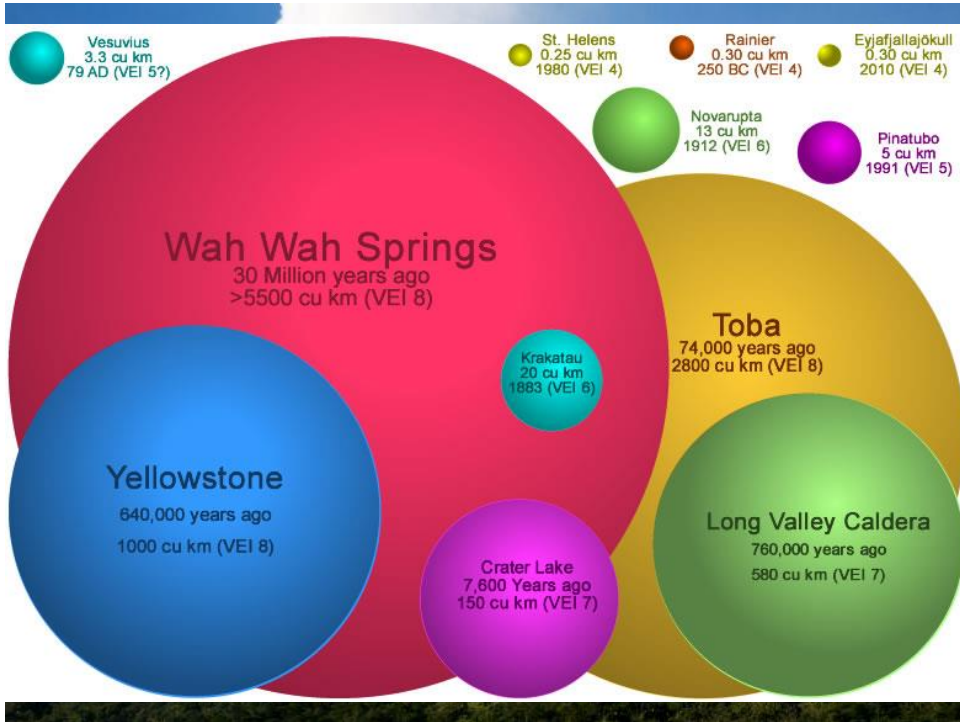
**N.B.** The Sempang-Grahen Zone of pre-Toba age is not distinguished in these sections. It comprises the part of section A between the Toba-tuff eruption and the hypothetical pre-Toba volcanic volcano to the left of it; this part of the section was already a graben-like depression on the top of the Batak submission prior to the Toba eruption.

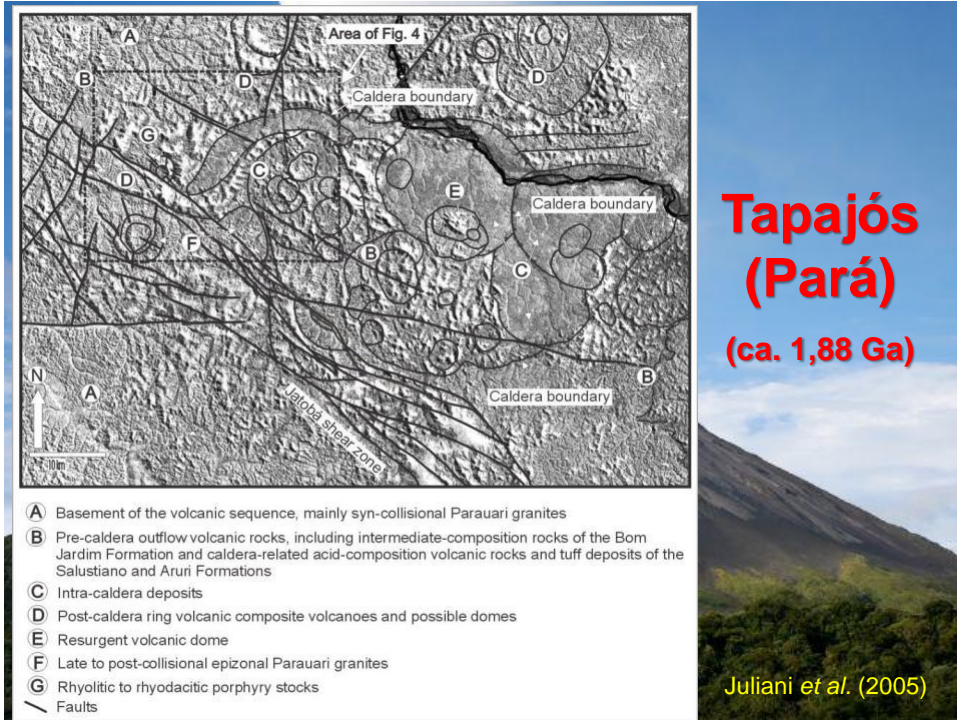
Fig. 5. Van Benneken's (1939) original depiction of caldera formation and resurgent doming at Toba. Annotations have been added in bold italics.

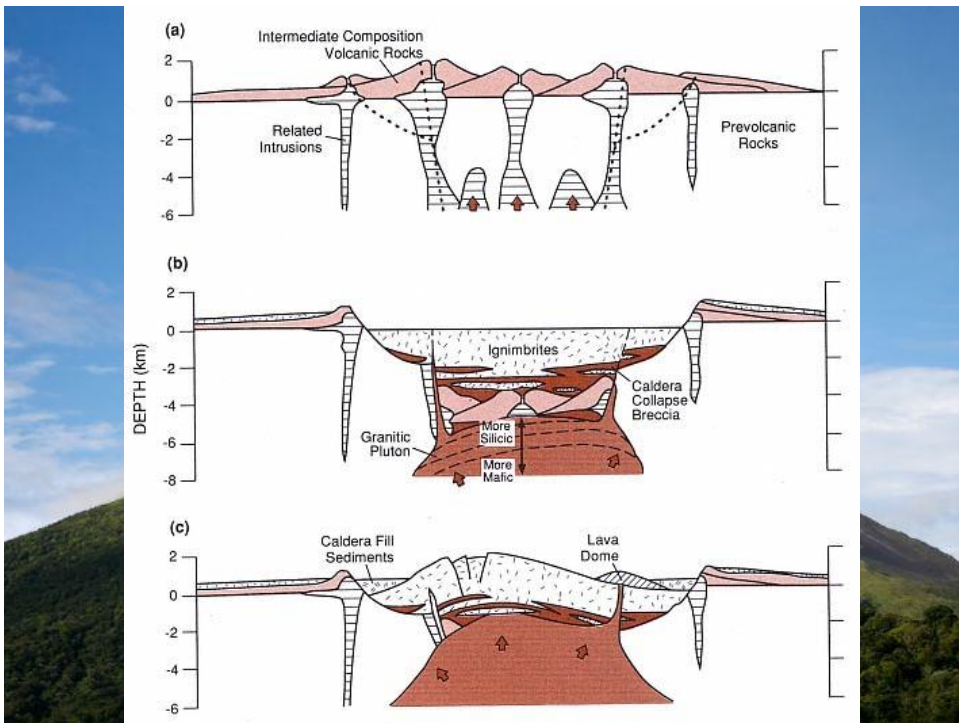
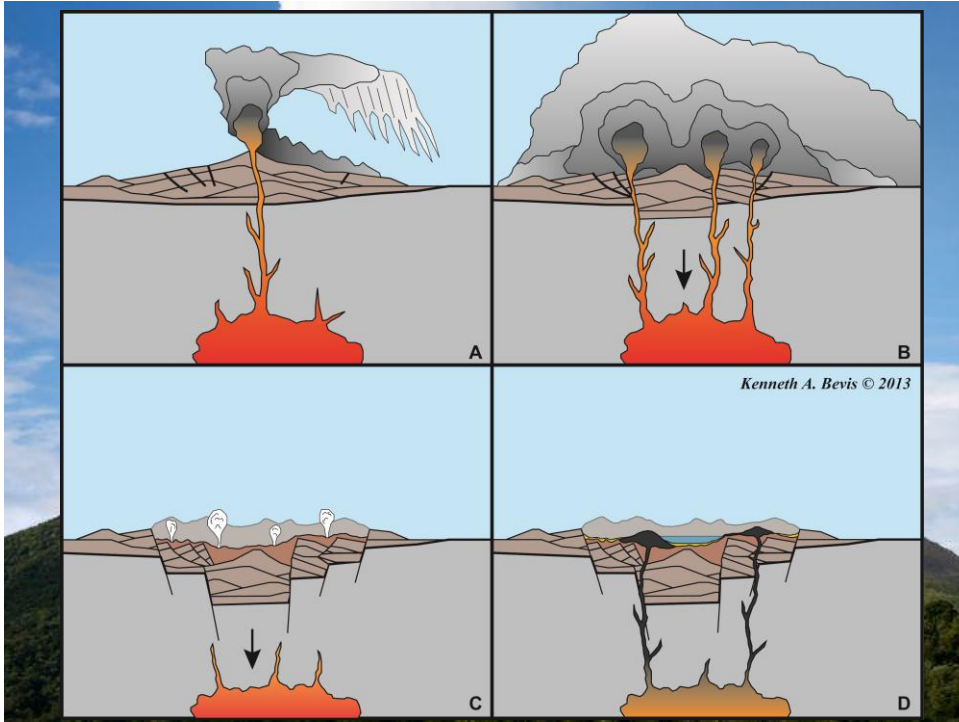


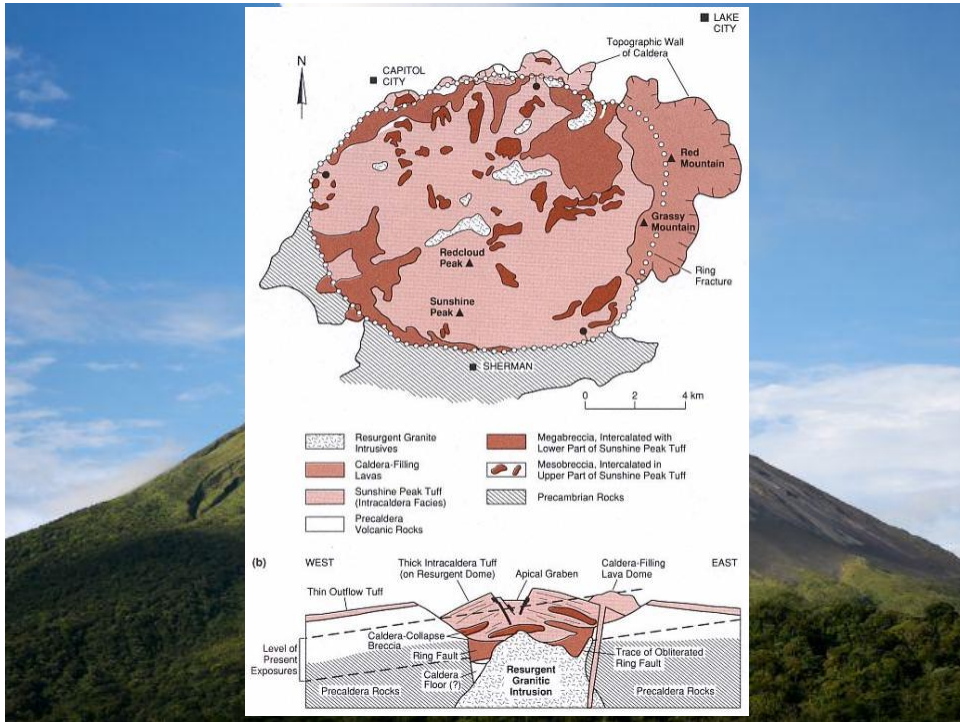












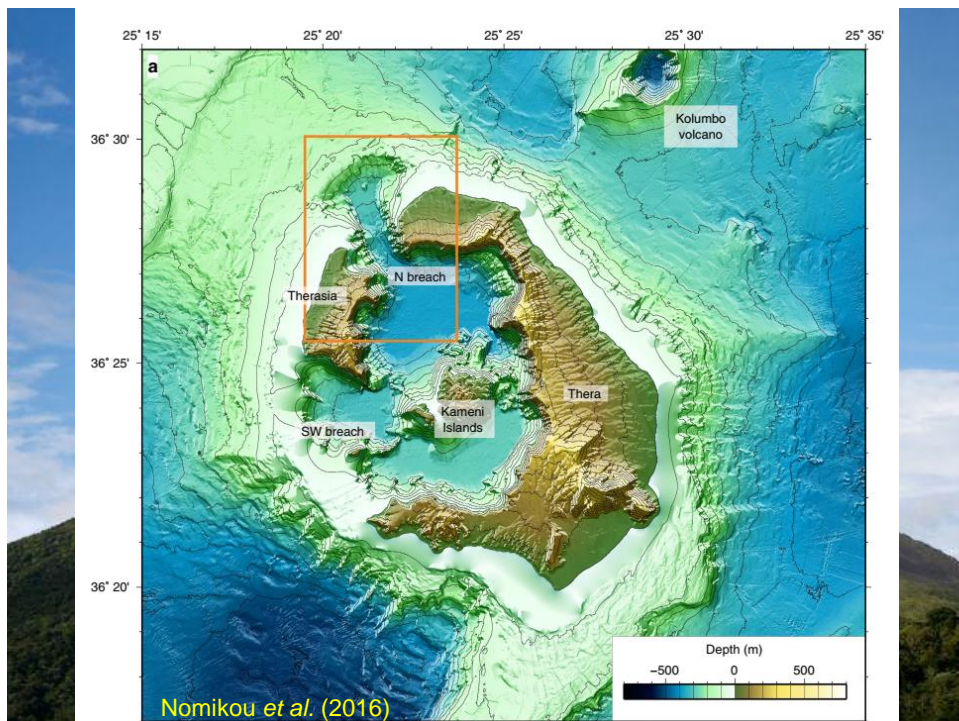


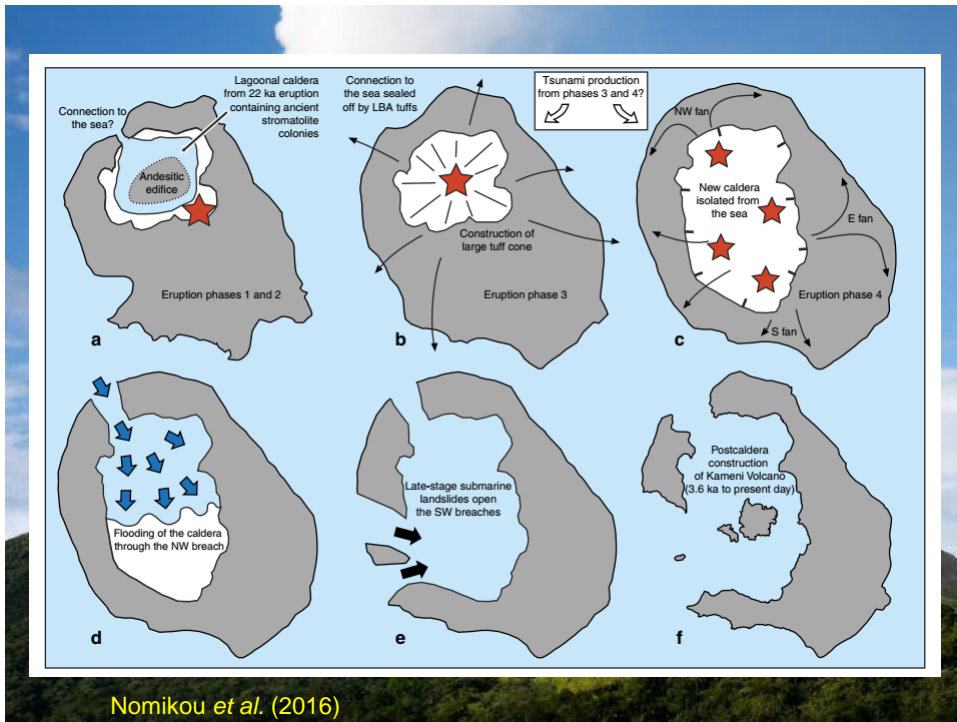
## Desenvolvimento de uma Caldeira Vulcânica

- Vulcanismo pré-caldeira ou pré-colapso → vulcanismo, tumescência, domos de lavas e pequenas atividades explosivas
- Subsidência da caldeira → Colapso associado a vulcanismo em larga escala, iniciado na zona central (comumente estrato-vulcões) que evoluem para vulcanismo nas falhas anelares e radiais, com grande produção de ignimbritos e cinzas vulcânicas

## Desenvolvimento de uma Caldeira Vulcânica

- Vulcanismo pós-caldeira ou pós-colapso → vulcanismo causado pela re-alimentação da câmara magmática, errático ou formando vulcões anelares (internos e externos), radiais, em estruturas tectônicas prévias, domos ressurgentes.
- Há novo soerguimento nessa fase e intrusão de subvulcânicas como diques e stocks de pórfiros





## Depósitos Formados em Caldeiras Vulcânicas

- **Estágio pré-caldeira:** vulcanoclásticas e lavas, principalmente pequenos domos. Raramente preservado e de difícil identificação
- **Estágio sin-caldeira:** nas fases iniciais formam-se estrato vulcões e quando evolui para o vulcanismo anelar, grandes depósitos de ignimbritos e tefras. Pode ser fortemente explosivo, pulverizando os depósitos pré-formados

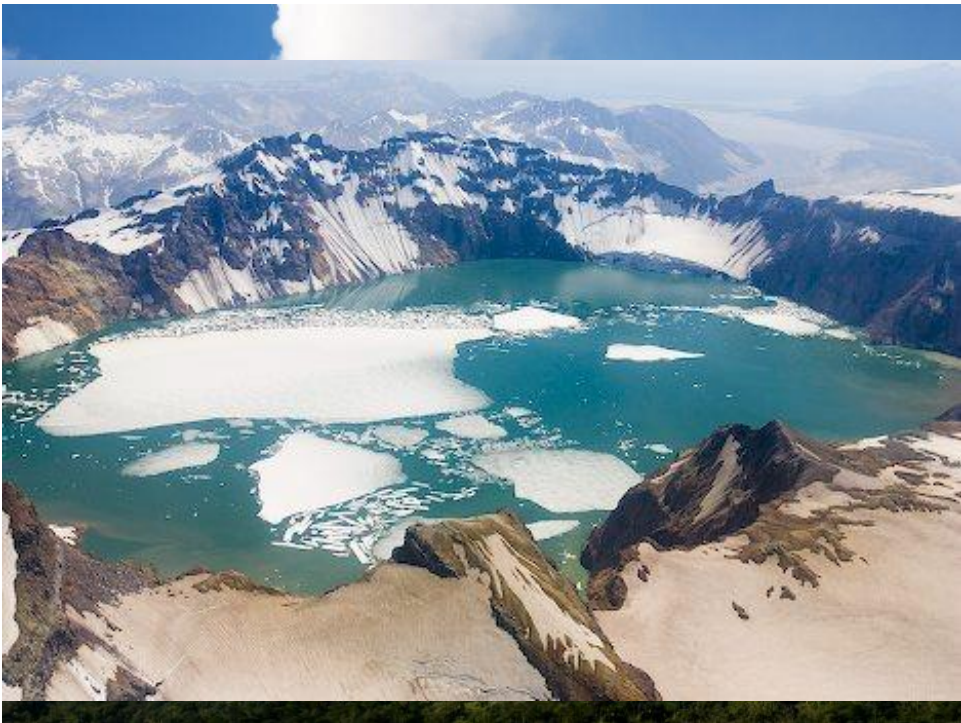


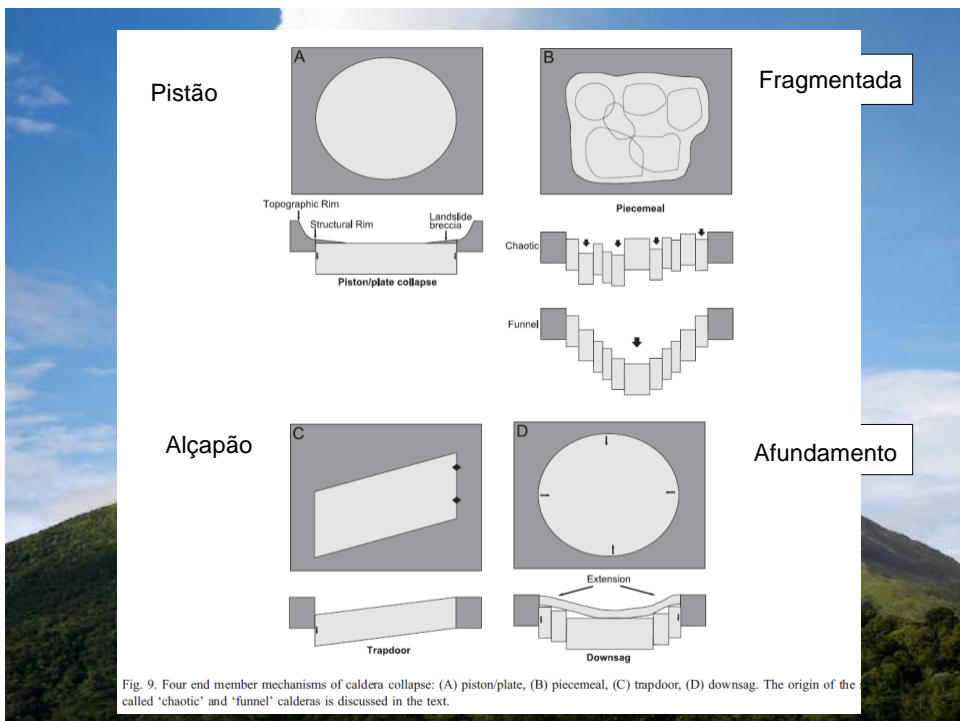
## Depósitos Formados em Caldeiras Vulcânicas

- **Estágio pós-caldeira:** ignimbritos, domos de riolitos, sub-vulcânicas, pórfiros. Destacam-se os **domos ressurgentes** e depósitos associados aos vulcões anelares e radiais.
- **Intra-caldeira:** rochas vulcanoclásticas, ignimbritos, sedimentos lacustres, depósitos de fluxo de massa, escorregamentos de grande blocos as paredes das caldeiras. Precedem e acompanham o estágio pós-caldeira. Depósitos de leques aluviais são comuns. Podem ter depósitos marinhos, fluviais e eólicos.

## Desenvolvimento de uma Caldeira Vulcânica

- **Hidrotermalismo e mineralização** → pode ocorrer ao longo de toda evolução da caldeira, mas essa é a fase mais importante
- Esses estágios podem ser recorrentes na formação de uma caldeira





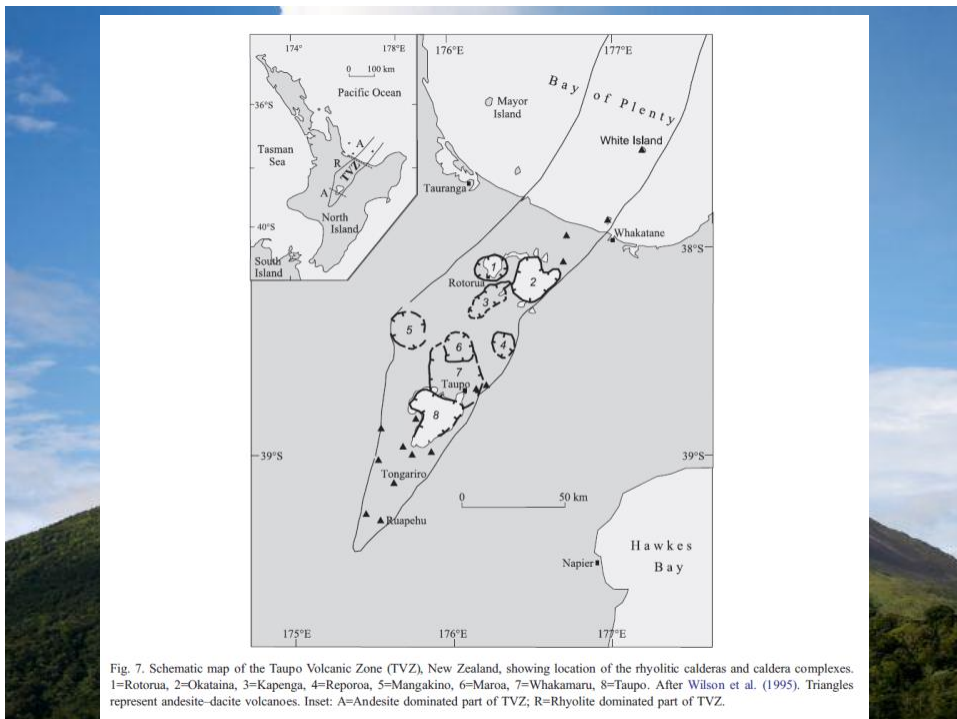
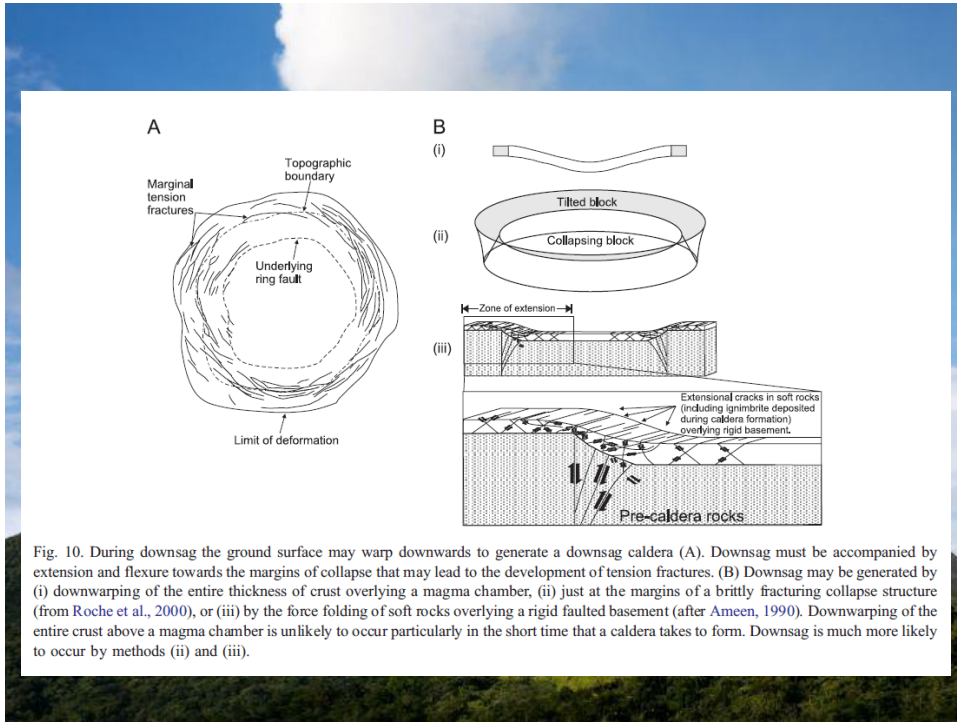


Table 1  
Comparison of classifications by Williams (1941), Williams and  
McBirney (1979) and Lipman (1995)

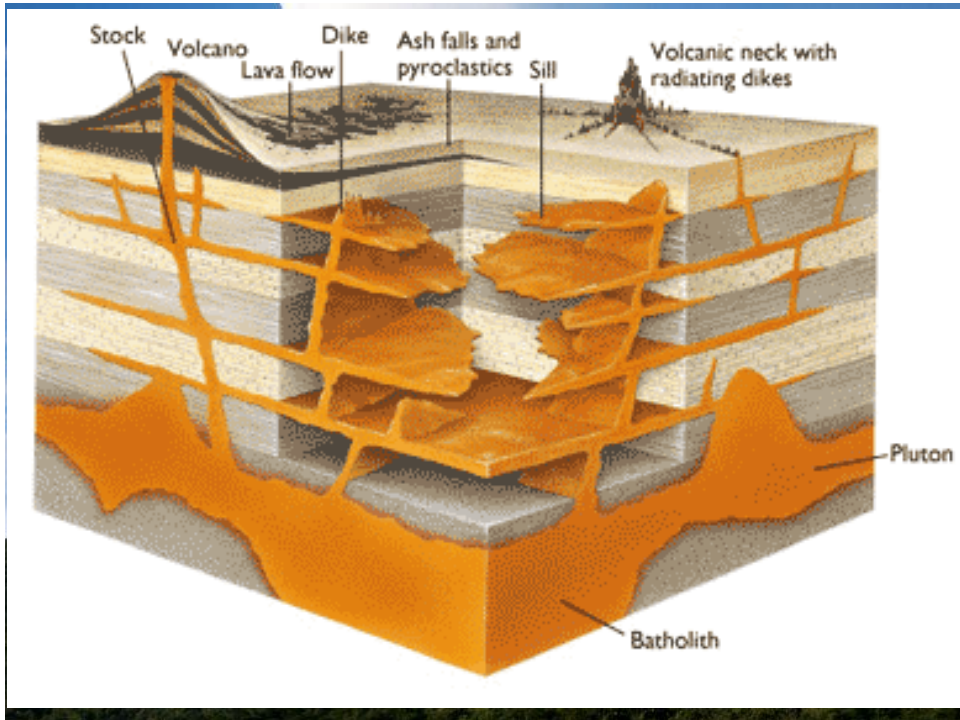
Williams (1941)	Williams and McBirney (1979)	Lipman (1995)
Explosion		
Collapse		
Krakatau	Krakatoan	Plate (piston)
Kilauea	Hawaiian	Piecemeal
Katmai	Katmai	Downsag
	Valles	Trapdoor
	Galapagos	Funnel
	Masaya	
	Atitlan	
Cryptovolcanic		
Glen Coe		
Miscellaneous		
Erosion		
Volcanic graben		
Summit		
Sector		
Volcanic vents or fissure troughs		
Major volcano- tectonic depressions		

## Classificação

*Cole et al. (2005)*



## Relevos Vulcânicos



## Derrames (*lava flows*)



## Tubos ou Tuneis de lava



## Nahuku Lava Tube

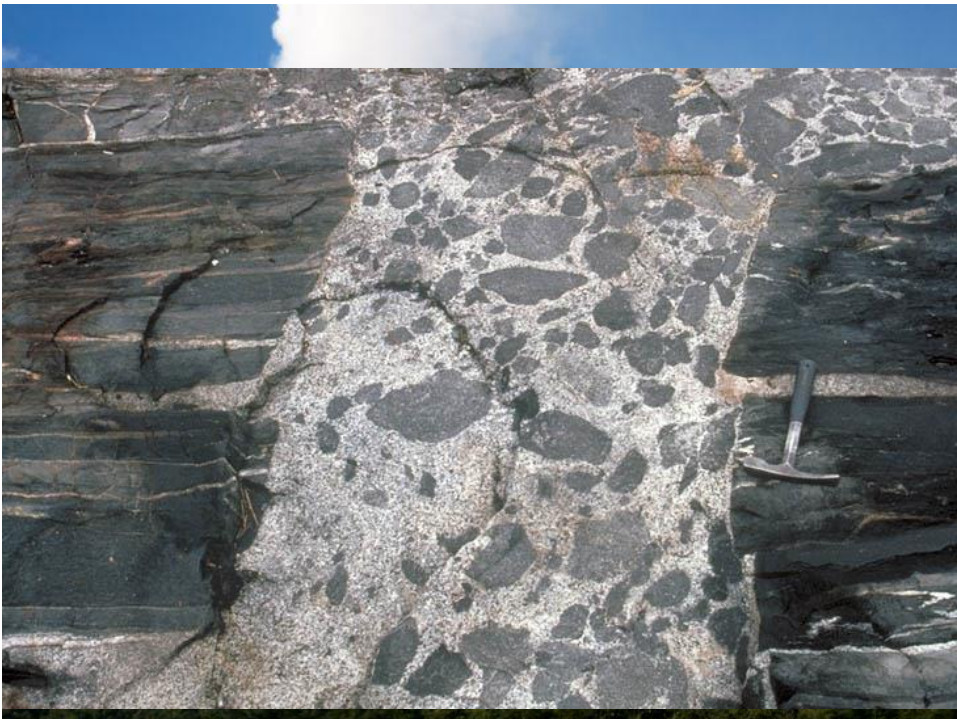


(Próximo do cume da caldeira do vulcão Kilauea no Parque Nacional dos Vulcões)

# Diques (*dikes*)







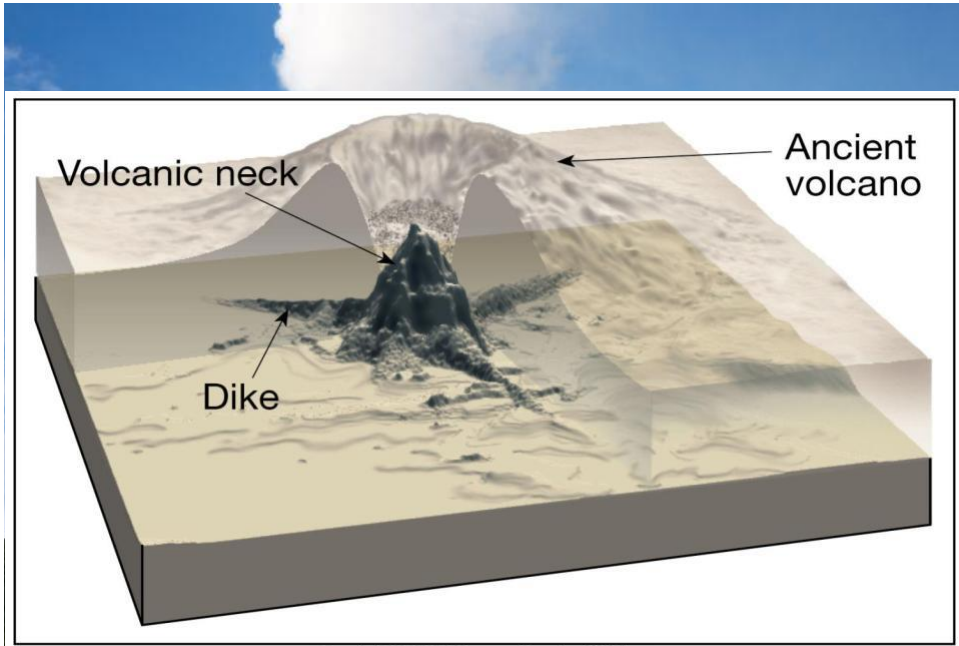
## **Sills**



## **Necks ou Plugs Vulcânicos**

- São remanescentes da erosão de edifícios e condutos vulcânicos
- Exemplo: Shiprock, N.M.





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## Neck vulcânico Shiprock, N.M.







## ***Pipes vulcânicos***

- São formados por explosões intensas, de origem profunda.
- Exemplo: Kimberley, África do Sul



**Pipe vulcânico**

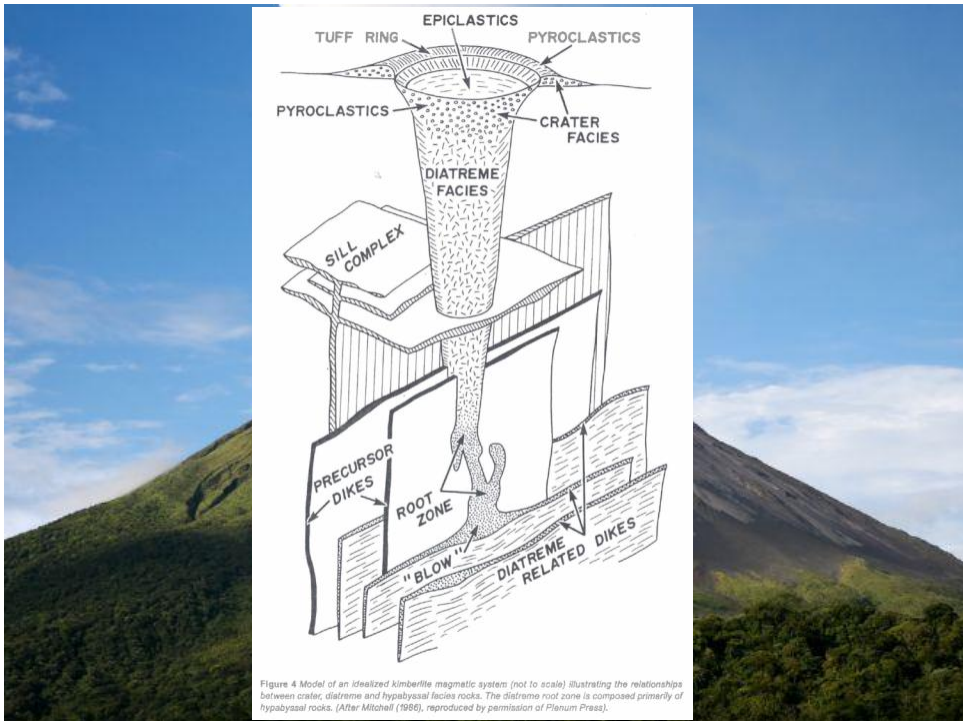
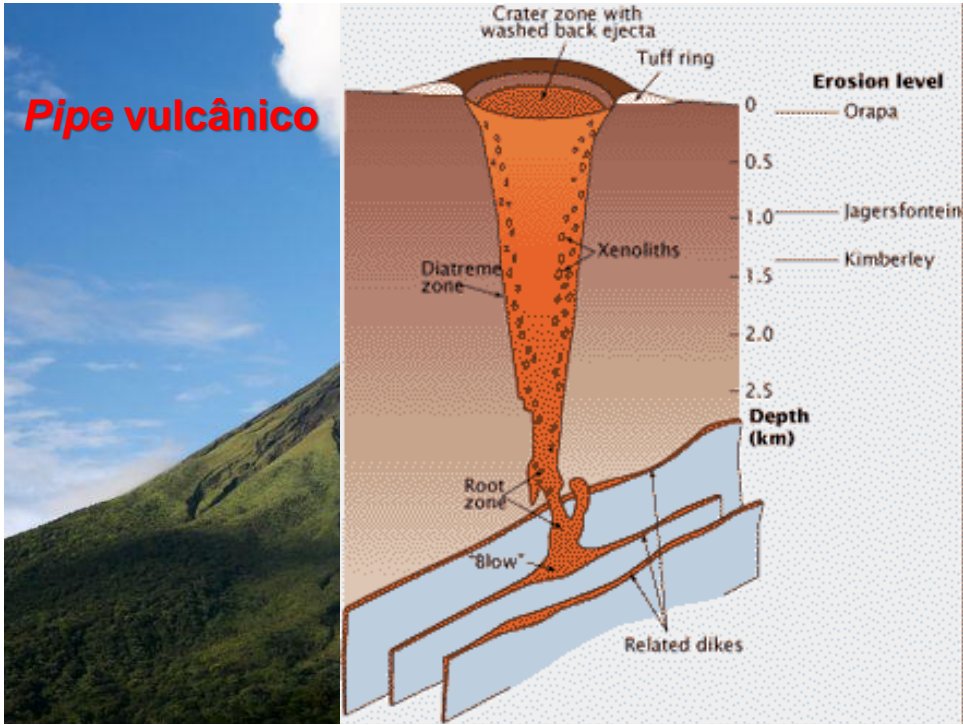
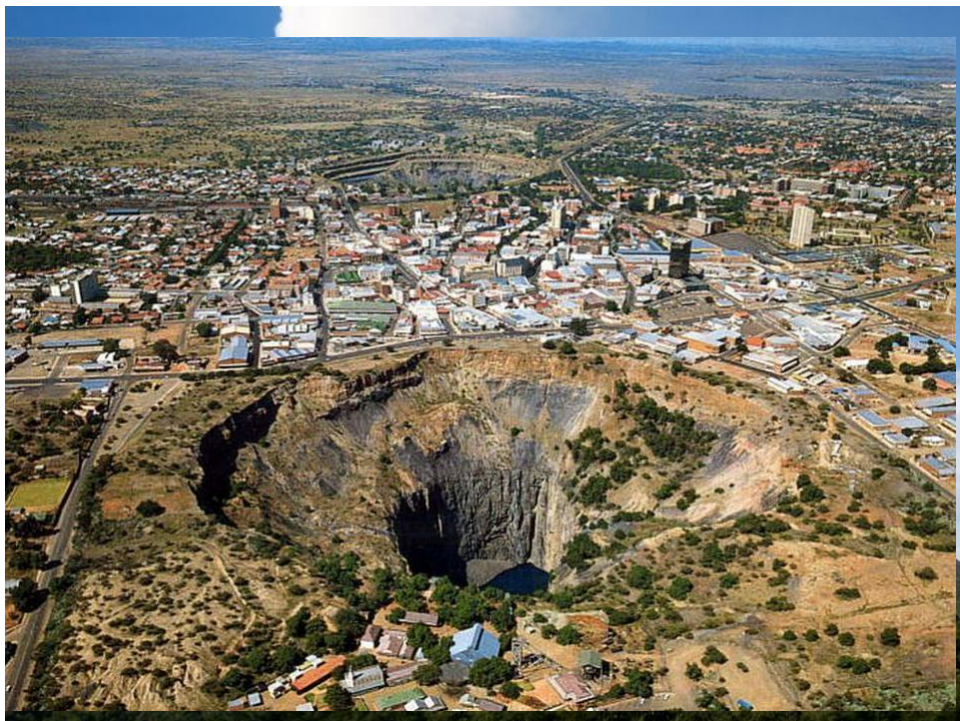
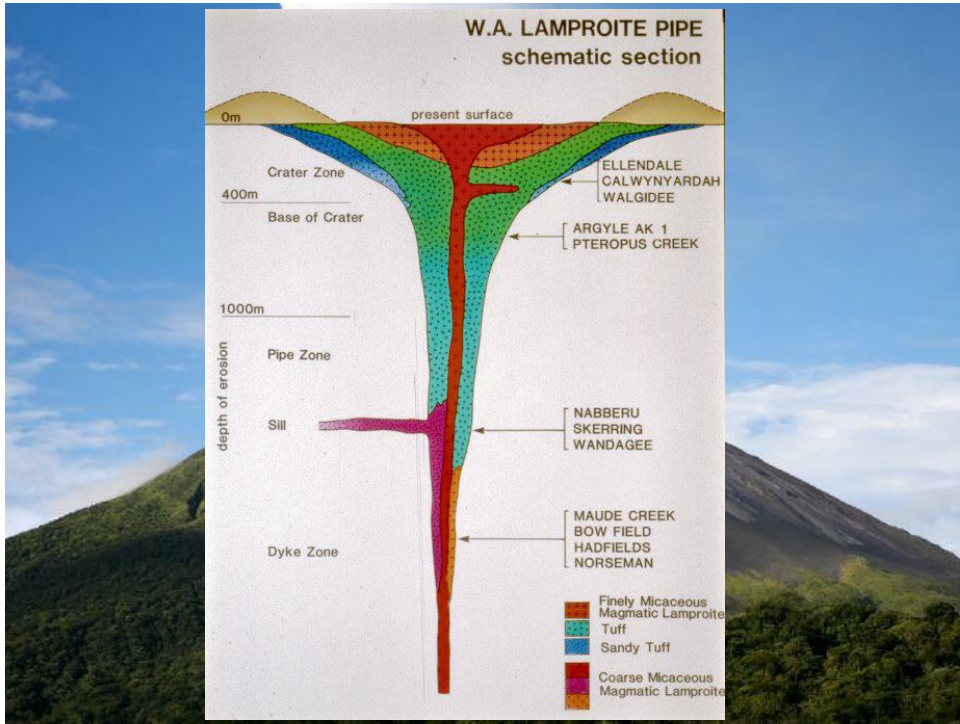
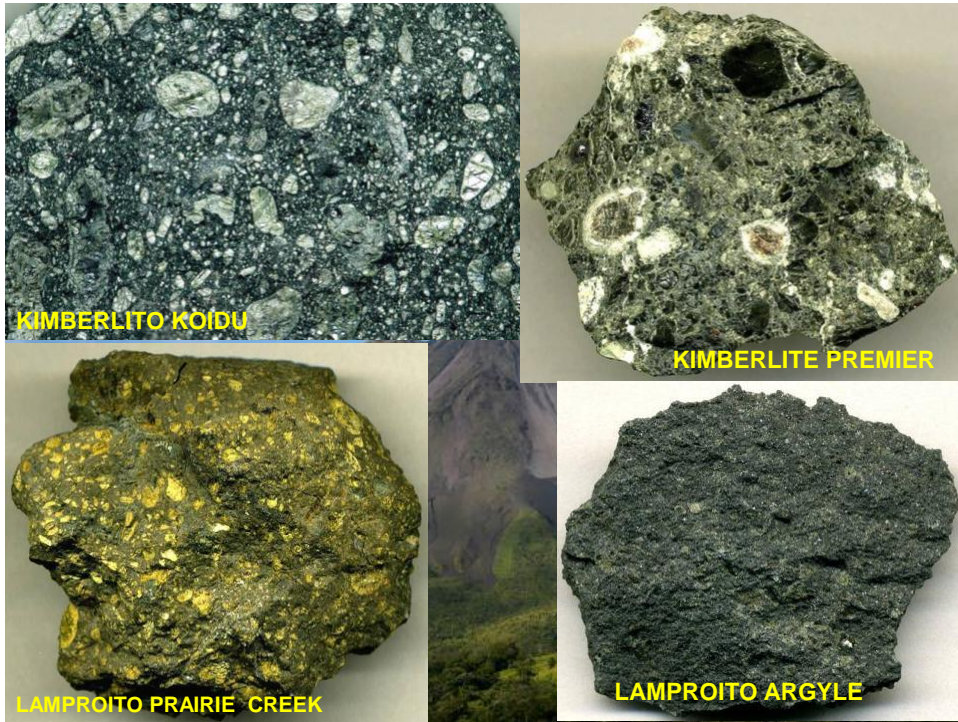


Figure 4 Model of an idealized kimberlite magmatic system (not to scale) illustrating the relationships between crater, diatreme and hypabyssal facies rocks. The diatreme root zone is composed primarily of hypabyssal rocks. (After Mitchell (1986), reproduced by permission of Plenum Press).



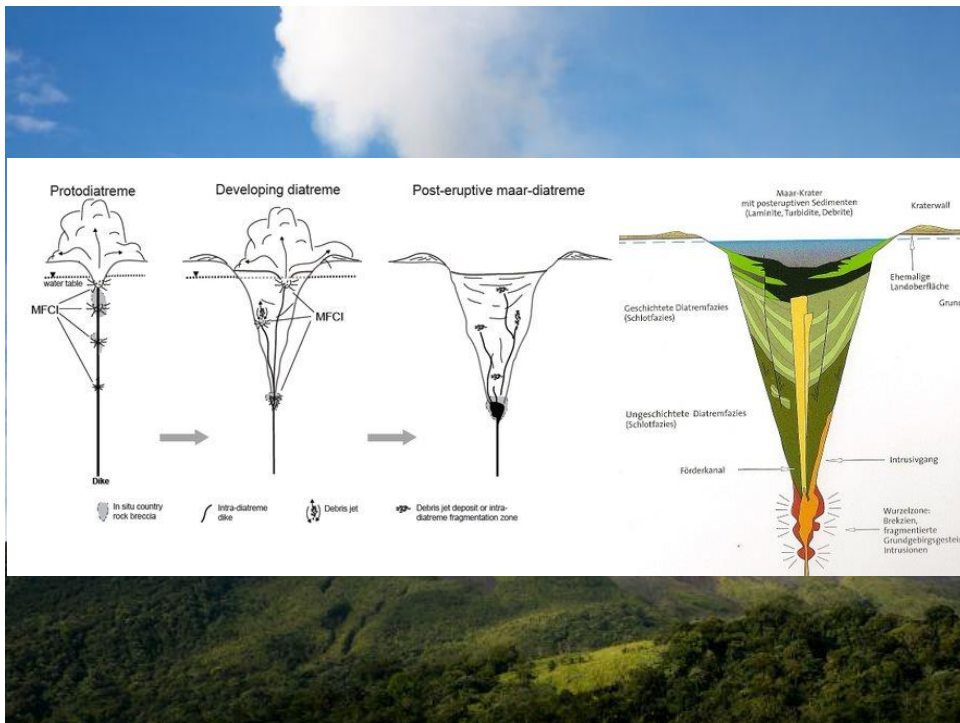


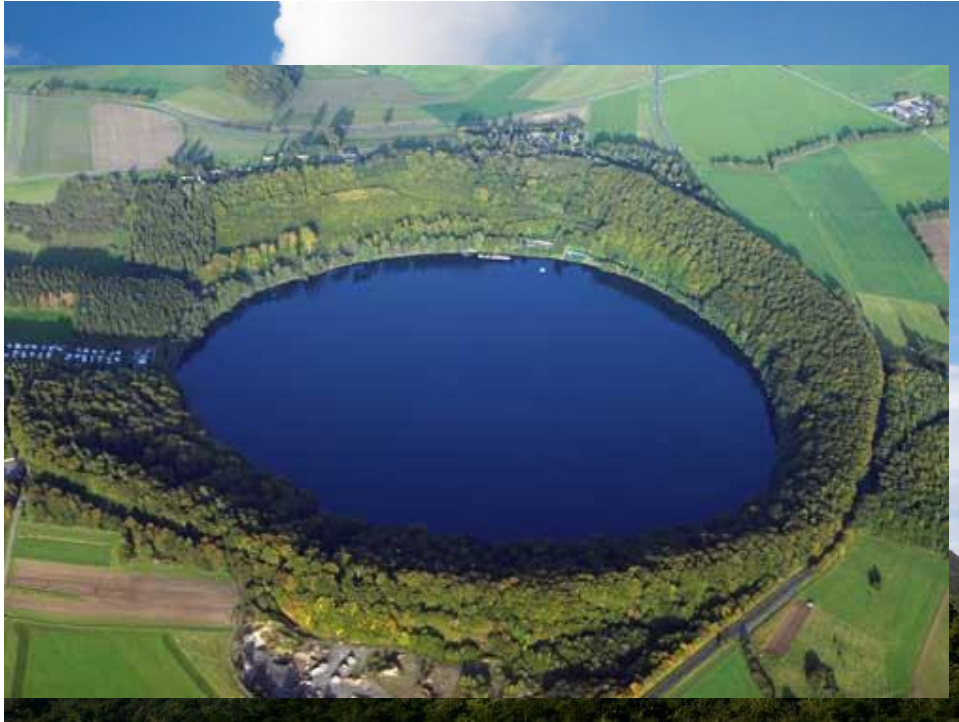
## Maar

- Formados por explosões freato-magmáticas
- Cratera pouco profunda gerada pela explosão de vapor devido ao aquecimento causado pelo magma





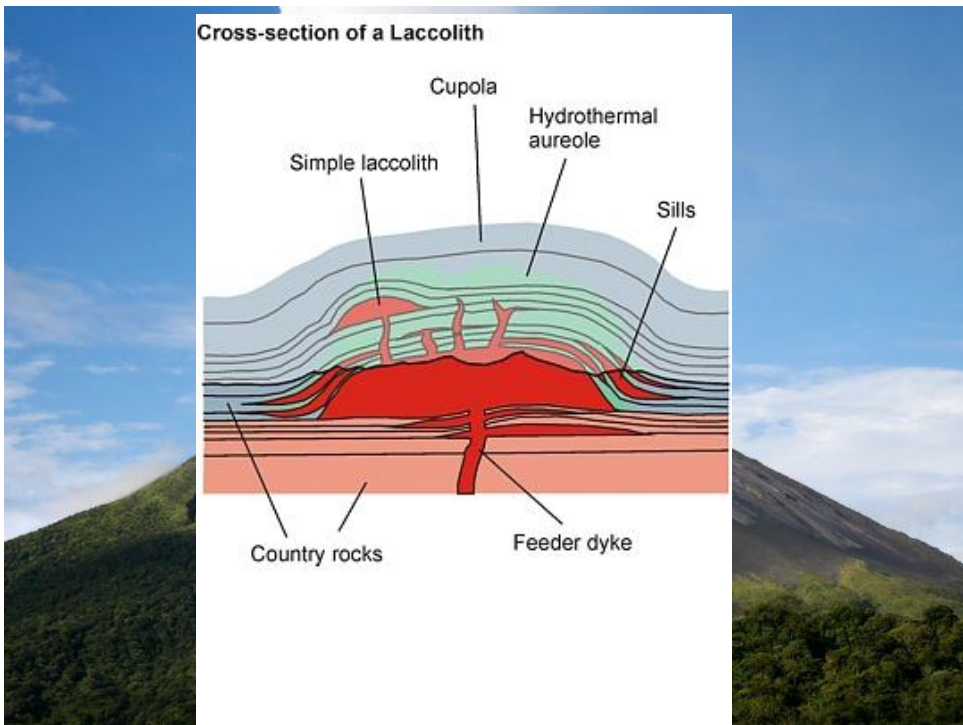
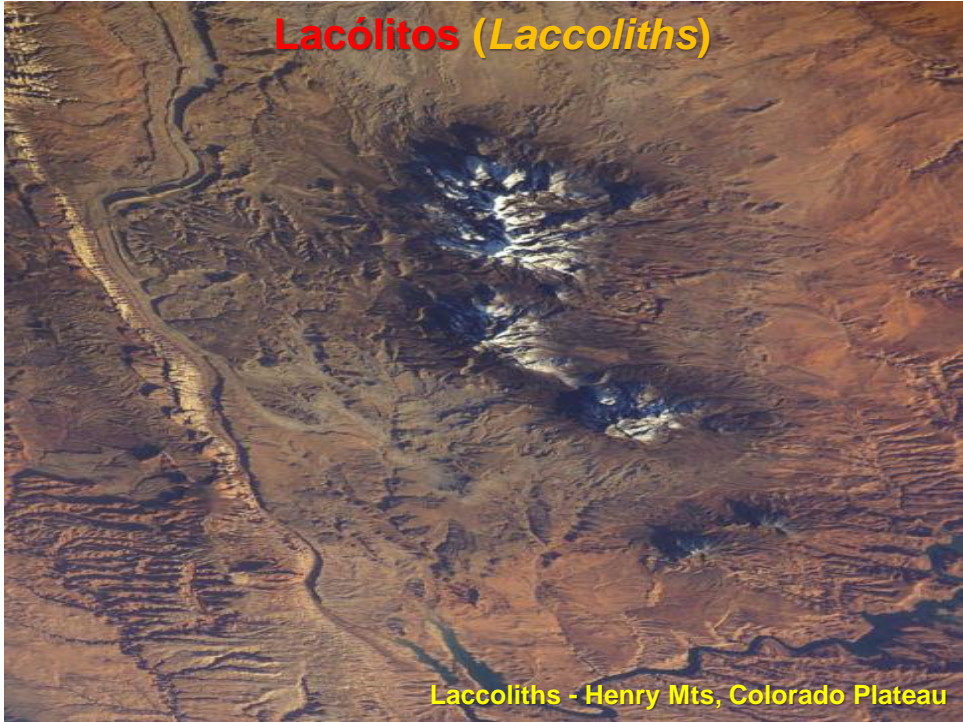


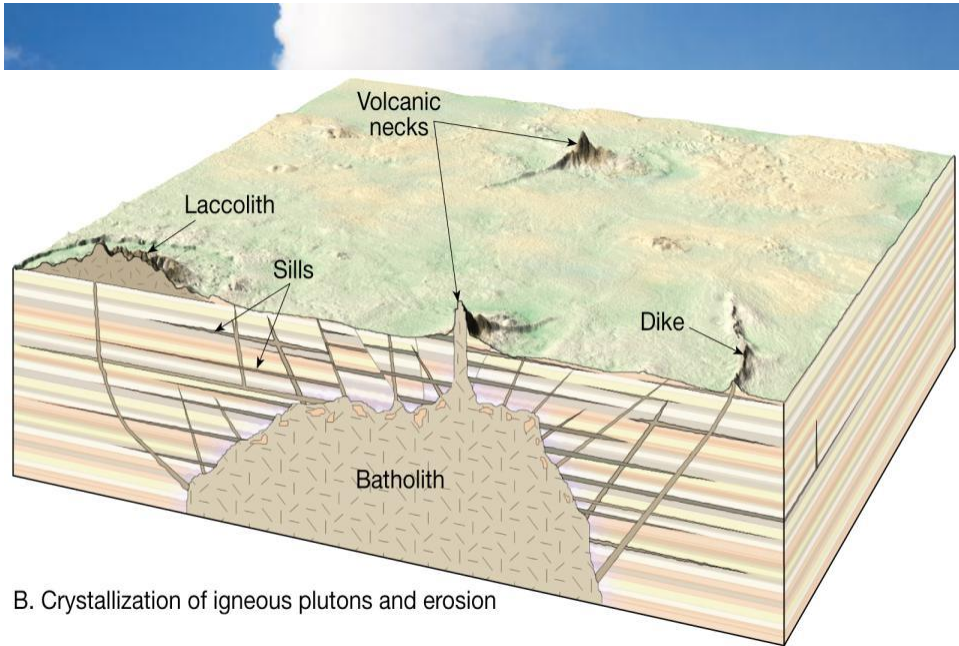


**Hornitos (“rootless” cone) ou pseudo-crateras**  
(formados por explosões quando a lava encontra gelo ou água)



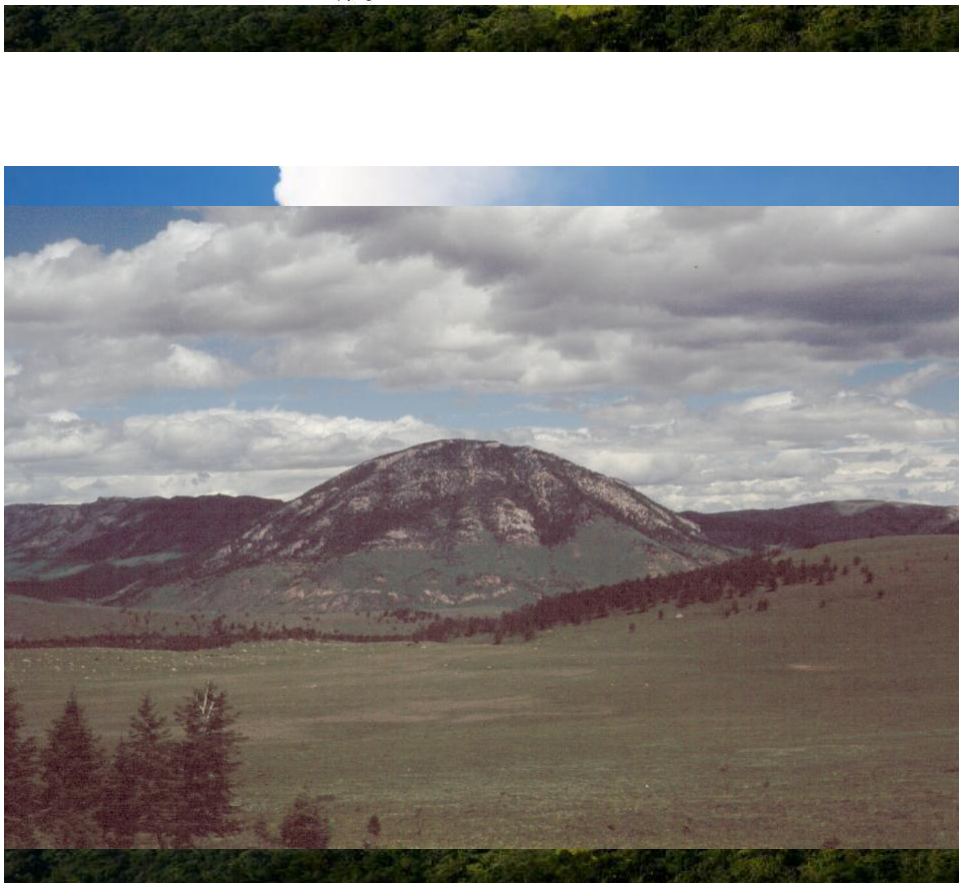
Myvatn Lake (Islândia).

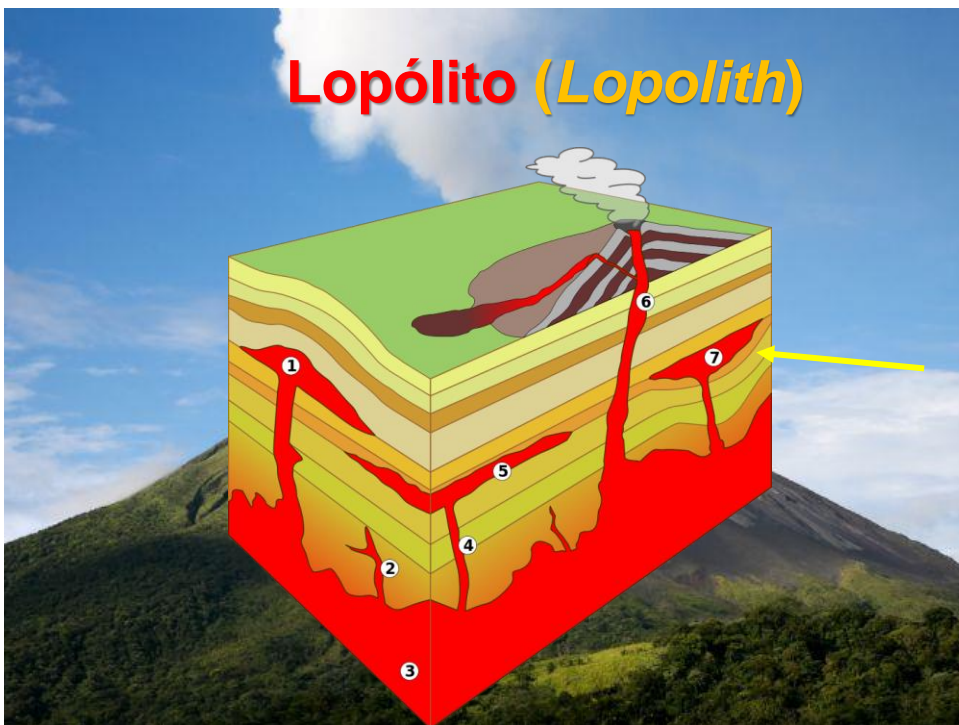




B. Crystallization of igneous plutons and erosion

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## Facólito (*Phacolith*)

### Phacolith

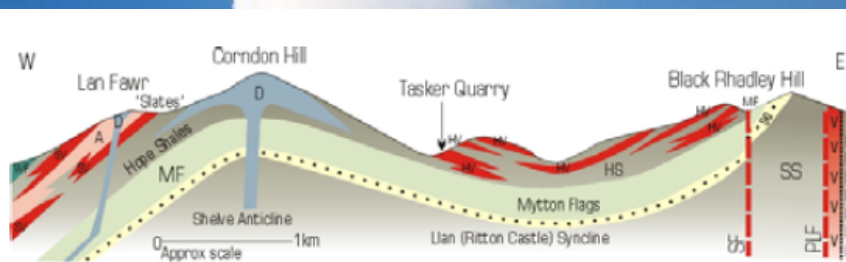
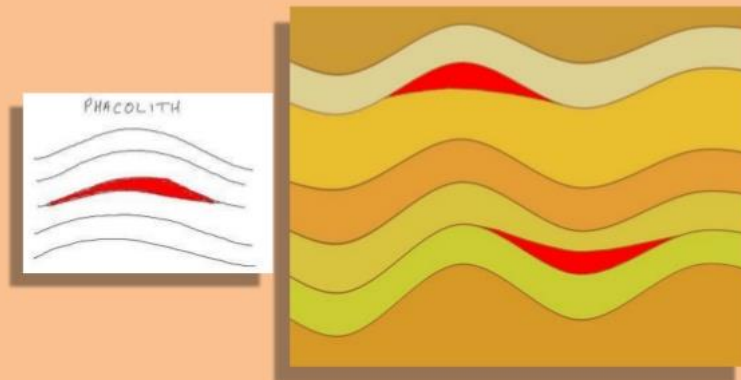
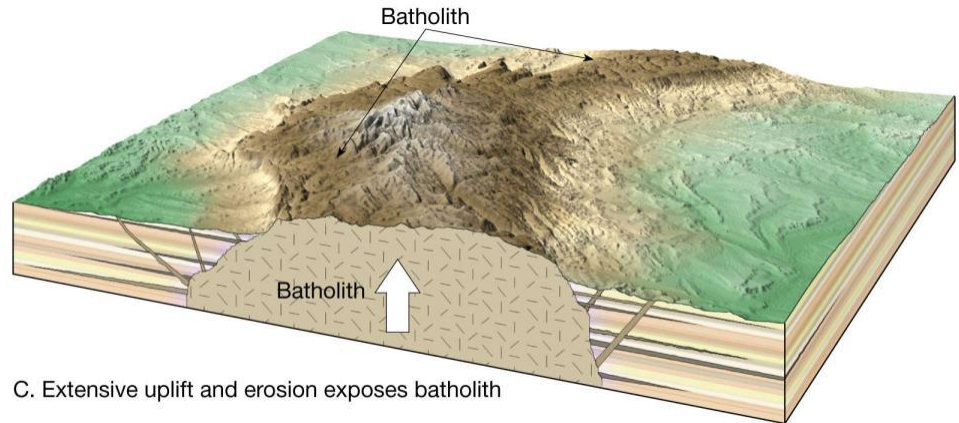


Figure 35. Shelveian folding in southern Shelve Inlier showing Shelfe Anticline and Llan (Ritton Castle) Syncline, and Corndon phacolith. WV, Weston Formation; SV, Stapeley Volcanics; A, Andesite; D, Dolerite; HV, Hyssington Volcanics; HS, Hope Shales; MF, Mytton Flags; SQ, Stiperstones Quartzite; SS, Shineton Shales; SF, Stiperstones Fault; PLF, Pontesford-Linley Fault; V, Uriconian Volcanics; L, Longmyndian.  
© Copyright 2006 Peter Toghil

# Batólito (*Batholith*) (Ambiente Plutônico)



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# Sierra Nevada Batholith



## 2.3.2. Minor Intrusions

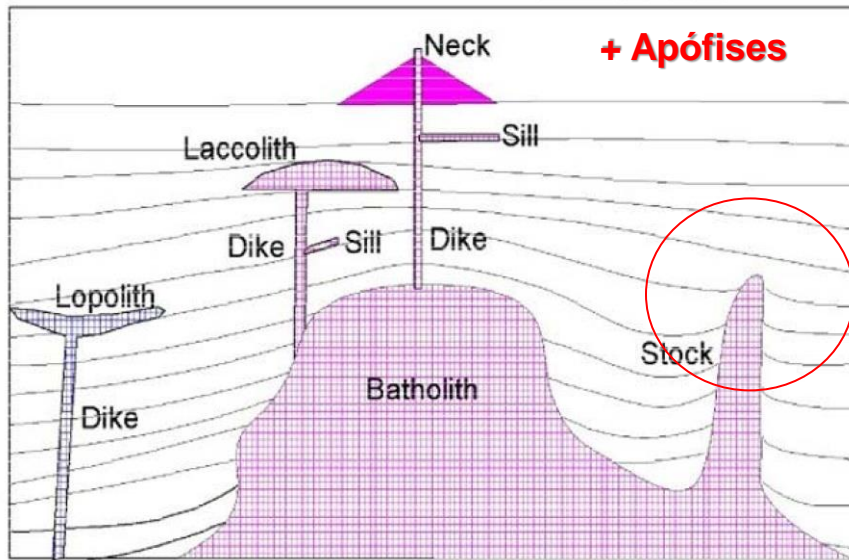


Figure 1. Cartoon showing occurrence of major types of intrusive body

## Estruturas Anelares

*(Ring Structures – Ring complexes)*

Uma ou diversas câmaras magmáticas expostas por erosão profunda, geralmente por mais de 2 km, em uma estrutura de uma caldeira inferida



Diehl (1990)

Fig. 2: Satellite image of the Brandberg Complex (Produced and permission for publication granted by the Satellite Application Centre, MIKOMTEK, CSIR).



## Montanhas de domos (campo de domos)

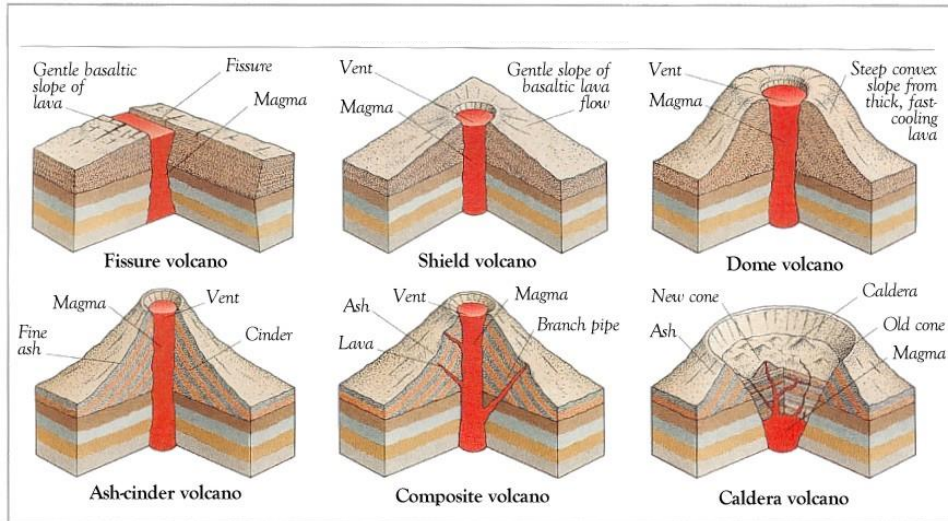
Pequenos corpos de magma intrusivos, na superfícies ou próximos da superfícies (criptodomos)



## Depósitos Geotermiais



# TIPOS DE VULCÕES



## ERUPÇÕES NÃO EXPLOSIVAS

- Havaiana (*Hawaiian*)





Grande Ronde River in Washington State (USA) – Self et al. (2014)



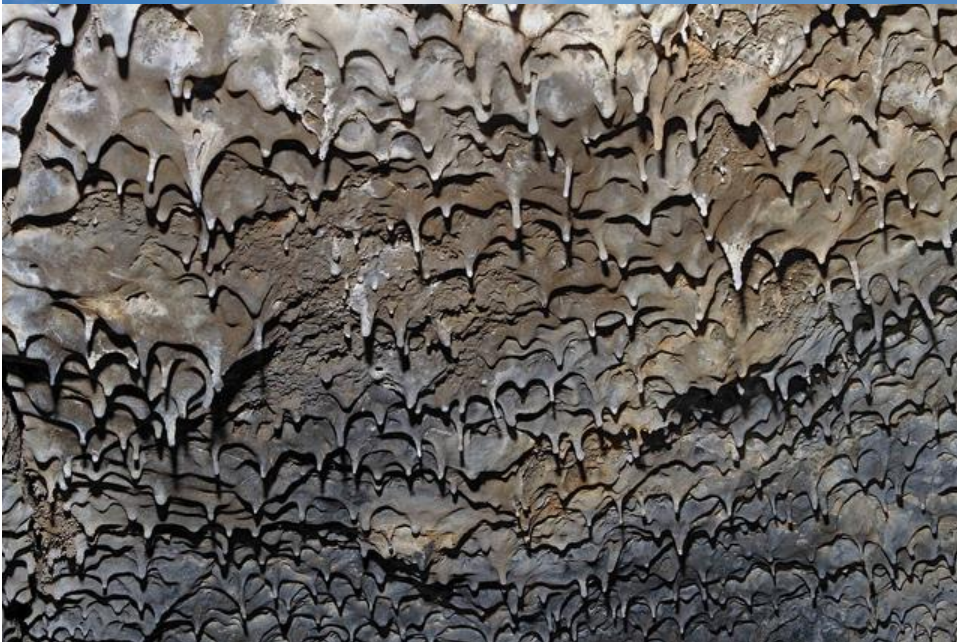
Disjunções colunares – Ver disjunções poliedrais



**Tubo de Lava (*Lava Tube*)**  
Hawaii



***Lava Drips/Sicles (ou Sickles)***





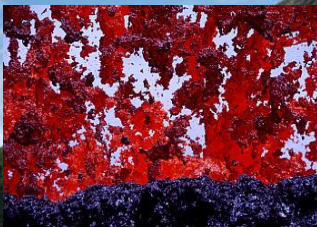
## ERUPÇÕES BASÁLTICAS EXPLOSIVAS

- Islândica (*Icelandic*)
- Havaiana (*Hawaiian*)
- Stromboliana (*Strombolian*)

## Depósitos Relacionados aos Vents Vulcânicos

### *Spatter*

- Lava fluida ejetada no vent
- Fragmentos achatados com bordas de resfriamento
- Muralhas, pequenos cones, domos



# Escoria vulcânica (Scoria)





## Fire Fountains (Kilauea)



## Depósitos Relacionados aos Vents Vulcânicos

- **Escória (Scoria)**
  - Erupções Strombolianas
  - Lavas altamente vesiculadas
  - Marro-avermelhada a preta
- **Reticulito**
  - Paredes rompidas das vesículas
  - Textura favo de mel
- **“Púmice basáltica”**



## Depósitos Relacionados aos Vents Vulcânicos

- Lágrimas de Pele
  - Deusa Havaiana dos vulcões
  - Lava ejetadas das fontes
  - Sempre associados com cabelo de Pele





# Piroclastos

## Tipos

- Fragmentos Juvenis – formados pelo magma resfriado, vítreo ou devitrificado
- Fragmentos conatos – formados por rochas co-magmáticas
- Fragmentos acidentais – fragmentos das rochas encaixantes
- Fragmentos líticos – clastos de rochas pré-existentes, onde se encaixam os condutos dos magmas
- Cristais – fenocristais ou fragmentos de cristais do magma removido pela atividade explosiva

## Fragmentos Juvenis

Types of Juvenile Pyroclast



Bombs



Pumice or Scoria



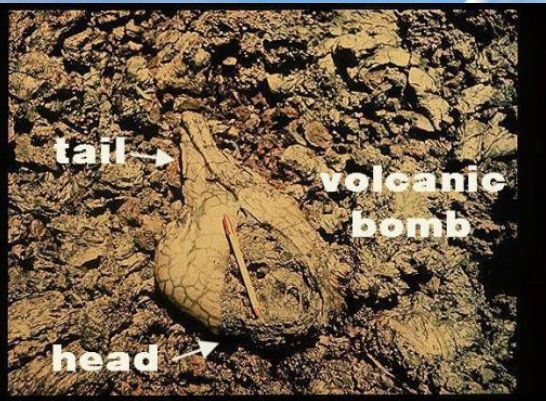
Achneliths



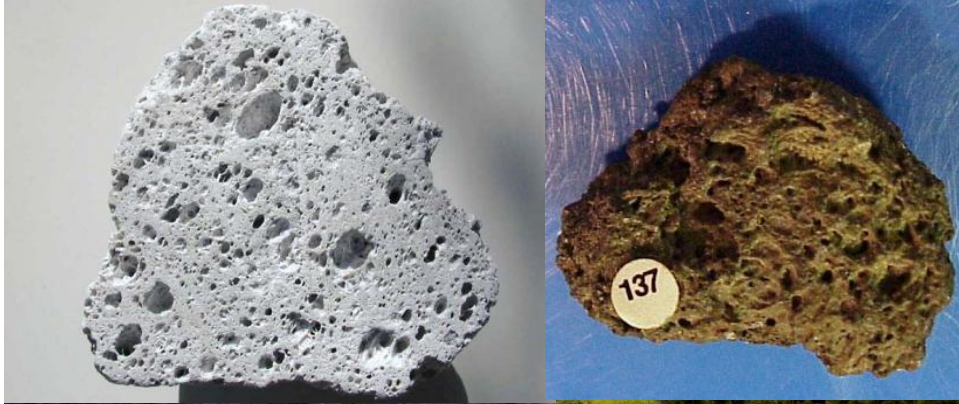
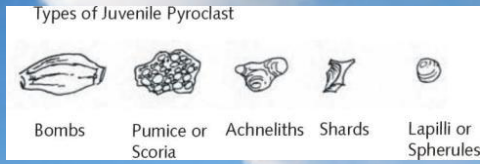
Shards



Lapilli or Spherules



# Fragmentos Juvenis



Ácido/intermediário/misturado = Púmice  
Sempre arredondados pela erupção

Básico/alcalino = Escória

Muitos dos fragmentos piroclásticos podem ser claramente identificados como fragmentos de bolhas de vidro vulcânico.

Isso indica que a vesiculação explosiva é o mecanismo dominante da fragmentação e indica também o tipo da erupção.

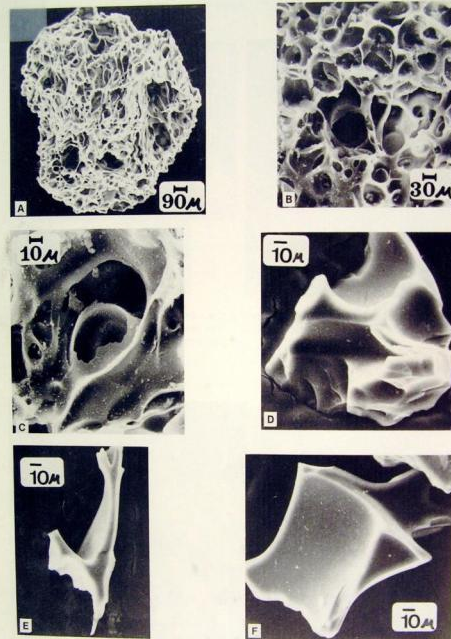
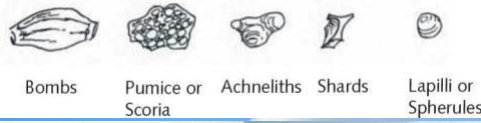


Figure 6. Vesicular dacite from the 1973 block and ash flow of Santiaguito Volcano, Guatemala. A, B, C show general and detailed views of a typical glassy pyroclast in the flow. D, E, F are some typical shards. The high surface area of such particles undoubtedly aids in the fluidization of small particles in the flow, because diffusion of gas from the glass is facilitated as well as heat transfer. (From Rose, Boris, and Pearson, 1977. Copyright © 1977 by Springer Verlag.)

Rose (1987) Clastic Particles

# Fragmentos Juvenis

Types of Juvenile Pyroclast

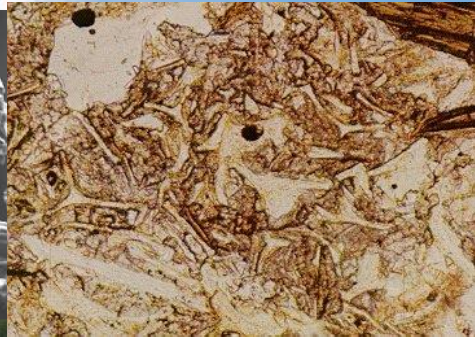
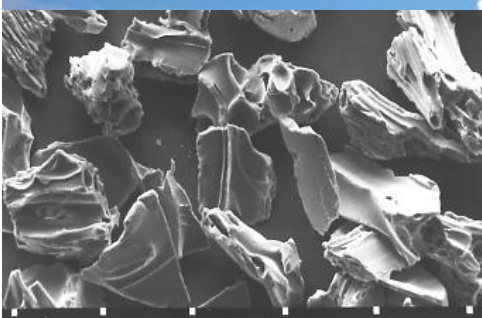
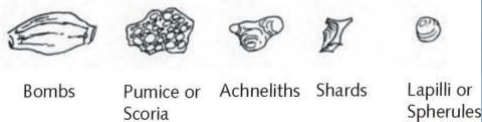


**Achnelitos**  
(gotas de vidro – Lágrimas de Pele)  
**Achneliths**  
(glassy droplets) – (Pele's Tears)

Achnelitos e escória podem ser aglutinados e unidos por fusão quando formados em spatter cones e muralhas muito quentes.

# Fragmentos Juvenis

Types of Juvenile Pyroclast



Fragmentos juvenis de vidro vulcânico  
(Juvenile glass shards)

Fragmentos de vidro vulcânico em tufo vítreo  
(Glass shards in a vitric tuff/ash)



# Fragmentos Juvenis

Types of Juvenile Pyroclast

				
Bombs	Pumice or Scoria	Achneliths	Shards	Lapilli or Spherules



**Lapilli Acrescionário  
(Accretionary lapilli)**

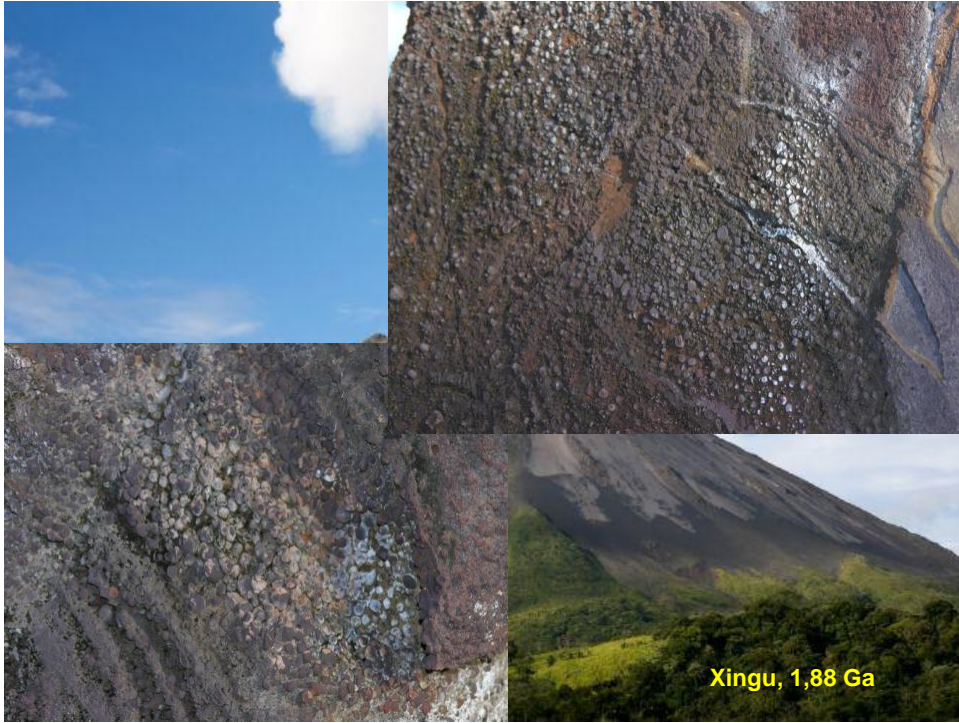


Camada de lapilli tufo no vulcão Kileaua (Hawai)

**IMPORTÂNCIA – Indicam explosões freato-magmáticas → Água no Sistema**  
**O vapor de água e as cargas eletrostáticas na pluma de erupção fazem com que os grão se aglutinem em camadas concêntricas.**









## Depósitos Piroclásticos de Queda (Tephra)

Fragments de queda

coarse agglomerates

ash, lapilli, pumice + bombs

fine ash

ash

rained-out ash

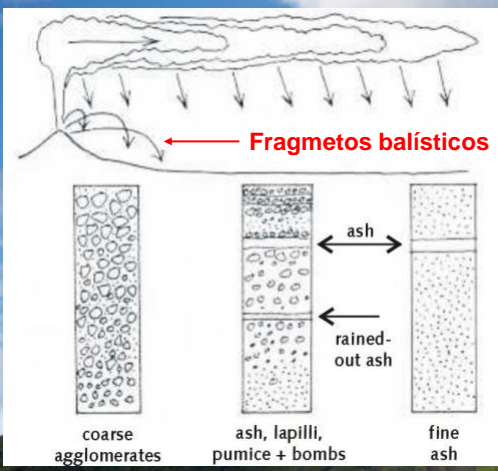
Tufo de Queda (Air Fall tuff)

Deformação do leito de tufos pela queda dos fragmentos (Bomb sags in bedded ash/lapilli)



Xingu, 1,88 Ga

## Depósitos Piroclásticos de Queda (Tephra)



Estratificação devida à diferentes erupções são melhor observadas próximas ao vulcão

Gradação reverse ocorre devido ao aumento da atividade vulcânica e alargamento do cone. Para pumice em corpo de água o mesmo ocorre.

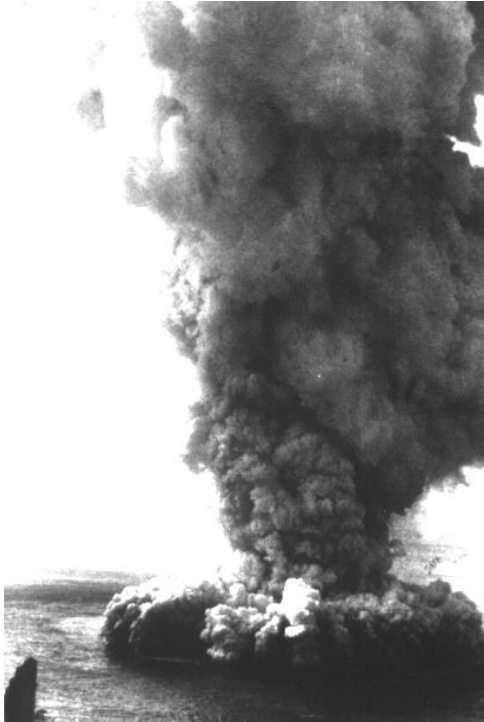
Incrementos de fragmentos líticos mais próximo ao vulcão



Xingu, 1,88 Ga

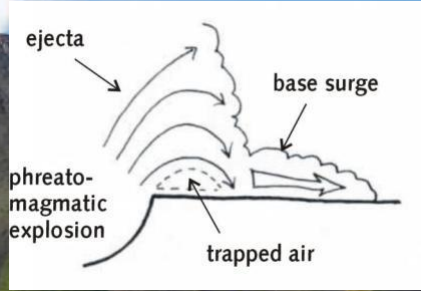


Xingu, 1,88 Ga

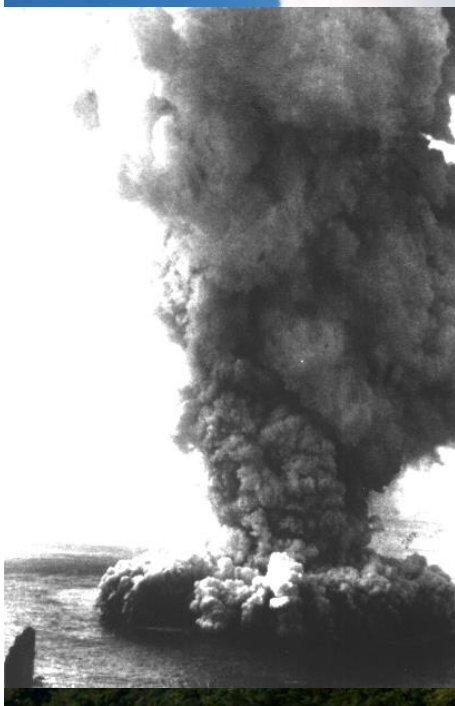


## Surges Piroclásticos

Fluxos de matérias piroclásticas formados por suspensões de partículas + gases, de baixa densidade



Base surge



## Surges Piroclásticos

Formas de climbing dunes



Base surge

**Surges Piroclásticos**

Climbing dune forms

Estratificação cruzada  
(Cross bedding)

Base surge





## Depósitos Epiclásticos Vulcanoclásticos



Os materiais vulcânicos inconsolidados ou pouco consolidados são facilmente retrabalhados e se depositam nas proximidades dos depósitos primários. A fonte é exclusivamente vulcânica e são coevos ao vulcanismo

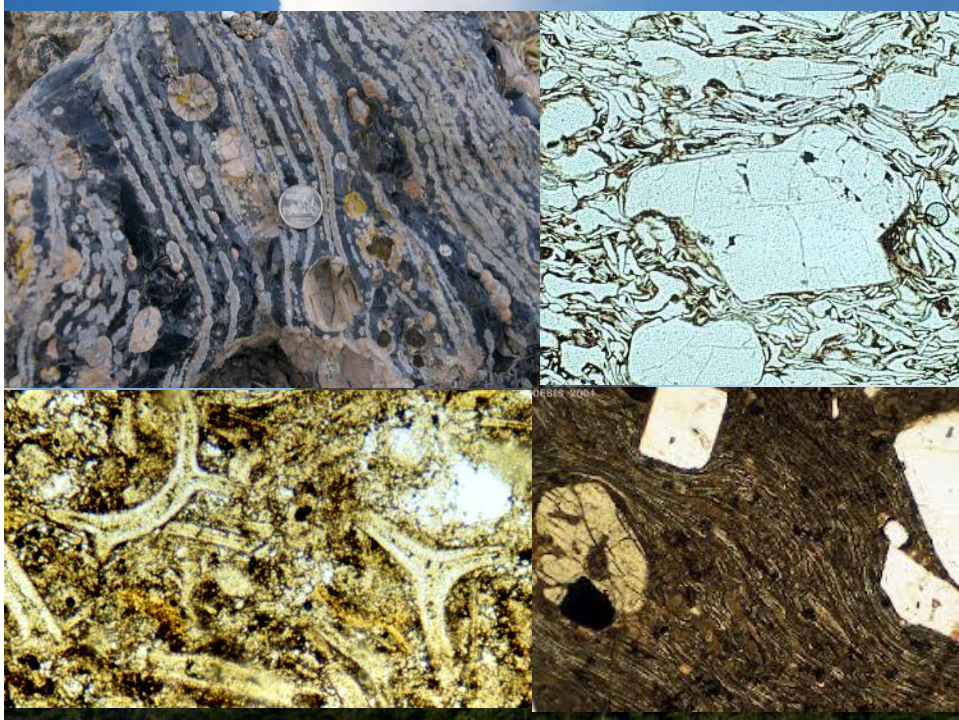
## Depósitos epiclásticos vulcanoclásticos comumente são formados por fluxo de massa



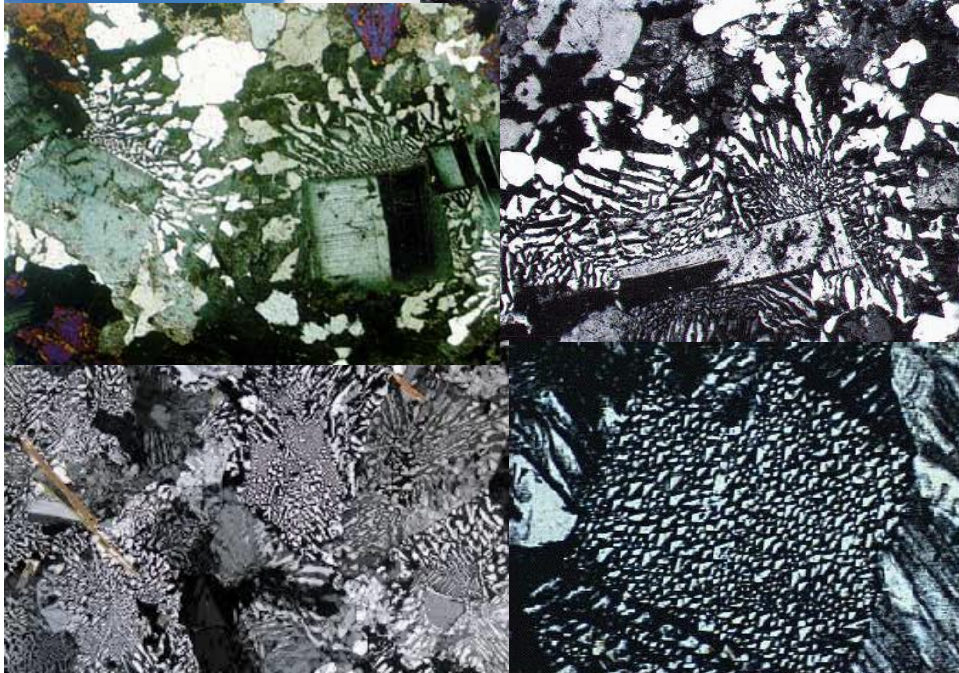
## Textura hialofítica (vítrea)



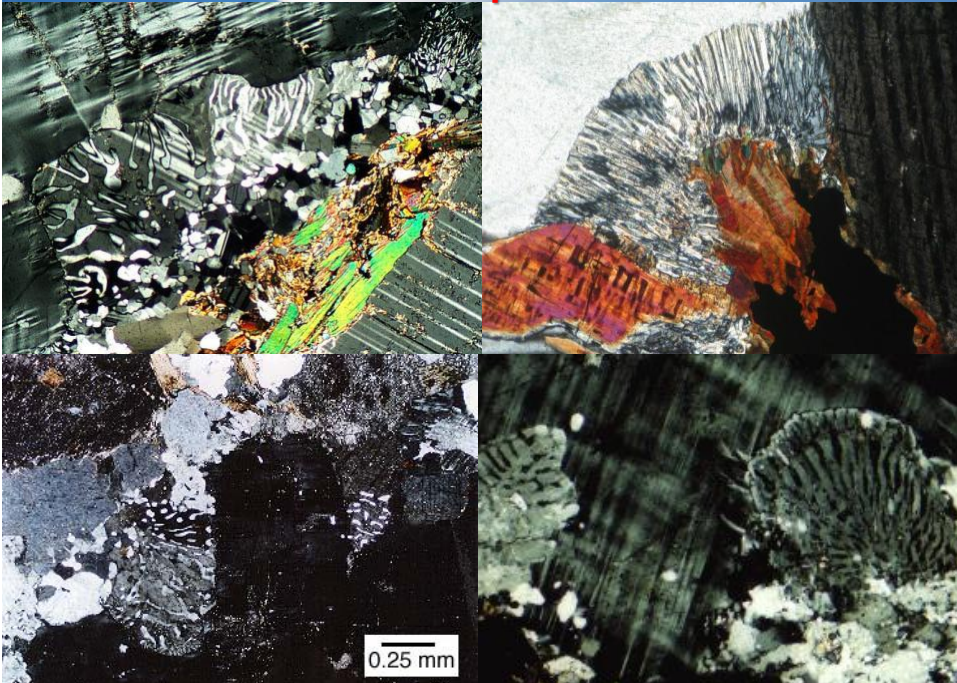




### Texturas Granofiricas



### Mirmequitas



### Cavidades Miarolíticas

