Portable Broadband Seismology
A PI Perspective

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Field Broadband Seismic Data Needs

WAVEFORMS

and

TIMING

!!!!!

Field Broadband Seismic System Needs

Scientific Needs

- **Waveforms**: Good sensors (broad or intermediate band; simple and uniform response)
- **Timing**: Good clocks (high-precision timing; timing corrections easily handled within digitizing system)

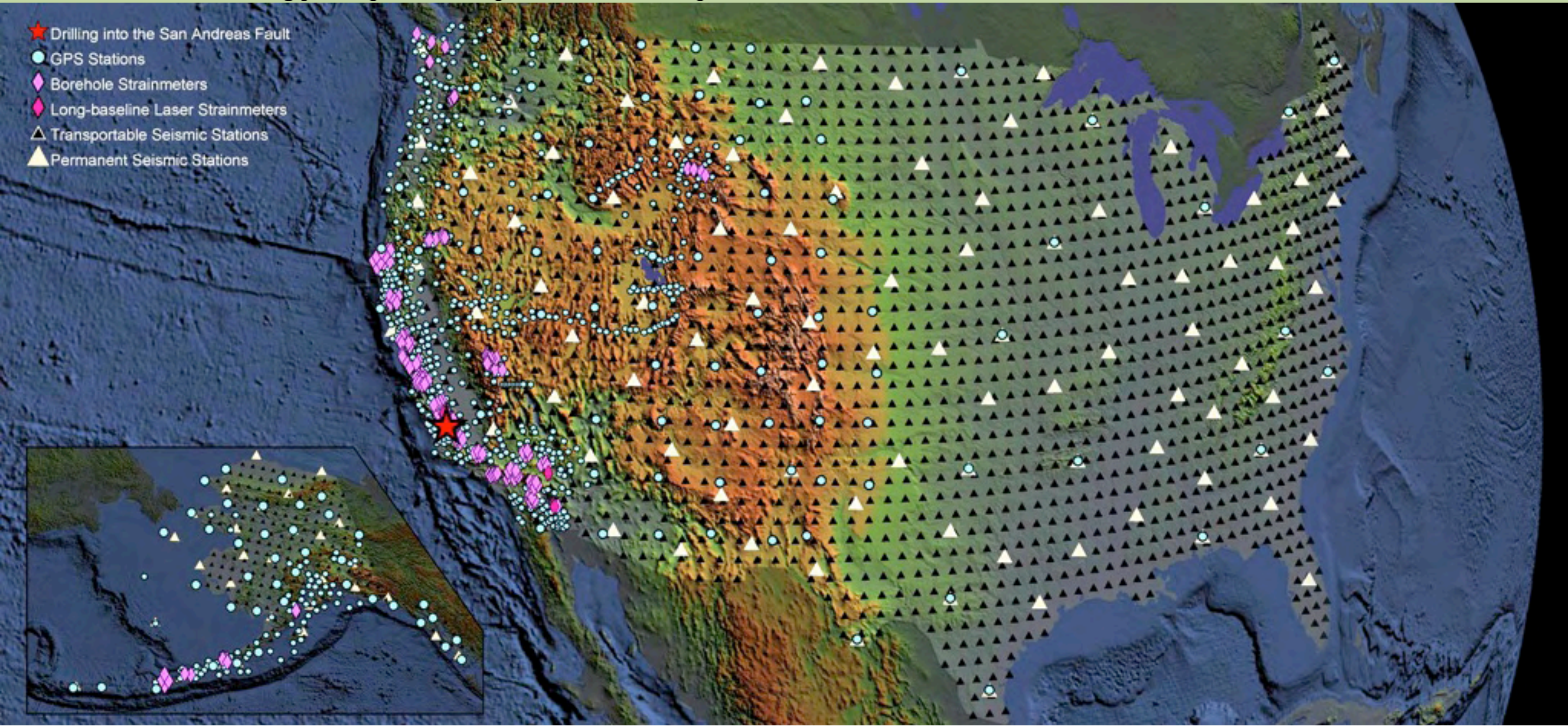
Field Needs

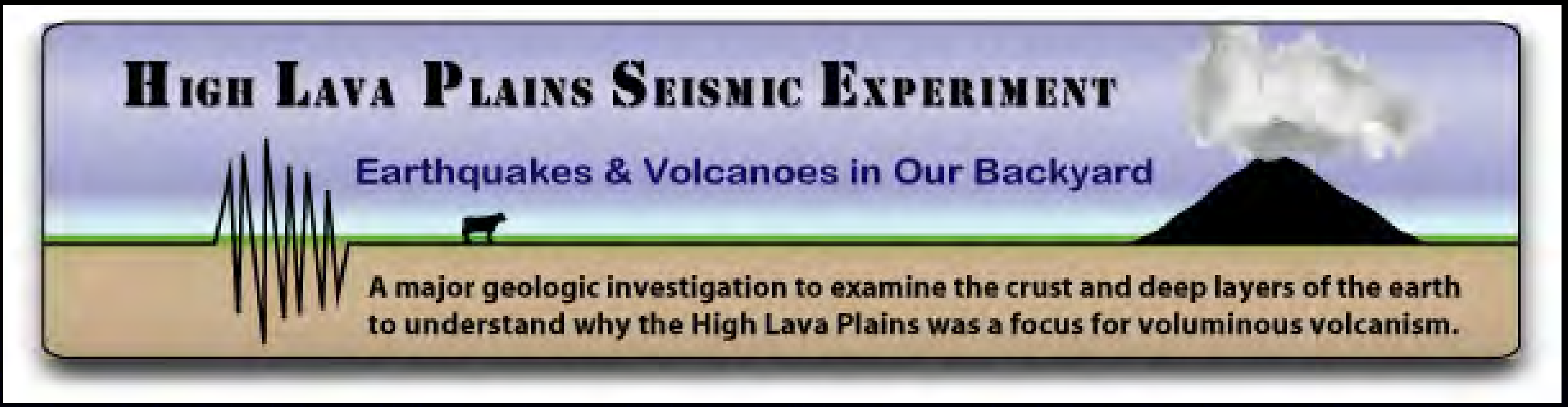
- **Robustness**: Equipment can handle broad range of operating environments
- **Simplicity**: Deployment and servicing/maintenance are straightforward, problem-free, and safe

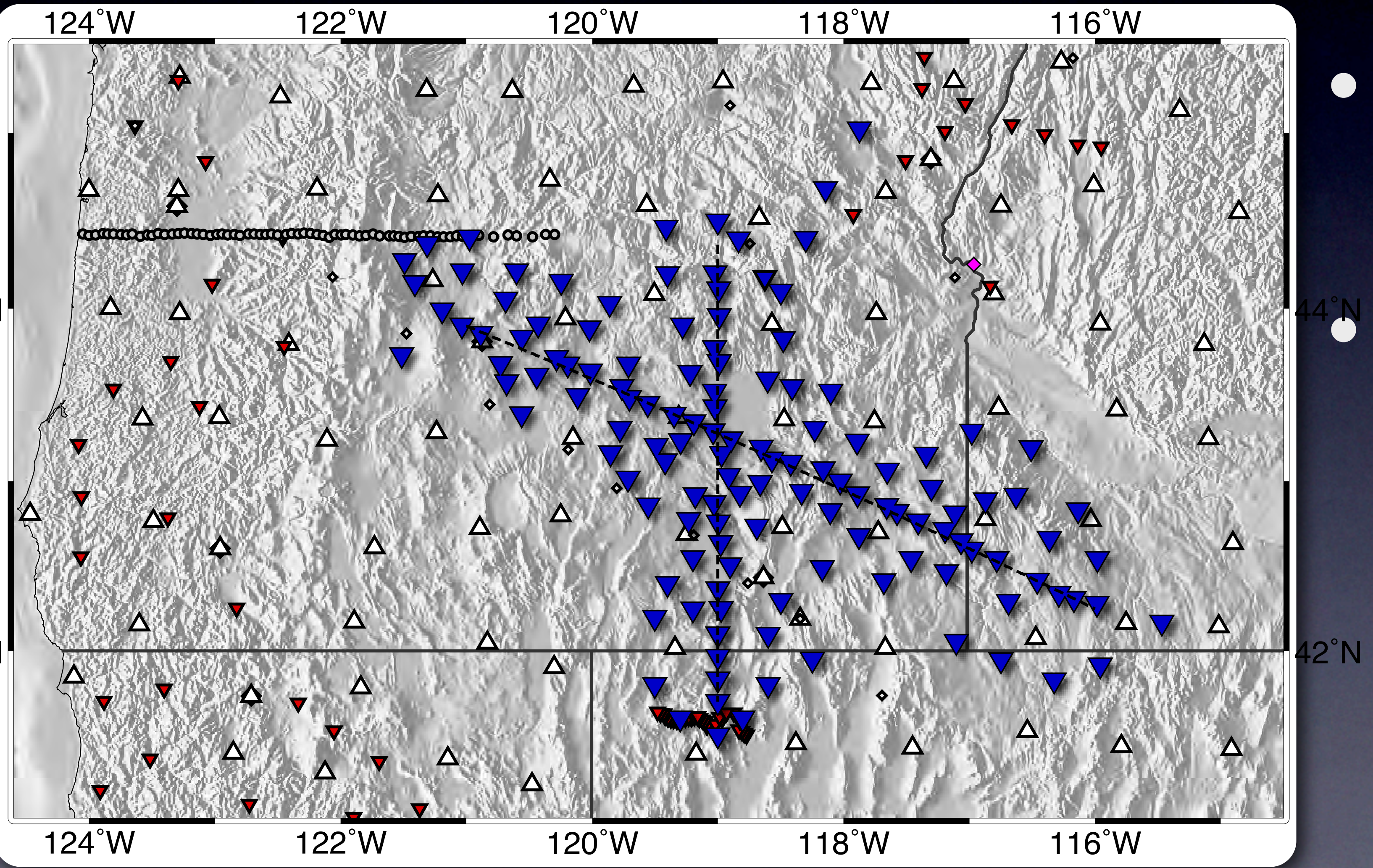
EarthScope: Instrumentation

“Integrated observational system of systems” ($200 million)

SAFOD: 3.1 km borehole into the San Andreas Fault
PBO: 1099 geodetic stations; 81 strainmeter/seismic stations
USArray: 2605 seismic and 30 magnetotelluric stations
Topographic imaging: 1000s of km^2 high resolution topography/InSAR swaths
Geochronology: Age dating of wide range of rocks

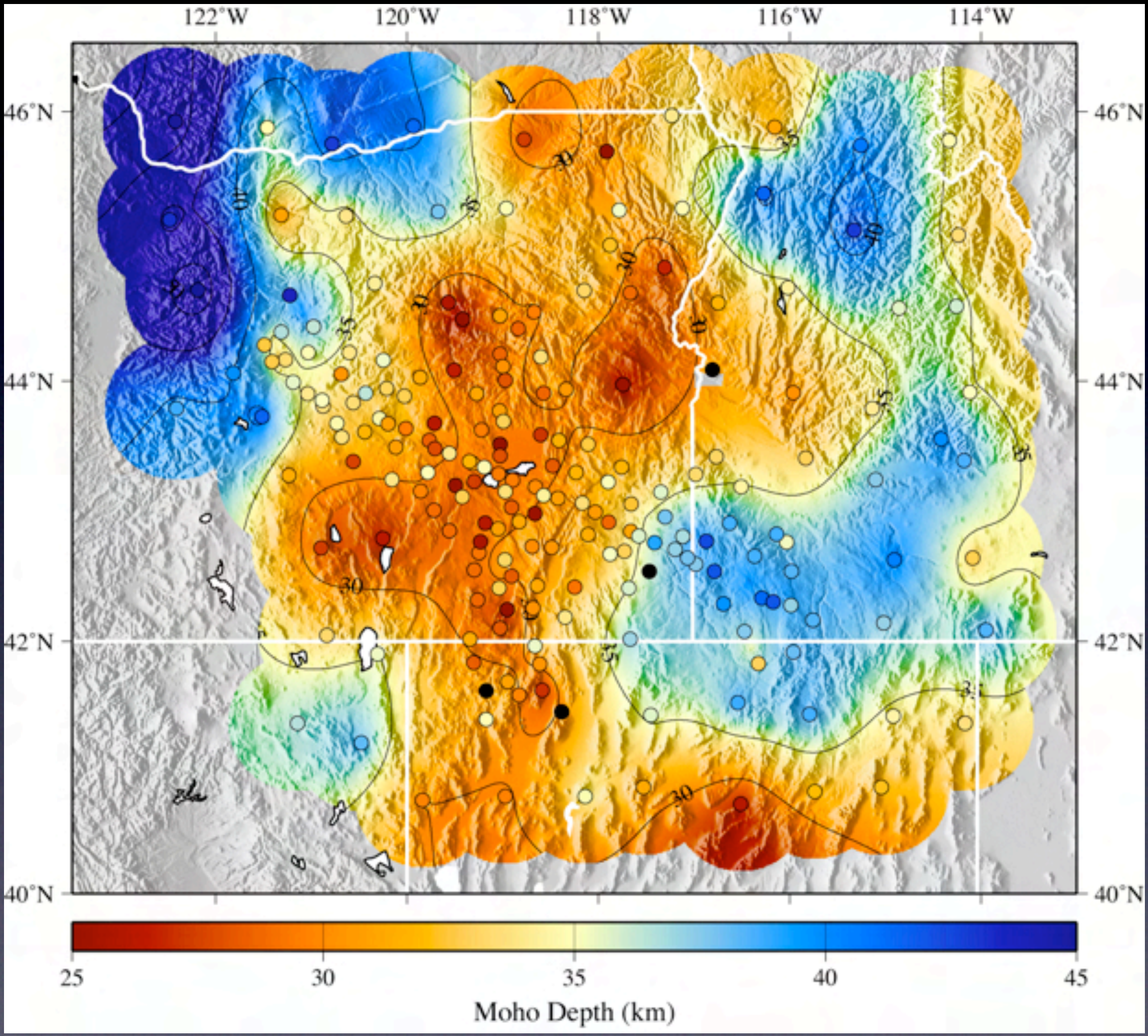






- Natural source experiment operated from Jan. 2006 to Sept. 2009
- 118 total broadband sites occupied
- Active source experiment included ~3,000 geophones and 15 1-ton shots in Fall 2008

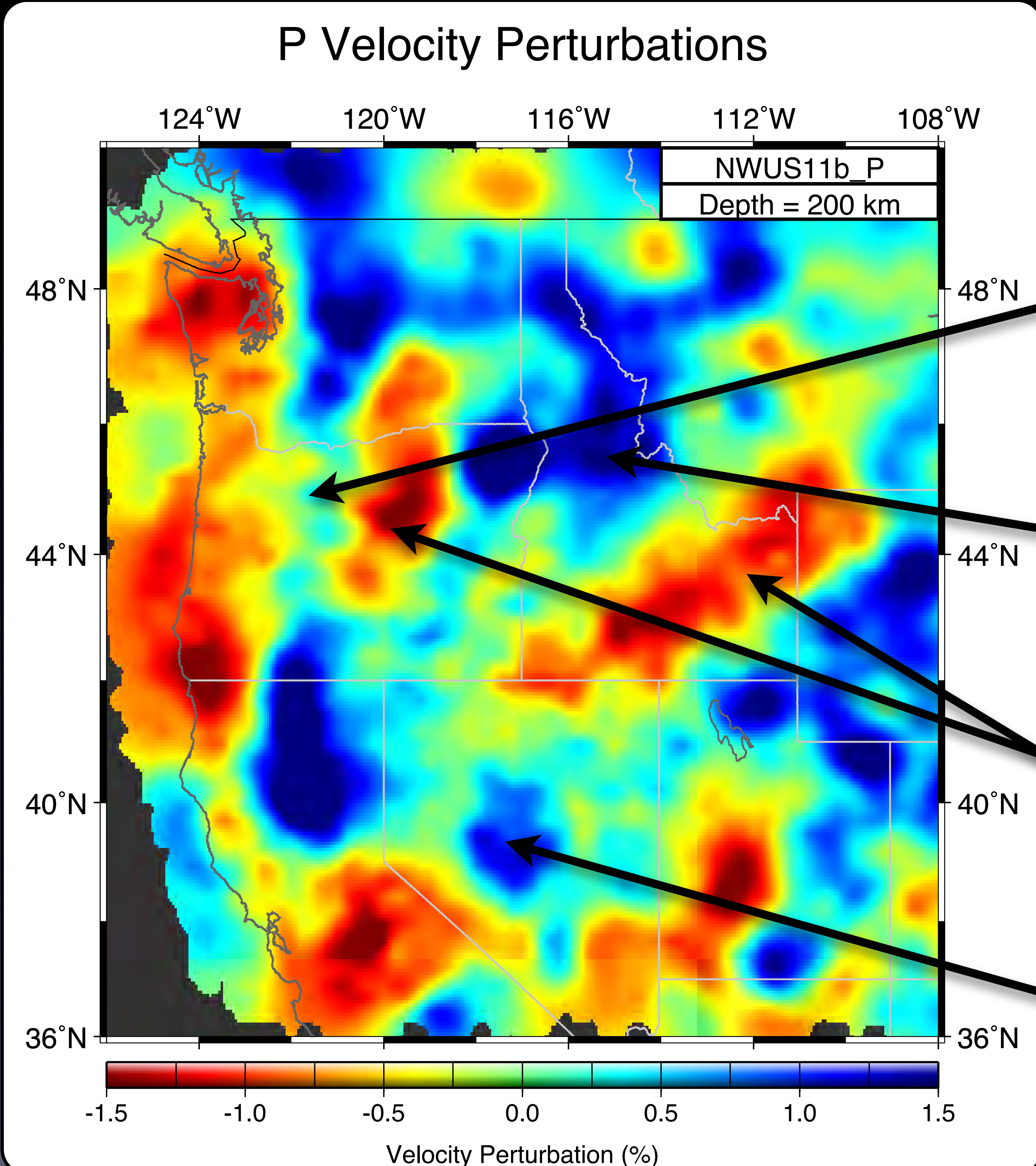
High Lava Plains Crustal Thickness



- Thin areas
  - High Lava Plains (~28 km)
  - Great Basin (~30 km)
- Thick areas
  - Cascades (~50 km)
  - Idaho Batholith
  - Owyhee Plateau (~42 km)
  - Modoc Plateau
- Sharp transitions
  - Cascades - HLP
  - HLP - Owyhee Plateau
  - Blue Mt. - Idaho Batholith

Eagar et al., *JGR*, 2011

Mantle Tomography

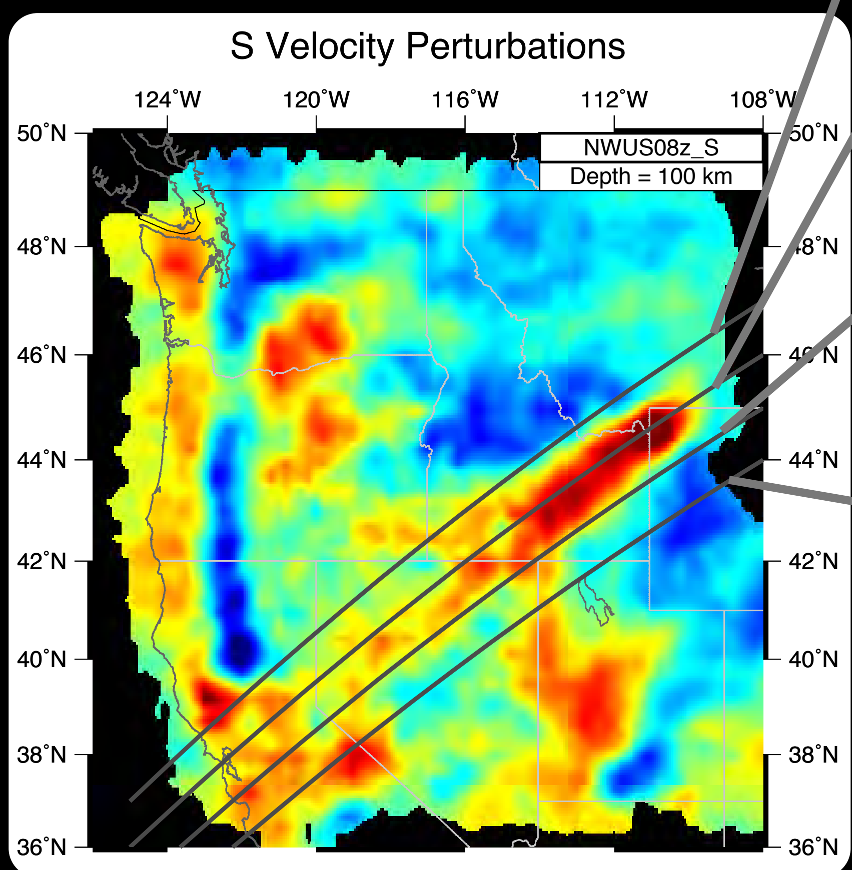


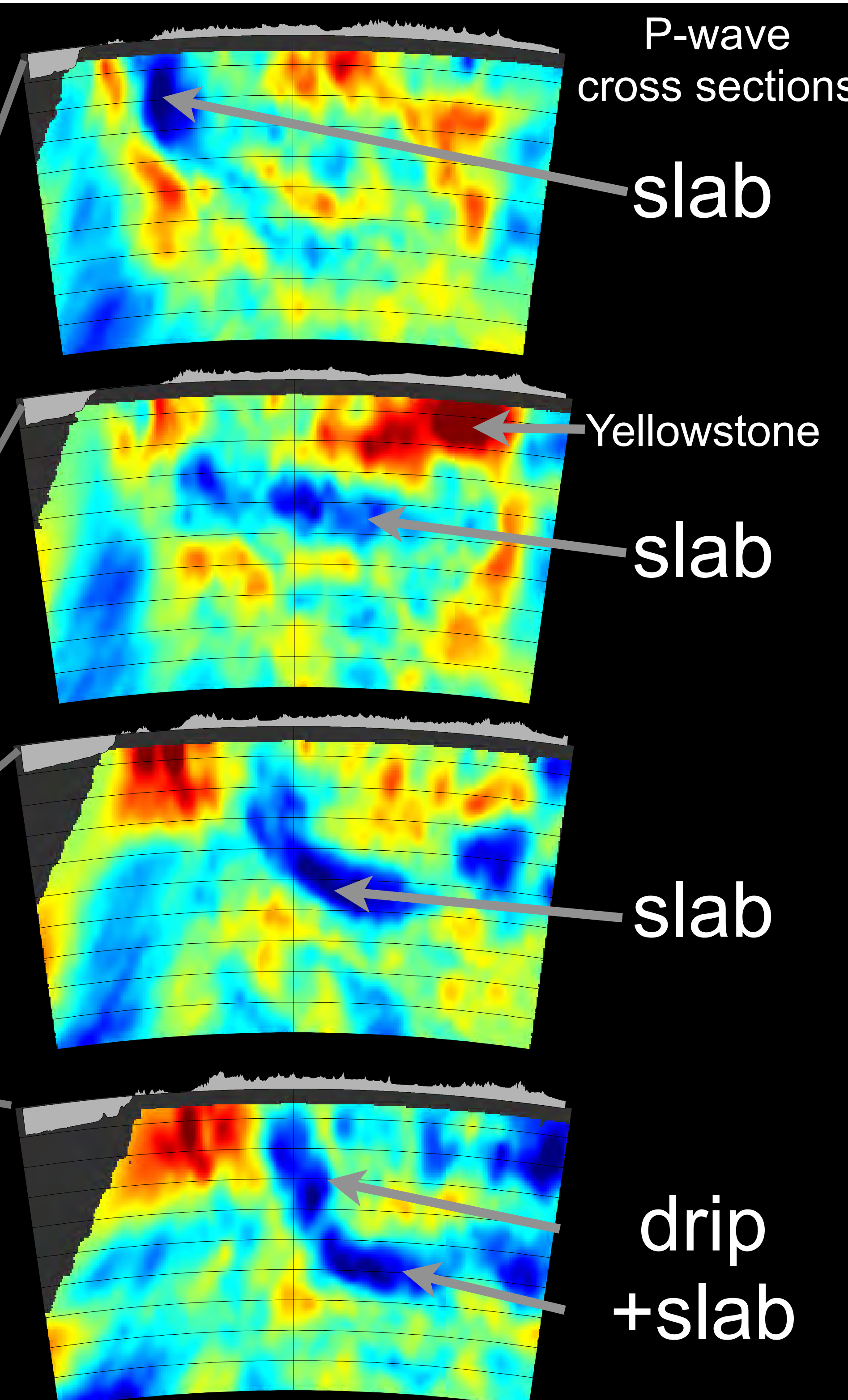
- *Apparent* gap in Juan de Fuca slab (inversion artifact)
- High velocities beneath cratonic North America
- Low velocities beneath central Oregon and SRP/Y
- Central Nevada anomaly

Roth et al., *GRL*, 2008;
James et al., submitted to *EPSL*, 2011

Complex Mantle Structure Beneath Snake River Plain / Yellowstone System

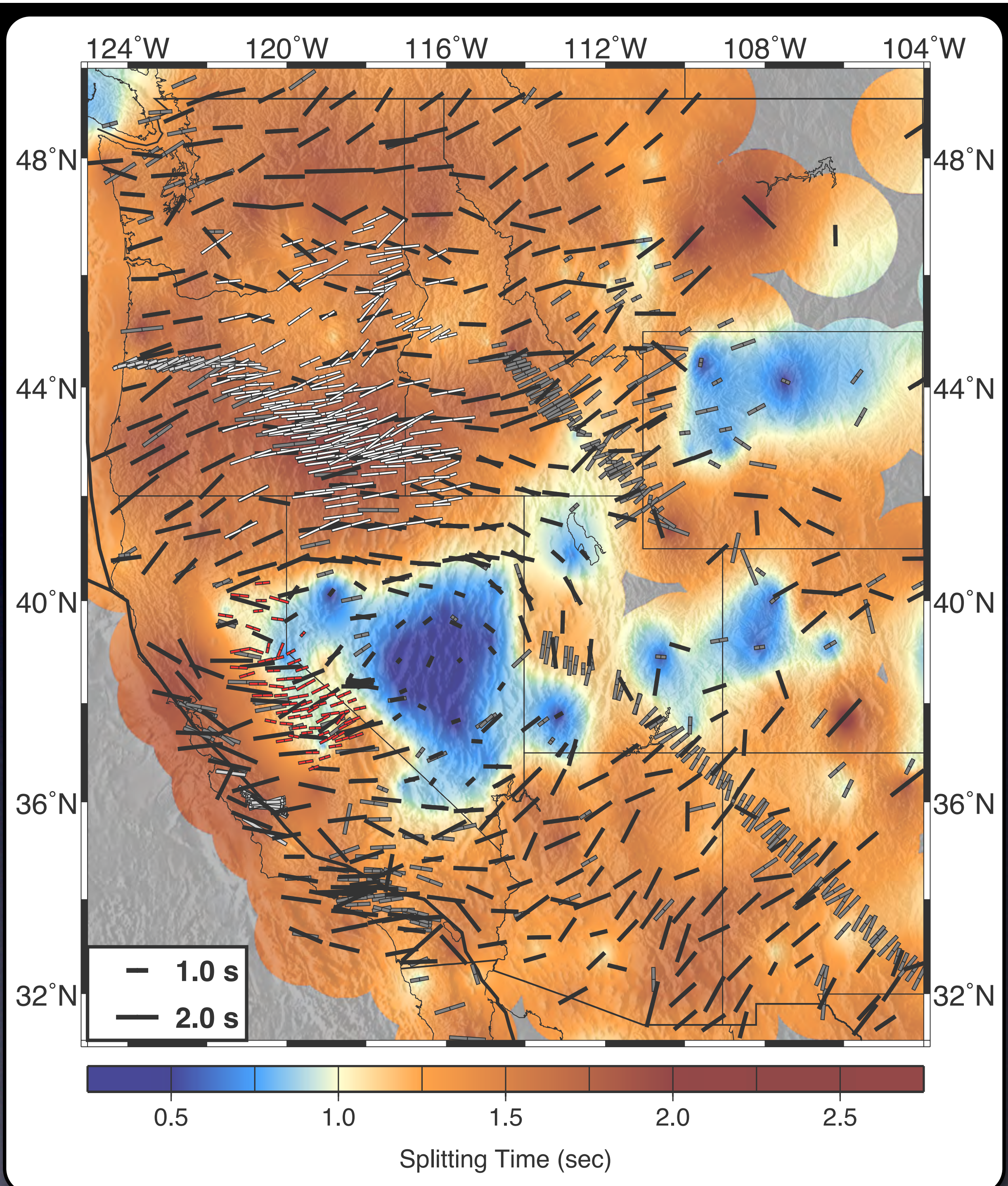
James et al., submitted to *EPSL*, 2011





SKS Splitting Beneath the Western U.S.

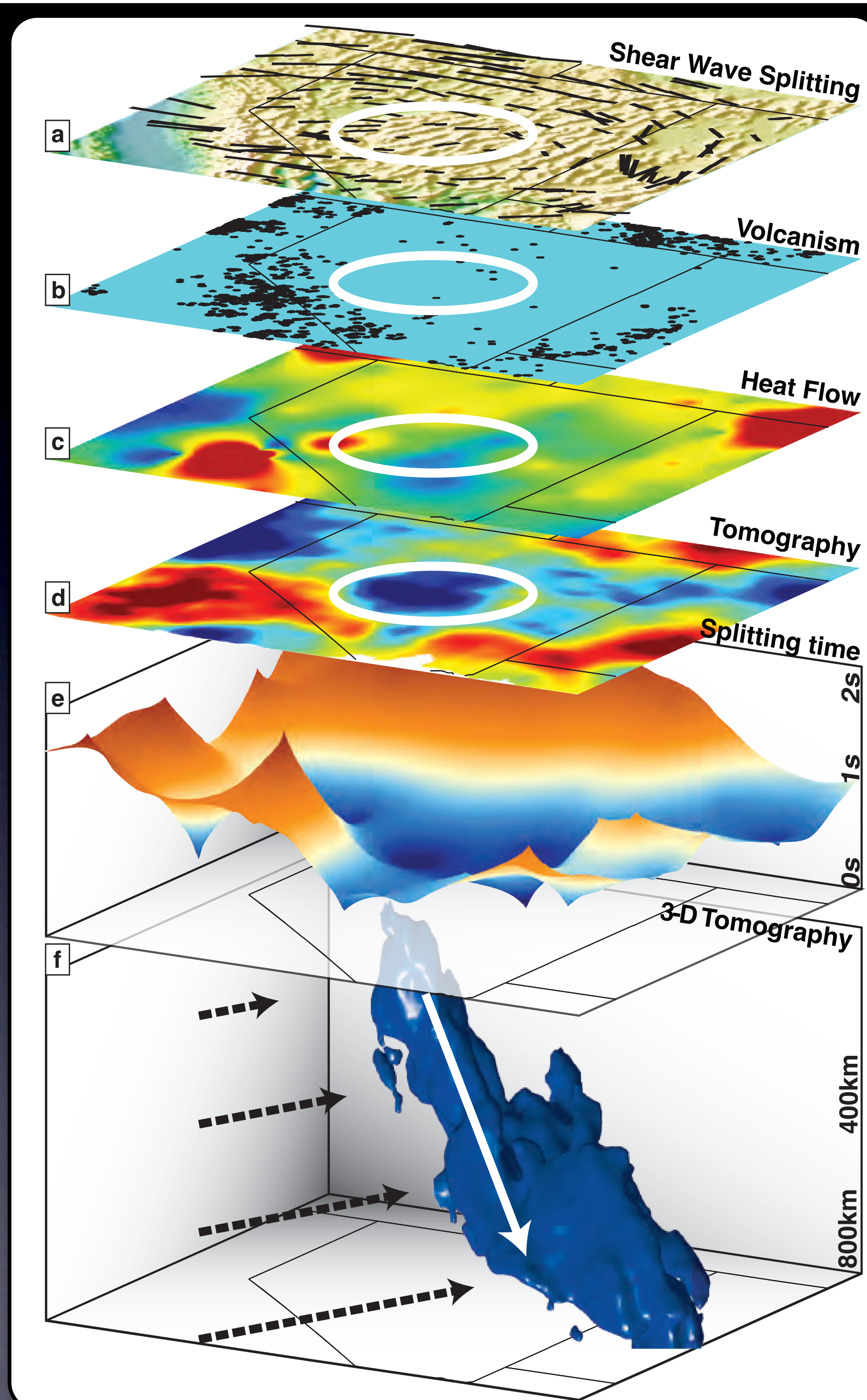
- Clear, broad-scale regional similarities over 100's of km
- Large splitting times across most of region
- Significant complexity over shorter spatial scales in some regions
- Very small splitting times beneath Great Basin



Fouch and West, in prep, 2011

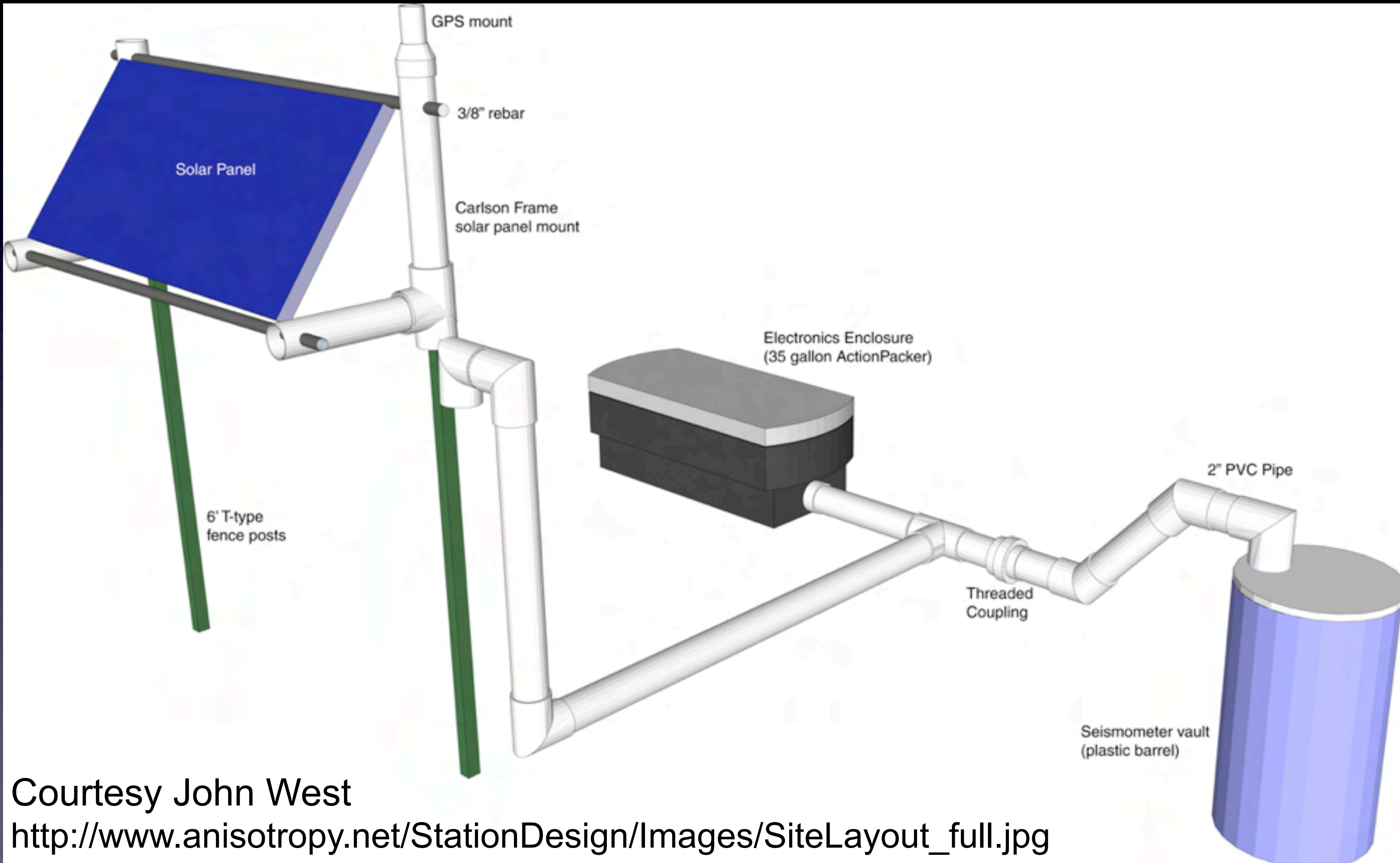
Mantle Drip Beneath the Great Basin

- Region of small splitting times correlates with:
  - Very limited post-10My volcanism
  - Regionally low heat flow
  - Cylinder of increased seismic velocities tilted to NE
- *Consistent with models of a mantle drip*



West et al., *Nature Geoscience*, 2009

Standard Vault Design



Courtesy John West
http://www.anisotropy.net/StationDesign/Images/SiteLayout_full.jpg

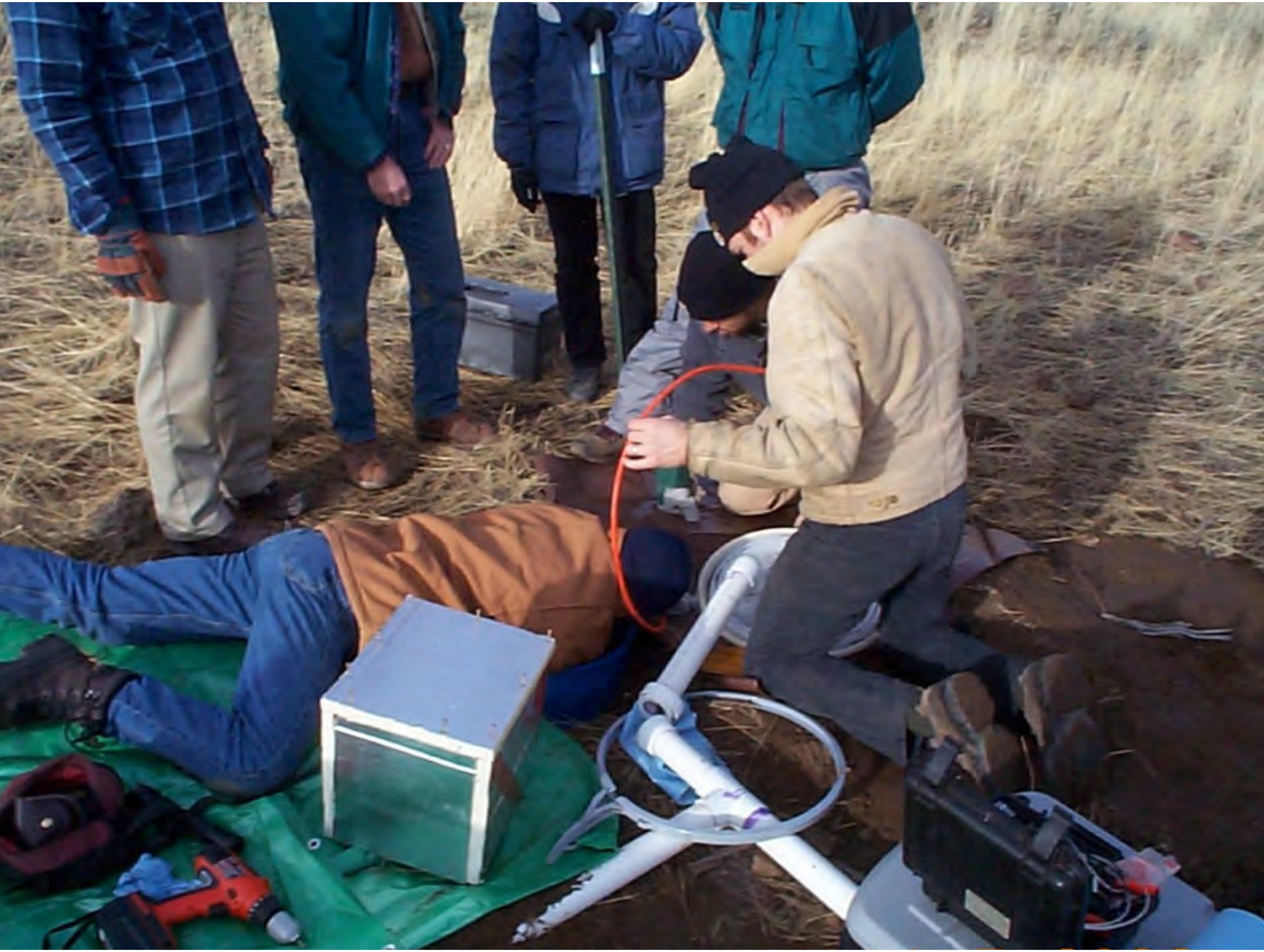
Huddle Test

Digging the Sensor Vault: Riley Butte

Digging the Sensor Vault: Riley Butte

Typical Field Crew Housing

Mixing Concrete for the Sensor Vault




Plastic Pipe

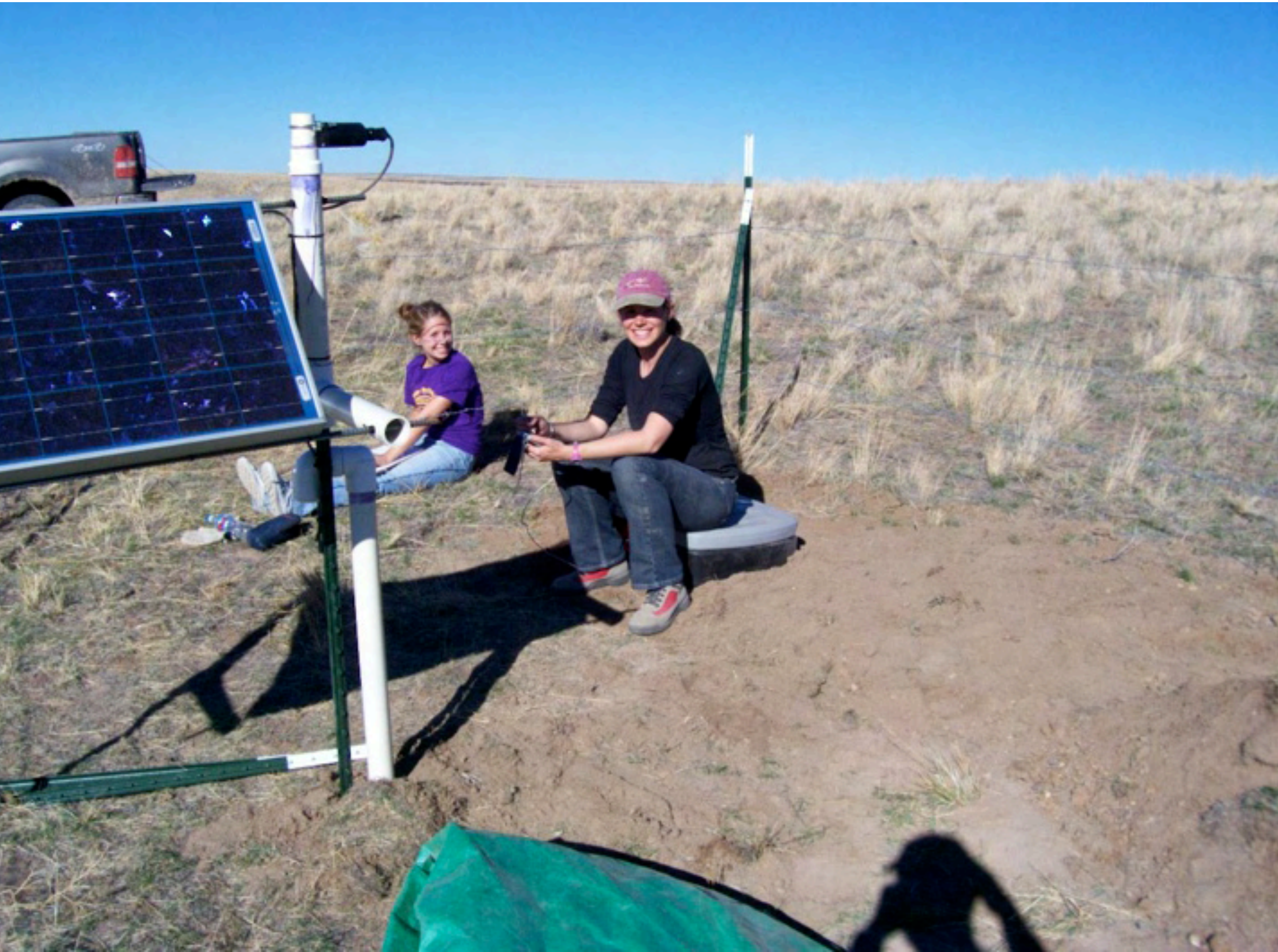

T397
OR075

Seismometer Installation: Hammond Ranch

Duct Tape and Cable Ties Required

Building the Fence: John Day (Holliday Ranch)

Installed Site



PI Perspective: Present & Future

- Systems are robust and get us the data we need - the primary outcome of the “broadband revolution”
- System design and components haven’t changed significantly in 25+ years (except GPS timing)
- Time to strongly consider the next “revolution”
  - **Q:** How can we collect similarly high-quality data while reducing time and risk/exposure to crews?
  - **A:** Can’t simply continue to develop minor upgrades to equipment and retrofit existing gear to work in harsh environments

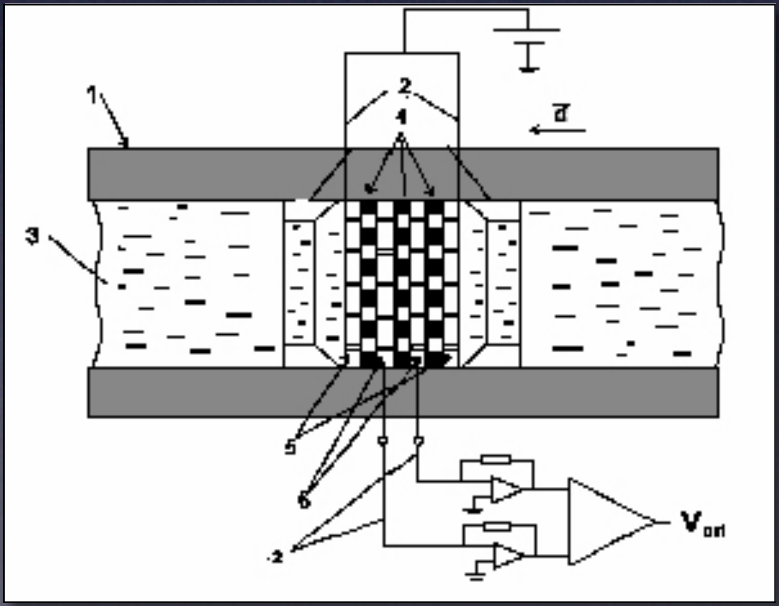
Thoughts on Future Wants and Needs

- ***Reduce power requirements***
  - Solar power: reduce panel footprint or eliminate
- ***Simplify the deployment process***
  - Sensor (installation; smaller form factor and footprint)
  - Datalogger/digitizer/timing
- ***Improve servicing strategies (time, $$$, safety)***
  - Telemetry: State of Health; data samples
  - Robotic data retrieval
  - Feasible for broad range of conditions (environmental; across political boundaries)

Planetary Microseismometer

- Developed by Prof. Hongyu Yu (ASU)
- Molecular Electronic Transducer (MET) technology
  - Useful technology for a range of inertial sensors
  - Specialized electrolytic cell
  - Measure hydrodynamic motion at surface of electrodes positioned on surface of electrochemical cells
  - Can use a range of electrolyte chemistries
  - Currently developing MEMS-sized sensing cell fabrication technology through NASA PIDDP grant
  - Industry partner: MET Tech, Inc.

MET sensing cell



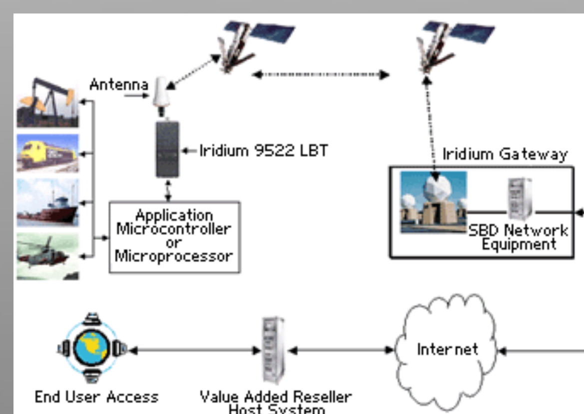
Sketch of MET Sensing Cell

Geodetic Data via NetRS to SBD Iridium
4 units built (3 Greenland, 1 Antarctica)

- **Streams GPS position data (BINEX open format) from a Trimble NetRS t a microcontroller + Iridium modem that sends data through the Iridium Network to an operations base where it is repackaged to look like the original stream**

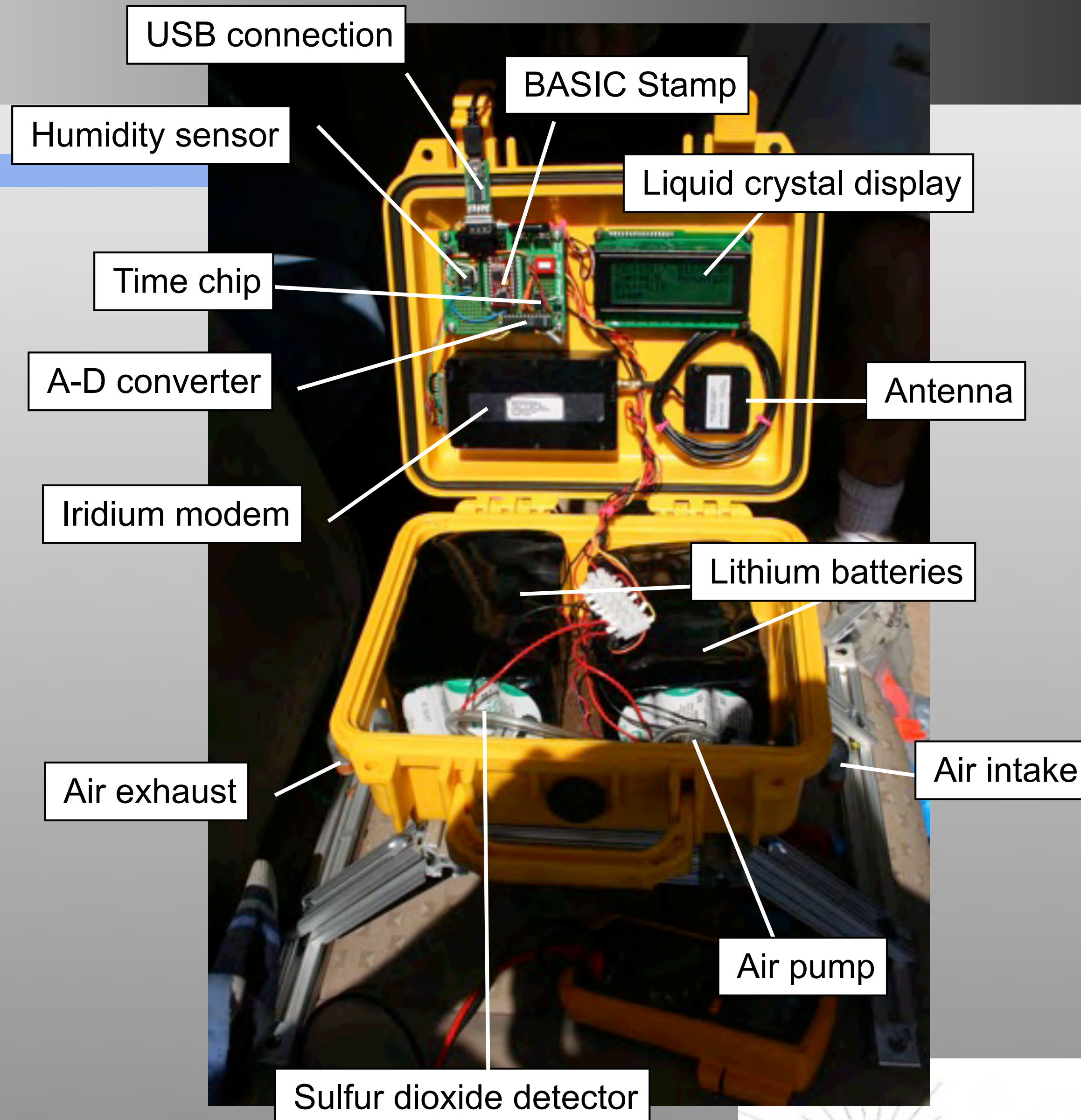
- **Remote Unit Configuration:**
  - **Records position every 30 sec, 35kb/hour**
  - **7200 epochs/day, (100-220bytes/epoch) ~1mbyte/day**
  - **Download/receive frequency: Every 4-5 mins.**
  - **Receiver and Format: Trimble NetRS in BINEX, 9600bps**
  - **Connection Method: Iridium Modem, LBT9522 with DOD Sim car**

- **Operations base Details:**
  - **PC Computer located at UNAVCO, Boulder, Colorado**
  - **Communication with Iridium Network is via TCP/IP Direct IP Sockets.**
  - **Runs a Linux simple application (shell script) that reassembles the data into 24hr UTC break files.**



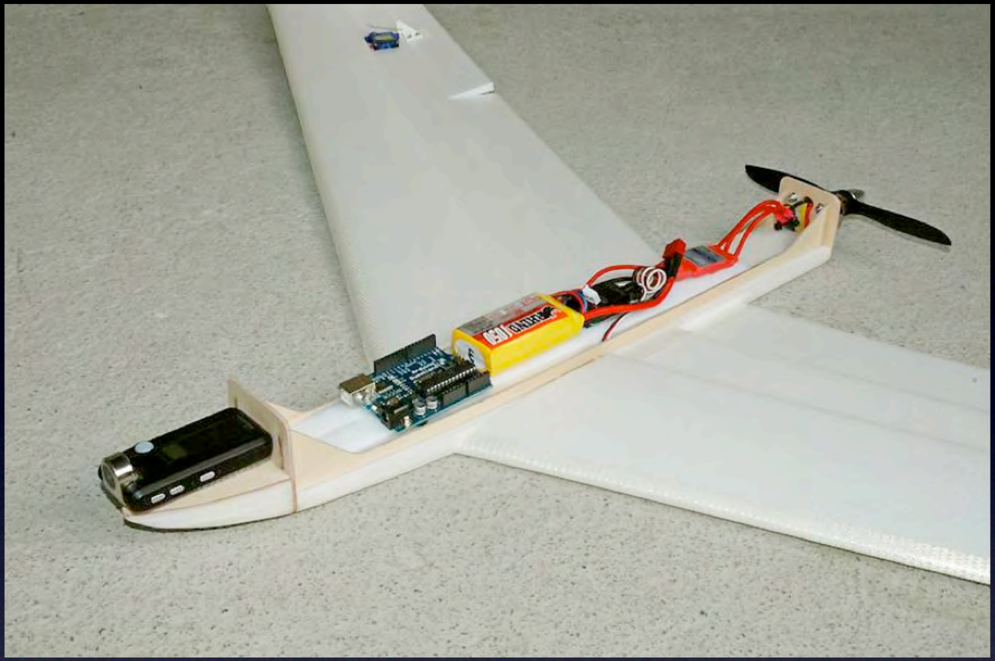
Field deployment: Volcano Monitor

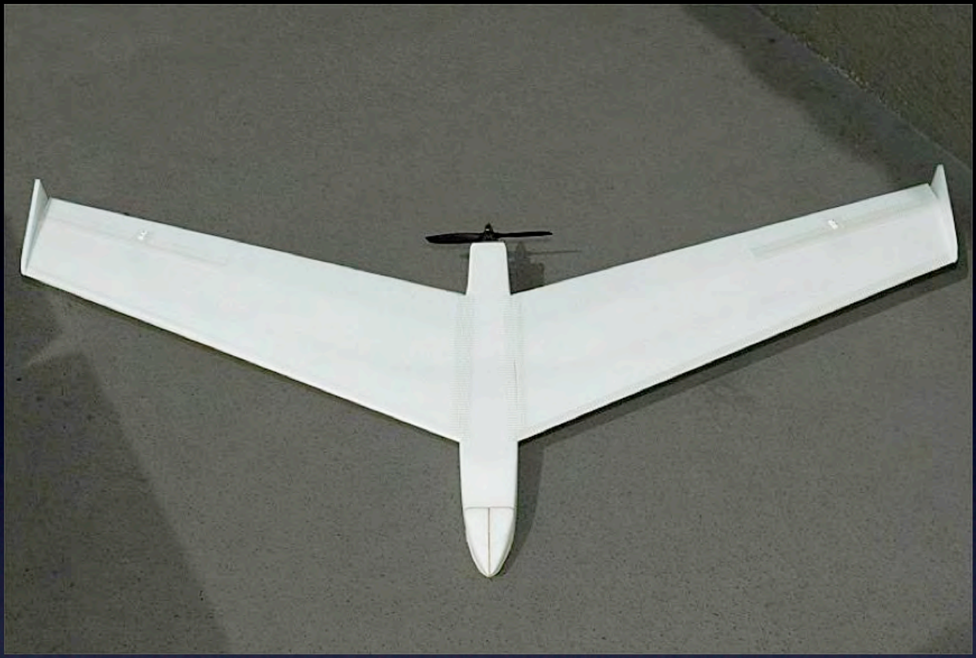
- Deployment: two units deployed on Kilauea Volcano, Hawai'i (volcanic gas detection) running since November 2007
- Weight: <4 kg
- Data collected every hour (normal mode)
- "Burst mode" = collection every min/10 mins
- 1 year lifetime (normal mode)
- expendable units
- Data being used by HVO
- Data being used by US Park Service (Volcanoes National Park) for assessing environmental conditions in the Park



Courtesy Alberto Behar, ASU

UAV “Data Mule”





- Developed by Prof. Sri Saripalli (ASU)
- 400 gm Unmanned Aerial Vehicle (UAV)
  - Includes navigation computer, GPS, 10 Mp camera
  - 40 mph flight speed
- 1.5 kg payload capacity
- $1,000 per vehicle

ASU UAV “Data Mule”

Images at 300 m AGL

Loiter radius: 100m

- Data mule flies to remote site based on flight plan or automatic navigation
- Can be tasked to “loiter” at specific waypoints
- Design is to fly to site, make contact with ground recording system, loiter during WiFi data transfer

Acknowledgements

- ***ASU***: John West, Jeff Roth, Kevin Eagar
- ***DTM***: David James, Steven Golden, Peter Burkett*, Rick Carlson, field teams
- ***USArray***: TA team; Array Network Facility
- ***IRIS***: PASSCAL; Data Management Center
- Funding:
  - ***NSF***: EarthScope Science, Continental Dynamics
  - ***NASA***: Planetary Instrument Definition and Development Program