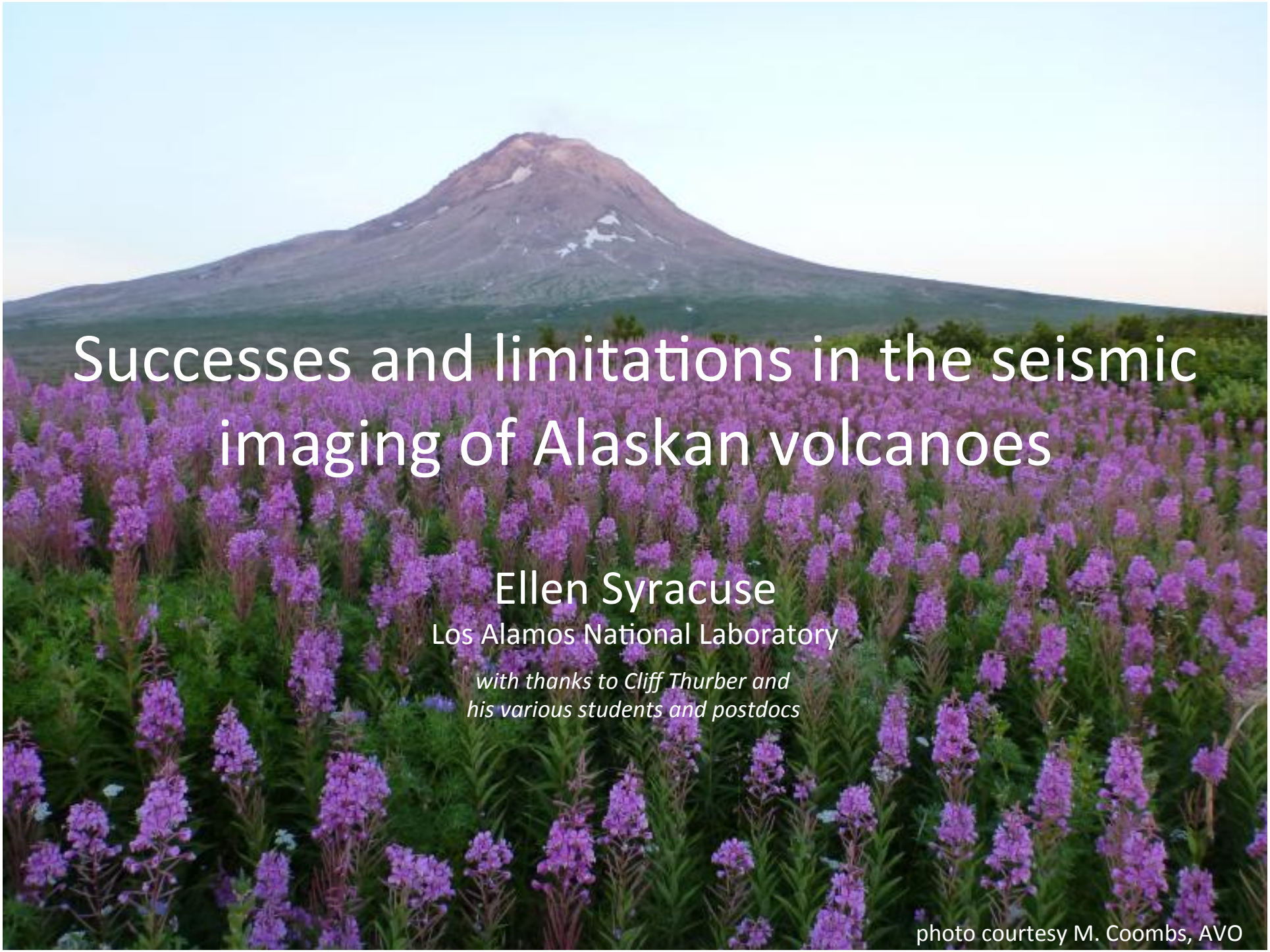
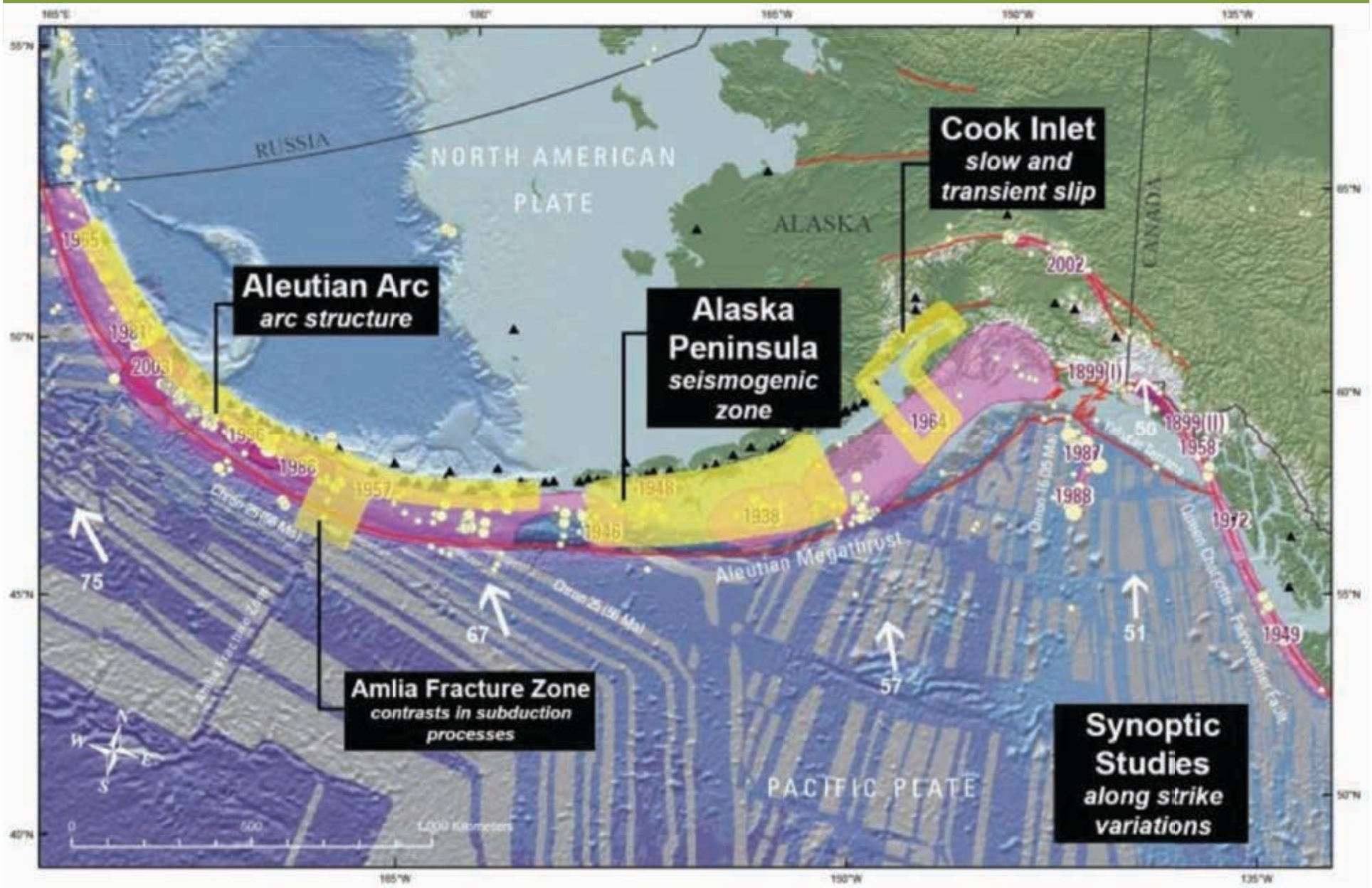


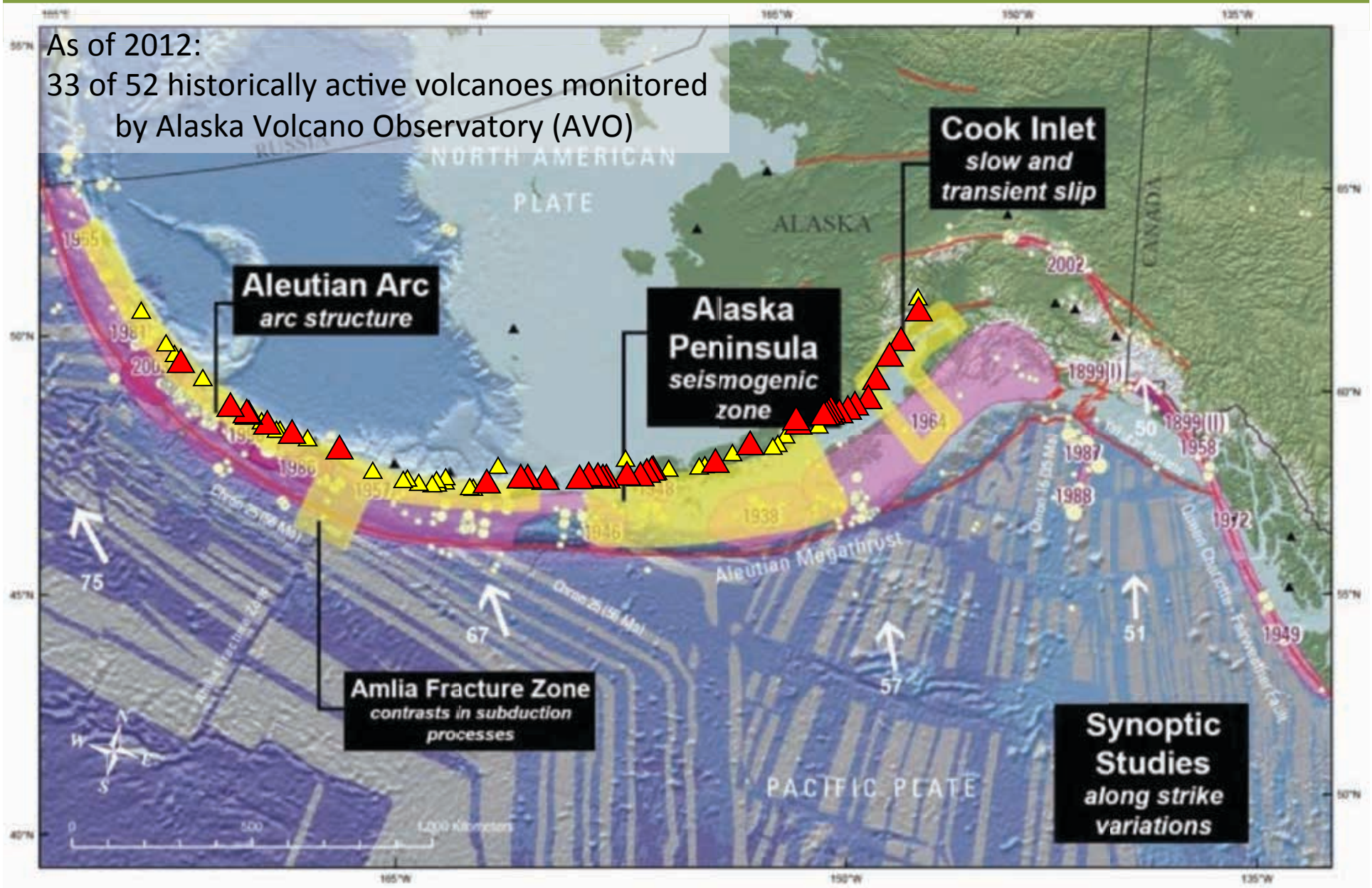
Successes and limitations in the seismic imaging of Alaskan volcanoes

Ellen Syracuse
Los Alamos National Laboratory

with thanks to Cliff Thurber and his various students and postdocs

photo courtesy M. Coombs, AVO


Cook Inlet
slow and transient slip
Aleutian Arc
arc structure
Alaska Peninsula
seismogenic zone
Amlia Fracture Zone
contrasts in subduction processes
Synoptic Studies
along strike variations
RUSSIA
NORTH AMERICAN PLATE
ALASKA
CANADA
PACIFIC PLATE
Aleutian Megathrust
1965
1957
1946
1938
1964
2002
1899 (I)
1899 (II)
1958
1987
1988
1972
1949
2003
1996
1986
1948
75
67
57
51
50


As of 2012:
33 of 52 historically active volcanoes monitored
by Alaska Volcano Observatory (AVO)
Cook Inlet
slow and transient slip
Aleutian Arc
arc structure
Alaska Peninsula
seismogenic zone
Amlia Fracture Zone
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NORTH AMERICAN PLATE
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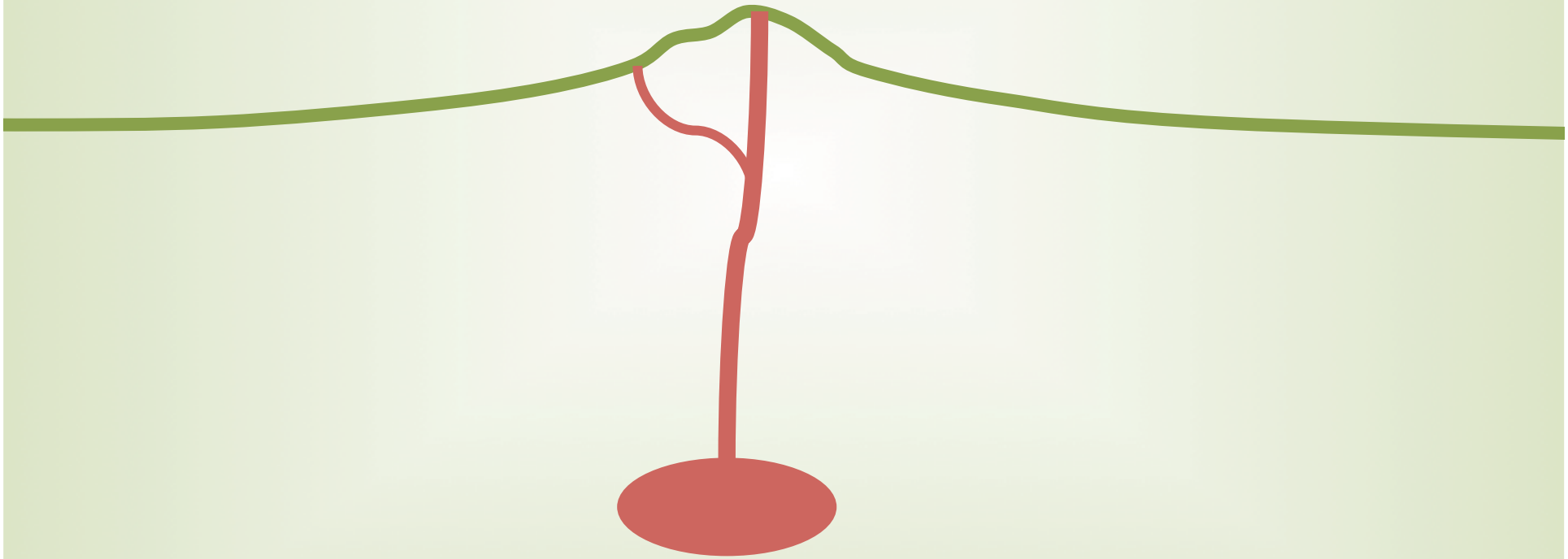
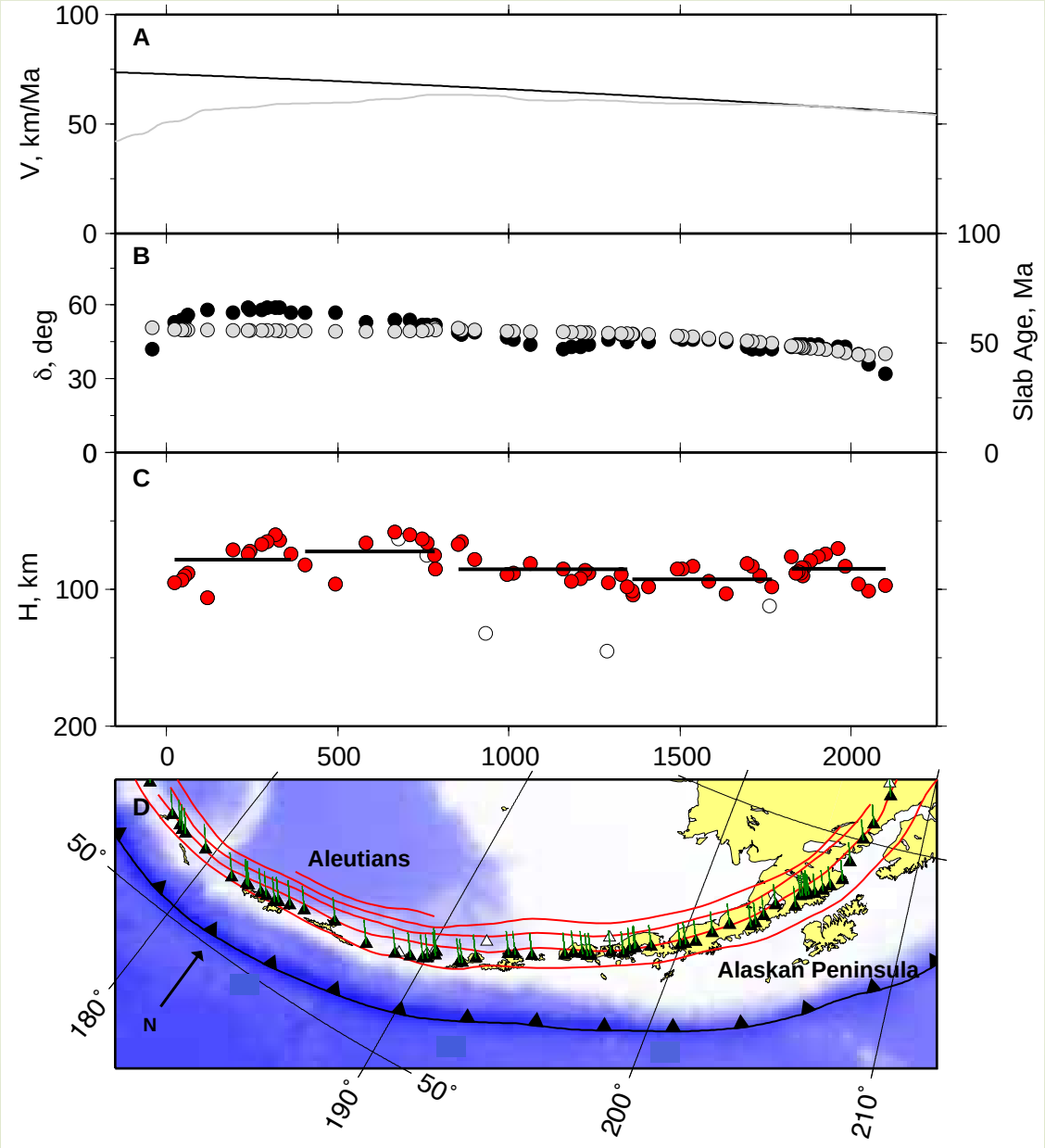
1899(I)
1899(II)
1958
1987
1988
1972
1949
1946
1938
1957
1965
1981
75
67
57
51
50

Why image volcanoes?

- eruption forecasting
- identify magma storage region
- estimate amount of magma available
- identify magma pathways

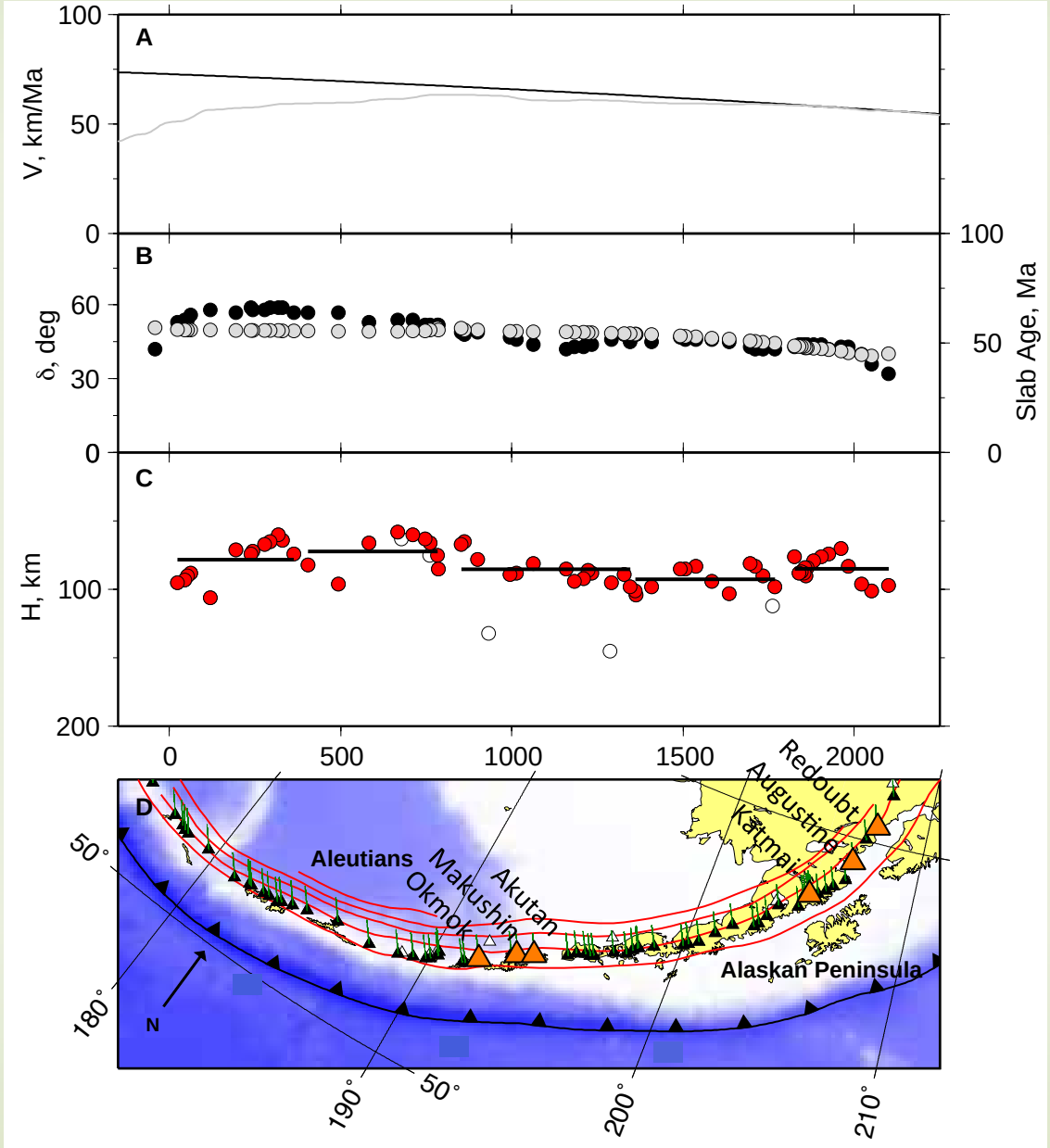


Along-arc variations



Syracuse & Abers, 2006

Along-arc variations

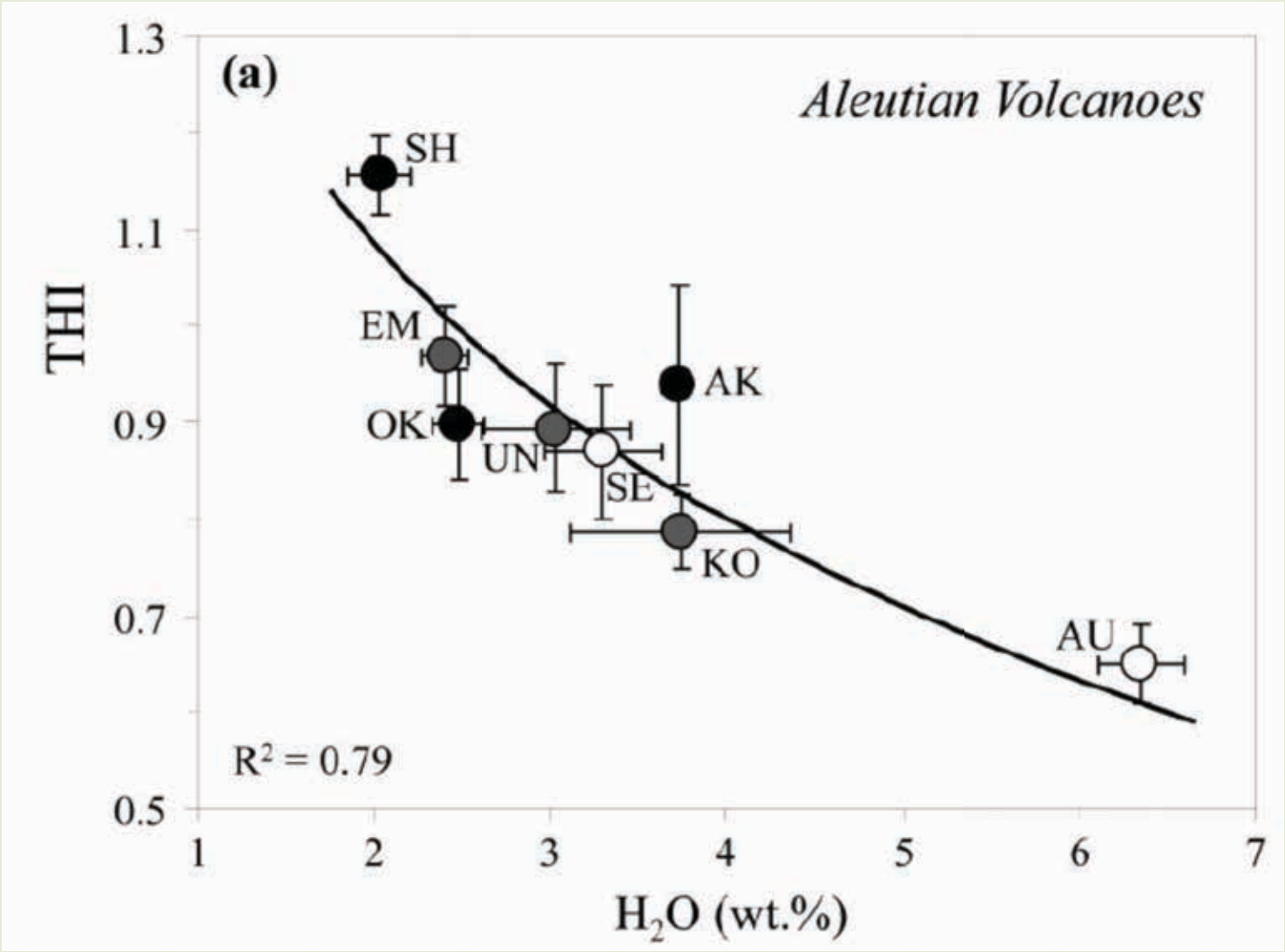


Syracuse & Abers, 2006

Along-arc variations

more mafic

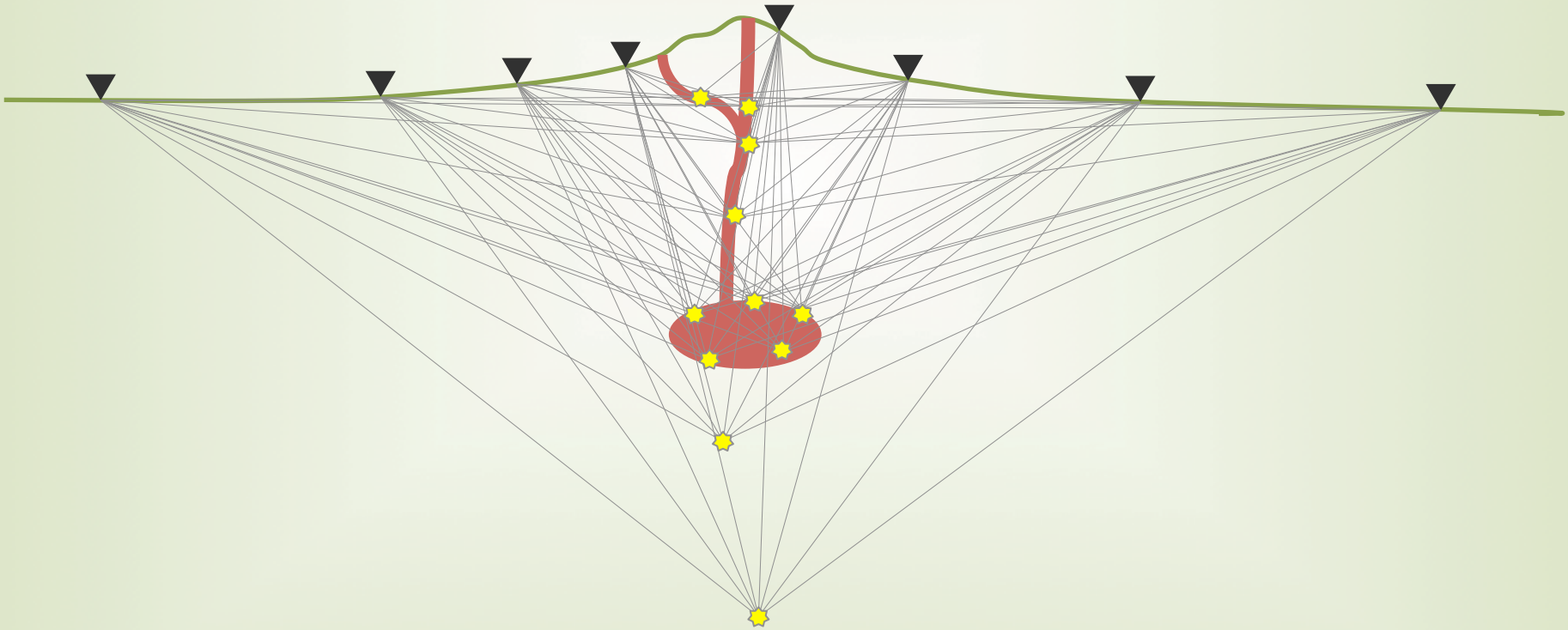
more silicic



Zimmer et al., 2010

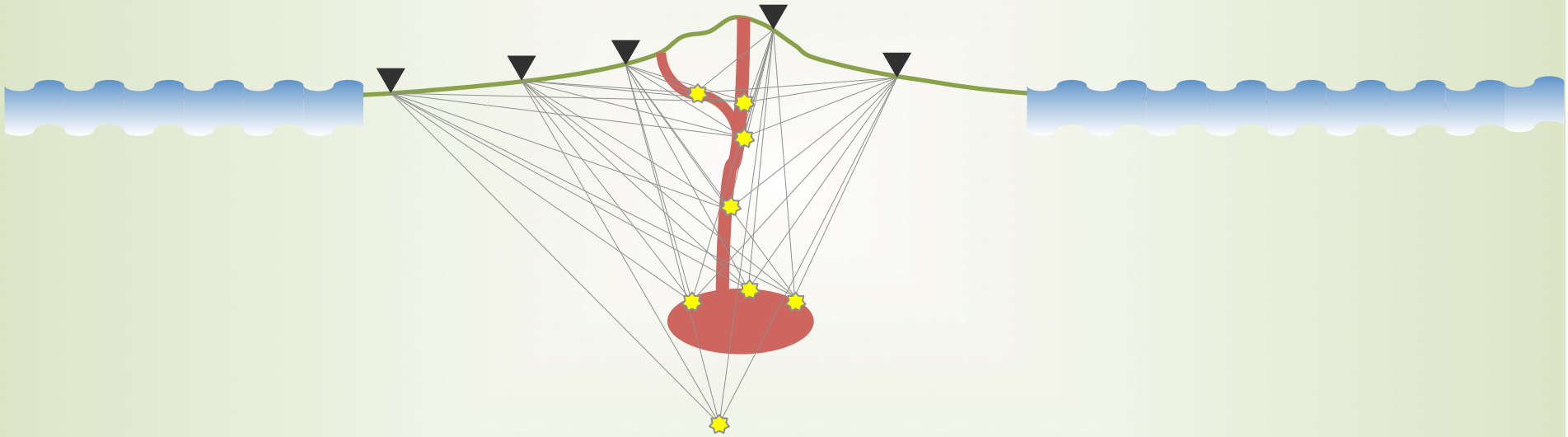
Limitations/challenges

· small onshore footprint



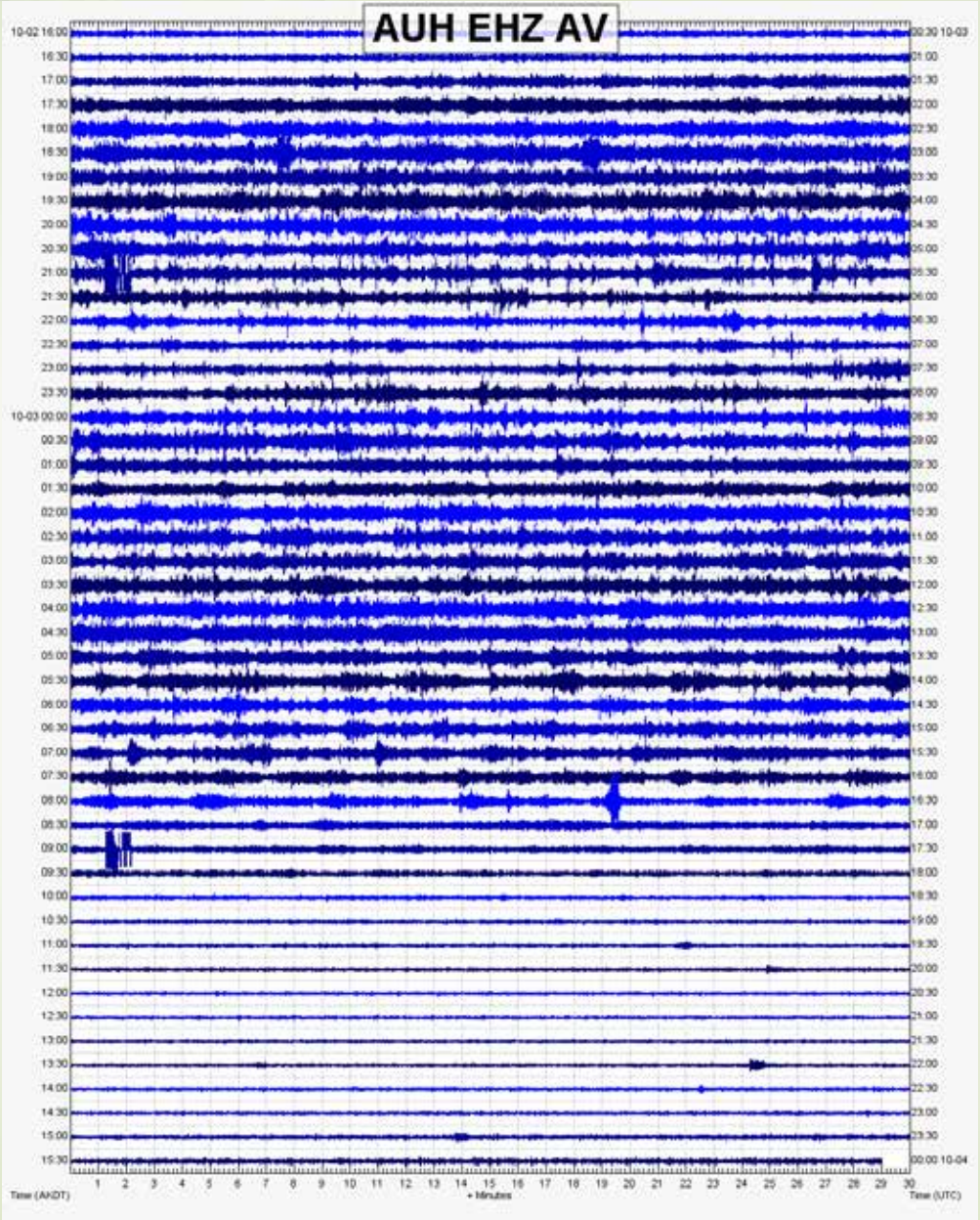
Limitations/challenges

· small onshore footprint



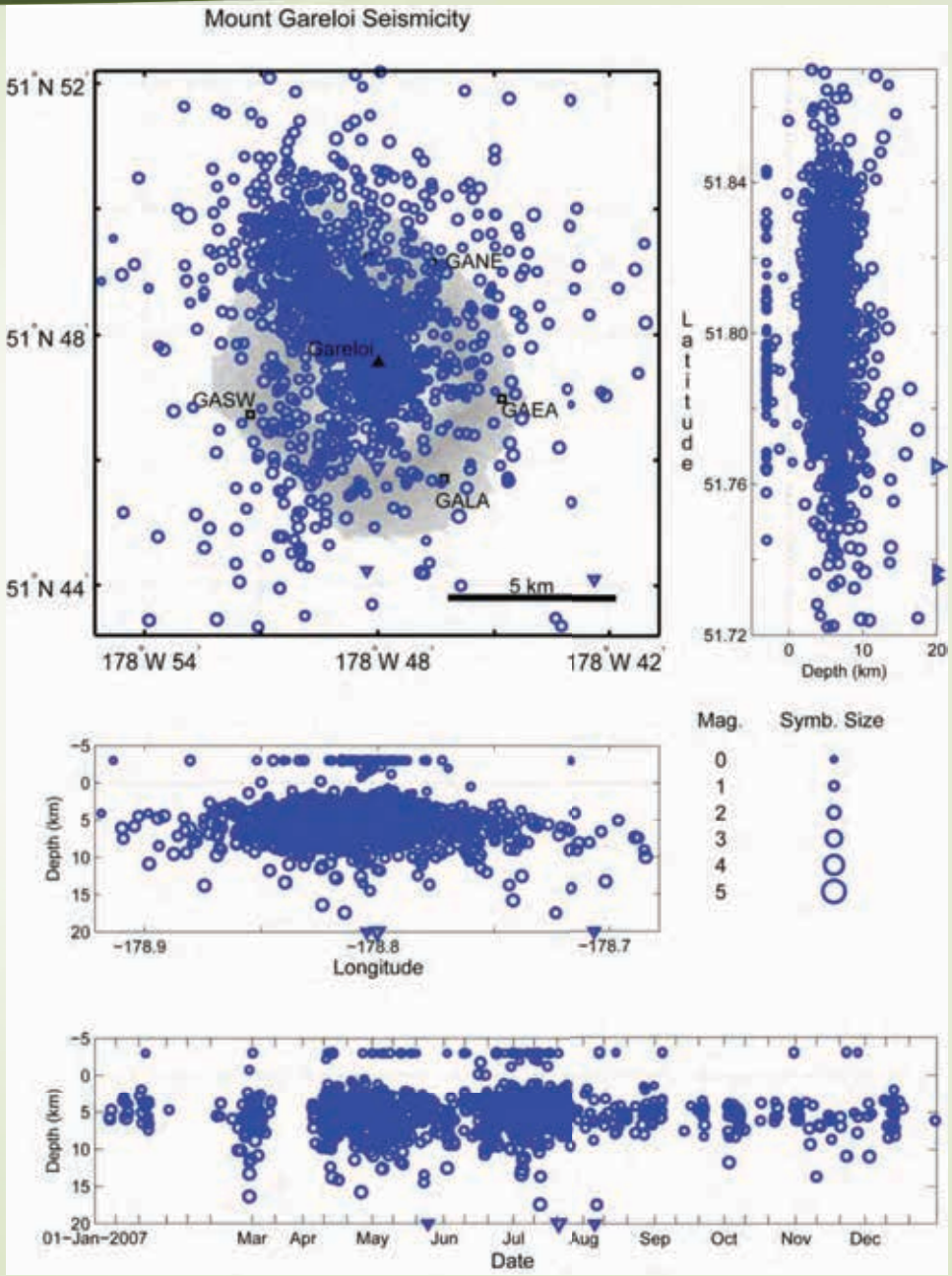
Limitations/challenges

· small onshore footprint
· noisy data



Limitations/challenges

· small onshore footprint
· noisy data
· temporally variable seismicity

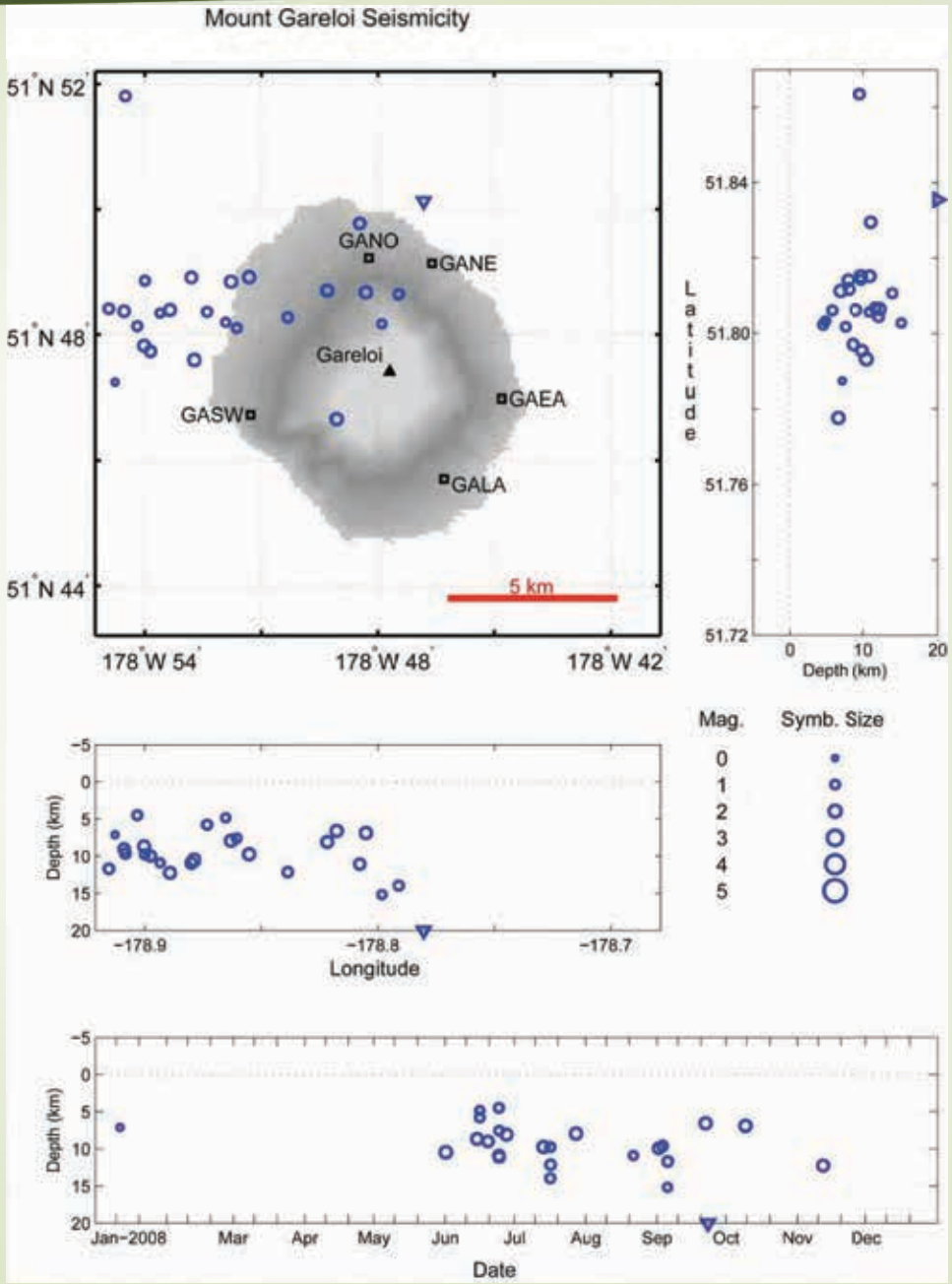


2007

AVO/UAF

Limitations/challenges

· small onshore footprint
· noisy data
· temporally variable seismicity

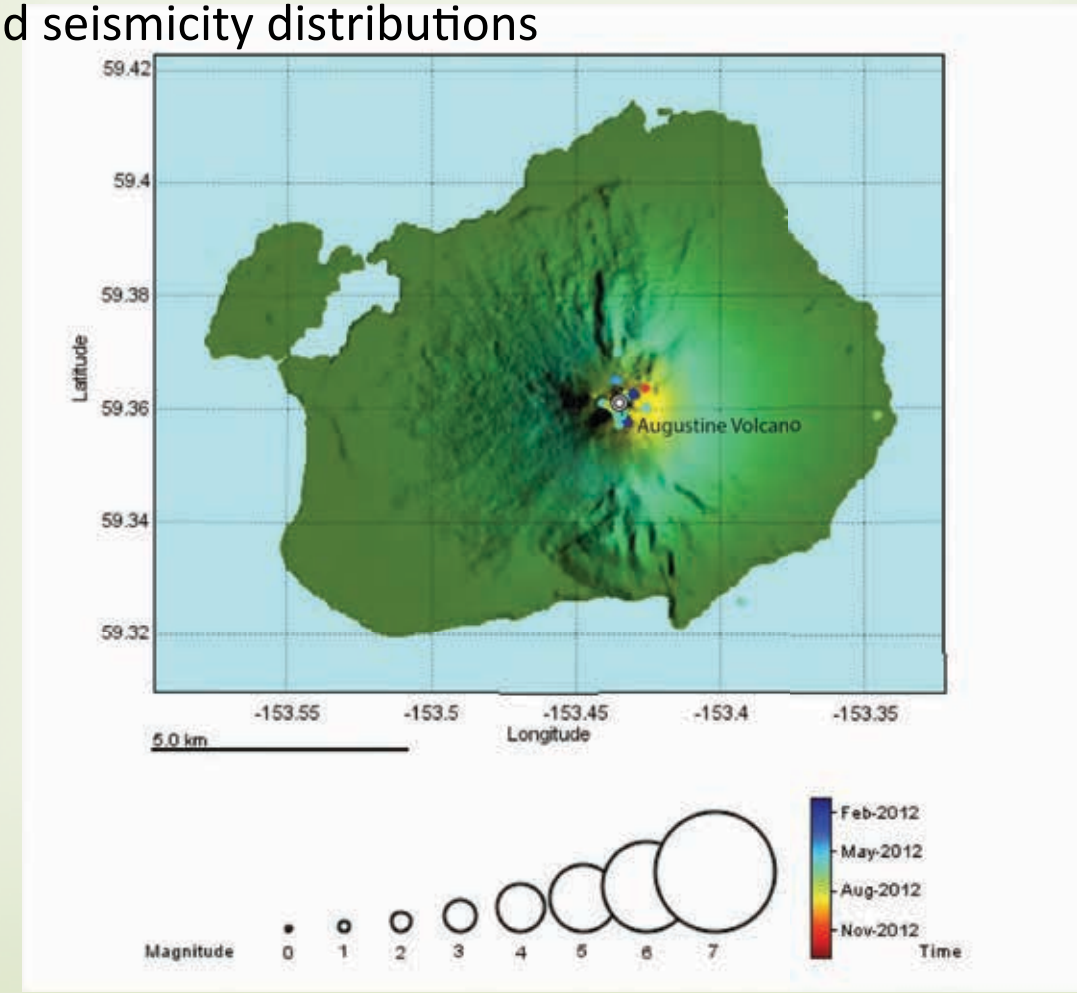


2008

AVO/UAF

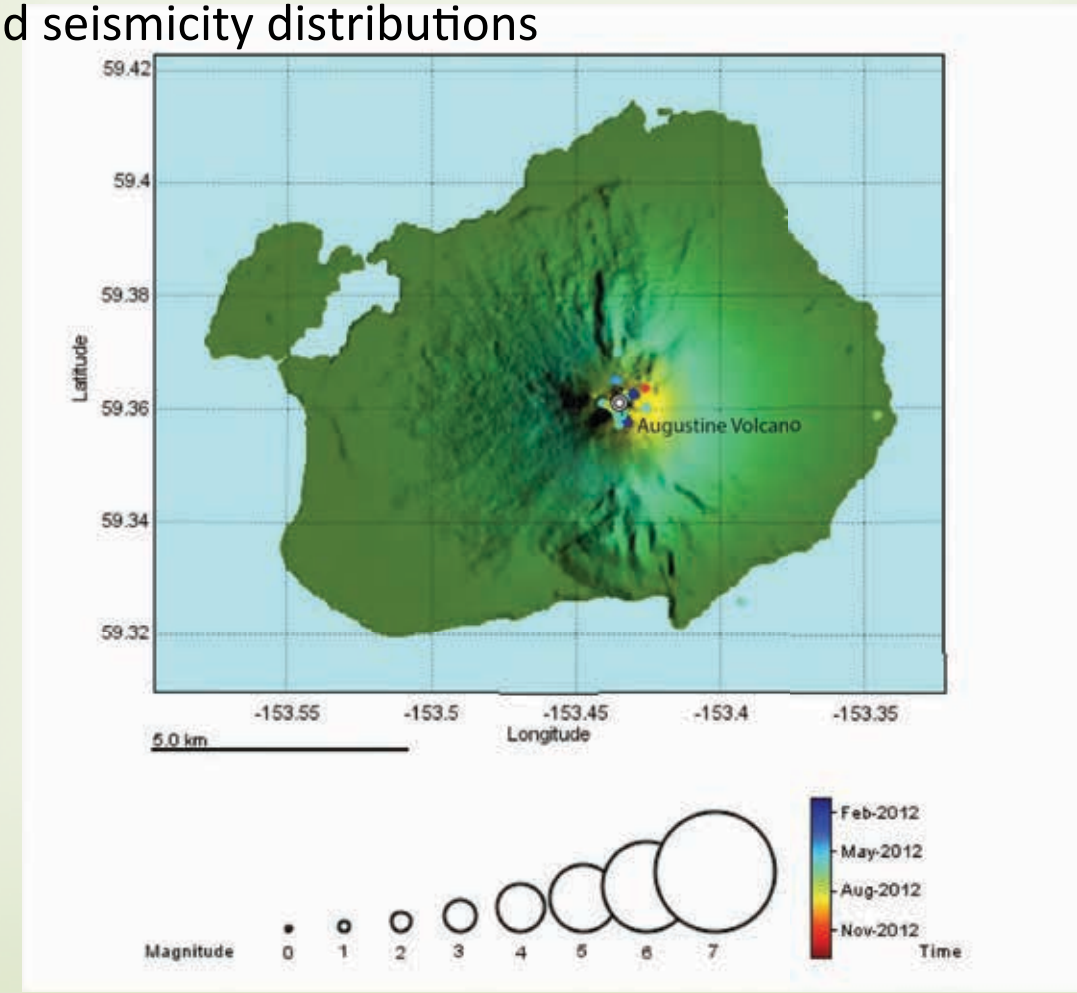
Limitations/challenges

· small onshore footprint
· noisy data
· temporally variable seismicity
· potentially limited seismicity distributions



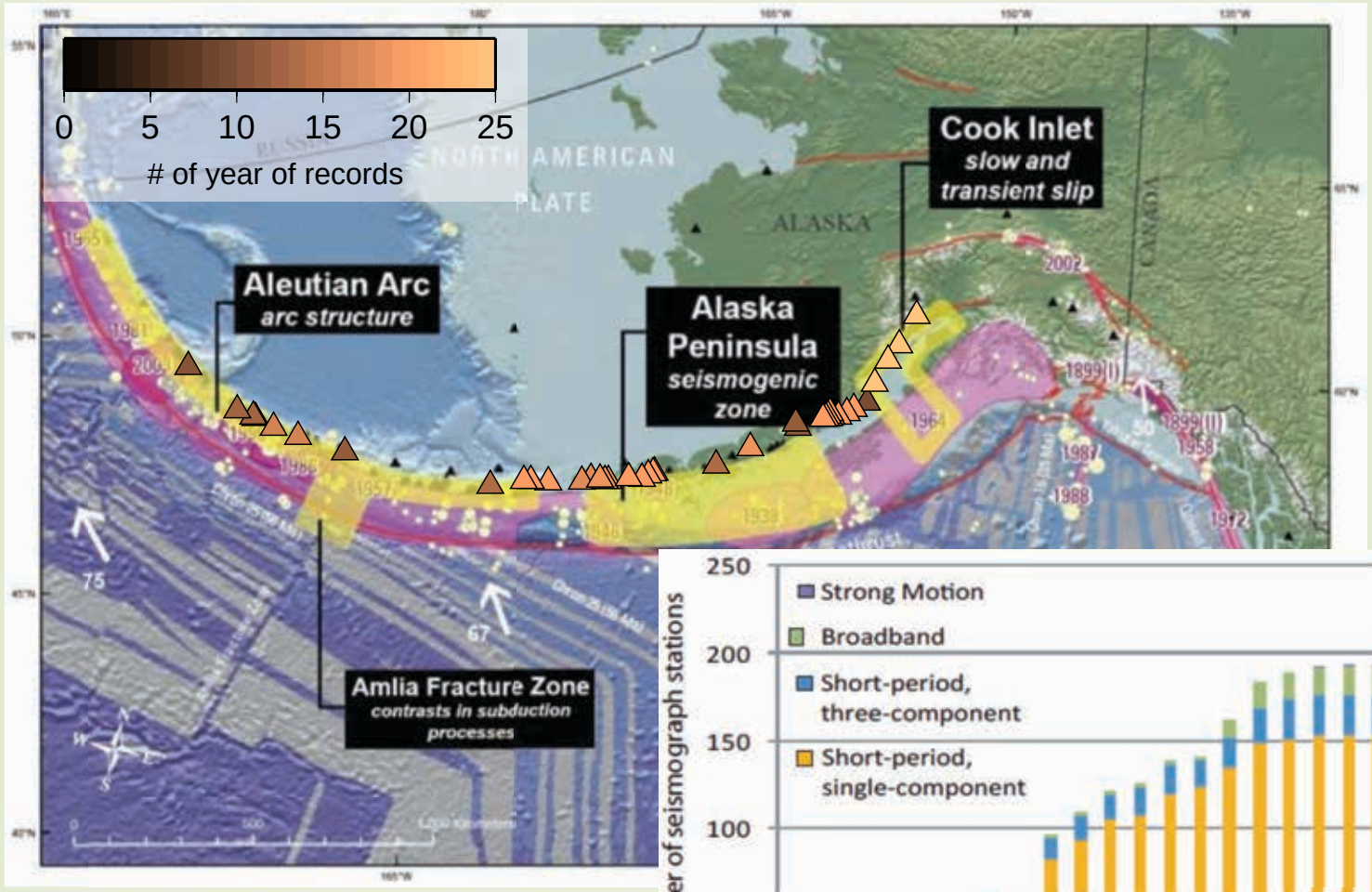
Limitations/challenges

· small onshore footprint
· noisy data
· temporally variable seismicity
· potentially limited seismicity distributions
· remote locations
· station outages



On the up side…

· up to 27 years of records for some volcanoes

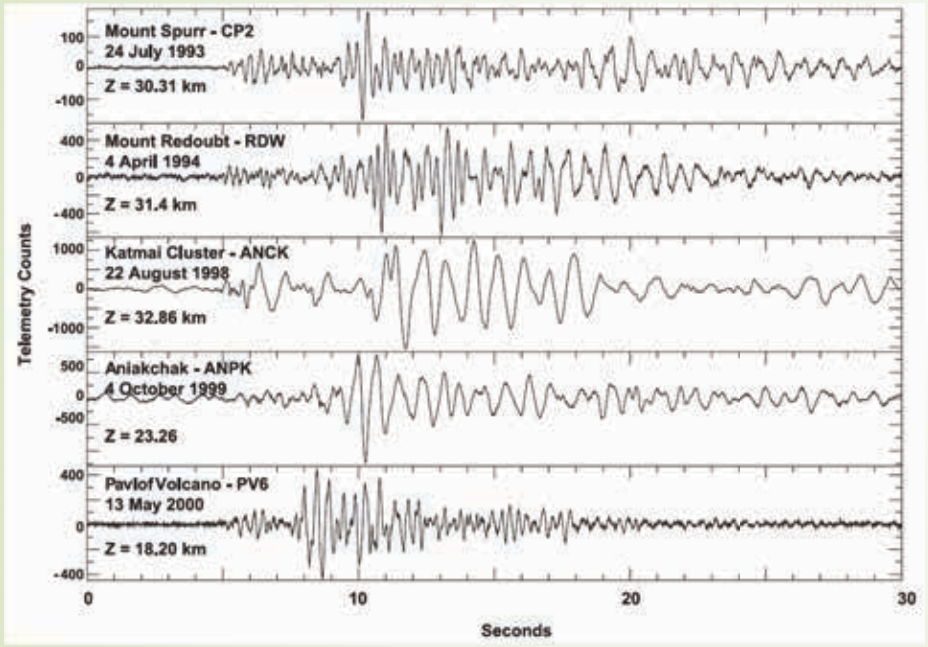


AVO/UAF

On the up side…

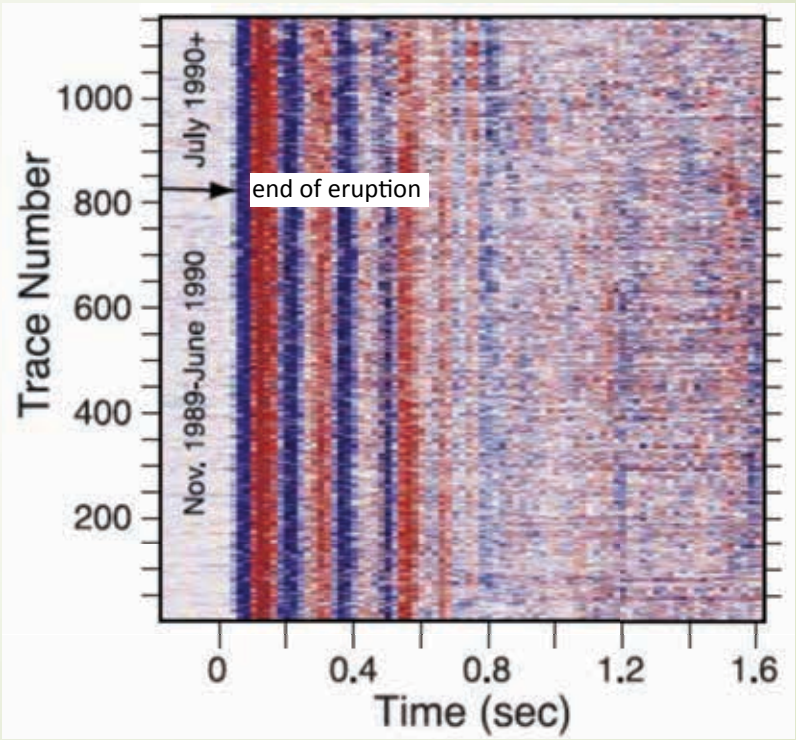
· up to 27 years of records for some volcanoes
· range of types of seismicity

DLPs: deep long-period earthquakes



Power et al., 2004

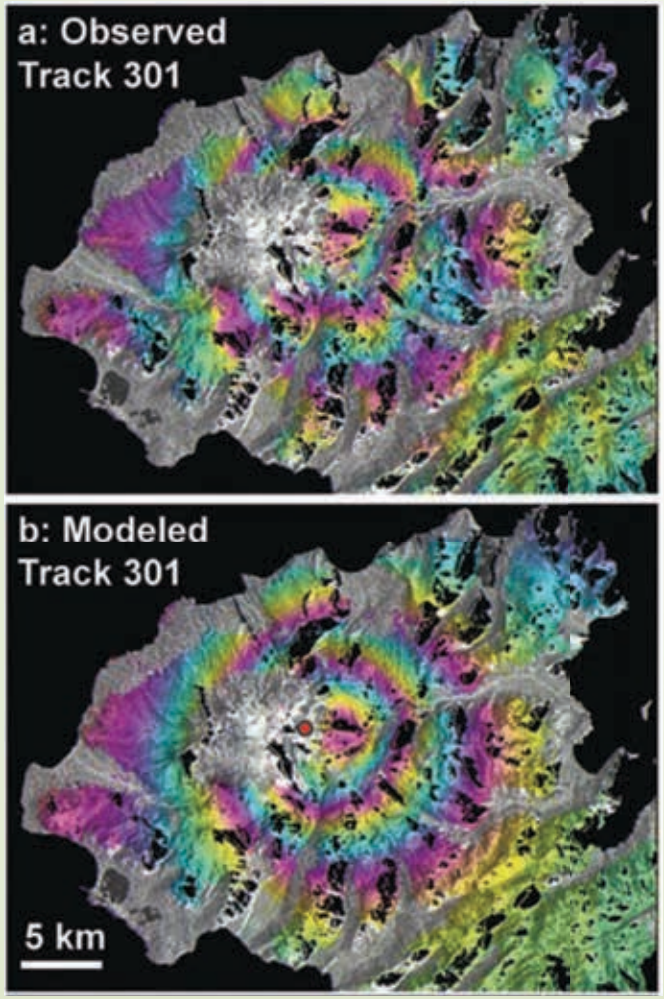
repeating earthquakes



DeShon et al., 2007

On the up side…

· up to 27 years of records for some volcanoes
· range of types of seismicity
· additional geophysical constraints on deformation

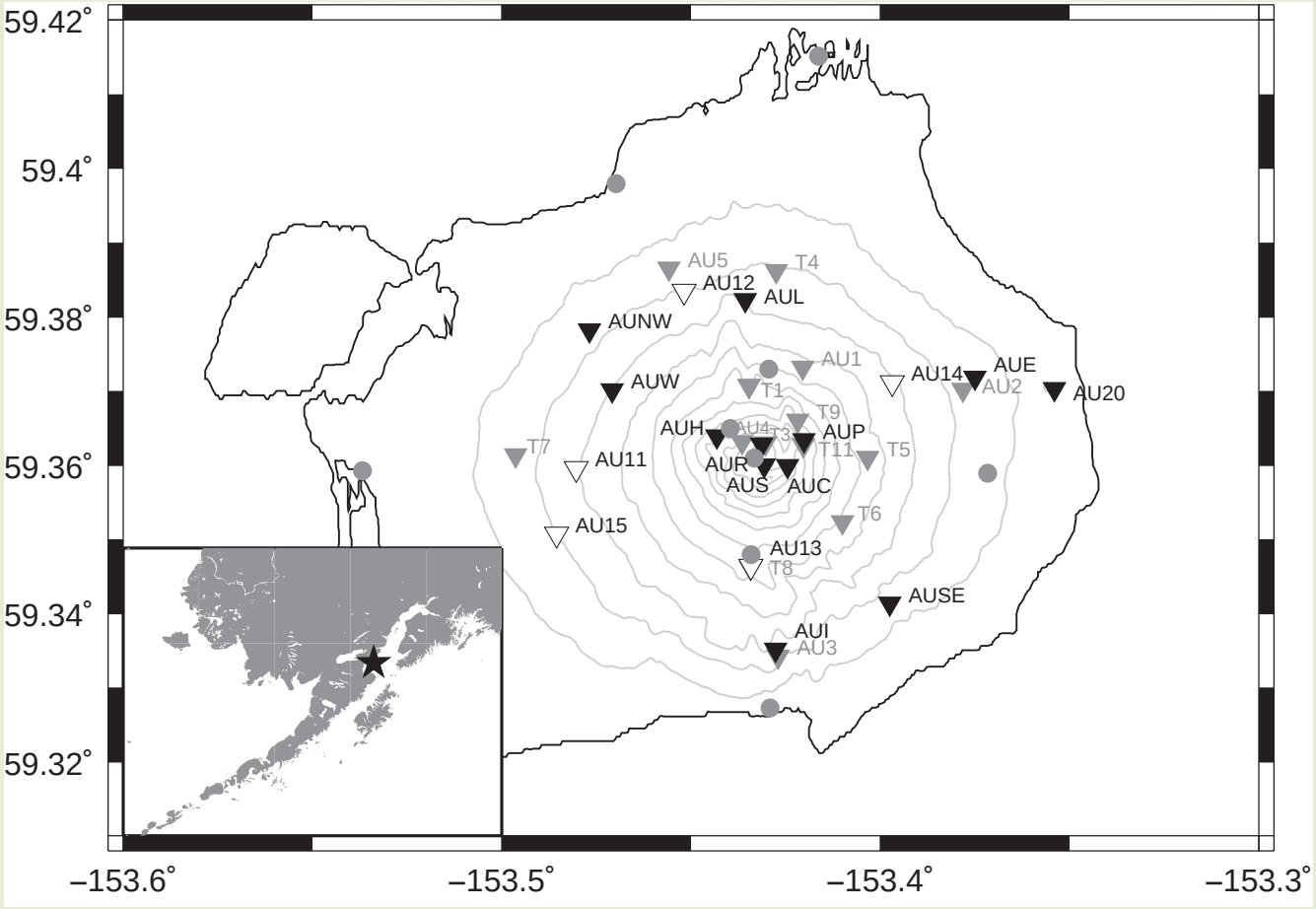


Lu et al., 2002

M. Kaufman/AVO/UAF

Augustine Volcano

· supplemented by temporary seismic data
· double-difference earthquake location & tomography



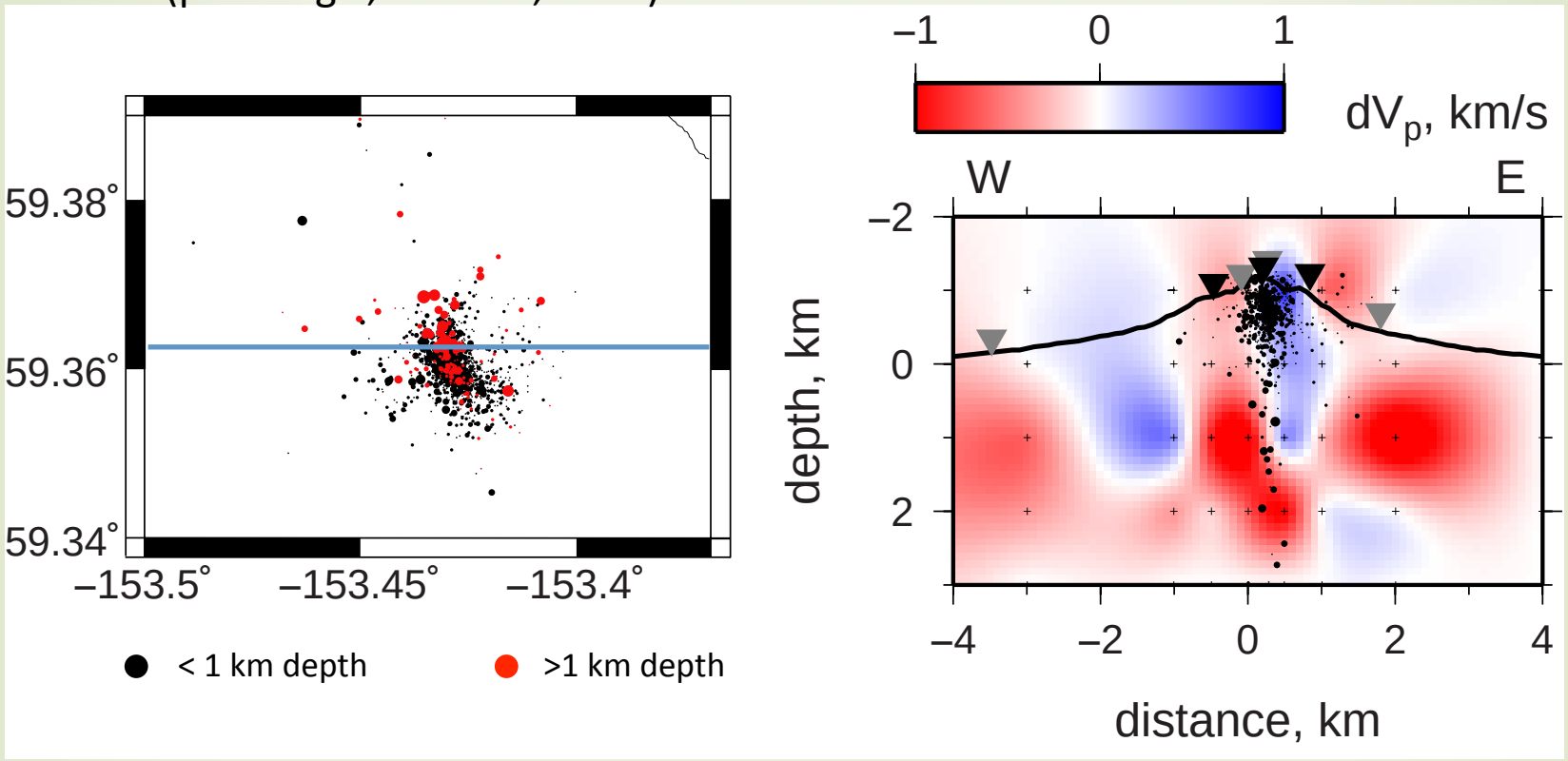
Syracuse et al., 2011

Augustine Volcano

most recent eruption: 2006

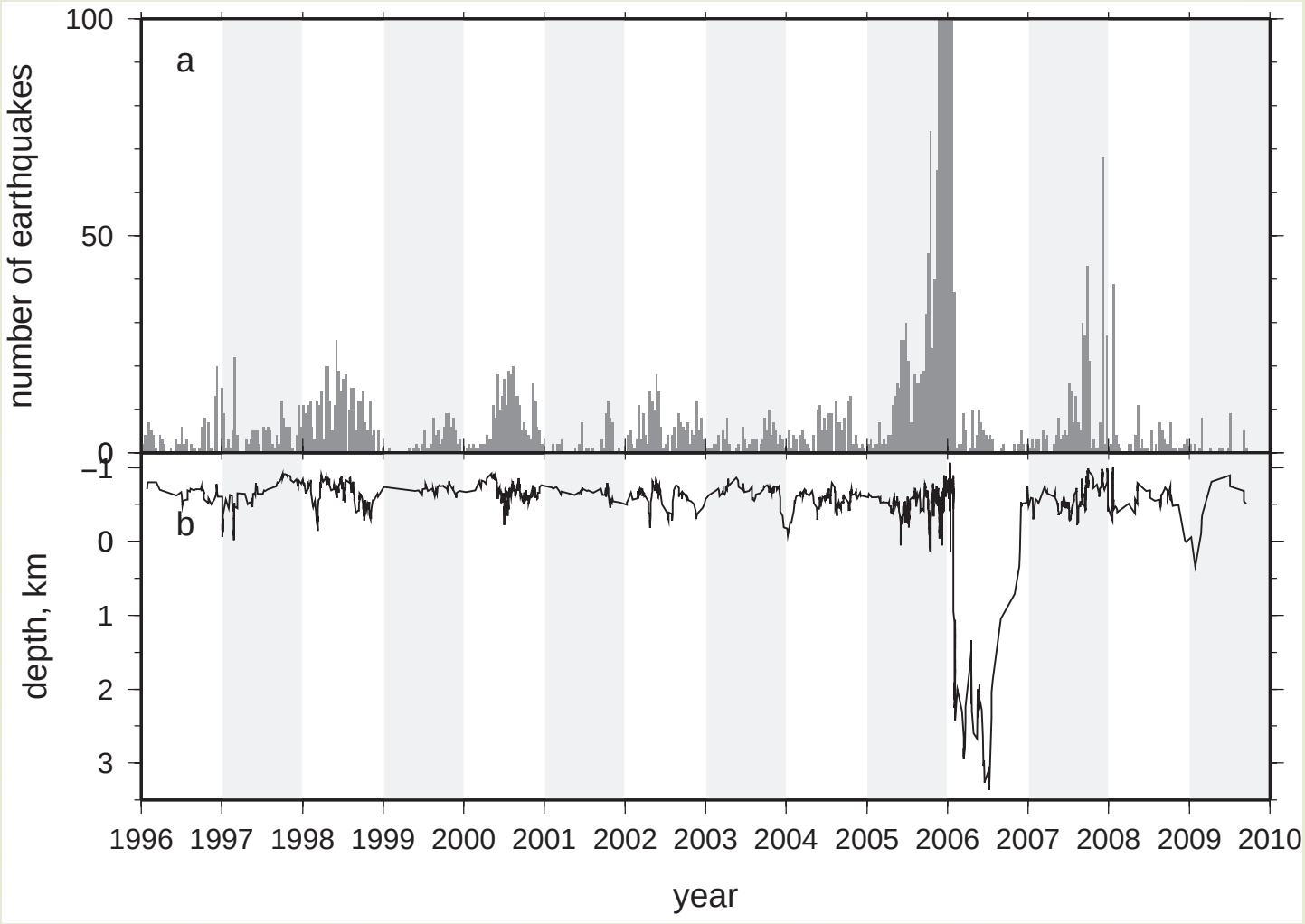
magma chamber depth:

- 2-4 km & 7-12 km (InSAR; Lee et al., 2010)
- 12-15 km (petrologic; Zimmer, 2009)



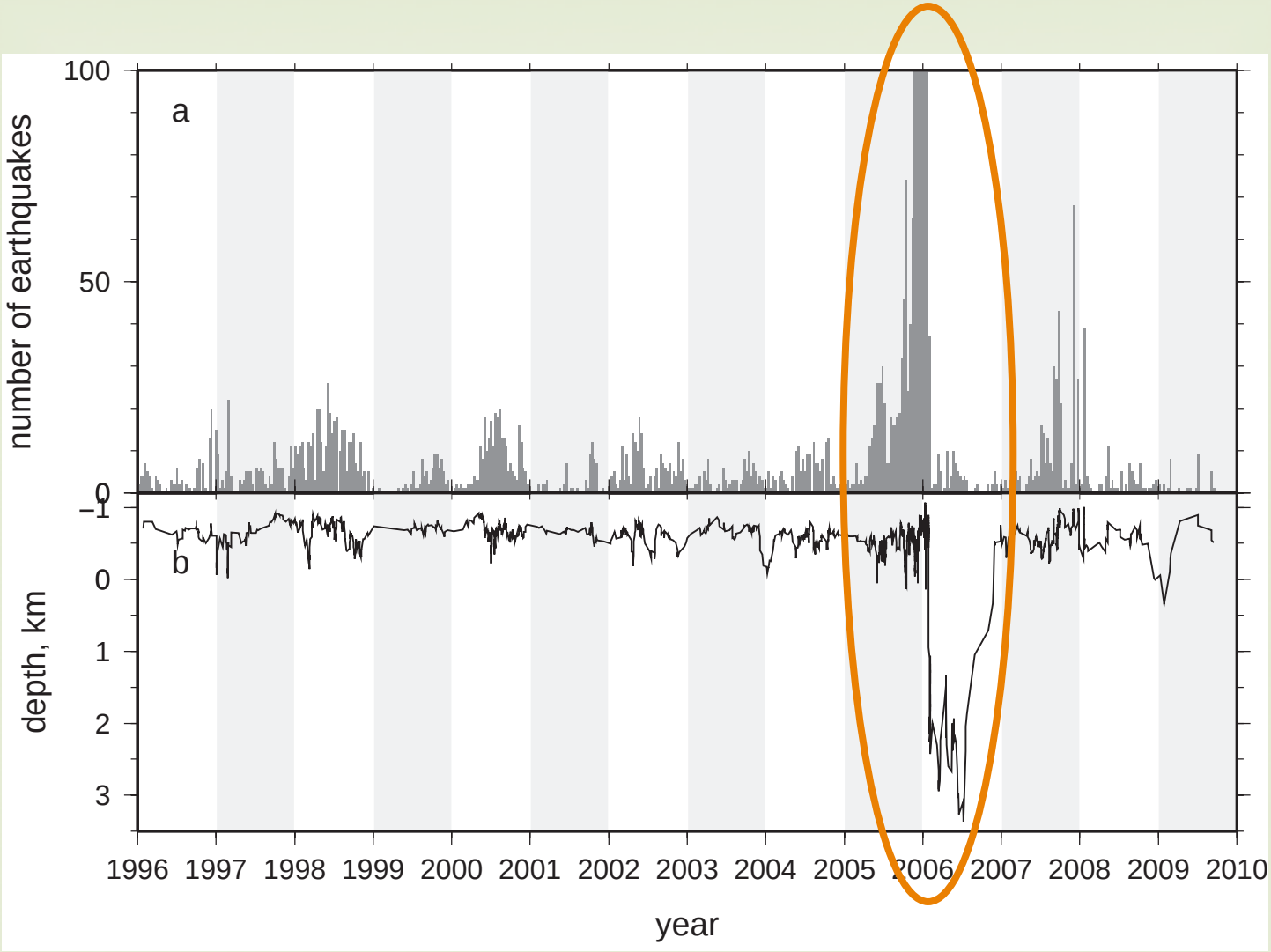
Syracuse et al., 2011

Augustine Volcano – 2006 eruption



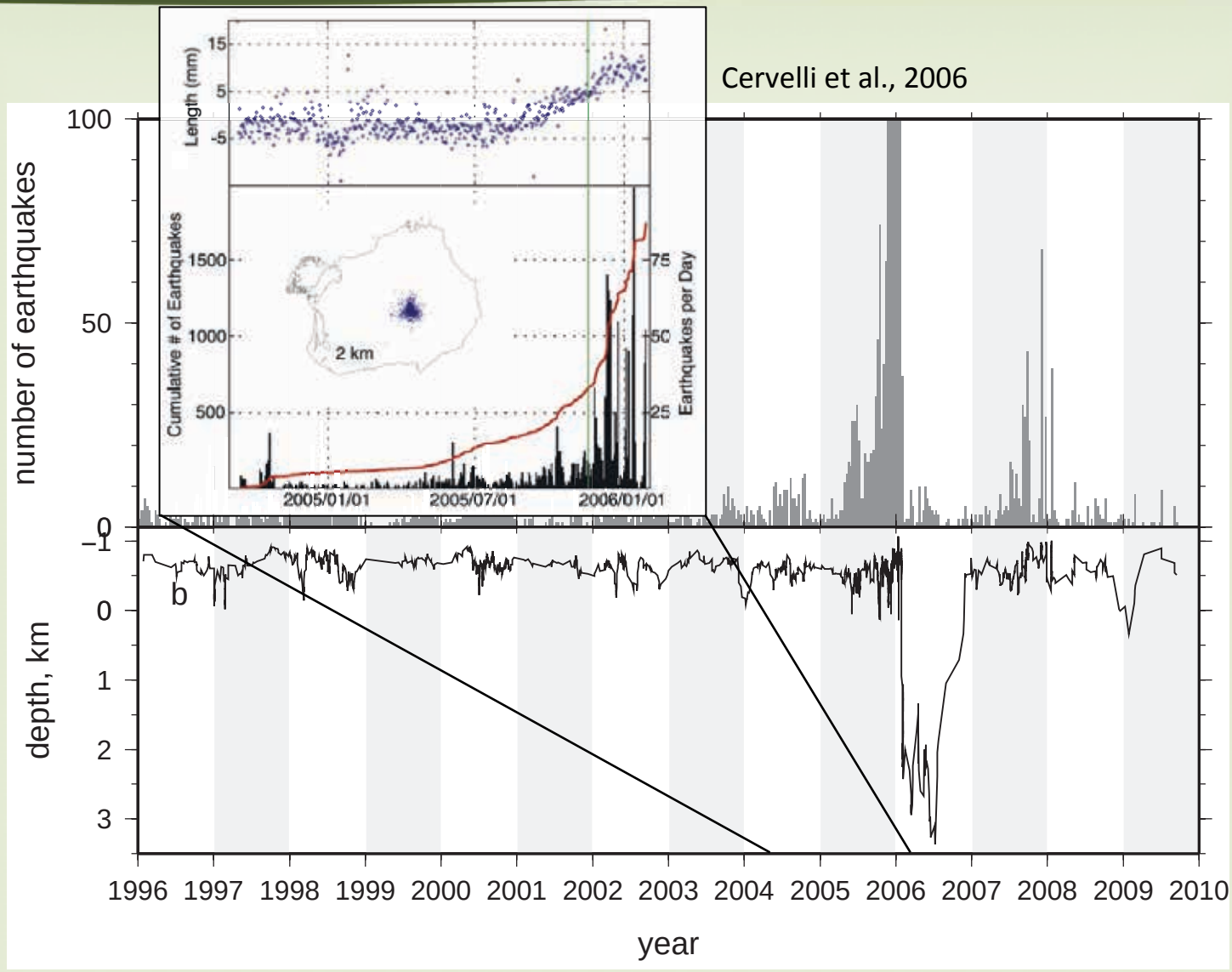
Syracuse et al., 2011

Augustine Volcano – 2006 eruption



Syracuse et al., 2011

Augustine Volcano – 2006 eruption

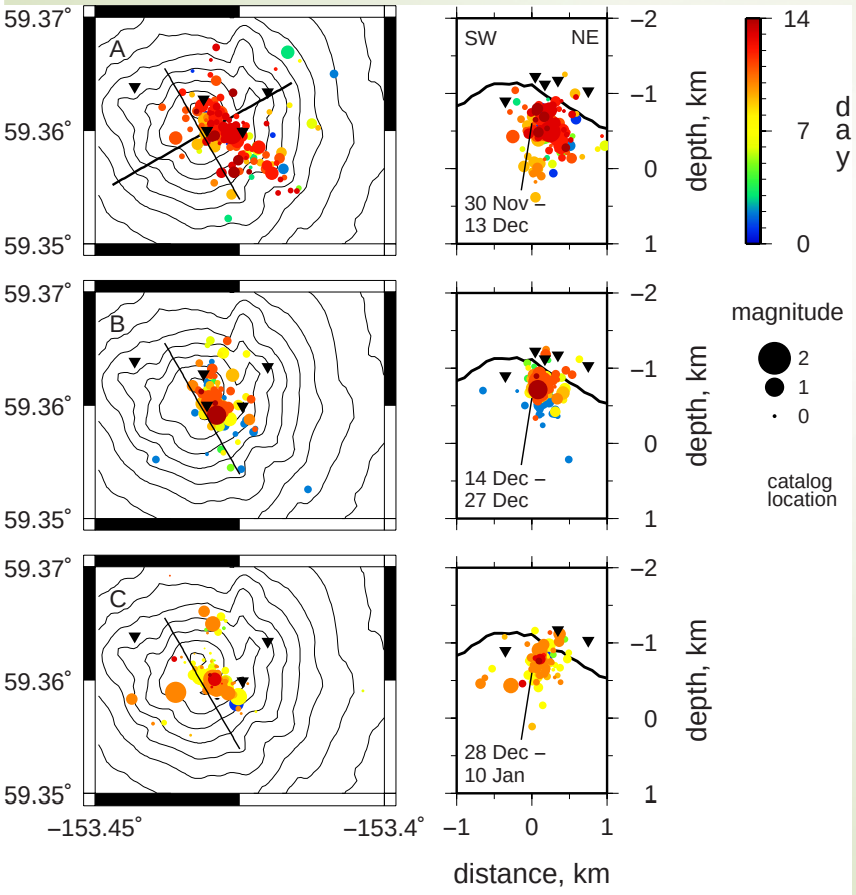


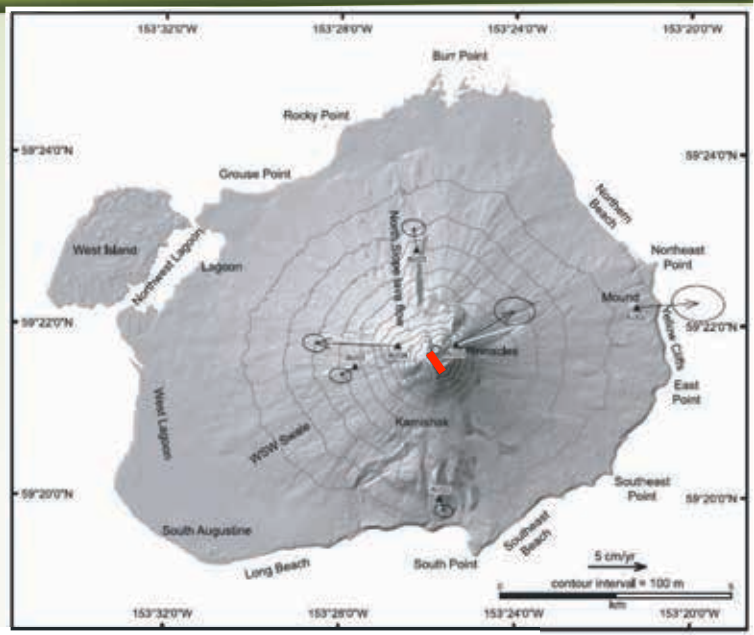
Cervelli et al., 2006

Syracuse et al., 2011

Augustine Volcano – 2006 eruption

near-summit seismicity



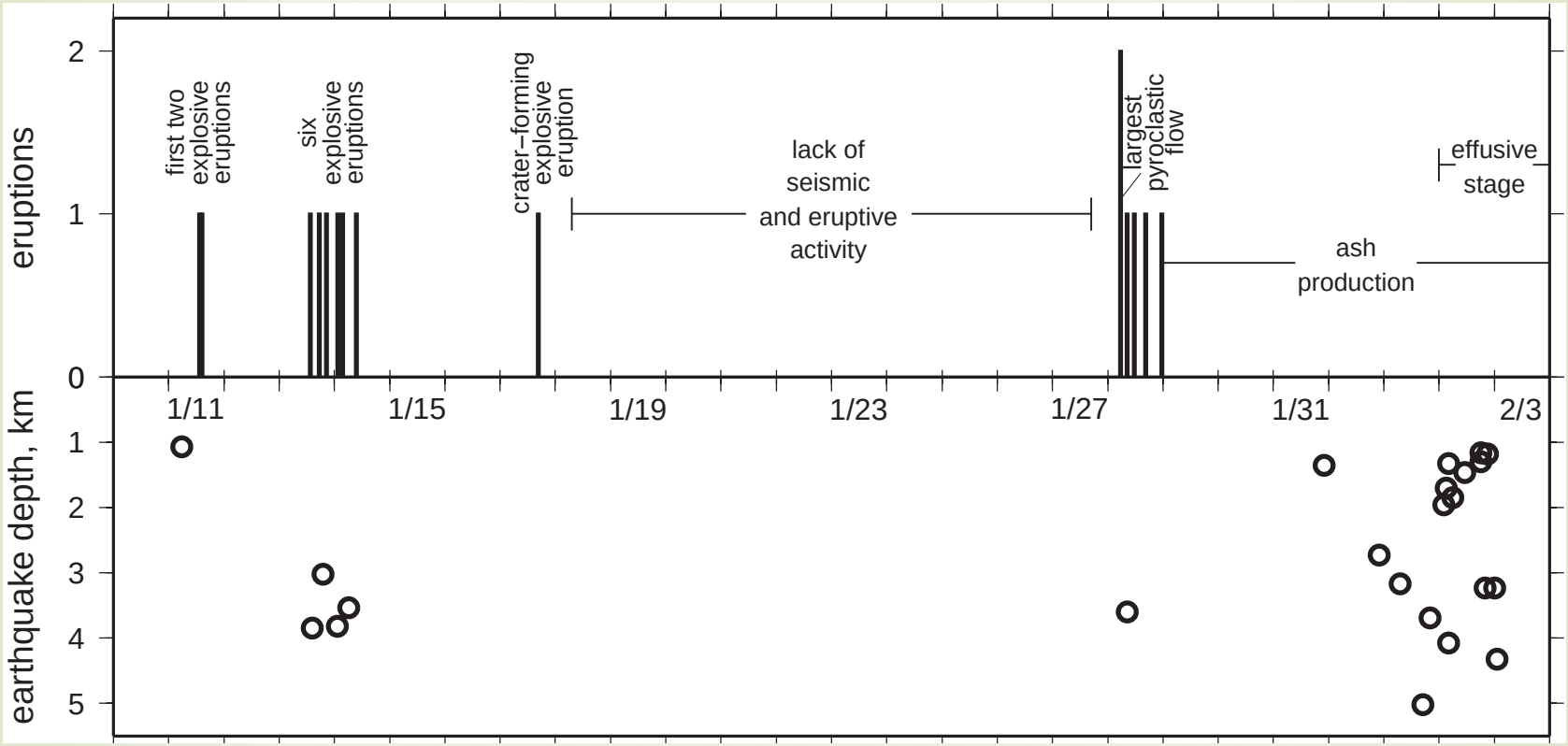


Cervelli et al., 2006

Syracuse et al., 2011

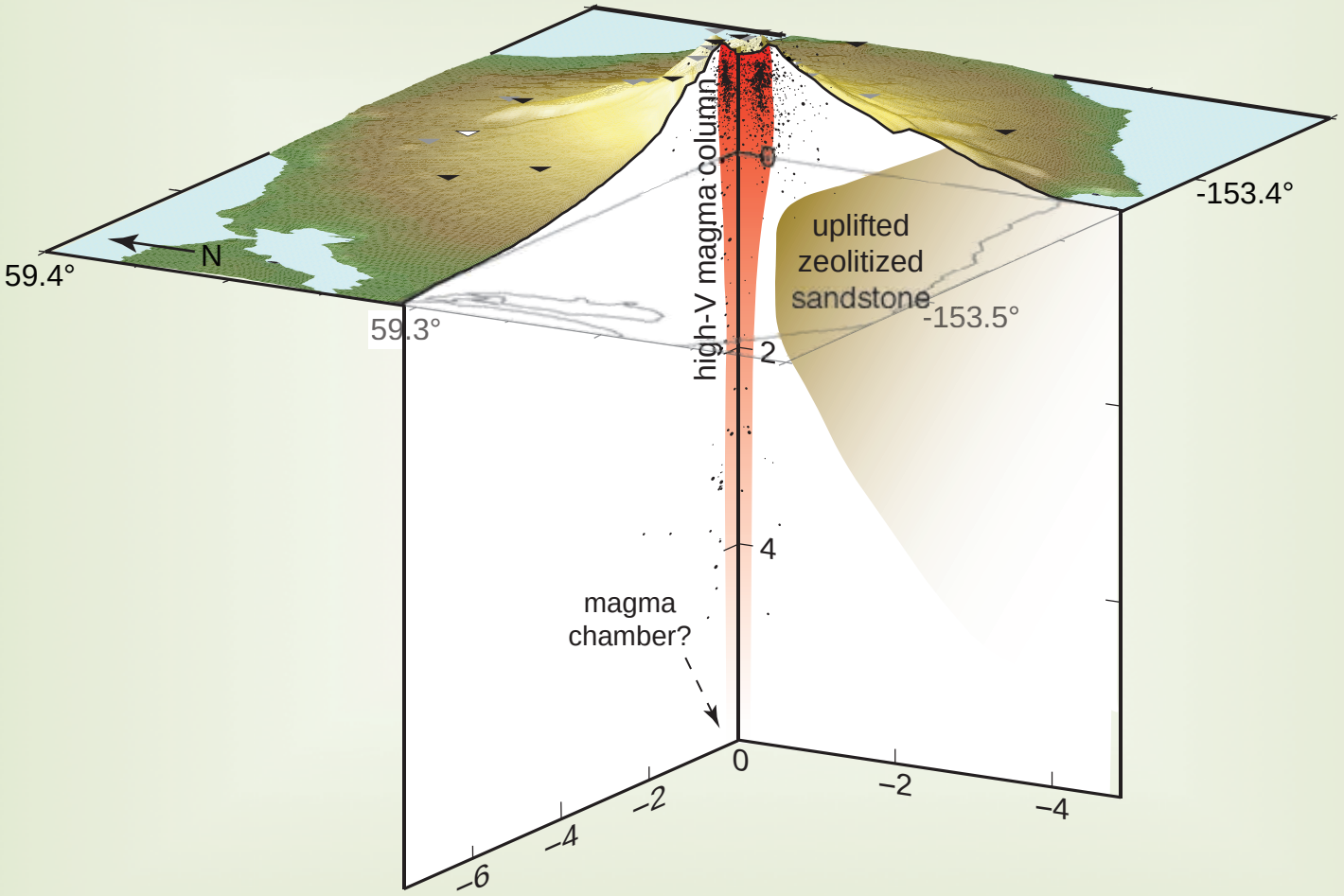
Augustine Volcano – 2006 eruption

"deep" long period seismicity



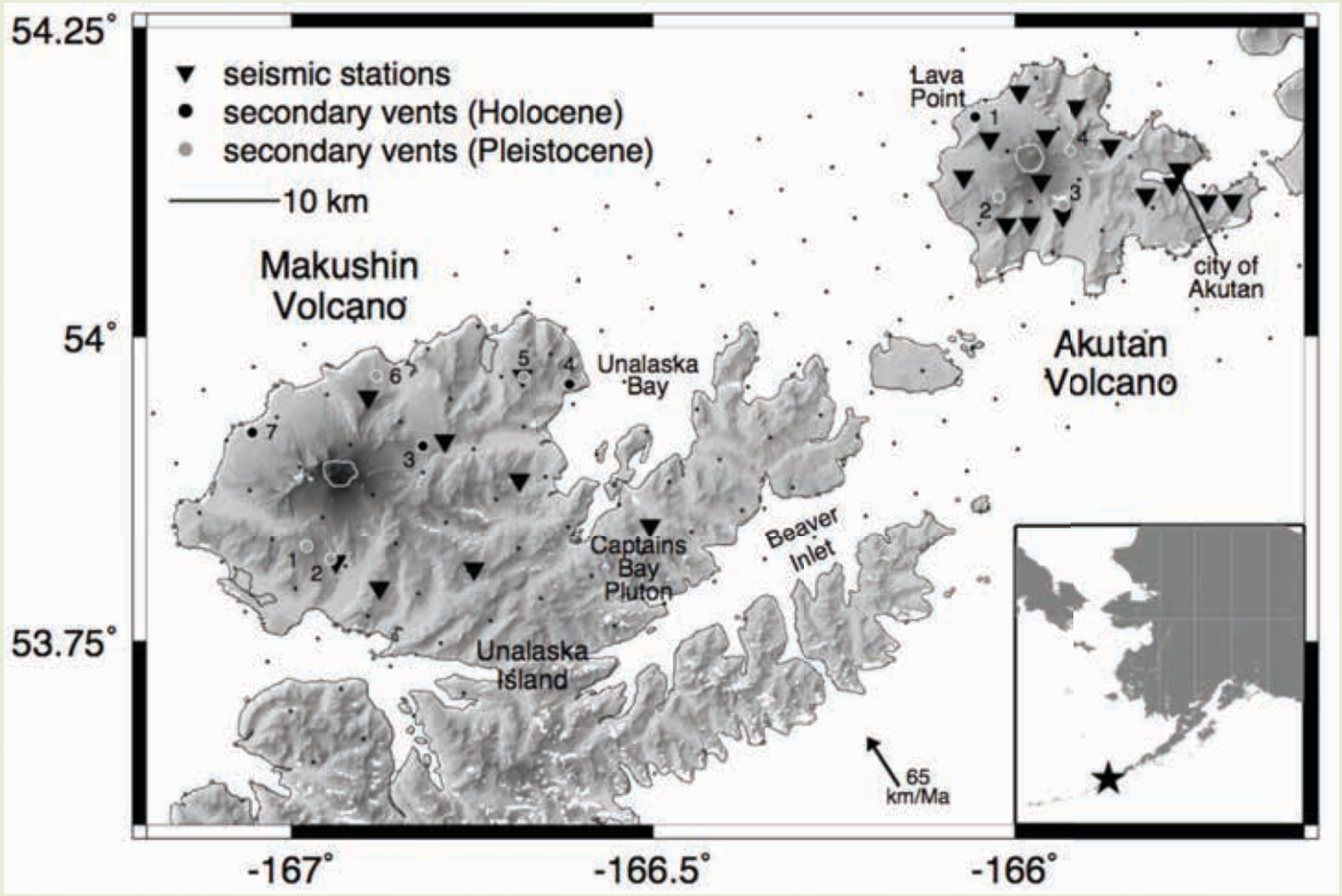
Syracuse et al., 2011

Augustine Volcan



Syracuse et al., 2011

Akutan & Makushin Volcanoes

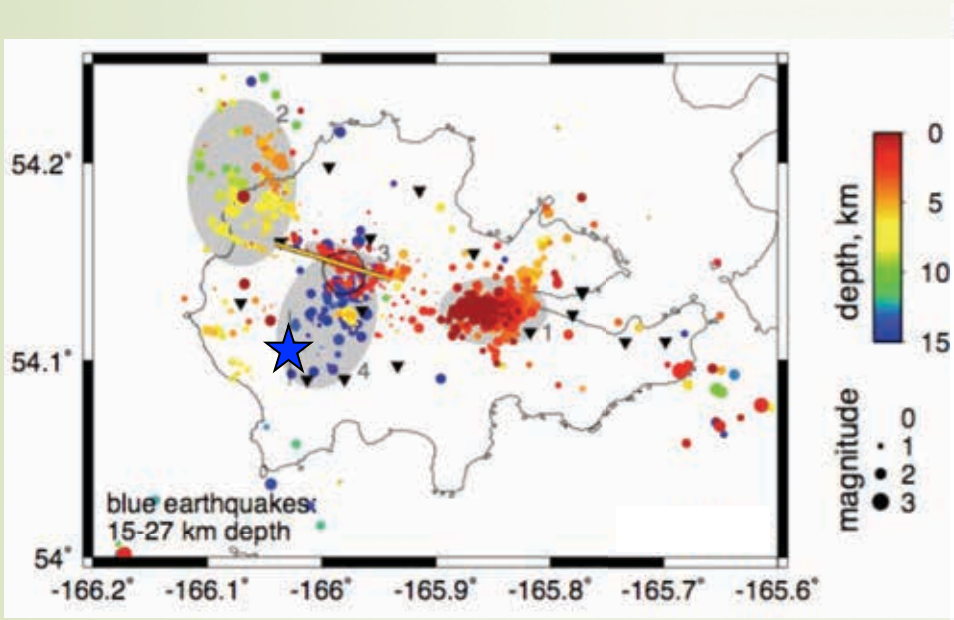


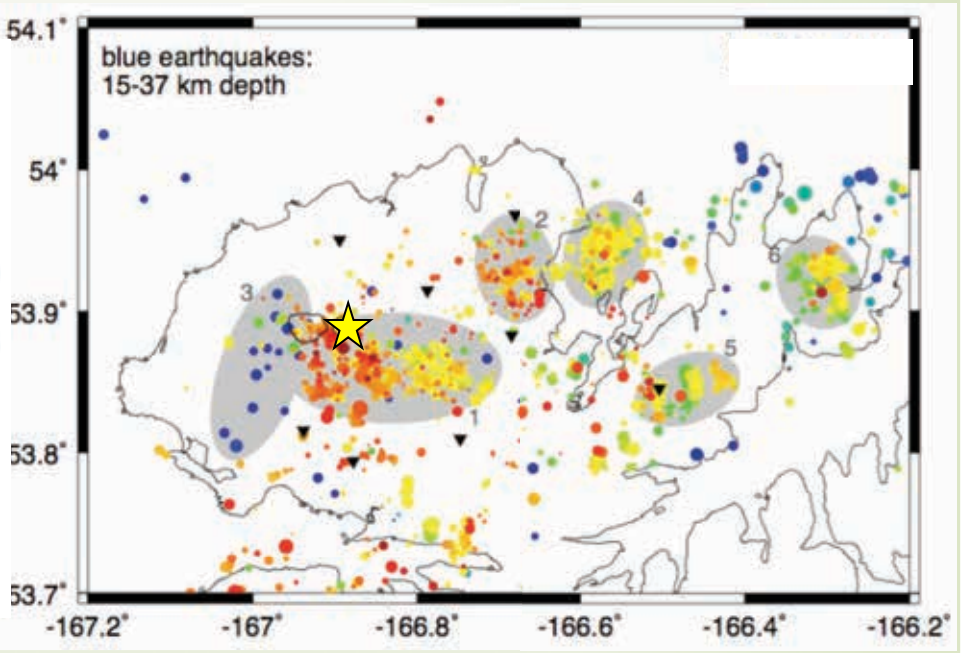
Syracuse et al., 2015

Akutan & Makushin Volcanoes

Akutan:
most recent eruption: 1992
magma chamber depth:
- 13 km (InSAR; Lu et al., 2000)
- 4 km (GPS; Ji and Herring, 2011)
- 4.5 km (petrologic; Zimmer, 2009)

Makushin:
most recent eruption: 1995
magma chamber depth:
- 7 km (InSAR; Lu et al., 2002)
- 5-6 km (petrologic; Zimmer, 2009)



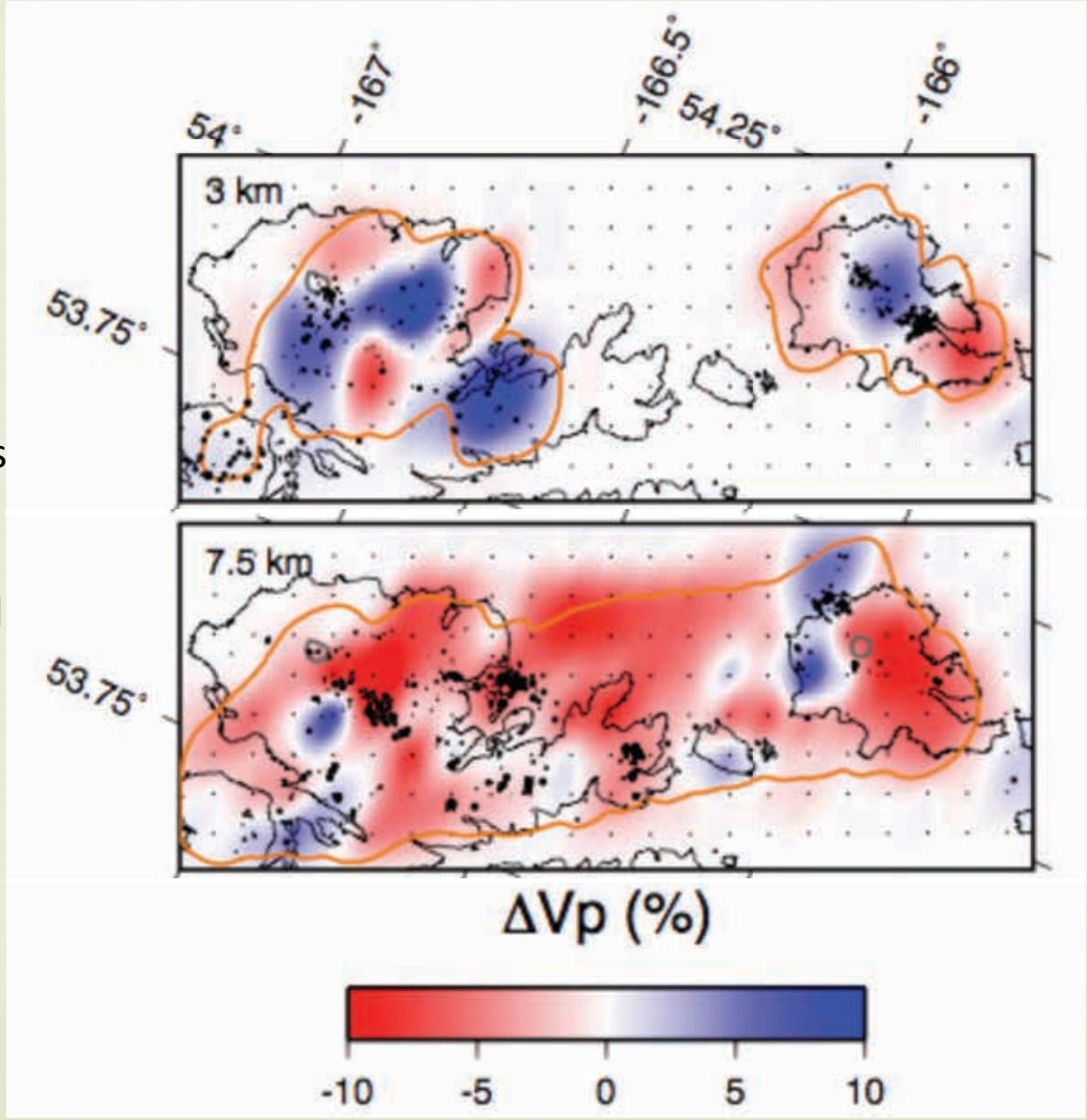


Syracuse et al., 2015

Akutan & Makushin Volcanoes

Makushin:

· more complex structure
· high-V Captains Bay pluton
· low-V region surrounded by eqs

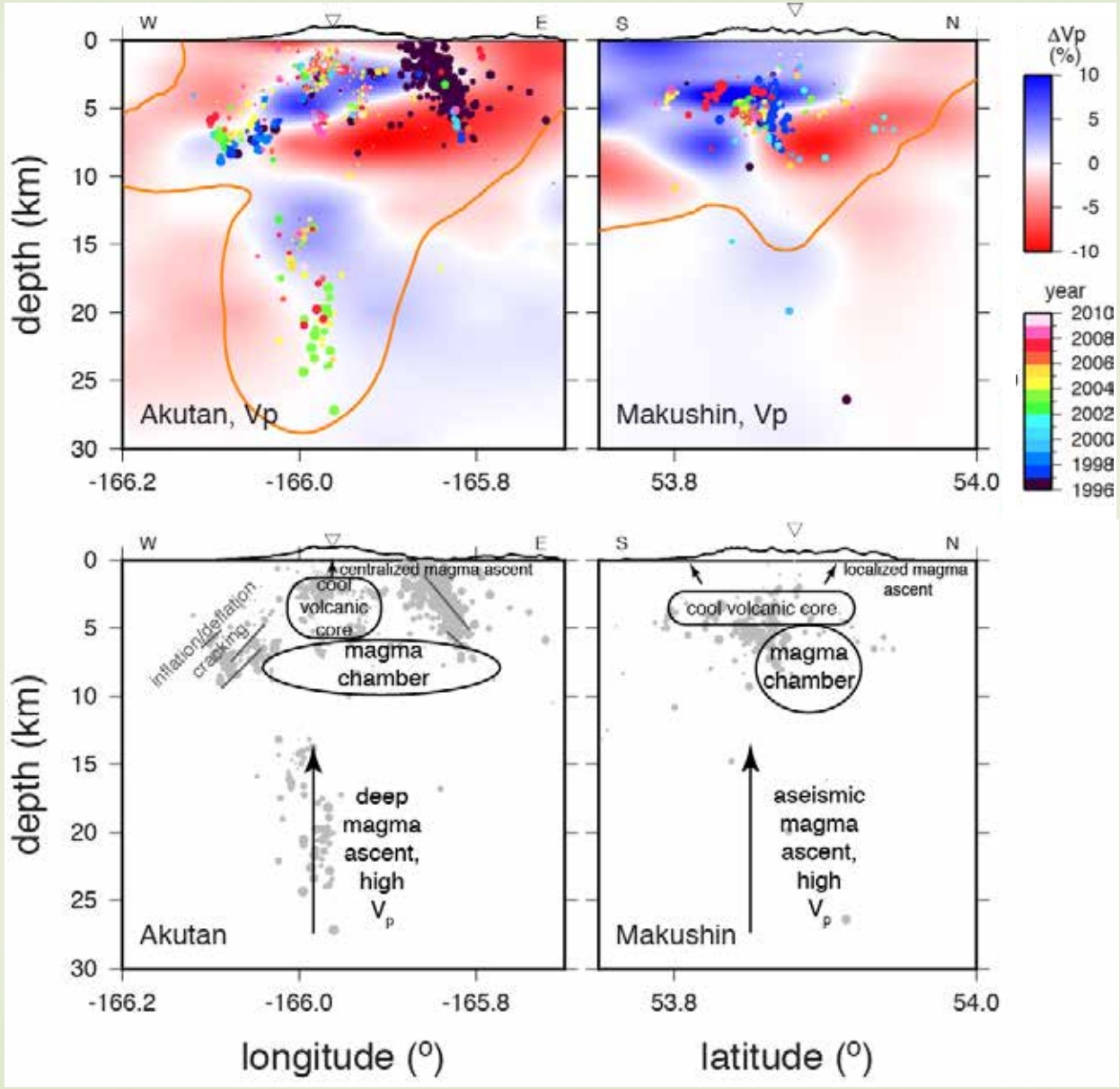


Akutan:

· simpler structure
· high-V volcanic core
· low-V region surrounded by eqs

Syracuse et al., 2015

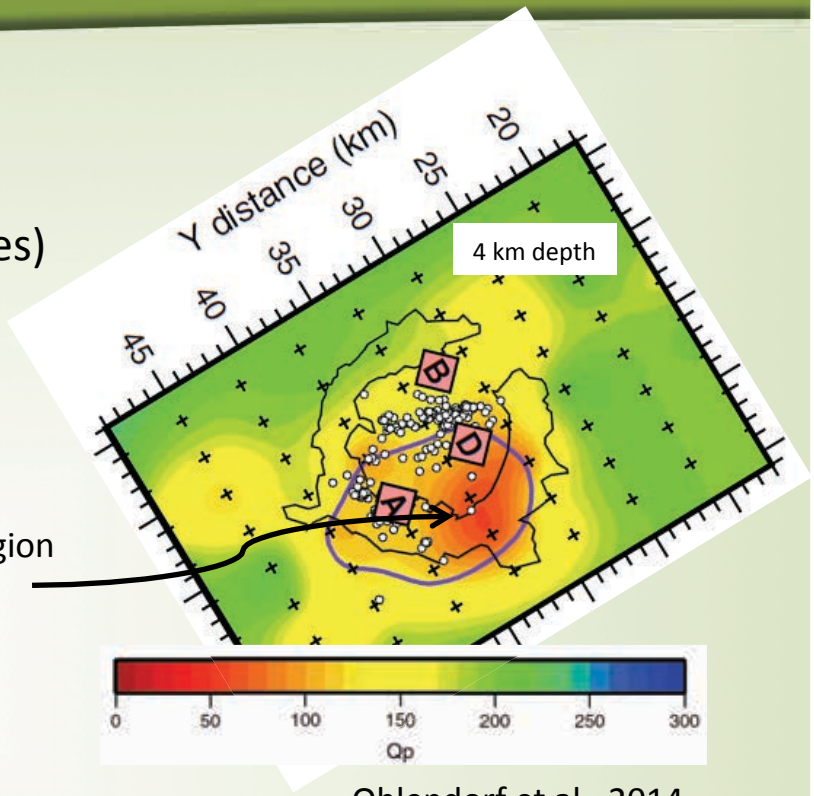
Akutan & Makushin Volcanoes



Syracuse et al., 2015

Okmok Volcano

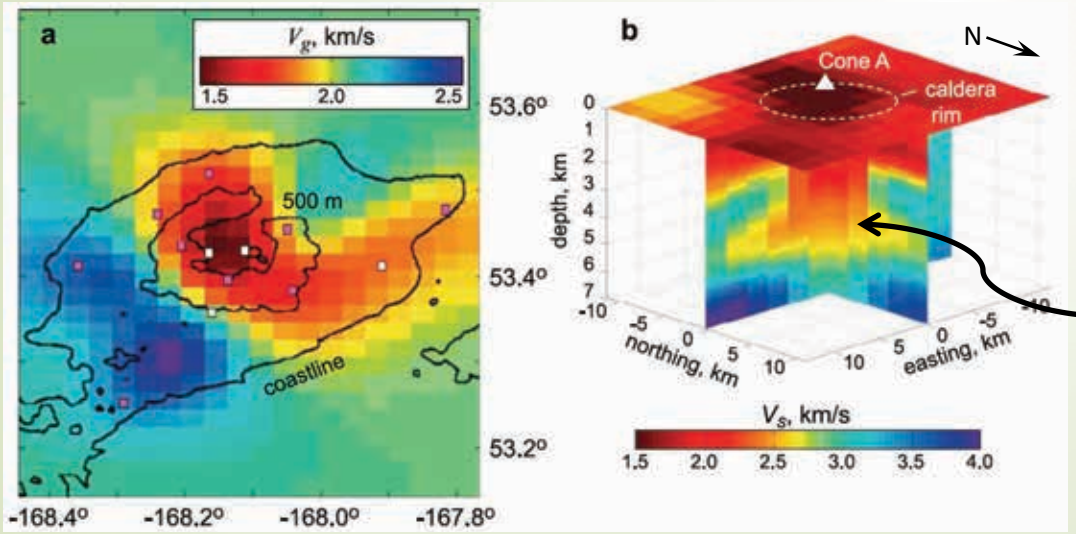
most recent eruption: 2008
magma chamber depth:
- 2-4 km (InSAR, GPS; various studies)
- 4 km (petrologic; Zimmer, 2009)



highly attenuating region
at 0-6 km depth

Ohlendorf et al., 2014

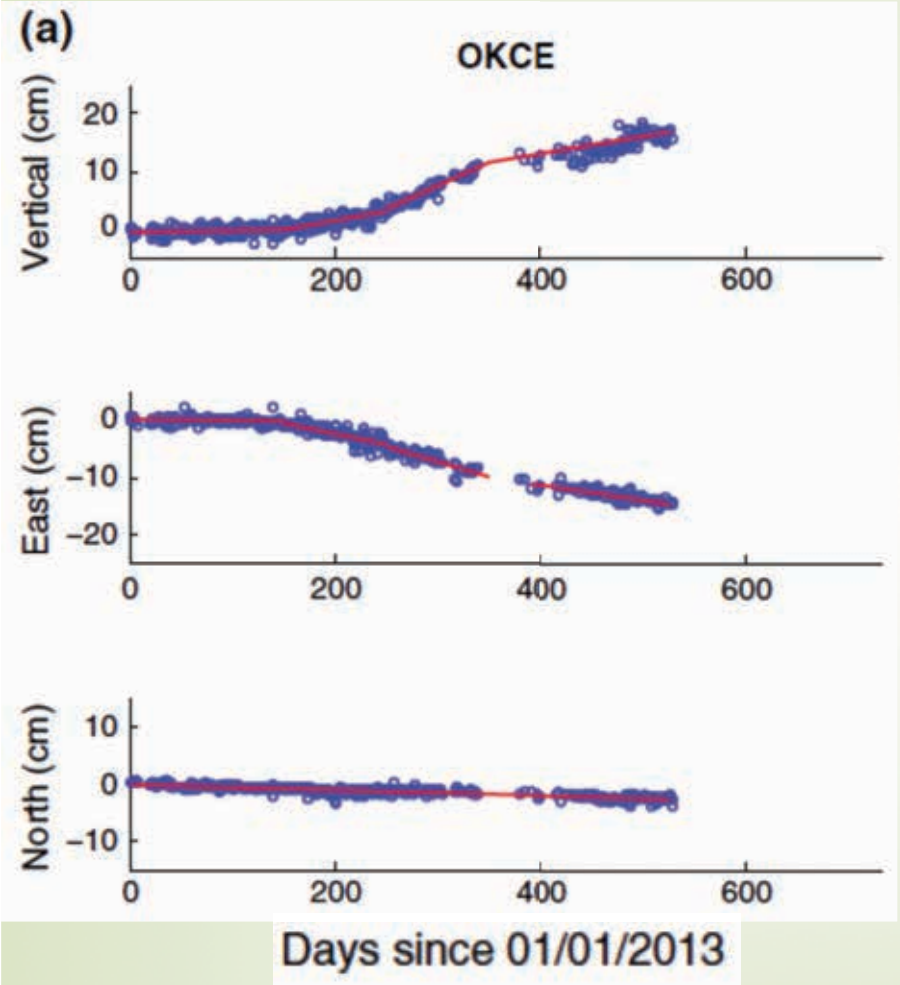
0.3 Hz



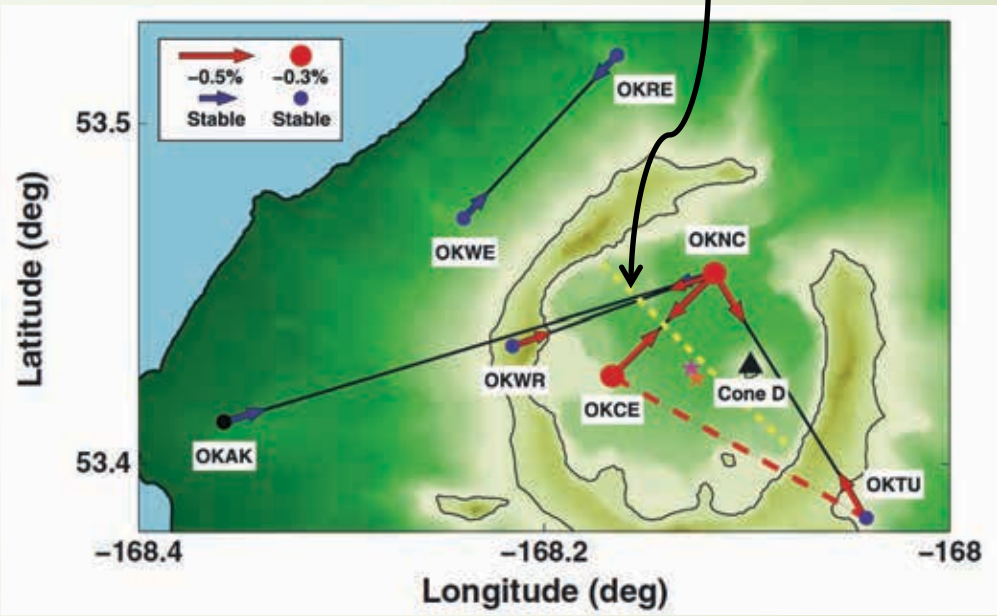
low-V magma reservoir
at 4-5 km depth

Masterlark et al., 2010

Okmok Volcano



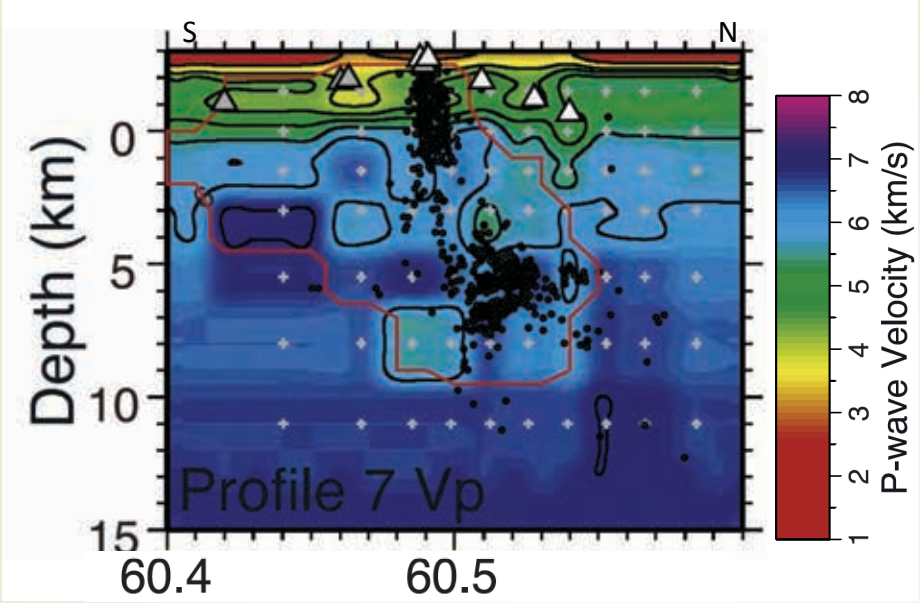
velocity decrease during 2013 inflation event



Bennington et al., 2015

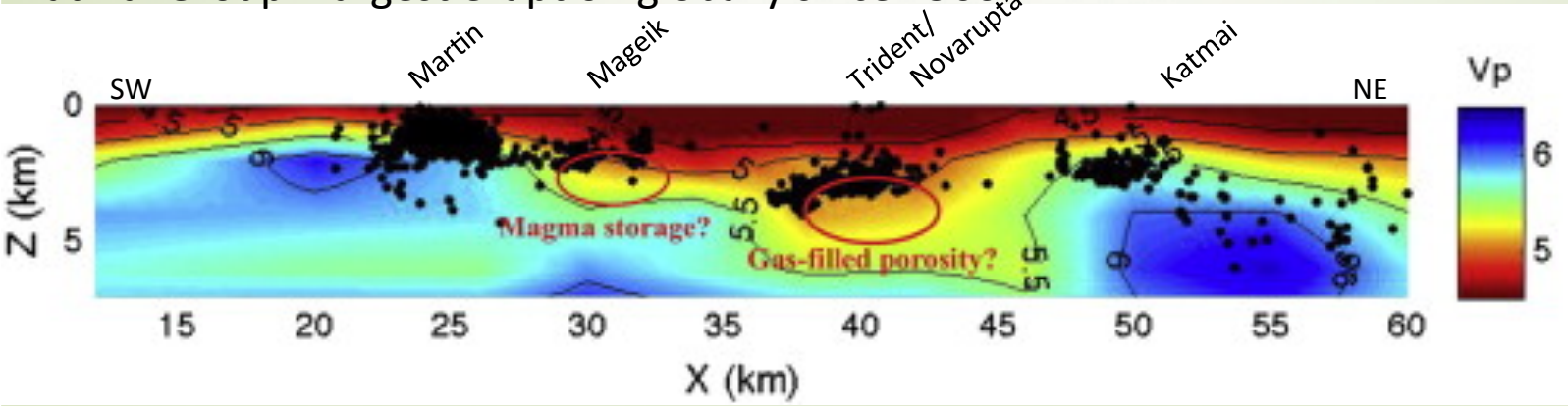
Redoubt Volcano & Katmai Group

Redoubt - most recent eruptions: 2009, 1989-1990



DeShon et al., 2007

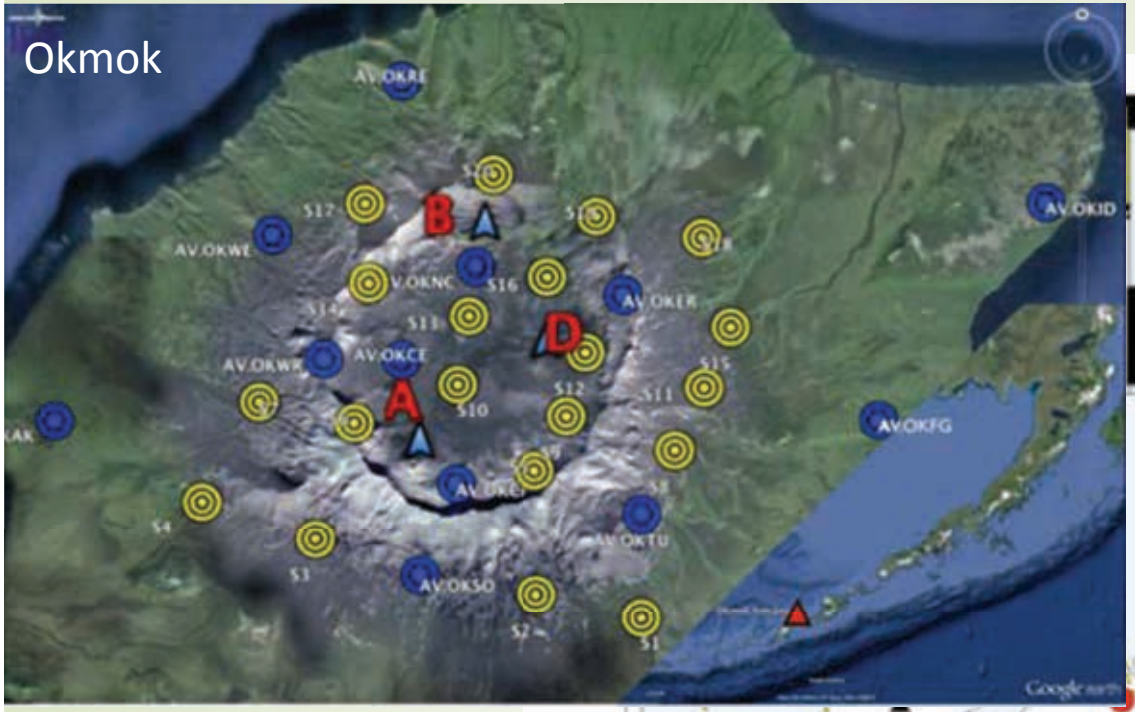
Katmai Group - largest eruption globally since 1900



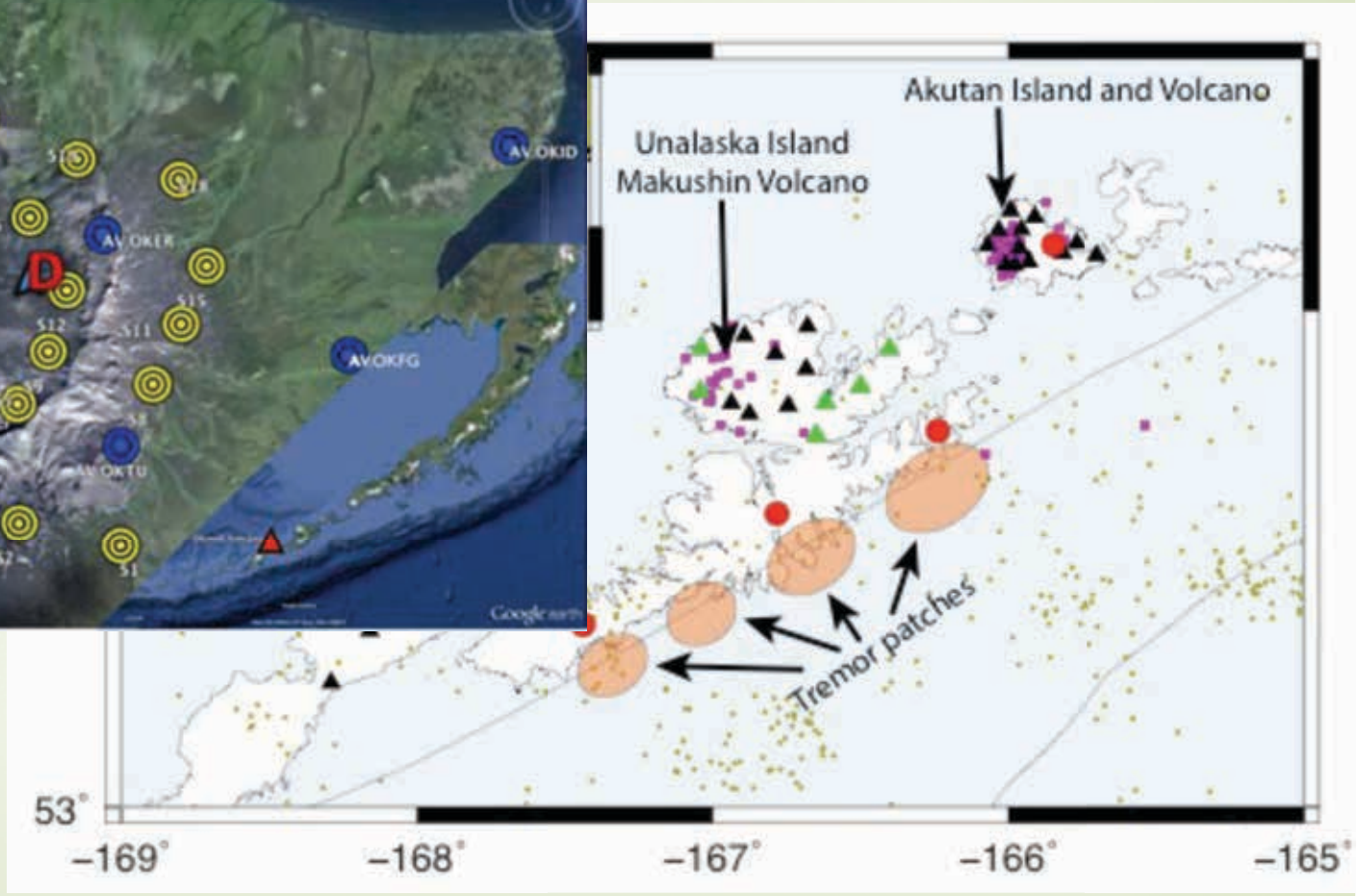
Murphy et al., 2014

Current and future work

· also, Cleveland Volcano, instrumented summer 2015



PIs: Bennington, Key (GeoPRISMS)



PIs: Thurber, Ghosh, Prejean (EarthScope)

Conclusions

· Seismic imaging of Alaskan volcanoes presents a unique set of challenges, but much can be done with existing data

· At resolvable depths, a wide range of seismic structures associated, including
  · high-velocity intrusives
    - cooled magma along conduits
    - plutons
  · largely aseismic low-velocity regions associated with magma storage

  · but some volcanoes show little structure
    - transient features?
    - need more instrumentation!