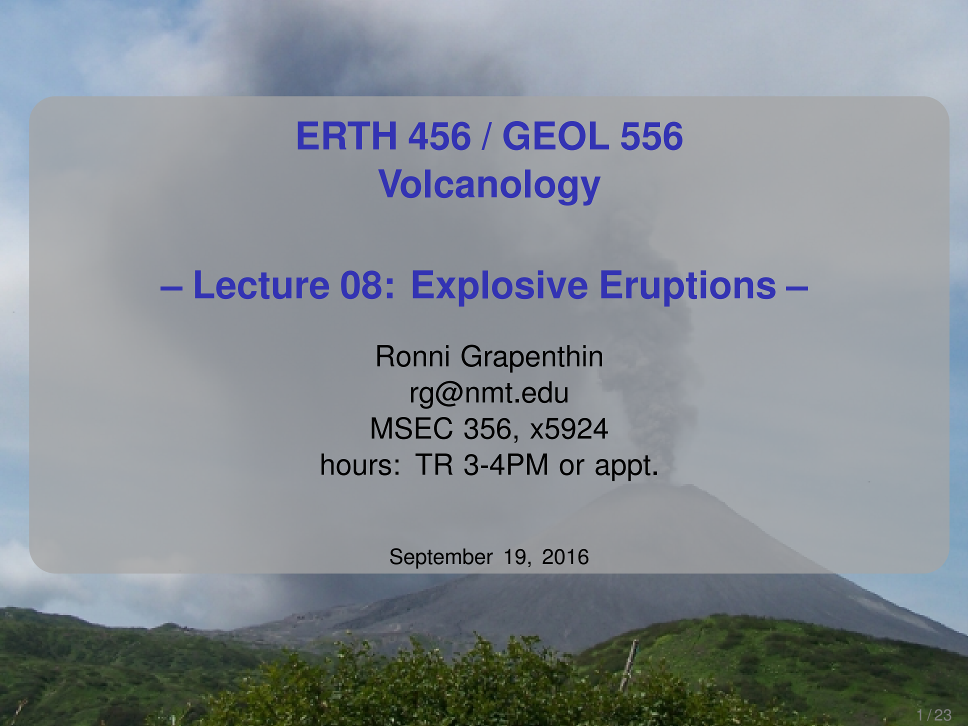

ERTH 456 / GEOL 556
Volcanology

– Lecture 08: Explosive Eruptions –

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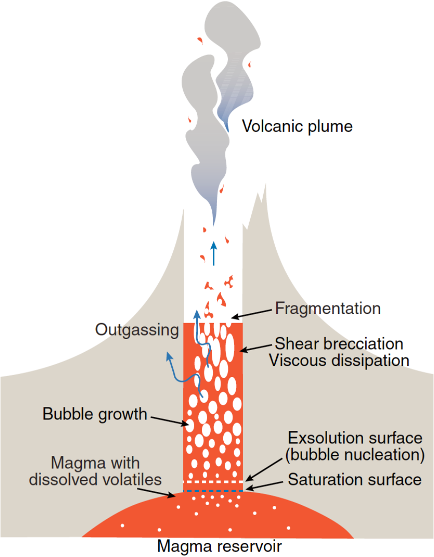
hours: TR 3-4PM or appt.

September 19, 2016

What happens once magma makes it to the surface?

Volcano Anatomy



Gonnermann & Manga, 2007

Quiz: Why doesn't this work?

`https://youtu.be/g7Ovo9ohllI?t=41s`

How do we get an explosive eruption?

- fragmentation at top of magma column (don’t lose all gases through conduit wall)
- sufficient flow velocity
- vent geometry

USGS, 2016; Framepool, 2011

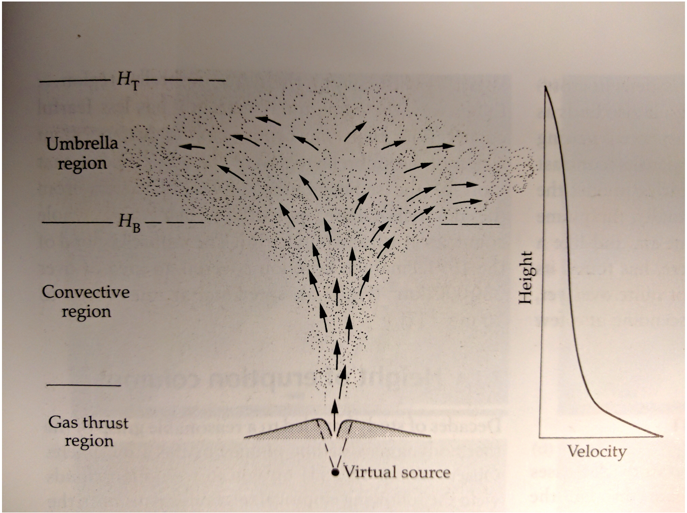
Makeup of Explosive Eruptions

- volcanic plumes
- pyroclastic fall deposits
- pyroclastic density currents

Makeup of Explosive Eruptions

ISS Crew, 2008

Plume Basics

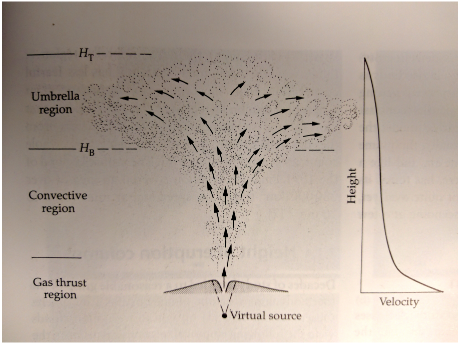


Francis & Oppenheimer, 2004

H_B: height of neutral buoyancy; H_T: maximum plume height ($H_T \approx 1.4 H_B$)

Plume Basics - Gas Thrust Region

- magma vesiculates and fragments, accelerates as low viscosity gas+particle mix
- ejection velocity mostly governed by proportion of volatiles
- plinian eruptions of silicic magmas (4-5 wt% volatiles): $>$500 m/s (supersonic)



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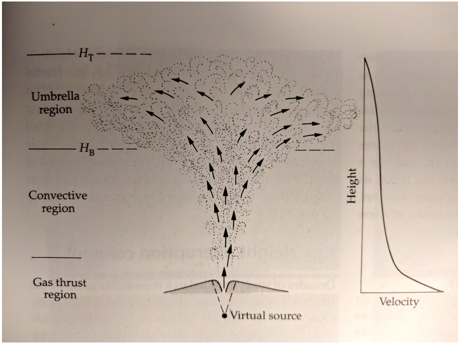
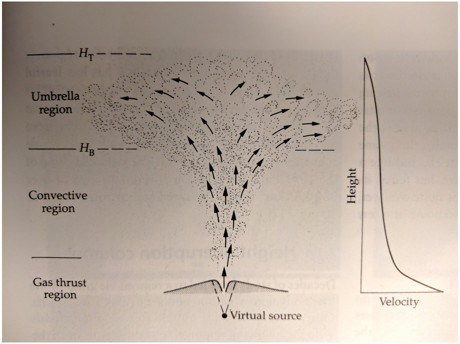
- plinian eruptions of silicic magmas (4-5 wt% volatiles): $>$500 m/s (supersonic)
- denser than atmosphere but propelled by momentum
- starts to entrain ambient air: **gas thrust/jet phase**
- air heated by pyroclasts, reducing bulk density of plume
- up to a few km high



Francis & Oppenheimer, 2004

Plume Basics - Convective Region

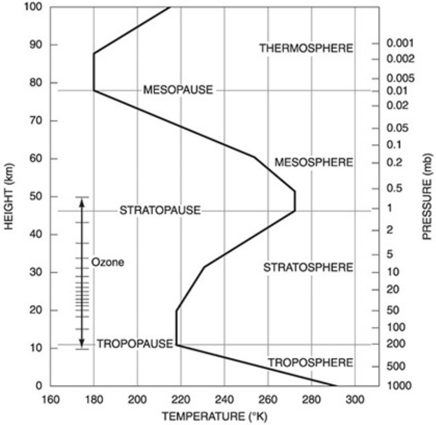
- hot gas is buoyant in atmosphere
- **convective region** owes buoyancy to heating of entrained air
- may lift plume several 10s of kilometers high



Francis & Oppenheimer, 2004

Plume Basics - Convective Region

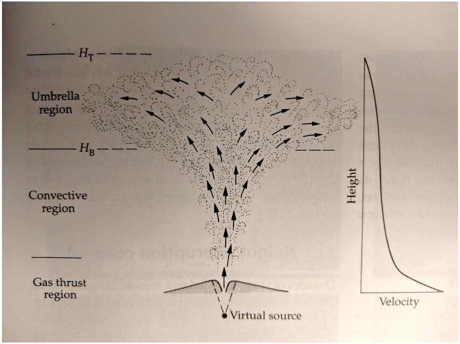
- hot gas is buoyant in atmosphere
- **convective region** owes buoyancy to heating of entrained air
- may lift plume several 10s of kilometers high
- can cross tropopause and puncture stratosphere
- ascent rates of 10s-100s m/s
- humid troposphere increases this:
  - condensation of water vapor yields latent heat
  - freezing of liquid water: more latent heat
- plume widens in cross section, density contrast lessens with altitude



Francis & Oppenheimer, 2004

Plume Basics - Umbrella Region

- plume will rise until reaching H_B: plume density == atmosphere density
- plume retains momentum, can rise a few kms more to H_T



Francis & Oppenheimer, 2004; Takehiro Koyaguchi;

Plume Basics - Umbrella Region

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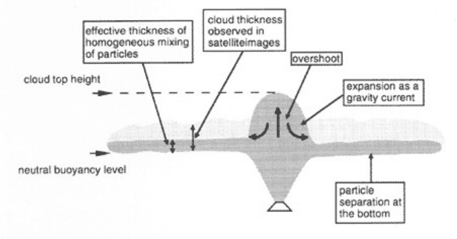
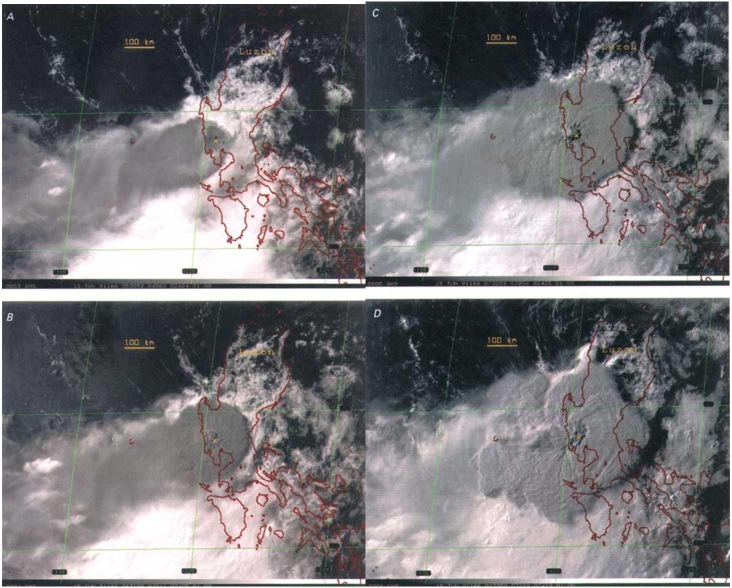
- plume retains momentum, can rise a few kms more to H_T
- horizontal spreading sets in, even upwind(!), gravity current driven
- most of tephra fallout from umbrella's base
- Pinatubo 1991 umbrella cloud covered area of 230000 km^2



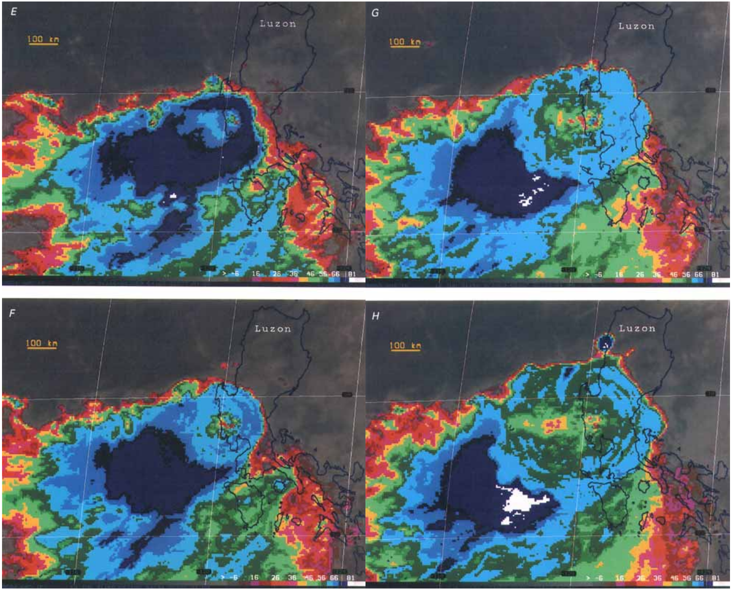
Francis & Oppenheimer, 2004; Takehiro Koyaguchi;

Plume Basics - Pinatubo



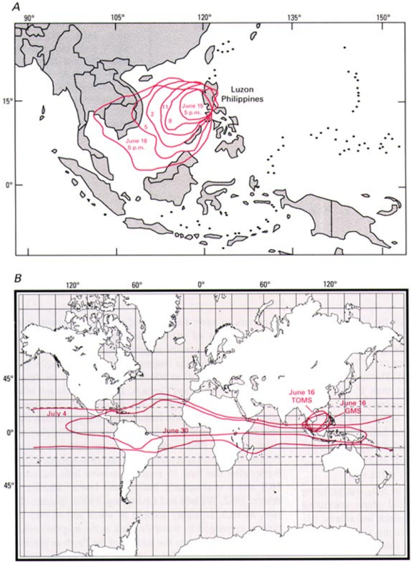
visible wavelengths from 13:40-16:40 local time *Self et al., Fire & Mud*

Plume Basics - Pinatubo



Thermal-infrared wavelengths from 13:40-16:40 local time *Self et al., Fire & Mud*

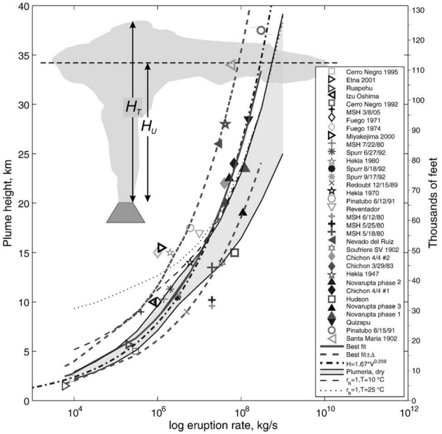
Plume Basics - Pinatubo



Self et al., Fire & Mud

Plume Basics - Plume Heights

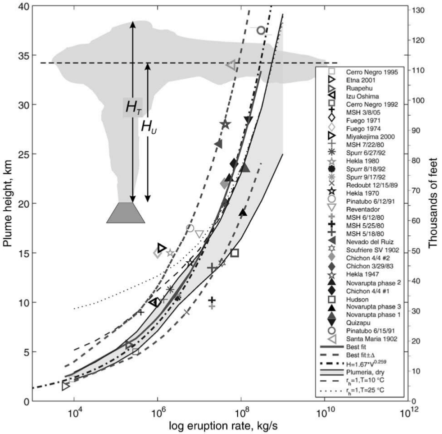
- relationship between height of a plume (H_T in km) and **dense rock equivalent** magma discharge rate (Q in m^3/s)



Mastin et al., 2009

Plume Basics - Plume Heights

- relationship between height of a plume (H_T in km) and **dense rock equivalent** magma discharge rate (Q in m^3/s)
- $H_T = 2.00Q^{0.241}$ (Mastin et al, 2009) (converted mass eruption rate kg/s to discharge rate m^3/s)



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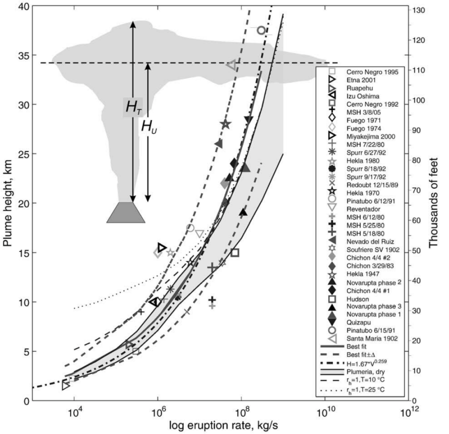
- i.e. 16-fold increase in eruption rate required to double plume height



Mastin et al., 2009

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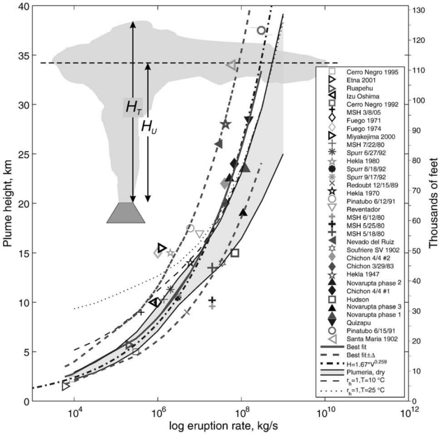
- i.e. 16-fold increase in eruption rate required to double plume height
- tracking Q through eruption and integrating gives total erupted mass



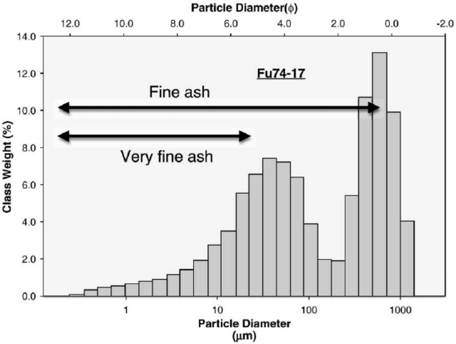
Mastin et al., 2009

Pyroclastic Fall Deposits

- deposits used to assign magnitude and intensity to prehistoric eruptions
- **deposit magnitude:** thickness or mass as function of distance from vent
- generally exponential thinning of tephra deposits from vent
- use to estimate total volume
- distal segment most difficult to asses (wide distribution, poorly preserved)

Pyroclastic Fall Deposits

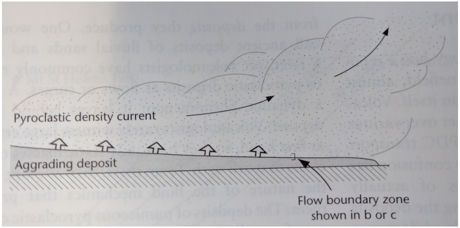
- **eruption intensity:**infer from relationships between grain size, grain density, column height, depositional characteristics
- large uncertainties introduced during field sampling (point samples)
- total grain size distribution (TGSD) is more important (input for ash dispersion models)
- TGSD difficult to measure:
    - deposits are widespread
    - grain size varies up section
    - distal deposits again poorly preserved
- critical data for source plume models



Fuego Volcano, *Rose & Durant, 2009*

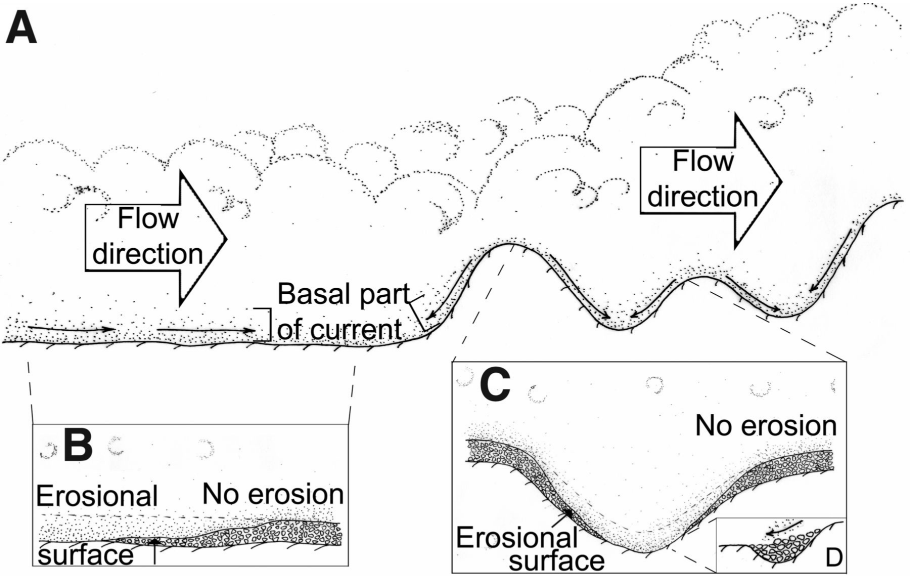
Pyroclastic Density Currents

- hot gravity gravity driven currents
- travel at high velocities
- can form by lava dome or (sub- / ultra-) plinian column collapse
- high velocities, high temperatures make direct measurements impossible



Francis & Oppenheimer, 2004

Pyroclastic Density Currents



http://geology.gsapubs.org/content/40/11/1035/F3.expansion.html

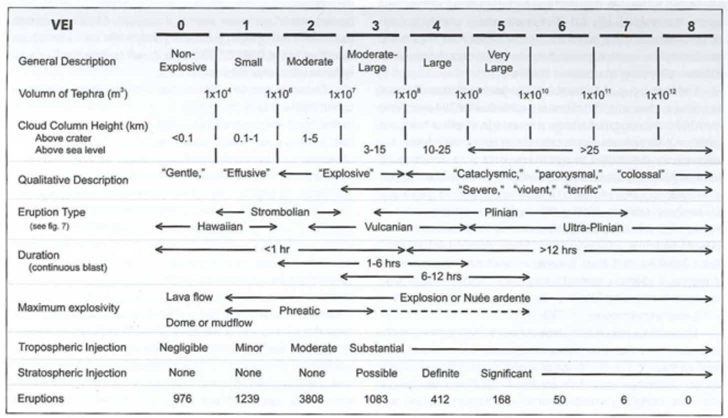
Pyroclastic Density Currents - Unzen 1991

`https://www.youtube.com/watch?v=Cvjwt9nnwXY`

Volcanic Explosivity Index

- Devised by Chris Newhall & Stephen Self in 1982
- “Richter scale for eruptions” (note, we don’t use Richter scale anymore)
- based on volume of tephra, plume height
- often criticized / used for things it wasn’t made to do
- recently revised by Houghton and others (2013, Geology) to account for small explosive events

Volcanic Explosivity Index

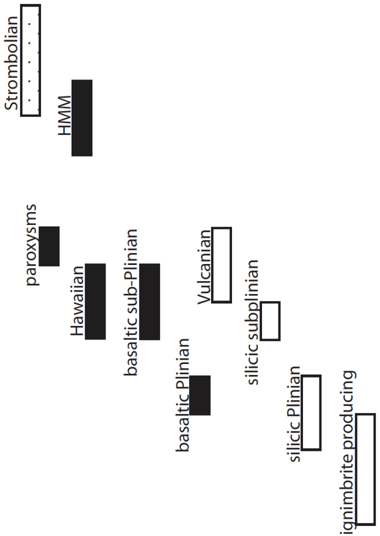


VEI	0	1	2	3	4	5	6	7	8
General Description	Non-Explosive	Small	Moderate	Moderate-Large	Large	Very Large			
Volumn of Tephra (m^3)		1x10^{4}	1x10^{6}	1x10^{7}	1x10^{8}	1x10^{9}	1x10^{10}	1x10^{11}	1x10^{12}
Cloud Column Height (km) Above crater Above sea level	<0.1	0.1-1	1-5	3-15	10-25	←	>25		→
Qualitative Description	"Gentle,"	"Effusive"	← "Explosive"	→	← "Cataclysmic,"	"paroxysmal,"		"colossal"	→
				←		"Severe," "violent," "terrific"			→
Eruption Type (see fig. 7)		← Strombolian	→	←		Plinian	→		
	← Hawaiian	→	←	Vulcanian	→ ←		Ultra-Plinian		→
Duration (continuous blast)	←		<1 hr	→	←	>12 hrs			→
		←	1-6 hrs		→				
				←	6-12 hrs	→			
Maximum explosivity	Lava flow	←			Explosion or Nuée ardente				→
		←	Phreatic	→	- - - - - -	- - →			
	Dome or mudflow								
Tropospheric Injection	Negligible	Minor	Moderate	Substantial					→
Stratospheric Injection	None	None	None	Possible	Definite	Significant			→
Eruptions	976	1239	3808	1083	412	168	50	6	0

Newhall & Self, 1982; Siebert et al., 2010

Volcanic Explosivity Index+

New VEI	Old VEI	Volume range m^3	Eruption style
-6	0	1E-2 to 1E-1	
-5	0	1E-1 to 1E0	
-4	0	1E0 to 1E+1	
-3	0	1E+1 to 1E+2	
-2	0	1E+2 to 1E+3	
-1	0	1E+3 to 1E+4	
0	1	1E+4 to 1E+5	
1	1	1E+5 to 1E+6	
2	2	1E+6 to 10E+7	
3	3	1E+7 to 1E+8	
4	4	1E+8 to 1E+9	
5	5	1E+9 to 1E+10	
6	6	1E+10 to 1E+11	
7	7	1E+11 to 1E+12	
8	8	>1E+12	



Houghton et al., 2013