VOLCANISM IN THE AMERICAN SOUTHWEST

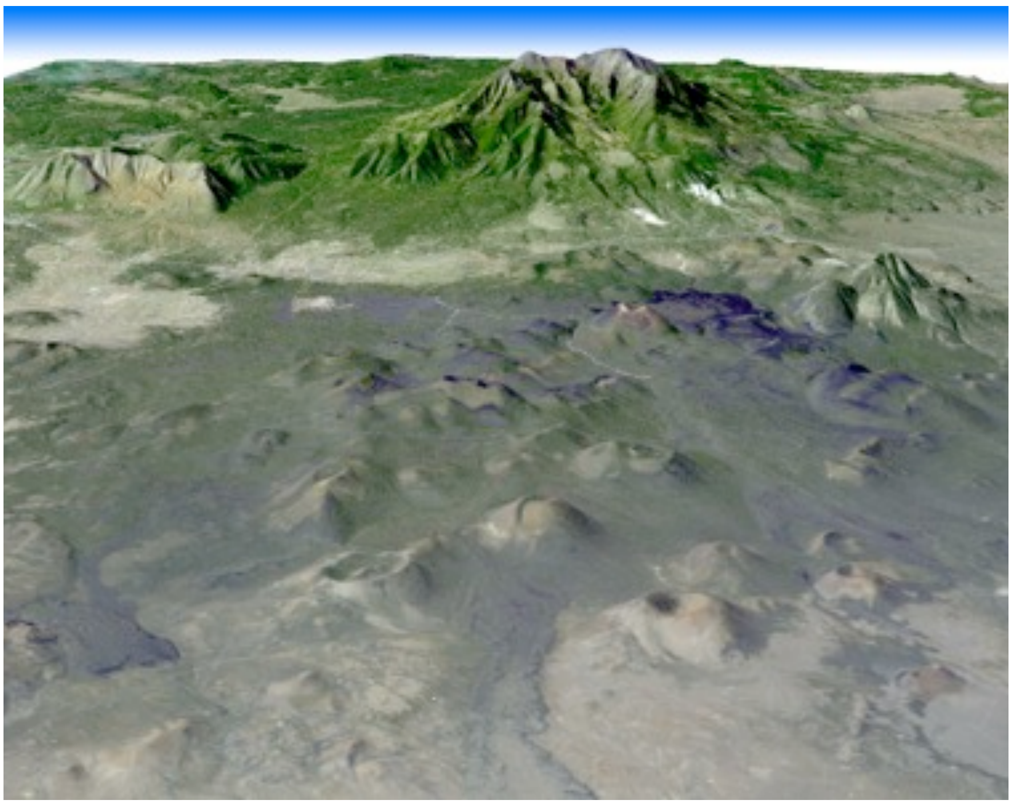
Presentation Volume

Organizers:

Jake Lowenstern, USGS; Michael Ort Northern Arizona Univ.; Greg Valentine, University at Buffalo; Laz Kestay, USGS; Nelia Dunbar, New Mexico Tech; Sue Perry, USGS; John Bwarie, USGS

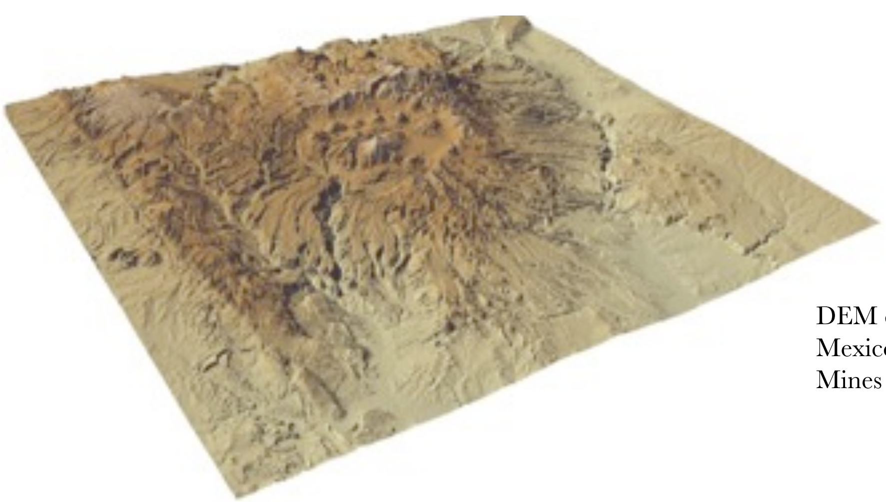
OCTOBER 18-20, 2012

Join us in Flagstaff for a 2-day discussion (and optional fieldtrip) to explore past, present and future of volcanism in the American Southwest.



ASTER image of San Francisco Peaks from NASA Earth Observatory

The following volume contains most of the presentations during October 18-19, 2012 at the VASW meeting in Flagstaff. Each presentation can be found either through a link in the agenda or by enabling the bookmarks view in the pdf. In addition, the entire volume is searchable through the FIND function. Higher resolution images and slides may be available through the actual authors/ presenters.



DEM of the Valles region, northern New Mexico. Image from the New Mexico Bureau of Mines and Geology.

Volcanism in the American Southwest

October 18-19, 2012

Meeting Location:
U.S. Geological Survey
2255 North Gemini Drive
Flagstaff, AZ 86001

Meeting Purpose: Bring together volcanologists, network operators, land managers, and emergency managers to start a conversation about southwestern volcanoes and identify how to best prepare for future activity.

Organizers: **Jake Lowenstern**, **Laz Kestay**, SAFRR Project: Science Application for Risk Reduction (**Sue Perry** and **John Bwarie**) all from USGS; **Nelia Dunbar** NMBGMR; **Greg Valentine**, University at Buffalo, **Michael Ort**, Northern Arizona University

Meeting Outcomes:

- Communicate who would be responsible for what during a crisis
- Communicate the roles and limitations of USGS
- Communicate the roles of other federal agencies (NOAA, FAA, military)
- Raise understanding of resources available to state and local EM
- Use discussion panels to determine what else could be needed (e.g., regional plans regular ongoing activities, etc.)
- Increase awareness of volcanism and vulnerabilities in the American Southwest.
- Ponder eruption probabilities in regions with rare, distributed, volcanism.

October 18, 2012

7:45-8:00 "Registration", coffee, etc.

8:00-8:10 Introduction to the Flagstaff Campus and meeting logistics *Laz Kestay, and Jake Lowenstern, both at USGS*

8:10–8:30 Self-introductions, facilitated (Name, agency, relevant responsibilities)

8:30–9:00 Pondering the consequences of a volcanic eruption in the American Southwest: *Tina Neal, USGS*

9:00–9:30 Scenario for an eruption in the San Francisco Peaks Volcanic Field: effects on Northern Arizona and beyond: *Steve Self, NRC*

9:30–10:00 Volcanism in the American Southwest over the last million years: what happens here, how often, and why? *Greg Valentine, University at Buffalo and Michael Ort, Northern Arizona University*

10:00–10:20 BREAK (10:18 is GREAT ARIZONA SHAKEOUT!).

10:20–10:50 From the trenches: Anecdotes from actual eruptions and crises in the US and abroad. *John Ewert, USGS*

10:50–11:20 Scenarios for eruptions in New Mexico: Valles Caldera, Taos, Zuni-Bandera, etc.: *Nelia Dunbar, New Mexico Bureau of Geology and Mineral Resources*

11:20–11:50 Seismic and other networks in the southwest: how would we monitor volcanic unrest? *Paul Earle, USGS*

Lunch (11:50–13:10):

13:10–13:40 An Introduction to incident response and the Incident Command System: *Ellis Stanley, Dewberry*

13:40–14:40 PM 3 Minute Presentations (*Sixteen poster presenters give quick overviews of what they'll show at their poster*)

14:40–15:40 Poster session: Attendees circulate through the first 12 posters.

Coffee served during poster session

15:40-16:10 Eruption potential and hazard, Valles Caldera, New Mexico: *Fraser Goff, Ret., Los Alamos National Laboratory*

16:10–17:10 Panel Discussion: Incident Response in the context of volcanic unrest in AZ, NM, UT: Incorporating science into decisions for public safety: *Lou Trammell, Director of AZDEM, Robert Rowley, Coconino County; Alan Sinclair, BIA; Ellis Stanley, Dewberry; Wendy Blackwell, NMDHSEM*

17:10-17:40 Capstone Talk: Impact of Sunset Crater eruption on prehistoric groups in Northern Arizona: lessons on human adaptation to disasters*: Mark Elson, Desert Archaeology, Inc.*

17:40 Adjourn for Day. Dinner on your own.

Day 2 October 19, 2012

8:00–8:30 Small group planning: identifying challenges of Southwest volcanism.

8:30–9:00 The view from social science: how people will think and behave during an extended crisis with large uncertainties: *Katherine Thompson, Columbia University*

9:00–9:30 Monitoring dike intrusions with GPS networks: past experience and future potential: *Bill Hammond, University of Nevada, Reno*

9:30–10:00 3 Minute Presentations (8 final posters)

10:00–10:20 Break

10:20–11:20 Panel Discussion: Seismic and geodetic monitoring in the southwest: What do networks need to do and to provide? Panel members *Keith Koper, UU; Paul Earle, USGS; Bill Hammond, UNR; David Brumbaugh, NAU; Rick Aster, New Mexico Tech*

11:20–11:50 Volcanic ash plumes and their impact to aviation in the Western United States: *Jeff Osiensky and Scott Birch, NOAA/National Weather Service*

11:50-13:00 Lunch

13:00–14:00 Discussion: What (if anything) should we do next?

14:00-14:10 Volcano Readiness Wrap-Up *John Bwarie, USGS SAFRR*

AFTERSESSION: SOUTHWEST VOLCANO PROBABILITIES

14:10–14:40 Modeling mafic lava flows with an eye to emergency response (*Laz Kestay, USGS*)

14:40-15:45 Poster session: Attendees circulate through the day's posters.

Coffee served during posters.

15:45–16:45 Panel Discussion: Geology, geochronology, and probabilistic modeling of volcanism in the U.S. Interior (*Greg Valentine, U. Buffalo; Bill McIntosh, NMT; Duane Champion, USGS; Chuck Connor, U. S. Florida; Jorge Vazquez, USGS*)

16:45–17:15 Overview of the field trip for 10/20: *Michael Ort, Nancy Riggs, Northern Arizona University)*

Adjourn

Day 3 October 20, 2012

Optional field trip to Sunset Crater National Monument

Poster Session A: Day 1: October 18, 14:40-15:40
Oral Session 1: Day 1 at 13:40

Poster Session	Oral Session	Authors	Title
A	1	Alfano et al.	Characterization of the 1000 AD Sunset Crater eruption and its pyroclastic products
A	1	Aster et al.	Earthquakes in the Central Rio Grande Rift and the Socorro Magma Body
A	1	Brumbaugh	Seismic monitoring of the San Francisco volcanic field
A	1	Chamberlin et al.	Ignimbrite calderas and a large radiating mafic dike swarm of Oligocene age, Rio Grande Rift, New Mexico: Possible implications to restless calderas
A	1	Crumpler et al.	Environmental consequences of large volume lava flow fields in the southwest: Preliminary inferences from mapping the McCartys lava flow field, New Mexico
A	1	Crumpler et al.	The New Mexico volcano collection and resource: Volcanoes of New Mexico website developed by the New Mexico Museum of Natural History and Science
A	1	Driedger	Volcano work groups and effective communication partnerships for volcanic hazards education
A	1	Koper et al.	Capabilities of University of Utah Seismograph Stations for monitoring seismicity in Utah
A	1	Lu et al.	InSAR mapping of Holocene volcanoes in the western conterminous U.S. – preliminary results
A	1	Ramsey and Driedger	Spatial database of Holocene and Latest Pleistocene volcanic vents in the western conterminous U.S.
A	1	Venzke	Data compiled by the Smithsonian about volcanoes in the southwestern United States
A	1	White	Uncertainties regarding explosive maar-diatreme eruptions within volcanic fields
A	1	Zimmerer and McIntosh	Postcaldera magmatism at three Rio-Grande-rifted calderas: Implications for assessing volcanic hazards at active caldera systems in the USA

Poster Session B: Day 2: October 19, 14:40-15:45
Oral Session 1: Day 1 at 13:40
Oral Session 2: Day 2 at 09:30

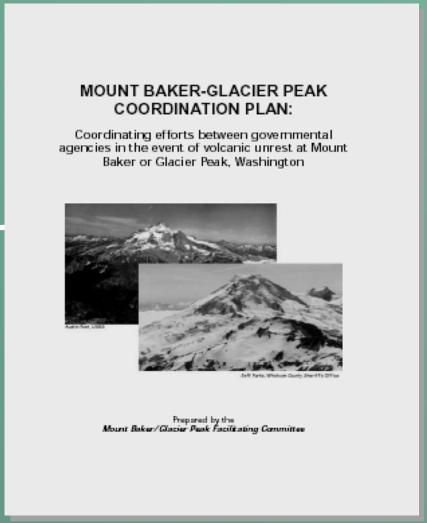
Poster Session	Oral Session	Authors	Title
B	2	Bleacher et al.	Surface textures and relationships indicative of endogenous growth at the McCartys and Carrizozo flow fields, New Mexico
B	2	Cortés et al.	Intrinsic conditions of magmas in Lunar Crater Volcanic Field, Nevada
B	2	Courtland et al.	Into the cone: a ground penetrating radar study of cone-building processes at Cerro Negro volcano, Nicaragua
B	1	Cousens and Henry	Geochemistry and hazard assessment of Pliocene-Quaternary volcanism beneath the central Siera Nevada and adjacent Great Basin, northern California and western Nevada
B	2	Haller	Estimating remobilization rate of ash deposited during the Puyehue (Southern Andes) eruption in 2011
B	1	Henry and Cousens	Young volcanism of the Lake Tahoe–Reno–Fallon area, California and Nevada: The geologic record
B	2	Johnson et al.	Tephra dispersal and deposition from the Marcath eruption, Lunar Crater volcanic field, Nevada
B	2	Karlstrom et al.	Focusing of melt by magma chambers in time and space: theory and application to Mount Mazama, Crater Lake, Oregon
B	2	Kiyosugi et al.	Relationship between dike and volcanic conduit distribution in a highly eroded monogenetic volcanic field: San Rafael, Utah
B	2	Roggensack and Moore	Experimental determination of H_2O and CO_2 solubility in basalt and basaltic andesite
B	1	Vazquez et al.	Timing of late Pleistocene volcanism at Big Pine volcanic field: insights from volcanic stratigraphy, cosmogenic ^{36}Cl dating and paleomagnetism.
B	1	Widom et al.	Petrogenetic processes in the Lunar Crater volcanic field, Nevada

Pondering consequences of a volcanic event in the American Southwest: Challenges for emergency management and scientific response

Christina Neal
US Geological Survey
Alaska Volcano Observatory
October 2012

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

WORKSHOP OBJECTIVES



MOUNT BAKER-GLACIER PEAK COORDINATION PLAN:

Coordinating efforts between governmental agencies in the event of volcanic unrest at Mount Baker or Glacier Peak, Washington

Prepared by the
Mount Baker/Glacier Peak Facilitating Committee

- Communicate who is responsible for what in a crisis
- Communicate roles and limitations of USGS
- Communicate roles of other federal agencies (NOAA, FAA, DOD)
- Understand resources available for emergency management
- Discuss needs (e.g. regional plans, regular ongoing activities, etc.)
- Increase awareness of volcanism and vulnerabilities in the SW
- Ponder eruption probabilities in regions with rare, distributed volcanism

USGS

Please jot down 1-2 main questions or concerns you have about preparing for the next episode of volcanic unrest or eruption in the American Southwest.

USGS

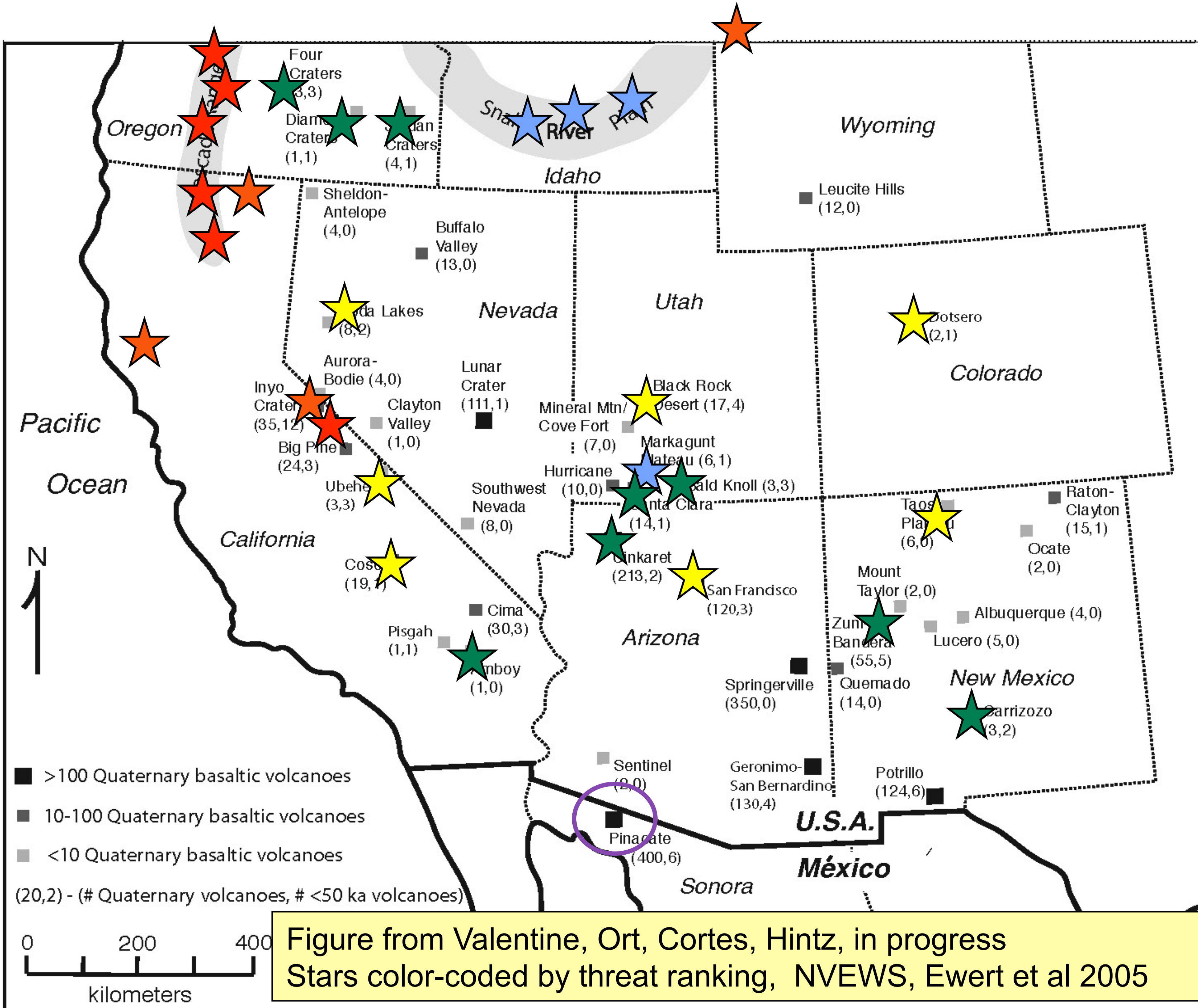
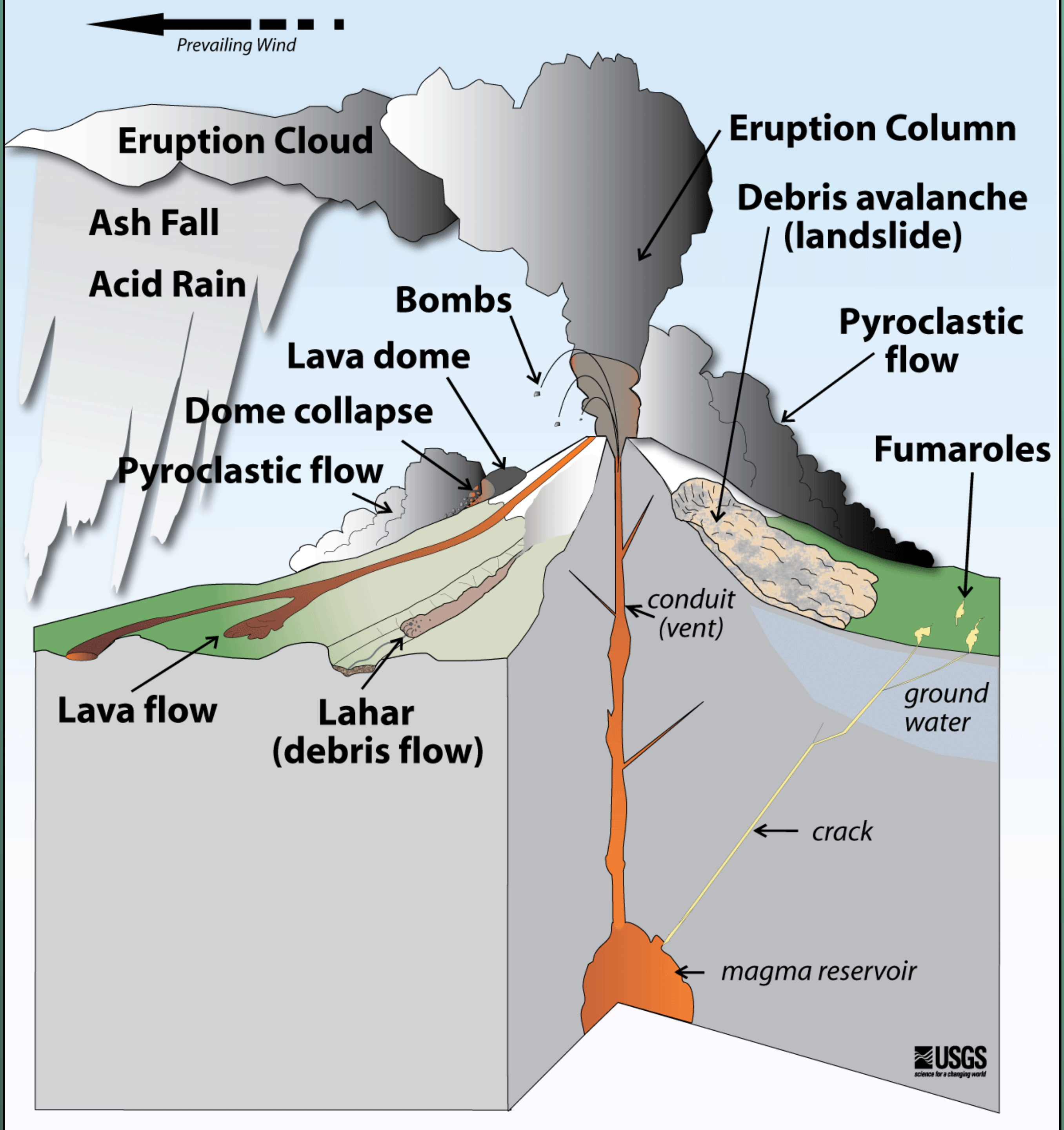
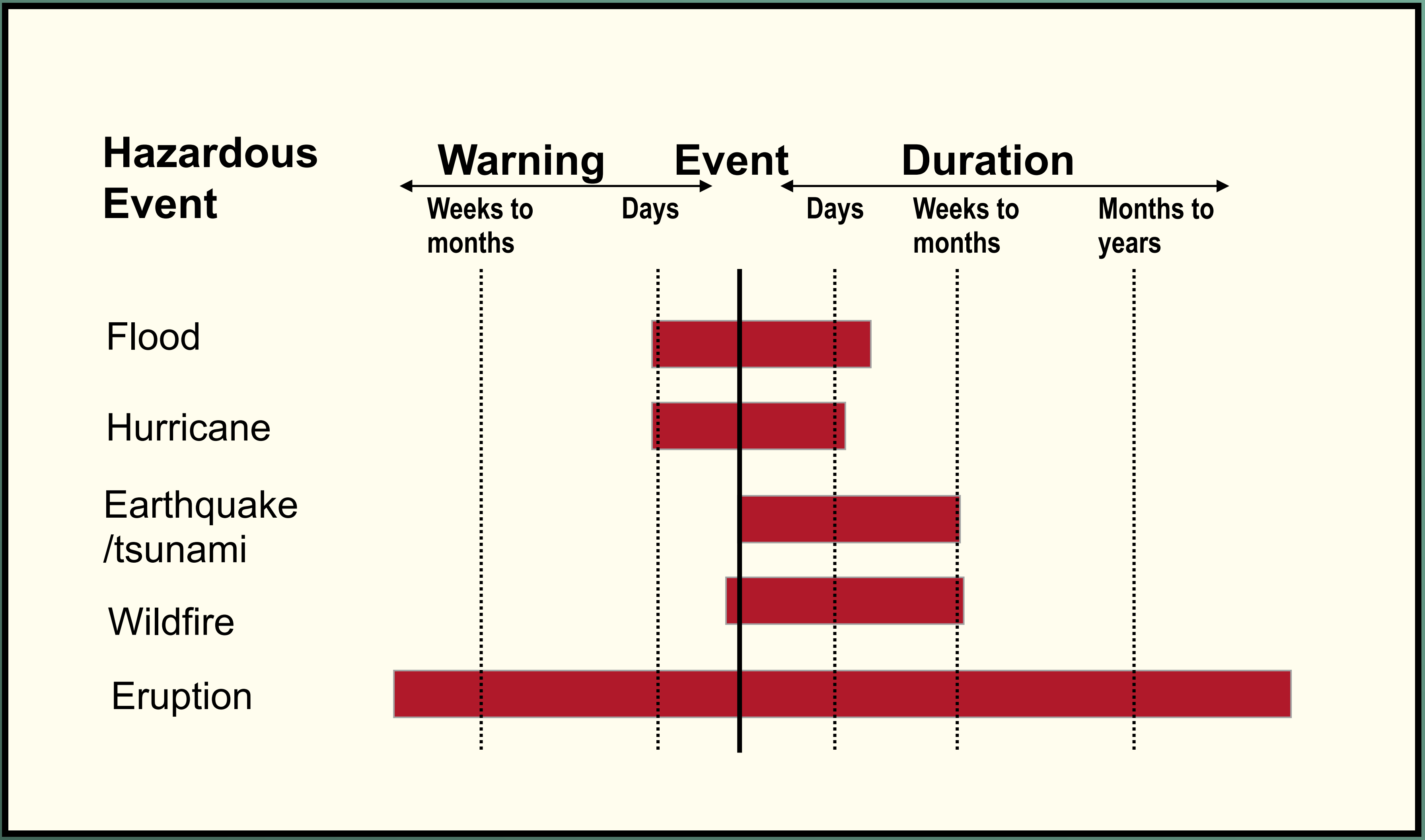


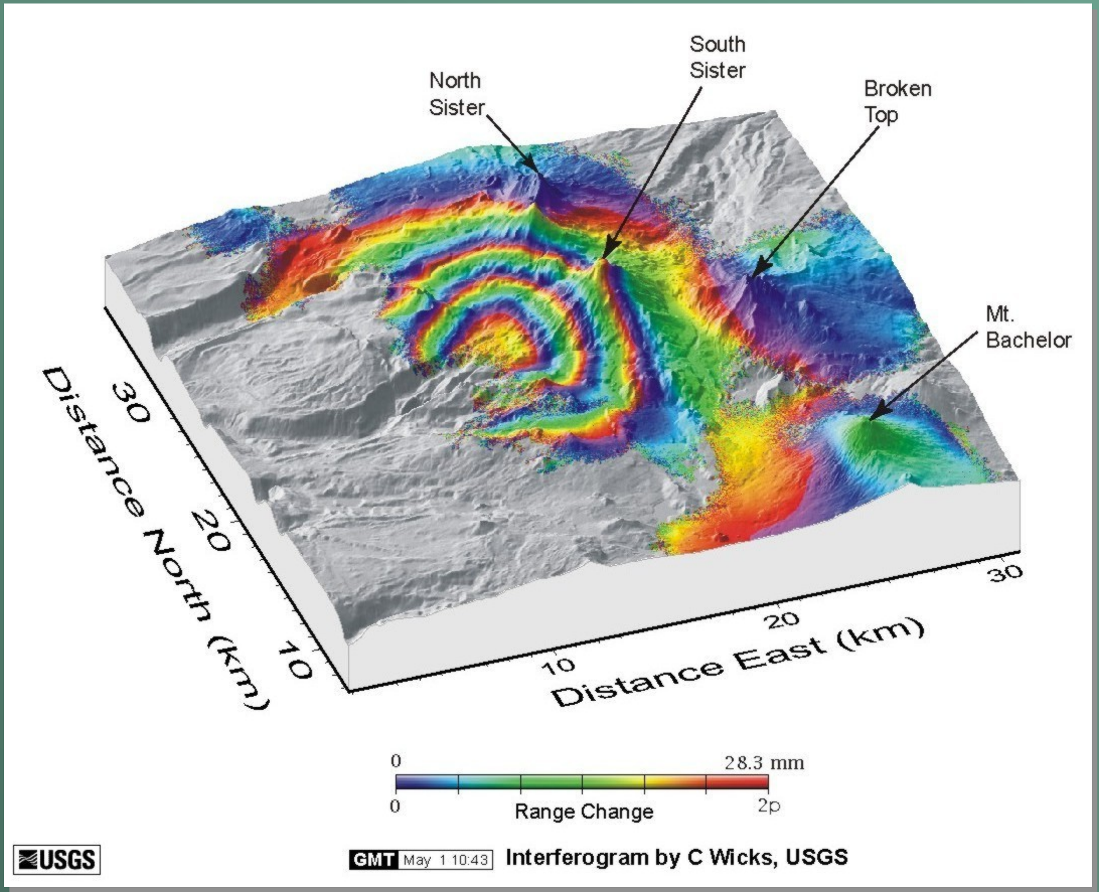
Figure from Valentine, Ort, Cortes, Hintz, in progress
Stars color-coded by threat ranking, NVEWS, Ewert et al 2005


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

Eruptions compared to other natural hazard events



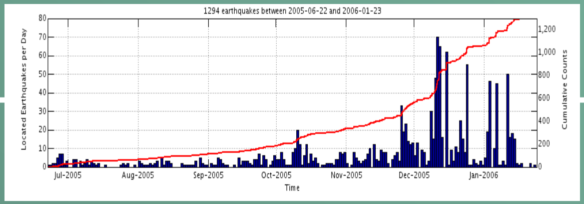
Detection of unrest



USGS

Uplift in Three Sisters area, central Oregon (2001)

Unrest prompts many questions:



- Where is relevant monitoring data?
- Who is responsible for integration and interpretation?
- Increased monitoring: By whom? Funding? Data management?
- Permitting issues (federal/state/tribal, etc.) to address?
- Is it time to do a hazard and/or risk assessment? How is that best accomplished?
- *How much energy to invest in planning at this stage?*

USGS

AVO/USGS Volcanic Activity Notice

Volcano: **Little Sitkin** (CAVW #1101-05-)

Current Volcano Alert Level: ADVISORY
Previous Volcano Alert Level: UNASSIGNED

Current Aviation Color Code: YELLOW
Previous Aviation Color Code: UNASSIGNED

Issued: Thursday, August 30, 2012, 4:20 AM AKDT (20120830/1220Z)
Source: Alaska Volcano Observatory
Notice Number: 2012/A10
Location: N 51 deg 57 min E 178 deg 32 min
Elevation: 3898 ft (1188 m)
Area: Aleutians Alaska

Volcanic Activity Summary: At approximately 19:15 AKDT (04:15 UTC) last night, a swarm of high-frequency earthquakes began at Little Sitkin Volcano. The continuation of this anomalous seismic activity through the night prompts AVO to raise the Aviation Color Code to YELLOW and the Volcano Alert Level to ADVISORY. No eruptive activity is currently indicated.

Little Sitkin is monitored by a 4-station seismic network as well as satellite imagery. Little Sitkin Island is located 35 km (21 mi) northwest of Amchitka and 320 km (200 mi) west of Adak in the remote western Aleutian Islands. The last eruption of Little Sitkin is questionable and may have been in the early 1900s.

National Volcano Alert Level System

Volcano alert level

TERM	DESCRIPTION
NORMAL	Typical background, non-eruptive state
ADVISORY	Elevated unrest above known background activity
WATCH	Heightened/escalating unrest with increased potential for eruptive activity. timeframe variable, **OR,** minor eruption underway that poses limited hazards
WARNING	Highly hazardous eruption underway or imminent

Aviation color code

COLOR	DESCRIPTION
GREEN	Volcano is in normal non-eruptive state
YELLOW	Volcano is exhibiting signs of elevated unrest above known background levels
ORANGE	Volcano is exhibiting heightened/escalating unrest with increased potential of eruption; timeframe variable **OR,** eruption underway with no or minor ash emissions
RED	Eruption is forecasted to be imminent with significant emission of ash into the atmosphere likely **OR**, Eruption is underway with significant ash into the atmosphere

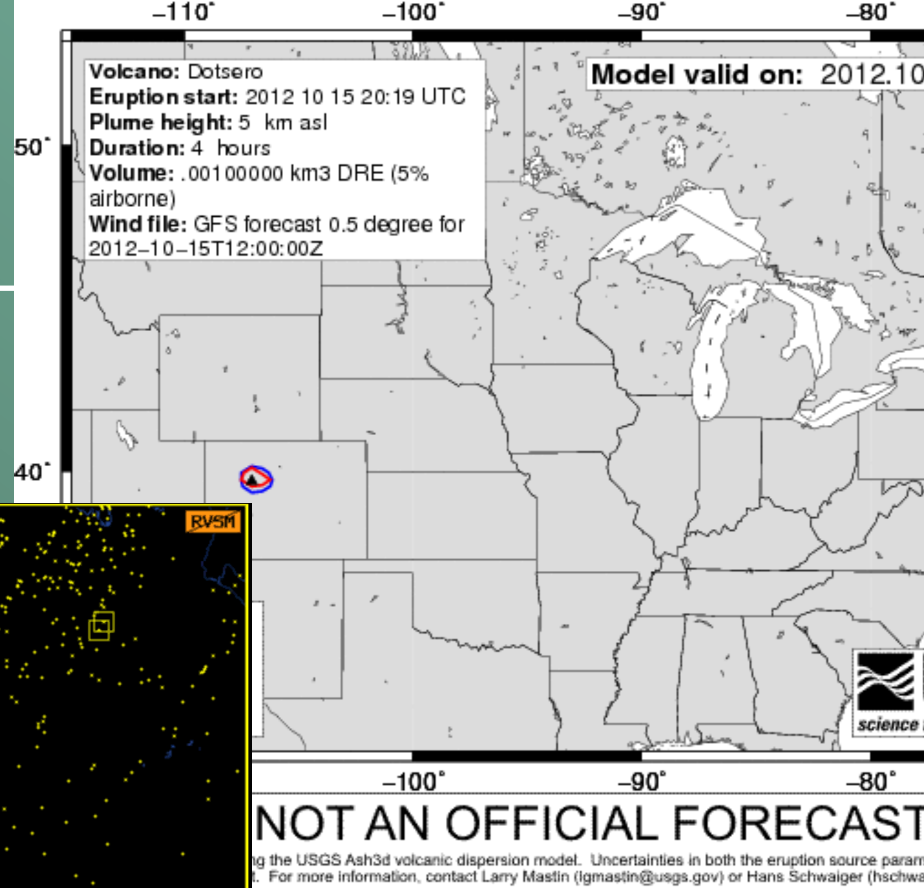
USGS

Accelerating unrest…more questions:

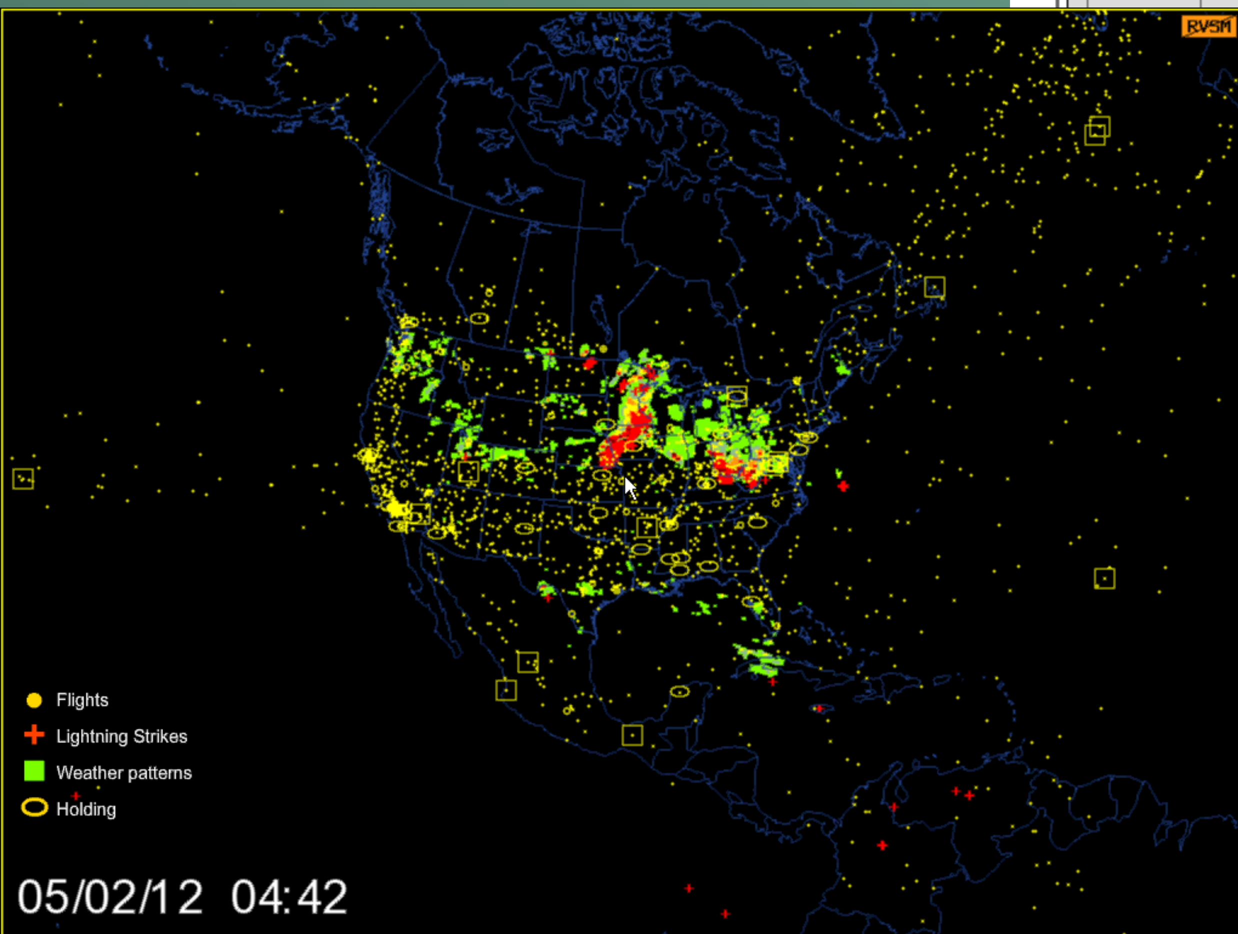
- Interagency coordination critical: who does what?
- Who are the authoritative sources for hazard information and 'call to action' guidance?
- How do we ensure a consistent message? Time for ICS/JIC?
- Can/should scientists develop probability statements?
- What are the scientific opportunities?

USGS



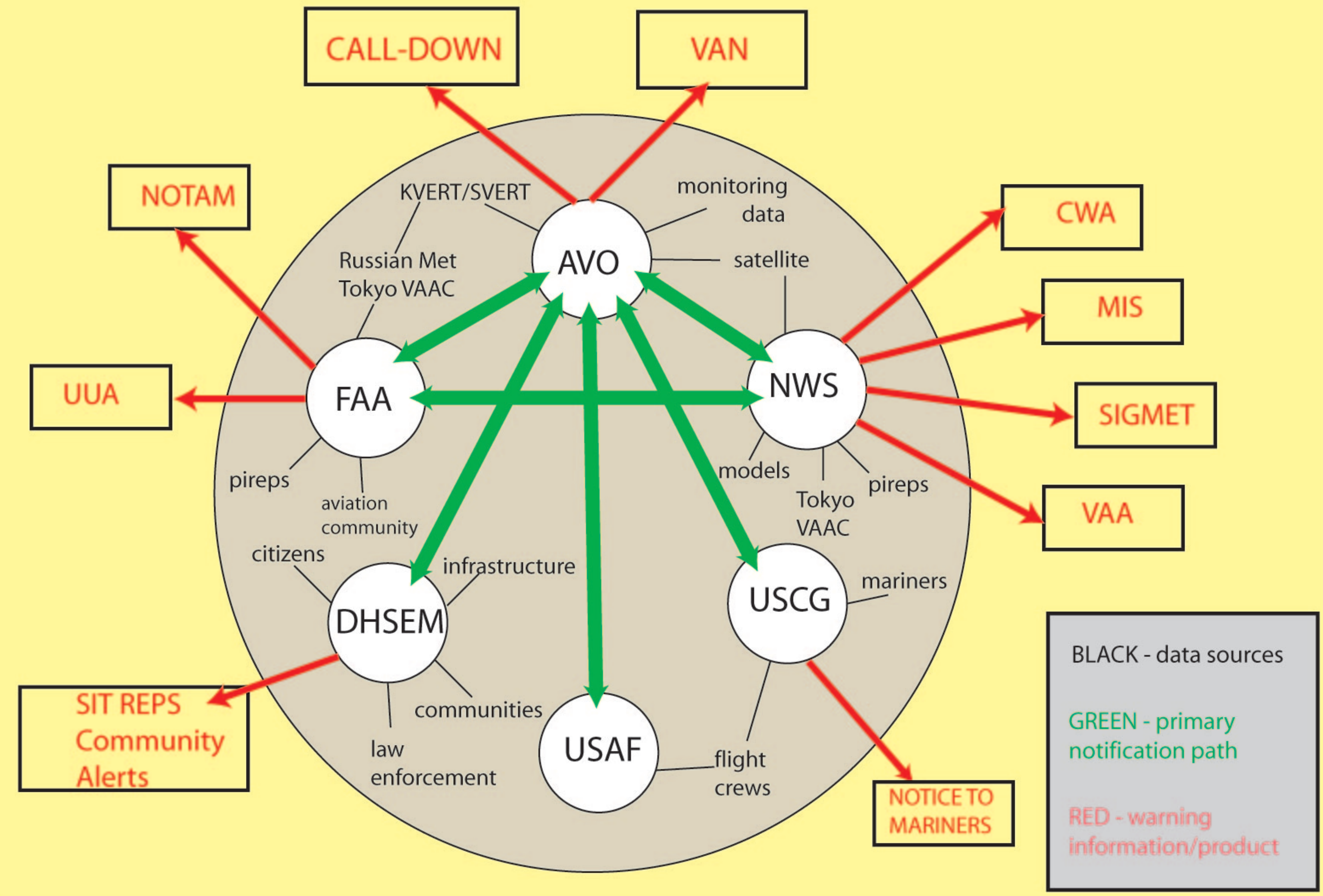



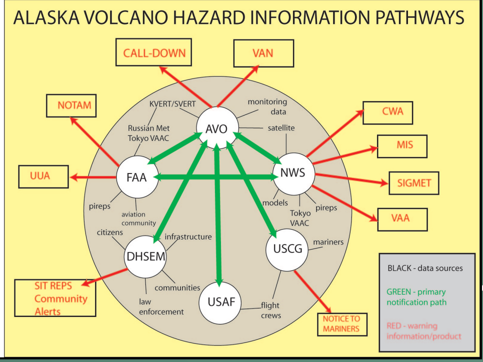
Volcano: Dotsero
Eruption start: 2012 10 15 20:19 UTC
Plume height: 5 km asl
Duration: 4 hours
Volume: .00100000 km3 DRE (5% airborne)
Wind file: GFS forecast 0.5 degree for 2012-10-15T12:00:00Z
Model valid on: 2012.10
–110˚
–100˚
–90˚
–80˚
50˚
40˚
science
NOT AN OFFICIAL FORECAST



RVSM
Flights
Lightning Strikes
Weather patterns
Holding
05/02/12 04:42

ALASKA VOLCANO HAZARD INFORMATION PATHWAYS





The fog of eruption response

- Managing information explosion (incoming and demand for)
- Can agencies handle increased staffing/spending loads?
- Are we updating hazard and risk assessments and guidance as the eruption progresses?
- A coordinated science response underway?
- Is the hazard message getting through? How do we know?

In the aftermath:

- Is it really over?
- Hazards and impacts will continue; long term monitoring plan?
- Managing field access to scientists, media, the public
- Capturing impacts, lessons learned

USGS

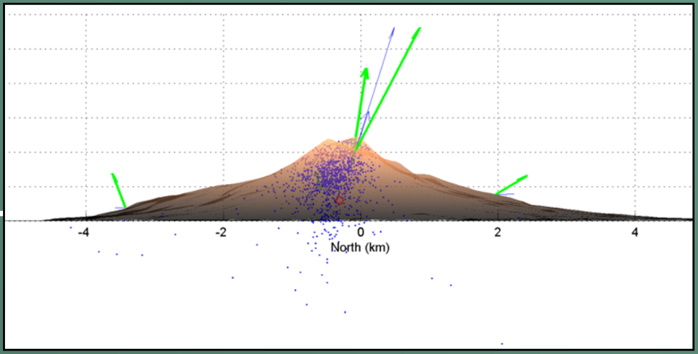
Particular challenges for EM

- Planning for a low probability, potentially high consequence event
- Widespread unfamiliarity within affected sectors
- Potentially large uncertainties throughout the event
- Impacts will likely span multiple jurisdictions
- Potential for chronic impacts and hazards even after eruption is over

USGS

Particular challenges for scientists

- Recognizing the unrest, converging on an interpretation
- Rapid marshalling of appropriate expertise
- Explaining uncertainties clearly
- Supporting response needs
- Taking advantage of science opportunities



USGS

P. Cervelli, USGS

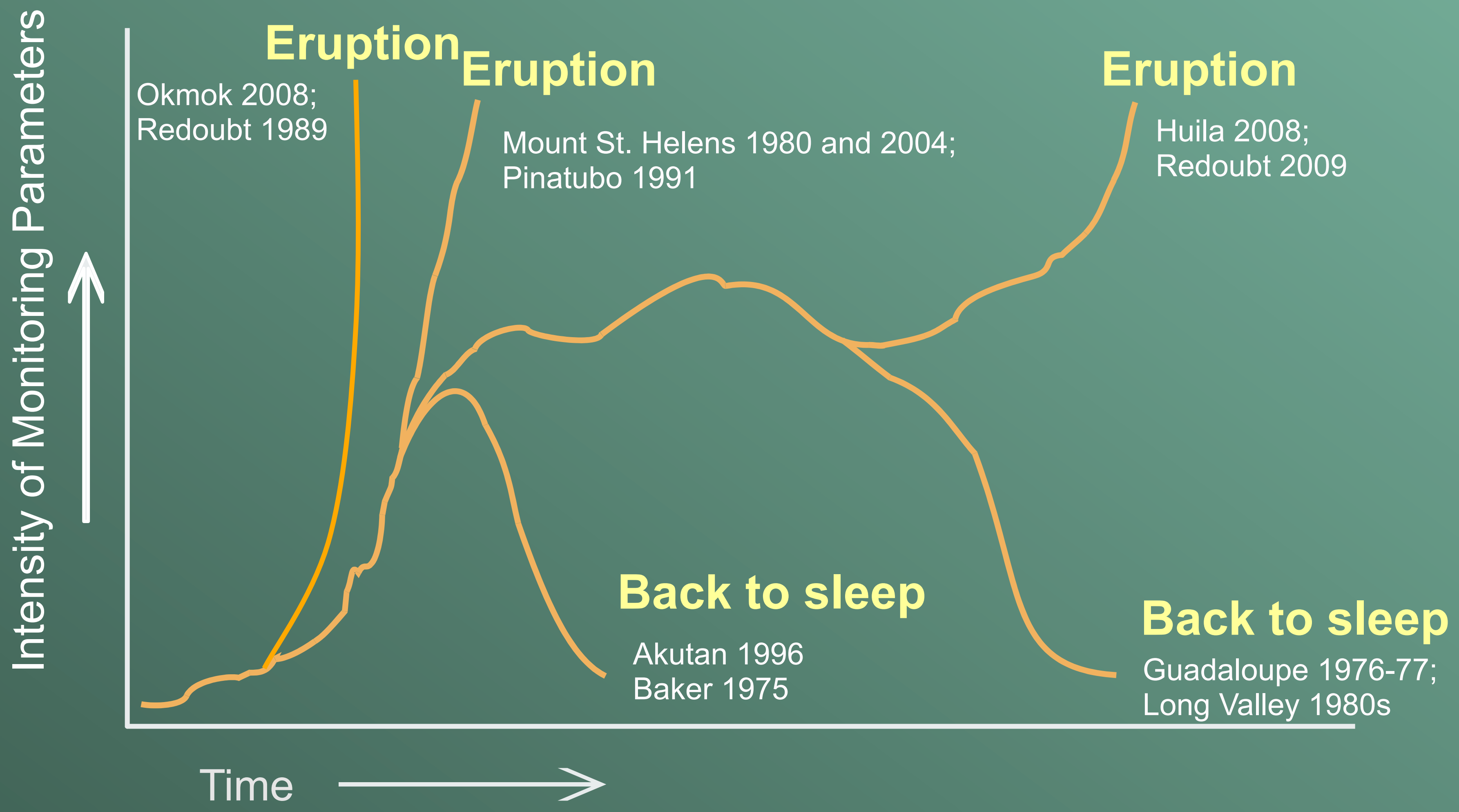
Cross-cutting challenge

"The potential hazards (of a likely eruption in the SW) while appreciable, are less extensive than at a reawakening stratovolcano, but assessment is complicated by the fact that a new eruption could occur at an unknown location within a broad area with widely varying land use patterns."

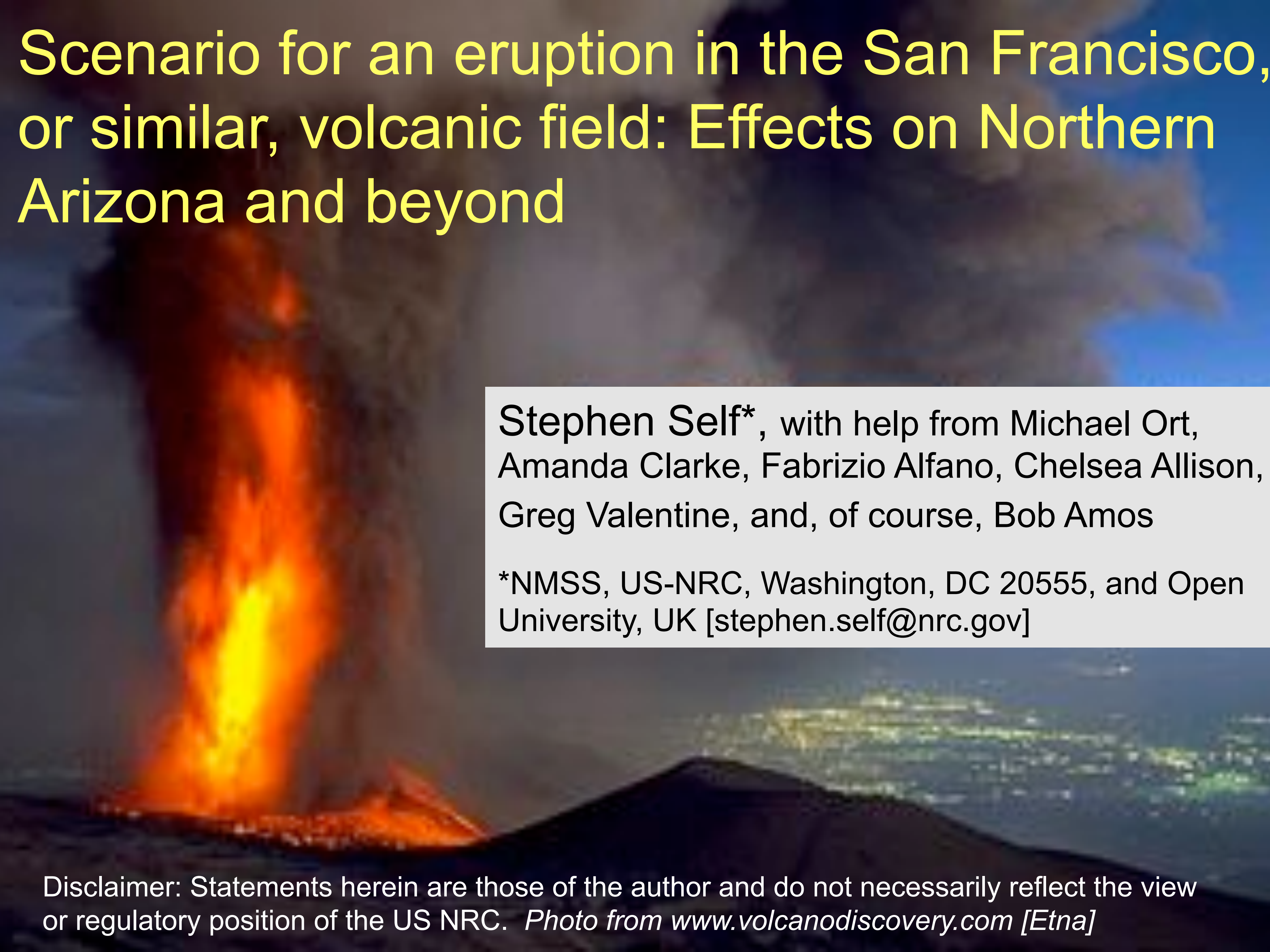
Ort and Valentine, this meeting

USGS

Uncertain trajectories



Scenario for an eruption in the San Francisco, or similar, volcanic field: Effects on Northern Arizona and beyond



Stephen Self*, with help from Michael Ort, Amanda Clarke, Fabrizio Alfano, Chelsea Allison, Greg Valentine, and, of course, Bob Amos

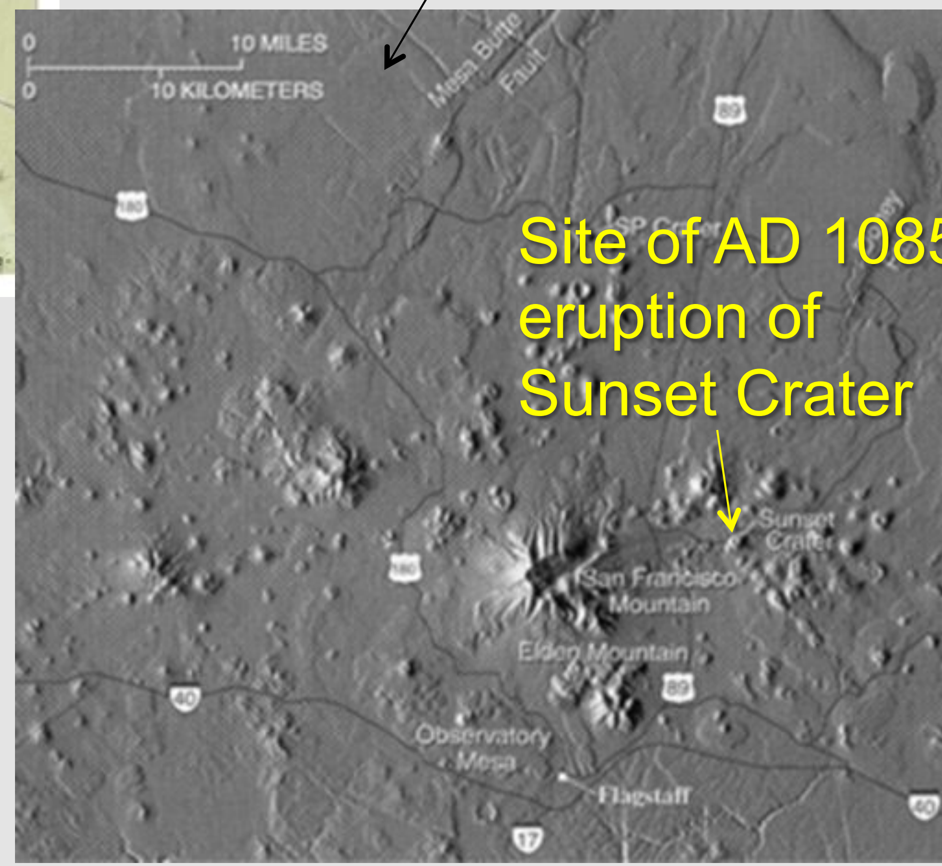
*NMSS, US-NRC, Washington, DC 20555, and Open University, UK [stephen.self@nrc.gov]

 Photo from www.volcanodiscovery.com [Etna]

What, when, where?

SFVF contains products of wet & dry eruptions. Sunset was essentially dry

San Francisco Volcanic Field



Next talk -- Volcanism in the American Southwest over the last million years: what happens here, how often, and why? *Greg Valentine and Michael Ort*

Plus see *Ed Venzke's* poster for a perspective of the young end of this time spectrum.

Topics

- Deposits of the Sunset Crater eruption –> a "scenario"
- Fissure and lava flows
- Fallout deposits – possible hazards
- Style, sequence, and duration of eruption
- Consequences for hazard and risk, and future work

Sunset Crater scoria cone, San Francisco Volcanic Field, Flagstaff, AZ

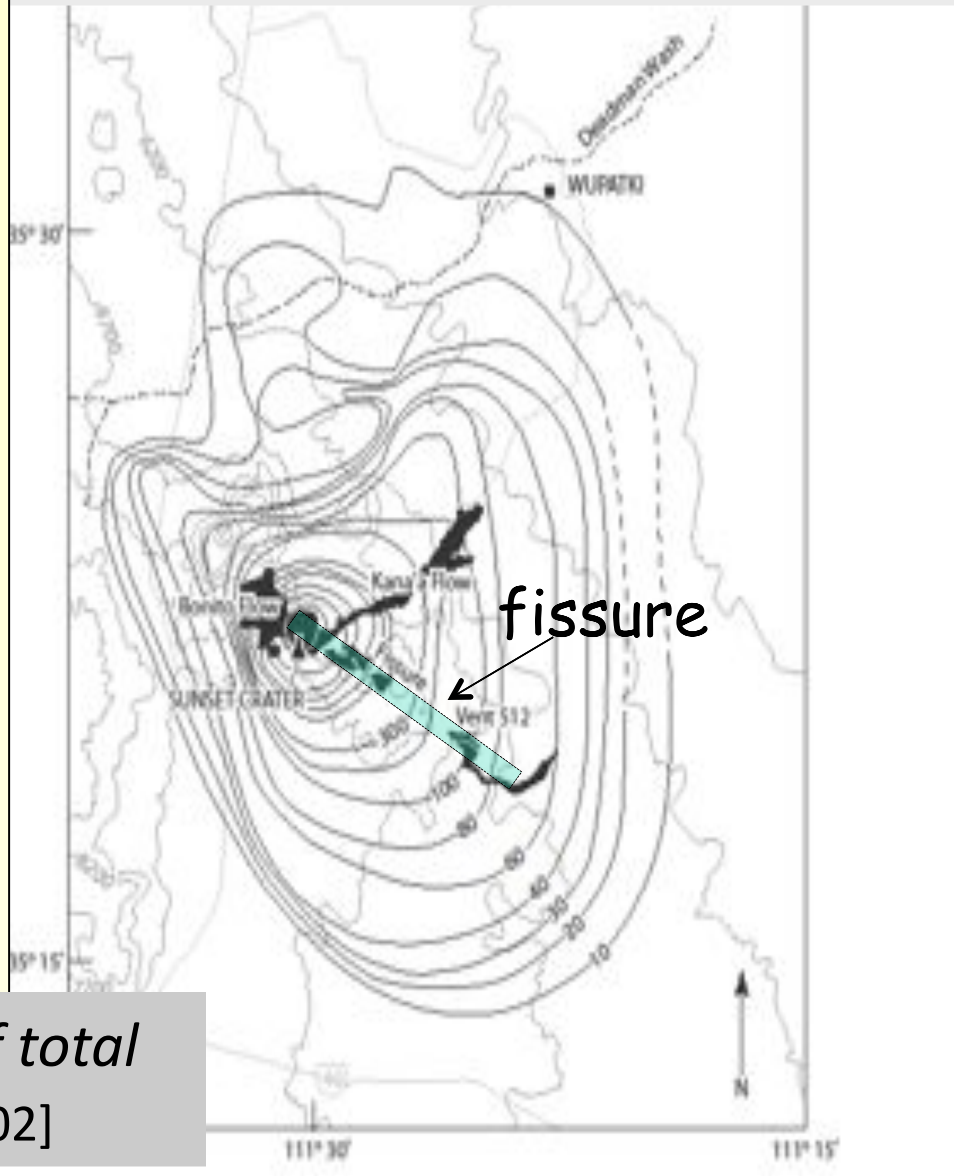
Products of Sunset eruption *– recognition permits us to develop a scenario, from which we can consider aspects raised in Tina Neal's talk*

Sunset scoria ***cone*** formed at NW end of 10-km-long [6 mile] eruptive fissure

Broad (1.6-km-wide [1 mi] base), ~ 300-m-tall [980 ft] cone grew at same time as ***multiple scoria fall units*** were deposited

Three lava flows; longest flowed down a pre-existing valley for 11 km [7 mi]; lavas formed over most of period of activity; Vent 512 lava "oldest"

Fissure active at various points for much of event; erupted homogenous ***basalt magma***



Map of lavas, cone, and thickness of total fallout deposit in cm [Hooten & Ort 2002]

Fissure and lava flows

Vent 512 lava buried by fall units 2 - ?5; stopped flowing earliest; slabby pāhoehoe

Kana´a flow: longest, 11 km [7 mi]; from vent under SE flank of Sunset cone; lavas formed over most of eruption – distal parts of flow have no tephra cover but base of lava rests on up to 6 scoria fall units; slabby to spinose pāhoehoe

Bonito flow: from Sunset vent; complex history - early parts carry rafted cone blocks [Holm 1987]; most has tephra/ash cover, but later breakouts from inflating flow have no cover

Hazards – very local, but could cause forest fires in some areas

Cone and fall deposits – *for details of fall deposits see the Fabrizio Alfano et al. poster*

Sunset scoria cone: grew over extended period; dimensions depend on topography engulfed; reconstructed itself after rafting events during effusion of Bonito lava flow; most of flow thickly mantled by scoria fall units

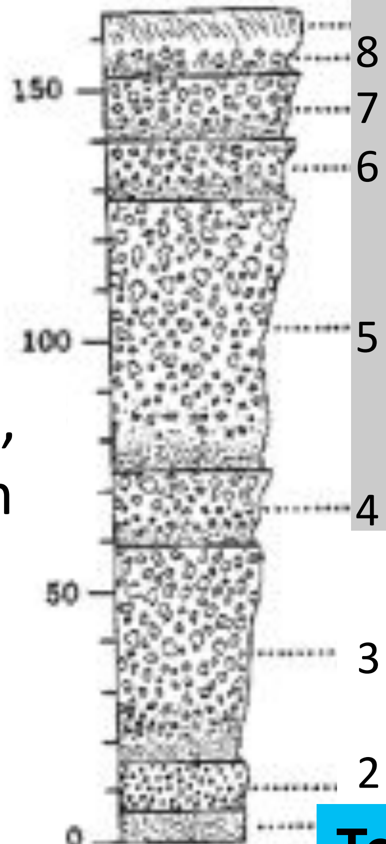
Sunset cone formed upon pre-Sunset cone(s) and possibly partly buried early Kana´a vent cone/spatter pile

Formation featured violent Strombolian activity, interpreted from coeval scoria fall deposits. **Hazard***: burial of small area, fire*
Cone volume: 0.25 - 0.35 bulk, or ≤ 0.2 km^3 DRE, depending on dimensions used; *not huge but at upper end of global spectrum*

250-m –high 1986 fire fountain at Pu`u `Ō`ō , Kilāuea (helicopter for scale) [photo by Colin Wilson]

Cone and fall deposits - 2

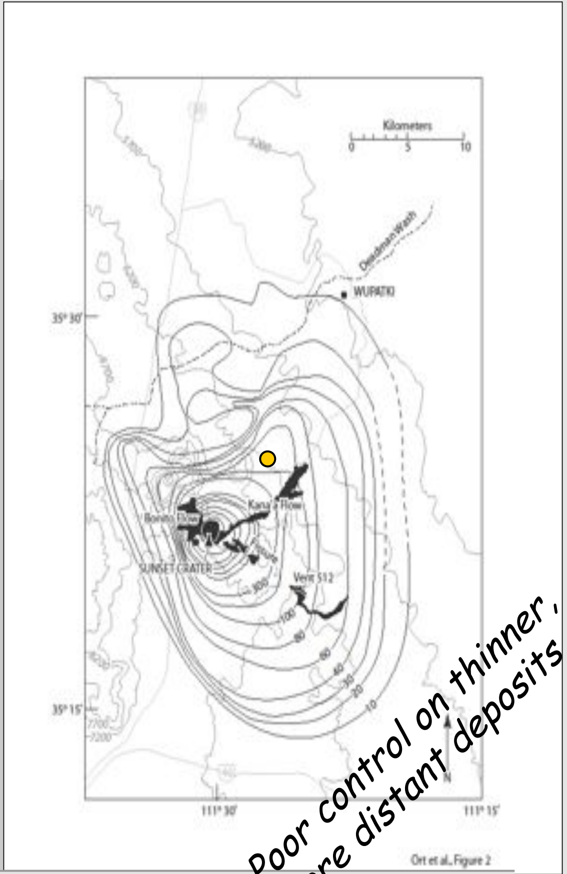
Site 62

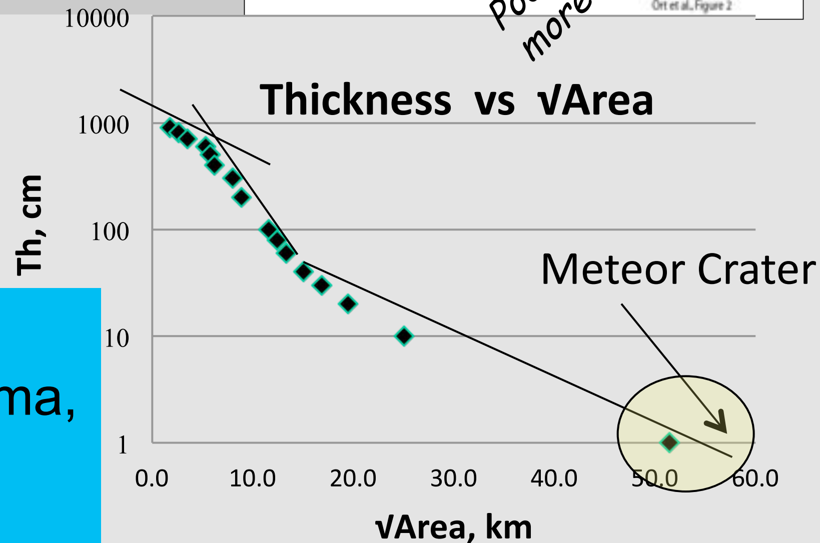


Th, cm

Sunset fallout deposits are wide-spread compared with other those from other Strombolian eruptions (next slide)

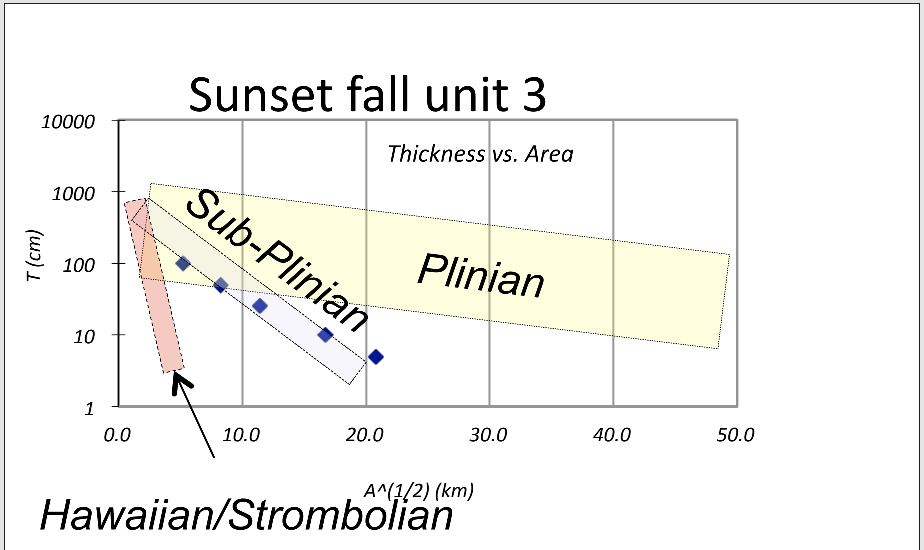
From a hazards perspective, it is the widely-distributed finer ash component of the ejecta that is of major concern, and this is rarely preserved, even for young events





Total fall deposit volume: 0.7km^3 bulk, ≈ 0.35 km^3 magma, a little less than the Mount St Helens 1980 eruption

Cone and fall deposits - 3



Comparison of tephra thinning relationships on thickness vs √area plot, showing known basaltic deposit fields [Houghton & Gonnermann 2007]

Isu-Oshima 1986, 1-km-high fire-fountain, accompanied by 17-km-high columns and followed by cone growth and lava flows

Not known if other SFVF or SW volcanic fields have such widespread fall deposits (next slide). Sunset's eruption column heights, from 7-23 km [< 75,000 ft] above sea level*, reach well above aircraft cruising altitude

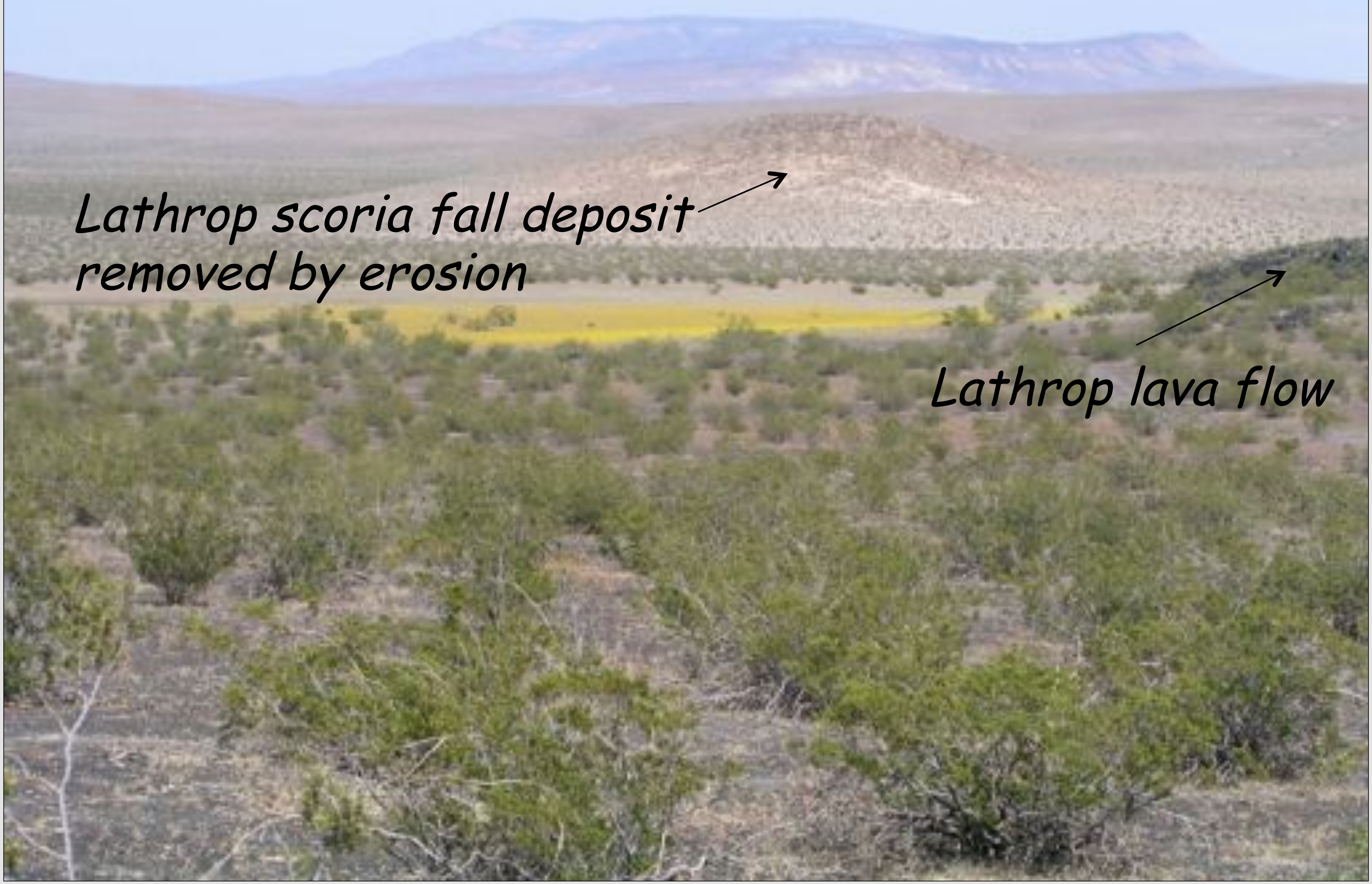
Fabrizio's poster gives details of the Sunset fall deposit, showing it to be one of the most widespread of its kind yet studied*.

Colton (1950s) remarked on ash fall in Kansas; > 650 km away; would require 15+ km-high ash column and cloud and 80 m/s winds for a 63 micron ash particle to reach there – thus not impossible!

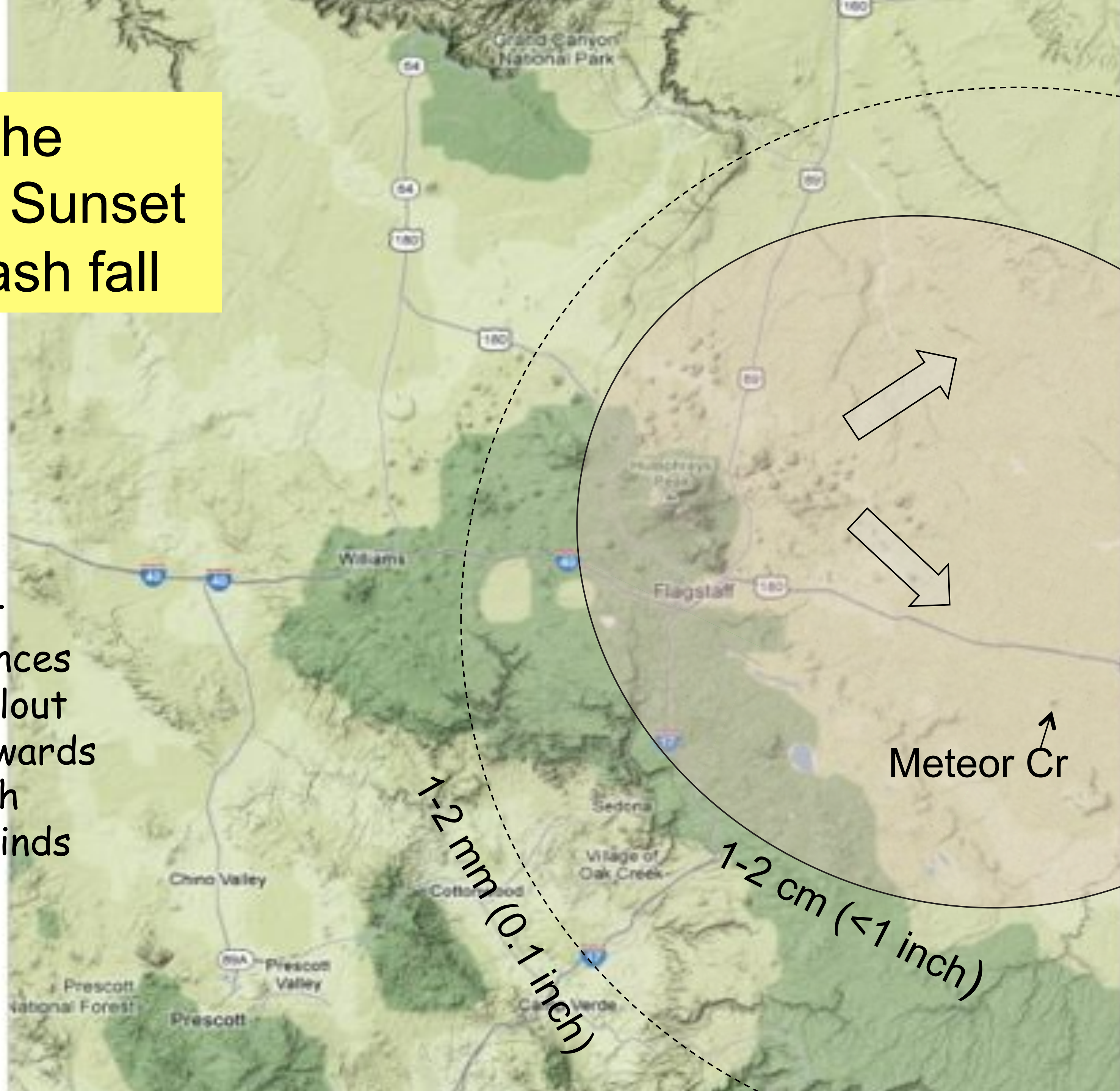
SW Nevada Volcanic Field, near Beatty, NV

Lathrop Wells cone, 74,000 years old.
Work by Greg Valentine (e.g., 2007) shows this cone was also formed by "violent Strombolian" eruptive activity

Lathrop Wells deposits, alternate view

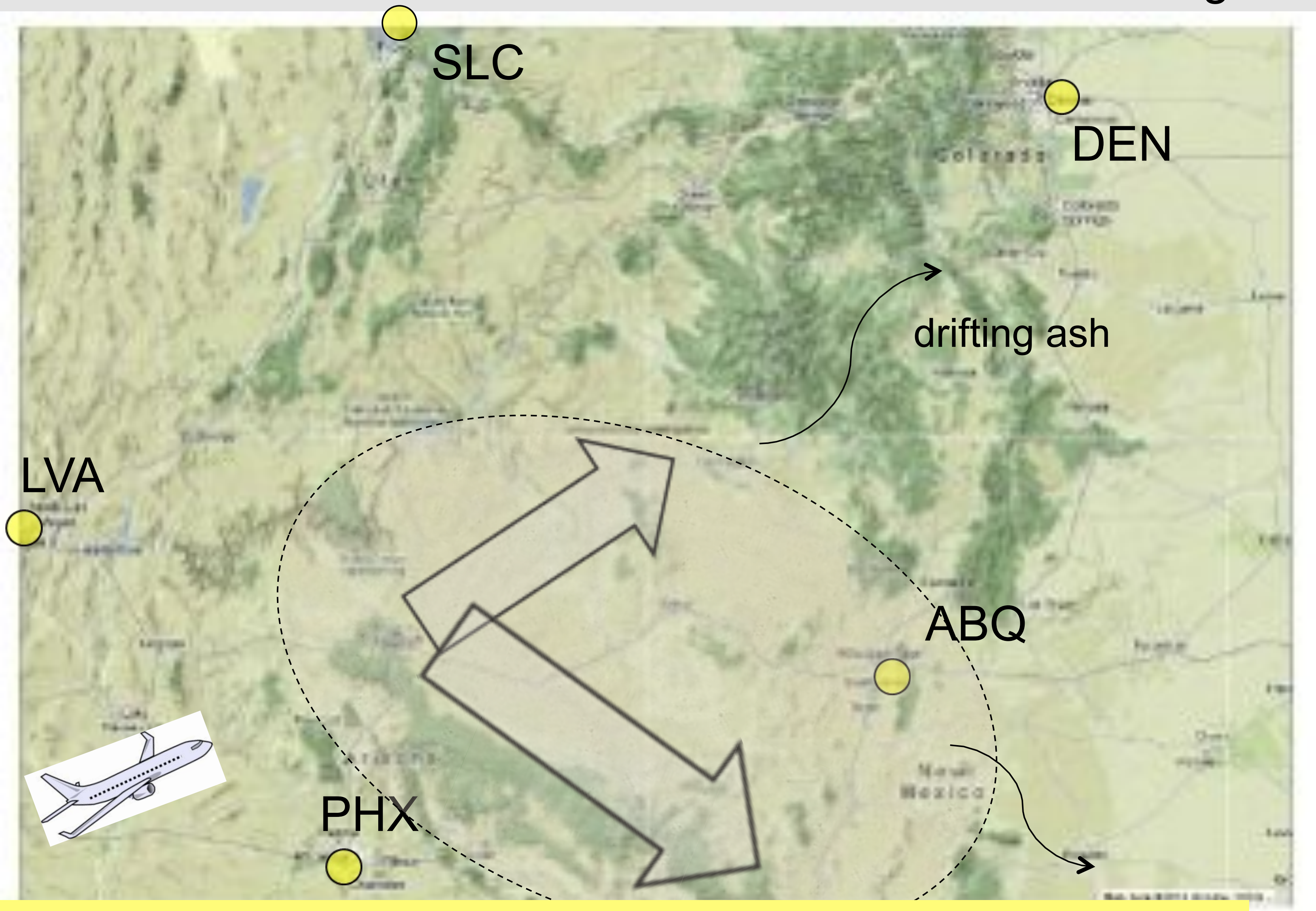


A guess at the dispersal of Sunset scoria and ash fall



shows dispersal axes for various fallout units, but at greater distances prediction of fallout pattern is ? SE-wards is consistent with hi-level winter winds

A “what-if” look at aviation and ash in the 4 Corners region

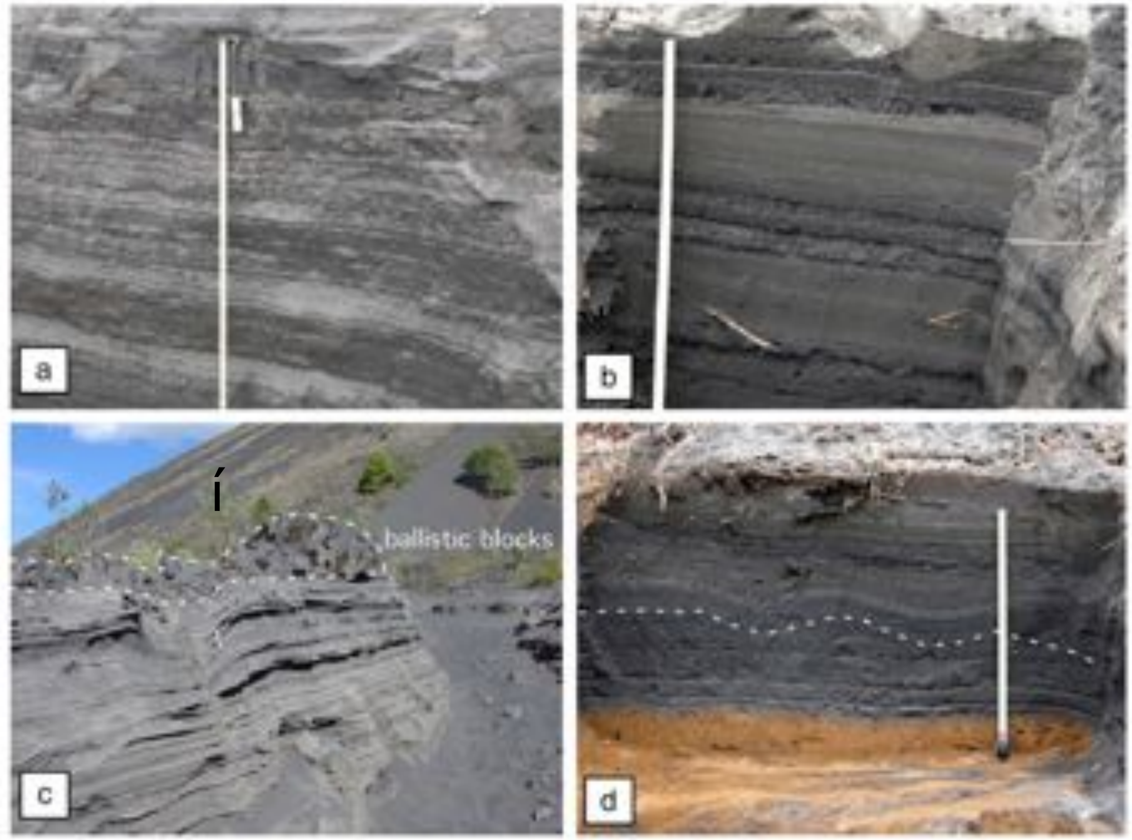


Remember that the ash cloud that brought European aviation to a standstill for 10 days in Spring 2010 left no traceable deposit!

Possibility of greater amounts of fine ash and surface-wind-induced re-distribution of ash

Re-distribution will occur during, and for months to years after, the eruption, *affecting surface and local air transport.* *(Next slide)*

[Not discussing gas release (sulfur gases, etc.) from such eruptions, but see the poster by Larry Crumpler et al.]



Ash-rich Paricutín deposits, 1943-49 (Pioli et al. 2008); wet SW USA eruptions also produce much fine ash. Paricutín (Mexico) was a Strombolian eruption.

Fallout of ash from Chaiten (Chile) 2008, with re-distribution by surface winds

[Image from S. Carn, IAVCEI Remote Sensing Commission.]

Wind-streaks of ? Sunset ash NE of Flagstaff area. Eolian erosion is impt.!

Style, sequence, and duration of eruption

- Compared to similar eruptions worldwide, Sunset eruption was relatively large, and high intensity (at times), yielding high-altitude ash clouds.
- Eruption followed typical Strombolian sequence: fissure, cone-building & fall deposit-forming phases; lavas, late explosions formed red agglutinate deposit on crater rim at top of Sunset cone.
- **Duration of eruption** *is still uncertain, but is important for hazard assessments.* From **~ 2 months** (based on length of Kana´a flow) to a maximum of **1-2 years**, based on the almost complete lack of reworking of fall unit tops (from the work of Michael Ort and others).

Similar recent eruptions	Cone (km^3)	Fall deposit (km^3)	Lava (km^3)	Total magma volume (km^3)
Sunset Crater	< 0.2	> 0.35	0.15	> 0.70?
Tolbachik 1975	0.2 (2 cones)	0.2	0.3	0.70
Heimaey 1973	0.02	>> 0.01	0.2	> 0.23
Paricutín 1943+	0.15	0.2-0.3?	0.60	> 0.95
Jorullo 1759+	< 0.1(2 cones)	0.19	0.4	~ 0.6

Summary & future work, for hazard and risk assessment

- The type of eruptions discussed here have rather localized deposits, EXCEPT for the *ash component*. For a Sunset-scale eruption, there would be only a trace of fine ash fall-out beyond Northern Arizona and where it travels and falls out depends on wind-directions (thus on altitude of column/cloud and season of year). *Ash from Paricutín fell in Mexico City, > 400 km away!*

- Primary and wind-redistributed ash will be a hazard for communication routes such as I-40, and for local airports, but a major issue would be *risk to aviation for flights crossing the region and landing at PHX, etc*.

- **Sunset and Lathrop Wells are just a couple of case studies** – we need to know the range and types of basaltic eruptions and deposits in the Southwest; frequency of dry and wet eruptions, etc., etc.?

- **Durations of eruptions** are as important as recognizing the styles, deposits, and sizes (volumes) – *persistence of hazard and risk is extremely devastating* on communities, services, scientists, etc. (e.g., Montserrat Island and Soufriere Hills eruption). + re-distribution?

Some good news?

- Many basaltic, Strombolian style, eruptions in the American Southwestern have produced much *ash,* and future ones will repeat this.

- Ash causes disruptions to surface transport systems and many services, is an abrasive nuisance, and in suspension can cause respiratory problems. However, ***basaltic ash*** *is not recognized to carry minerals that cause severe health hazards*.

- On the longer term there may be *beneficial ash-deposit-induced changes in soil properties*, such as > in moisture content, dependent on location of the next eruption and the local geologic setting.

Date of Sunset eruption

Sunset fissure was thought to have become active in AD1064, with eruption lasting until c. AD 1250 (Pilles 1979; see also Holm and Moore 1989).

Newer paleomagnetic work (Ort et al. 2002) narrowed down duration to 40-60 years within the period AD 1020-1170.

Wupatki pueblo

Recent dendrochronological [Elson, Ort et al., 2009] and dendrochemical studies (Sr isotopes + content of P and S in tree rings) suggest eruption at AD 1085, i.e., 927 years ago.

A total eruptive volume of >= 0.7 km^3 places the Sunset eruption above that of Mount St. Helens AD 1980 in terms of amount of magma expelled, and probably makes this the largest basaltic eruption in the lower 48 in last ~ 1000 years). Possibly the Inyo – Mono rhyolitic lava-flow and explosive activity (California) ~ 600 years ago was more voluminous? Cinder Cone (near Mt Lassen, CA), ~ 350 years ago may be the youngest Strombolian eruption

Basaltic volcanism in the American Southwest over the last million years: what happens where, how often, and why?

G.A. Valentine[1] and M.H. Ort[2]

[1]Dept. of Geology and Center for Geohazards Studies
University at Buffalo

[2]School of Earth Sciences and Environmental Sustainability
Northern Arizona University

Outline

- Overview of Quaternary basaltic volcanism
- Types of eruptive processes and hazards
- Region-scale frequency and uncertainties
- Conceptual models for the volcanism
- What warning might we have?
- Hazards management and challenges

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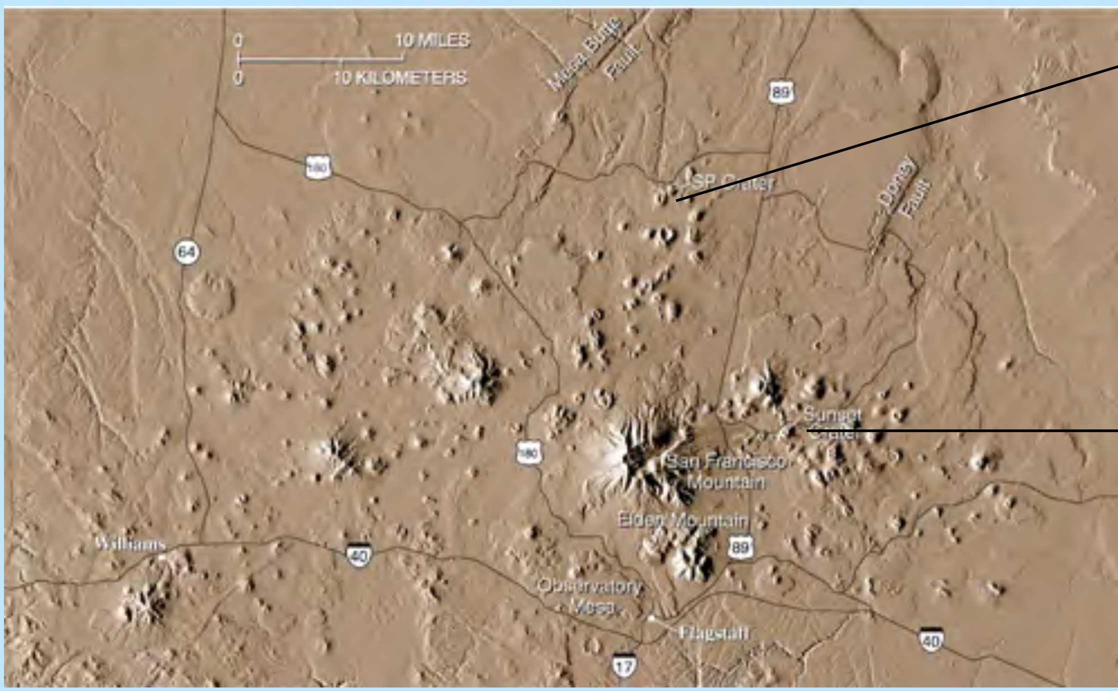
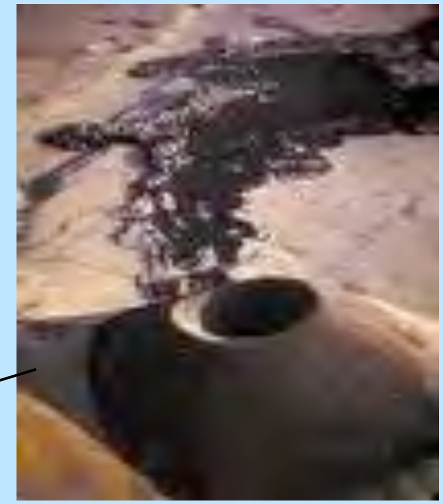
Basaltic volcanoes in the Southwest

- Small volume
- Monogenetic
- Occur in "fields" with up to a few hundred individual volcanoes





Scoria-cone volcanoes

Basaltic volcanism in the geologically recent past

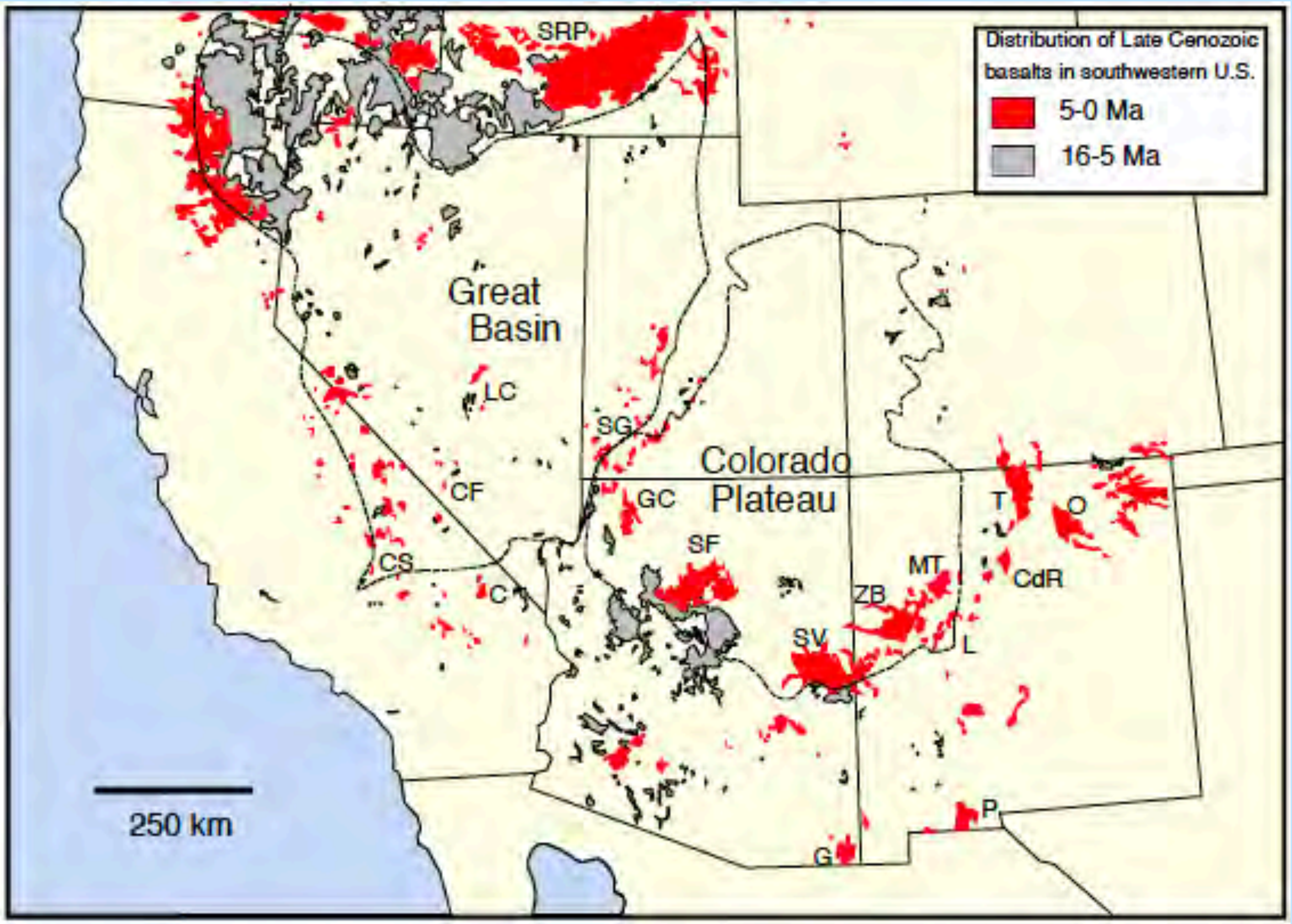
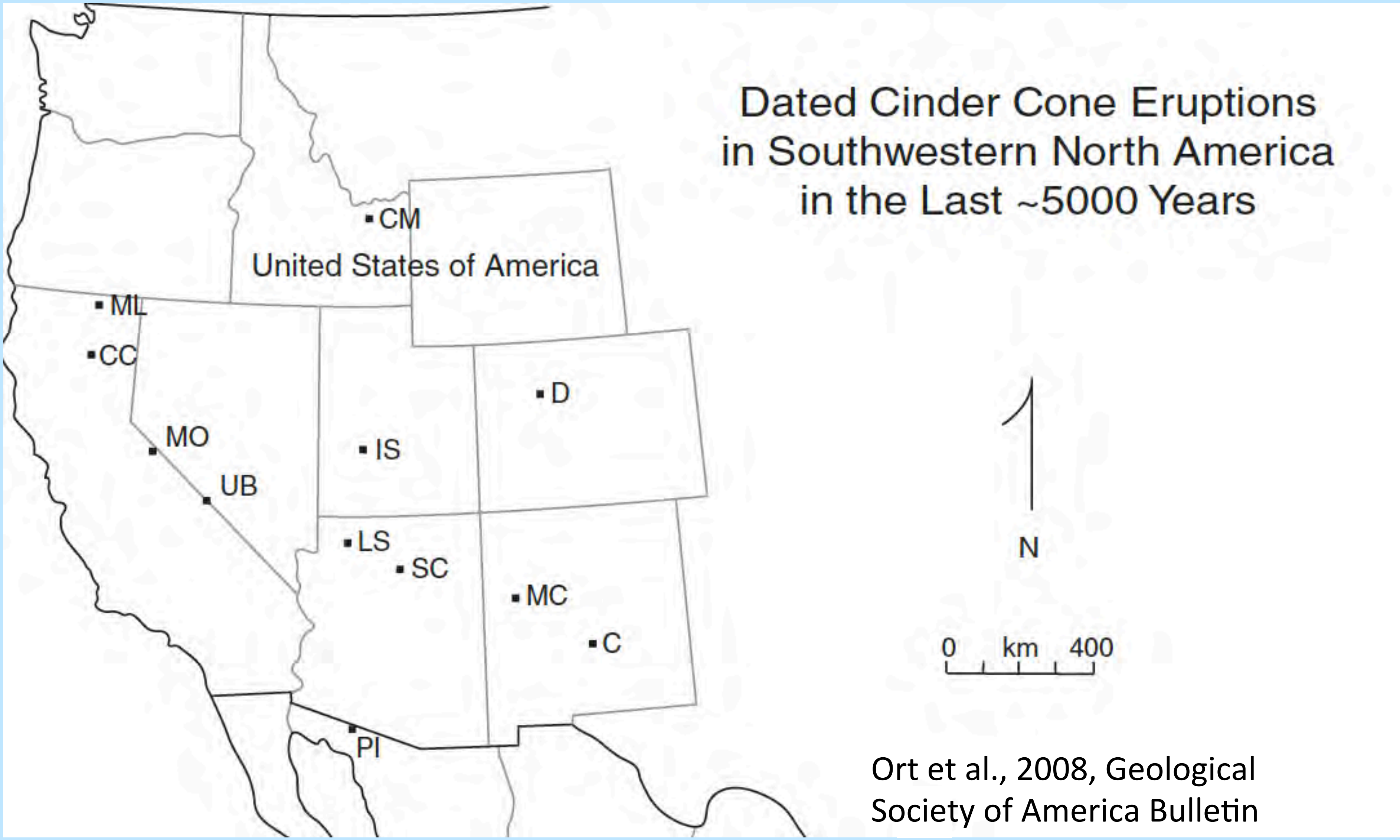


Figure 4.1. Map of the western United States showing the distribution of basalt erupted during the past 16–5 and 5–0 Ma (after Fitton et al., 1991). Labeled volcanic fields are: BP: Big Pine, C: Cima, CdR: Cerros del Rio, CF: Crater Flat; CS: Coso; G: Geronimo; GC: Grand Canyon; L: Lucero; LC: Lunar Crater; MT: Mount Taylor; O: Ocate; P: Potrillo; SF: San Francisco; SG: St. George; SRP: Snake River Plain; SV: Springerville; T: Taos; ZB: Zuni-Bandera.

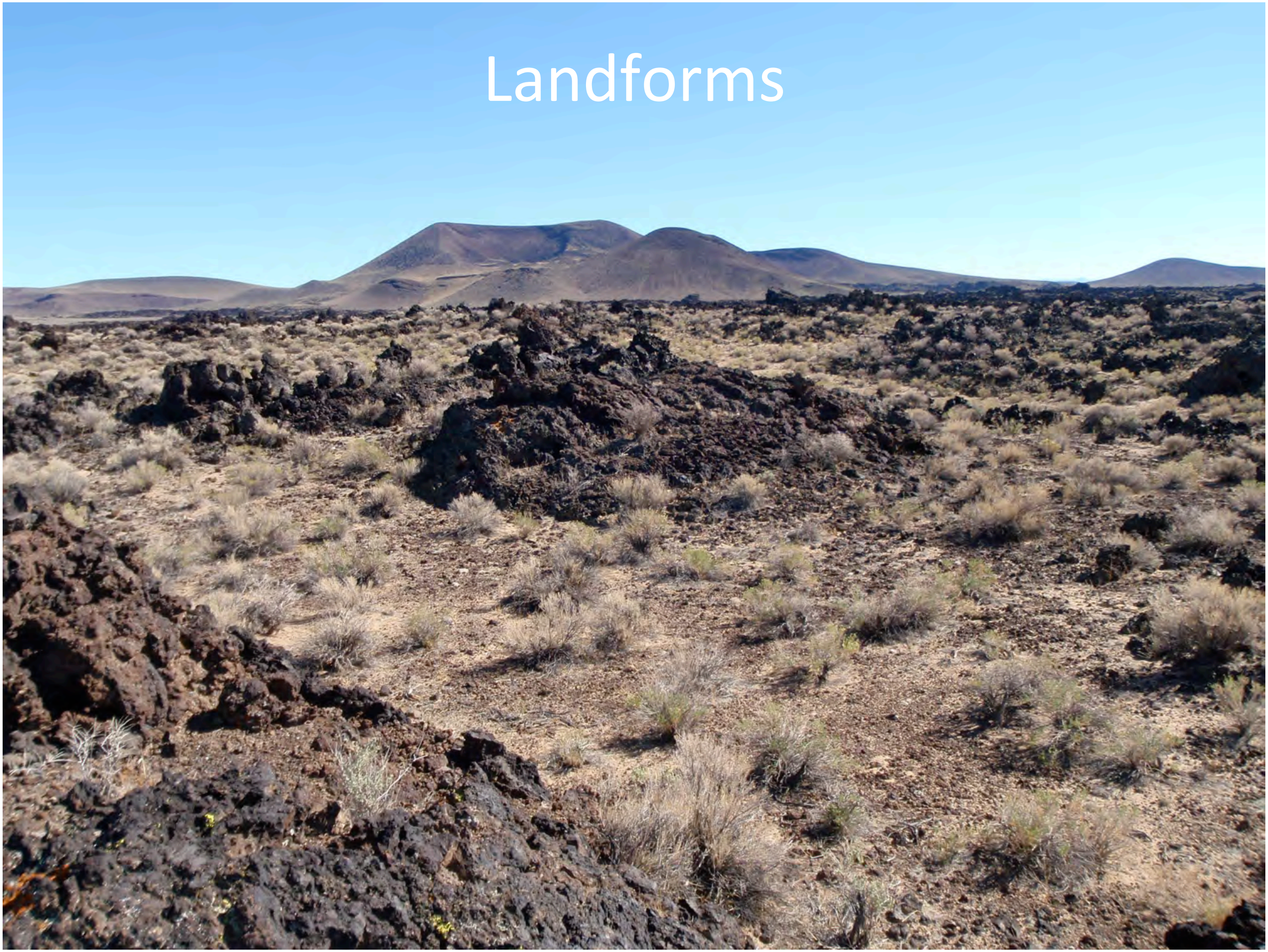
Based upon Smith and Luedke (1983, USGS), Fitton et al. (1991, J. Geophys. Res.), as presented by Perry et al. (1998, Los Alamos Nat. Lab.)

Basaltic volcanism on human time scales

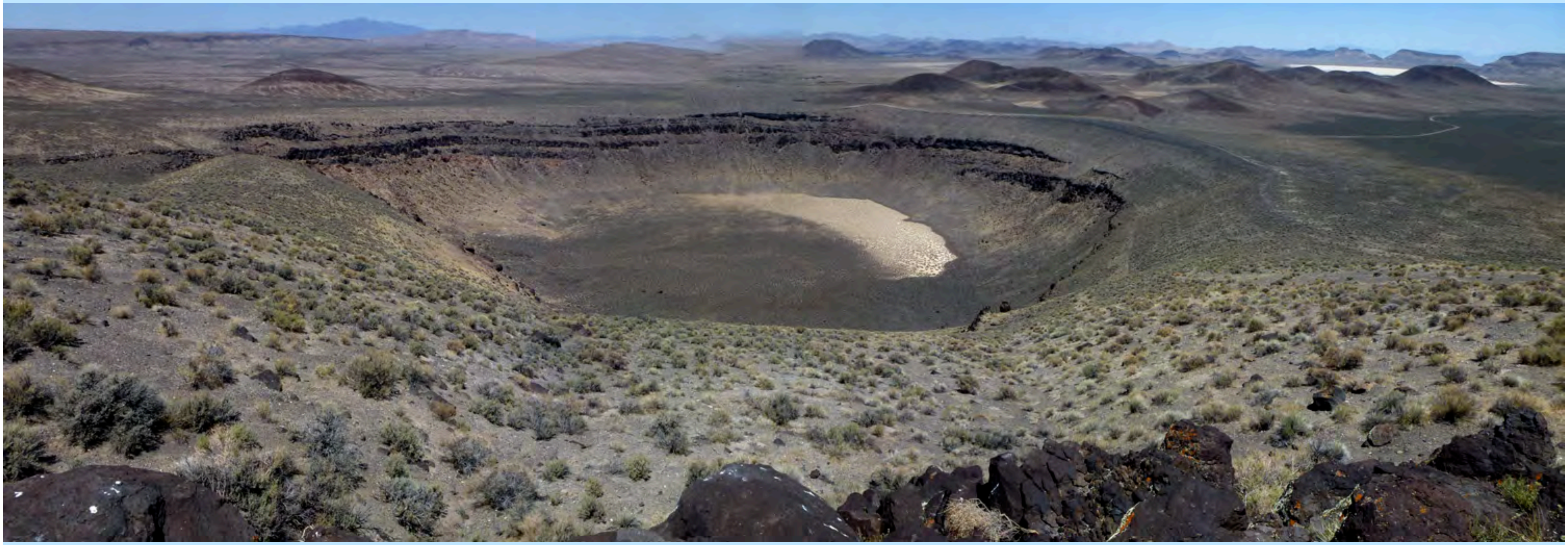


Ort et al., 2008, Geological Society of America Bulletin


Landforms


Landforms

Landforms



Landforms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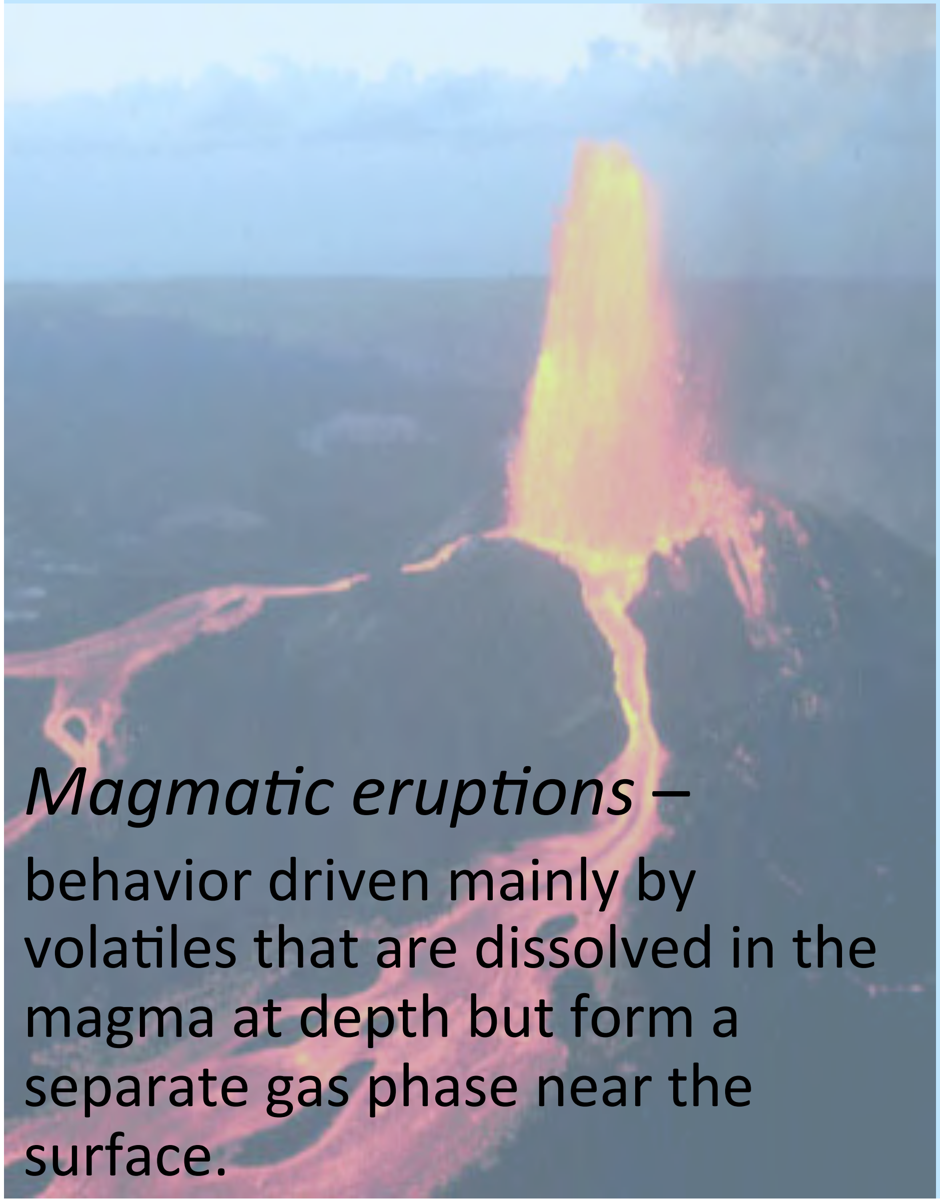
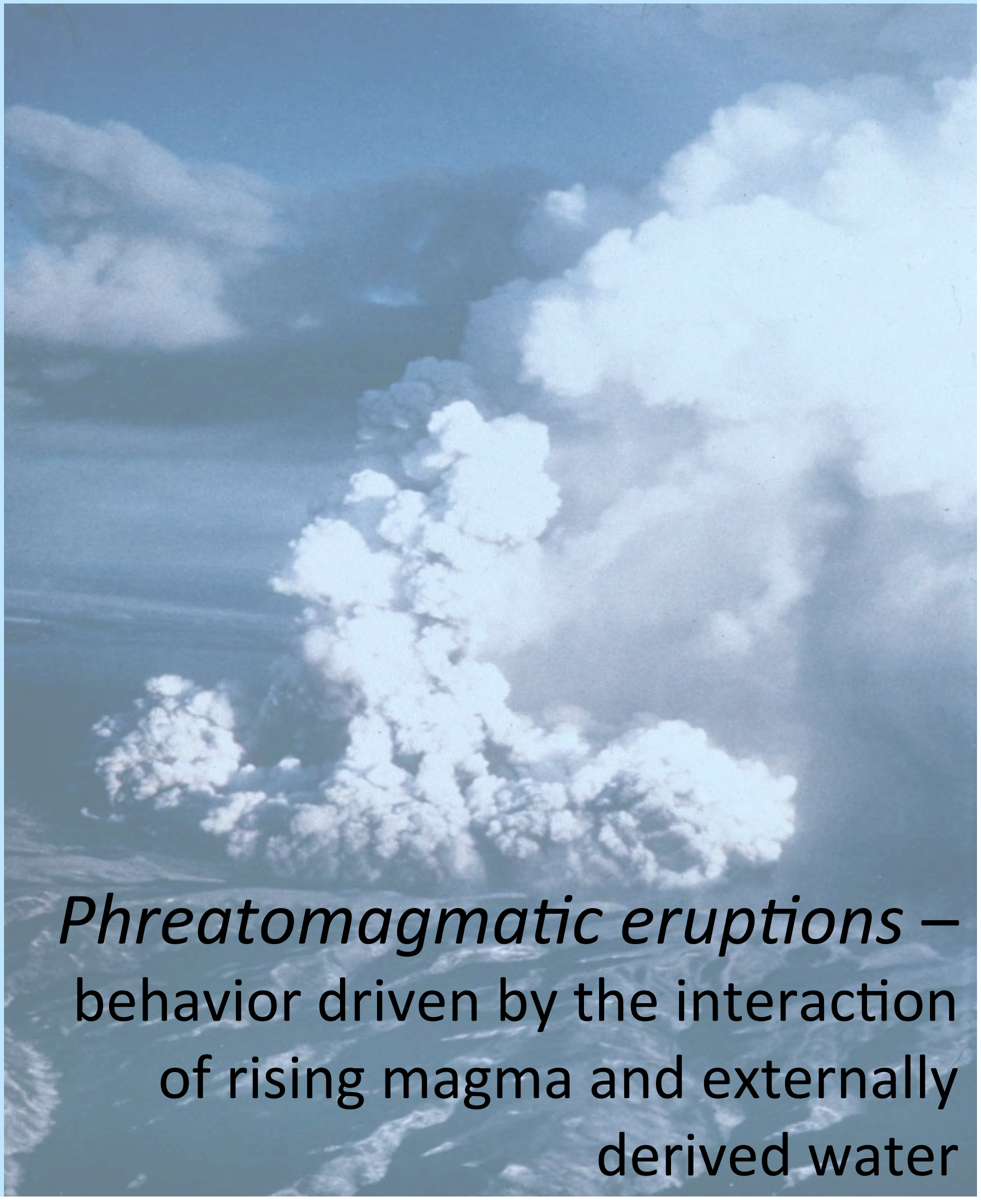
Types of eruptive processes and hazards



Magmatic eruptions –

behavior driven mainly by volatiles that are dissolved in the magma at depth but form a separate gas phase near the surface.

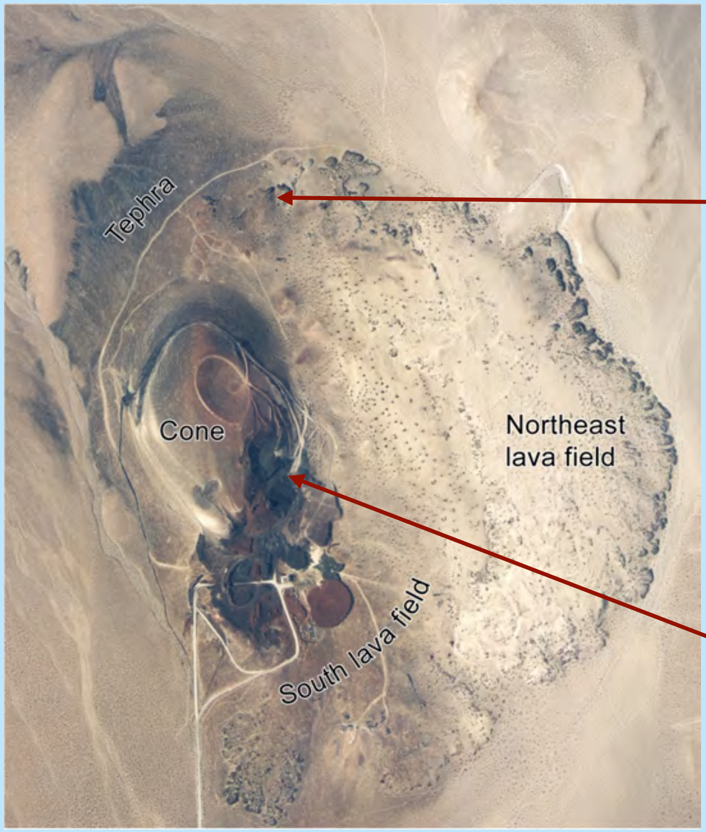


Phreatomagmatic eruptions –

behavior driven by the interaction of rising magma and externally derived water

Magmatic eruptive processes and hazards

Lathrop Wells Volcano (NV)



Types of Explosive Activity

Downwind dispersal of tephra from a buoyant plume (violent Strombolian)

Ballistic ejecta build the cone (Strombolian)

Hazards
- inundation by cone and lava fields
- tephra fall loading
- perturbed surface processes
- downwind ash plume

Phreatomagmatic eruptive processes and hazards

Hazards
•pyroclastic surges
•tephra fall loading
•subsidence of crater or burial by tuff cone
•perturbed surface processes
•downwind ash plume

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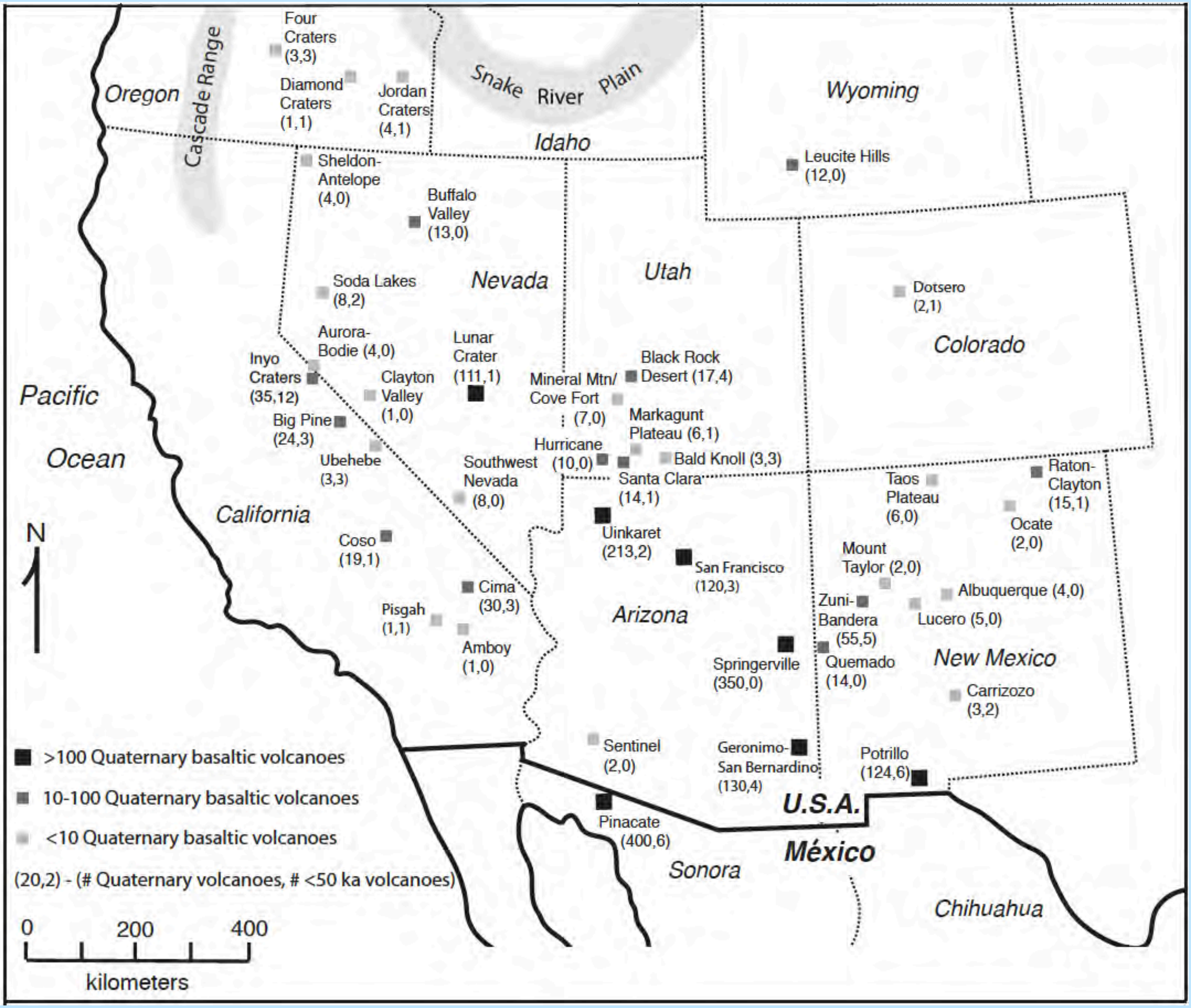

Work in progress by Valentine, Ort, Cortés, Hintz

Number of Quaternary basaltic volcanoes

- ~1400 Quaternary basaltic volcanoes
  - 2/3 of them in a NW-SE trending belt from Lunar Crater (NV) to Potrillo (NM)
- Average recurrence interval ~700 – 1000 yrs
  - Similar to the recurrence interval between eruptive episodes at individual intermediate composite volcanoes
- Data problems
  - Lack of detailed physical volcanological mapping to identify monogenetic events (compared to vents)
  - Inconsistent age data – only a fraction dated, a range of techniques, and often difficult to track down details
  - Age data mainly driven by research needs, rather than hazard assessment

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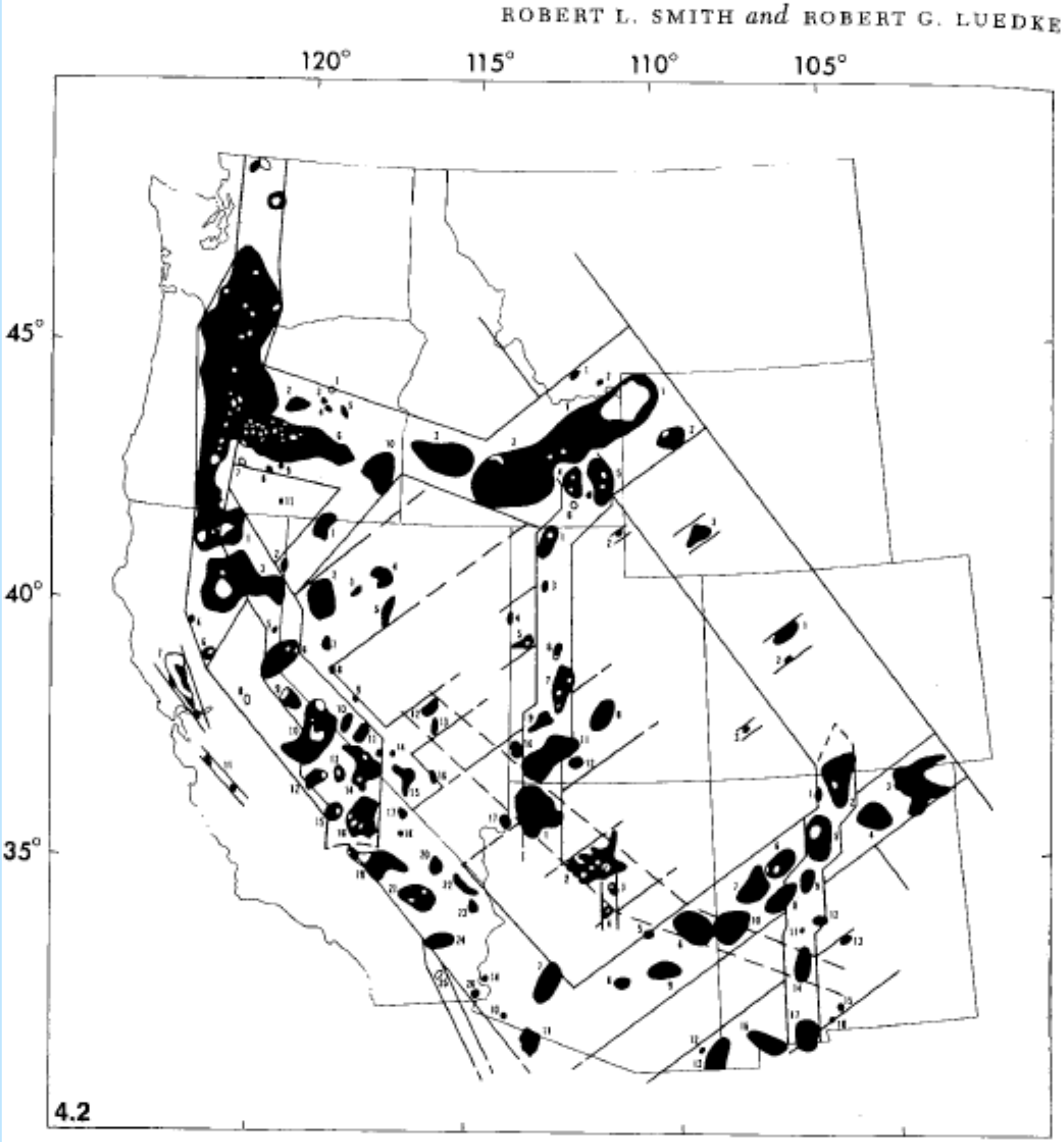
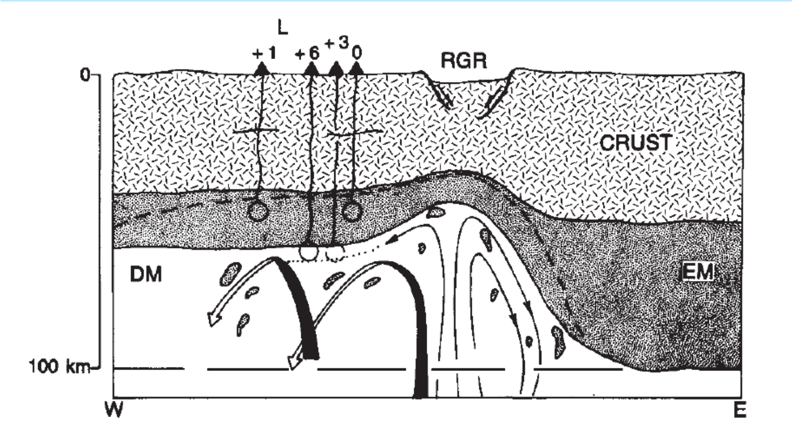
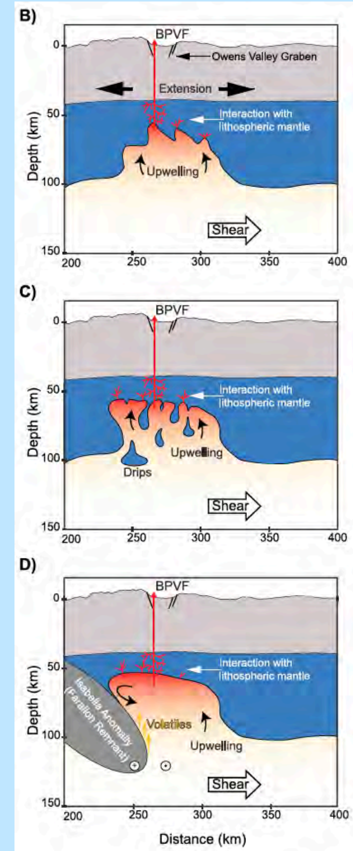
Smith & Luedke (1984) - lineaments



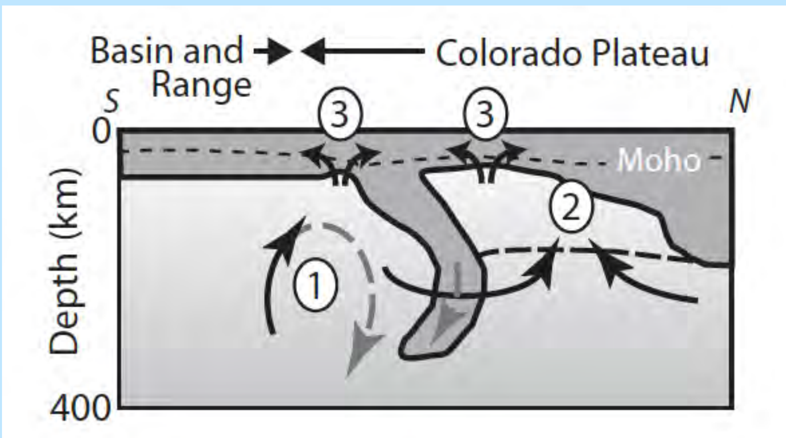
Black – basalts between 0-5 Ma



Rio Grande Rift
Perry et al., 1988, *Nature*



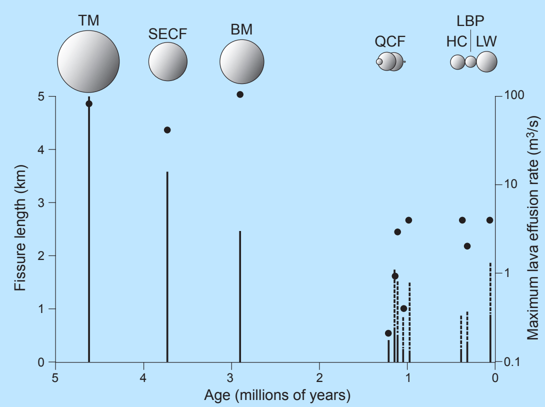
Sierran front – Basin & Range transition
Gazel et al., 2012, *G-Cubed*



Colorado Plateau margins
Reid et al., 2012, *Geology*

Models for:

- Thick and thin lithosphere
- Lithospheric mantle dripping
- Asthenospheric mantle upwelling
- Shear-induced melt focusing
- Heterogeneity is common theme



Central Basin and Range
Valentine & Perry, 2007, *Earth & Planetary Science Letters*

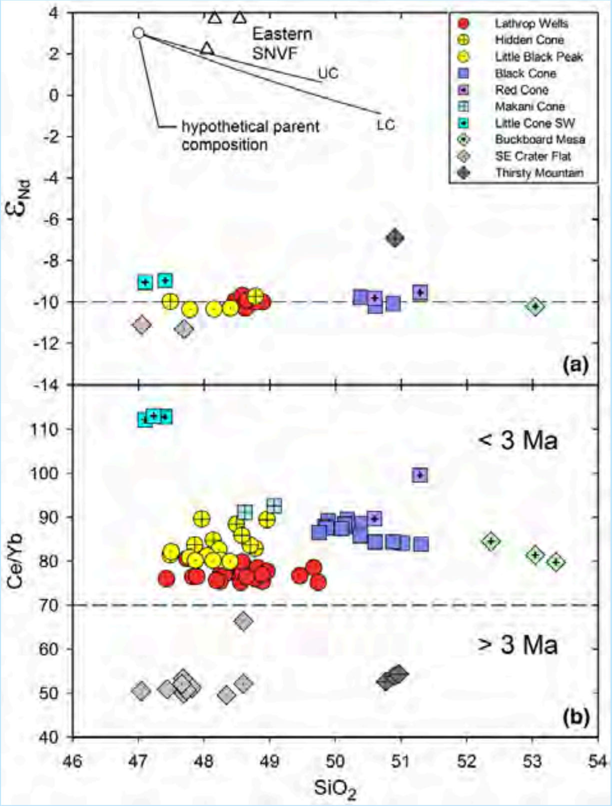
What do conceptual models mean for hazards?

- Controls on volcano location and eruption style
- Relations between eruption size and timing
- Range of ascent rates → ***warning times***

Example – Isotope and trace element data combined with major elements at Southwest Nevada Volcanic Field suggest:

- Magma sources had varied compositions
- Magmas did not interact with crust (rapid ascent)
- Lower degree of partial melting in younger volcanoes corresponds with increase in explosivity

(Valentine & Perry, 2007, EPSL)

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Warning and Monitoring

- We have few data on precursors for intraplate volcanism
- The area to be monitored is vast, and we have little data to indicate where is highest risk
- Many similarities with earthquake hazards, as “hypocenter” poorly located in advance and precursory signs are few

Monitoring Techniques

- Do we build and maintain a seismic network sufficient to recognize ascending magma with enough time to install more complete network before eruption?
- Would InSAR (Interferometric Synthetic Aperture Radar) monitoring work? If little crustal residence time for magma, do we expect much ground deformation?
- Likely little advance warning from gas or geothermal systems (deep groundwater, few springs)


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Hazards management and challenges

- Need to better constrain regional frequency
- Need better models for individual major volcanic fields and controls on monogenetic eruption styles
- Potential short lead time → monitoring difficult
- Broad region, small events with no pre-existing volcanic edifice → monitoring difficult
- In addition to direct effects on population and infrastructure, potential aviation effects

Strategy Needed

- Given: Monitoring difficult, prediction of precise location of eruptions and types of hazards is poor, event frequency is low
- Current state of regional assessment: probabilistic assessment needed, and should drive prioritization of further characterization and hazard planning
- Probabilistic assessment should include consequences of activity in addition to hazard (spatial-temporal probability of events)
- Preparation and planning for eruptions may need to take place based upon general probabilities (once those are determined) with assumption that advance warning of imminent eruption may not be forthcoming

Strategy

- As with earthquakes, build resistant infrastructure or accept loss of investment
- Difference from earthquakes: for most, the eruption takes time to affect sites away from vent – the hazard is not as sudden as an earthquake
- Can evacuate and lose investment but not life

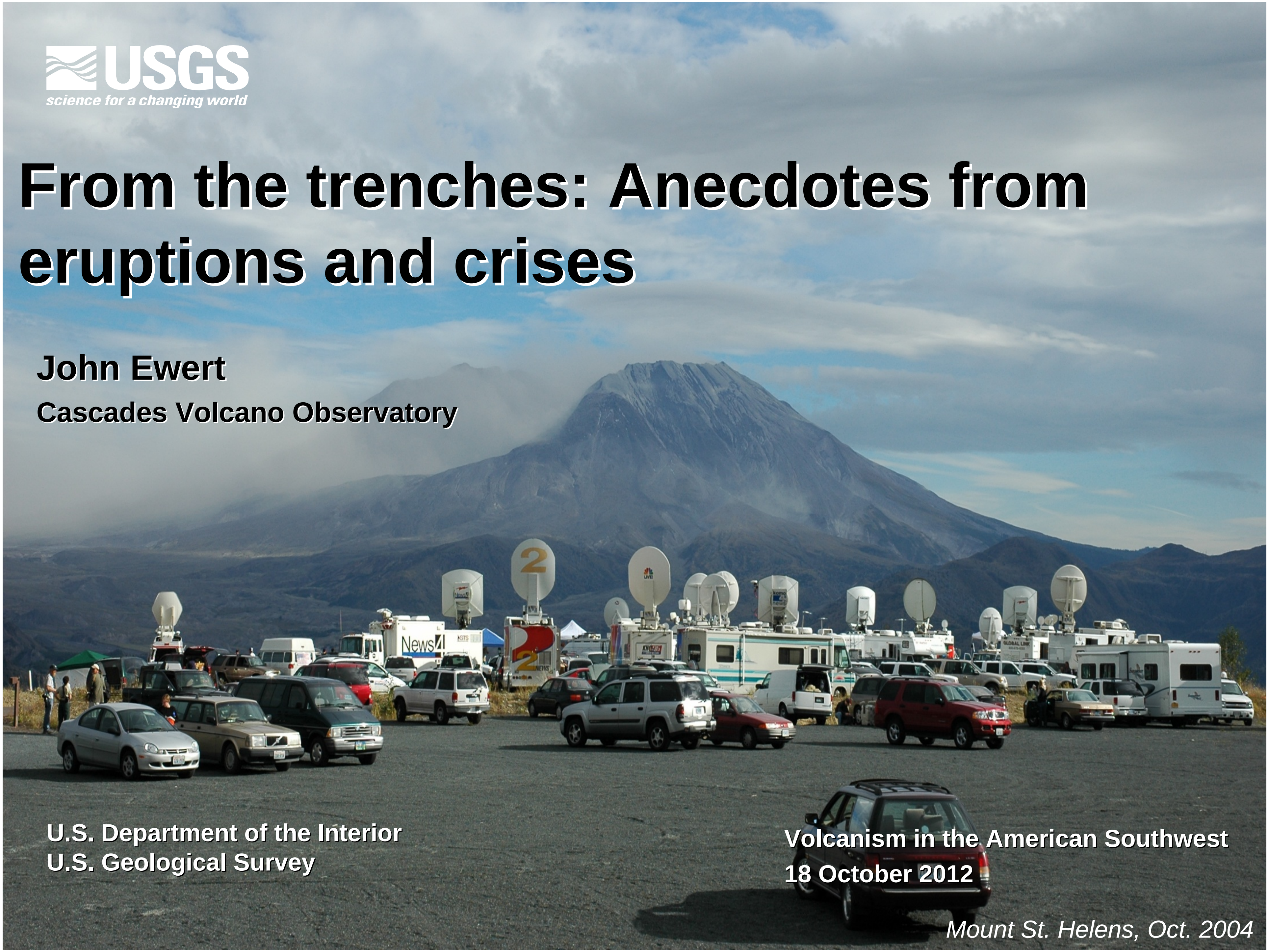
From the trenches: Anecdotes from eruptions and crises

John Ewert

Cascades Volcano Observatory

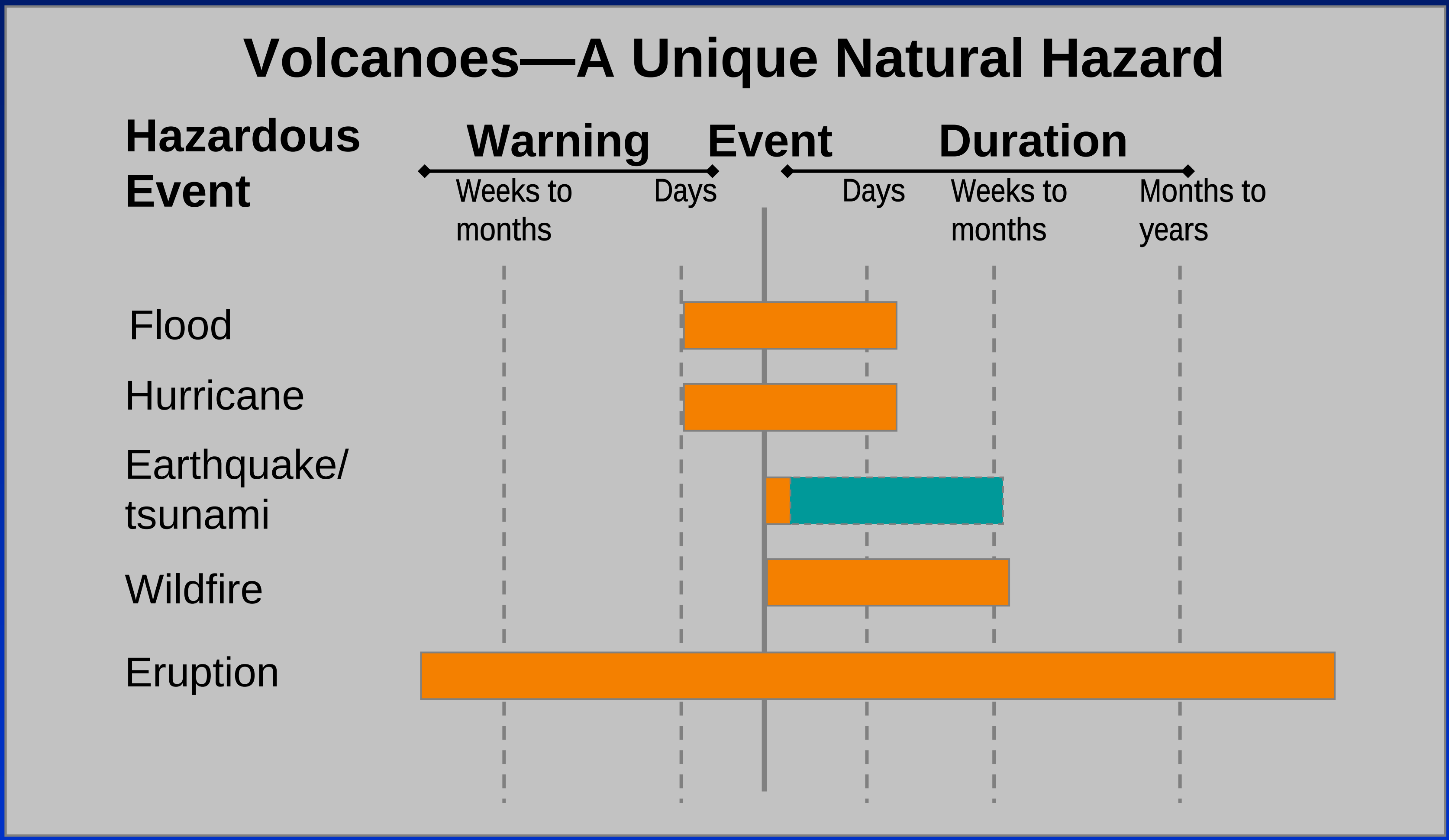
U.S. Department of the Interior
U.S. Geological Survey

Volcanism in the American Southwest
18 October 2012

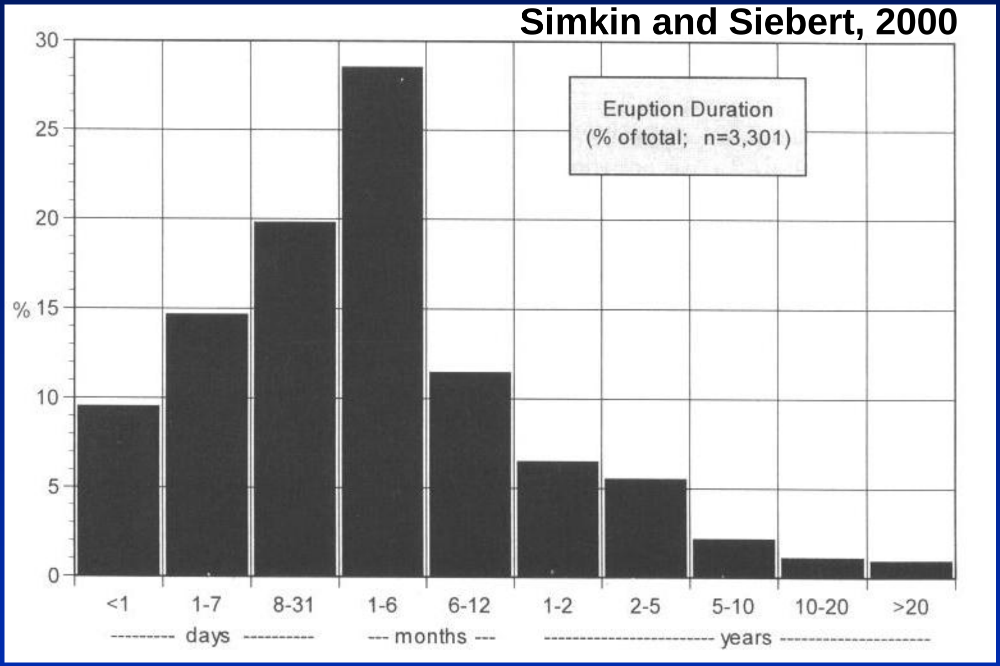


Mount St. Helens, Oct. 2004

Volcanoes provide more warning ahead of time, and hazardous conditions last longer than any other acute natural hazard



Eruption duration



The public, emergency managers, and other public officials would really prefer to have the hazardous event be over quickly so clean up and rehabilitation can commence.

Volcanic emergencies can last for months or years. Median duration is ~7 weeks.

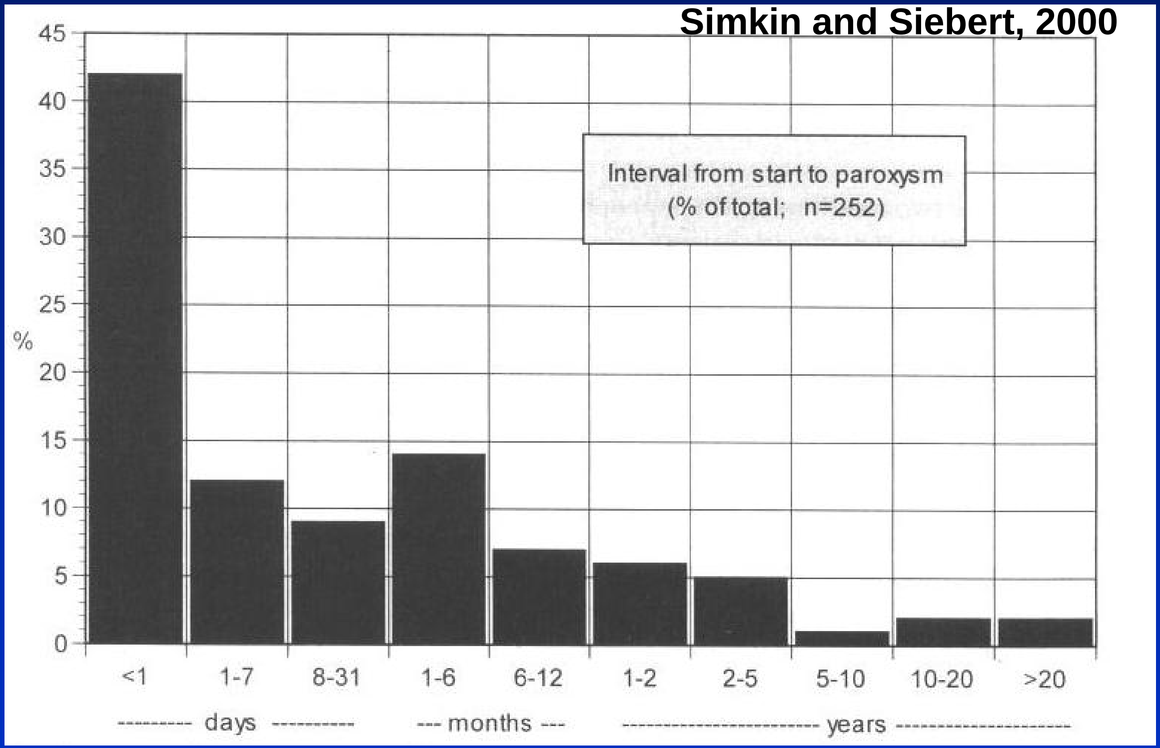
Tungurahua, Ecuador
1999 - present

USGS

Time lag from start to maximum eruption

Many catastrophic eruptions have provided little warning. Others may take years to produce the largest magnitude hazardous event.

Waiting for activity to start before installing monitoring or developing hazard communication and mitigation measures is folly.



Mount St. Helens, USA 1980 – 2 months
Huila, Colombia, 2008 –19 months
Okmok, Alaska, 2008 – 1.5 hours

USGS

How do we communicate ground hazards?

Volcano Alert Levels Used by USGS Volcano Observatories

Alert Levels are intended to inform people on the ground about a volcano's status and are issued in conjunction with the Aviation Color Code. Notifications are issued for both increasing and decreasing volcanic activity and are accompanied by text with details (as known) about the nature of the unrest or eruption and about potential or current hazards and likely outcomes.

Term	Description
NORMAL	Volcano is in typical background, noneruptive state or, *after a change from a higher level,* volcanic activity has ceased and volcano has returned to noneruptive background state.
ADVISORY	Volcano is exhibiting signs of elevated unrest above known background level or, *after a change from a higher level,* 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, **OR** eruption is underway but poses limited hazards.
WARNING	Hazardous eruption is imminent, underway, or suspected.

USGS alert-level system focuses on the state of the volcano with an emphasis on ash for the aviation community

How do we communicate aviation hazards?

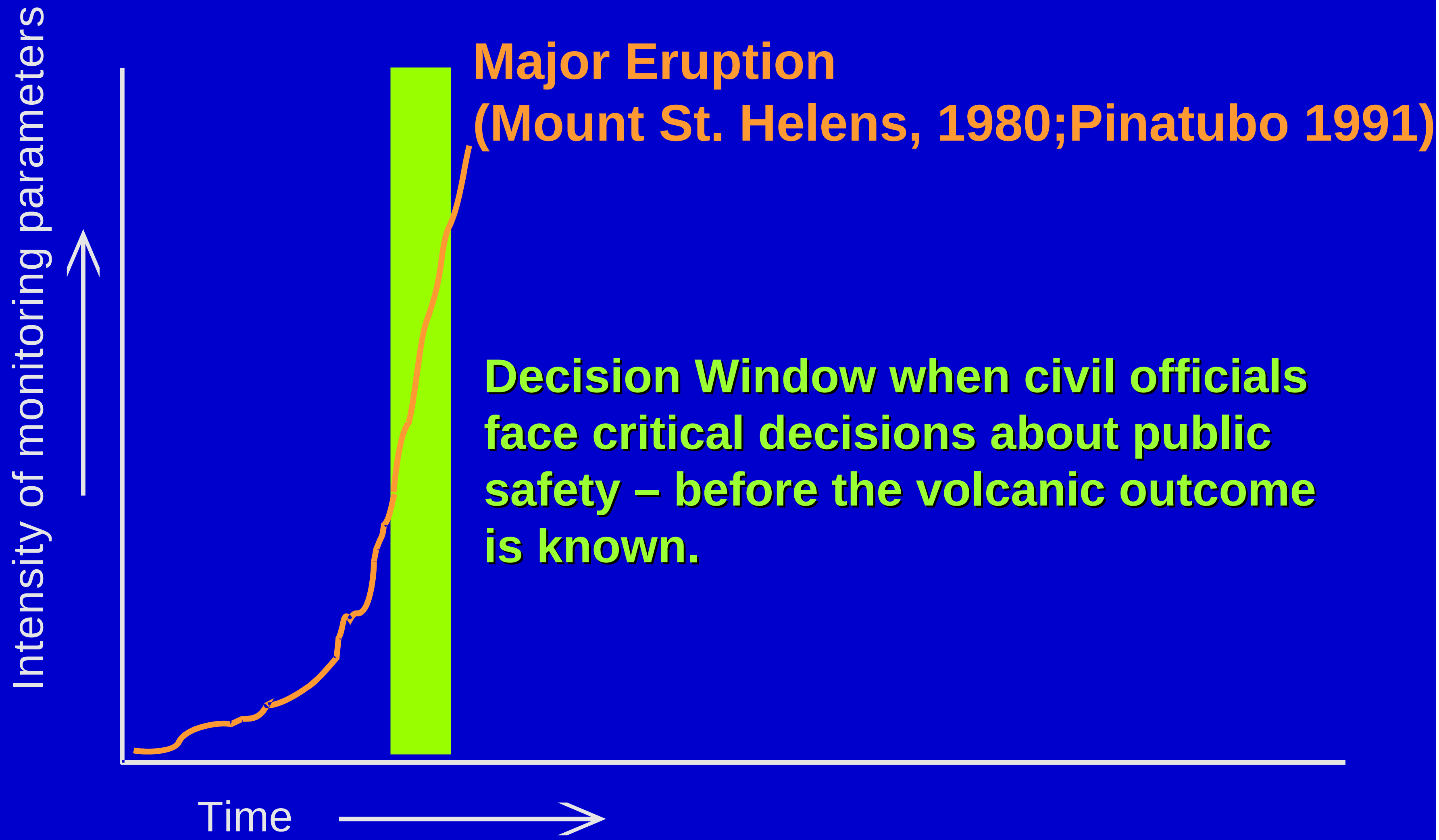
Aviation Color Code Used by USGS Volcano Observatories

Color codes, which are in accordance with recommended International Civil Aviation Organization (ICAO) procedures, are intended to inform the aviation sector about a volcano's status and are issued in conjunction with an Alert Level. Notifications are issued for both increasing and decreasing volcanic activity and are accompanied by text with details (as known) about the nature of the unrest or eruption, especially in regard to ash-plume information and likely outcomes.

Color	Description
GREEN	Volcano is in typical background, noneruptive state or, *after a change from a higher level,* volcanic activity has ceased and volcano has returned to noneruptive background state.
YELLOW	Volcano is exhibiting signs of elevated unrest above known background level or, *after a change from a higher level,* 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, **OR** 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 **OR** eruption is underway or suspected with significant emission of volcanic ash into the atmosphere [ash-plume height specified, if possible].

USGS

Challenge - Forecastability

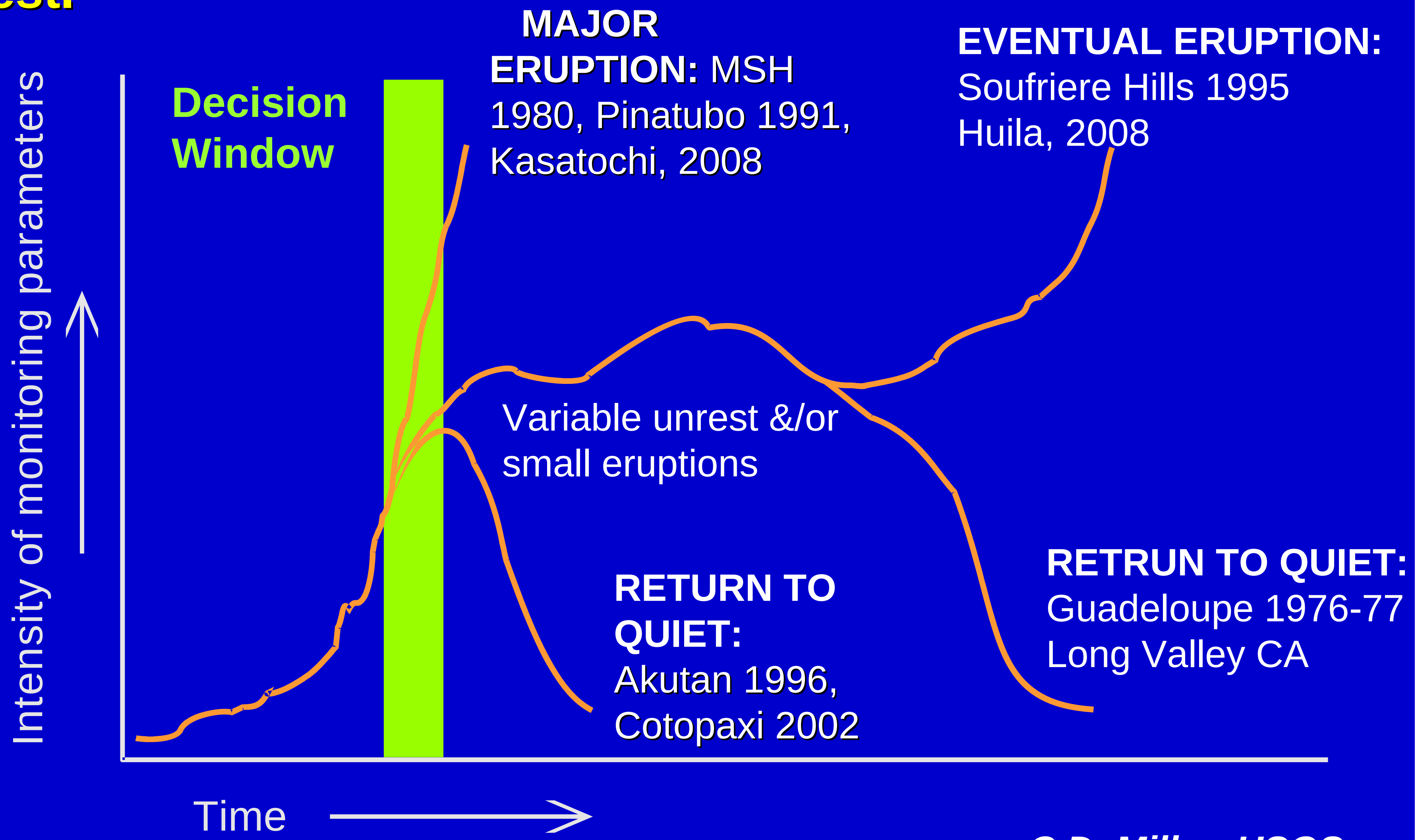


Decision Window when civil officials face critical decisions about public safety – before the volcanic outcome is known.

USGS

C.D. Miller, USGS

Schematic showing other possible outcomes of heightened unrest.



C.D. Miller, USGS

USGS

Communicating

Call Downs

ex. Mount St. Helens

Call downs are used when changing alert-levels, to update officials about a significant change in activity, or when eruptive activity ceases

How do you fit into this call down?

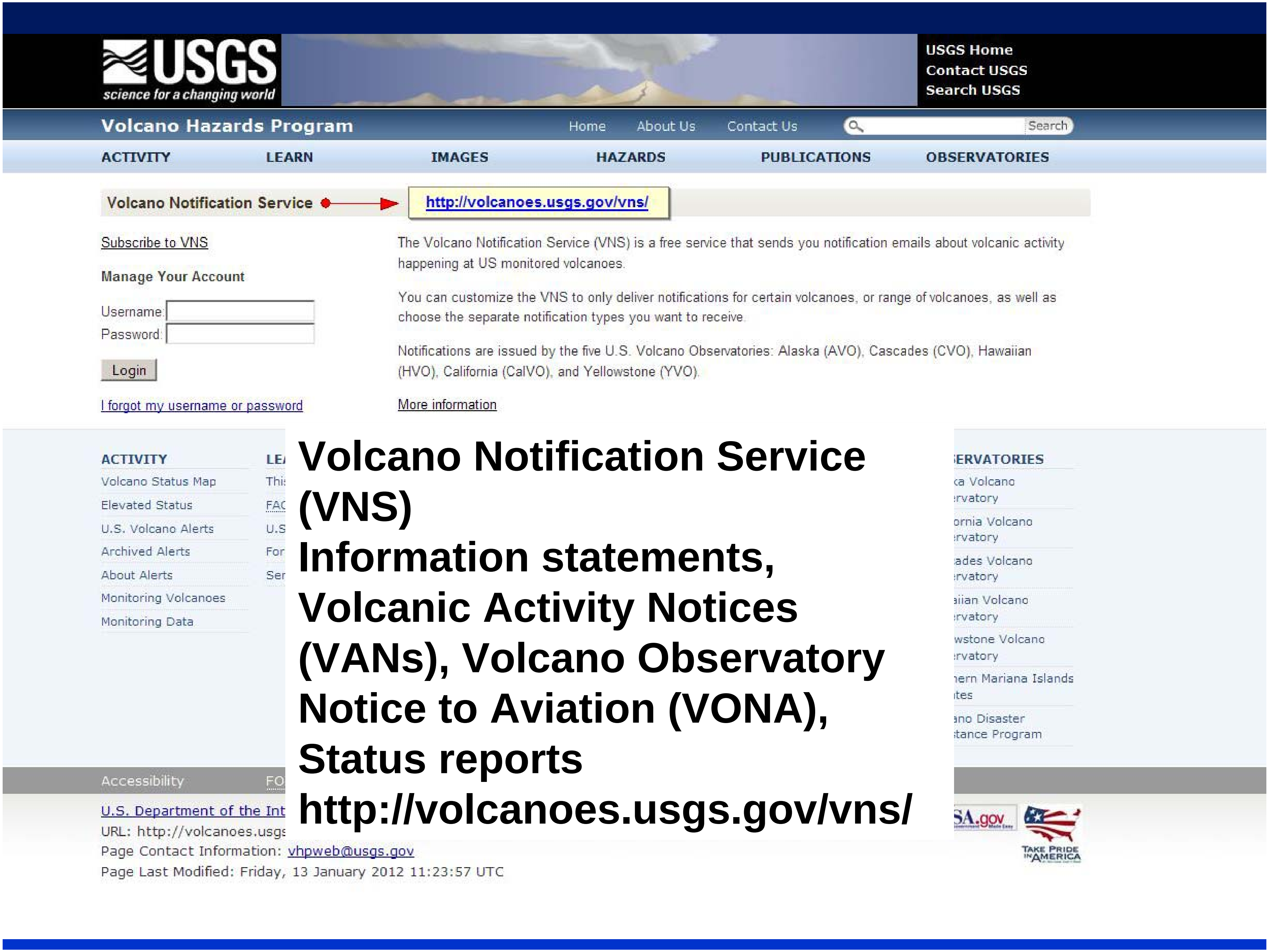
MSH CALLDOWN -- CONFIRMED EVENT

Make calls as brief as possible!

OPS/Duty Person **Call this list in # order – best to get a helper and have them call one side of list**	
1. **Duty Scientist 1** (cell) **360-601-1628** Note: (Duty Scientist1 calls Duty Scientist 2) (cell) **360-601-2501** Duty Scientist 2 calls SIC (cell) 360-624-8754 SIC calls Manny Nathenson 650-329-5292 and John Eichelberger 703-648-6711	2. **Seismic** (call one) Seth Moran **360-909-5462** or UW Hot Line **206-685-2068** or Paul Bodin **206-257-8047** or Bill Steele **206-601-5978** (see phone list for additional #s)
3. **Seattle FAA** **253-351-3520** Ask for pilot reports, have them call back on hot line 360-993-8989 if you are in OPS	4. **National Weather Service** **503-326-3720** Ask them to check for plume with NexRAD If in OPS, have them call back on hot line 360-993-8989. (this could take 6-10 min)
5. **Forest Service** **896-3473**	6. **WA State EMD** **800-258-5990**
7. **Washington VAAC** **301-763-8444**	8. **National Weather Service - hydrology 503-326-2356** Could event generate a lahars ? Notify NWS hydrology and also check AFMs.
9. **FAA HQ Com Center 703-904-4525**	10. **Air Force Weather Agency** (AFWA **402-294-1386 or 7264**
11. **BC Provincial Emergency Program** (PEP) (covers all Canada) **800-663-3456**	

Remember to call back and keep each group informed of event's progress every 15-20 minutes and when there are significant changes (including termination).

USGS



Volcano Notification Service (VNS)

Information statements, Volcanic Activity Notices (VANs), Volcano Observatory Notice to Aviation (VONA), Status reports

http://volcanoes.usgs.gov/vns/

2008 Chaitén eruption and response

2 May, 6 May, 8 May: Large explosive eruptions at Chaitén. *No real-time (telemetered) seismic monitoring*. VDAP assistance offered by U.S. Ambassador to Foreign Minister

8 May: VDAP contacts SERNAGEOMIN, offers real-time monitoring. Offer accepted

16 May: VDAP team to Chile

17 May – 6 June: SERNAGEOMIN-VDAP team installs real-time seismic monitoring system, assists with interpretation and forecasts

- Scientifically important eruption
  - ~VEI 5 (>1km3 magma, ash to 20 km; only a few VEI 5's each century)
  - Unusual eruption– important for understanding the most explosive volcanoes world-wide

USGS science for a changing world

USAID

3 May Photograph of Chaitén plume with lightning by Carlos Gutierrez/UPI/Landov

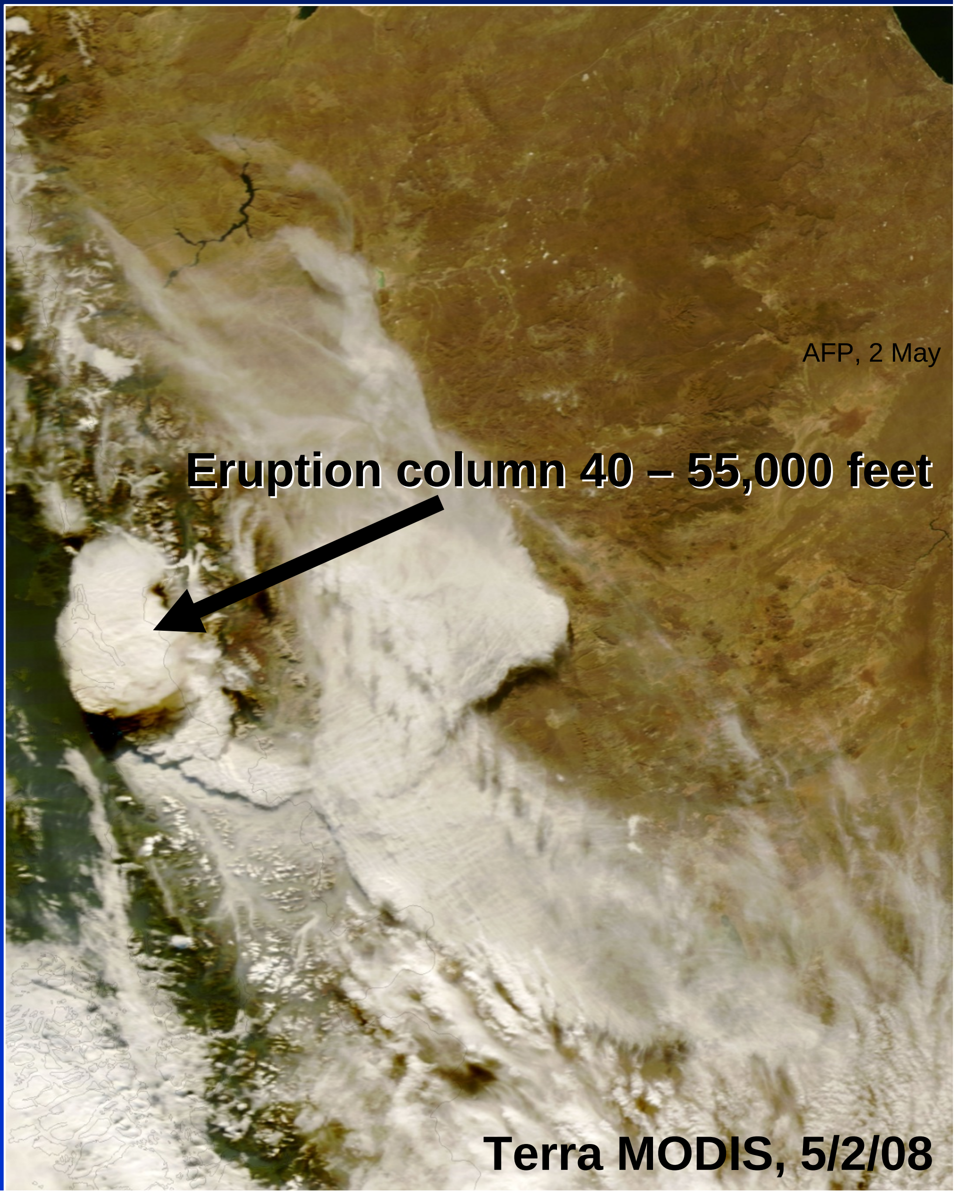
GOBIERNO DE CHILE SERNAGEOMIN

Sequence of Events

- Volcano is quiet for > 9000* years
- First earthquakes felt late 4/30/08 local time
- Eruption onset 27 hours later (~midnight 5/1/08)
- First rhyolite eruption since 1912 Katmai eruption in Alaska
- Initial eruption puts ash column to ~18 km, lasts 6 hours
- Nearly continuous ash emission with intermittent large explosions continued 2-8 May.
- Lava dome extrusion with sustained vapor & ash column 9 May 2008 – 2009

* Further studies, post eruption, found evidence of smaller eruptions ~500 ybp

USGS USAID GOBIERNO DE CHILE SERNAGEOMIN



Evacuations

- 2 May:1300 people evaucated from Chaitén
- 3 May: all (~4200 people) of Chaitén town evacuated
- 6 May: all people within 50 km of volcano evacuated
- In the sudden evacuation pets and livestock were left behind, but most were eventually relocated as well

Futaleufu, AFP, 2 May

Futuleufu, 4 May, El Mercurio

Chaitén, AFP, 2 May

USGS

USAID

GOBIERNO DE CHILE
SERNAGEOMIN

Aviation Operations and Impacts from the Chaitén Eruption May-June 2008

Encounters:

- Seven encounters between commercial aircraft flying into ash clouds from Chaitén in early May 2008
- Three aircraft experienced engine damage

Airport Closures

- Regional airports have occasionally been closed by the ash plumes from the eruption
- The airport at Chaitén is closed indefinitely
  - Chile closures: Chaitén, Osorno, Puerto Montt
  - Argentina closures:Bariloche, Esquel, Comodoro Rivadavia

Flight Cancellations

- Domestic: Several hundreds of domestic flights in Argentina and Chile
- International: Several dozens of International Flights from Santiago, Chile and Buenos Aires, Argentina cancelled

USGS USAID GOBIERNO DE CHILE SERNAGEOMIN

Devastation in Chaitén Town

AP Photo/Intendencia Regional de Los Lagos

- Sediment remobilized by intense rainfall
- Roughly 80% of town damaged
- Roughly 20-30% completely destroyed
- Extensive damage to airport and marine facilities
- Gov't of Chile now relocating entire town but meeting resistance

USGS
USAID
GOBIERNO DE CHILE
SERNAGEOMIN

Two events in Colombia: Tragedy and Success

1985: Small eruption and large lahar at Nevado del Ruiz causes 23,000 casualties

2008: Small eruption and large lahar at Nevado del Huila largely mitigated through community preparedness and evacuation

Nevado del Ruiz

23,000 people lost their lives hours after a small eruption at Nevado del Ruiz, Colombia in 1985

Above: Nevado del Ruiz
Right: The town of Armero after the about 1 month after the catastropic eruption on 13 November 1985

Slow response to developing crisis: ad hoc monitoring system; hazard assessment delayed; poor communication among scientists, public officials, and the public; general lack of appreciation for volcano hazards.

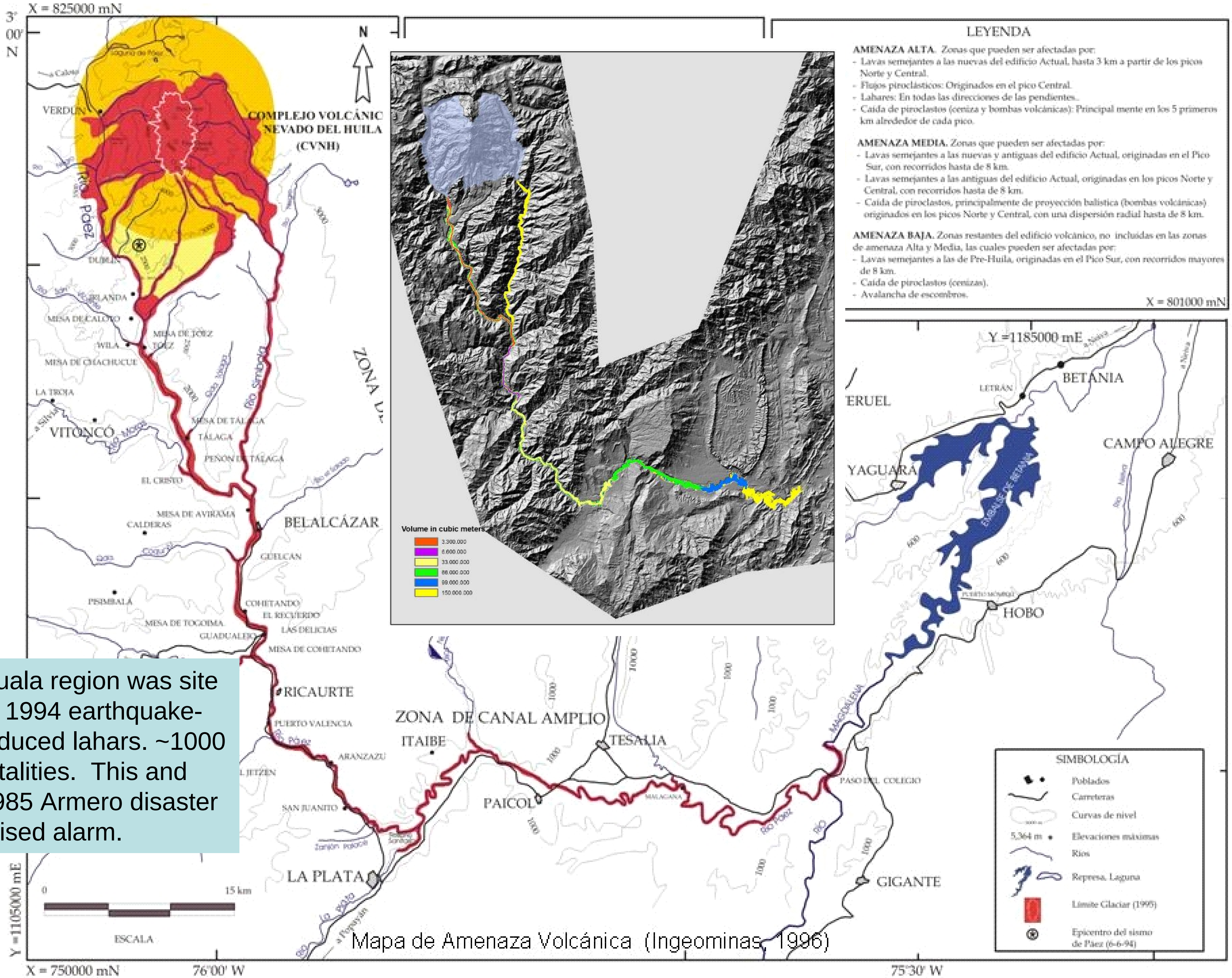
USGS

Huila, Colombia eruptions, Feb 18-19 and April 18, 2007 Climactic event November 20, 2008

Nevado del Huila (17,597')
Feb. 19, 2007 eruption, View from the SW

USGS

Huala region was site of 1994 earthquake-induced lahars. ~1000 fatalities. This and 1985 Armero disaster raised alarm.



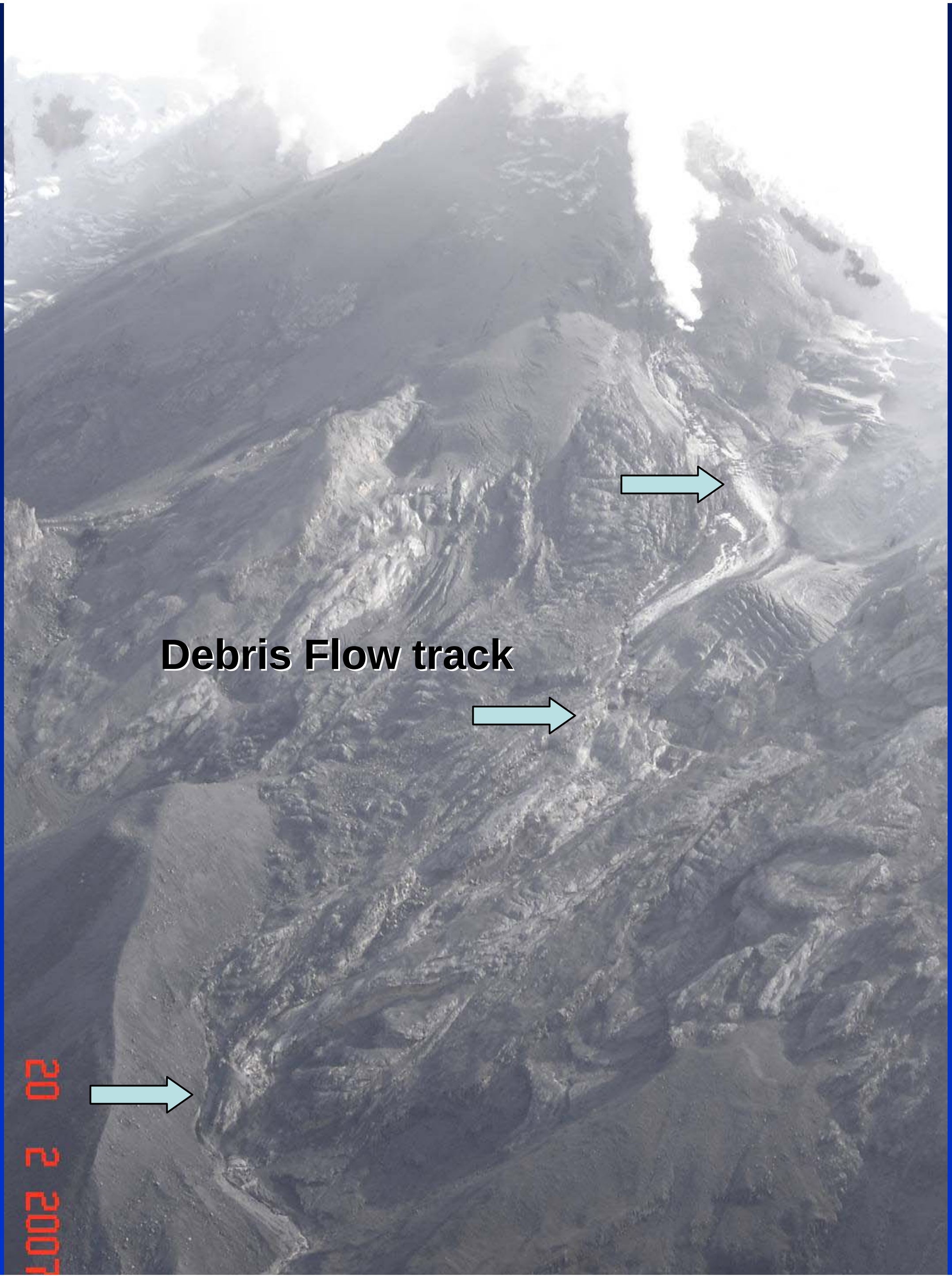
Mapa de Amenaza Volcánica (Ingeominas, 1996)

Nevado del Huila, Colombia, Feb. 19 phreatic eruption

View from the SW on Feb 20

Summit was split by a ~1 km long rift and a large volume of water was from end of the fissure

New mechanism for lahar generation



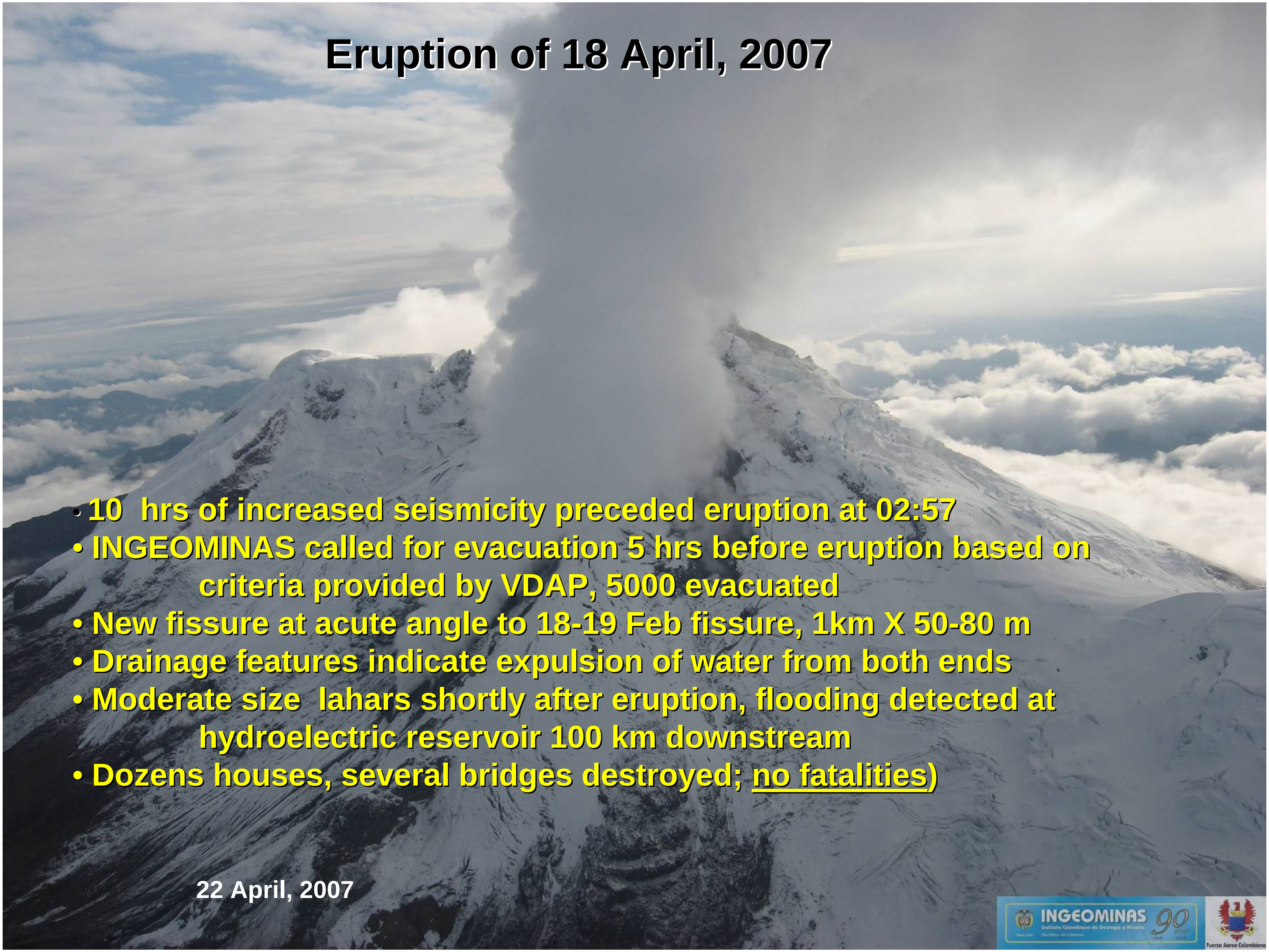
USGS

Crisis response to Huila, 2007-08 by INGEOMINAS & VDAP

AVIATION COLOR CODES: Initially developed by USGS AVO, now adopted by ICAO as world standard.	
GREEN	Volcano is in normal, non-eruptive state. *or, after a change from a higher level*: Volcanic activity considered to have ceased, and volcano reverted to its normal, non-eruptive state.
YELLOW	Volcano is exhibiting signs of elevated unrest above known background levels. *or, after a change from higher level*: Volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
ORANGE	Volcano is exhibiting heightened unrest with increased likelihood of eruption, *or*, Volcanic eruption is underway with no or minor ash emission *[specify ash-plume height if possible]*.
RED	Eruption is forecast to be imminent with significant emission of ash into the atmosphere likely. *or*, Eruption is underway with significant emission of ash into the atmosphere *[specify ash-plume height if possible]*.

Clear communication is critical to the success of any hazard warning system. INGEOMINAS adopted the USGS alert level code system to aid in hazards communication. INGEOMINAS and other GOC agencies embarked on intensive public education campaign

USGS


Eruption of 18 April, 2007
• 10 hrs of increased seismicity preceded eruption at 02:57
• INGEOMINAS called for evacuation 5 hrs before eruption based on criteria provided by VDAP, 5000 evacuated
• New fissure at acute angle to 18-19 Feb fissure, 1km X 50-80 m
• Drainage features indicate expulsion of water from both ends
• Moderate size lahars shortly after eruption, flooding detected at hydroelectric reservoir 100 km downstream
• Dozens houses, several bridges destroyed; no fatalities)
22 April, 2007
INGEOMINAS

Nevado del Huila, 2007

Two eruptions split the summit with two fissures, each ~ 1 km long

As far as we know, no juvenile material was erupted, just water and older material.

USGS

Scientific and other challenges:

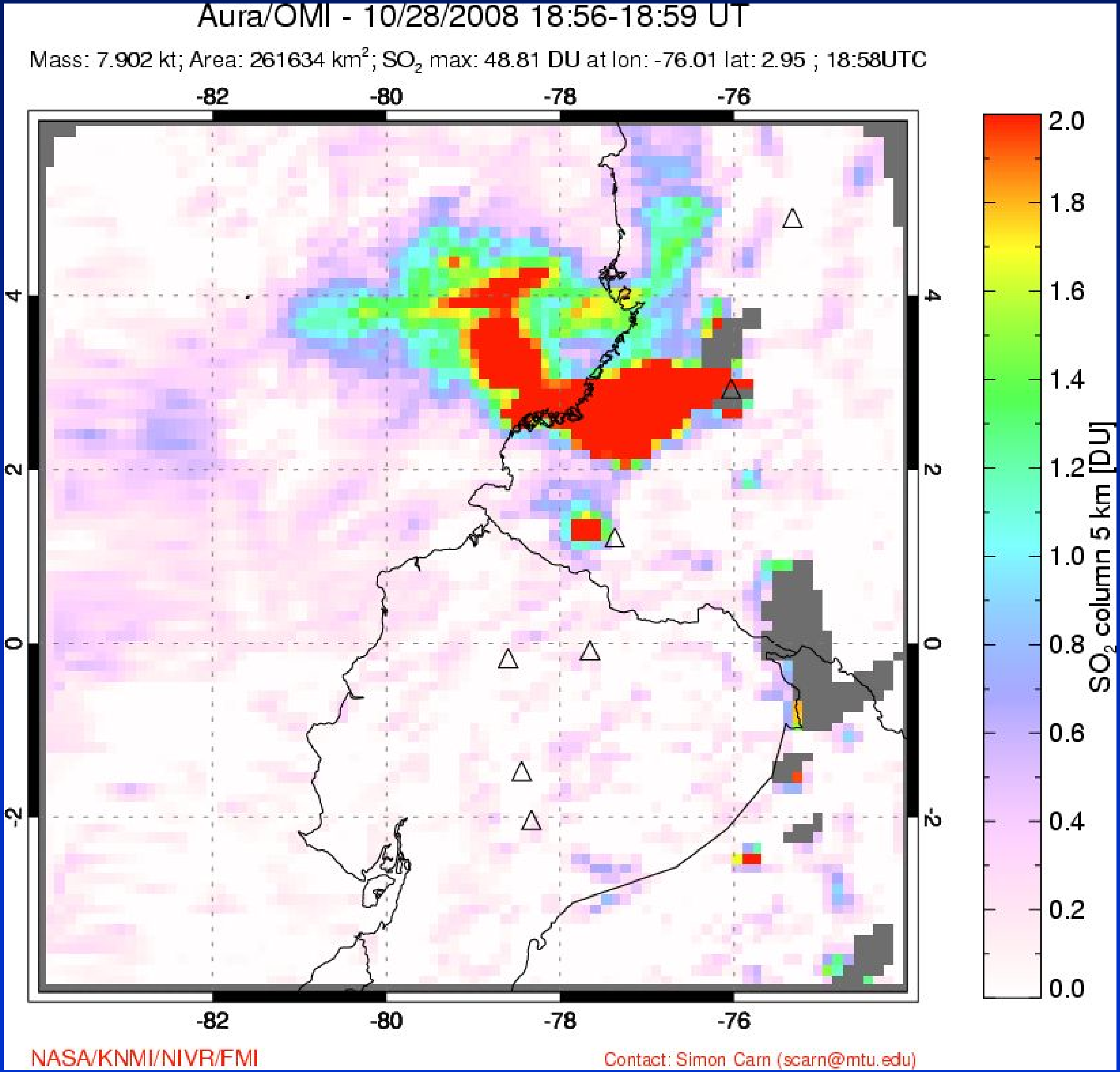
Problem 1: How do you expel millions(?) of cubic meters of water from both sides of the crack in a matter of minutes?

Problem 2: If this happens at a different volcano, how do you evacuate a valley population that is large and has had no historical lahar, or volcanic activity, in a few hours?

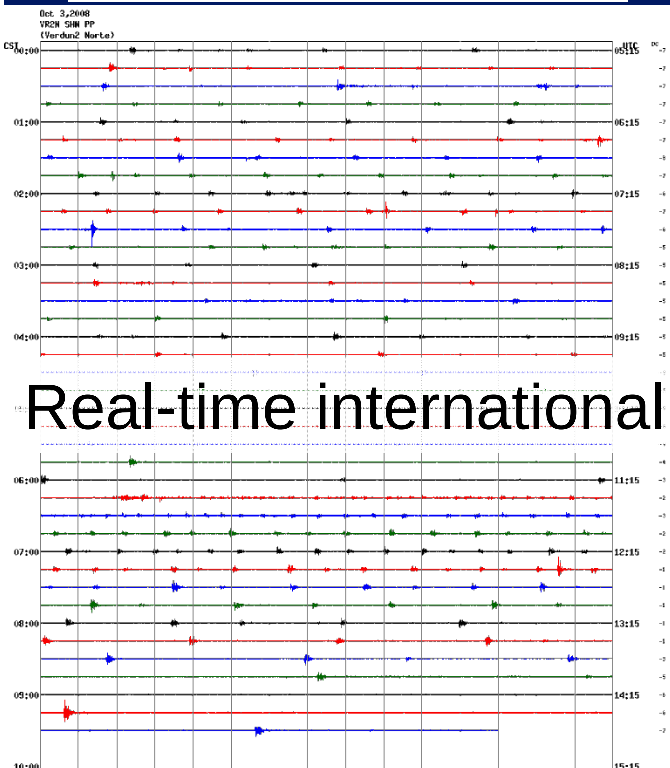
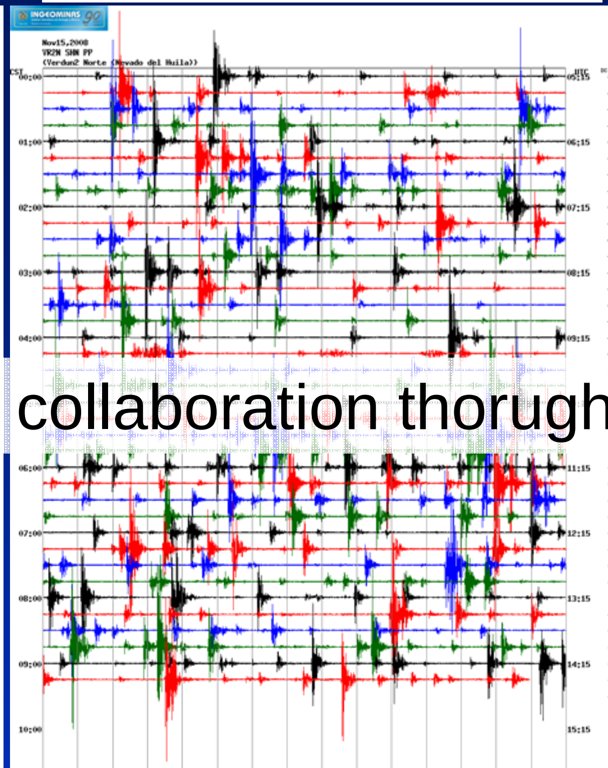
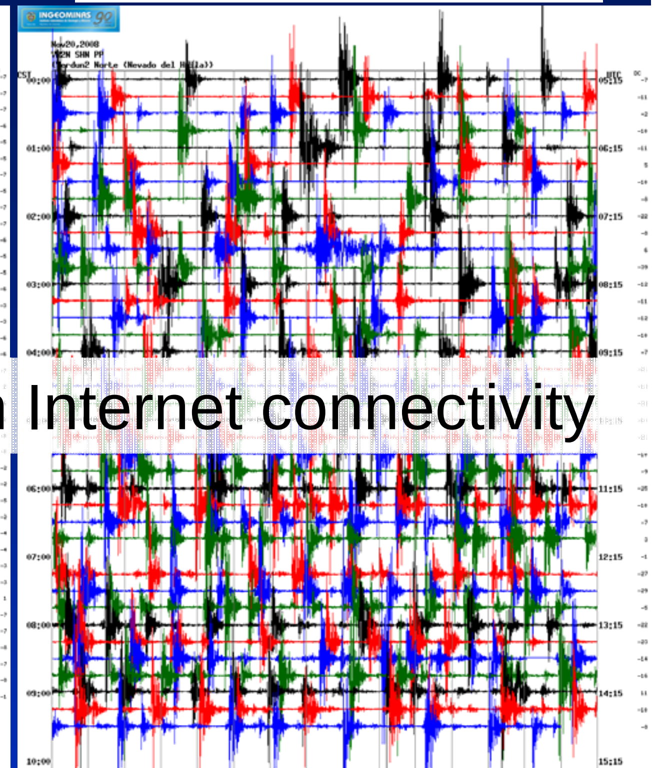
If we can get a handle on the process required for the first problem, we might have a better idea of when we have to worry about the second problem

Huila: A difficult study site (FARC)

Between April 2007 and October 2008 seismic and degassing activity waxes and wanes



03 Oct. 2008 (local)	15 Nov. 2008 (local)	19 Nov. 2008 (local)

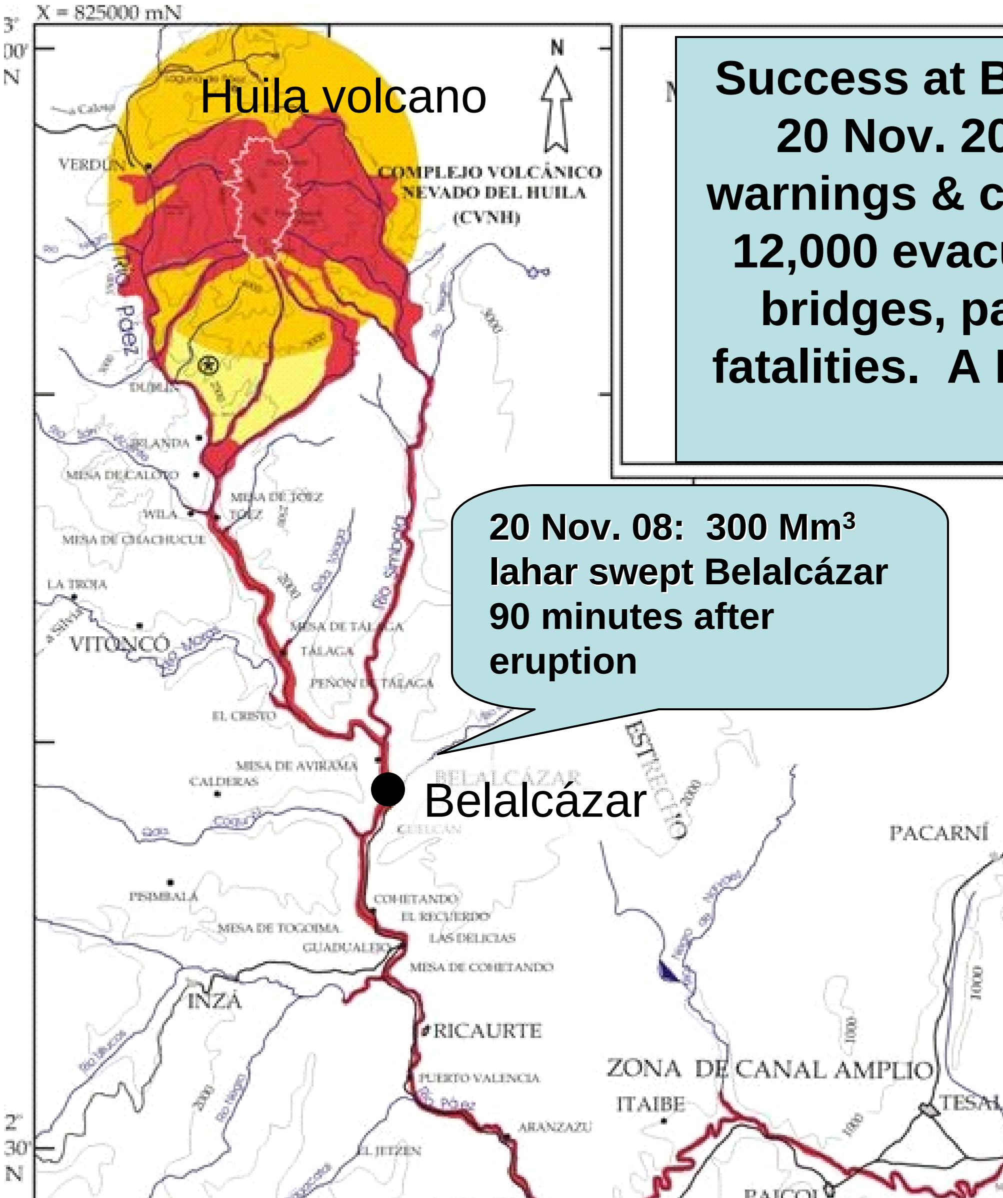




Real-time international collaboration thorugh Internet connectivity

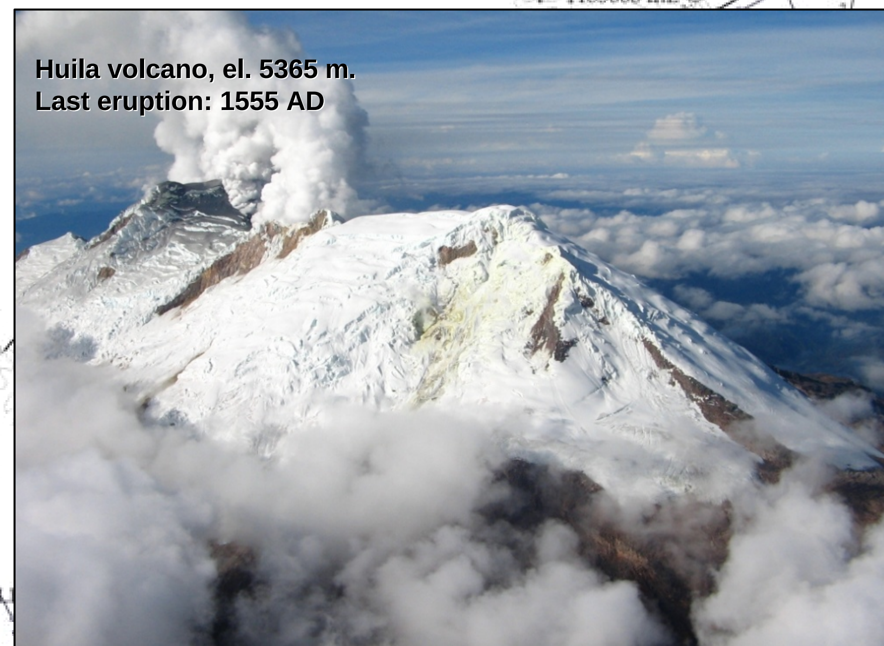
- 03 Oct: VDAP spots first interval of repetitive “drumbeat” earthquakes
- 19 Nov: USGS and INGEOMINAS Seismologists confer about the activity. INGEOMINAS raises alert and calls for evacuations at first explosion signal (~21:45).
- 20 Nov: VEI 3 eruption begins at 21:45 on 20 Nov. Ash column to 50,000’. Belalcázar (pop. 5000) completely evacuated by 22:05. Lahar inundates parts of Belalcázar at 22:20. No fatalities in Belalcázar.
- 21 Nov: Lava dome spotted.
- 22-24 Nov: Heavy rains cause more lahars. Up to 10 fatalities reported in remote areas.

Summary: At night and despite cloud cover, monitoring & communications worked. Evacuations took place & many lives were saved… a fitting memorial to those lost in Armero.

Success at Belalcázar, Colombia: 18 Apr. 2007 & 20 Nov. 2008. At night, monitoring worked, warnings & communications worked. 3,500 then 12,000 evacuated… The 2008 lahars destroyed bridges, parts of town, school, church. Few fatalities. A Major success for INGEOMINAS and VDAP



20 Nov. 08: 300 Mm^3 lahar swept Belalcázar 90 minutes after eruption



VDAP responded to initial events (Feb. and April 2007): Worked with INGEOMINAS to establish real-time monitoring, and effective communication systems. INGEOMINAS issued warnings and called for evacuations that saved lives when lahars swept through parts of Belalcázar on 18 Apr. 2007l and 20 Nov. 2008.

Belalcazar

November 2008

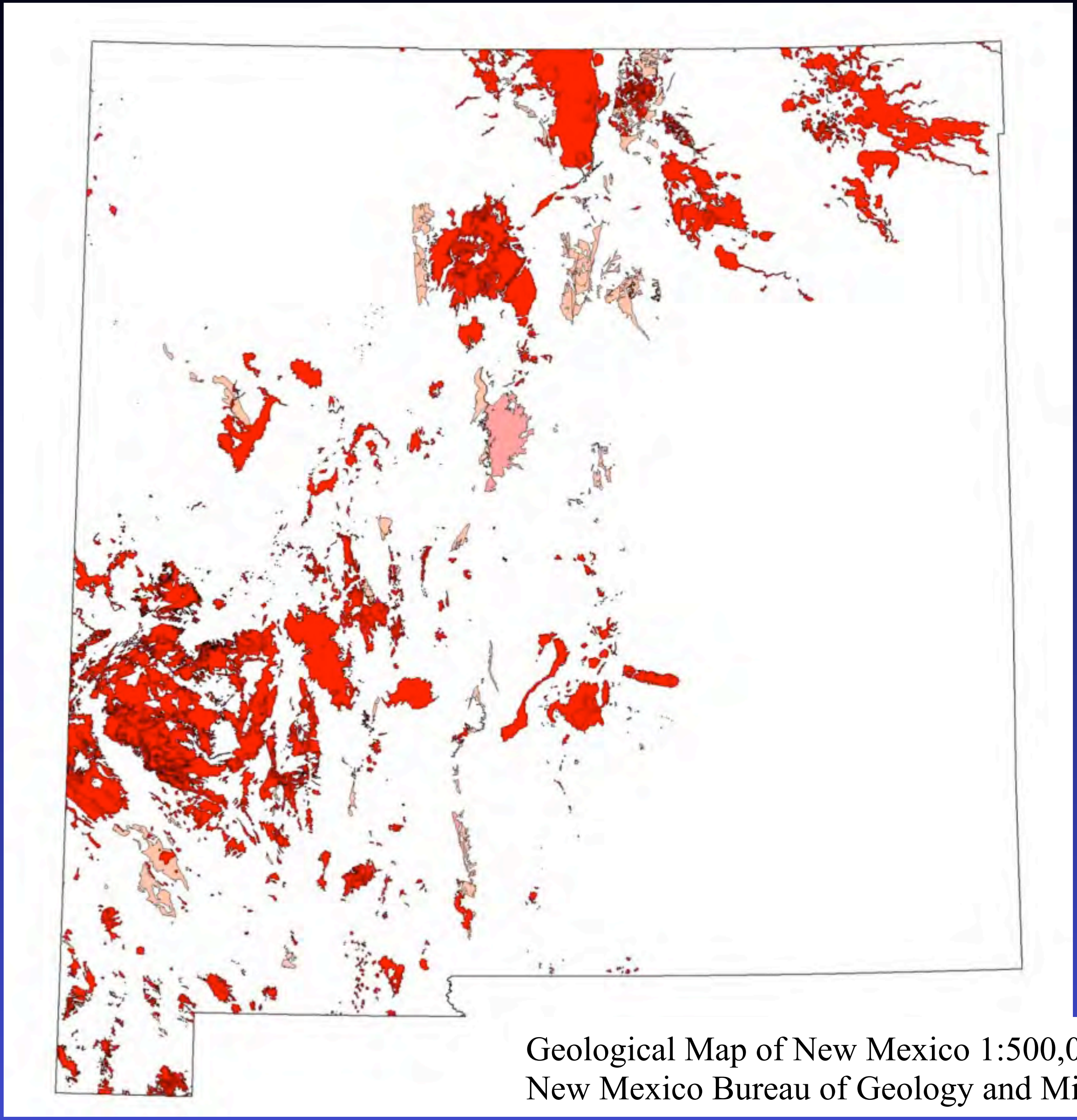
- Average depth of inundation: 22 m
- Velocity range (mínimums): 80 - 115 Km/h
- Volume of lahar: ~300 Mm^3
- Thickness of deposits: 11 - 14 m
- Runout: 100 km (to Betania reservoir)
- 10 fatalities

Volcanism in New Mexico: Past activity and future expectations

Nelia W. Dunbar, Bill McIntosh
New Mexico Bureau of Geology and Mineral Resources

New Mexico Bureau of Geology and Mineral Resources
NEW MEXICO TECH
Earth Science for the 21st Century

All volcanic and plutonic rocks in New Mexico

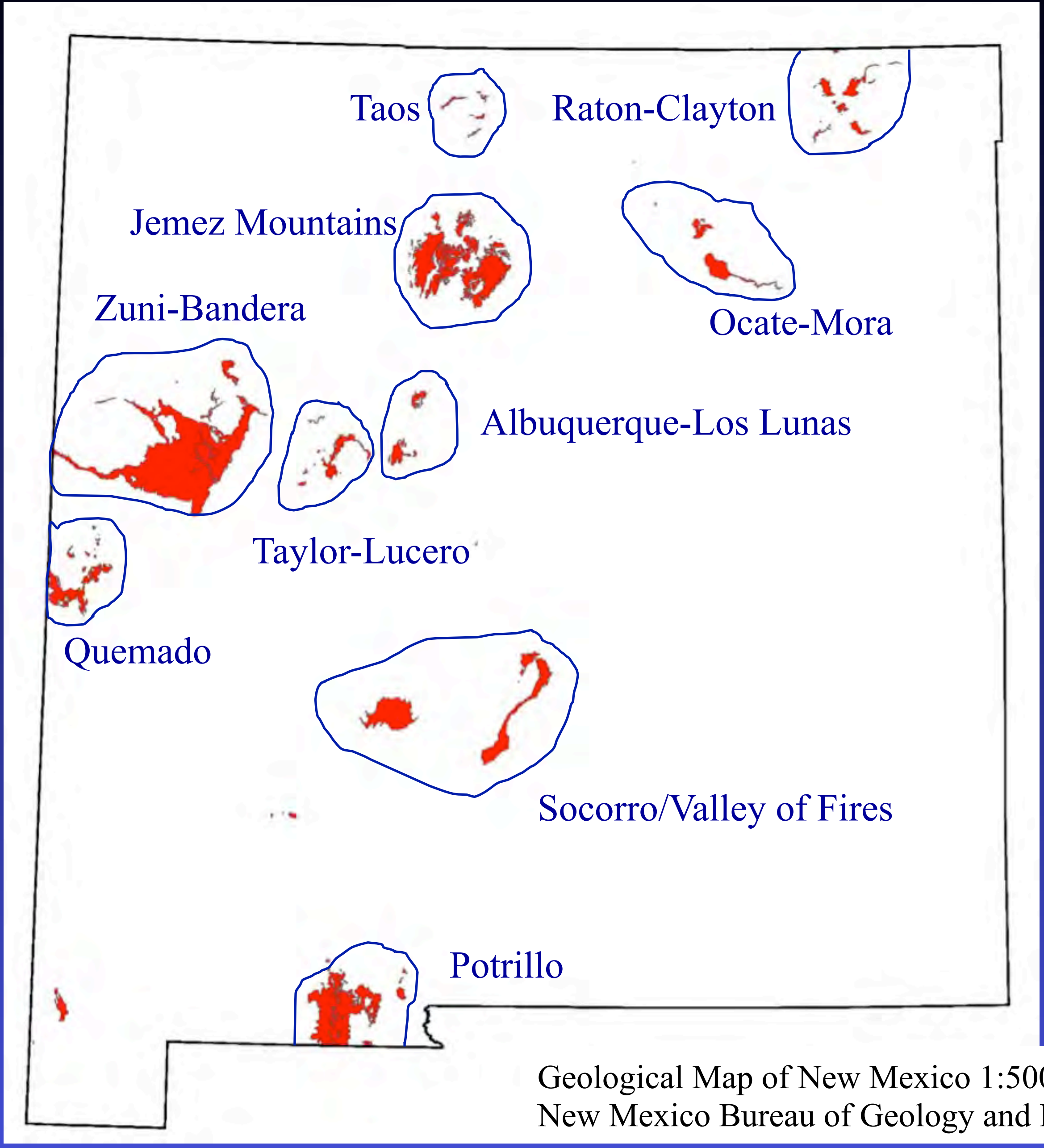


Geological Map of New Mexico 1:500,000
New Mexico Bureau of Geology and Minerals Resources, 2003

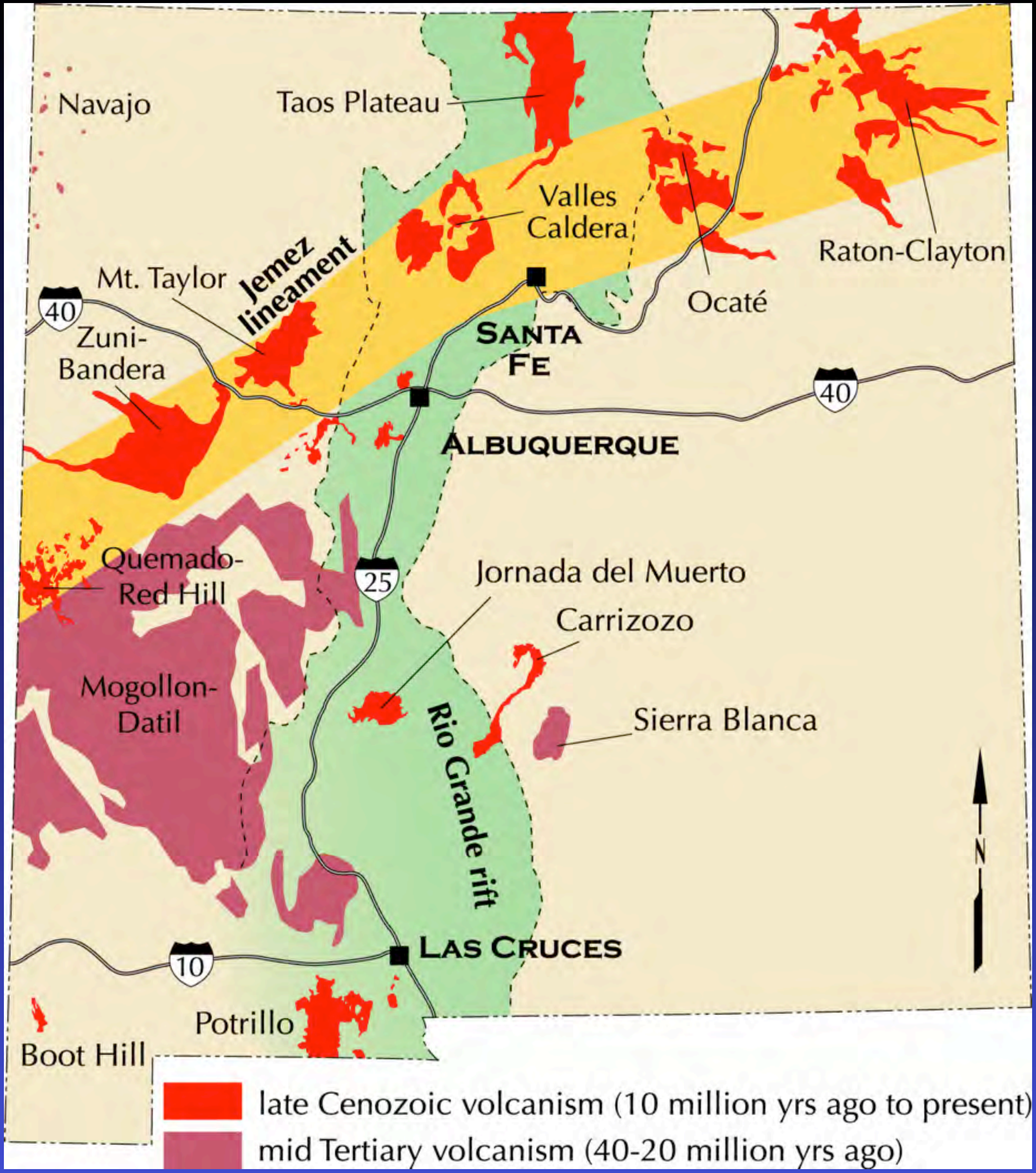
Young (<1.7 million years) volcanism in New Mexico

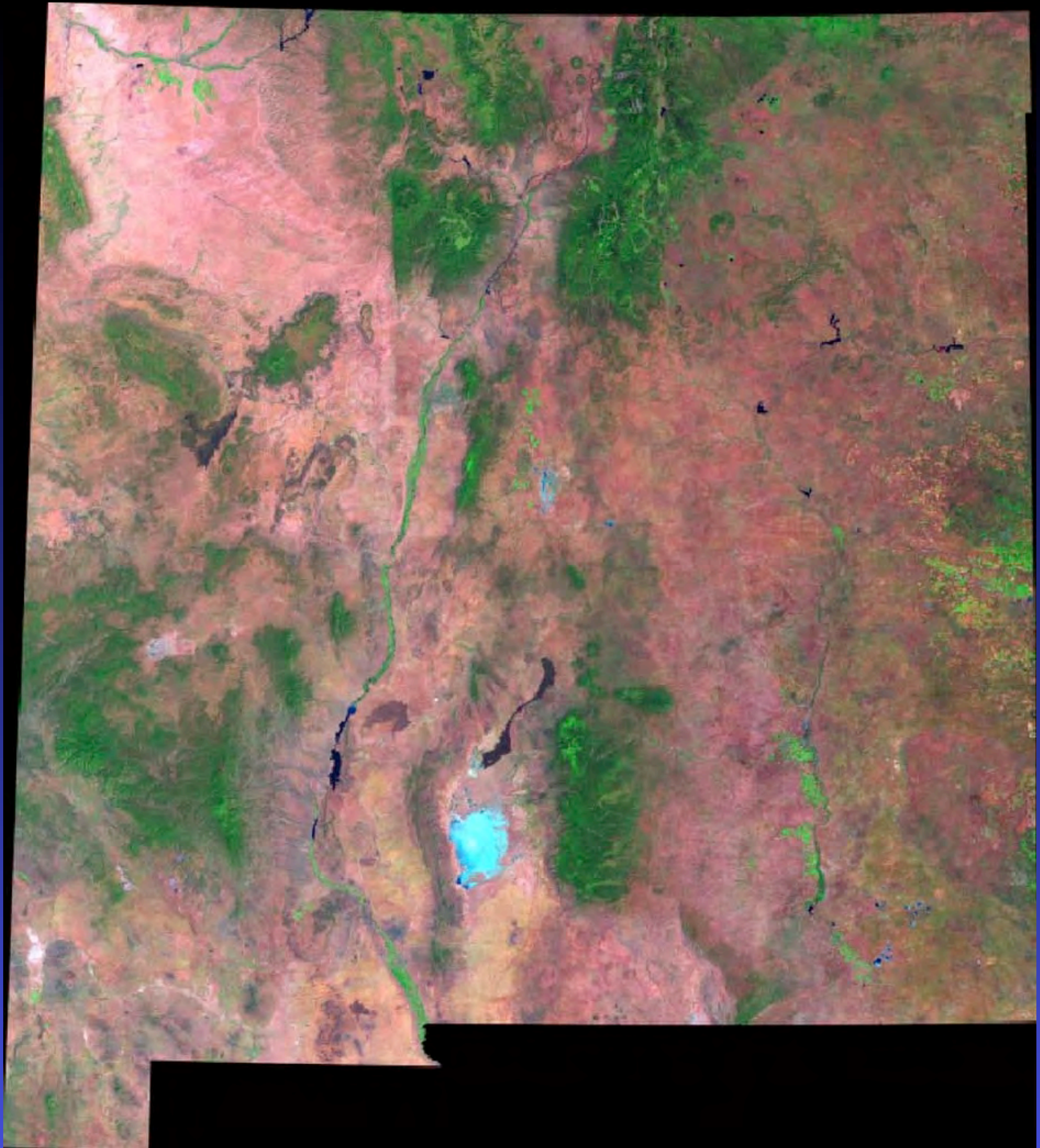
- Geographic distribution
- Two main eruptive styles
- Timing and recurrence
- Future activity?

Young volcanic rocks (<1.7 Ma) in New Mexico



Geological Map of New Mexico 1:500,000
New Mexico Bureau of Geology and Minerals Resources, 2003

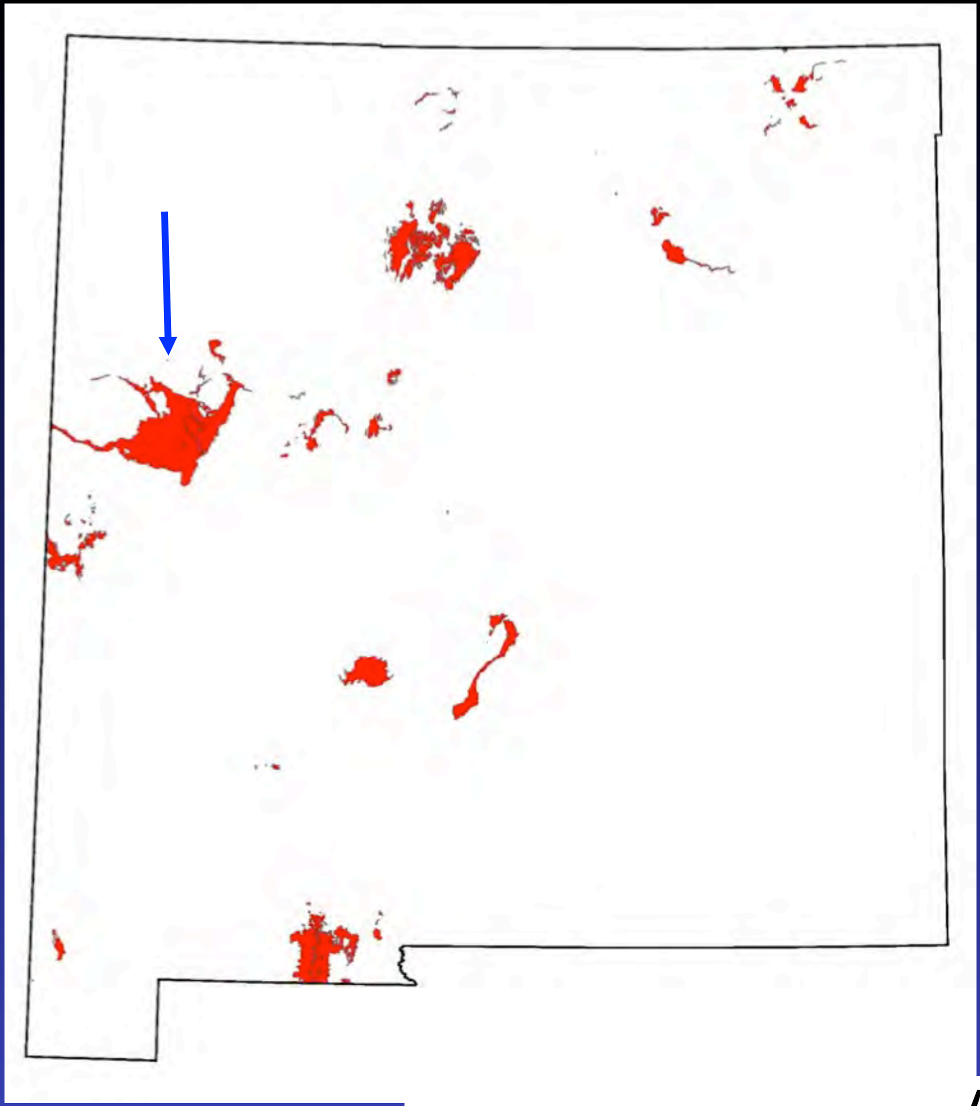

Navajo
Taos Plateau
Valles
Caldera
Raton-Clayton
Ocaté
Jemez
lineament
Mt. Taylor
40
Zuni-
Bandera
Santa
Fe
Albuquerque
40
Quemado-
Red Hill
25
Jornada del Muerto
Carrizozo
Mogollon-
Datil
Rio Grande rift
Sierra Blanca
N
Las Cruces
10
Potrillo
Boot Hill
late Cenozoic volcanism (10 million yrs ago to present)
mid Tertiary volcanism (40-20 million yrs ago)



Two main styles of volcanism represented in the young volcanic record in New Mexico

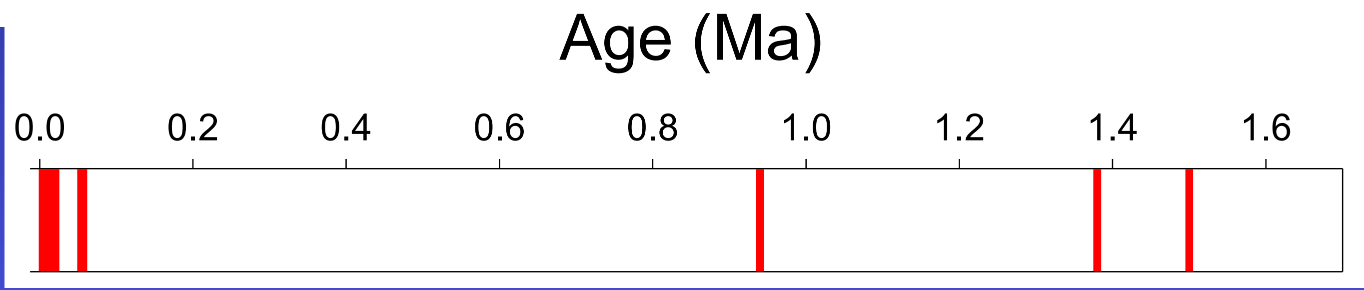
- Basaltic
- Rhyolitic

Zuni-Bandera



Many basaltic eruptions during the past 1.7 Ma, including the youngest volcanic eruption in New Mexico, the McCartys lava flow, dated at 3,900+/-1,200 years.

Dunbar and Phillips, 2004 (36-Cl)
Laughlin et al., 1994 (14-C, 3-He)
Laughlin et al., 1993 (Ar-Ar)
Crumpler et al., 1982 (K-Ar)
Anders et al, 1981 (K-Ar)



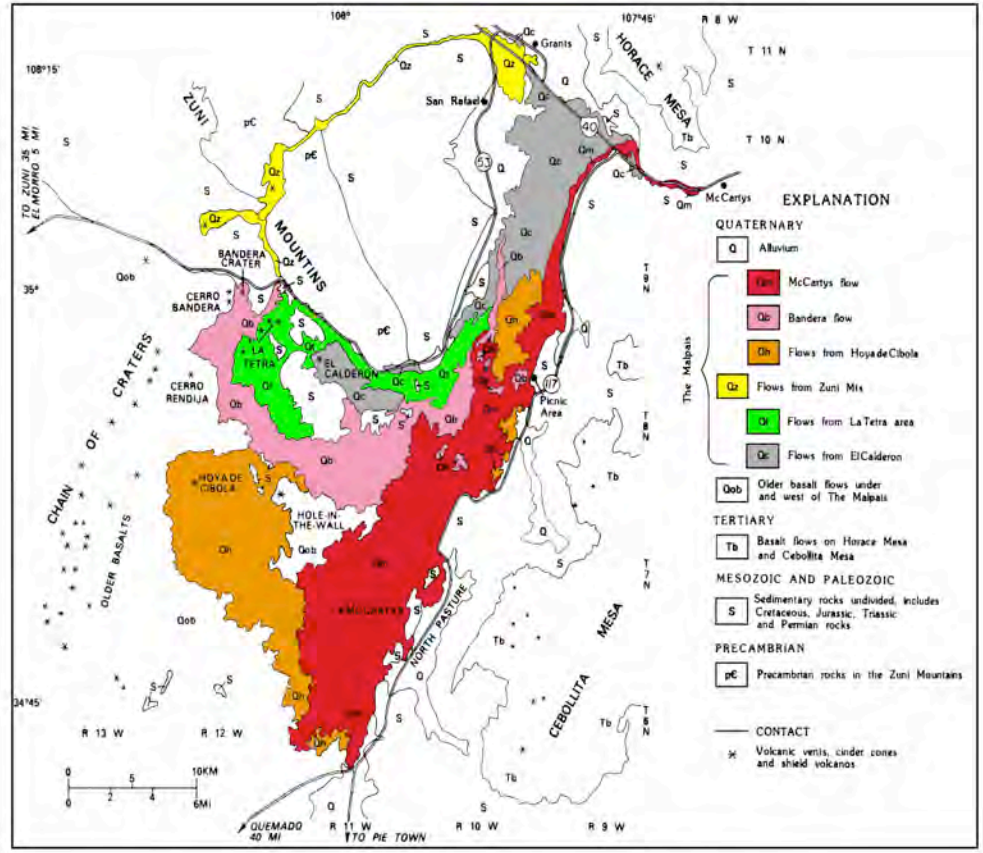
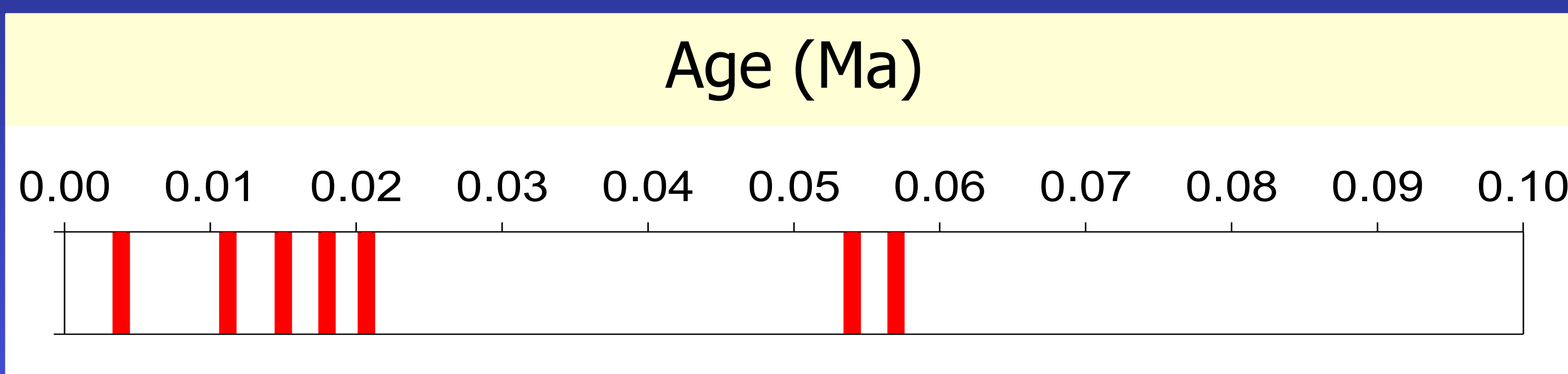
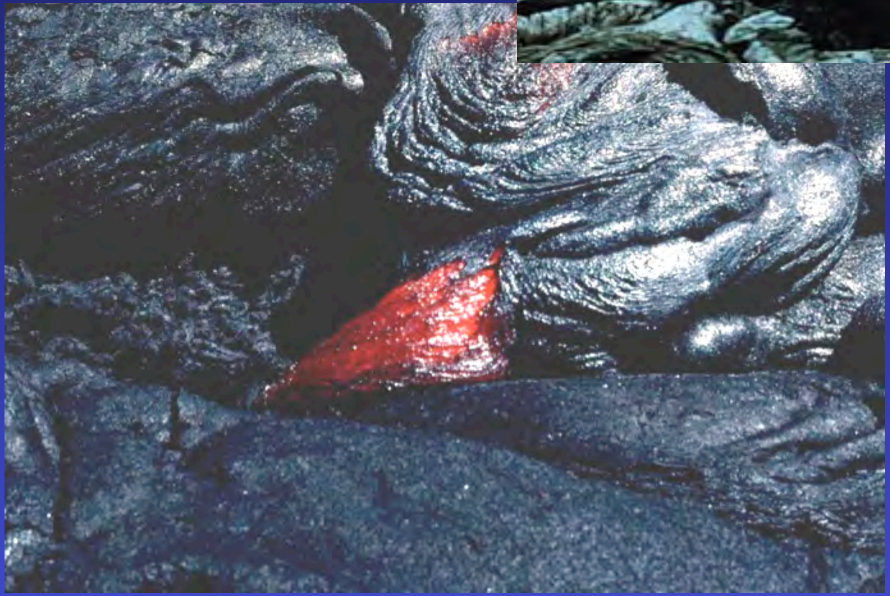


Figure 1. Geologic map of El Malpais and surrounding area, New Mexico.



Three main volcanic features

- Lava flows (pahoehoe and a’a)
- Lava tubes
- Cinder cones



Pahoehoe lava

McCartys flow

A'A lava

USGS photos

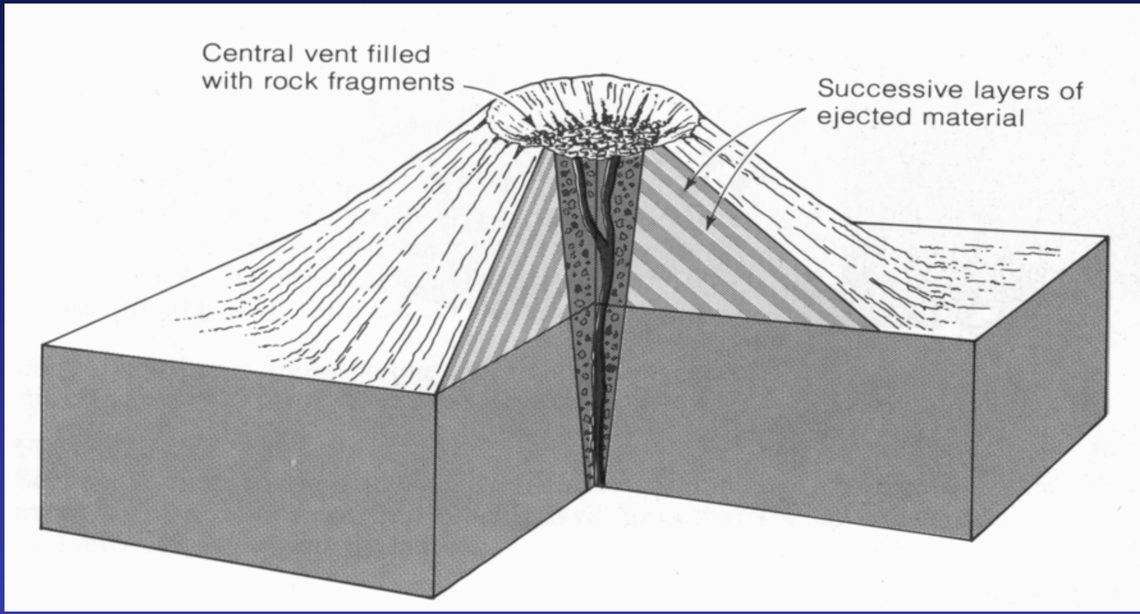
Bandera flow

Lava Tubes

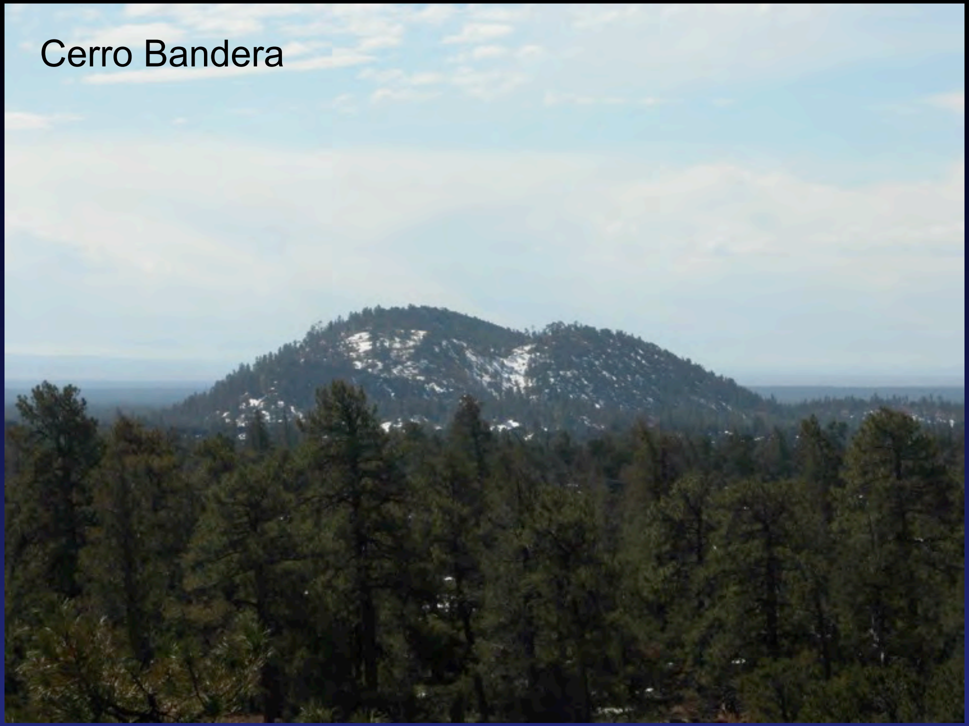
USGS photo

Cinder cones

Photo- Christina Heliker



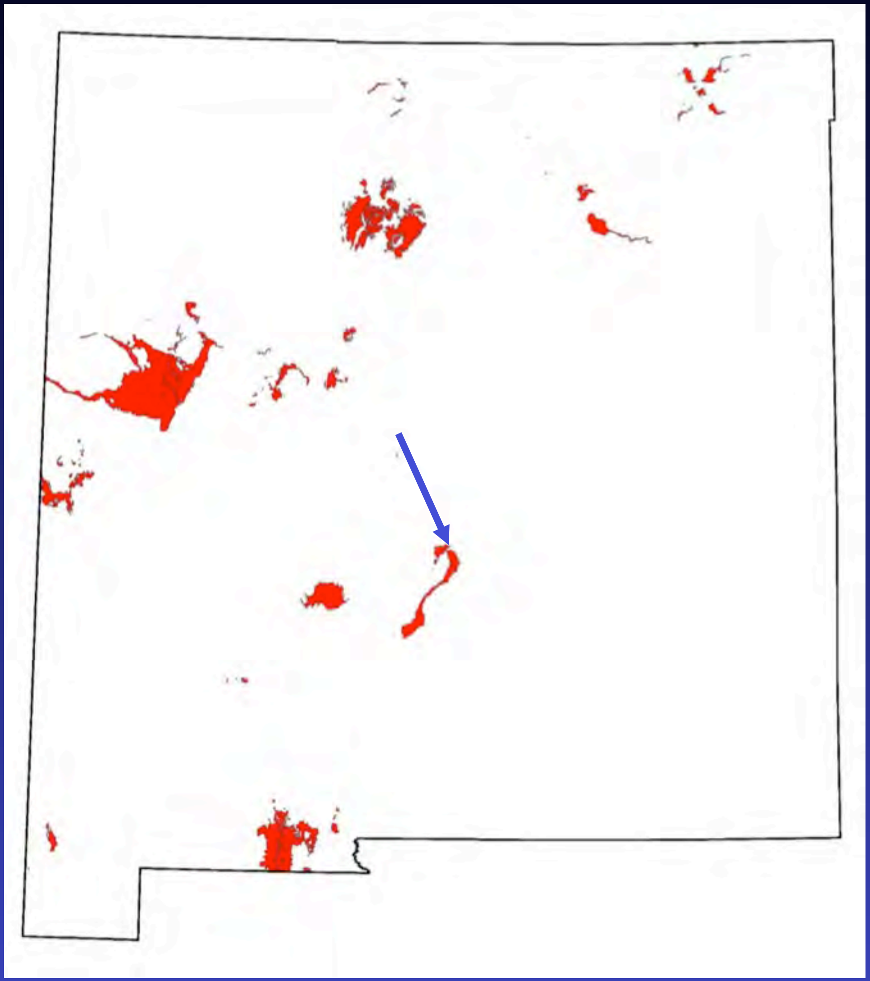
From "Earth" Press and Seiver, 1982


Cerro Bandera


Chain of Craters


Bandera Crater

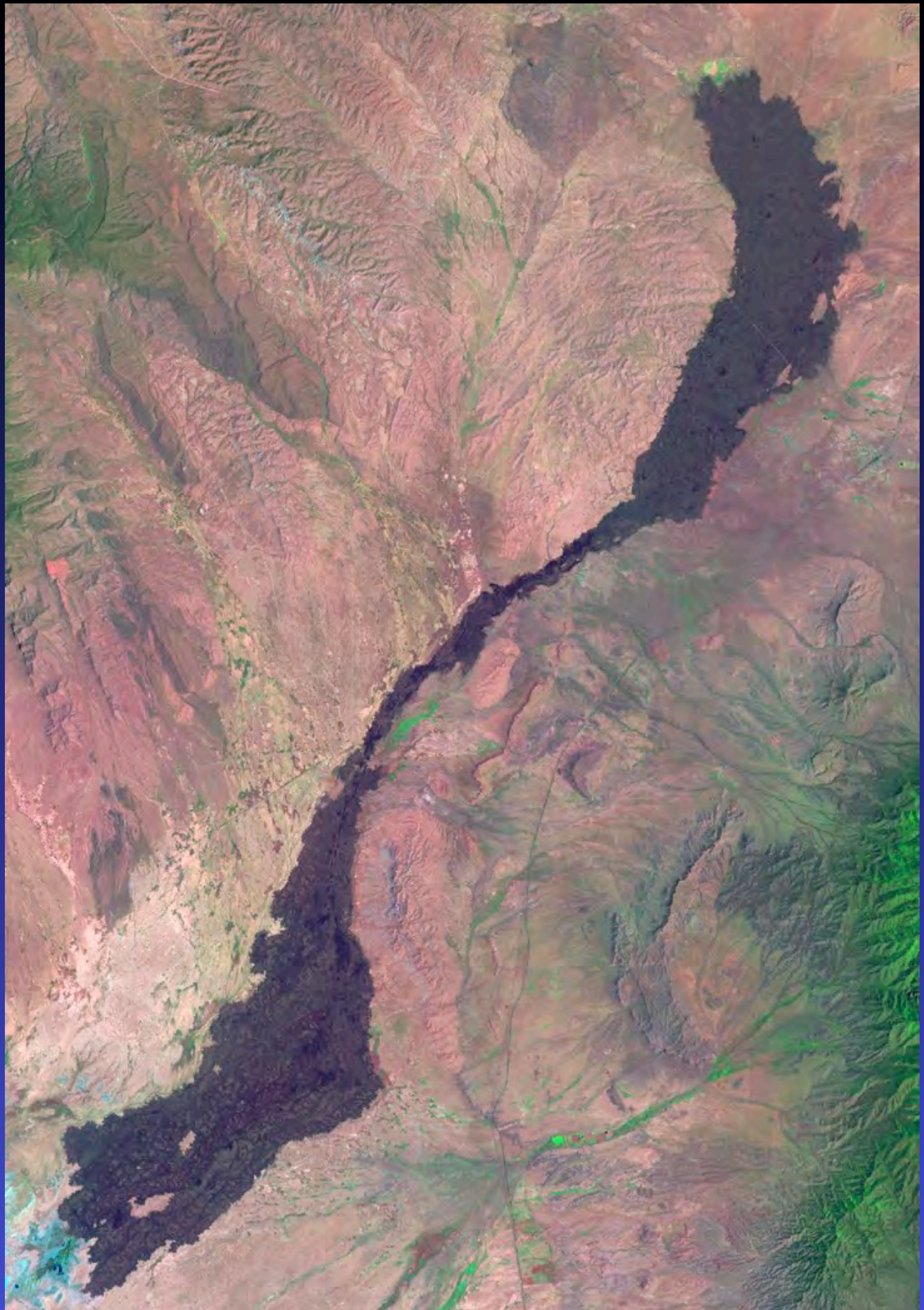
Carrizozo Malpais lava flows



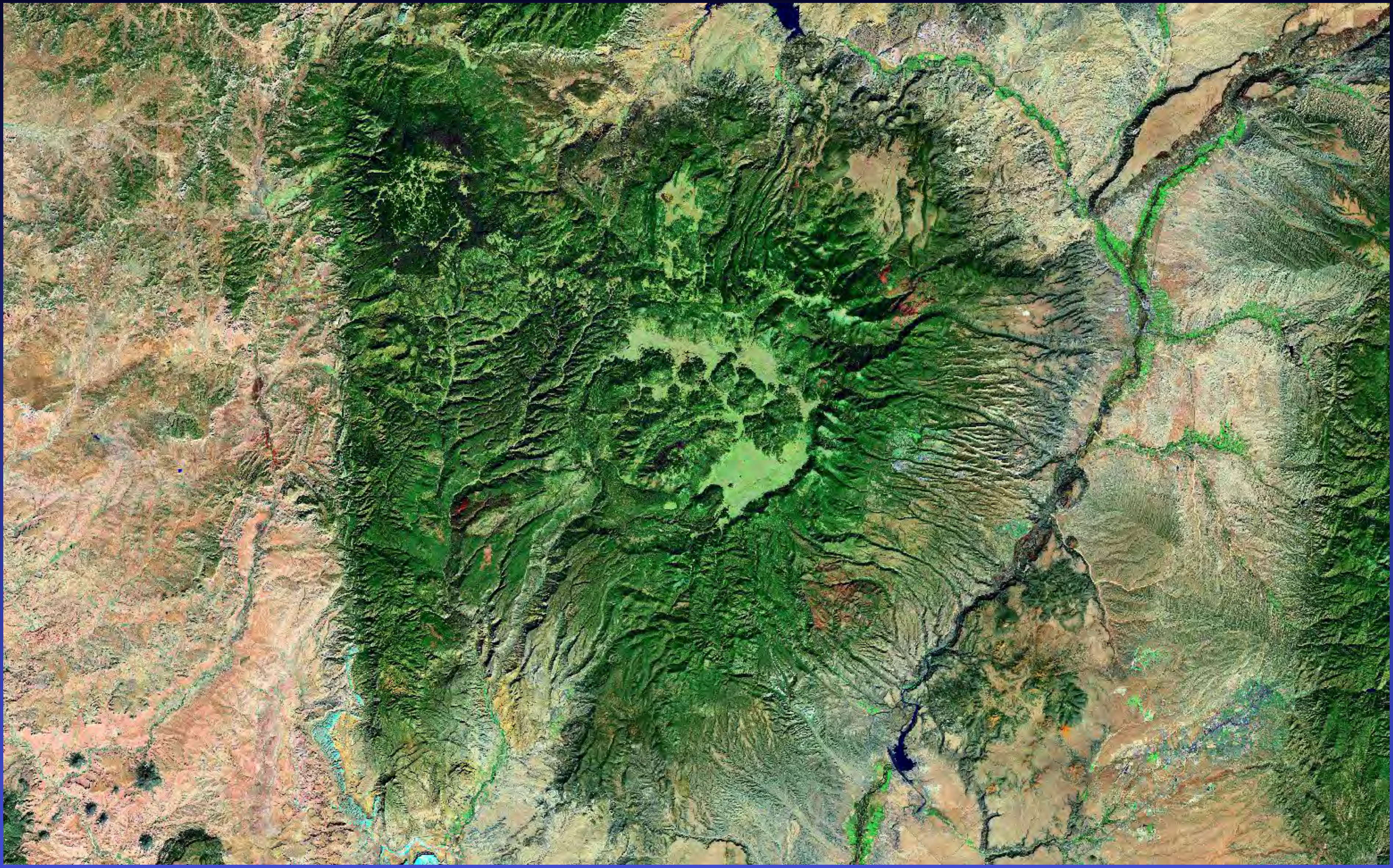
In contrast to the Zuni-Bandera volcanic field, where there are many overlapping lava of different ages, the Carrizozo lava flow appears to be a single, isolated event.

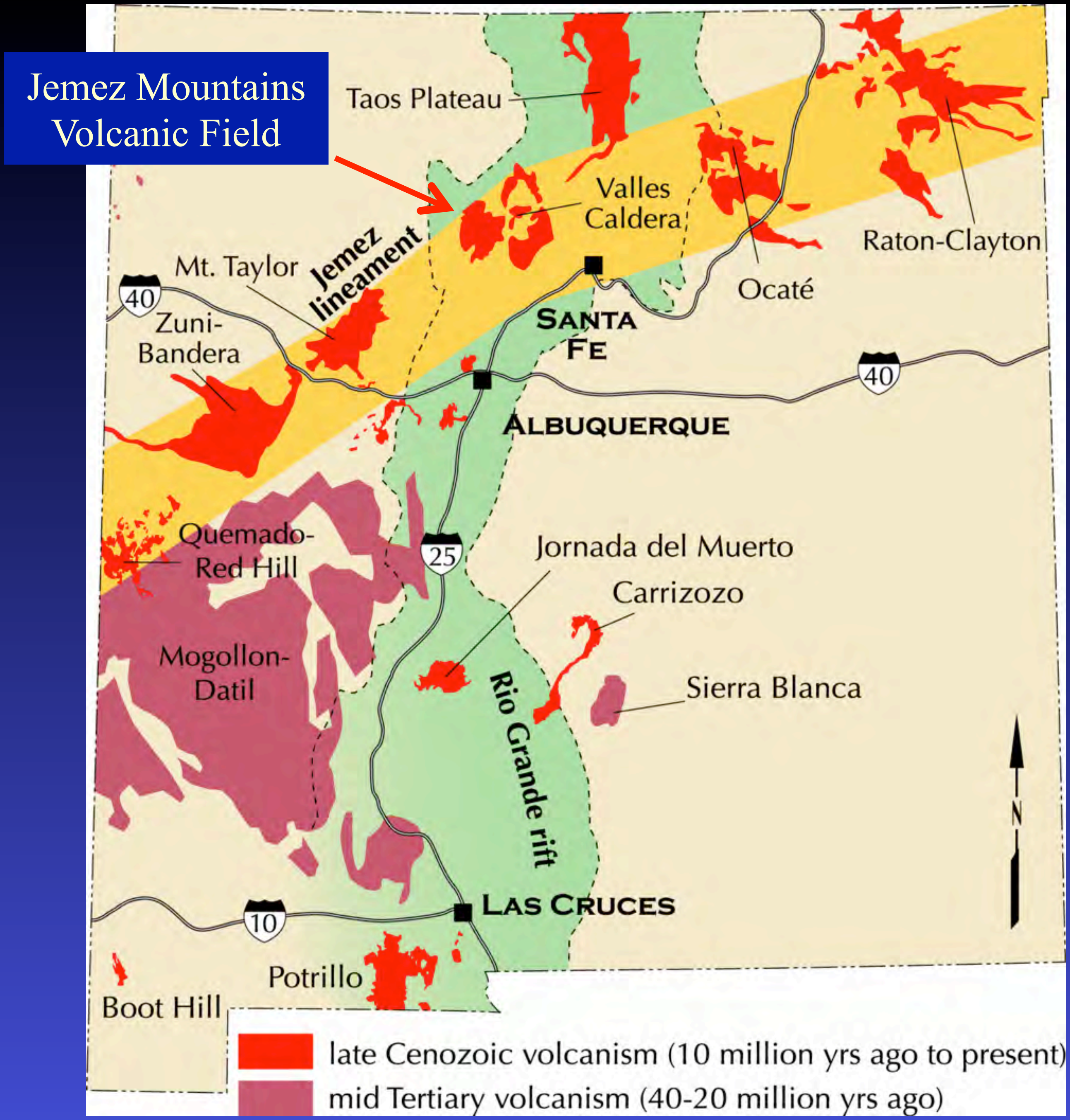
Two lava flows (upper and lower), both dated at 5,200±700 years by ^{36}Cl and 4,300±1000 years by ^{3}He.

Dunbar, 1999 (^{36}Cl)
Anthony et al. 1998, (^{3}He)

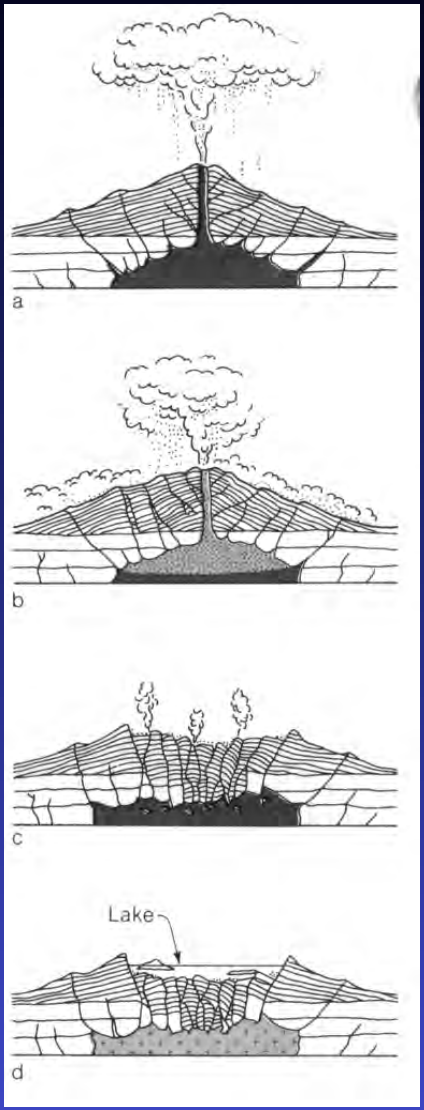


Jemez Mountains Volcanic Field



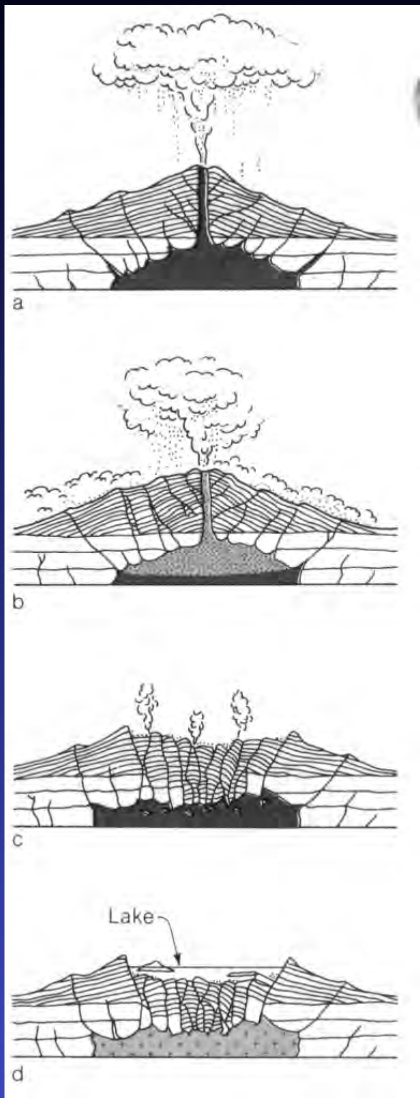

Jemez Mountains
Volcanic Field
Taos Plateau
Valles
Caldera
Raton-Clayton
Ocaté
Jemez
lineament
Mt. Taylor
40
Zuni-
Bandera
Santa
Fe
40
Albuquerque
Quemado-
Red Hill
25
Jornada del Muerto
Carrizozo
Mogollon-
Datil
Rio Grande rift
Sierra Blanca
N
Las Cruces
10
Potrillo
Boot Hill
late Cenozoic volcanism (10 million yrs ago to present)
mid Tertiary volcanism (40-20 million yrs ago)

Silicic Volcanism



Press and Siever, 1978

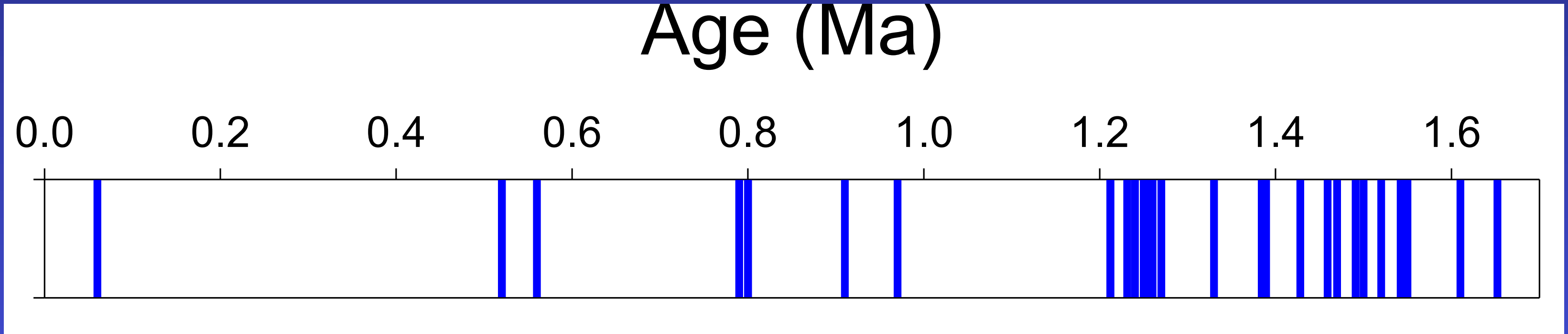
Mayon Volcano
Photograph by C.G. Newhall on September 23, 1984



Press and Siever, 1978

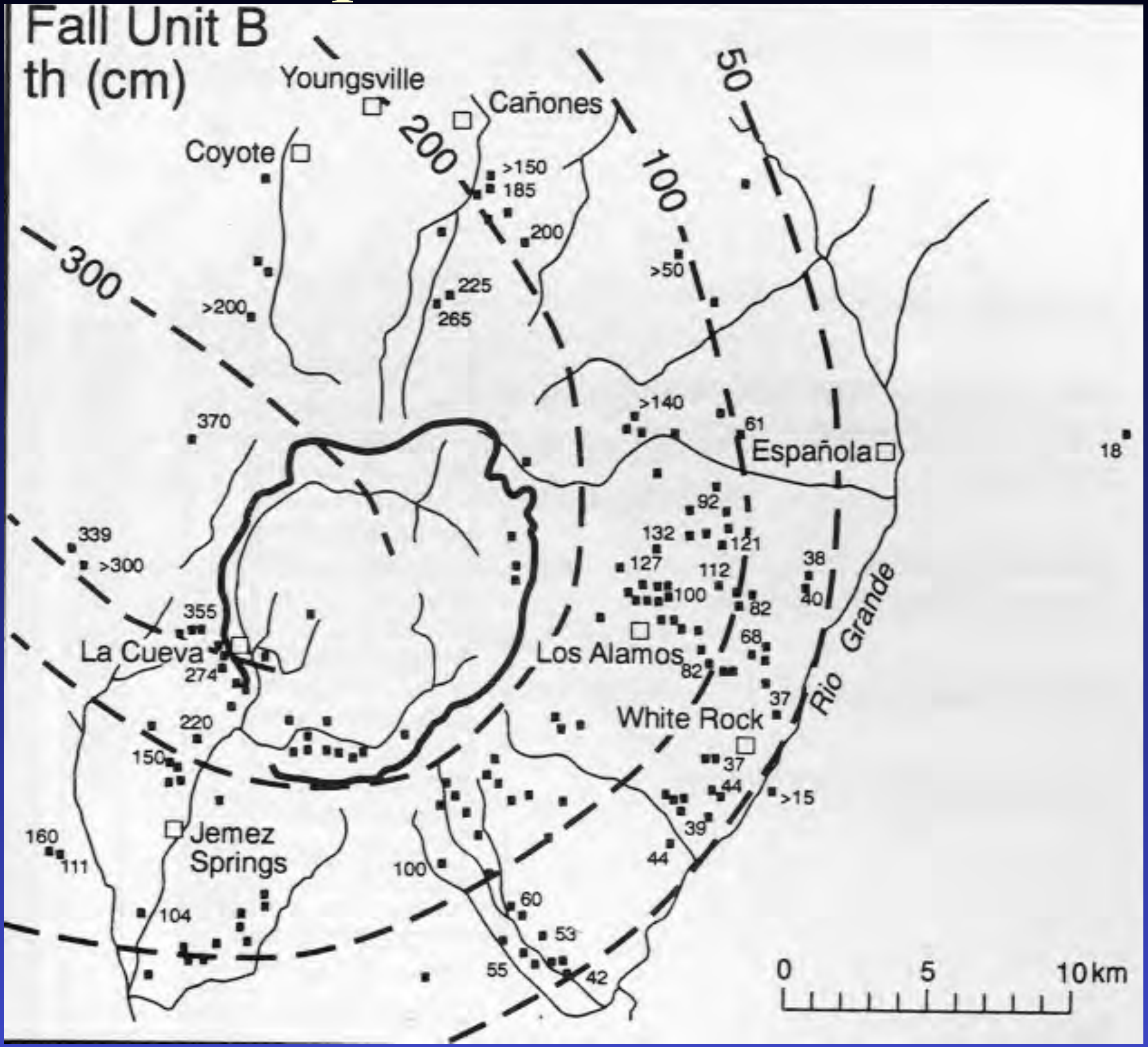
Jemez Mountains Volcanic Field

- Active for at least the past 16 Ma
- Activity during the past 1.7 Ma is rhyolitic
- Many eruptions over the past 1.7 Ma
- Two major explosive events, one at 1.6 Ma and one at 1.2 Ma each consisting of an ashfall as well as ignimbrite eruption, each erupting several hundred cubic kilometers of magma.




Ashfall

Map of fall extent



From Self et al., 1996

Tephra from 1.2 Ma eruption in Socorro, NM (~300 km to the south)

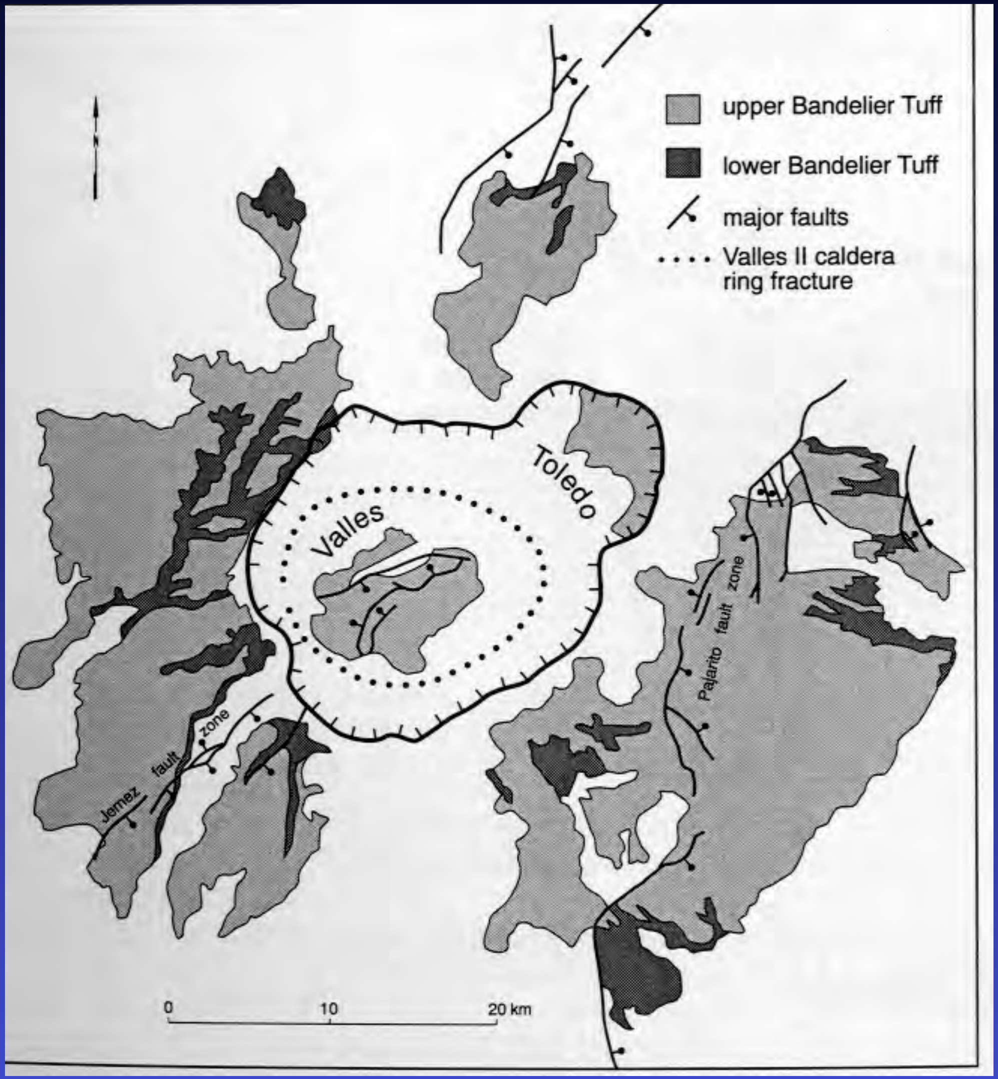

Ignimbrite

Landscape and landscape evolution are likely to have may have been significantly impacted by eruption of the Bandelier Tuff.

The large, silicic Bandelier Tuff eruptions would have completely covered the landscape near the vent.

Stream morphology and surface runoff could have been affected.

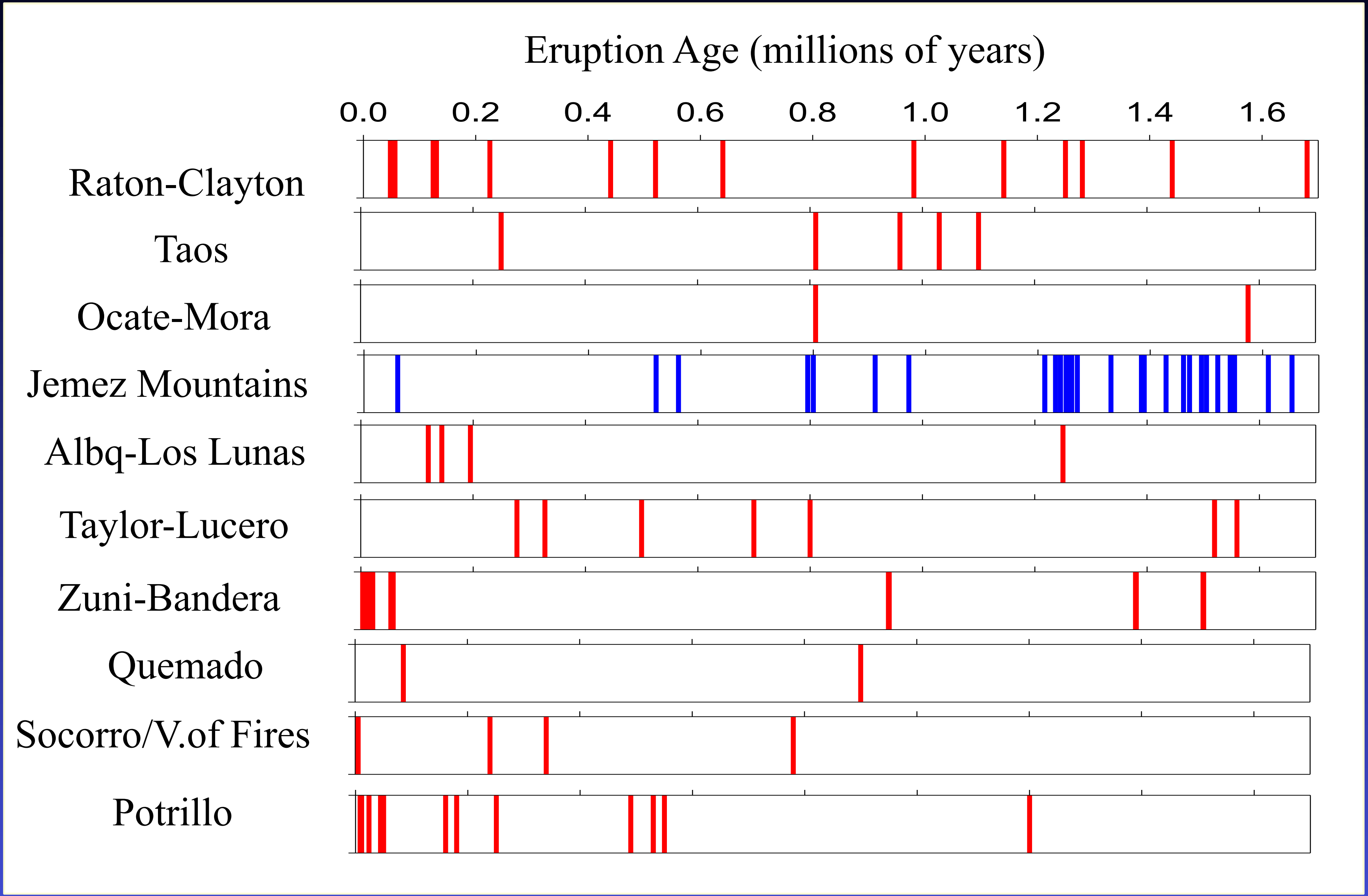
Flood deposits near Socorro indicate that rivers were dammed, forming lakes that later broke through the dams, transporting volcanic material hundreds of km from source.

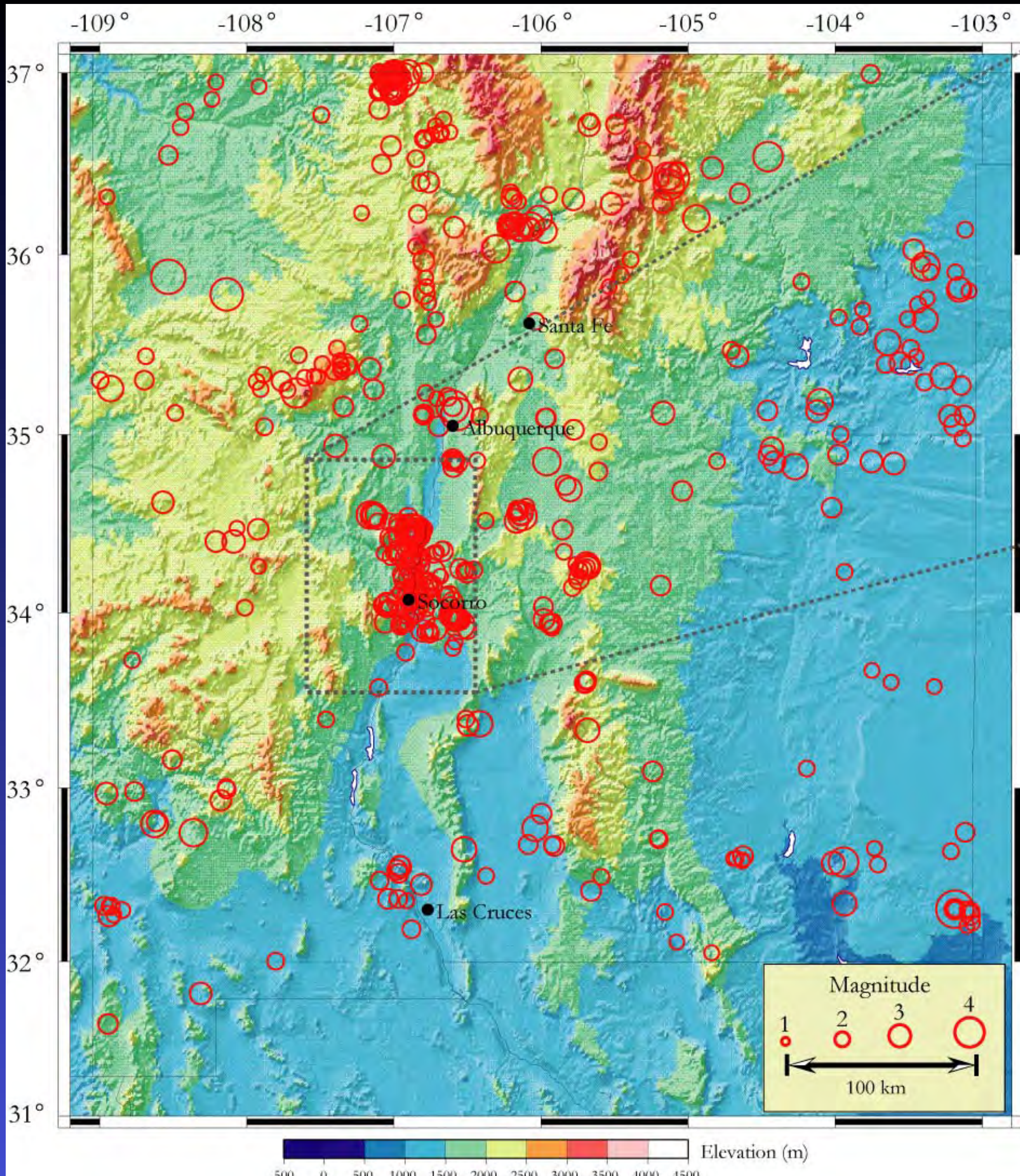


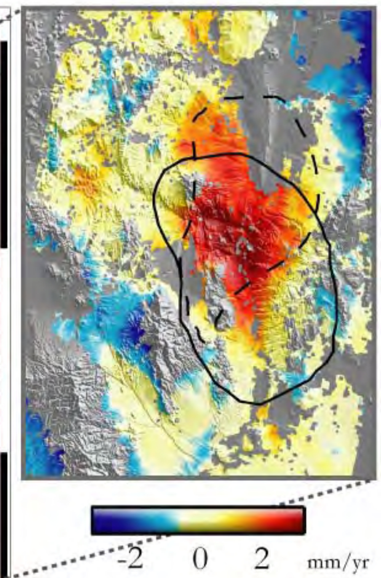
From Self et al., 1996

The youngest eruptive activity in the Jemez Mountain Volcanic field is the El Cajete/Banco Bonito eruptive event, which occurred at around 60,000 years ago. This eruption may signal the start of a new eruptive cycle in the Jemez Mountains (Wolff and Gardner, 1995)

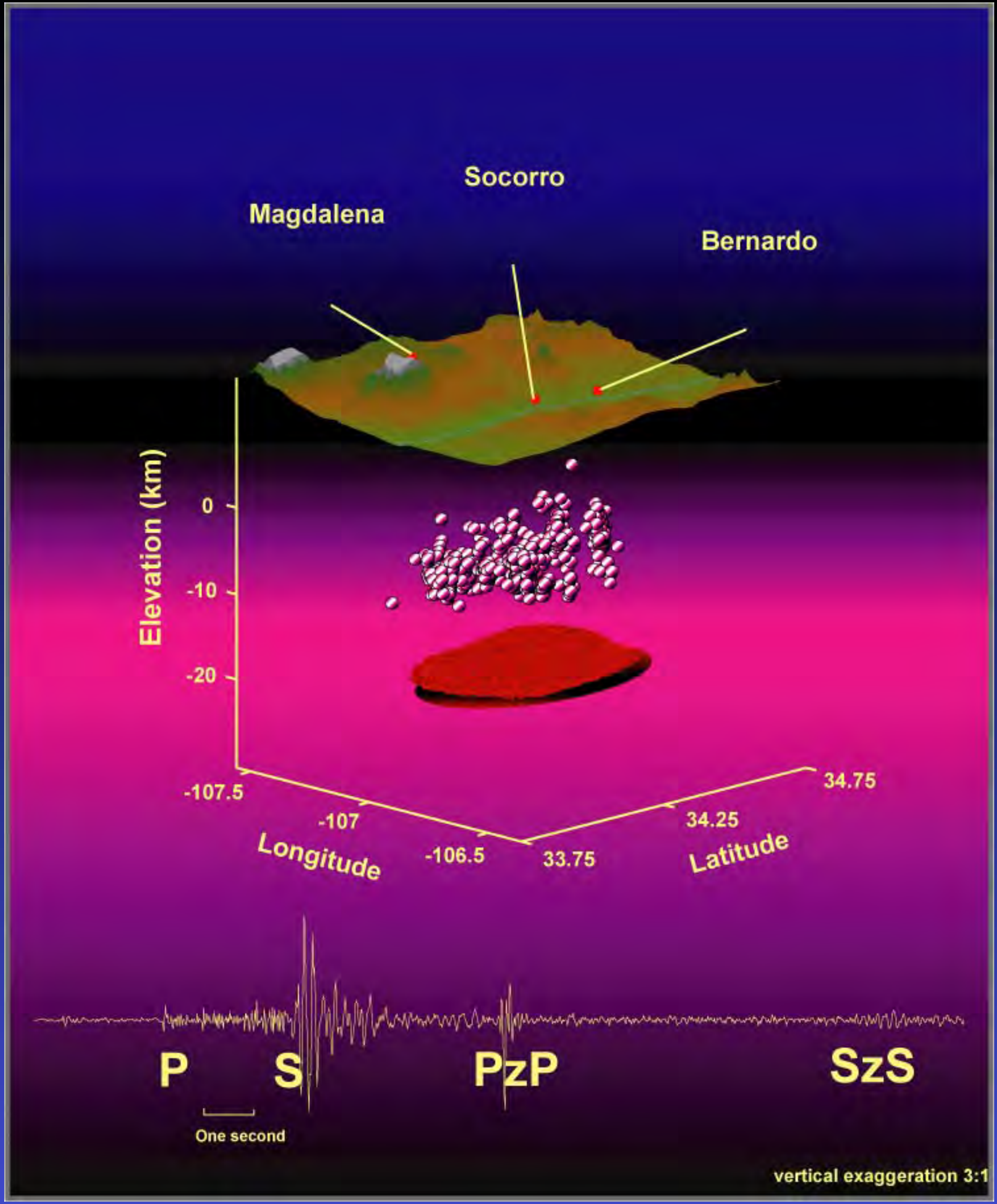
Summary of Young Volcanic Activity in New Mexico







Uplift rate in millimeters/year from satellite INSAR, shown with the outline of the Socorro magma body estimated in two studies of mid-crustal seismic reflections.



http://www.ees.nmt.edu/outside/Geop/pictures/SMBperspective1_big.jpg

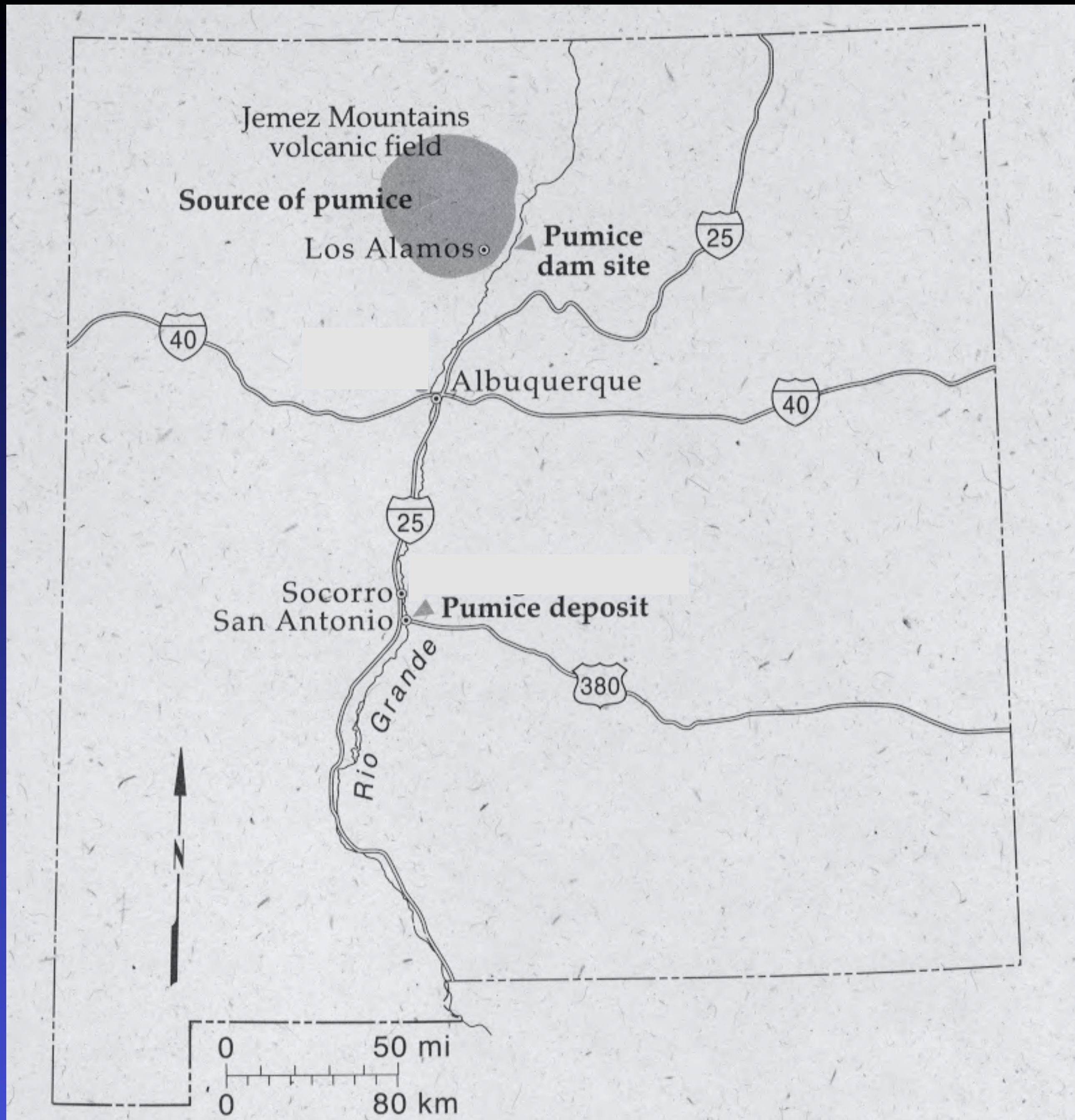
Conclusions

- Volcanism has been temporally common and geographically widespread throughout the past 1.7 Ma in New Mexico.
- This volcanism in New Mexico has been largely bimodal, consisting of relatively small, geographically distributed basaltic events, and a concentration of small to large volume silicic events from the Jemez Mountains Volcanic Field.

River damming by silicic eruptions

Damming of rivers, and subsequent floods, associated with large eruptions, can affect river evolution and channel morphology

An example of this occurred during large eruptions of the Lower Bandelier Tuff (Cather, 1991).


Jemez Mountains
volcanic field
Source of pumice
Los Alamos
Pumice
dam site
25
40
Albuquerque
40
25
Socorro
San Antonio
Pumice deposit
Rio Grande
380
N
0
50 mi
0
80 km

Quaternary Volcanism and Landscape Evolution

– Basaltic lava flows tend to flow in low-lying areas, hence down drainages. Basaltic lavas may cause damming of drainages and changing of stream patterns

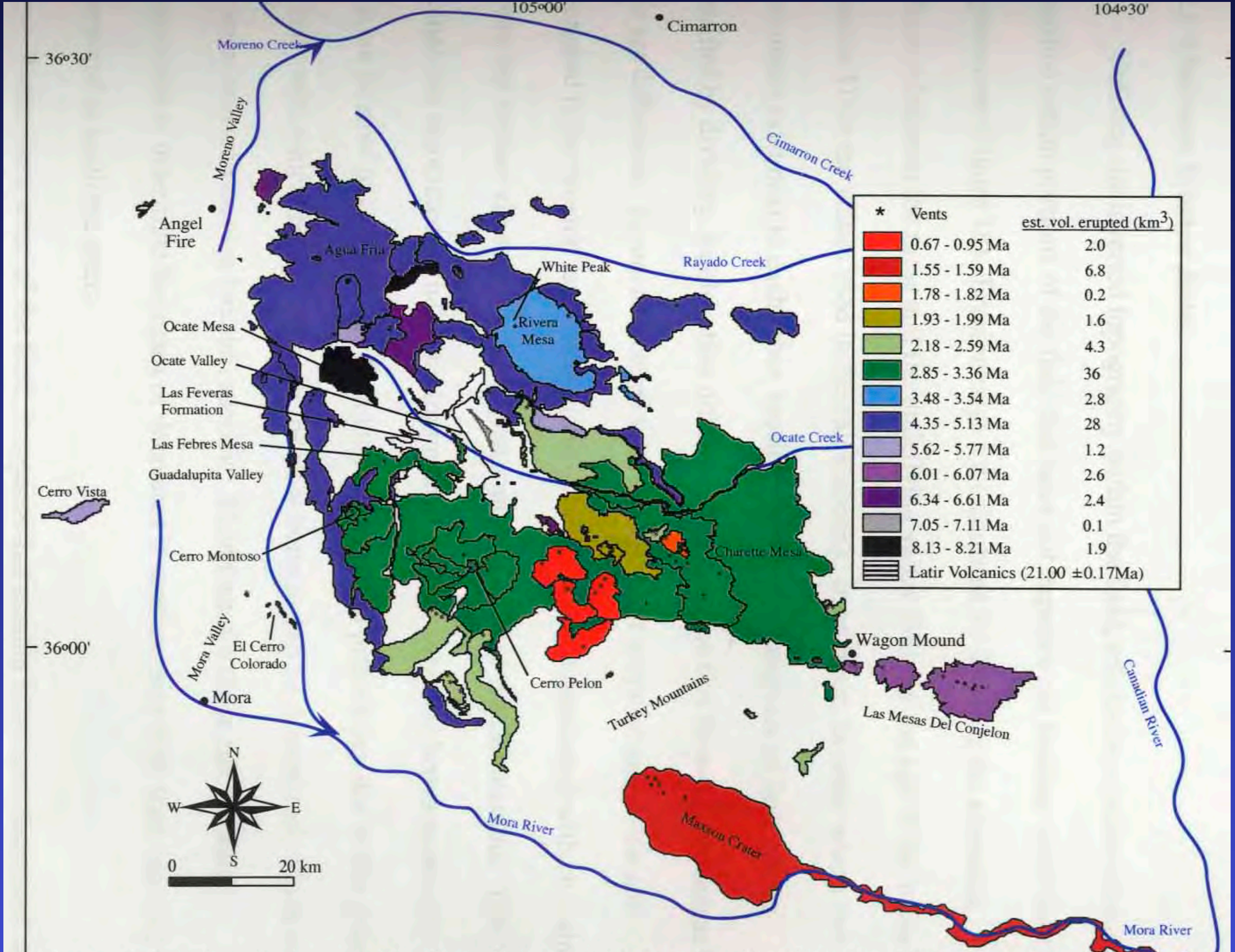


Figure 17. Geochronologic map of the Ocate Volcanic field, NM, based on O'Neill and Mehnert (1988). Nomenclature and major drainages of the Ocate Volcanic field. Rivers and creek locations approximately drawn.

Conclusions Part 2

- The effect of Quaternary volcanism on climate in New Mexico was probably negligible
- However, the effect on landscape evolution, particularly through disruption of drainage patterns, may have been significant.

Cosmogenic Cl-36 age determination

Exposure technique, with Cl-36 produced by cosmic rays interacting with geologic materials at the earth's surface

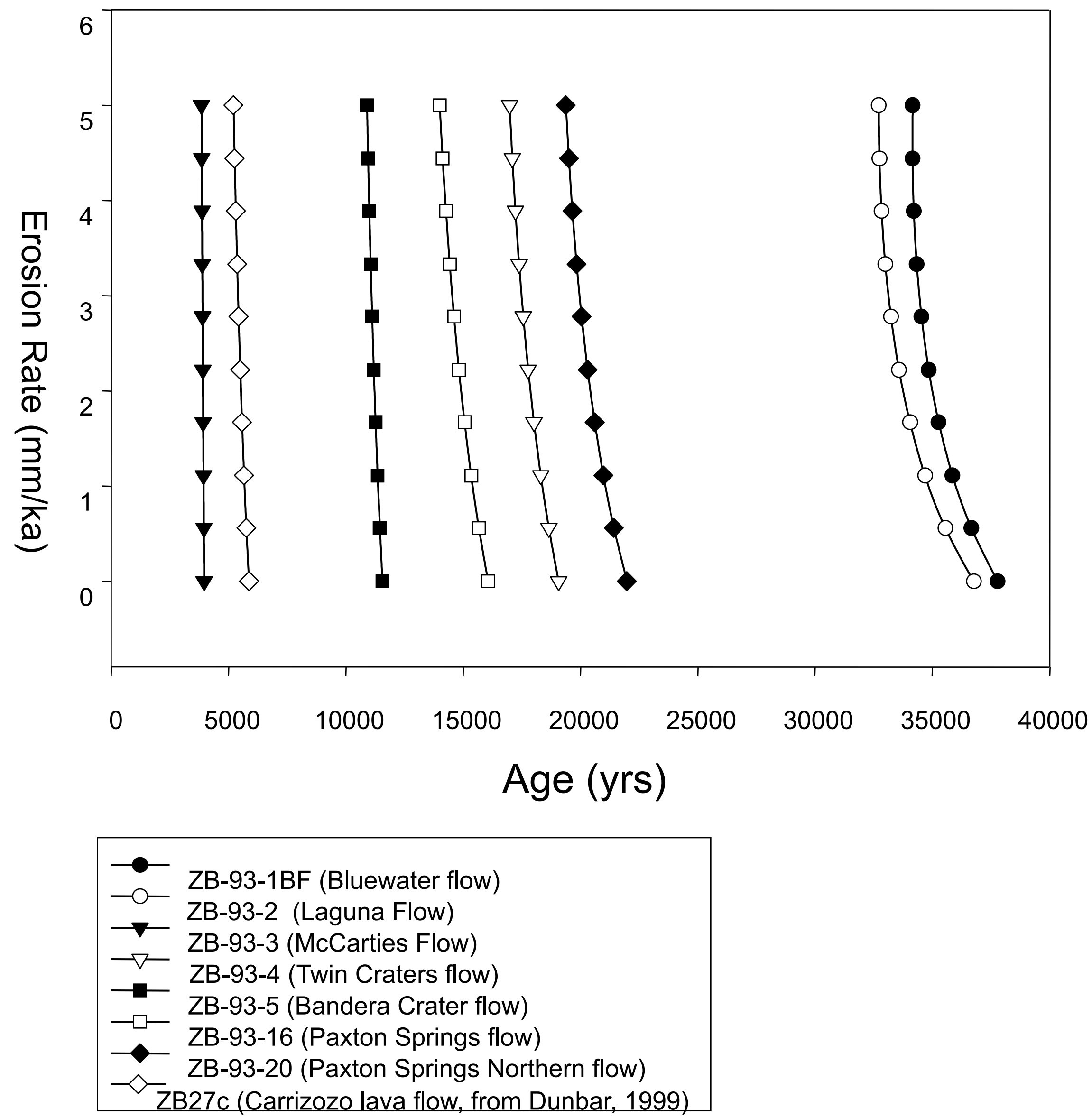
-Chlorine-36 is generated by 3 main reactions:

- -Neutron activation of Cl-35
- -Direct spallation of K
- -Direct spallation of Ca

-Amount of Cl-36 in a rock is dependent on the length of time that the rock has been exposed at the earth's surface, and is also a function of rock chemical composition, location and elevation

Data needed for Cl-36 analysis

-Latitude, longitude and elevation of rock (GPS, topo)
-Shielding of sampled rock (field observation)
-Major element composition of rock (XRF, NAA)
-Cl content of rock (specific ion electrode)
-Cl-36/Cl-35 (tandem accelerator mass spectrometer)



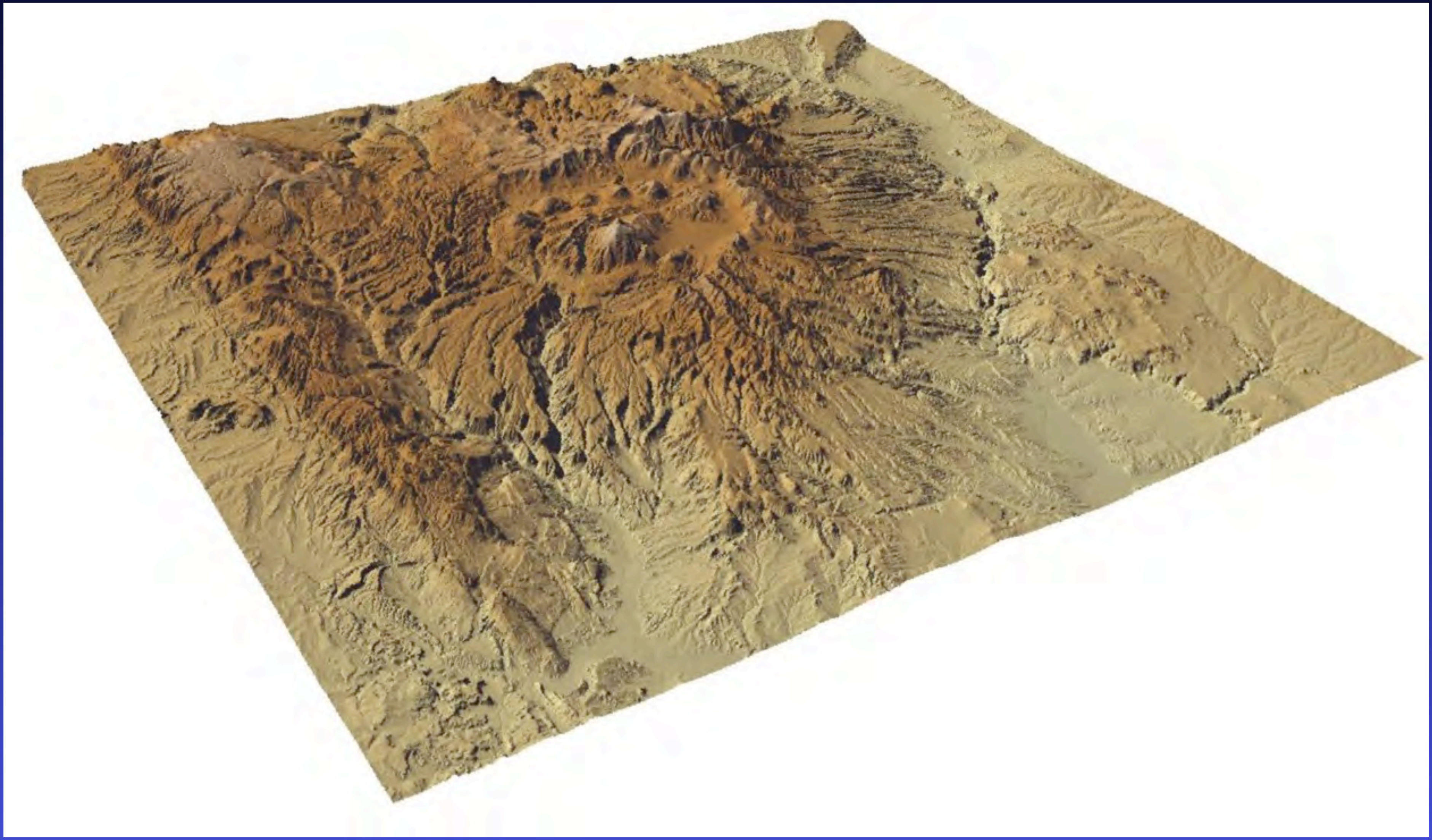
Erosion Rate (mm/ka)
6
5
4
3
2
1
0
0
5000
10000
15000
20000
25000
30000
35000
40000
Age (yrs)
ZB-93-1BF (Bluewater flow)
ZB-93-2 (Laguna Flow)
ZB-93-3 (McCarties Flow)
ZB-93-4 (Twin Craters flow)
ZB-93-5 (Bandera Crater flow)
ZB-93-16 (Paxton Springs flow)
ZB-93-20 (Paxton Springs Northern flow)
ZB27c (Carrizozo lava flow, from Dunbar, 1999)

Quaternary eruptions in New Mexico are unlikely to have had significant impact on climate.

- The eruptions either probably emitted sulfur, but were of low volume and explosivity (most of the basaltic eruption)

- Or, were of high volume and explosivity, such as the Bandelier Tuff, but didn't contain sulfur in the magma and hence didn't emit sulfur during the eruption (Dunbar and Hervig, 1992)

Shortly after the large, explosive eruption at 1.25 million years ago a series of domes erupted, ending at around 0.5 million years.



Seismic Monitoring in the Southwest
Are we ready for an Eruption?


USGS
USGS
USGS
USGS
USGS

The USGS National Earthquake Information Center

Who are we? NEIC is part of the **U.S. Geological Survey**, is located in Golden, Colorado

The NEIC has five main missions:

1) Monitor global earthquakes, 24/7, and disseminate this information to:
   - Aid organizations (USAID, RedCross, etc)
   - US Government (White House, State Dept., Local, etc)
   - General Public, Media
   - Academic community

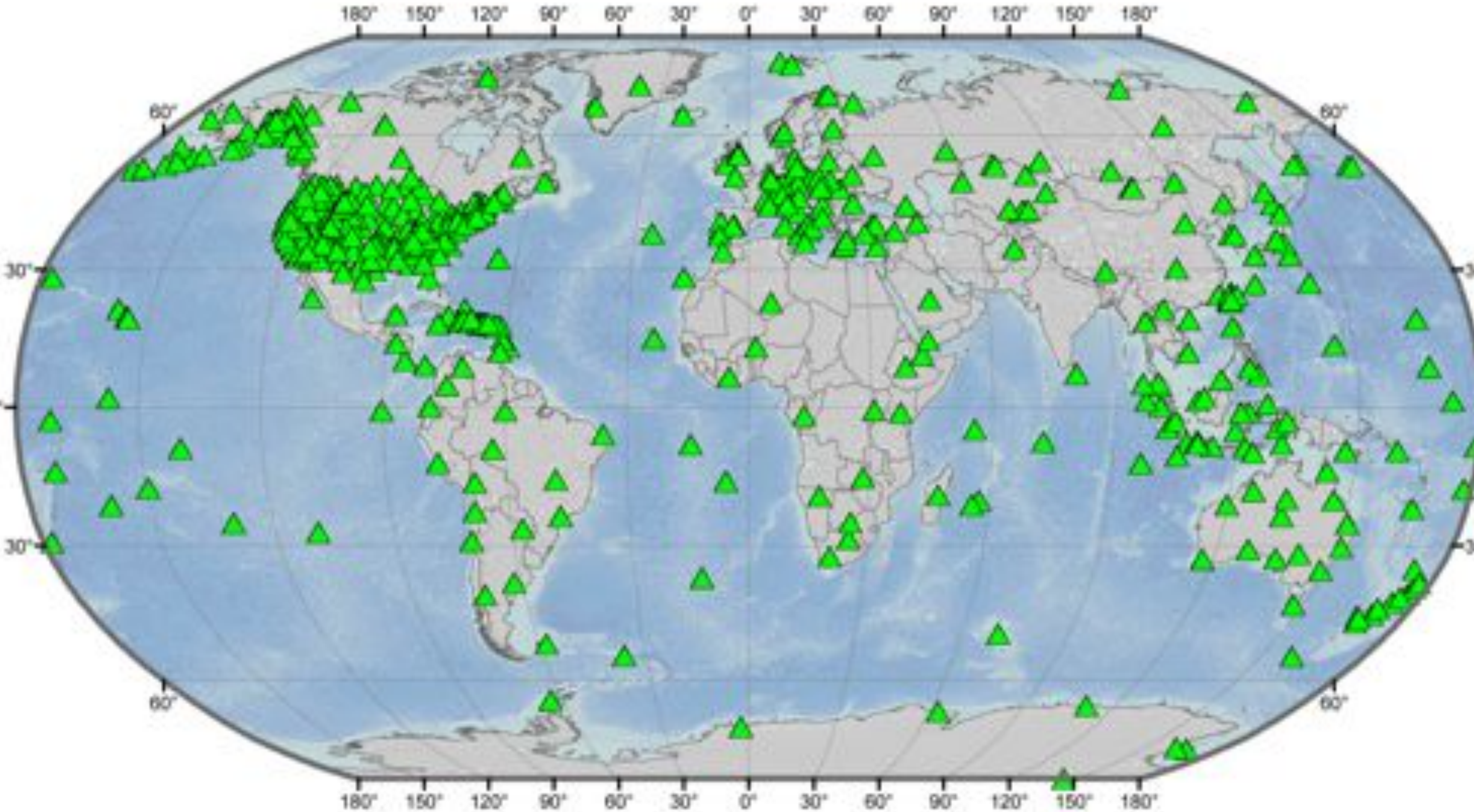
2) Produce a comprehensive earthquake catalog (M 4.5 globally M 2.5 within the US)

3) Integrate, use and distribute realtime seismic data from:
   - Global Seismic Network (GSN)
   - Advanced National Seismic System Backbone Network (ANSS)
   - US regional networks
   - Many foreign networks

4) Pursue an active research program which improves the ability to locate earthquakes and to understand earthquake processes.

5) Backup U.S. regional seismic networks

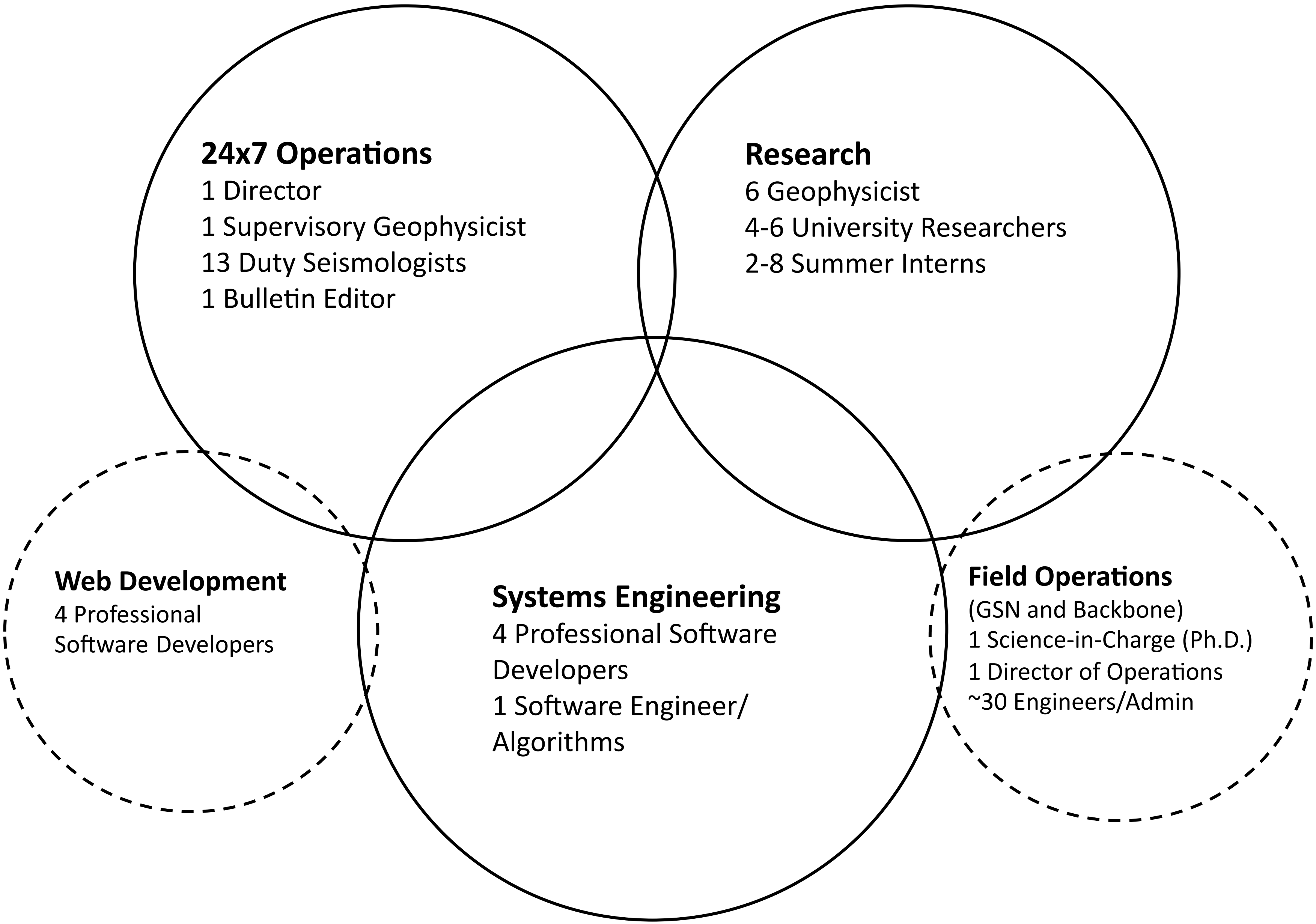
Real-time Waveform Data used by NEIC



~1,500 stations (BB/SP), ~ 5,000 channels

NEIC is the National Operations Center for the ANSS Authoritative for regions within the U.S. not covered by ANSS regional seismic networks

The National Earthquake Information Center



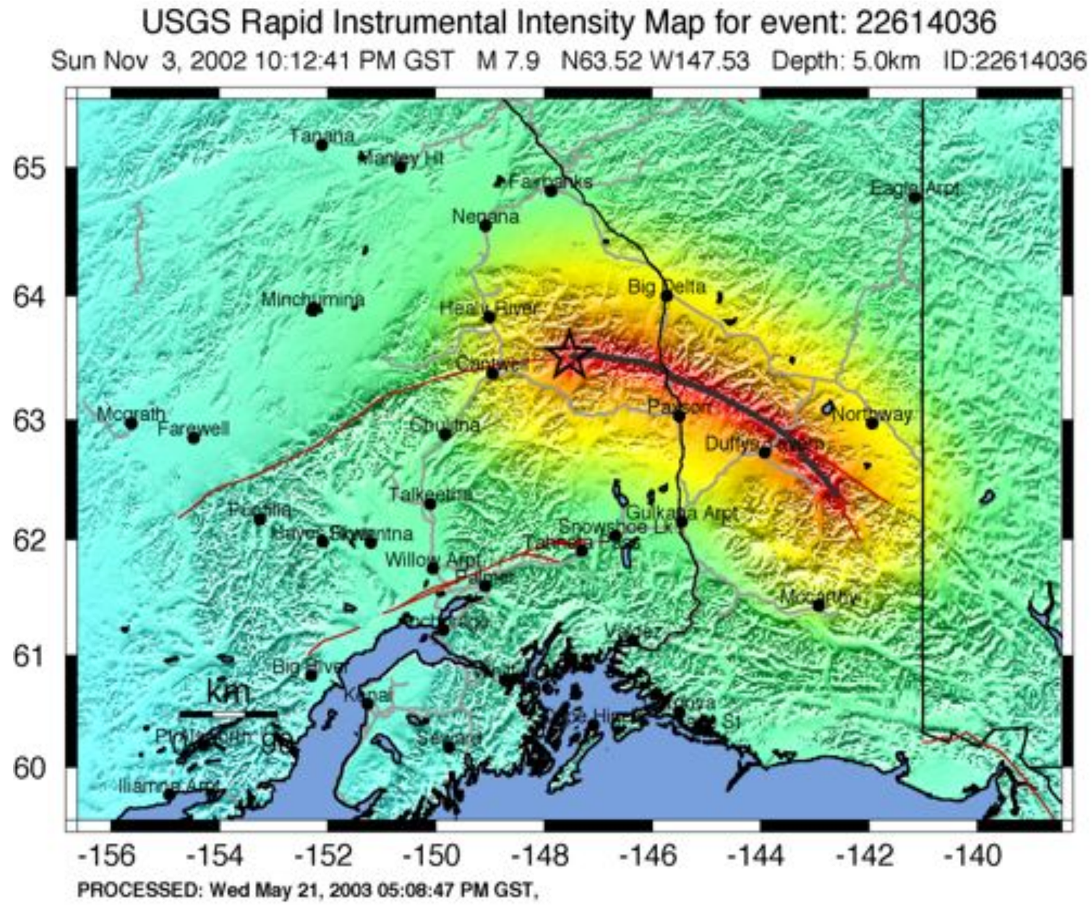
Robust 24/7 environment

NEIC and Earthquake Hazard Program higher level products

ShakeMap

Empirical or instrumentally constrained estimates of ground shaking in the epicentral region of an earthquake.

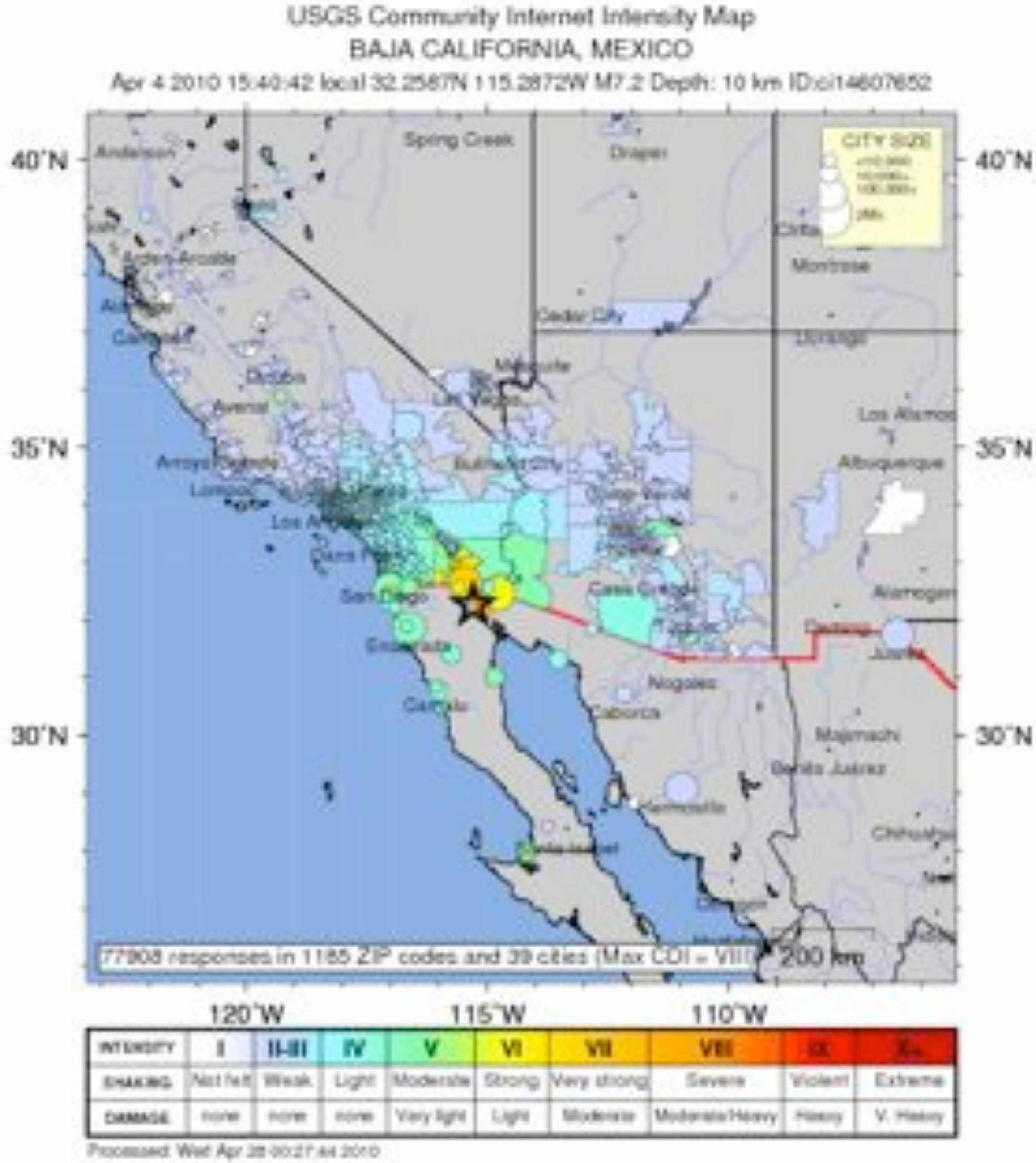
Adjusted in the hours after an event to account for earthquake finiteness - i.e. large earthquakes are not point sources, but rather occur over large areas (10's of km^2).

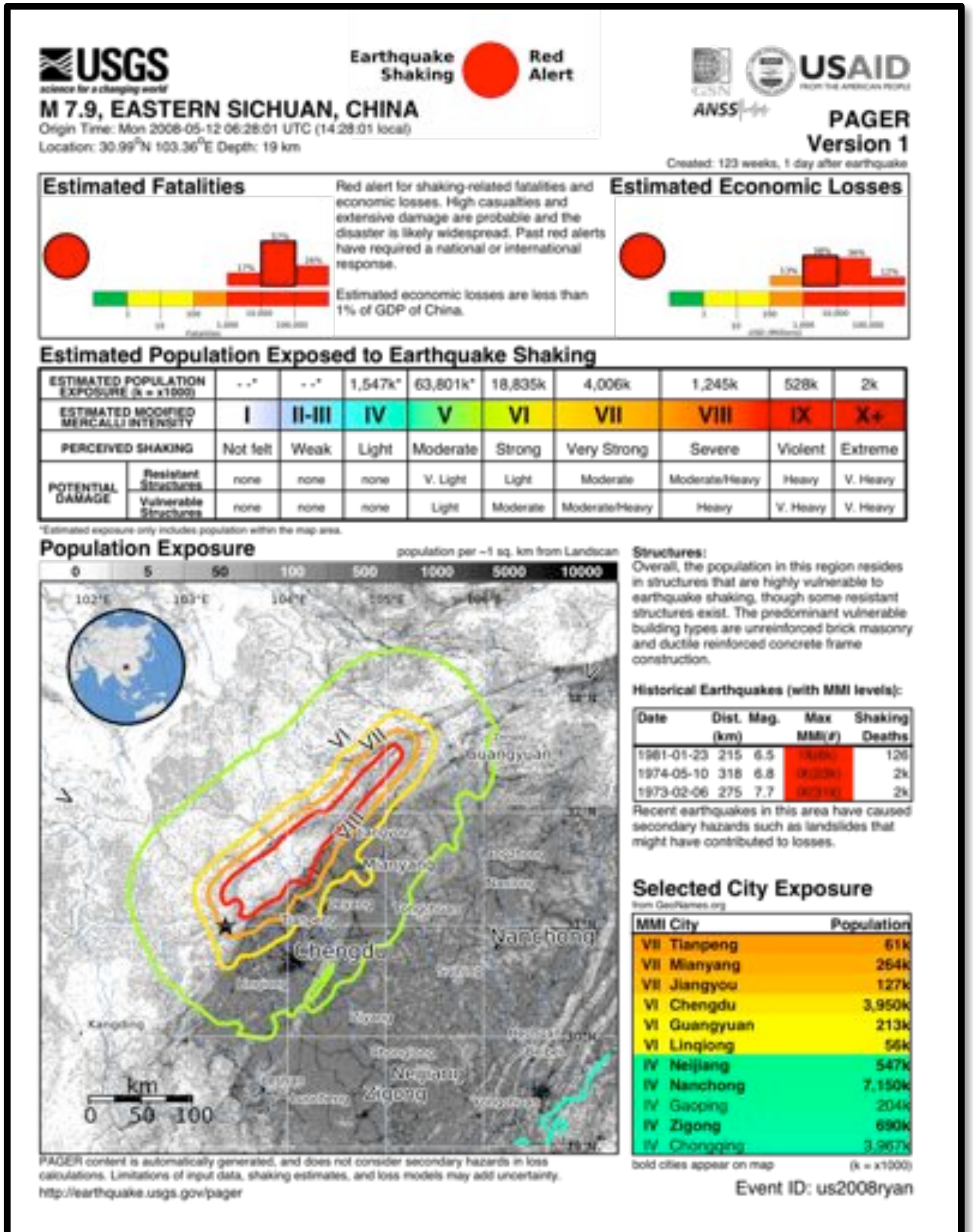


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-14	1.4-39	3.9-92	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

"Did You Feel It"

Internet questionnaire based Intensity Maps

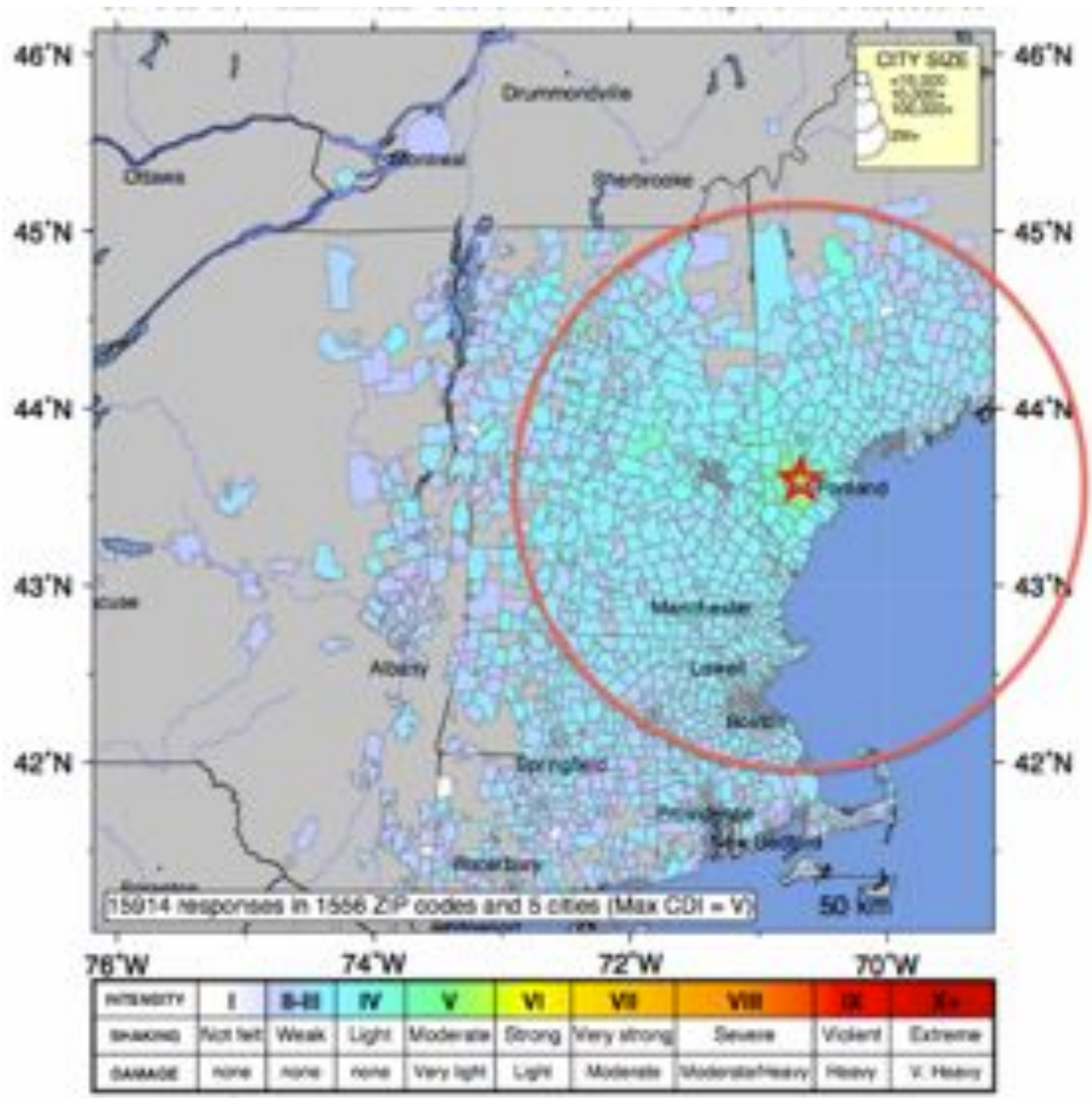




Estimating earthquake impact

Prompt
Assessment of
Global
Earthquakes for
Response

Event Detection and Characterization using Social Media



Earthquake Detections based solely on Twitter data that precede seismically based events.

NEIC/ANSS Earthquake Information Product Benchmarks "Top 10 List"

- **Earthquake Notification Service and Twitter**
  - *~350,000 subscribers to ENS*
  - *30,000+ Twitter followers (@USGSted)*
  - *Add about 50 new users per day to both ENS and USGSTED*
  - *4M+ emails in 24 hours following the M9.0 Tohoku, Japan EQ*

- **Web Services**
  - *Average ~1 million pageviews per day*
  - *500,000 pageviews in 4 hours following the M5.4 Alum Rock, CA EQ*
  - *20,000 DYFI? entries/sec (peak)*
  - *100 million pageviews in 30 days following on the M7.9 China EQ of 2008*

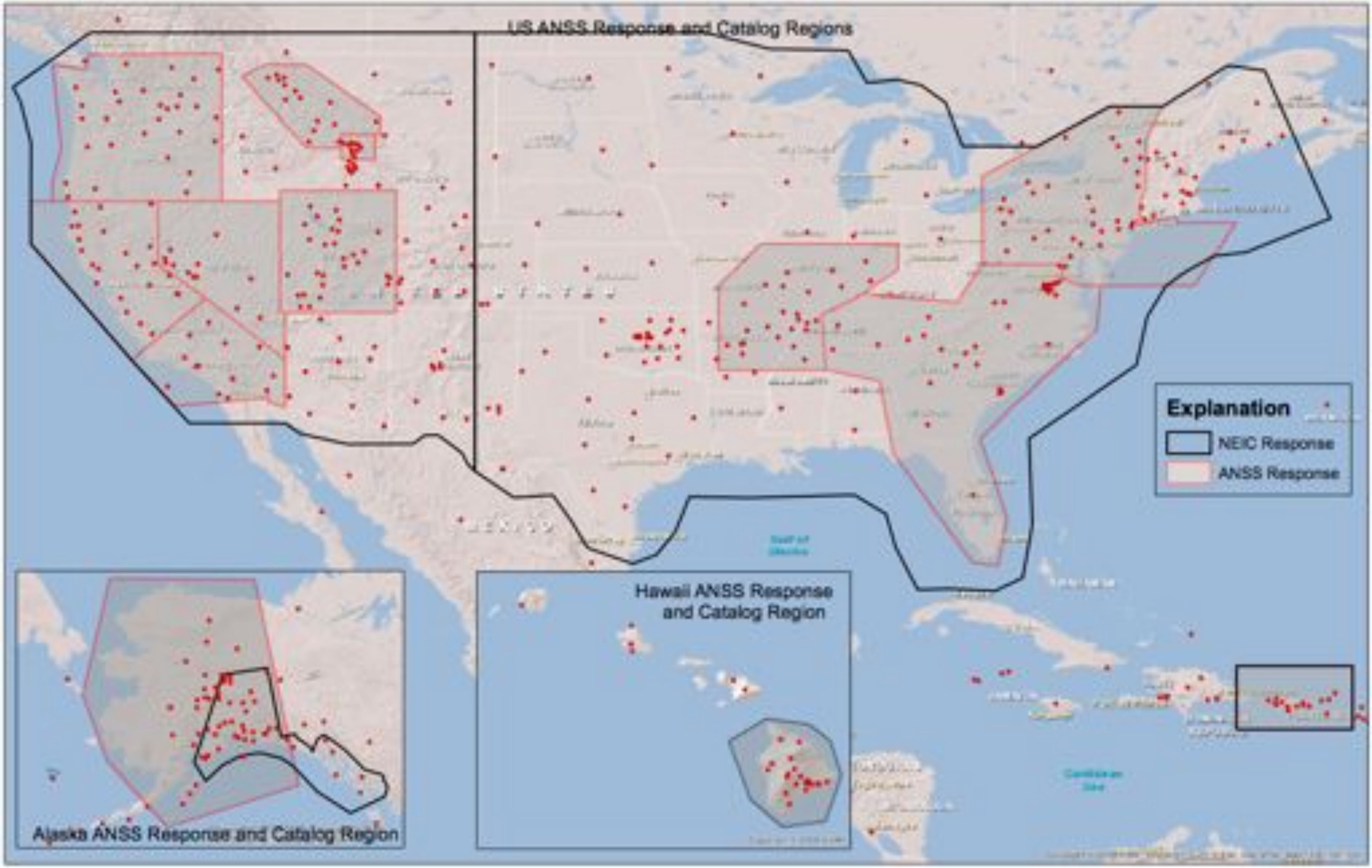
- **Did You Feel It?**
  - *More than 1.5 million entries since 2000*
  - *148,459 entries for the Aug 23, 2011 M5.8 Mineral, VA EQ*

Focus on monitoring in the Southwest

Permanent Seismic Monitoring in the South West

- National (NEIC, ASL, ANSS and GSN)
- Nevada (University of Nevada Reno)
- Utah + Yellowstone (University of Utah)
- Arizona
  - Arizona Integrated Seismic Network
  - Arizona Earthquake Information Center (AEIC)
- New Mexico
  - New Mexico Tech
  - Los Alamos National Laboratory
- Western Texas
  - University of Texas El Paso
- Mexico
  - Servicio Seismologico Nacional – UNAM
  - Departamento de Sismologia - CICESE

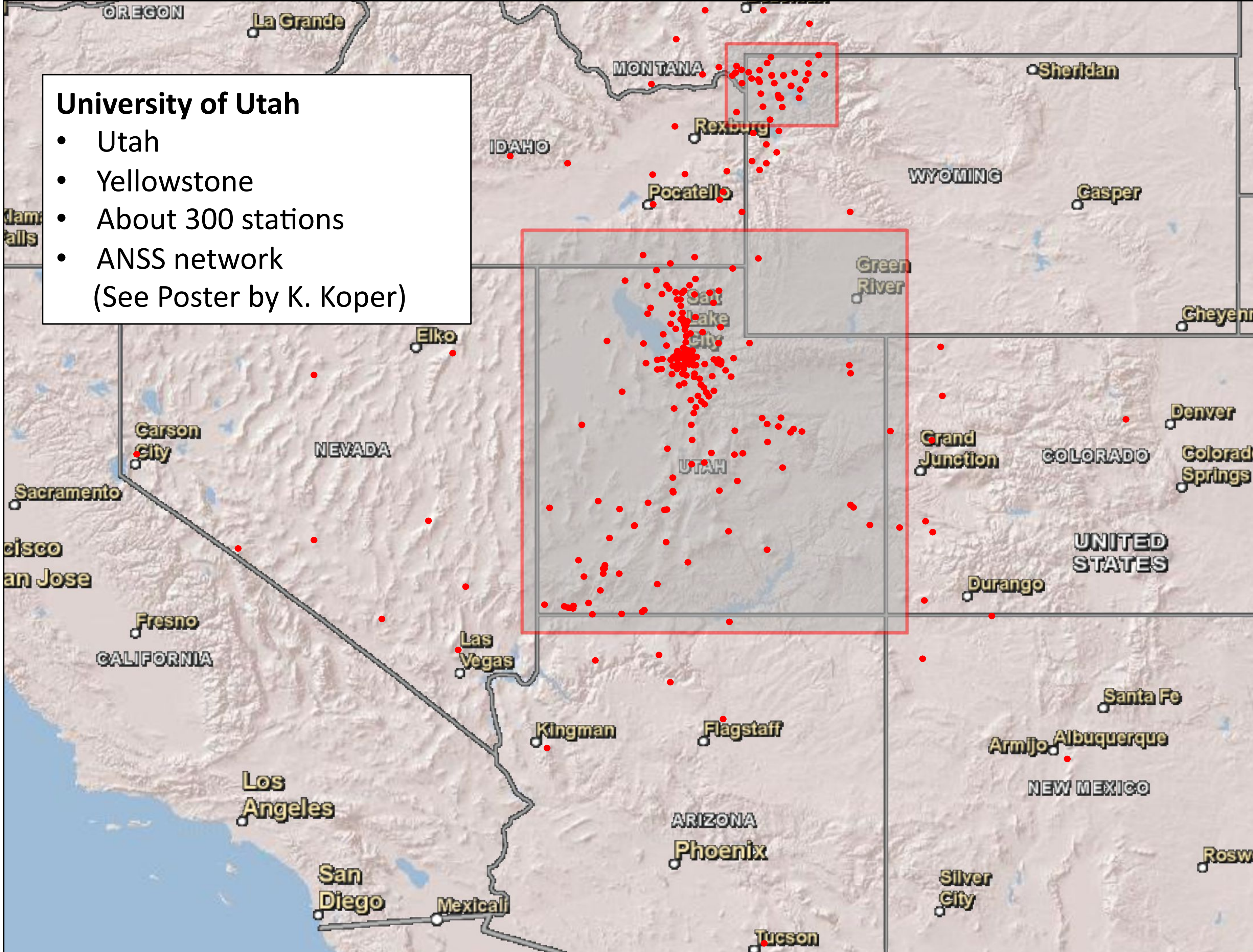
National Level Monitoring: realtime stations at NEIC



University of Utah

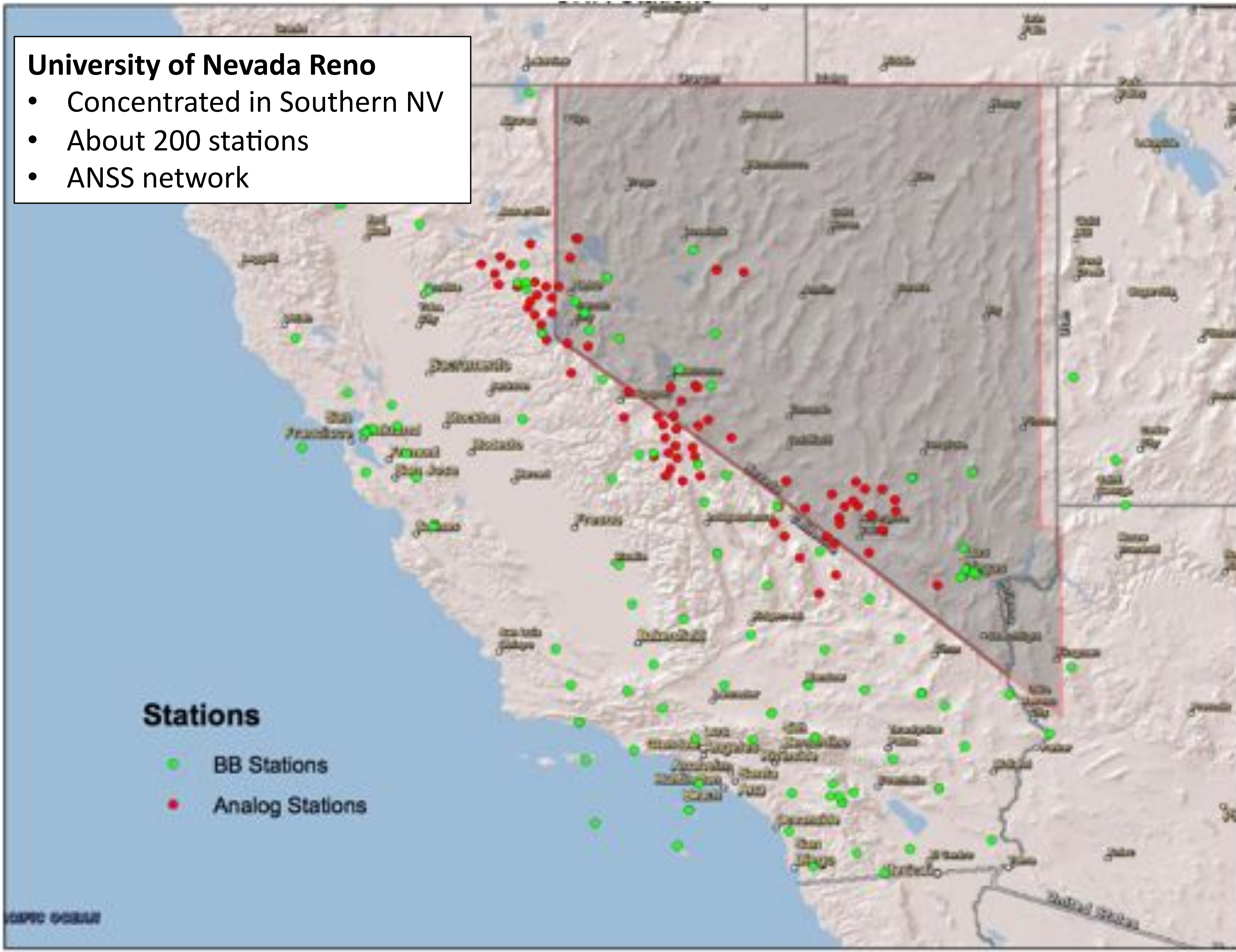
- Utah
- Yellowstone
- About 300 stations
- ANSS network

(See Poster by K. Koper)

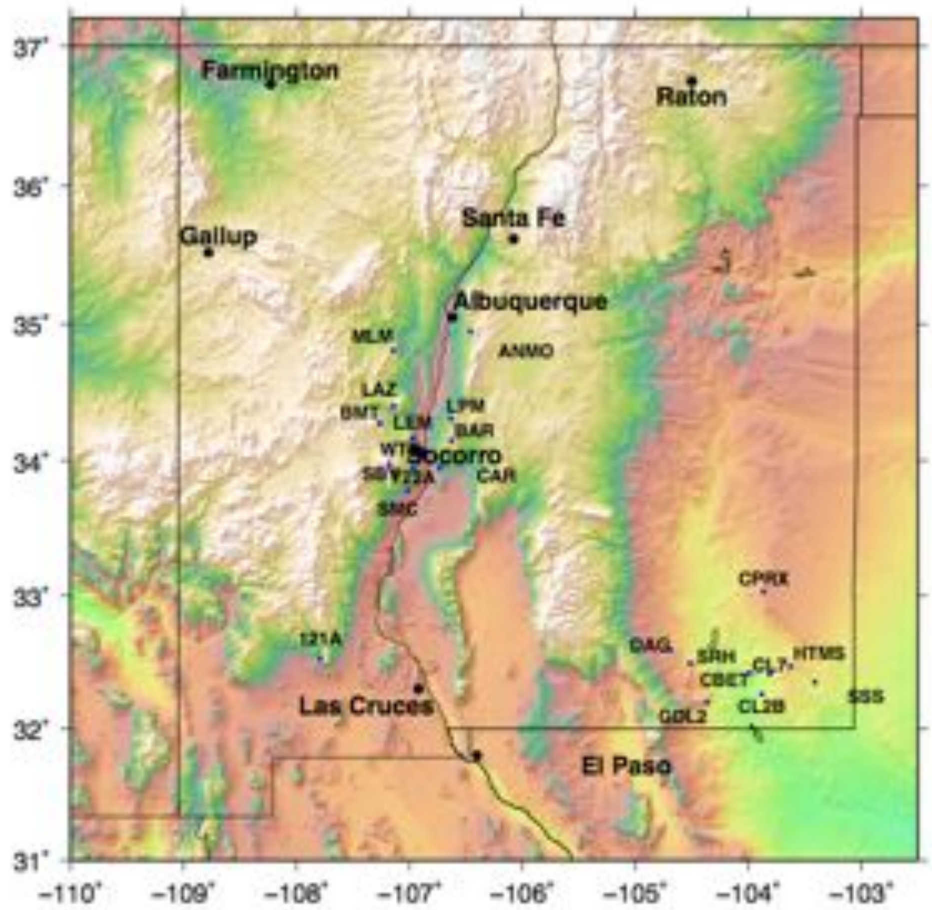


University of Nevada Reno

- Concentrated in Southern NV
- About 200 stations
- ANSS network

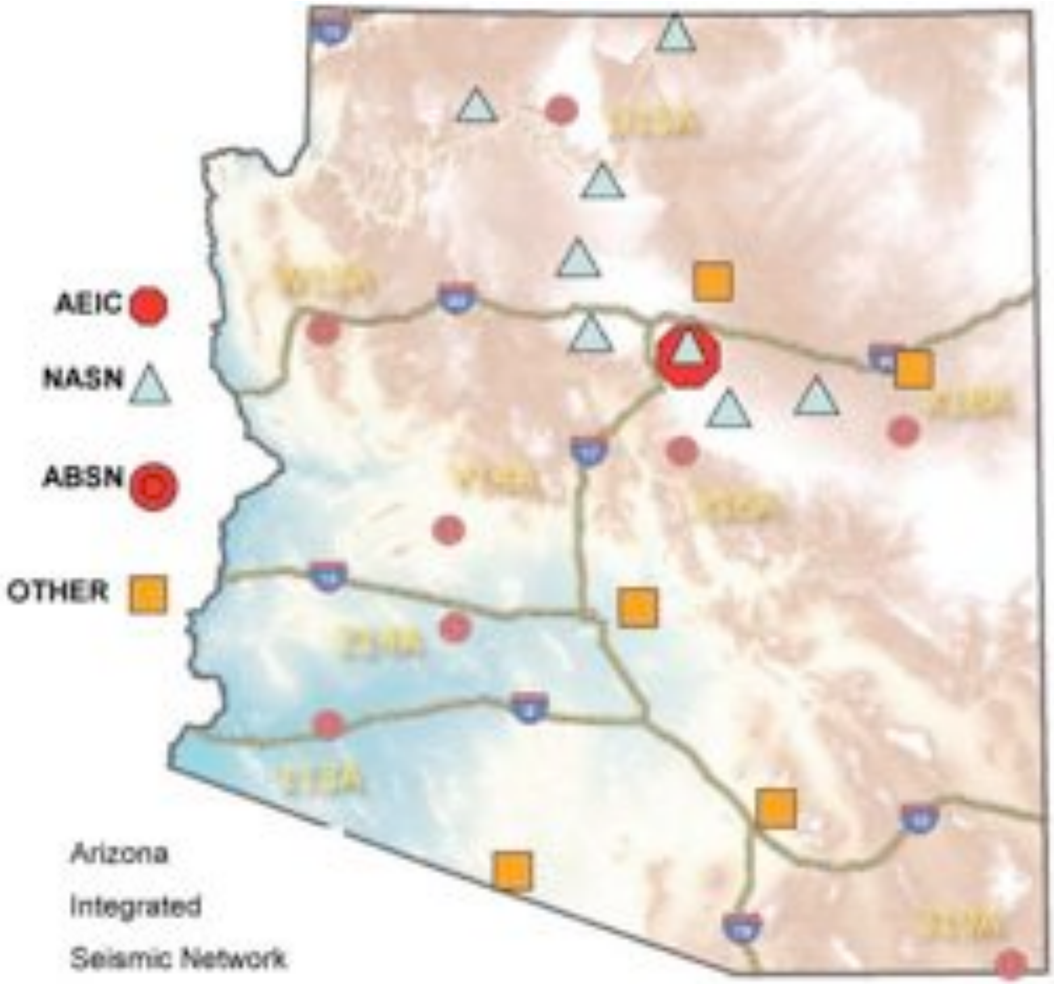


New Mexico Seismic Networks



- New Mexico Tech Seismic Network
- Los Alamos Seismic Network
- About 30 stations
- Concentrated Socorro, Los Alamos, and Southeast NM

See Rick Aster's poster this meeting
Map provided by Jana Pursley



Arizona Integrated Seismic Network

- 16 station core network + 4 national stations
- Expanded through the adoptions of 8 US Array stations
- Supported by Arizona emergency Management, Arizona Geologic Survey, and three state universities.
- Arizona Earthquake Information Center (AEIC) conducts monitoring

See David Brumbaugh's poster this meeting

Map from Arizona Earthquake Information website

Detection and Response Capabilities

- **Magnitude threshold:** Highly variable most regions about M2.5 but lower in regions of dense stations coverage.
- **Response times:** variable based on region and magnitude. Less than 20 minutes for M >= 4.0. Some regions including Nevada and Utah produce faster solutions with lower threshold.

In many regions, the detection threshold of permanent networks not sufficient for volcanic monitoring.

Portable Systems for Rapid Deployment

USGS

- Golden: 32 portable systems
- Volcano Hazard program: multiple systems at several observatories

IRIS

- RAMP 30 to 50 portable systems
- Potentially hundreds

Utah

- 1-2 broadband systems and 6 short-period analog seismometers

Reno

- A ton of old stuff but 3-4 reasonable kits
- 5 good sensors currently deployed could be swapped out
- Two simultaneous deployments possible but sensor quality goes down

Plenty of systems available for installation once unrest is discovered

Processing of portable deployment data

- In much of the Southwest, there is no set procedure for processing the numerous events associated with a volcanic unrest
- Local networks may not have the recourses
- Processing flow will depend on where the event occurs and would involve existing regional networks with assistance from USGS Volcano and Earthquake programs

USGS Volcano Hazard Program and NEIC Interoperability

Working group led by the Volcano Program to improve interoperability of volcano observatories and leverage the NEIC 24/7 operations.

Initial Goals

Technical Goal

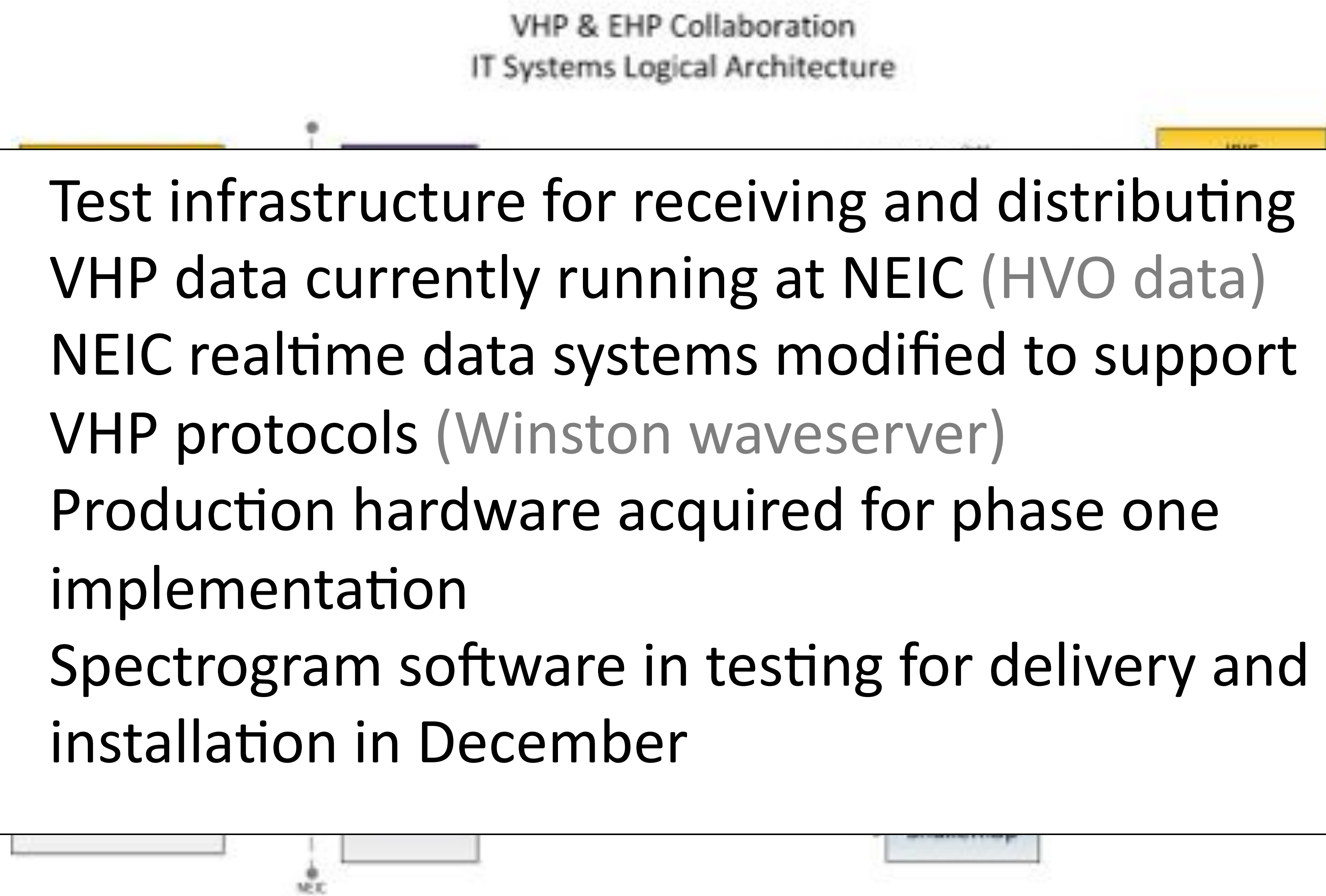
- Centralized repository for realtime seismic data. These data will be accessible to all volcano observatories, the NEIC, and to the IRIS data management center for permanent archiving.
- Centralized production of basic volcano monitoring products e.g. spectrograms and helicorder displays.
- Provide data and products in a robust, monitored 24/7 environment

Operational

- NEIC to assist in routine "off hours" volcano checks
- Assistance in monitoring volcanoes entering a potentially eruptive phase

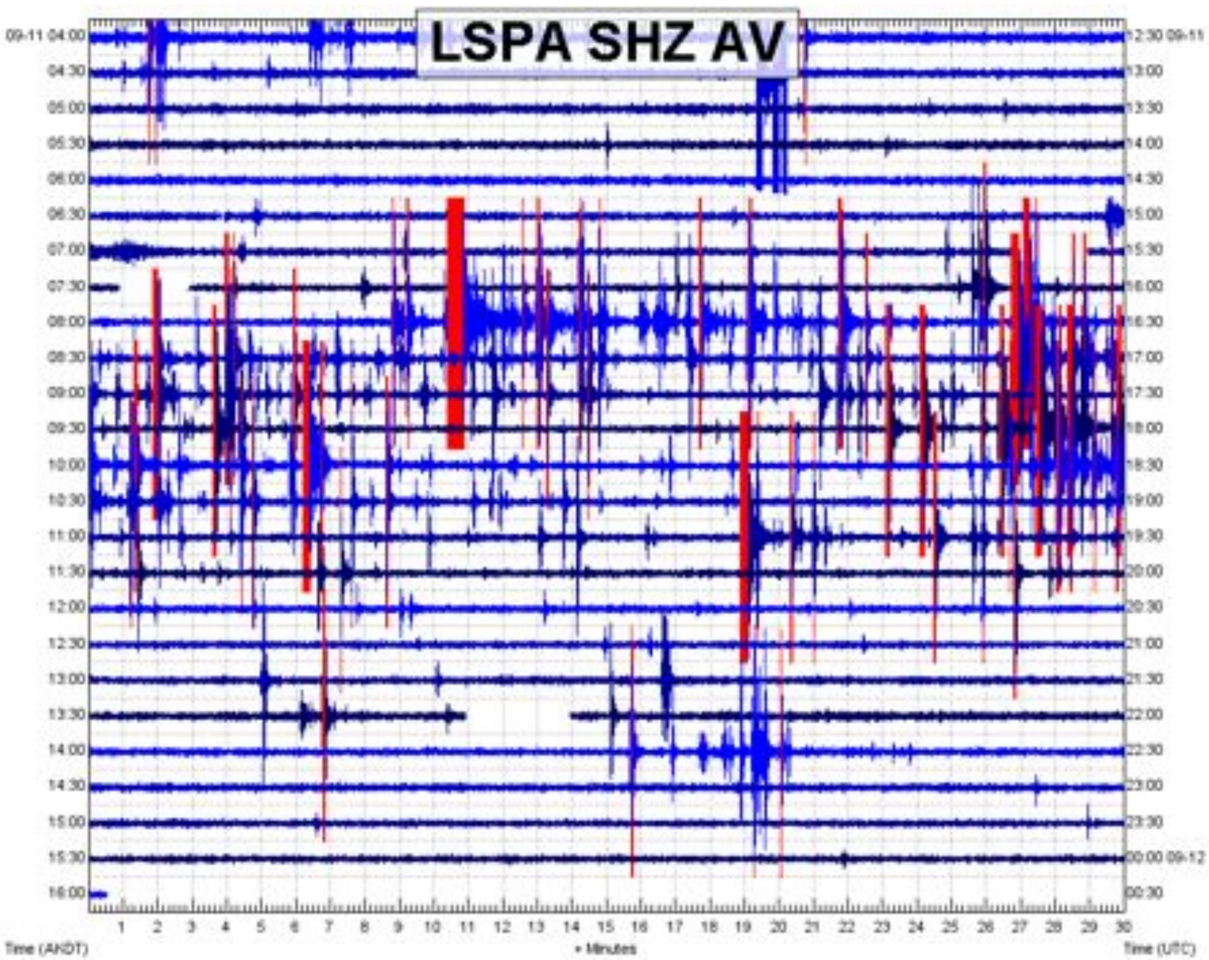
Note: All alerting responsibilities will remain with the volcano observatories

Technical Progress



- Test infrastructure for receiving and distributing VHP data currently running at NEIC (HVO data)
- NEIC realtime data systems modified to support VHP protocols (Winston waveserver)
- Production hardware acquired for phase one implementation
- Spectrogram software in testing for delivery and installation in December

Operational Progress



NEIC conducting test checks both routine and during a period of unrest

Site visits between VHP and NEIC

Initial training and follow up planned

Working on standardized logging procedures

Summary

The good:

- Portable instrumentation available
- Infrastructure to consolidate and distribute realtime data close
- Moving towards better National and regional coordination for monitoring

Needs improvement:

- Initial detection of impending eruptive cycle
- Further work needed in planning from event processing in the event of volcanic unrest

Volcanism in the American Southwest Poster Introductions

Earthquakes in the Central Rio Grande Rift and the Socorro Magma Body

Richard Aster, Susan Bilek, Jana Stankova-Pursley, Emily Morton

New Mexico Tech

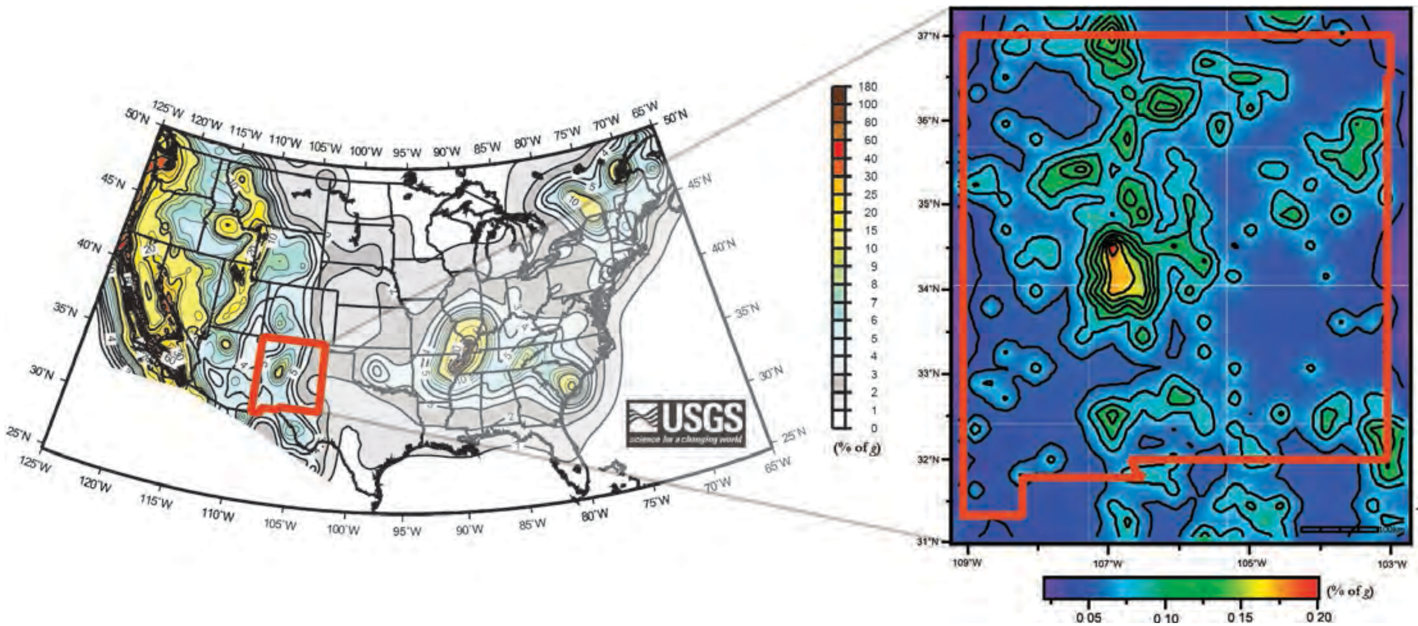
Department of Earth and Environmental Science

NEW MEXICO TECH

SCIENCE • ENGINEERING • RESEARCH UNIVERSITY

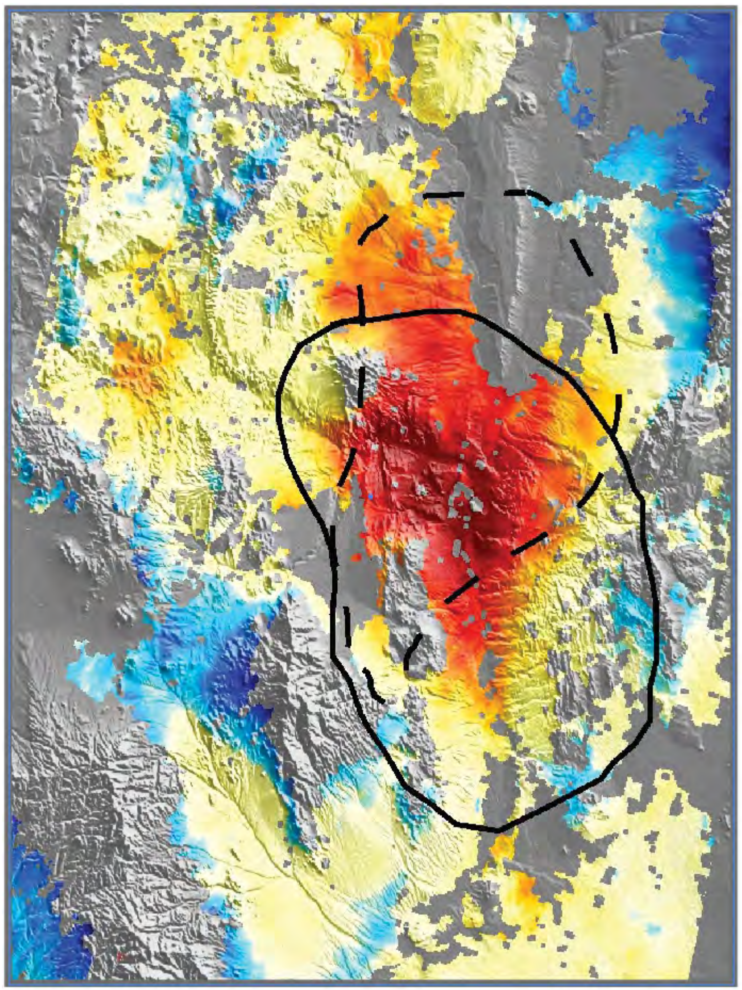
Synopsis

- The seismic (and perhaps volcanological) hazard of the central Rio Grande rift is dominated by the influence of the mid-crustal (19 km) Socorro magma body.

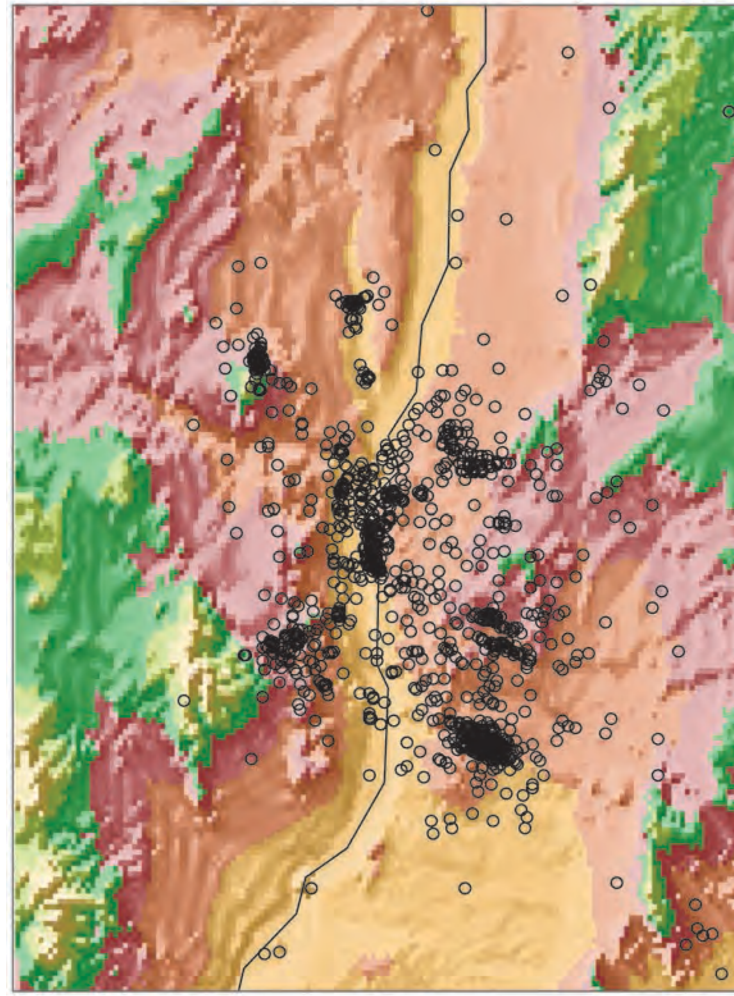


Earthquake ground motion (% g) with a 10% probability of being exceeded in 50 years, estimated for the conterminous United States by the U.S. Geological Survey from earthquake and geologic data (Frankel et al., 2002; left), and in a detailed map for New Mexico (Sanford et al., 2002; right). Note the especially strong influence of the Socorro region to state-wide ground motion probabilities due to stress perturbations from the inflating SMB.

- The SMB is a geodetically and seismically active feature associated with up to ~ 2 mm/y of inflation and persistent swarm seismicity.

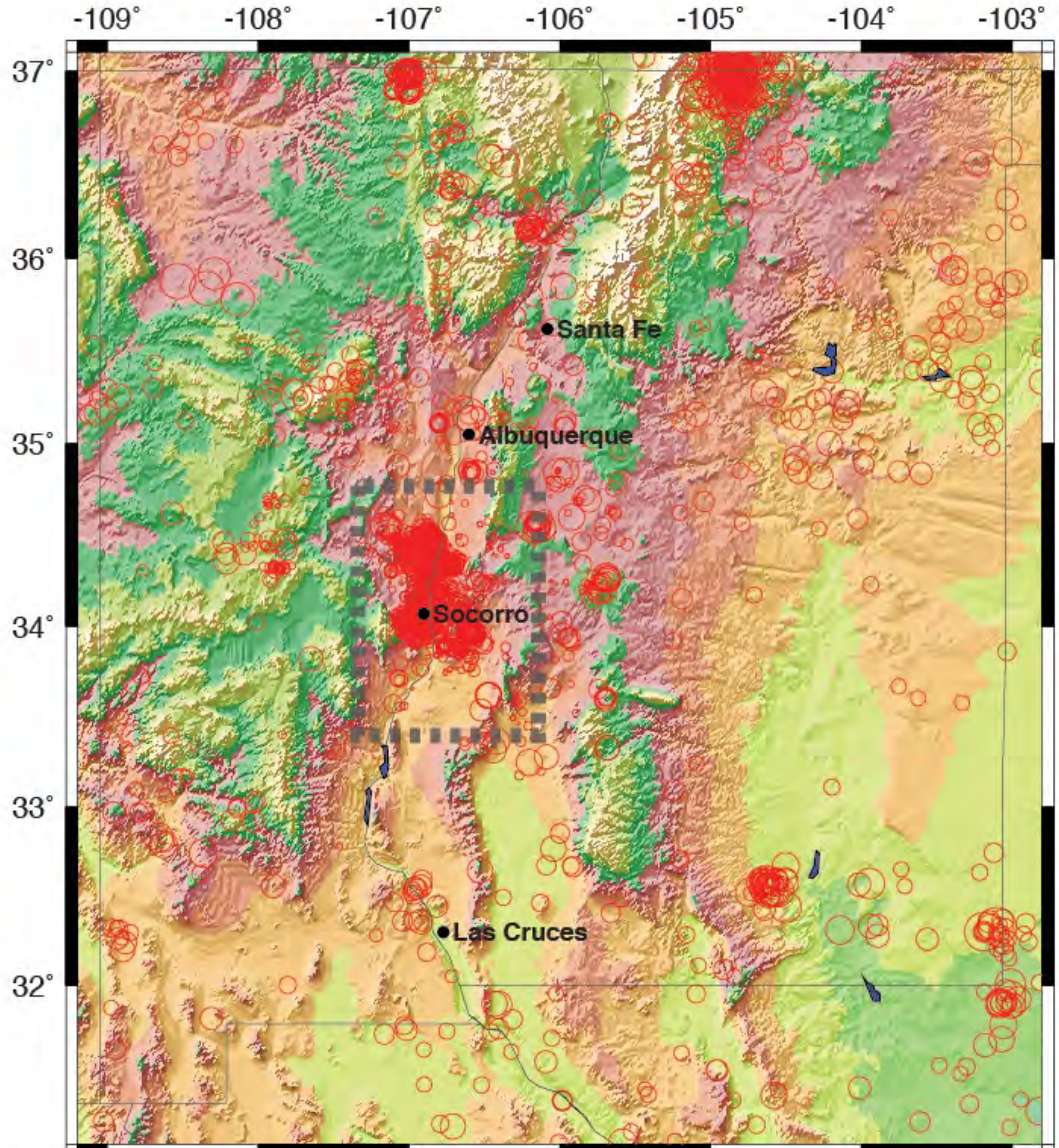


After Fialko and Simons (2001)

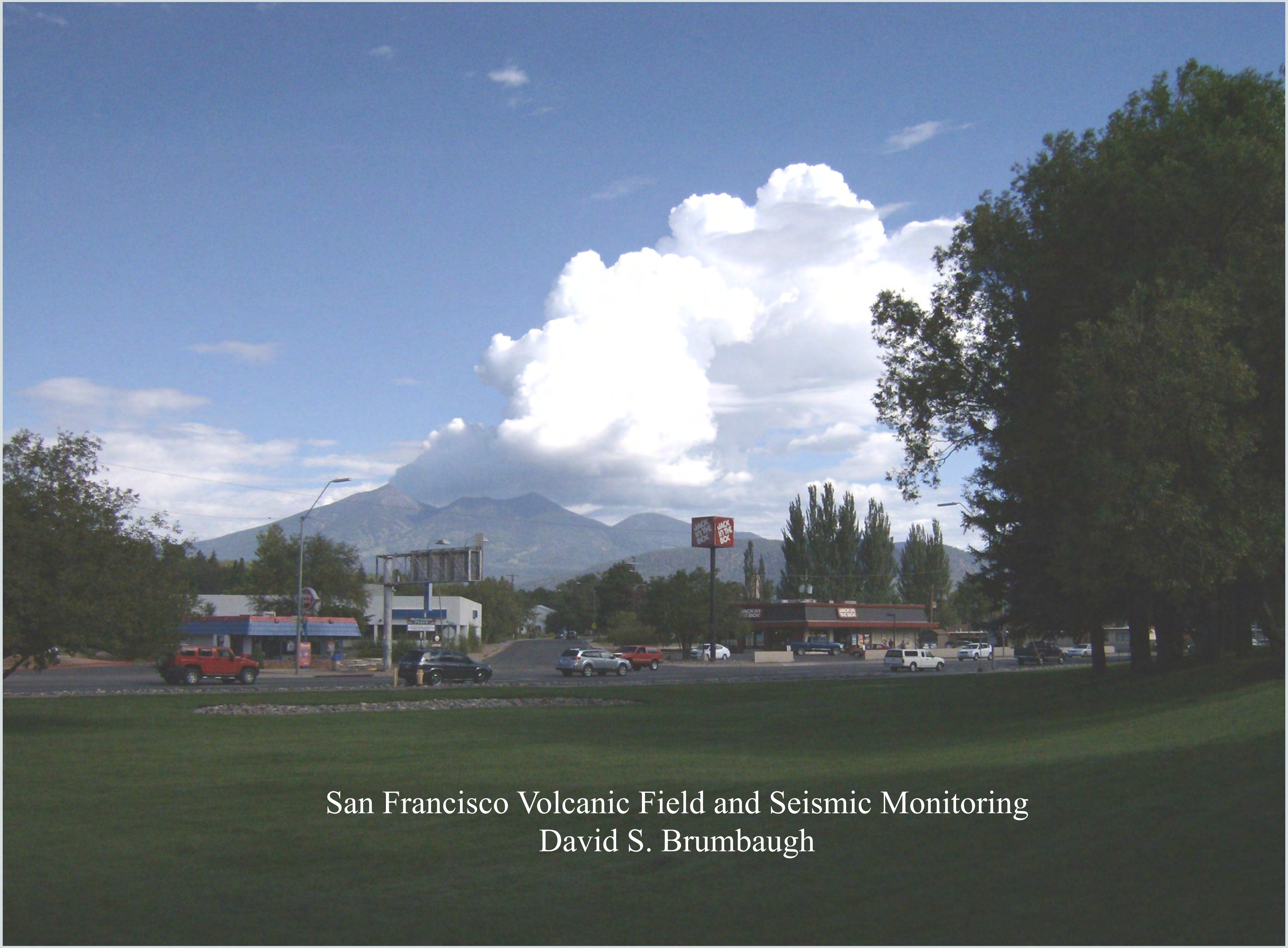


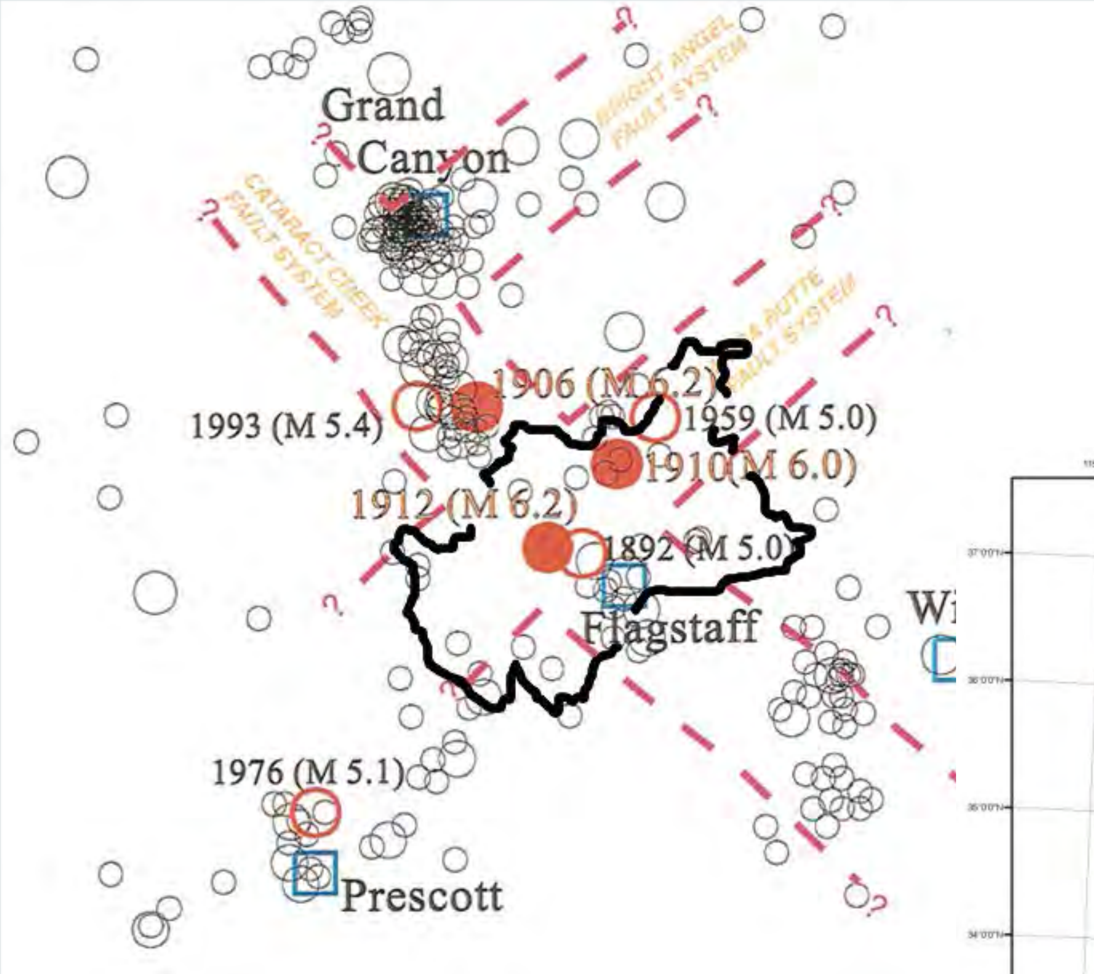
Seismicity, 1962 - 2012.

- Long-term monitoring (50 years) and historical felt reports (to the 1860s) from the SMB region indicate that persistent swarm seismicity in a magmatically influenced area can be sustained for a century or more. In a monogenic cinder cone eruption scenario, presumably(?) we would see strong anomalous indications of very shallow activity prior to eruption (e.g., a Paricutin-like scenario).

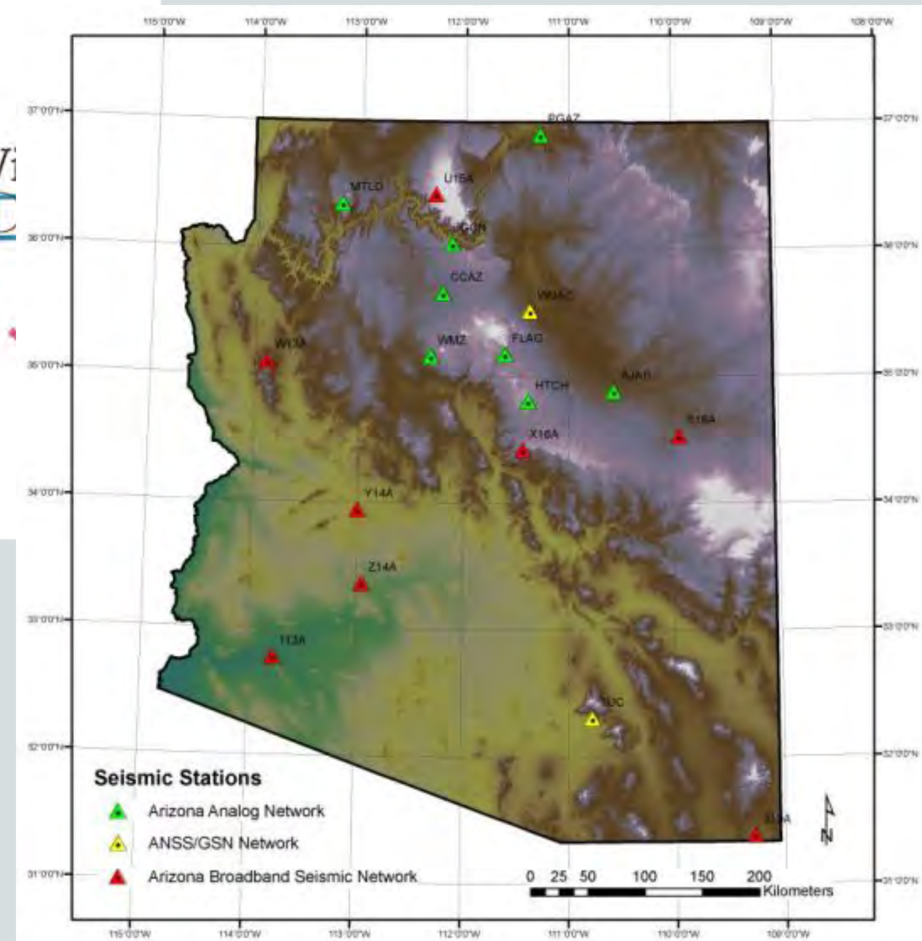


Seismicity, 1962 - 2012.

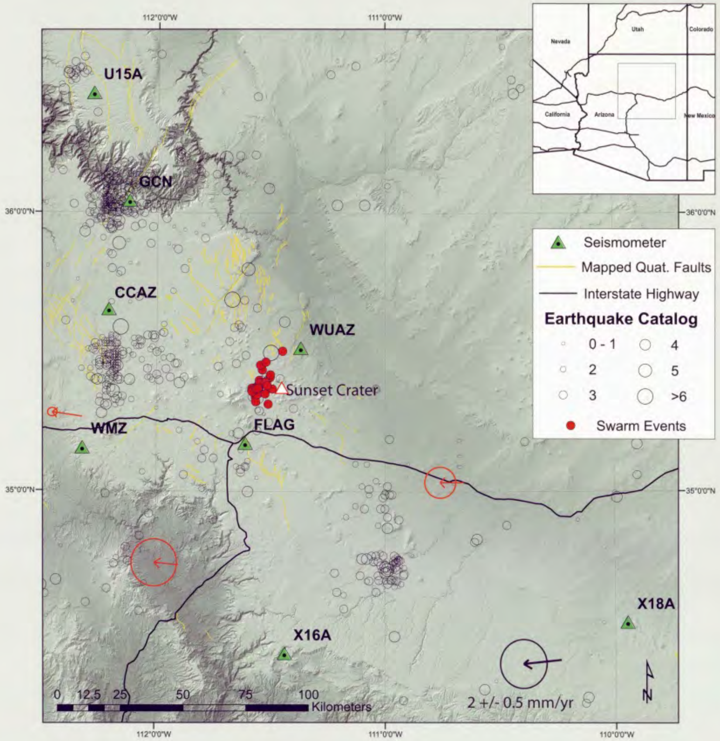

San Francisco Volcanic Field and Seismic Monitoring
David S. Brumbaugh

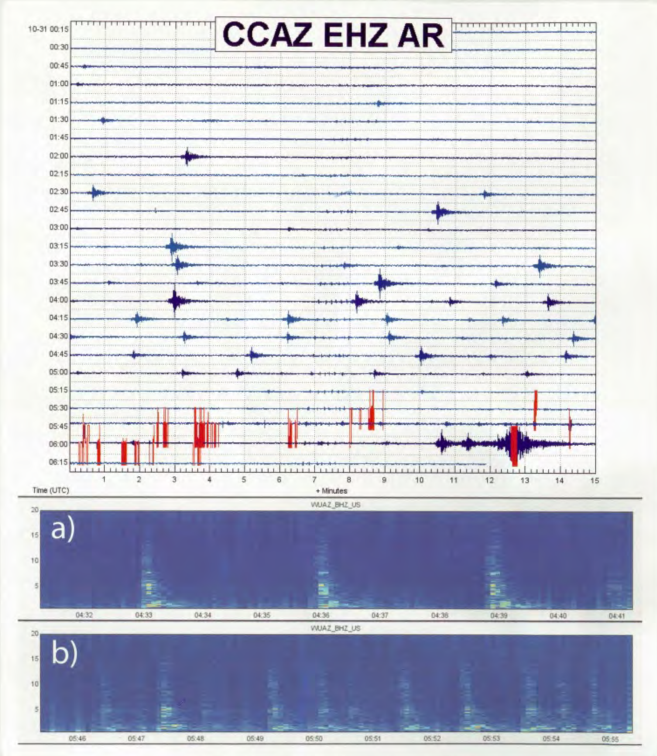


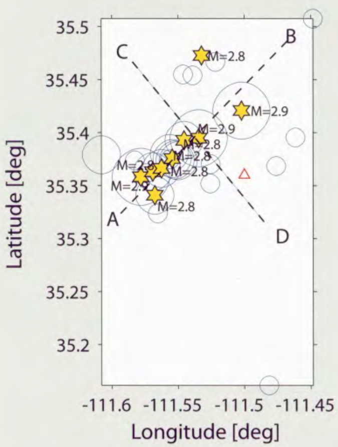
Grand Canyon
BRIGHT ANGEL FAULT SYSTEM
CATARACT CREEK FAULT SYSTEM
1906 (M 6.2)
1993 (M 5.4)
1959 (M 5.0)
1910 (M 6.0)
1912 (M 6.2)
1892 (M 5.0)
Flagstaff
1976 (M 5.1)
Prescott

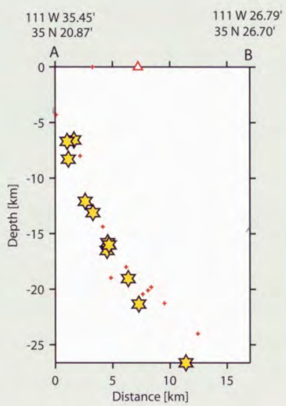


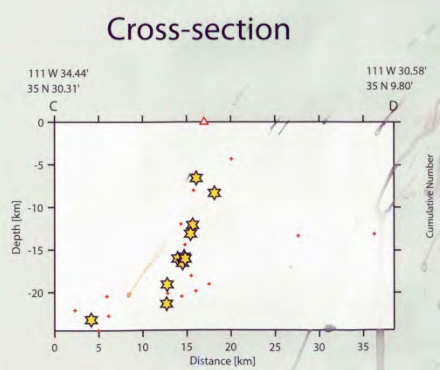
Seismic Stations
Arizona Analog Network
ANSS/GSN Network
Arizona Broadband Seismic Network
0 25 50 100 150 200
Kilometers

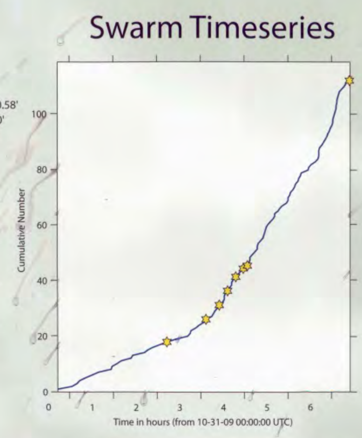




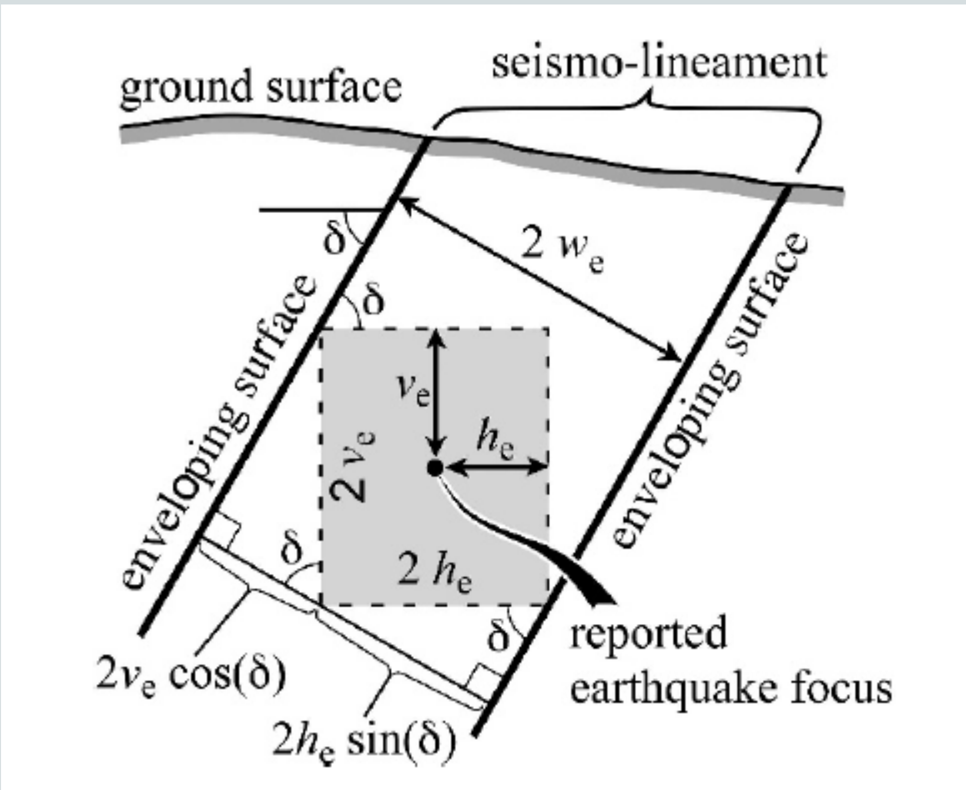


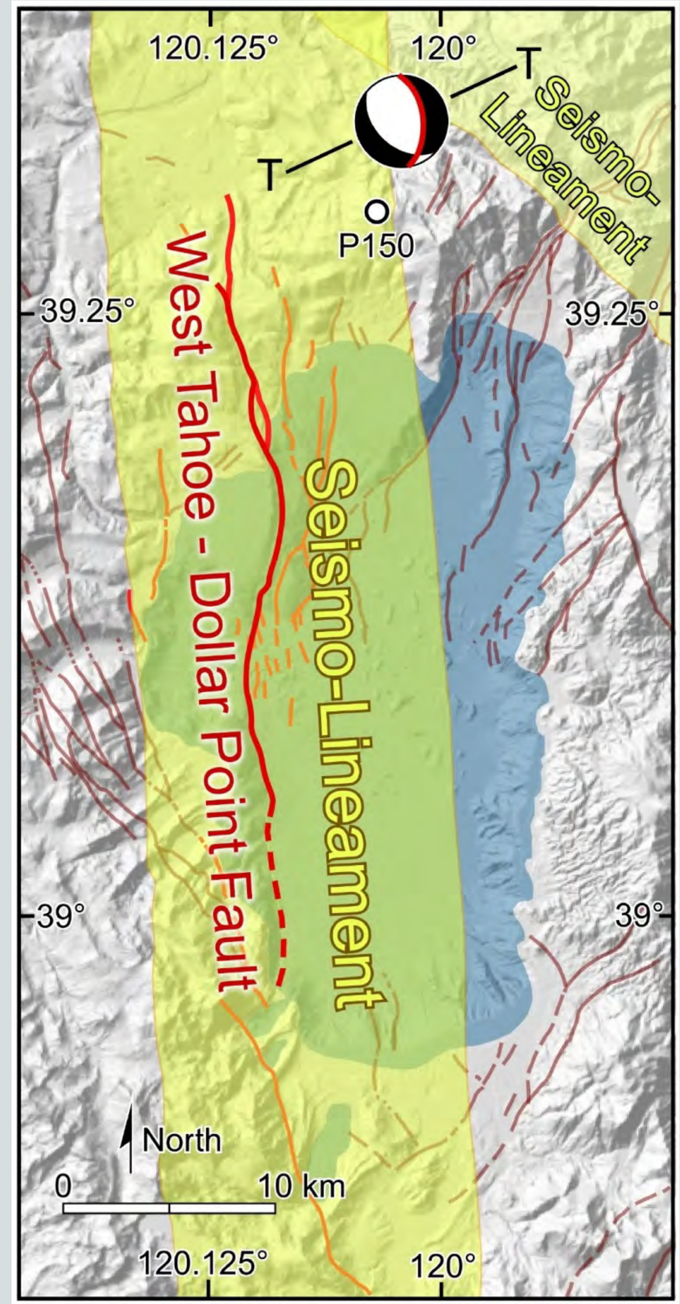


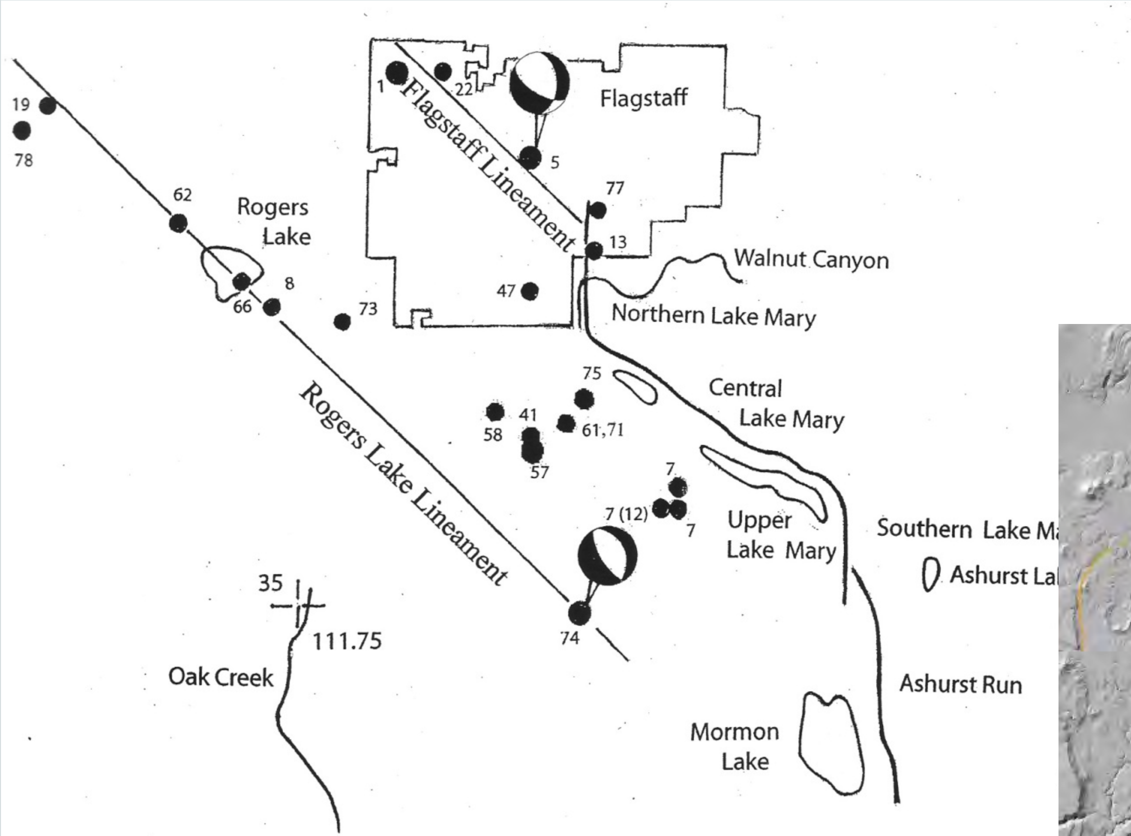


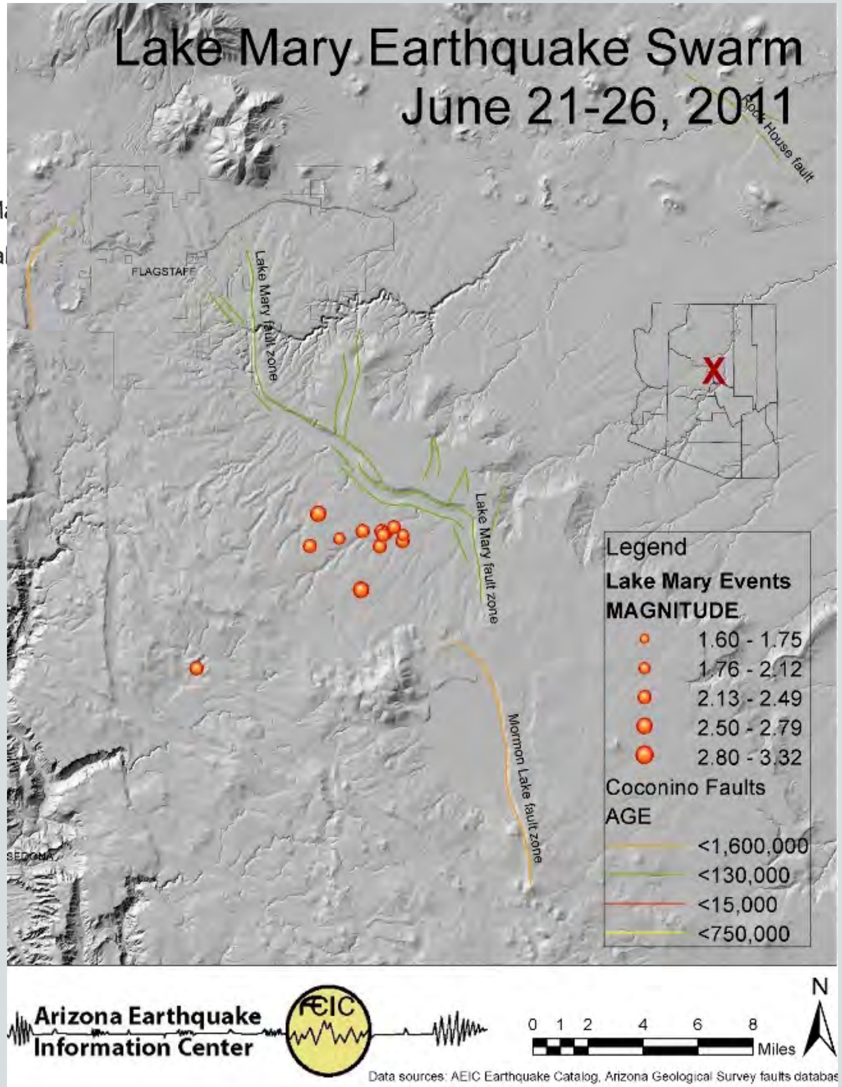


Location Map (above left) of 31 located earthquakes occuring over ~ six hours on October 31, 2009 (red dots). Historic seismic activity shown with open circles and symbolized by magnitude (source: AEIC earthquake catalog). Heliocorder plot of the timeseries of earthquakes as recorded at analog seismic station CCAZ (above right). Power spectrum for a select group of earthquakes shown below the helioplot. Spectrum "a" shows three earthquakes of duration magnitude ~2.5 occuring near the middle of the timeseries. Spectrum "b" shows a series of a dozen earthquakes of duration magnitude ~1.5 - 1.9, which are unidentifiable from noise in the helioplot above. Note the rate of earthquakes has increased during this part of the time series. Plan view and cross-section slices of located earthquakes shown with equal horizontal and vertical scales (above bottom). Stars indicate the largest earthquakes of duration magnitude 2.7-2.9 and shown in the time series plot (above bottom right).


seismo-lineament
ground surface
2 w_e
δ
δ
δ
δ
enveloping surface
enveloping surface
v_e
h_e
2 v_e
2 h_e
$2v_e \cos(\delta)$
$2h_e \sin(\delta)$
reported
earthquake focus


120.125°
120°
T
T
Seismo-
Lineament
P150
39.25°
39.25°
West Tahoe - Dollar Point Fault
Seismo-Lineament
39°
39°
North
0
10 km
120.125°
120°


Flagstaff
Flagstaff Lineament
Rogers Lake
Rogers Lake Lineament
Walnut Canyon
Northern Lake Mary
Central Lake Mary
Upper Lake Mary
Southern Lake Ma
Ashurst La
Ashurst Run
Mormon Lake
Oak Creek
35
111.75
1
22
5
19
78
62
77
13
8
66
73
47
75
41
58
61,71
57
7
7 (12)
7
74


Lake Mary Earthquake Swarm
June 21-26, 2011
FLAGSTAFF
Lake Mary fault zone
Lake Mary fault zone
Mormon Lake fault zone
SEDONA
Legend
Lake Mary Events
MAGNITUDE
1.60 - 1.75
1.76 - 2.12
2.13 - 2.49
2.50 - 2.79
2.80 - 3.32
Coconino Faults
AGE
<1,600,000
<130,000
<15,000
<750,000
Arizona Earthquake Information Center
0 1 2 4 6 8
Miles
N
Data sources: AEIC Earthquake Catalog, Arizona Geological Survey faults databas

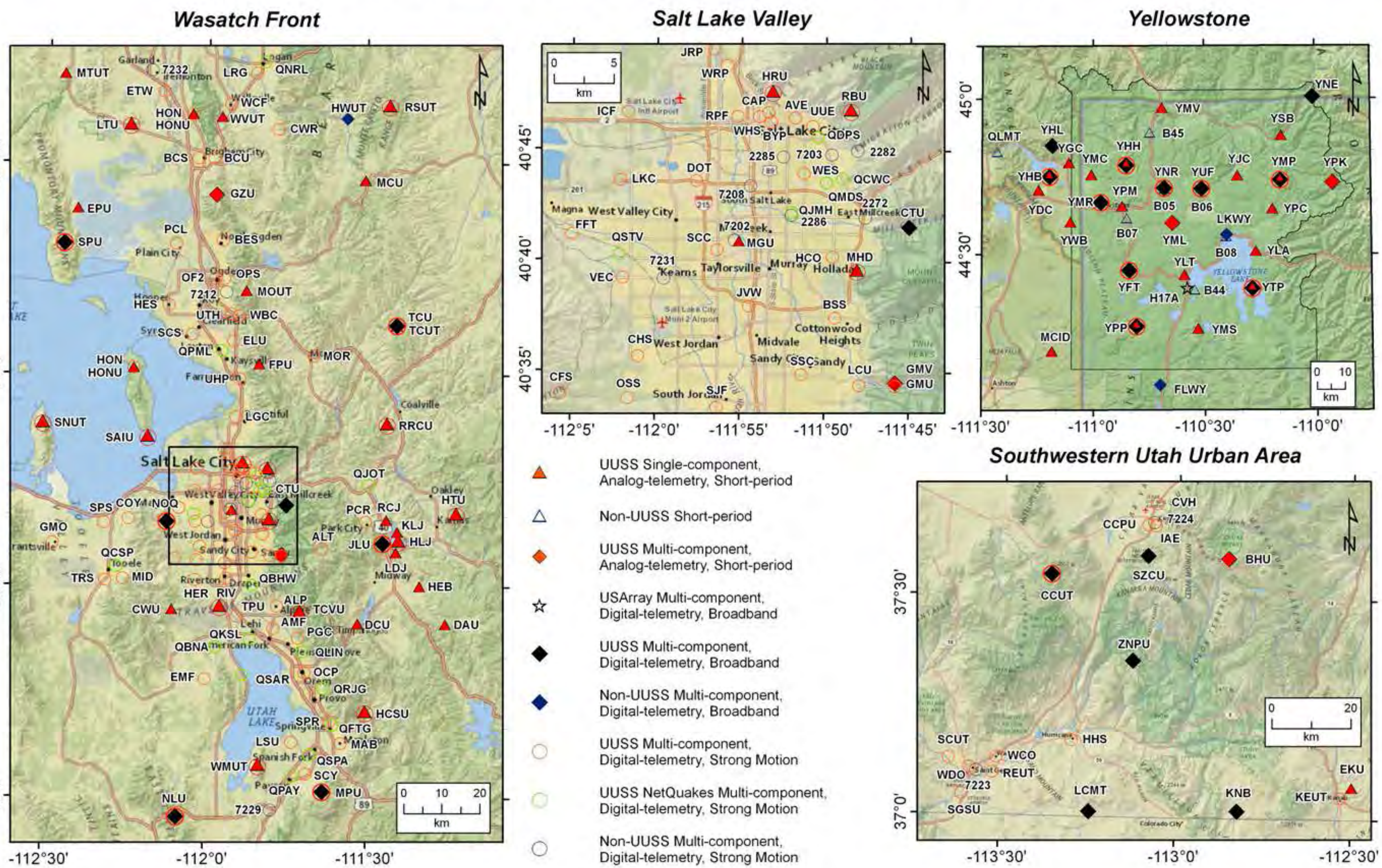
Capabilities of University of Utah Seismograph Stations for Monitoring Seismicity in Utah

Keith Koper, Kris Pankow, Relu Burlacu, Katherine Whidden, Jim Pechmann, Mark Hale, and Paul Roberson

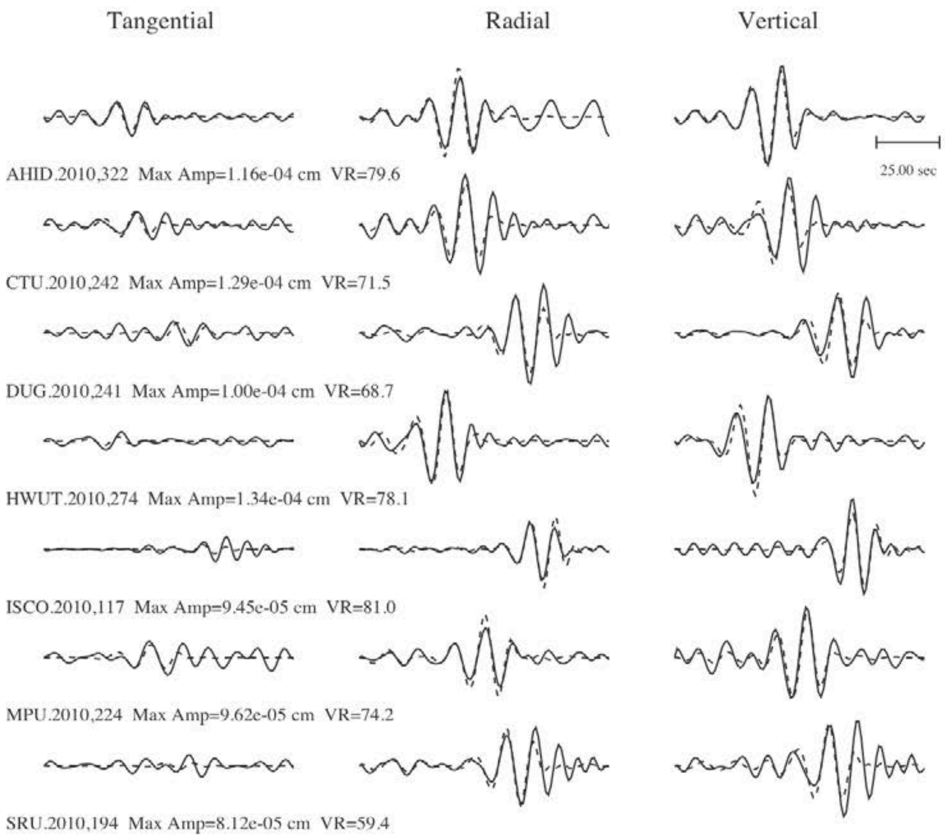
UUSS
UNIVERSITY OF UTAH
SEISMOGRAPH STATIONS
quake.utah.edu

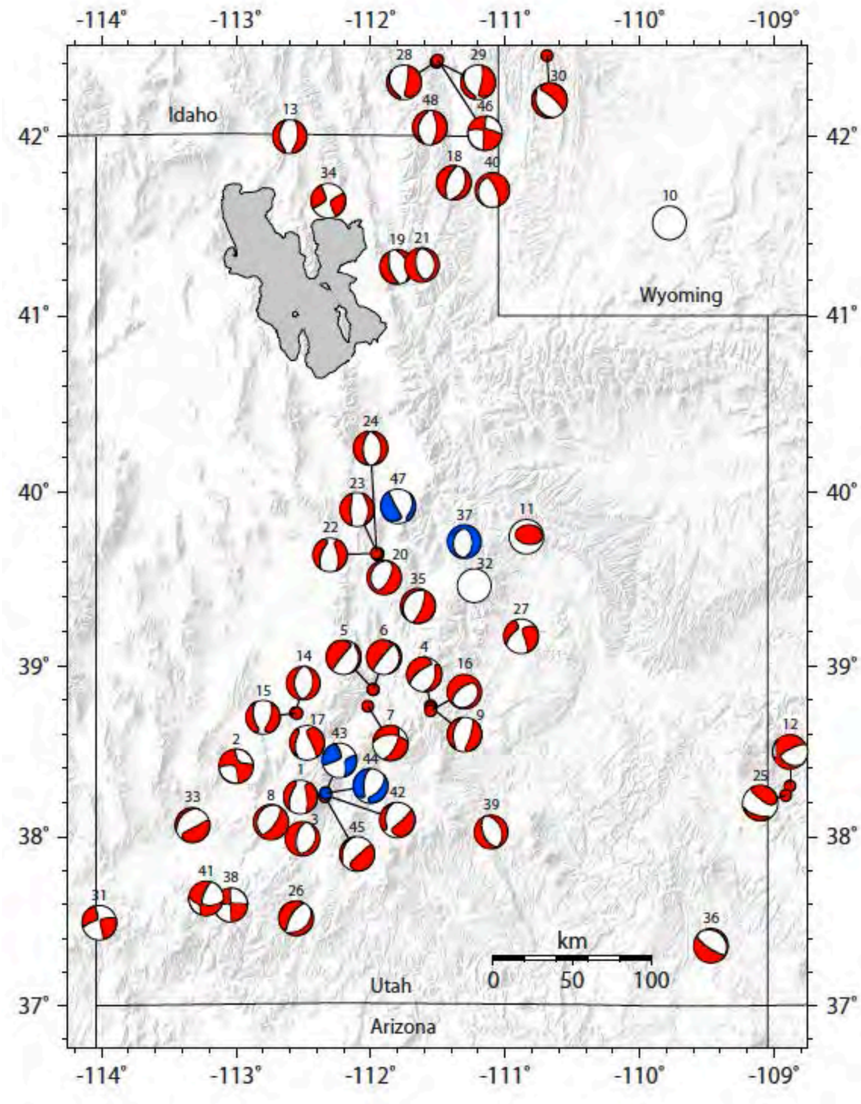
October 18, 2012

Utah Regional/Urban Seismic Network (October 2012)

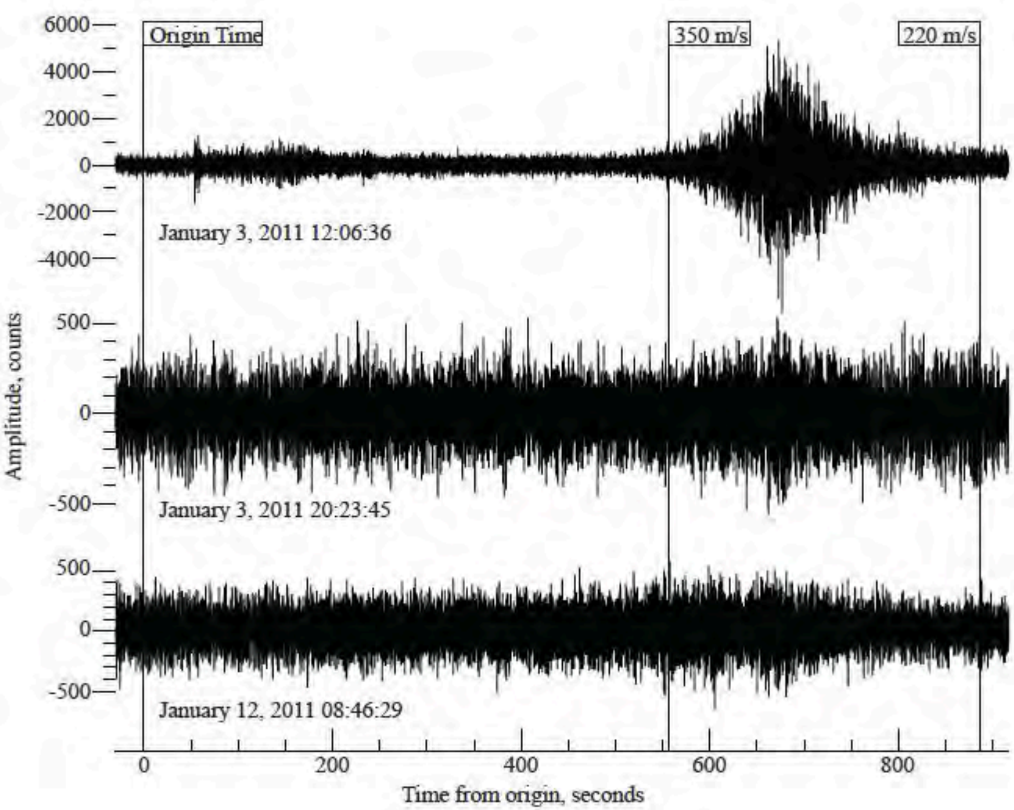


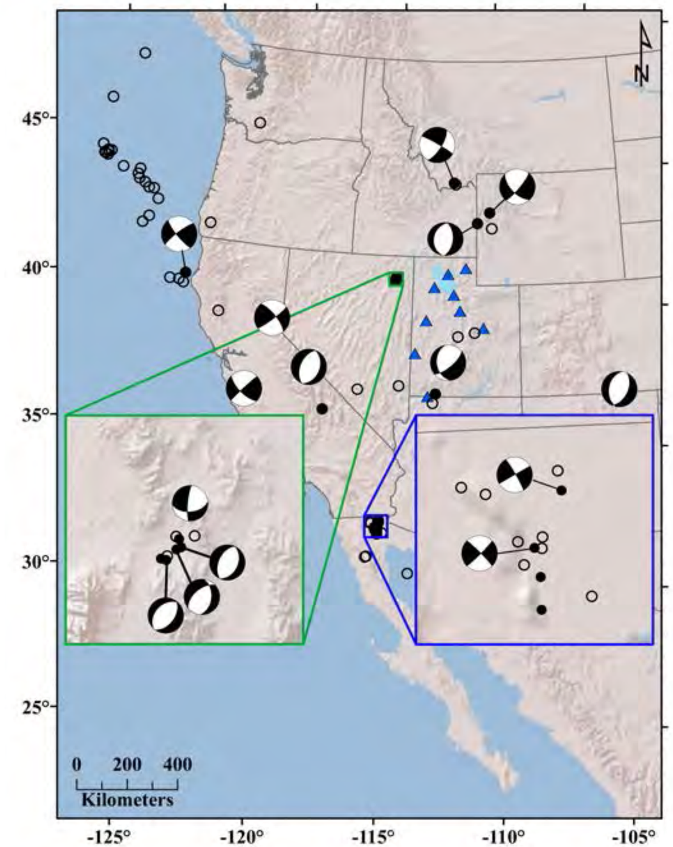
Full Moment Tensor Inversion





Infrasound Network





Volcanism in the American Southwest

Flagstaff 18-19 october 2012

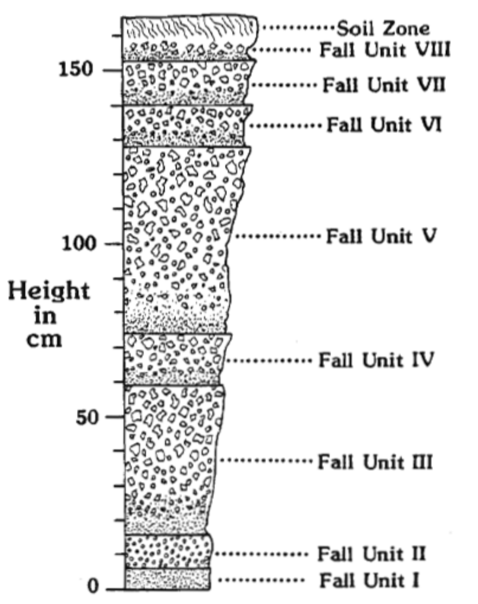
Characterization of the 1085 AD Sunset Crater eruption and its pyroclastic products

Fabrizio Alfano[1], Laura Pioli[2], Amanda Clarke[1], Michael Ort[3], Stephen Self[4]

1. SESE (Arizona State University, USA)
2. Department of Mineralogy (University of Geneva, Switzerland)
3. SESES (Northern Arizona University, USA)
4. CEPSAR (The Open Universty, UK).

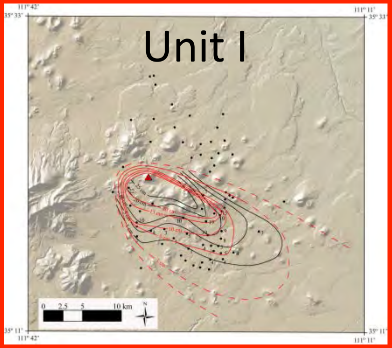
The tephra deposit

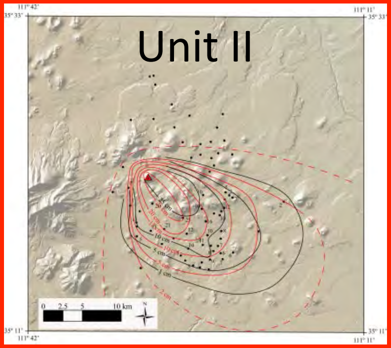
- 300 m scoria cone
- 3 lava flows
- 8 major fallout units (Amos 1986)
  - Lithic poor
  - well sorted
  - non-welded
  - Inversely graded

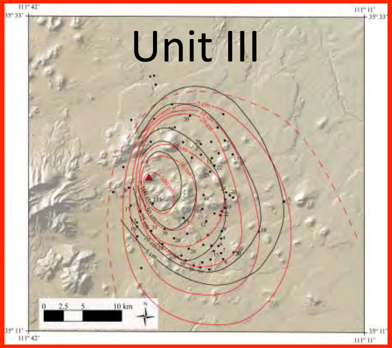


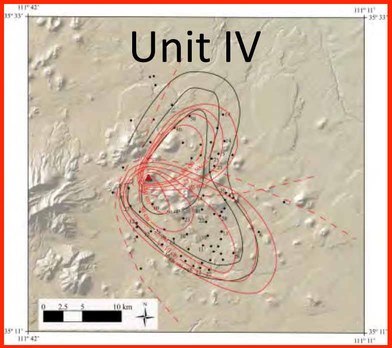
Amos (1986)

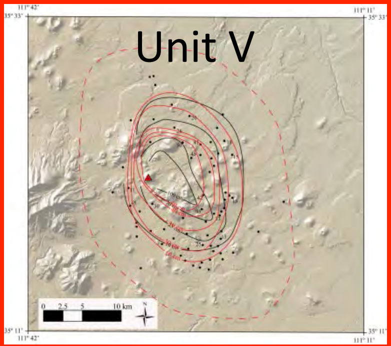
Characterization of the tephra deposit

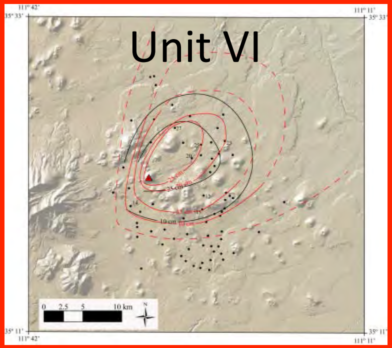


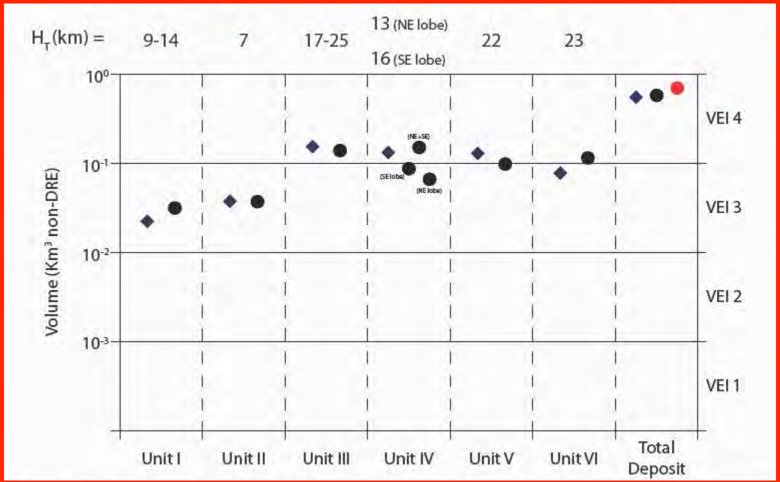






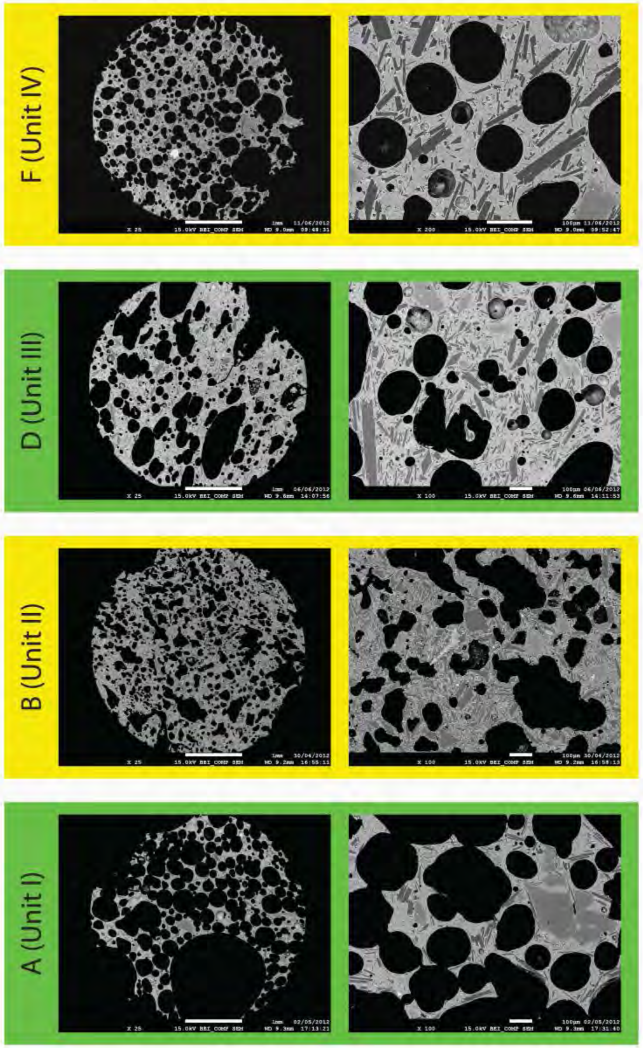


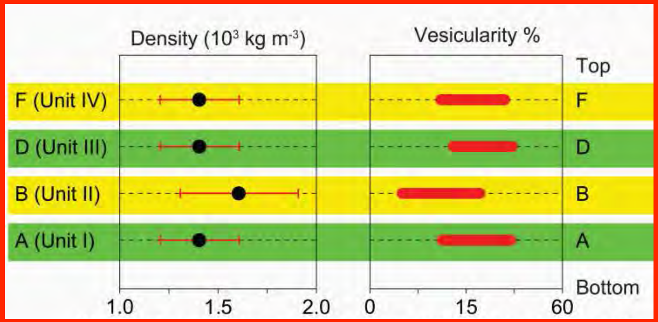




- Dispersed over an area of about 500 km^2
- Up to 12 m thick
- Total cumulative volume about 0.6 km^3 non-DRE
- Column height between 7 and 25 km

Characterization of the textures





	Density (10^3 kg m^{-3})	Vesicularity (%)	Aspect Ratio	N_A (mm^{-2})	N_V (mm^{-3})	N_V^{corr} (mm^{-3})
F (Unit IV)	1.37	43	0.8 ± 0.1	1.5 x 10^2	1.1 x 10^4	1.0 x 10^2
D (Unit III)	1.53	36	0.8 ± 0.1	1.3 x 10^2	1.1 x 10^4	0.9 x 10^2
B (Unit II)	1.66	31	0.7 ± 0.2	3.5x 10^2	3.4 x 10^4	2.2 x 10^2
A (Unit I)	0.97	60	0.8 ± 0.1	1.1 x 10^2	1.1 x 10^4	1.5 x 10^2

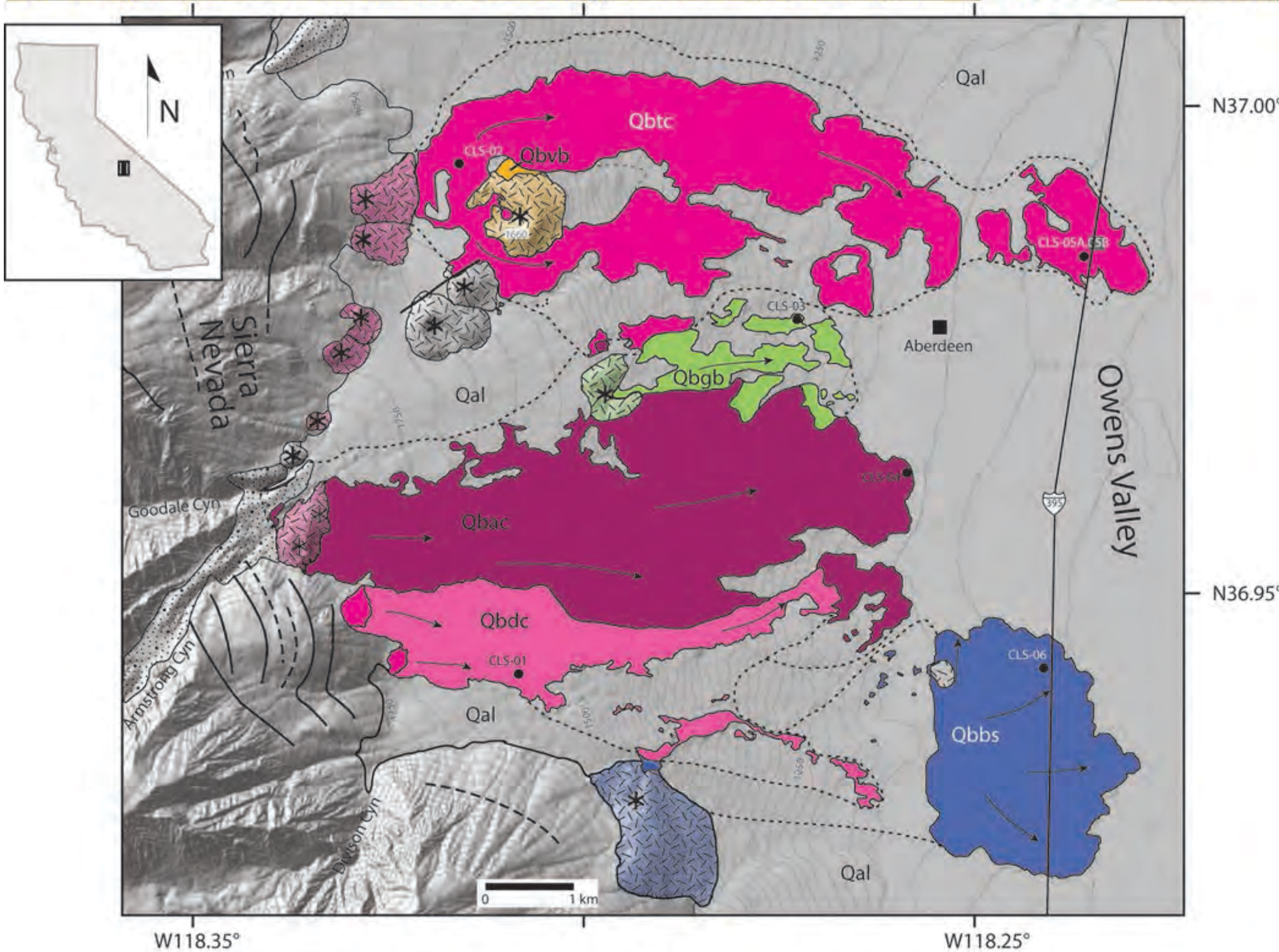
Vesicularity was determined assuming a DRE of 2.4 x 10^3 kg m^{-3} (Amos 1986).
N_A: number of vesicle per unit area.
N_V: number of vesicle per unit volume.
N_V^{corr}: N^V corrected for the measured vesicularity.

Timing of late-Pleistocene volcanism at Big Pine volcanic field from volcanic stratigraphy, cosmogenic ^{36}Cl dating, and paleomagnetism

J.A. Vazquez[1], J.M. Woolford[2], A. Zohar[2], E.A. Nagy-Shadman[3], D.E. Champion[1]

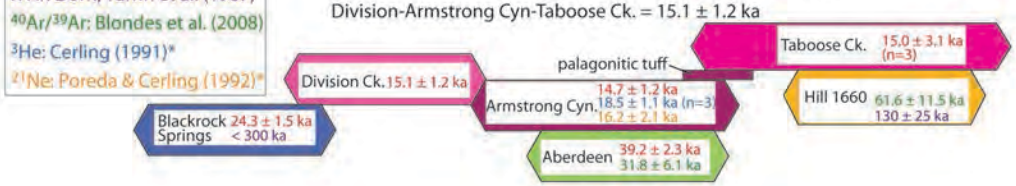
USGS

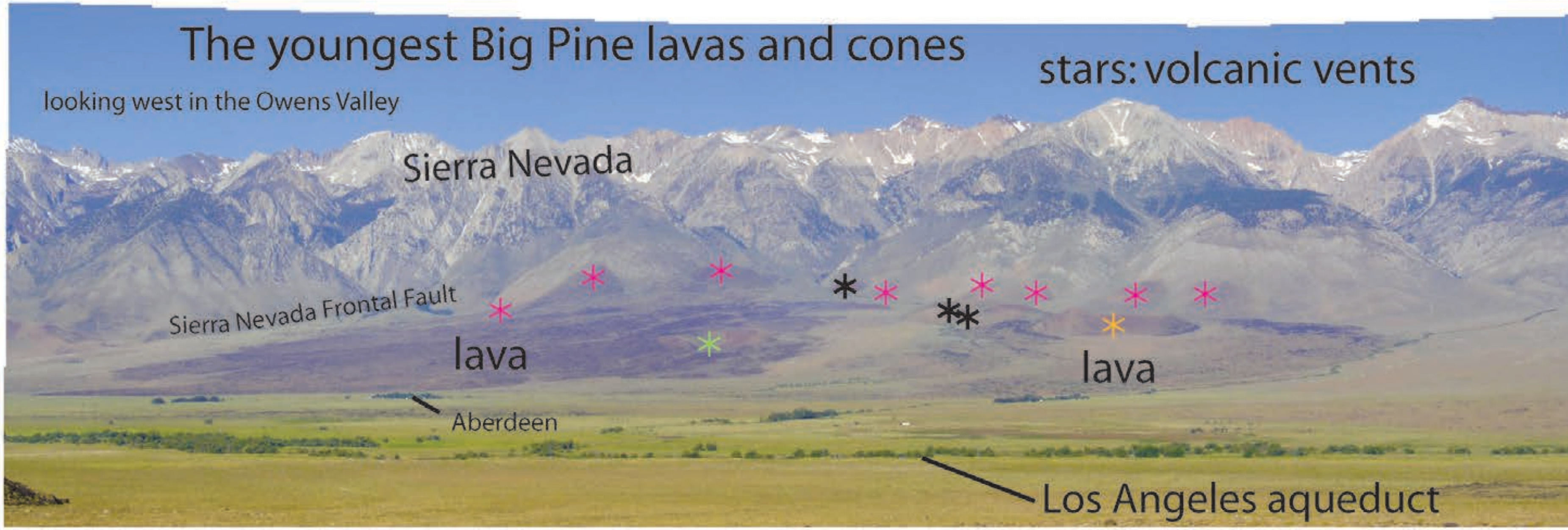
[1]US Geological Survey
[2]CSU-Northridge
[3]Pasadena City College



Lava stratigraphy & ages (±1σ)

Division-Armstrong Cyn-Taboose Ck. = 15.1 ± 1.2 ka




The youngest Big Pine lavas and cones
stars: volcanic vents
looking west in the Owens Valley
Sierra Nevada
Sierra Nevada Frontal Fault
lava
lava
Aberdeen
Los Angeles aqueduct

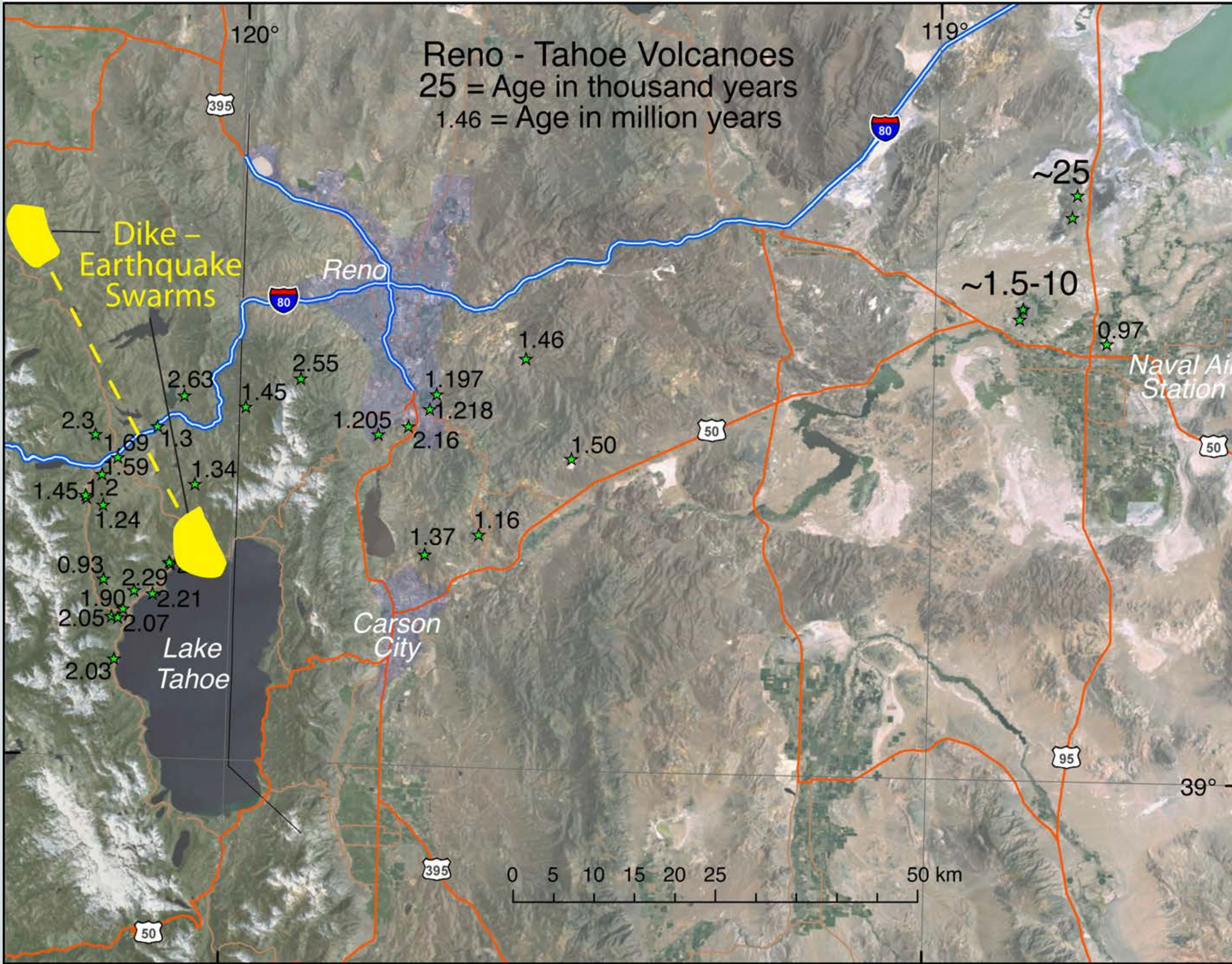
Christopher D. Henry & Brian Cousens

Young Volcanism of the Lake Tahoe – Reno – Fallon Area, California and Nevada: The Geologic Record

Reno - Tahoe Volcanoes
25 = Age in thousand years
1.46 = Age in million years
120°
119°
39°
395
80
Reno
Carson City
Lake Tahoe
Naval Air Station
50
95
~25
~1.5-10
0.97
1.46
2.55
2.63
1.45
1.197
1.218
1.205
2.16
2.3
1.3
1.69
1.59
1.34
1.50
1.45
1.2
1.24
1.16
1.37
2.5
2.2
0.93
2.29
1.90
2.21
2.05
2.07
2.03
0 5 10 15 20 25 50 km


Soda Lakes maars
Less than 10,000 years old
Possibly 1500 years old


10/2006
1969
2012
Reno
1.37 Ma Cinder Cone and Lavas
50
Lincoln Hwy
Carson City
© 2012 Google
Image © 2012 DigitalGlobe
Image USDA Farm Service Agency
805 m
Google earth
Imagery Date: 10/28/2006
1994
lat 39.215505° lon -119.712561° elev 1684 m
Eye alt 4.14 km



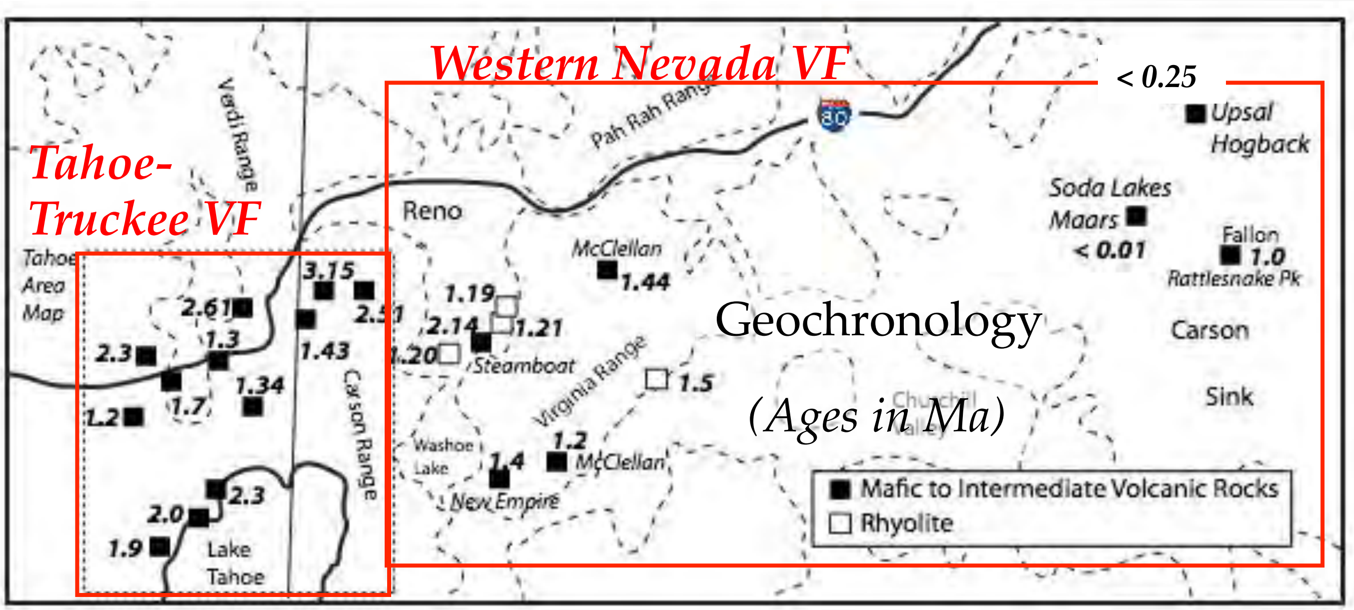
Reno - Tahoe Volcanoes
25 = Age in thousand years
1.46 = Age in million years
120°
119°
39°
Dike – Earthquake Swarms
Reno
Carson City
Lake Tahoe
Naval Air Station
~25
~1.5-10
0.97
1.46
2.55
2.63
1.45
1.197
1.218
1.205
2.16
2.3
1.69
1.3
1.59
1.34
1.50
1.45
1.2
1.24
1.16
1.37
0.93
2.29
1.90
2.21
2.05
2.07
2.03
395
80
50
95
0 5 10 15 20 25 50 km

Geochemistry and hazard assessment of Pliocene-Quaternary volcanism beneath the central Sierra Nevada and adjacent Great Basin, northern California and western Nevada

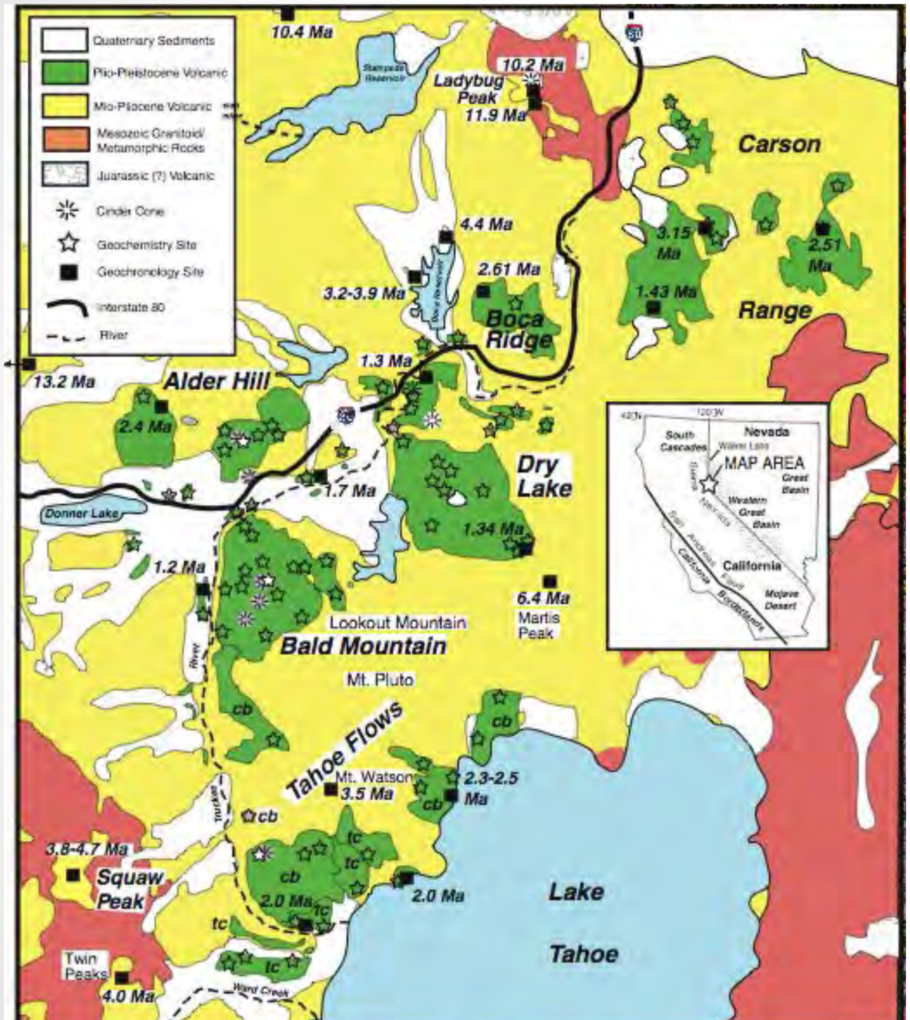
Brian Cousens, Carleton University

Christopher Henry, NBMG

(and students)



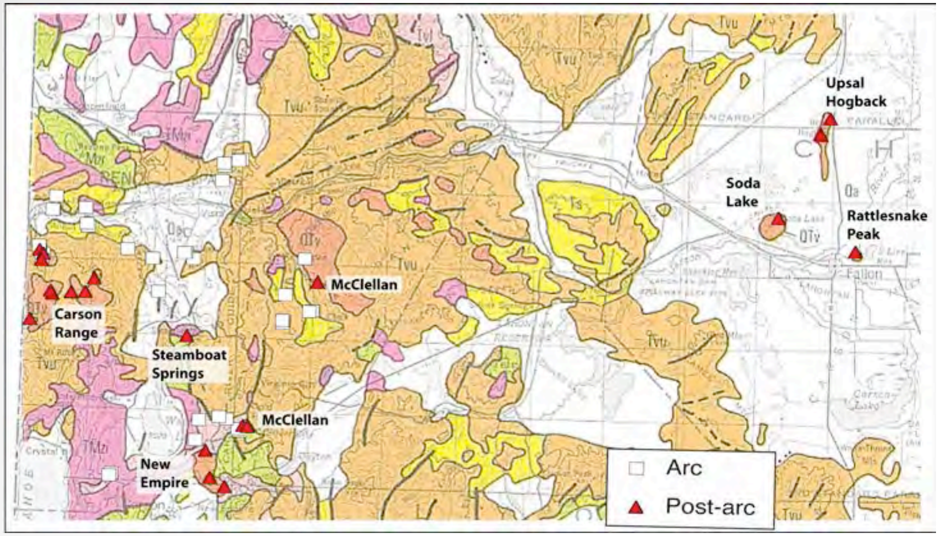
Tahoe-Truckee Volcanic Field 2.6-0.9 Ma



Thanks to Bill Wise, Art Sylvester, UCSB

- Immediately follows Mio-Pliocene arc volcanism of Ancestral Cascades arc
- Mildly alkaline to potassic lavas, cinder cones
- Melts of metasomatized lithospheric mantle
- Youngest eruption 0.9 Ma (Kortemeier et al.)
- 2003-04 deep earthquakes; associated with magma migration

Western Nevada Volcanic Field 2.5 Ma–3 kyr

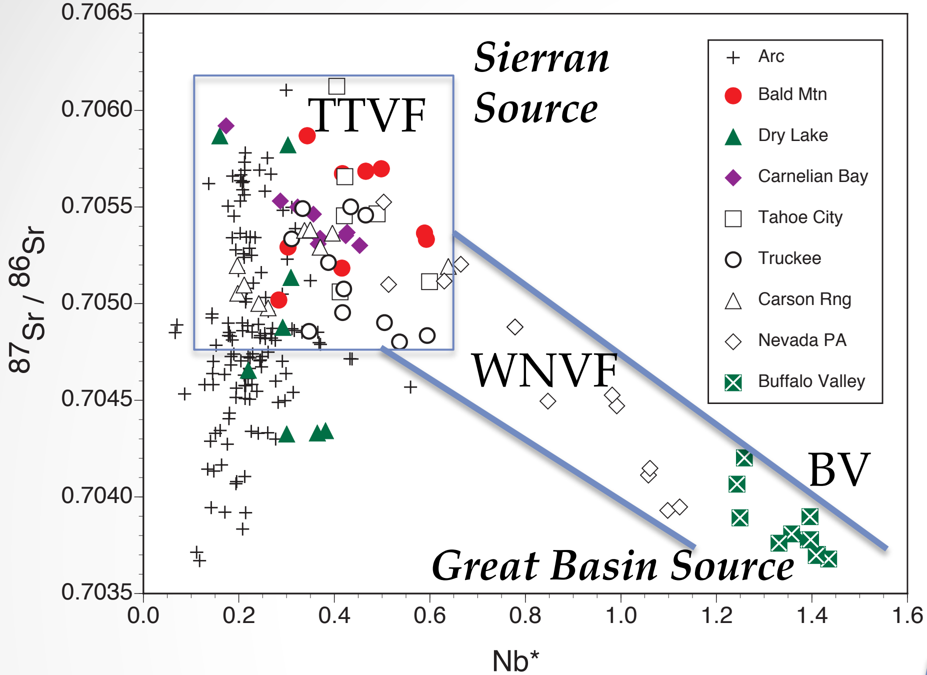


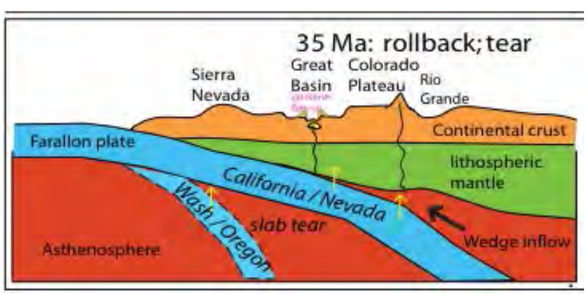
Bombs and blocks, Upsal Hogback

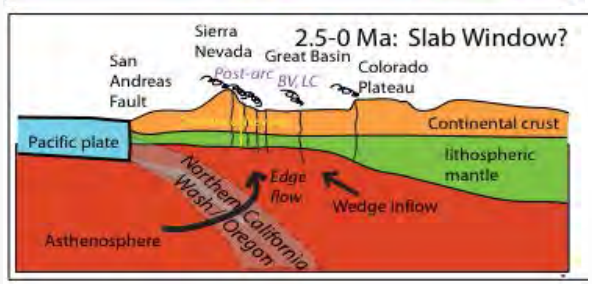
Crossbedded ash deposits, Soda Lakes

- Western lavas and cinder cones coeval with TTVF
- Low-degree melts of enriched asthenosphere
- Upsal Hogback ~ 25 kyr, Soda Lake maars ~3kyr
- Phreatomagmatic volcanoes – explosive
- Potential threat to USN air station, Fallon; 6,000 residents

Different Sources, Different Hazard Threat?





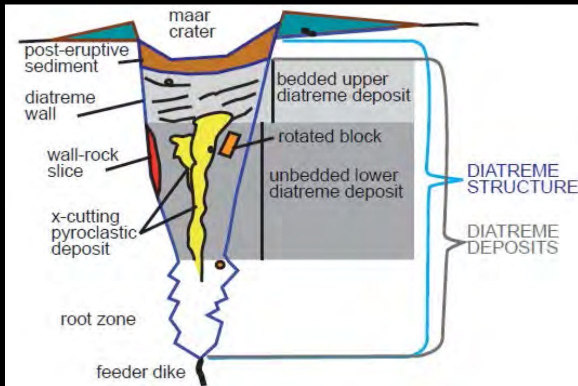


- Geochemical gradation between TTVF east to WNVF/ Buffalo Valley (**Sierran** lithosphere to **Great Basin** asthenosphere)
- Most Tertiary-Pliocene volcanism in Sierra Nevada/ Great Basin sourced from lithospheric mantle
- TTVF retains Sierran Source due to thick lithosphere; Pliocene-Holocene WNVF erupted through thinned lithosphere, underlying asthenosphere can melt
- ***Both sources produce explosive events***

James White

Uncertantitities regarding explosive maar-diatreme eruptions within volcanic fields

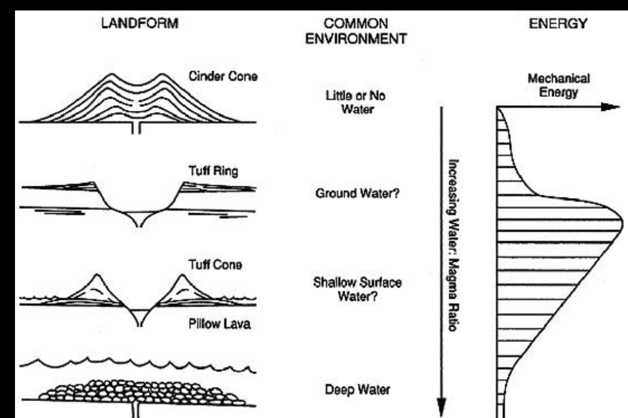
What's a maar-diatreme?



Ukinrek Maars 1995.
Photograph courtesy of Game McGimsey

Previous certainties

Photo: Carl Fries (www.mnh.si.edu)

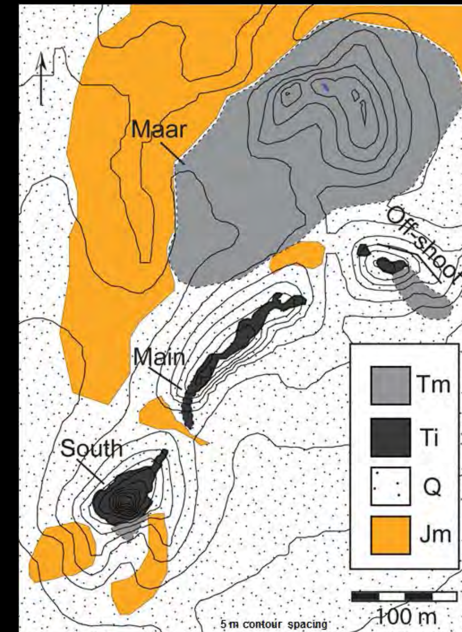


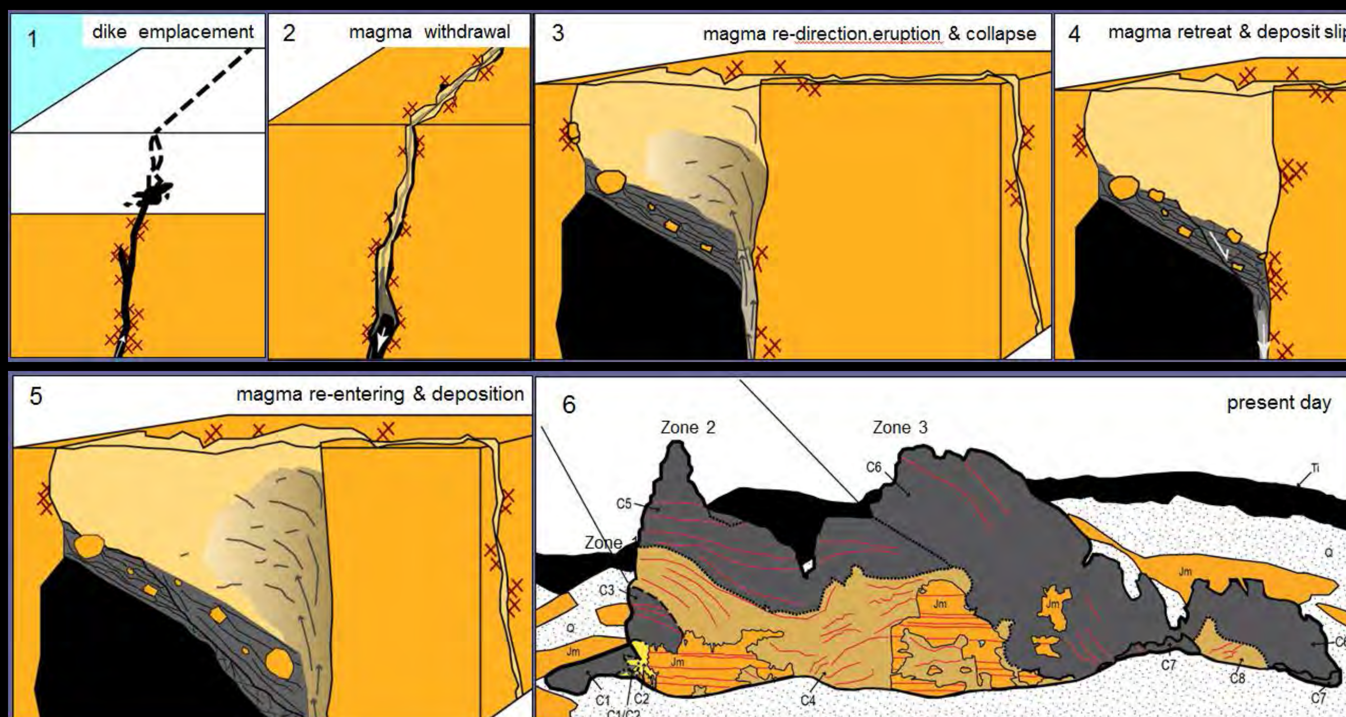
Bang now, bang later?

Shortly after 0200 hours on 28 September 1965, residents of Volcano Island in Lake Taal were awakened by a rumbling, roaring, and hissing noise. People on the west-central coast of the island saw incandescent material shooting high in the air from the general vicinity of the newly formed cinder cone. This initial fountaining of basaltic spatter, cinders, and pumice was described as appearing like an enormous Roman candle. The color was distinctly red, not red-orange or orange. Some describe the fountaining as vertical, others describe it as directed toward the lake (toward the west) at perhaps 45 degrees from the vertical.

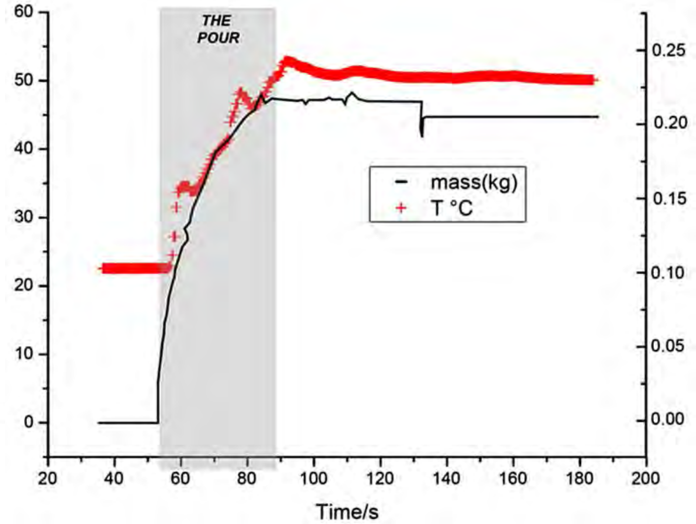
Magma withdrawal takes eruptions underground

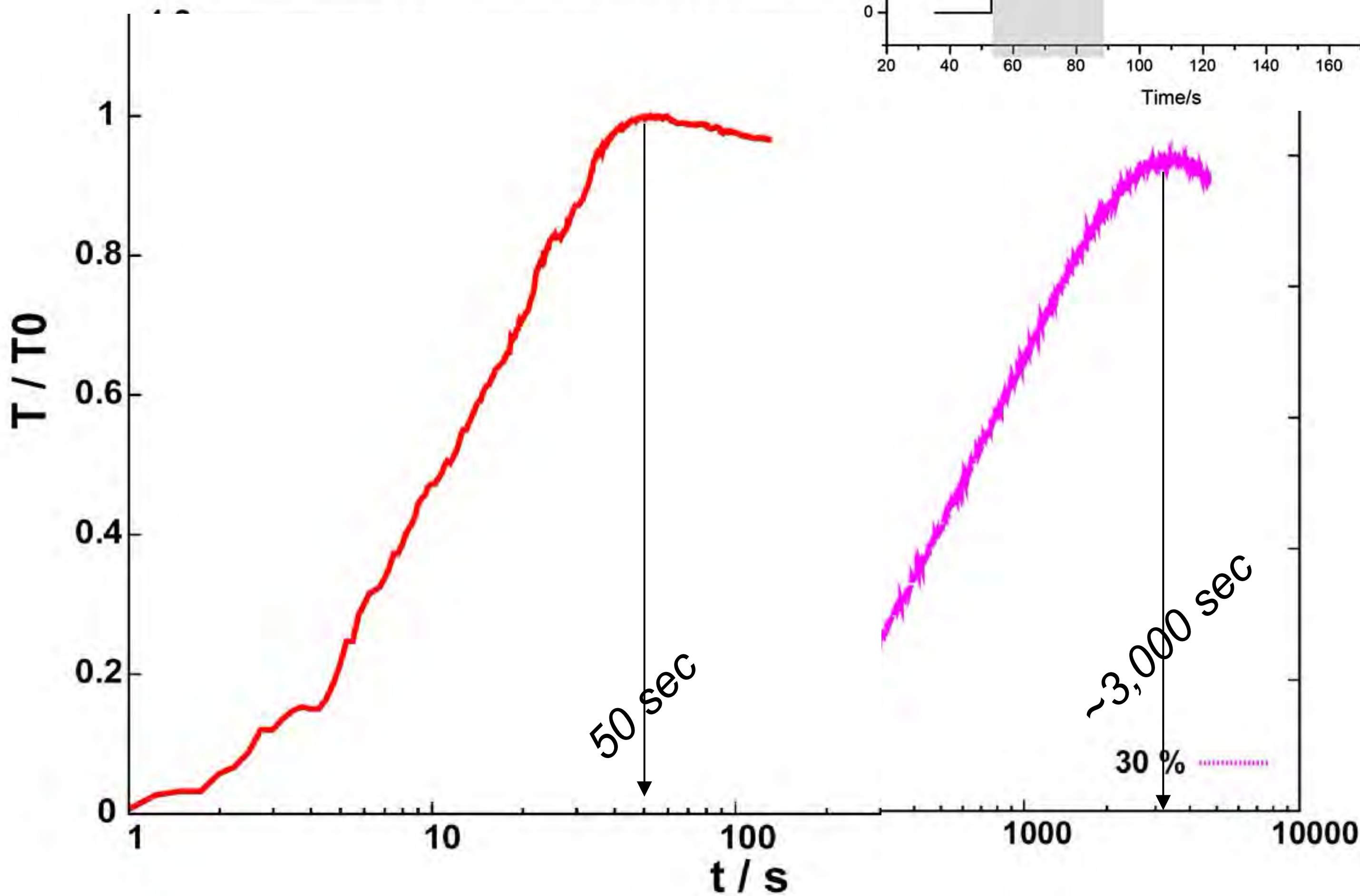
(N. Lefebvre et al. 2012)





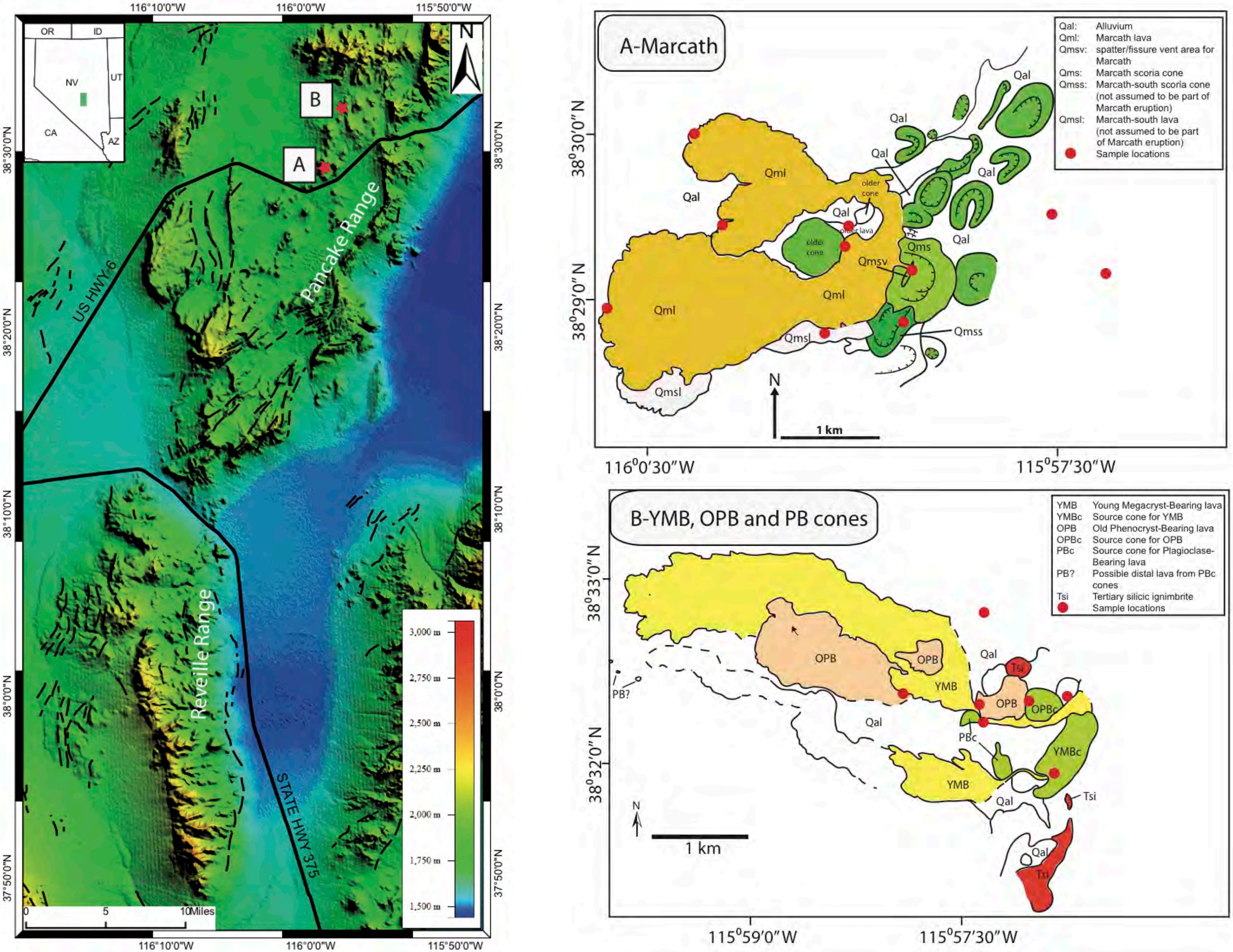
Dirty coolants and the real world

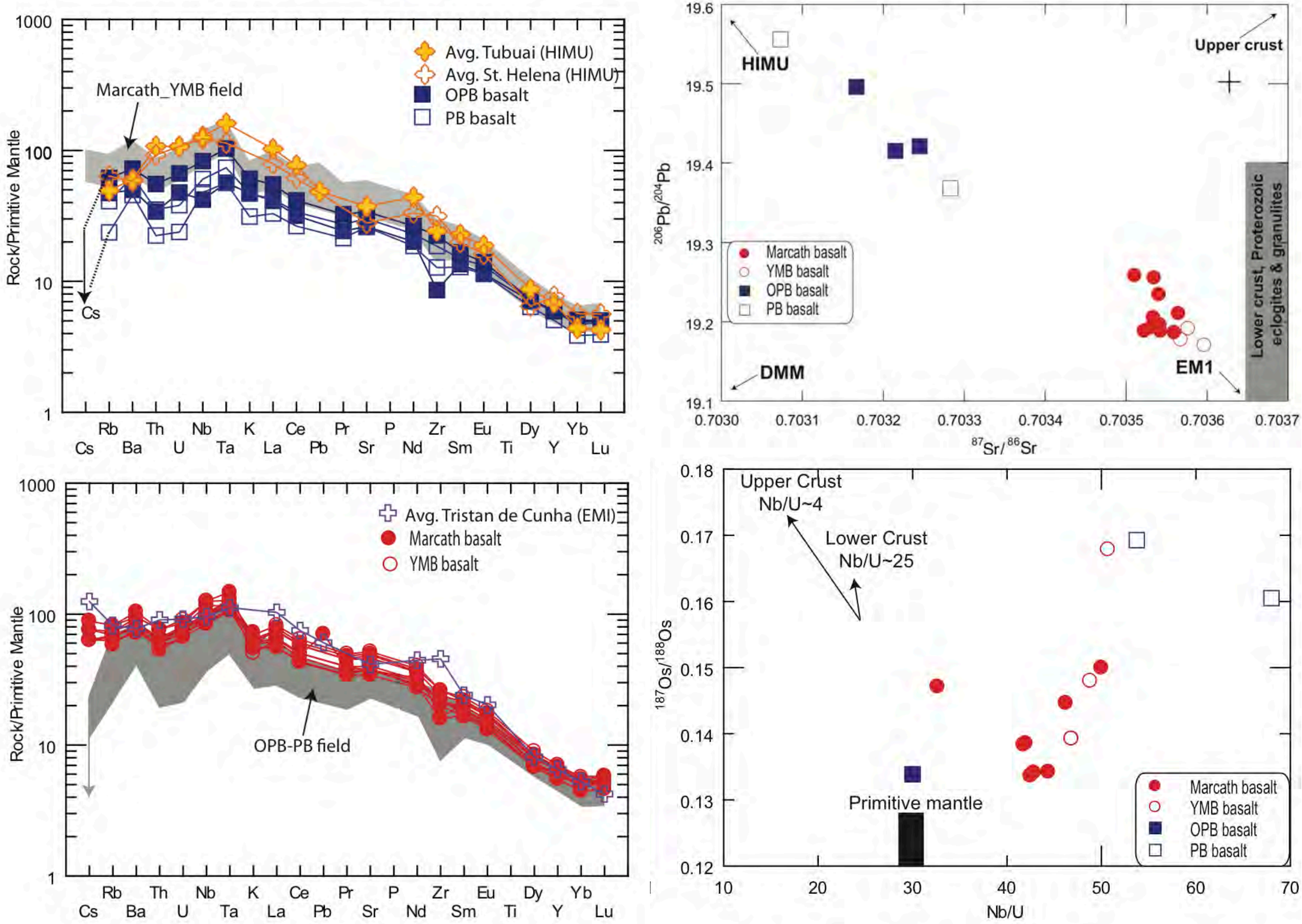


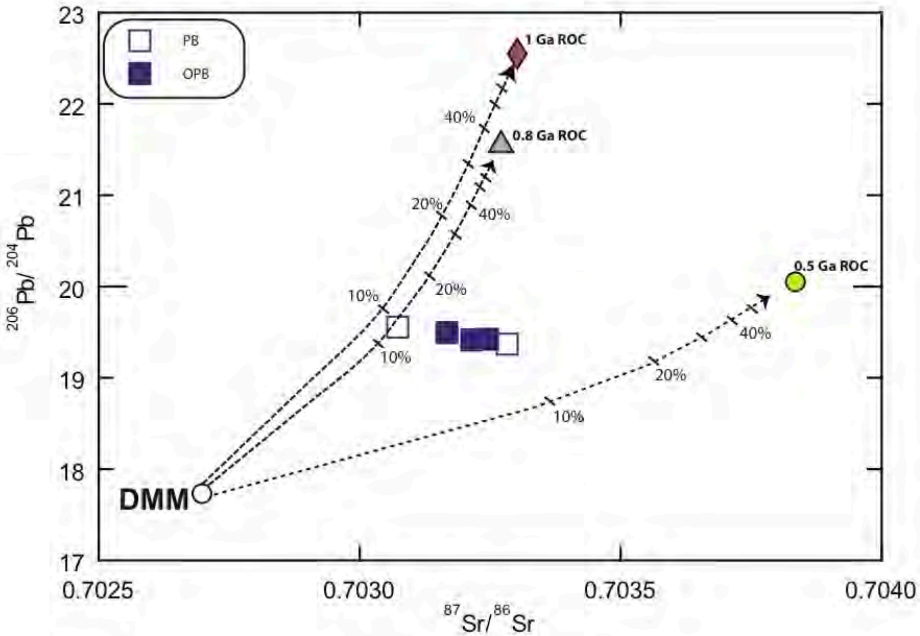


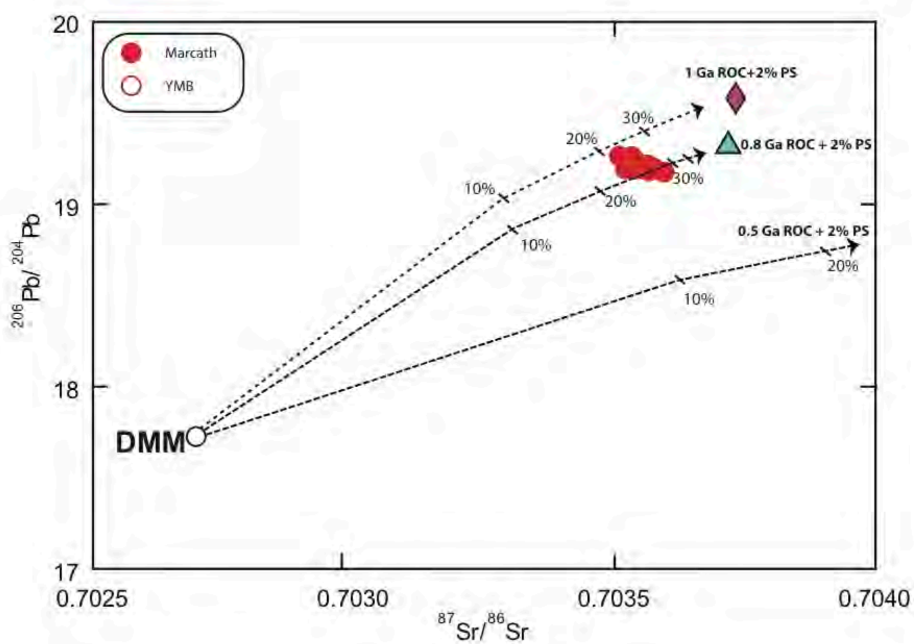
Petrogenesis of Monogenetic Volcanoes in the Lunar Crater Volcanic Field

Caco Cortes & Greg Valentine, U. Buffalo
Gene Smith & Rachael Johnsen, UNLV
Fara Rasoazanamparany &
Liz Widom & Dave Kuentz, Miami U.


116°10'0"W
116°0'0"W
115°50'0"W
38°30'0"N
38°20'0"N
38°10'0"N
38°0'0"N
37°50'0"N
OR
ID
NV
UT
CA
AZ
N
B
A
US HWY 6
Pancake Range
Reveille Range
STATE HWY 375
3,000 m
2,750 m
2,500 m
2,250 m
2,000 m
1,750 m
1,500 m
0
5
10Miles
A-Marcath
Qal: Alluvium
Qml: Marcath lava
Qmsv: spatter/fissure vent area for Marcath
Qms: Marcath scoria cone
Qmss: Marcath-south scoria cone (not assumed to be part of Marcath eruption)
Qmsl: Marcath-south lava (not assumed to be part of Marcath eruption)
Sample locations
Qal
Qml
older cone
older lava
Qms
Qmsv
Qmss
Qmsl
1 km
38°30'0"N
38°29'0"N
116°0'30"W
115°57'30"W
B-YMB, OPB and PB cones
YMB Young Megacryst-Bearing lava
YMBc Source cone for YMB
OPB Old Phenocryst-Bearing lava
OPBc Source cone for OPB
PBc Source cone for Plagioclase-Bearing lava
PB? Possible distal lava from PBc cones
Tsi Tertiary silicic ignimbrite
Sample locations
OPB
YMB
OPBc
YMBc
PBc
PB?
Qal
Tsi
1 km
38°33'0"N
38°32'0"N
115°59'0"W
115°57'30"W


Rock/Primitive Mantle
1000
100
10
1
Avg. Tubuai (HIMU)
Avg. St. Helena (HIMU)
OPB basalt
PB basalt
Marcath_YMB field
Cs
Rb Th Nb K Ce Pr P Zr Eu Dy Yb
Cs Ba U Ta La Pb Sr Nd Sm Ti Y Lu
$^{206}Pb/^{204}Pb$
19.6
19.5
19.4
19.3
19.2
19.1
HIMU
Upper crust
Marcath basalt
YMB basalt
OPB basalt
PB basalt
DMM
EM1
Lower crust, Proterozoic eclogites & granulites
0.7030 0.7031 0.7032 0.7033 0.7034 0.7035 0.7036 0.7037
$^{87}Sr/^{86}Sr$
Rock/Primitive Mantle
1000
100
10
1
Avg. Tristan de Cunha (EMI)
Marcath basalt
YMB basalt
OPB-PB field
Rb Th Nb K Ce Pr P Zr Eu Dy Yb
Cs Ba U Ta La Pb Sr Nd Sm Ti Y Lu
$^{187}Os/^{188}Os$
0.18
0.17
0.16
0.15
0.14
0.13
0.12
Upper Crust
Nb/U~4
Lower Crust
Nb/U~25
Primitive mantle
Marcath basalt
YMB basalt
OPB basalt
PB basalt
10 20 30 40 50 60 70
Nb/U

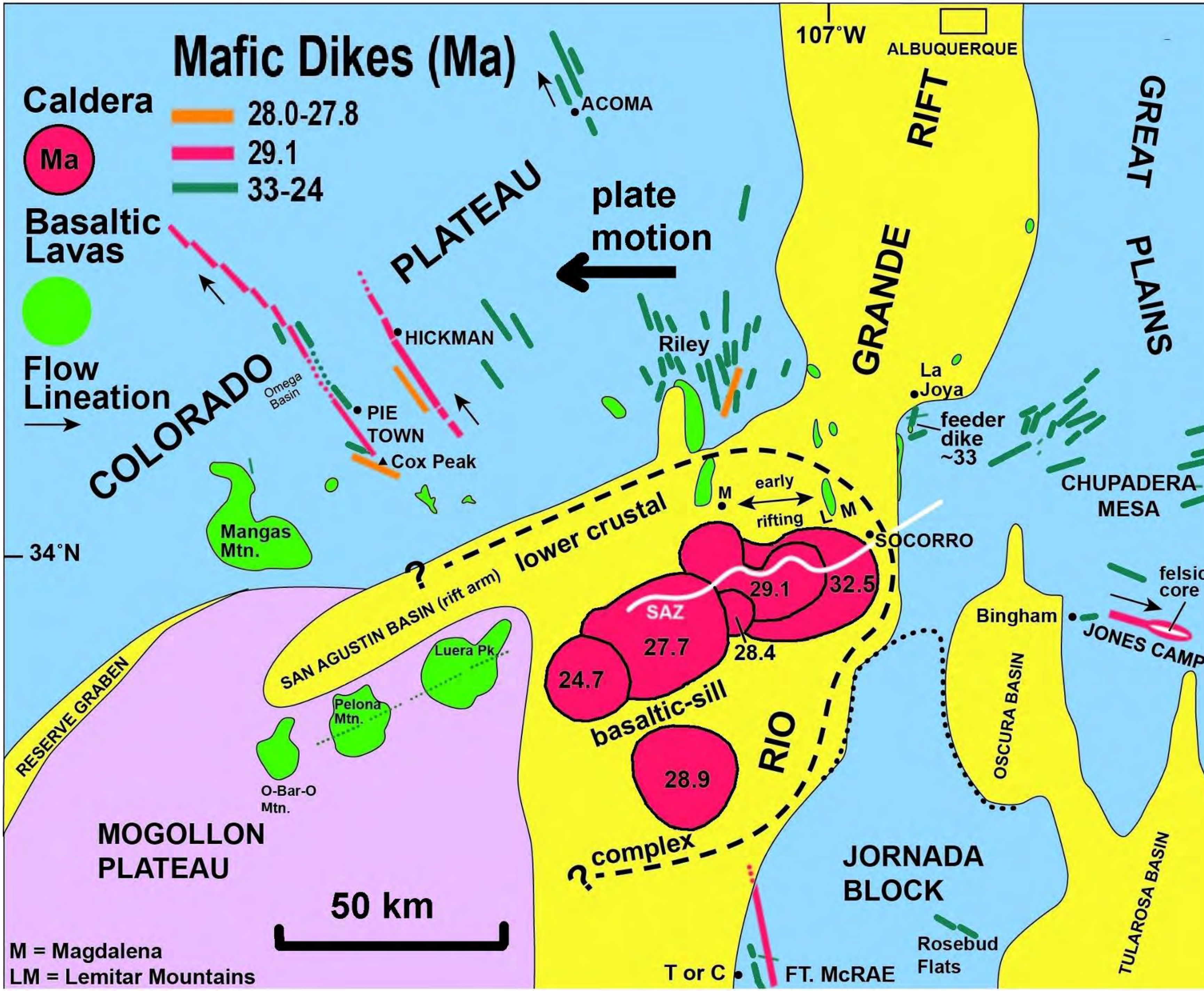




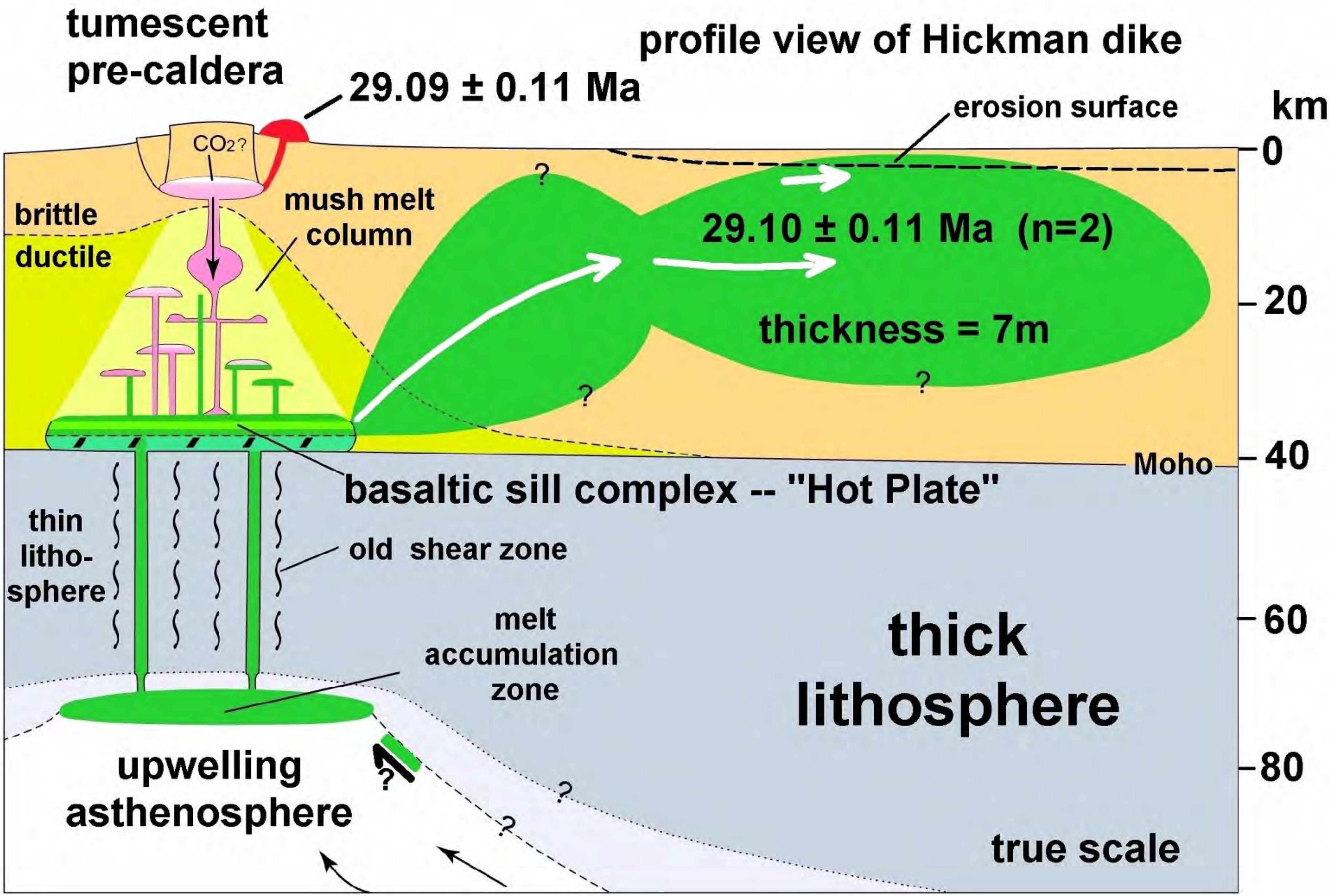
- **PB/OPB (~HIMU)**
  MORB mantle + 0.8 Ga recycled oceanic crust (ROC)
- **Marcath/YMB (~EMI)**
  MORB mantle + ROC + 2% Sediment
- **We propose that LCVF monogenetic volcanism relates to melting of mantle metasomatized by ancient subduction processes**

Ignimbrite Calderas and a Large Radiating Mafic Dike Swarm of Oligocene Age, Rio Grande Rift, New Mexico: Possible Implications to Restless Calderas

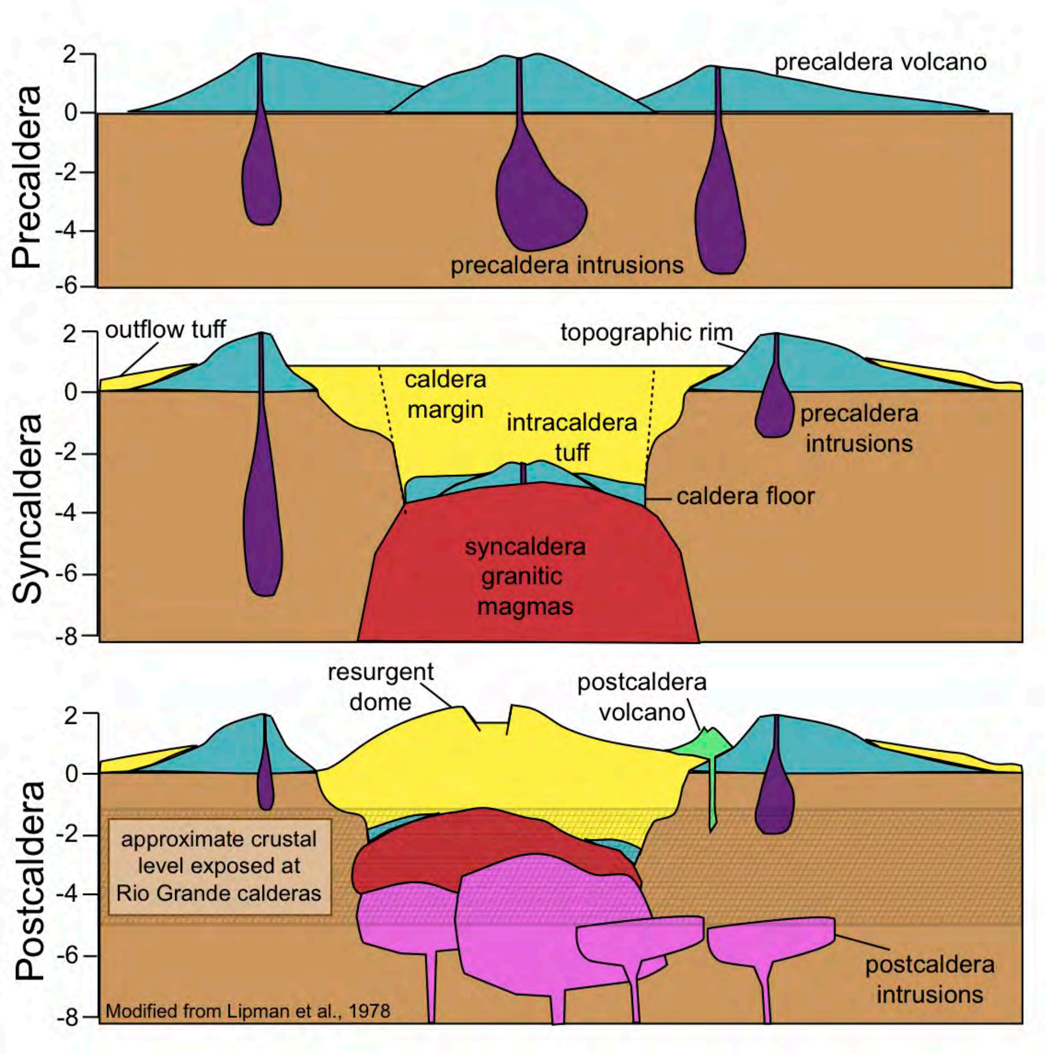
R.M. Chamberlin, W.C. McIntosh, N.W. Dunbar,
and M.I. Dimeo*,
New Mexico Bureau of Geology and Mineral Resources,
New Mexico Tech
and Evolving Gold Corp*.



Mafic Dikes (Ma)
Caldera
Ma
28.0-27.8
29.1
33-24
Basaltic Lavas
Flow Lineation
107°W
ALBUQUERQUE
ACOMA
RIFT
GREAT PLAINS
PLATEAU
plate motion
GRANDE
COLORADO
Omega Basin
HICKMAN
PIE TOWN
Cox Peak
Riley
La Joya
feeder dike ~33
CHUPADERA MESA
Mangas Mtn.
34°N
lower crustal
early rifting
M
L M
SOCORRO
29.1
32.5
SAZ
27.7
28.4
24.7
SAN AGUSTIN BASIN (rift arm)
Luera Pk.
Pelona Mtn.
O-Bar-O Mtn.
RESERVE GRABEN
basaltic-sill
28.9
RIO
Bingham
JONES CAMP
felsic core
OSCURA BASIN
MOGOLLON PLATEAU
complex
JORNADA BLOCK
TULAROSA BASIN
50 km
Rosebud Flats
T or C
FT. McRAE
M = Magdalena
LM = Lemitar Mountains

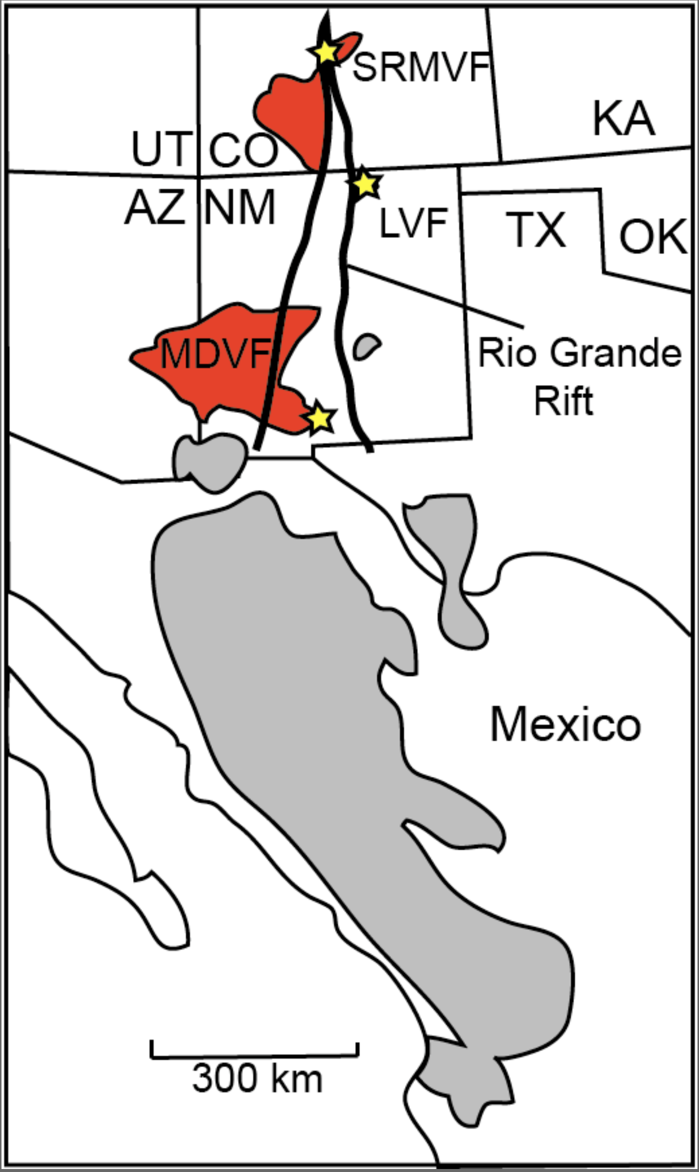

tumescent
pre-caldera
profile view of Hickman dike
29.09 ± 0.11 Ma
erosion surface
km
CO2?
?
brittle
ductile
mush melt
column
29.10 ± 0.11 Ma (n=2)
thickness = 7m
?
?
0
20
40
Moho
basaltic sill complex -- "Hot Plate"
thin
litho-
sphere
old shear zone
melt
accumulation
zone
thick
lithosphere
60
80
upwelling
asthenosphere
?
?
?
true scale

Postcaldera magmatism at three Rio-Grande-rifted calderas: Implications for assessing volcanic hazards at active caldera systems in the USA

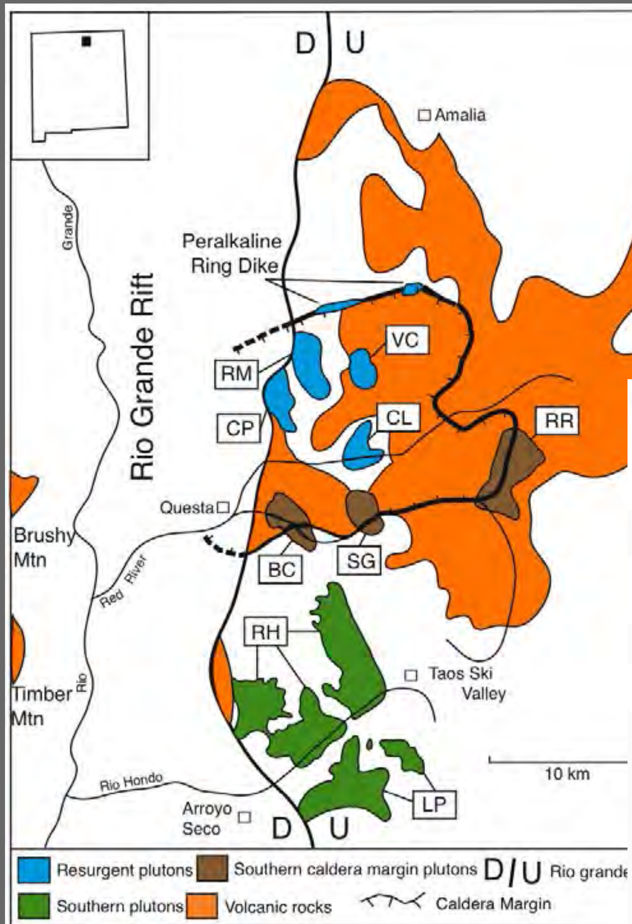


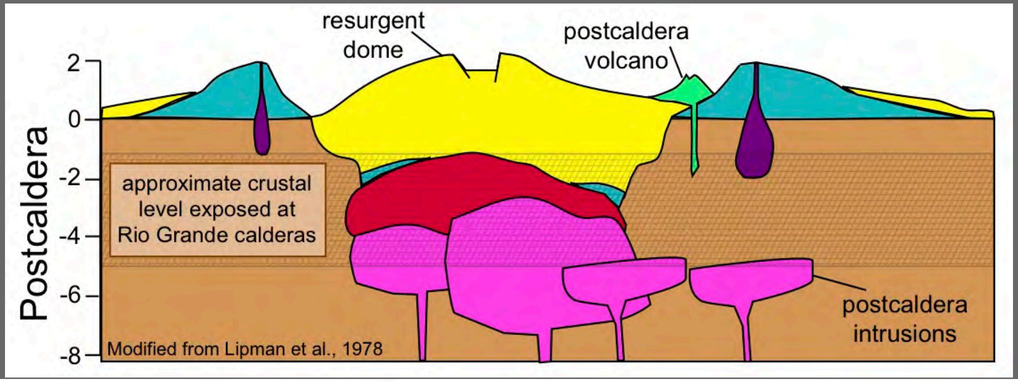
Matthew J. Zimmerer and William C. McIntosh - VASW October 18-20th

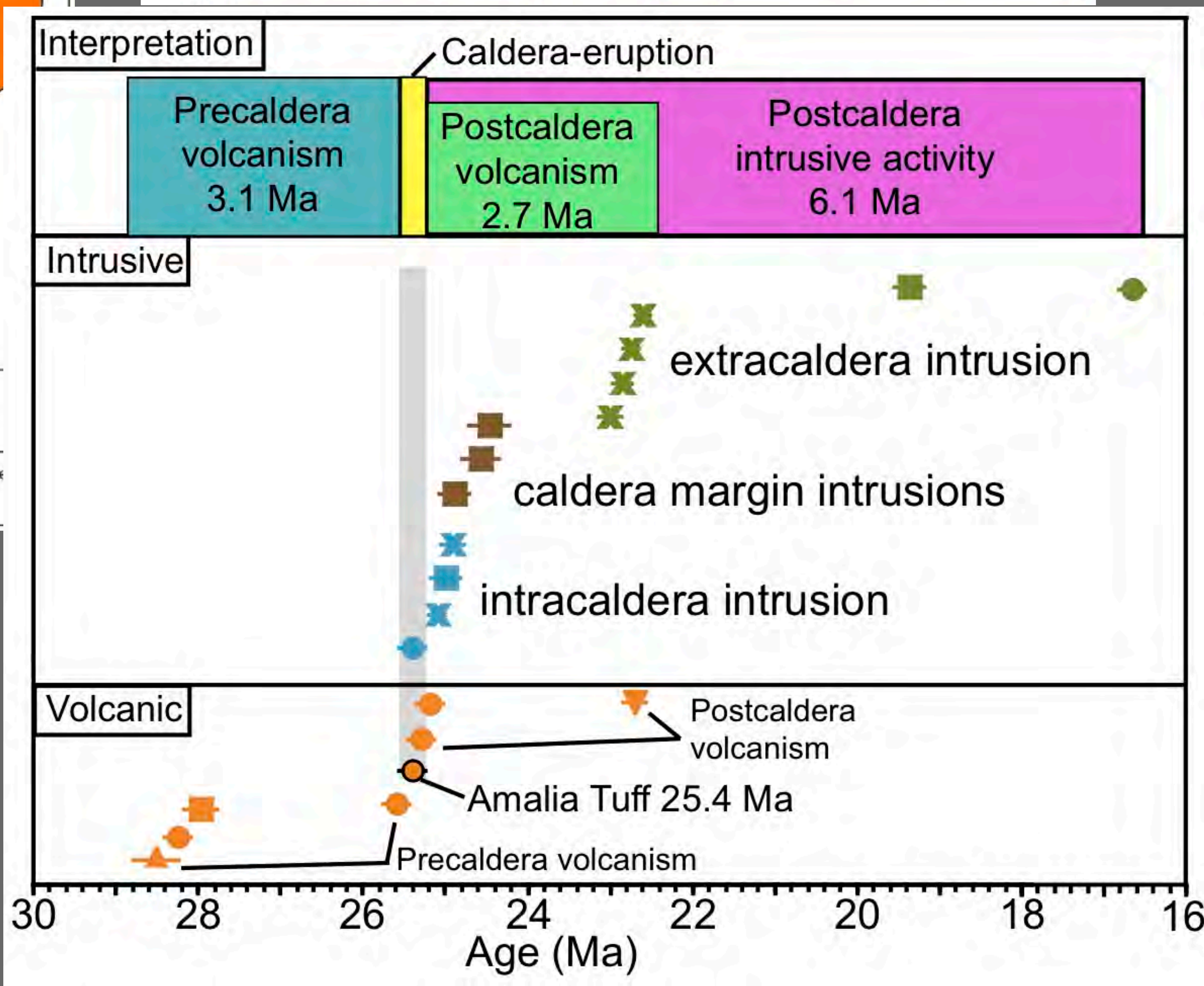
Using extinct calderas to understand active calderas



Modified from McIntosh et al., 1992







Questa caldera

ENVIRONMENTAL CONSEQUENCES OF LARGE VOLUME LAVA FLOW FIELDS IN THE SOUTHWEST: *PRELIMINARY INFERENCES FROM MAPPING THE McCARTYS LAVA FLOW FIELD, NEW MEXICO*

L.S. CRUMPLER[1], J.E. BLEACHER[2], S. SELF[3], J.R. ZIMBELMAN[4], W. B. GARRY[5], J. C. AUBELE[1]

(1) NM Museum of Natural History, (2) Planetary Geodynamics Laboratory, NASA Goddard Space Flight Center, (3) Dept. of Earth and Environmental Sciences, The Open University, UK., (4) Smithsonian Institution, National Air and Space Museum (5) Planetary Science Institute, Tucson, AZ

~3200 years bp

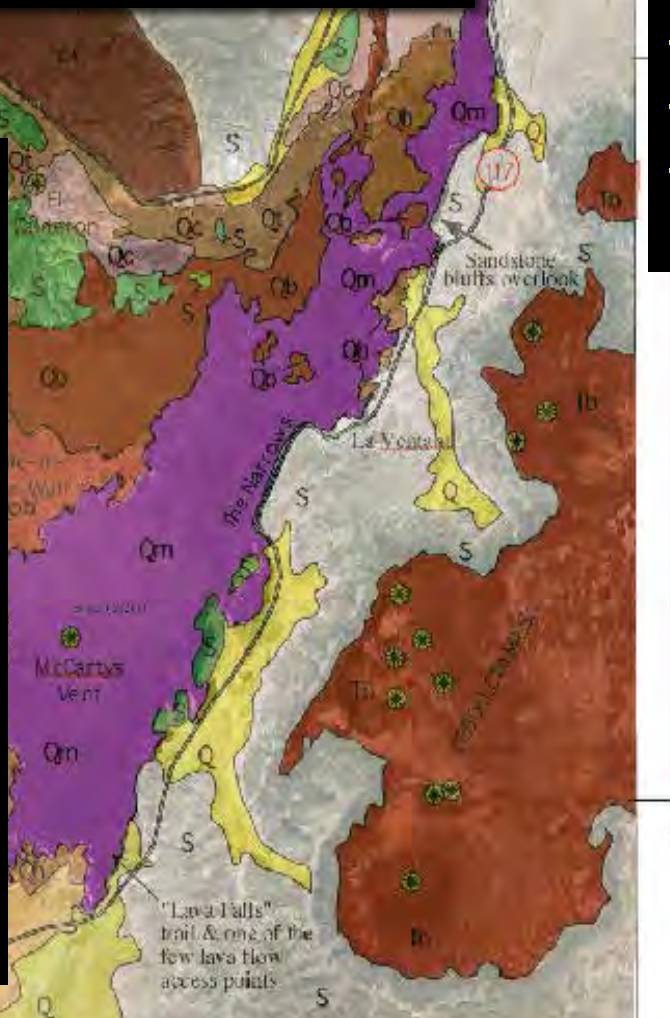
-3 to 6 km^3

-one of largest young lava flows

Why study this?

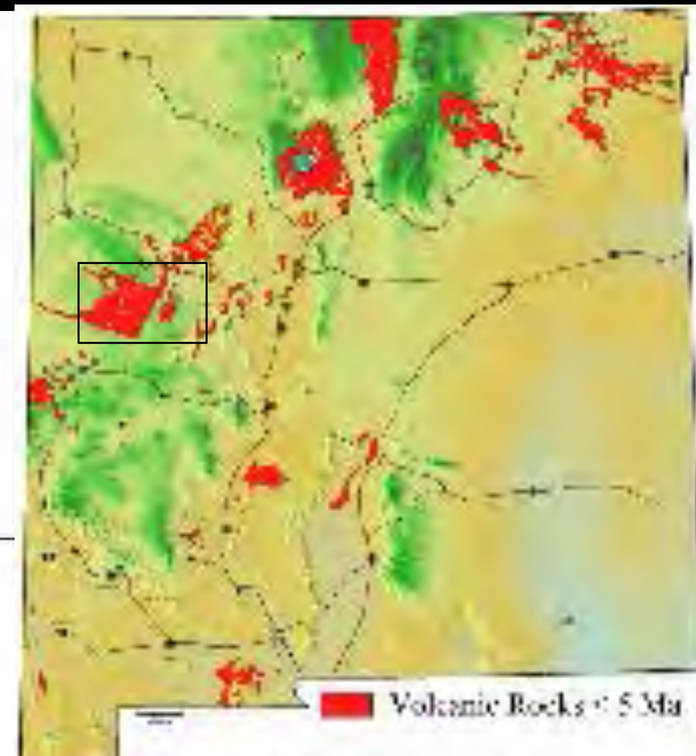
Laki fissure eruption was one of the most globally disruptive volcanic events of recorded history

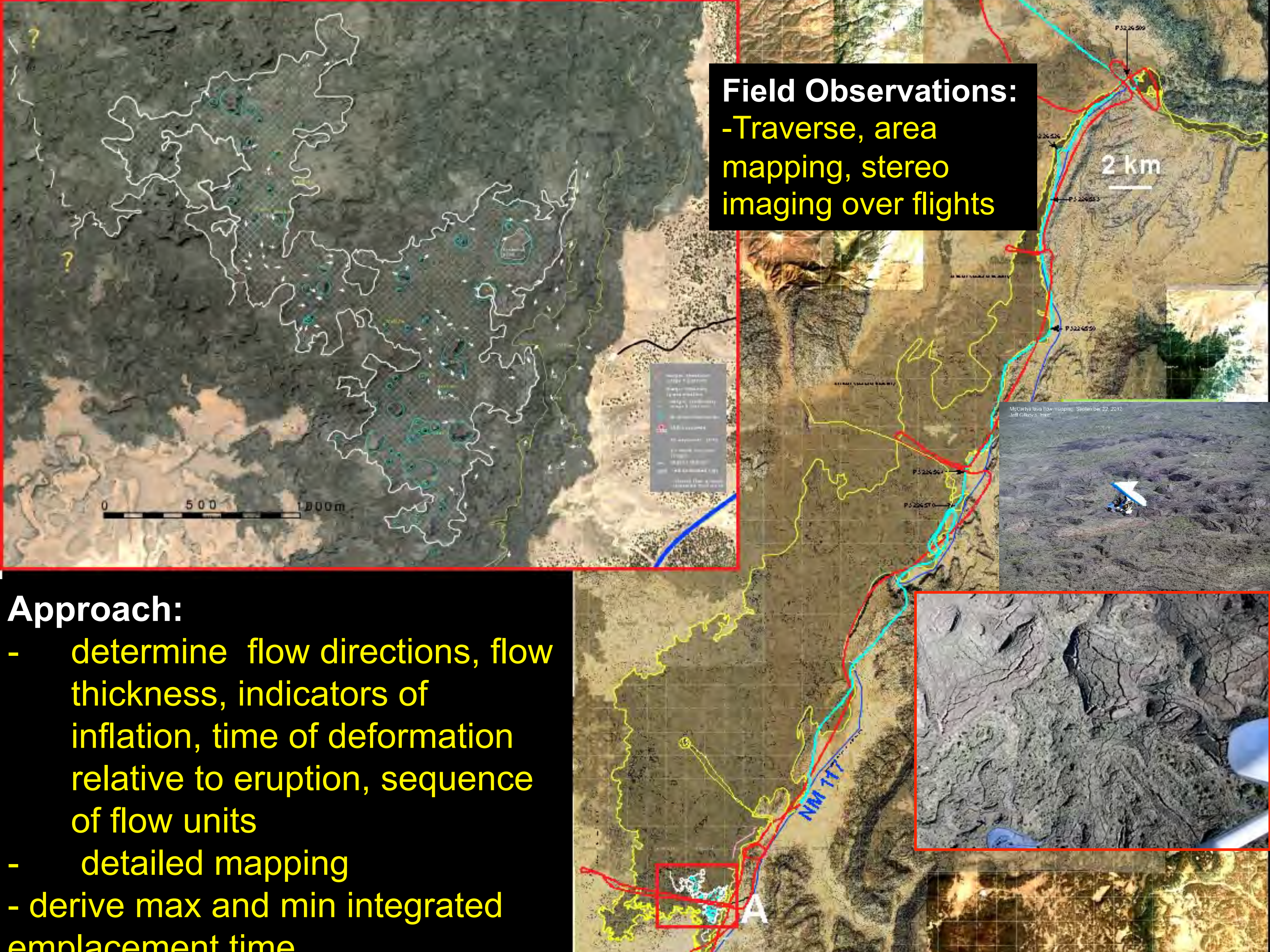
All lava flows are not benign events…



Question:

-Environmental effects?
-Volume?
-Aerosols?
-Emplacement time?





Field Observations:
-Traverse, area mapping, stereo imaging over flights

Approach:
- determine flow directions, flow thickness, indicators of inflation, time of deformation relative to eruption, sequence of flow units
- detailed mapping
- derive max and min integrated emplacement time

ENVIRONMENTAL CONSEQUENCES OF LARGE VOLUME LAVA FLOW FIELDS IN THE SOUTHWEST:
PRELIMINARY INFERENCES FROM MAPPING THE McCARTYS LAVA FLOW FIELD, NEW MEXICO

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Conclusion:

- 2 to 10 years
-10 – 30 Tg sulfur
-≥ 10 - 100 large copper smelters

- Large lava flows can have regional, continental, and global consequences

The New Mexico Volcano Collection and Resource: Volcanoes of New Mexico Website Developed by the New Mexico Museum of Natural History & Science

L.S. Crumpler, J.C. Aubele, R. Elsinger, and M.Celeskey
New Mexico Museum of Natural History and Science

Geoliteracy and the Volcano Connection

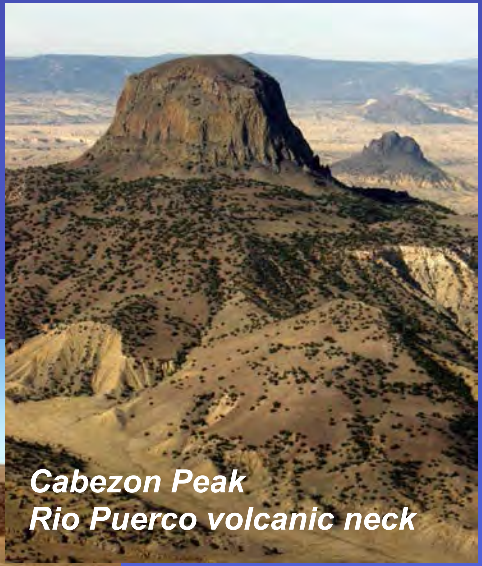
- The science of Geology is frequently perceived as “difficult to understand” by the general public

- BUT - geologic landscapes are popular tourist and recreational attractions

- AND - the general public is fascinated by volcanoes

- However - they frequently have no idea that their local landscape has been produced by volcanism

- Or - they may think that nothing in their own “backyard” can be interesting or significant



Cabezon Peak
Rio Puerco volcanic neck

Albuquerque Volcanoes Fissure eruption
Cinder/spatter cones

Bandera Crater Cinder/spatter cone

The New Mexico Volcano Collection and Resource: Volcanoes of New Mexico Website Developed by the New Mexico Museum of Natural History & Science

L.S. Crumpler, J.C. Aubele, R. Elsinger, and M.Celeskey
New Mexico Museum of Natural History and Science

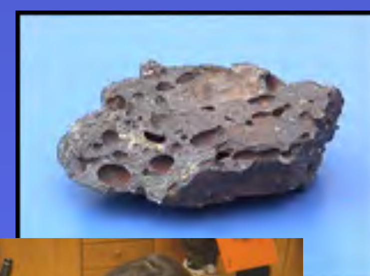
Informal Education -
Learning that takes place outside the formal classroom

Museums, science centers, zoos, aquariums, visitor centers, nature centers, botanical gardens.

Museum Field Trips and classes

- **Accessible and non-threatening**
- **Community resource**
- **Serve a wide and diverse audience**
- **Underrepresented audiences**
- **Self-selected and self-directed**
- **Family/group learning**
- **Object-based learning**
- **Exhibits, Educational Programs, research collections**

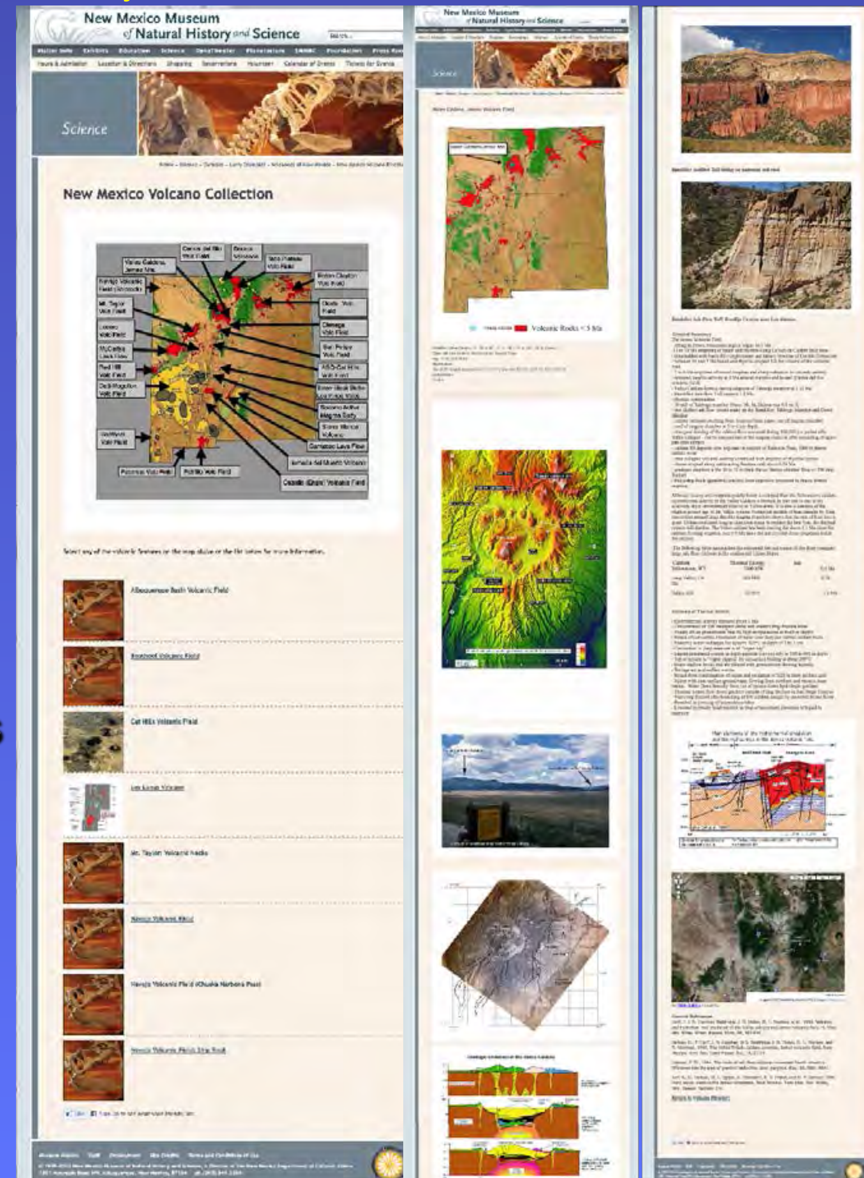
BUT - volcanoes do not fit on shelves!



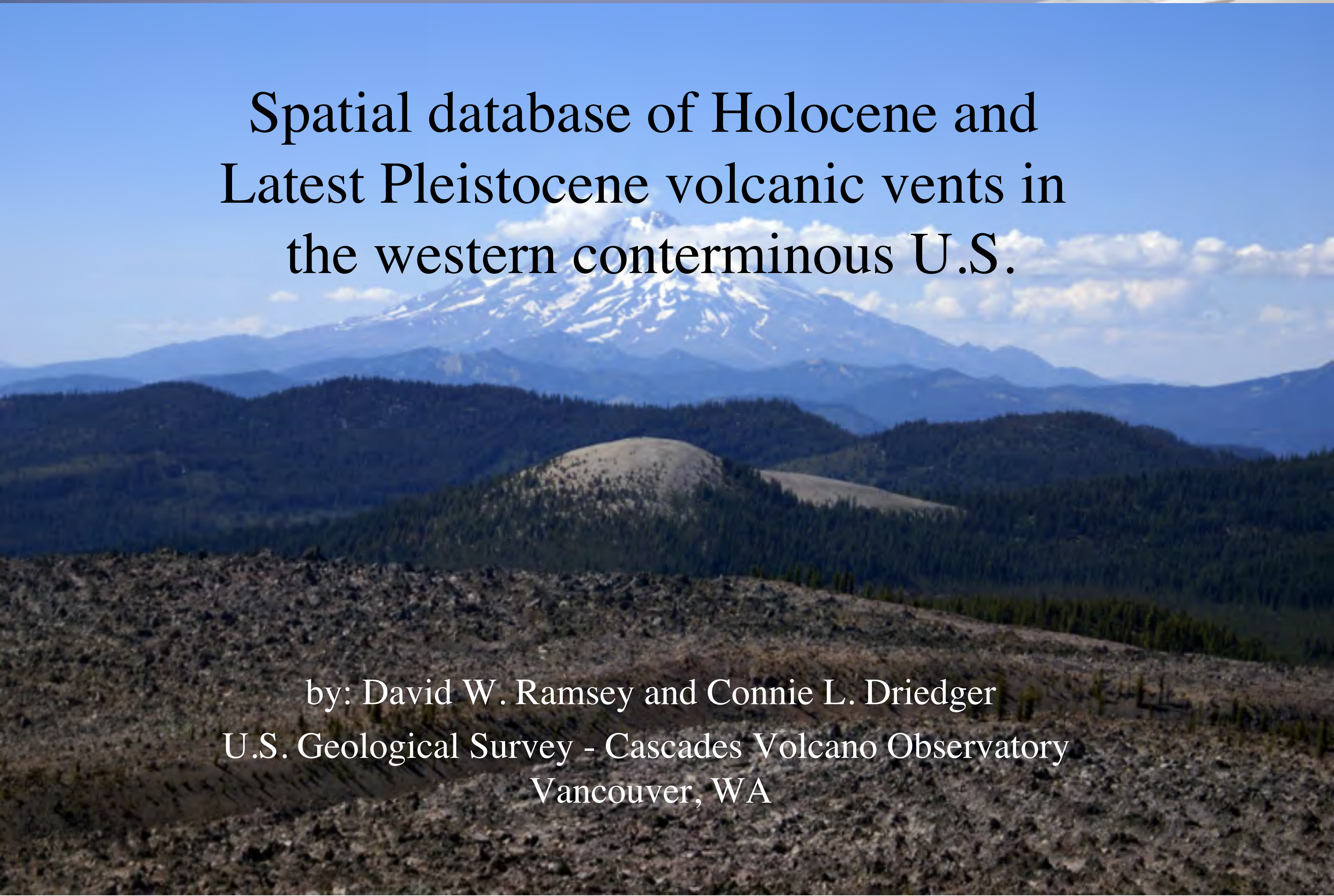
Volcanoes in Your Backyard Museum exhibit

The New Mexico Volcano Collection and Resource: Volcanoes of New Mexico Website Developed by the New Mexico Museum of Natural History & Science

L.S. Crumpler, J.C. Aubele, R. Elsinger, and M.Celeskey
New Mexico Museum of Natural History and Science



- A multi-media approach to public outreach
- Videos and educational posters for local audiences
- An online "collection" of volcanic edifices and eruptive styles
- An updated resource for geoscientists, land-use professionals, and the public
- Images, maps, and detailed information
- Layers of information for multiple use
- Local/regional "personal" connection
- Web-based self-directed learning



Spatial database of Holocene and Latest Pleistocene volcanic vents in the western conterminous U.S.

by: David W. Ramsey and Connie L. Driedger
U.S. Geological Survey - Cascades Volcano Observatory
Vancouver, WA


Baker
Glacier Peak
Rainier
St. Helens
Adams
Indian Heaven
West Crater
Hood
Washington
Jefferson
Blue Lake Crater
Belknap
South Sister
Bachelor
Davis Lake
Cinnamon Butte
Crater Lake
Craters of the Moon
Jordan Craters
Diamond Craters
Hell's Half Acre
Wapi Lava Field
Yellowstone
Medicine Lake
Shasta
Brushy Butte
Twin Buttes
Tumble Buttes
Lassen Volcanic Center
Soda Lakes
Clear Lake
Mono Lake Volcanic Field
Long Valley Caldera
Mono-Inyo Chain
Red Cones (Mammoth Mtn.)
Ubehebe Craters
Black Rock Desert
Markagunt Plateau
Bald Knoll
Santa Clara
Uinkaret Field
Golden Trout Creek
Coso Volcanic Field
Lavic Lake
Amboy
Salton Buttes
Sunset Crater
Zuni-Bandera
Carrizozo
Valles Caldera
Dotsero
UNITED STATES

Vent_type	Label	Description	Age	Feature
vent	awp	Andesite of Wizard Island; Pyroclastic	Holocene	Wizard Island
cinder cone		basaltic	Holocene	Little Black Peak
fissure vent	rgm	Rhyolite of Glass Mountain	Holocene	Glass Mountain
cinder cone	Qb2	Quaternary basaltic and basaltic andesitic rocks; 12 to 25 k.y.	late Pleistocene	Imagination Peak
cinders	bdt	Basalt of Twin Buttes	late Pleistocene	N of Black Butte
vent, concealed	bh	Basaltic andesite of Hillman Peak; Lava (concealed by talus;t)	late Pleistocene	E of Hillman Peak
dome	Qd2	Quaternary dacitic rocks; 12 to 25 ka	late Pleistocene	N of Merrill Lake

Feature	Publication	Database_publication	POINT_X	POINT_Y
Wizard Island	Scientific Investigations Map 2832	Scientific Investigations Map 2832	-122.146146	42.938884
Little Black Peak	Volcanoes of the World - Third Edition	GVP website	-105.937066	33.785306
Glass Mountain	Scientific Investigations Map 2927	Scientific Investigations Map 2927	-121.504699	41.601329
Imagination Peak	Geologic Investigations Series Map I-2569	Data Series 313	-122.200956	42.551056
N of Black Butte	Scientific Investigations Map 2899	Scientific Investigations Map 2899	-121.232202	40.55997
E of Hillman Peak	Scientific Investigations Map 2832	Scientific Investigations Map 2832	-122.16493	42.951693
N of Merrill Lake	Miscellaneous Investigations Series Map I-2005	DS in progress	-122.331539	46.132328

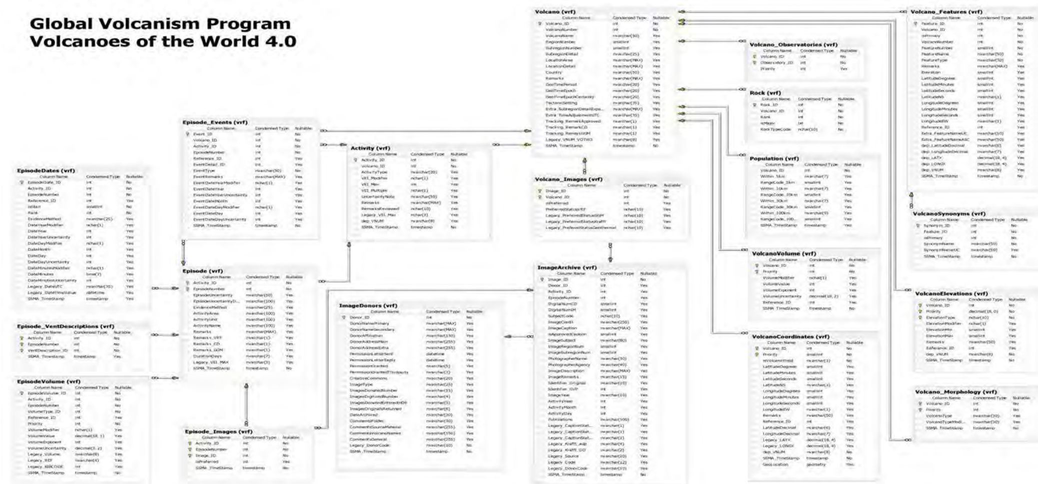
got vents?

Data compiled by the Smithsonian about volcanoes in the southwestern United States

Edward Venzke (Global Volcanism Program, Smithsonian Institution)

A database of volcanoes with Holocene activity, referred to as the Volcanoes of the World (VOTW) database, is maintained by the Smithsonian's Global Volcanism Program (GVP). The role of GVP is to compile data about volcanoes world-wide, providing a standardized and accessible source of information that can be used by a wide range of researchers, officials, and the public. Referenced sources are varied, but material is primarily extracted from published research papers.

The GVP database schema has recently been redesigned in a variety of ways to allow increased flexibility and the ability to compose complex search queries. Submissions of new research findings are always welcome from the volcanological community to improve and expand the database.



Sunset Crater

Zuni-Bandera

Santa Clara

Black Rock Desert

Dotsero

Name	State	Last Known Eruption	Primary Volcano Type	Volcano Number	Legacy VNum
Soda Lakes	Nevada	Unknown	Maars	326010	1206-01-
Santa Clara	Utah	Unknown	Volcanic field	327010	1207-01-
Bald Knoll	Utah	Unknown	Cinder cones	327030	1207-03-
Markagunt Plateau	Utah	<= 1050 CE	Volcanic field	327040	1207-04-
Black Rock Desert	Utah	1290 CE ± 150	Volcanic field	327050	1207-05-
Dotsero	Colorado	2200 BCE ± 300	Maar	328010	1208-01-
Uinkaret Field	Arizona	1100 CE ± 75	Volcanic field	329010	1209-01-
Sunset Crater	Arizona	1075 CE ± 25	Cinder cone	329020	1209-02-
Carrizozo	New Mexico	3250 BCE ± 500	Cinder cones	327110	1210-01-
Zuni-Bandera	New Mexico	1170 BCE ± 300	Volcanic field	327120	1210-02-

List of Holocene volcanoes in Nevada, Utah, Colorado, Arizona, and New Mexico. Last known eruption, primary morphological type, new VOTW 4.0 volcano numbers , and legacy volcano numbers (as previously published) and are shown.

There are 10 volcanoes from the states of Nevada, Utah, Colorado, Arizona, and New Mexico (table 1) thought to have been active in the last 10,000 years. Data collected includes the basics of location, elevation, primary name, synonyms, feature names, morphological type, and captioned photographs. GVP staff also writes a paragraph summarizing the geological and volcanological history of each volcano. All known eruptions are listed, with dates (when available), location and deposits, and types of eruptive events.

Three of the ten volcanoes have no dated eruptions, but are believed by researchers to be Holocene based on other evidence. Another six have only one dated eruption each in the Holocene. Zuni-Bandera has two eruptions known, at 1170 BCE ± 300 years and 8710 BCE ± 300 years. In addition, there are another 28 volcanic areas that were active in the Pleistocene epoch; two of those, Steamboat Springs (Nevada) and Valles Caldera (New Mexico), have exhibited recent fumarolic activity.

Data compiled by the Smithsonian about volcanoes in the southwestern United States

Edward Venzke (Global Volcanism Program, Smithsonian Institution)

Sunset Crater

Zuni-Bandera

Santa Clara

Black Rock Desert

Dotsero

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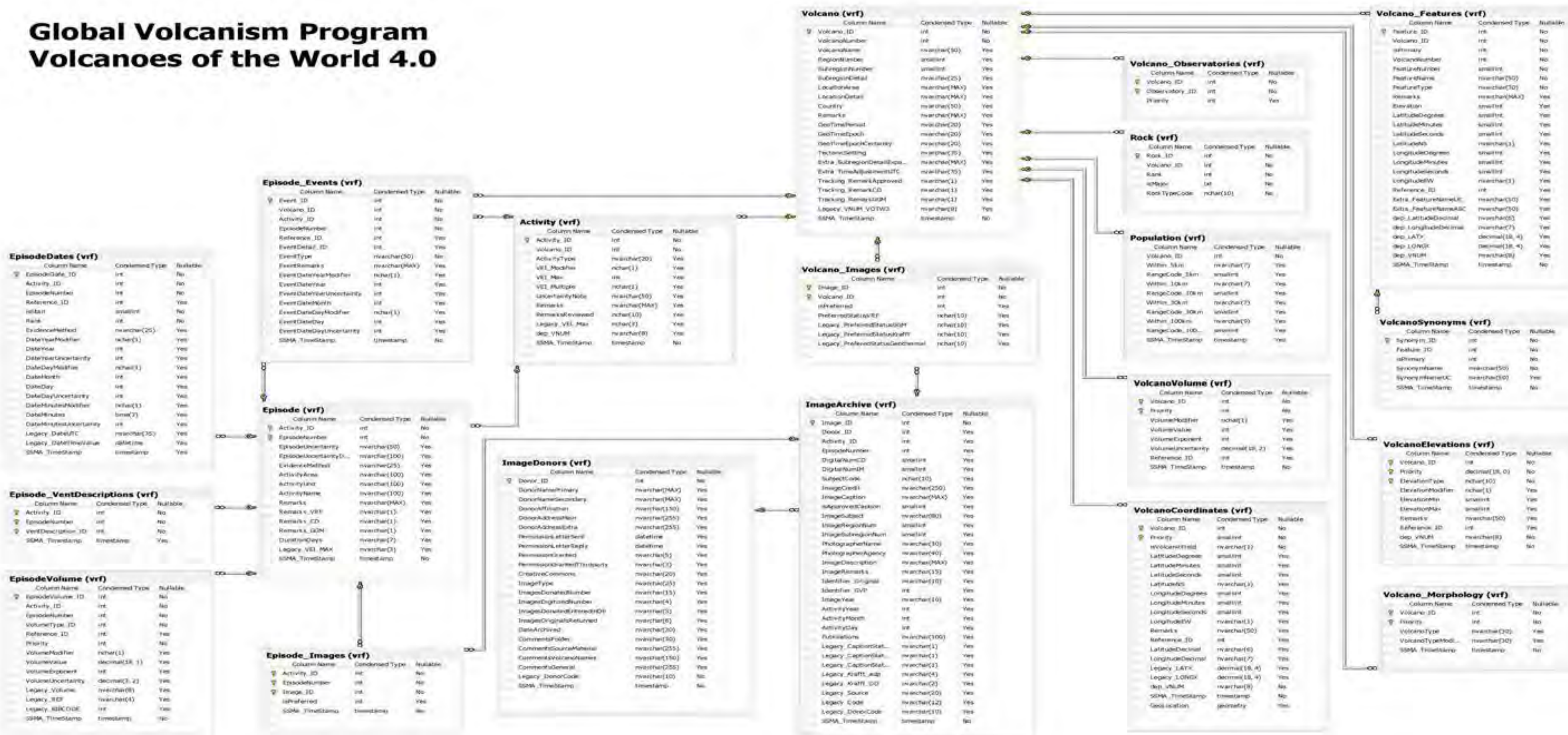

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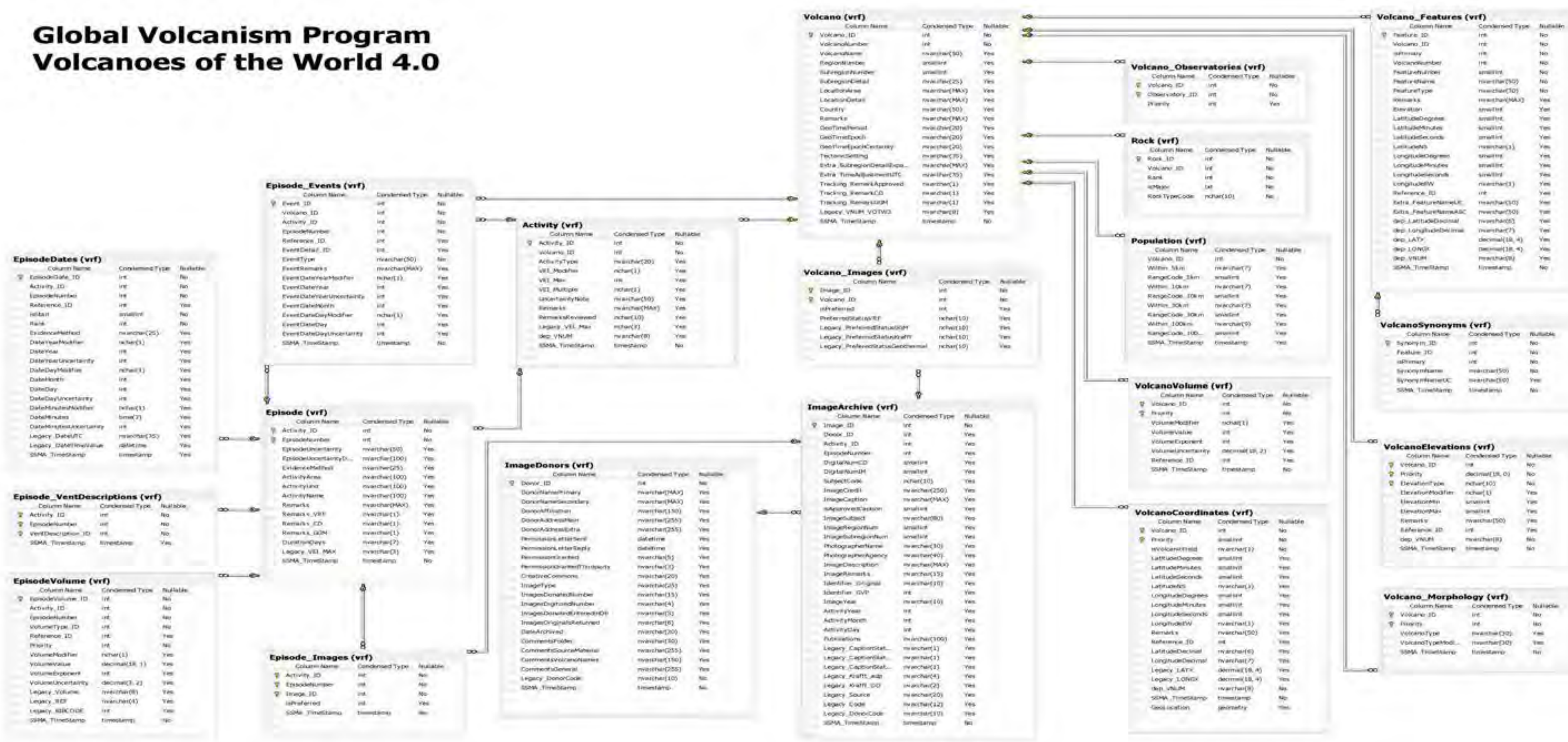


CAROLYN DRIEDGER

Volcano work groups and effective communication partnerships for volcanic hazards education

ADAGE #1
"DISASTER STRIKES WHEN MEMORY OF THE MOST RECENT EVENT HAS BEEN FORGOTTEN."
OLD JAPANESE PROVERB

- Use the memory/knowledge of previous volcanic eruptions to inform your decision making.
- Keep alive the memory of previous events.
- Plan like another event is about to happen.
- Be vigilant.

USGS

ADAGE #2
"A CRISIS IS A POOR TIME TO BE SHAKING HANDS WITH YOUR PARTNERS IN RESPONSE."

EMERGENCY MANAGEMENT SAYING

- Build trust with partners NOW.
- Learn about partners' work cultures, vocabularies, and ways of doing business.
- Make a plan based upon needs, and choose partners comprehensively.
- Exercise your plan—repeatedly.

ADAGE #3
"GETTING A 'YES' OR 'NO' ANSWER FROM A SCIENTIST IS LIKE CHASING A RAT IN A ROUNDHOUSE."

COWLITZ COUNTY SHERIFF LES NELSON DURING 1980 ERUPTION OF MOUNT ST. HELENS

- Get to know your partners' information needs and what each offers.
- Become familiar with mechanisms for information transfer.
- Make a plan and communicate it in the languages of those who will use it.
- Exercise all facets of your plan, including communication.

USGS

ADAGE #4
"COMMUNITY MEMBERS PREFER COMMUNITY-BASED HAZARDS PLANNING USING COMPETENT AND CREDIBLE INDIVIDUALS…"

LASKER, 2004

- Work with competent local partners.
- Reconcile protective actions with local needs.
- Encourage grass-roots outreach by community members.
- "Institutionalize" knowledge of hazards and preparedness using multiple institutions within your community.

USGS

Z. Lu, C.Y. Zhao, W.J. Lee, L.Y. Ji, M. McLay, D. Dzurisin
presented by John Ewert

InSAR mapping of Holocene volcanoes in the western conterminous U.S. – preliminary results

Eruption Potential & Hazard, Valles Caldera, New Mexico

Fraser Goff, Univ. New Mexico
(Los Alamos Nat'l Lab, retired)

WHY VALLES IS "FAMOUS" (Valles Caldera Nat'l Preserve, 2000)

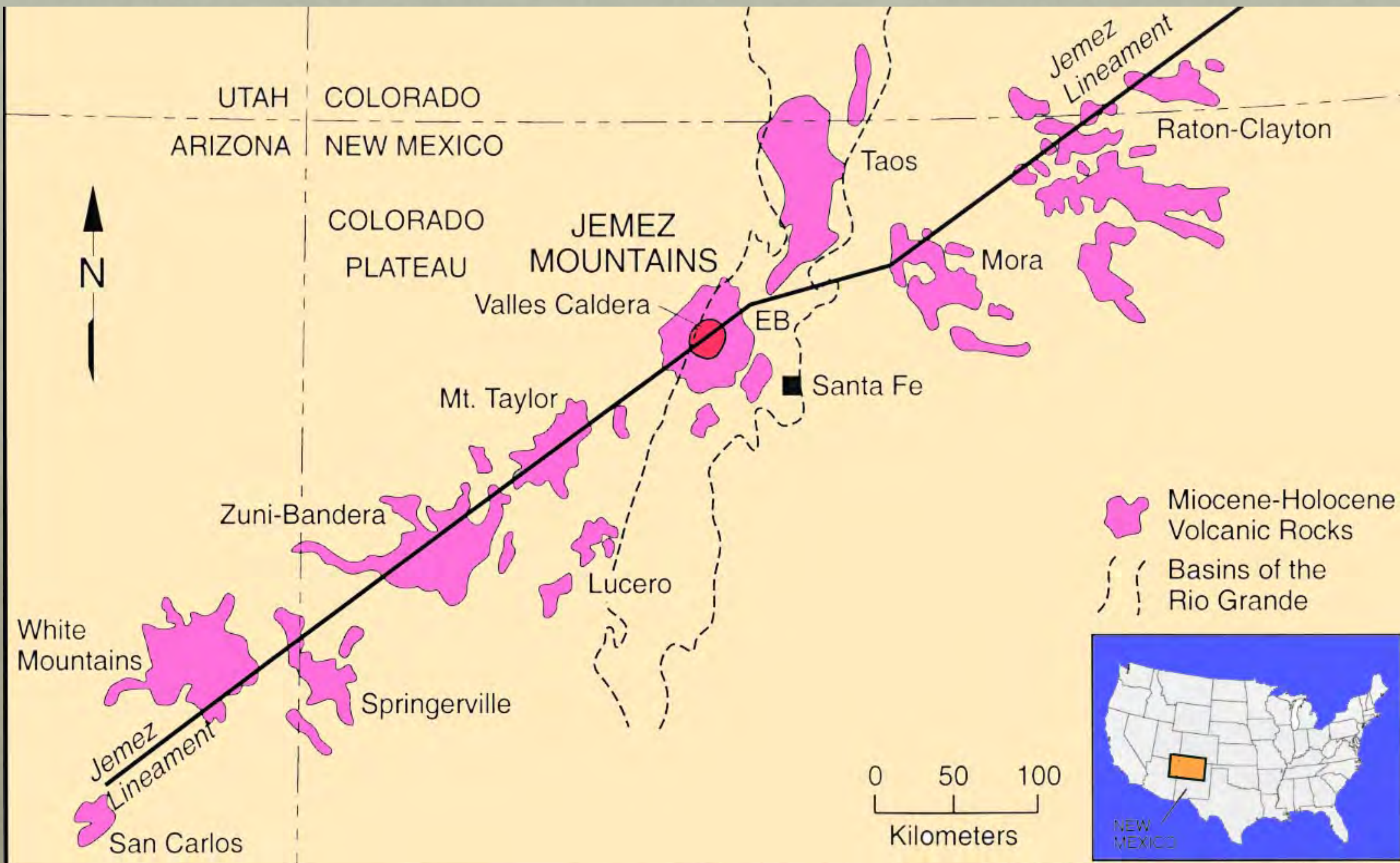
Elk, Skiing, Tours, etc.

Movies & Advertising

WHY VALLES IS GEOLOGICALLY "FAMOUS"

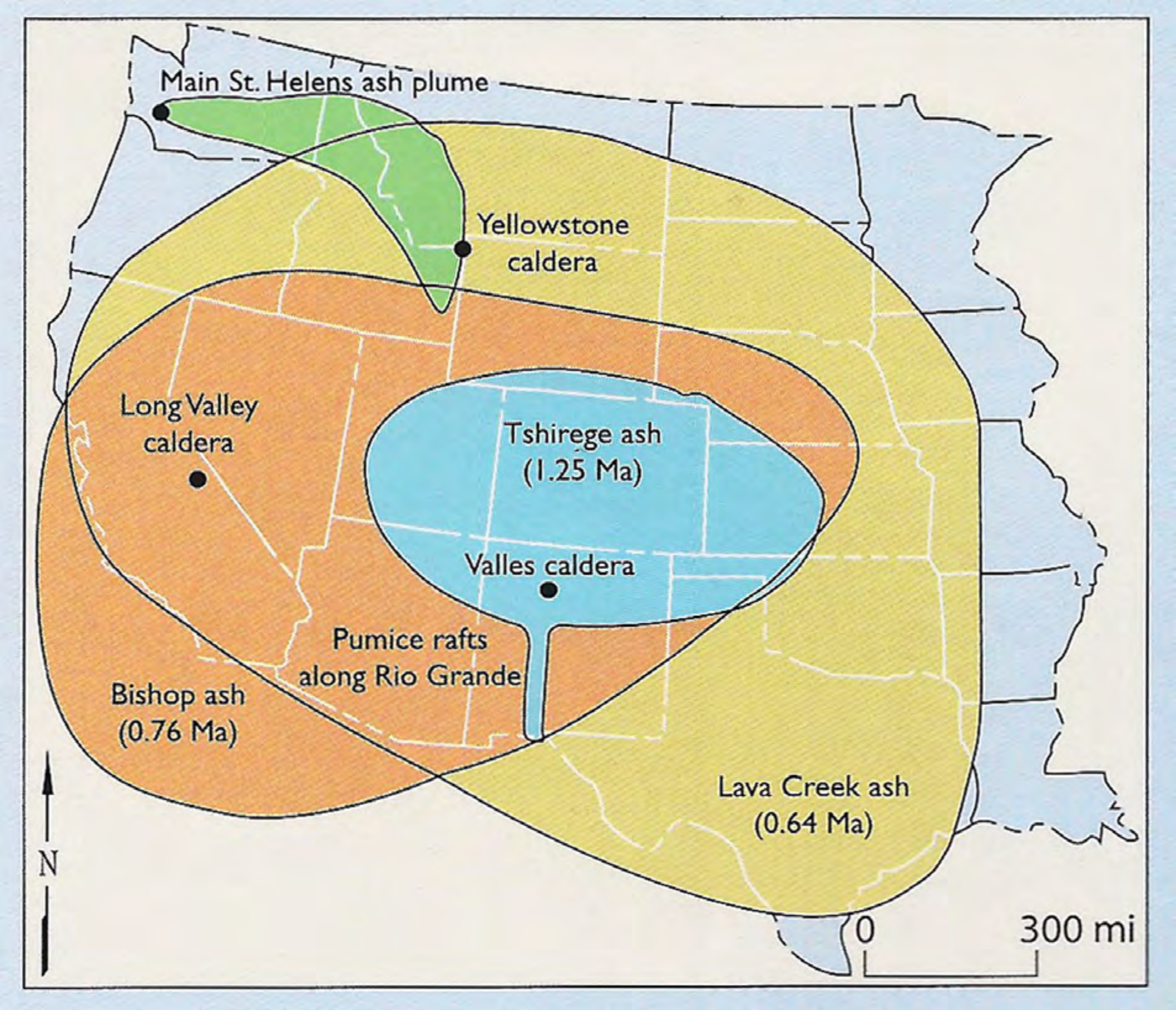
- Type example of resurgent caldera (source of Bandelier Tuff, chemically zoned ash-flows); many post-caldera eruptions; 1.25 Ma – 40 ka
- Early plate tectonic concepts tested at Cerro Santa Rosa and Jaramillo Creek
- Contains classic liquid-dominated geothermal reservoir (260 to 300 °C); site of first Hot Dry Rock geothermal experiment
- Two glacial-interglacial climate cycles recorded in intracaldera lake beds

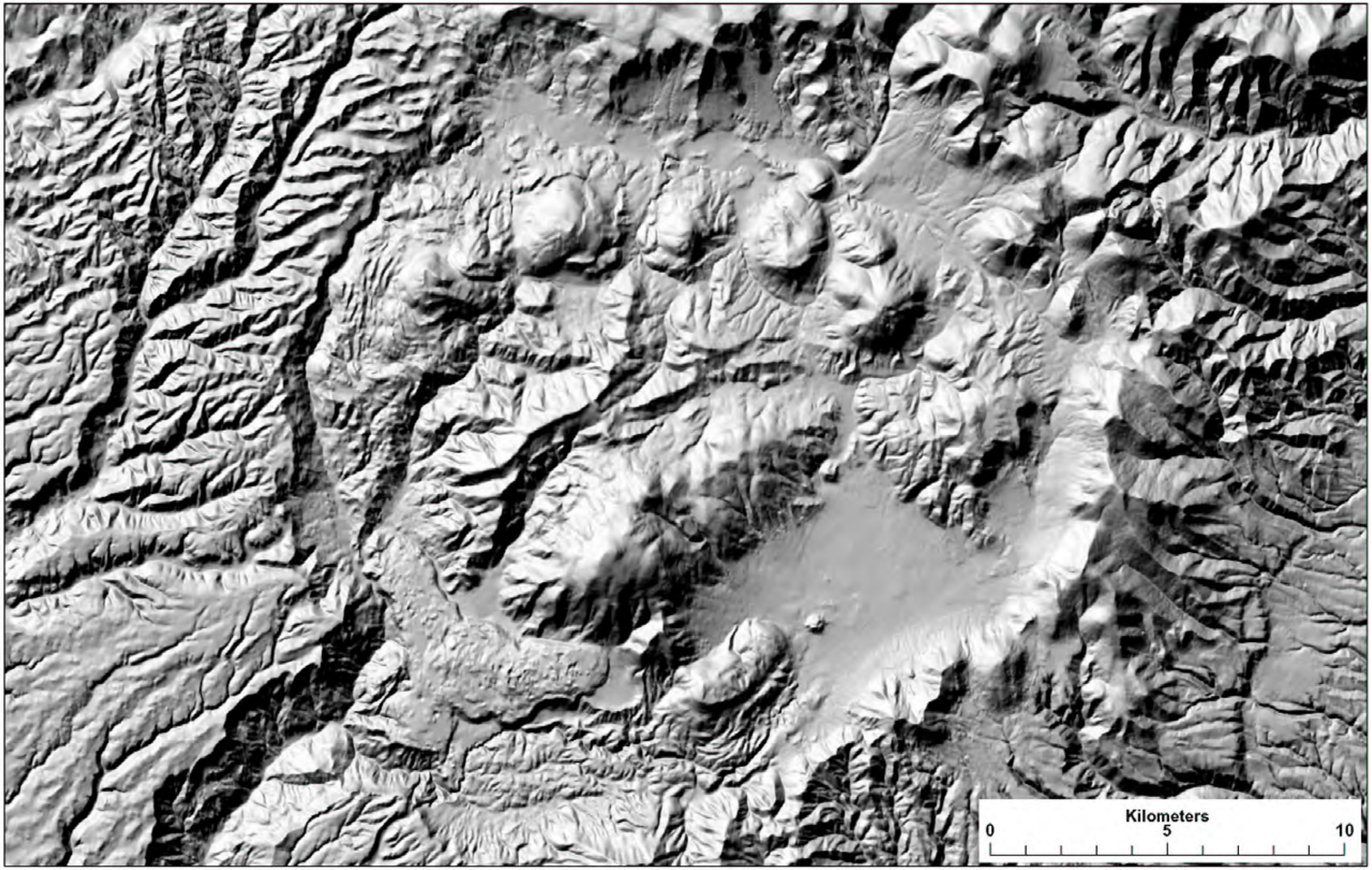
REGIONAL AND TECTONIC SETTING



Bandelier Tuff, 1.25 Ma (400 km^3)

Comparative Ash Distributions, Quaternary USA Calderas




Kilometers
0
5
10

Valles Post-caldera Eruptions

- **25 lava dome, lava flow and pyroclastic eruptions**
- **Typical erupted volumes: ≤10 km^3 (≤2.5 mi^3)**
- **Age span: 1.23 Ma to 40 ka**
- **Average eruption frequency: 1 eruption per 50 kyr**
- **But dates show highly erratic repose times between eruptions**
- **Consequently, predicting the date of next eruption is impossible**

Valles Contains Active Magma Chamber

- Potent shallow geothermal system; maximum drilled temperature = 650 °F @ 10,600 ft (342 °C @ 3200 m)
- Location coincident with youngest post-caldera eruptions
- Large primordial ^3He anomaly ($^3He/^4He$ $R/R_A \leq 6$); indicates current mantle-magmatic source (values of 6 to 9 common at active volcanoes with magma chambers)
- Well-defined cylindrical seismic anomaly at 5-15 km depth

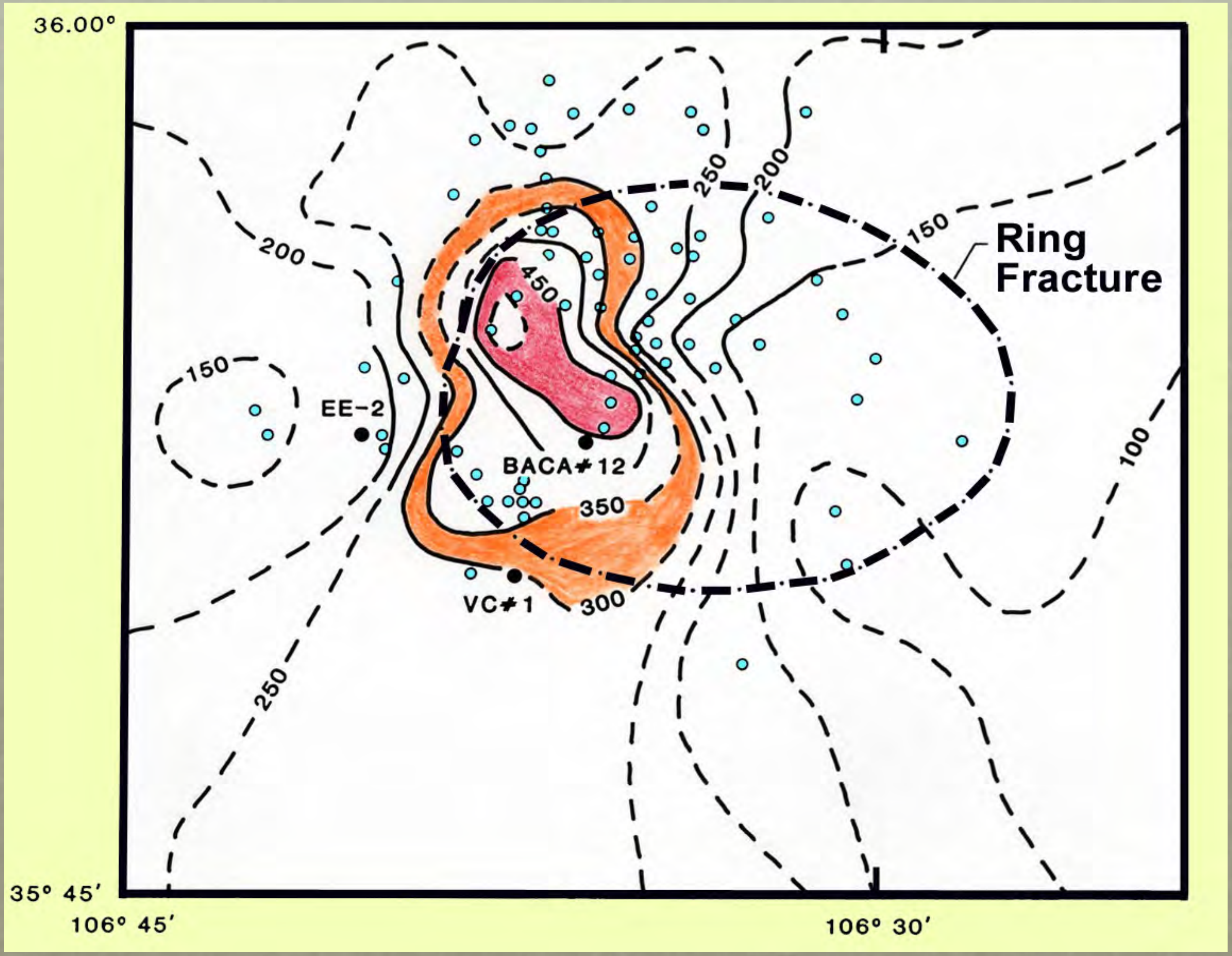
Thermal Features, Valles Caldera

- **Acid-SO_4 springs and fumaroles inside caldera, pH ≤ 2, T ≤ 94°C, gases rich in H_2S**
- ***High primordial He ($^3He/^4He \leq 6\ R/R_A$)***

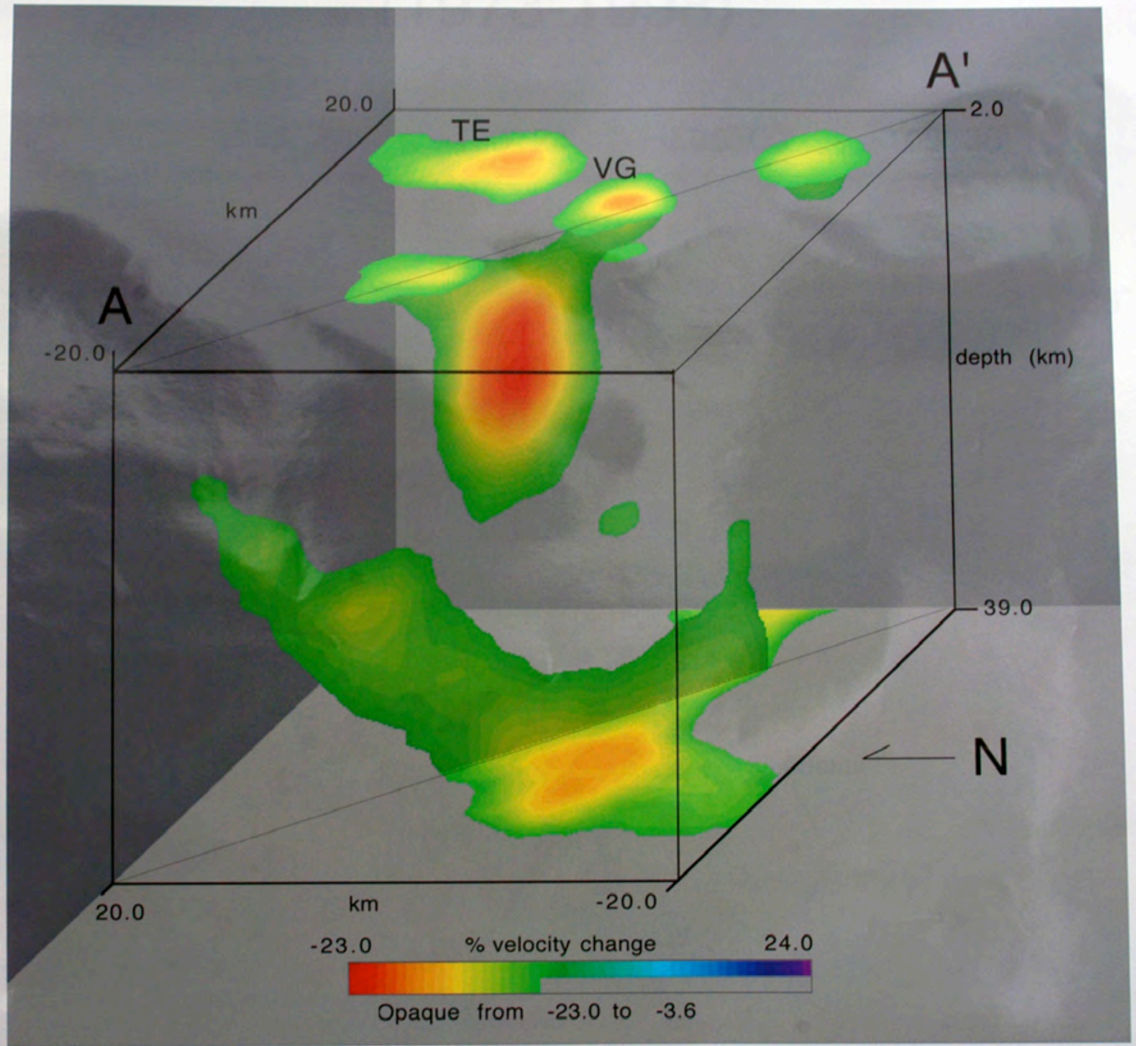
Valles Geothermal Reservoir

- Reservoir temp about 220 to 300 °C (maximum drilled temp is 342 °C at 3260 m)
- Only 20 MWe proven (1 MWe enough power for 1000 people)
- Development ceases in 1984

Shallow Temperature Gradients



Valles Caldera 3-D Low Velocity Anomalies

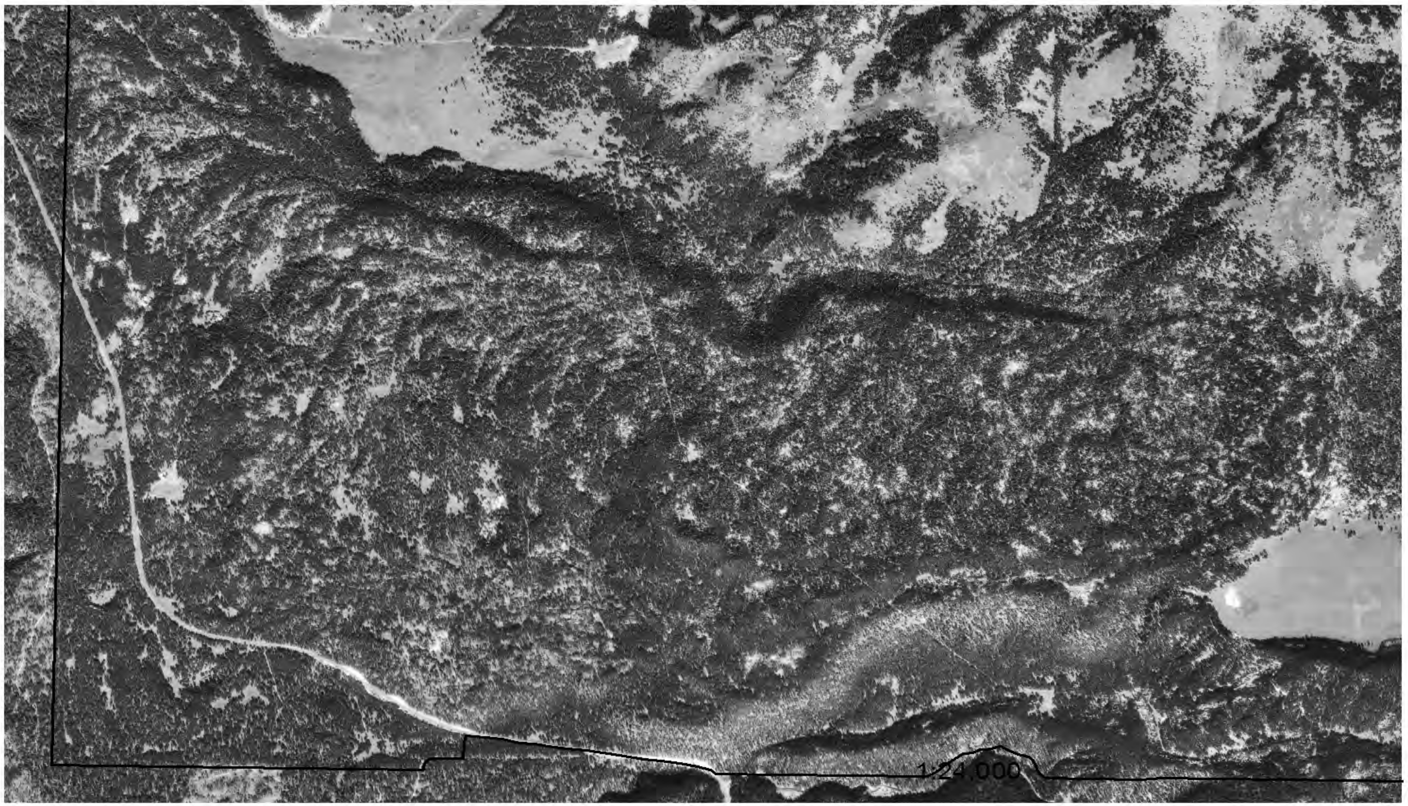


TE = Toledo Embayment, VG = Valle Grande

Valles Will Probably Erupt Again

- The BIG QUESTIONS:
- Where? (from southern caldera)
- Eruption style? (tuffs and lava)
- Volumes? (≤10 km^3)
- Warning? (possibly ±3 months)
- WHEN?

East Fork Member, Banco Bonito Flow
(unique magma batch, ≈40 ka, ≤4 km^3)

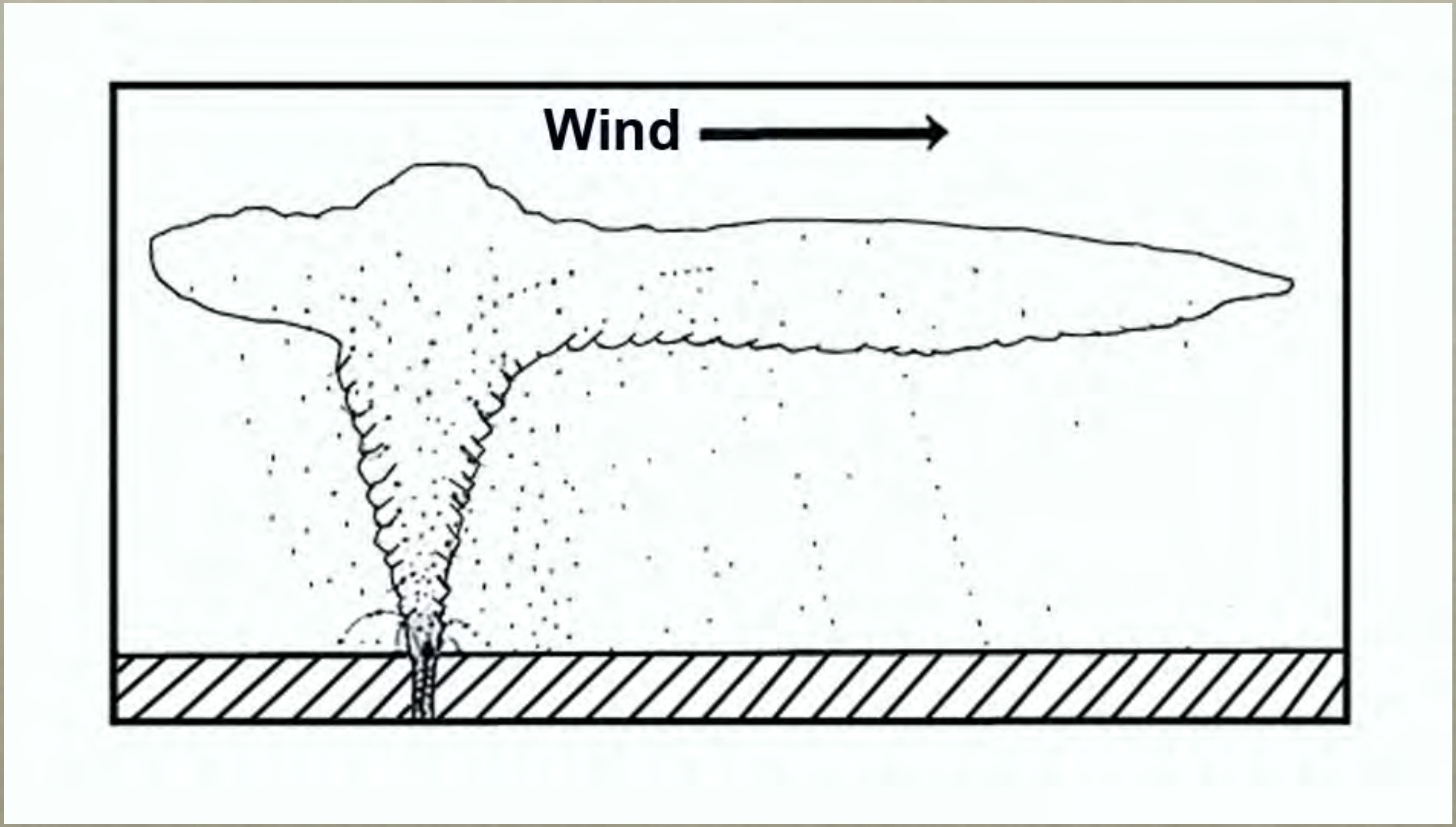


East Fork Member, Pyroclastic Deposits
(unique magma batch; 55 ± 6 ka; ≥10 km^3)

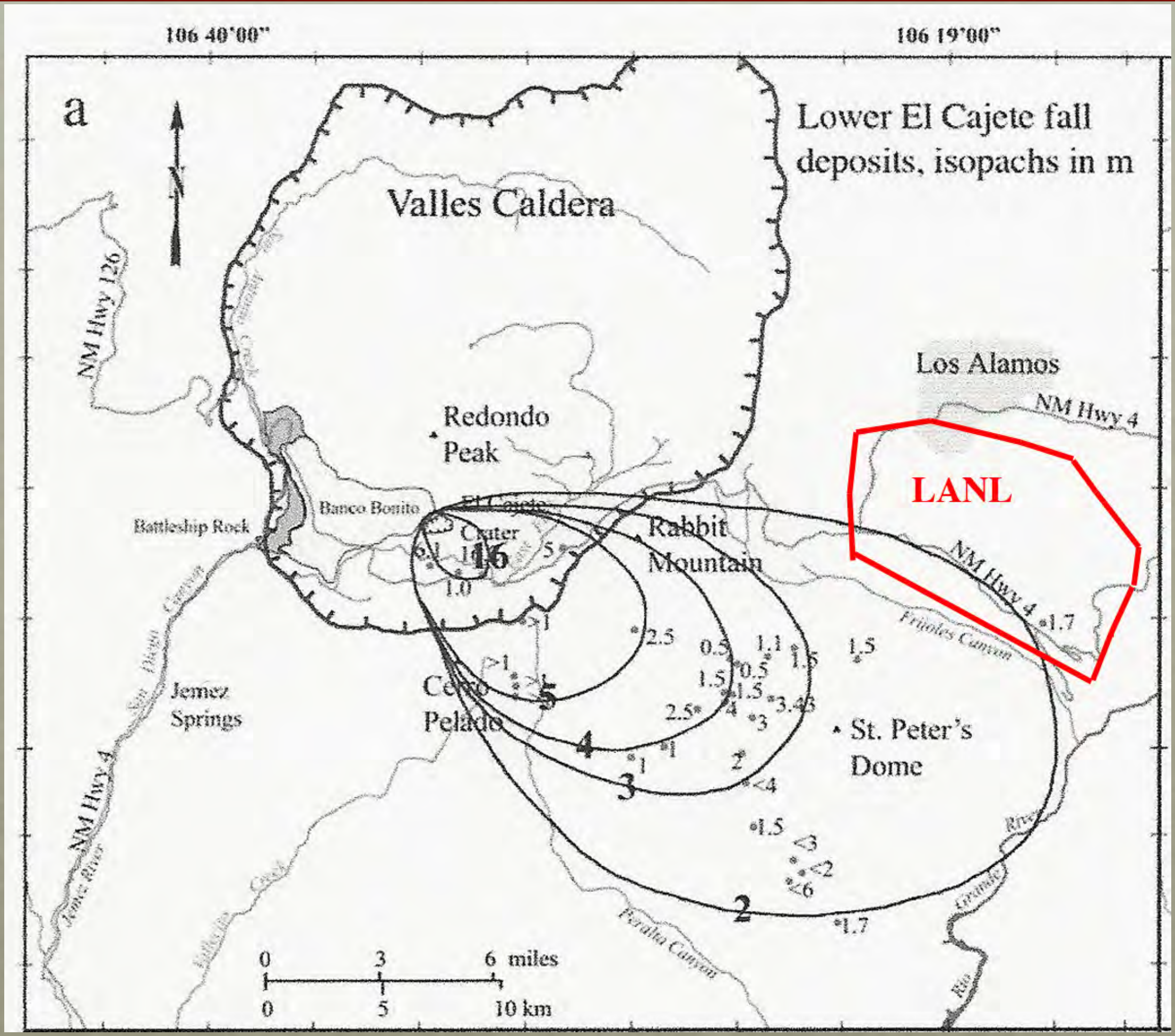
Battleship Rock Ignimbrite

El Cajete Pyroclastic Beds

Pyroclastic Fall Deposits (start with water-rich magma)



Lower El Cajete Pumice
(isopachs in meters)



Pinatubo, 1991
Example of 8-10 km^3 Pyroclastic Eruption

- Earthquakes begin mid-March
- First steam explosion, April 2
- Eruption forecast successful
- Massive evacuations include Clark Air Base
- Lava dome, June 7 to 12
- Climactic eruption, June 15; lasts 9 hours
- Coincides with a typhoon
- 200 to 300 deaths; impacts on property

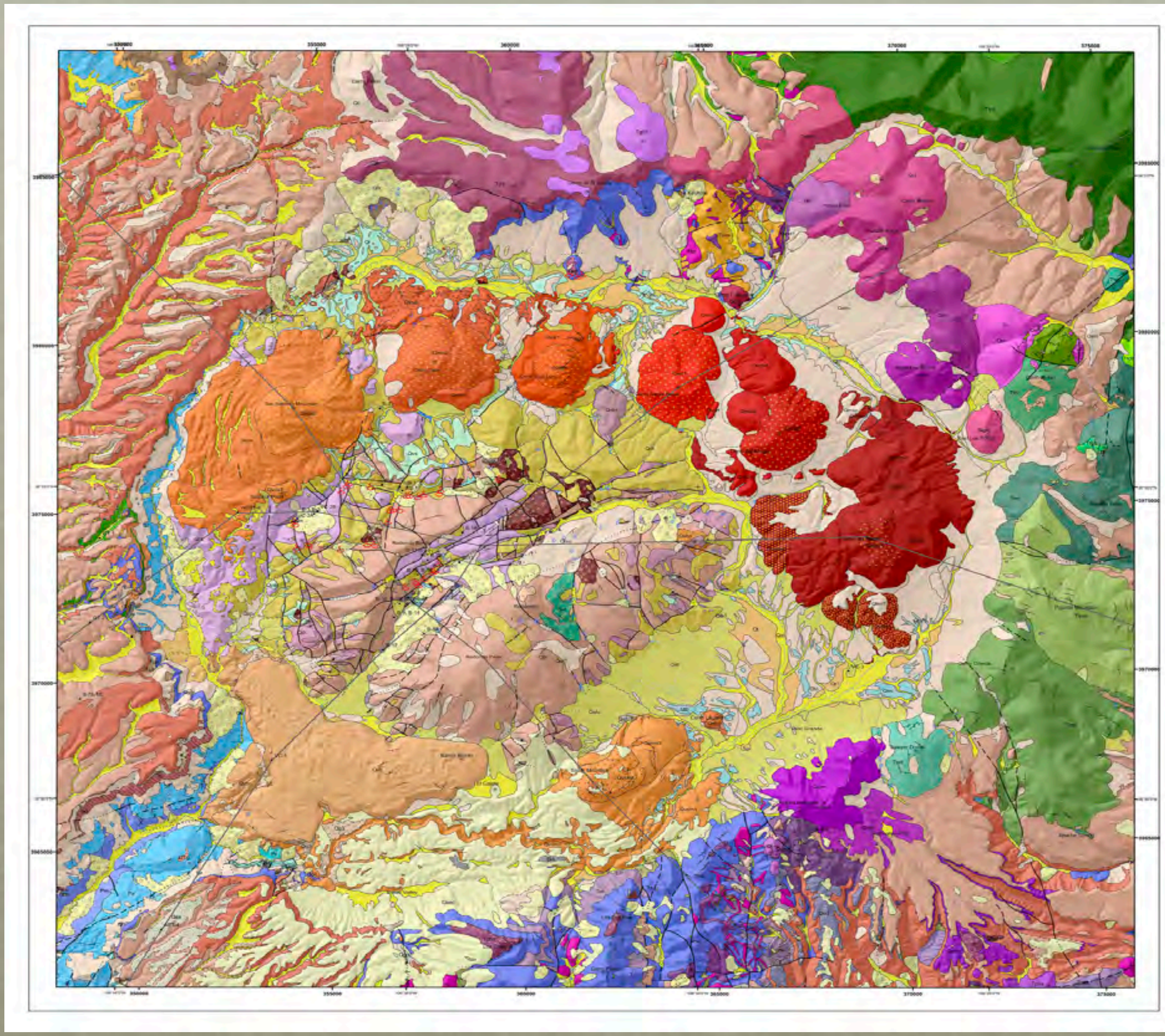
Valles Eruption Hazard

- Bandelier Tuff scale ignimbrite eruption unlikely
- El Cajete type pyroclastic fall eruption more likely
- Source: southern caldera
- Warning: ±3 months
- Volume: ≤10 km^3
- Distribution: partially dependent on prevailing winds and topography; could drastically affect >250 km^2 (>100 mi^2)
- When?

Valles Eruption Monitoring

- Presently NO coordinated plan
- Seismic
- GPS and leveling
- Periodic He and/or other gas sampling of fumaroles
- Periodic temperature surveys of springs and fumaroles
- Other?

2011 Valles Geologic Map
(1:50,000 scale; covers 1050 km^2)



Human Adaptation to Catastrophic Events: Lessons from the 11th Century CE Eruption of Sunset Crater Volcano

Mark D. Elson, Desert Archaeology, Inc.
Michael H. Ort, Northern Arizona University

Disaster

- Damaging or destructive event: an event that causes serious loss, destruction, hardship, unhappiness, or death. (http://encarta.msn.com/)

- An unexpected natural or man-made catastrophe of substantial extent causing significant physical damage or destruction, loss of life or sometimes permanent change to the natural environment. (http://en.wiktionary.org/)

Disaster

- Disasters change *both* the physical and cultural environment – world view and ideology affected.
- Disasters increase vulnerability and decrease safety – the world is no longer predictable.
- Stress resulting from disasters brings out core values of a culture, making them ideal for anthropological study.

Chaitén Volcano, Chile

Galeras Volcano, Colombia

Santiaguito Volcano, Guatemala

Soufrière (Sulphur) Hills Volcano, Montserrat, Caribbean

Parícutin Volcano, Michoacán, Mexico, 1943-1952. Parícutin very similar to Sunset Crater in eruption style and size.

Disaster Research

- Disasters originally viewed as deviation from normal ecosystem and social function. Now viewed as basic and often chronic element of environments

Parícutin Volcano, 1943-1952, with a'a lava crossing recently harvested cornfield

Disaster Research

- Social Vulnerability is a core element in disaster impact and Community Resilience is a core element in disaster recovery

Parícutin Volcano, 1943-1952

The Questions

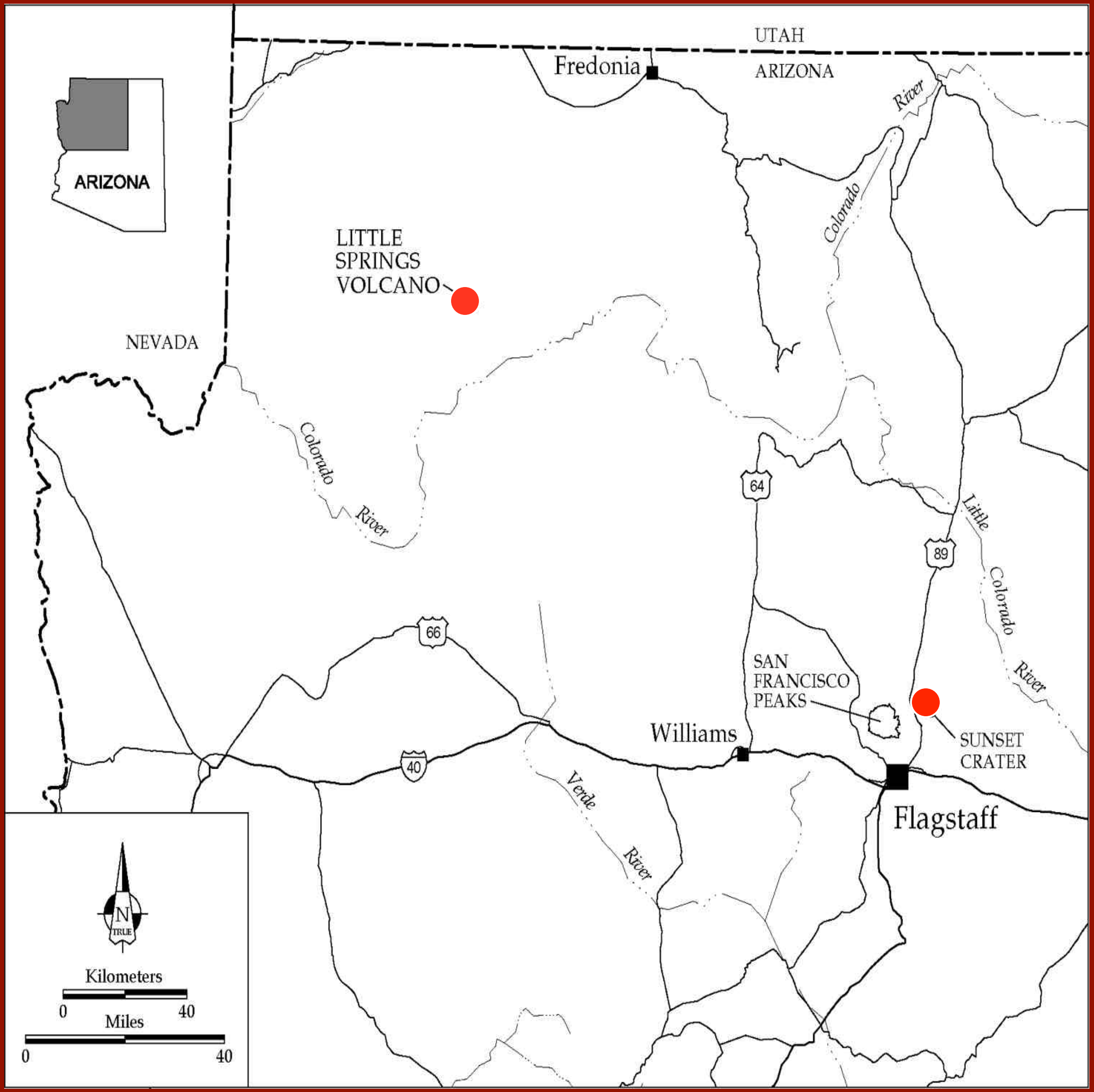
1. Are there patterns in human behavior that allow us to model how groups react and adapt to disasters?

2. Can these patterns help us in dealing with modern disasters?

***Sunset Crater* and *Little Springs* volcanoes are ~200 km apart.**

Both erupted in late 11th century A.D., within 1 or 2 generations or < 100 years.

At time of eruptions, areas occupied by small groups with similar social system and level of complexity – dry-land subsistence farmers living in the ponderosa--piñon-juniper transition zone.



Sunset Crater Volcano

Sunset Crater cinder cone is 300 m high with a 2.5 km^2 base. Scoria cone and lava flows cover 8.0 km^2. New data suggest eruption occurred ca. 1085 CE.

Distribution of Sunset Crater cinders = 2,300 km^2 (900 mi^2)

Sunset Crater tephra deposits 40-50 cm thick found in a pithouse 5.5 km west of volcano.

Little Springs Volcano

Little Springs eruption had little or no cinder and ash fall. Flowing lava formed 120-m-tall spatter rampart.

Only 6 km^2 beneath lava flows and lava bomb field heavily impacted.

Prehistoric settlement occurred up to edge of lava and on flow top itself.

Human Fascination?

Volcanoes are highly symbolic features: they ooze from the bowels of the earth and have the power to turn the day into night (ash fall) and the night into day (glowing fire fountain).

Human Fascination?

An eruption is a *full sensory assault* – seen, smelled, felt, and heard – *the past was a very quiet place* with thunder loudest sound regularly experienced.

Volcanoes and humans have a long history – our reaction to volcanoes is a deeply buried, primordial emotion, shared with our ancestors for hundreds of thousands, if not millions, of years.

Chaitén Volcano, Chile 2008

Kilauea Volcano, Hawai'i, 2005

Volcanoes are awe-inspiring events – it is easy to connect them to the deities

Volcanism, human ritual, and mythology (now called “traditional history”) go hand in hand:

Most groups living near active (and often inactive) volcanoes have volcano rituals and accounts of eruptions in their traditional histories.

Hopi, Zuni, Acoma, Laguna, and Navajo have likely volcano eruption accounts.

Volcanoes are never considered to be benevolent -- they are almost always malevolent, often quite evil, and usually *occur because some one or some group has screwed up very big time.*

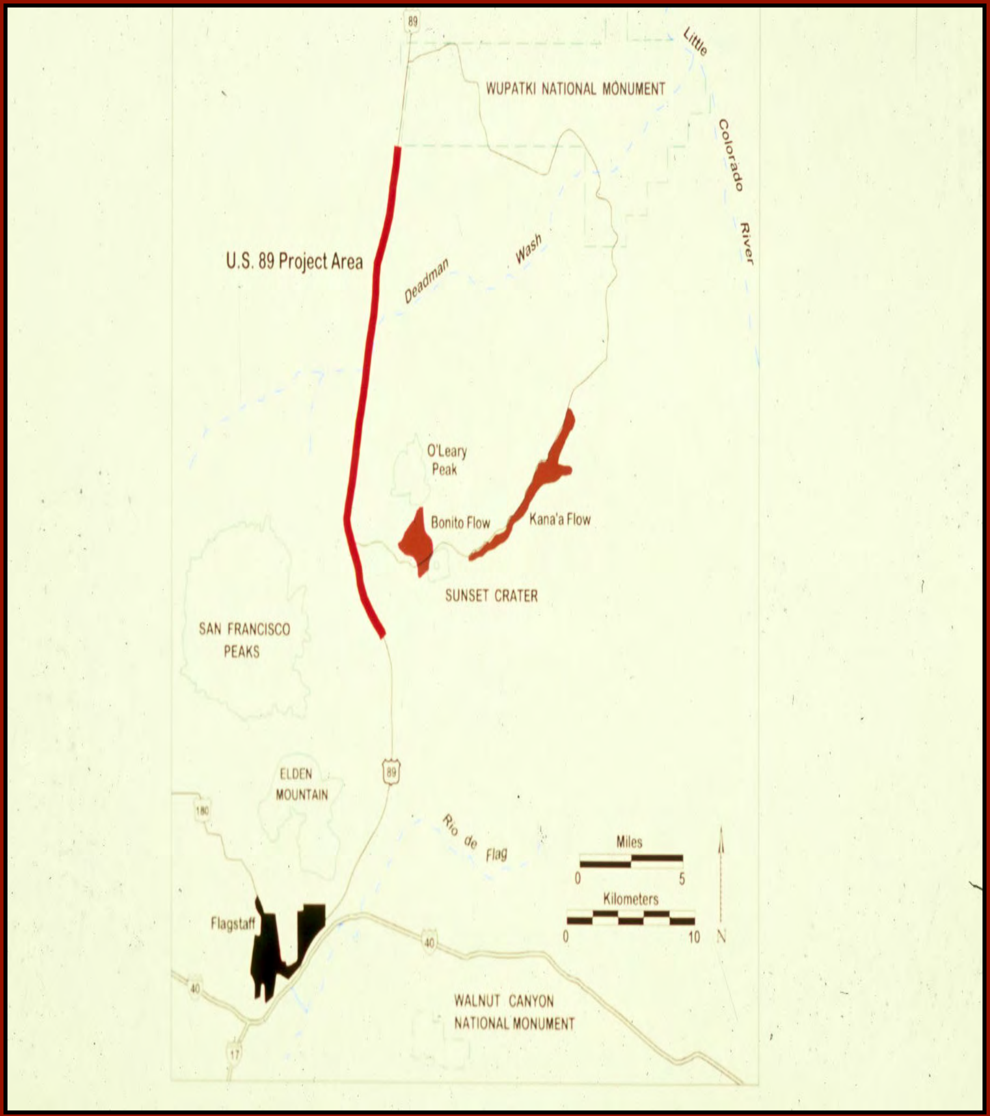
Palatsmo (Sunset Crater)

Kana’a Katsina

“Hisat yaw tutskwa poniniyku, qömavkwitsing”

Long time ago the ground trembled, a big black smoke came

The U.S. 89 Archaeological Project



41 prehistoric sites investigated in 26.7 km right-of-way prior to ADOT road widening

Sunset Crater and associated lava flows within 5 km of U.S. 89 project area

Elevation gradient from 5,700-7,300 ft

Roomblock and plaza

Large habitation site

NA 181, Homestead Site
(A.D. 1050 – 1150)

Farmstead

Small habitation site

NA 25,766,
Plainview Site
(A.D. 1075 -1125)

Pithouse

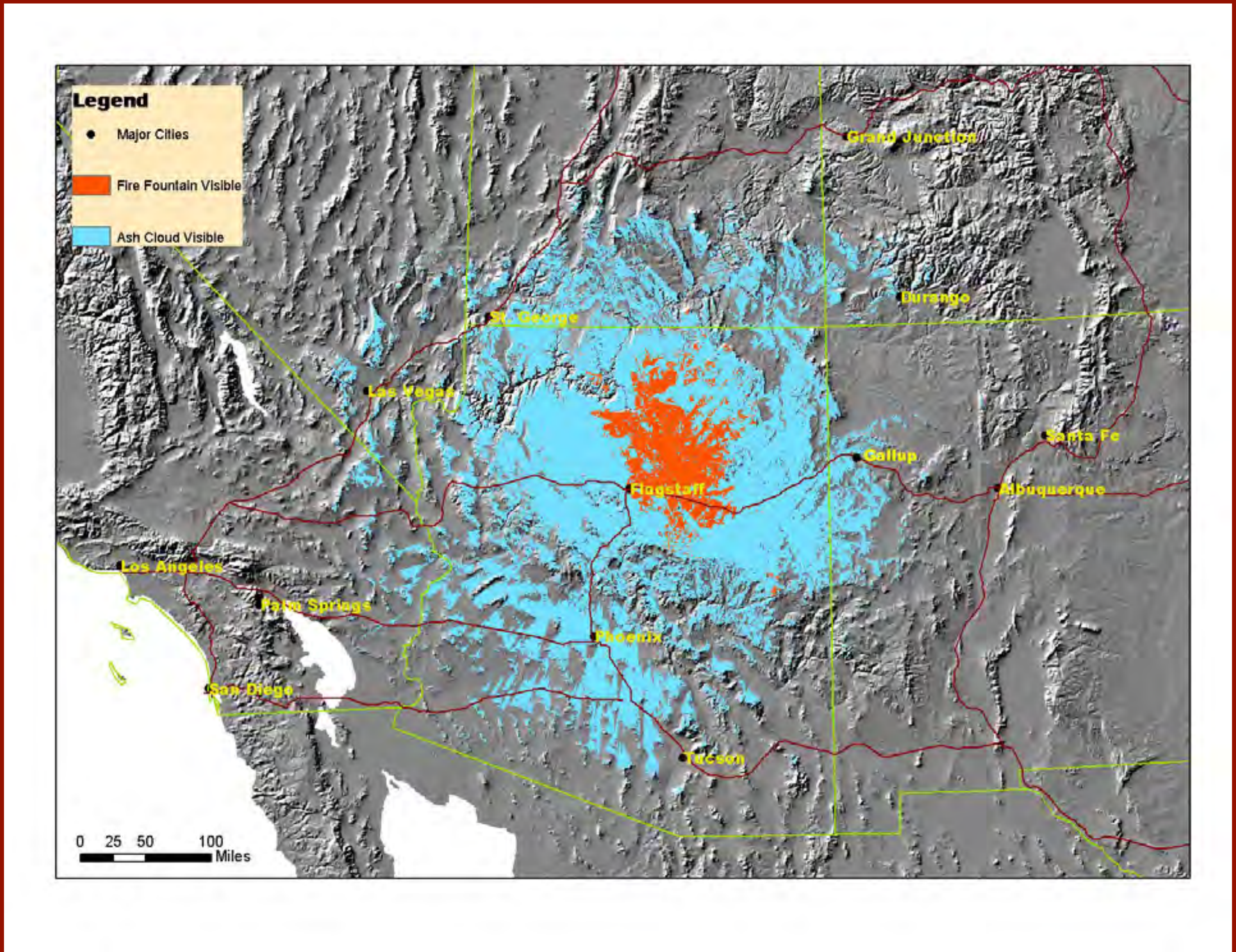
Large habitation site

NA 20,700,
Lenox Park Site
(A.D. 850 – 950)

Pithouse reconstruction, ca. A.D. 1050-1125, Flagstaff area, northern Arizona (reconstruction by Robert Ciaccio)

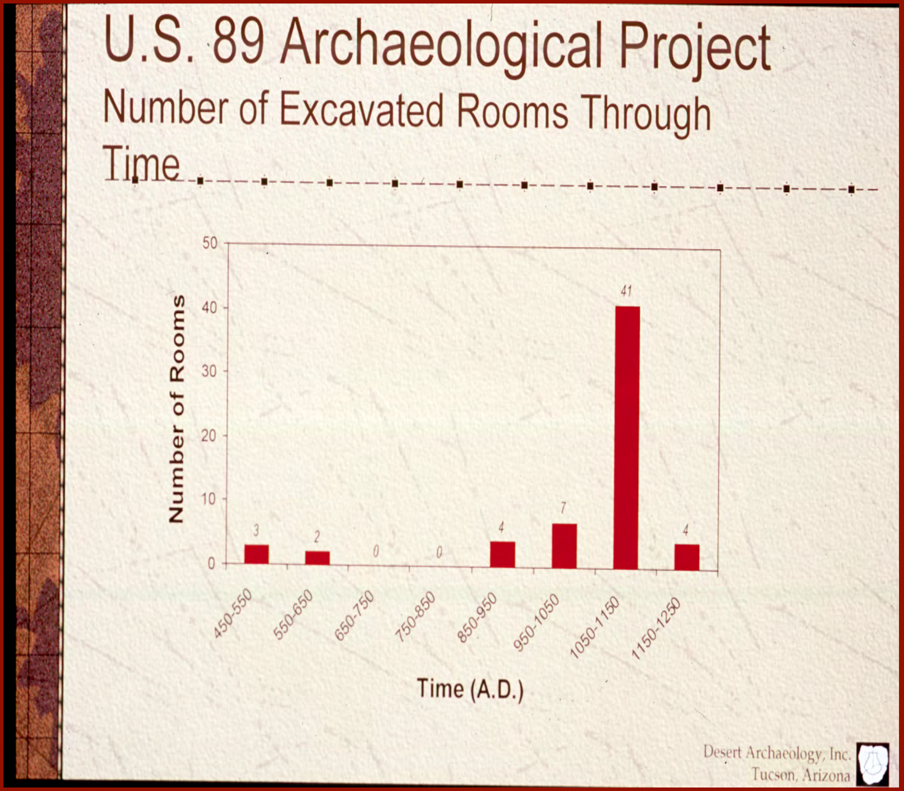
Agricultural field areas and water control features in volcanic tephra, Strawberry Crater area

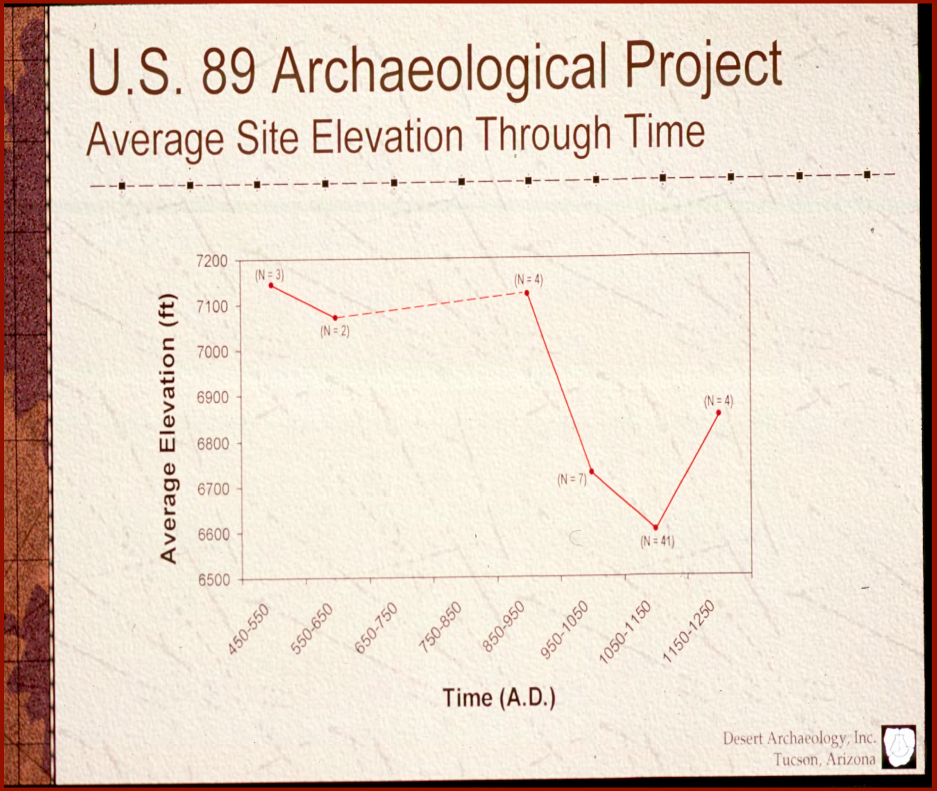
Sunset Crater Viewshed
Digital Elevational Modeling



Viewshed based on a 4-6 km high ash plume and a 260-660 m high fire fountain.

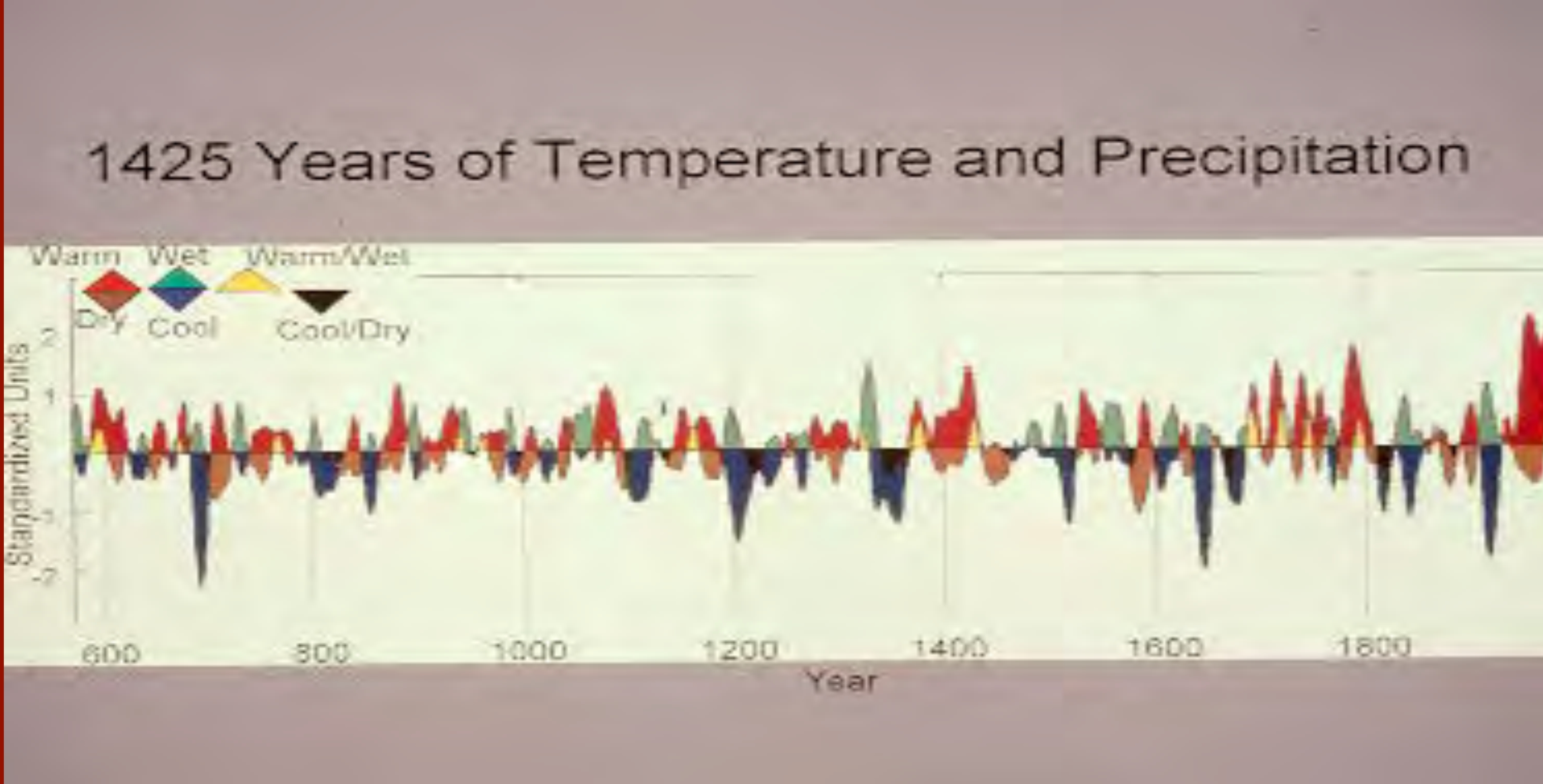
Plume visible from distances as great as 400 km: from Palm Springs, CA, Las Vegas, NV, Durango, CO, and Arizona-Mexico border.





Two clear trends following Sunset eruption (ca. A.D. 1075-1100):

1) Increase in numbers of rooms
2) Decrease in site elevation

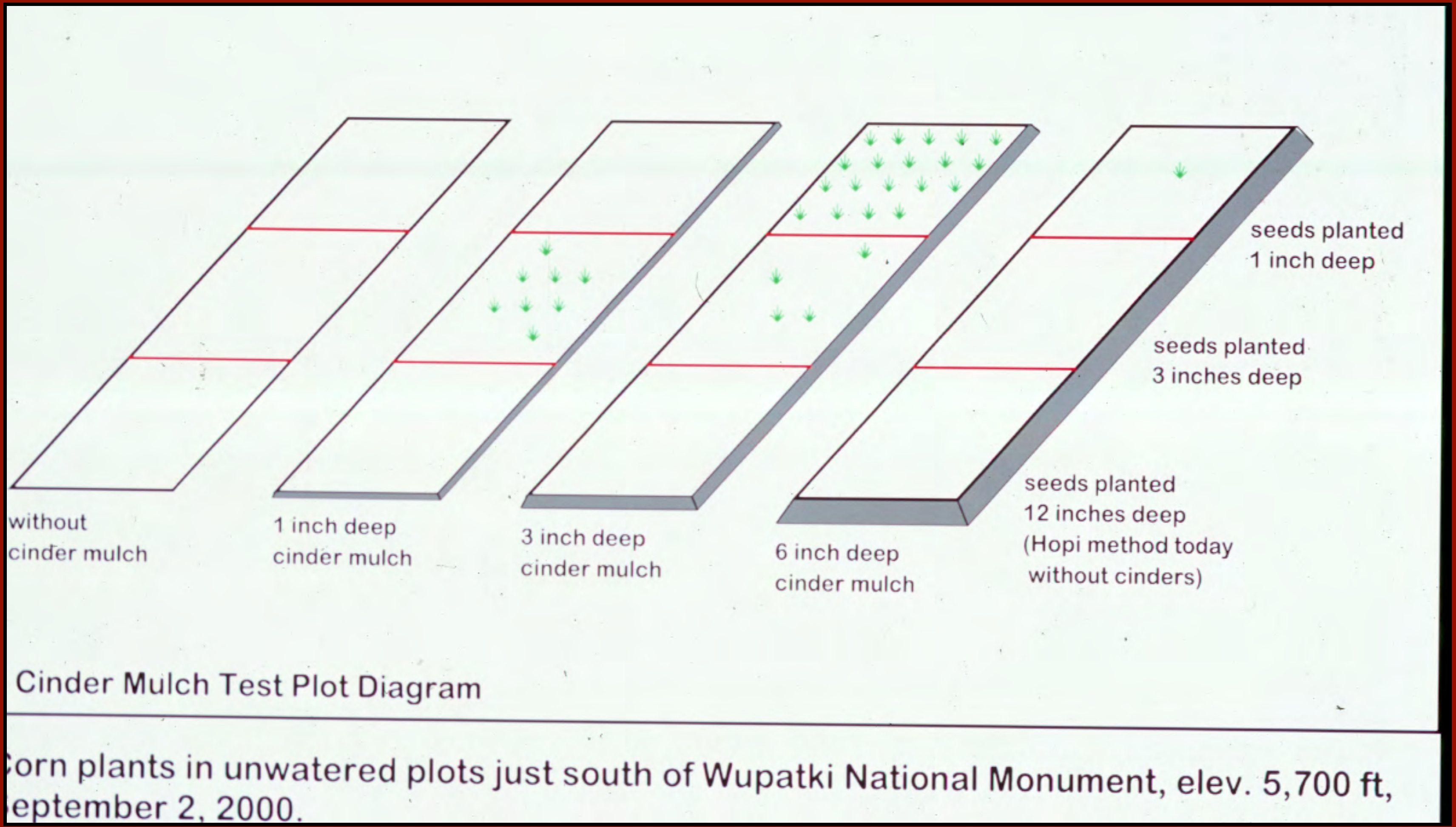


No significant climate change during general A.D. 1050-1100 eruption period – eruption very localized.

Note 2 Standard Deviation increase in warmth (red and yellow) starting in 1950, as measured from bristlecone pine trees in the mountains outside of Flagstaff. Global Warming (DOH!)?

Corn agriculture mainstay of subsistence. Corn needs at least 25 cm of yearly precipitation, 15 cm of which must fall during growing season. Below 6,200 ft (1,900 m) in elevation, this requirement not met, limiting zone of prehistoric occupation to areas above this elevation.

Cinder Mulch Agriculture, 5,700 ft (1,737 m)

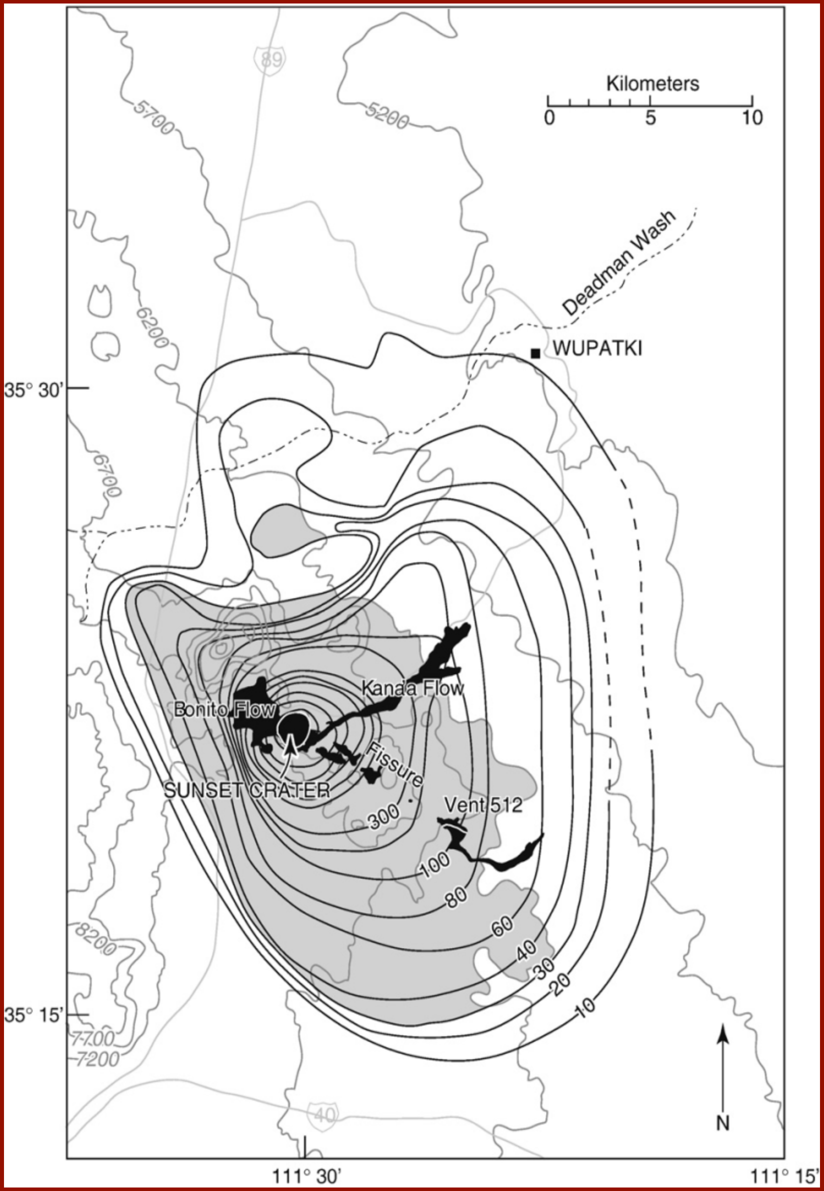


Experimental and modern data indicate that "cinder mulch" cover of 3-10 cm (1-3 in) ideal for corn agriculture. Same data indicate that corn will not grow with cinder cover greater than 15-20 cm (> 6 in).

Isopach Map of Sunset Crater Tephra Deposits (cm)

Agriculture is not possible with more than 15-20 cm of cinders.

Light stipple marks the high density pop. areas above 6,200 ft (1,900 m) with >30 cm cinders that had to be abandoned = <u>265 km^2</u>



Demographic estimates from Coconino NF survey data suggest 1,000-2,000 people forced to migrate and become:

<u>Volcano Refugees</u>

Corn Rock

Pieces of Sunset Crater lava with corn impressions from site 4 km from lava flow

AND ALOHA HAWAI'I???

Experimental archaeology at its finest

Major Disclaimer – neither ADOT nor any granting agencies paid for this trip to Hawaii to play in the lava. Trip paid for by participants.

Corn Rock Behavioral Model

Experimental and ethnobotanical data, plus interviews with Hopi and Purépeche Indians at Parícutin, indicate that **corn rocks deliberately made and probably a ritual item**.

1. Corn offering at hornito
2. Very fluid spatter fell on corn, forming casts
3. ~40 kg broken off and carried to site 4 km away from closest lava flow
4. Some corn casts put in wall of structure

Sunset Crater Eruption

1. Prior to eruption, areas below 6,200 ft (1,900 m) too dry to farm.

2. Cinder mulch from ca. 1085 CE eruption opened lower elevations, such as Wupatki, to farming.

3. An area of 265 km^2 abandoned due to deposition of more than 30 cm of cinders, creating ~1,000-2,000 volcano refugees.

Sunset Crater Eruption

4. Displaced populations likely moved in with kin, but environment too marginal to support large number of new people.

5. Refugees moved to lower elevations with cinder mulch cover – some outside migration occurred as well. New technology of “cinder mulch agriculture.”

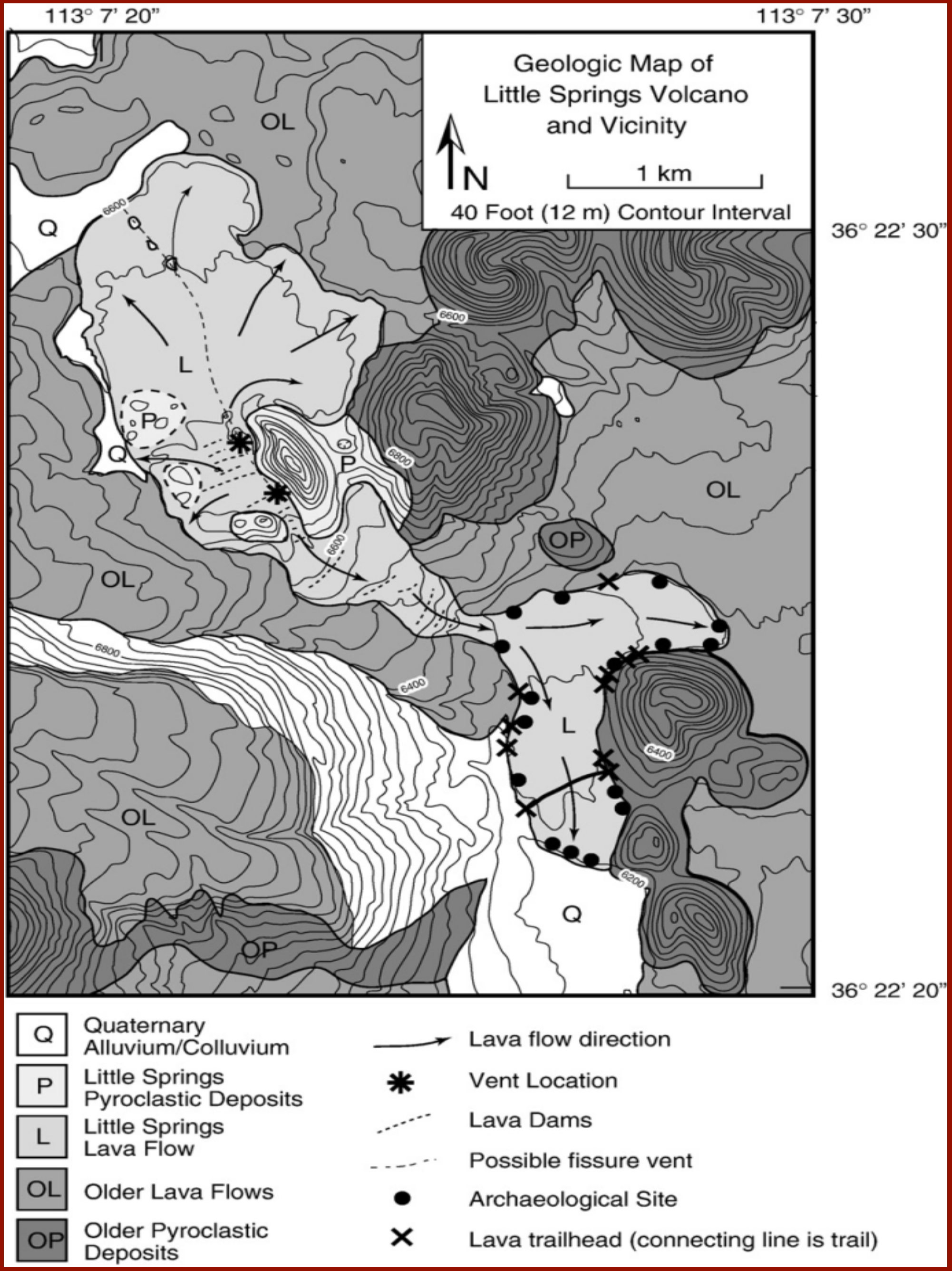
6. Initiation of volcano-related ritual behavior suggests alteration in existing belief and ideological systems.

Little Springs

Little Springs lava flow showing northern and southern lobes ("L" in figure; arrows show direction of flow from the two vents).

Black ovals in southern lobe are archaeological sites.

"X" in southern lobe indicates trail head; line across southern lobe is Trail 1.

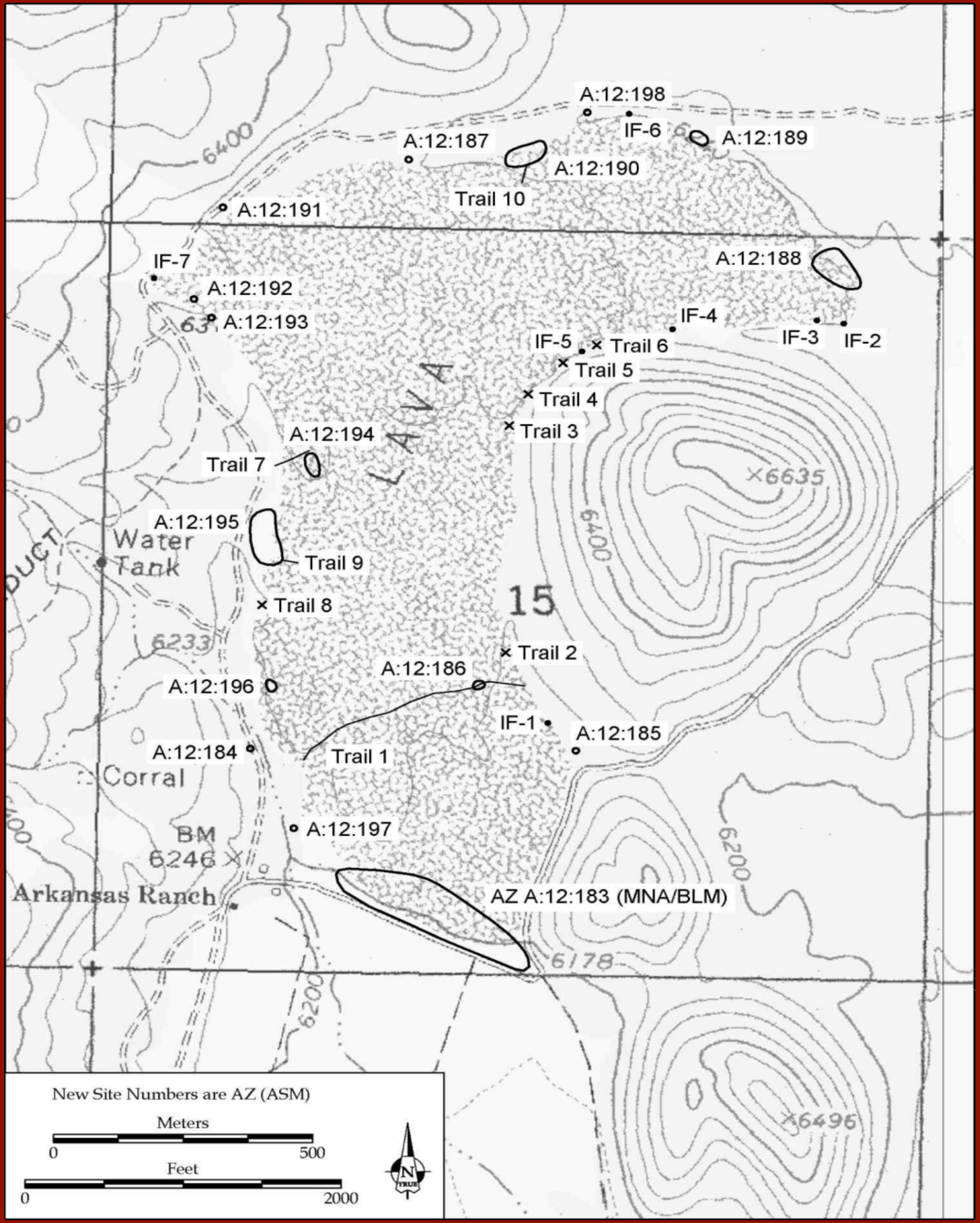


Southern Lava Lobe

Only edges of southern lobe surveyed.

16 sites and 10 trails/trail heads recorded with 48 structures on ground surface at base of flow and 150 structures on flow top.

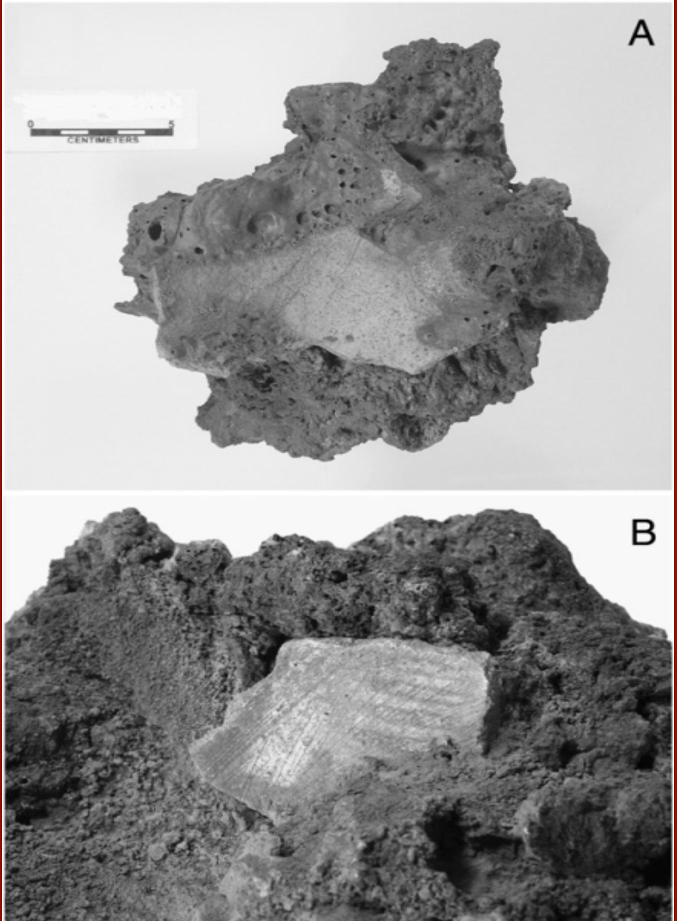
Largest site (A:12:183) had 10 structures at base and 45+ structures on top.

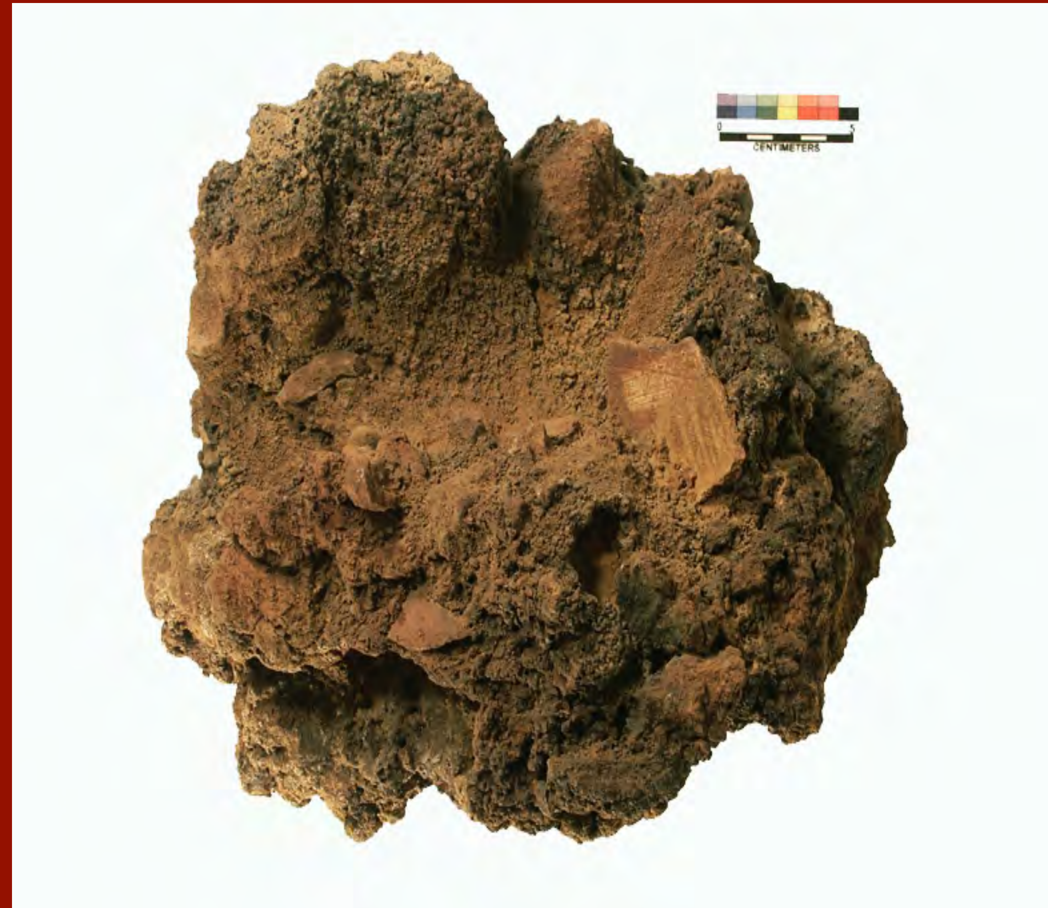


Most flow top structures expediently constructed “dugouts” made by digging lava bombs and blocks out of the flow and dry stacking them around edges. Less than 10 artifacts noted with 150 flow top structures. Structures at base of flow better made with surrounding artifact scatters.

Well-constructed trails, smooth enough to run on – significant engineering; much more energy invested in trails than structures.





Plain ware and decorated sherds in Little Springs lava from site 0.7 km east of lava flow. Decorated sherd is Hurricane Black-on-Gray, A.D. 1050-1200 (best fit 1050-1125). Like “corn rock,” probably made by placing artifact at base of hornito or top of spatter rampart.

Little Springs Volcano

- Small in extent with no cinder fall, so area impacted <10 km^2. Survey data estimate ~45 sites, containing 150-450 people, abandoned.
- Well-constructed trails with hidden ground level access indicate concern for rapid movement.
- Expedient structure construction and lack of artifacts on flow top suggest defensive purpose.

Disasters are highly idiosyncratic

- Dependent on history of particular social-environmental adaptation
- Dynamic process; creates feedback loop
- No simple predictable cause-and-effect relationship

"Different parts of the same society can react … in different ways depending on … local history and natural and social resources" (Bawden and Reycraft 2000)

Catastrophe Theory

Environmental Variables:

- Event magnitude
- Event frequency
- Event duration
- Event speed of onset
- Areal extent of event
- Spatial dispersion of event
- Temporal spacing (periodicity)
- Event time of onset

Catastrophe Theory

Social Variables:

- Resource distribution
- Level of capital investment in resource exploitation
- Level of technological efficiency
- Type of economic system
- Experience with event
- Population density
- Wealth
- Level of sociopolitical complexity
- Areal extent of a given polity

Community Resilience

- Small, low density population, decision-making at household or small site level
- Limited hierarchy allows rapid response – information does not have to trickle down from top before action can be taken

Community Resilience

- Little investment in site infrastructure – houses easily rebuilt using local materials in 1-2 weeks
- Agricultural risk reduction strategy already in place due to marginal nature of environment: 1-5 ha field plots in different microenvironments

Community Resilience

- Wide kinship network likely including kin outside area of disaster impact
- Religion and ritual integral part of social and economic systems – modern research shows that religious faith allows for quicker acceptance of events and initiation of recovery process

Impact Scale

Catastrophic events with the most significant impact on human populations have:

- High degree of *uncertainty*
- *Sudden occurrence* with little warning
- *Prolonged duration*
- *Broad scope of damage* (environmental, cultural, and human physical damage)
- Occurrence at *night*
- Heavy survivor *exposure to the dead and injured* (Mileti, Drabek, and Hass 1975)

Hazards Management

- Need to eliminate hierarchical levels – level of “real” decision-making must be lowered for rapid response
  - Decision-making authority and hazards training at small group level (ward, neighborhood, etc.)
- Communication critical in nested hierarchy – fail-safe systems (e.g., satellite phones) absolute necessity

Hazards Management

- Idiosyncratic nature of disasters necessitates flexibility in response. Accurate and timely feedback critical in decision making and innovation.
- Both social and environmental variables must be considered – in many cultures these are interrelated and not easily separated.
- Faith-based organizations play important role in acceptance of event and recovery process.

MYTH BUILDING

Three years ago my village existed tranquilly … all parts of this region were beautiful, with fruit trees in the village, green pastures, beautiful fields that demonstrated the riches of the area, with cattle and sheep and droves of horses … now there remains for me only a remembrance and a pride to have known it as it existed …”

Caledonio Gutierrez, January 1, 1946

Diorama showing the 1943-1952 eruption of Parícutin Volcano outside cathedral in Nuevo San Juan, Michoacán, Mexico

Highly inaccurate, but very colorful for closing slide, reconstruction of 11th Century A.D. Sunset Crater
(Arizona Highways Magazine, late 1950s).

A Final Note

Is the frequency of catastrophic events increasing? In general, the answer is NO.

We are well within the average of 15-20 magnitude 7+ earthquakes and 50-70 volcano eruptions worldwide. Floods, hurricanes, and tornadoes, however, may be increasing.

Increased media worldwide has made us much more aware of catastrophes.

A Final Note

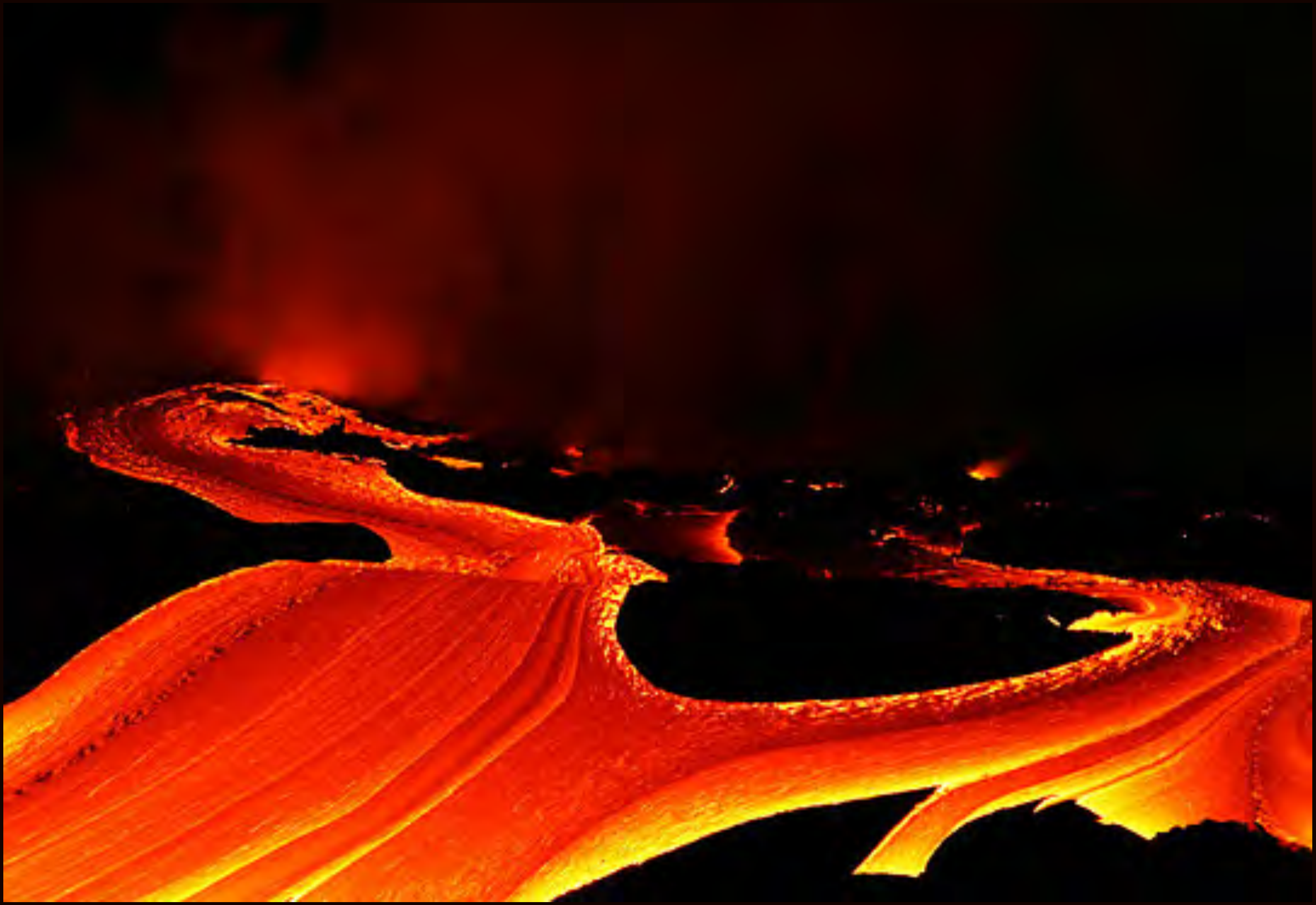
Is the frequency of deaths, injuries, and property damage increasing? The answer is YES.

Population growth has forced occupation of catastrophe-vulnerable areas, such as floodplains, volcano flanks, ocean shores.

We are also becoming increasingly urban. Greater risk of death/injury in cities.

Demographic estimates suggest that about 500 million people – or 10% of the world's population – live in areas of active volcanism.

-- As population increases, we are becoming increasingly urban and moving into areas unsafe for habitation.



Kilauea Volcano, Hawai’i

Center for Research on Environmental Decisions

COLUMBIA UNIVERSITY

The View From Social Science:

How people will think and behave during an extended crisis with large uncertainties

Katherine Fox Thompson

Columbia University Psychology

Center for Research on Environmental Decisions

Volcanism in the American Southwest | October 19, 2012

The Psychology of Hazard Communication

1. The problems with probability
2. The importance of instrumentality
3. The trouble with timing

Why Don't People Prepare for Hazards?

To be prepared, people must:

- pay **attention** to the message
- **understand** the message
- **believe** the message
- initiate **action**

1. The Problems With Probability

30% Doesn't Always Equal 30%

- when given probability information, people often:
  - misinterpret it (Budescu et al. 2009)
  - ignore it
    - optimism bias (Shepperd et al. 2002)
  - misuse it
    - failure to understand weather forecasts (Gigerenzer et al. 2005)
  - and distort it
    - **over-weighting** of rare events (Kahneman & Tversky 1979)

attention | **understanding** | **belief** | action

Experience Matters

- experience-based learning leads to **under-weighting** of rare events (Hertwig & Erev 2009)
- when prior experience with the rare, negative event is zero, people ignore descriptive warnings (Barron, Leider, & Stack 2008; Halpern-Felsher et al. 2001; Miron-Shatz et al. 2010)

Emotion Drives Action

- humans are a "dual process" machine
  - slow, deliberative, analytic reasoning
  - quick, heuristical, emotional reasoning
- emotional processing system is a better motivator for action than the analytic system (Loewenstein, Weber, & Hse 2001)

✓ avoid probabilities when you can

And when you do need to use them:

- acknowledge the experience-description disparity
- include vivid, emotional context

2. The Importance of Instrumentality

Too Much Worry Can Be Counterproductive

- rare, extreme events pose "dread risk" (Slovic 1987)
- **emotional numbing** can make us ignore risk (Linville & Fischer 1991; Weber 2006)
  - be wary of over-emotional appeals

People Need to Feel Agency

- **Instrumentality:** the feeling that there are actions you could take that will help you
- people who feel instrumentality are more likely to act
- and: people who feel instrumentality also judge the risk as higher (Spence et al. 2011)
- actionable risk statements encourage instrumentality (Wood et al. 2012; Mileti)

Motivations Differ Among People

- **promotion-focused** people are motivated by:
  - goals & aspirations
  - improving the current situation
- **prevention-focused** people are motivated by:
  - duties & "oughts"
  - keeping the current situation from getting worse
- promotion-focused people are motivated by **values-based** messaging
- prevention-focused people are motivated by **risk-avoidance** messaging (Higgins 1997; Cesario, Grant, & Higgins 2004)

✓ use actionable risk statements

And when you're explaining why *people should take those actions, include both values-based and risk-avoidance motivations.*

3. The Trouble With Timing

Long Time Horizons Reduce Concern

- certain concepts are **psychologically distant:**
  - things **far away** in **space** or **time**
  - **highly uncertain** things
- psychological distance leads to **abstract thinking**
- abstract thinking doesn't lead to actions
- fortunately, concrete thinking about an event can bring it psychologically closer
- focusing on the details of a future/uncertain event can promote concrete preparatory actions (Trope & Liberman 2010)

attention | understanding | **belief** | **action**

We Have a "Finite Pool of Worry"

- we only have so much mental energy to spend on concerns (Hansen, Marx, & Weber 2004)
- adding volcanic eruptions to the **Finite Pool of Worry** will crowd other things out
- (but on the other hand, more salient every-day concerns will crowd volcanoes back out)

We Adjust to the New Norm

- **hedonic reappraisal:** we acclimate to long-term bad situations (Brickman & Campbell 1971)
- emotions (fear, anxiety, worry) are relative to our current baseline
- alerts that are based on a hierarchy will lose their power if left in place for too long

✓ Be aware that the power of your message will fade over time

People get desensitized to risk, so you need to be able to get their attention over and over

- and to do that, you need to make the risk concrete

Three Take-Aways from Psychology

1. Avoid probability, unless you also give vivid context.
2. Use actionable risk statements.
3. Be ready to keep re-engaging people's attention.

Thank You!

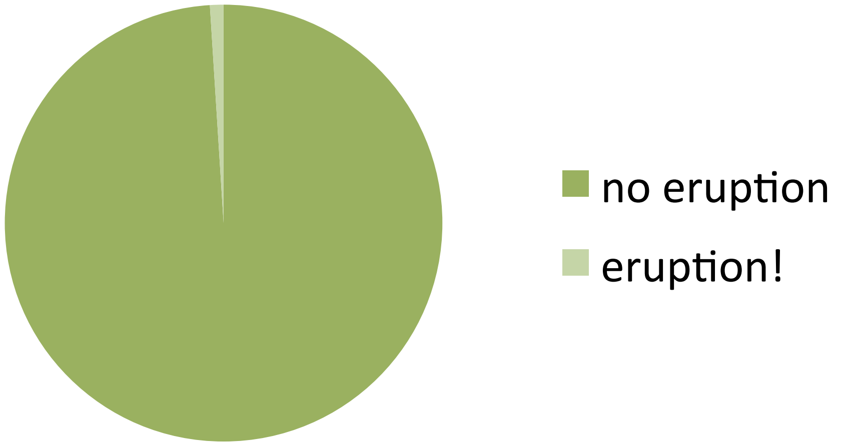
And thanks to CRED,
SAFRR, & USGS project #GG009261

Words to be Wary of

word	scientific meaning	public perception
uncertainty	scientifically constrained range of possible outcomes	not knowing
risk	probability; hazard x vulnerability	a danger; an unlikely event
error	uncertainty within a measurement or model	a mistake
bias	an offset from the observed value	unfair, deliberate distortion
anomaly	deviation from a long-term average	abnormal event

Format of Probability Information

- using proportions can improve understanding of risk (Visschers et al. 2009)
  - e.g., a 1 in 10 chance of your home flooding
  - though beware the denominator effect
- don't use graphs unless you zoom in on the risk
  - pie charts are almost always a terrible idea:



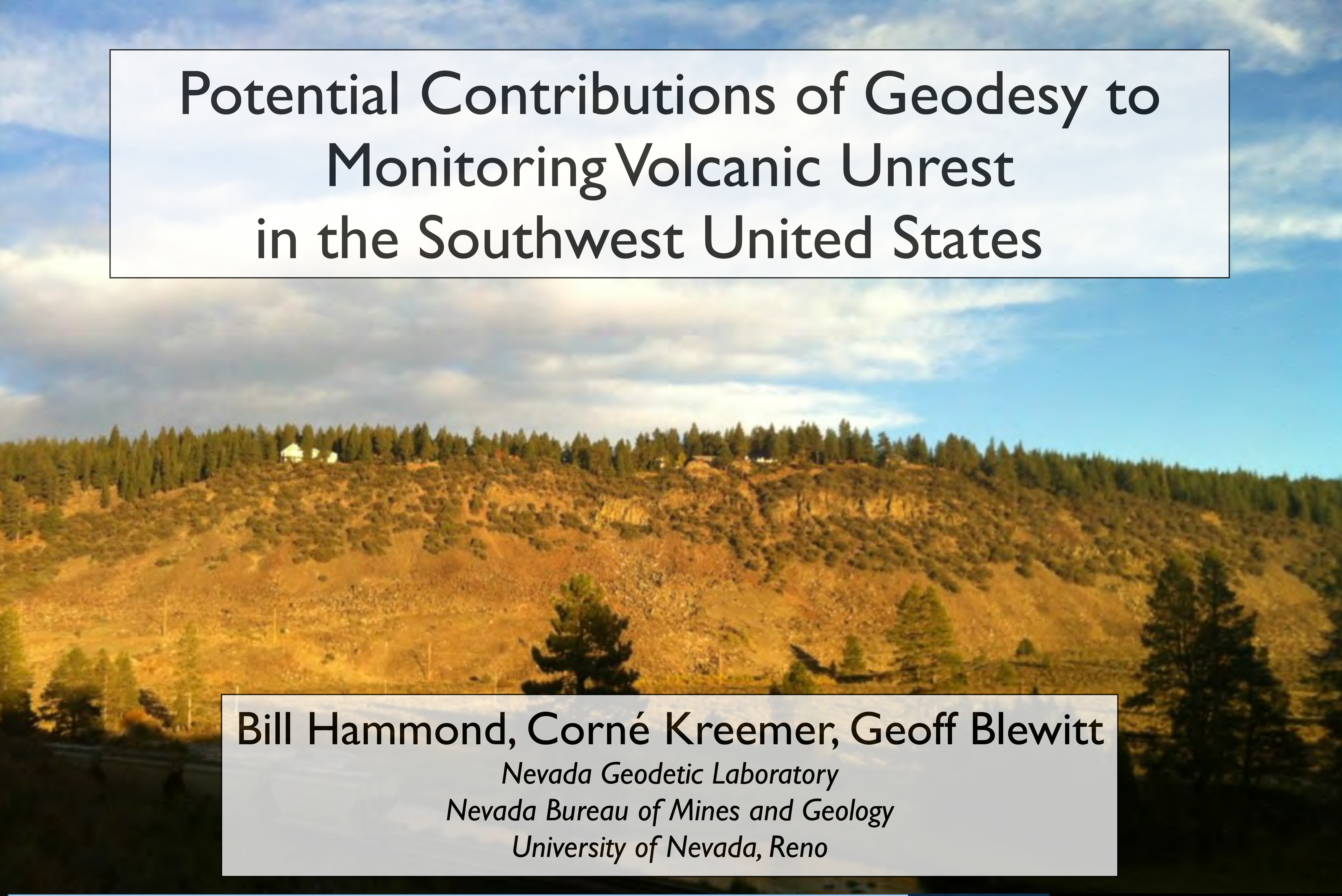
Temporal Discounting

- outcomes in the future are worth less than outcomes now
  - would you rather have $100 today, or $130 one year from now?
- some discounting is rational (inflation, investment opportunities), but people discount more than that
- we discount money, health, environmental damage
  - ...natural hazards combine all of those

Mental Models

- a mental model is the way someone understands a concept like volcanoes:
  - what causes eruptions
  - what the main dangers are
- for your warning to make sense, it must connect somewhere with existing mental models
  - e.g., showing a seismograph to Indonesian villagers
- mental models can be changed
  - but you have to do it incrementally, not wholesale
  - and some of the building blocks for the model are set in stone

Potential Contributions of Geodesy to Monitoring Volcanic Unrest in the Southwest United States



Bill Hammond, Corné Kreemer, Geoff Blewitt

Nevada Geodetic Laboratory

Nevada Bureau of Mines and Geology

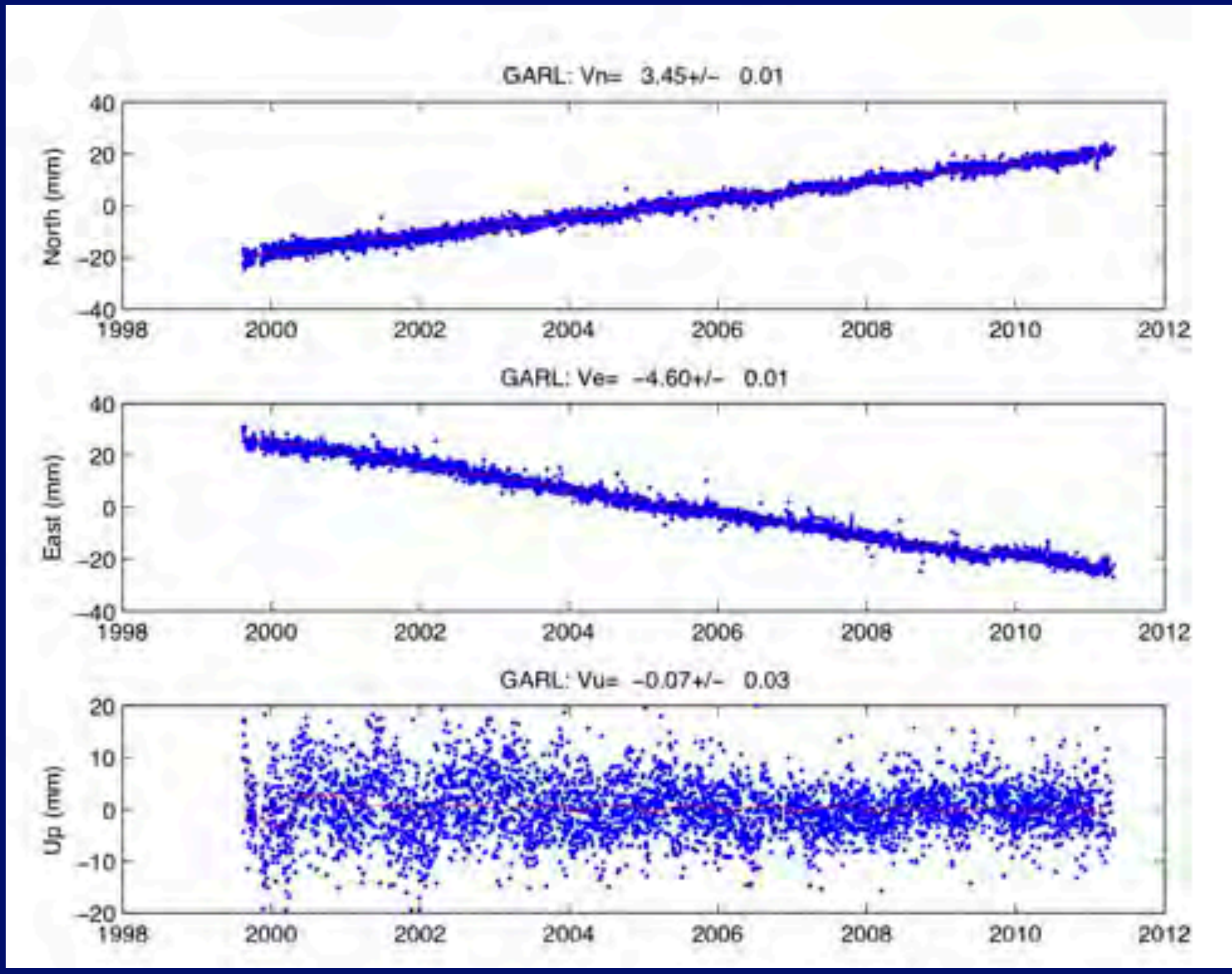
University of Nevada, Reno

This Talk

- What is Geodesy? Earth Shape.
  GPS & InSAR
- MAGNET GPS Network and data products
- Case studies:
  - Great Basin episode magmatic unrest (Slide Mountain)
  - Other swarms (Mogul, Hawthorne)
  - Detection threshold.
- Status of low latency geodesy and prospects for the future of GPS (Brawley example)

GPS Geodesy

- Geodesy = shape of the Earth
- Each dot is a daily mm-precision measurement of position (latitude, longitude, height)
- Many dots. Trends ~linear.
- Active tectonic deformation.
- Slow steady loading that stores elastic energy in the Earth's crust (which is a prelude to earthquakes).
- Basin and Range has multiple interoperable networks including...

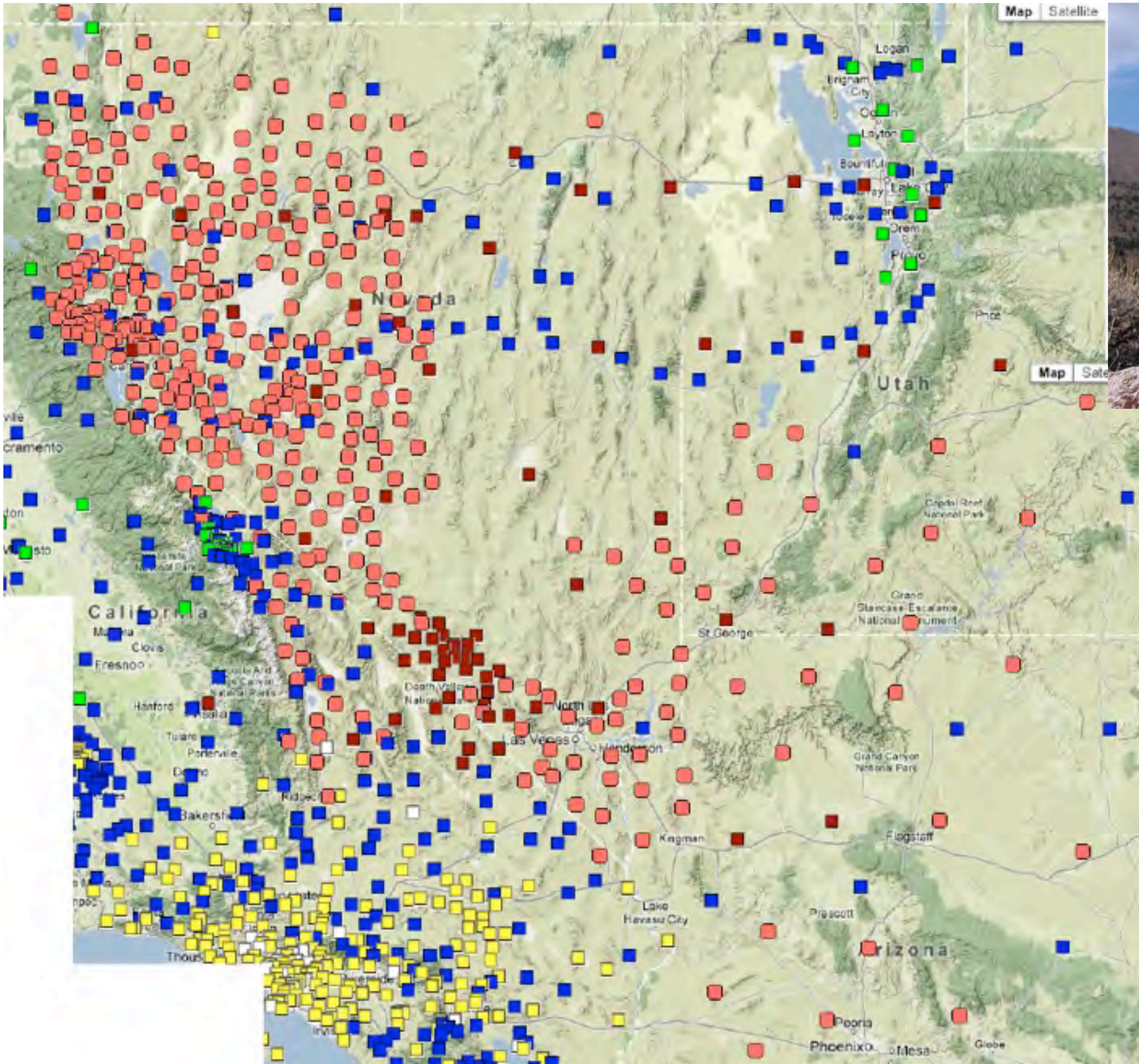


MAGNET: The Mobile Array of GPS for Nevada Transtension

MAGNET*

http://geodesy.unr.edu

* the Mobile Array of GPS for Nevada Transtension



- Rapid expansion last 5 years
- 371 stations, 62 receivers
- ~20 km spacing in west NV
- Complement to EarthScope PBO, +other networks
- Western Great Basin, S.NV, E. CA, AZ, UT
- Data products include processed time series, velocity fields, strain rate maps...

GPS velocity field of the Great Basin reveals relationship to the Pacific/North America plate boundary

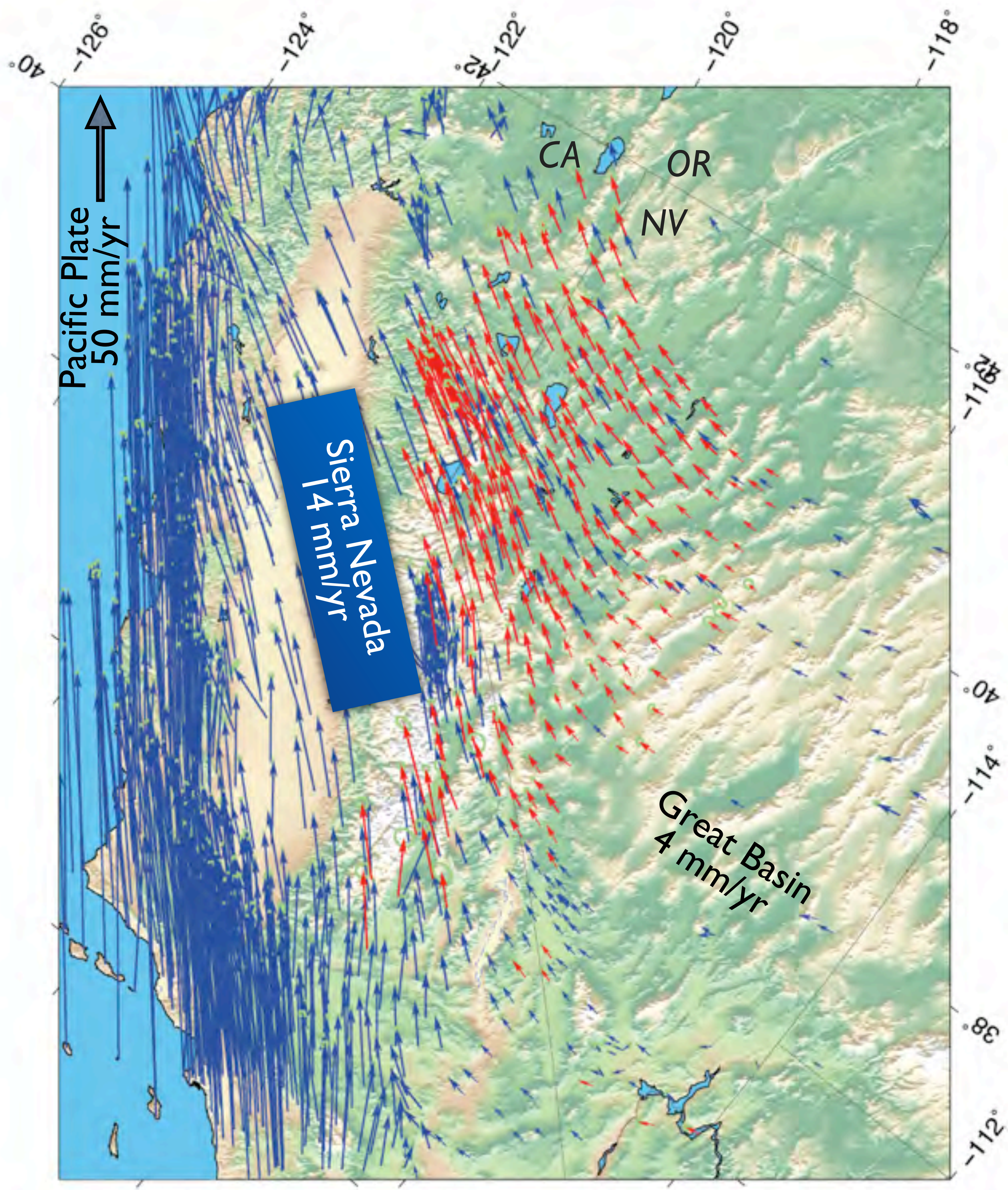
- San Andreas - Sierra Nevada/Great Valley microplate - Walker Lane - GB

- Walker Lane acts as an intracontinental shear zone, with a small component of extension.

- uniaxial extension in Basin and Range

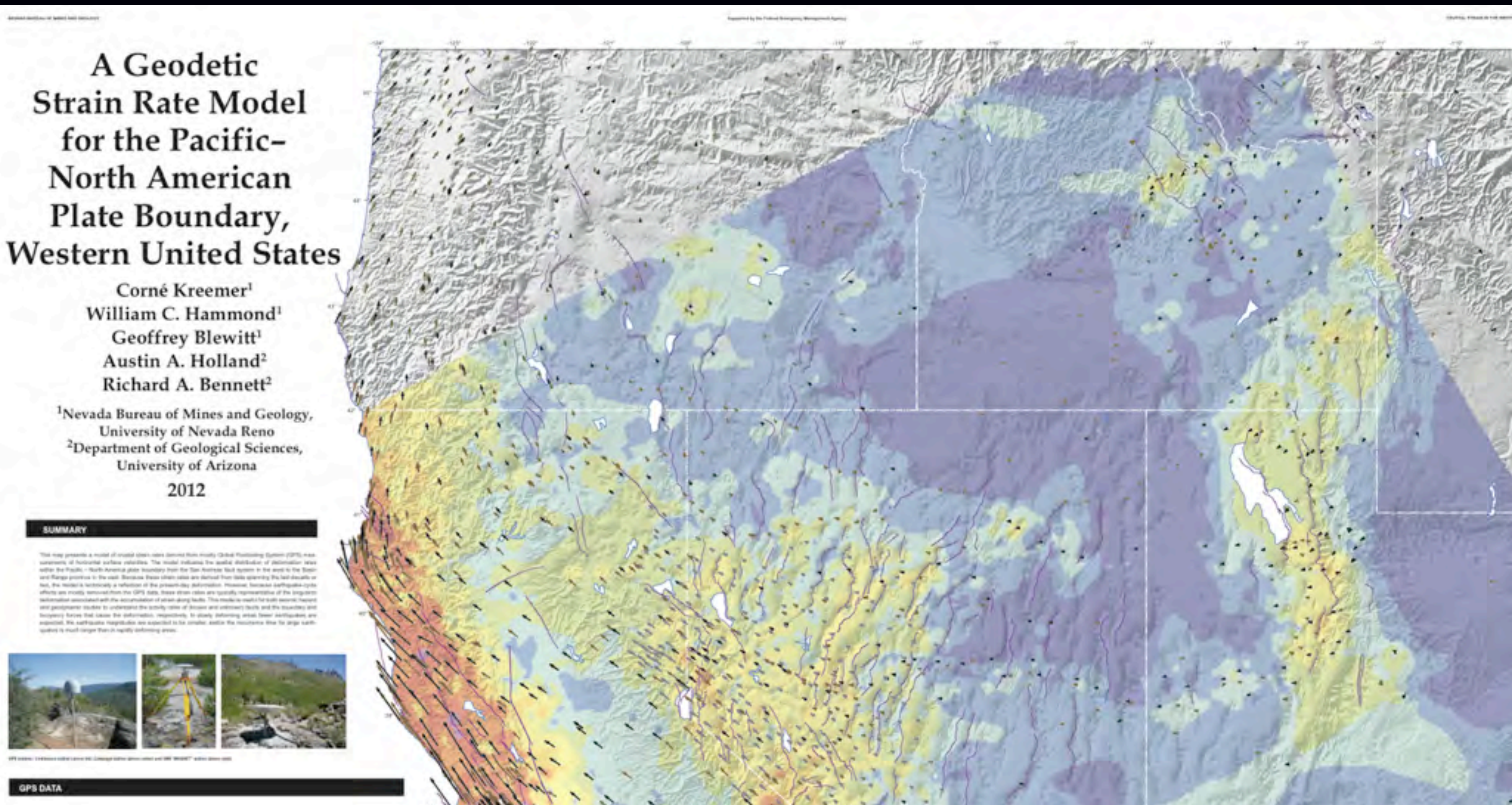
blue = continuous GPS stations
red = MAGNET semi-continuous

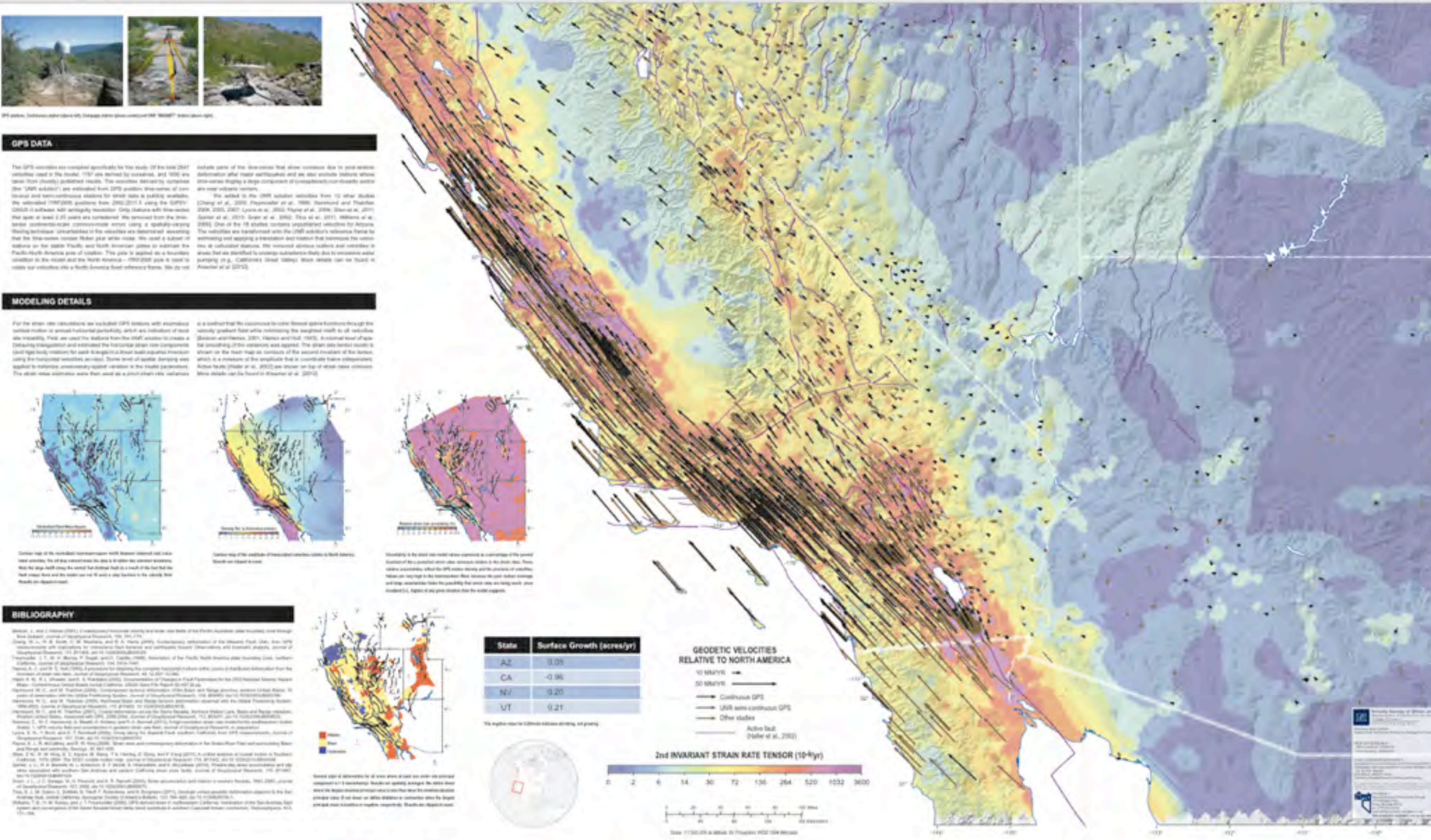
- velocities in North America fixed reference frame



Strain Rate Map

- Portrays intensity of deformation rate with color
- Strain rates show high correlation with seismic hazard maps

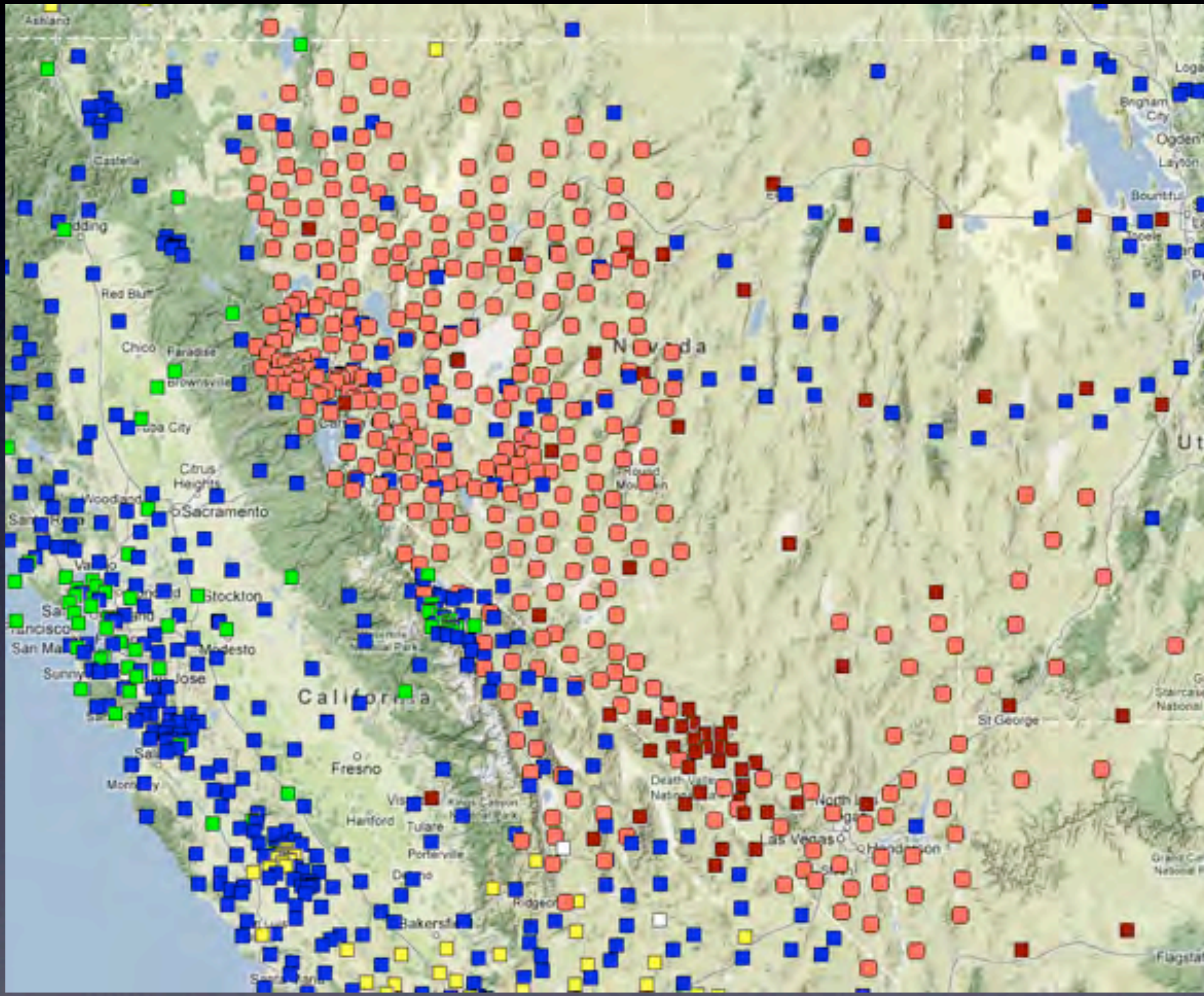




- Kreemer et al. (2012) map now available from NBMG publications sales
- Obtain digital map free at http://www.nbmg.unr.edu/dox/m178.pdf (small charge for printing)
- Contemporary strain rates have strong correlation to distribution of recent volcanism, e.g around edges of Basin and Range province.

Case Studies in Nevada

- 2003 Slide Mountain
- 2008 Mogul
- 2011 Hawthorne
- inside MAGNET
- Which of them had a magmatic component?



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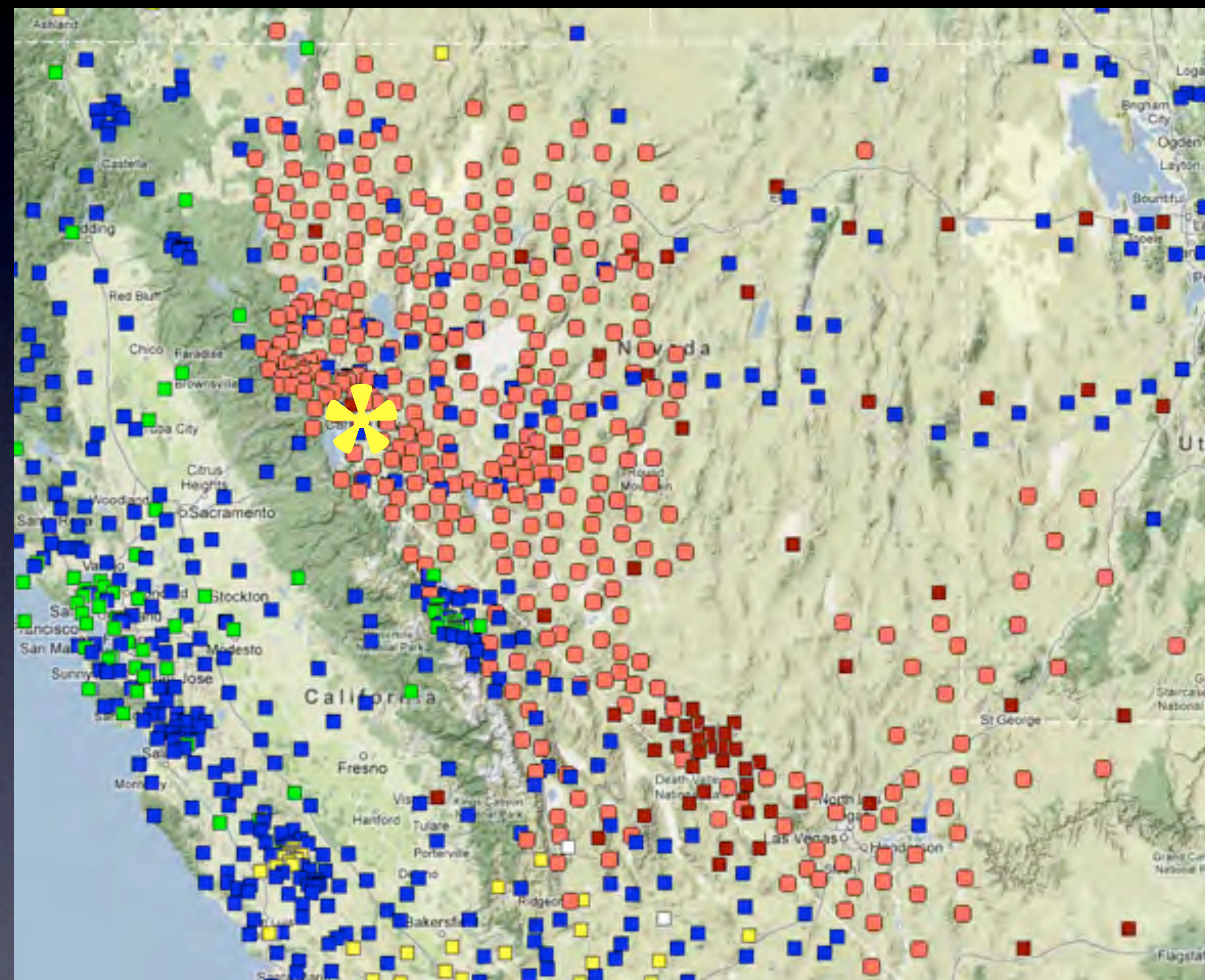

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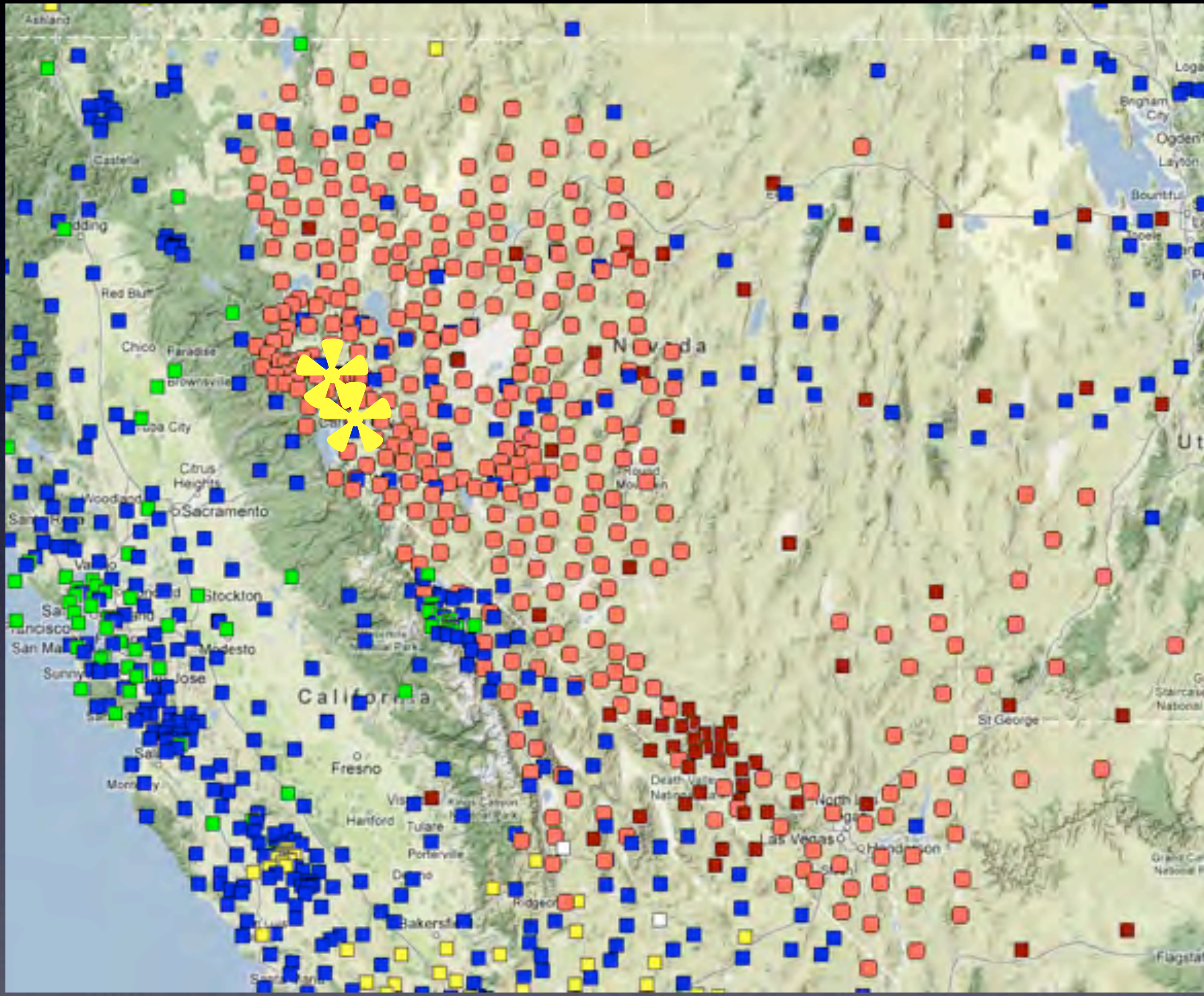

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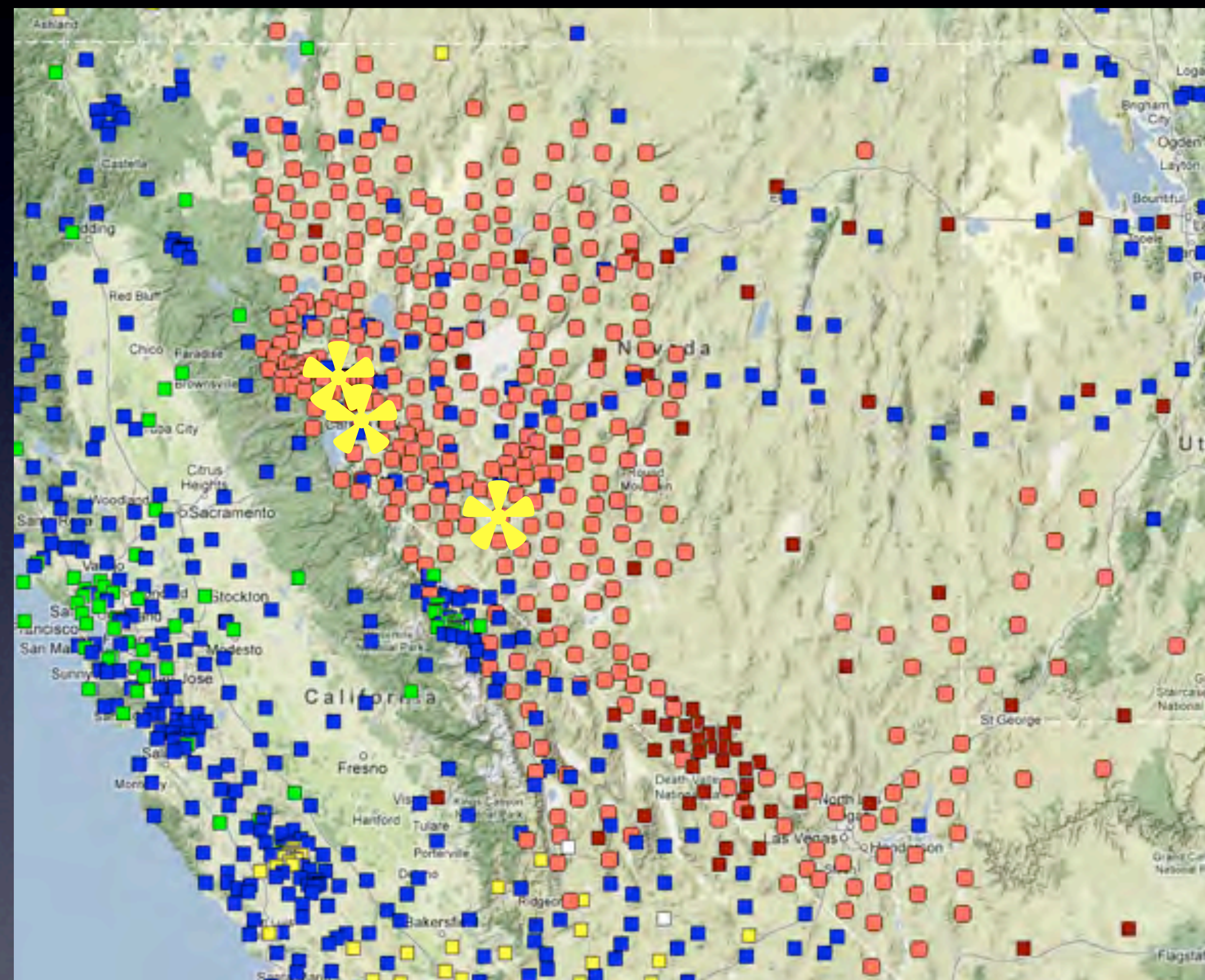
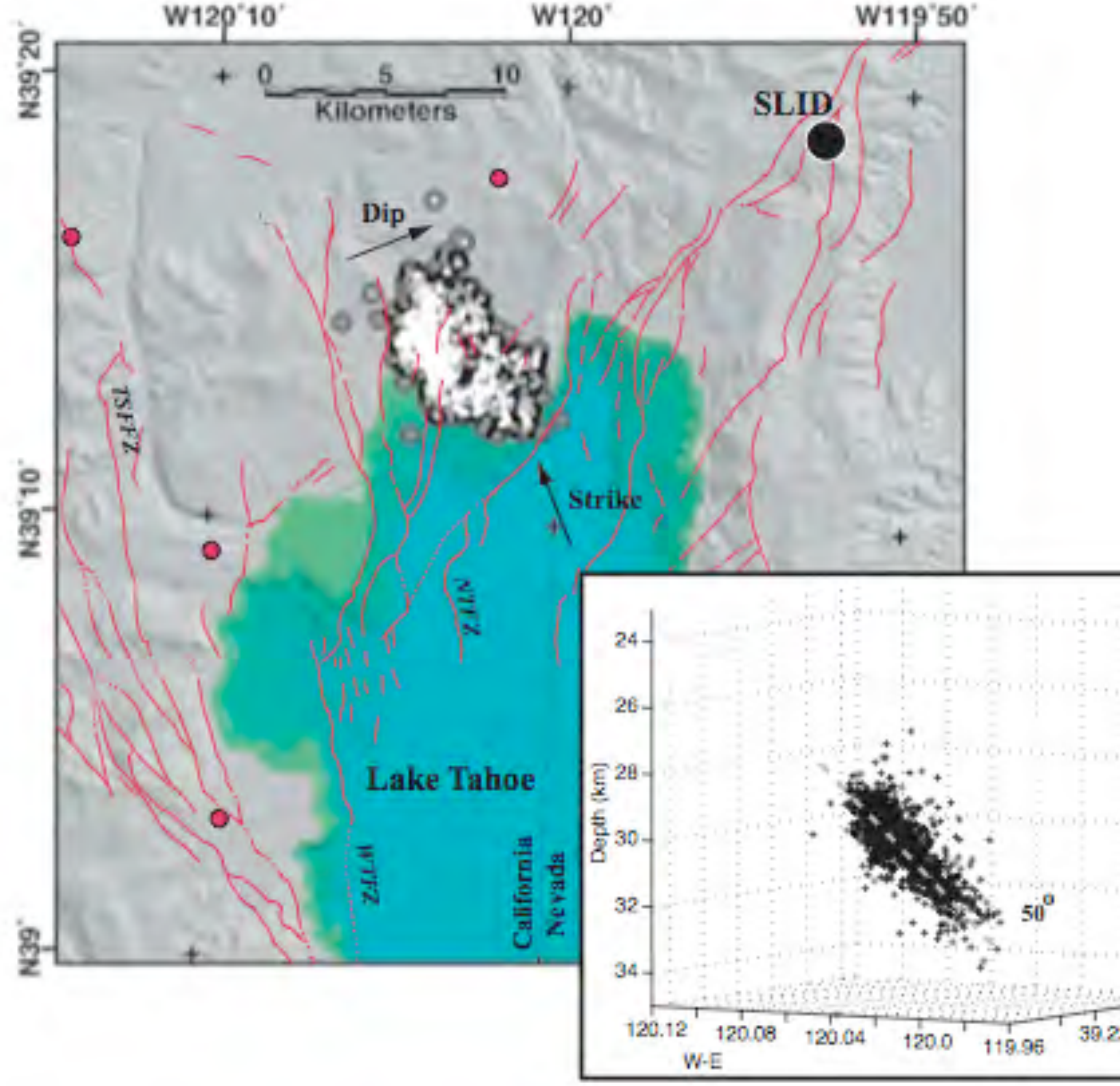
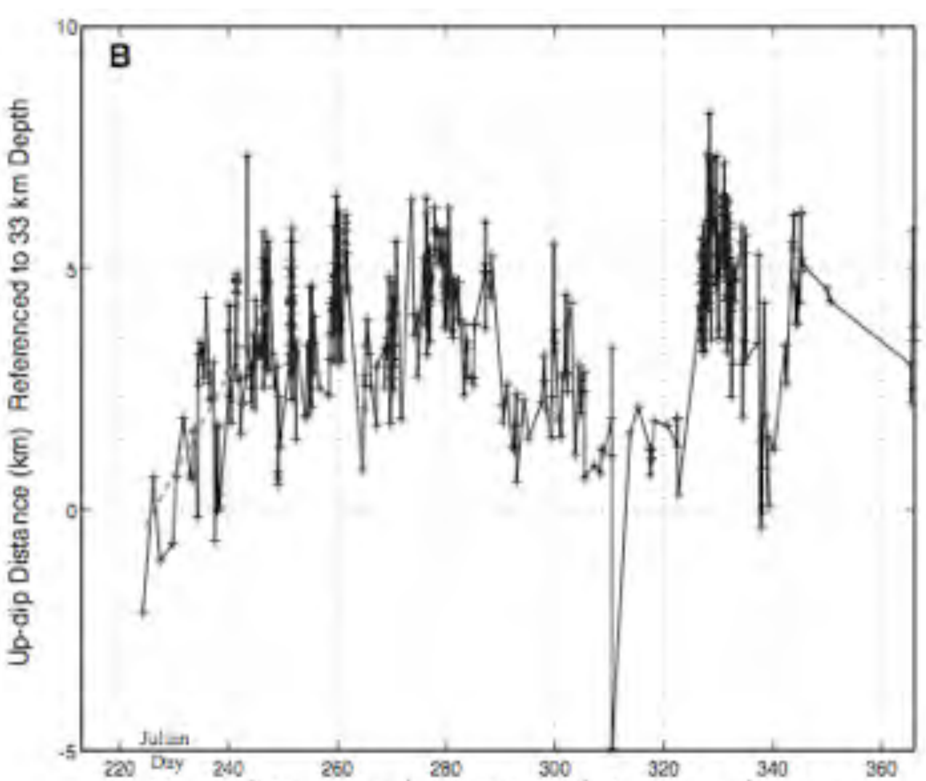
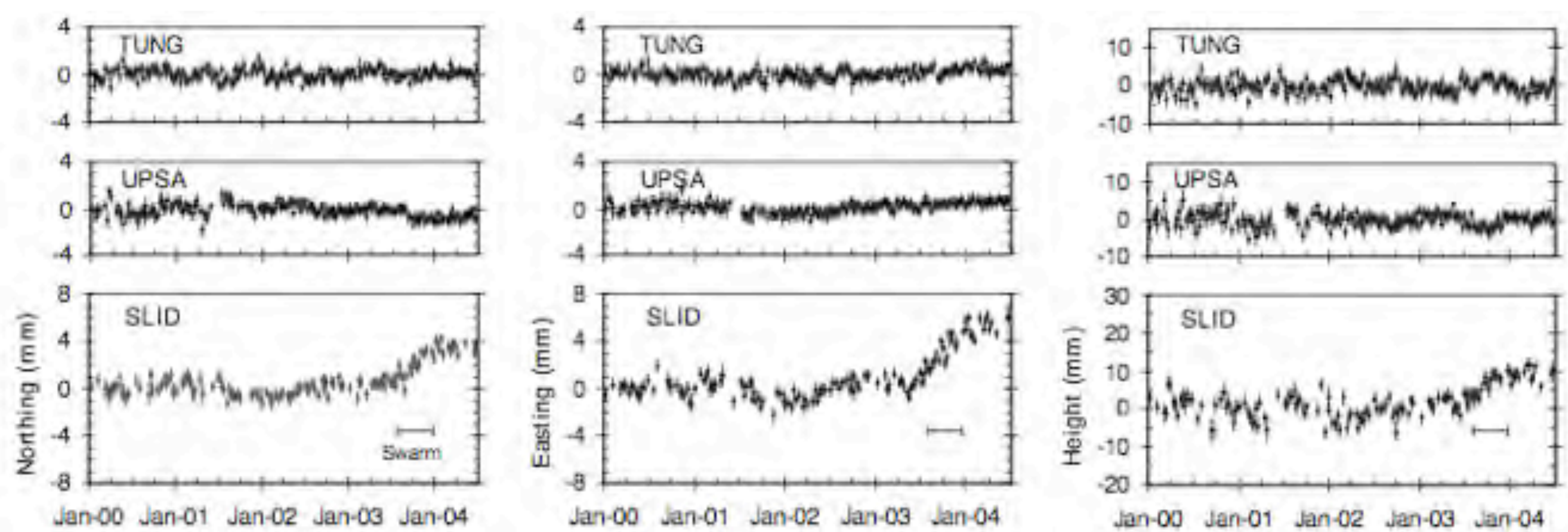


Case Study 1: 2003 Slide Mountain

- Lower crustal seismicity (33 km depth) shallowed by 5 km over period of ~1 month.
- Moment tensors, progression, displacement at GPS site SLID consistent with tensile opening and filling with magma
- 1 cm displacement
- Geodetic ~M_W 6.1, far larger than sum of seismic moment
- Findings published in Science paper Smith et al. 2004

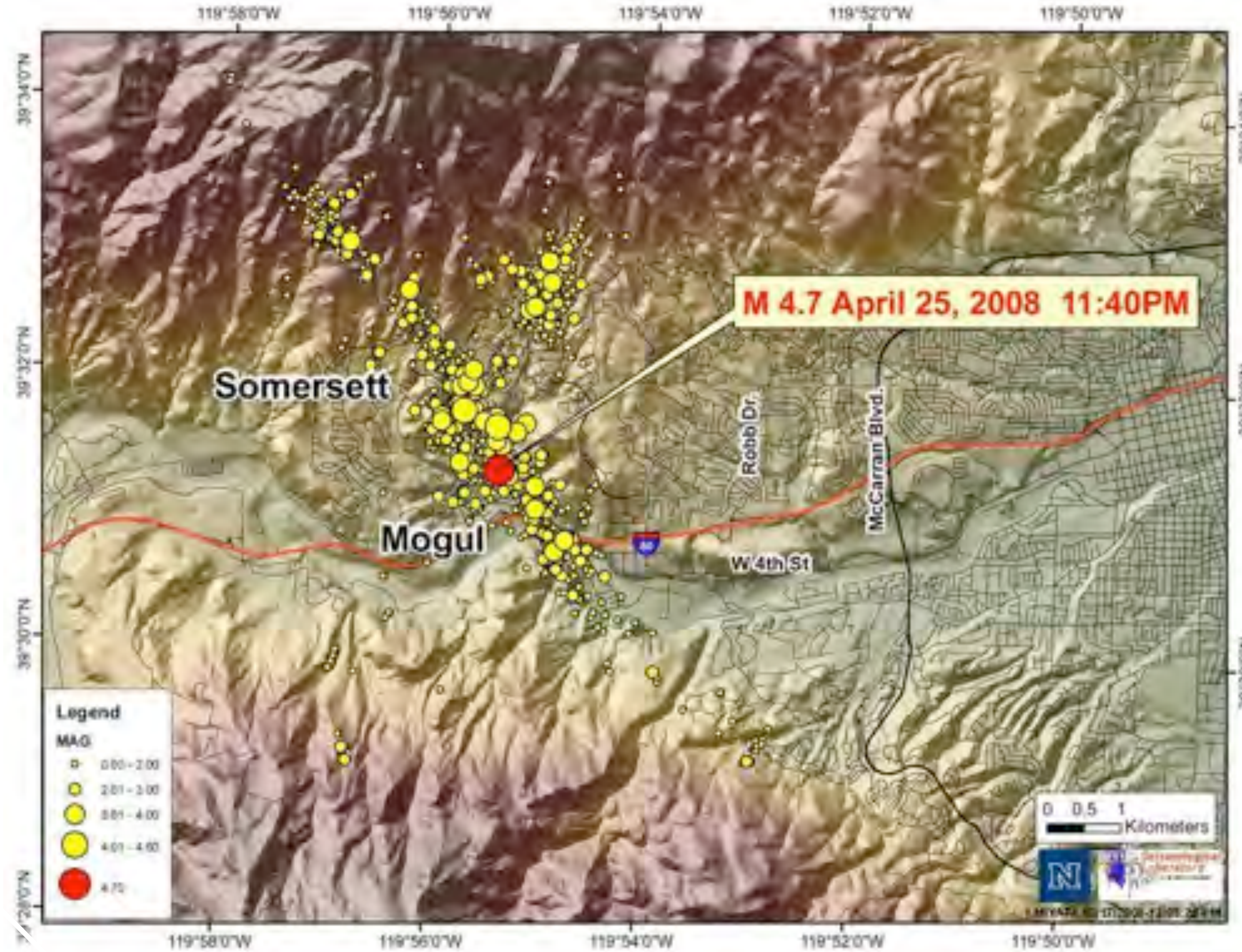


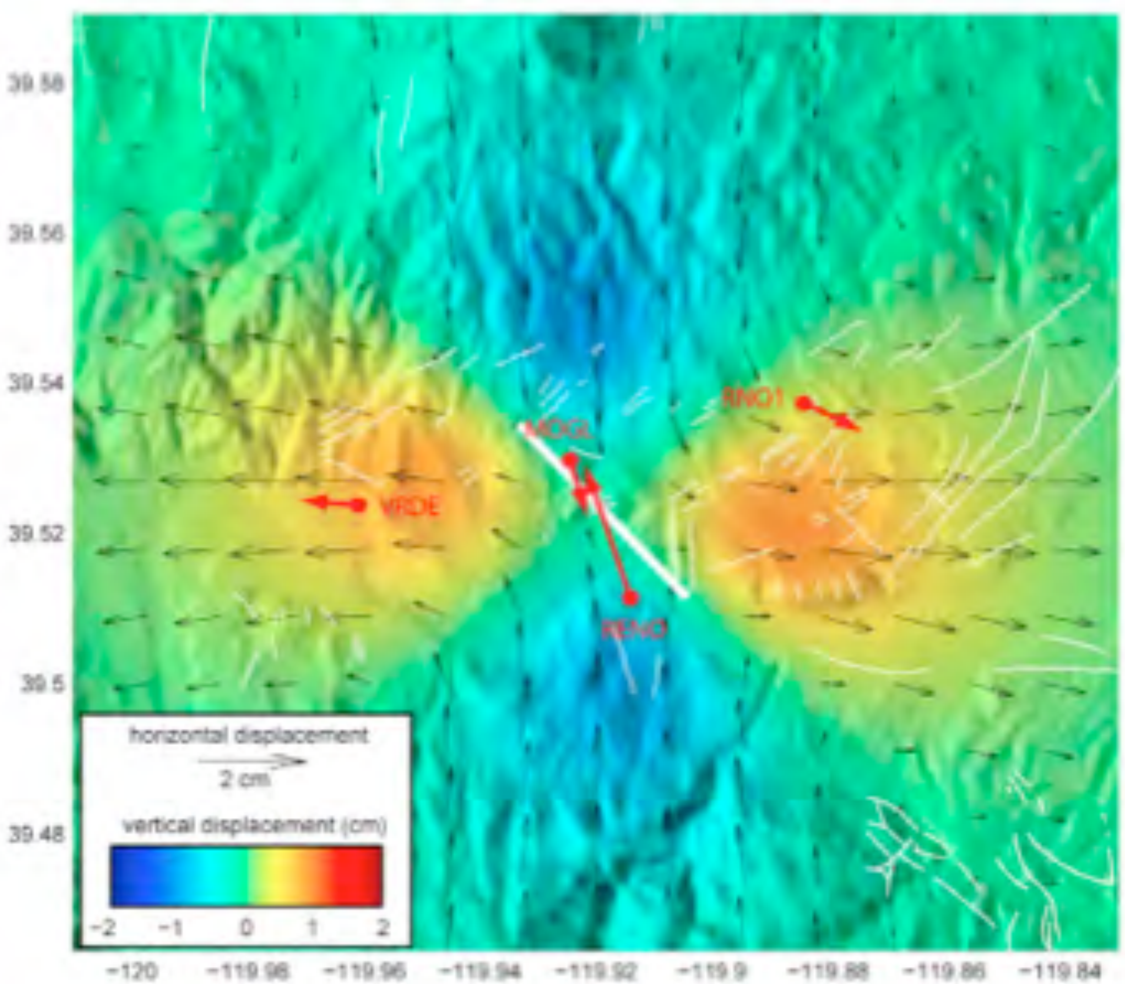




Case Study 2: 2008 Mogul Swarm

- Intense shallow seismicity inside Reno city limits, 1000s of felt earthquakes, maximum earthquake M_W 5.0
- GPS finds moment equivalent to >M5.3 (at least 2x the slip) in an event lasting several months.
- However data indicate coseismic and postseismic strike slip on plane, no evidence for magmatic filling of dike...

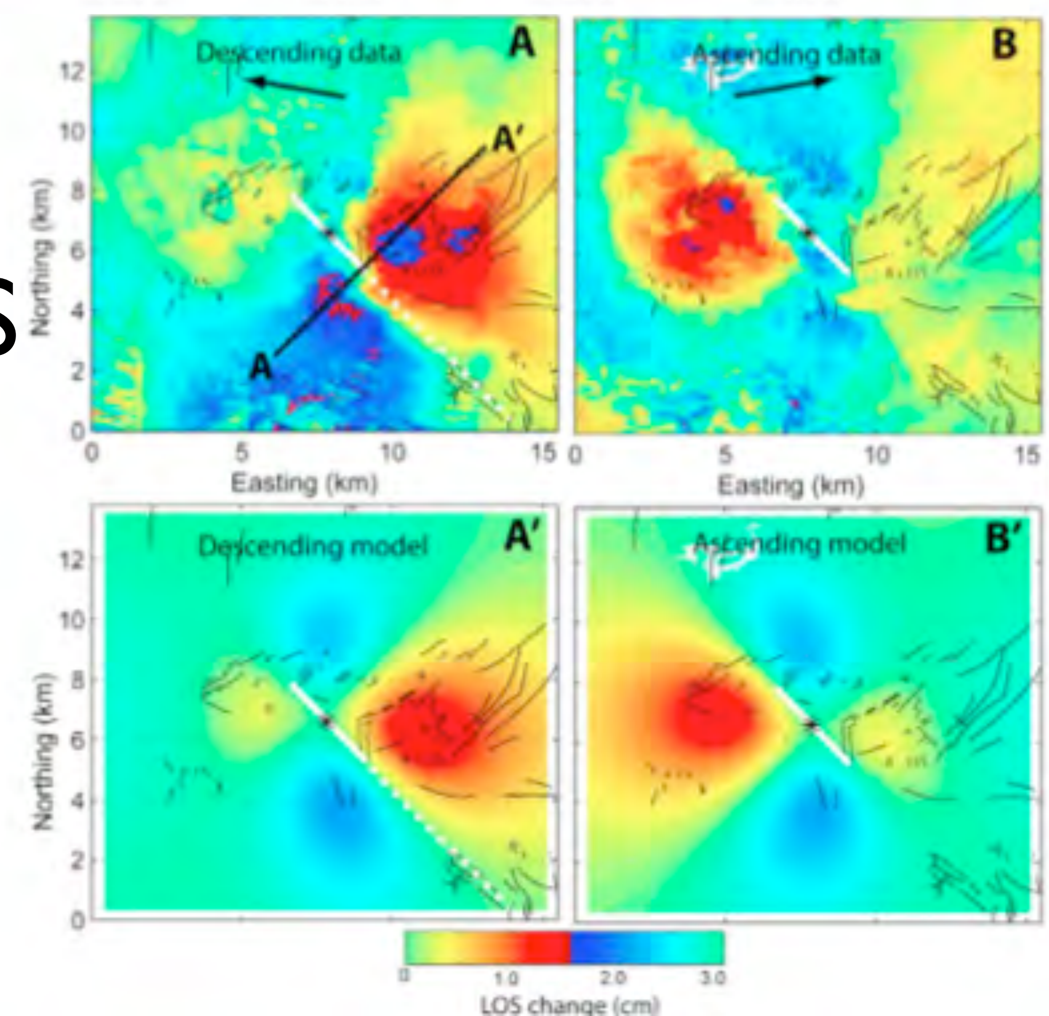




InSAR+GPS

observations
and
modeling

Bell et al. 2012



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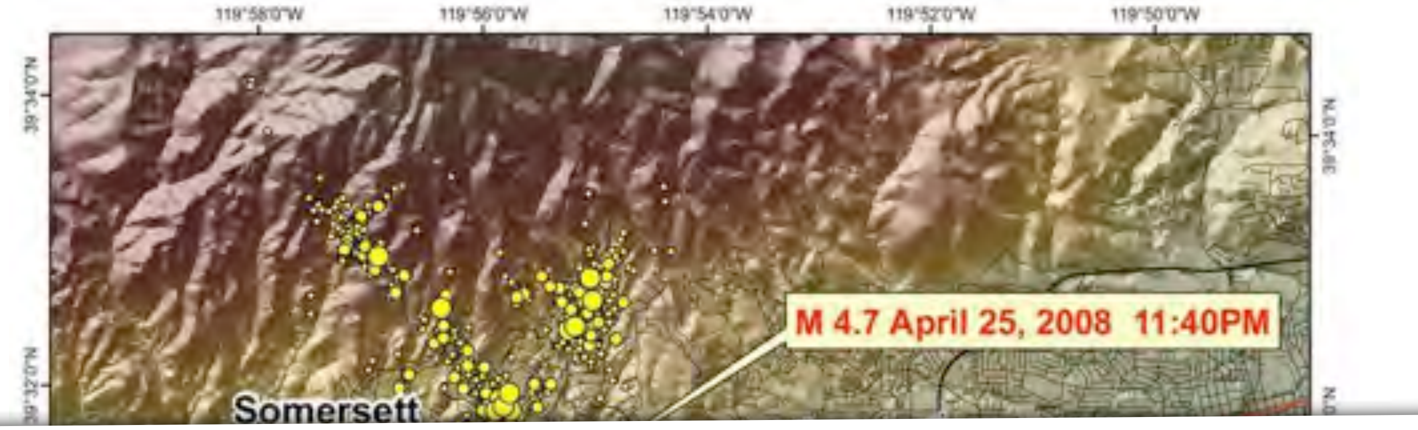

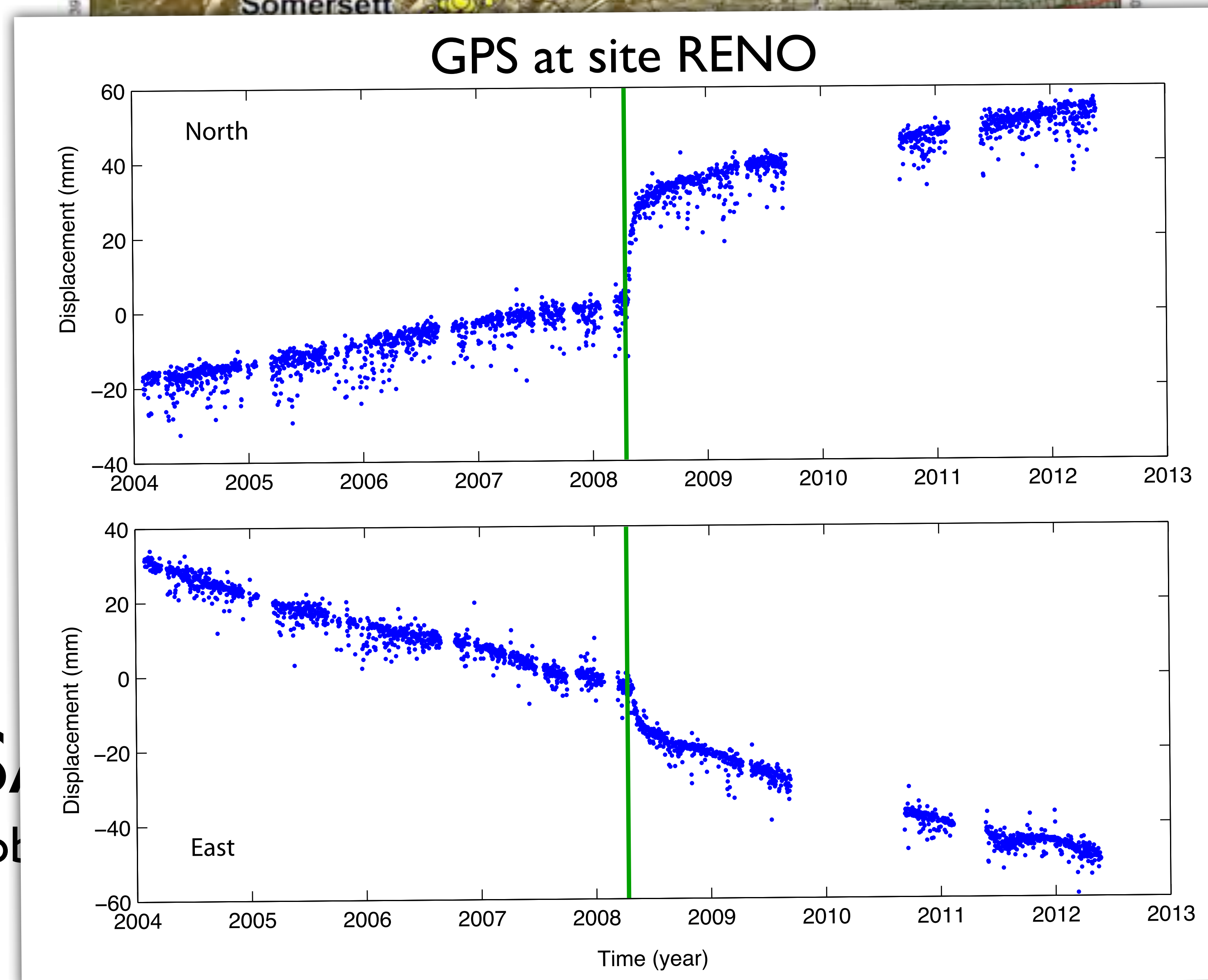

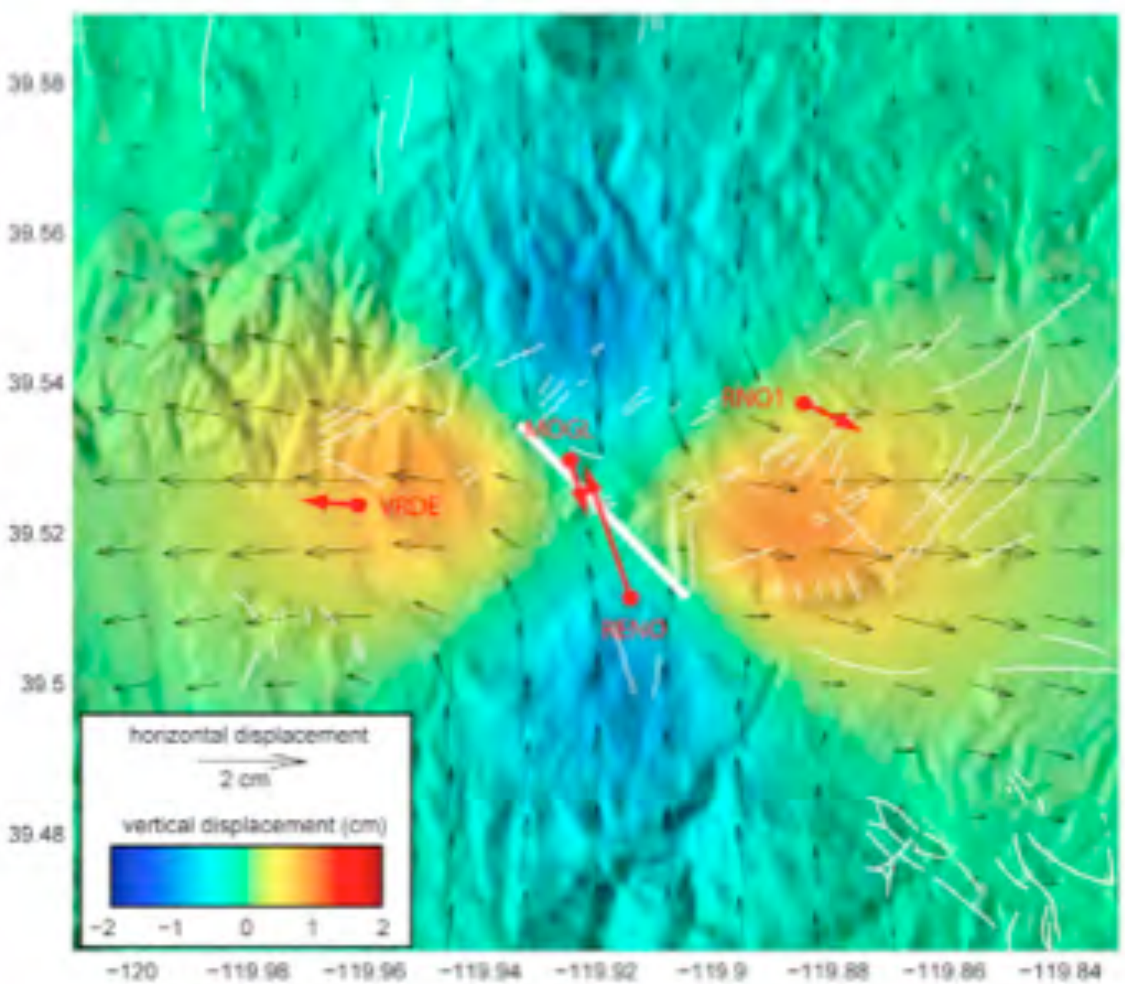

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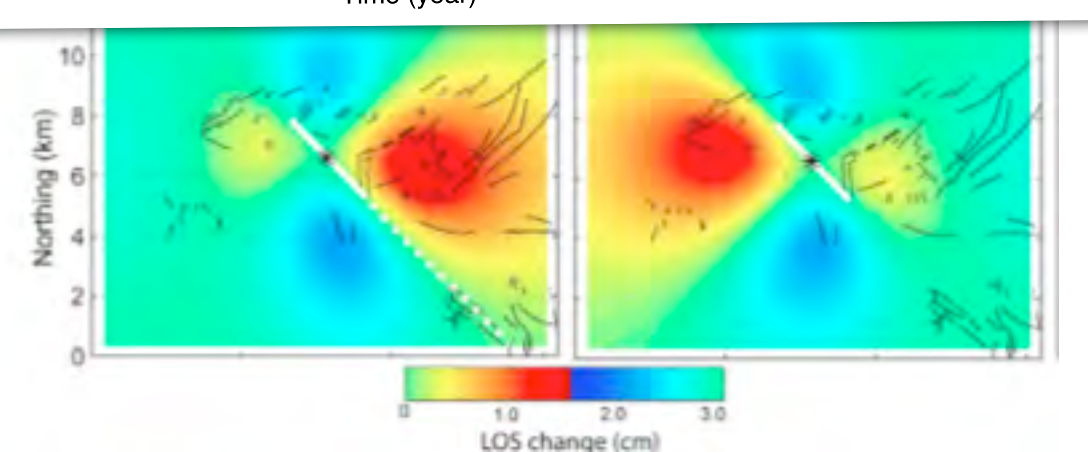
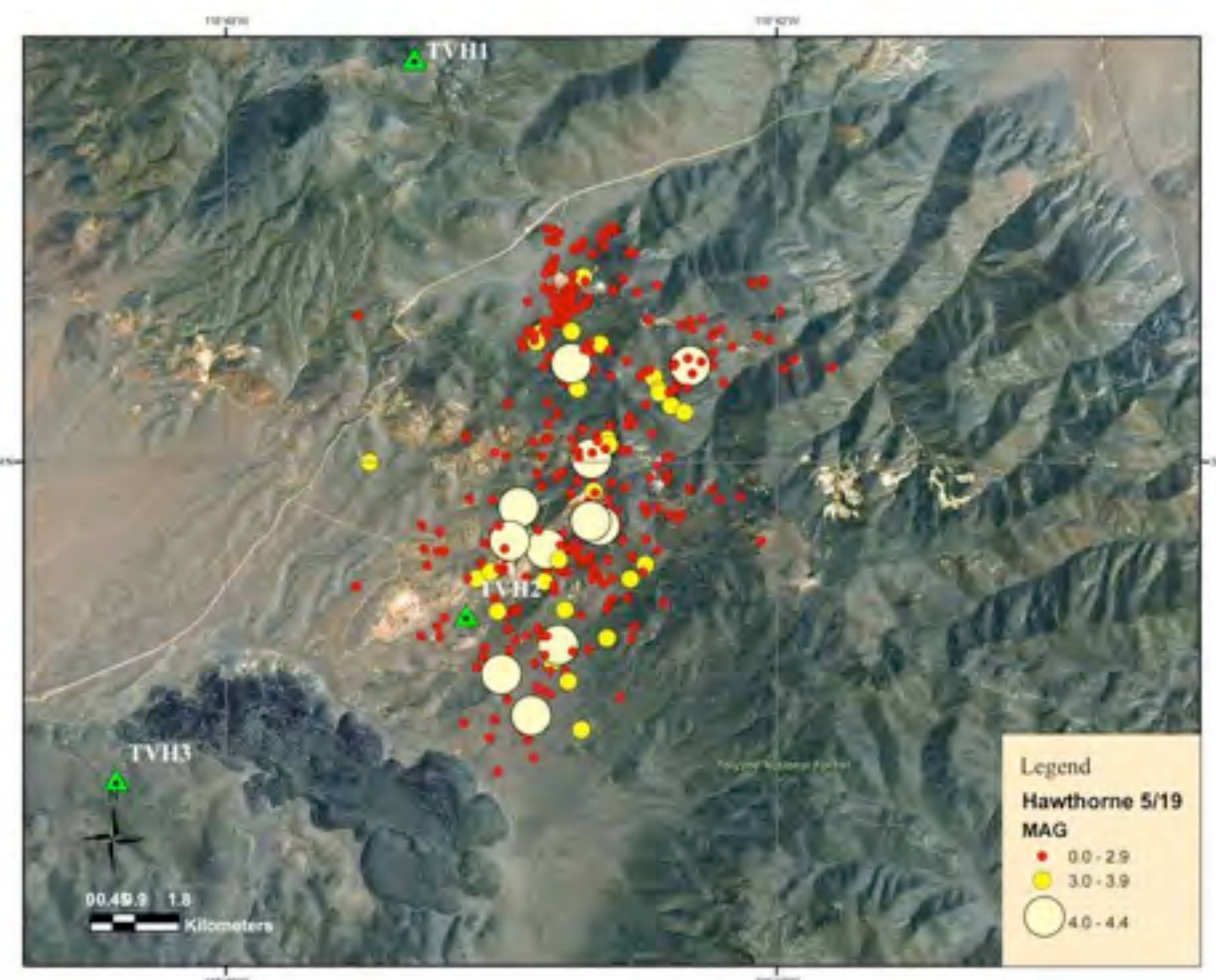
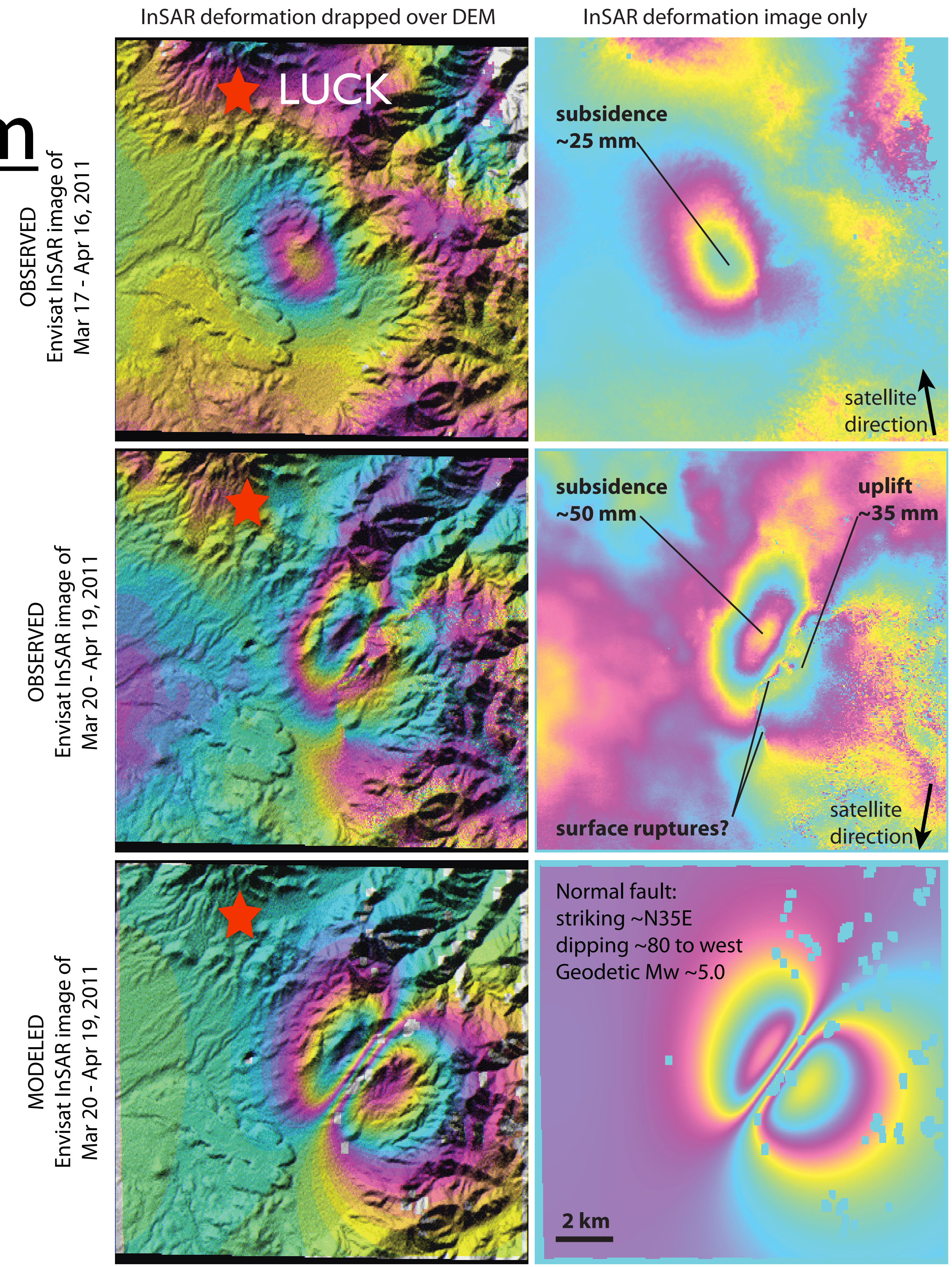
Bell et al. 2012



Case Study 3: 2011 Hawthorne Swarm

- Vigorous seismicity, ~10 M4+ earthquakes.
- Deployed GPS in ~12 existing pre-surveyed MAGNET GPS sites.
- Small but coherent InSAR signal, 25-50 mm
- Barely resolvable, but corroborative 5 mm displacement at GPS site LUCK (6 km away)





Source: US Geological Survey, Volcano Science Center

From Zhong Lu, USGS

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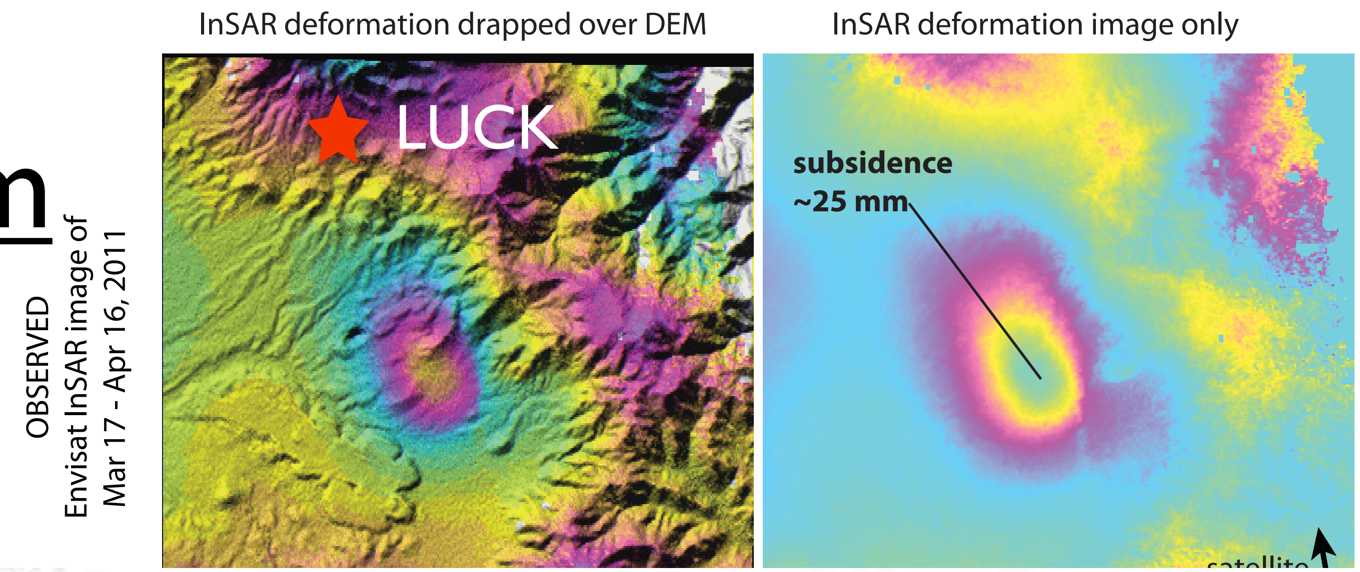
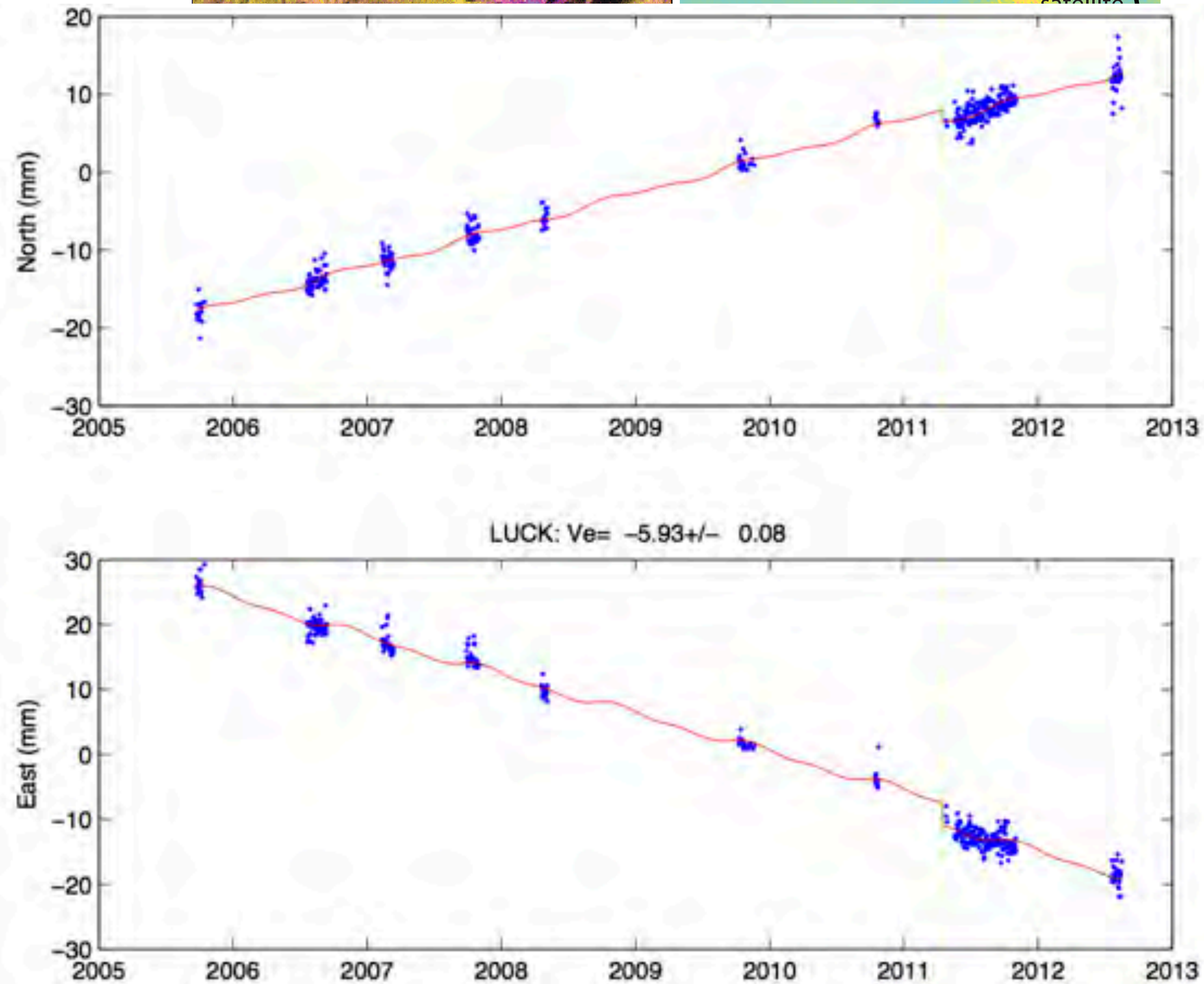
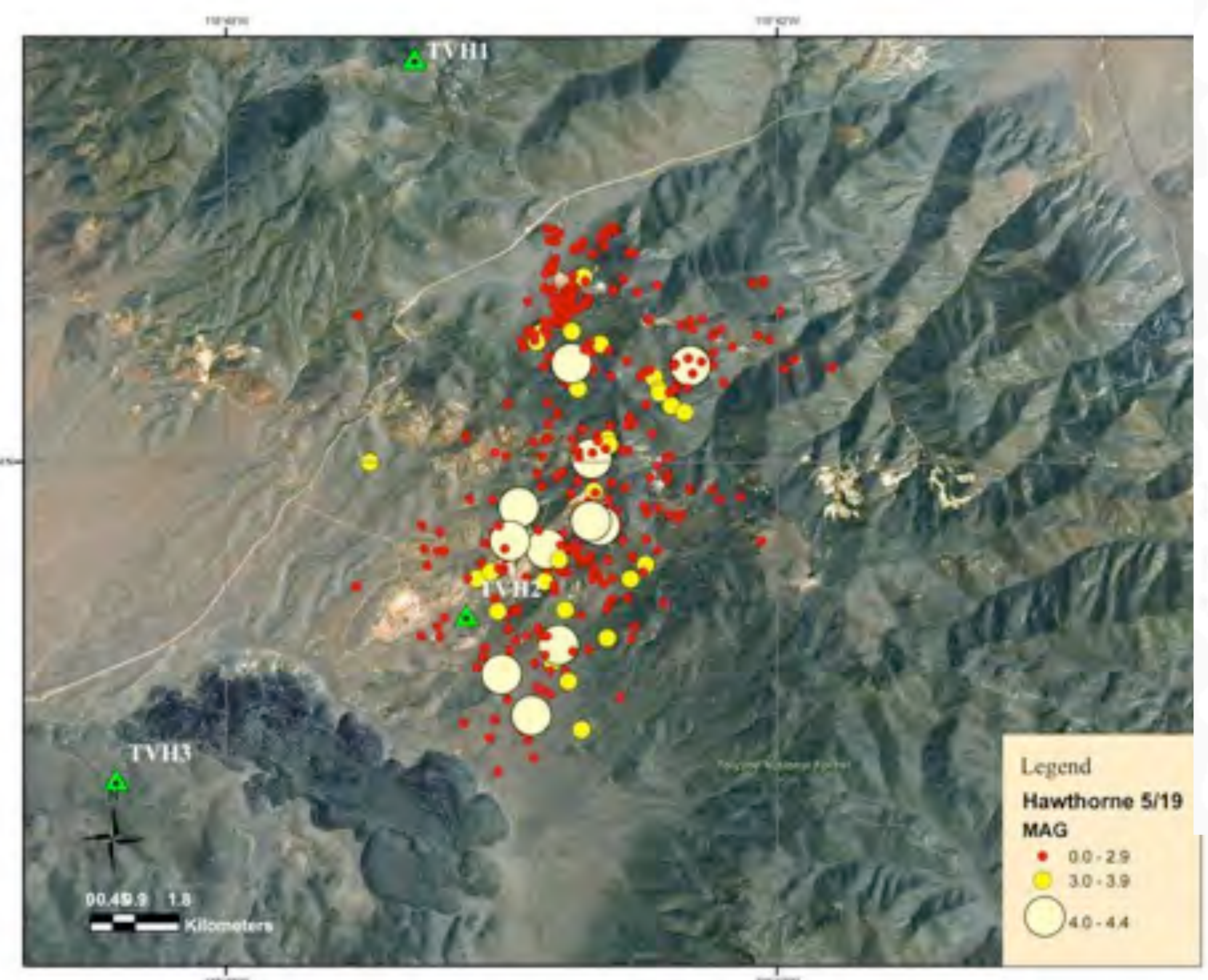






Source: US Geological Survey, Volcano Science Center

From Zhong Lu, USGS

Latency

- Satellite based InSAR is great, but orbit repeat times (and lack of a US satellite mission) limit suitability for rapid event characterization
- GPS networks work best when networks are surveyed before displacements.
- GPS processing latency and precision improving
- New GPS service from UNR, 4000 stations, 5 minute solutions next day delivery.
- Brawley example...

Case Study 4: August 26, 2012 Brawley Swarm

- Example of low latency GPS results (next day)
- Processed 5 minute time series and earthquake source parameters from sum of several M5+ events
- e.g. 50 mm offset at P499
- Service now available for 4000 stations globally

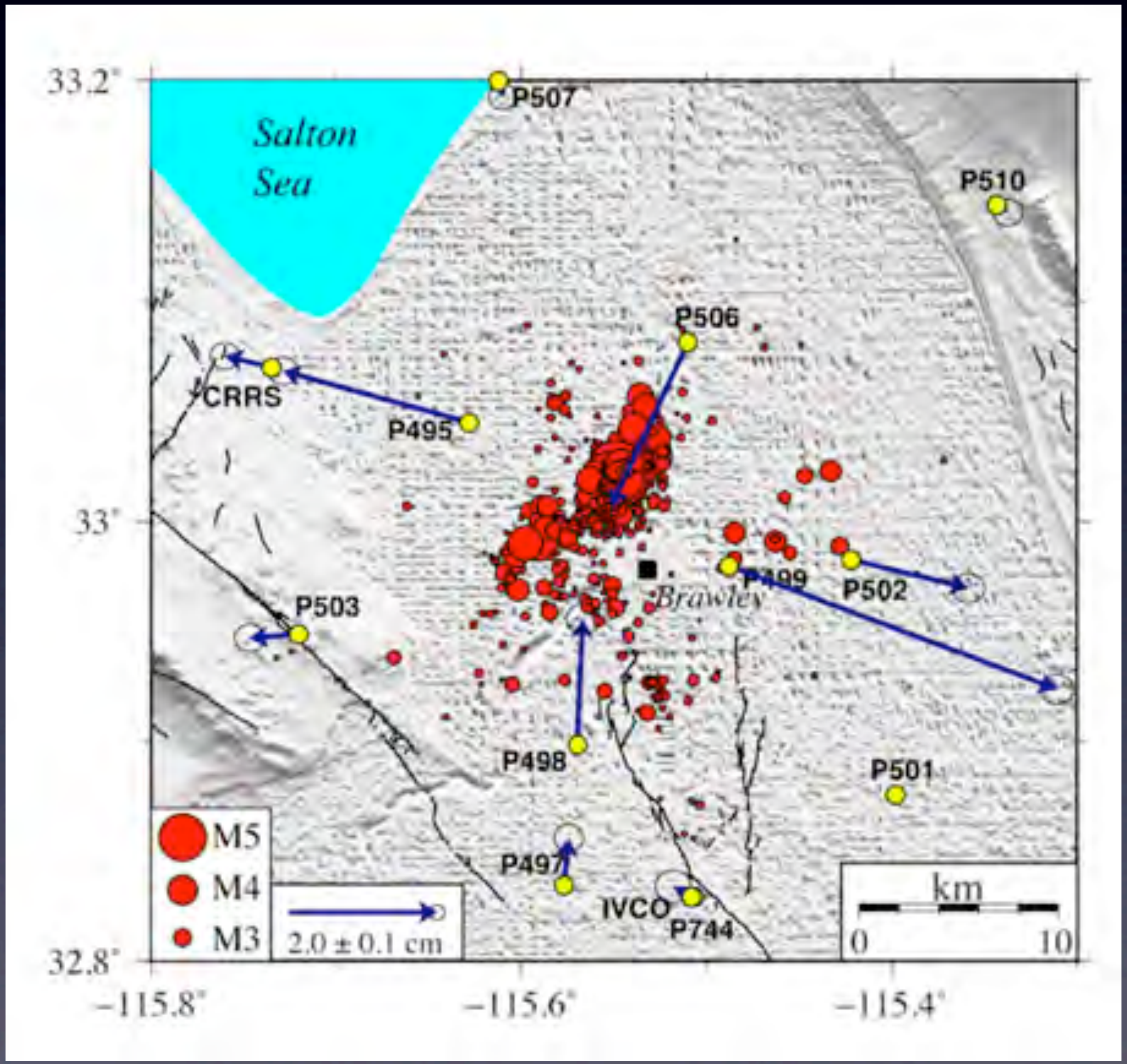
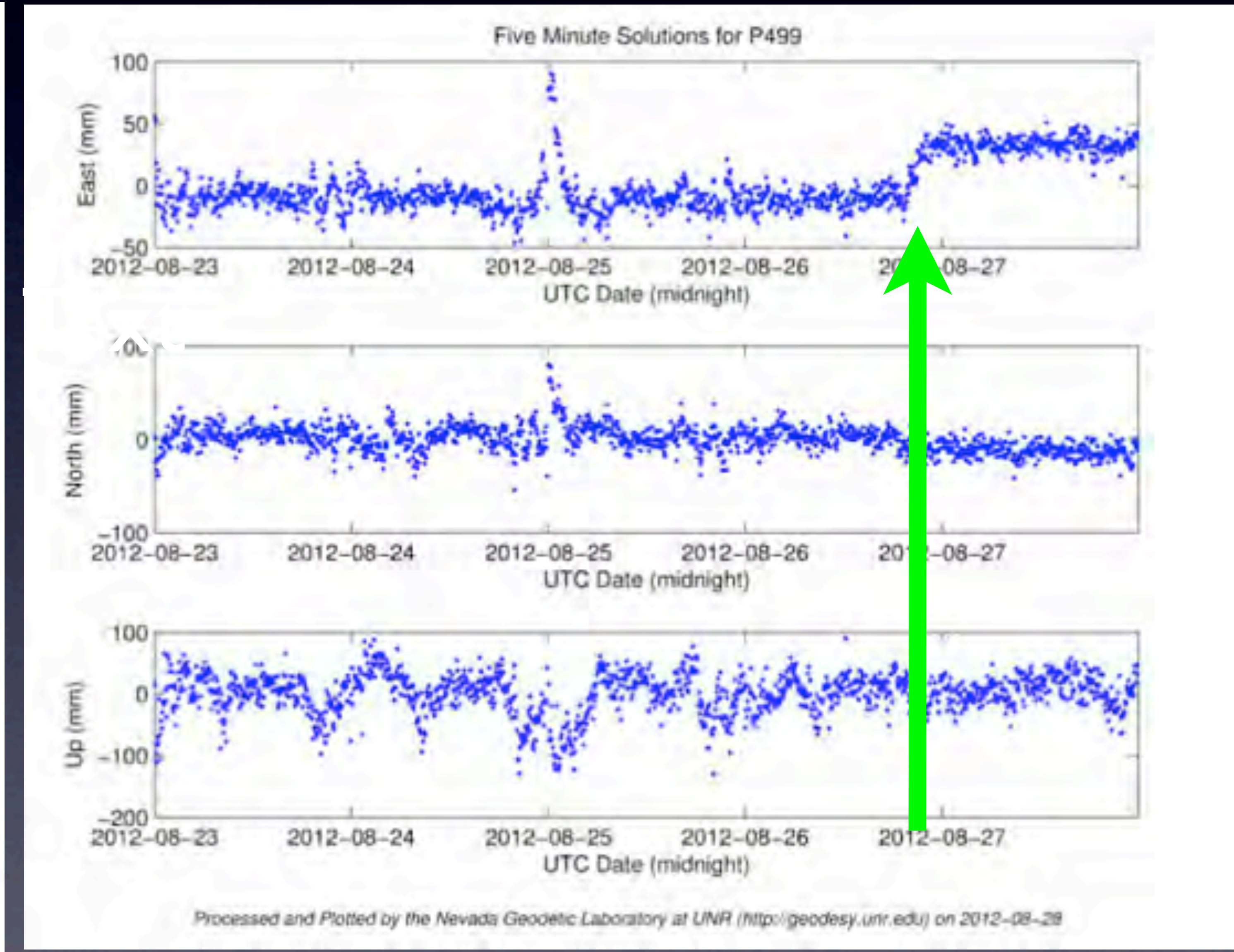


Figure and results from T. Herring (MIT)



Processed next day 5 minute results (G. Blewitt at UNR)

more information at: http://www.unavco.org/highlights/2012/brawley.html

Which Events Were Magmatic?

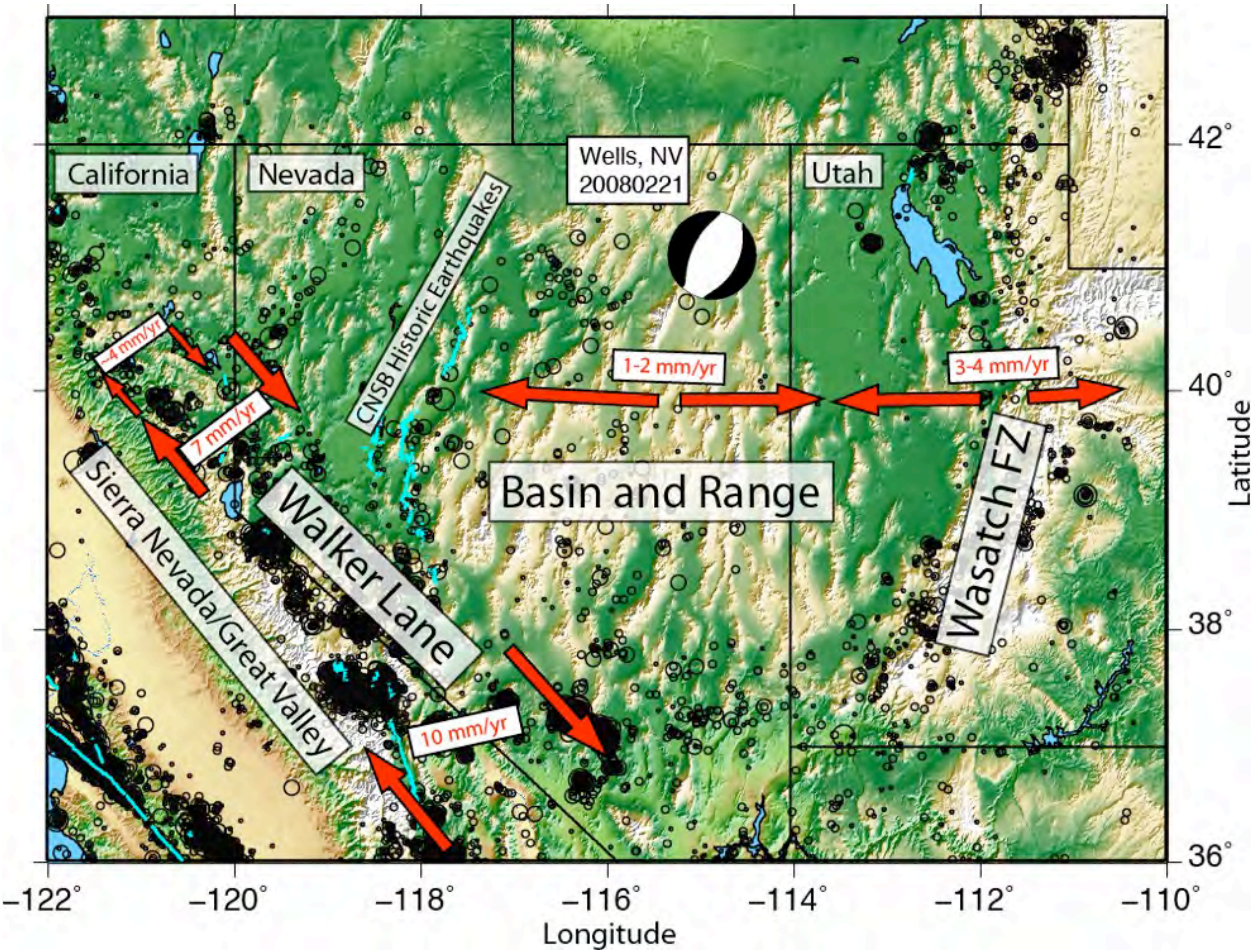
Relationship between geodetic displacement and seismic moment can be diagnostic of magmatic component.

	$M_{geodetic} > M_{seismic}$?	Inflation?	Magmatic?
Slide Mtn.	Y	Y	Y
Mogul	Y	N	N
Hawthorne	N	N	N
Brawley	N	N	N

Conclusions

- Magmatism and volcanism can happen away from the large (well instrumented) volcanic centers. A flexible observation strategy is needed.
- Geodesy can measure the small deformations associated with magmatic movements, and provide important diagnostics to recognize magmatism (e.g. Slide Mountain).
- InSAR offers valuable blanket coverage, but latency can be weeks to months (need a US mission).
- GPS has mm precision, but requires pre-surveys in ground networks. Low latency possible, but telemetry is needed.

Questions?

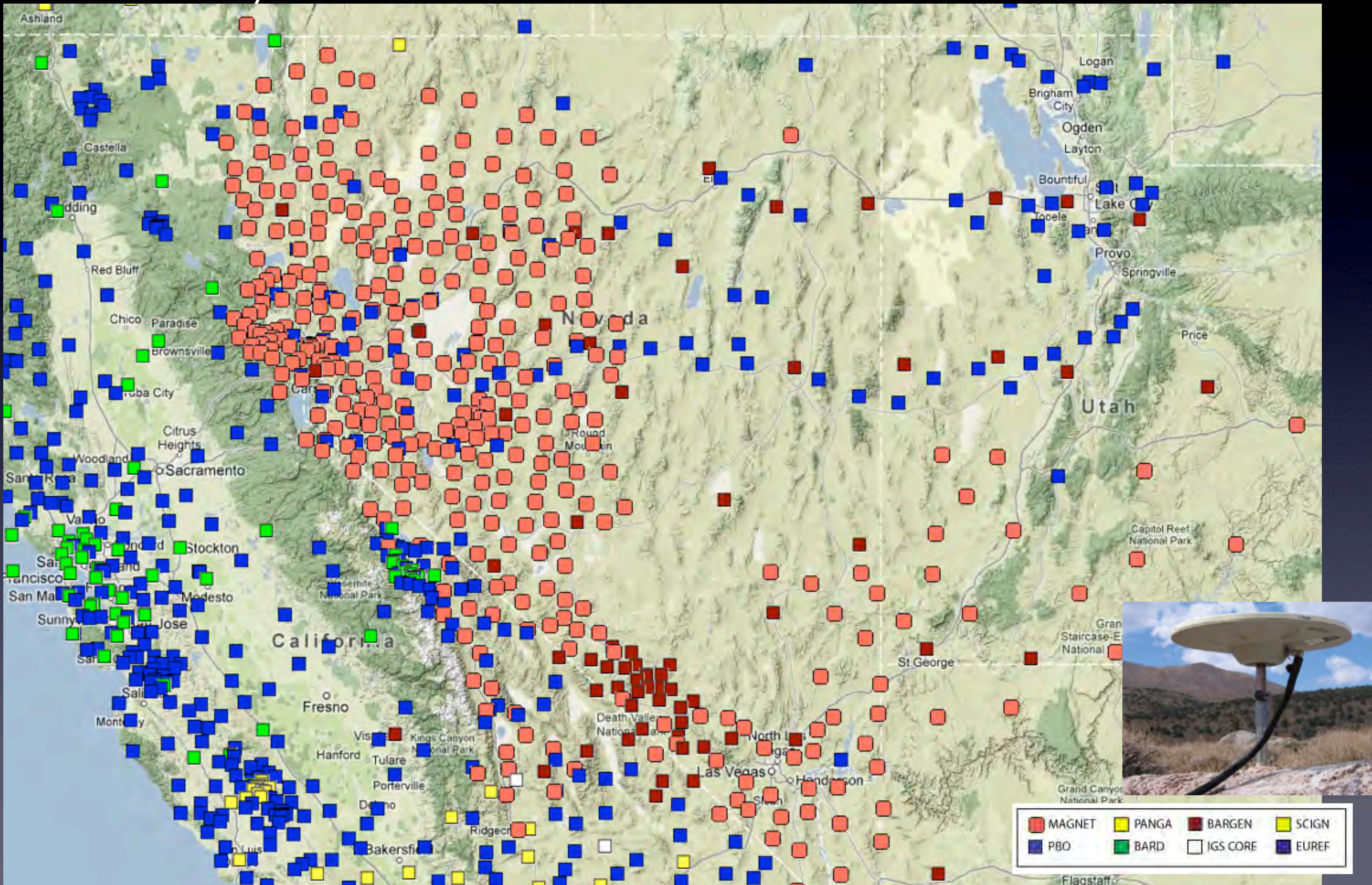

California
Nevada
Wells, NV
20080221
Utah
CNSB Historic Earthquakes
~4 mm/yr
7 mm/yr
1-2 mm/yr
3-4 mm/yr
Basin and Range
Walker Lane
Wasatch FZ
Sierra Nevada/Great Valley
10 mm/yr
42°
40°
38°
36°
Latitude
−122°
−120°
−118°
−116°
−114°
−112°
−110°
Longitude

MAGNET: The Mobile Array of GPS for Nevada Transtension

MAGNET*

http://geodesy.unr.edu

* the Mobile Array of GPS for Nevada Transtension



Great Basin GPS velocity field reveals relationship to the Pacific/North America plate boundary

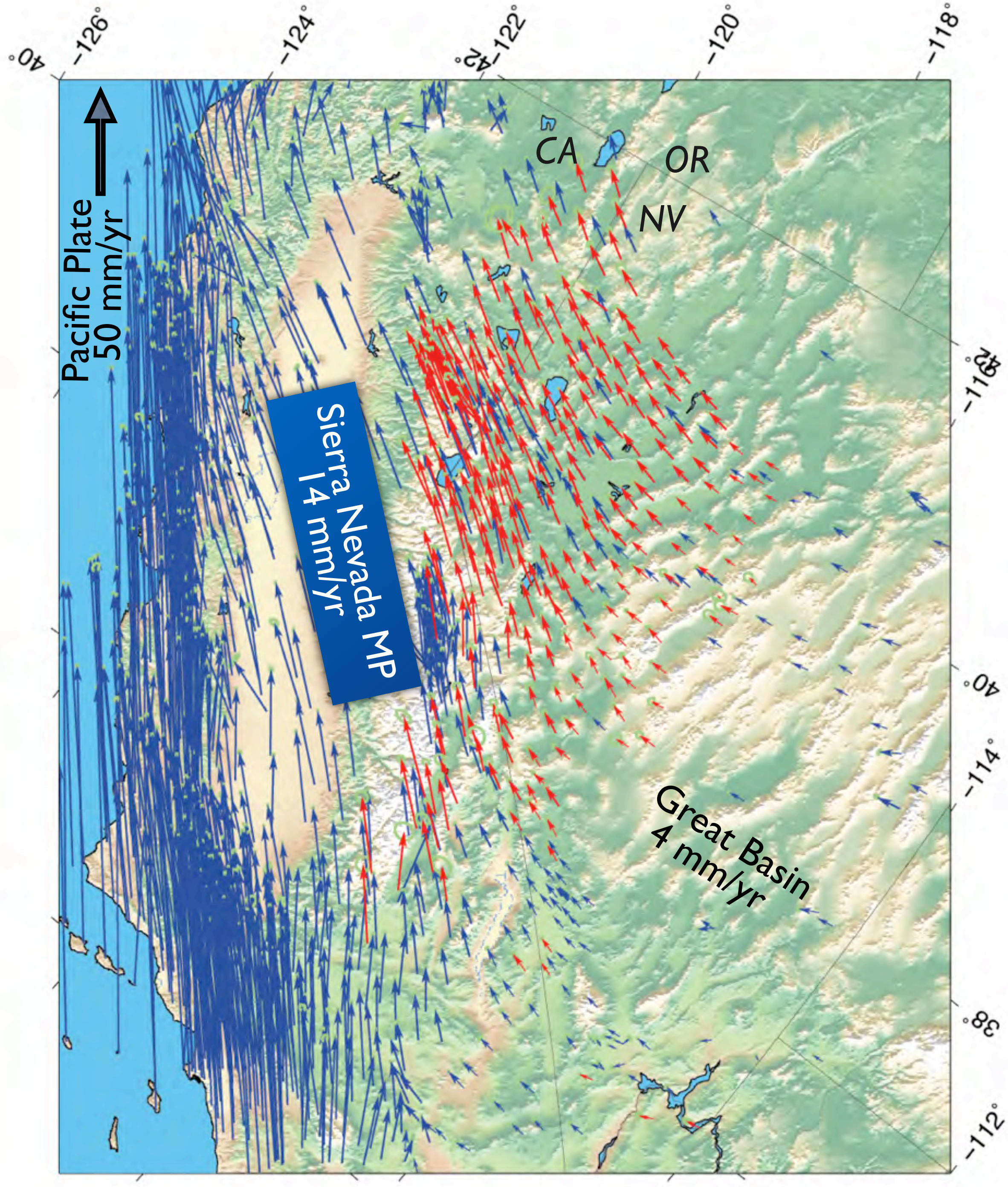
- San Andreas - Sierra Nevada/Great Valley microplate - Walker Lane - GB

- Walker Lane is an intracontinental shear zone, with a small component of extension.

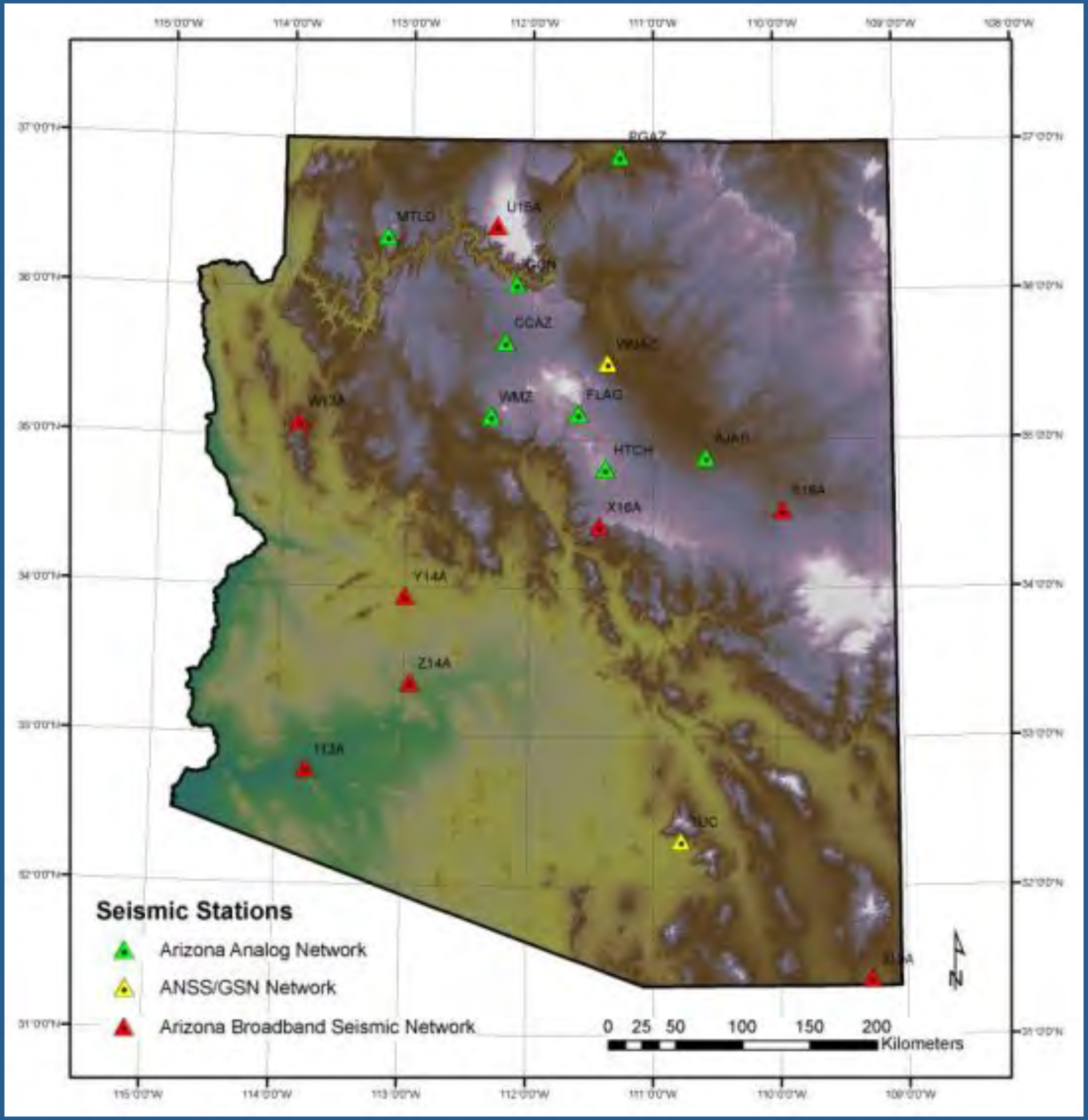
- Extension in Basin and Range

blue = continuous GPS stations
red = MAGNET semi-continuous

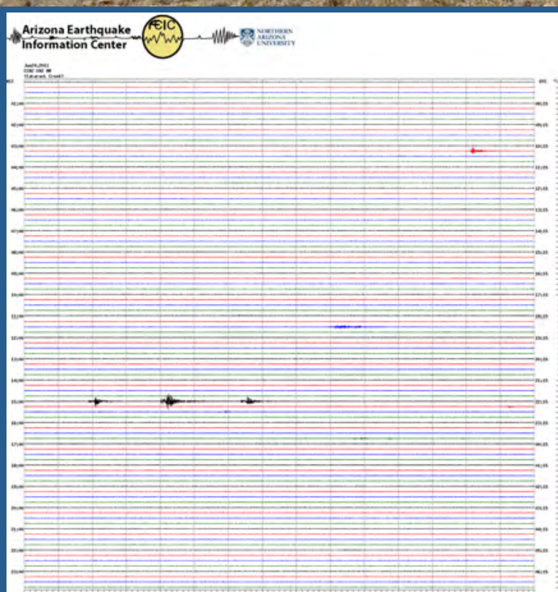
- Velocities in North America fixed reference frame



Arizona Integrated Seismic Network




2001 2 21


Arizona Earthquake
Information Center
AEIC

Clockwise from above: installation of a TA station. Completed station with components buried and only the transmit antenna and solar panel visible. AISN broadband station U15A north of the Grand Canyon.

Responding to a volcanic crisis in the southwestern U.S.

Rick Aster, New Mexico Tech

Volcanoes present a wide variety of eruption and risk/hazard scenarios, but these are some common threads related to monitoring.

- *Detection.* Volcanic regions in the southwestern U.S. (and globally, for that matter) are generally poorly monitored, and initial precursors may be small. The first early warning of activity may come from incidental information (e.g., reports of unusual phenomena from local residents and special follow-up by the scientific community). Existing regional networks (designed to monitor larger earthquakes over regional scales) will be of limited use once localized activity is confirmed.

- *Initial Response.* Upon confirmation of potential magmatic activity, Information flow will depend critically on our community ability to deploy portable instrumentation and collect and analyze locally acquired data (e.g., from seismographs, tiltmeters, GPS, gas, repeated LIDAR, etc.). Such instrumentation is available from NSF/university consortium (IRIS) and USGS sources but may not be optimally configured for this task.

- *Continued Response.* Near-real time monitoring and assessment of activity will require telemetered networks and a dedicated assessment and response team for both scientific interpretation and potential action. The longer-term dedication of such resources during what could be a protracted crisis will require non-routine resources to sustain.

Capabilities of University of Utah Seismograph Stations for Monitoring Seismicity in Utah

Keith Koper, Kris Pankow, Relu Burlacu, Katherine Whidden, Jim Pechmann, Mark Hale, and Paul Roberson

UUSS
UNIVERSITY OF UTAH SEISMOGRAPH STATIONS
quake.utah.edu

October 18, 2012

UUSS Fast Facts

UUSS is a research, educational, and public service entity within the University of Utah that is dedicated to understanding earthquakes and earthquake hazards in the Intermountain West.

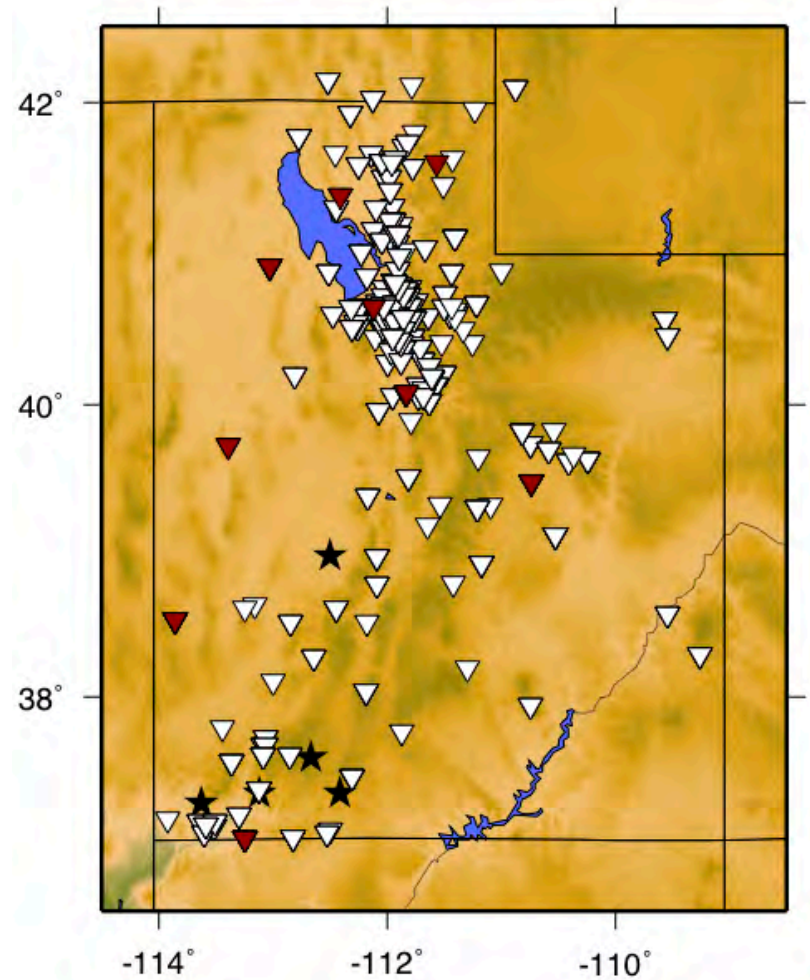
UUSS was founded in 1966.

For FY12-13 there are 12.083 FTE and approximately another 12 hourly workers.

Operational funding is approximately 45% state of Utah, 55% USGS for activities in Utah.

UUSS operates a second seismic network in Yellowstone under a separate USGS contract (27 stations recording 96 channels).

194 Seismic Stations Recording 642 Channels of Data at 100 sps



9 Infrasound Stations Recording 36 Channels of Data at 100 sps

"Regional" and "Urban Strong Motion" Stations

(22 cm diam., 18 cm high)

similar in size to bowling ball

UUSS Capabilities

(1) *Nearly all events larger than M3 in Utah are automatically detected, located, and publicized within 10 minutes of OT.*

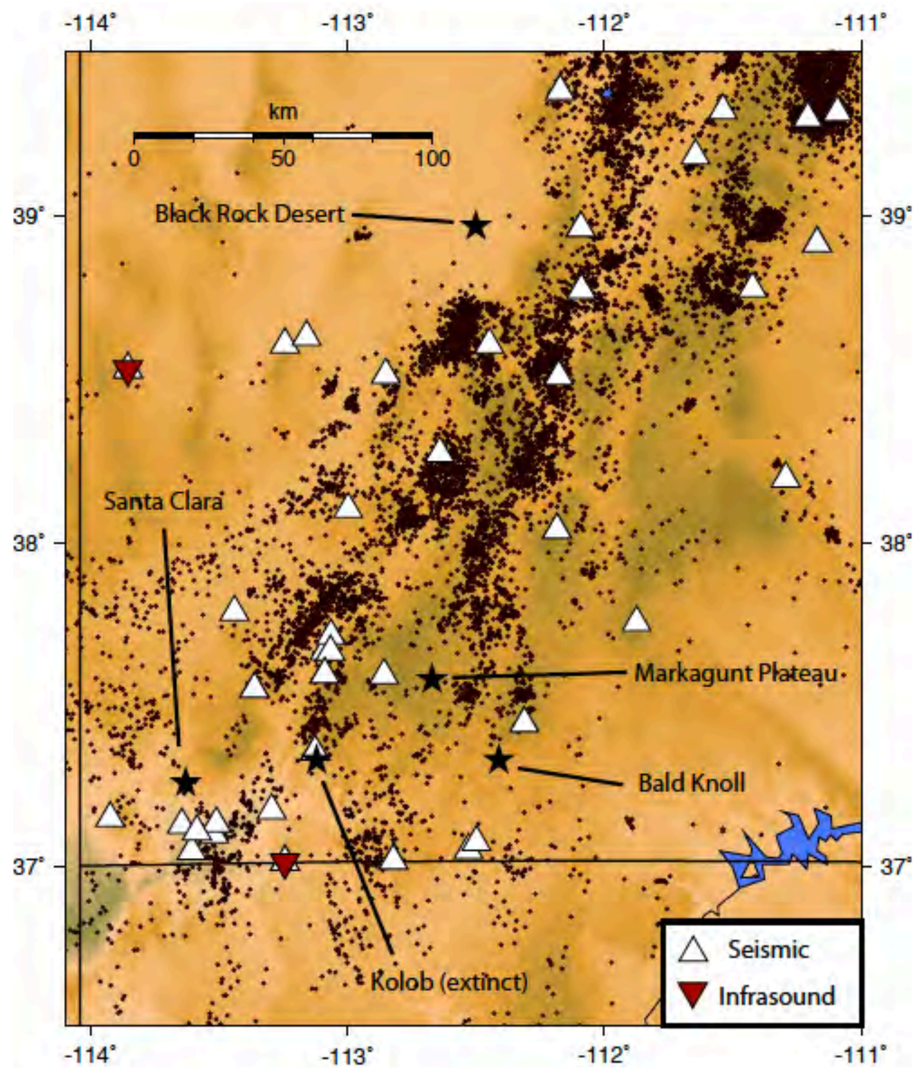
(2) *A duty seismologist is on-call 24/7, via pager, to review and update the automatic solutions.*

(3) *Detection threshold for seismic events is M1.5 for the Intermountain Seismic Belt and M2-2.5 for other regions in the state.*

(4) *Full moment tensor inversion is routinely done for events M>3.5. This includes statistical tests on the significance of any isotropic component.*

(5) *Data from nine infrasound arrays are currently telemetered in near-real-time to the UUSS data center.*

(6) *UUSS maintains ~ 6 portable, analog, short-period, seismometers that could be deployed rapidly to a volcanic area.*



Volcanic Ash Impacts to Aviation

Jeff Osiensky

Aviation and Volcanic Ash Program Manager, NWS Alaska Region - Anchorage

Scott Birch

Regional Aviation Meteorologist, NWS Western Region – Salt Lake

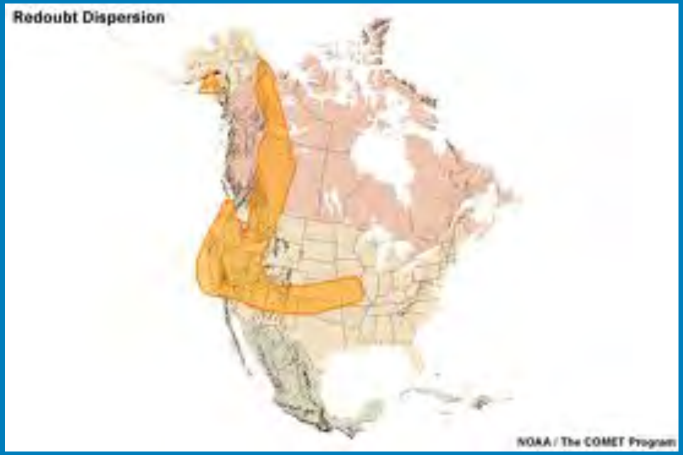
Volcanism in the American Southwest
USGS Flagstaff
October 19, 2012

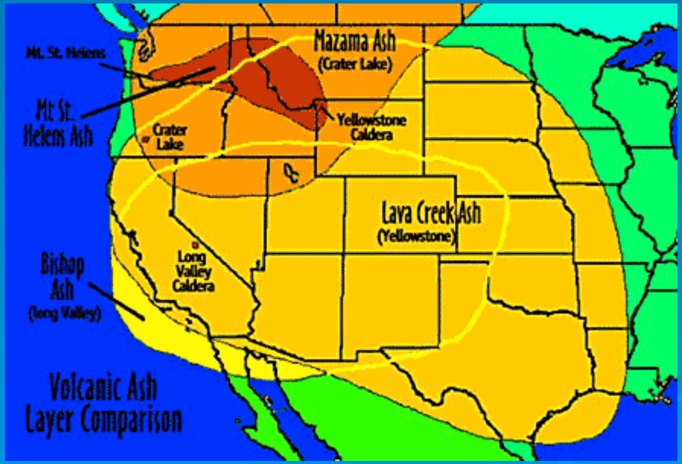
Types of Hazards

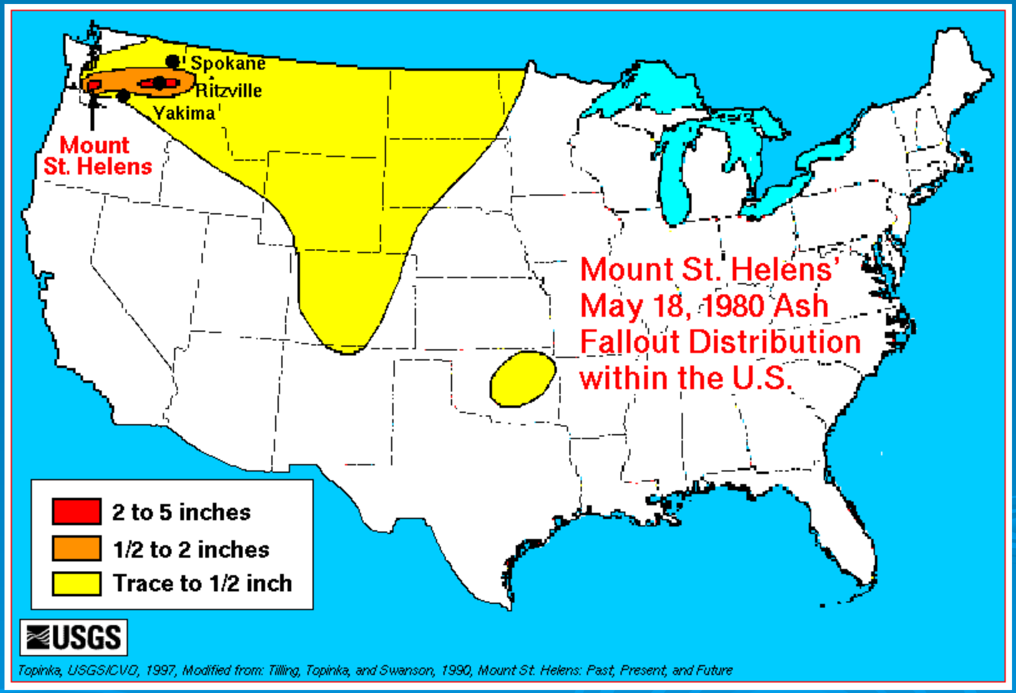
- Distal (Distant)
  - Airborne ash cloud over 100s to 1000s of km
  - Thinning, lower concentrations, sets up in layers
  - Impact: based upon exposure
- Proximal (Nearby)
  - Fallout, airborne hazards
  - Higher concentrations with larger particle sizes
  - Other hazards such as significant ash deposition, lahars, ?

Observations, Modeling

Large U.S. Eruptions



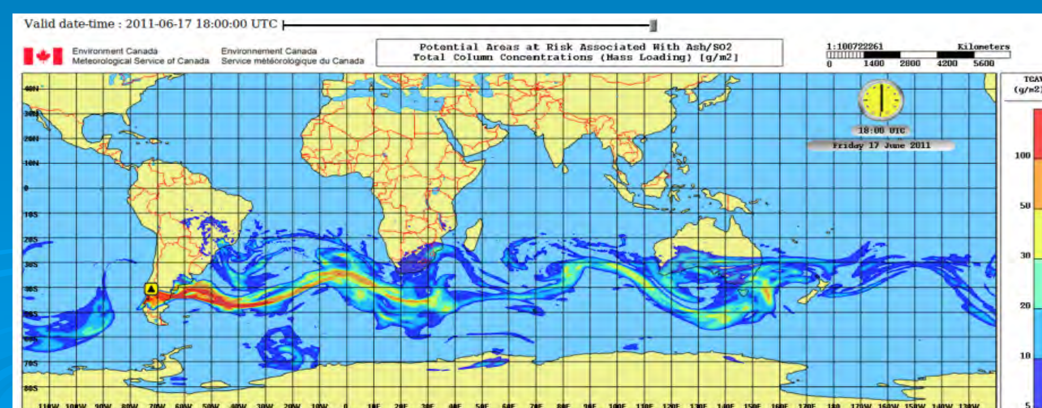




International Eruptions

- Cordon Caulle, Chile
  June 2011

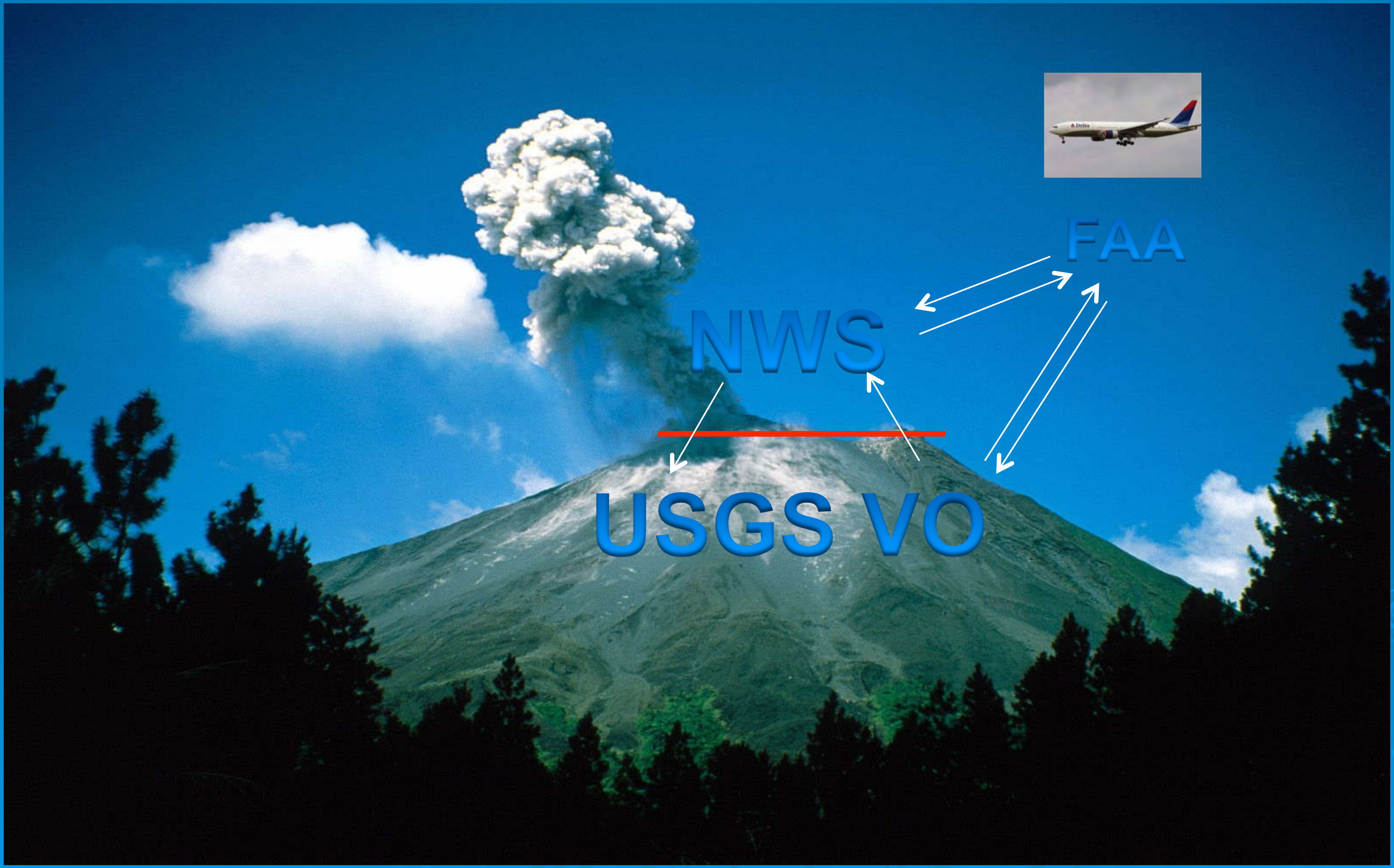


Impacts to Aviation

- Abrasion to windscreen and airframe
- Clogging of the pitot tubes (intakes) which causes instrumentation to fail
- Ash/SO_2 makes its way into the cabin
- Radio interference
- High concentrations cause engines to seize

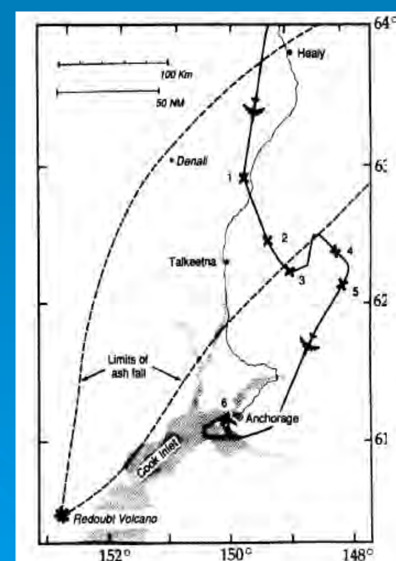
Responsibilities



Mt. Redoubt – December 1989

- [Mt Redoubt]

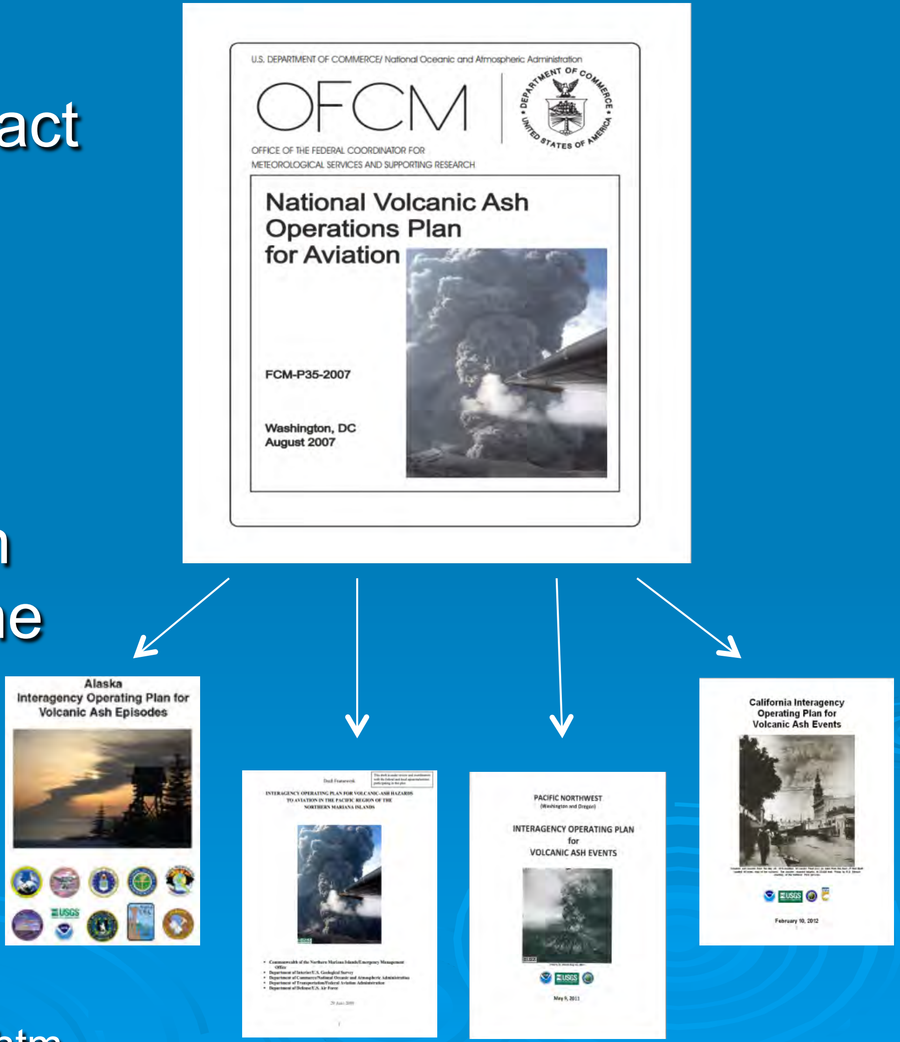
General map of south-central Alaska showing the location of Redoubt Volcano and other Quaternary volcanoes in the Cook Inlet region.



Map showing position of KLM flight path (heavy solid line) and limits of detectable ash fall (heavy dashed lines) from December 15, 1989 eruption of Redoubt Volcano. Times (AST) of principal events for KLM Flight 867 include: *1*=11:40, airplane begins descent from 35,000 feet; alters course to avoid ash cloud. *2*=11:46, airplane encounters ash cloud at 25,000 feet. *3*=11:47, airplane loses power on all 4 engines after climbing to 27,900 feet. *4*=11:52, airplane engines 1 and 2 restart at 17,200 feet. *5*=11:55, airplane engines 3 and 4 restart at 13,300 feet; resumes flight to Anchorage. *6*=12:25, airplane lands at Anchorage International Airport. Map modified from flight route data provided by National Transportation Safety Board (1990) and FAA Flight Standard Division, Anchorage.

Volcanic Ash Response Plans

- Government agencies
- Low frequency – high impact event
- Plan defines roles & responsibilities
- USGS/NWS exploring response plans for all high impact volcano areas in the U.S.



http://www.ofcm.gov/p35-nvaopa/fcm-p35.htm

Agency Responsibilities California Plan

Responsible Agency/Office	Volcanic Ash Emergency Responsibilities
USGS CALVO	• Initiate emergency call downs • Change aviation color code to RED • Extend to 24/7 operations • Technical experts for the media and public
NOAA W-VAAC	• Issue VAA • Run HYSPLIT model • Coordinate with CALVO, MWO/AWC and adjacent VAACs
NOAA MWO/AWC	• Issue volcanic ash SIGMET • Coordinate with W-VAAC, CWSU and FAA
FAA ARTCC	• Issue NOTAM • Provide SIGMET to Flight Crews • Solicit PIREPs
CALEMA	• Provide information statements to the public and operational areas • Coordinate with participating agencies via California State Emergency Plan
NOAA/NWS WFO	• Issue public and marine ashfall advisories and warnings • Notify Air Traffic Control Towers in the vicinity of volcano and/or ash • Technical experts for ash trajectory and wind forecasts

Stakeholders

- NOAA/National Weather Service
- USGS Volcano Observatories
- Federal Aviation Administration
- Dept. of Defense
- State Emergency Management Agencies

Questions?

Lassen Peak May 22, 1915

USGS
science for a changing world

Modeling Mafic Lava Flows with an Eye to Emergency Response

Laszlo Kestay (formerly Keszthelyi)

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

Take Home Message

All Models are wrong.

Some are useful.

Outline

Key Questions Considered

- Size and speed of evacuation required?
- When and where can reconstruction start?

Three real world examples of lava hazards

Cooling Models

Lava Advance Models

Conclusions

USGS

Real World Examples

- Kalapana, HI
  - ~180 structures destroyed over 11 months by tube-fed inflated pahoehoe flows.
- Zafferana, Sicily
  - Tube and channel-fed aa flow subjected to many lava diversion attempts with some success over 11 months.
- Goma, Congo
  - Fissures spread into city within hours. Eruption lasts only a few days. ~147 dead, thousands of building destroyed, hundreds of thousands displaced.

USGS

Real World Examples

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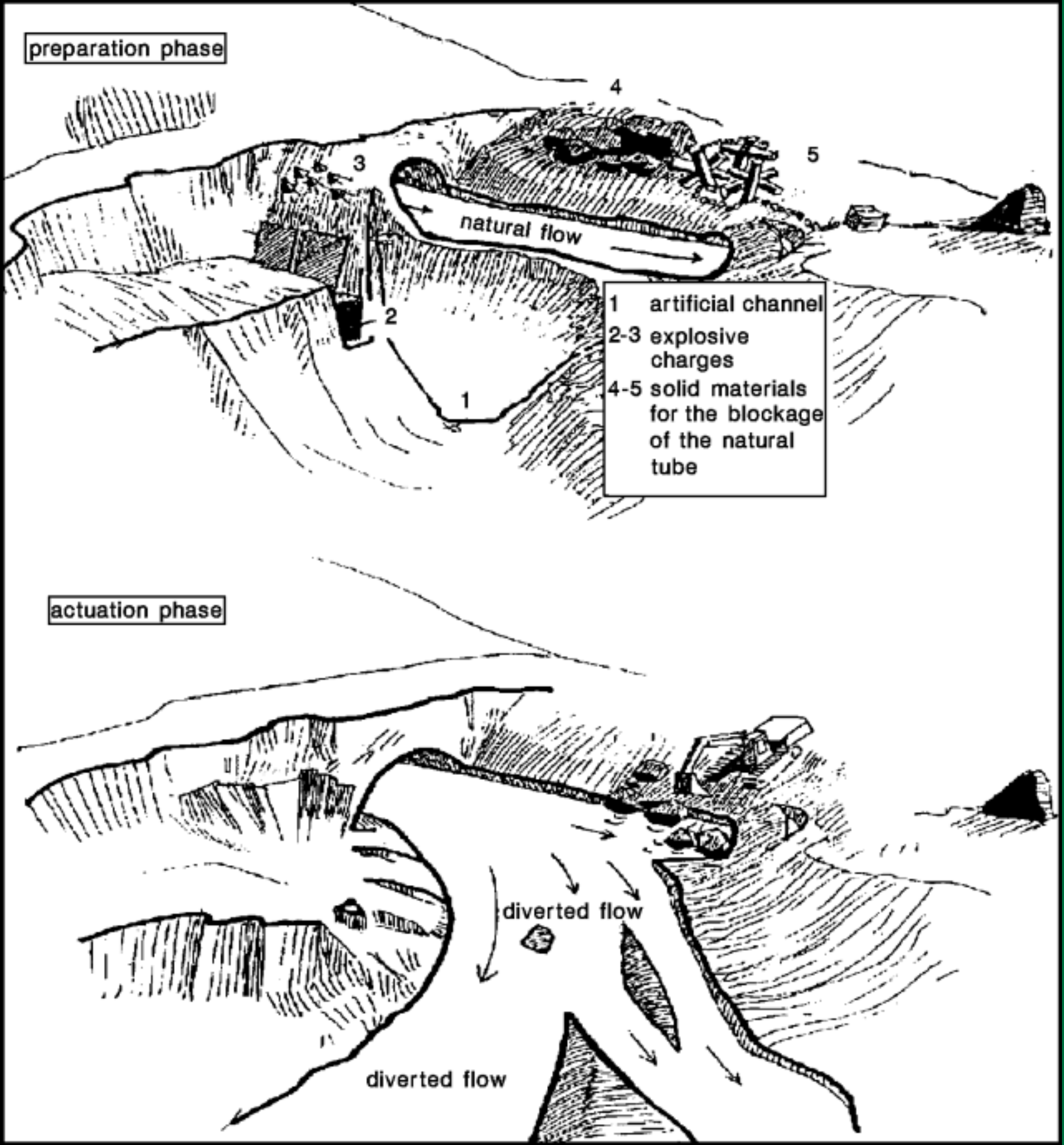
USGS



preparation phase
4
3
5
natural flow
2
1
1 artificial channel
2-3 explosive charges
4-5 solid materials for the blockage of the natural tube
actuation phase
diverted flow
diverted flow

Real World Examples

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  - ~180 structures destroyed over 11 months by tube-fed inflated pahoehoe flows.
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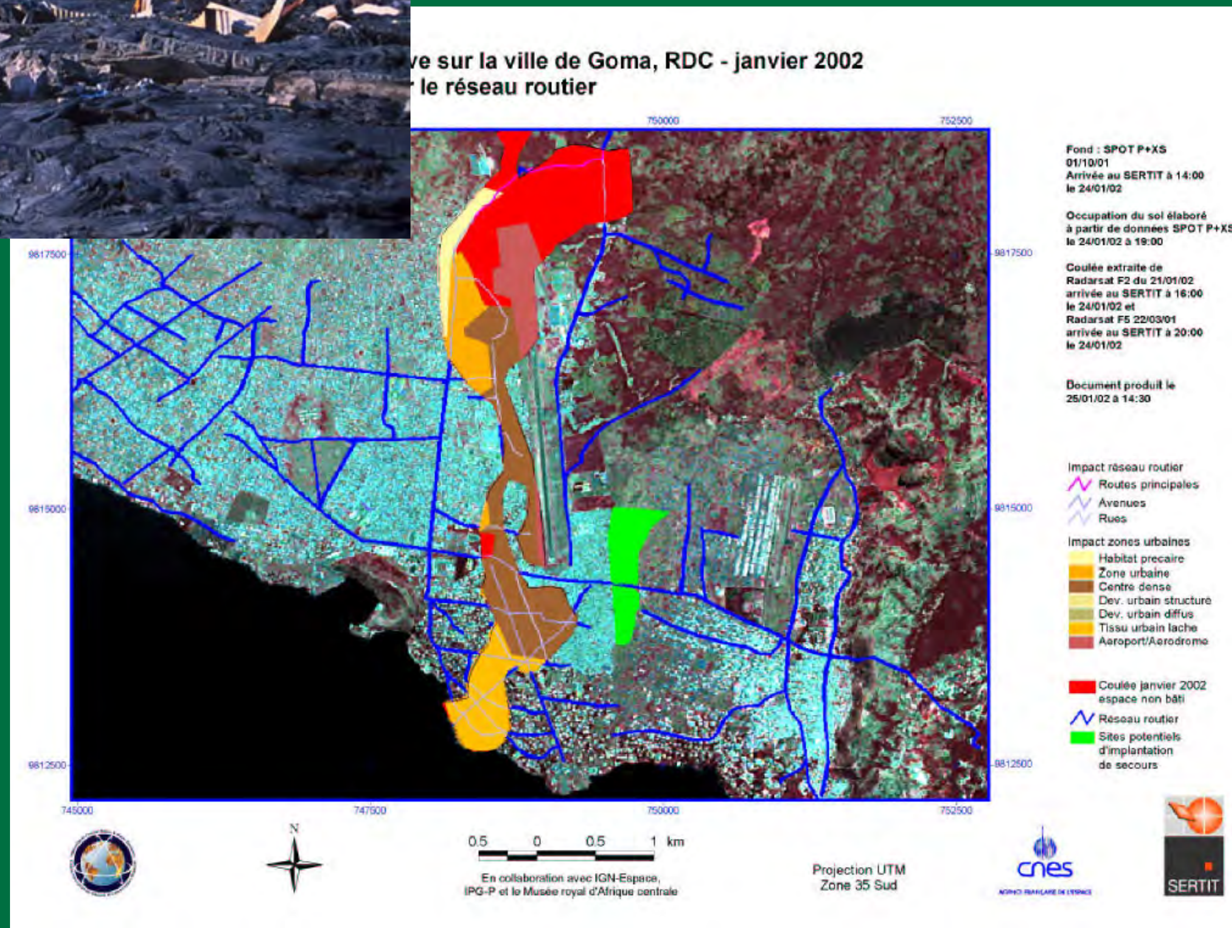


Figure 17: RMS2 product.

USGS

When can I go home?

You can walk on top of a lava flow after just a few minutes. But dangers are hidden below.

- Methane explosions from decomposing vegetation.
- Underground stores of fuel or sewage heat slowly and then explode.
- Rain can produce thick steam that can kill people.
- Solid lava can be hot enough to soften and destroy bulldozer treads.

USGS

USGS

Lava Cooling Models

All lava cooling models must consider

- Heat lost by thermal radiation
- Heat lost to the atmosphere
- Heat lost to rain
- Thermal properties of lava – including bubbles!
- Crystallization of the lava

Requires numerical solution but some simple approximations possible. Expect crust to grow as square root of time.

USGS

"Keszthelyi" Lava Cooling Models

- Designed for investigating the cooling of the upper part of pahoehoe lava flows.
- Numerical method is simple but includes many details of lava thermal properties (bubbles, glass formation, crystallization across a temperature range, temperature dependent thermal properties).
- Simple expression for heat loss from boiling rainwater.

USGS

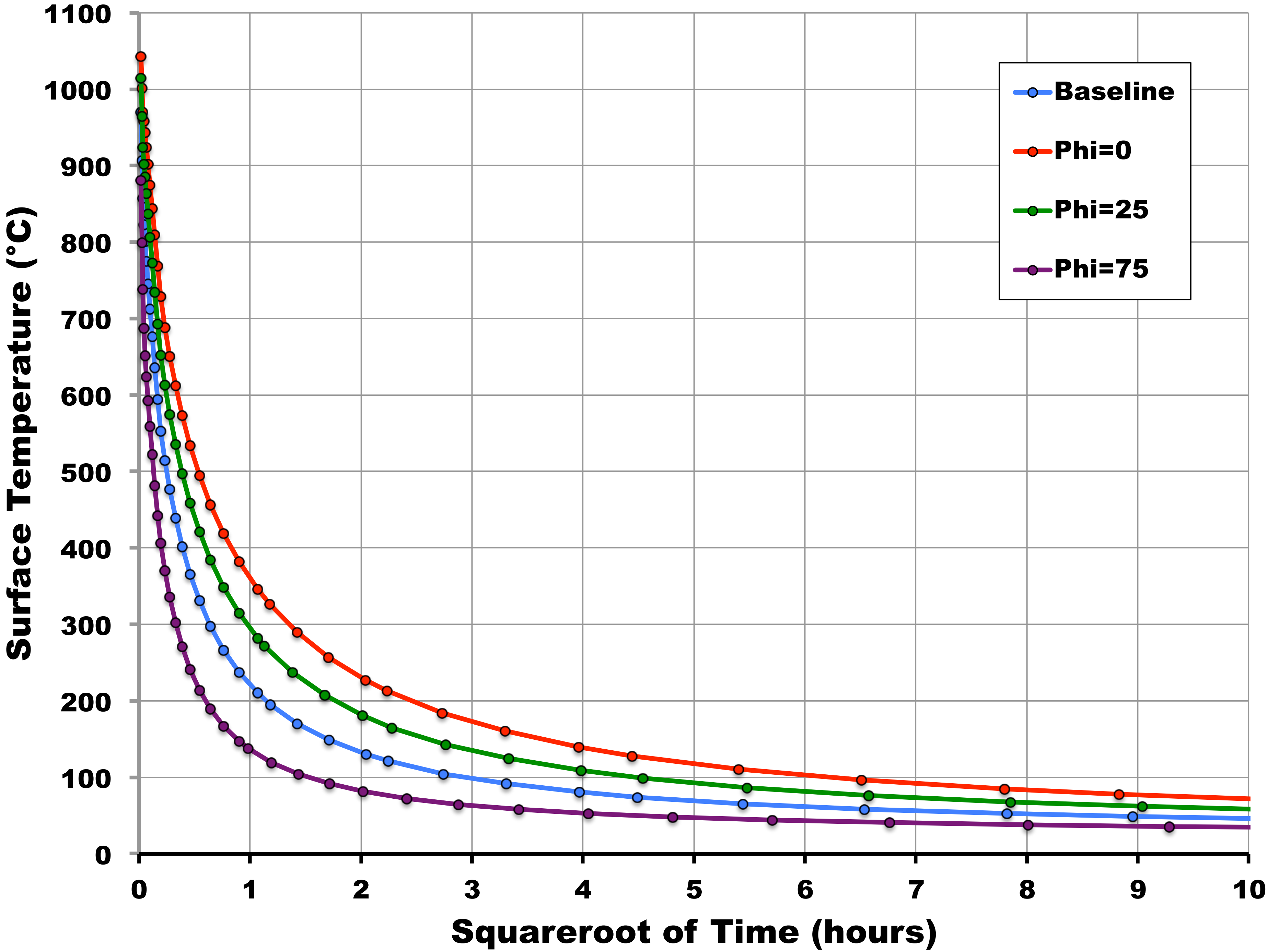
Model Results

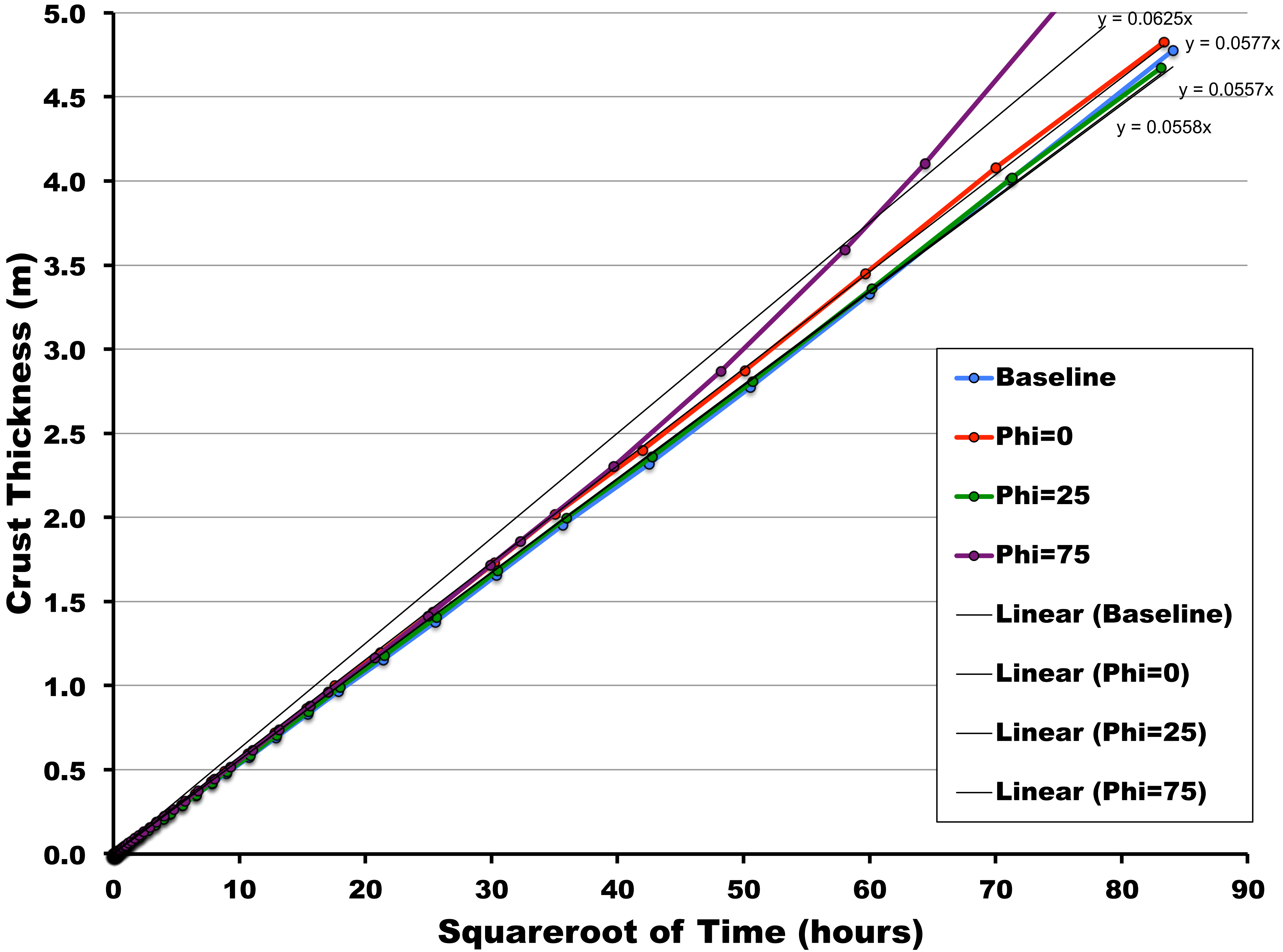
Many parameters, especially bubble content, affect the rate at which the surface cools.

- This has important implications for remote sensing of volcanic eruptions, but the surface will be just warm to the touch in a few days, no matter what.

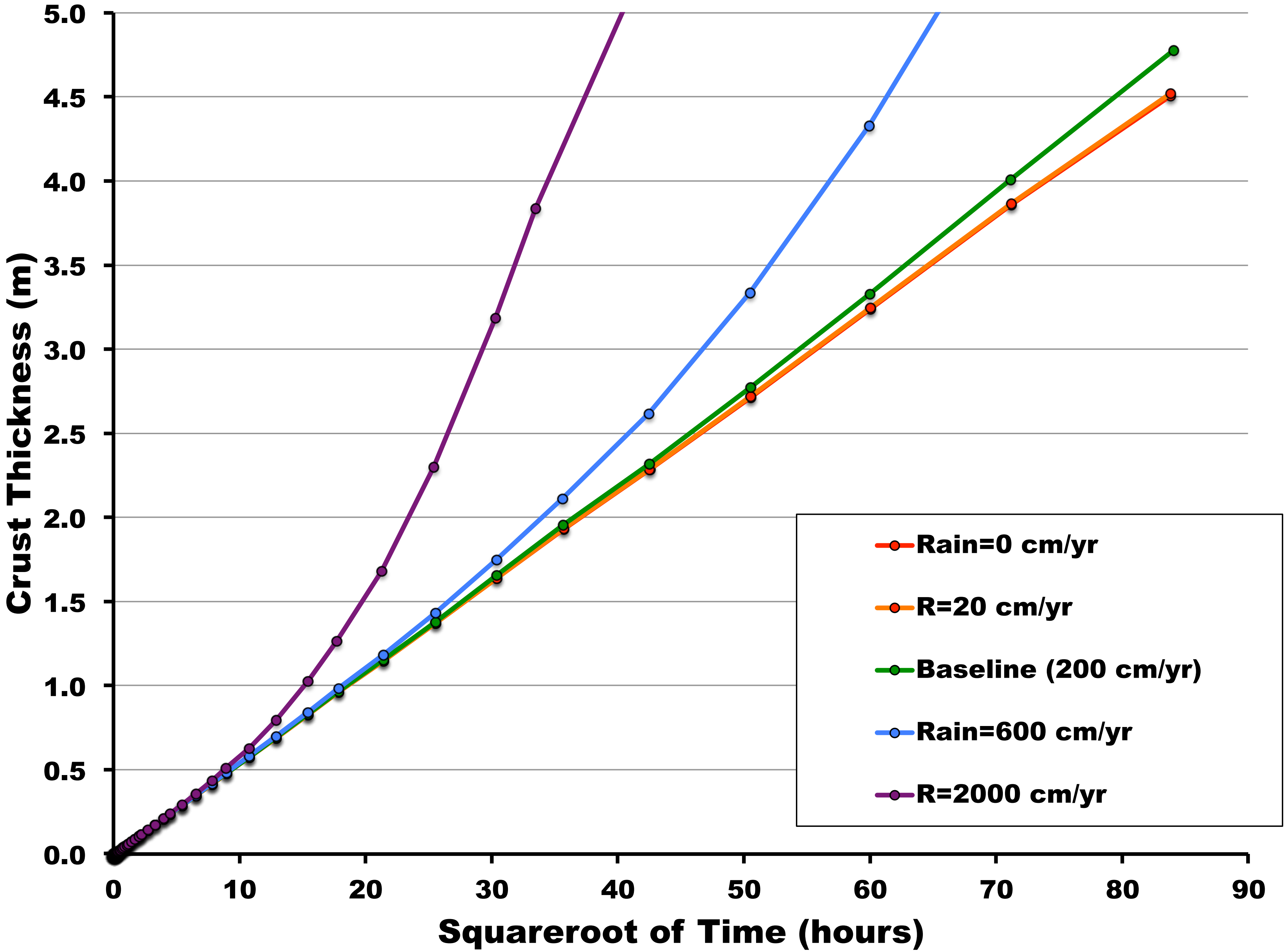
The thickness of the upper solidified crust is insensitive to all parameters but rain.

- It will take decades for a flow to cool to a safe temperature naturally in the American SW.
- The interior of the flow can be cooled quickly by adding copious amounts of water.


Surface Temperature (°C)
1100
1000
900
800
700
600
500
400
300
200
100
0
Baseline
Phi=0
Phi=25
Phi=75
0
1
2
3
4
5
6
7
8
9
10
Squareroot of Time (hours)



Crust Thickness (m)
Squareroot of Time (hours)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
0
10
20
30
40
50
60
70
80
90
y = 0.0625x
y = 0.0577x
y = 0.0557x
y = 0.0558x
Baseline
Phi=0
Phi=25
Phi=75
Linear (Baseline)
Linear (Phi=0)
Linear (Phi=25)
Linear (Phi=75)



Crust Thickness (m)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
Squareroot of Time (hours)
Rain=0 cm/yr
R=20 cm/yr
Baseline (200 cm/yr)
Rain=600 cm/yr
R=2000 cm/yr

When Can I Go Home?

- It is possible to walk on top of the lava flow quite safely within a few days.
- Plan to dump large amounts of water onto the lava flow (a) where explosions are possible; (b) where people, lava, and thunderstorms may mix; and (c) before digging into the lava.
- Without water cooling, use caution for many years, even decades, before digging deep into the flow.

USGS

Modeling the Length of Lava Flows

History

- 1800's – recognized that longer flows were low viscosity (basalt).
- 1969-1980's – simple models based on lava flow geometry.
- 1990's-2000 – tests of simple relationships fail.
- 2000 onward – complexity of real lava flows halt most attempts to fully modeling lava flows.

However, important simple statements can be made without fully understanding lava flows.

USGS

Bingham Model

THREE METHODS OF CALCULATING YIELD STRENGTH

1. $\tau_y = \rho g \sin\theta \; H$

2. $\tau_y = \rho g \dfrac{H^2}{w_f}$

3. $\tau_y = \rho g \sin^2\theta \; 2 w_b$

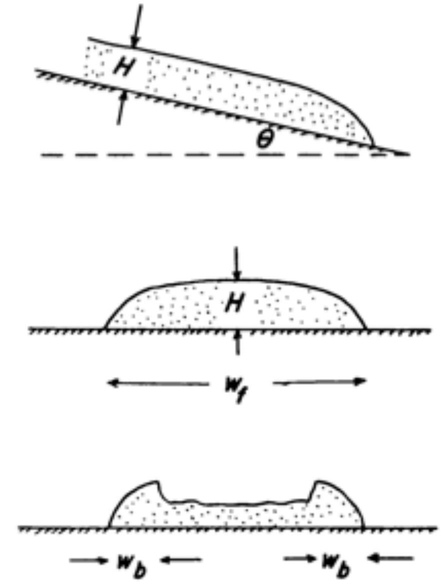


Fig. 1. Three methods of calculating the yield strength (τ_y) of a Bingham plastic flow. All three methods require an estimate of the density of the flow (ρ) and the acceleration of gravity at the surface of the planet (g). The first method (Eq. 1) also requires the topographic gradient ($\sin\theta$) and the thickness of the flow (H). The second method (Eq. 2) is independent of the gradient but requires the width (w_f) and thickness (H) of the flow. The third method (Eq. 3) requires the width of its levee (w_b) and the topographic gradient ($\sin\theta$).

USGS

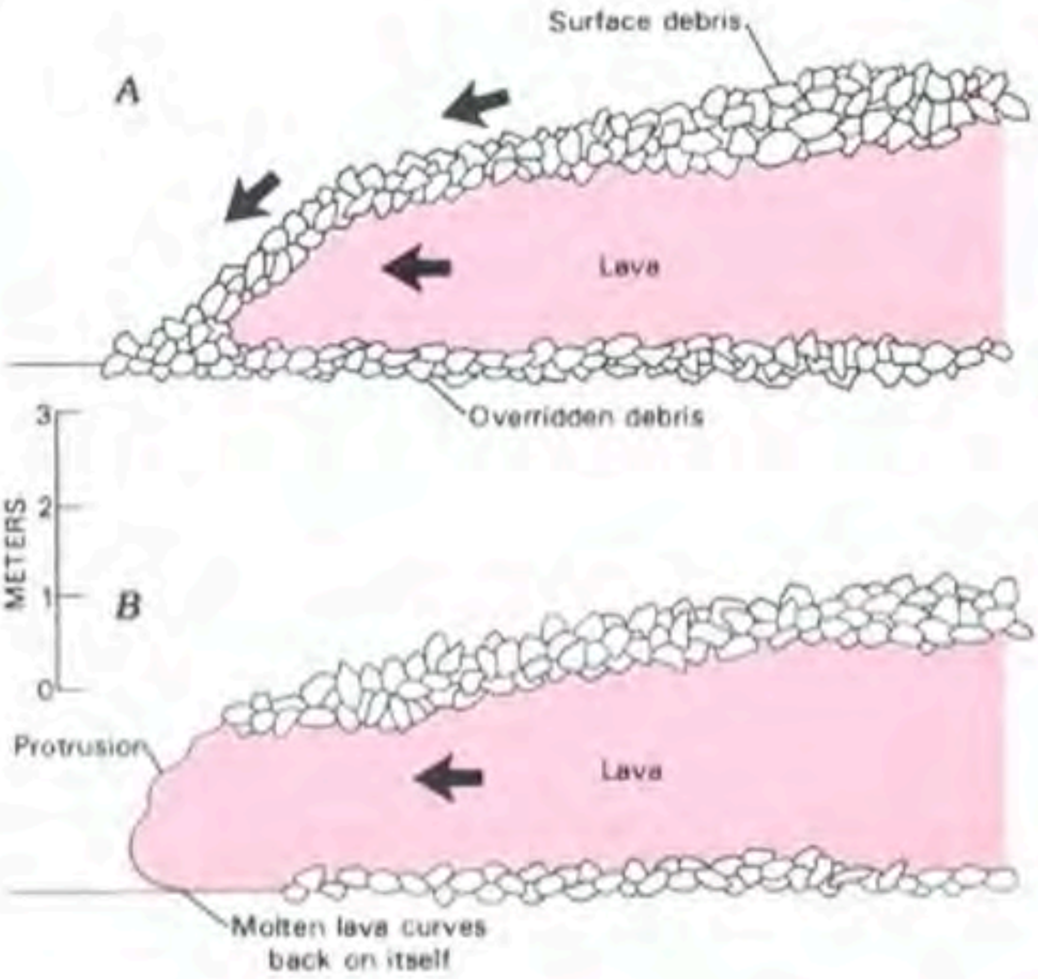


FIGURE 58.12.—Diagrammatic profiles of flow at Lower Powerline Road on April 5. ***A***, The flow is typical aa, with an upper surface of debris overlying molten, incandescent lava. Upper surface moves as a unit with greater speed than underlying layer so that debris avalanches and falls down front and is then overridden by flow. ***B***, Surface of molten lava. Where surface of molten lava is exposed at the front, it is smoothly curved, with some rounded protrusions, and curves back upon itself at the base.

USGS

Real Complexities

Need to consider 4 different cases:

- Two fundamentally different flow geometries
  - Sheet flows
  - Narrow pathways
- Two fundamentally different crusts
  - Stationary crust
  - Mobile crust

USGS

What Controls the Length of a Lava Flow?

Within a flow regime, higher flow rate will make a longer lava flow.

But at lower flow rate, the flow regime switches to a more insulating mode, allowing a longer flow.

Any realistic type of eruption can feed lava flows many tens of kilometers (tens of miles) long.

USGS

Can we say where the lava will go?

In general, lava will simply go downhill.

In general, lava flows have a typical thickness

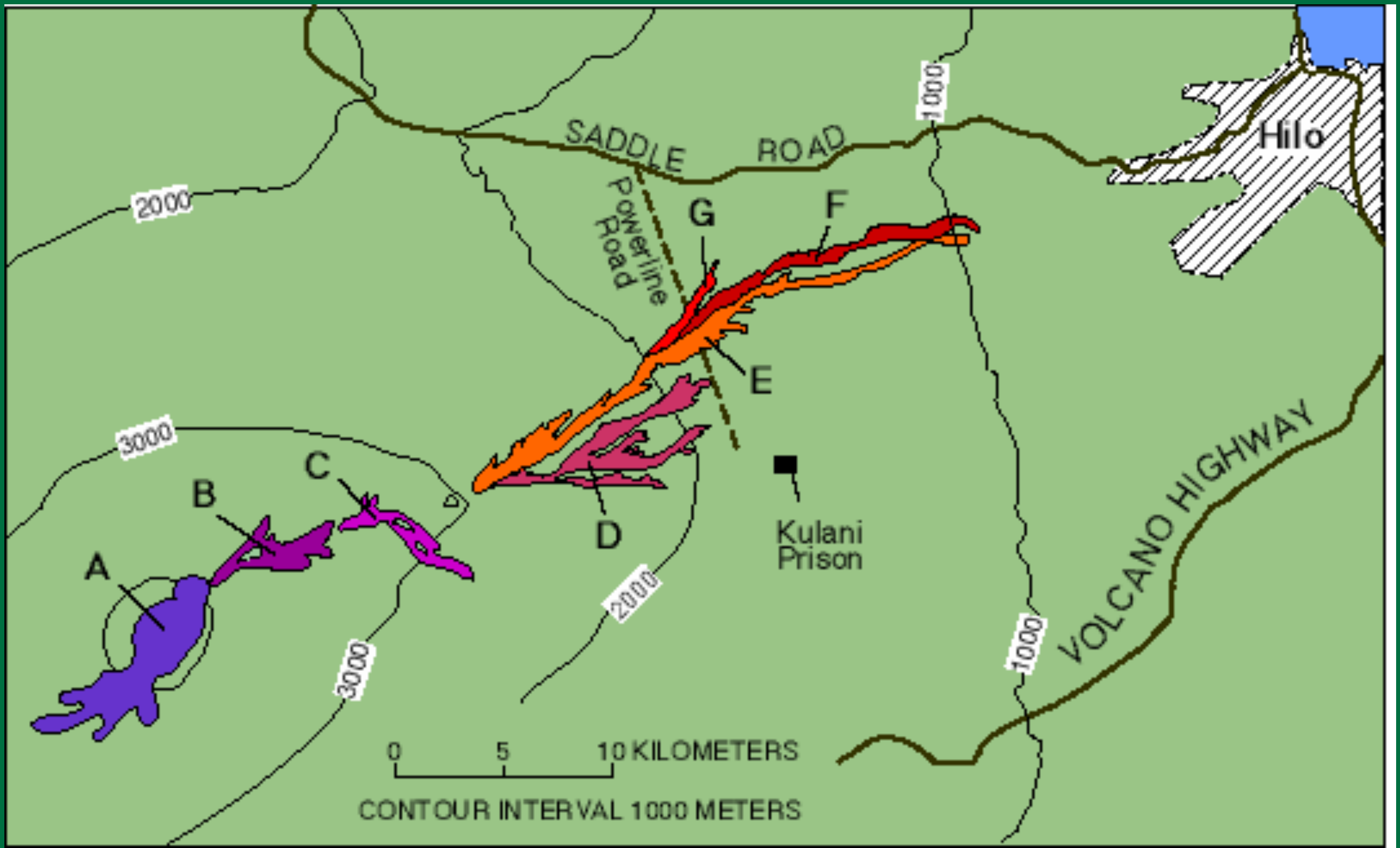
So if you have the volume of lava erupted and the topography, you should be able to predict where the lava goes with some confidence without worrying about all those details!

USGS

Can we say where the lava will go?

Can only guess what the volume will be.

Lava flows are complicated!



Summary

Models can provide useful insights, but lava flows are too complicated to model in detail.

Models are best when they are constantly re-evaluated with abundant input from good monitoring of an ongoing eruption.

People with extensive experience with real lava flows should always review model outputs before decisions are made based on them.

USGS

Argon geochronology (K-Ar or Ar-Ar)

traditional workhorse method for dating volcanic rocks

Limitations for young volcanic rocks:

Rhyolites (sanidine bearing): ±<1 ka, no young limit

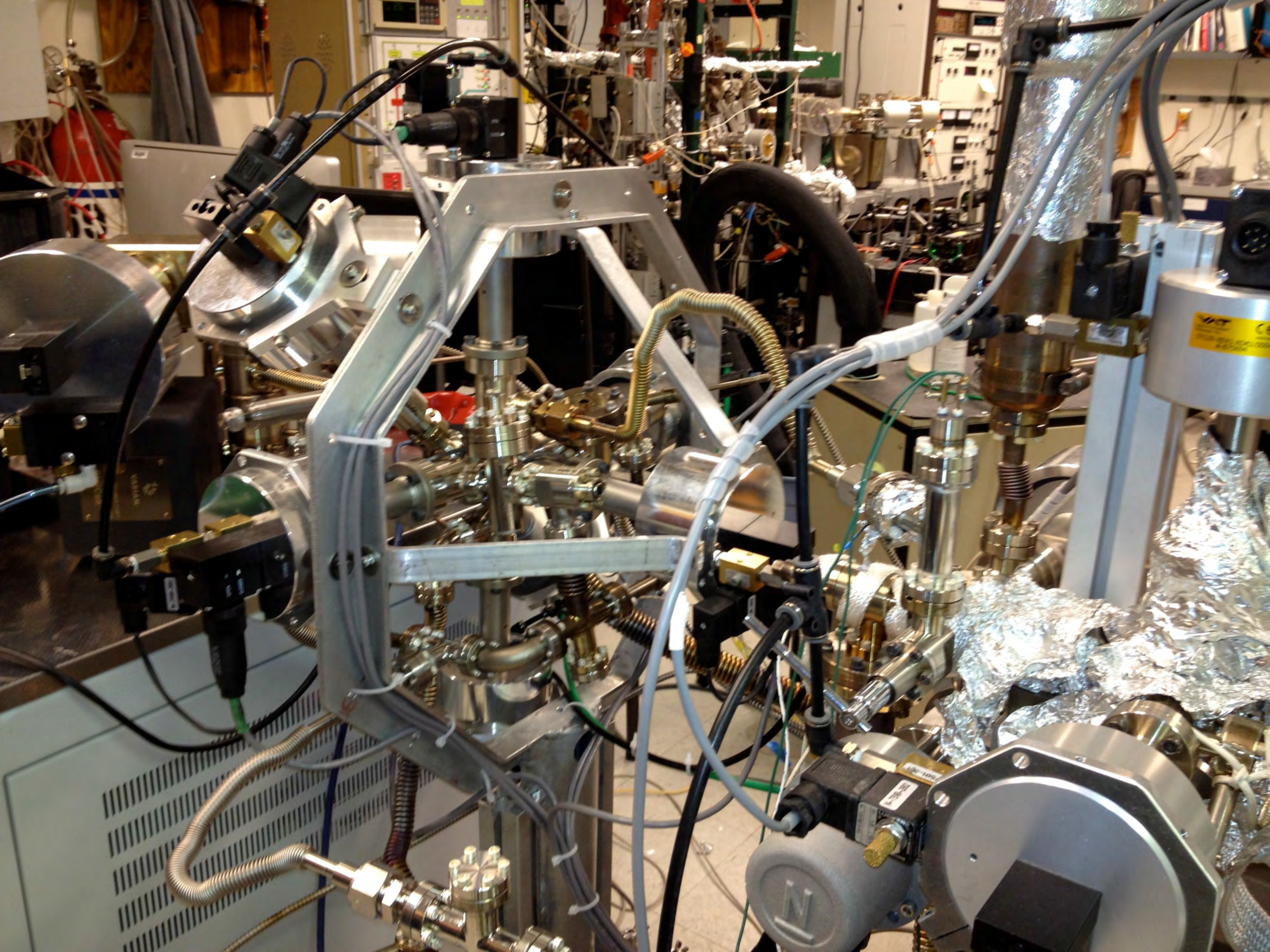
Basalts: ±5 ka to ±100 ka, therefore less useful for rocks < 100 ka

alternative methods: ^{14}C, cosmogenic (^{36}Cl, ^{3}He), OSL, etc.

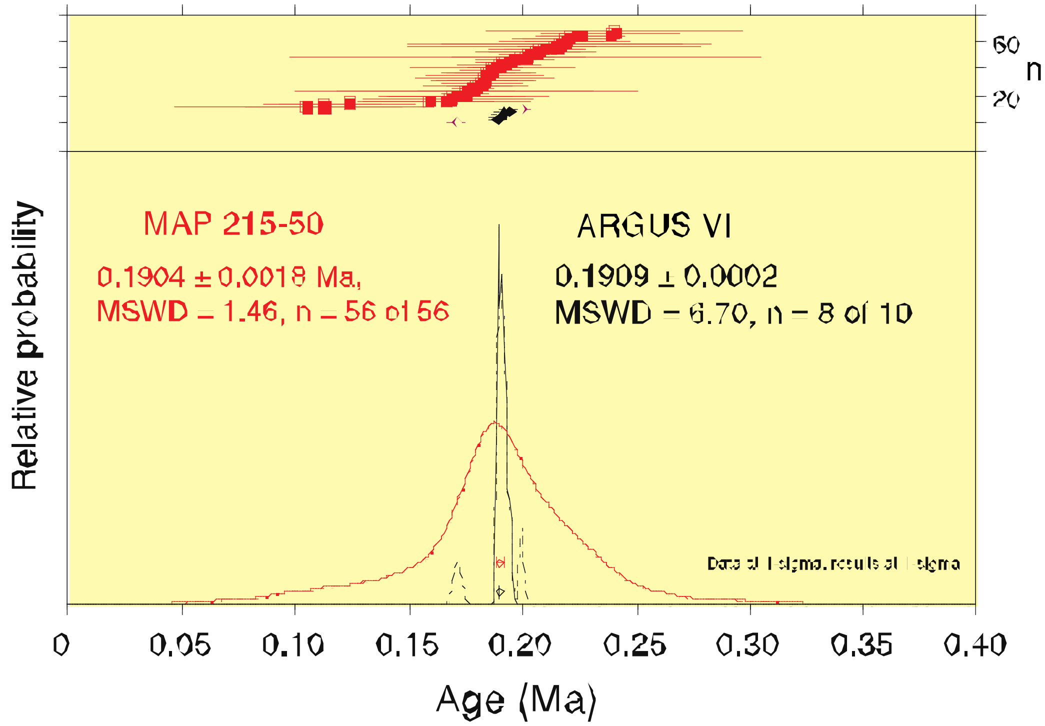
New generation mass spectrometers - Thermo Argus

order of magnitude improvement

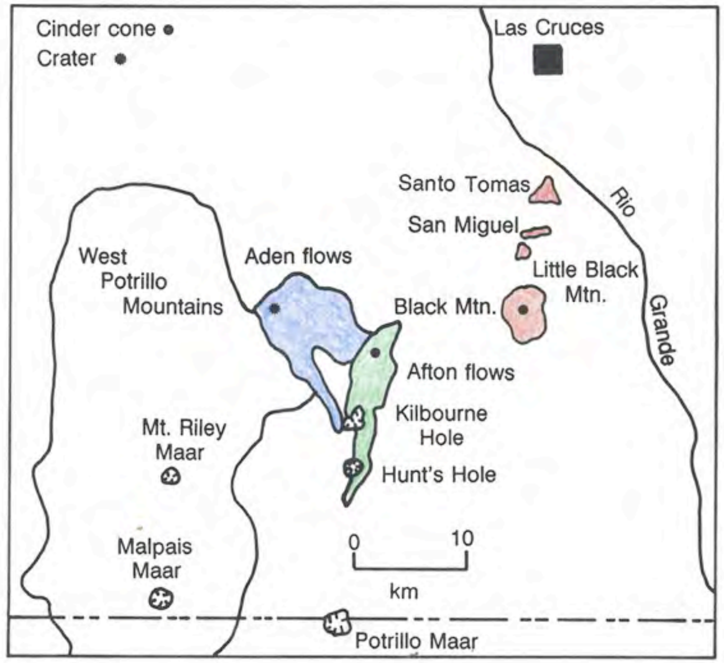
will allow dating of basalts as young as 1 ka to 10 ka

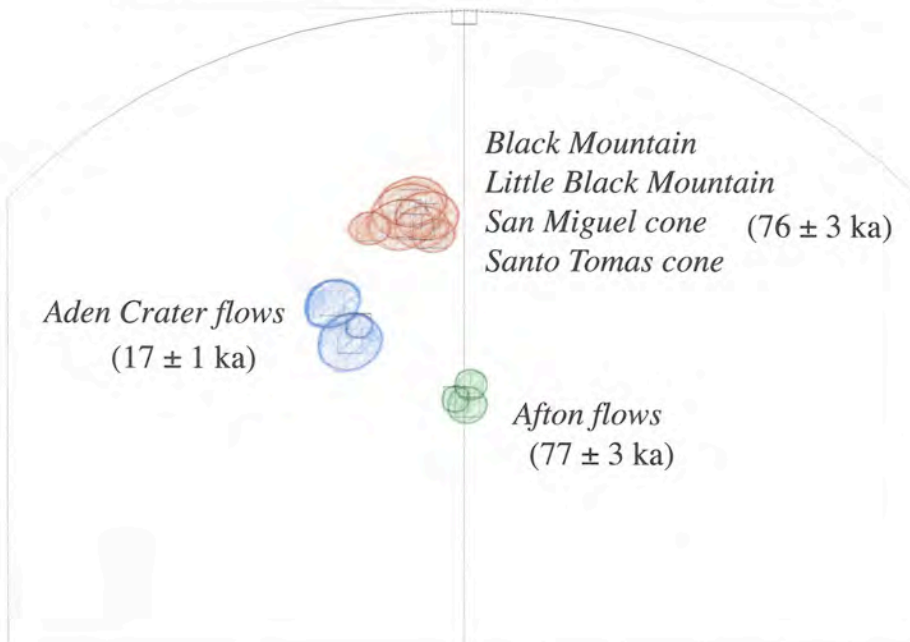


Compare MAP15-50 and ARGUS VI for a young sample



ARGUS VI provides ~ 10X improvement in precision. Can also see outliers


Cinder cone
Crater
Las Cruces
Santo Tomas
Rio
San Miguel
West
Potrillo
Mountains
Aden flows
Little Black
Mtn.
Black Mtn.
Grande
Afton flows
Kilbourne
Hole
Mt. Riley
Maar
Hunt's Hole
0
10
km
Malpais
Maar
Potrillo Maar


Black Mountain
Little Black Mountain
San Miguel cone
Santo Tomas cone
(76 ± 3 ka)
Aden Crater flows
(17 ± 1 ka)
Afton flows
(77 ± 3 ka)

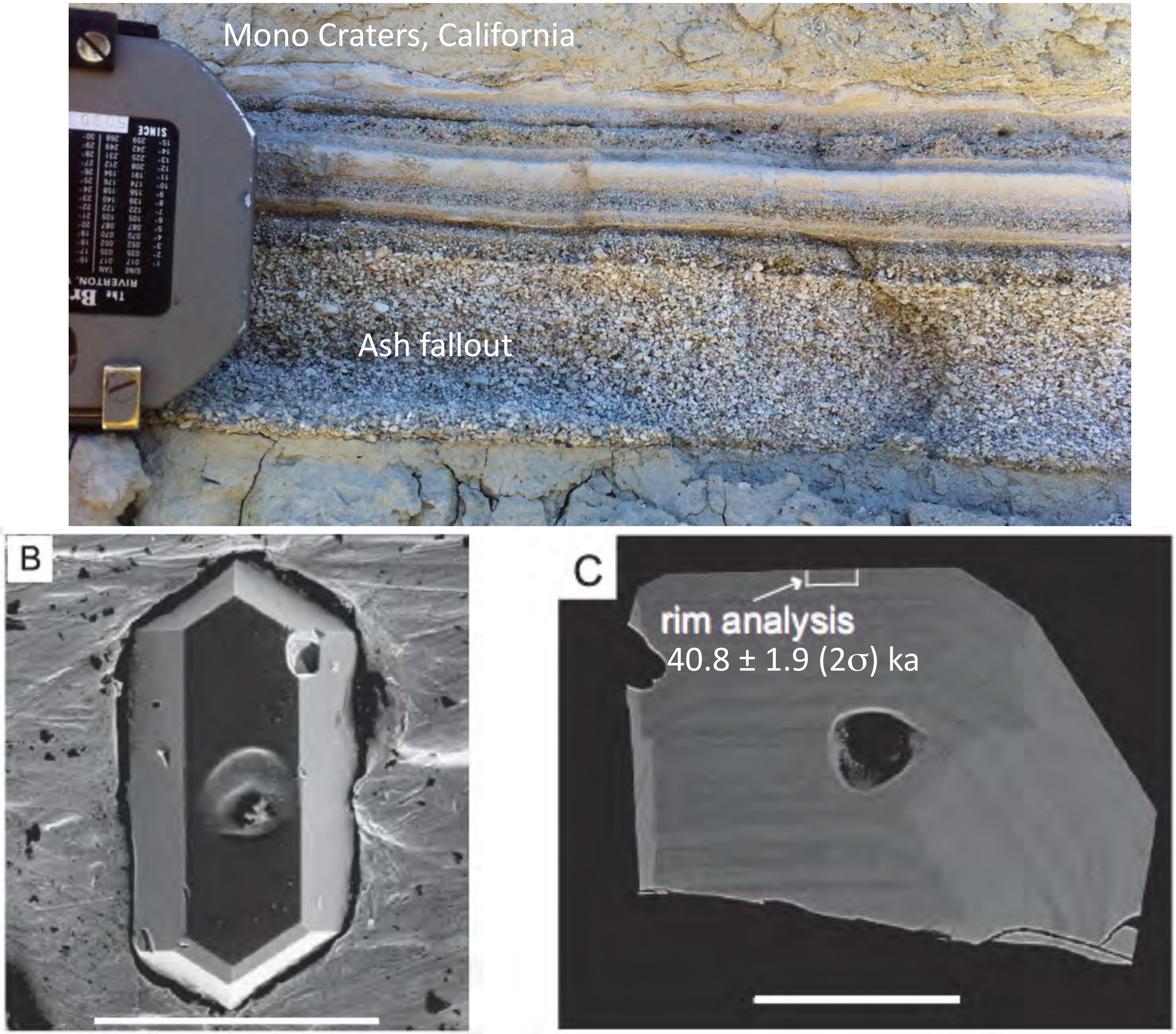
USGS
science for a changing world

STANFORD UNIVERSITY
SCHOOL OF EARTH SCIENCES
EARTH·ENERGY·ENVIROMENT

The Stanford–U.S. Geological Survey SHRIMP Ion Microprobe—A Tool for Micro-Scale Chemical and Isotopic Analysis

Answers to many questions in Earth science require chemical analysis of minute volumes of minerals, volcanic glass, or biological materials. Secondary Ion Mass Spectrometry (SIMS) is an extremely sensitive analytical method in which a 5–30 micrometer diameter "primary" beam of charged particles (ions) is focused on a region of a solid specimen to sputter secondary ions from 1–5 nanograms of the sample under high vacuum. The elemental abundances and isotopic ratios of these secondary ions are determined with a mass spectrometer. These results can be used for geochronology to determine the age of a region within a crystal thousands to billions of years old or to precisely measure trace abundances of chemical elements at concentrations as low as parts per billion. A partnership of the U.S. Geological Survey and the Stanford University School of Earth Sciences operates a large SIMS instrument, the Sensitive High-Resolution Ion Microprobe with Reverse Geometry (SHRIMP–RG) on the Stanford campus.

The Stanford-USGS SHRIMP–RG in the room constructed specifically for the instrument in the basement of the Green Earth Sciences Research Building, Stanford University. Control console is at right, behind two black computer monitors. Specimen chamber is at extreme right, behind the control console. The primary ion source is out of view behind the specimen chamber. Secondary ions sputtered from the specimen move from right to left through the doubly focusing mass spectrometer, which is maintained at high vacuum. The white "SHRIMP RG" object in the center of the image is the laminated electromagnet of the 1-m-radius magnetic sector. The large curved stainless steel box left of the magnet is the electrostatic analyzer of the 1.2-m-radius electrostatic sector. Mass- and energy-selected secondary ions are counted by an electron multiplier in the cylindrical device in the lower left foreground.


Mono Craters, California
Ash fallout
B
C
rim analysis
40.8 ± 1.9 (2σ) ka

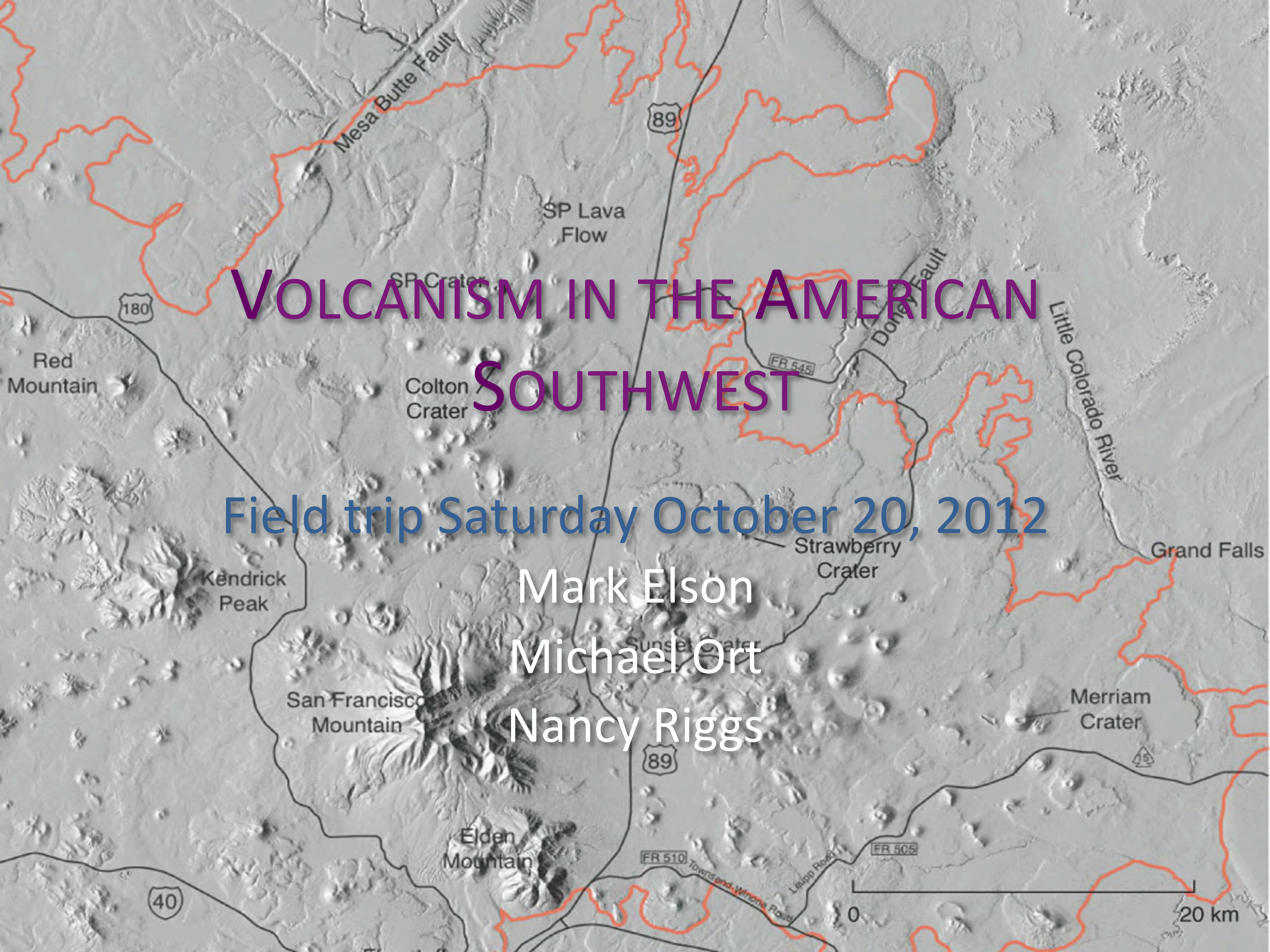
Strategy Needed

- Given: Monitoring difficult, prediction of precise location of eruptions and types of hazards is poor, event frequency is low
- Current state of regional assessment: probabilistic assessment needed, and should drive prioritization of further characterization and hazard planning
- Probabilistic assessment should include consequences of activity in addition to hazard (spatial-temporal probability of events)
- Preparation and planning for eruptions may need to take place based upon general probabilities (once those are determined) with assumption that advance warning of imminent eruption may not be forthcoming

VOLCANISM IN THE AMERICAN SOUTHWEST

Field trip Saturday October 20, 2012

Mark Elson
Michael Ort
Nancy Riggs



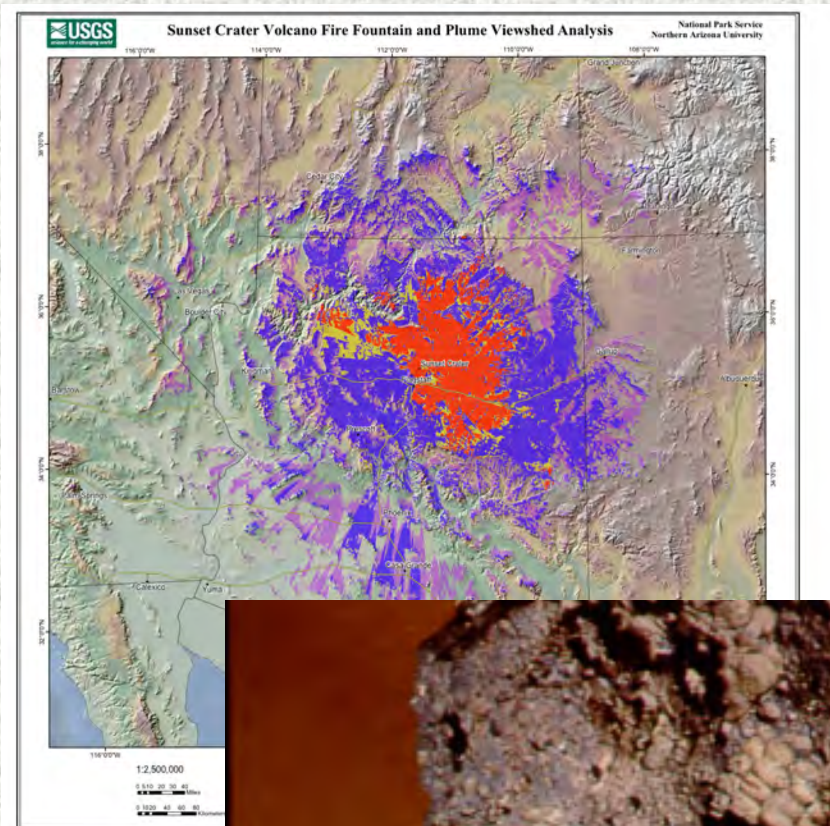
LOGISTICS

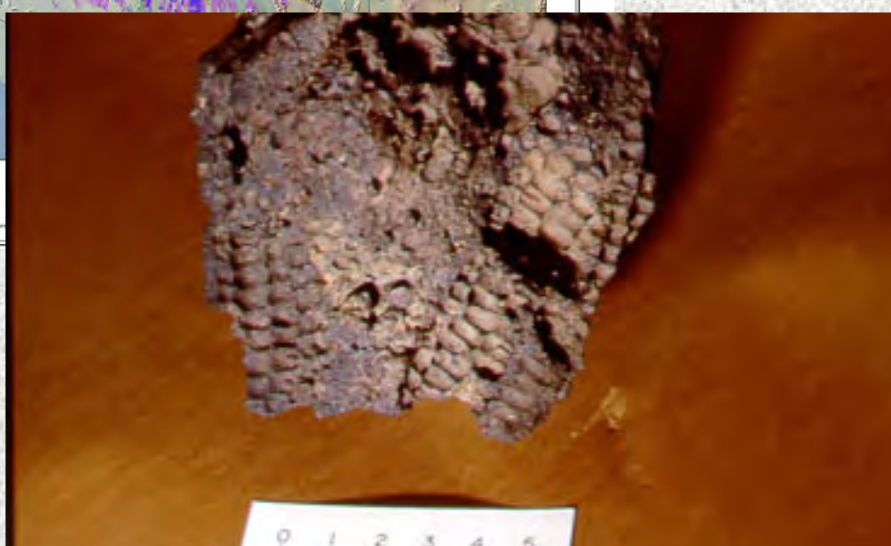
- Meet HERE at 8.30
- Park OUTSIDE the gate – Buffalo Park (just to the north) is easy / convenient or just on the street
- Lots of dry grass at SP/Colton: long pants strongly recommended!

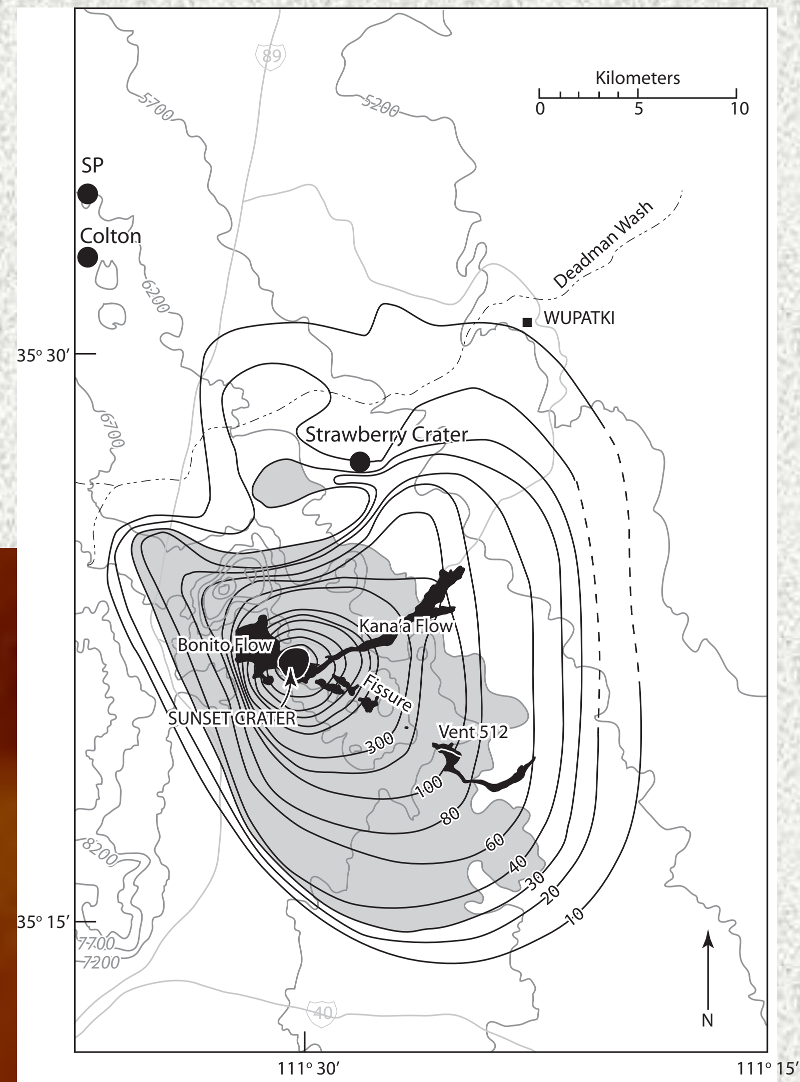
LOGISTICS

- Bring sunscreen!
- Bring water (lots of water)
  - elevations from 7200' / 2200 m in the morning to 6000' / 1800 m in the afternoon
  - forecast is for warm (75 ^{o}F / 25 ^{o}C) and windy
- Lunch is on your own
  - Natural Grocers (cow barn on the corner of South Milton and Butler) has pre-made sandwiches
  - Safeway, Frys, etc.

Stop 1: Medicine Fort







Stop 2: Strawberry Crater

* Sunset ash, ~10 cm
* 50 ka – 130 ka(??)
* Brittle deformation of crater-rim blocks during breaching event

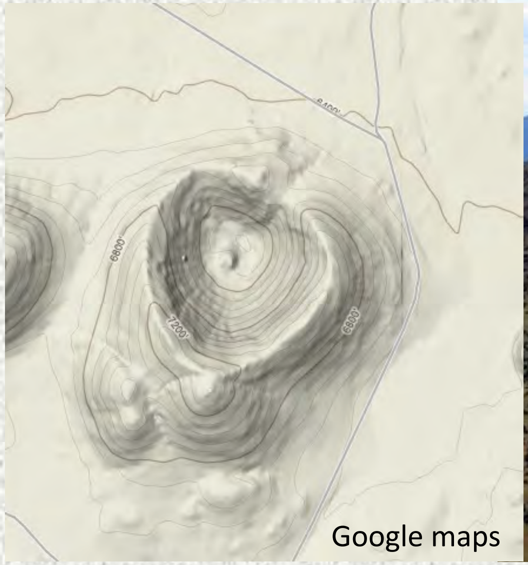
Stop 3: SP Crater

Breached and rehealed cone
Limited tephra blanket
Thick lava flow; ~ 8 km^3

A. Seligman photos

Stop 4: Colton Crater

Cone-building facies
Explosive (phreatomagmatic) eruptive stage
Cone breaching



Google maps

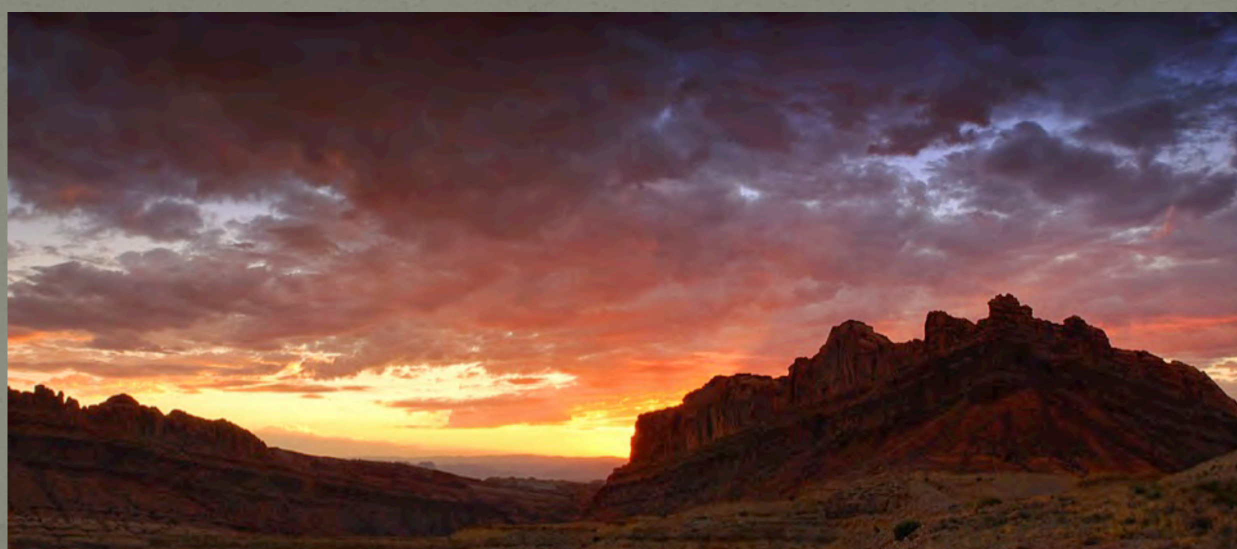

K House photo

Volcanism in the American Southwest Poster Introductions

Relationship Between Dike and Volcanic Conduit Distribution in a Highly Eroded Monogenetic Volcanic Field: San Rafael Swell, Utah

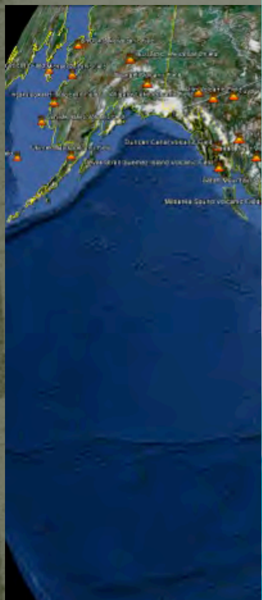
Koji Kiyosugi[1], Chuck Connor[1], Paul Wetmore[1], Brian Ferwerda[1], Aurelie Germa[1], Laura Connor[1] and Amanda Hintz[*2]

[1] Department of Geology, University of South Florida, Tampa, Florida
[2] Utah Geological Survey, Salt Lake City, Utah
[*] Presenting Author



UNIVERSITY OF SOUTH FLORIDA

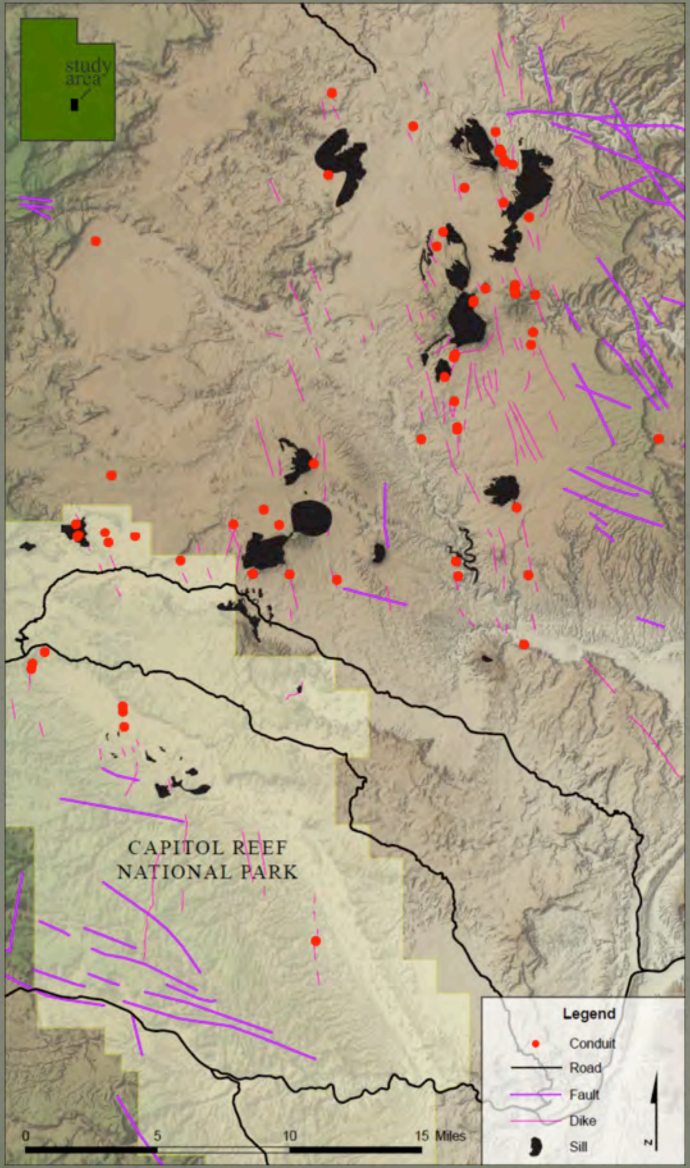
Study Areas

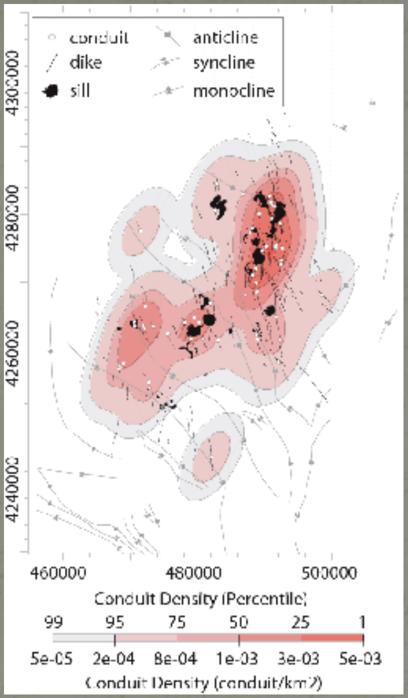


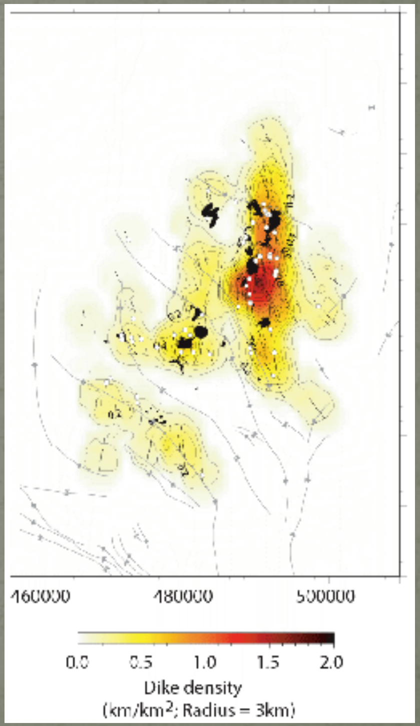

North America
Europe
Asia
Africa
South America
Australia


Google earth

Analysis of the San Rafael Subvolcanic Complex







Volcanic Fields: Past and Present

Izu-Tobu Volcano Group, Japan

Abu Monogenetic Volcano Group, Japan

Southwest Nevada Volcanic Field Nevada, USA

Black Rock Desert Volcanic Field, Utah, USA

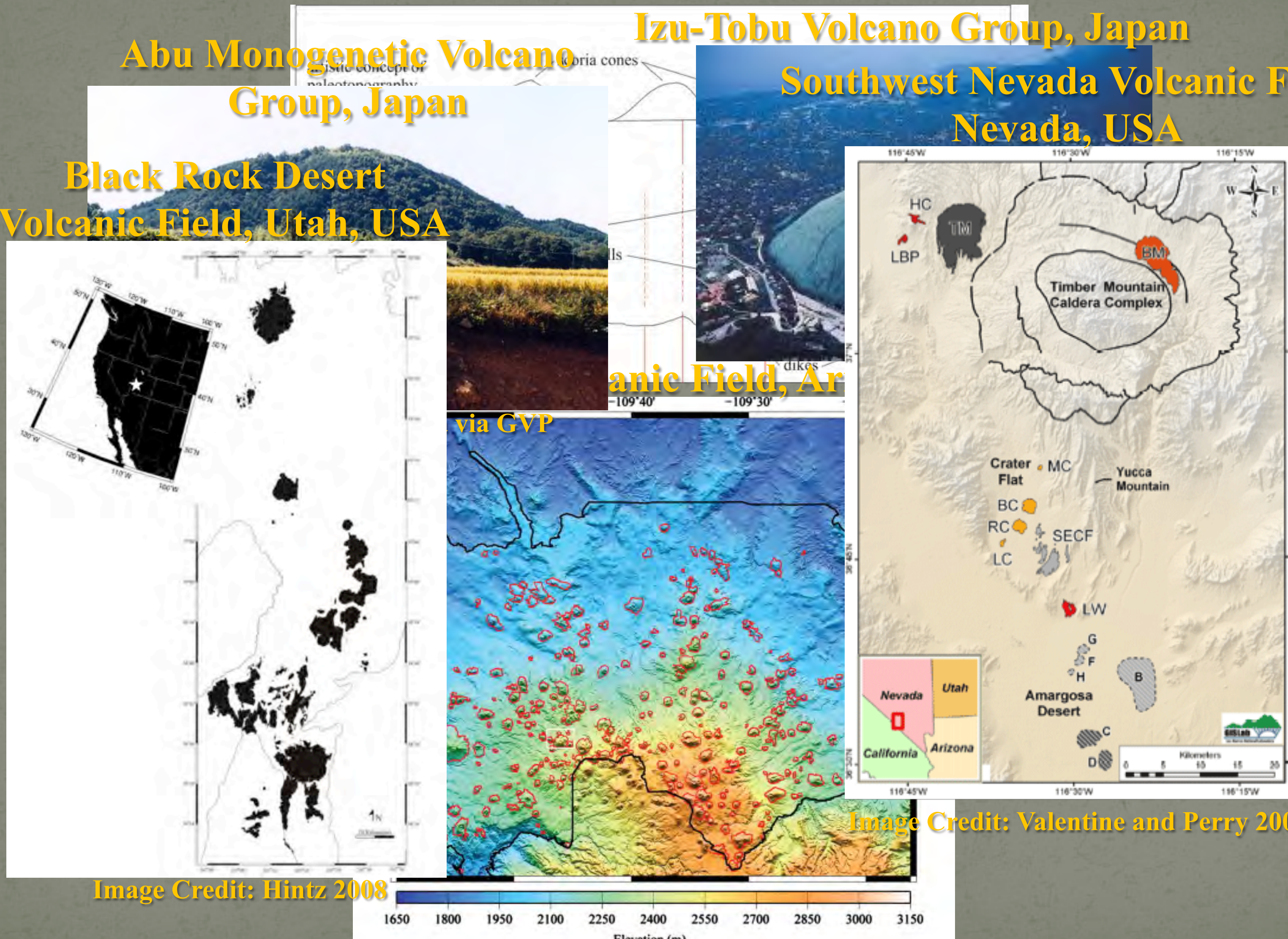


Image Credit: Valentine and Perry 2007

Image Credit: Hintz 2008

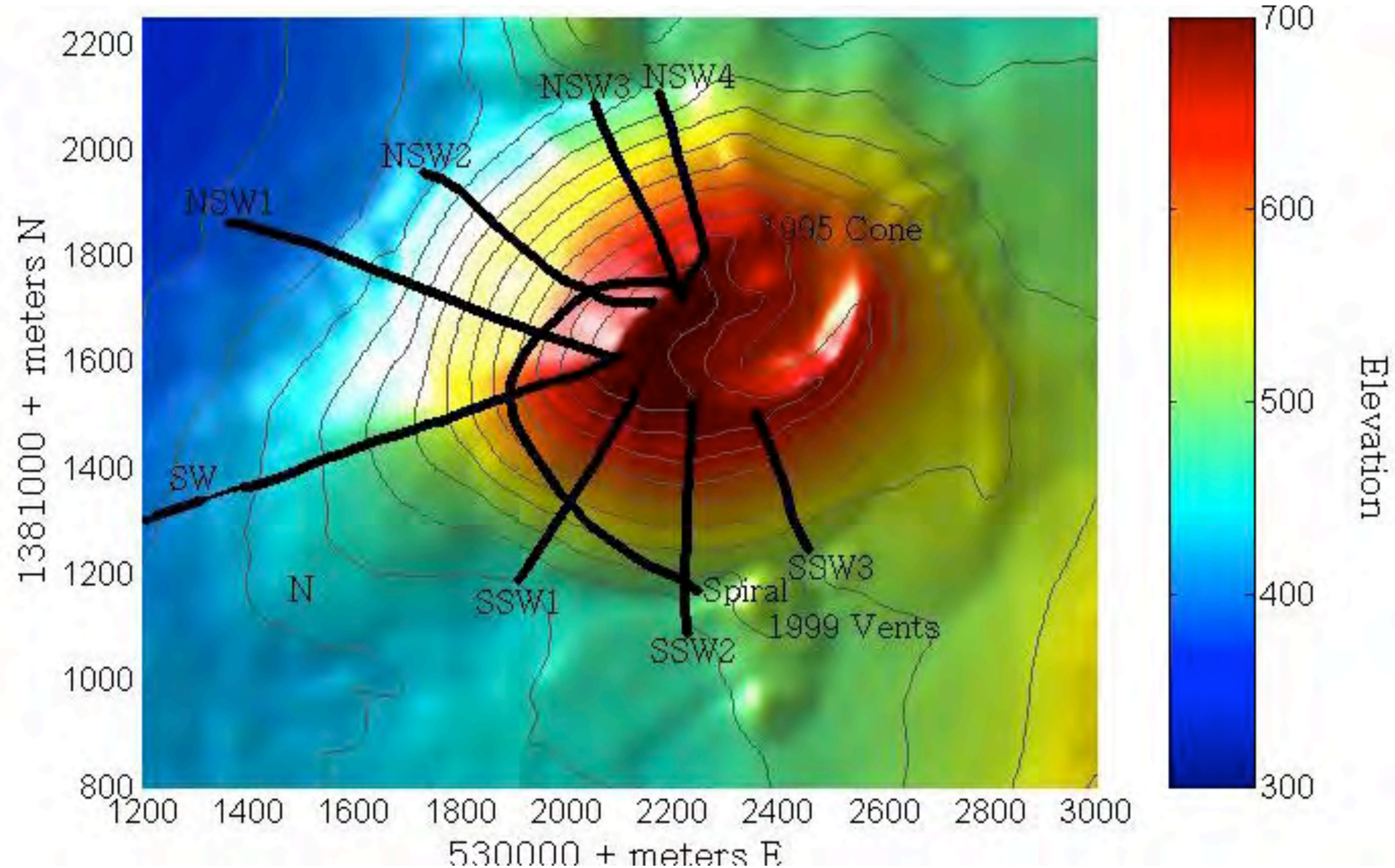
Image Credit: Howell et al. 2012

Into the cone:

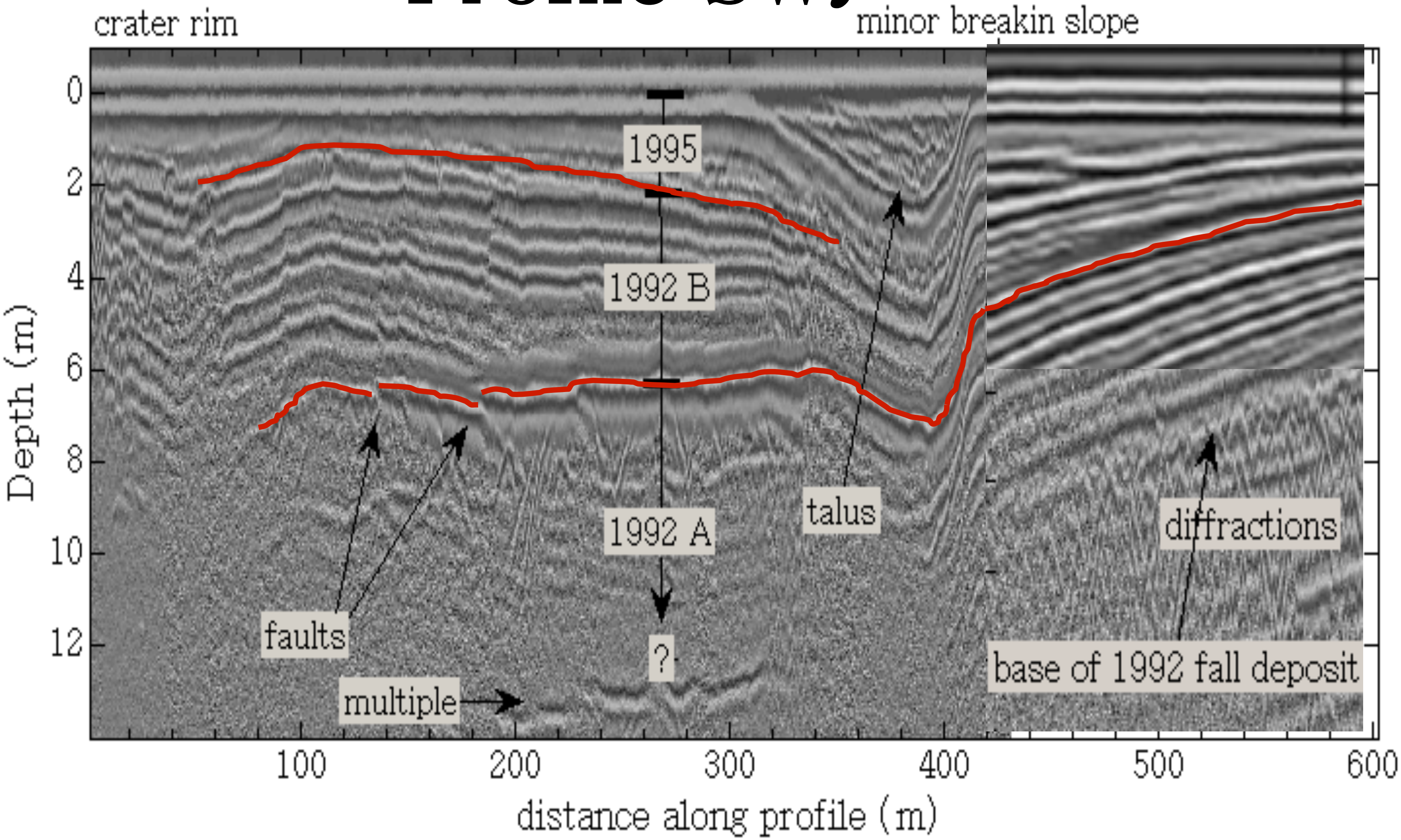
A ground penetrating radar study of Cerro Negro volcano, Nicaragua♪
♪

Leah Courtland, Sarah Kruse, Chuck Connor♪
University of South Florida♪

Cerro Negro GPR Locations♪

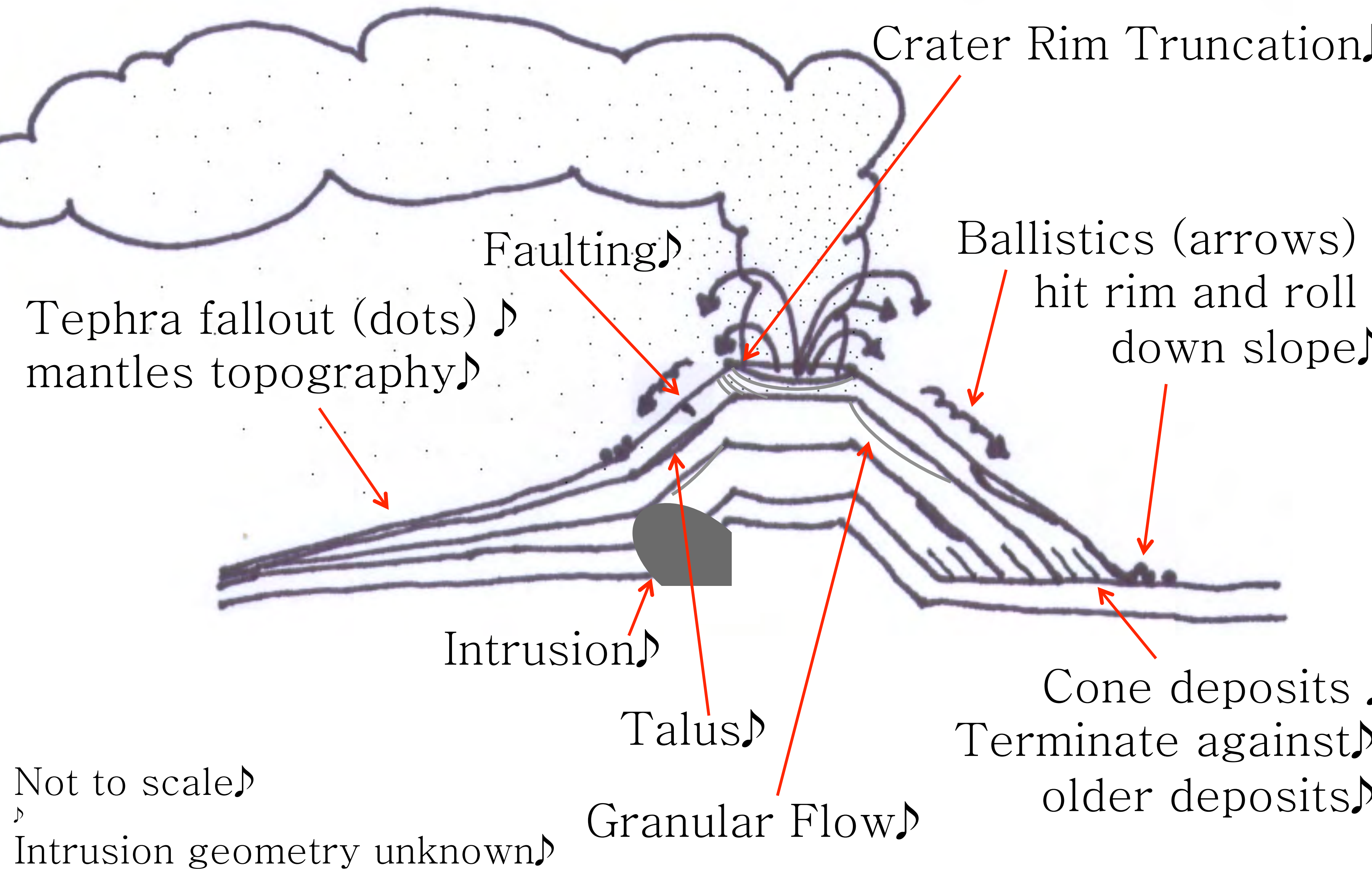


Profile SW♪

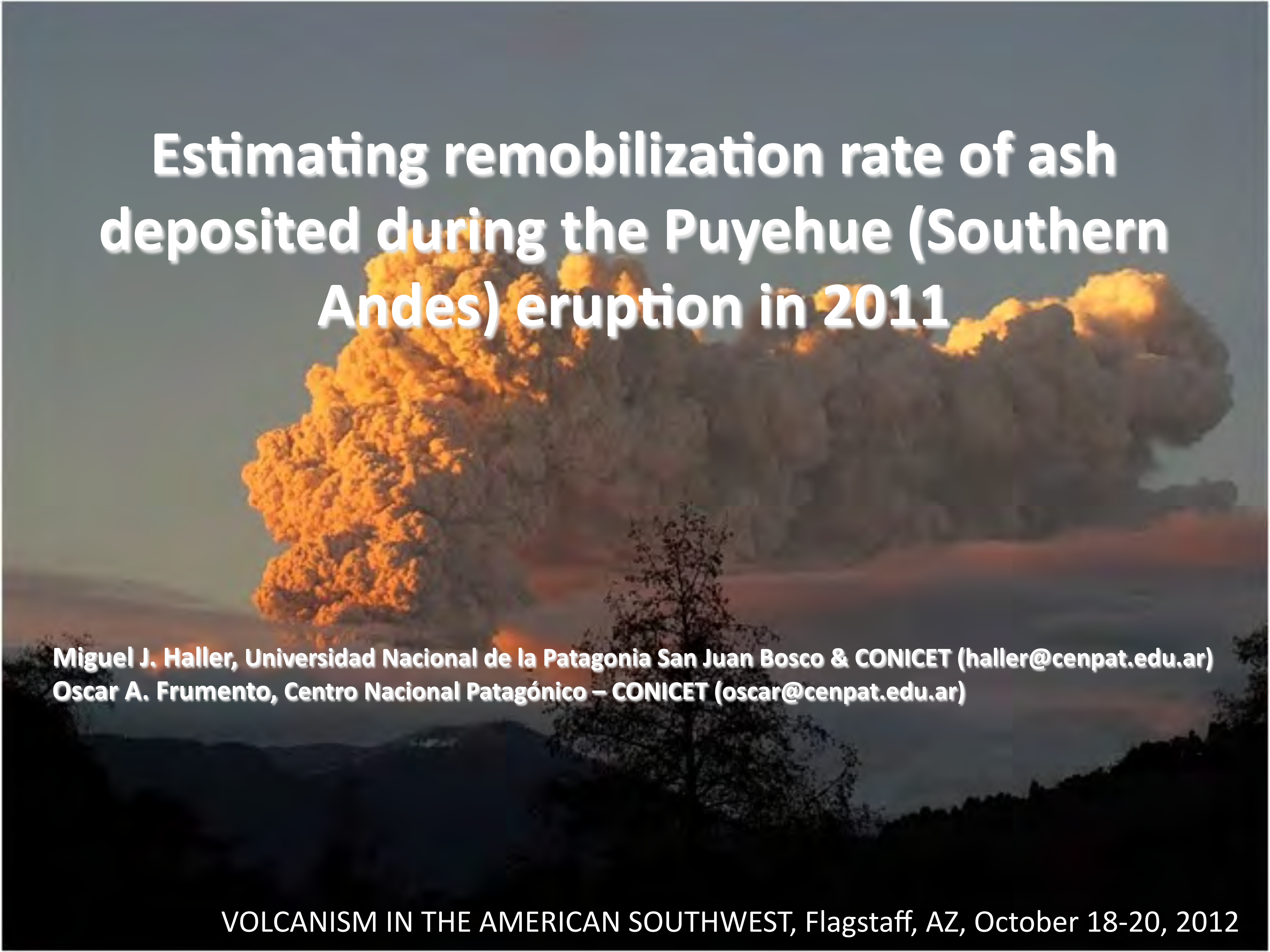


♪
Profile crests crater rim and continues outward in the direction of maximum plume deposition. ♪
Up-cone: 100 MHz antennas♪   Farther down: 50 and 200 MHz♪

Cone Building Processes♪

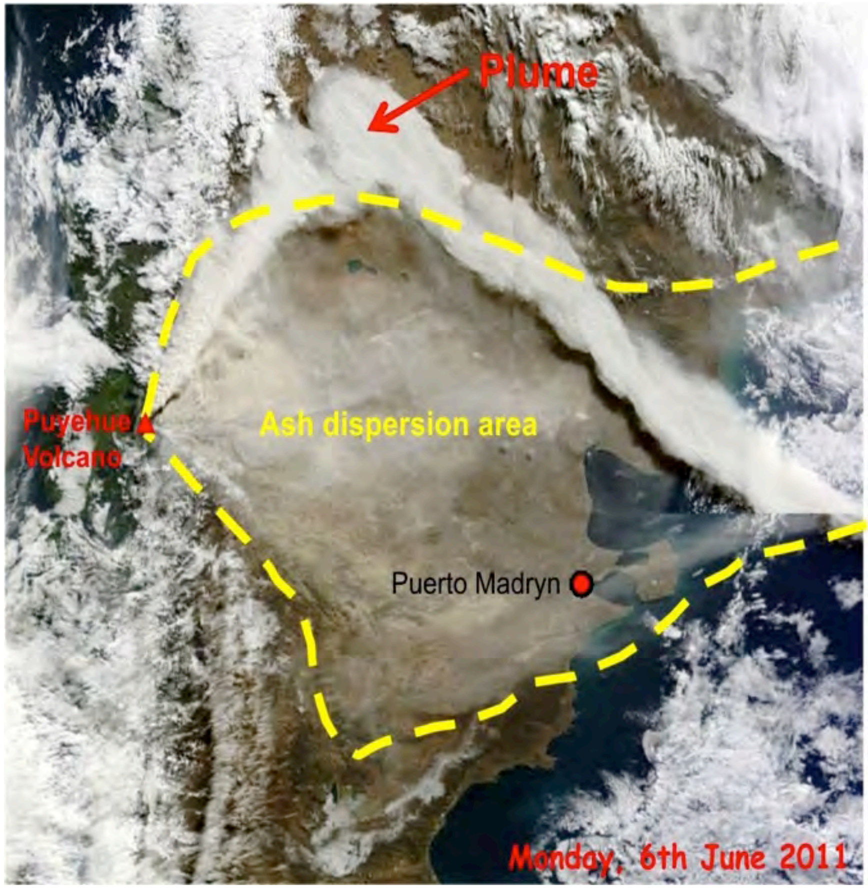


Estimating remobilization rate of ash deposited during the Puyehue (Southern Andes) eruption in 2011



Miguel J. Haller, Universidad Nacional de la Patagonia San Juan Bosco & CONICET (haller@cenpat.edu.ar)
Oscar A. Frumento, Centro Nacional Patagónico – CONICET (oscar@cenpat.edu.ar)

VOLCANISM IN THE AMERICAN SOUTHWEST, Flagstaff, AZ, October 18-20, 2012

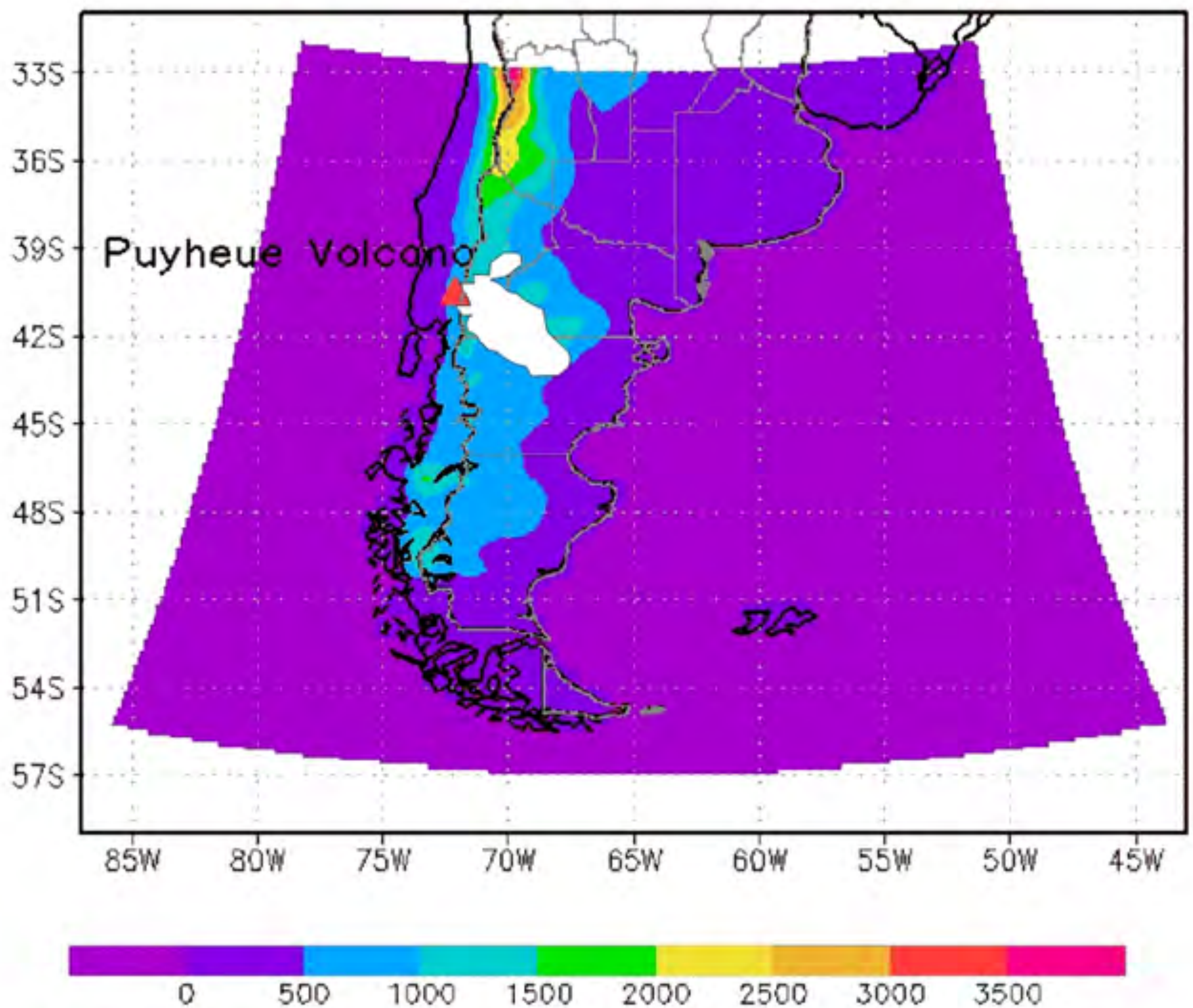


During ten days of vigorous eruptive activity, about 2.5 billion tons of ash fell over an area of more than 29,000 square miles.

How long will it last?

Resupended ash heavily affected urban and rural population in northern Patagonia for several months. Local and provincial authorities, as well the media and neighbors inquired repetitively about the temporal extension of the phenomena.

REGCM4 - **REG**IONAL **C**LIMATE **M**ODEL



The **Reg**ional **C**limate **M**odeling system, RegCM4, is a numerical modeling to obtain an objective forecast of the future state of the atmosphere by solving a set of equations that describe the evolution of variables (temperature, wind speed, humidity, pressure) that define the state of the atmosphere. The model is interactively coupled to an aerosol scheme which includes a dust emission model.

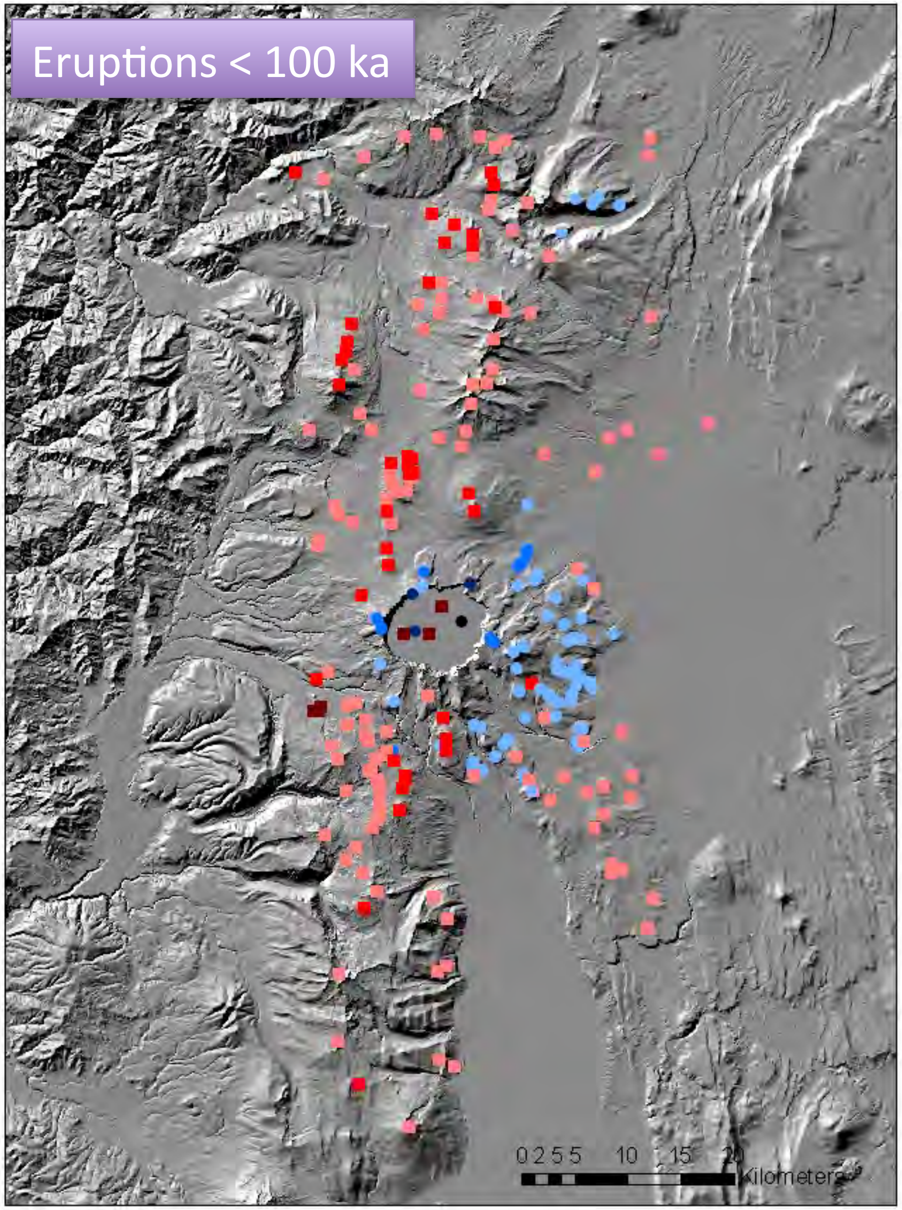
The Coupled dust-REGCM4 regional climate model allowed us to estimate the time that the remobilization of Puyehue volcano ashes - and decreasing of the consequent adverse effects in central Patagonia - would take.

Focusing of melt by magma chambers in time and space: theory and application to Mount Mazama, OR

Leif Karlstrom
Stanford University

Red symbols: basalt/andesite
Blue symbols: dacite/rhyolite

Darker symbols: more recent eruptions



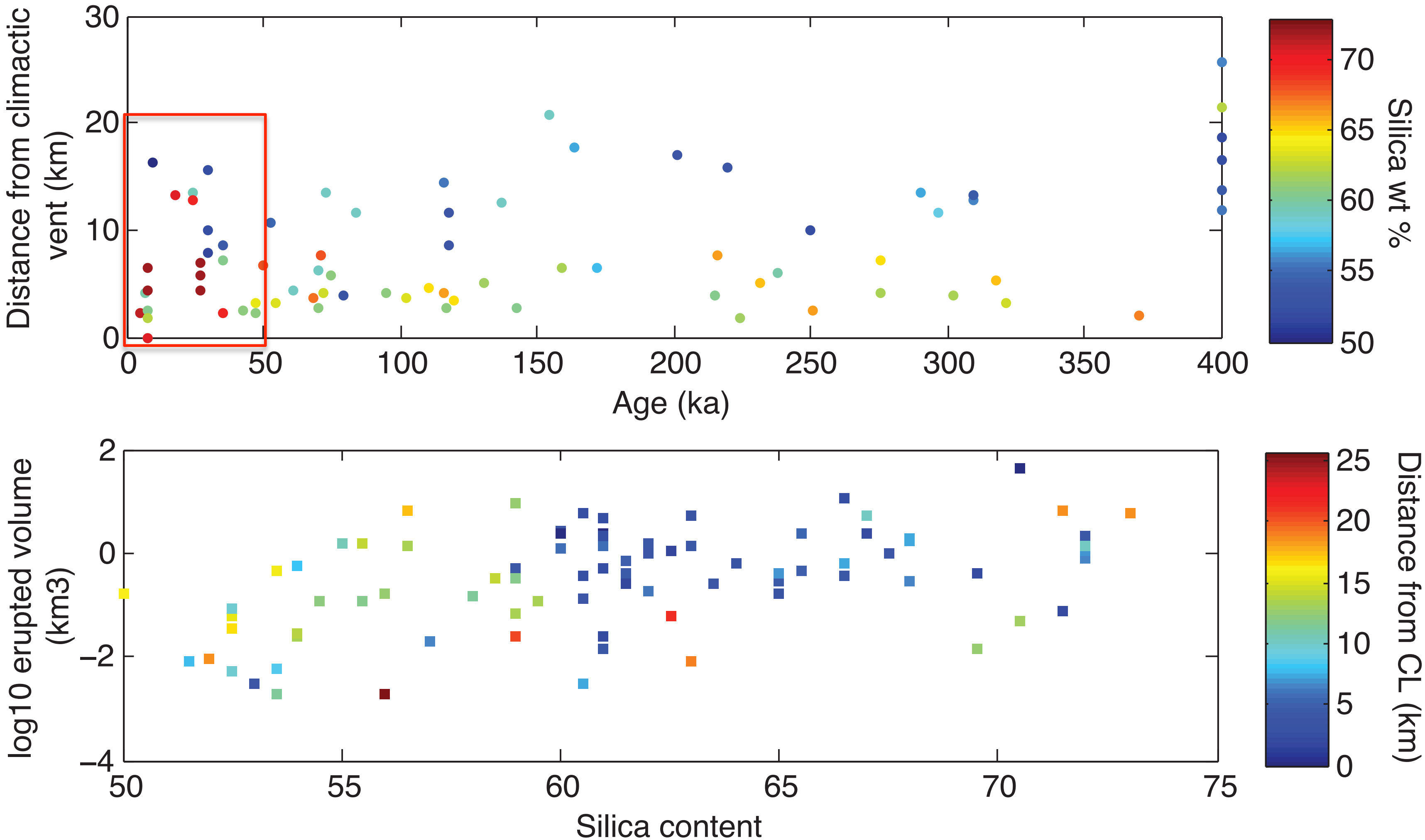
Questions:

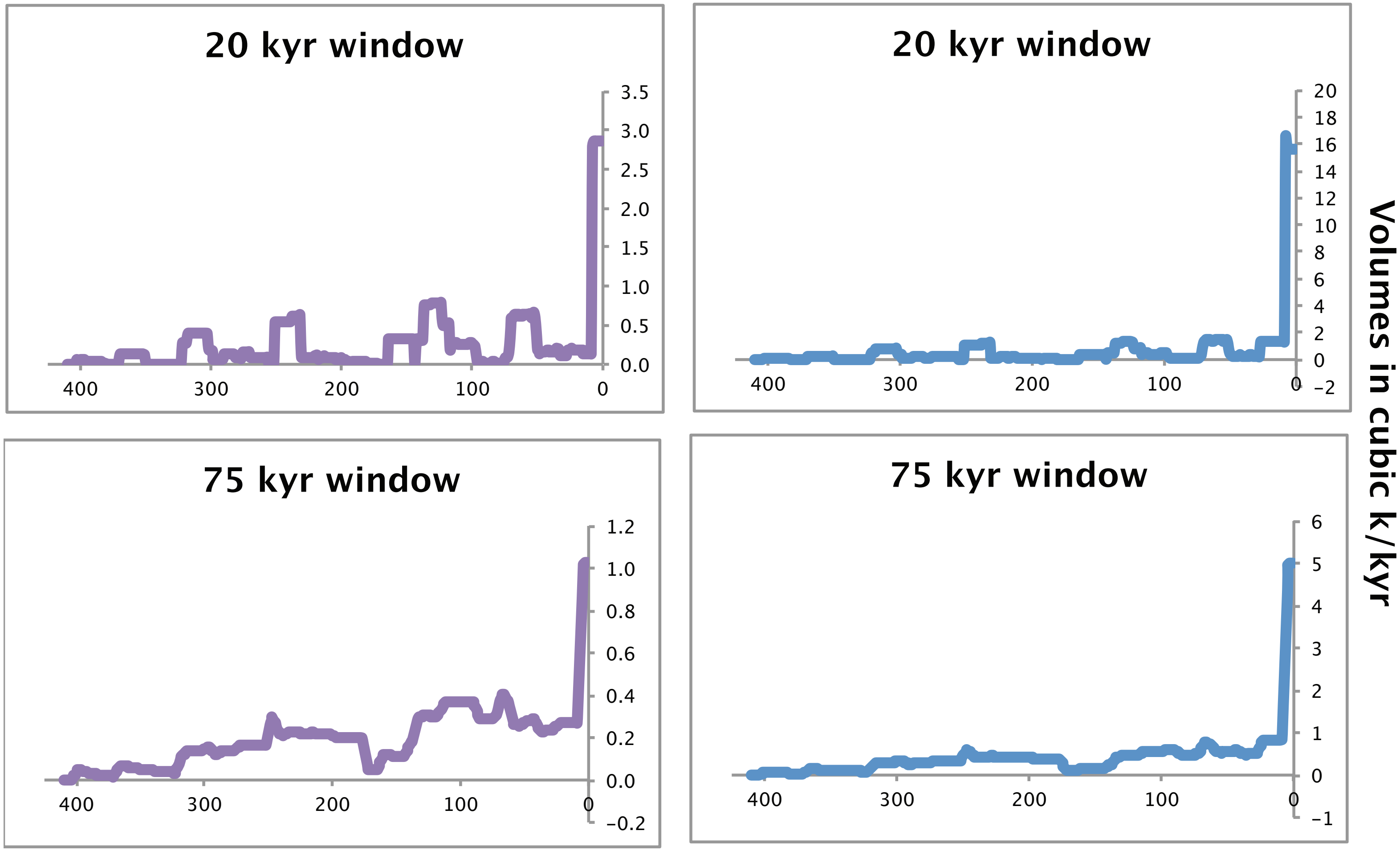
1) What governs the spatiotemporal distribution of eruptions (monogenetic vs central vent) at long lived centers?

2) What conditions led to the 7.7 ka caldera forming Crater Lake eruption?

Figure courtesy Heather M.N. Wright

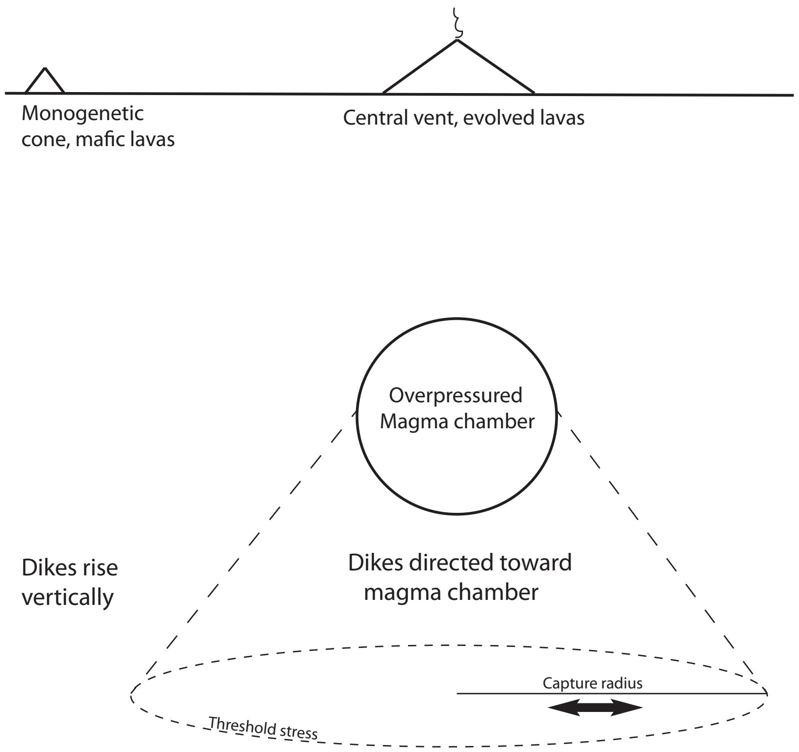
Data from last 400 ka, Mazama OR

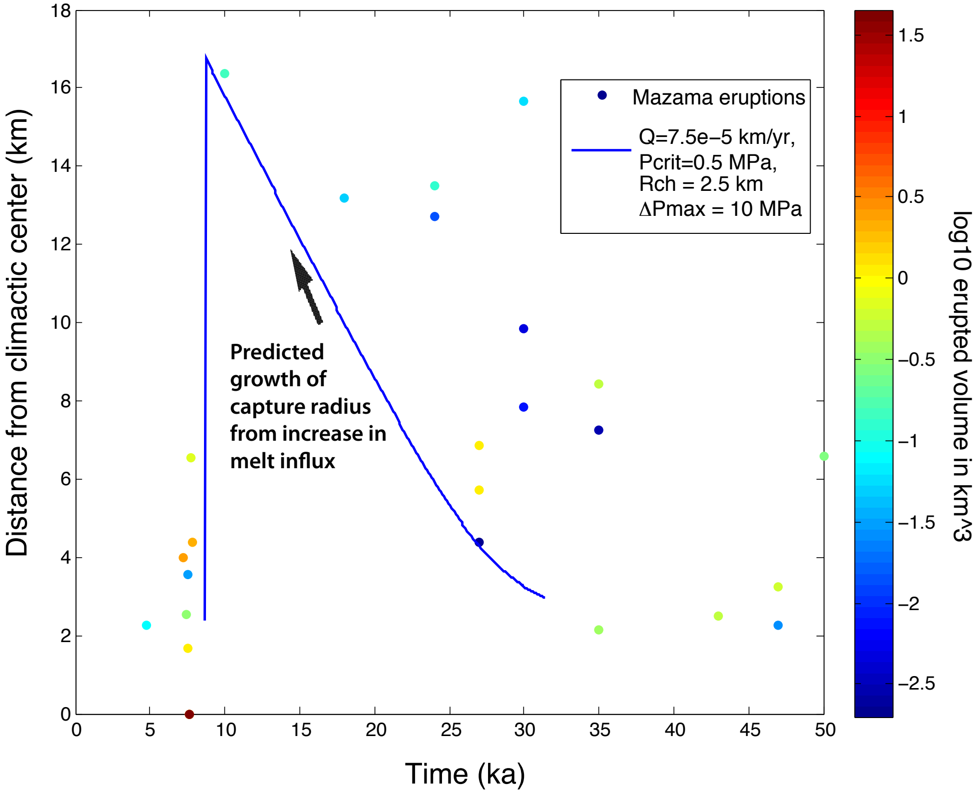




Large increase in erupted volumes leading up to caldera forming eruption,
Even larger when corrected for storage of magma

Ascent trajectory of dikes may be affected by magma chambers: Oscillating vent spacing in time?





Predicts observed “gap” in eruptions leading up to climactic event

Experimental Determination of H_2O and CO_2 Solubility in Basalt and Basaltic Andesite

Kurt Roggensack[1] and Gordon Moore[2]

[1]School of Earth and Space Exploration Arizona State University
[2] Chemistry Department, Arizona State University (now at Univ. Michigan)

Important Role of Volatiles in Volcanism

- Melt generation, mantle melting
  - Suppression of mantle solidus temperature
  - Volume and composition of primary magmas

- "Magma Chamber" behavior (H_2O and CO_2)
  - Physical properties (density and viscosity)
  - Chemical properties (crystal growth)

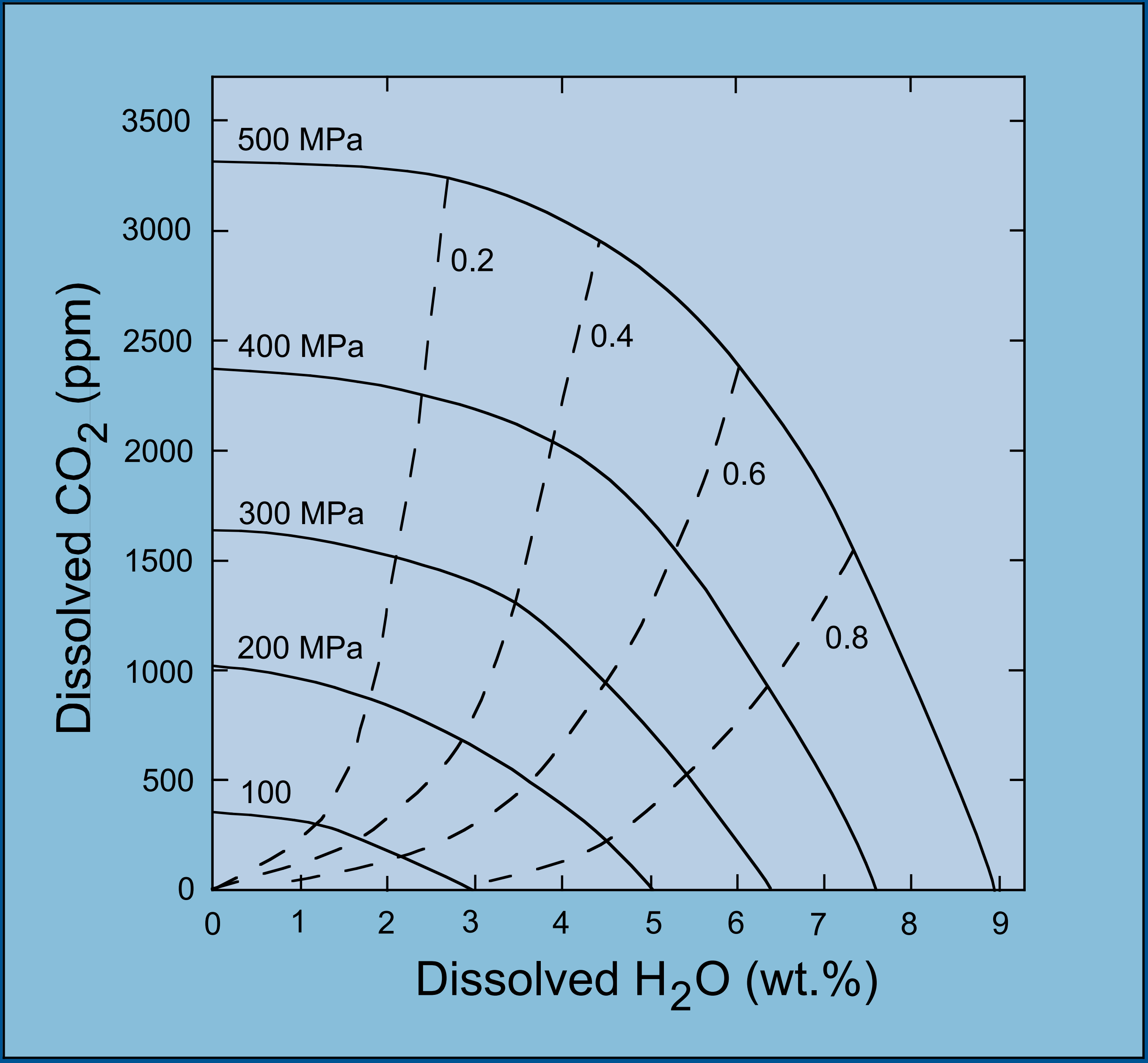
- Eruption energy!

Volcanic Gas

H_2O	0.5 to 7 wt. %
CO_2	up to 1,000s of ppm
Sulfur	100s ppm
Chlorine	100s ppm

(Also nitrogen, argon, helium, neon)

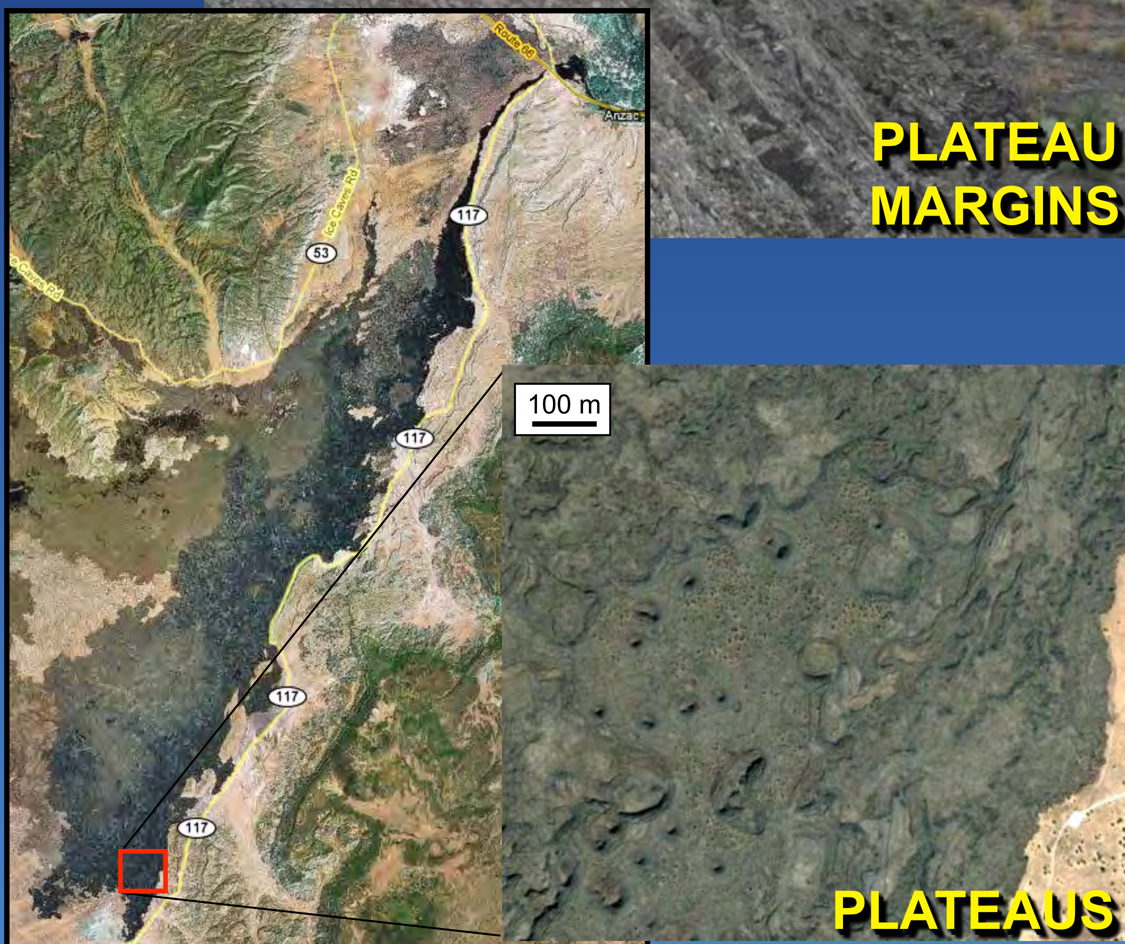
H_2O and CO_2 Solubility Experiments



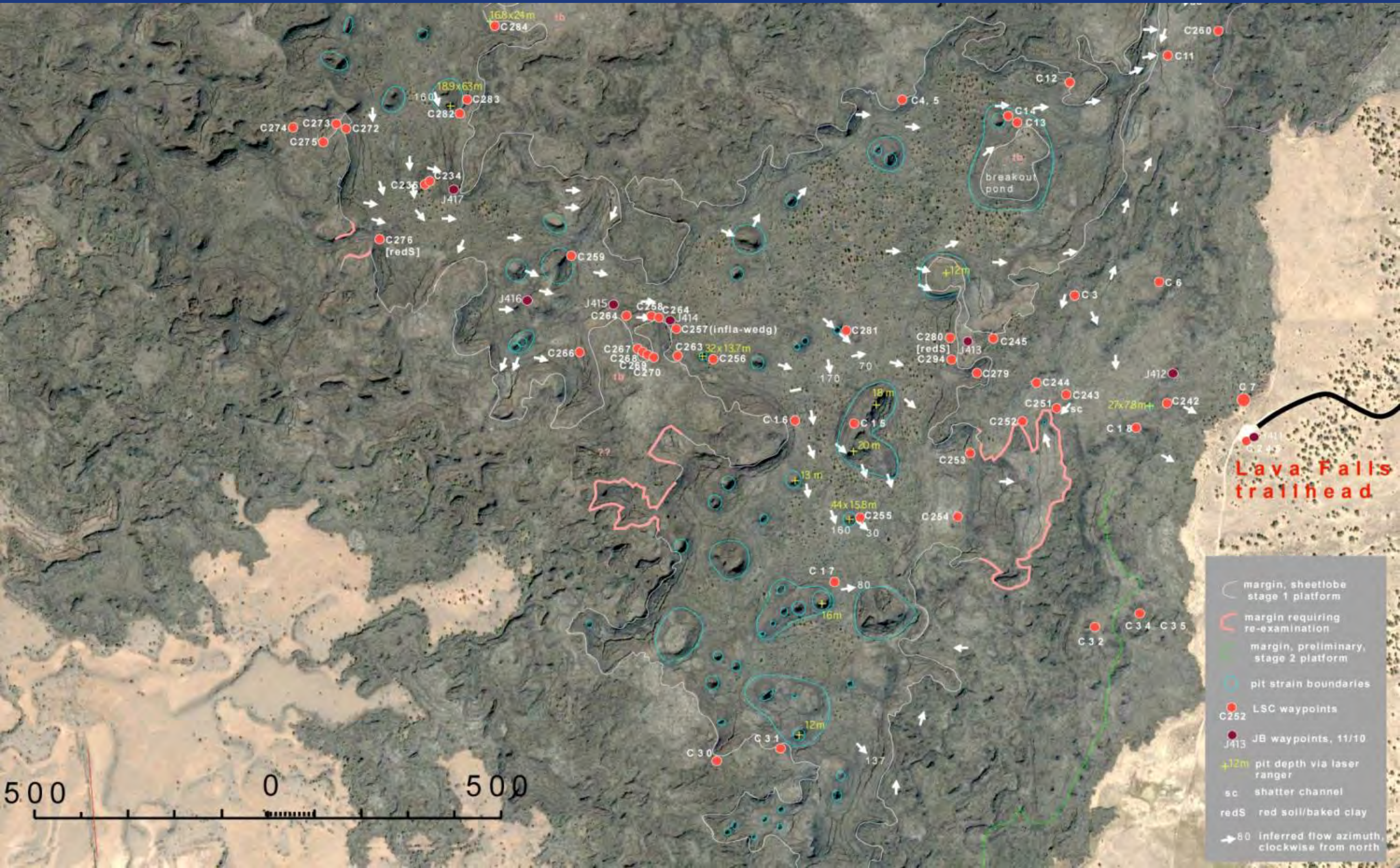
SURFACE FEATURES INDICATIVE OF INFLATION AT THE McCARTYS & CARRIZOZO FLOWS, NM

JE Bleacher, LS Crumpler, WB Garry, JR Zimbelman, S Self, JC Aubele

SURFACE FEATURES

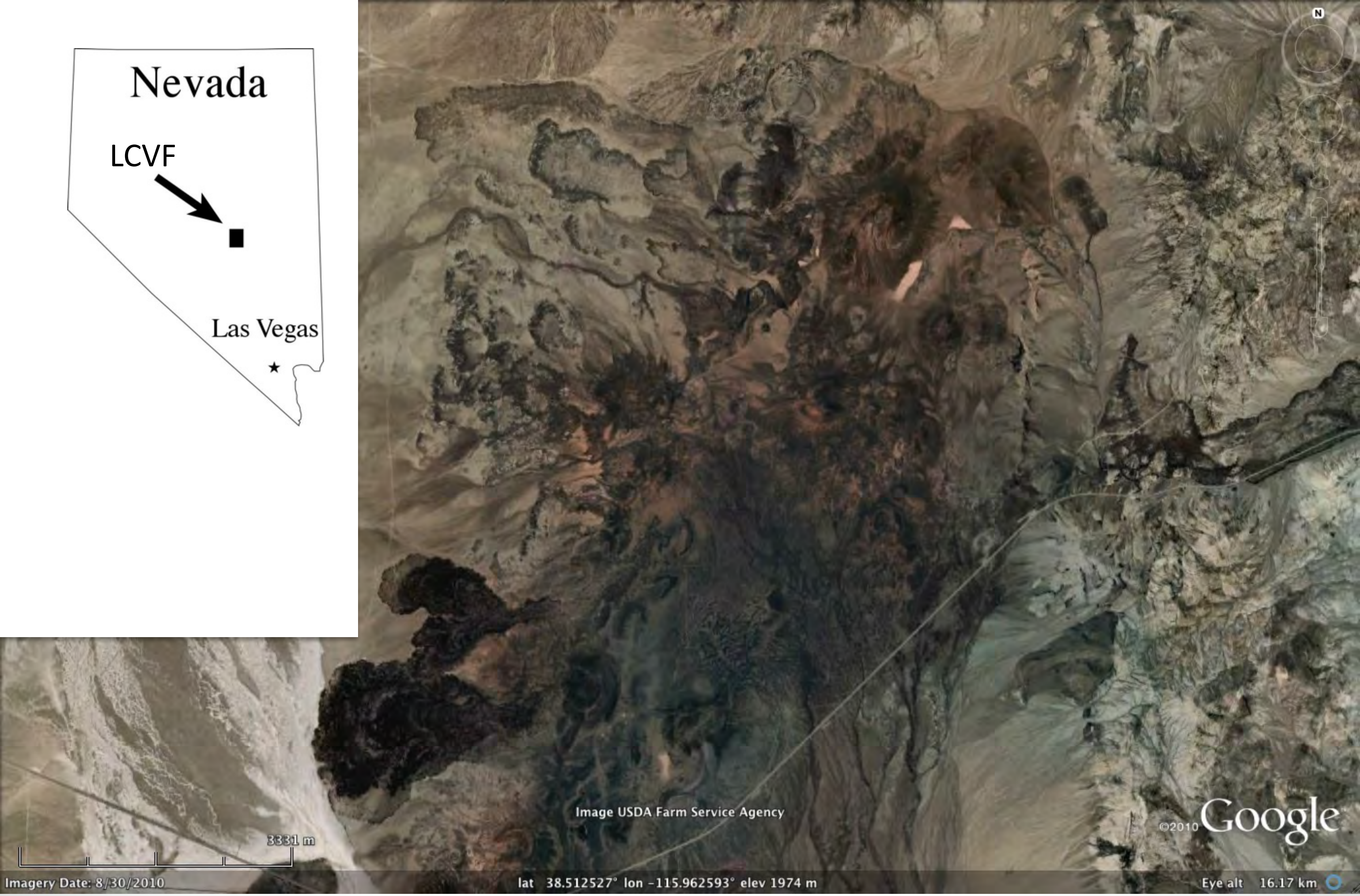


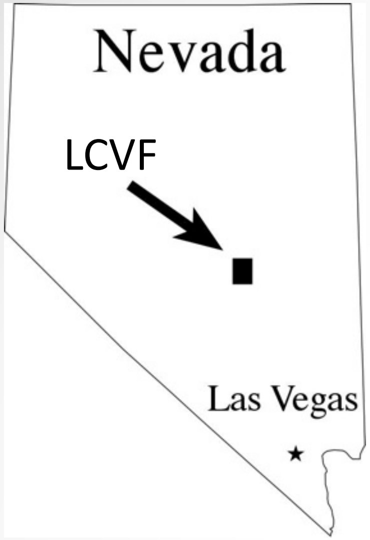
USING FEATURES & TEXTURES TO MAP EMPLACEMENT HISTORY

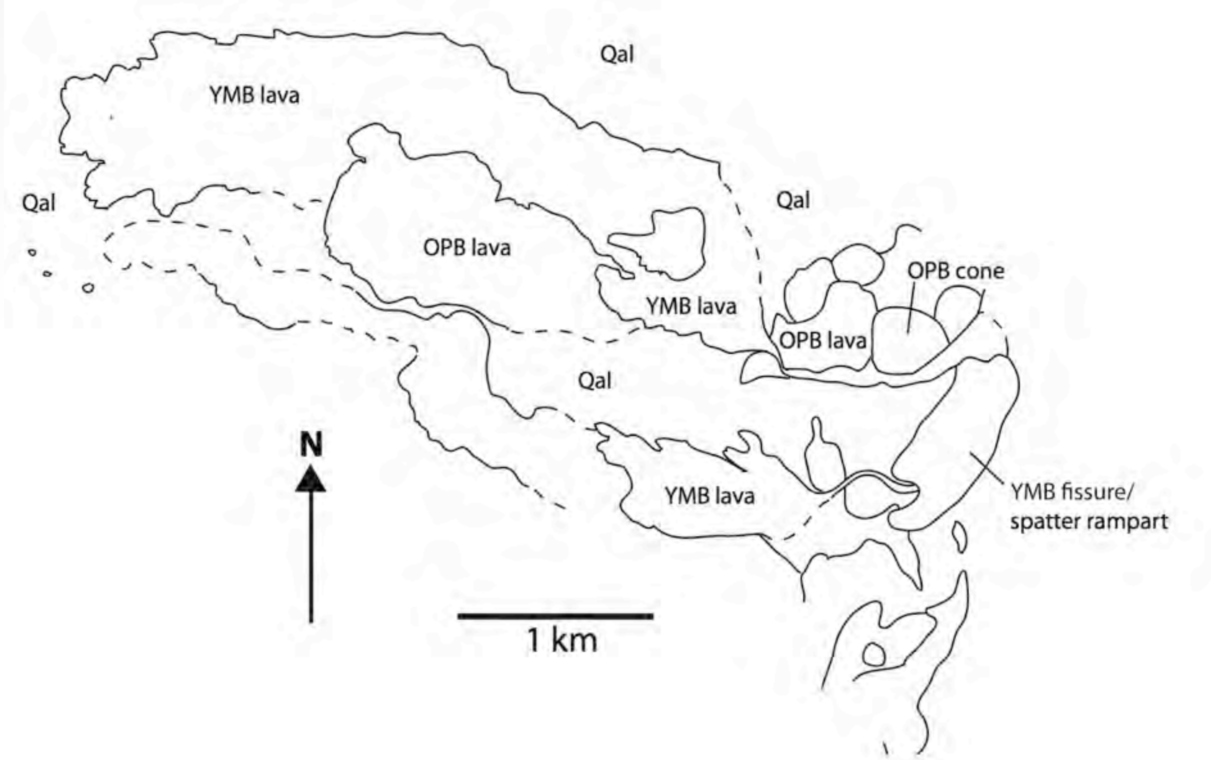


Intrinsic Conditions of magmas in Lunar Crater Volcanic Field, Nevada.

Joaquin A. Cortes[1], Eugene I. Smith[2], Racheal Johnsen[2], Gregory A. Valentine[1], Elisabeth Widom[3]

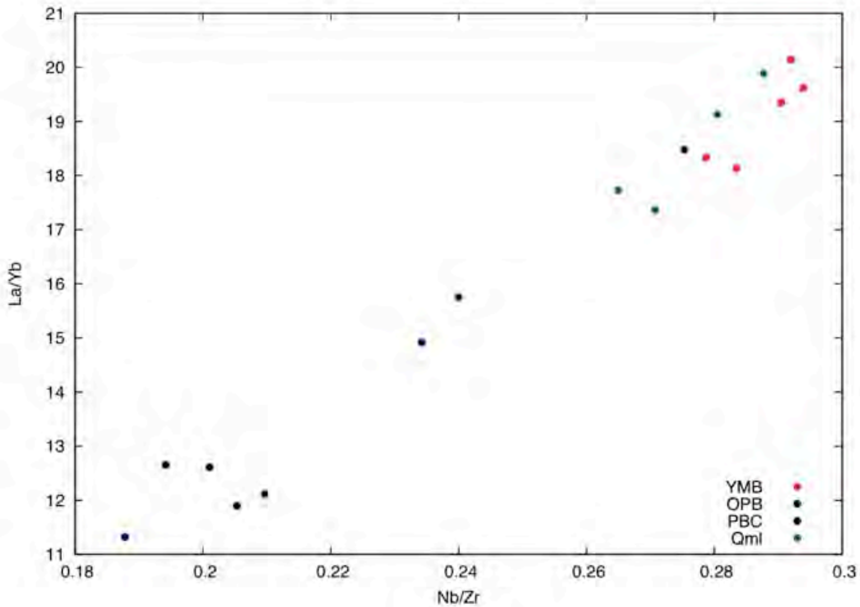

Nevada
LCVF
Las Vegas
Image USDA Farm Service Agency
©2010 Google
3331 m
Imagery Date: 8/30/2010
lat 38.512527° lon -115.962593° elev 1974 m
Eye alt 16.17 km

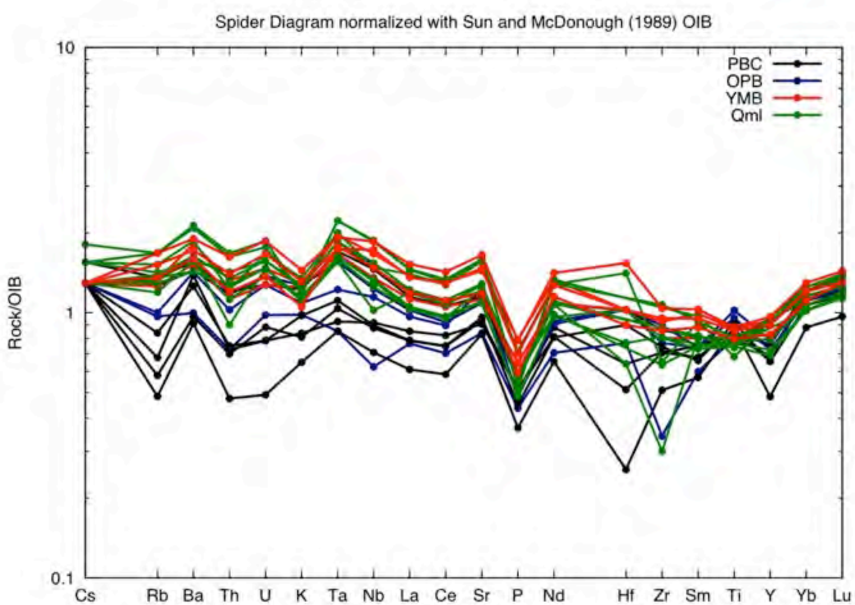




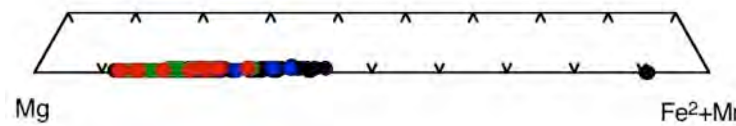
YMB (Younger, Megacryst-bearing) ⟷ Qm (Marcath Volcano)

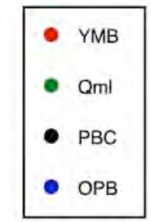
{ OPB (Older, Phenocryst-bearing)
PBC (Older, Megacryst-bearing)



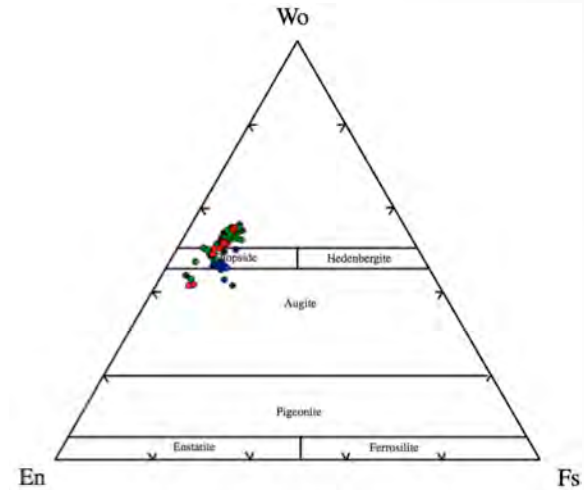


Olivine composition

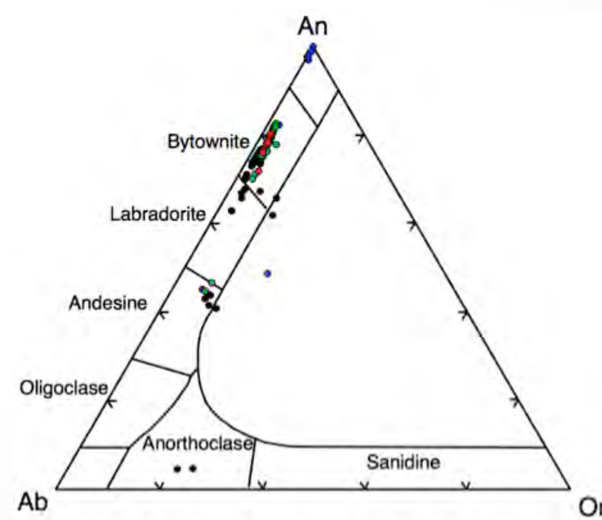




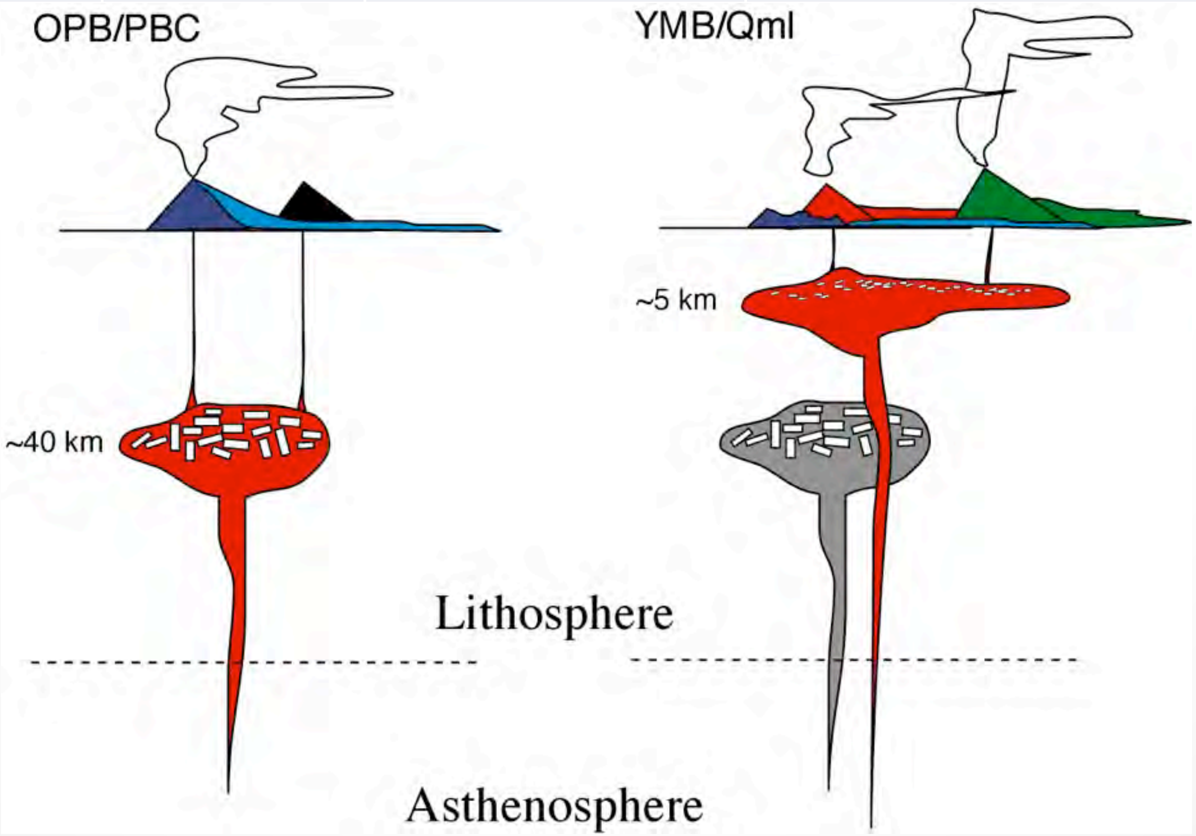
Cpx composition



Fd composition



Unit	P(kbar)	T(ºC)	fO_2
Qml	3-6/10-13	900-1050	ΔQFM+2 - ΔQFM+3
YMB	3-5/12-15	900-1000/~1050	ΔQFM - ΔQFM+3
PBC	12-13	1050-1100	ΔQFM+3 - ΔQFM+5
OPB	9-10	1050-1100	ΔQFM+3 - ΔQFM+5



Tephra dispersal and deposition from the ~38 ka Marcath eruption, Lunar Crater Volcanic Field, Nevada

Peter J. Johnson,* Greg A. Valentine, Marcus I. Bursik

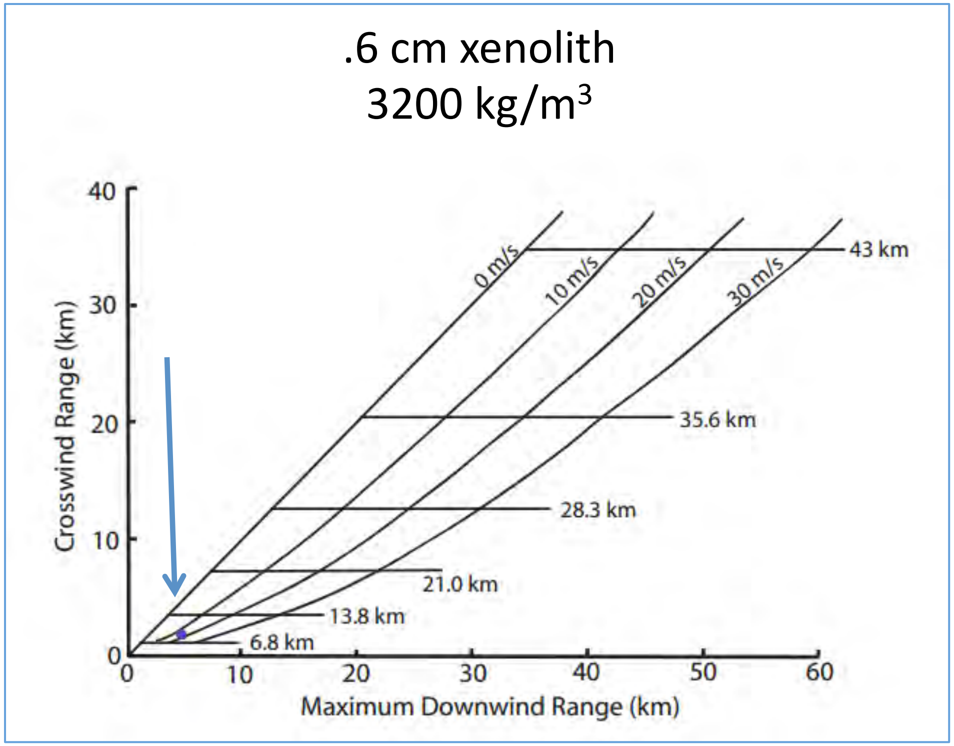
Department of Geology, University at Buffalo (SUNY), Buffalo, NY 14260

Introduction

- Lunar Crater Volcanic Field (LCVF) is in central NV, near major flight paths
- Explosive volcanism presents hazards to aircraft
- Most recent event produced two tephra deposits
- We reconstruct the larger of these eruptions

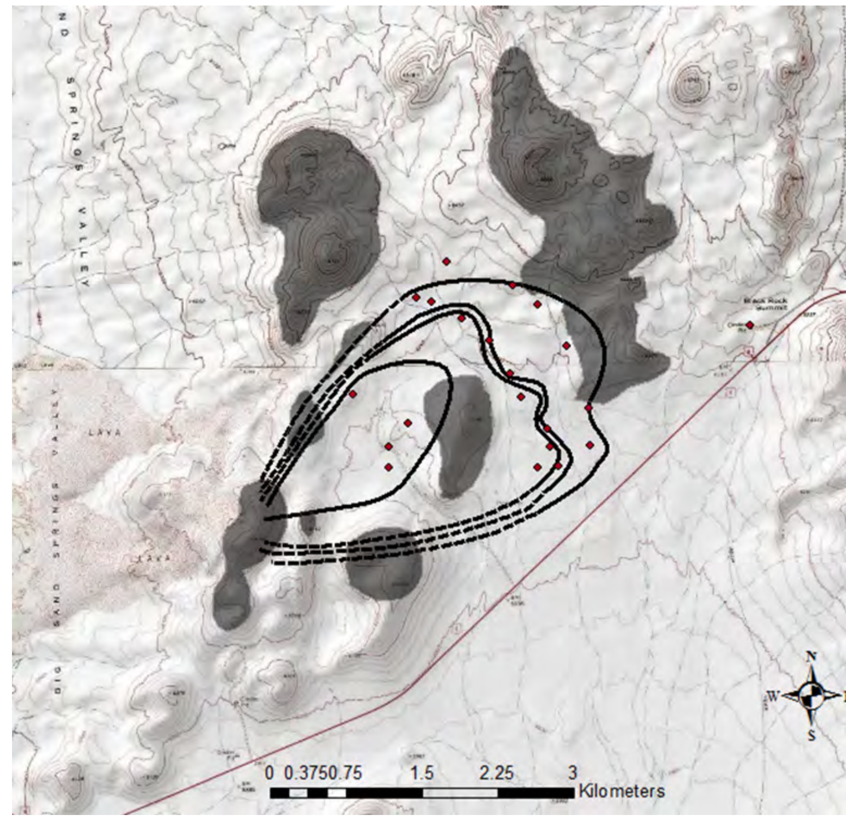
Eruption column height

- Height is directly related to hazards to aircraft
- Used methods of Carey and Sparks (1986)
- Calculated elevation of ~7 km in winds of ~15 m/s, from the southwest



Volume

- Useful for classifying eruptions (e.g. VEI)
- Also can be used to determine eruption duration
- Estimated based on isopachs
- ~.007 km^3, or .002 km^3 dense-rock equivalent (VEI 2)
- Eruption probably lasted a few hours



Mapping volcanic rocks, heat flow and groundwater with magnetic and electromagnetic data: Applications to volcanic hazards

Carol Finn, Benjamin Drenth, Paul Bedrosian

United States Geological Survey, Denver, Colorado

Using Magnetic data to map volcanic rocks: an example from NM

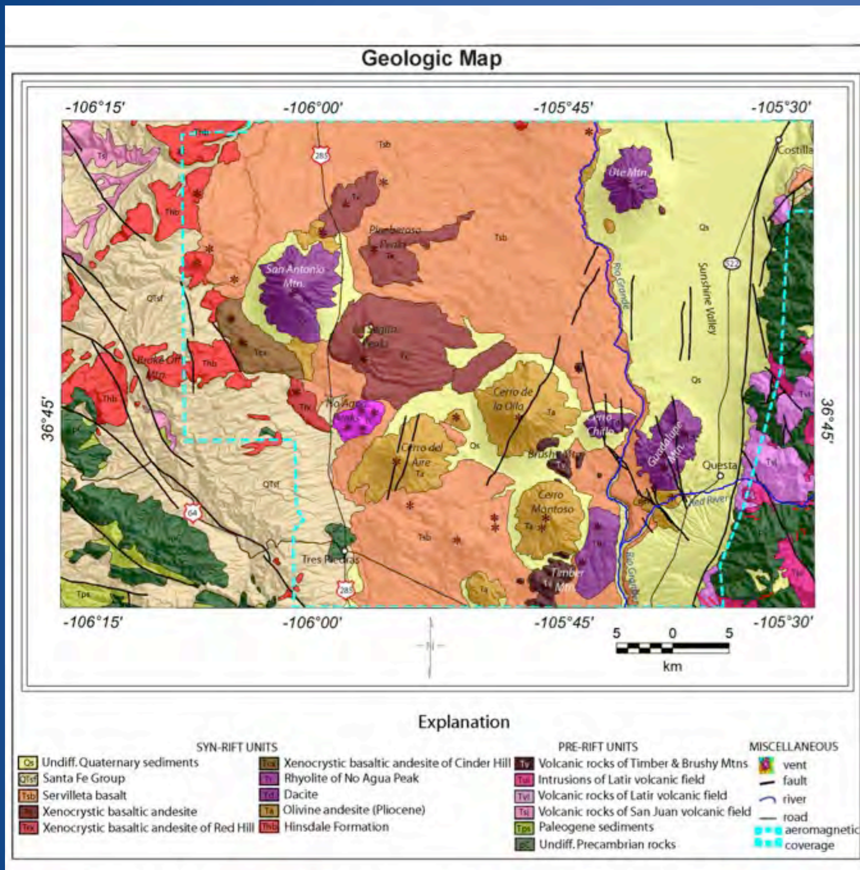
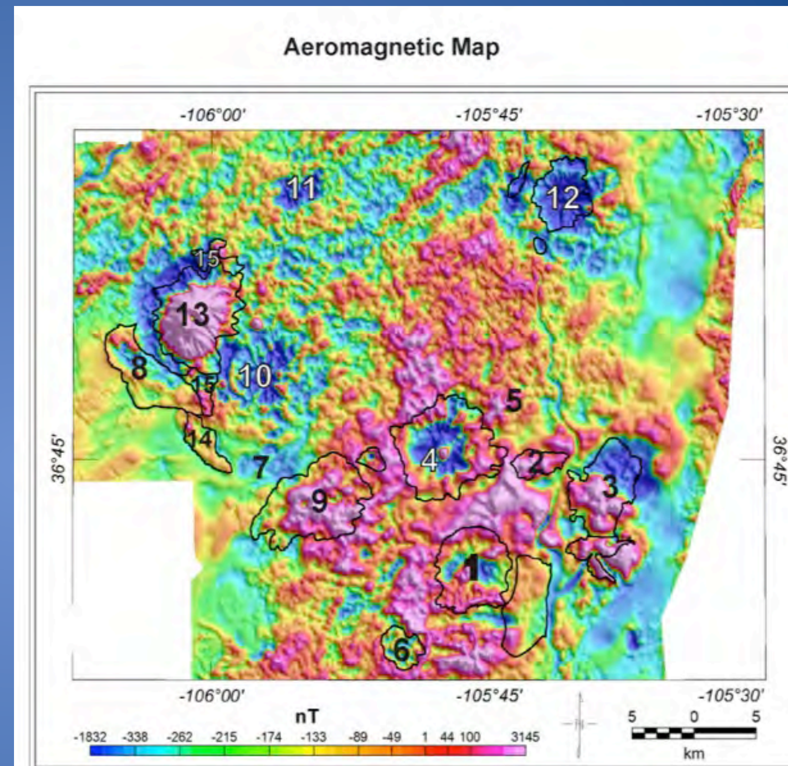


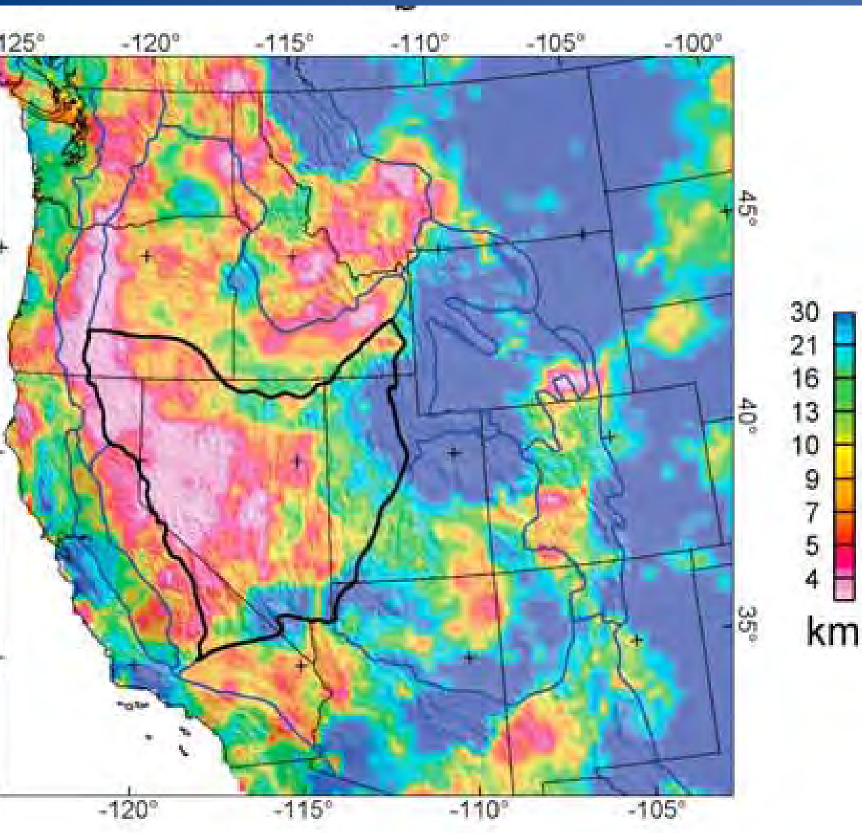
Figure 2: Geologic map of the northern Taos Plateau region. Based on unpublished mapping (Ren Thompson, Peter Lipman, and others) and the 1:500,000 scale geologic map of New Mexico (Anderson and Jones, 1994; Green and Jones, 1997).



(From Drenth et al, 2009)

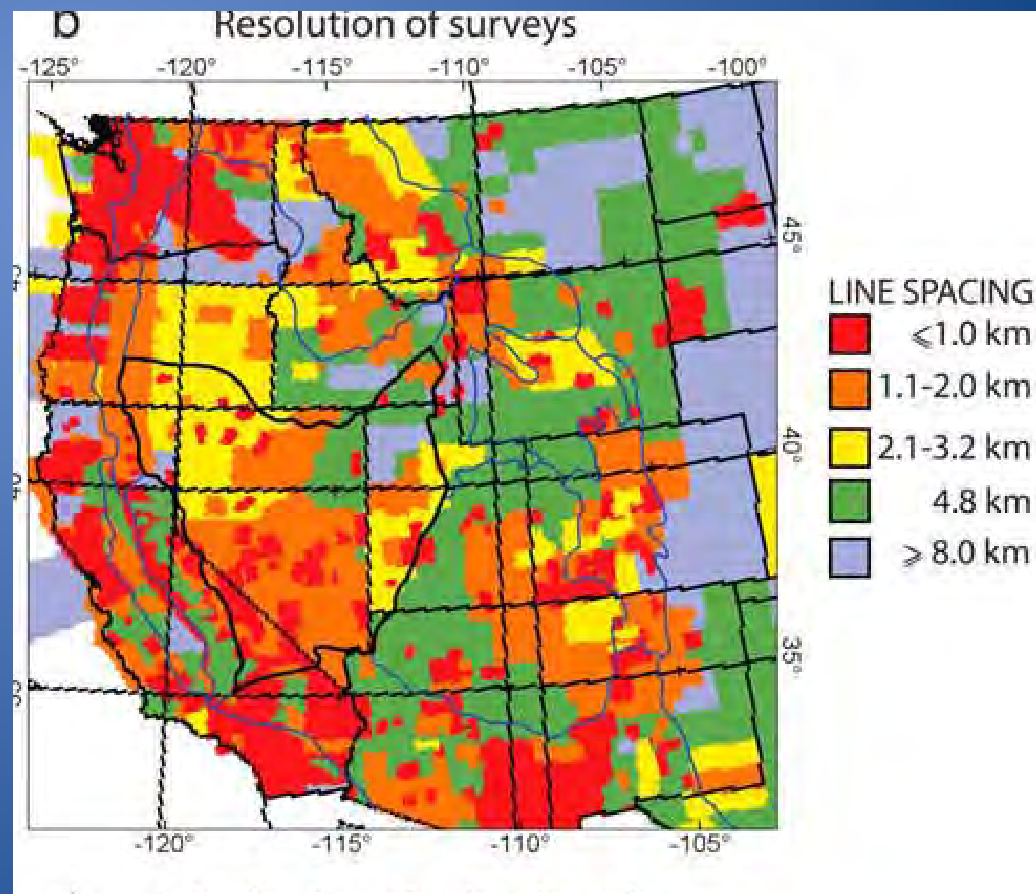
- Aeromagnetic highs (red colors) indicate normally magnetized volcanic rocks and lows (blue colors indicate reversely magnetized rocks
- The polarities can help determine ages. Magnetic anomalies can map volcanic rocks beneath the surface .

Using Magnetic data to infer heat flow: An example from the western US



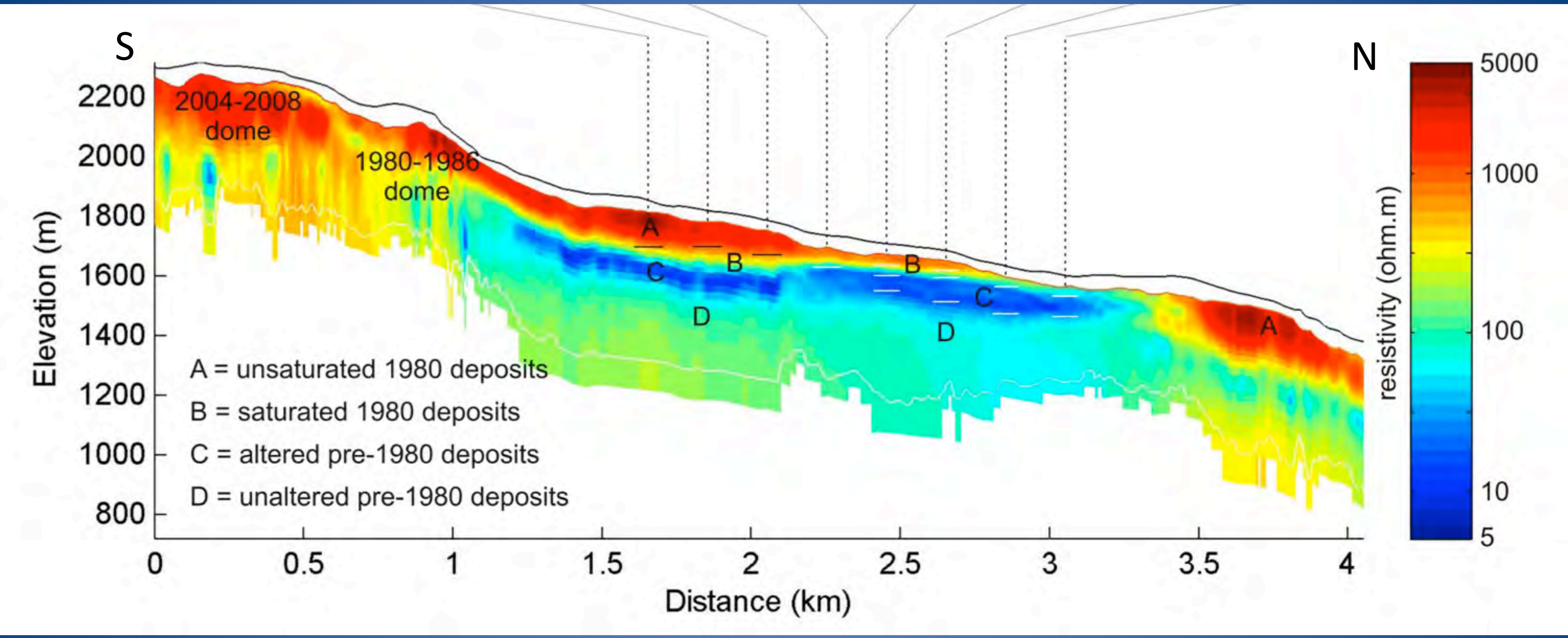
(From Bouligand and others, 2009)

- Depth to bottom of magnetic layer
- Correlated with temperature at which rocks lose magnetism (580° C).
- Shallow depths can indicate areas with high heat flow and perhaps heat sources for eruptions



- Aeromagnetic data publically available for entire US
- Variable quality

Electromagnetic data map groundwater: An example from Mt. St. Helens



- Groundwater poses a hazard when it is heated by magma and violently released, as eruptions of either pure steam or steam mixed with fragmented magma or country rock.
- Identifying groundwater helps determine the hazard from magma-water interactions.
- EM data only locally available

Optional final stop: Sunset Crater visitor's center

- Free entrance ☺ (if we don't all go, tell them that you are with the Riggs-Ort field trip)
- Look around, enjoy the exhibits
- Diane Chung, NPS superintendent for Flag area monuments, would like your ideas:
  - general comments on the exhibits
  - how to better educate the public about potential for future eruption