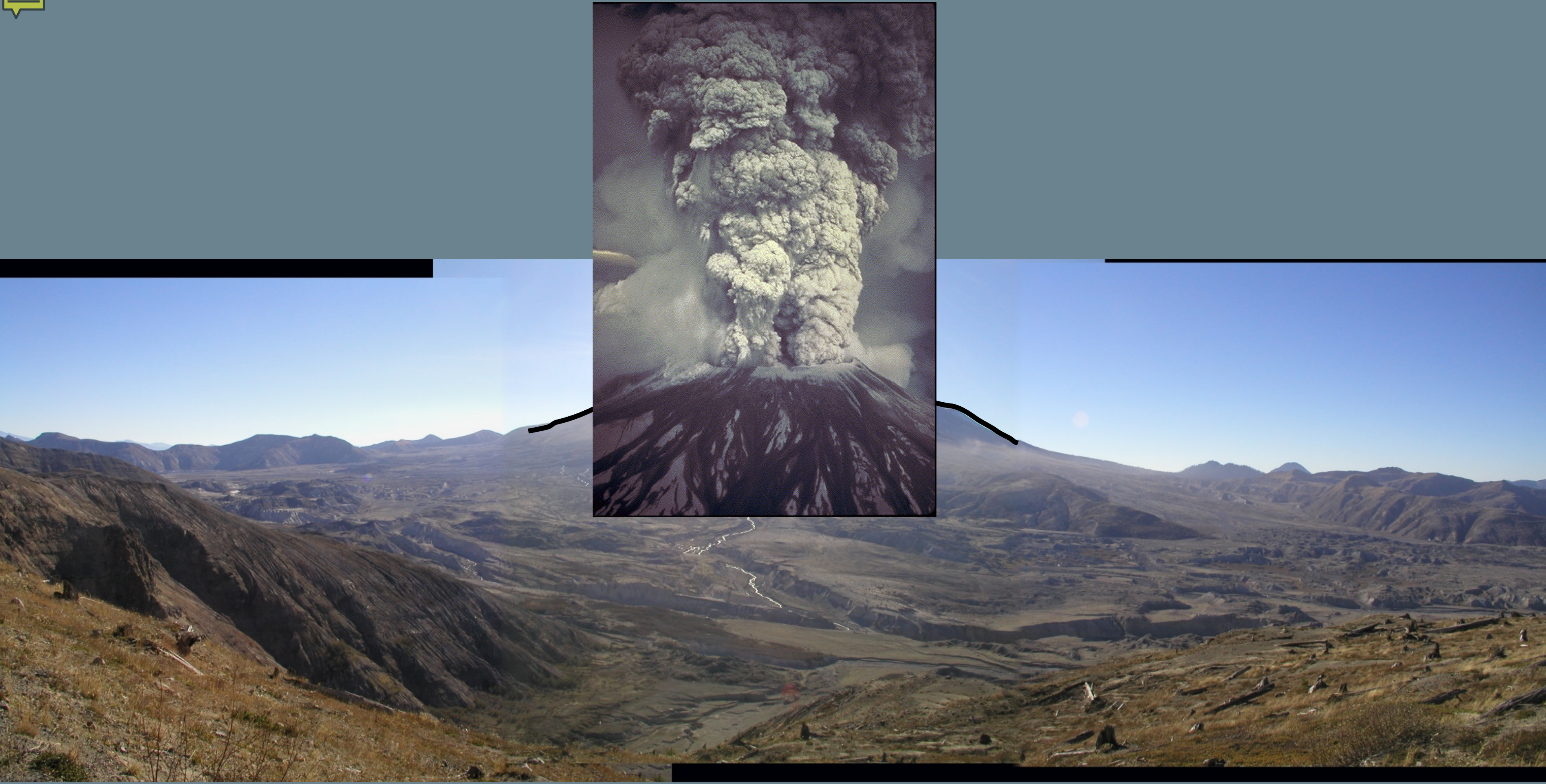
WHEN IS A SURGE NOT A SURGE? THAT IS THE PERPLEXING QUESTION

(for emergency managers)

The road from nuclear blasts to Mount St. Helens and beyond

GSA Seattle October 24, 2017

Catherine Hickson PhD PGeo
Tuya Terra Geo Corp



Mount St Helens, May 18, 1980

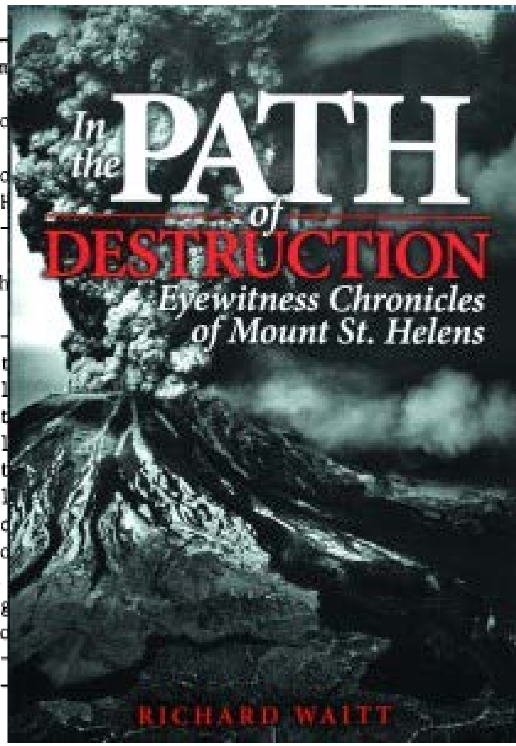
37 years, 5 months, and 6 days ago…..

Eyewitnesses – there were many!

Rosenbaum and Waitt, 1981 USGS 1250

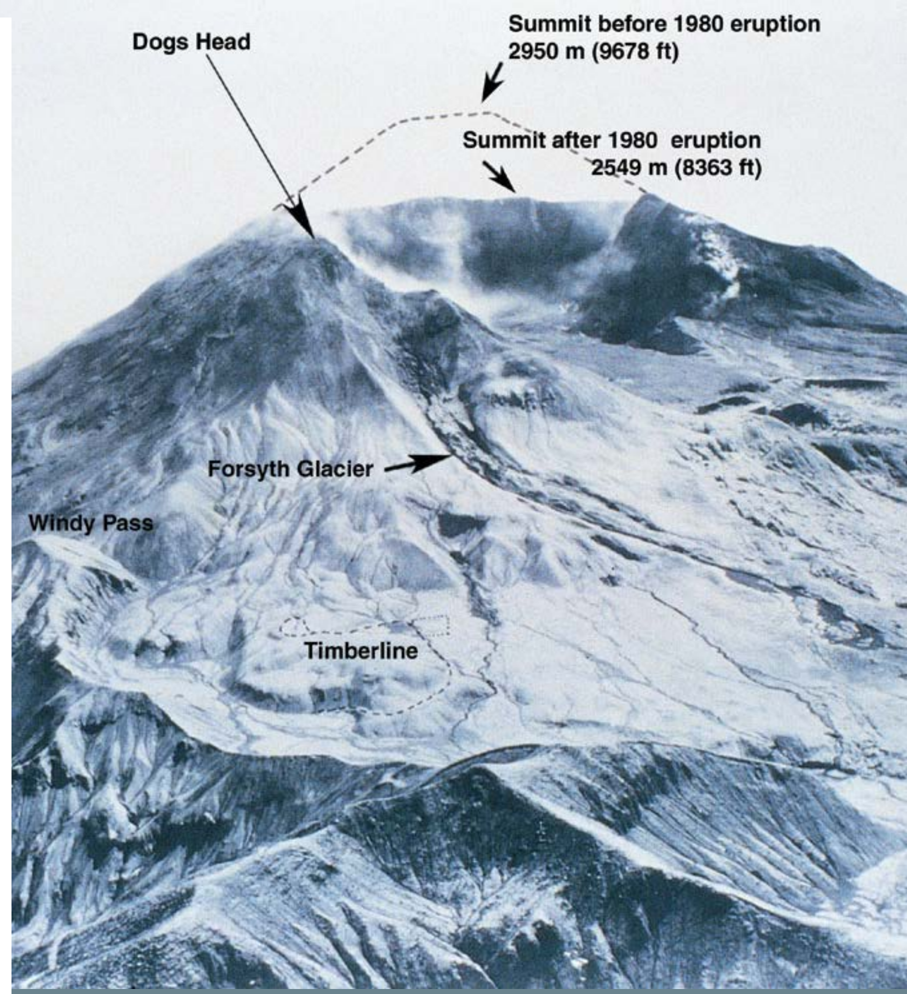
Table 5.—Locations of eyewitnesses to the May 18 eruption

Site No. (fig. 35)	Location at the time of eruption	No. in party	No. at inter-view	Names of those interviewed	Remarks
0	In a sm over		2	K. and D. Stoffel-----	This account was previously published (Stoffel, 1980).
8SE	North o		2	K. Anderson, K. Kilpatrick.	
15E	Near ro St. H		2	P. and C. Hickson-----	Took photographs of initial stages of the eruption.
15ENE	---do--		2	L. McCulley, J. Findley.	The witnesses drove to the locality after the start of the eruption.
12Wa	On high Fork		2	T. and M. Kearny------	Took photographs of initial stages of the eruption.
12Wb	---do--		1	F. Valenzuela---------	Do.
9W	On nort Toutl		3	J. and A. Sullivan, M. Dahl.	
8W	On sout Toutl		1	D. Crockett-----------	Took video tape of part of his experience.
13NW	On sout Toutl		1	C. McNerney-----------	Drove down the North Fork Toutle valley outrunning the blast cloud.
17NW	At a ro 504 c Fork		2	G. and K. Baker-------	Do.
17NEa	On ridg of Mo		1	K. Ronholm------------	Took photos of initial stages of the eruption.
17NEb	---do--		2	W. and L. Johnson.	
17NEc	---do--		4	G. Rosenquist, J. and L. Harvey, W. Dilly.	Took photos of the initial stages of the eruption.
20NW	On north side of ridge, south of Hoffstadt Creek.	4	1	J. Scymanky-----------	Four persons at this locality were severely burned when overrun by the blast cloud. Three subsequently died.



The father of pyroclastic (base) surges <u>Jim Moore</u>

Understanding the event; 1000's of papers, reports, many authored by Jim Moore.



TOPOGRAPHIC AND STRUCTURAL CHANGES, MARCH–JULY 1980—PHOTOGRAMMETRIC DATA

By JAMES G. MOORE *and* WILLIAM C. ALBEE

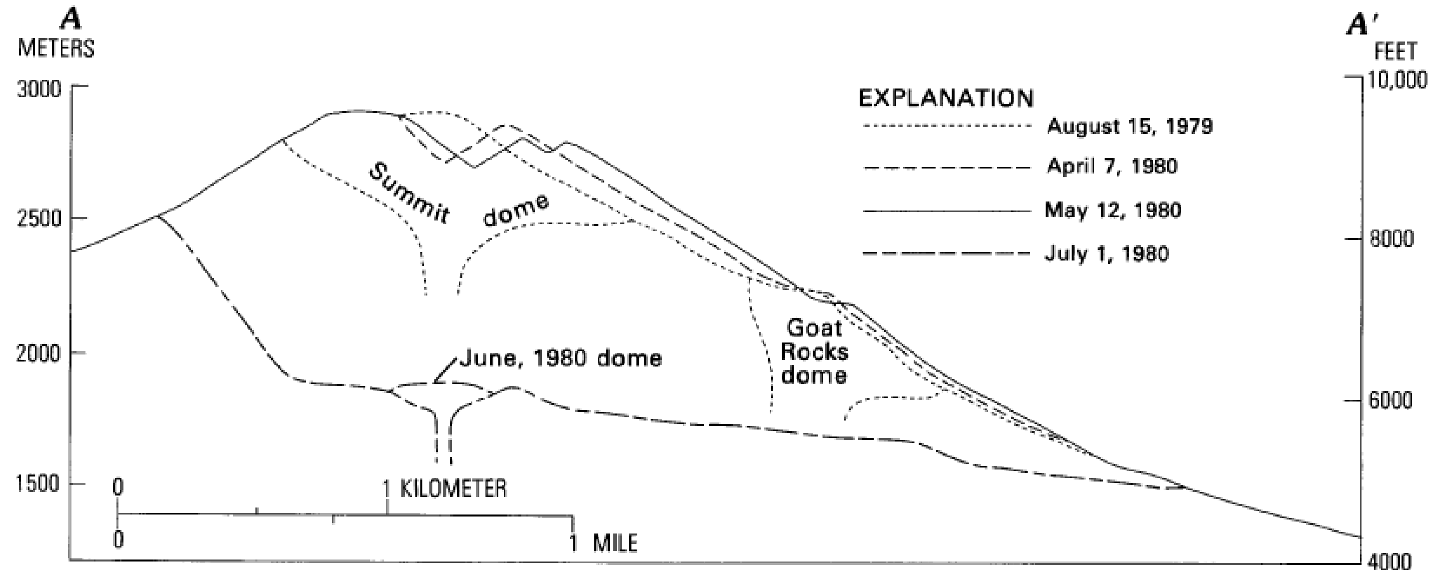


Figure 73.—South-north profiles of Mount St. Helens, August 1979 to July 1980. Scale slightly reduced from figure 68.

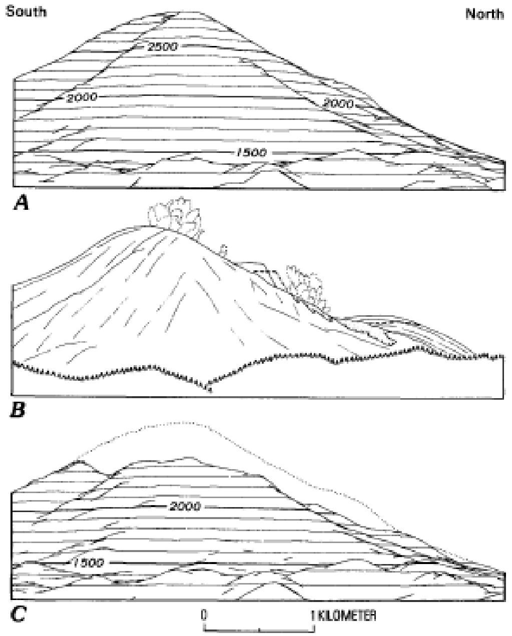
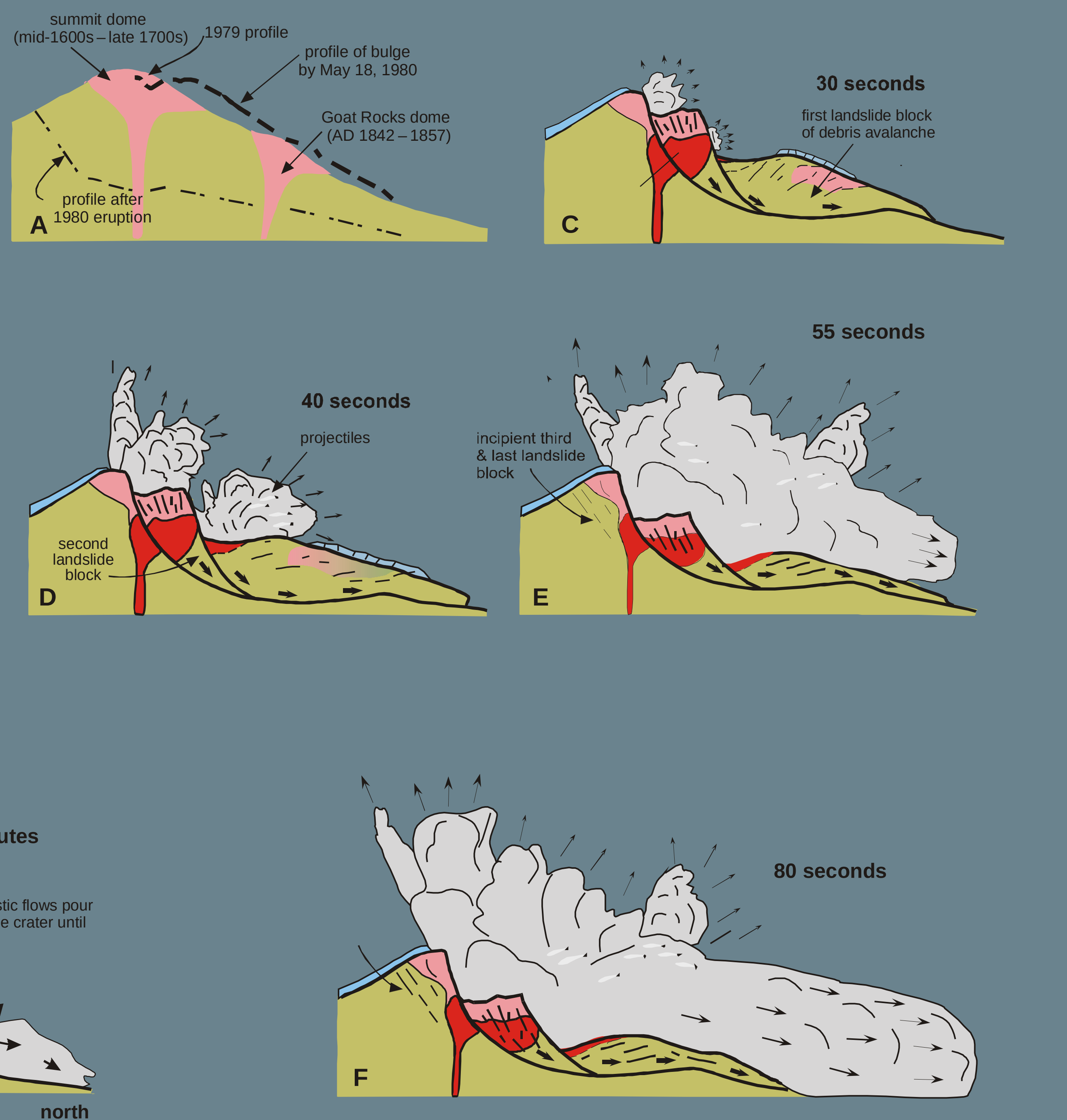
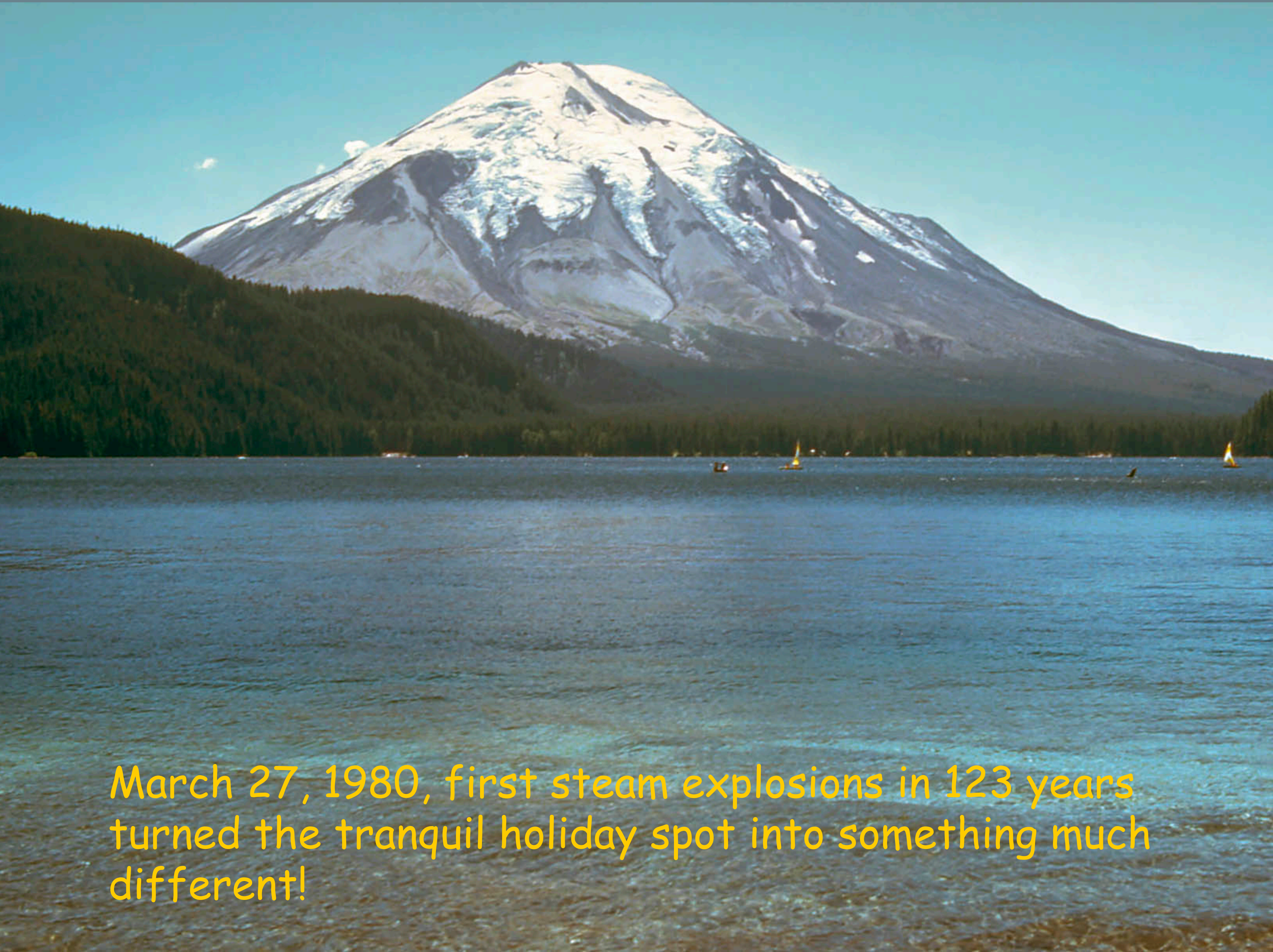
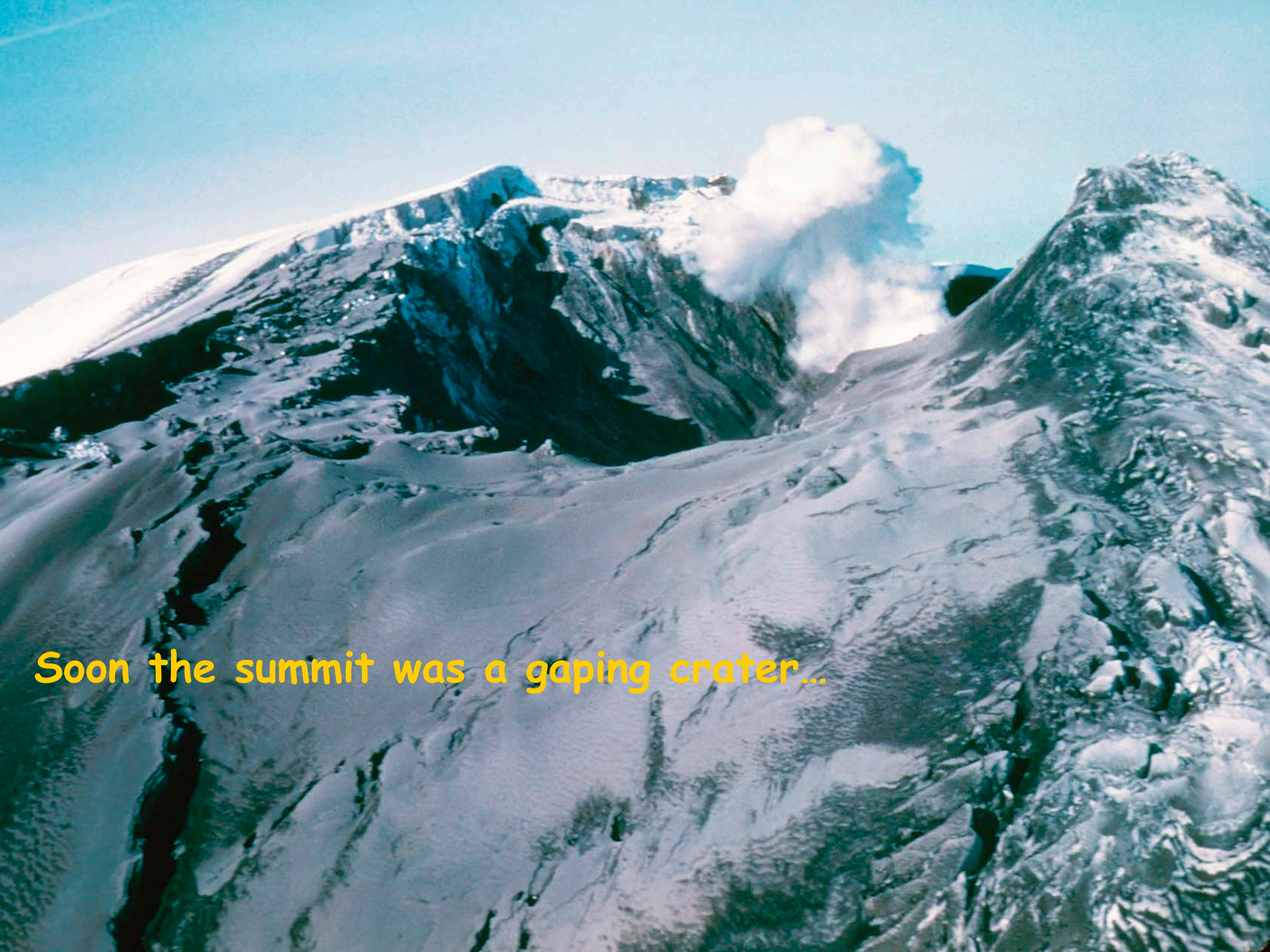


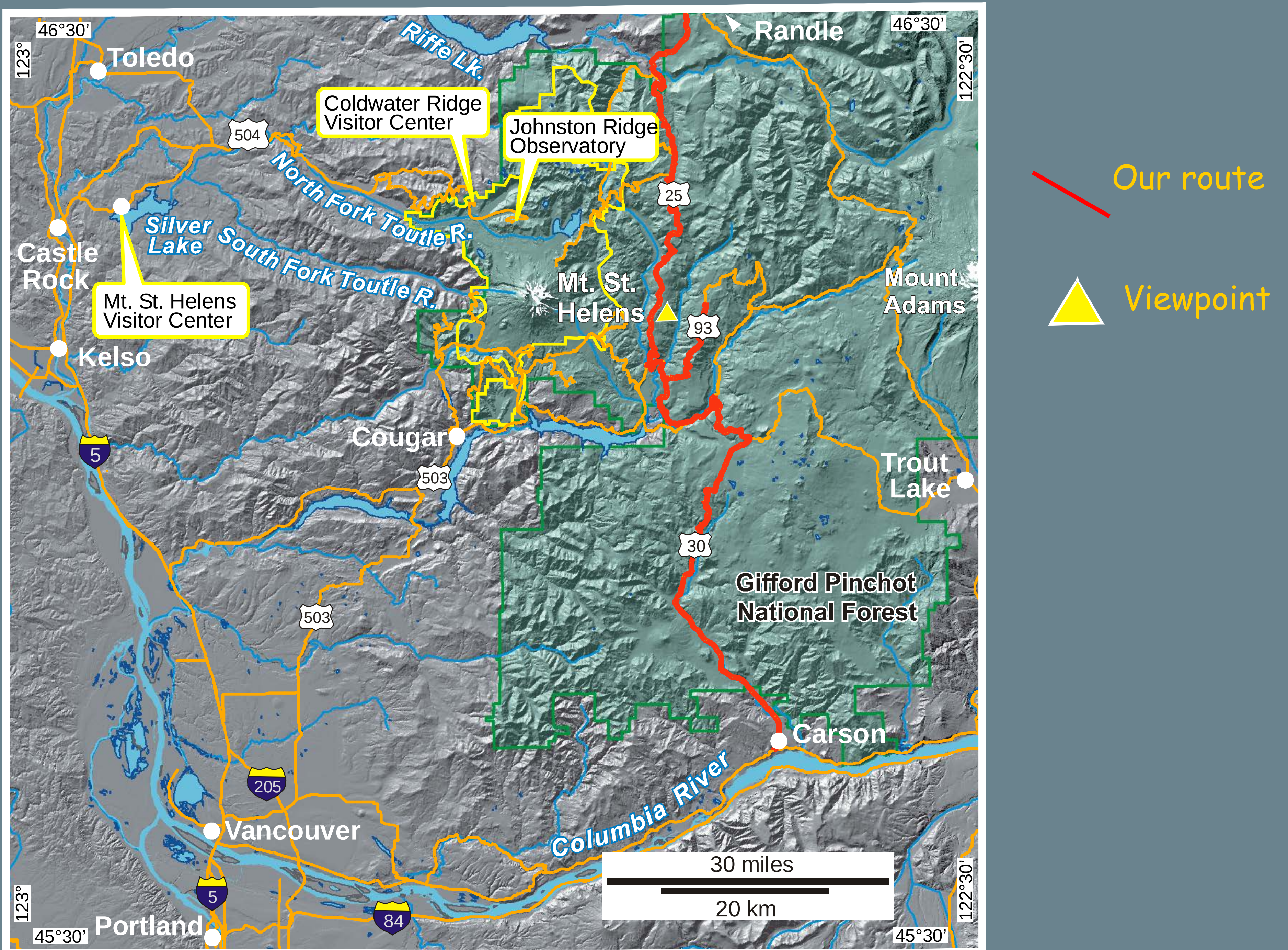
Figure 75.—Perspective views of Mount St. Helens from 15 km to the east. A, computer-generated model showing topography, August 15, 1979. Contours in meters. B, Sketch from photograph by Paul and Carol Hickson at about 0832:39, May 18, 1980. Dashed line, profile of landslide block in photograph 4 s later. Ice and snow avalanches shown by light-dotted pattern. C, Computer-generated model showing topography, July 1, 1980. Preeruption profile shown by dotted line. Scale is approximate.




March 27, 1980, first steam explosions in 123 years turned the tranquil holiday spot into something much different!

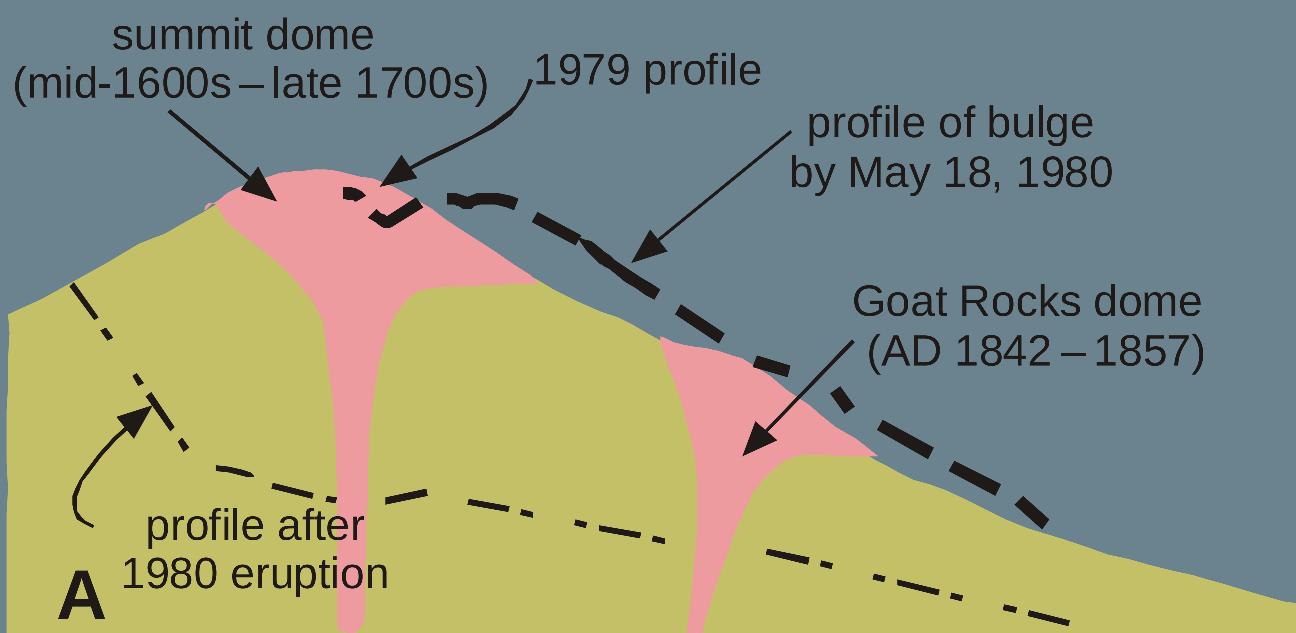

Soon the summit was a gaping crater…


Goat Rocks, site of the mid 1800's eruption
The "bulge" began to grow at a rate of over 2 m a day


46°30'
123°
Toledo
Riffe Lk.
Randle
46°30'
122°30'
Coldwater Ridge
Visitor Center
Johnston Ridge
Observatory
504
25
North Fork Toutle R.
Silver
Lake
South Fork Toutle R.
Castle
Rock
Mt. St. Helens
Visitor Center
Mt. St.
Helens
93
Mount
Adams
Kelso
Cougar
5
503
Trout
Lake
30
Gifford Pinchot
National Forest
503
Carson
205
Columbia River
Vancouver
30 miles
20 km
5
84
123°
45°30'
Portland
45°30'
122°30'
Our route
Viewpoint

Growing bulge, March 22 to May 18, 1980

Sunset, looking west, May 17,1980



Mt. St. Helens – May 17, 1980

25 seconds

29 seconds

39 seconds

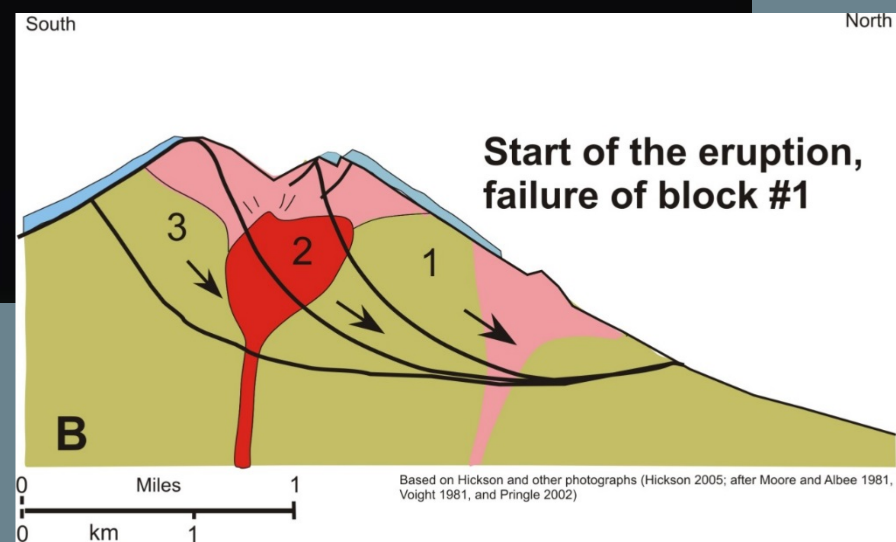
55 seconds

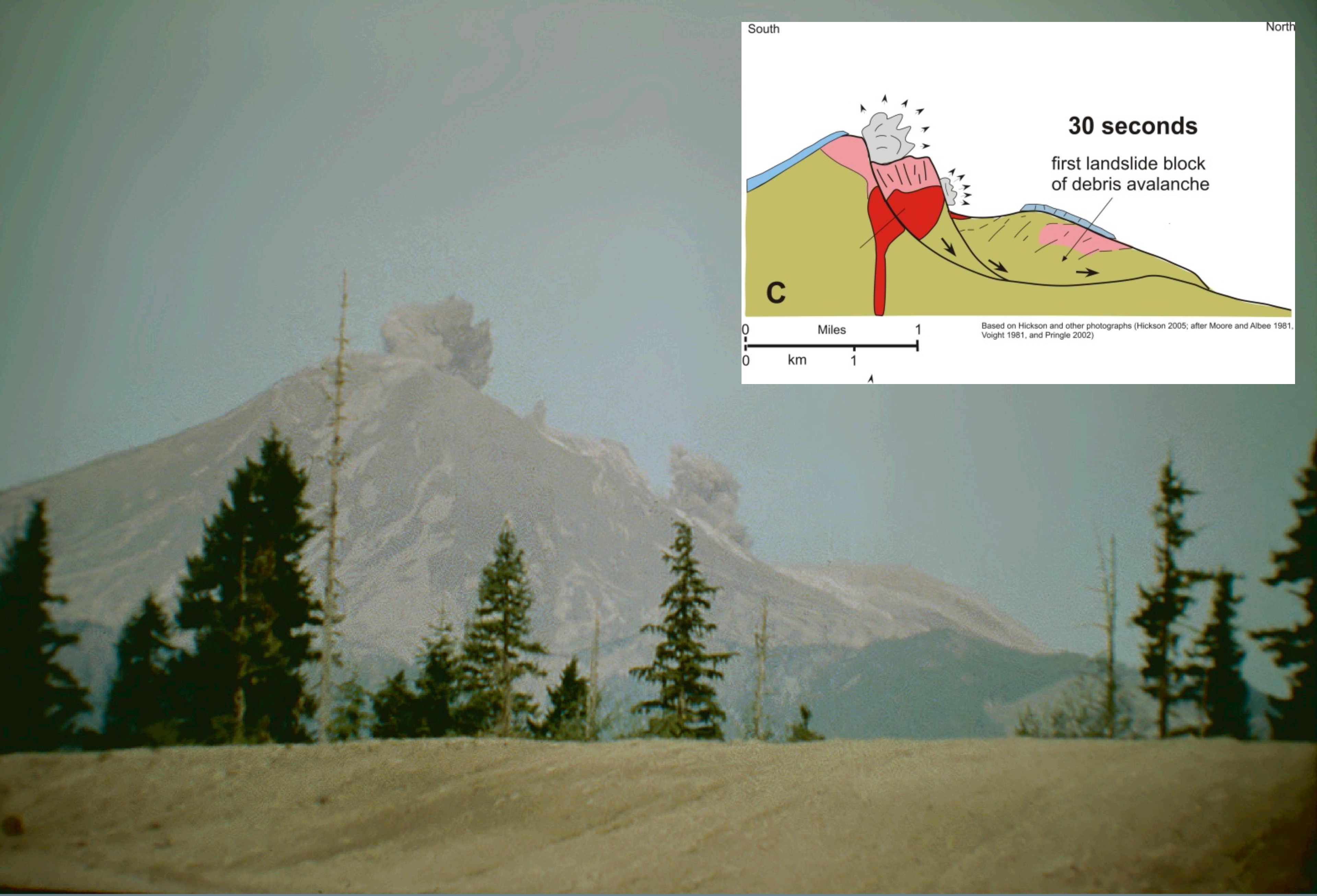
70 seconds

80 seconds

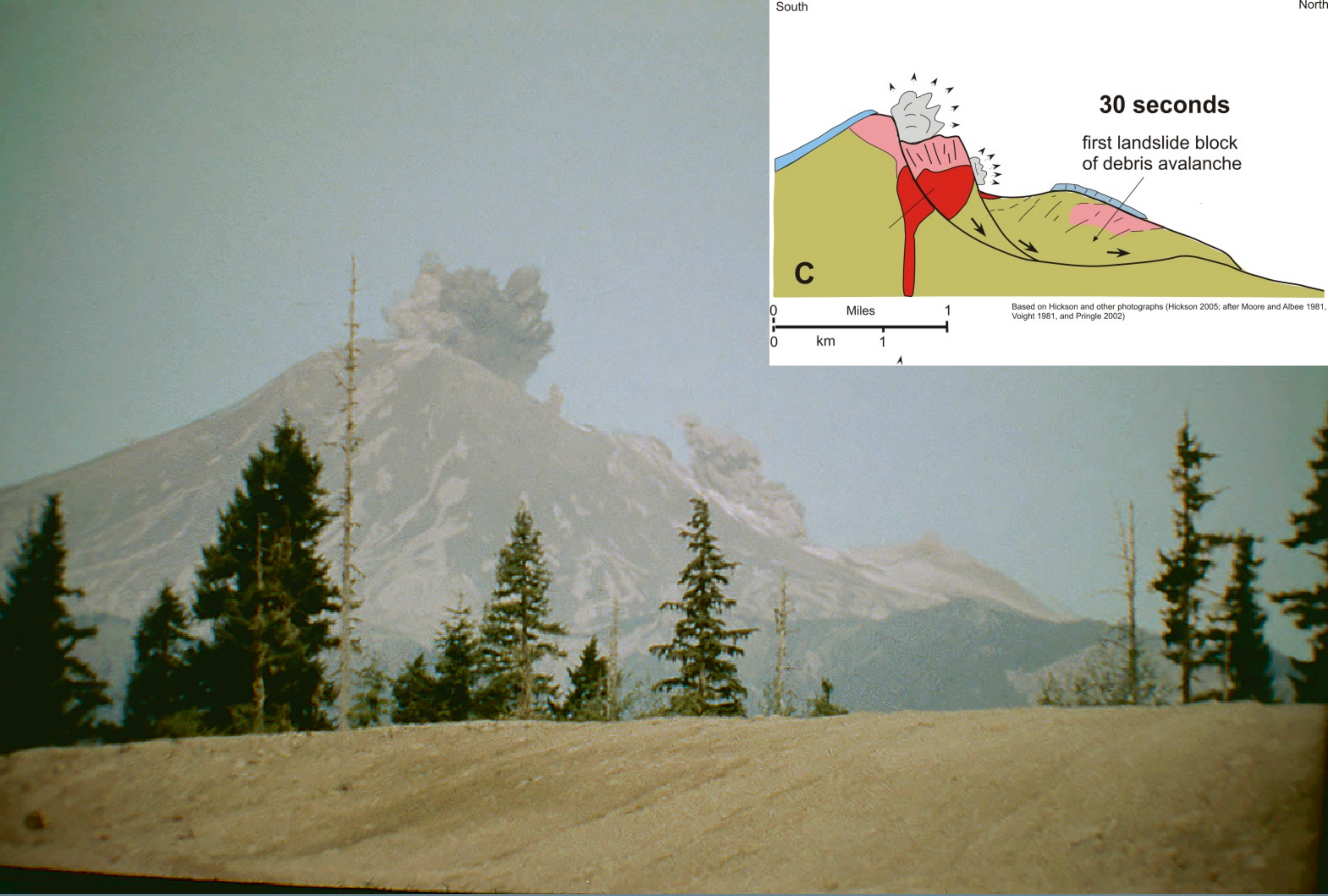
120 seconds


from the car window.

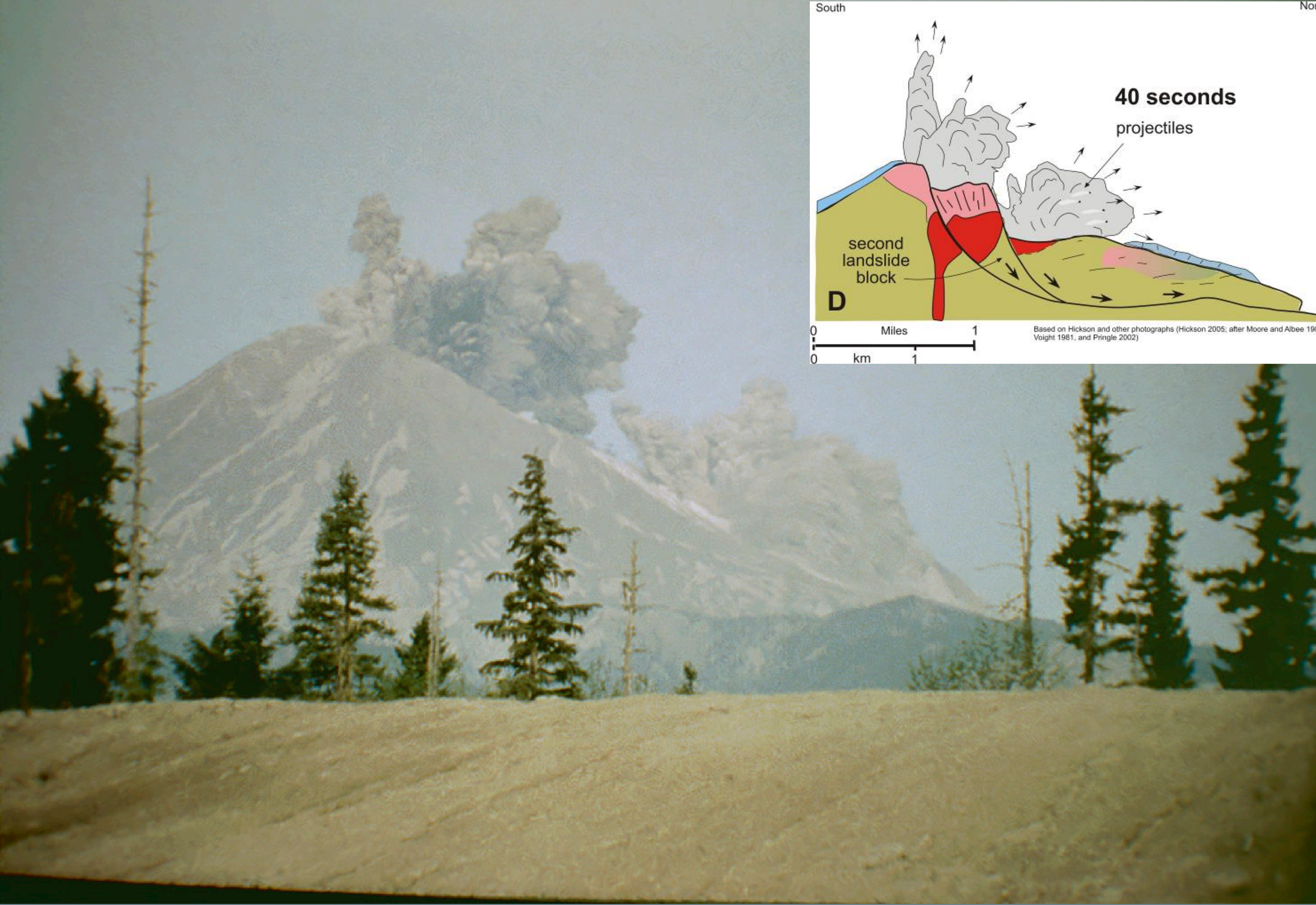

South
North
Start of the eruption, failure of block #1
3
2
1
B
0
Miles
1
0
km
1
Based on Hickson and other photographs (Hickson 2005; after Moore and Albee 1981, Voight 1981, and Pringle 2002)



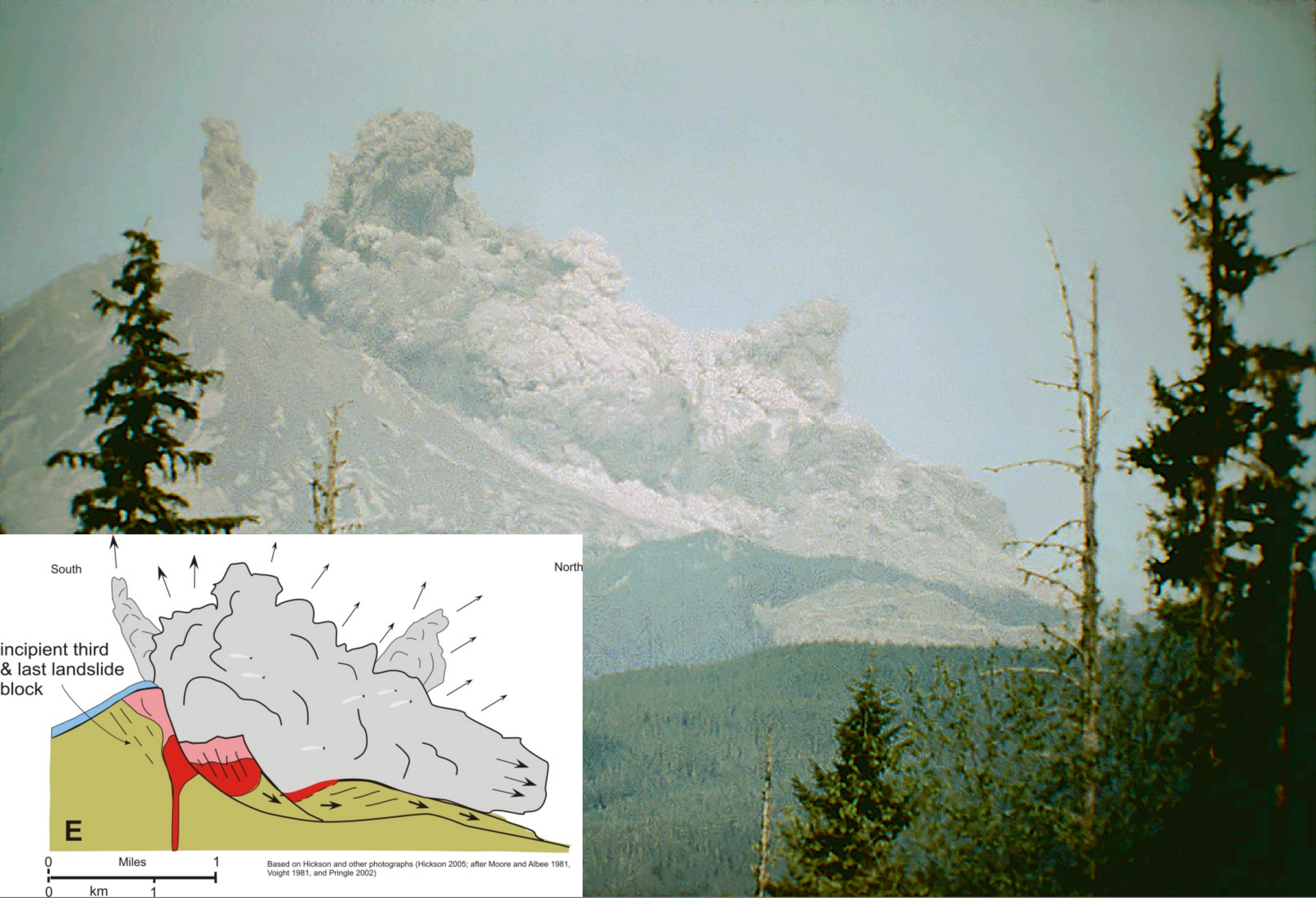
25 seconds after the start of the landslide



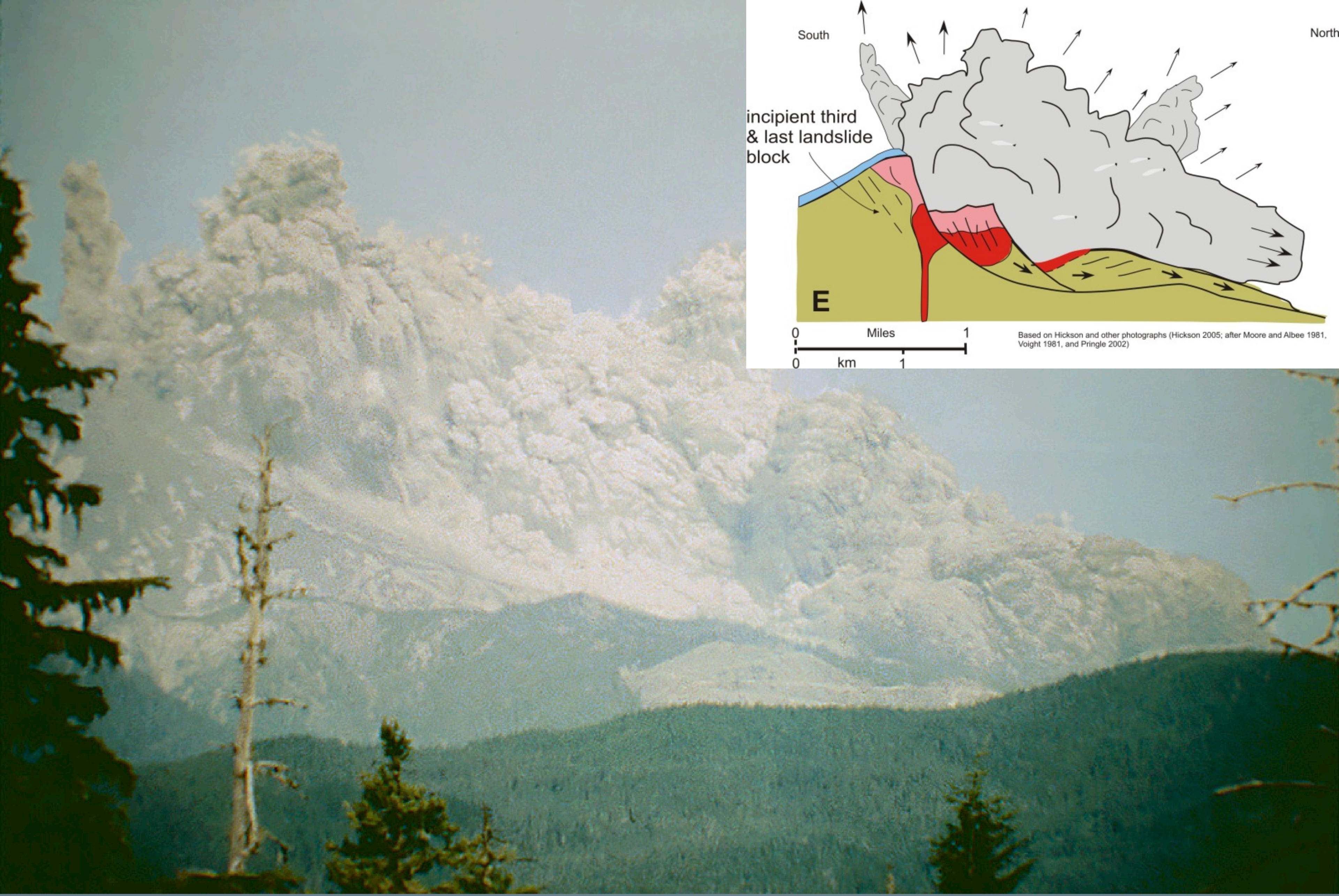
29 seconds after the start of the landslide



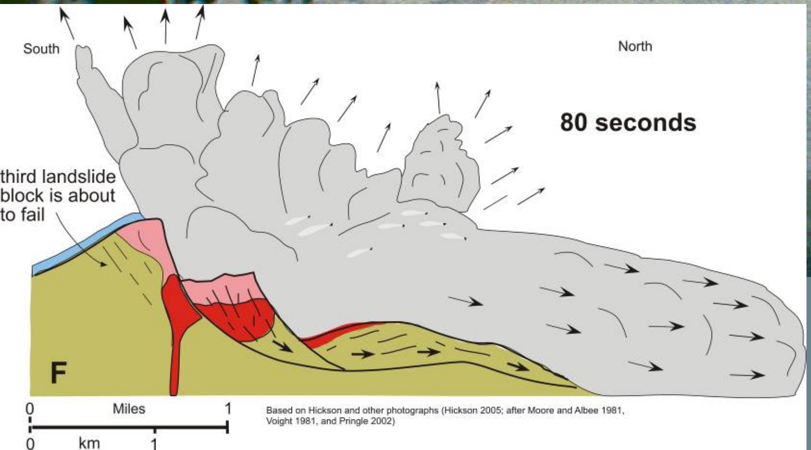
39 seconds after the start of the landslide



55 seconds after the start of the landslide



70 seconds after the start of the landslide



80 seconds after the start of the landslide

2 minutes after the start of the landslide


From the car window.

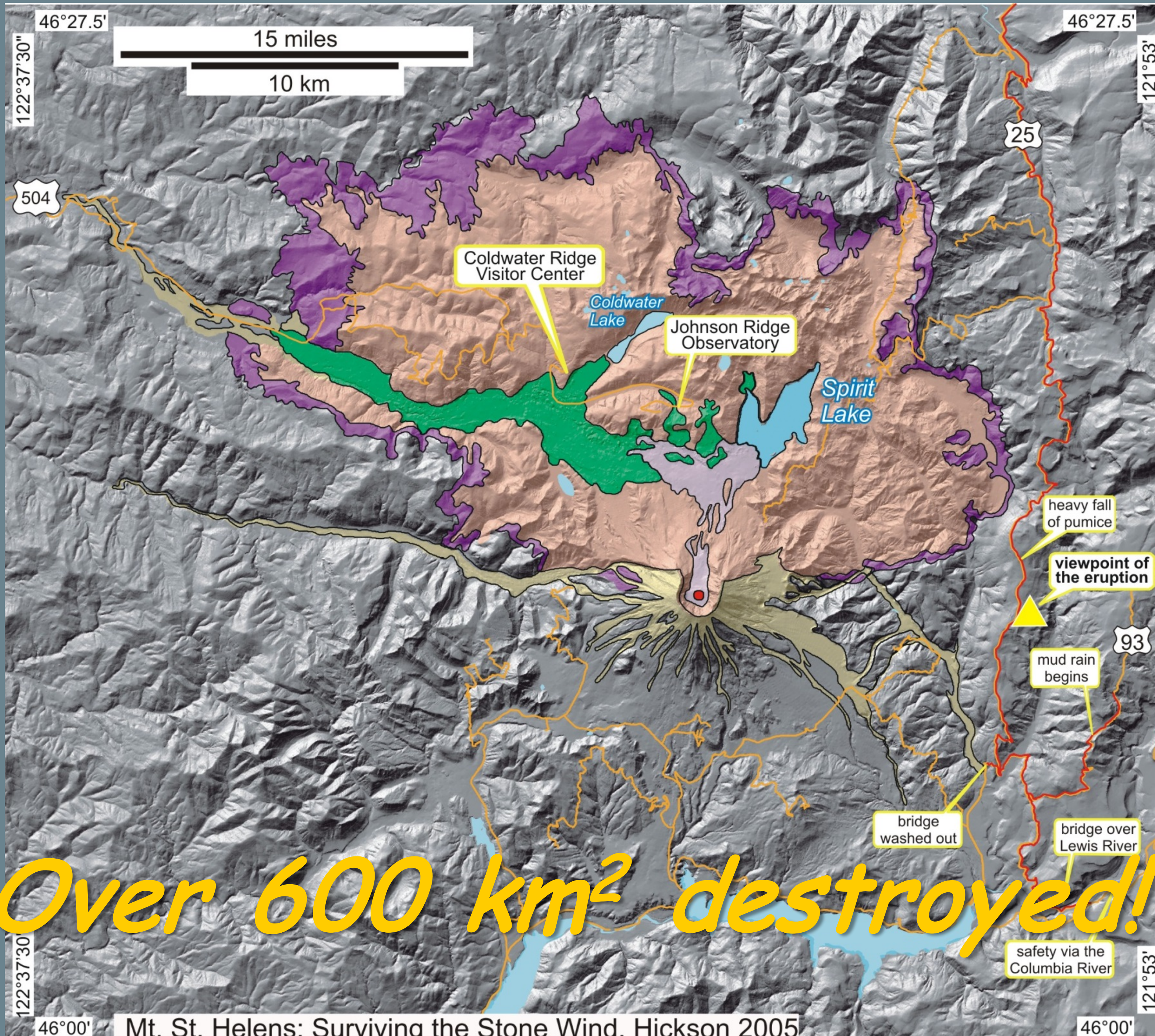
From the car window.

Approximately 15 minutes after the start of the eruption, the column was well developed and had begun to spread laterally.

The Plinian eruption column was now 25 km in height; the surge cloud had rolled over the landscape and was now hanging low to the ground.

The Pyroclastic Surge

What was the impact of this event?



Over 600 km^2 destroyed!

The pyroclastic surge killed most of the people, plants and animals; it was under-represented in terms of its hazard potential.

Over 600 km^2 of alpine to sub alpine environment was destroyed, including the soil layer in many areas.

Turbulent flow vs laminar flow This was the “flavour” of the 1970’s, thinking changed after May 18, 1980.

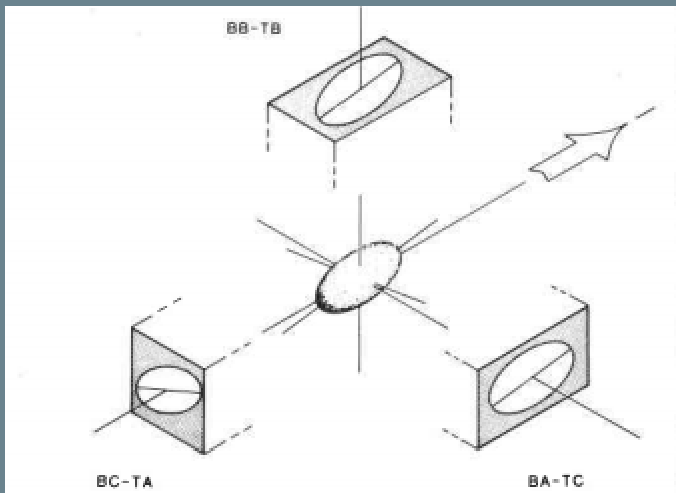


FIG. 7. Block diagram of the average grain, showing orientation with respect to the flow. Arrow shows flow direction.

Weighted vector analysis applied to surge deposits from the May 18, 1980 eruption of Mount St. Helens, Washington

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Received June 12, 1981
Revision accepted November 20, 1981

Deposit was characterized by angular, fractured clasts and organic matter

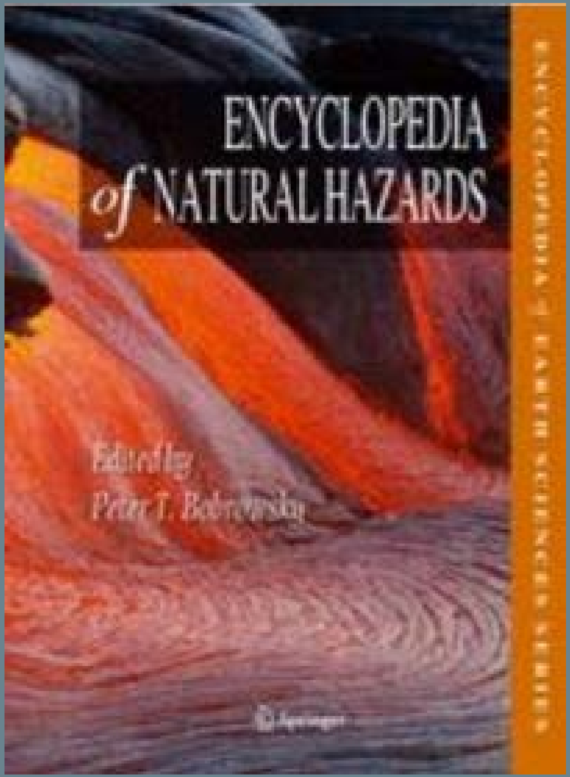
BASE SURGE

Synonyms

Pyroclastic surge; Ground surge; Blast; Ground based surge; Surtseyan Eruption; Pyroclastic density flow

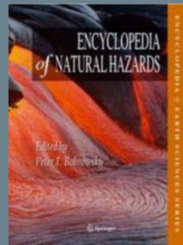
Definition:

Base Surge. A destructive, dilute, fast moving (30m/s) turbulent density current (flow) of particles and gas and/or liquid that is the result of an explosion.



Not just semantics – hydrovolcanic (phreatomagmatic) events often have little warning and travel farther and are destructive at great distances.

BASE SURGE



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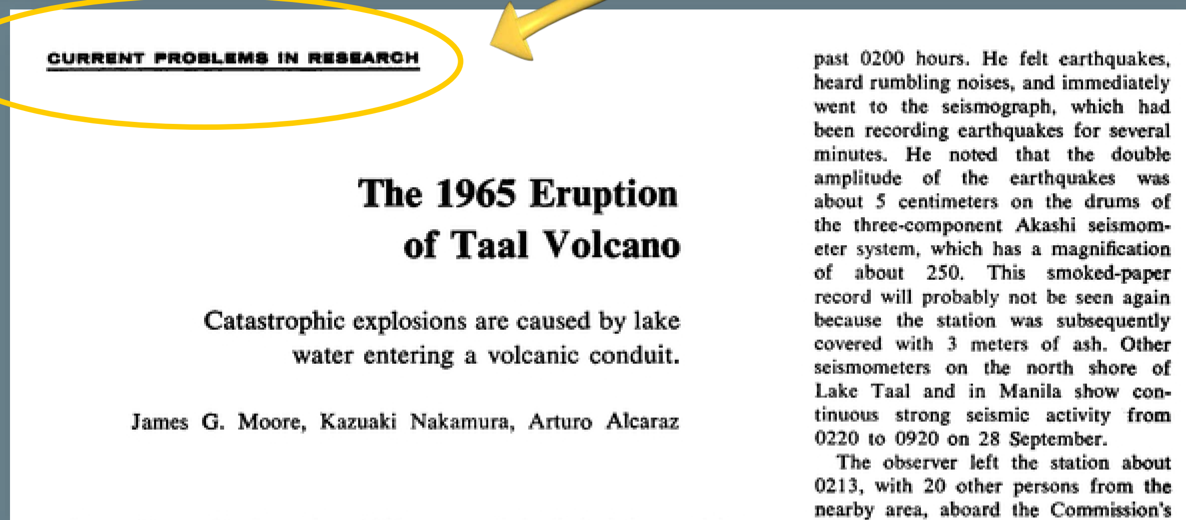


CURRENT PROBLEMS IN RESEARCH

The 1965 Eruption of Taal Volcano

Catastrophic explosions are caused by lake water entering a volcanic conduit.

James G. Moore, Kazuaki Nakamura, Arturo Alcaraz

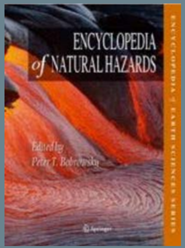
past 0200 hours. He felt earthquakes, heard rumbling noises, and immediately went to the seismograph, which had been recording earthquakes for several minutes. He noted that the double amplitude of the earthquakes was about 5 centimeters on the drums of the three-component Akashi seismometer system, which has a magnification of about 250. This smoked-paper record will probably not be seen again because the station was subsequently covered with 3 meters of ash. Other seismometers on the north shore of Lake Taal and in Manila show continuous strong seismic activity from 0220 to 0920 on 28 September.

The observer left the station about 0213, with 20 other persons from the nearby area, aboard the Commission's

Moore, J.G., Nakamura, K., Alcaraz, A., 1966a. The September 28-30, 1965 Eruption of Taal Volcano, Philippines. Bulletin of Volcanology 29-1: 75-76.

Moore, J.G., Nakamura, K., Alcaraz, A., 1966b. The 1965 Eruption of Taal Volcano. Science, New Series 151- 371: 955-960.

BASE SURGE



Synonyms

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Hickson, 2013

Base surges are highly destructive and dangerous (Nakada 2000). The term has been used to describe high velocity (up to 30 m/s) flows of material emanating from explosions. The term was first used to describe the ground hugging clouds seen following underwater and underground nuclear explosions (Trinity Atomic Web Site). In photographs of nuclear explosions there is a characteristic ring-shaped cloud that moves outward close to the ground – the base surge (Trinity Atomic Web Site Figure 2.97). It was first documented at the eruption of Capelinhos volcano, Azores October 10th, 1957 and then adopted by the volcanological community based on the work of **James G. Moore (1966a&b)** and his observations of the eruption of Taal volcano in the Philippines.

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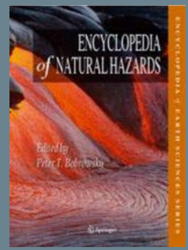
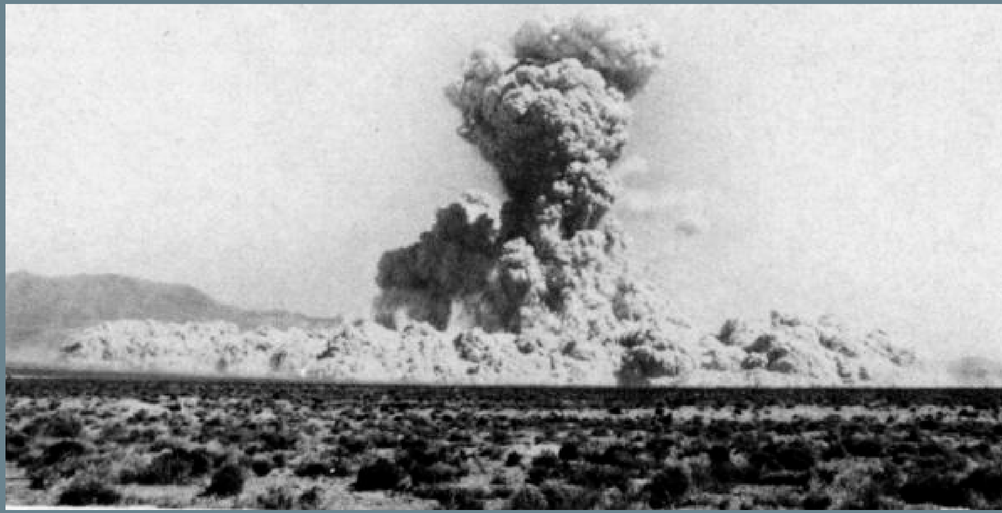
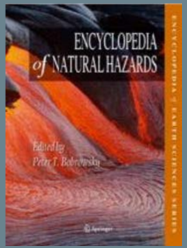


J.G. Moore, adopted the term "base surge" to describe phreatic to phreatomagmatic explosions and their fine grained (pulverized, broken clasts), bedded deposits. The term has become synonymous with "Surtseyan eruptions" which are phreatomagmatic (hydromagmatic). From these early observations, the term has been used in a number of ways making its precise definition in volcanological literature problematic. The term has also been used to describe the turbulent, dilute flow fronts visible in pyroclastic flows.



Trinity Atomic Web Site

BASE SURGE



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Hickson, 2013

Thus the usage of the term now spans cold, wet, phreatic explosions, to moderate temperature wet phreatomagmatic (or hydromagmatic) explosions (usually now referred to as "pyroclastic surges"), to the basal portions of hot dry pyroclastic flows. Work by Sulpizio *et al*. (2008) and others using large scale experiments shows the continuum and the useage of the term "pyroclastic density current" (PDC) has now become more common. In all cases (wet or dry) the explosive discharges can be extremely vigorous and will propel eruption plumes of particles and gases many kilometers into the air. The resultant surges can sculpt the landscape by being highly erosive near source, stripping and scouring underlying soils and vegetation and more distally, depositing material as pyroclastic surge (base surge) deposits.

From the perspective of a hazard mapper and one concerned with risk assessment, the following things need to be considered: understanding if the deposit represents a single event or multiple events is critical....

Are the mapped units from events that are easy to predict? Might it expand beyond the assumed boundaries of areas thought to be safe?.....

Did the mappers identify all the deposits? Is there a clear understanding of what the deposits represents?

As was seen at Mt. St. Helens, the deposits left in the geological record belay the magnitude of the destructiveness of event; the erosive near-vent impact may be missed entirely in the historic record. Facies analysis continues to help unravel laminated strata associated with pyroclastic deposits where these inter-unit deposits represent a single complex event from a frequency- magnitude perspective, but careful stratigraphic analysis for phreatomagmatic base-surge events must be carried out around temperate region volcanoes.

Help your local emergency managers, hazard mappers and risk assessment team get it right!

Thank you!