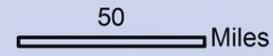
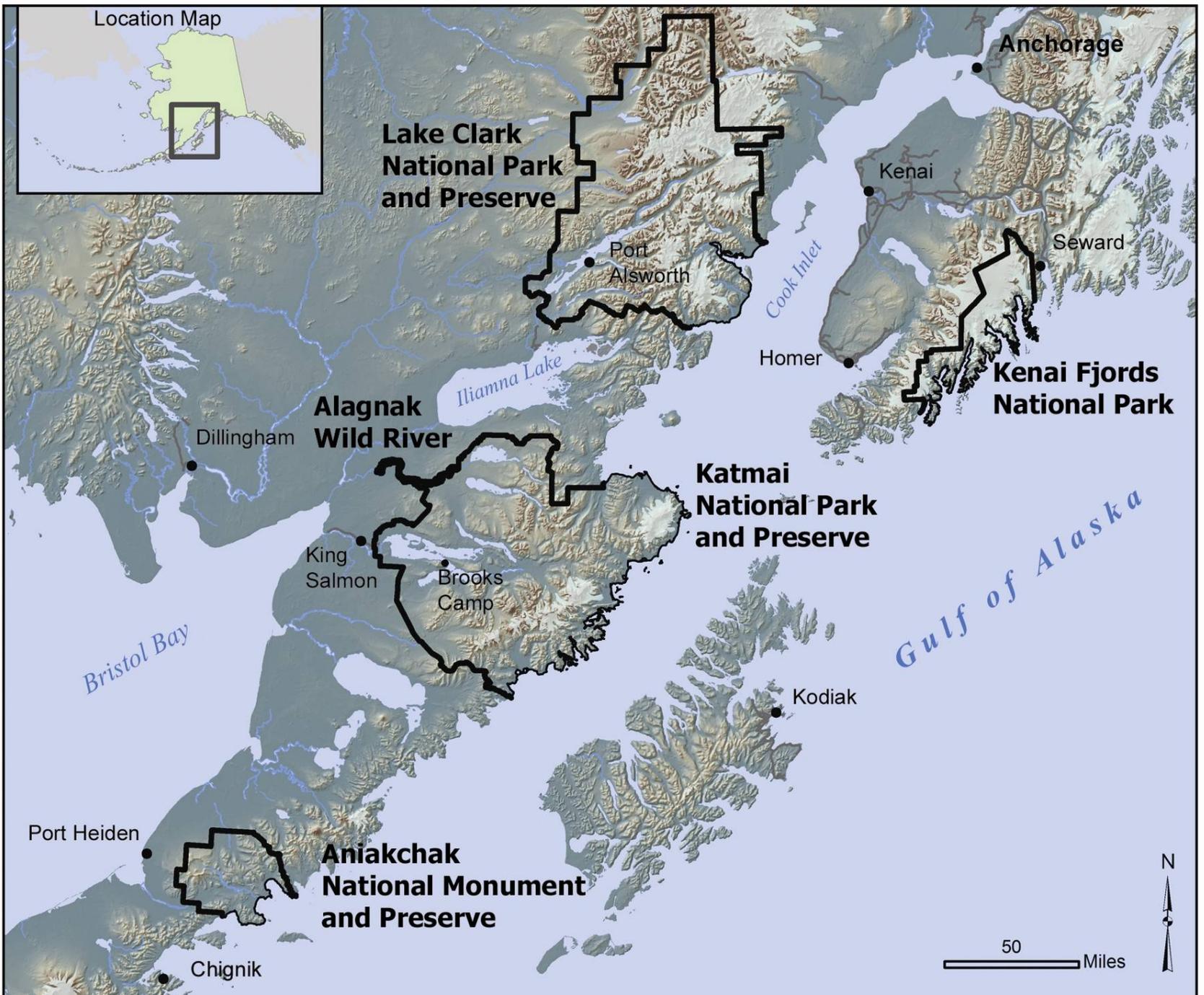


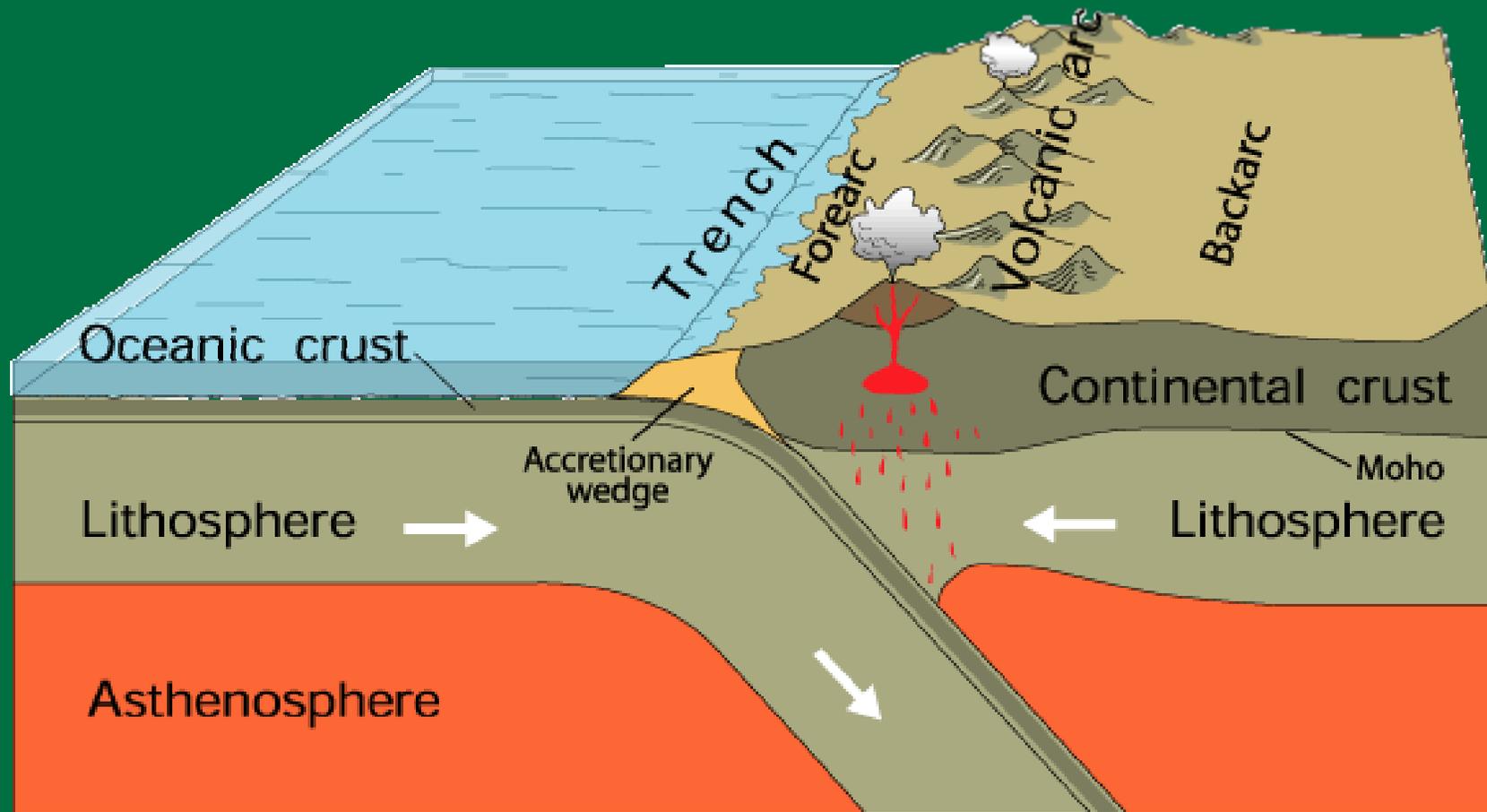


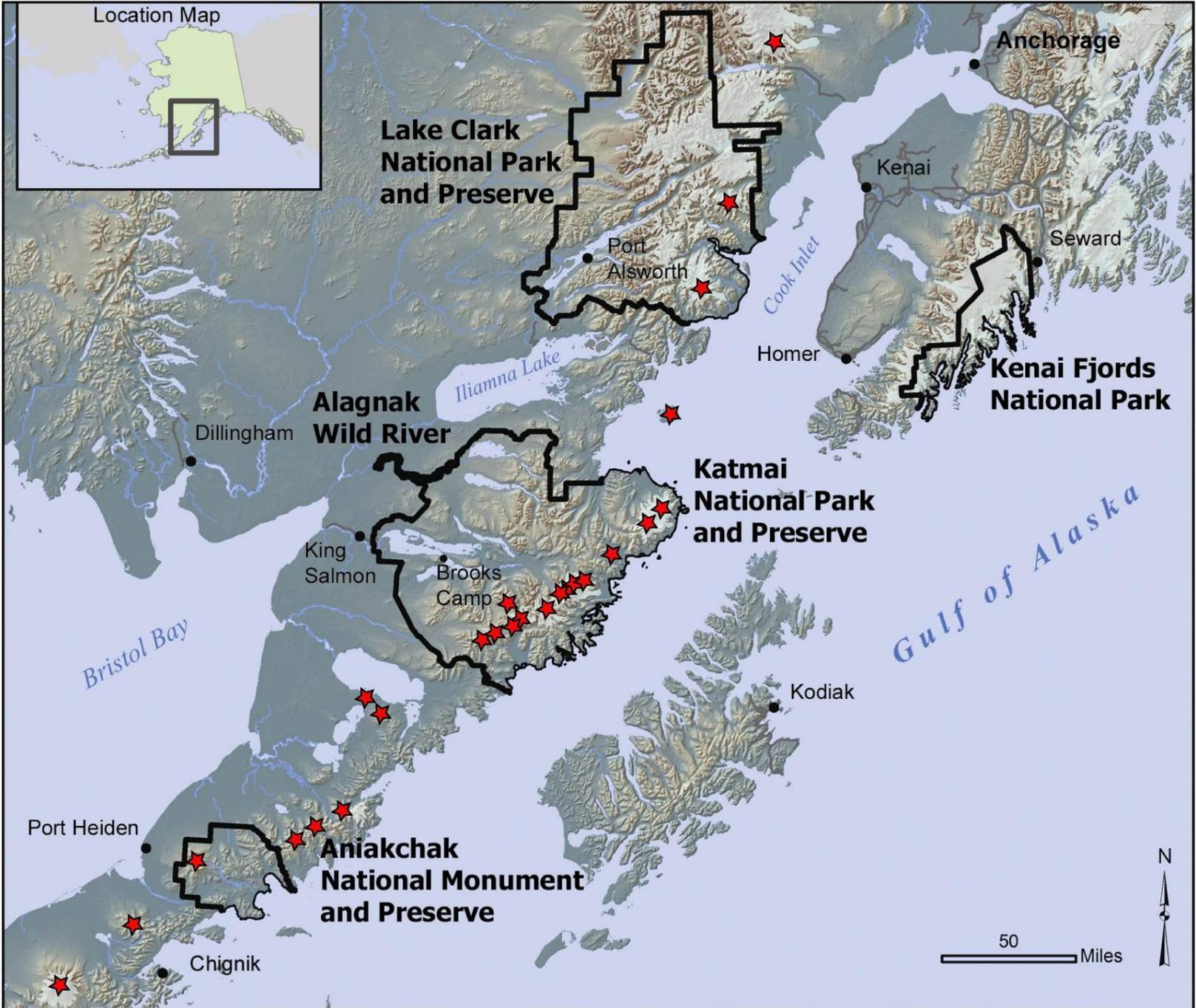
Restless volcanoes in (and near) Southwest Alaska Network Parks

Christina Neal
USGS Alaska Science Center
Alaska Volcano Observatory
March 2007



SUBDUCTION AND MAGMA GENERATION

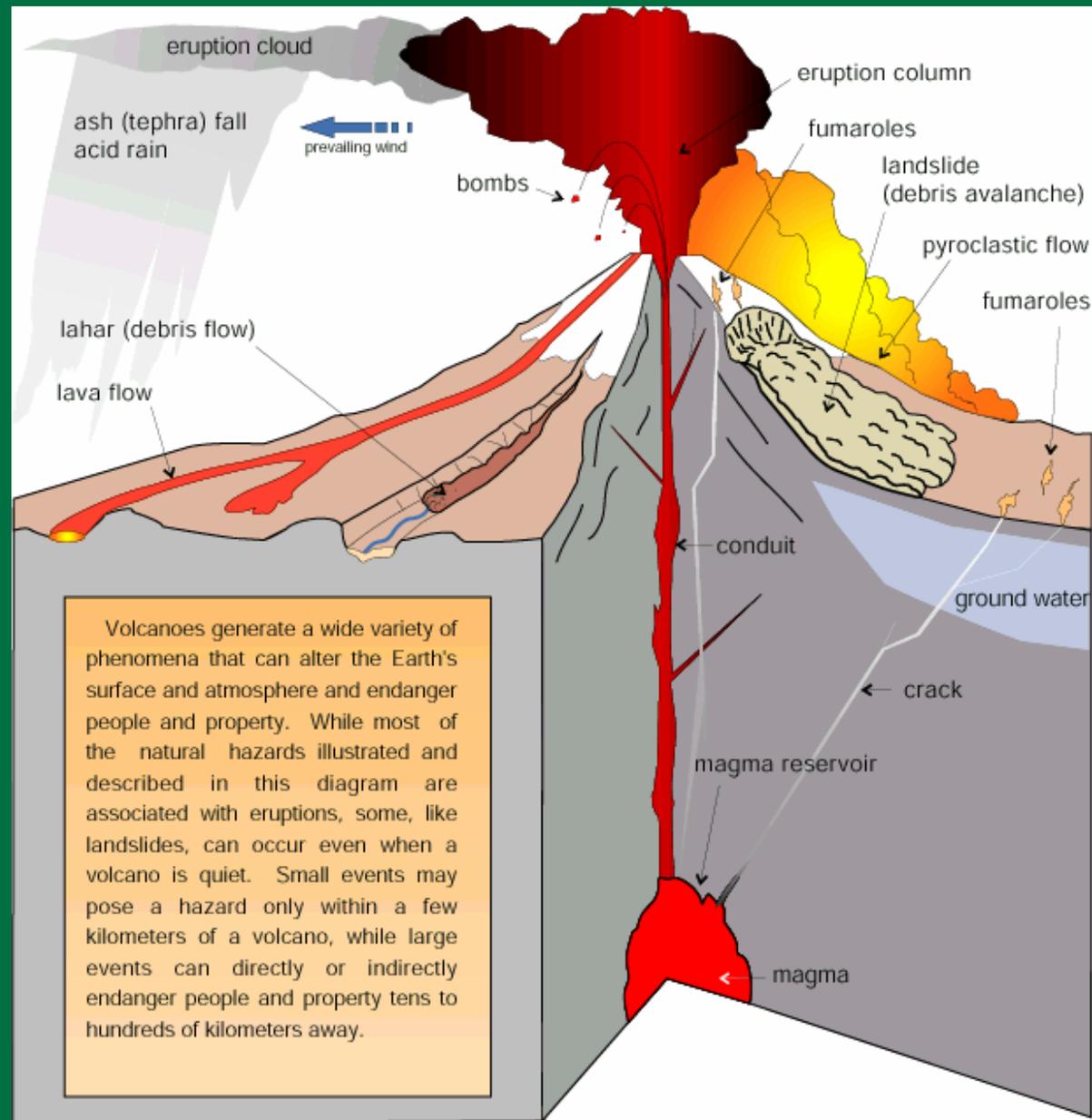


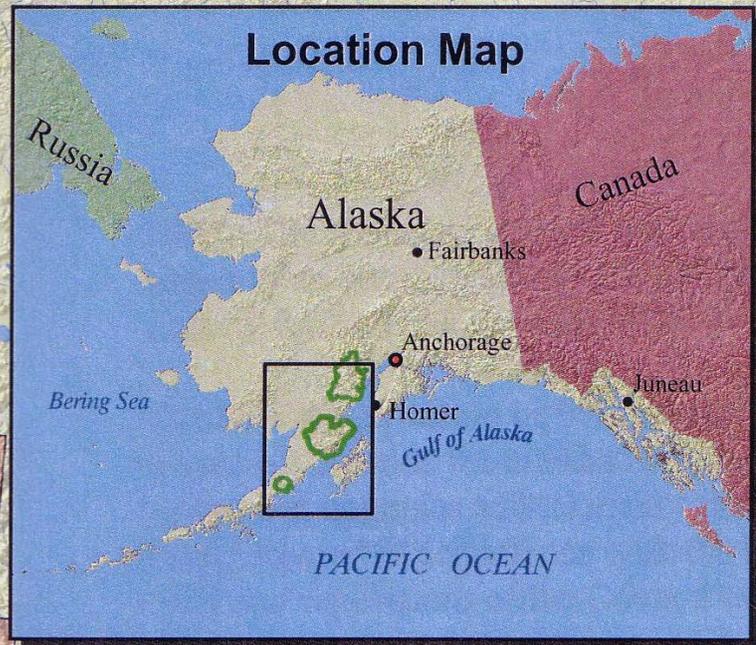


ALASKA'S Southwest VOLCANIC PARKS: LACL - KATM - ANIA

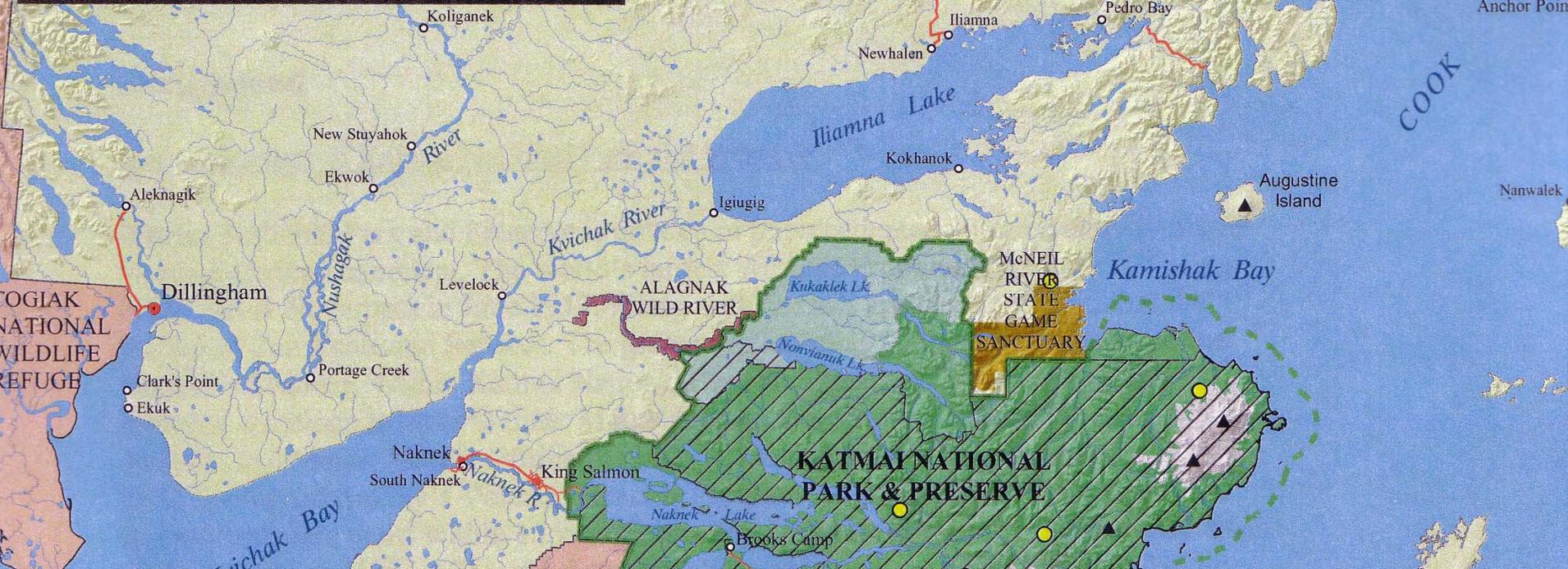
- 6 *historically* active volcanoes: Redoubt, Fourpeaked, Novarupta, Katmai, Aniakchak, Trident
- 3+ more with strong fumarolic or earthquake episodes (Martin, Mageik, Iliamna)
- 13+ volcanoes active in the last 10,000 years
- 3 caldera-forming eruptions in the Holocene
- Earth's largest eruption since 1815 = Novarupta
- *What volcanic surprises lurk beneath receding glaciers?*

All volcano hazards are represented in SWAN Parks; marvelous volcanic laboratories





LAKE CLARK: REDOUBT AND ILIAMNA



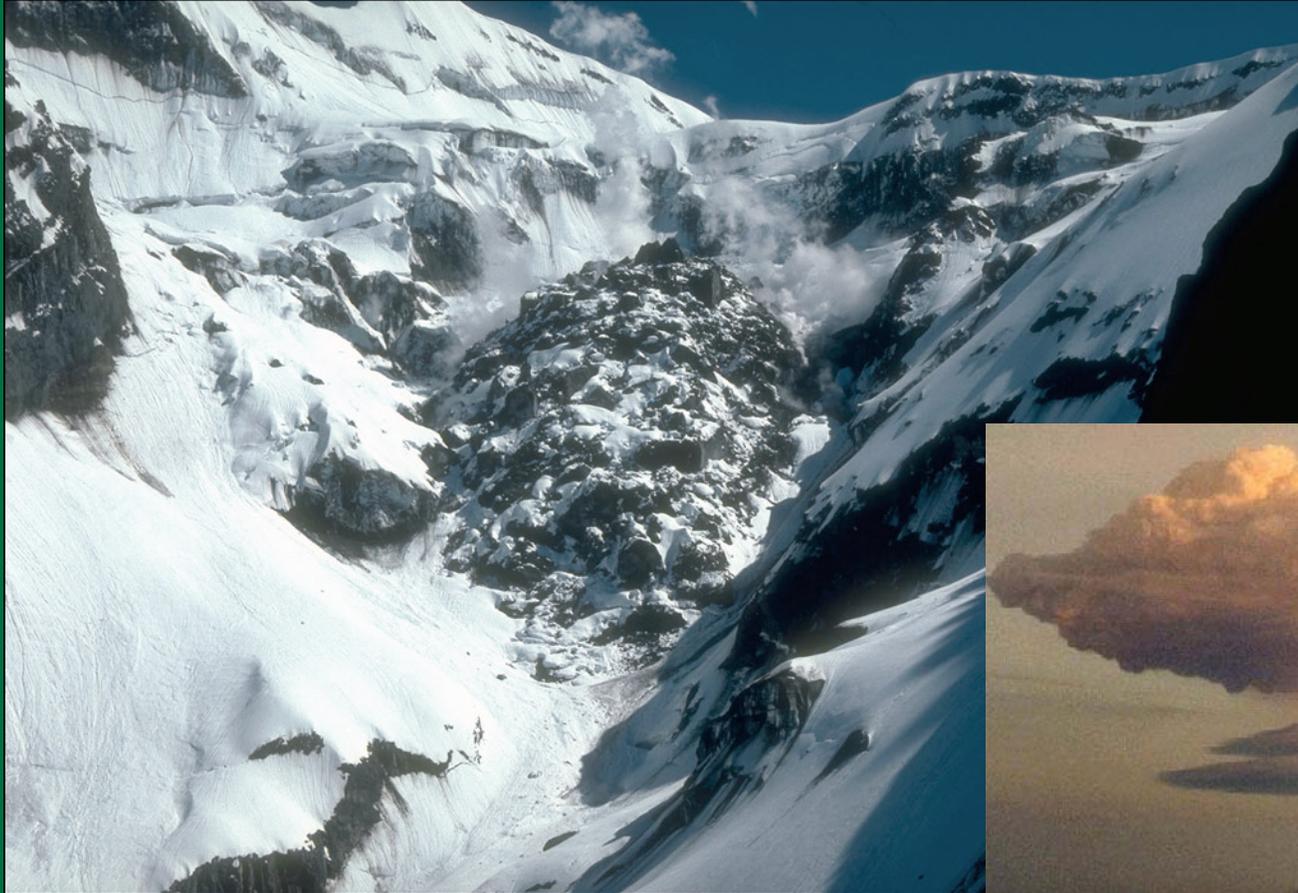
Lake Clark: Redoubt Volcano

- 3108 m, glaciated, andesitic stratovolcano
- 5 historical eruptions: ash clouds, ash fall, lava dome extrusion and collapse, pyroclastic flows, surges, lahars, possible tsunamis?
- 1989-90 eruption:
 - >160M\$ in damage
- 3 Holocene debris avalanches
- Drift River Oil Terminal 35 km downstream



Neil Moomey 2/24/07

Lava dome growth in the ice-filled summit crater: 1989-90



Hot debris + snow and ice = mudflows



Glacial ice quickly reclaims the crater

1996



2006



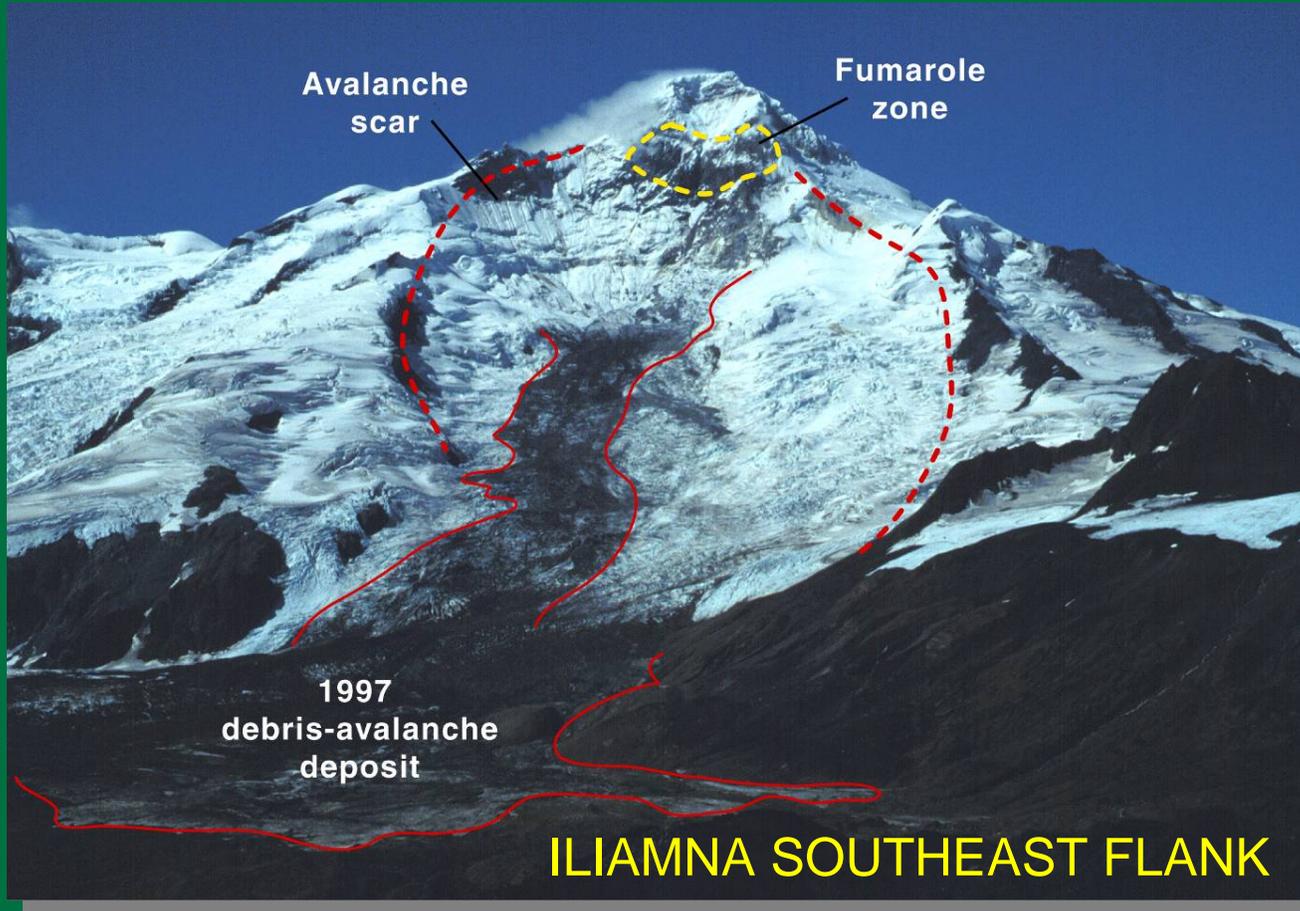
Volume of ice accumulated in crater since 1990: ?????? ~0.1 km³ lost in 1989-90

Lake Clark: Iliamna Volcano

- 3053 m, glaciated, andesitic stratovolcano
- No confirmed historical eruptions;
 - 2 possible historic tephras
- 1 plinian eruption in the last 7000 yrs
- Little known about Holocene eruptions
- 6 lahars (some without eruption)
 - in the last 2400 yrs
- Fumaroles: SO₂, H₂S, CO₂
- 1996 intrusion...no eruption



Iliamna: a rotten (if pretty) volcano



- Upper edifice consists of hydrothermally altered rock
- Concave, amphitheater-like depressions on edifice
- A non-eruptive hazard as well

Red Glacier

Katmai National Park:

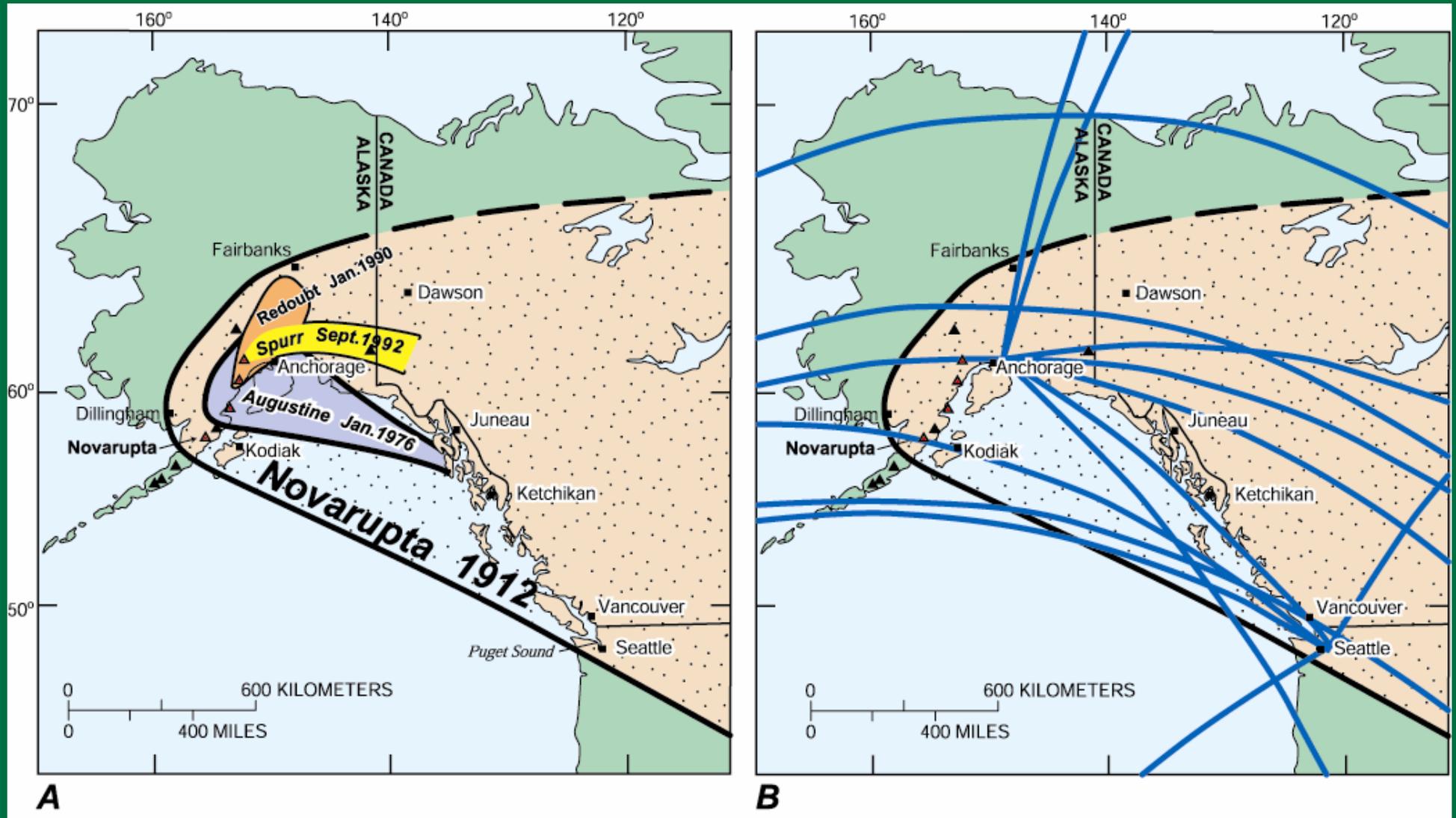
Douglas
Fourpeaked
Kaguyak
Devil's Desk
Kukak
Stellar
Denison
Snowy
Katmai
Novarupta
Griggs
Trident
Mageik
Martin
Alagogshak



Novarupta: source of the 1912 eruption



The 1912 eruption in perspective





GRIGGS



MAGEIK



MARTIN



TRIDENT (1953-1974)



**Snowy Mountain
volcanic center**

6770

6600+

7090

6875

**Mount
Denison**

**Mount
Steller**

NORTHEAST KATMAI VOLCANOES

**Snowy 'steaming
hole'**

**Photo J. Bundy,
NPS**

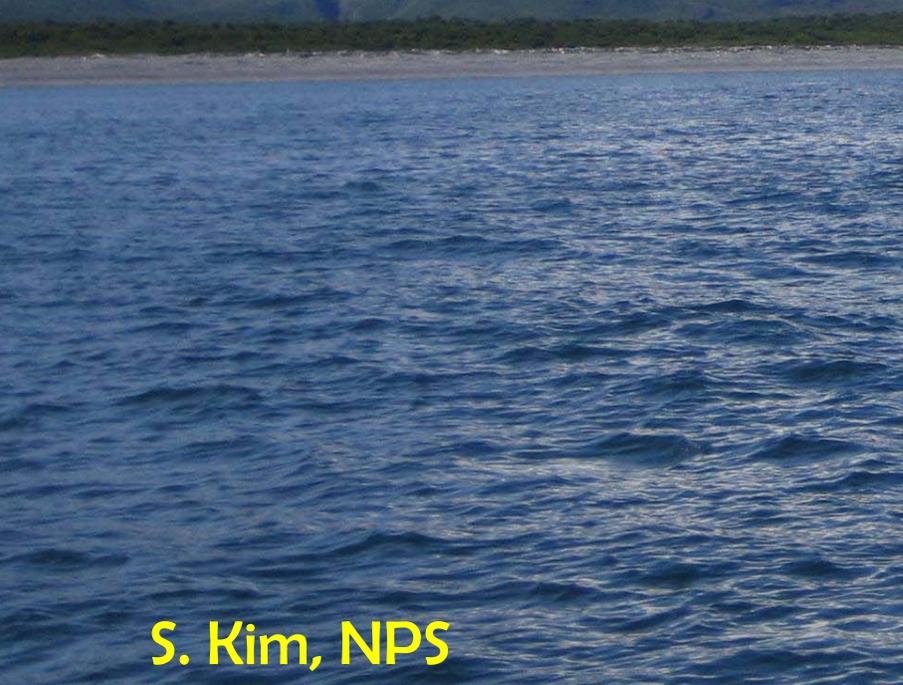
KAGUYAK



FOURPEAKED

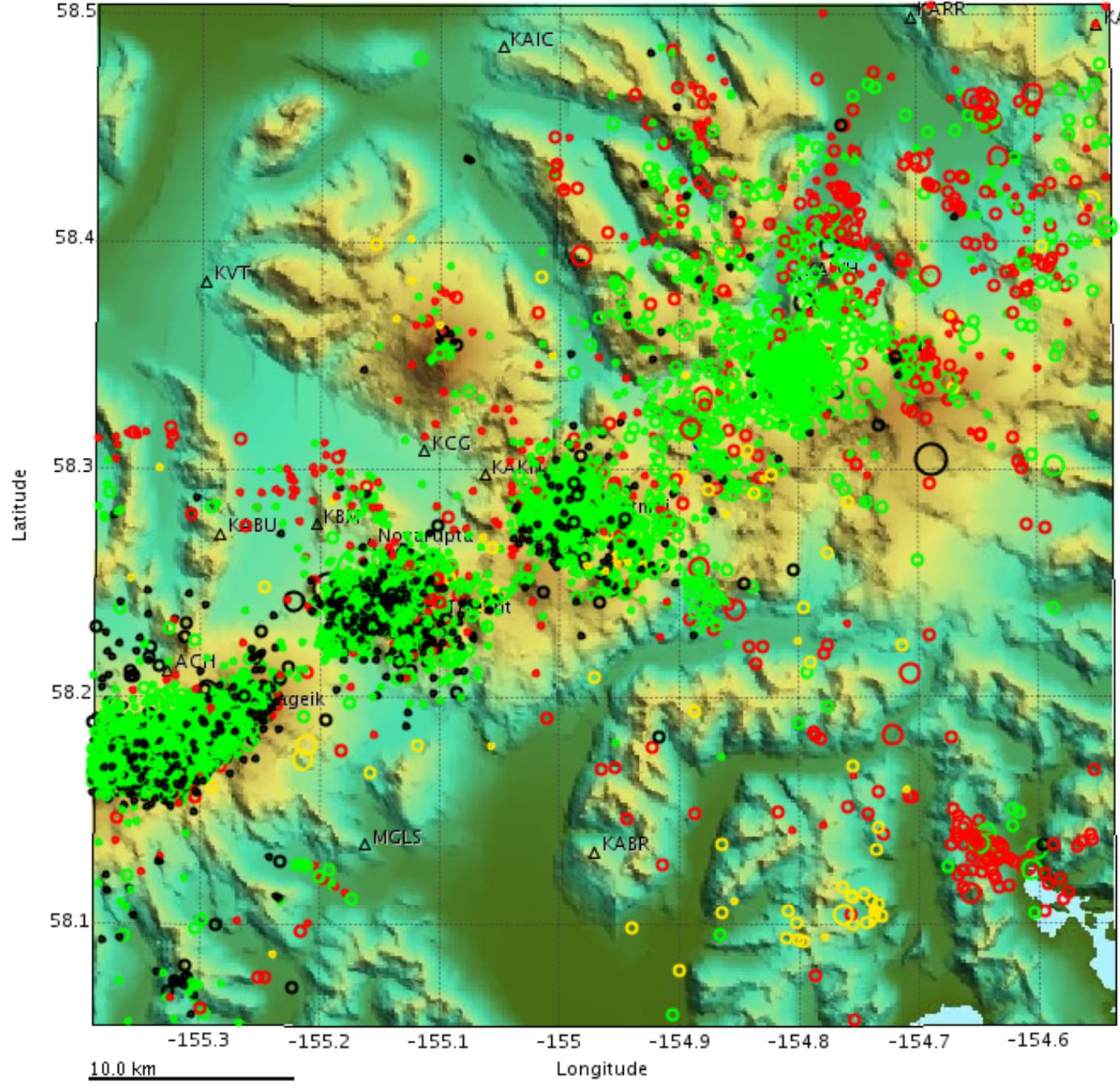


DOUGLAS



S. Kim, NPS

9891 earthquakes between 1997-03-01 and 2007-02-22



Katmai
seismicity
1997 - 2007

Depth (km)
0
5
10
20
40
70

Aniakchak

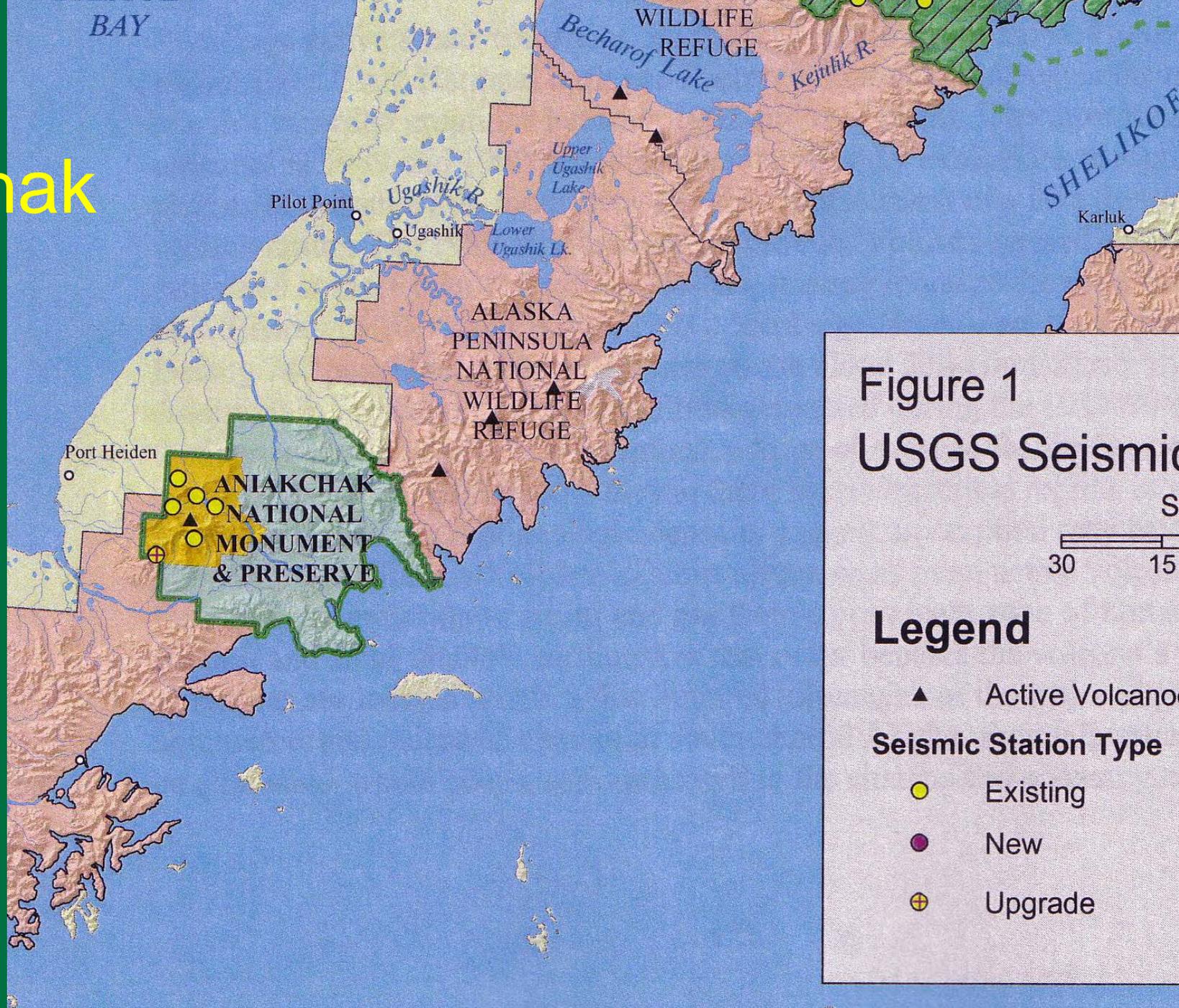


Figure 1
USGS Seismic

30 15

Legend

▲ Active Volcano

Seismic Station Type

● Existing

● New

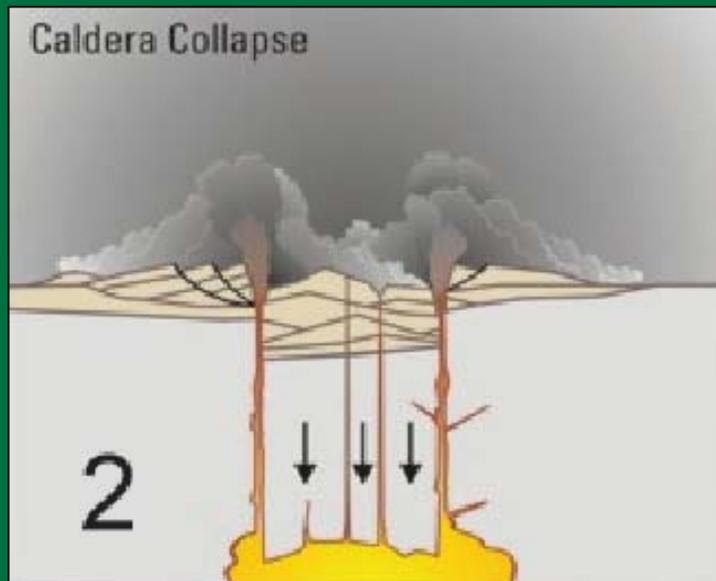
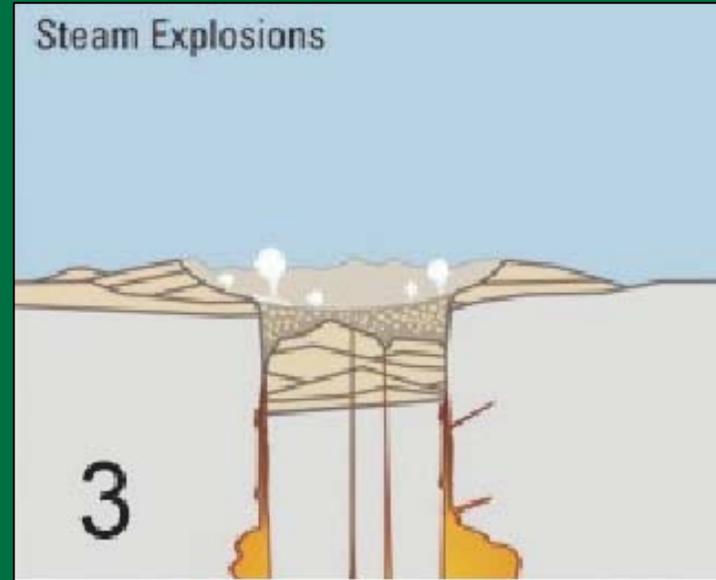
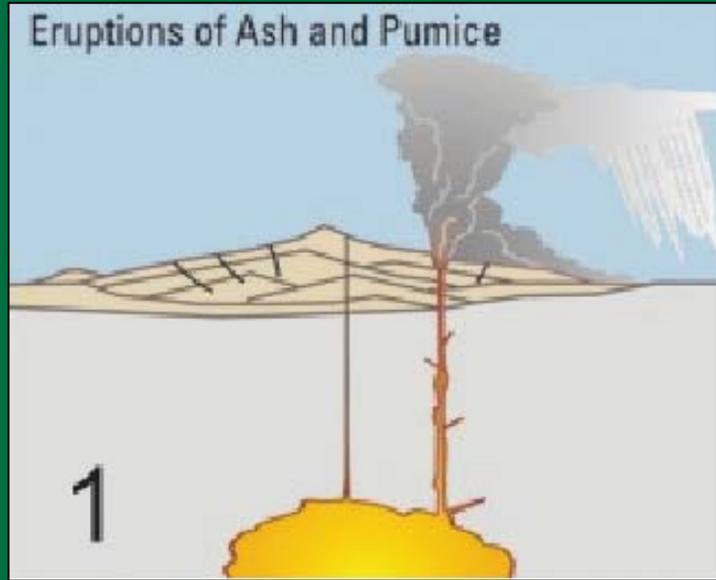
⊕ Upgrade

ANIAKCHAK CALDERA

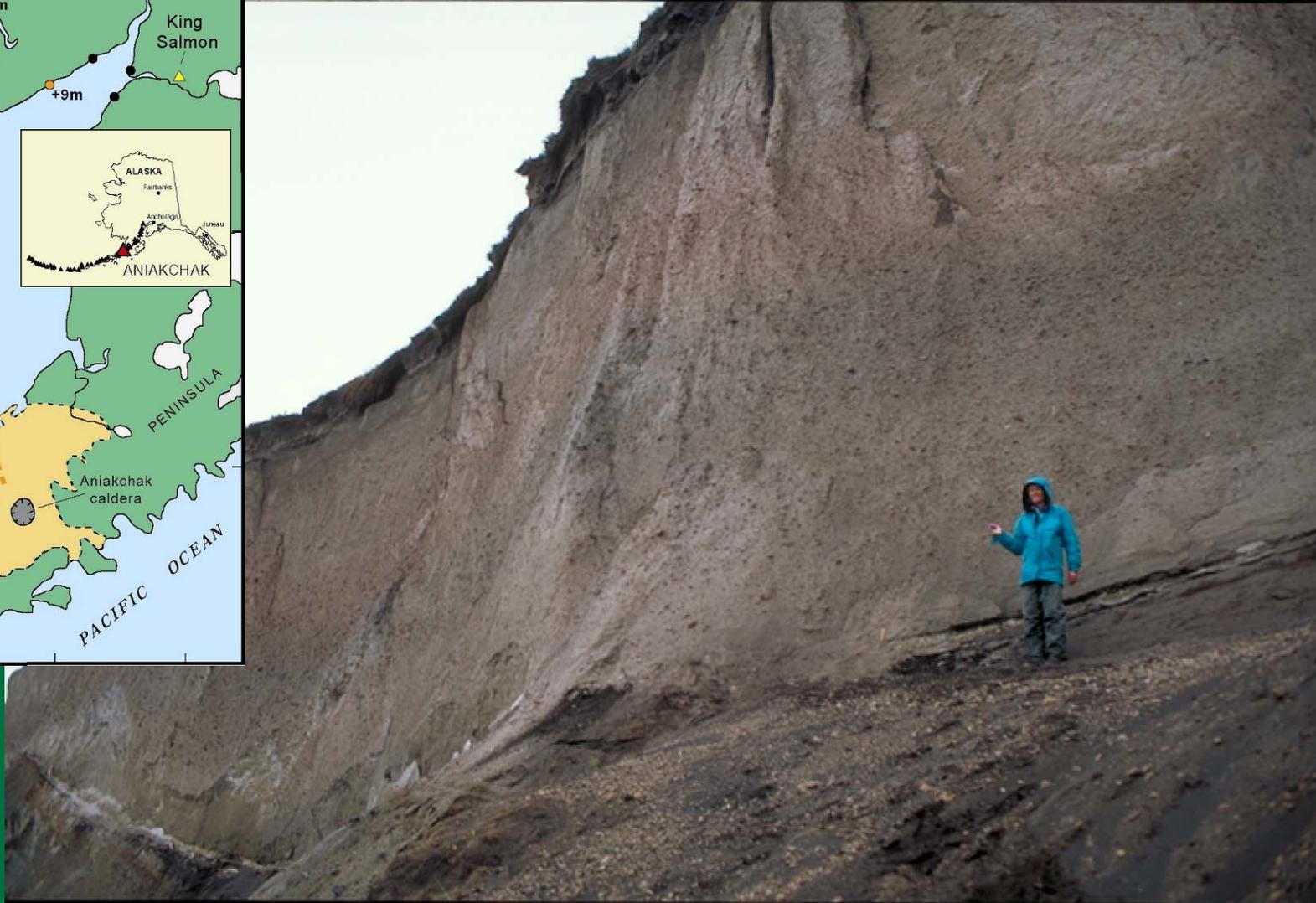
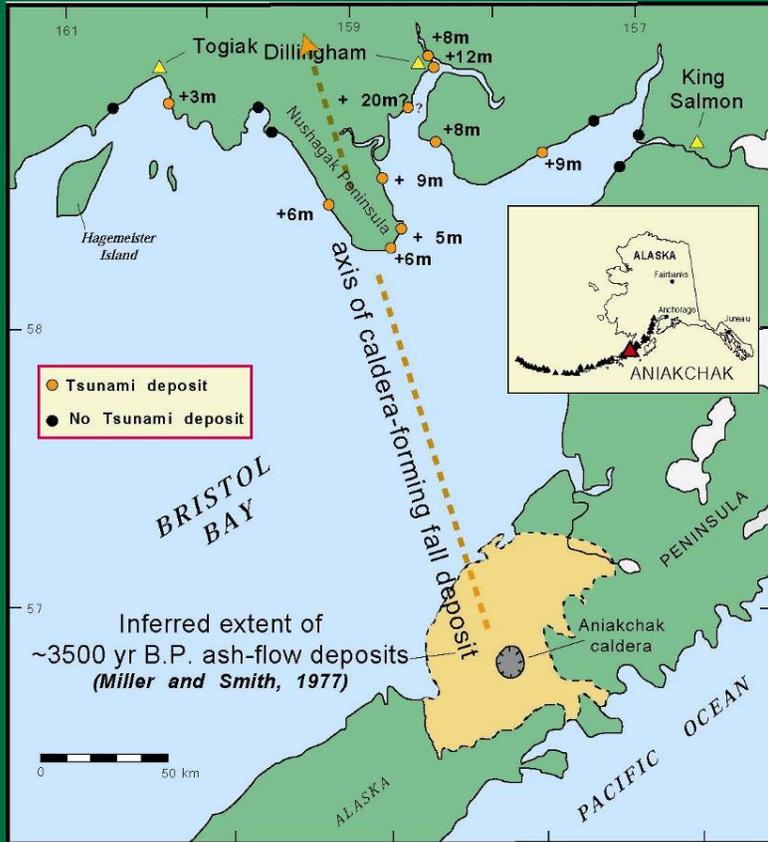


1645 BC \pm 4 years!

Caldera collapse at a stratovolcano



Tsunamis in Bristol Bay?



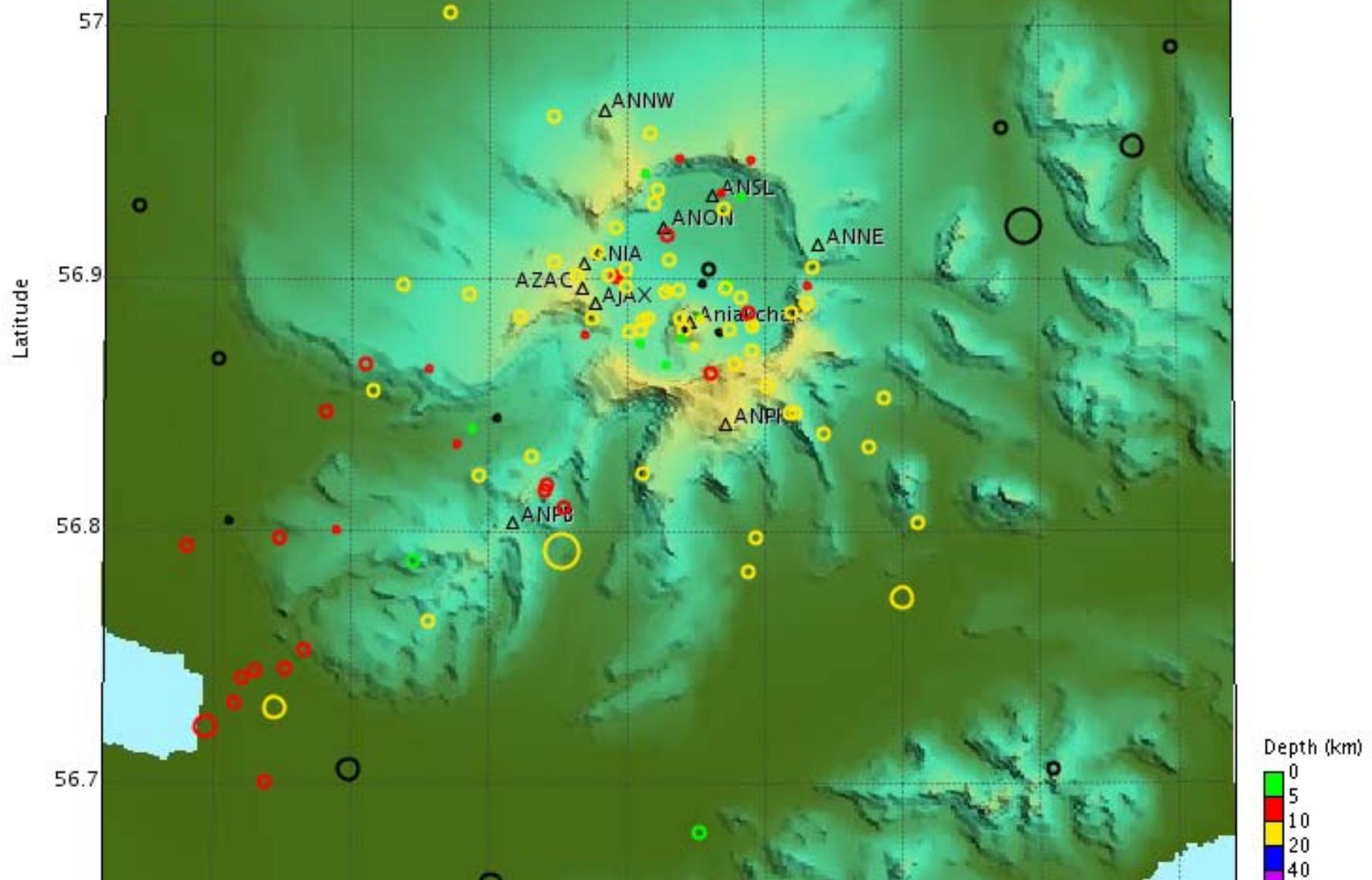
Draining of a large lake....



Multiple explosive and lava flow eruptions in the last 3500 years



Aniakchak 1997 – 2007

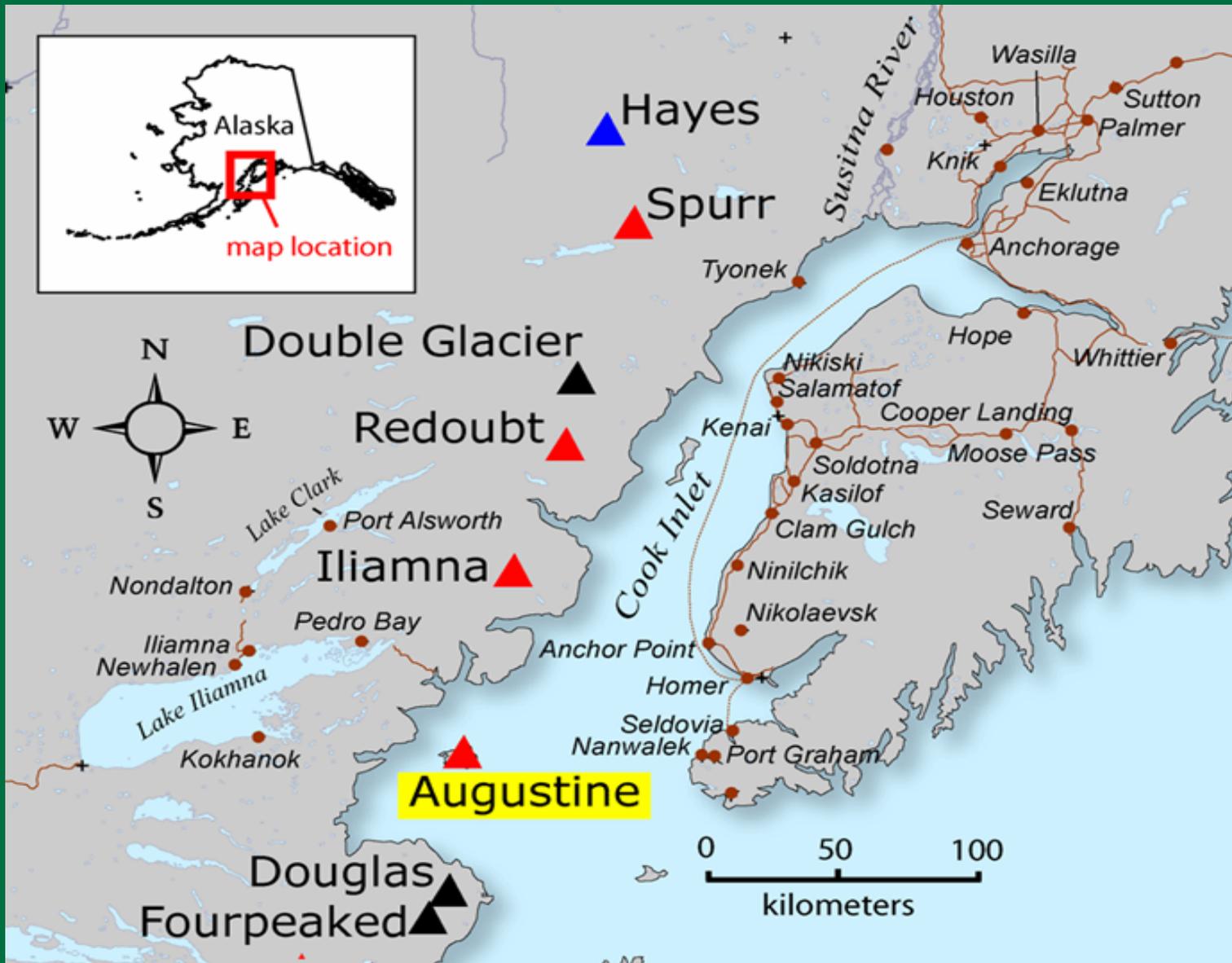


Carbon dioxide warm springs: magmatic signature



Fourpeaked volcano's surprise eruption: September 17, 2006





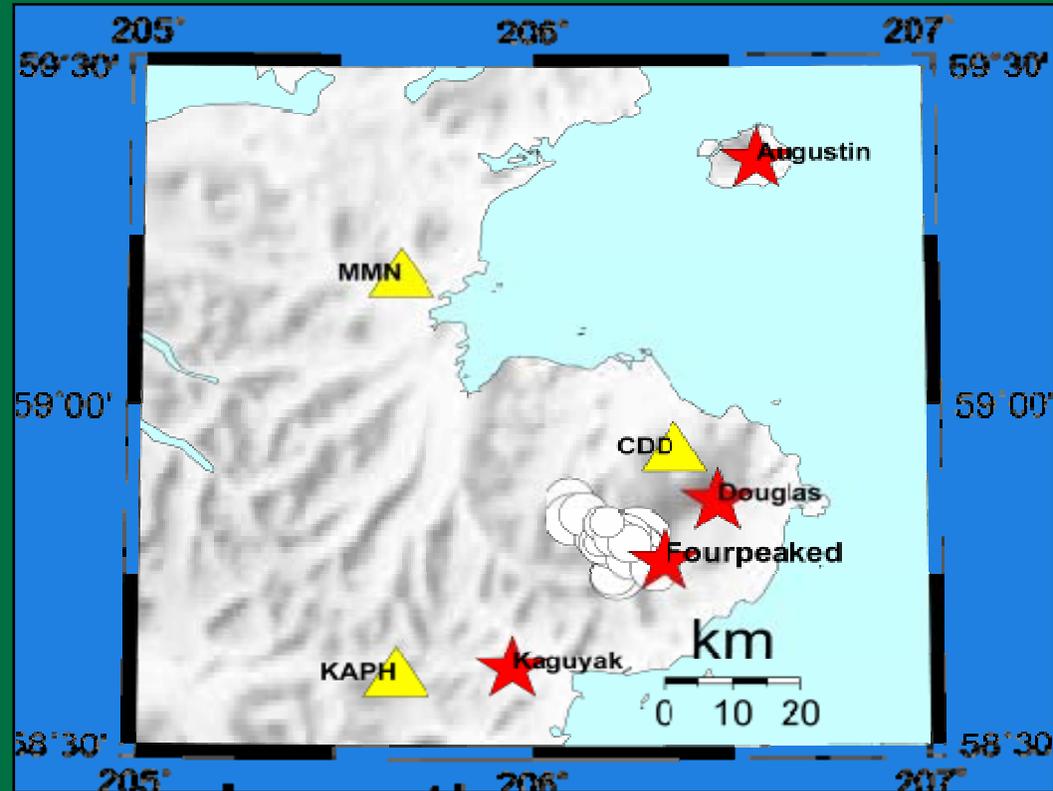
September 17, 2006

- Beginning ~8:15 PM AKDT AVO received reports of two discrete plumes from the Cape Douglas area.
- Plume height about 20,000 ft asl.
- Satellite images showed a cloud originating from near Fourpeaked, persisting throughout the night, extending about 12 mi NE
- No ash signature, no thermal anomalies associated with cloud.



Seismicity and air wave

- A small swarm of tectonic earthquakes occurred from 11:48am to 3:50pm ADT on 9/17.
- 16 events showed up on stations in Katmai, Oil Point, Augustine, and Kodiak. They have magnitudes between 0.8 and 1.8 and cluster to the NW of Fourpeaked.
- No explosion signals
- Infrasonic array in Fairbanks picked up a signal at 12:50pm 9/17; an origin time for Fourpeaked would have been 12:08 PM.



Gas and Ash Cloud Motion

- Image from the NWS King Salmon NEXRAD weather radar showing volcanic cloud at Fourpeaked volcano, 9/17/06 at 12:40 ADT.
- Ash cloud modeling showed that the plume would have spread west and then north over the next day
- This is consistent with pilot reports of a strong sulfur smell in ~200 miles west of Anchorage on 9/18
- Other satellite data showed a prominent SO₂ cloud

Ash fall

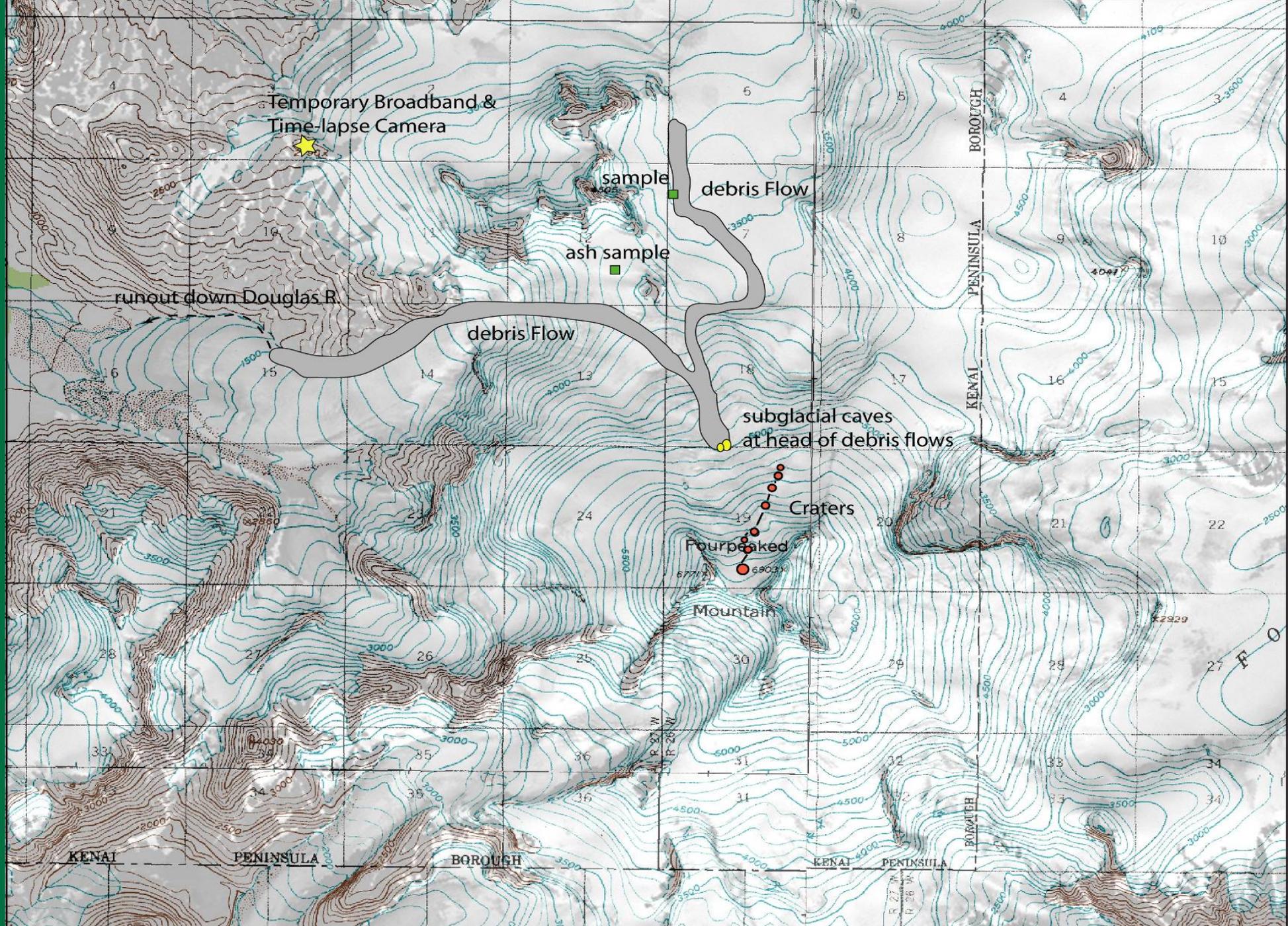
- Ash fall collected from Fourpeaked glacier composed of crystal and rock fragments, including pyrite and hydrothermally altered material
 - no juvenile material representing “new” magma
- Several reports of very light ash fall (“dusting”), in Homer and near Nonvianuk Lake outlet in Katmai National Park.

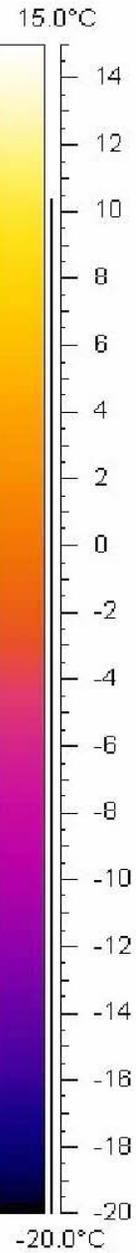
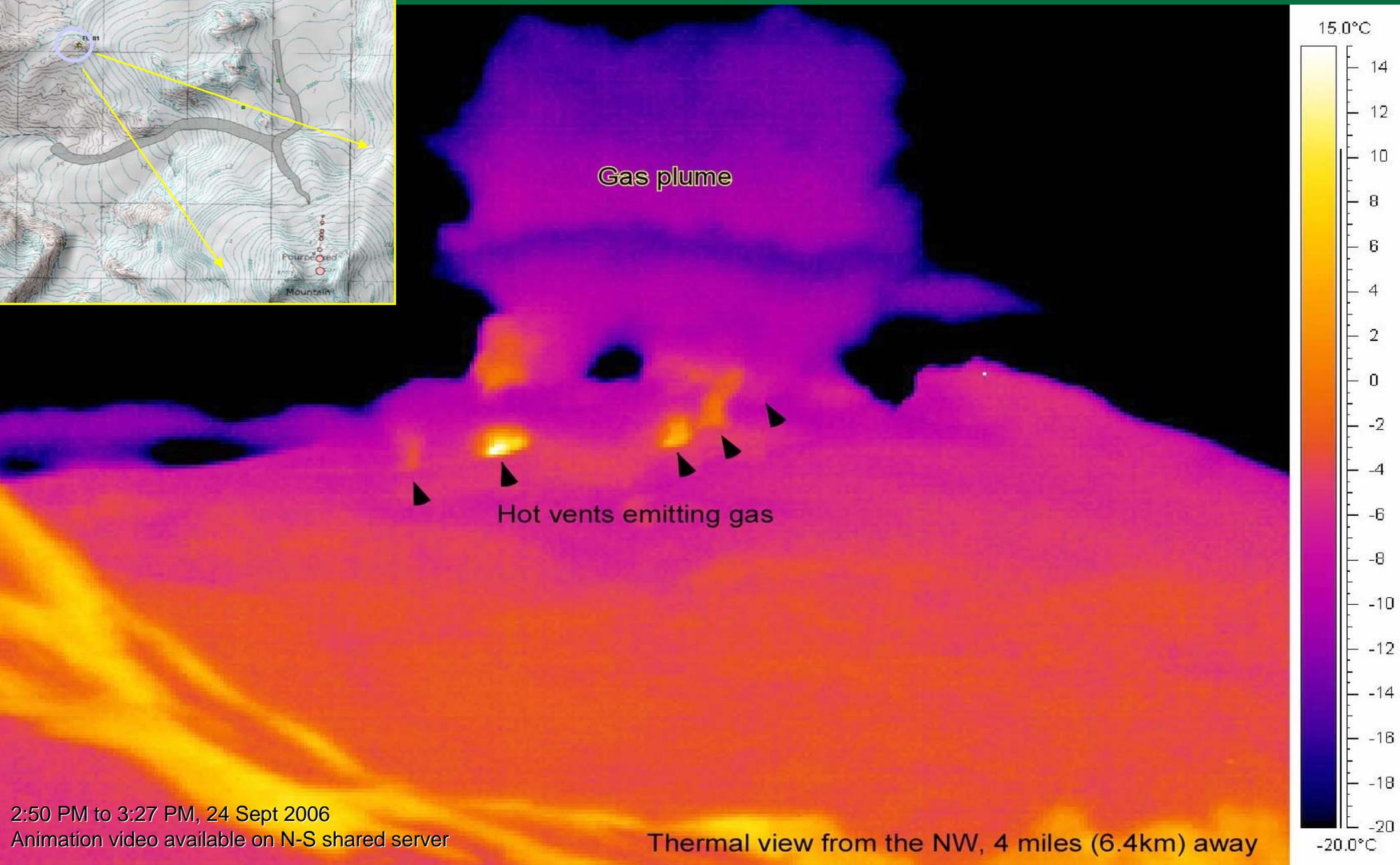




Debris flow levee







2:50 PM to 3:27 PM, 24 Sept 2006
Animation video available on N-S shared server

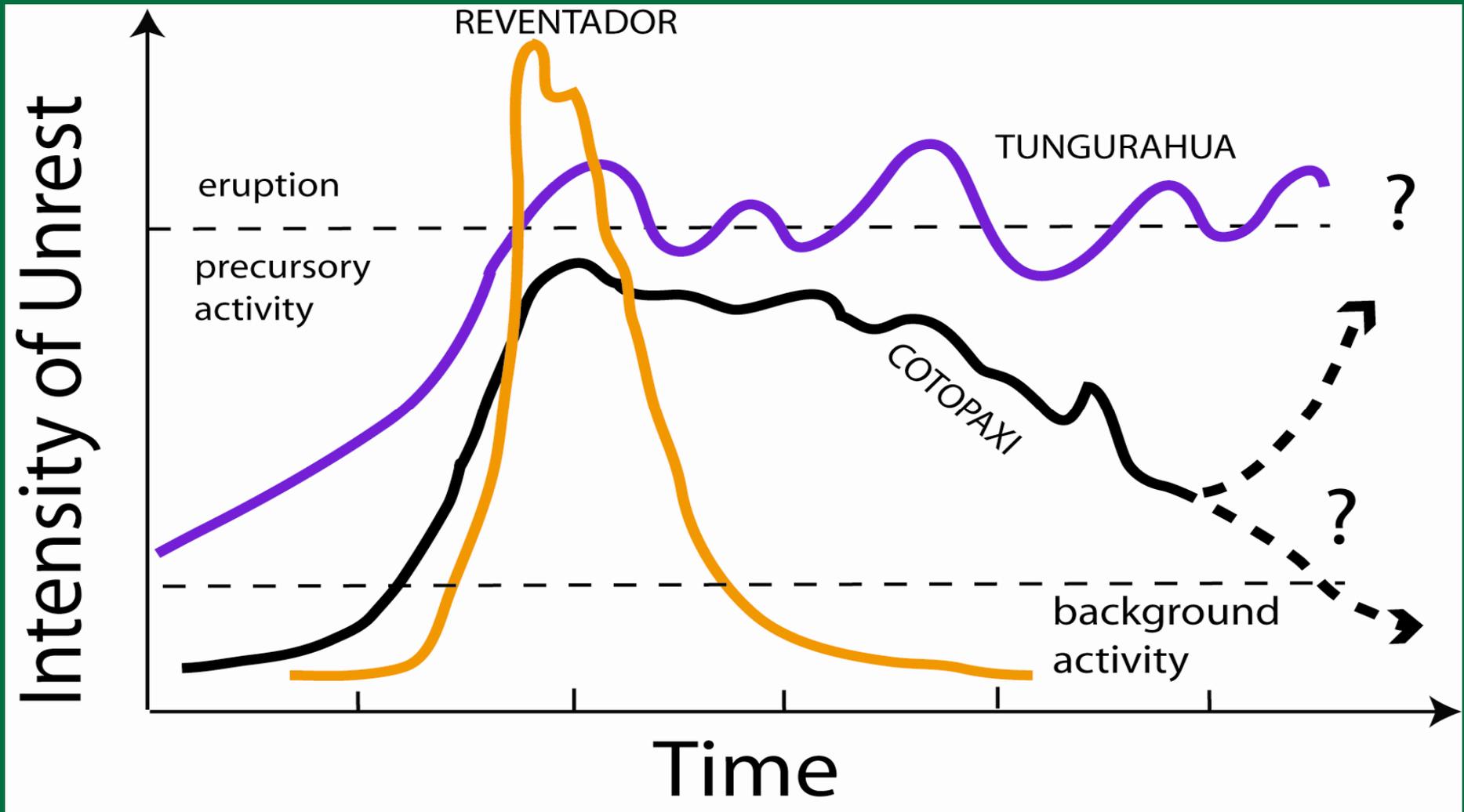
Thermal view from the NW, 4 miles (6.4km) away

What is happening? strong volcanic gas output suggests magma is involved

- Significant amounts of SO_2 , CO_2 , and H_2S measured into the late fall; SO_2 into 2007
- Gas data for 9/23/06:
 - SO_2 ~ 2300 tonnes/day
 - H_2S ~ 140 tonnes/day
 - CO_2 ~ 800 tonnes/day

Intrusion?
Recent or old?
Uncorked
hydrothermal
system? Typical
at Fourpeaked?

The outcome of such unrest is uncertain

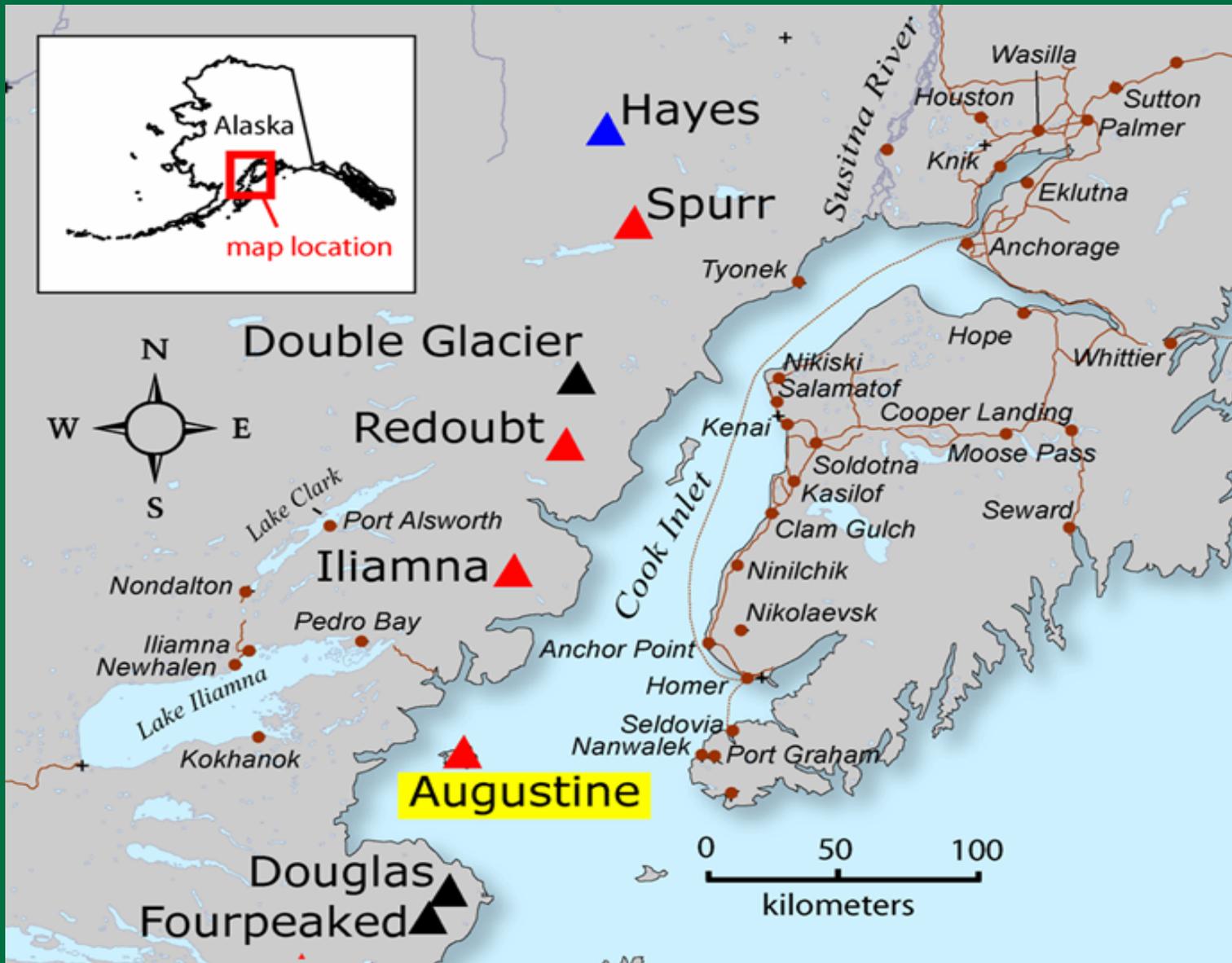




The 2005 - 2006 eruption of Augustine Augustine Volcano, Alaska

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

Photo courtesy Dennis Anderson





Past eruptions at Augustine

- Major historical eruptions: 1986, 1976, 1964, 1935, 1883 (vulcanian/subplinian: ash, lavas, flank collapse)
- Minor eruptions poorly known 1812, 1902, 1908, 1971
- 13+ debris avalanche deposits recognized over the past 2200 years (Beget and Kienle, 1992)

1883 (Oct 6 – into 1884)

- Large explosive eruption (larger than 1976, 1986)
- Flank collapse into Cook Inlet
- Tsunami at Port Graham
- Ash fall on Kenai Peninsula, Kodiak



1896



**“Typical” Augustine eruption 1976 and 1986:
Opening explosions, decreasing intensity, lava dome growth**



1976 (Jan 22 – April 24)



1986 (March 27 – Sept 10)

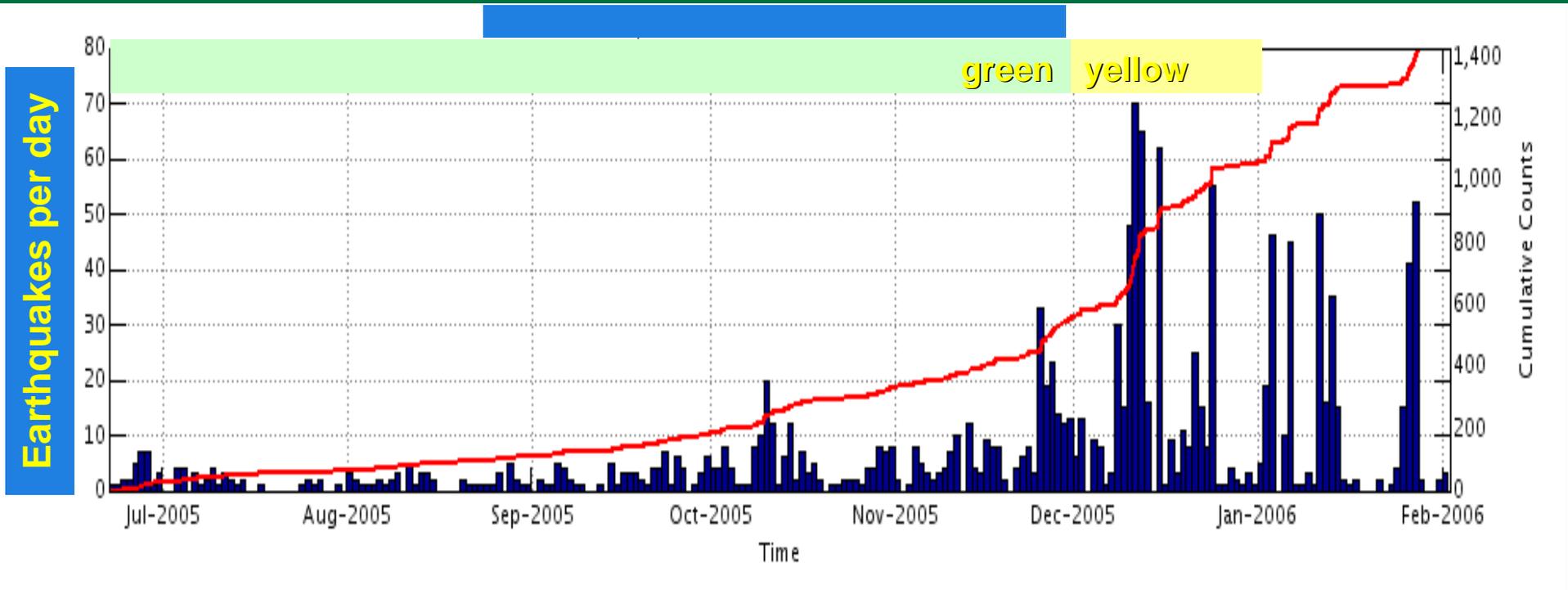
Augustine at rest: 1986 - 2005

- Few earthquakes
- Very low gas output
- Cooling fumaroles
- No deformation



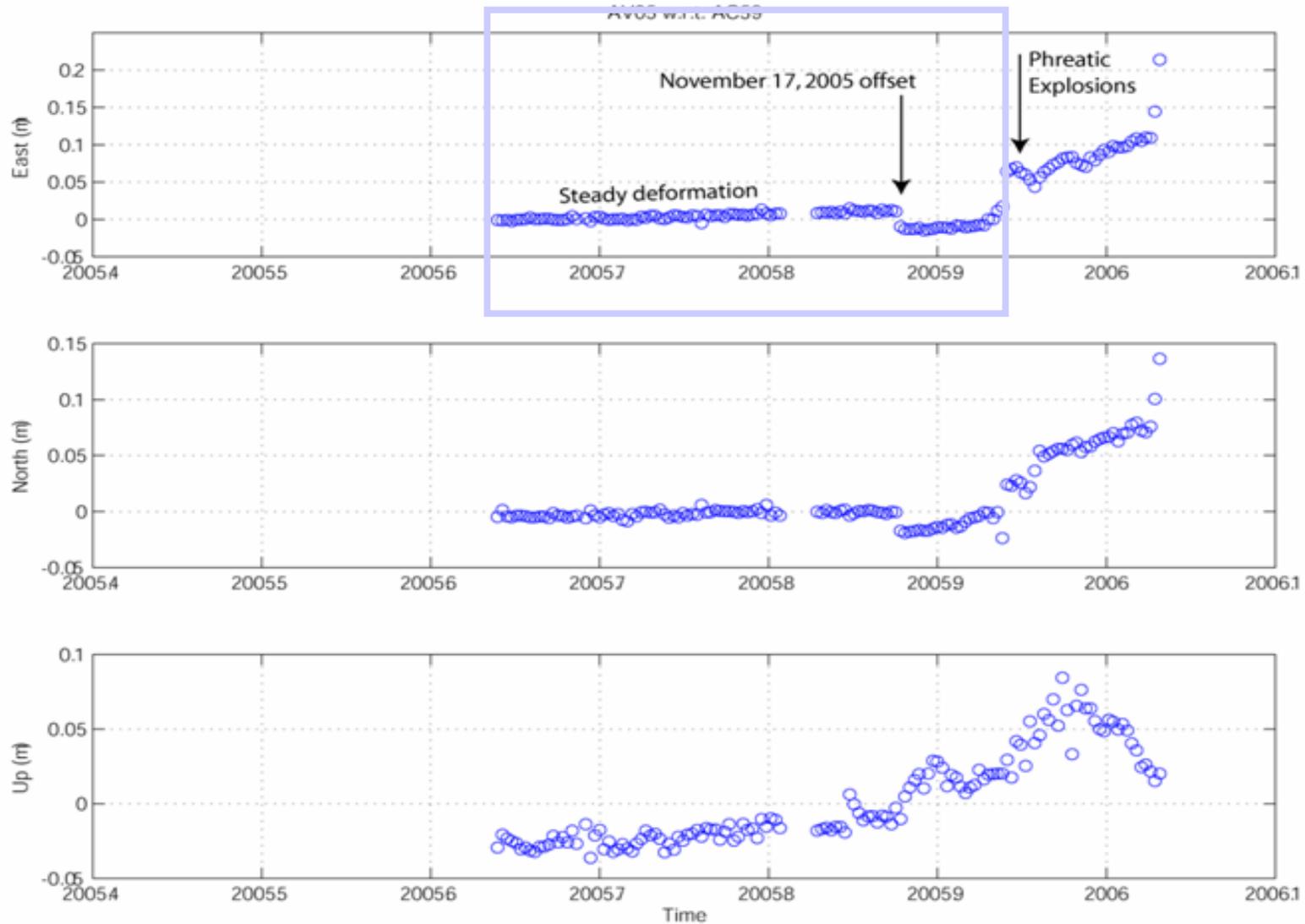
However, it would certainly erupt again..

2005: Rate of earthquakes increases

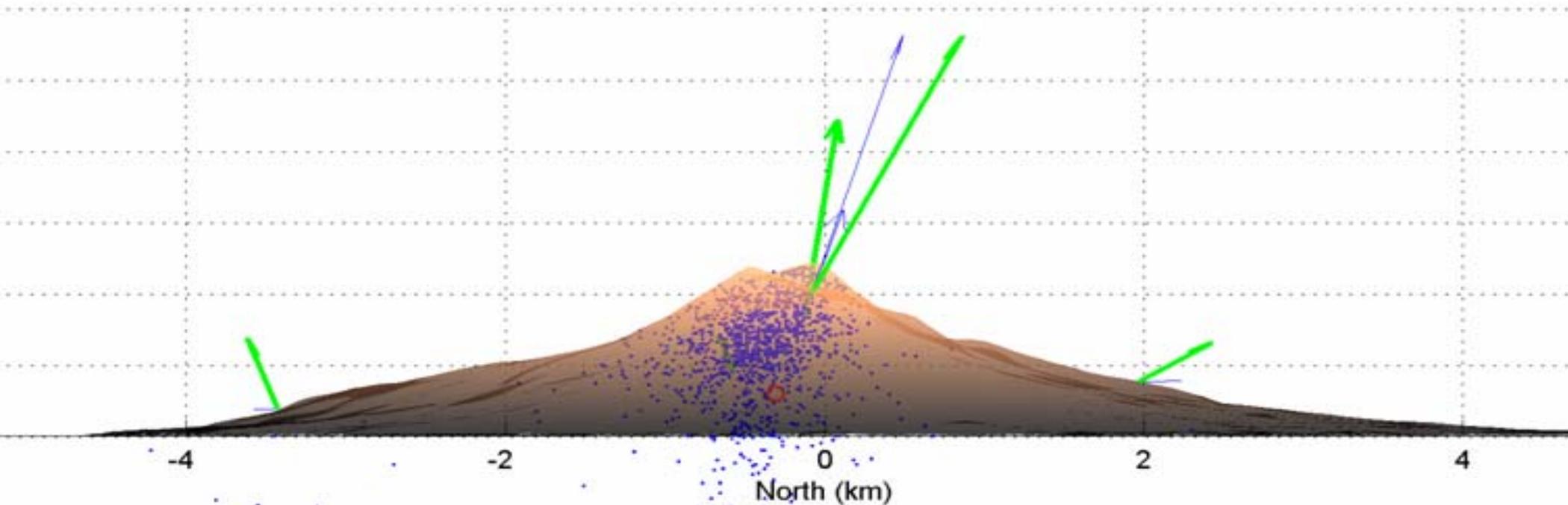


Move from Color Code Green to Yellow on Nov. 29, 2005

Inflation detected with continuous GPS



Ascending magma causes the volcano to 'swell'





Airborne gas measurements show increases in gas output (SO_2 , CO_2 , H_2S)



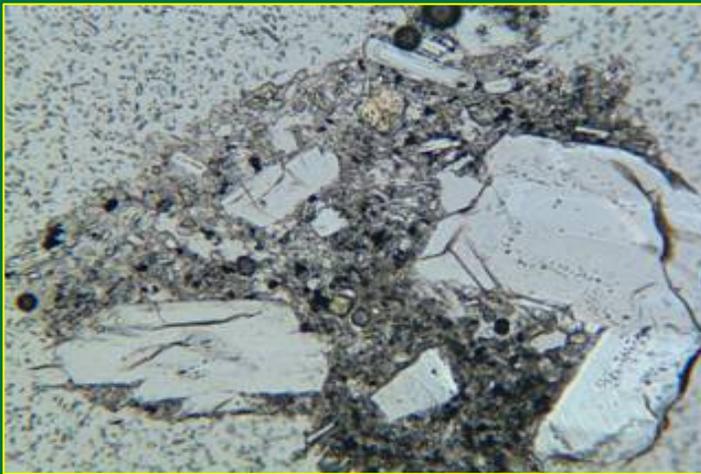
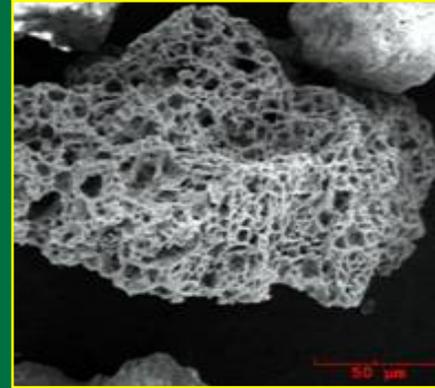
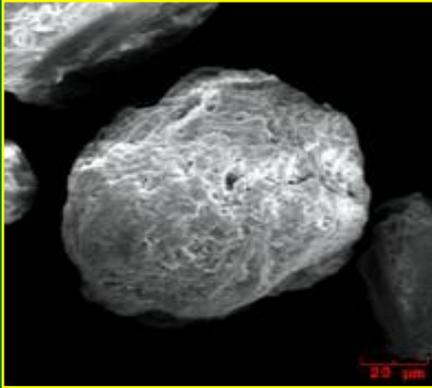
mid-December 2005

- Fisherman reports heavy steaming
- Brief elevated seismicity (rockfalls or explosions?)
- Sulfur smell in SW Kenai Peninsula towns
- Plume seen by satellite – first true ‘eruption’ – ash on the snow

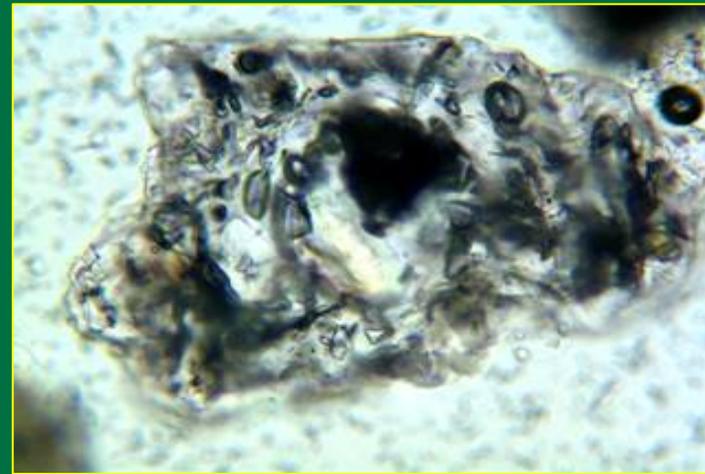


December 12, 2005



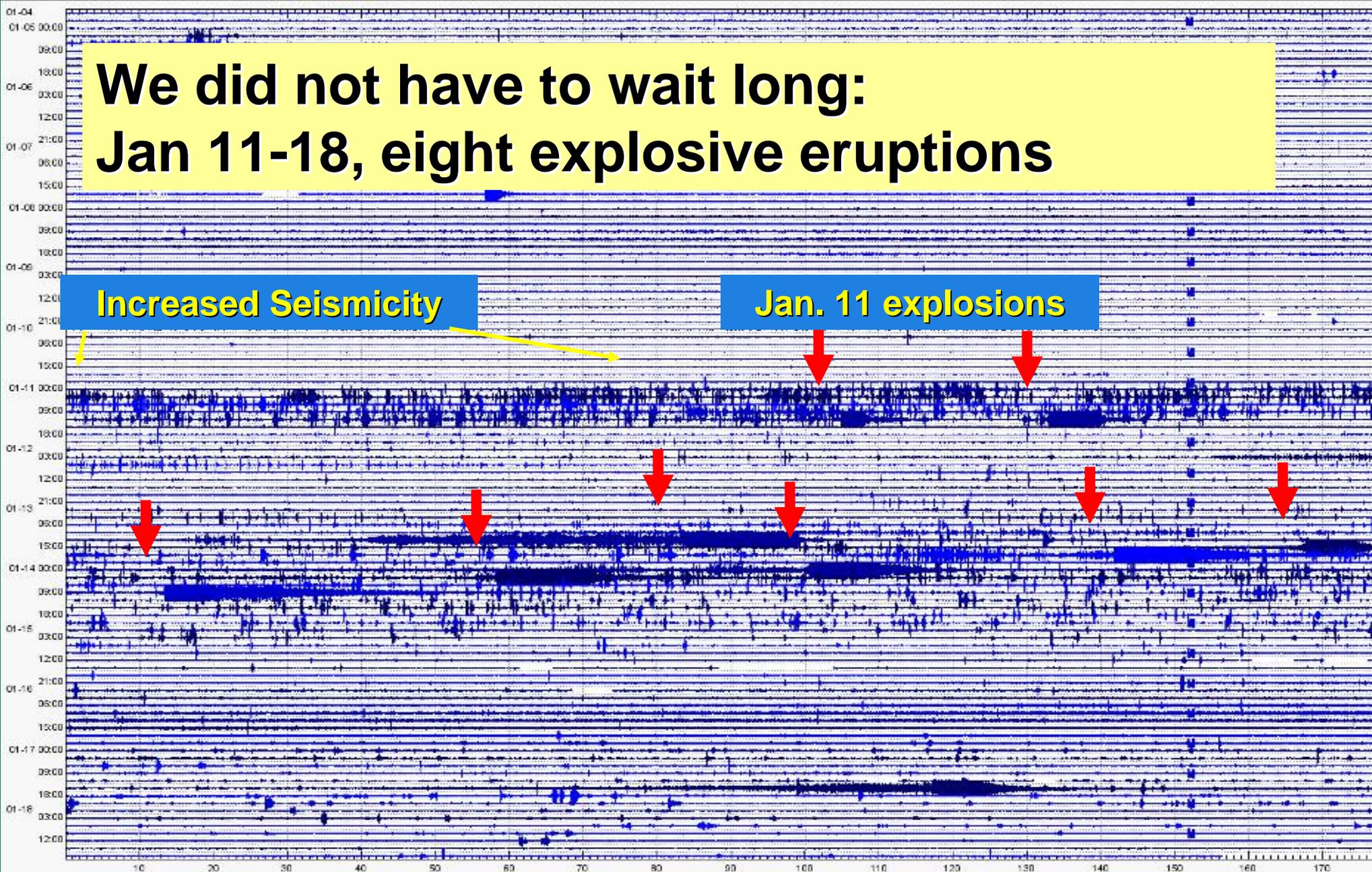


Dense, crystal rich, "dome rock"



Unaltered, pumice with clear glass

Early ash (K.Wallace and P. Izbekov)
Likely phreatic



**We did not have to wait long:
Jan 11-18, eight explosive eruptions**

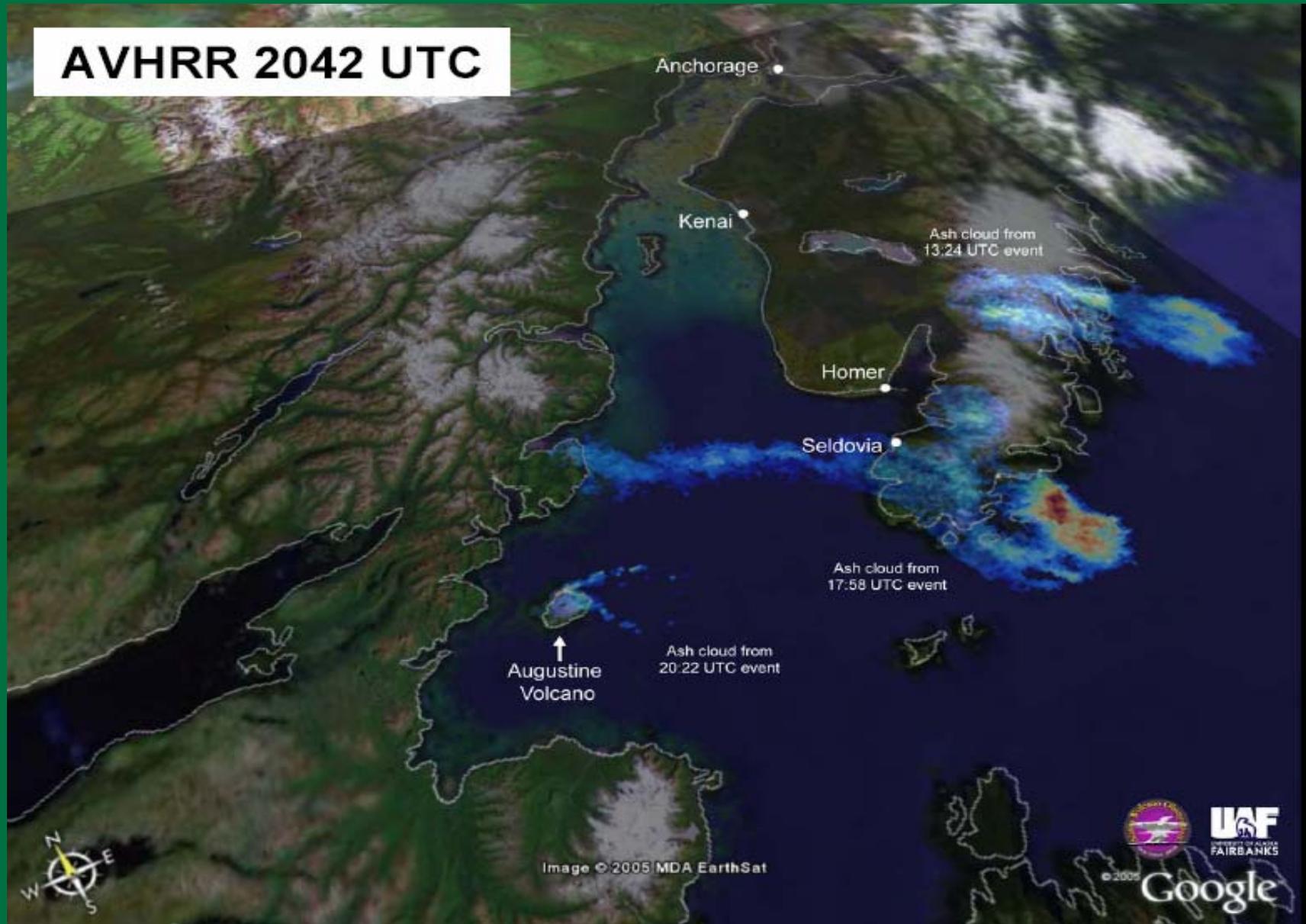
Increased Seismicity

Jan. 11 explosions

Thirteen explosive events occurred between January 11 and 28, 2006 and produced ash clouds as high as 50,000 ft

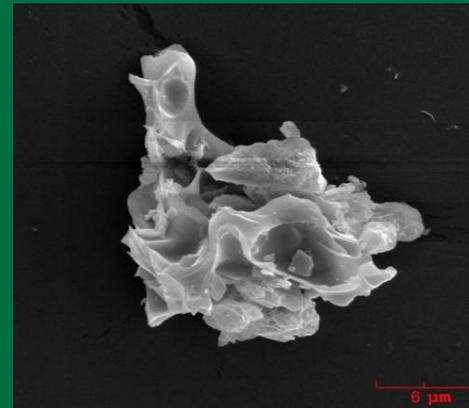
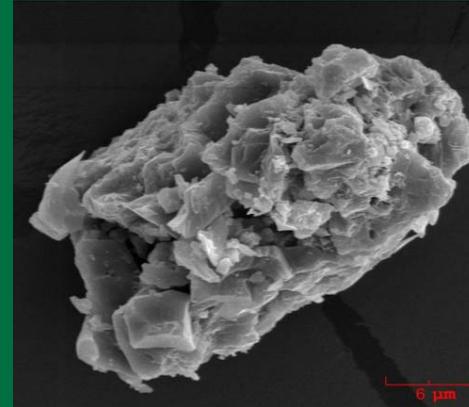
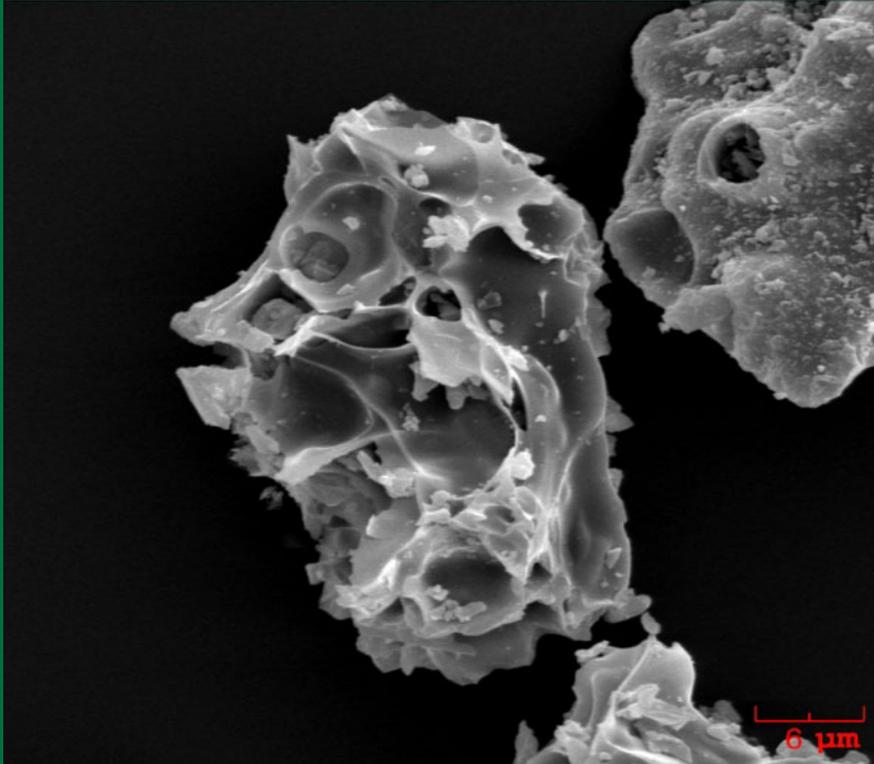


AVHRR 2042 UTC



January 13, 2006: 5 ash clouds move east

Ash collected in Homer – fell with snow



SEM images by Pavel Izbekov, AVO-UAFGI

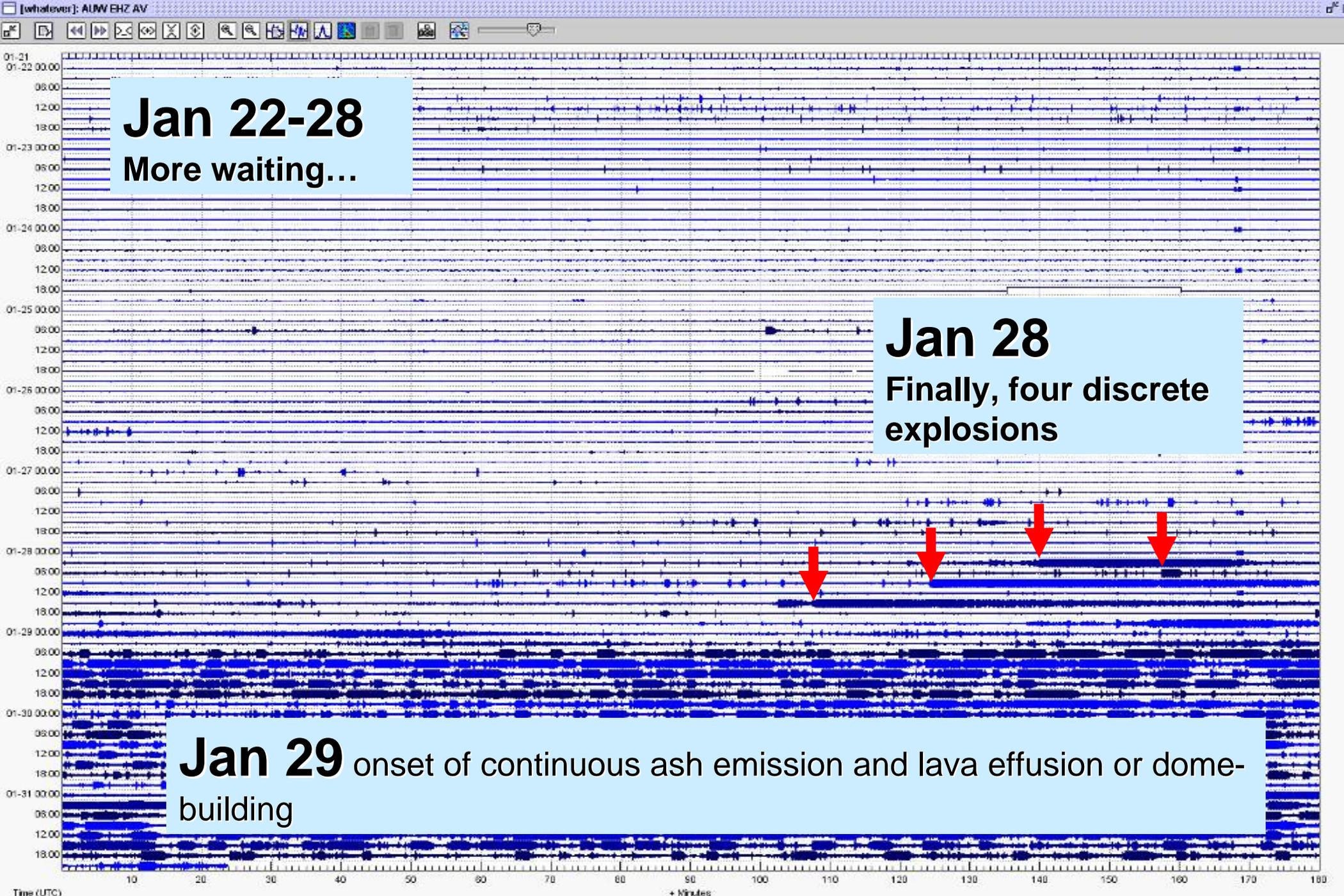
Grain of salt is about 60 microns across....

New lava dome at the summit

January 16, 2006



Game McGimsey



Jan 22-28
More waiting...

Jan 28
Finally, four discrete
explosions

Jan 29 onset of continuous ash emission and lava effusion or dome-
building

Continuous ash and lava emission phase



Courtesy of MODIS Rapid Response Project at NASA/GSFC

During this phase, steam, ash and gas clouds extended hundred miles at heights of 15,000 to 20,000 ft

Following continuous
explosions...



Feb. 1, 2006
Nighttime thermal infrared
ASTER image



February 8, 2006

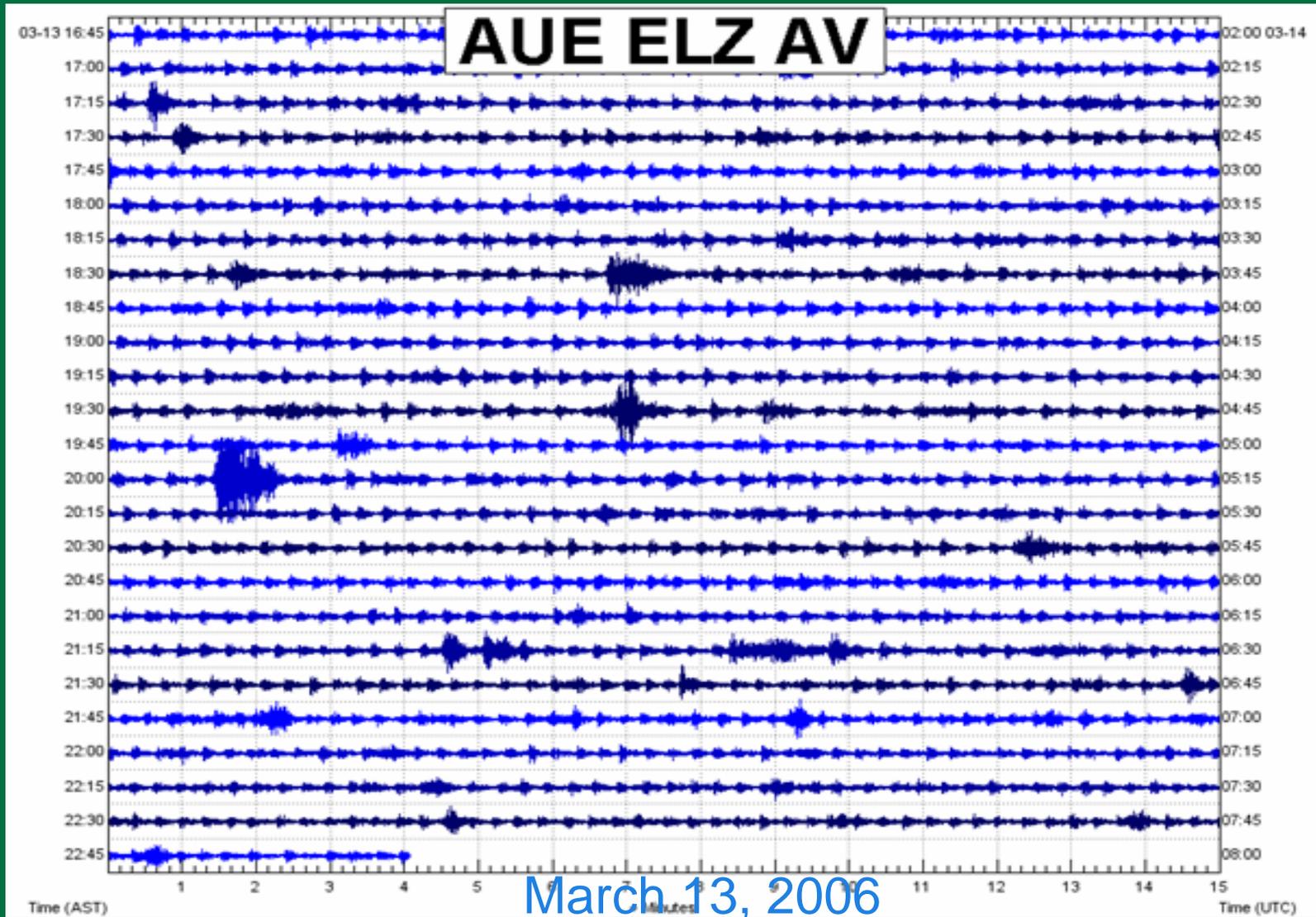
Effusive (lava flow producing) phase

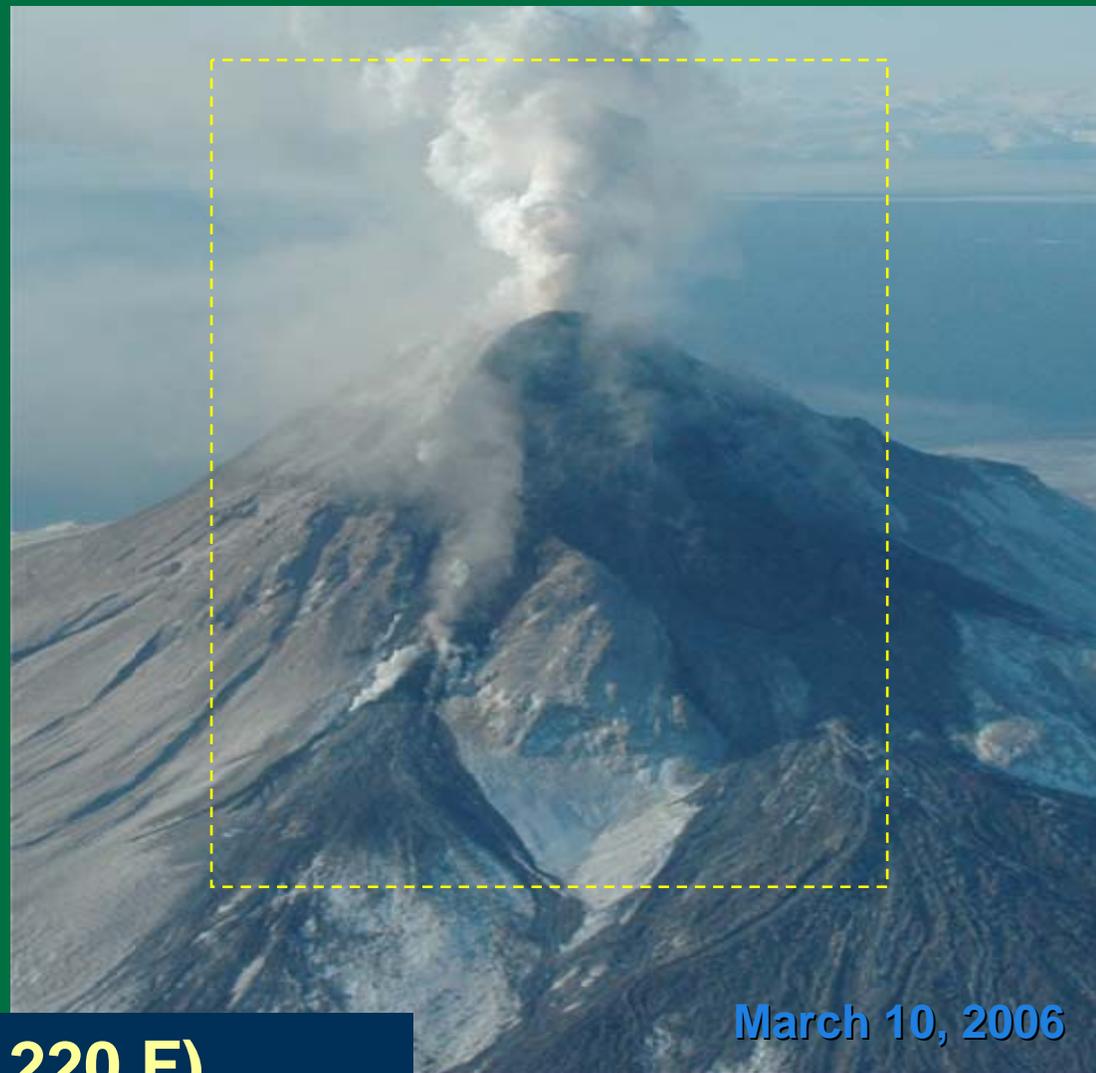
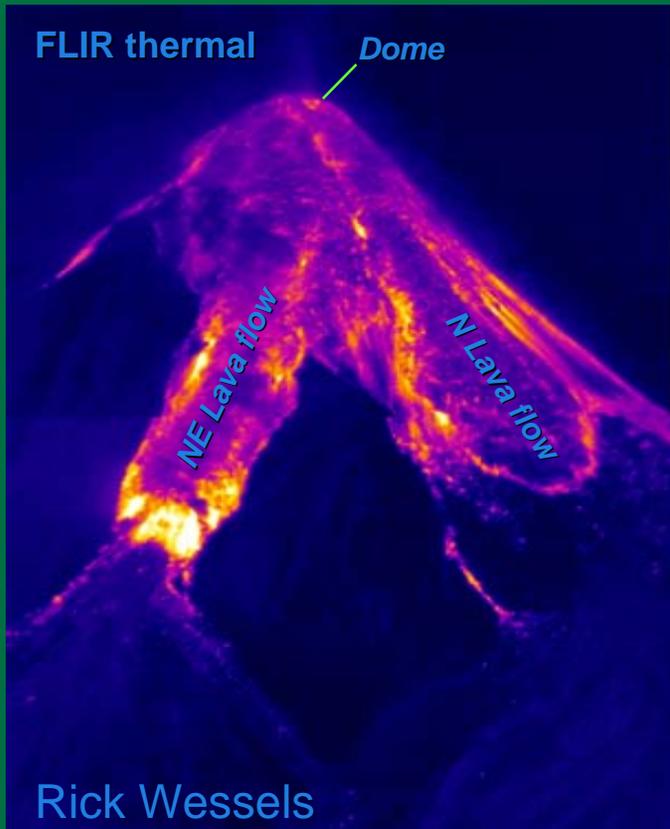


March 6, 2006

Lava dome and flow on the north flank. Photo taken by a time-lapse camera at Burr Point.

Drumbeat earthquakes: rapid lava effusion





Max T in toe of flow ~660C (1220 F)

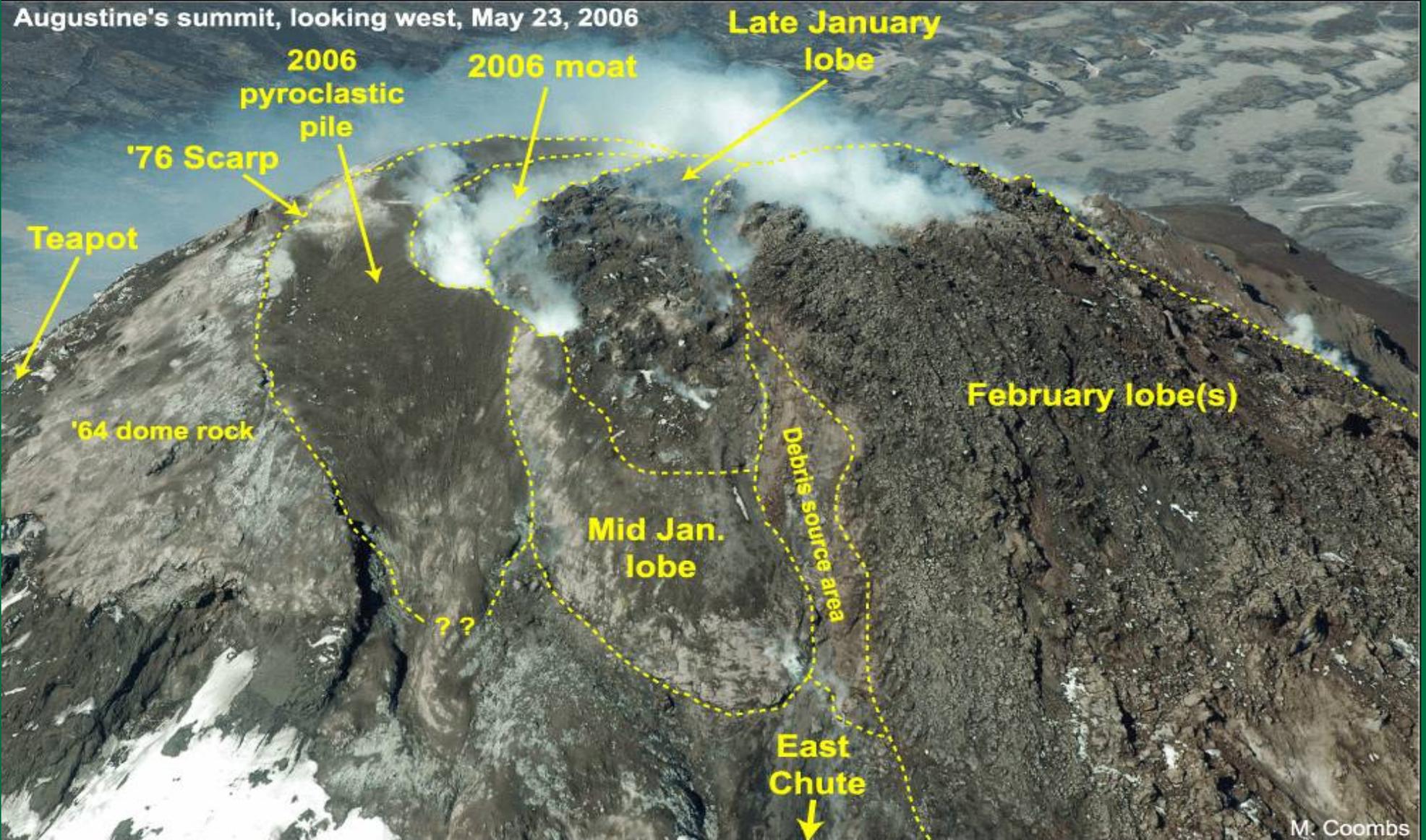
NE flow toe ~50 m thick, moving down steep (30-40 degree) slope

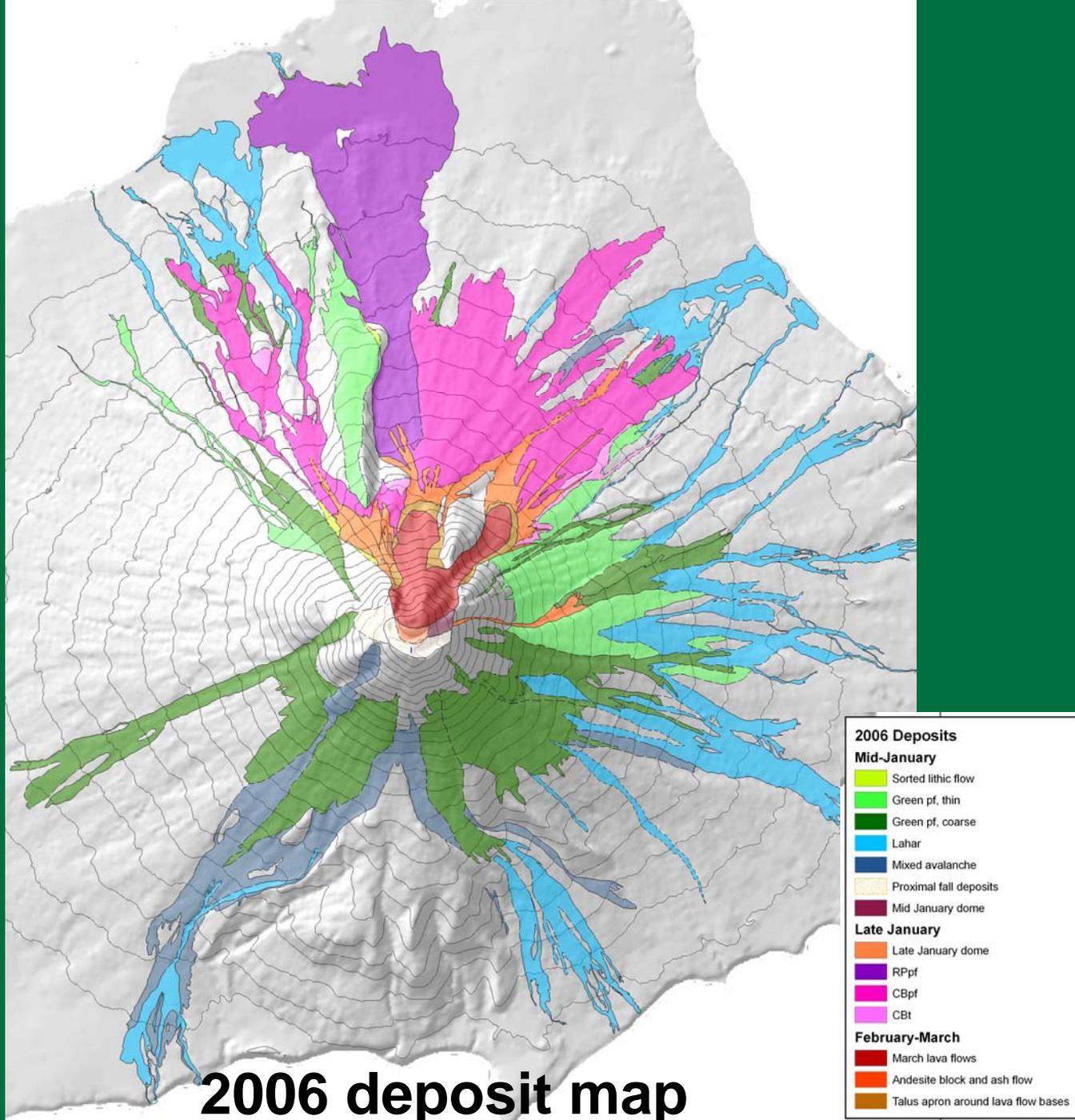
Effusion stops by late March, early April

April 6, 2006



New summit morphology





2006 deposit map

Rock types



“Cinderblock” – conduit material?



Pumice – stored magma triggered by influx?



Scoria – new magma in system?

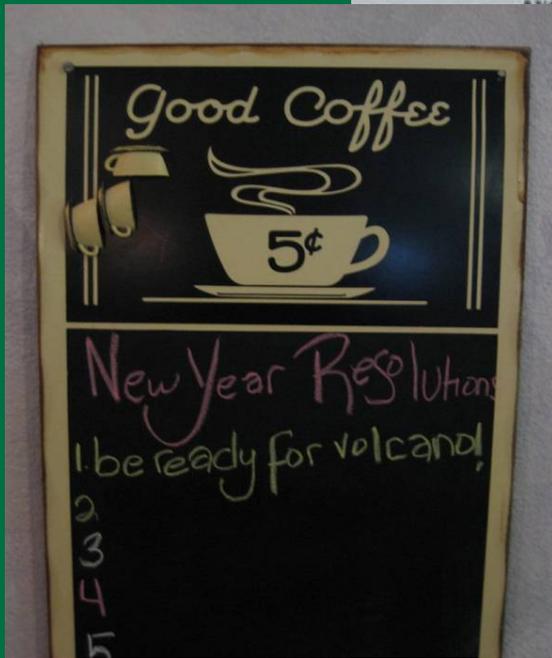


Banded pumice – mixture of High and low silica andesite

What's happening now?

- **Seismicity down...**
- **Deformation has flat-lined**
- **SO₂ output < 200 tonnes per day**
- **Snow accumulating on nearly all surfaces**

Economic and cultural impacts



But, Alaskans know how to make
the best of it....

