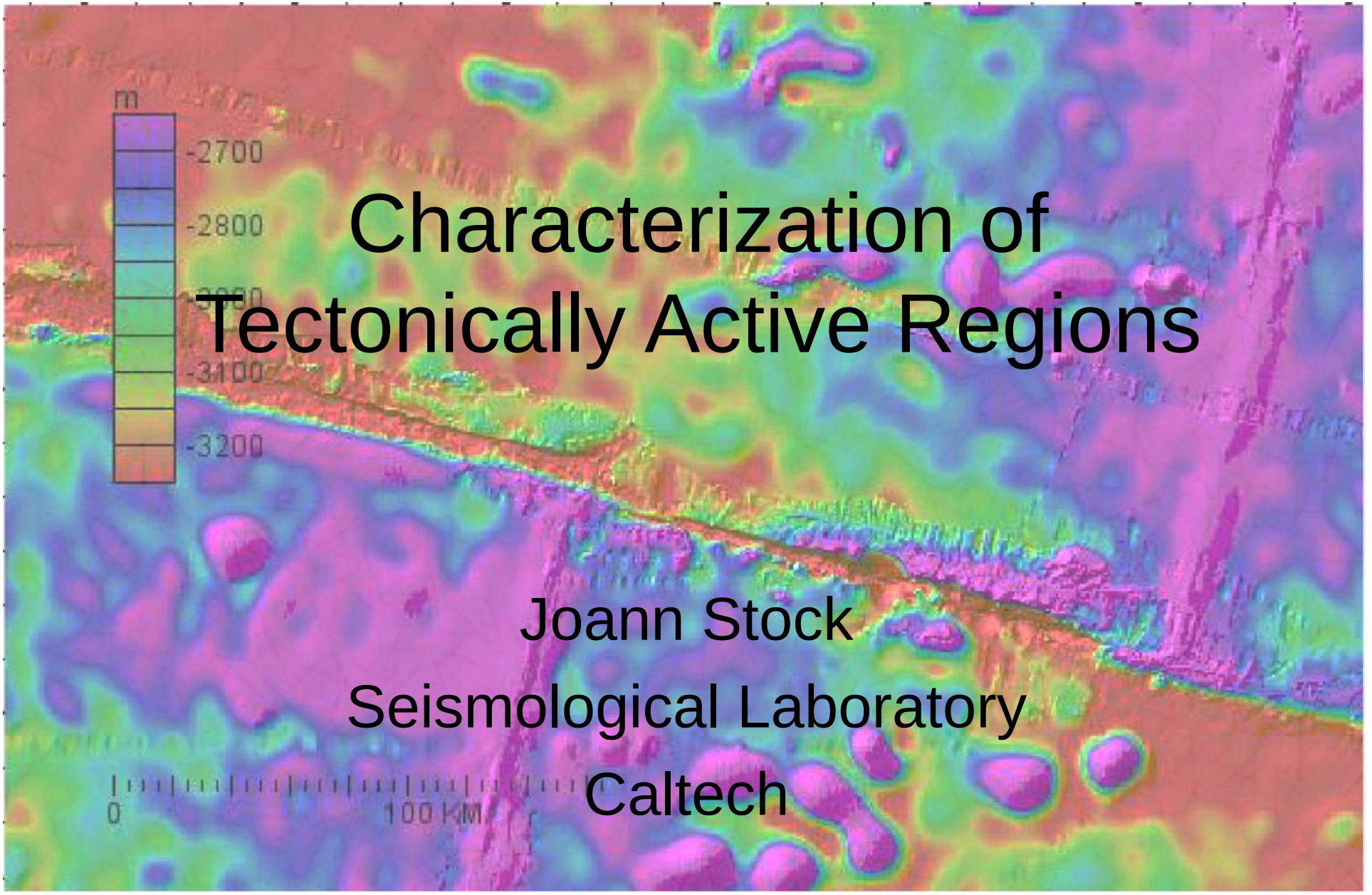


Characterization of Tectonically Active Regions

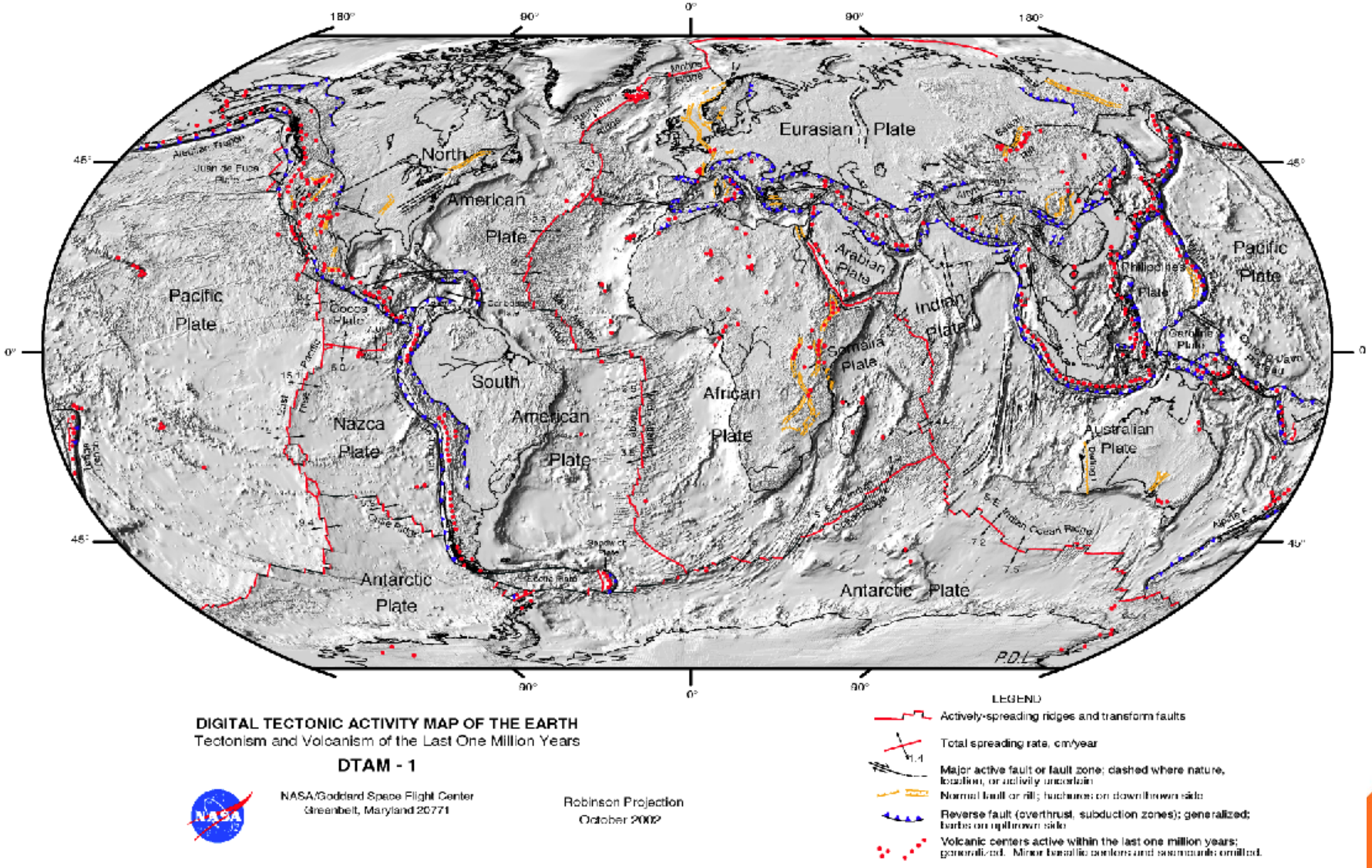
Joann Stock
Seismological Laboratory
Caltech

Cause of Tectonics

Planetary Heat Loss – Styles of Tectonics

- Plate Tectonics (Earth)
- Plumes and Volcanism (Earth, Mars, Venus, Mercury)
- Stagnant Lid Convection (Venus)

Tectonically Active Regions of Earth



DIGITAL TECTONIC ACTIVITY MAP OF THE EARTH
Tectonism and Volcanism of the Last One Million Years

DTAM - 1

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

Robinson Projection
October 2002

LEGEND

- Actively-spreading ridges and transform faults
- Total spreading rate, cm/year
- Major active fault or fault zone; dashed where nature, location, or activity uncertain
- Normal fault or rift; hachures on downthrown side
- Reverse fault (overthrust, subduction zones); generalized; barbs on upthrown side
- Volcanic centers active within the last one million years; generalized. Minor basaltic centers and seamounts omitted.

G221.001

Earthquakes outline Earth's plate boundaries

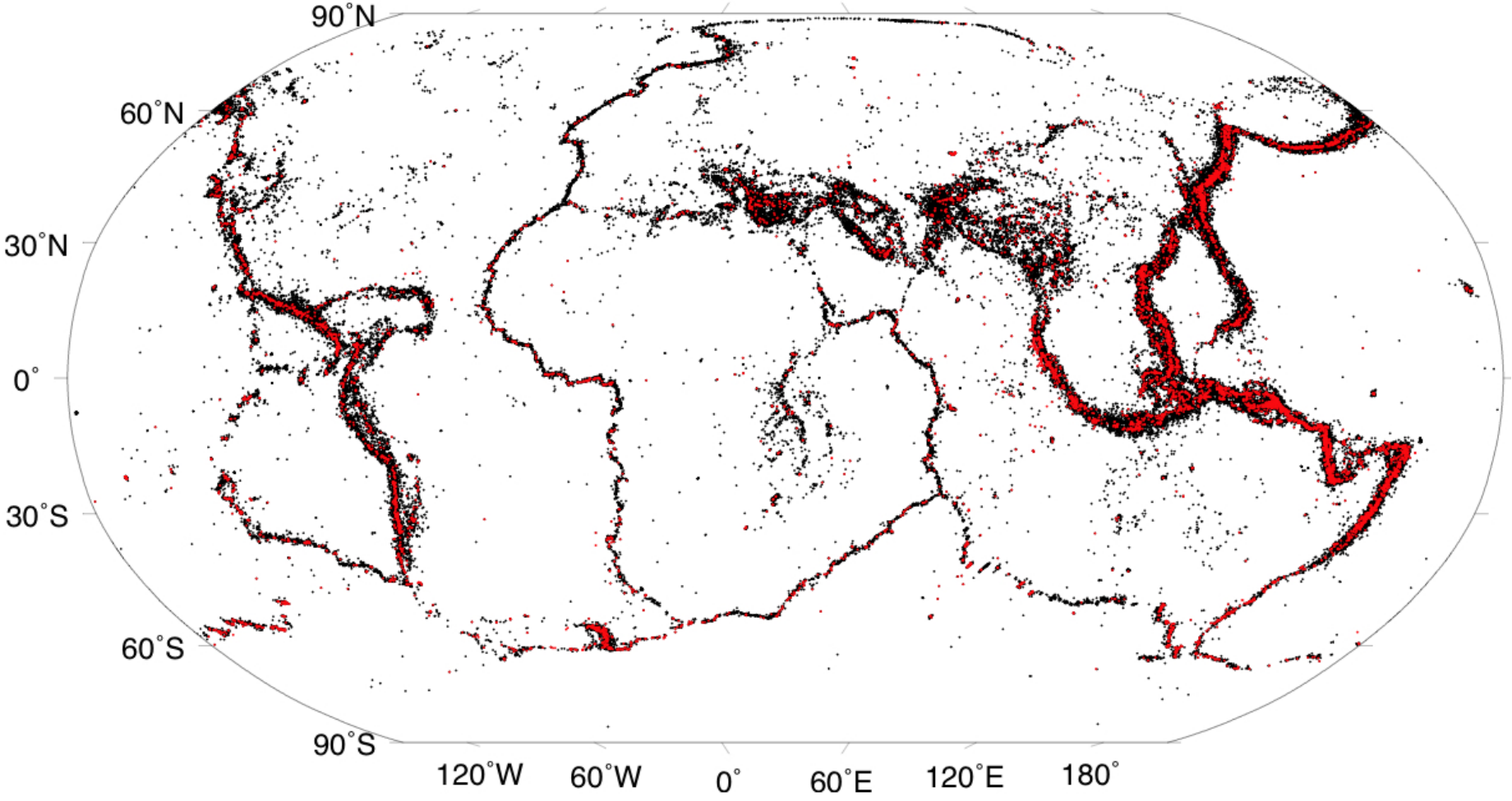


Figure from MORVEL web site: http://geoscience.wisc.edu/~chuck/MORVEL/morvel_info.html

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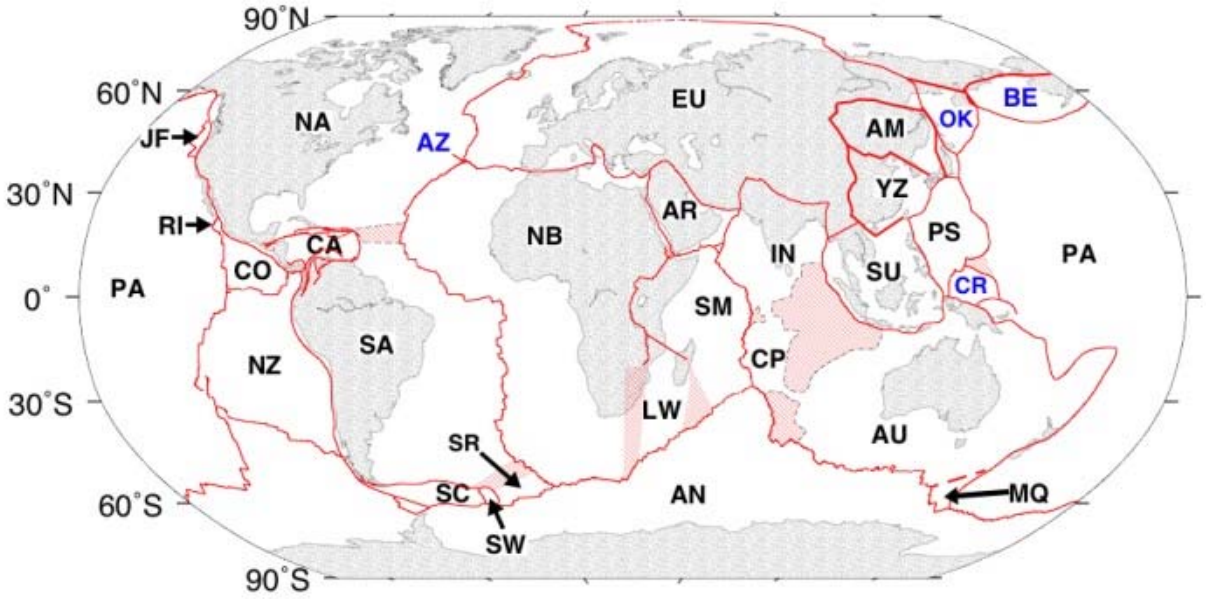
Modern plate velocity field

- Marine magnetic anomalies
- Transform faults: Multibeam swath bathymetry
- Satellite radar altimetry → gravity anomalies
- Earthquake slip vectors
- GPS observations used for plates labeled in blue



Models: MORVEL (DeMets et al., GJI 2010) and NNR-MORVEL56 (Argus et al., 2011)

Add gravity, seismicity, geological mapping, seismic imaging → geodynamics

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Which of these could we see from space?

Visible/ Detectable

- Gravity field
- Geoid
- Surface deformation field
- Topography (fault scarps)

Not visible

- Ocean floor bathymetry
- GPS measurements
- Earthquake locations (hypocenters)
- Earthquake slip vectors

Poorly resolved

- Marine magnetic anomalies

Which of these could we see from space?

Visible/ Detectable

- Gravity field
- Geoid
- Surface deformation field
- Topography (fault scarps, folds, grabens, volcanic constructs)
- Compositional variations of surface materials
- Atmospheric dust, gases

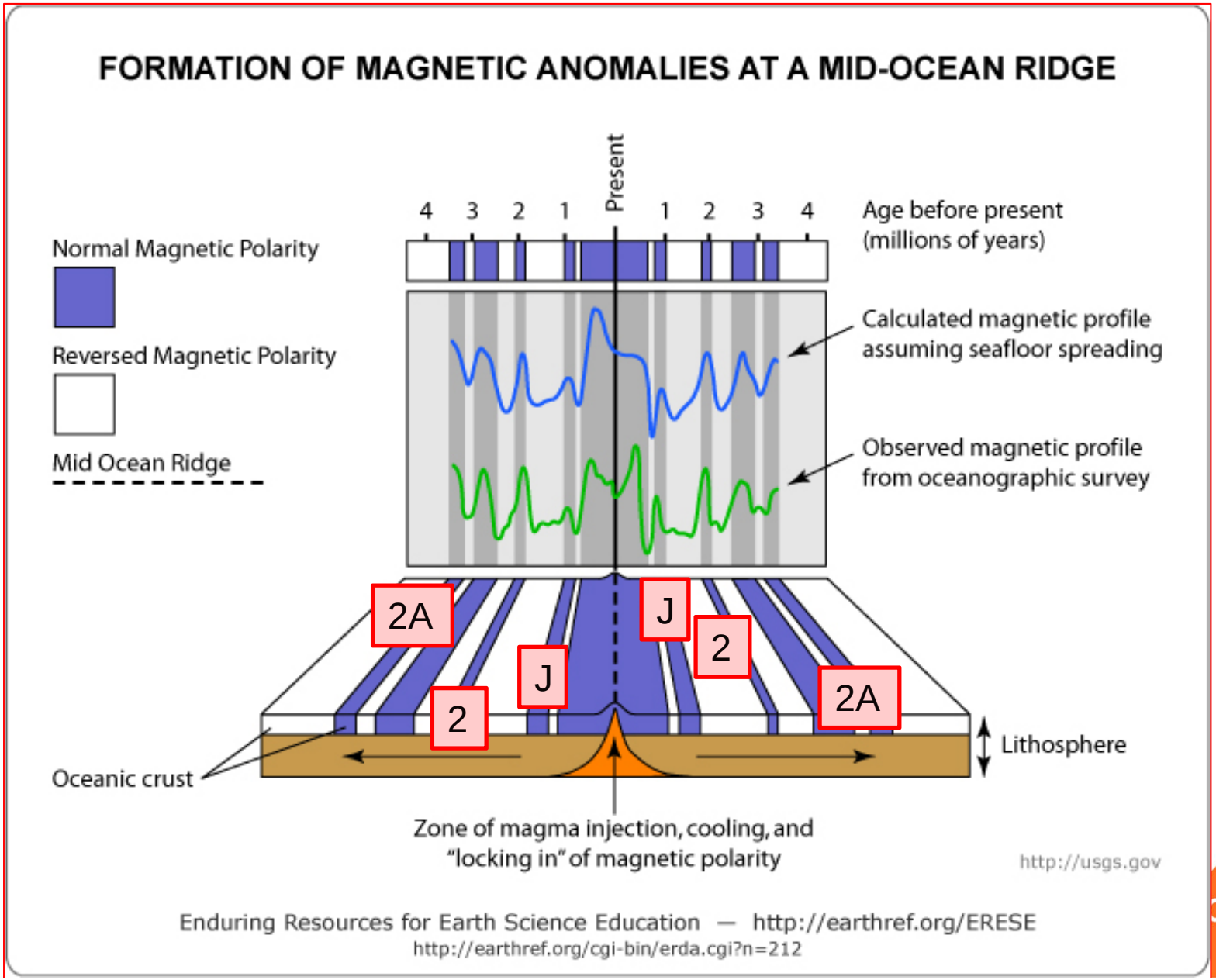
Not visible

- Ocean floor bathymetry
- GPS measurements
- Earthquake locations (hypocenters)
- Earthquake slip vectors

Poorly resolved

- Marine magnetic anomalies

Spreading processes at midocean ridges



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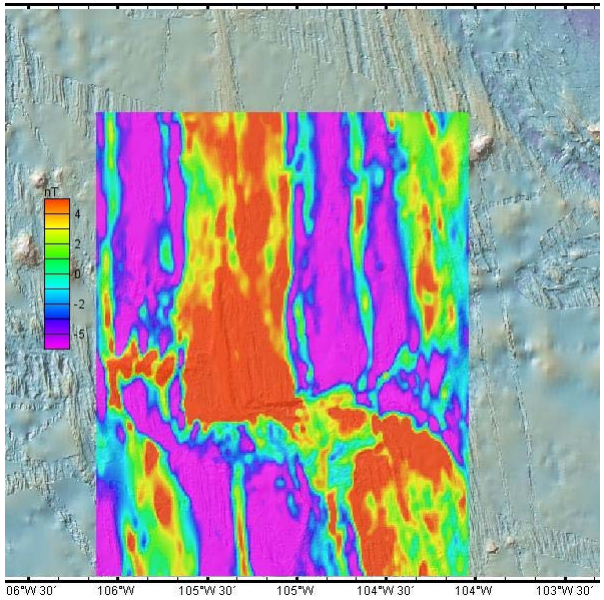
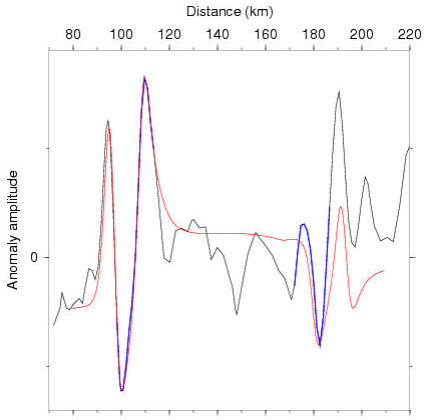
Modern plate velocity field: data used

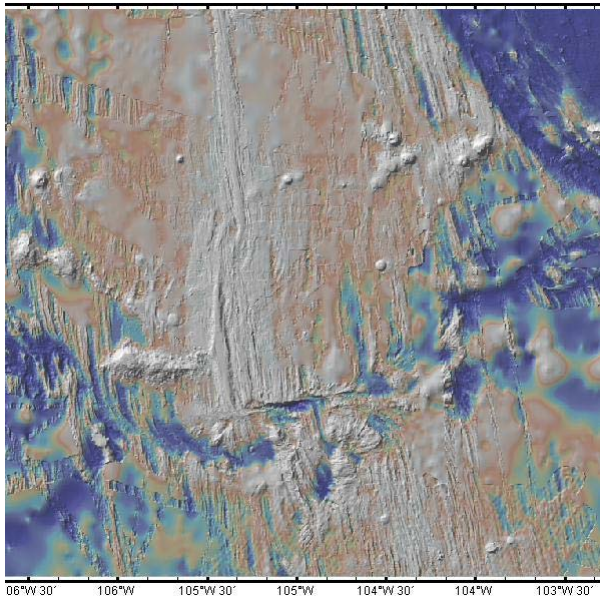
- Magnetic anomalies
- Transform faults offset the spreading segments



Magnetic anomaly



Magnetic profile
01010042



Bathymetry

Example: data from 16°N on East Pacific Rise (from GeoMapApp)

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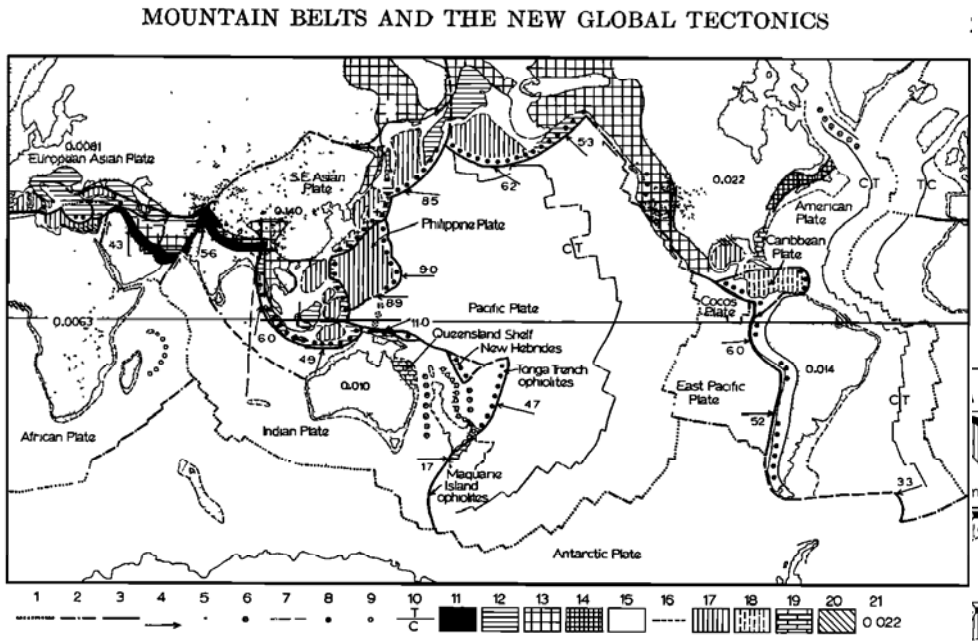
Link between plate convergence and mountain belt formation



Dewey & Bird, JGR 1970: 9 tectonic plates; mountain belts related to plate convergence

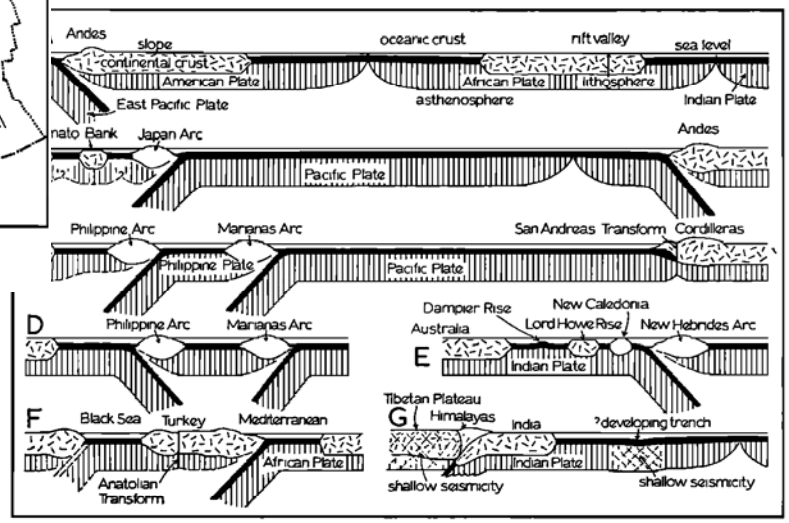


Fig. 2. Schematic sections showing plate, ocean, continent, island arc relationship. The ? developing trench indicated in (G) is from *Sykes* [1970].

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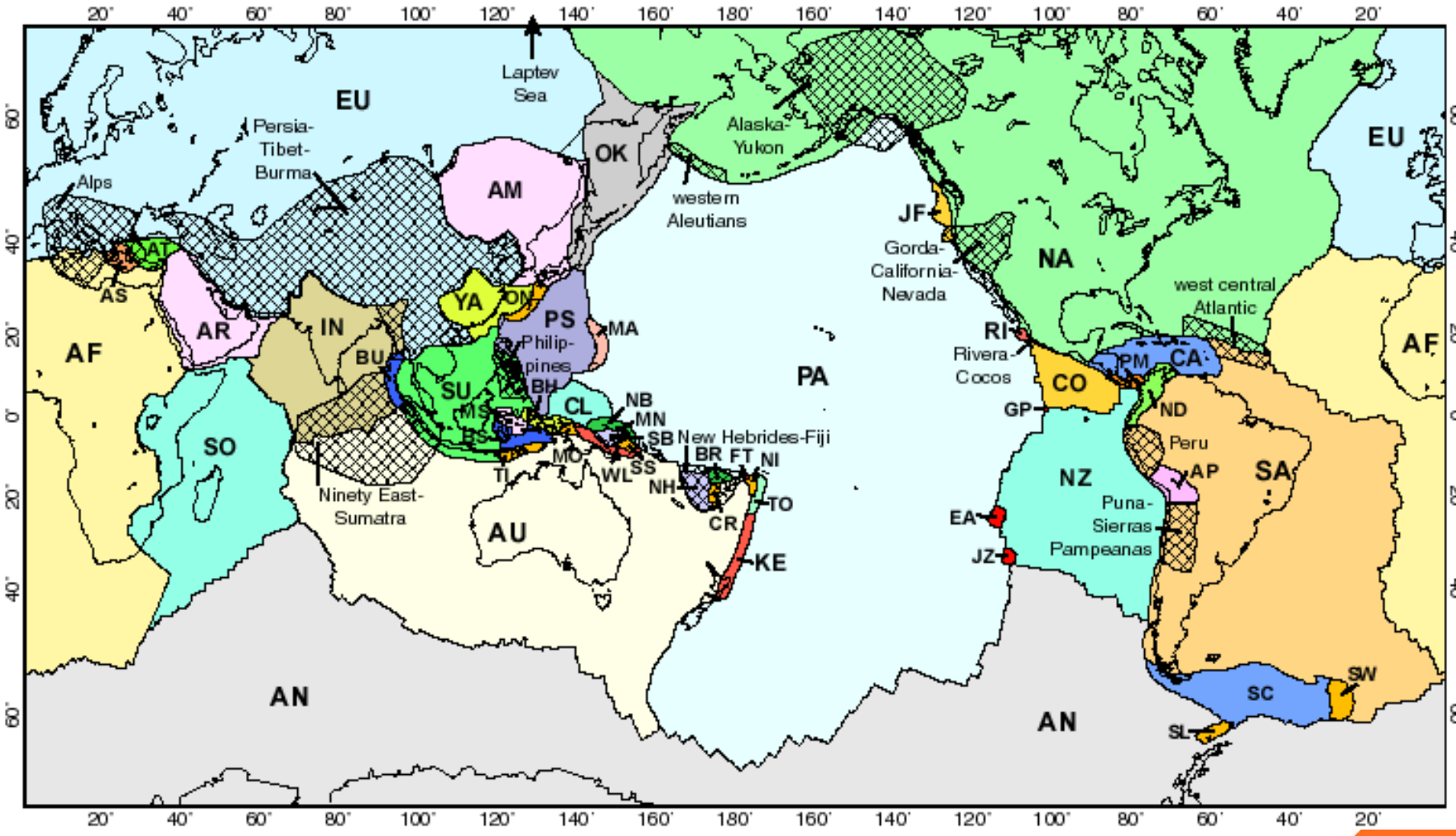
Peter Bird (G-cubed, 2002) model (56 plates)

Tectonic activity at narrow and broad plate boundaries



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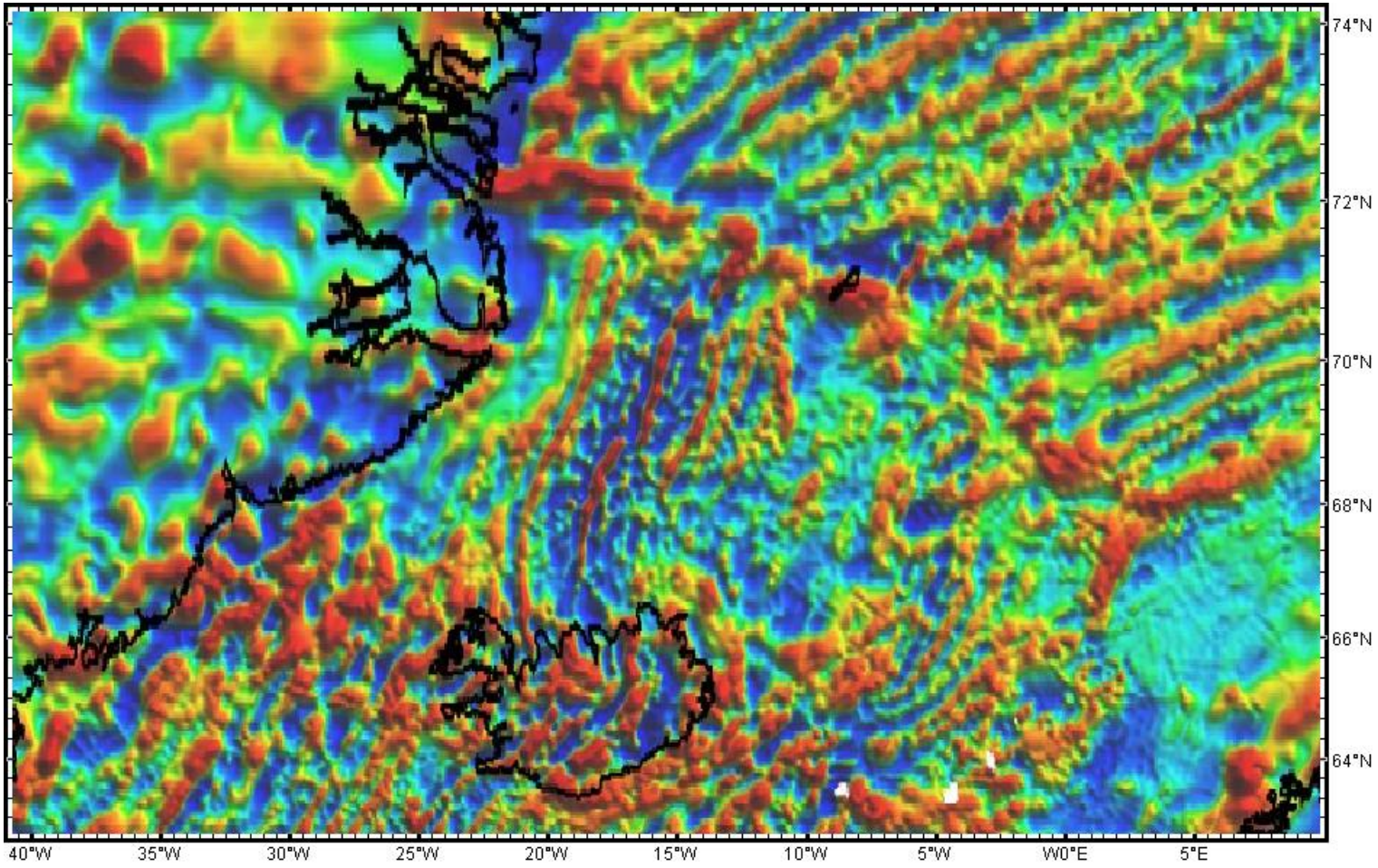
Iceland: Midocean Ridge on Land

Krafla rifting episode: 1975-1984



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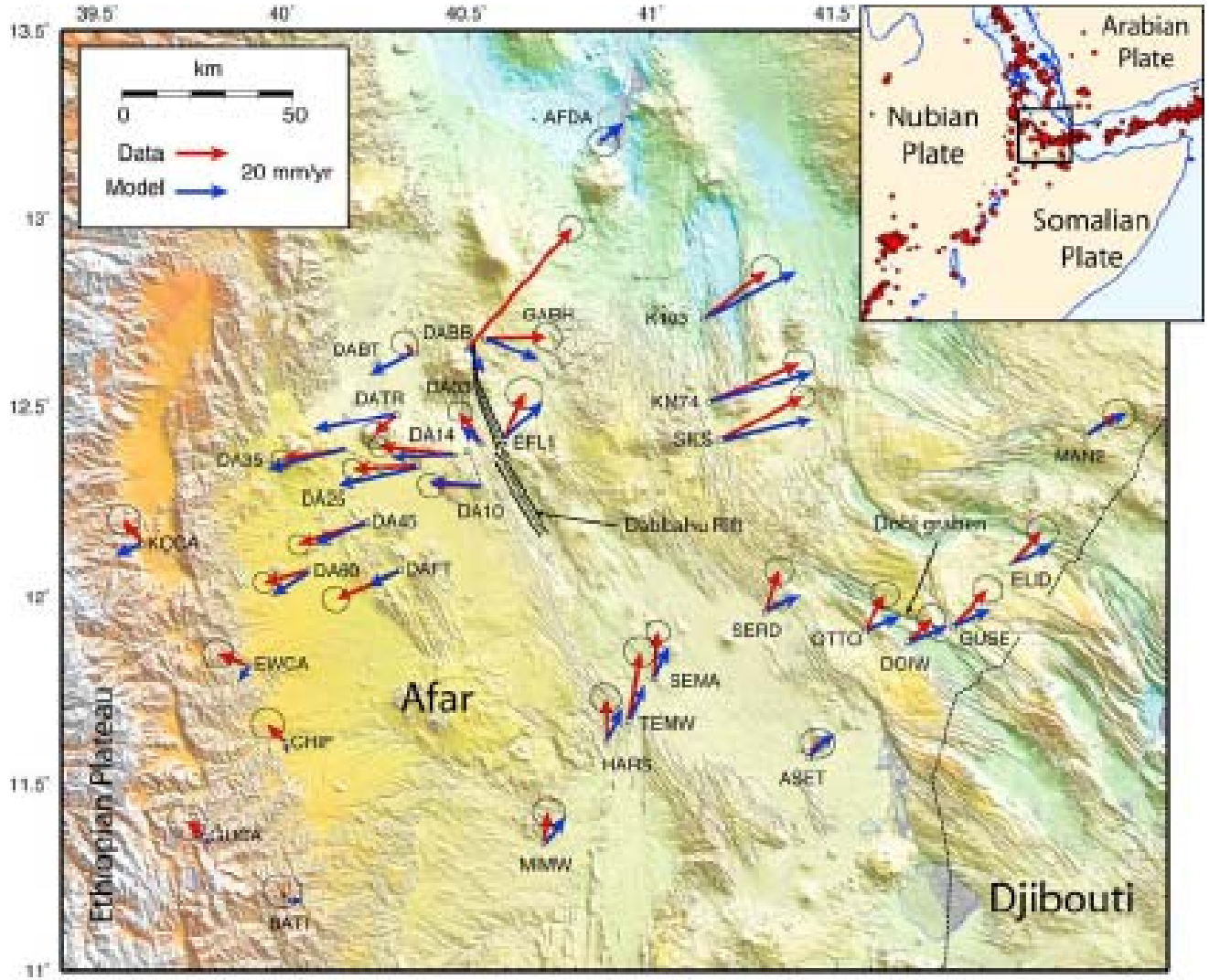
East African Rift (Afar)



Nooner et al, GRL 2009

Dike intrusion, faulting, post intrusion relaxation

Local intrusion events exceed plate motion rates

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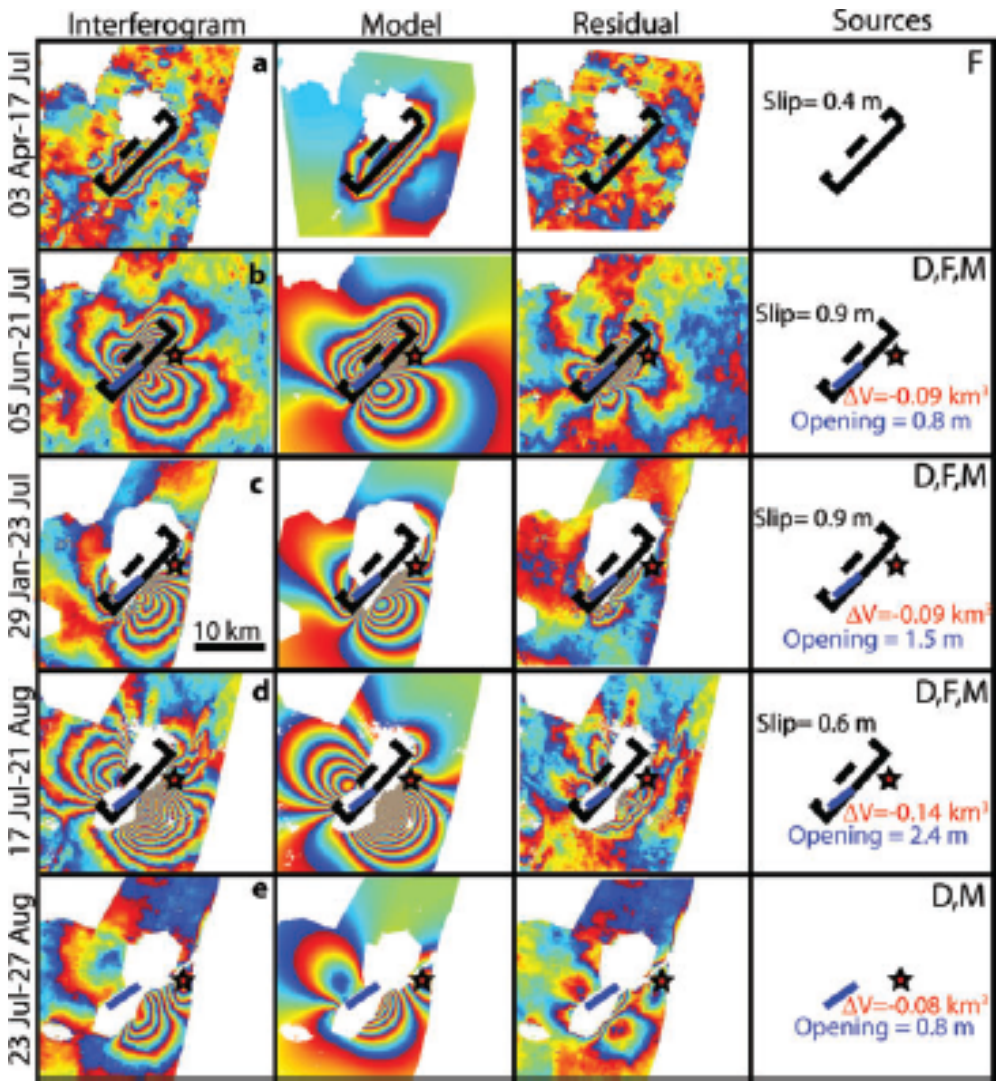
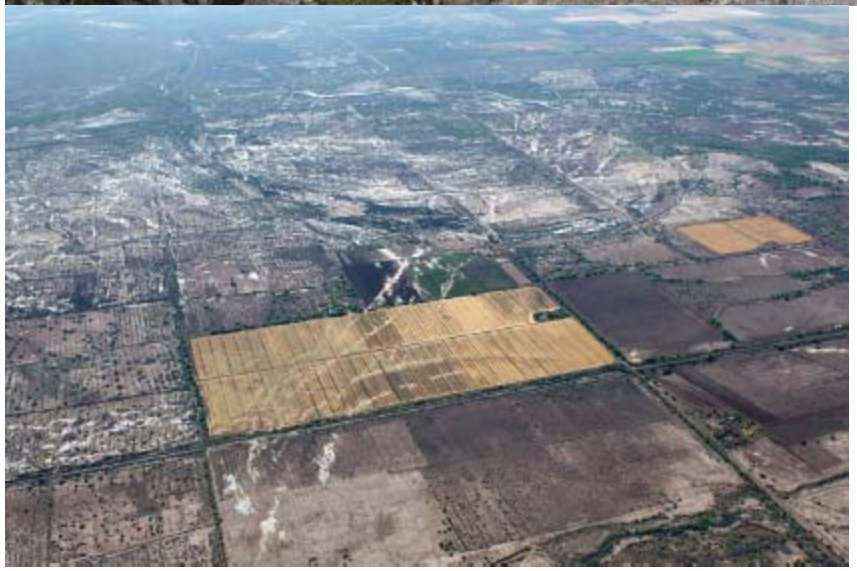


Biggs et al, GJI, 2009

Lake Natron (Tanzania) Rifting Episode, 2007

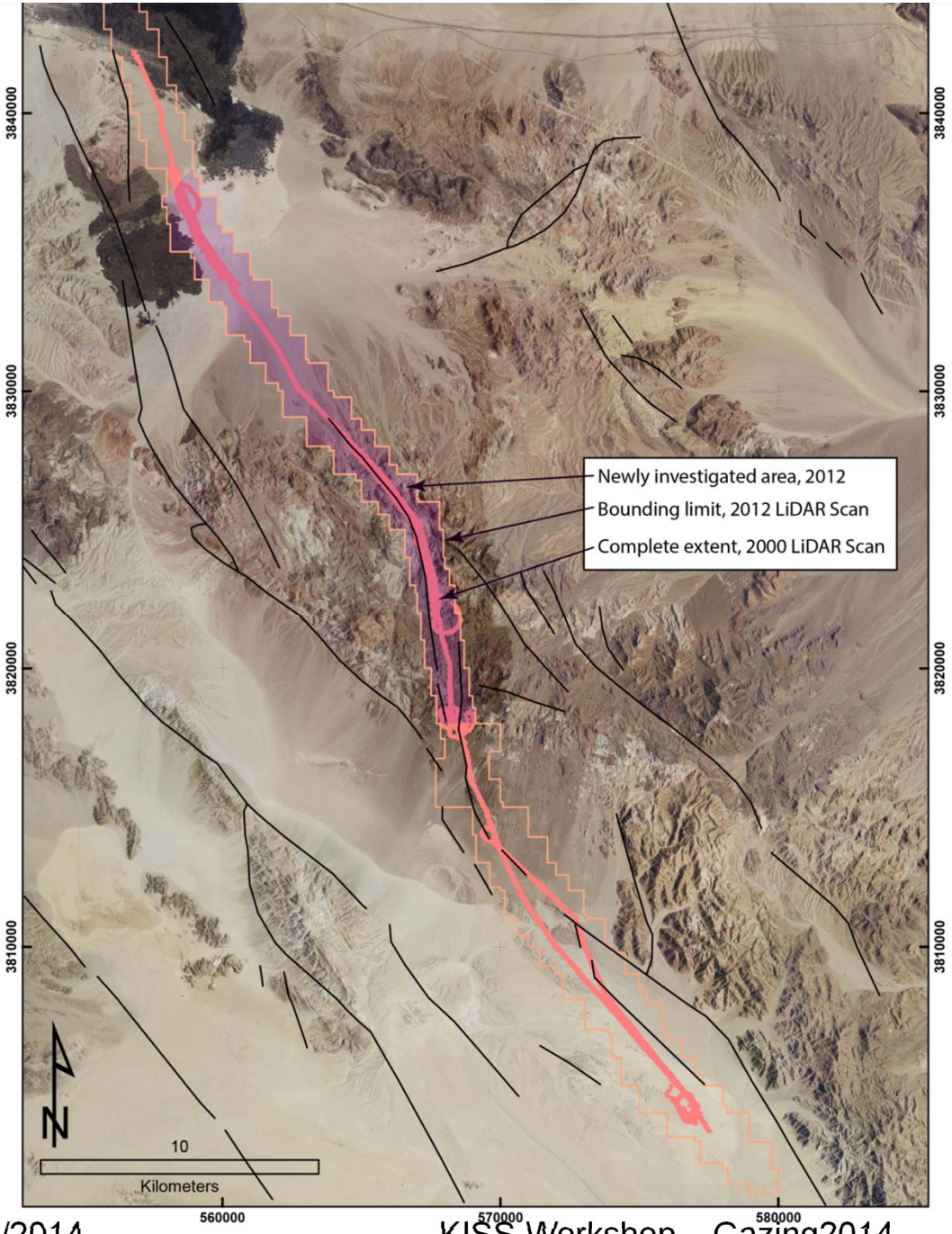
Active Faults on Earth
El Mayor-Cucapah Earthquake April 4, 2010

scarp



Sand blows, liquefaction

Fletcher et al., Geosphere, 2014: El Mayor-Cucapah Earthquake

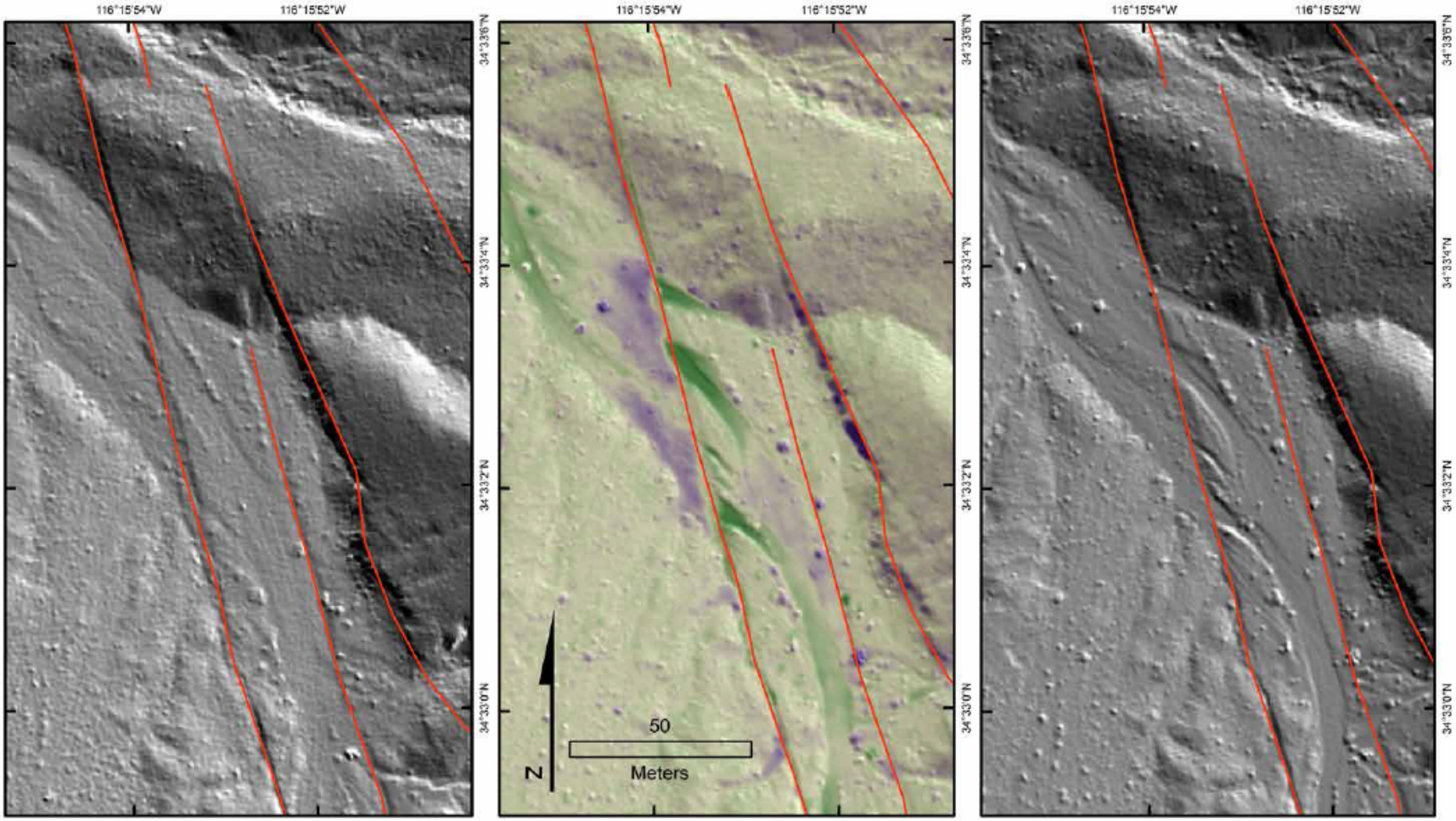


Hector Mine
earthquake
M=7.1
October 16, 1999

Caltech

Hector Mine earthquake M=7.1 October 16, 1999

Differencing Year 2000 LiDAR (left) and Year 2012 LiDAR (right)



Tectonic Structures of Other Planetary Bodies

Tectonic structures have been mapped on:

- Earth
- Moon
- Mars
- Venus
- Mercury
- Satellites of Jupiter (Callisto, Ganymede, Europa, Io)

Wrinkle ridges – compression
Lobate scarps – thrust faulting
Grabens – indicate extension

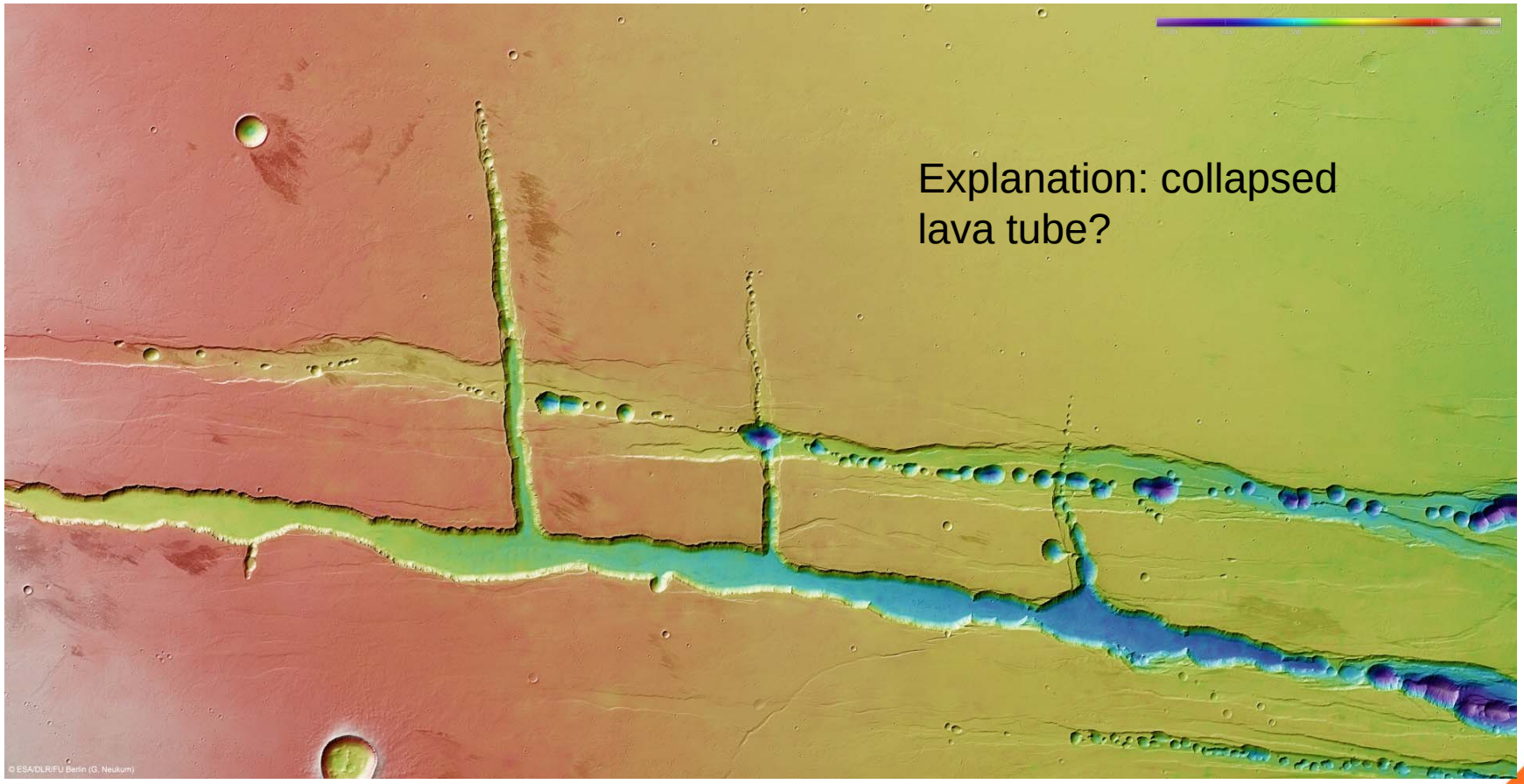
Features recognized on some of the Saturnian (Titan, Dione, Rhea, Tethys, Iapetus, Enceladus) moons; Triton (Neptune's Moon)

Earthquakes detected on Moon with seismometers; inferred to have occurred on Mars

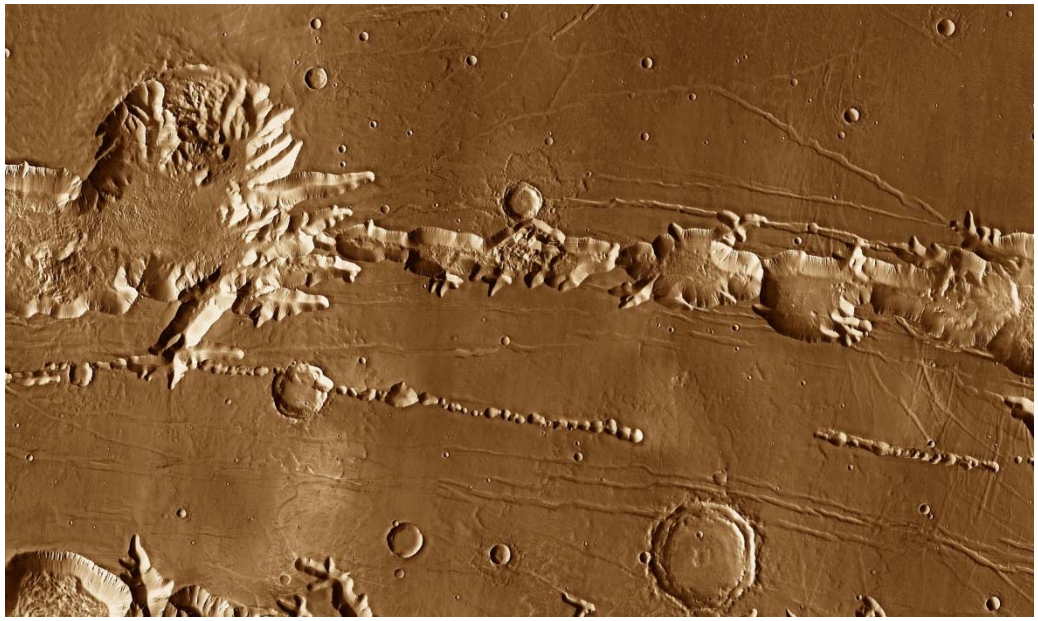
Tectonics on Mars – Active or Not?

Tractus Cadena pit-chains in Tharsis

Mars Express image, **Copyright** ESA/DLR/FU Berlin (G. Neukum)



Pit chains near Valles Marineris
(THEMIS mosaic, NASA/ASU)



Mars Orbital camera,
Alba Patera

Explanation: ??

Explanation: Dilatational Fault Slip (Ferrill et al., GSA Today, v. 14, #10, 2004)