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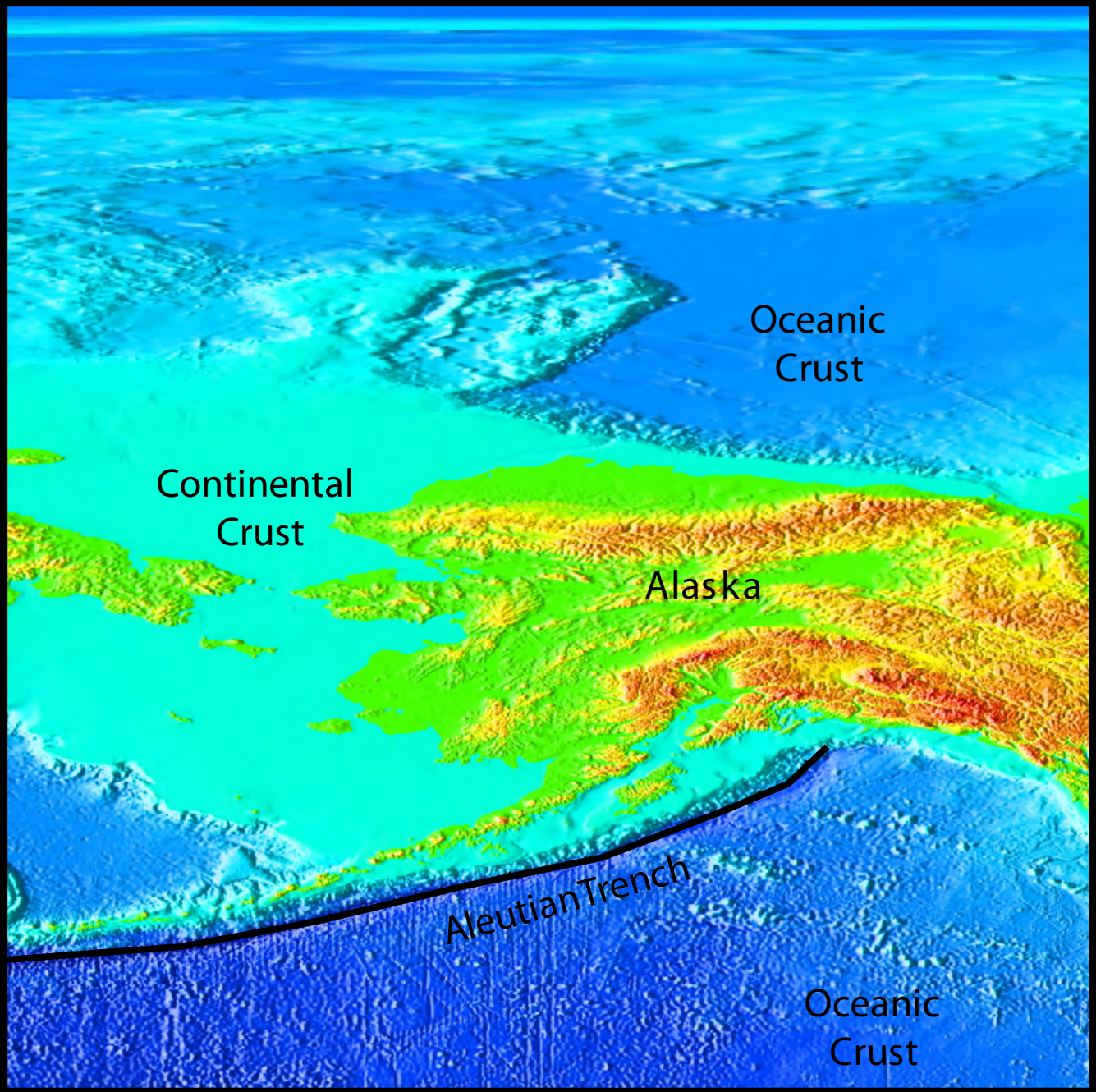
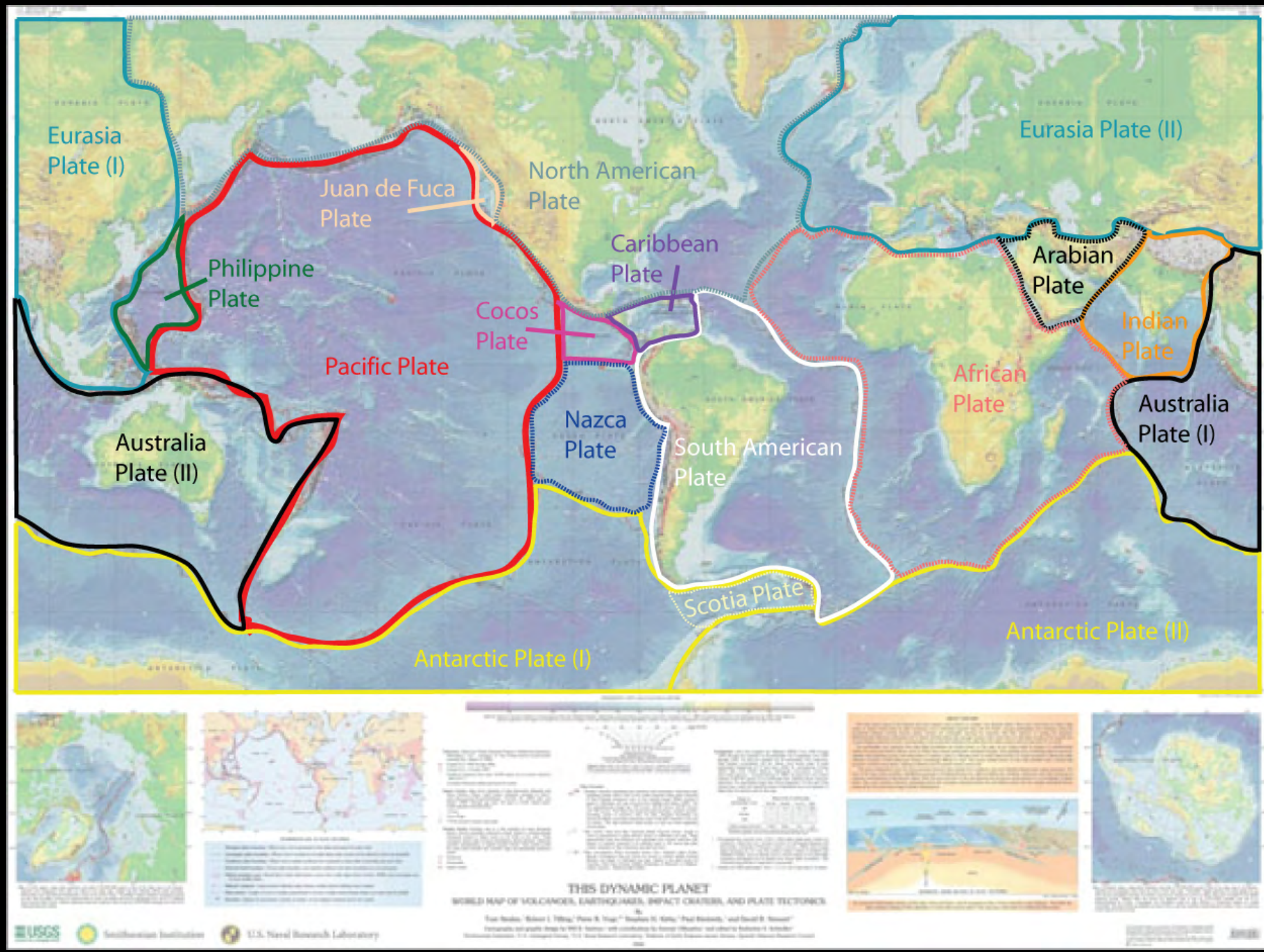
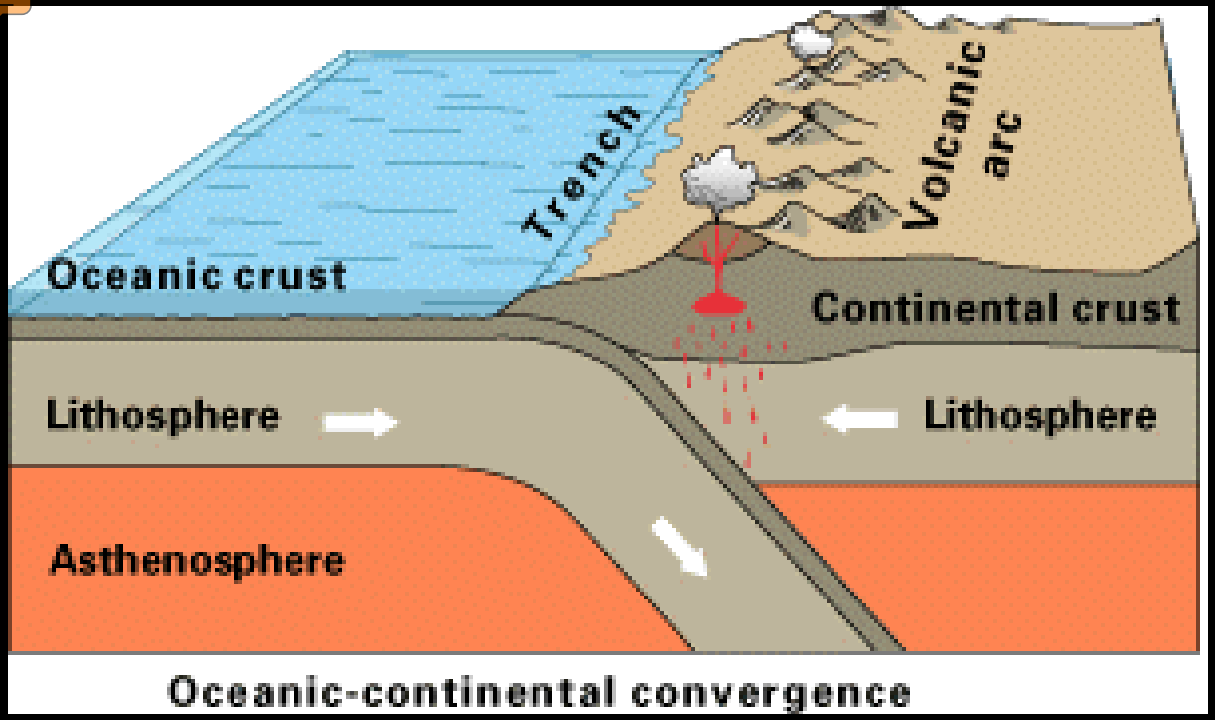
# Plate Tectonics Mapping

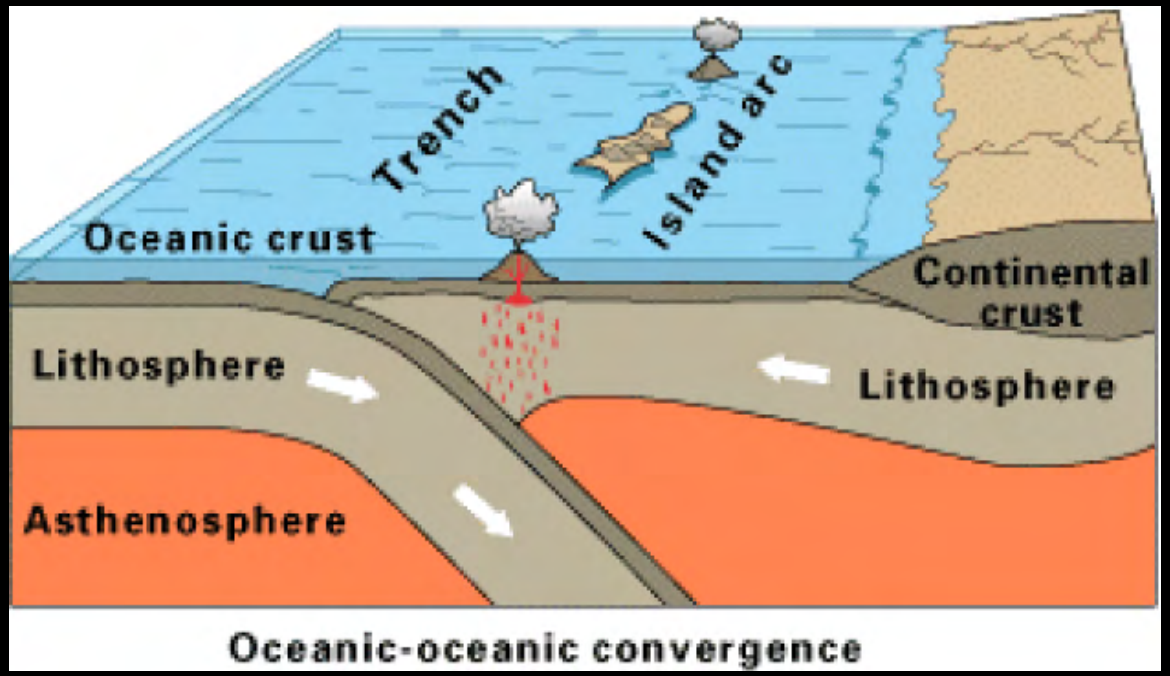
U.S. Department of the Interior
U.S. Geological Survey


Oceanic
Crust
Continental
Crust
Alaska
Aleutian Trench
Oceanic
Crust

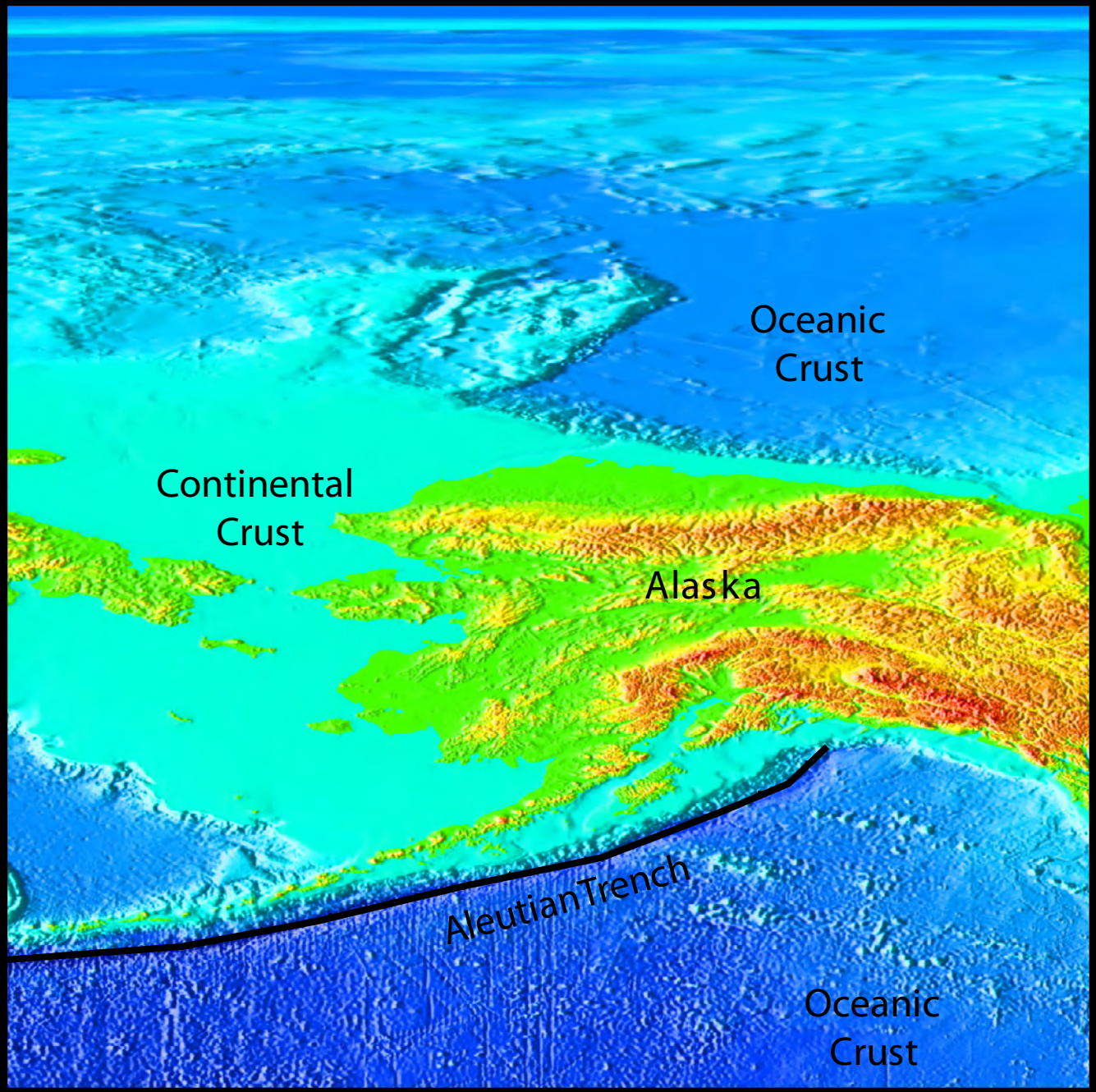

Eurasia Plate (I)
Juan de Fuca Plate
North American Plate
Eurasia Plate (II)
Philippine Plate
Caribbean Plate
Arabian Plate
Cocos Plate
Indian Plate
Pacific Plate
African Plate
Australia Plate (II)
Nazca Plate
South American Plate
Australia Plate (I)
Scotia Plate
Antarctic Plate (II)
Antarctic Plate (I)
THIS DYNAMIC PLANET
WORLD MAP OF VOLCANOES, EARTHQUAKES, IMPACT CRATERS, AND PLATE TECTONICS
USGS
Smithsonian Institution
U.S. Naval Research Laboratory




Oceanic-continental convergence




Oceanic-oceanic convergence


Oceanic
Crust
Continental
Crust
Alaska
Aleutian Trench
Oceanic
Crust

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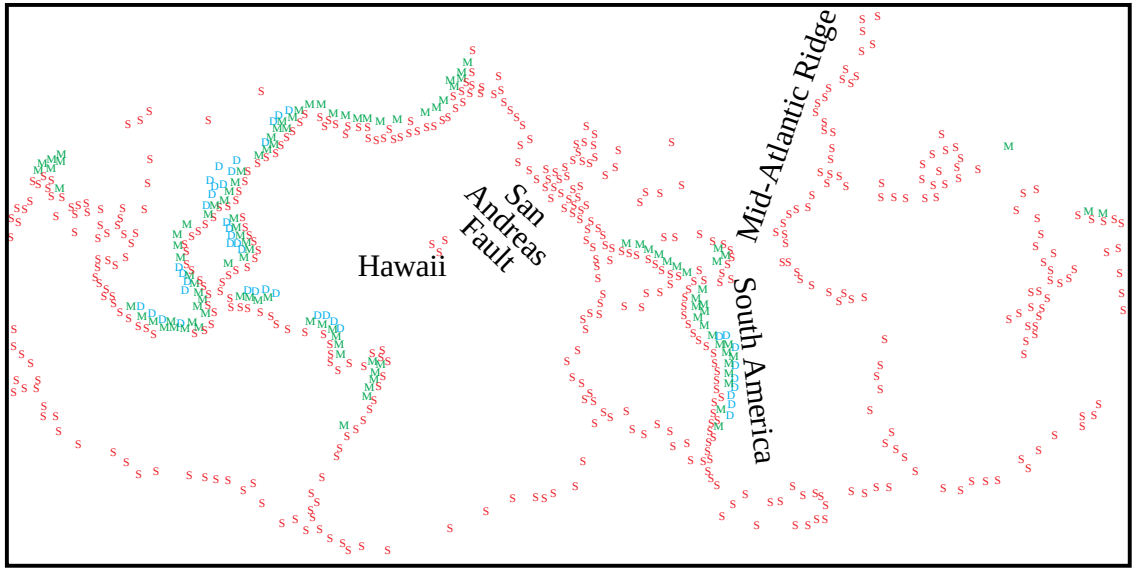
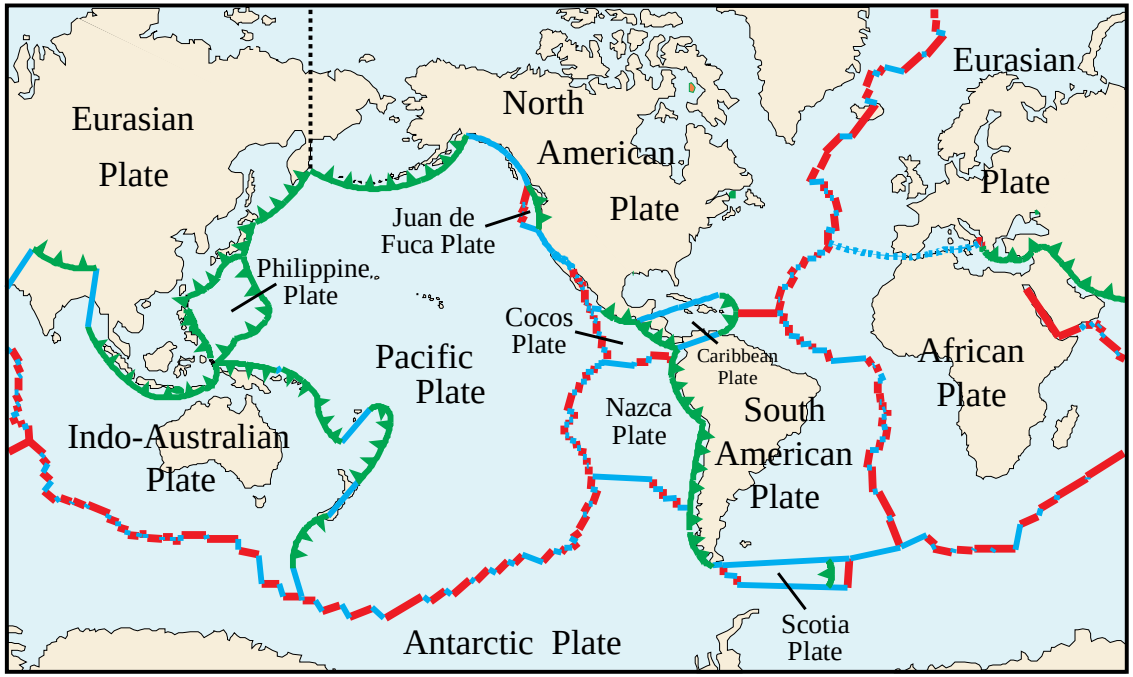
# Earthquake Mapping

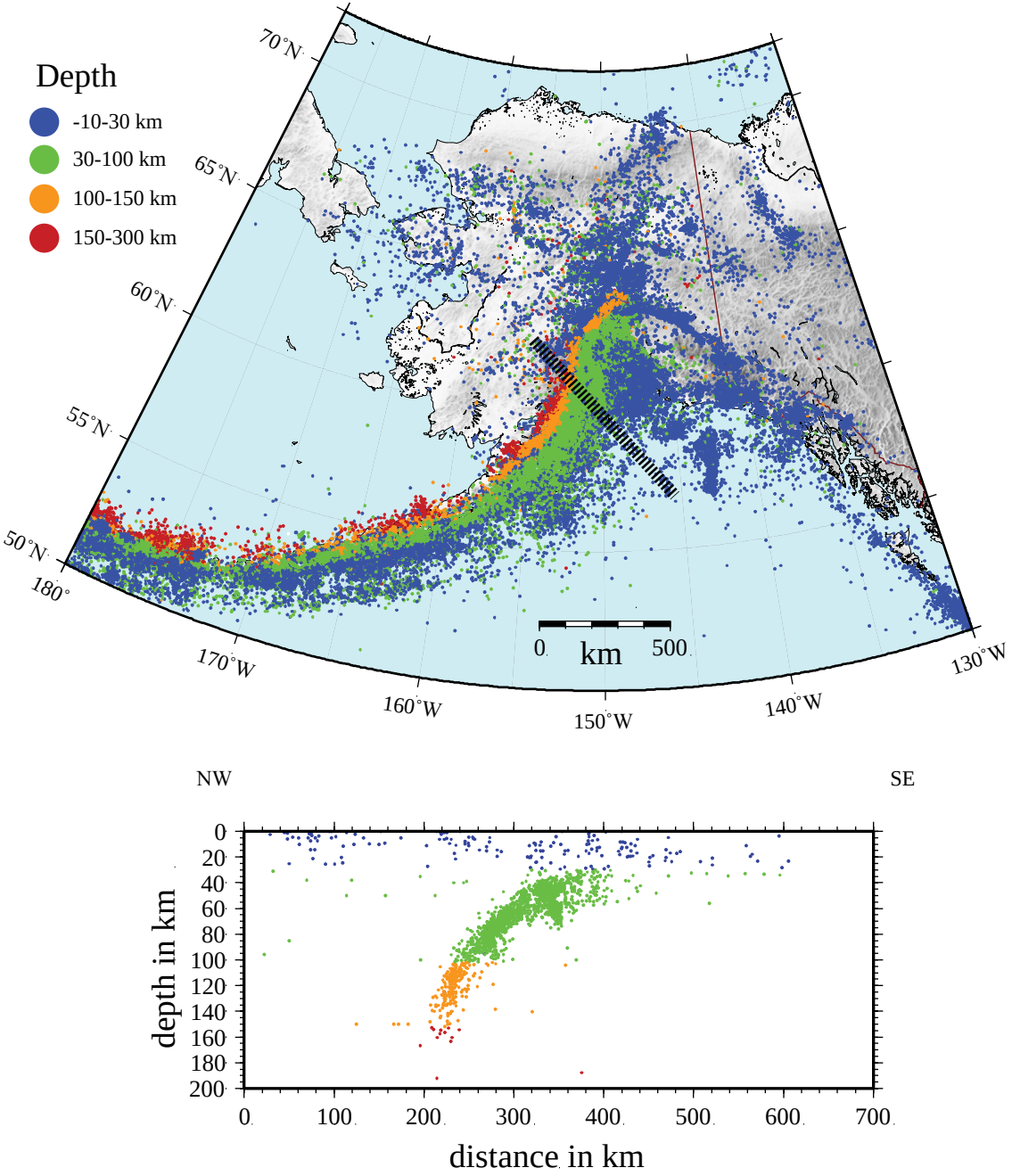
U.S. Department of the Interior
U.S. Geological Survey

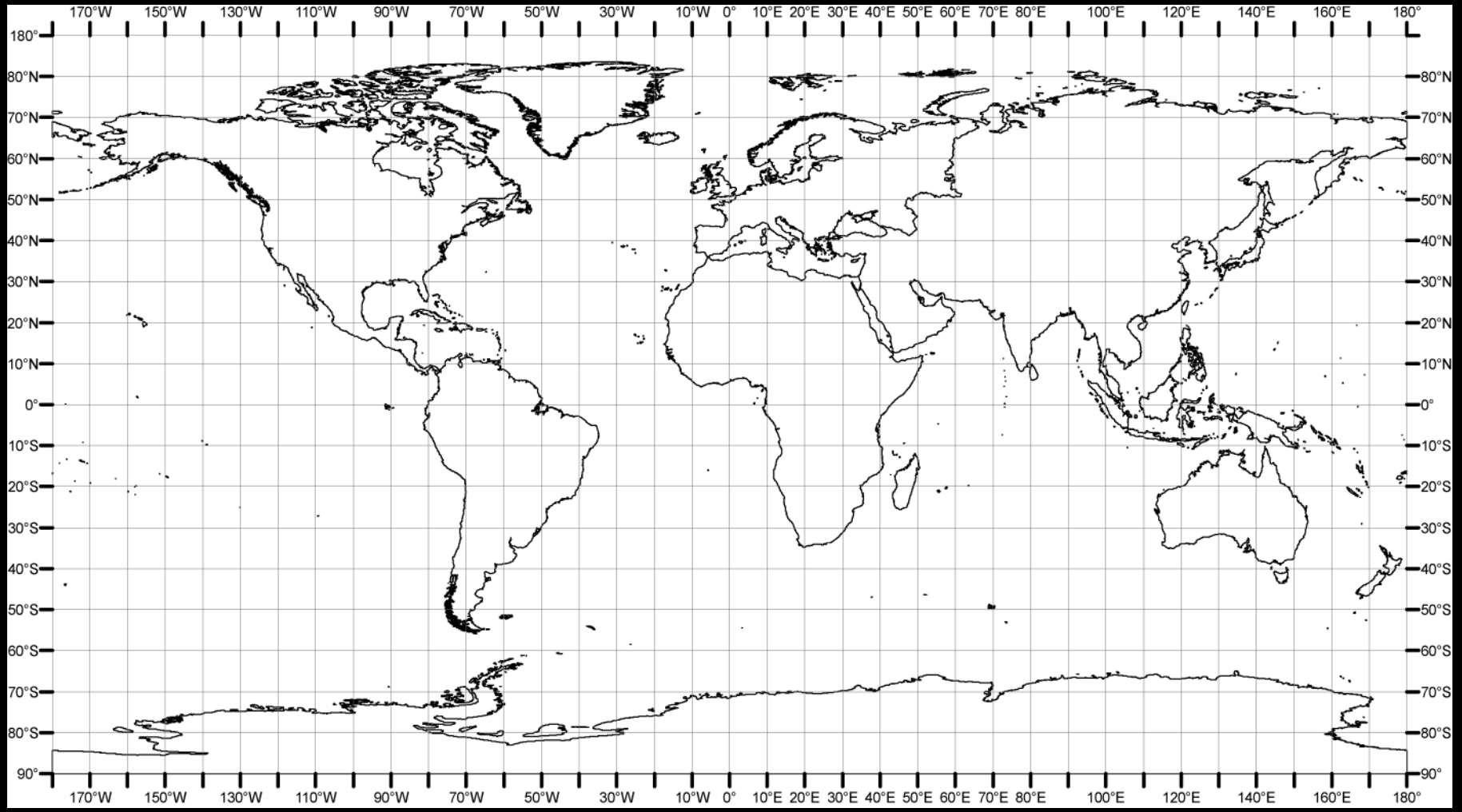


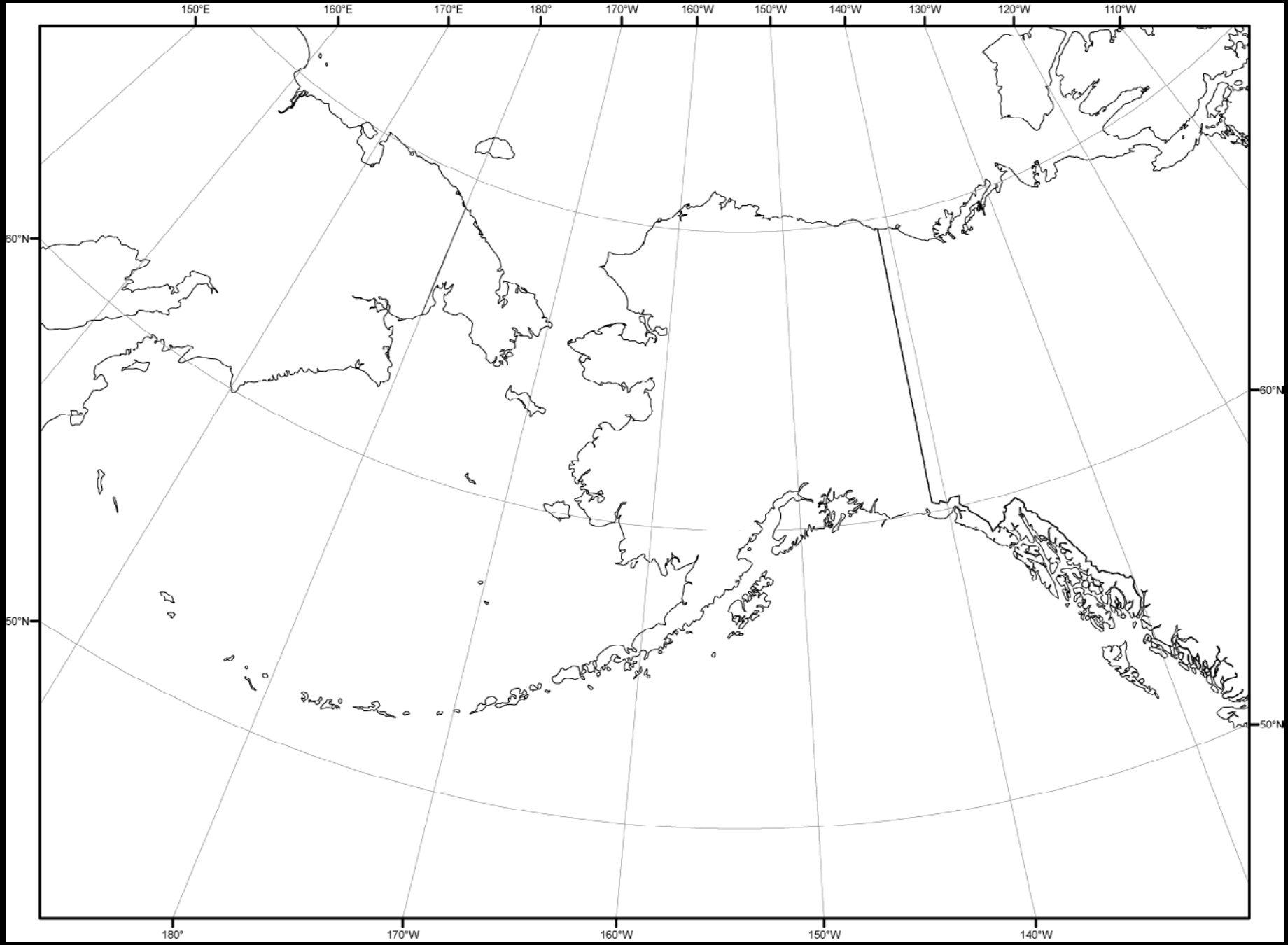

S = Shallow (< 40 miles) M = Intermediate (40 - 200 miles) D = Deep (> 200 miles)




Divergent Convergent "Teeth" on Overriding Plate Transform


Depth
-10-30 km
30-100 km
100-150 km
150-300 km
70°N
65°N
60°N
55°N
50°N
180°
170°W
160°W
150°W
140°W
130°W
0
km
500
NW
SE
depth in km
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
distance in km


170°W 150°W 130°W 110°W 90°W 70°W 50°W 30°W 10°W 0° 10°E 20°E 30°E 40°E 50°E 60°E 70°E 80°E 100°E 120°E 140°E 160°E 180°
180°
80°N 70°N 60°N 50°N 40°N 30°N 20°N 10°N 0° 10°S 20°S 30°S 40°S 50°S 60°S 70°S 80°S
90°


150°E
160°E
170°E
180°
170°W
160°W
150°W
140°W
130°W
120°W
110°W
60°N
50°N
180°
170°W
160°W
150°W
140°W

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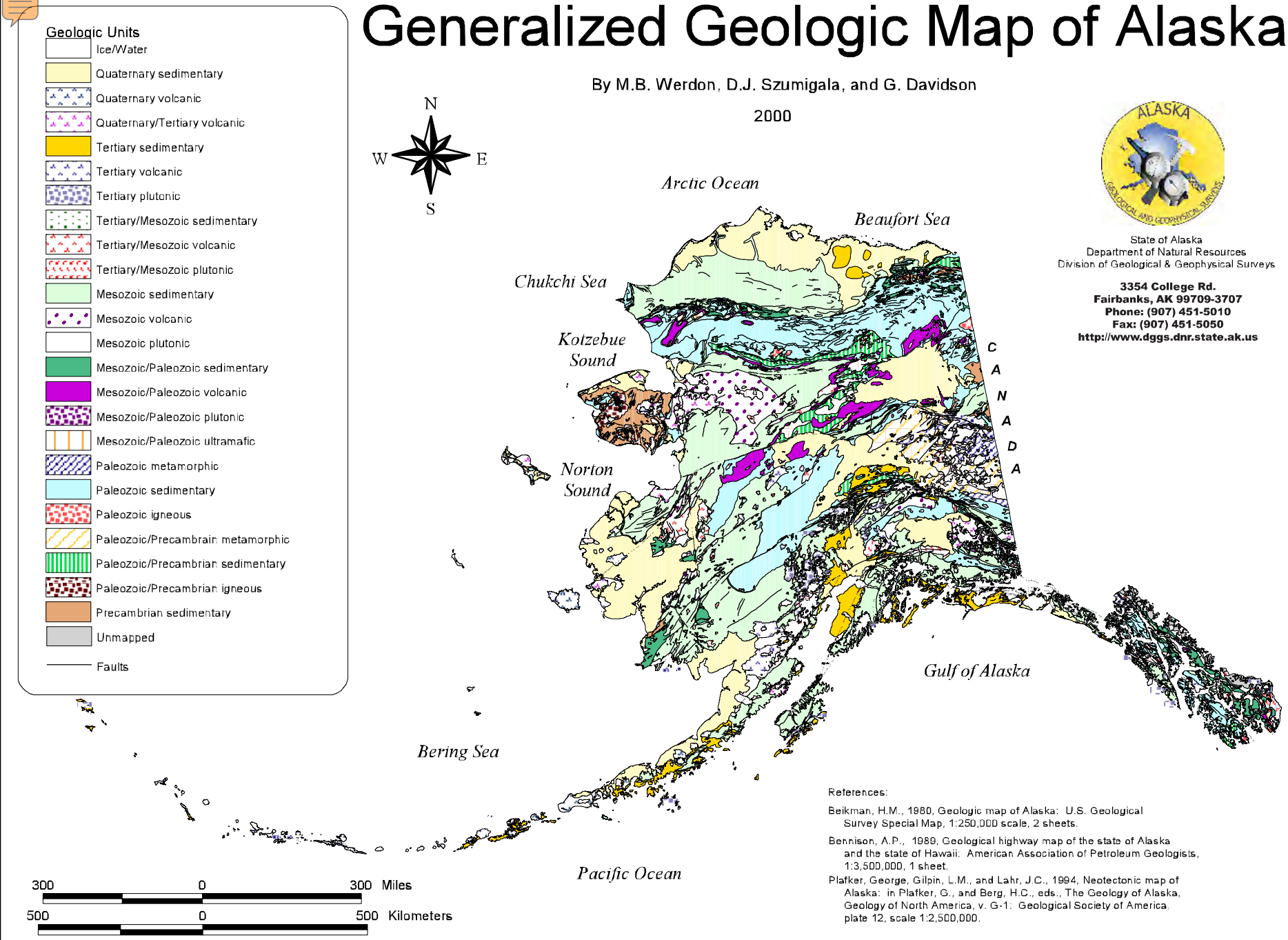
# Igneous Rocks - Coming to a Location Near You!

U.S. Department of the Interior
U.S. Geological Survey

# Generalized Geologic Map of Alaska

By M.B. Werdon, D.J. Szumigala, and G. Davidson

2000




State of Alaska
Department of Natural Resources
Division of Geological & Geophysical Surveys

**3354 College Rd.**
**Fairbanks, AK 99709-3707**
**Phone: (907) 451-5010**
**Fax: (907) 451-5050**
**http://www.dggs.dnr.state.ak.us**

References:

Beikman, H.M., 1980, Geologic map of Alaska: U.S. Geological Survey Special Map, 1:250,000 scale, 2 sheets.

Bennison, A.P., 1989, Geological highway map of the state of Alaska and the state of Hawaii: American Association of Petroleum Geologists, 1:3,500,000, 1 sheet.

Plafker, George, Gilpin, L.M., and Lahr, J.C., 1994, Neotectonic map of Alaska: in Plafker, G., and Berg, H.C., eds., The Geology of Alaska, Geology of North America, v. G-1: Geological Society of America, plate 12, scale 1:2,500,000.

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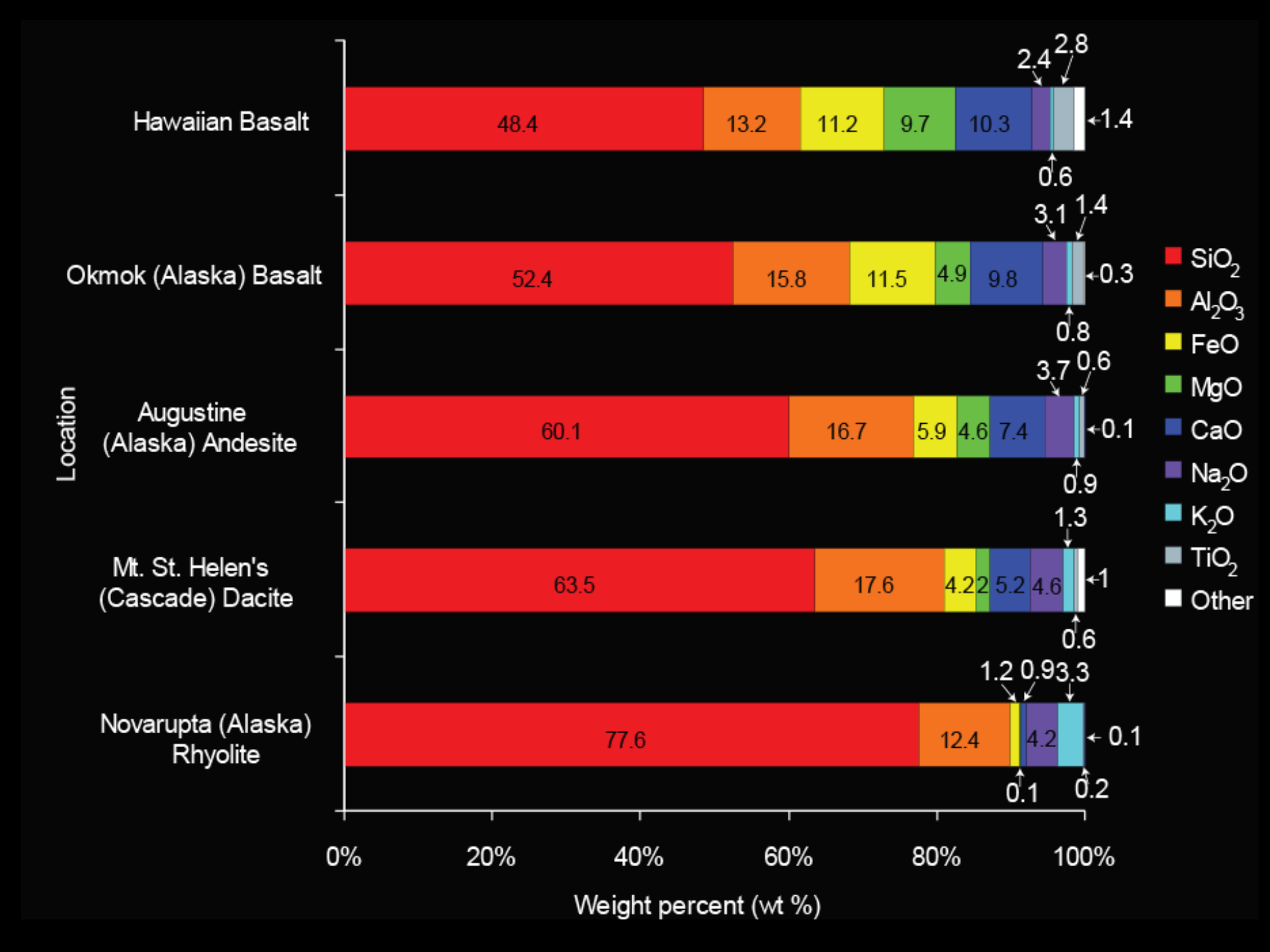
# Comparison of Hawaiian, Cascade, and Alaskan Volcanic Rocks

U.S. Department of the Interior
U.S. Geological Survey


Location
Hawaiian Basalt
48.4
13.2
11.2
9.7
10.3
2.4
2.8
1.4
0.6
Okmok (Alaska) Basalt
52.4
15.8
11.5
4.9
9.8
3.1
1.4
0.3
0.8
Augustine (Alaska) Andesite
60.1
16.7
5.9
4.6
7.4
3.7
0.6
0.1
0.9
Mt. St. Helen's (Cascade) Dacite
63.5
17.6
4.2
2
5.2
4.6
1.3
1
0.6
Novarupta (Alaska) Rhyolite
77.6
12.4
4.2
1.2
0.9
3.3
0.1
0.1
0.2
0%
20%
40%
60%
80%
100%
Weight percent (wt %)
SiO2
Al2O3
FeO
MgO
CaO
Na2O
K2O
TiO2
Other

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# Eruption 1, 2, 3…

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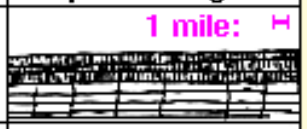
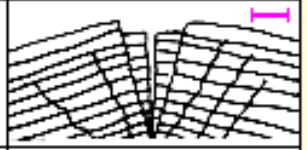
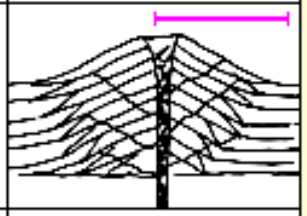
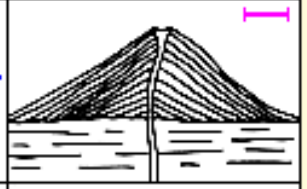
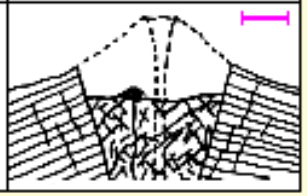
U.S. Geological Survey

# Types of Volcanoes

Increasing Violence
Increasing Viscosity

| Volcano Type | Characteristics | Examples | Simplified Diagram |
|---|---|---|---|
| **Flood or Plateau Basalt** | Very liquid lava; flows very widespread; emitted from fractures | Columbia River Plateau |   |
| **Shield Volcano** | Liquid lava emitted from a central vent; large; sometimes has a collapse caldera | Larch Mountain, Mount Sylvania, Highland Butte, Hawaiian volcanoes |  |
| **Cinder Cone** | Explosive liquid lava; small; emitted from a central vent; if continued long enough, may build up a shield volcano | Mount Tabor, Mount Zion, Chamberlain Hill, Pilot Butte, Lava Butte, Craters of the Moon |  |
| **Composite or Stratovolcano** | More viscous lavas, much explosive (pyroclastic) debris; large, emitted from a central vent | Mount Baker, Mount Rainier, Mount St. Helens, Mount Hood, Mount Shasta |  |
| **Volcanic Dome** | Very viscous lava; relatively small; can be explosive; commonly occurs adjacent to craters of composite volcanoes | Novarupta, Mount St. Helens Lava Dome, Mount Lassen, Shastina, Mono Craters |  |
| **Caldera** | Very large composite volcano collapsed after an explosive period; frequently associated with plug domes | Crater Lake, Newberry, Kilauea, Long Valley, Medicine Lake, Yellowstone |  |

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*Topinka, USGS/CVO, 1997, Modified from: Allen, 1975, Volcanoes of the Portland Area, Oregon, Ore-Bin, v.37, no.9*

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# VEI Alaska

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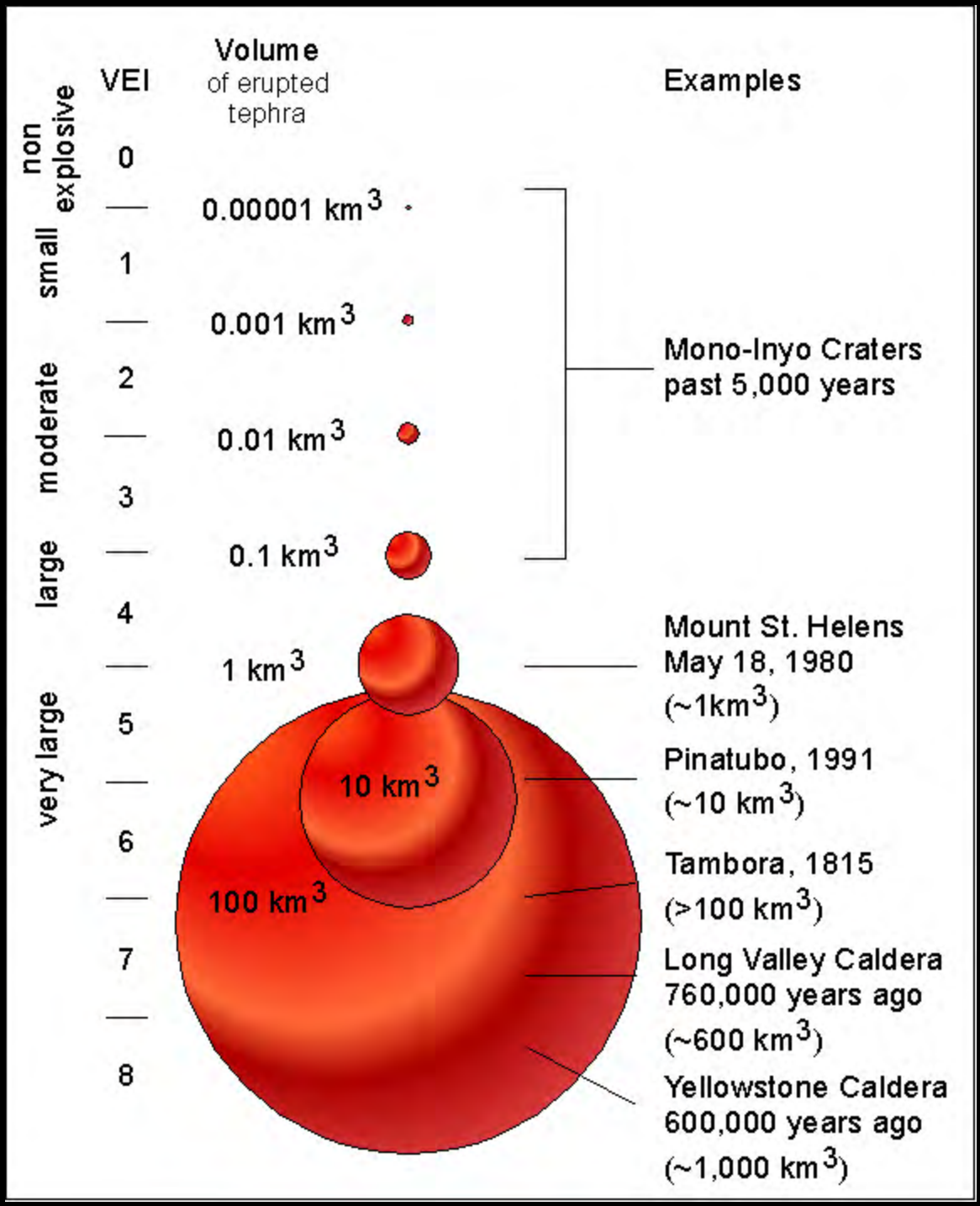
U.S. Geological Survey


VEI
Volume
of erupted
tephra
Examples
non explosive
small
moderate
large
very large
0
1
2
3
4
5
6
7
8
0.00001 km3
0.001 km3
0.01 km3
0.1 km3
1 km3
10 km3
100 km3
Mono-Inyo Craters
past 5,000 years
Mount St. Helens
May 18, 1980
(~1km3)
Pinatubo, 1991
(~10 km3)
Tambora, 1815
(>100 km3)
Long Valley Caldera
760,000 years ago
(~600 km3)
Yellowstone Caldera
600,000 years ago
(~1,000 km3)

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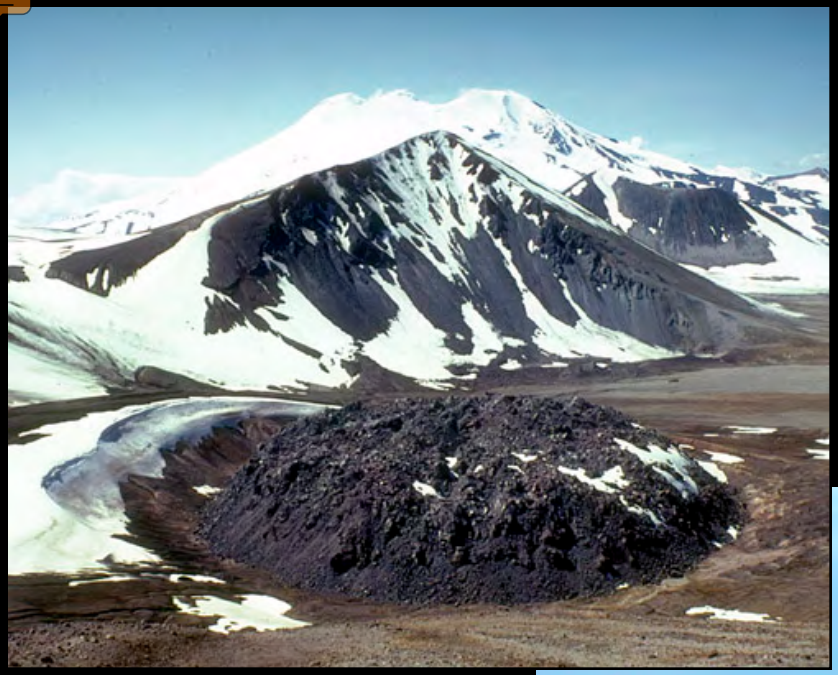
# Alaska's Volcanic Landforms and Features Information Search

U.S. Department of the Interior
U.S. Geological Survey


(A)


(B)



(*A*)

(*B*)

(*A*)

(*B*)

(*A*)

(*B*)

(*A*)

(*B*)

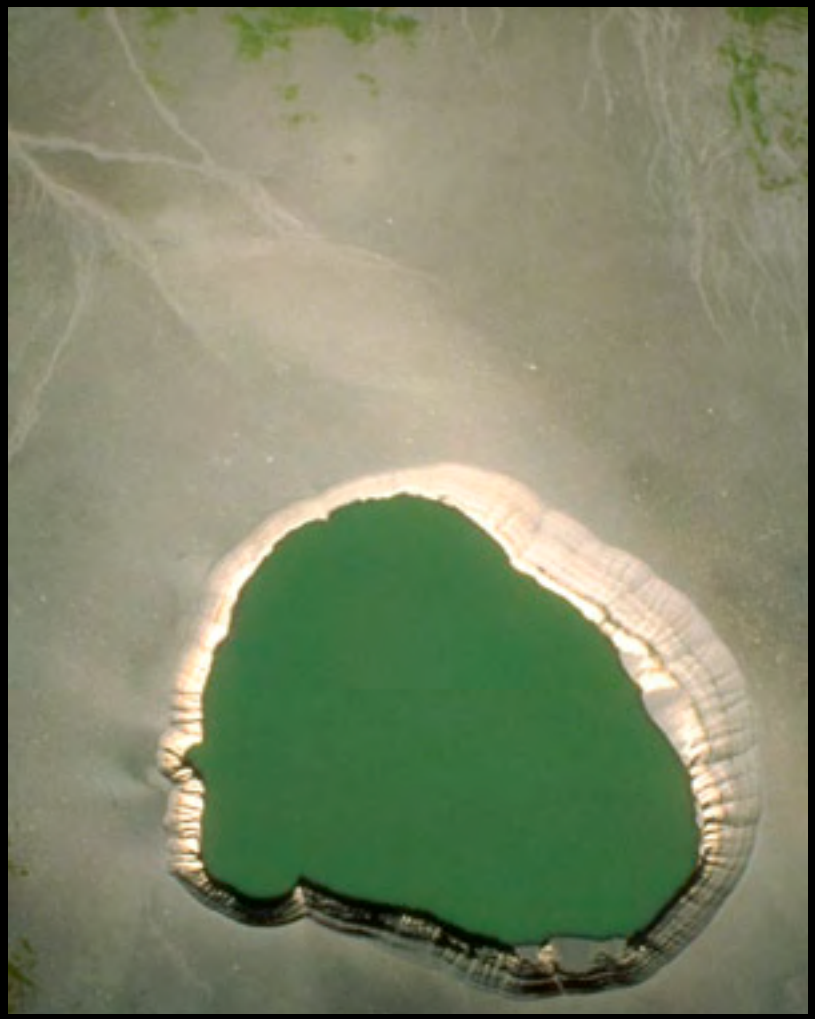
Mount Wrangell, a 4,317-m (14,163 ft)-high andesite shield volcano on the right skyline, is the only volcano in the Wrangell Mountains to have had documented historical activity consisting of several minor, possibly phreatic eruptions in the early 1900's. At left is Mount Zanetti, a 3,965-m (13,009 ft)-high cone. View is to the northeast. Photograph by B. Cella, National Park Service (NPS) , 1987. Image by Cella, B., National Park Service.

Vent Mountain in the foreground is a cinder cone inside Aniakchak Caldera. The caldera wall is in the background. Aniakchak Volcano is on the Alaska Peninsula. R.G. McGimsey, USGS, 06/28/97.

Augustine in the Cook Inlet is a composite, or strato-volcano. This image was taken looking northwest and volcanic ash covers the upper flanks of the summit. White steam is being emitted. J. Adleman, USGS, 02/24/06.

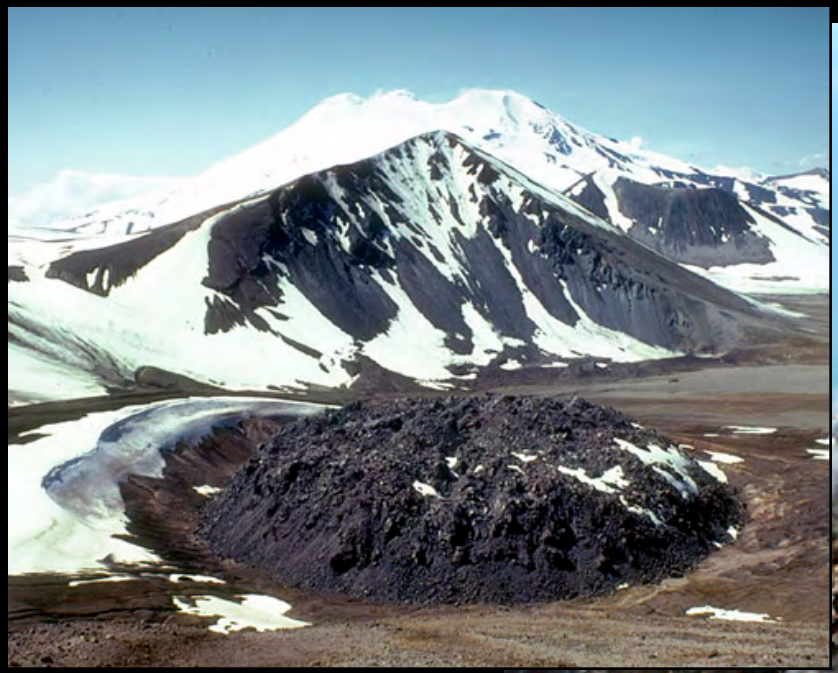
(a)

(b)

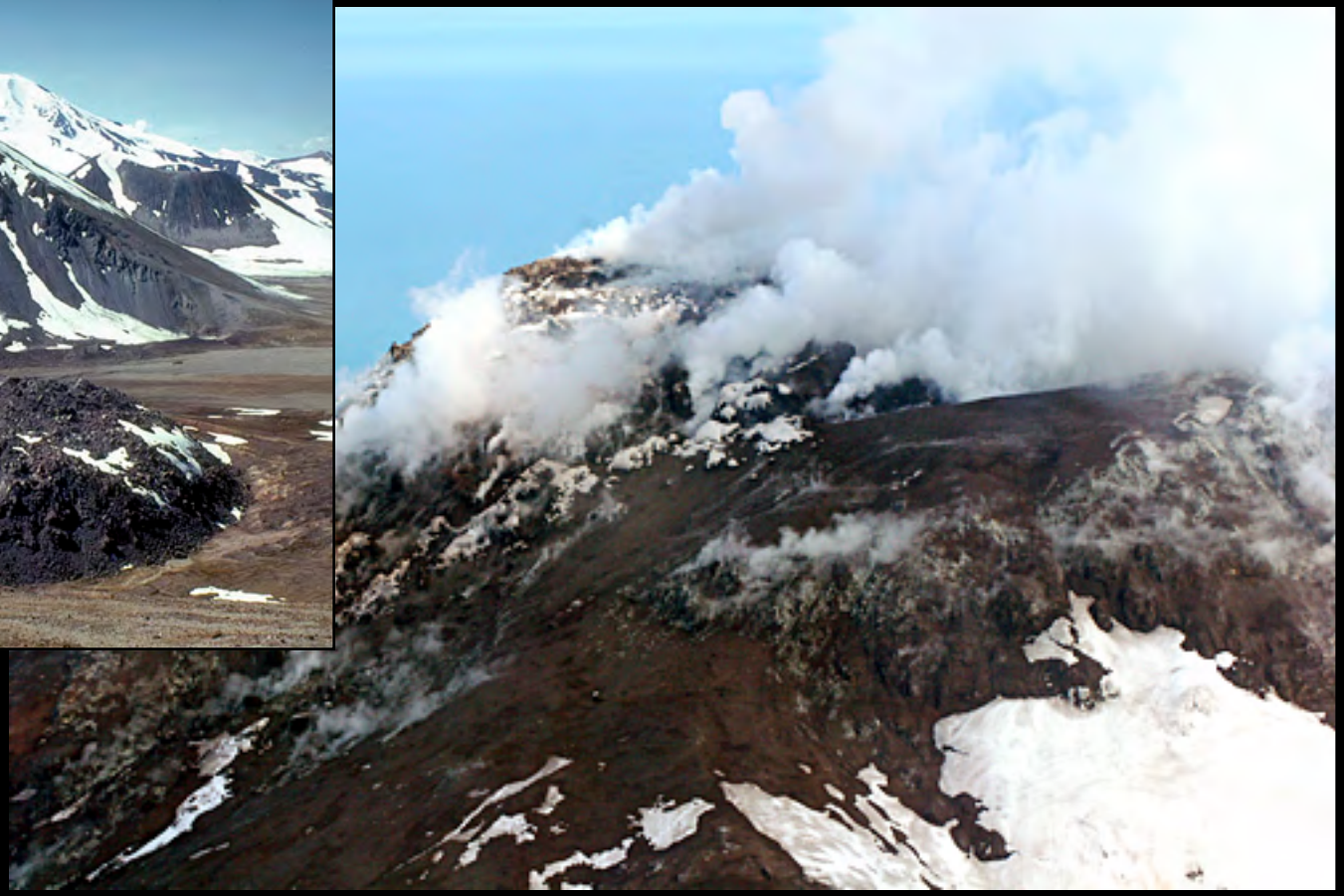


(*A*) Aerial view of a phreatomagmatic eruption of the East Maar of Ukinrek Maars. The Ukinrek Maars are located on the south shore of Becharof Lake on the Alaska Peninsula; the maar craters formed during a 10-day eruption in March and April of 1977. Juergen Kienle, University of Alaska Geophysical Institute (UAFGI), April 6, 1977.

(*B*) Near-vertical view of the east Ukinrek Maar crater, 300 m (980 ft) across. Part of smaller west Ukinrek Maar crater is visible at upper left. D. Dewhurst, U.S. Fish and Wildlife Service (USFWS), July 8, 1990.



(*A*)



(*B*)

(*A*) Aerial view of 80-m (260 ft)-high Novarupta, a blocky rhyolite (high silica) lava dome that marks the vent for the 1912 eruption that created the Valley of Ten Thousand Smokes in Katmai National Park and Preserve, Alaska. This eruption was the most voluminous on Earth in the 20th century, ejecting nearly 30 $km^3$ (7 $mi^3$) of material in 60 hours. Falling Mountain, a lava dome truncated by the 1912 eruption, is visible behind the Novarupta dome; snow-capped strato-volcano Mount Mageik can be seen at top of the photograph. T. Miller, U.S. Geological Survey, June 1979.

(*B*) Summit dome on Augustine Volcano, Cook Inlet, AK. J. Adleman, U.S. Geological Survey, May 12, 2006.

Aerial view, looking east, of Aniakchak caldera. Formed during a catastrophic ash-flow producing eruption about 3,400 years ago, Aniakchak caldera is about 10 km (6 mi) across and averages 500 m (1,640 ft) in depth. Voluminous post-caldera eruptive activity has produced a wide variety of volcanic landforms and deposits within the caldera. The volcano is located in Aniakchak National Park and Preserve on the Alaska Peninsula. M. Williams, National Park Service, 1977.

Large-pool thermal hot springs area southwest of Korovin Volcano and west-northwest of Kluichef Volcano on Atka Island in the Aleutians. Photograph taken by R.G. McGimsey, U.S. Geological Survey, July 14, 2004.

Fumarolic activity at the summit of Fourpeaked Volcano in Kamtai National Park and Preserve on the Alaska Peninsula. Photograph taken by J. Adleman, U.S. Geological Survey, November 4, 2006

View of 1997 basaltic andesite lava flow inside Okmok caldera, a 9.3 km (5.8 mi) diameter circular crater that truncates the top of a large shield volcano on the northeastern part of Umnak Island in the eastern Aleutian Islands. The most recent caldera-forming eruption at Okmok occurred about 2,400 years ago. Since then, numerous intracaldera eruptions have occurred, including the eruption that extruded these blocky lava flows onto the caldera floor. Photograph taken by C. Nye, Alaska Division of Geological and Geophysical Surveys

(*A*) Pyroclastic flow (deposits of volcanic ash, gas and pumice flows) deposits on the southwestern flank of Augustine Volcano, Cook Inlet, Alaska. Photograph taken by M. Coombs, U.S. Geological Survey, August 14, 2006.

(*B*) View southeast up the Valley of Ten Thousand Smoke from the Overlook Cabin in Katmai National Park and Preserve, Alaska. The valley has been filled with up to 200 m (660 ft) of pyroclastic flow deposits (ignimbrite) from the 1912 eruption of Novarupta volcano. The rim of Katmai Caldera is on the skyline at left. Photograph taken by R.G. McGimsey, U.S. Geological Survey, June 8, 1991.

(*A*) These small hills in the foreground of Alaska's Augustine volcano show morphology common to debris-avalanche deposits. This debris avalanche traveled roughly 11 km from the summit about 450 years ago. Courtesy of Smithsonian Institution, dated 1987.

(*B*) Debris avalanche deposits from the 1883 eruption of Augustine Volcano entered the Cook Inlet along the north shoreline of the island forming hummocky topography. Photograph by U.S. Geological Survey, April 27, 1986.

Togiak Tuya, Ahklun Mountains. The Ahklun Mountains form the highest range in Alaska west of the Alaska Range and north of the Alaska Peninsula. A tuya is a table mountain that forms when volcano erupts underneath a glacier. Photograph taken by Darrell S. Kaufman, Professor of Geology and Environmental Science at the Department of Geology of Northern Arizona University in Flagstaff, Arizona, dated 2004.

(*B*) Geyser Bight geothermal resource area. Dave Szumigala, 1985.

(*A*) ‘Old Faithful’ (spring G8) of Geyser Bight geothermal area, Umnak Island, Alaska (shown here at maximum activity), has had an eruption cycle of 12 minutes, (Shirley Liss, 1988). This area contains one of the hottest and most extensive areas of geothermal activity in Alaska. This is the only area in Alaska where sustained geyser activity has been documented; geothermal activity was observed at five springs during 1988 (Motkya and others,1993).

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# Alaska's Volcanic Types
# Food for Though!

U.S. Department of the Interior
U.S. Geological Survey

# Types of Volcanoes in Alaska

## Shield Volcano: Wrangell

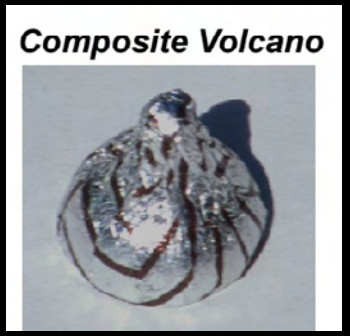
B. Cella, National Park Service, 1987


*Parks and Plates ©2005 Robert J. Lillie*

# Types of Volcanoes in Alaska

## Strato-cone or composite volcano: Augustine

J. Adleman, U.S. Geological Survey, February 24, 2006




*Parks and Plates ©2005 Robert J. Lillie*

# Types of Volcanoes in Alaska

Volcanic dome: Novarupta

T. Miller, U.S. Geological Survey, June 1979.

# Types of Volcanoes in Alaska

## Caldera: Akutan

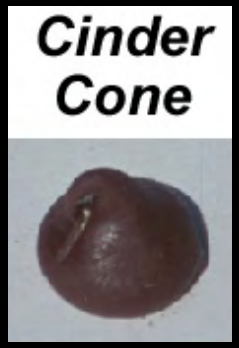
C. Read, U.S. Geological Survey, 06/07/07

***Ice Cream Cone***

# Types of Volcanoes in Alaska

Cinder cone: Vent Mountain in Aniakchak Caldera

R.G. McGimsey, U.S. Geological Survey, June 28, 1997.




*Parks and Plates ©2005*
*Robert J. Lillie*

# Types of Volcanoes in Alaska

## Strato-cone or composite volcano, caldera & dome


The lake-filled caldera of Kaguyak volcano reshaped a former strato-cone.
Then lava domes formed a peninsula and a small island.
C. Nye, Alaska Division of Geologic and Geophysical Surveys. August 1982.

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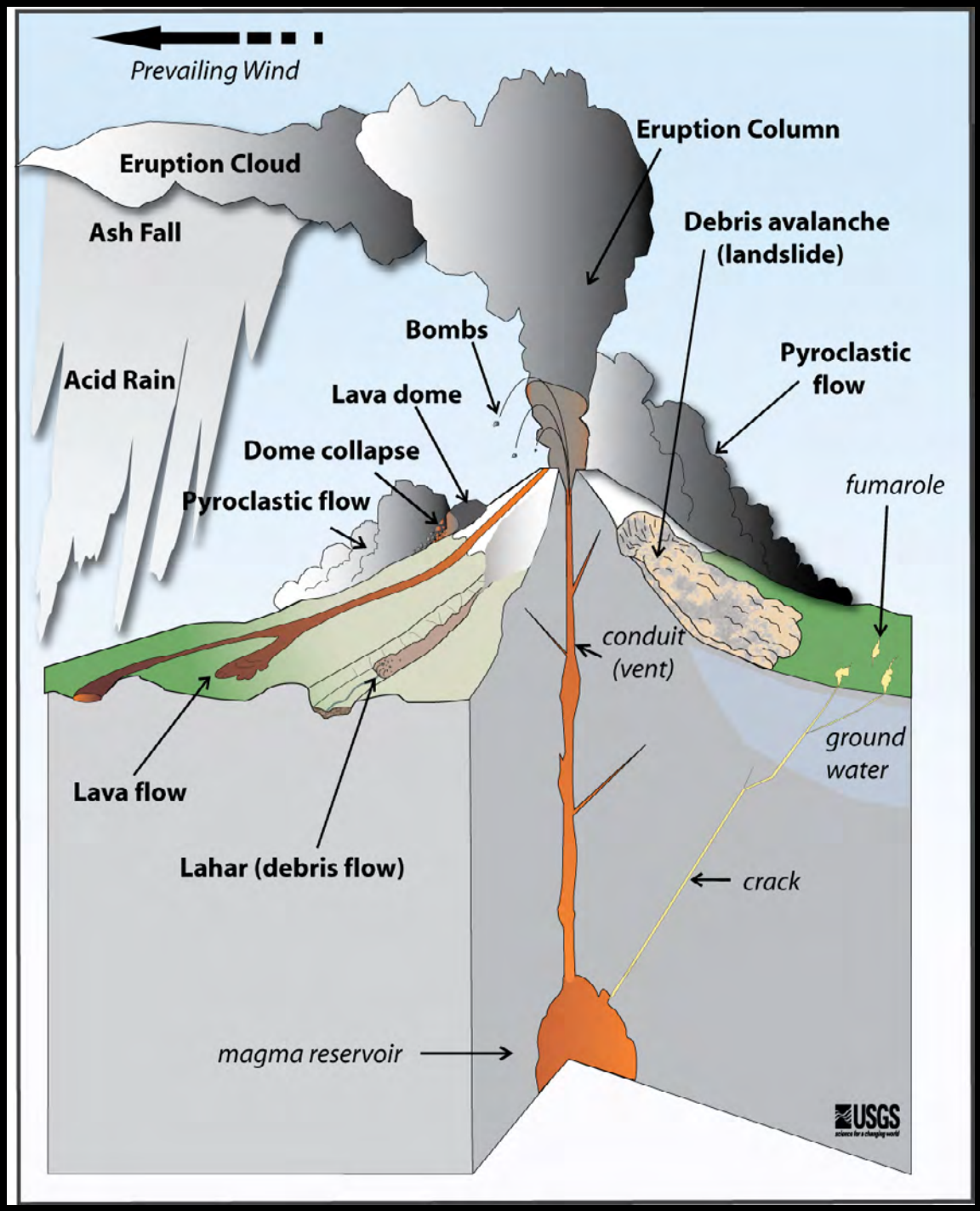
# We need all the assistance you have…


Prevailing Wind
Eruption Column
Eruption Cloud
Debris avalanche
(landslide)
Ash Fall
Bombs
Pyroclastic
flow
Acid Rain
Lava dome
Dome collapse
Pyroclastic flow
fumarole
conduit
(vent)
ground
water
Lava flow
Lahar (debris flow)
crack
magma reservoir
USGS

# USGS Volcano Hazards Alert-Notification System

| Term | Description |
|---|---|
| NORMAL | Volcano is in typical background, noneruptive state<br>or, after a change from a higher level,<br>volcanic activity has ceased and volcano has returned to noneruptive background state. |
| ADVISORY | Volcano is exhibiting signs of elevated unrest above known background level<br>or, after a change from a higher level,<br>volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase. |
| WATCH | Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain,<br>OR<br>eruption is underway but poses limited hazards. |
| WARNING | Hazardous eruption is imminent, underway, or suspected. |

| Color | Description |
|---|---|
| GREEN | Volcano is in typical background, noneruptive state<br>or, after a change from a higher level,<br>volcanic activity has ceased and volcano has returned to noneruptive background state. |
| YELLOW | Volcano is exhibiting signs of elevated unrest above known background level<br>or, after a change from a higher level,<br>volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase. |
| ORANGE | Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain,<br>OR<br>eruption is underway with no or minor volcanic-ash emissions [ash-plume height specified, if possible] |
| RED | Eruption is imminent with significant emission of volcanic ash into the atmosphere likely<br>OR<br>eruption is underway or suspected with significant emission of volcanic ash into the atmosphere [ash-plume height specified, if possible]. |

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# The Gas They Pass

U.S. Department of the Interior
U.S. Geological Survey

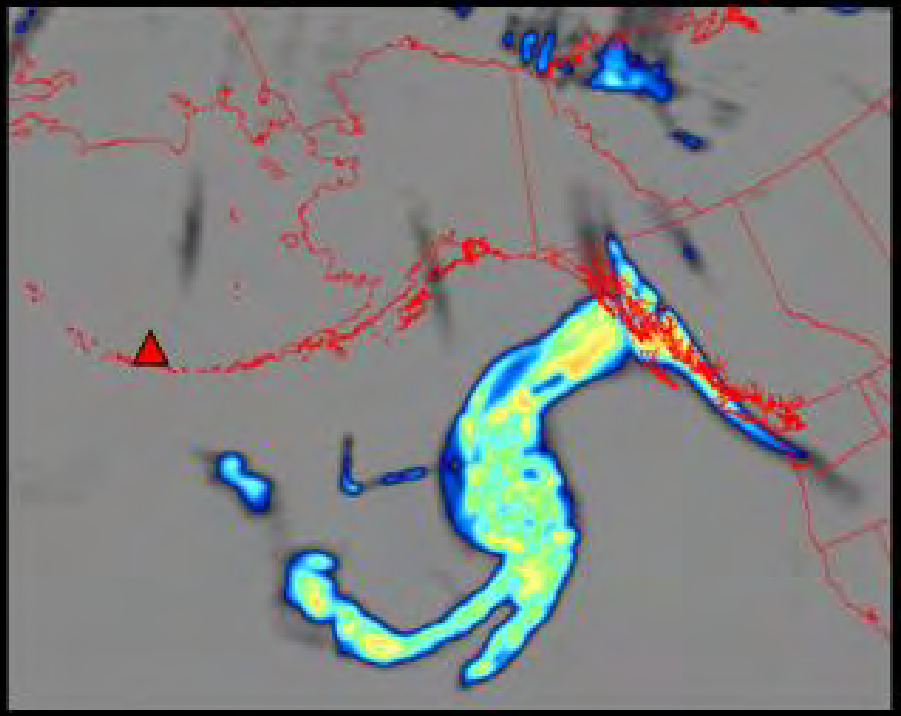
Fumarole on northwest side of Fourpeaked Mountain. Yellow staining on snow is result of sulfur emission from the vent. Photograph taken by C. Read, U.S. Geological Survey, February 22, 2007.

Steam plume emanating from the summit ice cauldron of Mt. Spurr. Photograph taken September 10, 2006, courtesy of J. Copen. Used with permission.

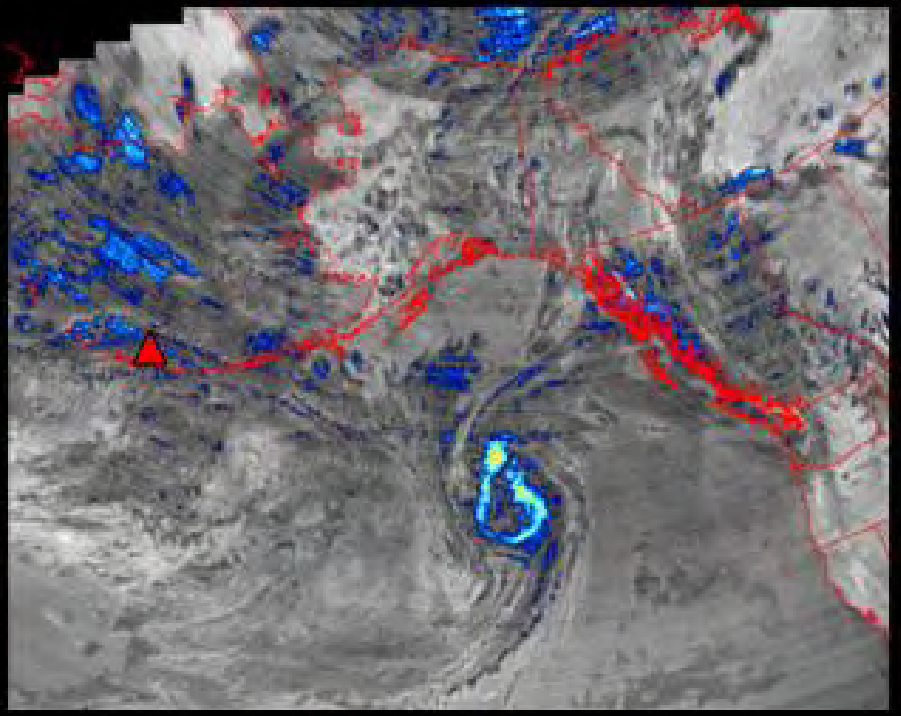
View of the east-southeast flanks of Augustine Volcano and steaming summit. Photograph taken by G. McGimsey, U.S. Geological Survey, June 2, 2006.

Martin summit crater, in Katmai National Park. The vigorous fumaroles at Martin and nearby Mageik often have been mistaken for volcanic eruptions. Photograph taken by C. Read, U.S. Geological Survey, August 26, 2006.

# August 10: 2300 UTC



Sulfur Dioxide Gas



Volcanic Ash

Kasatochi volcanic cloud as observed at 2300 UTC on August 10, 2008, approximately 3 days after the start and 2 days after end of the eruption. The image on the left shows $SO_2$ gas detected by the OMI sensor and the image on the right shows a smaller region of volcanic ash as indicated by a GOES thermal infrared brightness temperature difference image. The colors are related to the total column abundance (mass per area) of $SO_2$ and volcanic ash, with warmer colors indicating greater amounts of gas and ash. These data are from NASA's EOS-Aurasatellite and Ozone Monitoring Instrument (OMI), courtesy of Dr. Simon Carn, University of Maryland, Baltimore County.

View of the Okmok caldera's eruption plume viewed from Fort Glenn (ranch building in foreground) on August 3, 2008. The small peak to the left is Tulik, a stratocone outside of the caldera.  Photograph taken by J. Larson, University of Alaska, Fairbanks Geophysical Institute.

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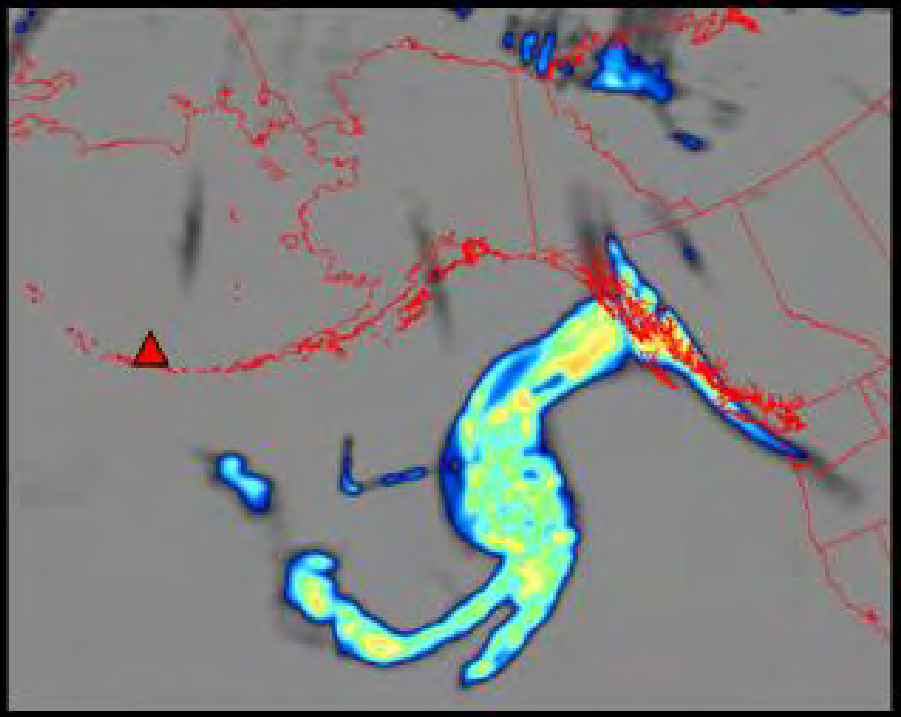
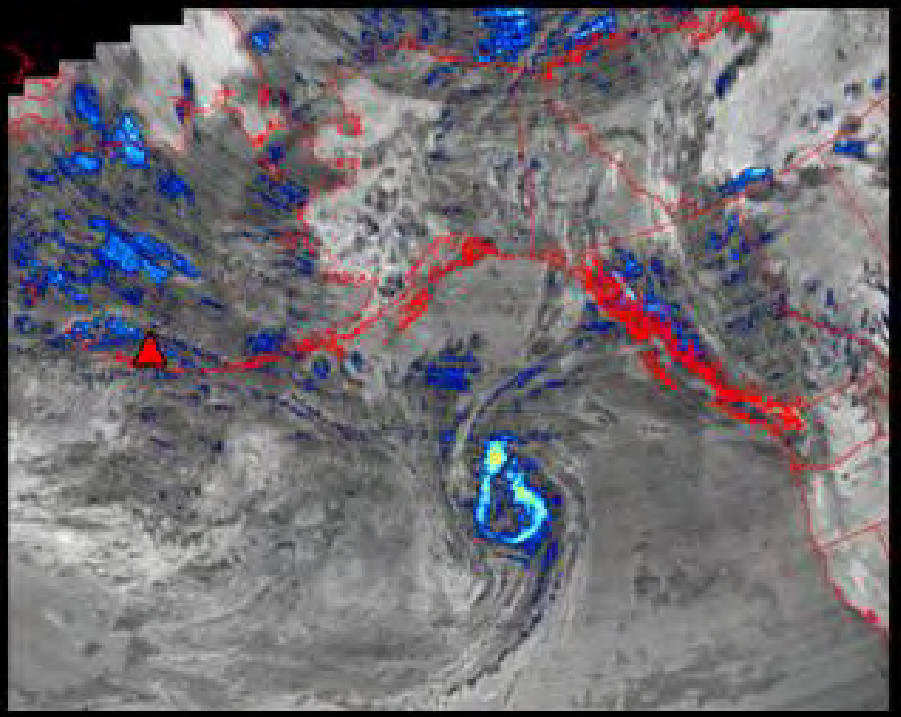
# The Gas They Pass

U.S. Department of the Interior
U.S. Geological Survey

# August 10: 2300 UTC



Sulfur Dioxide Gas



Volcanic Ash

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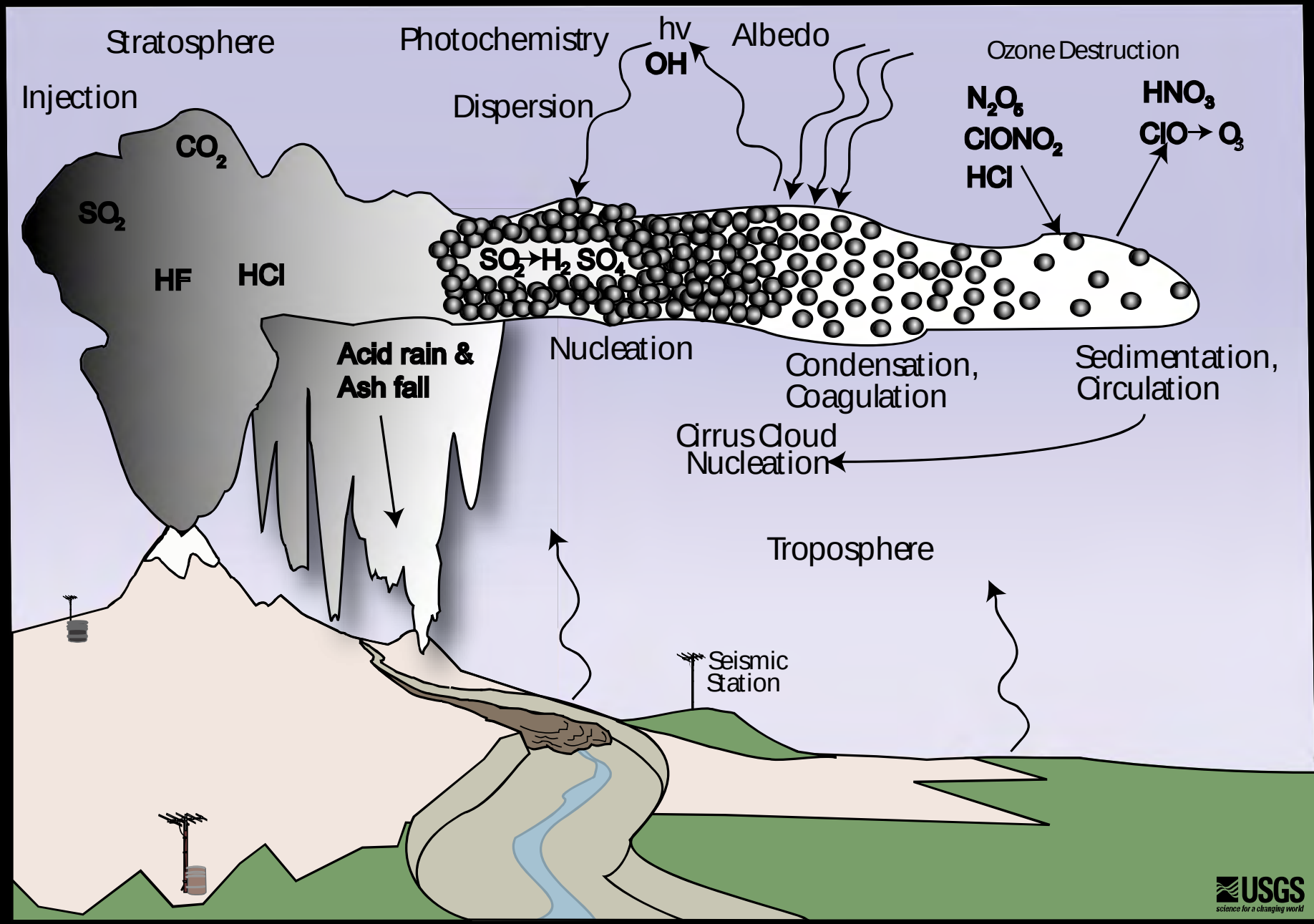
# What goes up must come down

U.S. Department of the Interior
U.S. Geological Survey


Stratosphere
Photochemistry
hv
OH
Albedo
Ozone Destruction
Injection
Dispersion
$N_2O_5$
$ClONO_2$
HCl
$HNO_3$
ClO → $O_3$
$CO_2$
$SO_2$
HF
HCl
$SO_2 \rightarrow H_2SO_4$
Acid rain &
Ash fall
Nucleation
Condensation,
Coagulation
Sedimentation,
Circulation
Cirrus Cloud
Nucleation
Troposphere
Seismic
Station
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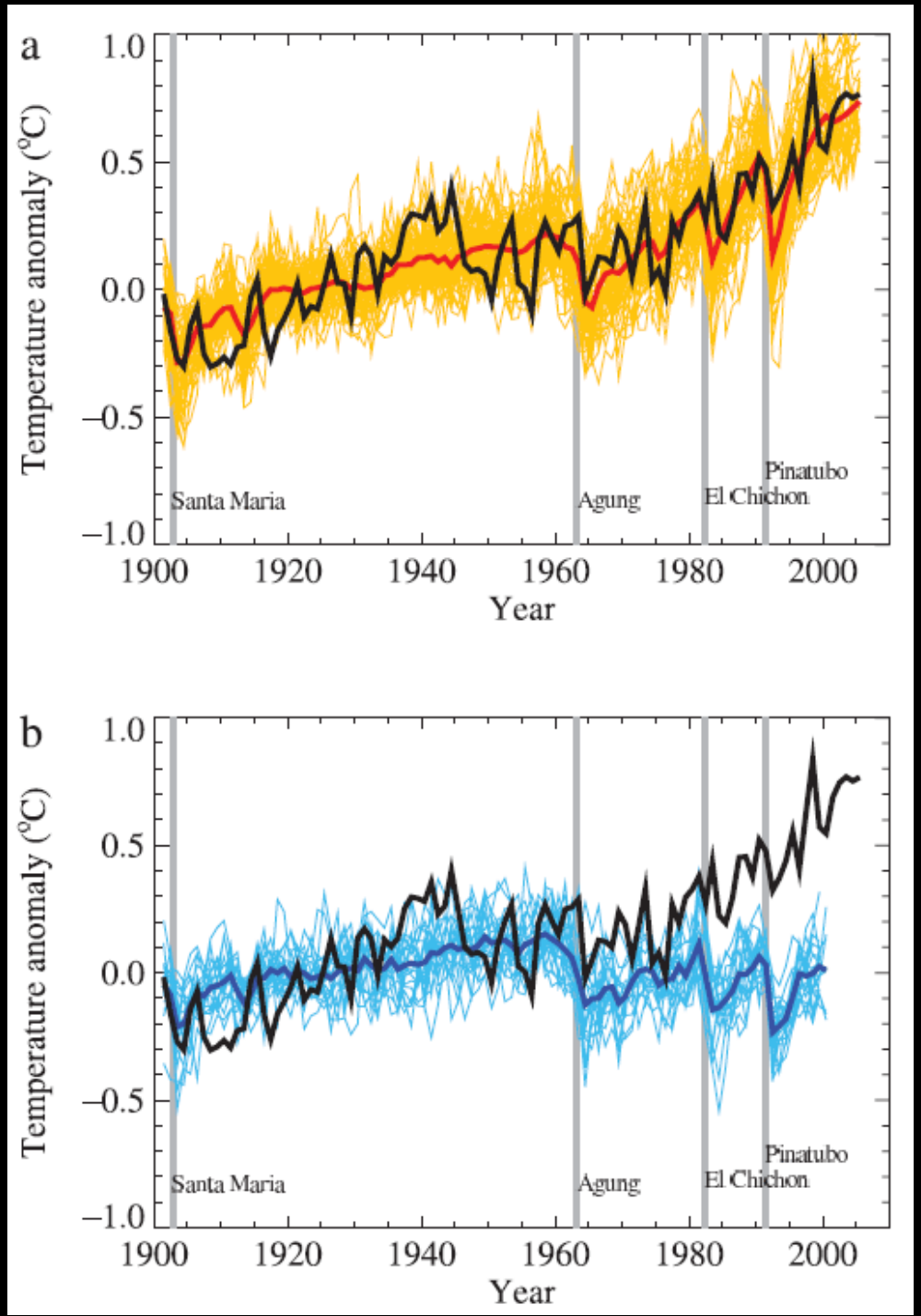
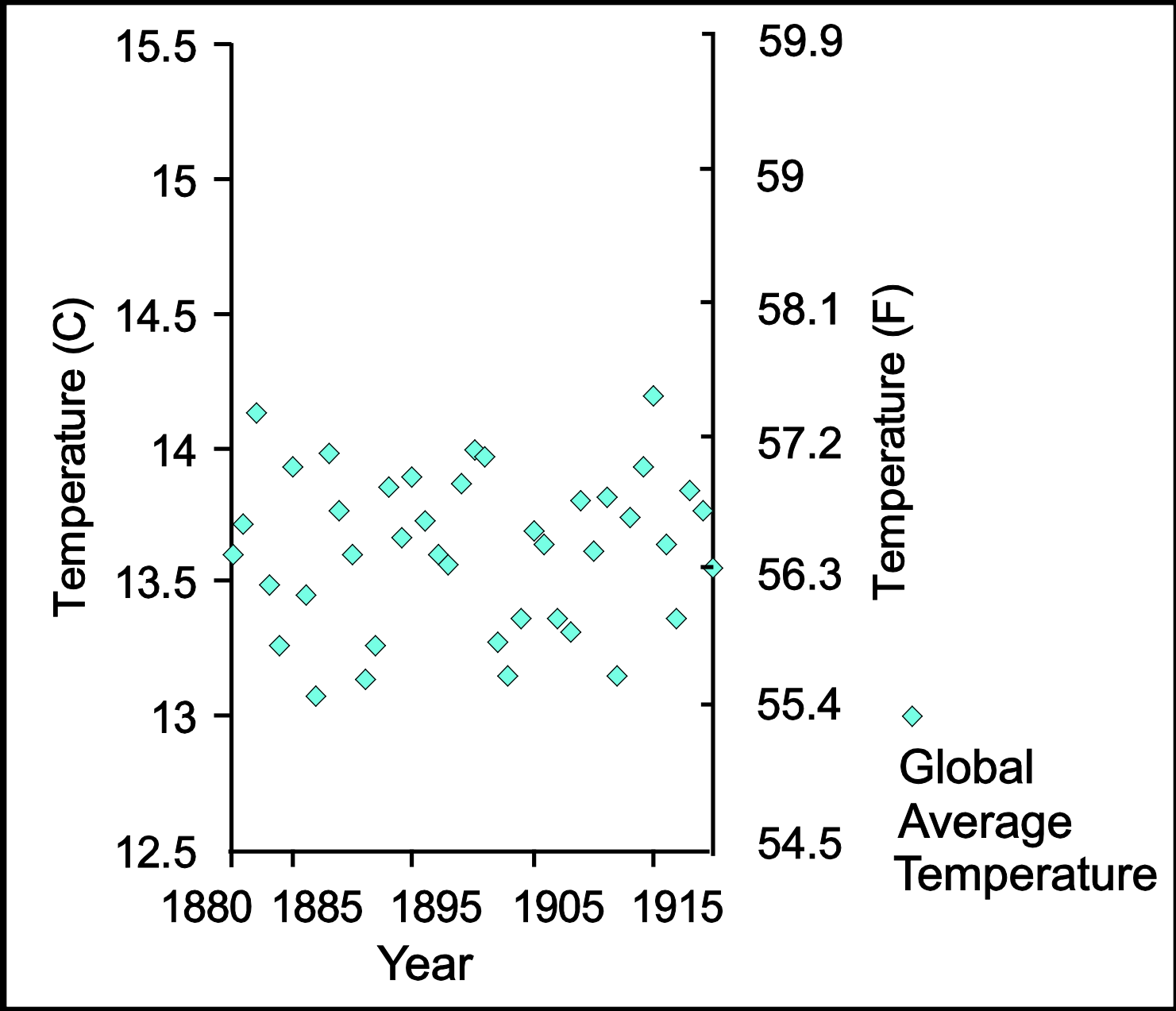
# Globally Averaged Temperature and Volcanic Eruptions

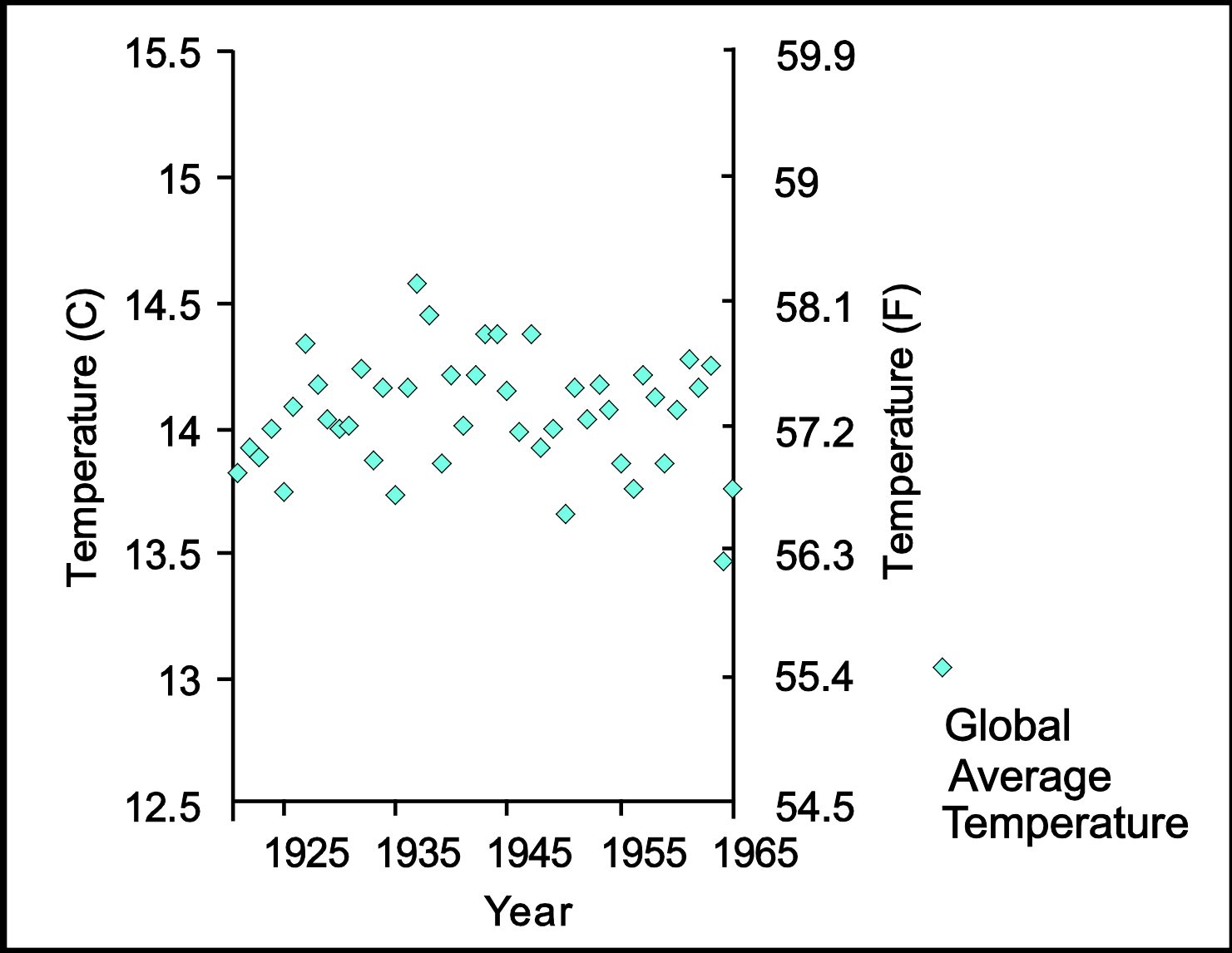
U.S. Department of the Interior
U.S. Geological Survey



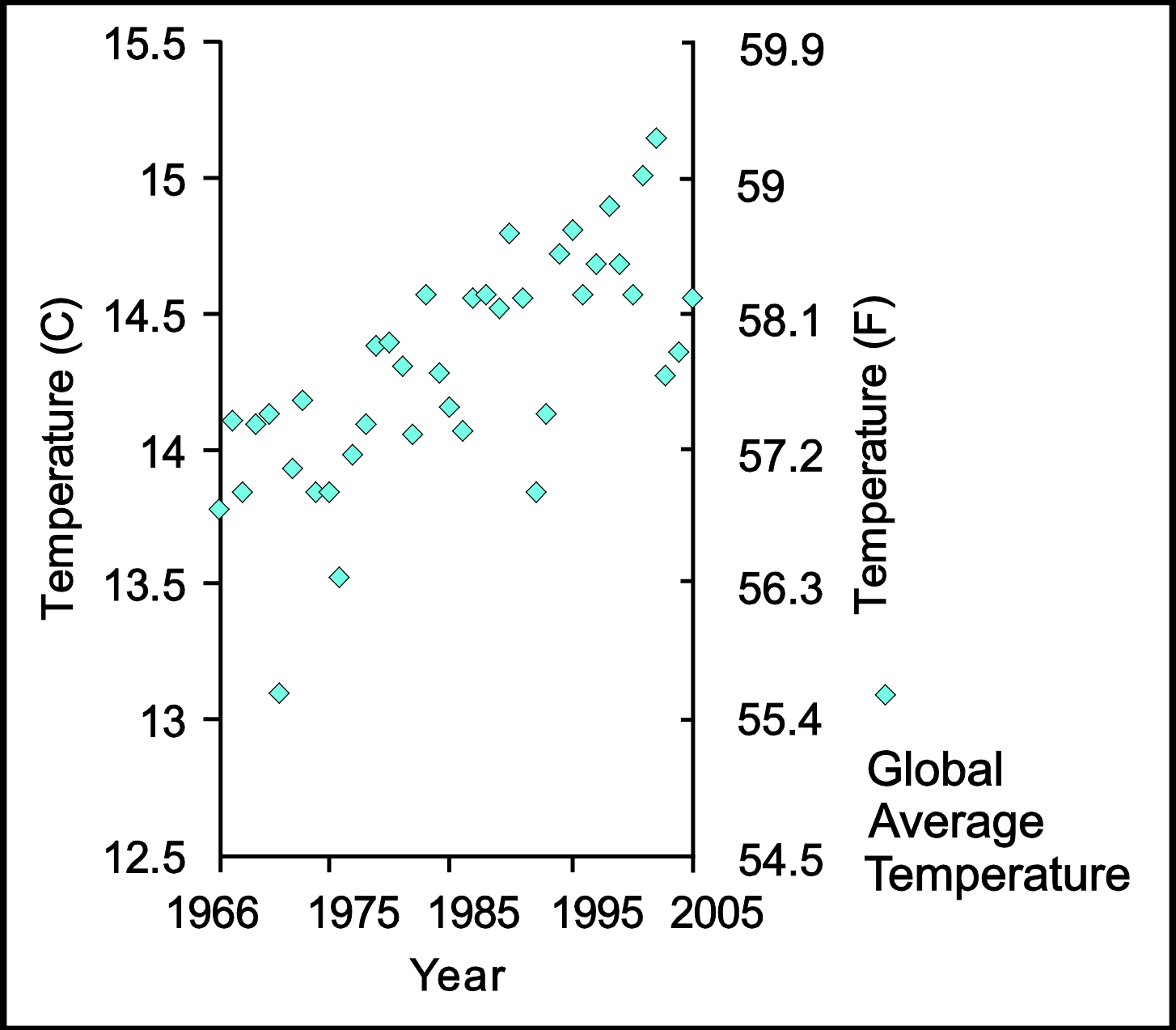

Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report Climate Change, 2007—The Physical Science Basis: Cambridge University Press, New York, 2007. Chapter 9 Understanding and Attributing Climate Change http://www.ipcc.ch/ipccreports/ar4-wg1.htm



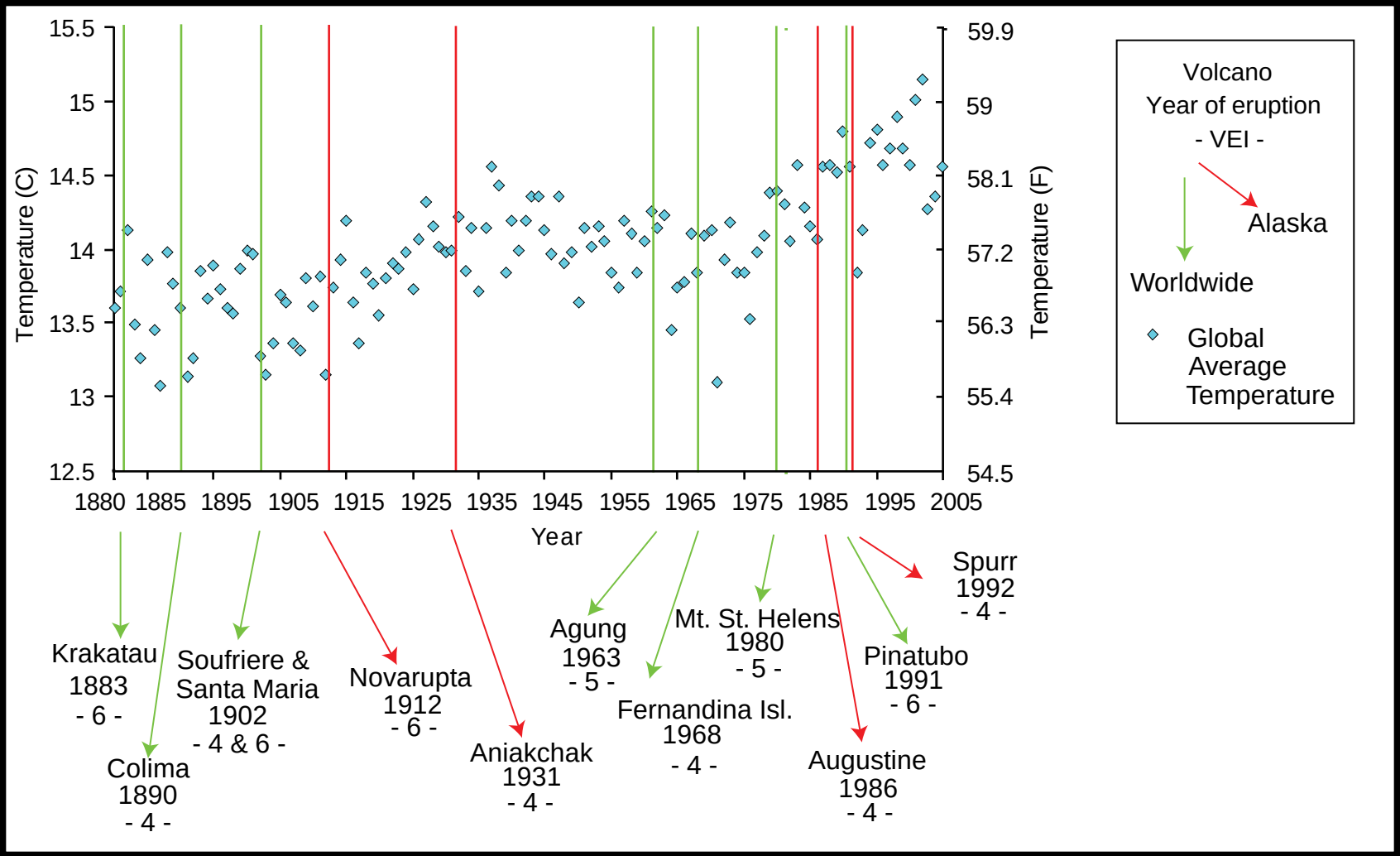

Global temp in °C and °F from 1880 to 2005 scatter plot of annual temperature and time for 1880-1920.




Global temp in °C and °F from 1880 to 2005 scatter plot of annual temperature and time for 1921-1965.




Global temp in °C and °F from 1880 to 2005 scatter plot of annual temperature and time for 1966-2005.

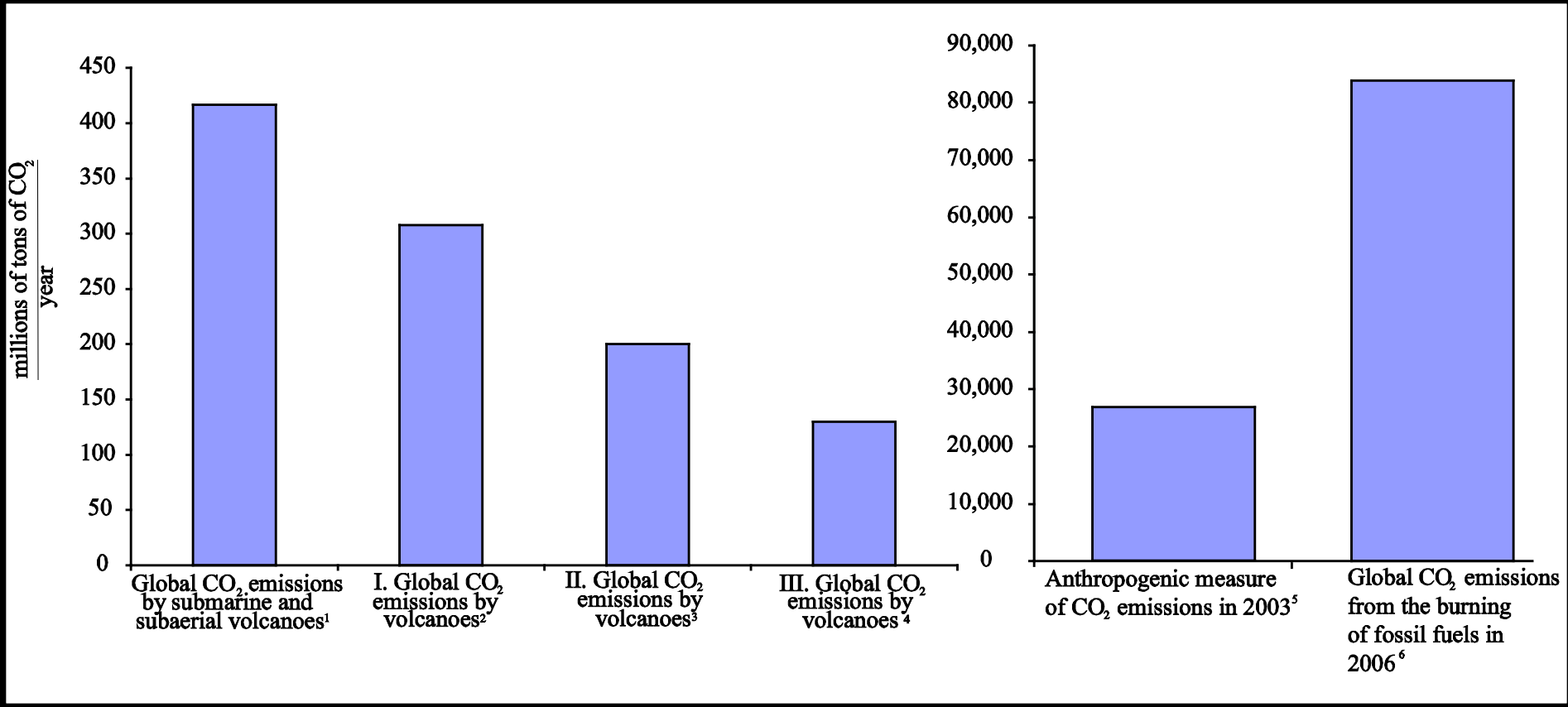



Global annual temperature and time for 1880-2005 and specified volcanic eruptions


# An Order of Magnitude

U.S. Department of the Interior
U.S. Geological Survey

# Millions of Tons of $CO_2$ emissions from Volcanic, Anthropogenic, and Burning of Fossil Fuels Sources



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# A Day in the Life of a Volcano Observatory

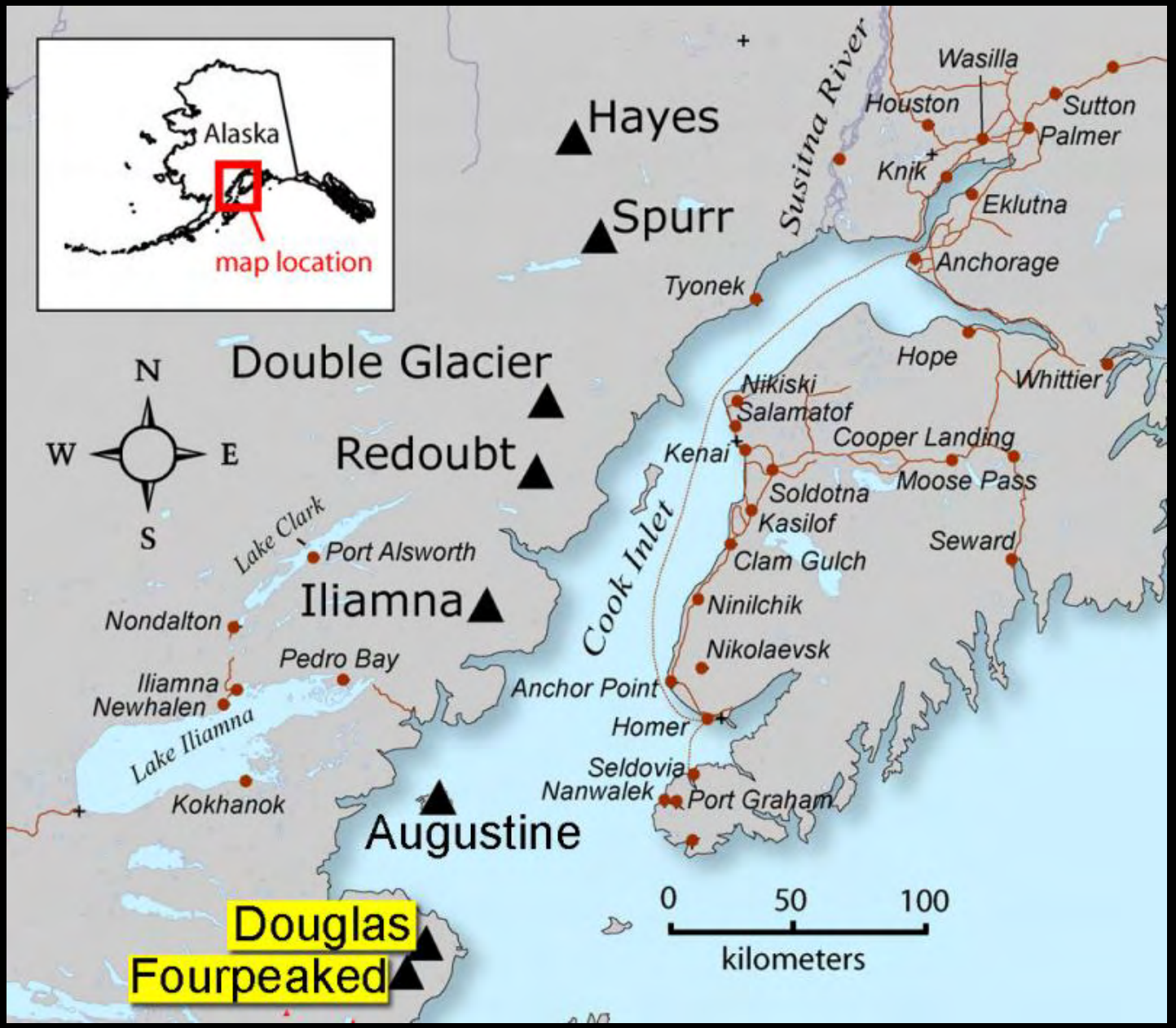
U.S. Department of the Interior
U.S. Geological Survey

| | |
|---|---|
| Green | No eruption anticipated. Volcano is in quiet, "dormant" state. |
| Yellow | An eruption is possible in the next few weeks and may occur with little or no additional warning. Small earthquakes detected locally and (or) increased levels if volcanic gas emissions. |
| Orange | Explosive eruption is possible within a few days and may occur with little or no warning. Ash plume(s) but expected to reach 25,000 feet above sea level. Increased numbers of local earthquakes. Extrusion of lava dome or lava flows (non-explosive eruption) may be occurring. |
| Red | Major explosive eruption expected within 24 hours. Large ash plume(s) expected to reach at least 25,000 feet above sea level. Strong earthquake activity detected even at distant monitoring stations. Explosive eruption may be in progress. |

Level of Concern Color Code

# Discussion 1 (D1)
# (Sept. 17 - 19)

It is September 17, a fine, crisp Sunday evening, and beginning at ~8:15 PM and over the next several hours, AVO received reports of two discrete plumes rising from the Cape Douglas area on the Alaska Peninsula within Katmai National Park and Preserve. The plumes reached approximately 20,000 ft above sea level. Cape Douglas from Main Street, Homer, Alaska, September 17, 2006. Photograph by Lanny Simpson, Alaska High Mountain Images, used with permission.



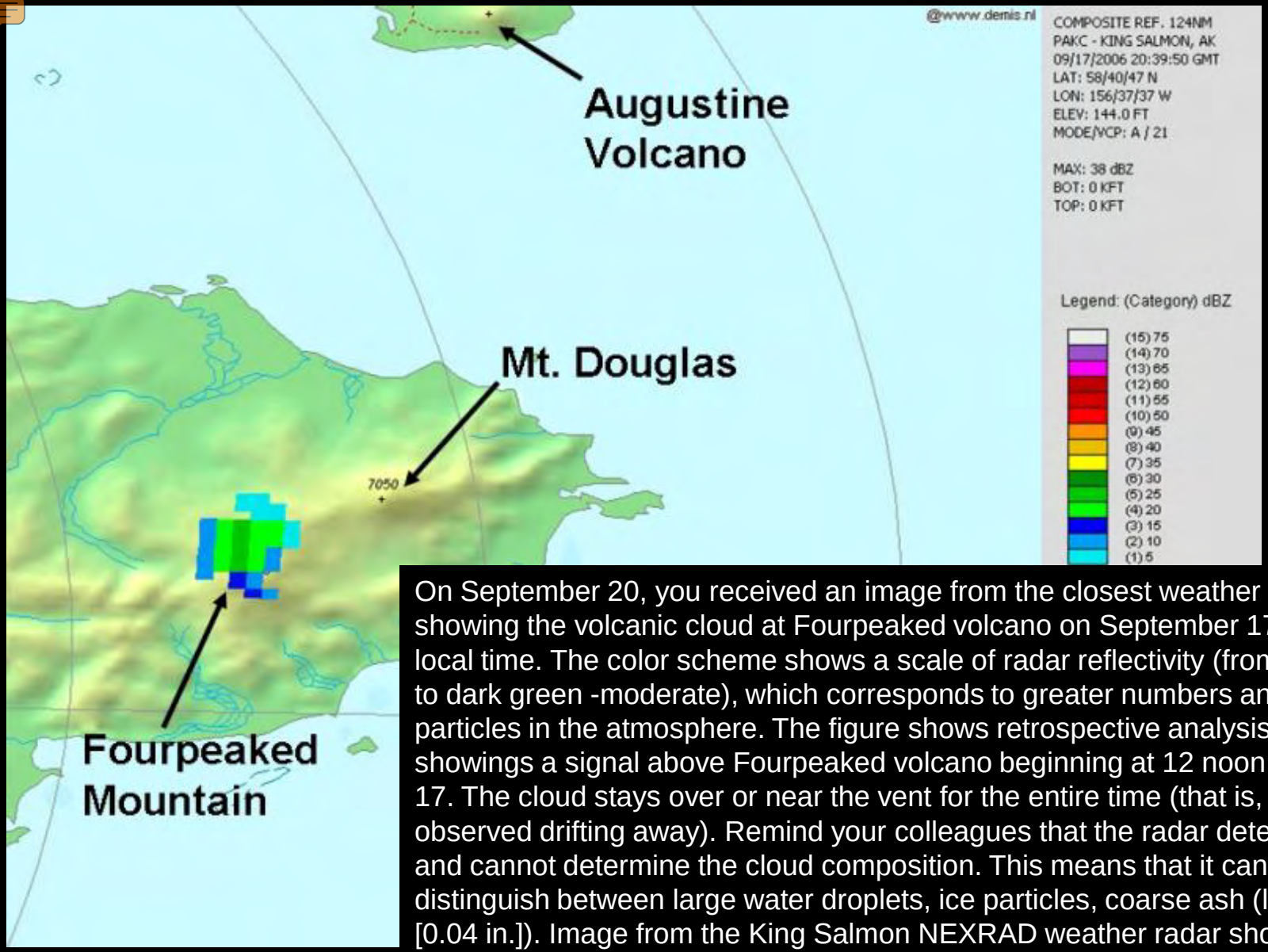

Location map of Fourpeaked and Douglas volcanoes. Image created by Seth Snedigar and J.R. Schaefer, Alaska Volcano Observatory/Alaska Division of Geological & Geophysical Surveys, dated September 18, 2006. http://www.avo.alaska.edu/image.php?id=11079

# Discussion 2 (D2)
# (Sept. 20 – 23)

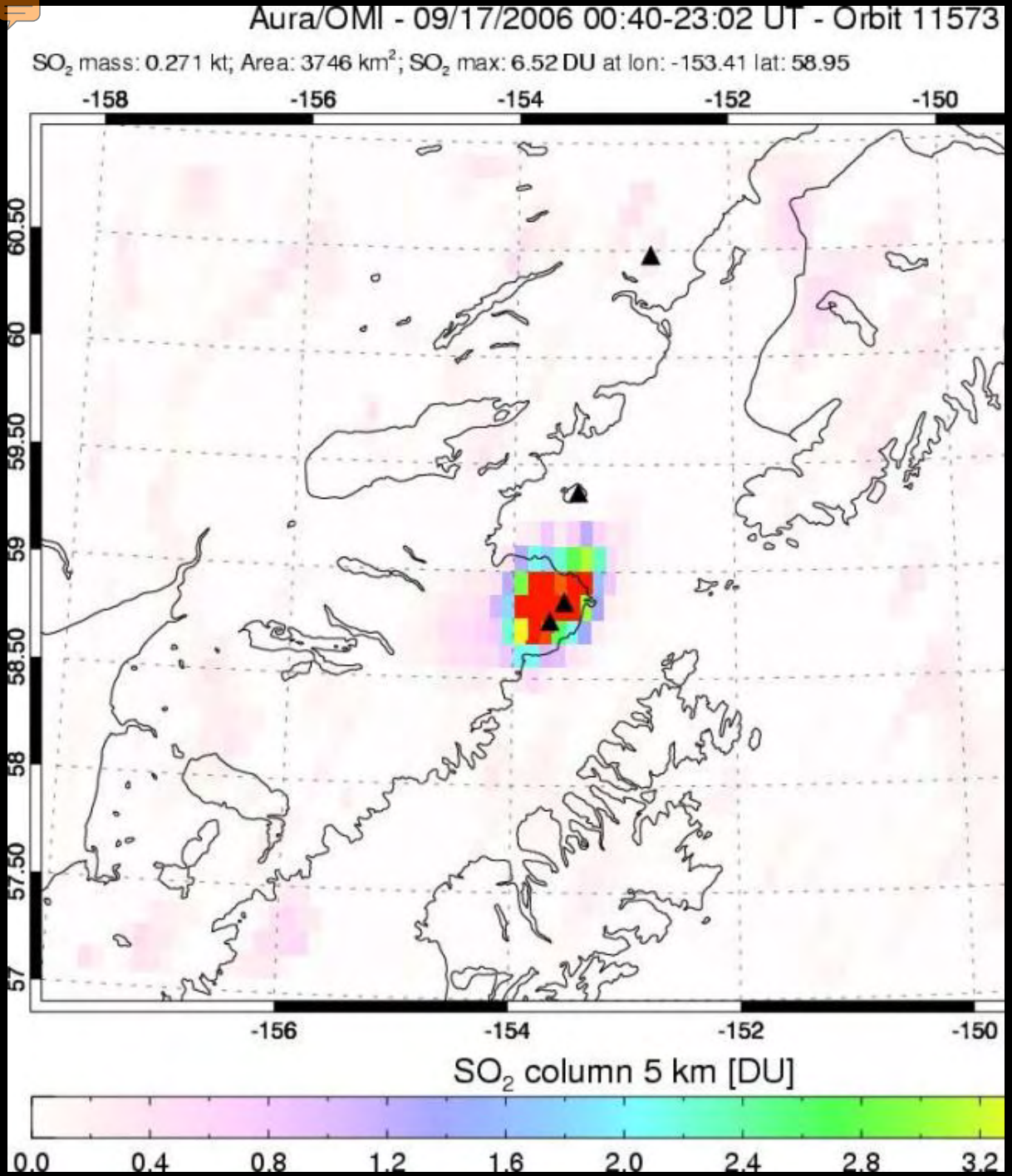
# D2. Geophysicists

You also observed two steam plumes at Fourpeaked. The two steam plumes appeared, vigorous, similar in size, white (no evidence of ash) and were rising to ~ 11,000 ft. Photograph taken by Guy Tytgat, Alaska Volcano Observatory/University of Alaska Fairbanks Geophysical Institute, September 20, 2006.

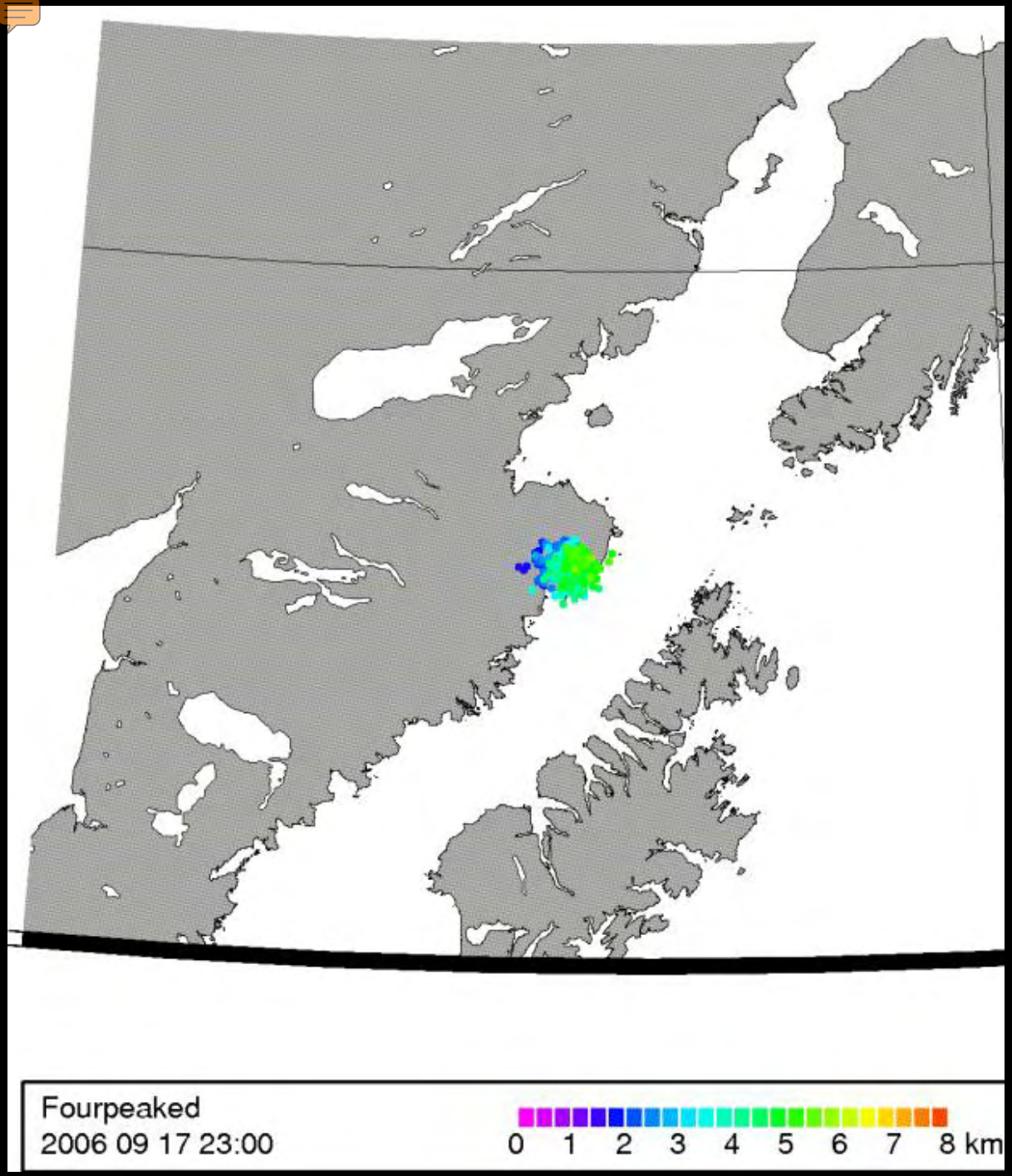
You also observed a surface flow on the glacial ice on the northwest side of the mountain. It appeared as mud flows coming out of the glacial crevasses and extending for quite a distance down the glacier. Photograph taken by Guy Tytgat, Alaska Volcano Observatory/University of Alaska Fairbanks Geophysical Institute, September 20, 2006.




On September 20, you received an image from the closest weather radar station showing the volcanic cloud at Fourpeaked volcano on September 17 at 12:40 PM local time. The color scheme shows a scale of radar reflectivity (from light blue-low, to dark green -moderate), which corresponds to greater numbers and/or sizes of particles in the atmosphere. The figure shows retrospective analysis of radar data showings a signal above Fourpeaked volcano beginning at 12 noon on September 17. The cloud stays over or near the vent for the entire time (that is, it is not observed drifting away). Remind your colleagues that the radar detects reflectors and cannot determine the cloud composition. This means that it can see but not distinguish between large water droplets, ice particles, coarse ash (like mm size [0.04 in.]). Image from the King Salmon NEXRAD weather radar showing the volcanic cloud at Fourpeaked Mountain volcano on September 17, 2006, at 12:40 ADT (20:40 UTC). Image dated September 19, 2006. This image was produced by David Schneider, U.S. Geological Survey/Alaska Volcano Observatory, using data and software provided by the NOAA National Climatic Data Center. http://www.avo.alaska.edu/image.php?id=11086.

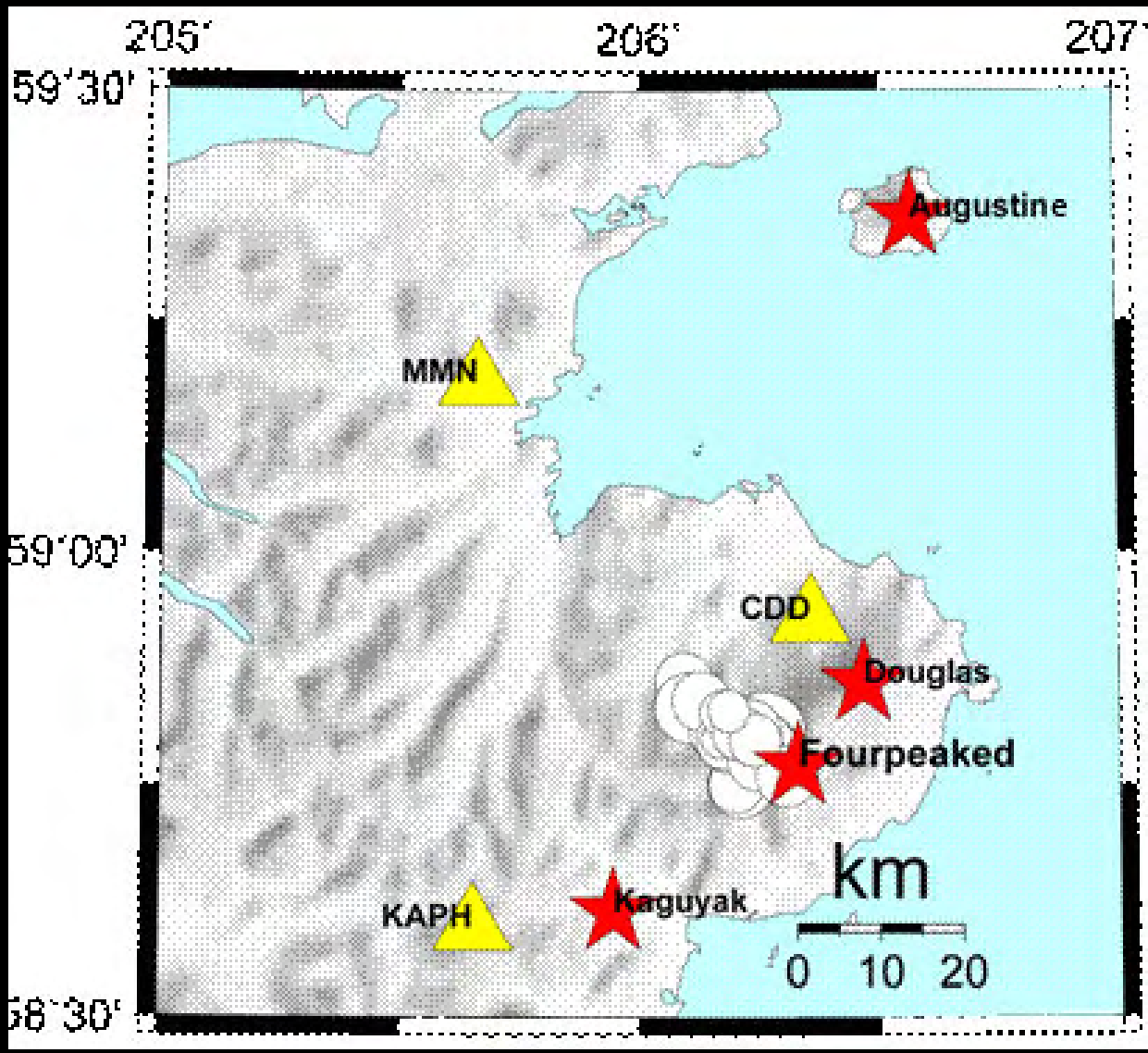



Also on September 20, colleagues (the volcanic emissions group at the University of Maryland Baltimore County, Baltimore, MD) emailed you an image showing the amount of sulfur dioxide in the atmosphere over Fourpeaked volcano at 3 PM on September 17. This image was created using data from the Ozone Monitoring Instrument (OMI) on NASA's EOS Aura satellite. This image confirms that the plume was volcanic! Nothing else you know of could produce approximately 300 tons of sulfur dioxide into the atmosphere except a volcano. Image showing the total amount of sulfur dioxide in the atmosphere over Fourpeaked Mountain volcano on September 17, 2006, as measured by the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite. Image created by the volcanic emissions group at the University of Maryland Baltimore County, Baltimore, Md., USA, dated September 19, 2006 (S.A. Carn, N.A. Krotkov, A.J. Krueger, and K. Yang). OMI was built by a Dutch/Finnish collaboration and managed by KNMI and NIVR in the Netherlands. http://www.avo.alaska.edu/image.php?id=11085.




Based on the satellite and weather radar data you now have, you ran the Puff volcanic ash dispersion model for the same time as the $SO_2$ OMI image you got from your colleagues in Maryland. The Puff generated image shows the predicted position of a volcanic cloud at 3 PM local time from Fourpeaked volcano on September 17. The Puff prediction showed the ash cloud to be 5 to 6 km asl. The color scheme at the bottom of the image shows the altitude scale (asl) for the ash cloud from 0 km (purple) to 8 km (red). Image from Puff volcanic ash dispersion model showing the predicted position of the volcanic cloud at 15:00 ADT (23:00 UTC) from Fourpeaked Mountain volcano on September 17, 2006. Image taken by Peter Webley, Alaska Volcano Observatory/University of Alaska Fairbanks, Geophysical Institute, dated September 20, 2006. http://www.avo.alaska.edu/image.php?id=11087.

On September 21, you notice that a small swarm of earthquakes was detected on the regional seismic network from 11:48 AM to 3:50 PM on September 17.
Sixteen of the earthquakes (white circles) were large enough to show up on stations in nearby Katmai, Oil Point, Augustine (yellow triangles), and in Kodiak (not pictured). The earthquakes magnitudes were between 0.8 and 1.8 and were clustered to the northwest of the Fourpeaked summit. The red stars are volcanoes (Alaska Volcano Observatory website).



On September 23, you went on a gas flight (a small airplane flight to make observations and use equipment to determine the types and amount of volcanic gases coming from the volcano). You saw a linear series of vents to the north and just below the summit of Fourpeaked. Gas was abundant. You measured carbon dioxide ($CO_2$), and you measured and could smell sulfur dioxide (rotten egg smell—$SO_2$), and hydrogen sulfide (striking a match smell—$H_2S$). Photograph taken by P. Cervelli, Geological Survey/Alaska Volcano Observatory September 23, 2006.

# D2. Geologists

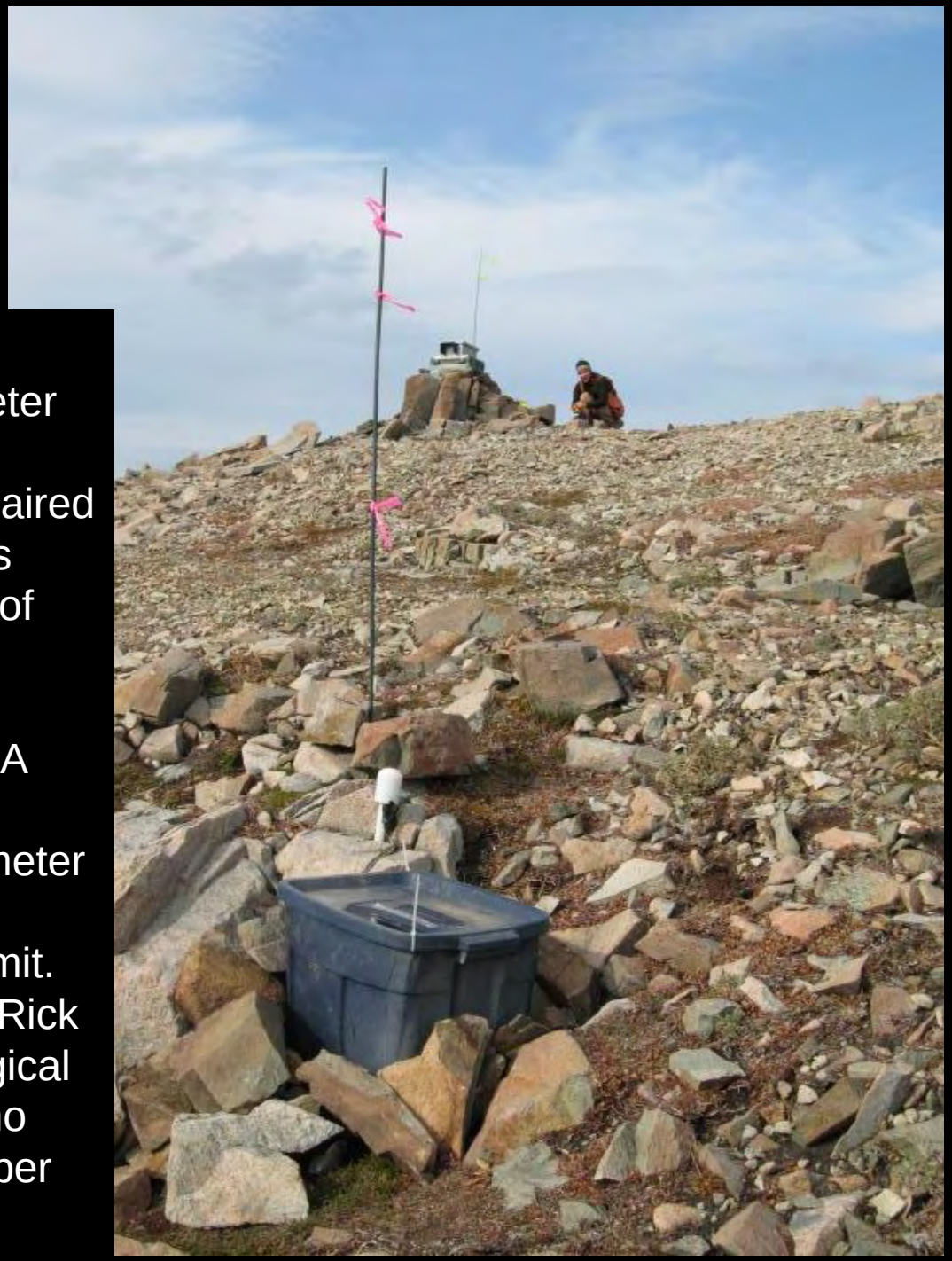
Terminus of Fourpeaked Glacier. Notice the dark-colored sediment issuing from an elongate tunnel in the ice that is distinctly different than the color of the proglacial lake. Photograph taken by K. Wallace, U.S. Geological Survey/Alaska Volcano Observatory, September 20, 2006. http://avo.alaska.edu/images/image.php?id=11102.

Looking toward the north-northwest, the southeast ridge of Fourpeaked volcano has distinct, white steam plumes. Photograph taken during the helicopter observation flight between 19:40 and 20:30 local time, looking NNW. SE Ridge in the foreground, top of the "headwall" at the extreme right of the photograph and both plumes in the background. Photograph taken by Guy Tytgat, Alaska Volcano Observatory/University of Alaska Fairbanks Geophysical InstituteI, September 20, 2006. http://avo.alaska.edu/images/image.php?id=11132.

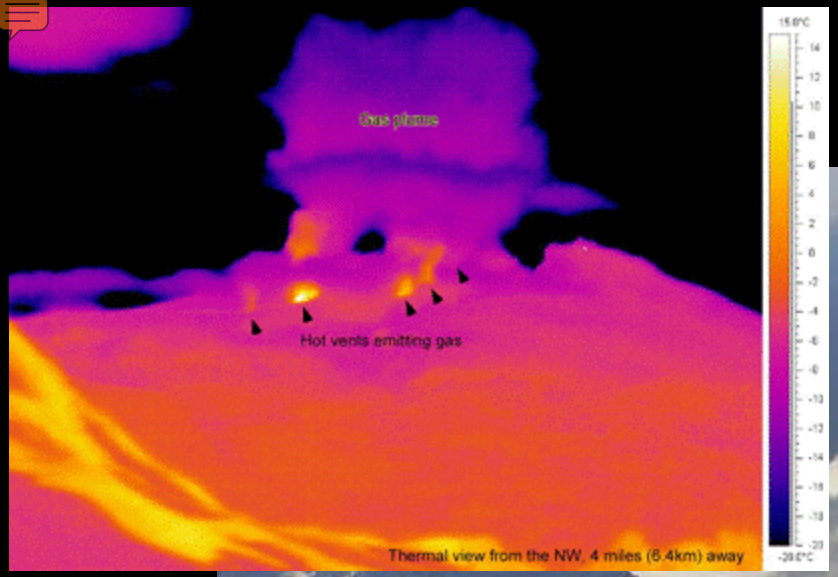
You observed the headwall of Fourpeaked Glacier just northeast of the summit of Fourpeaked volcano. Waterfalls were issuing from beneath the ice at the top of the headwall at an elevation of 5,000 feet (1,900 feet below the summit). Headwall of Fourpeaked Glacier NE of the summit of Fourpeaked volcano. Waterfalls were issuing from beneath the ice at the top of the headwall at an elevation of 5,000 ft (1,900 ft below the summit). A convective vapor plume was rising above the cloud deck between the summit (obscured by clouds) and the headwall region. Photograph taken by K.L., Wallace, Alaska Volcano Observatory/U.S. Geological Survey, September 20, 2006. http://avo.alaska.edu/images/image.php?id=11099.

# Discussion 3 (D3)
# (Sept. 24 - 26)

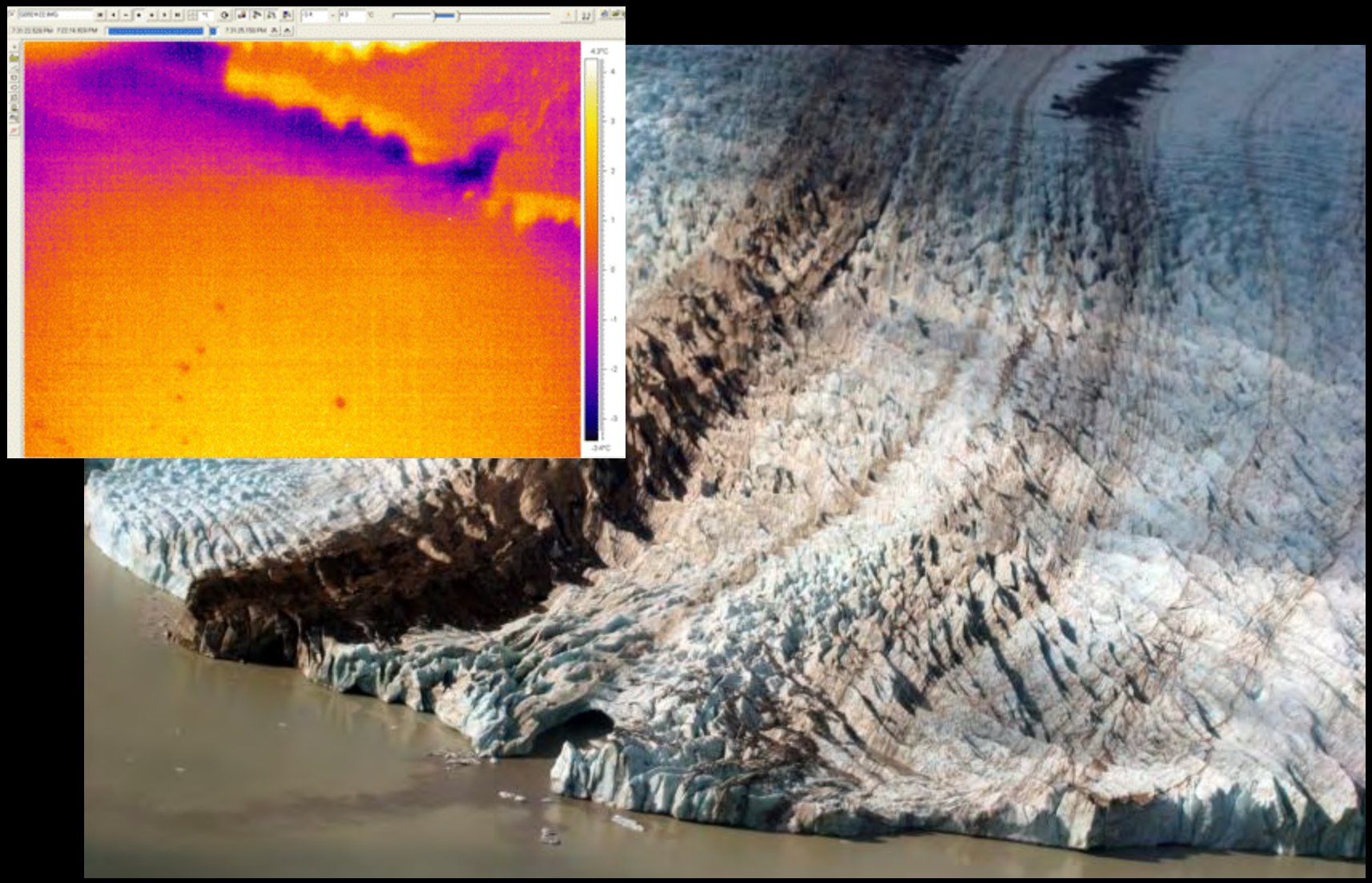
# D3. Geophysicists



The nearest, but inoperable, seismometer (used to detect earthquakes) was repaired and a new station was installed 7 miles east of the volcano. Both instruments are now sending data to AVO. A campaign (non-telemetered) seismometer was installed 4 miles northwest of the summit. Photograph taken by Rick Wessels, U.S. Geological Survey/Alaska Volcano Observatory, September 25, 2006.




Along the 1 km long crack on the side of the summit glacier discrete vents are emitting gas. Using your Forward Looking Infrared Radiometer (FLIR), you determined these are the hottest surface areas along the crack and they reach temperatures ~ 12° C (54° F). Steaming on the uppermost section of the northern flank of Fourpeaked volcano. Photograph taken by Jennifer Adleman, U.S. Geological Survey/Alaska Volcano Observatory, November 4, 2006. http://avo.alaska.edu/images/image.php?id=12359. Inset: Thermal image of chain of vents on Fourpeaked summit from 6.4 km (4 mi) NNW of summit. Black arrows on inset map show approximate field of view. FLIR image created by Rick Wessels, U.S. Geological Survey/Alaska Volcano Observatory, September 24, 2006. http://avo.alaska.edu/images/image.php?id=11462.



You used the FLIR to look at the water draining from inside a glacier lobe of glacial ice (of the Fourpeaked Glacier), which drains into a proglacial lake and the end of the lobe. The geologists thought that the water might have been warm and anomalous. You determined that it was cool. FLIR by Rick Wessels, U.S. Geological Survey/Alaska Volcano Observatory, September 24, 2006. Terminus of Fourpeaked Glacier. Notice the dark-colored sediment issuing from an elongate tunnel in the ice that is distinctly different than the color of the proglacial lake. Photograph taken by K. Wallace, U.S. Geological Survey/Alaska Volcano Observatory, September 20, 2006. http://avo.alaska.edu/images/image.php?id=11102.

# D3. Geologists

You had good views of the entire line of vents in the ice. You noted that the lower two pits were circular, the middle segment was elongate or maybe multiple, now coalesced vents, and it had multiple, vigorous steam sources and a fresh ring of ash around it. The upper region had at least three steam sources offset from the linear trend. There was no incandescence, although an outcrop of orange altered rock gave you a scare! Fumaroles on west side of Fourpeak Volcano. Photograph taken by Cyrus Read, Alaska Volcano Observatory/U.S. Geological Survey, September 24, 2006. http://avo.alaska.edu/images/image.php?id=11205

You collected samples from the lobate muddy surface flow and observed giant chunks of the glacier may have been ripped up during the formation of these flows (photographs taken by K.L. Wallace U.S. Geological Survey/Alaska Volcano Observatory, September 25, 2006 ).

# Aviation Color Code and Alert Level

| Color | Description |
|---|---|
| GREEN | Volcano is in typical background, noneruptive state<br>or, after a change from a higher level,<br>volcanic activity has ceased and volcano has returned to noneruptive background state. |
| YELLOW | Volcano is exhibiting signs of elevated unrest above known background level<br>or, after a change from a higher level,<br>volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase. |
| ORANGE | Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain,<br>OR<br>eruption is underway with no or minor volcanic-ash emissions [ash-plume height specified, if possible] |
| RED | Eruption is imminent with significant emission of volcanic ash into the atmosphere likely<br>OR<br>eruption is underway or suspected with significant emission of volcanic ash into the atmosphere [ash-plume height specified, if possible]. |

| Term | Description |
|---|---|
| NORMAL | Volcano is in typical background, noneruptive state<br>or, after a change from a higher level,<br>volcanic activity has ceased and volcano has returned to noneruptive background state. |
| ADVISORY | Volcano is exhibiting signs of elevated unrest above known background level<br>or, after a change from a higher level,<br>volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase. |
| WATCH | Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain,<br>OR<br>eruption is underway but poses limited hazards. |
| WARNING | Hazardous eruption is imminent, underway, or suspected. |

**USGS Aviation Color Code (top) and Volcanic Alert Level (bottom), 2006.**