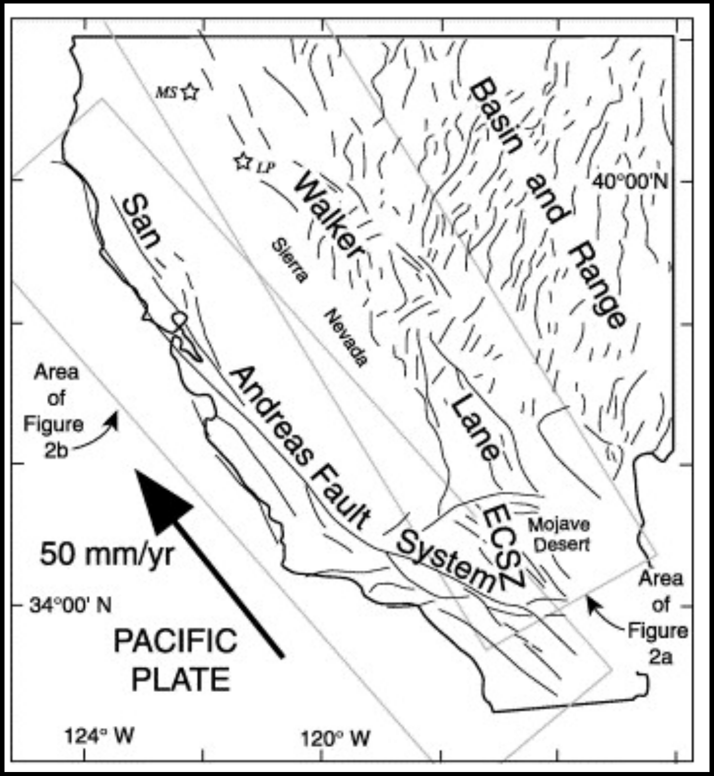
The Walker Lane RIFT SYSTEM:
A Natural Laboratory to Study Rift Initiation that Culminated in Seafloor Spreading
(in the Gulf of California)



Why am I in charge of this pitch? Because I am representing everyone who was at the Penrose I ran in Walker Lane last August (but heard about this meeting too late to apply)…..

As well as the people who are here…….Cathy Busby (UCSB), Graham Kent (UNR), Neal Driscoll (SIO), Chris Henry (UNR), Jim Faulds (UNR) Glenn Biasi (UNR), Ken Smith (UNR), John Louie (UNR), Bill Hammond (UNR), Alistair Harding (SIO), Geoff Blewitt (UNR), Corne Kreemer (UNR), Danny Brothers (USGS), Fred Phillips (NMIT), Jared Kluesner (SIO), Peter Lonsdale (SIO), Keith Putirka (Fresno St.), Debi Kilb (SIO), Pat Cashman (UNR), Paul Umhoefer (NAU), Gary Fuis (USGS), Dan Lizarralde (WHOI), Jeff Babcock (SIO), Kathie Marsaglia (CSUN)

Modern Tectonic Context

Walker Lane rift system - currently accommodates 20-25% of the plate motion between the Pacific and the North American plates

Provides a clear record of rift initiation…

and a time-transgressive view of

processes involved in strain localization.

Sierra Nevada microplate - Walker Lane system:
Global importance because of the many important concepts developed there and exported to other parts of the world (see below).

It remains, however, to integrate disparate geologic, geochemical, and geophysical discoveries into a comprehensive physically based process model for continental rifting.

This requires a long-term program that brings many different types of workers together.

listric normal faults, detachment faults and metamorphic core complexes, “chaos” (large-scale landslide deposits), calderas and geothermal fields (e.g. Long Valley), maar volcanoes and Pluvial lake deposits, vertical axis rotations of crustal blocks, strain partitioning, thermochronologic dating of ancient landscape surfaces and tectonic tilting events, root delamination, and the emplacement of huge batholiths

Attributes of Walker Lane-Gulf of California rift system

IMMEDIATE

GLOBALLY APPLICABLE SCIENTIFIC RESULTS

AT RELATIVELY LOW COST,

WITH MAJOR SOCIETAL IMPACT.

Including an amphibious approach

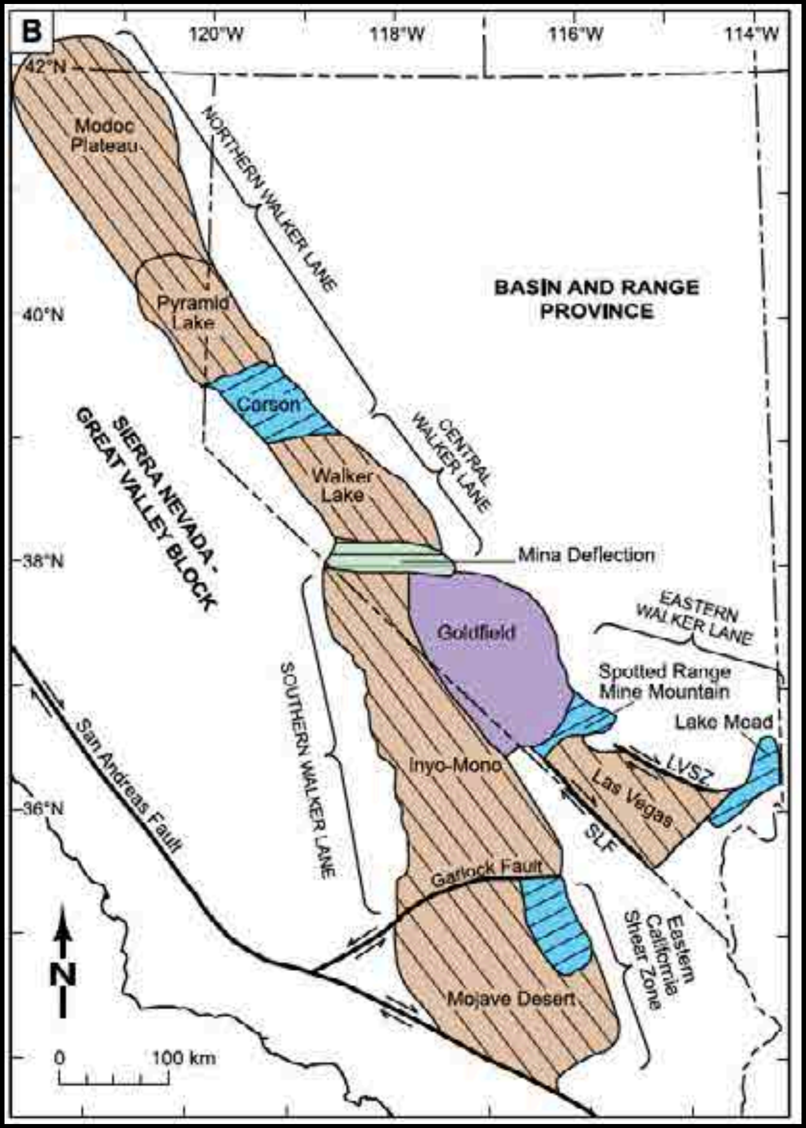
e.g. Pyramid Lake

Attributes…..

(1) Data infrastructure (e.g., geologic mapping, digital topography, seismic and geodetic studies)

Integrate disparate geologic maps and analytical data into a single user-friendly database in Google Earth - IMMEDIATE public impact.

Rifting studies can focus immediately on the KEY QUESTIONS.



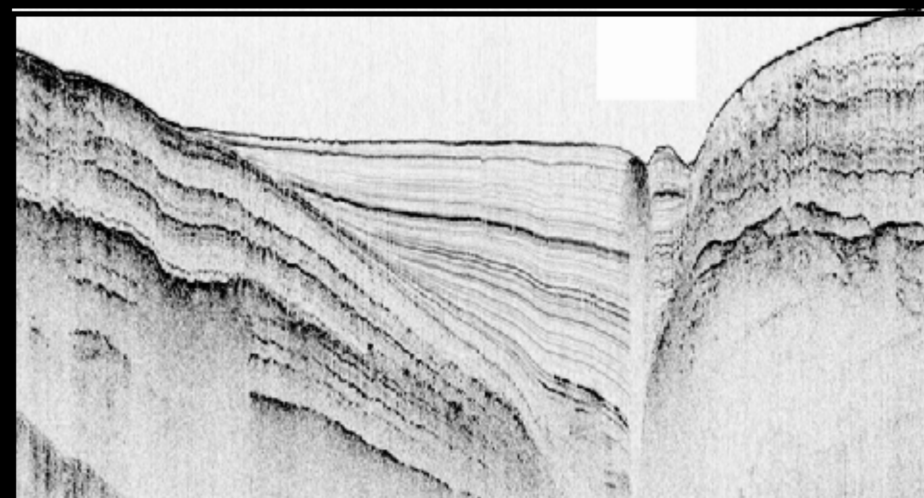
Attributes, continued:

(2) Ease and safety of physical access - THE POLITICAL REALITY - cost-effective experimentation and data acquisition - Improved scientific return with student and community access.

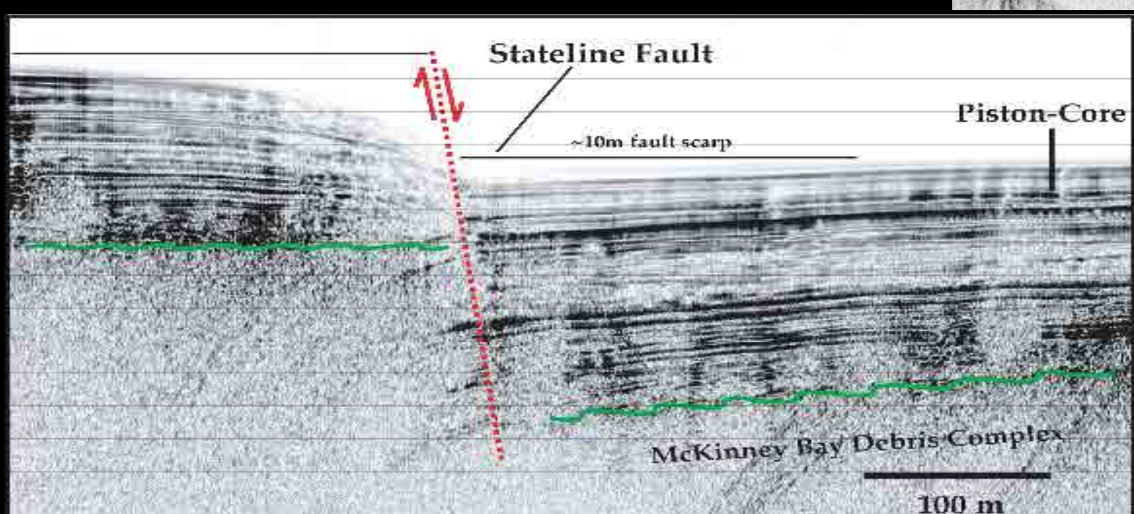
BROADER IMPACT - Students!!!!

Attributes, continued:

(3) Study sites that require access to ocean-going vessels may not begin until 2014 or later, whereas data collection on lakes can begin immediately.



Pyramid Lake, Walker Lane Rift System

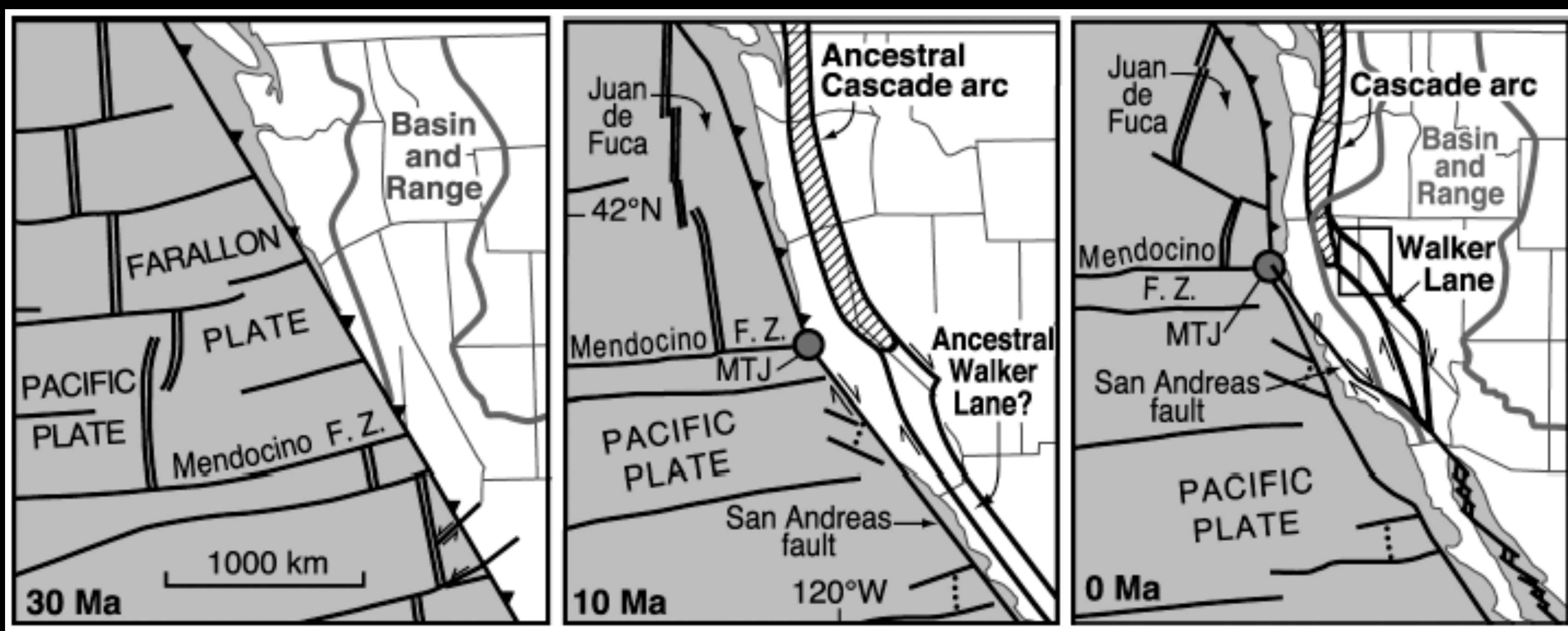


Lake Tahoe, Walker Lane Rift System

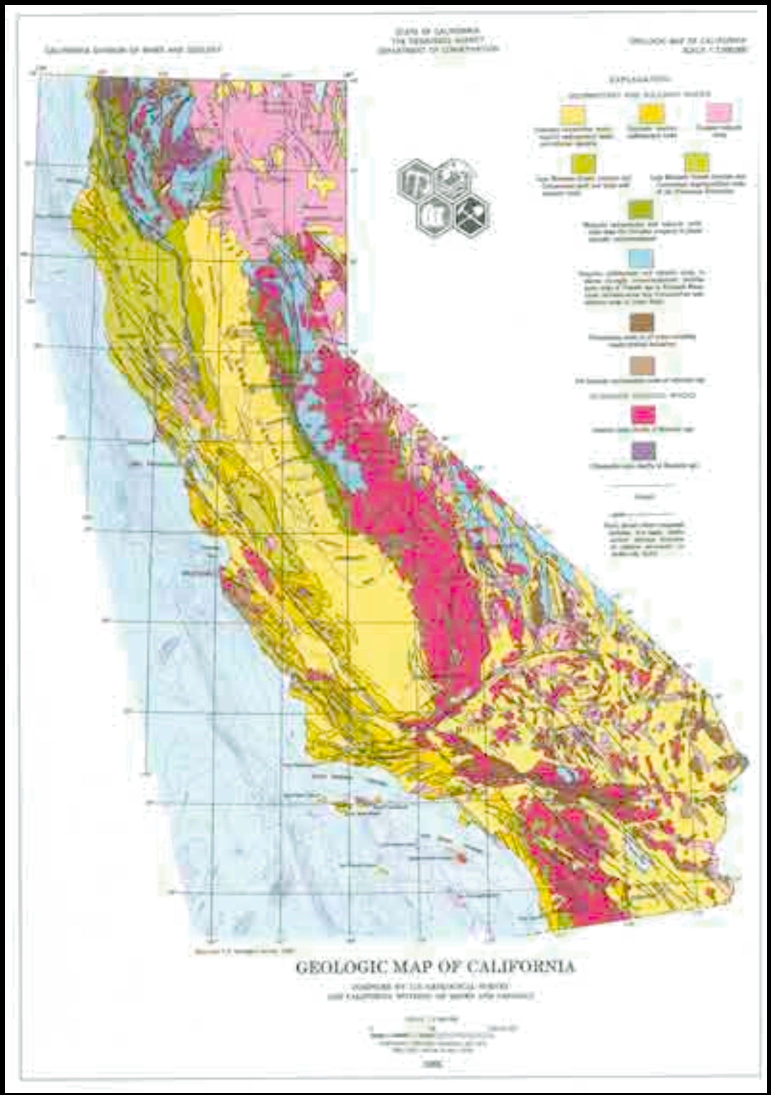
(4) Due to an on-going history of active rifting from southern Gulf of Ca to northern Walker Lane,

time and space transgressive processes can be observed -

Post breakup (Gulf) to new rift (Salton Trough) to rift initiation (Walker Lane)……..



…….across an array of continental crustal types with a variety of prior magmatic-tectonic histories.



Including Precambrian craton, Paleozoic passive margin, Paleozoic accreted terranes, Mesozoic to Cenozoic subduction margin.

(5) Outstanding exposure and preservation at the FULL RANGE OF STRUCTURAL LEVELS promoting interaction of a…

******Multidisciplinary team*******

that will be assembled and interact closely

in an

INTEGRATED AMPHIBIOUS APPROACH

e.g. volcanic and sedimentary basins, structural analysis, igneous and metamorphic petrology, deep-level magmatic processes, geochronology and isotope geochemistry,geophysical surveys of crust and mantle features, seismology, geodetics, active tectonics and surface dating, hyperspectral mapping of geology and alteration, economic geology, geothermal exploration, etc

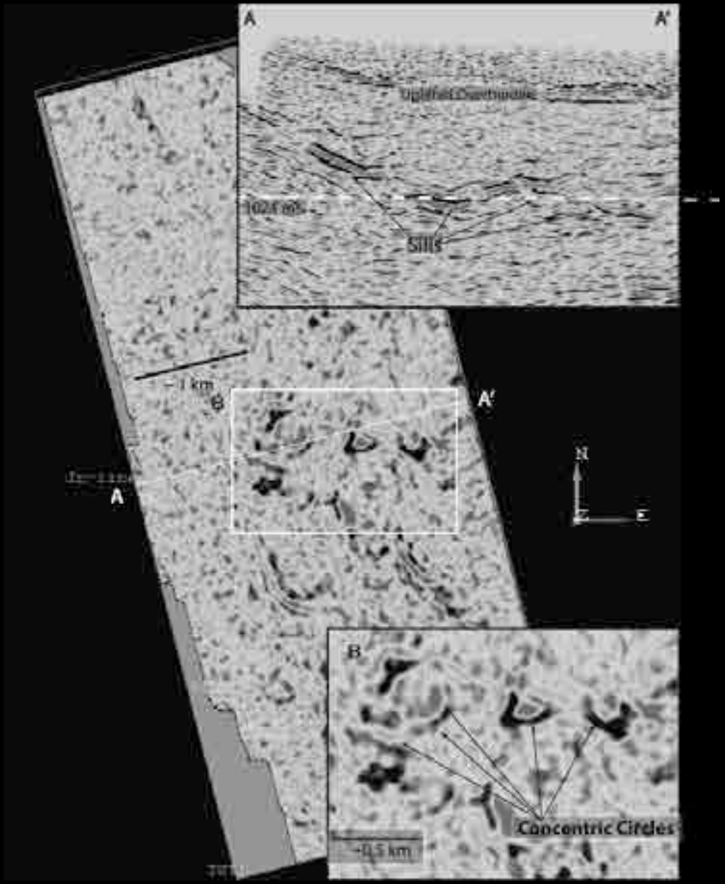
****THIS is what distinguishes us from core NSF*******

Attributes, continued:

(6) Active magmatism - evaluate volatile fluxes and sources; use new geochronologic techniques to date very young volcanic rocks and associated structures.

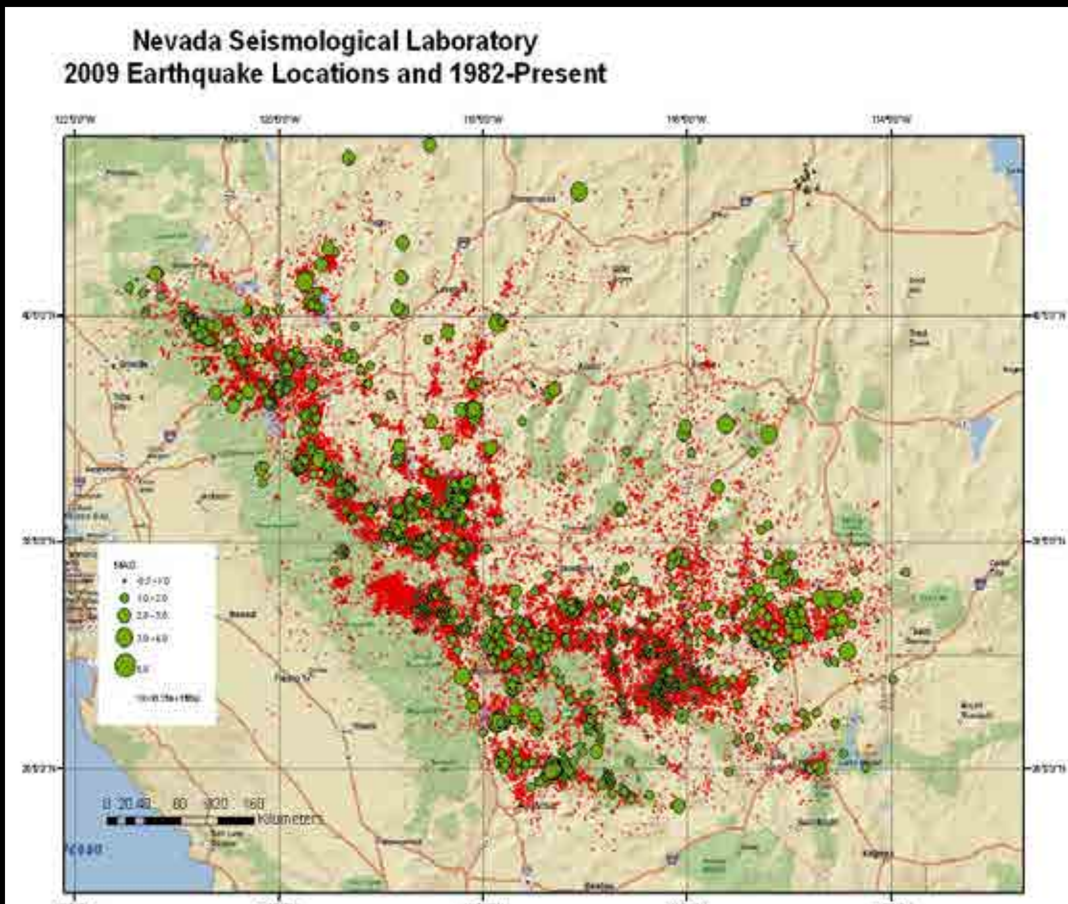
e.g. seismic reflection imaging

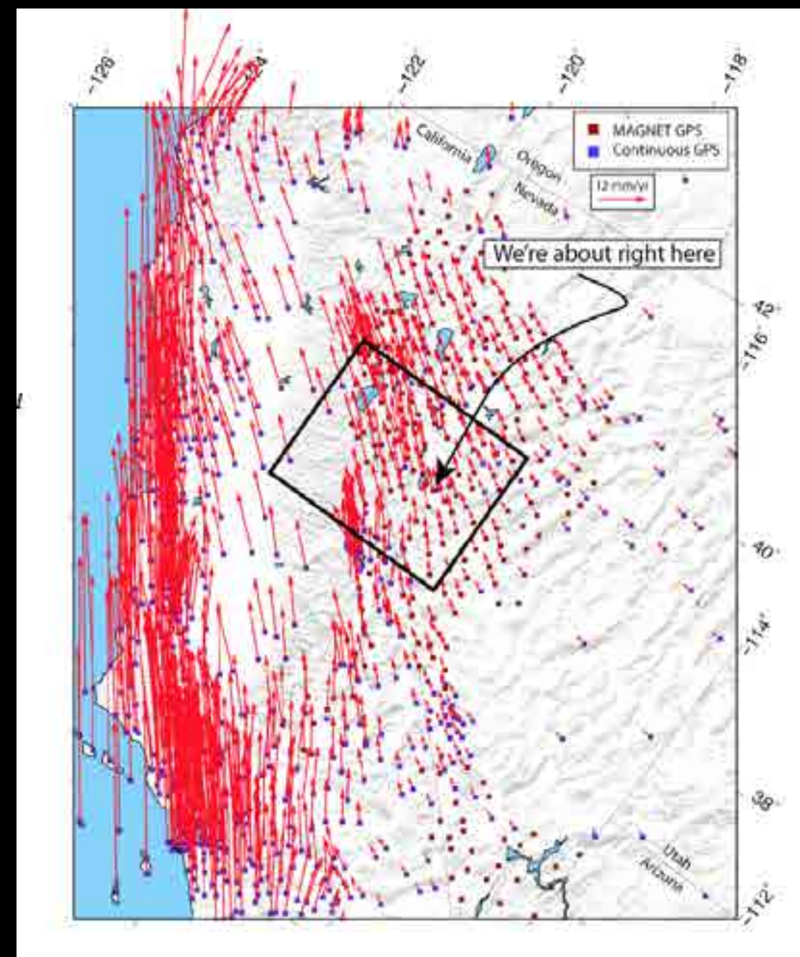
of mafic sills



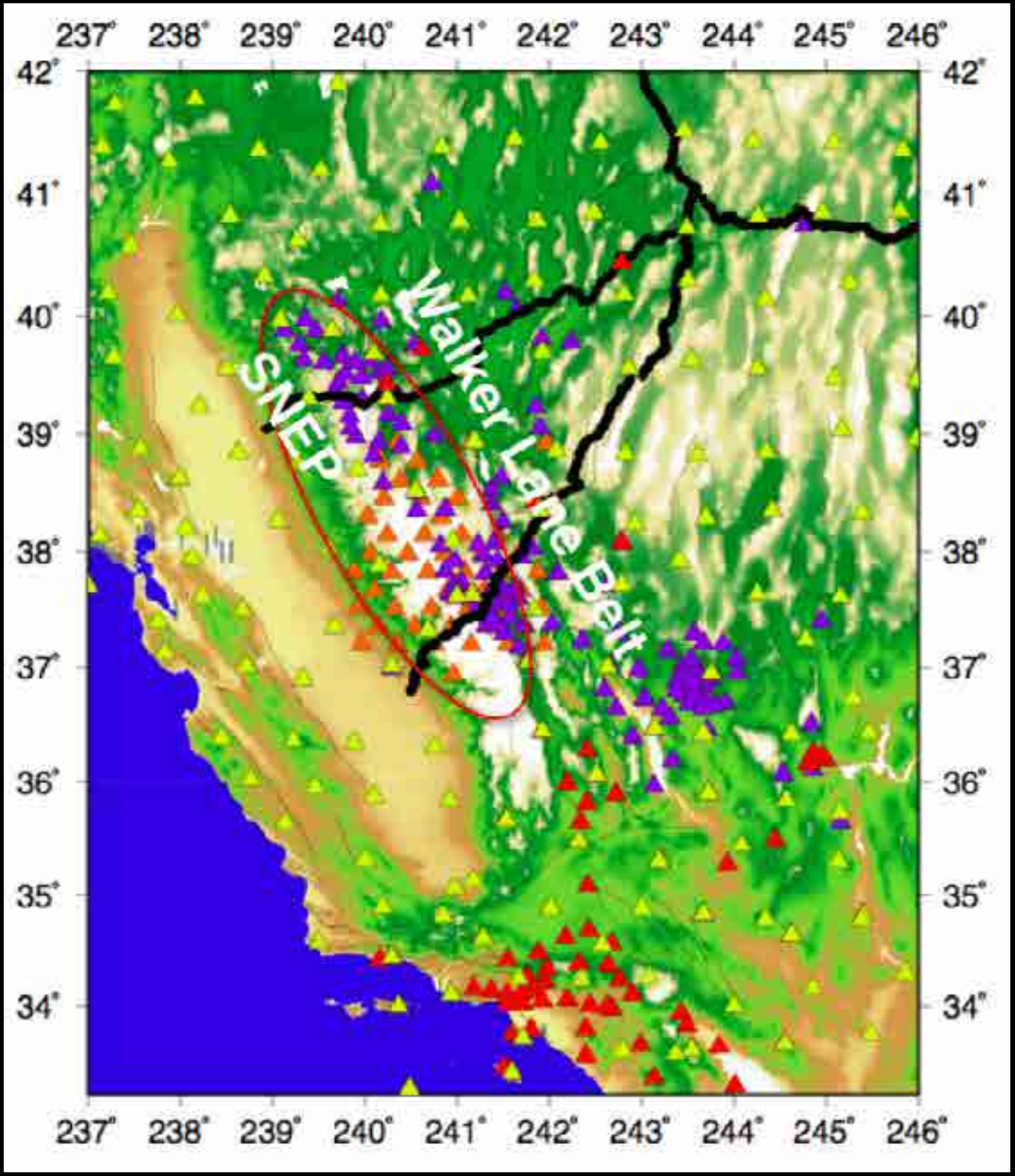
(7) Magmatism over past >26 Ma - can determine longer-term fault motion rates with dateable volcanic stratigraphy.

(8) Active tectonism - real-time measurements with GPS and seismic monitoring, discovery of previously unmapped faults with LIDAR, dating of very young fault surfaces with new cosmogenic techniques.





Attributes, continued:



(9) Portable array data already available from Sierra Nevada -

need to

EXTEND THIS TO WALKER LANE RIFT SYSTEM

To determine the structure of the lower crust and upper mantle.

Attributes, continued:

(10) Intense geothermal exploration - $300 MILLION from DOE and Industry in Nevada over next 5 years - $20 MILLION in seismic alone -

societal impact (green energy) and leveraging from other funding agencies.

Coso Geothermal Field

MATRIX ITEM 1: Why does rifting occur - specifically, how do extensional forces exceed the yield strength of the lithosphere?

Determine relative importance of:

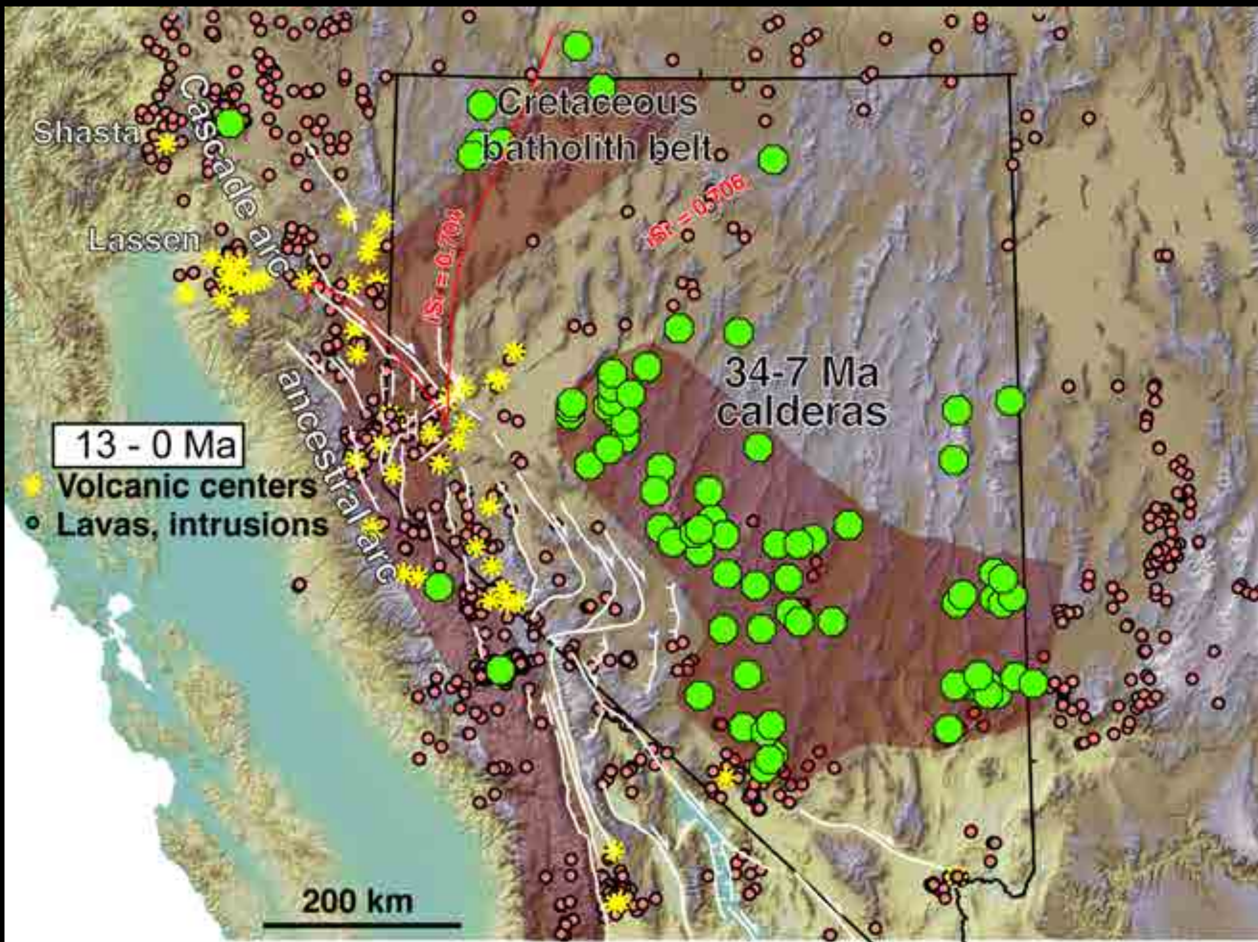
Regional forces:

1. Gravitational collapse of crust thickened in Sevier and Laramide orogenies (Paleocene)
2. Eocene to Miocene extension caused by slab rollback (Eocene to Miocene)
3. Change from subduciton margin to transform margin
4. Basin and Range extension due to growth of the San Andreas fault boundary (16 Ma-present)
5. Onset of transtension at ~12 Ma (due to change in Pacific plate motion)

Local body forces:

1. Positive and negative contributions of mantle buoyancy (e.g. root delamination, asthensopheric upwelling)

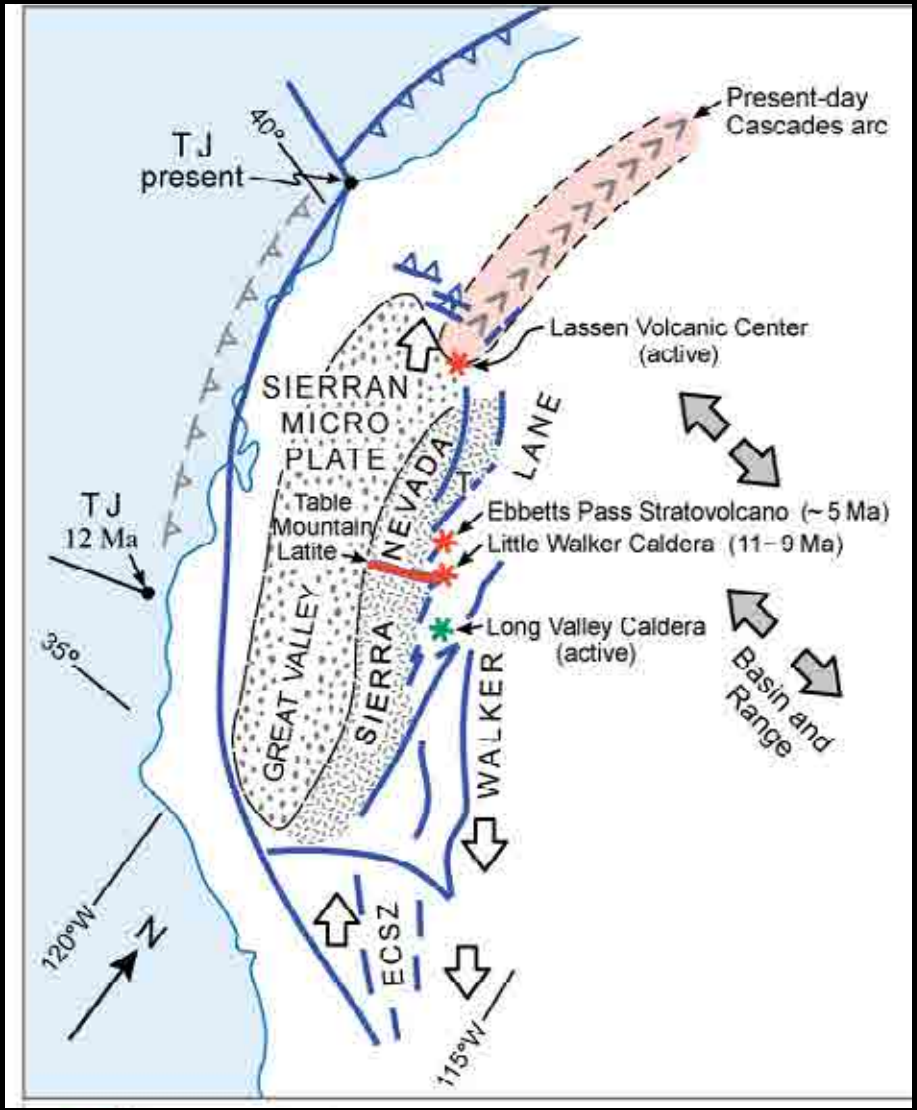
HYPOTHESIS: Walker Lane rift system formed between Cretaceous and mid-Cenozoic caldera batholithic belts (browns) - and cut through the Cretaceous batholith belt along the Ancestral Cascade Arc axis (orange dots).



Link with Cascadia

We are still discovering major volcanic centers and determining their tectonic controls……..

…but large volcanic centers appear to be located on transtensional stepovers:



ACTIVE:

Lassen arc stratovolcanic center

Long Valley rift caldera

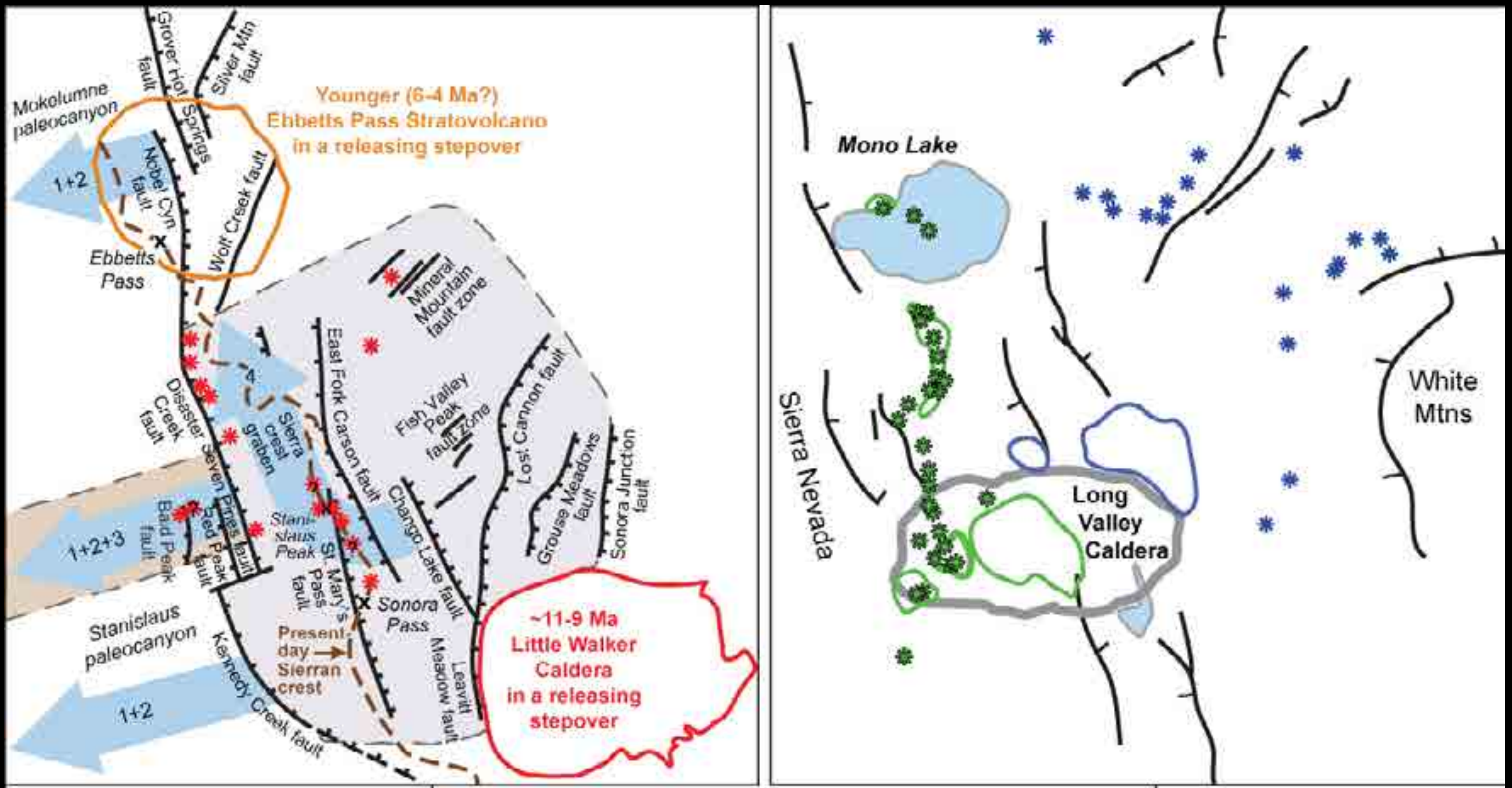
CENTERS NEWLY DISCOVERED:

Sierra Crest Graben Andesite Flood Lava Complex beneath Little Walker arc caldera (11 - 9 Ma)

Ebbetts Pass arc stratovolcanic center (5 Ma)

Miocene Little Walker Caldera (left) built atop grabens filled with fissure-fed flood andesite (lavender)

shown at same scale as the active Long Valley caldera (right)



NNW-SSE faults right transtensional, ENE-WSW faults left transtensional. Stars = vents.

STRATIGRAPHIC EXPRESSION OF RIFT INITATION

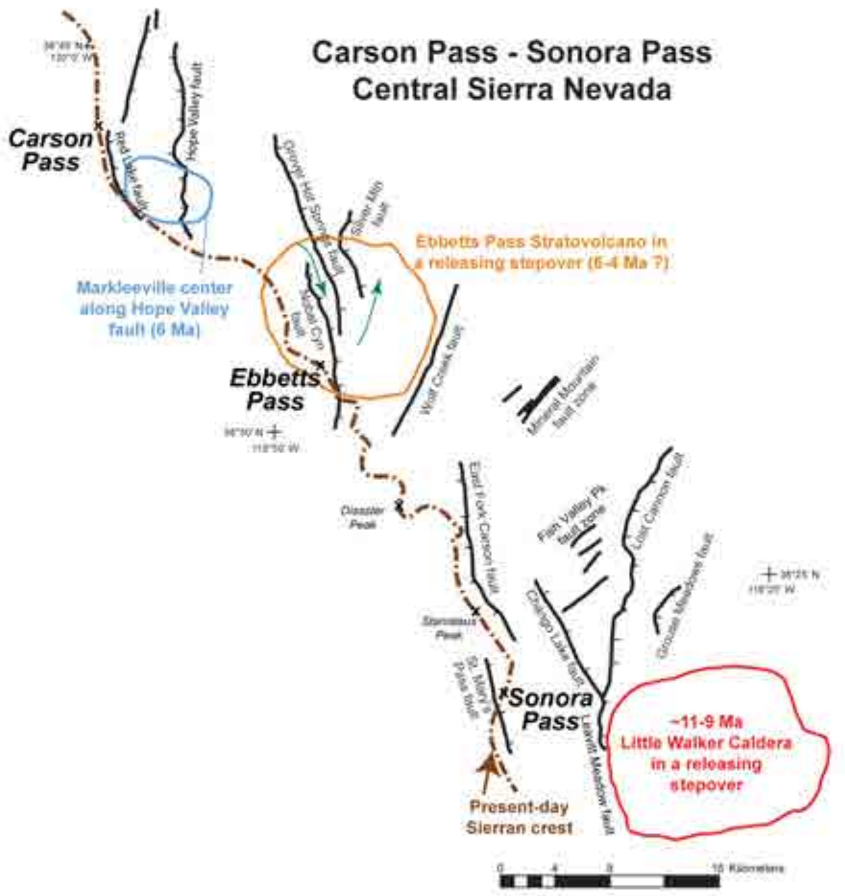
at ~12 Ma:

Extreme effusive eruptions of “flood andesite”

and

unusually large-volume, widespread landslide deposits

(Busby et al. in review)



Another major volcanic center sited on transtensional stepover:

Newly-discovered

5 Ma

Ebbetts Pass Stratovolcano

(Busby et al., unpublished data)

MATRIX ITEM 3: What controls the architecture of rifts and rift margins? SEDIMENTARY BASIN Outcrop and Lake Studies

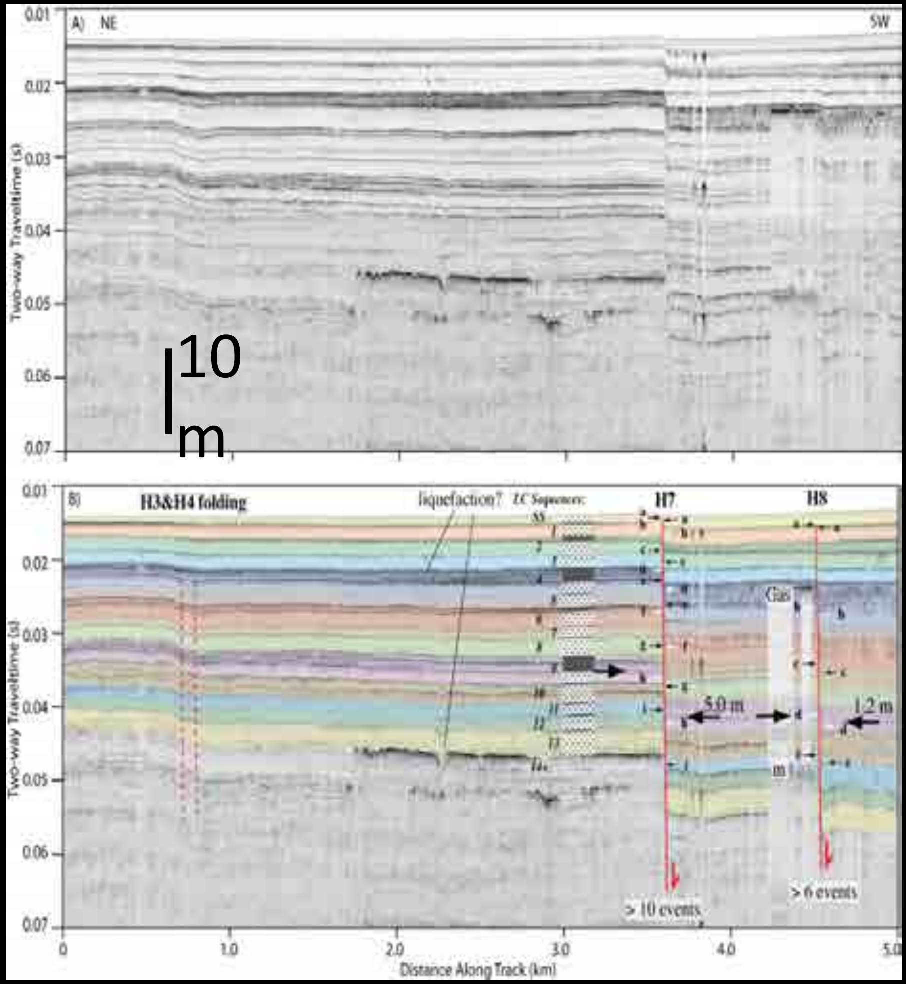
Great variety in:

drainage area sizes/bedrock geology/erosional processes

basin ages, sizes and structures, sedimentation rates, fault movement histories and paleoseismicity records

hazards record from landslides and seiches

paleoclimate record from outcrop and dill core



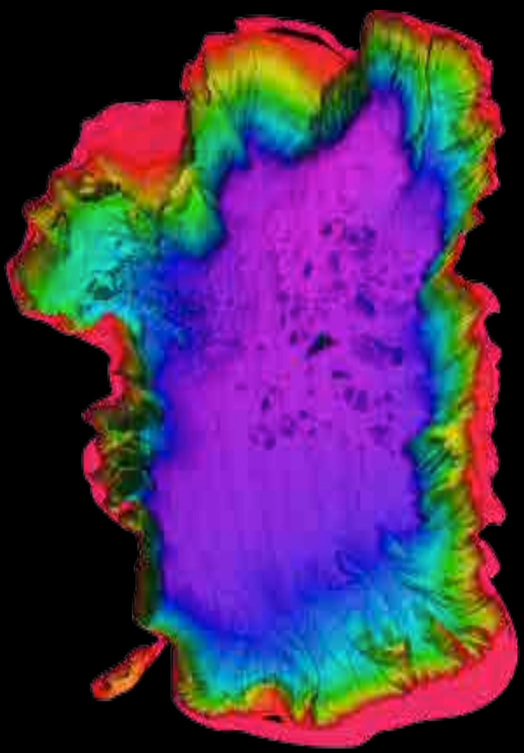
Salton Sea

Lake Tahoe/Pyramid Lake to Salton Sea to Gulf of CA:

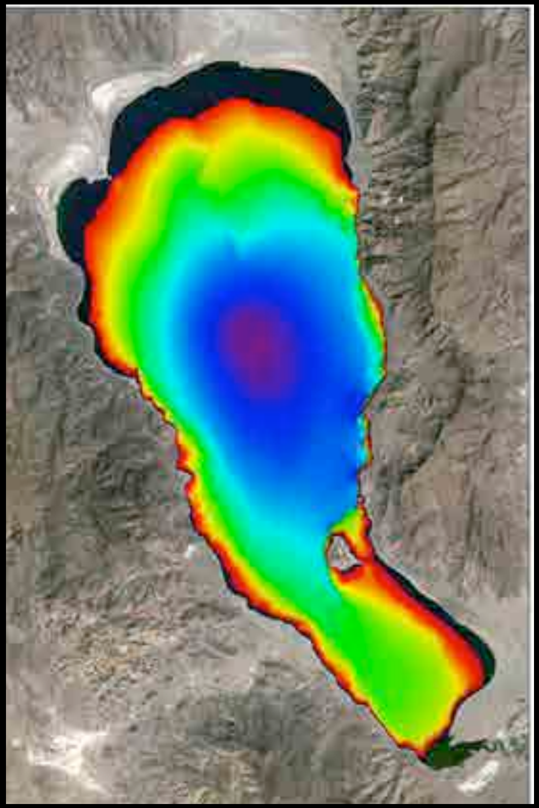
High resolution studies of modern lakes and the dissected deposits of Pleistocene pluvial lakes

Influence of Sedimentation on Rift Development

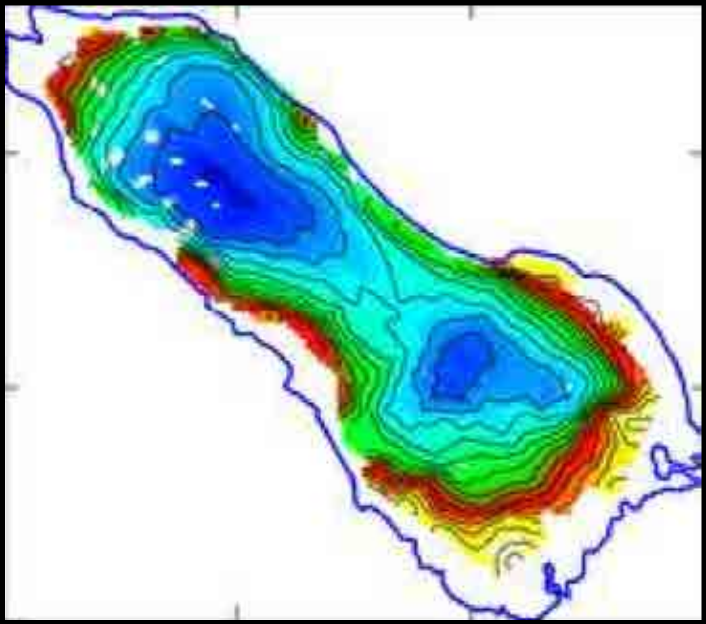
Lake Tahoe



Pyramid Lake

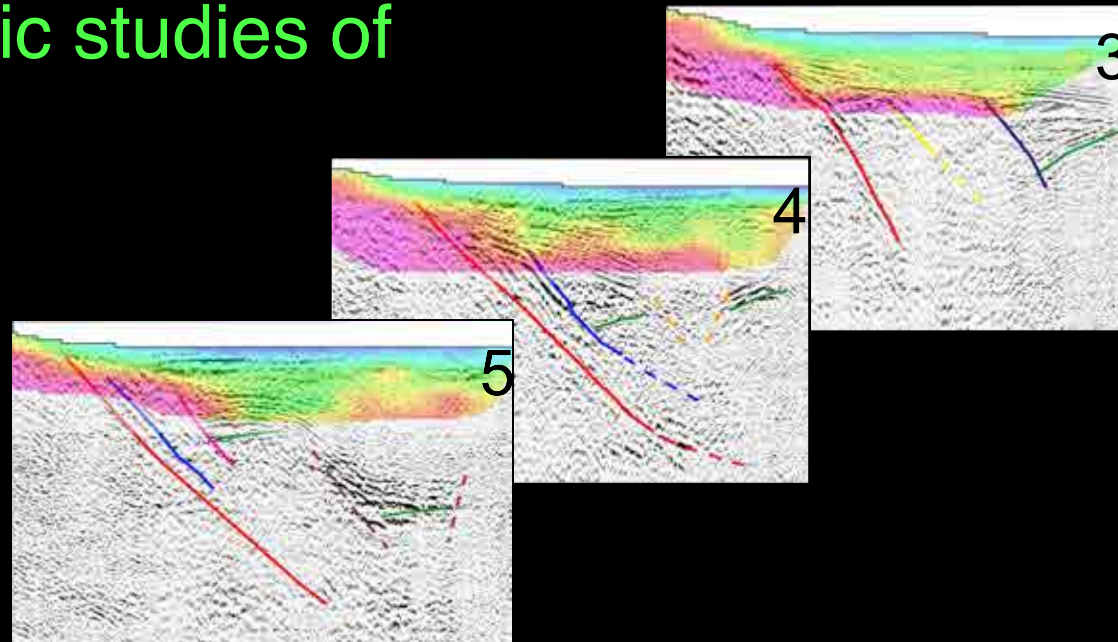


Salton Sea

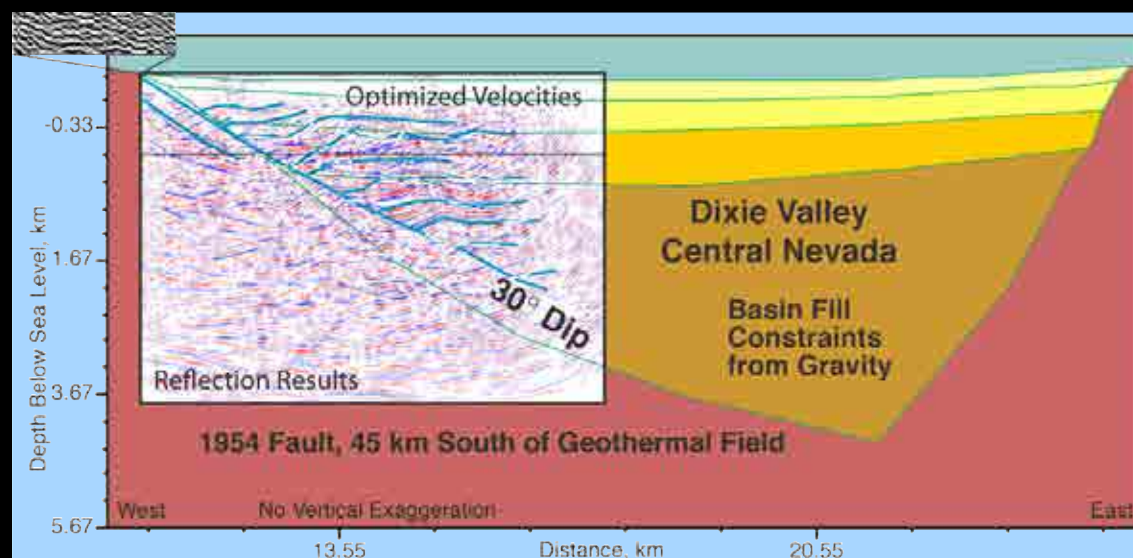


Examples of Seismic studies of basin architecture

Only the range-front fault breaks the surface



A fault that has been active at low angle since 23 Ma



WE PROPOSE A

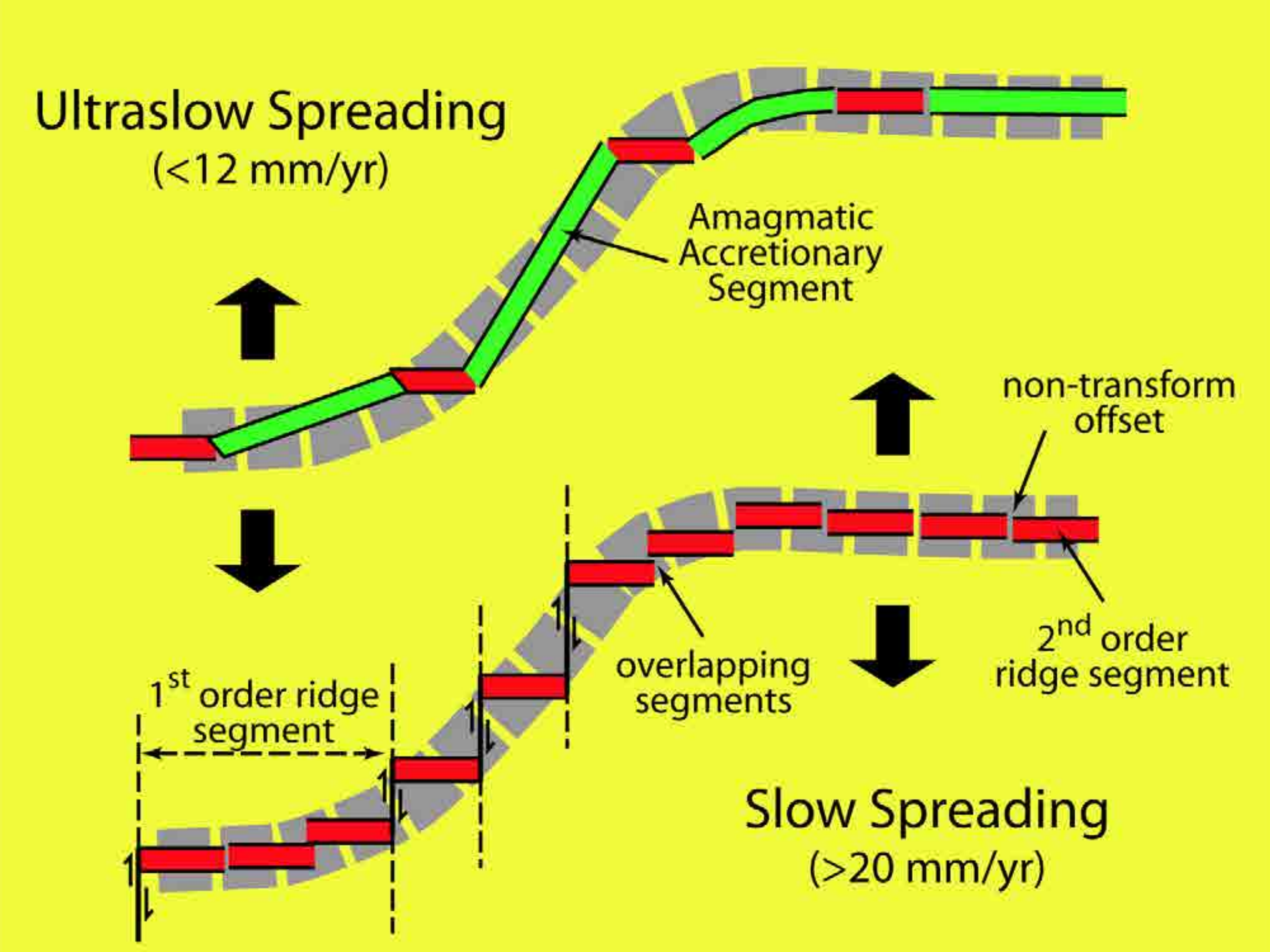
U.S. RIFT PROGRAM

to interface with Cascadia

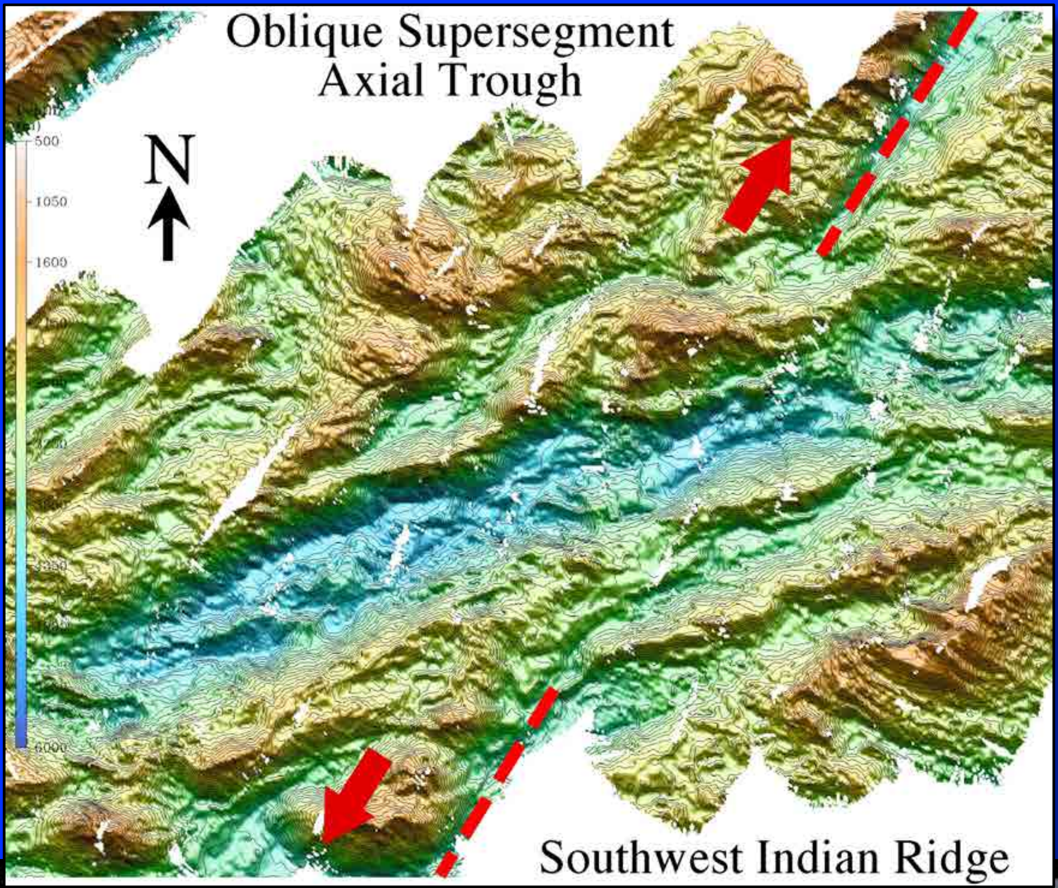
By comparing rift initiation in the Walker Lane and Rio Grande rift systems

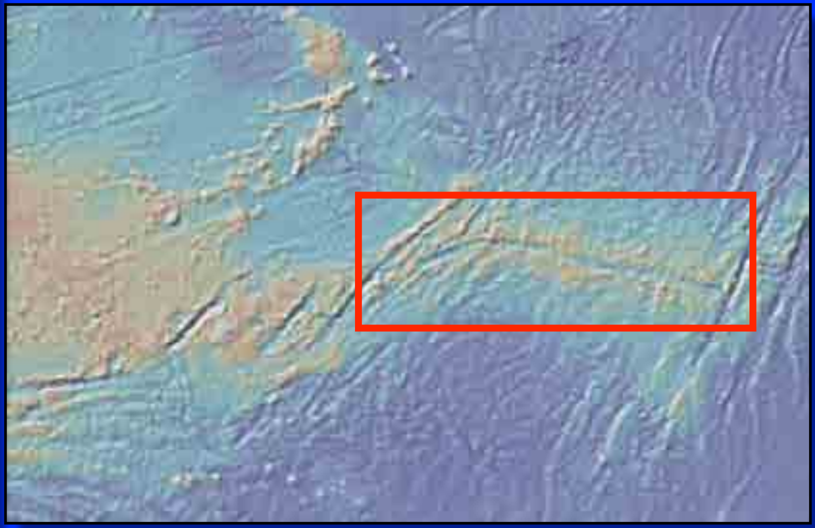
with the successful Gulf of CA rift

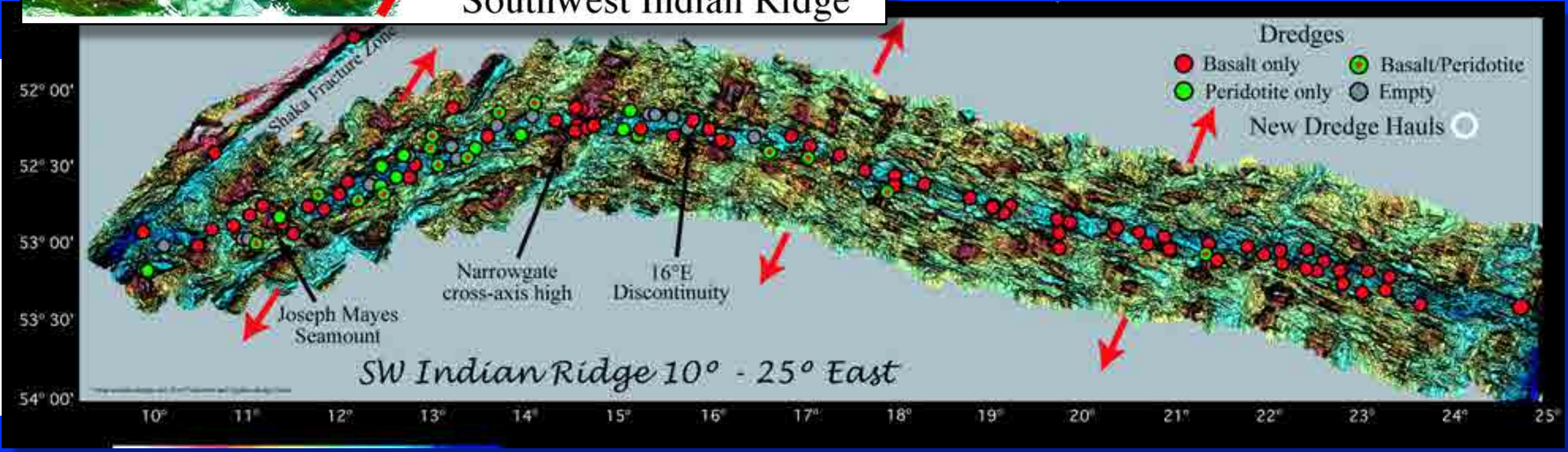
and the Mississippi Valley failed rift and the "mature" East Coast rift

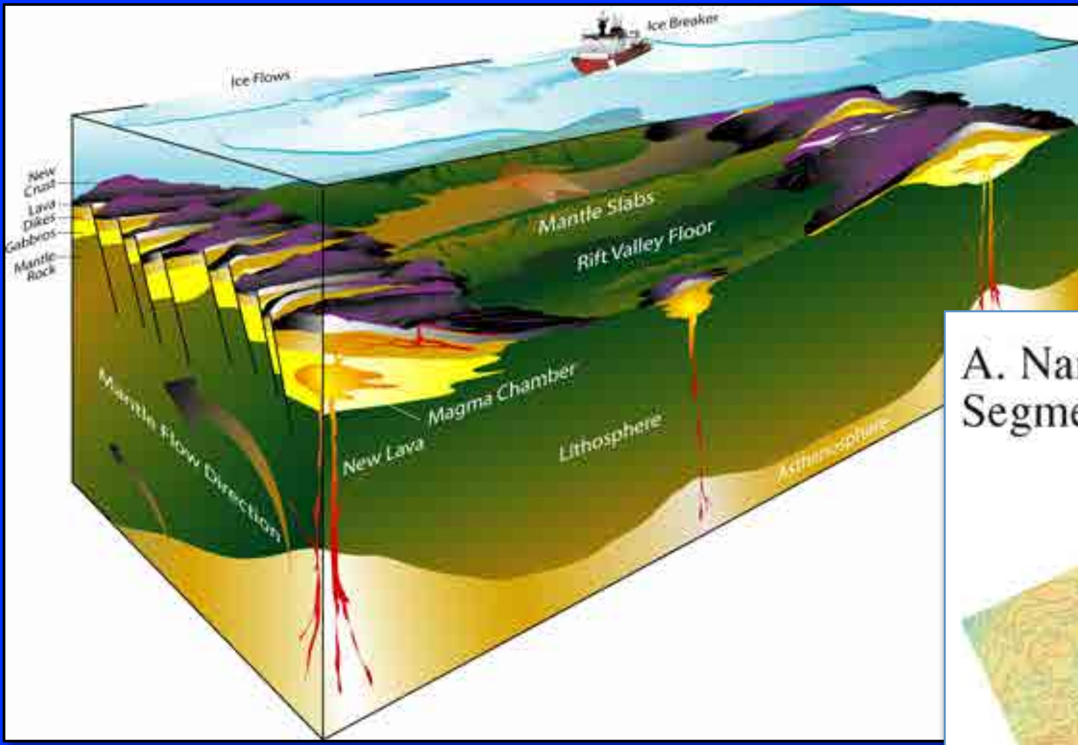

Ultraslow Spreading
(<12 mm/yr)
Amagmatic
Accretionary
Segment
non-transform
offset
overlapping
segments
2nd order
ridge segment
1st order ridge
segment
Slow Spreading
(>20 mm/yr)

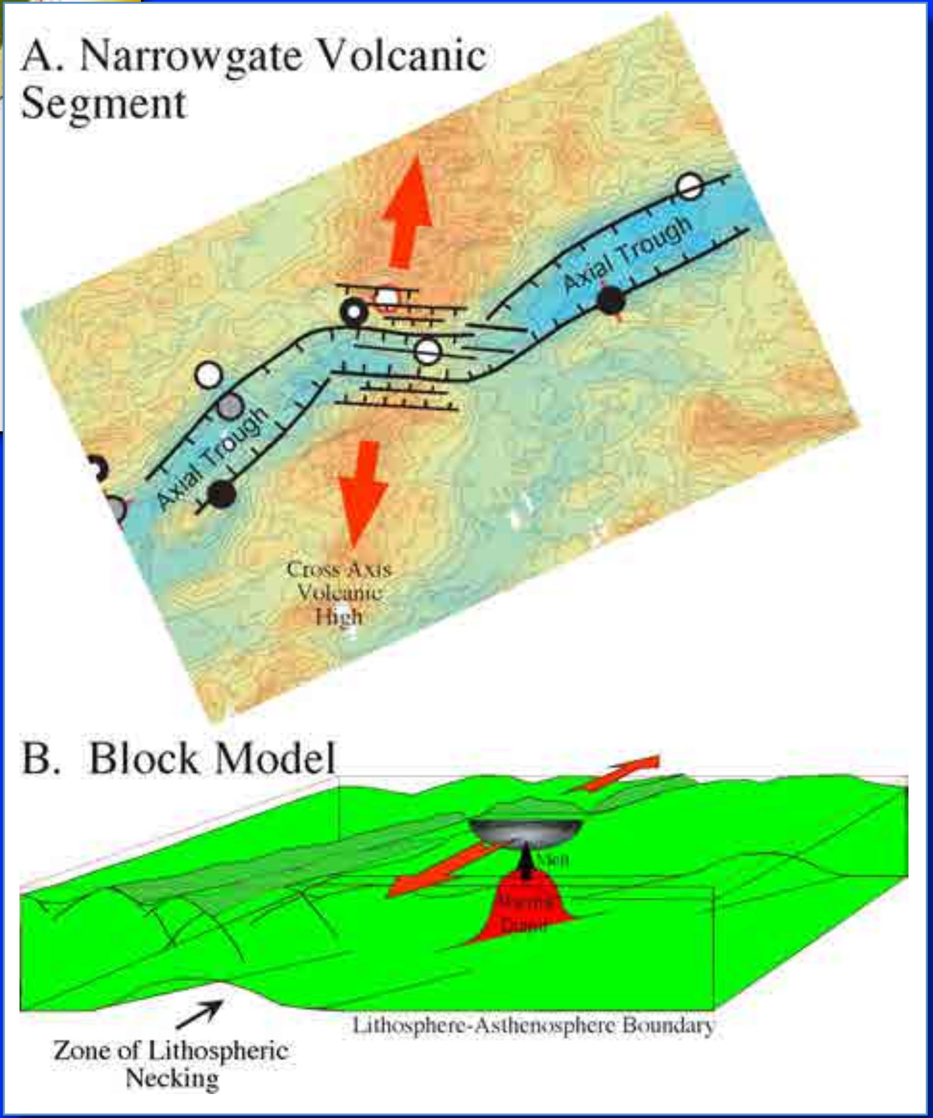
Ultraslow Spreading SW Indian Ridge



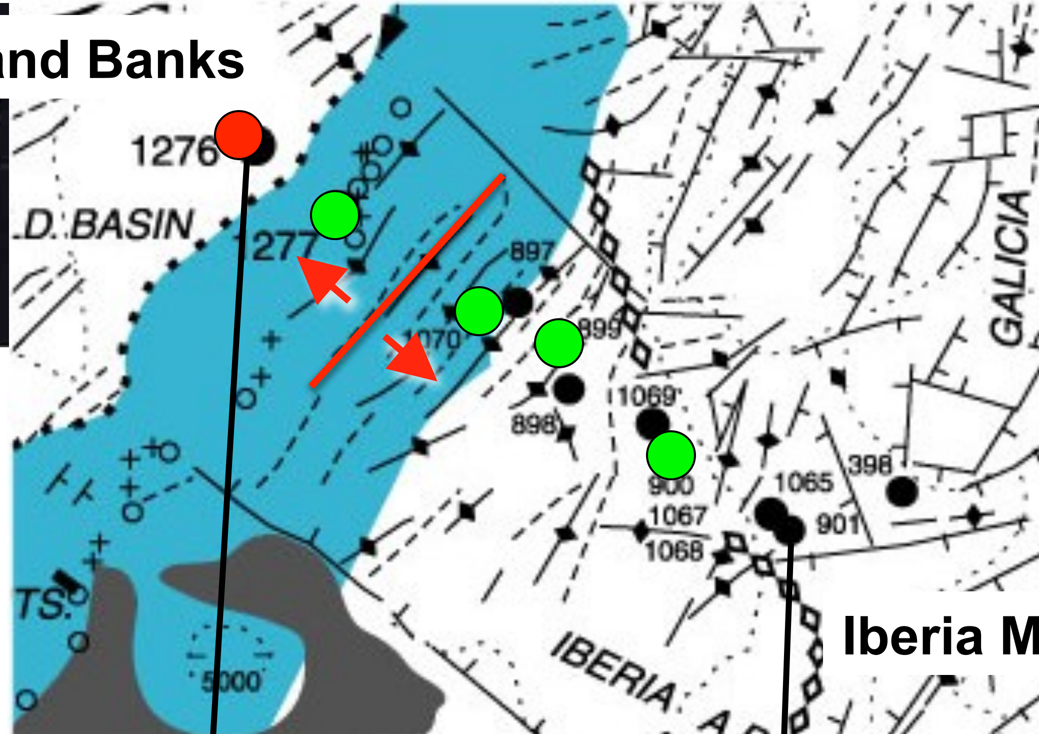





Ice Breaker
Ice Flows
New Crust
Lava
Dikes
Gabbros
Mantle Rock
Mantle Slabs
Rift Valley Floor
Mantle Flow Direction
Magma Chamber
New Lava
Lithosphere
Asthenosphere


A. Narrowgate Volcanic Segment
Axial Trough
Axial Trough
Cross Axis Volcanic High
B. Block Model
Zone of Lithospheric Necking
Lithosphere-Asthenosphere Boundary

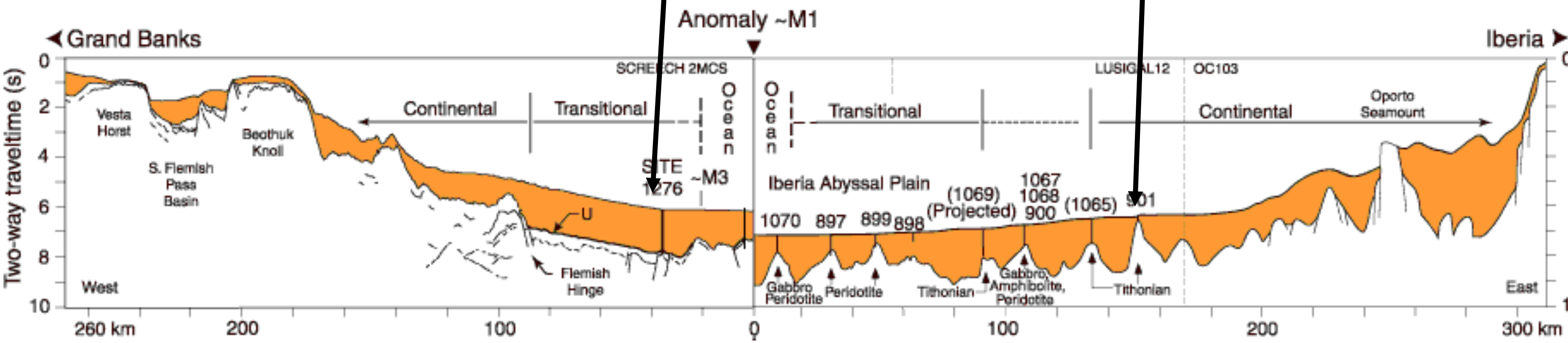
Grand Banks



Iberia Margin

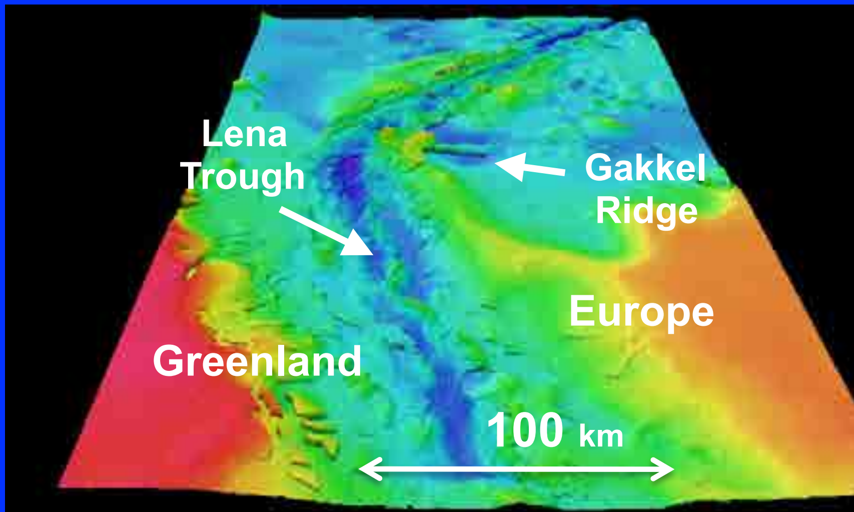
Drilling Legs:
149, 173, 210

120 Ma,
Mid-Cretaceous



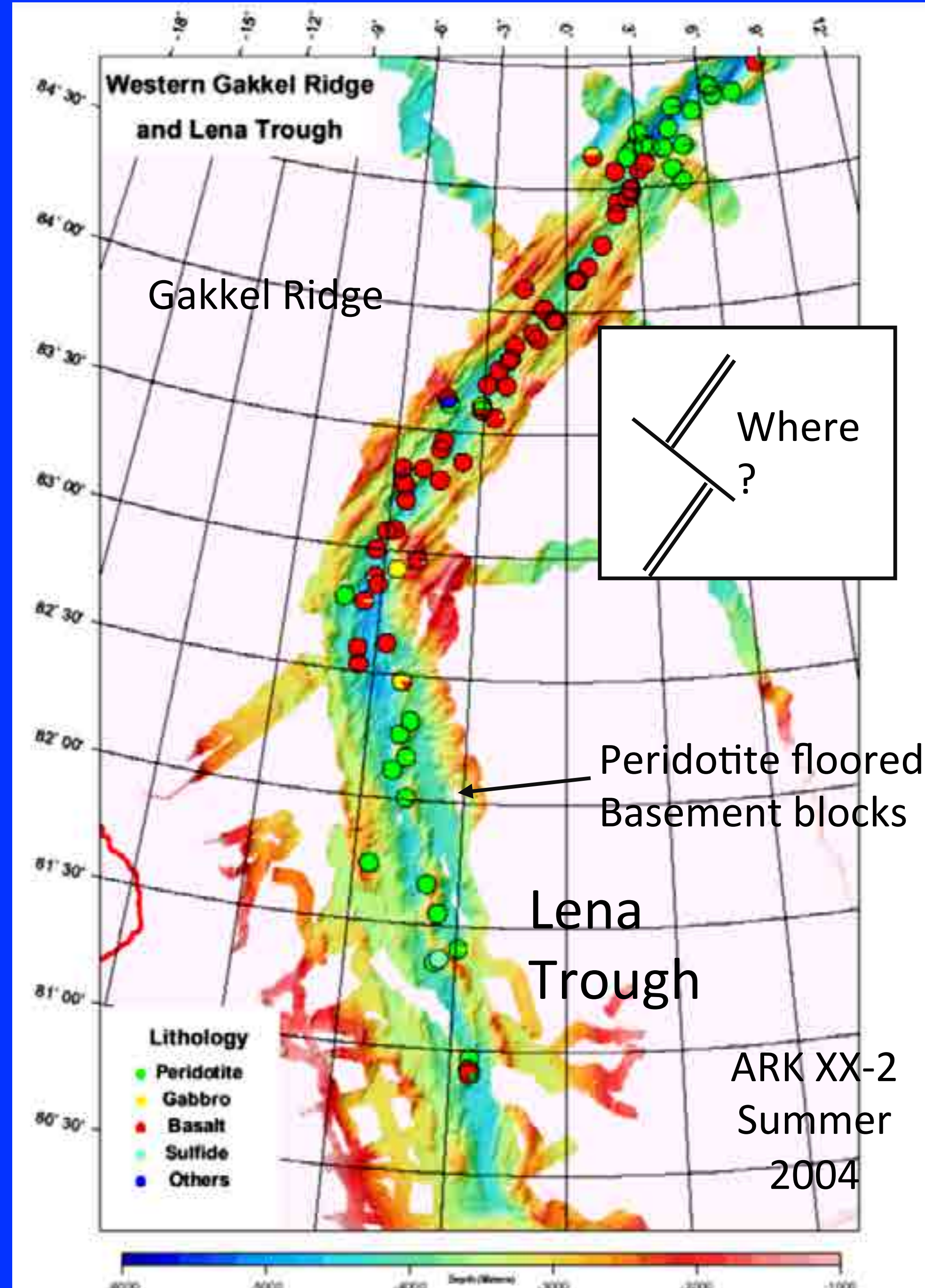
Gabbroic-Ultramafic!
"Amagmatic" extension

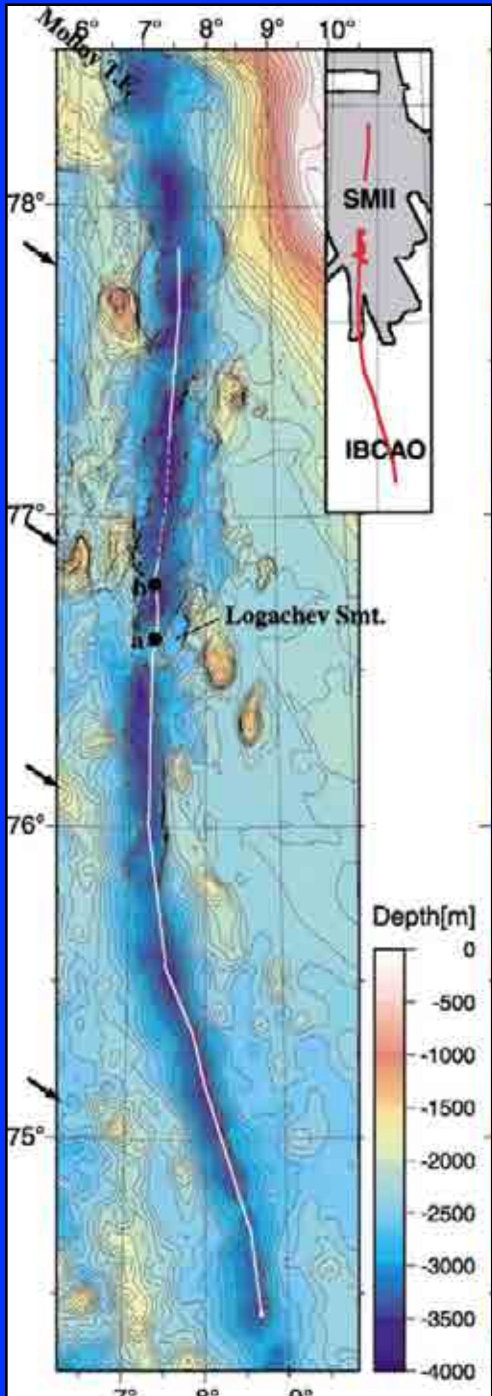
◀ Grand Banks　　　　Iberia ▶

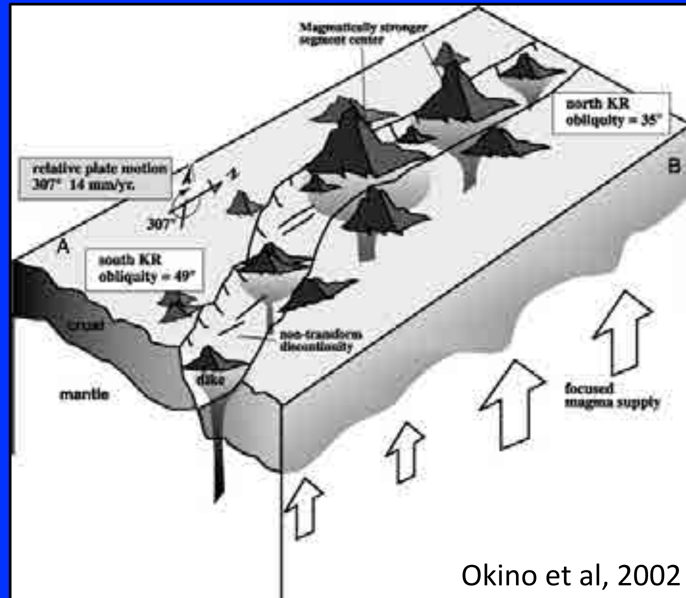


Lena Trough – a modern example of the ocean – continent transition

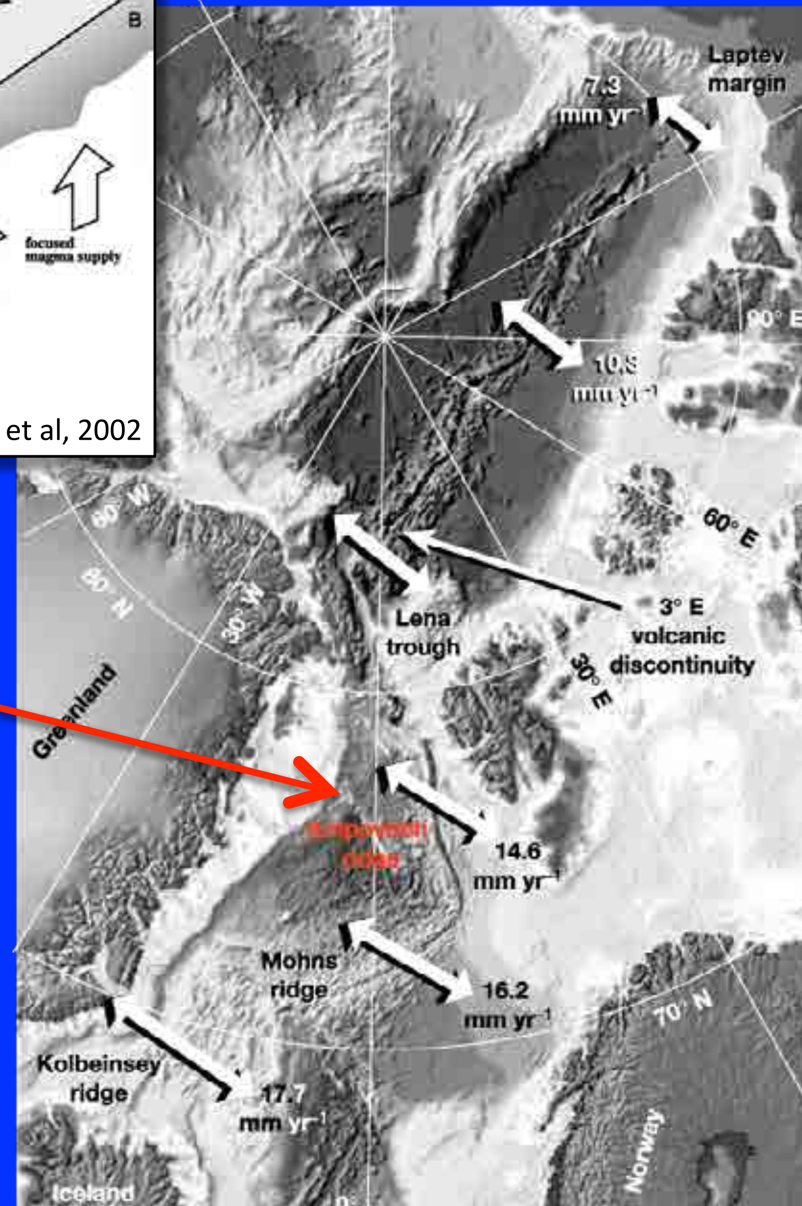
Amagmatic accretionary segments seen at ultra slow ridges spreading at an ESR <12 mm/yr are likely the characteristic plate boundary structure of non-volcanic rifted margins.

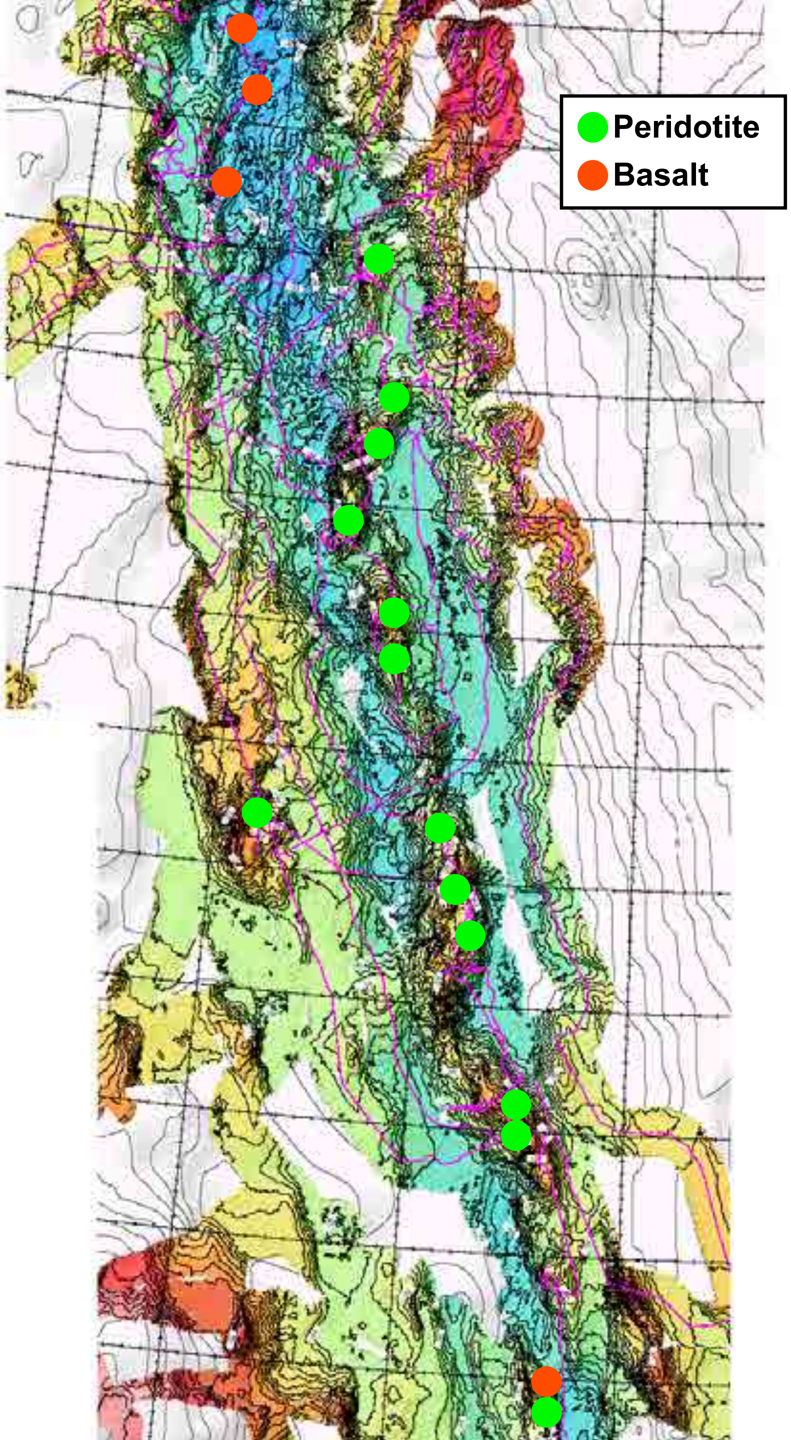






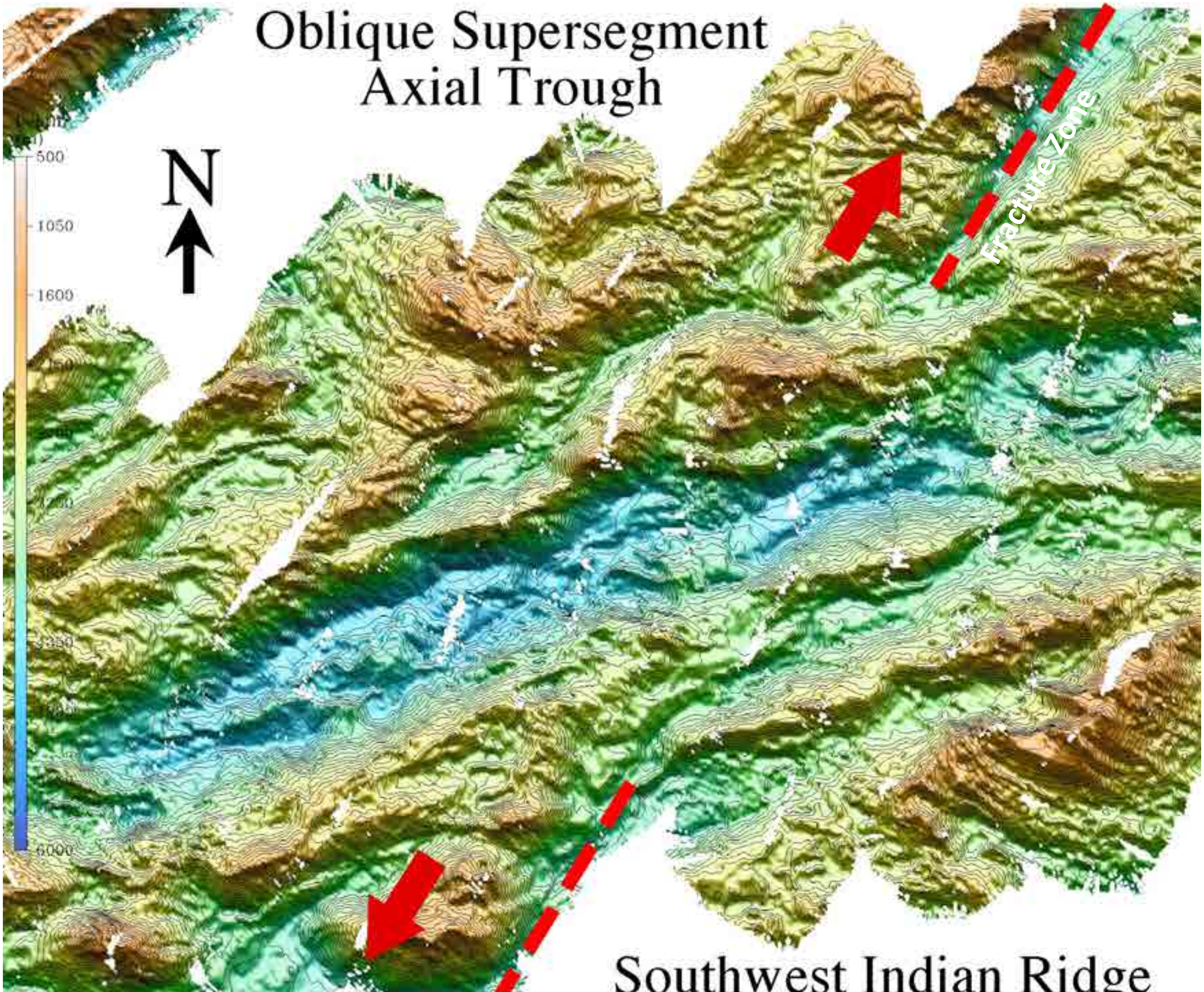
Knipovitch Ridge





“Amagmatic”!

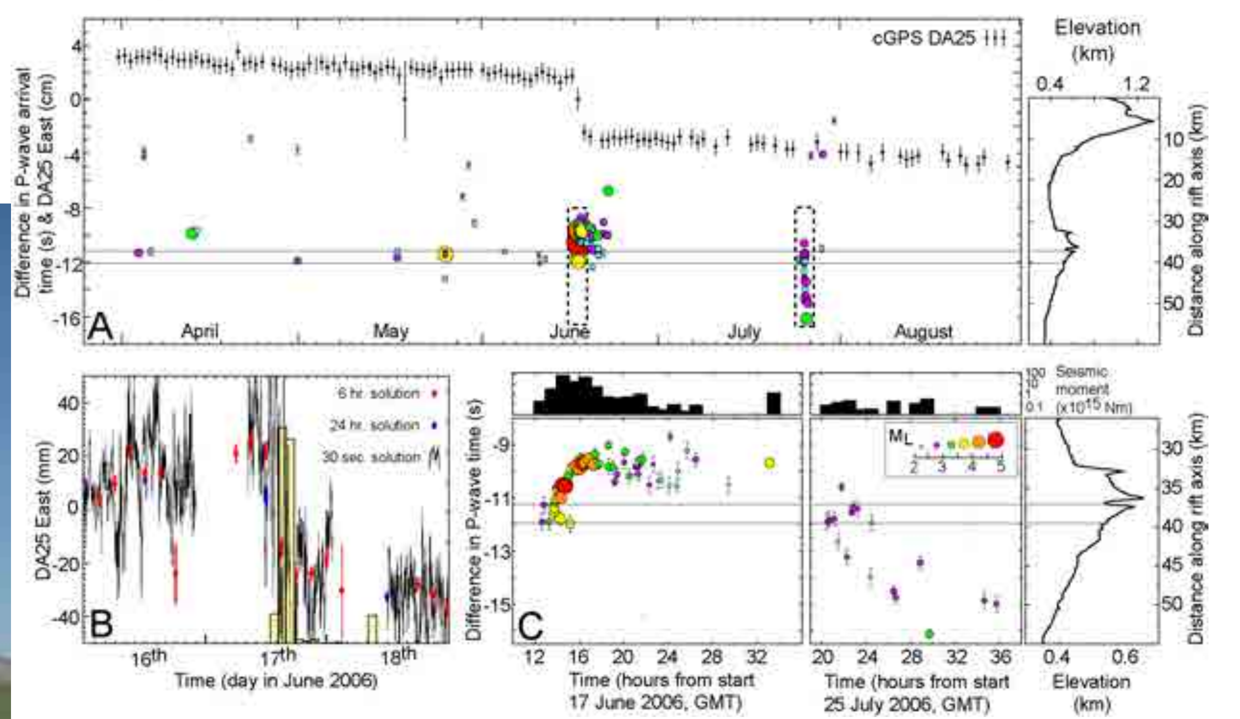
- Mostly ultramafic outcrop
- Little or no volcanism
- Volcanism at segment ends, not center (!)
- Very fertile mantle compositions
- Melting very variable
- Melt production, stagnation, etc....



Oblique Supersegment
Axial Trough
N
500
1050
1600
6000
Fracture Zone
Southwest Indian Ridge

- Rapid Response efforts in rifts – volcanic eruptions, dike intrusions, and large earthquakes – Tijuana EQ, EAR
- Dike intrusions in particular characterized by ML < 5 EQ's – generally not considered for rapid response– dike dimensions; track magma movement; aftershocks illuminate fault/dike dimensions
- Space-based geodesy (GPS, InSAR) – measure stress diffusion rates and vertical/horizontal crustal movements – determine mantle viscosity to rapid opening .
- CONSTRAIN RHEOLOGY, DIMENSIONS, ASEISMIC/SEISMIC STRAIN, MAGMA-VOLATILE FLUXES

Keir et al., figure 3



Submarine Landslides
Rapid Response Opportunities

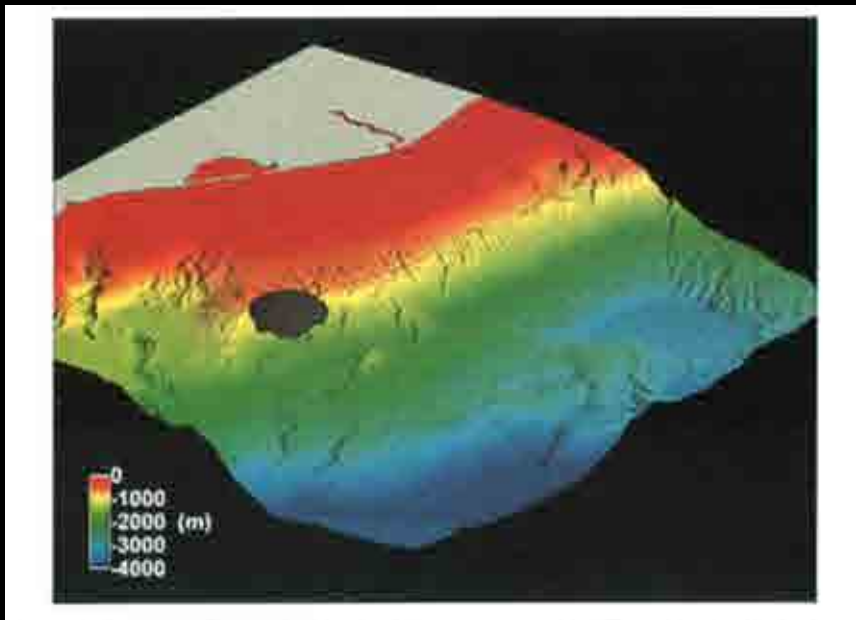
(Best data would be pre-, during-, post-failure but…)

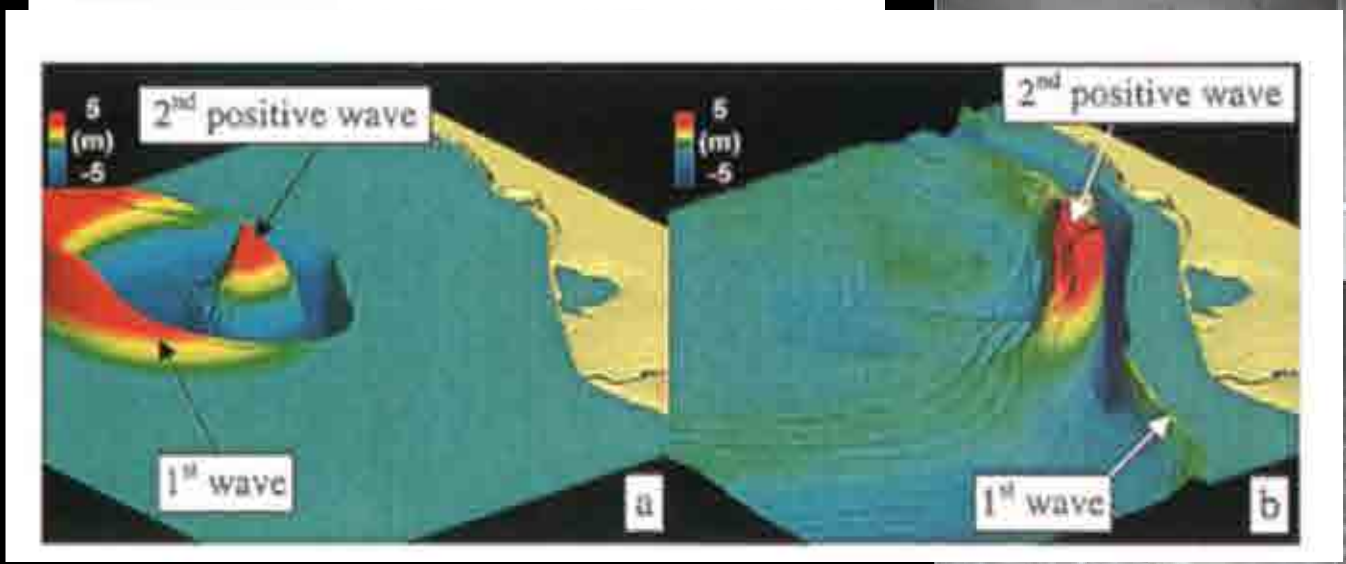
M. Hornbach, P. Flemings (Jackson School of Geosciences)
R. Harris (Oregon State University)
B. Dugan (Rice University)

GeoPRISMS
Rift Initiation & Evolution

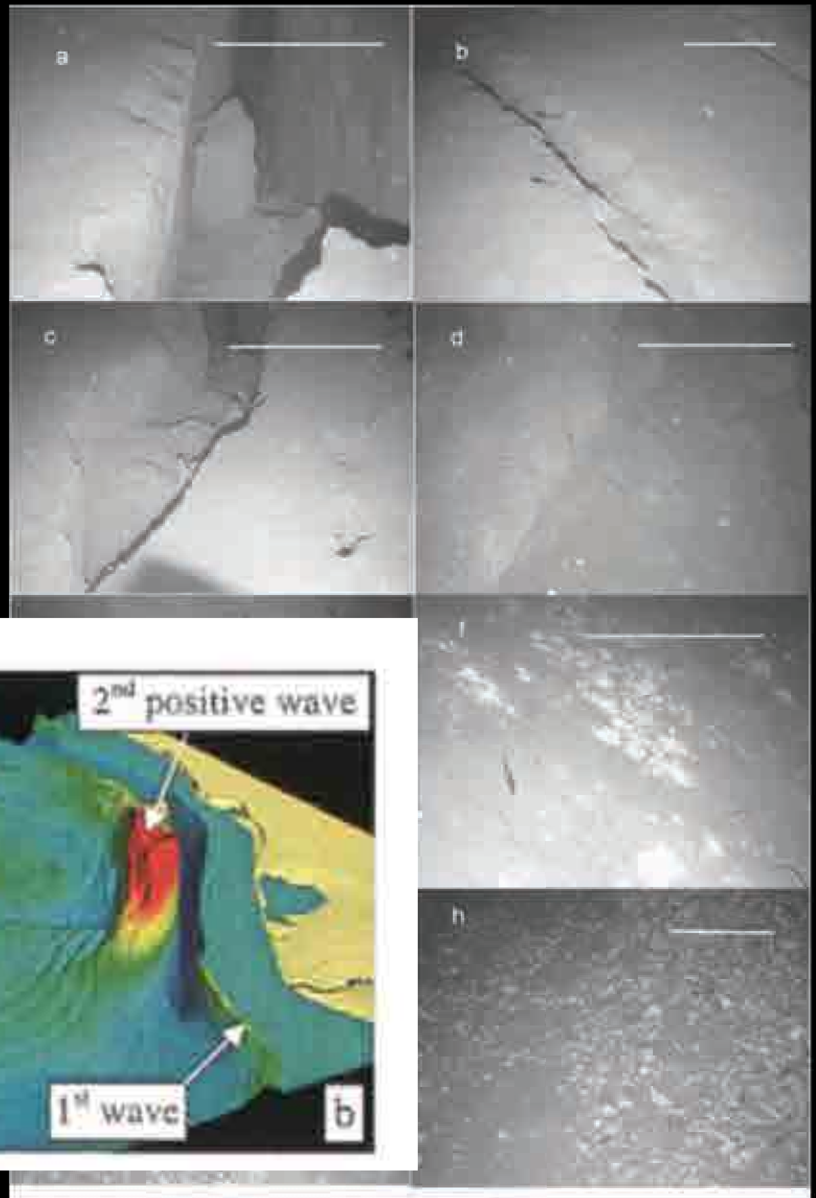
NSF

17 July 1998 Papua New Guinea Tsunami



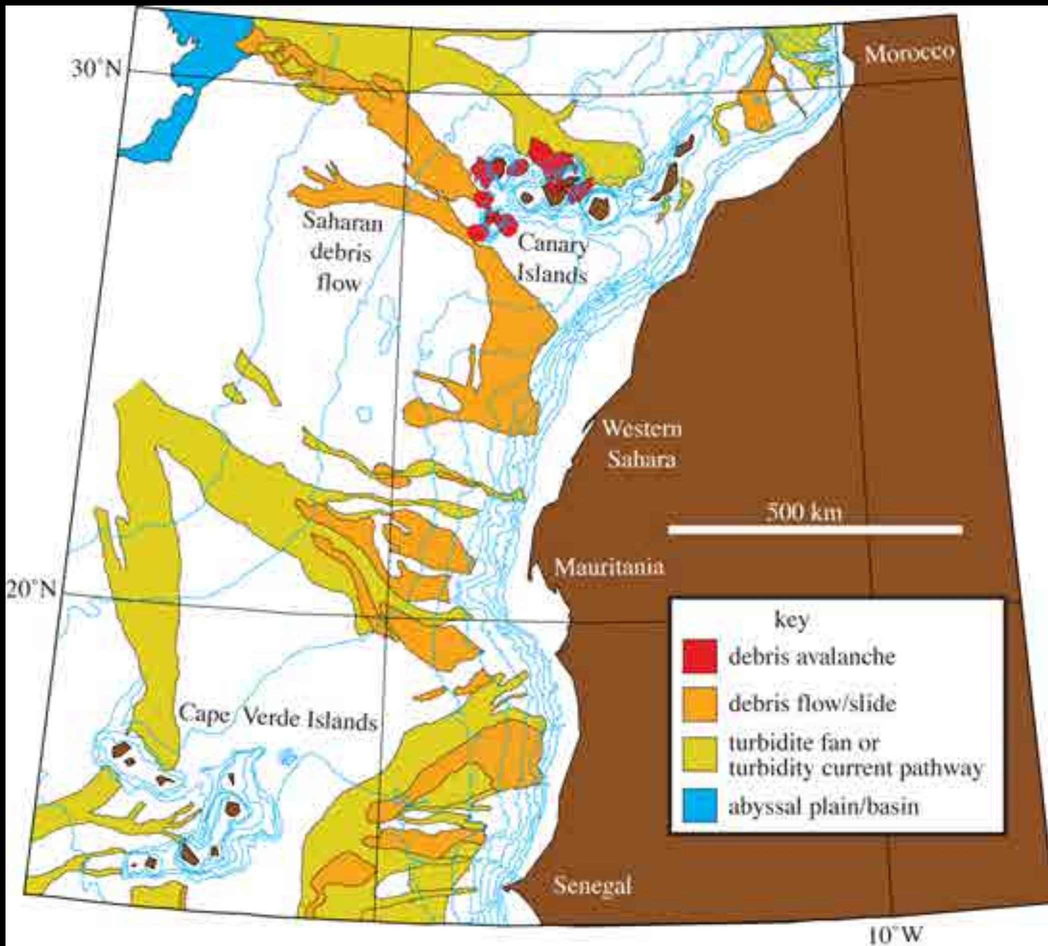


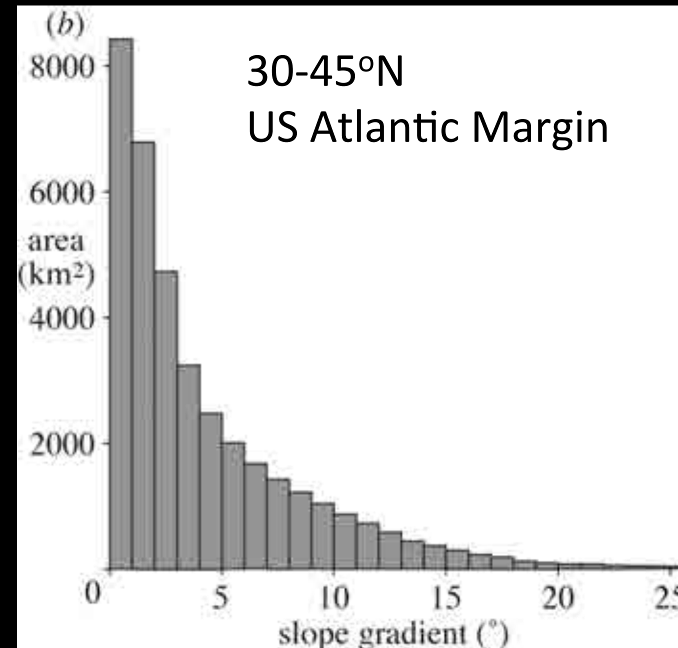
Heinrich et al., 2000

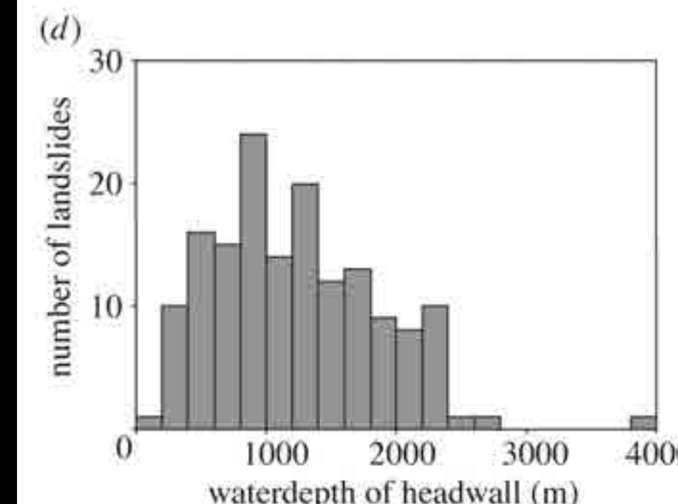


Tappin et al., 2002

Single Events, Margin-Scale Impacts







Masson et al., 2006

Why submarine landslides?

1) Widespread, large-scale margin evolution

2) Rapid, m-km but affect overall margin shape

3) Geohazard potential (process and society)

4) Integrates surface processes and feedbacks

5) Multi-disciplinary
    - geology, geophysics, geotechnics, fluids…

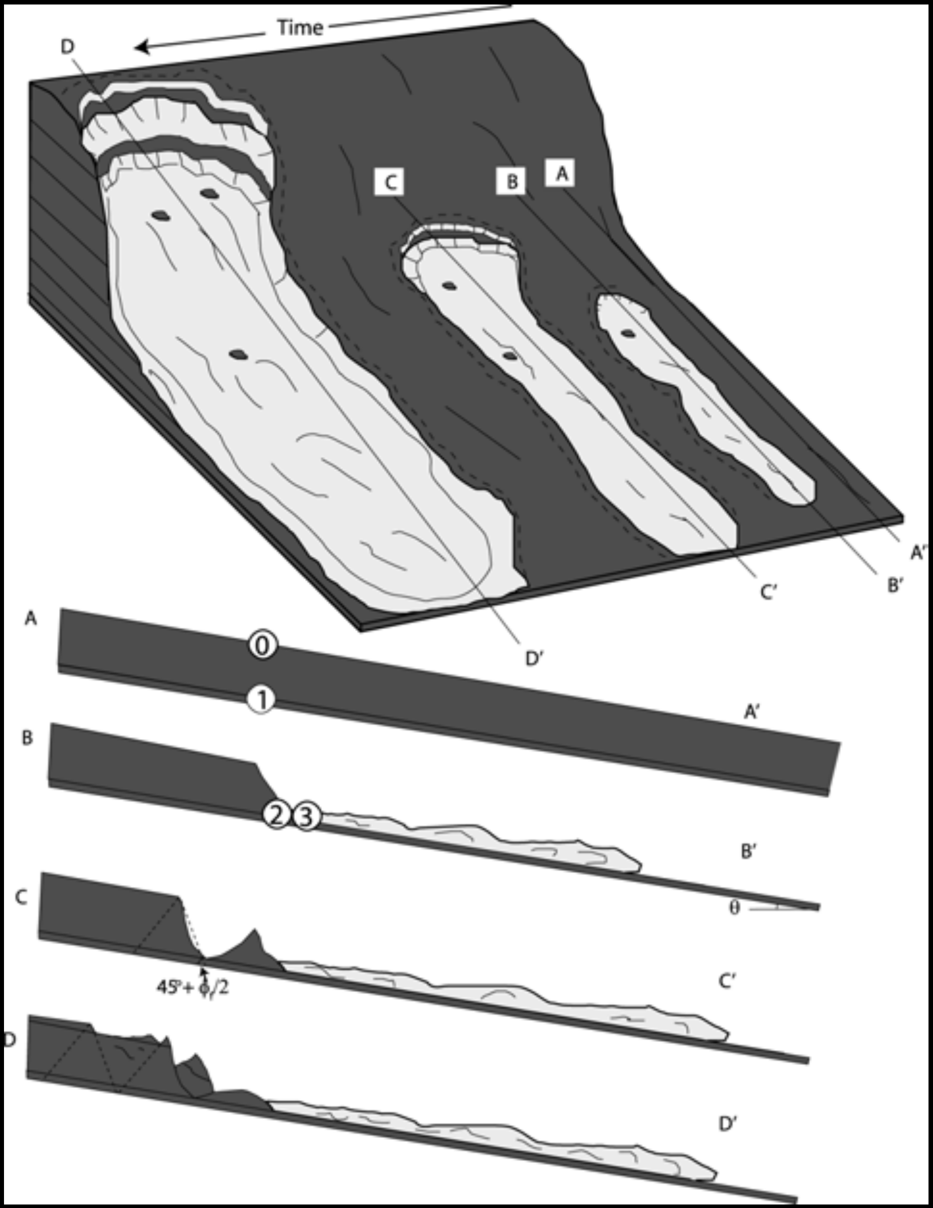
Key Data/Observations – Slide and Adjacent

1) Morphology and distribution

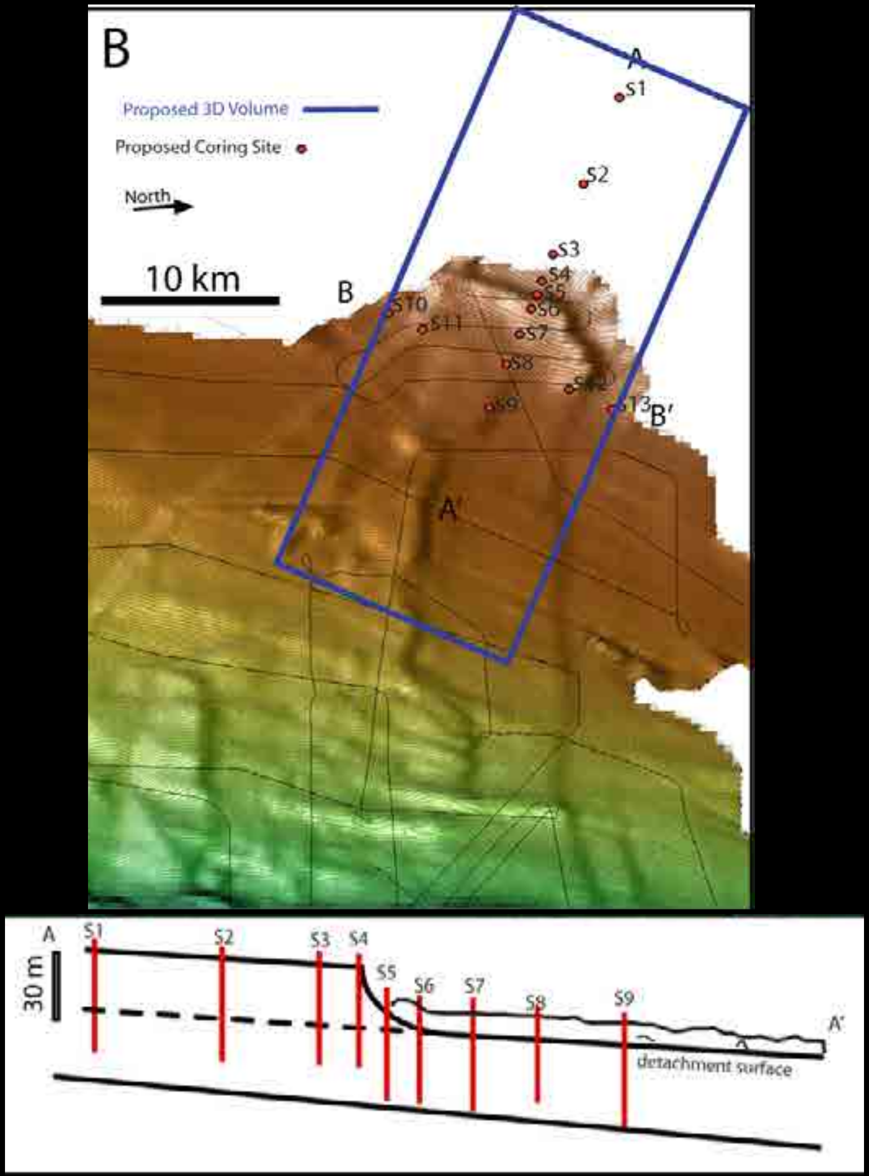
2) In situ pressure, temperature, and strength

3) Tilt and strain data

4) Multiple (4d) images or measurements



Sawyer et al., 2009



Hornbach et al. White Paper

GeoPRISMS-Addressable Questions

What dictates size, runout, and recurrence?
- margin shape and evolution

What drives failure along different margins?

What controls hazard potential?

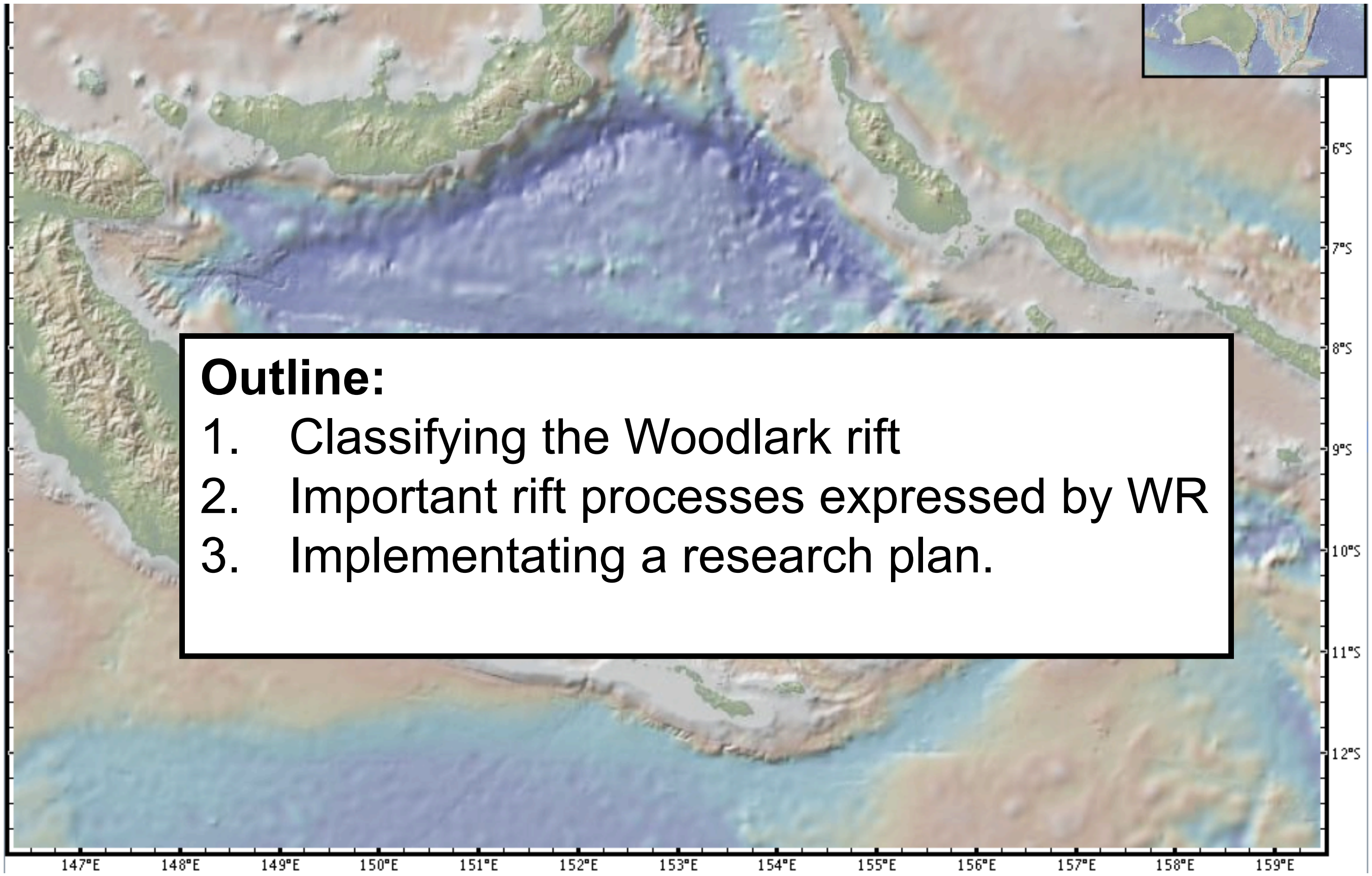
Is the failure evolving or stopping? Why?

How are different failures recorded in the strata?

Woodlark Rifting White Paper

Important processes and implementation

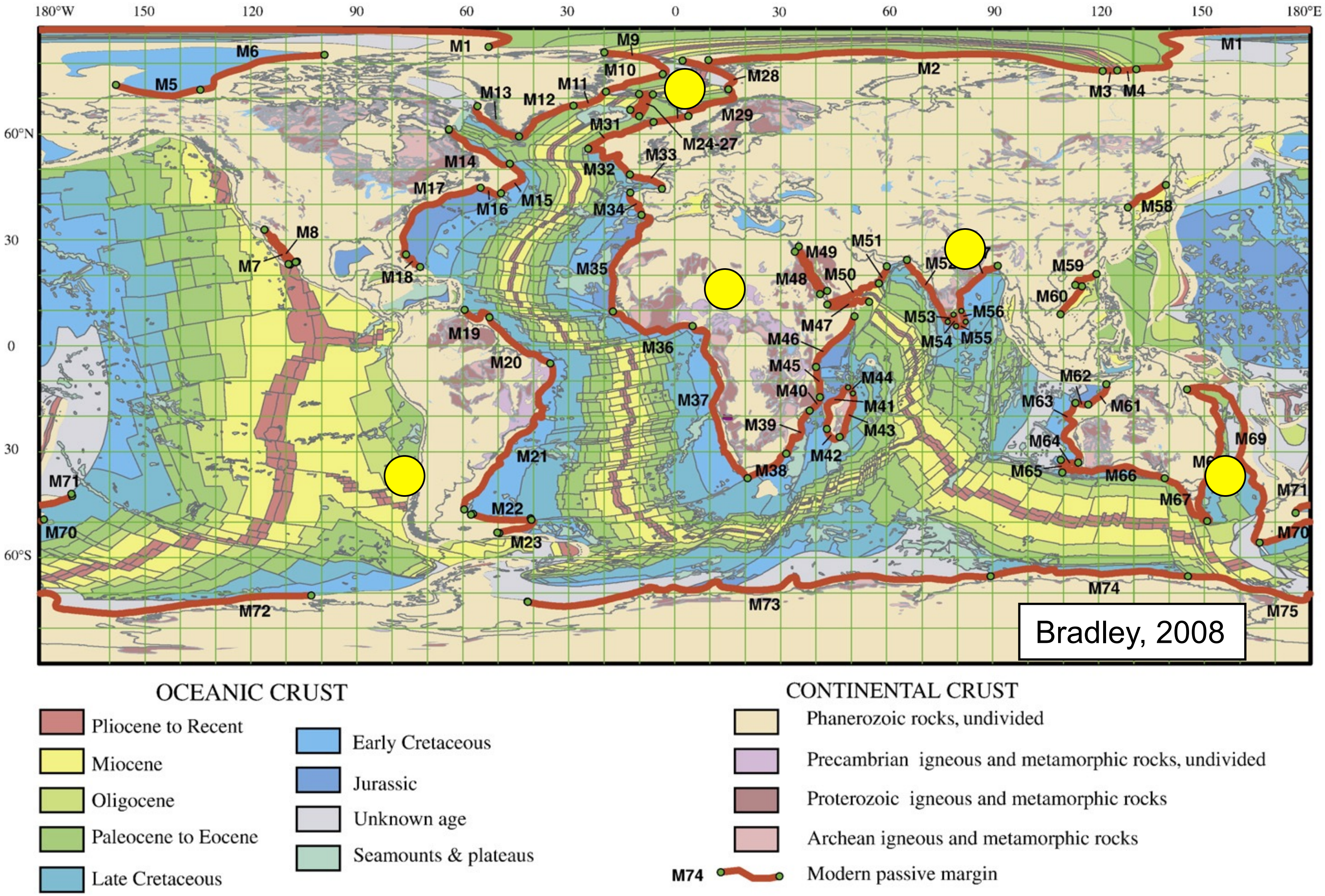
Paul Mann, Suzanne Baldwin, Paul Fitzgerald, Geoff Abers, Jim Gaherty, Laura Wallace, Guy Fitz, Nathan Daczko and others



Outline:

1. Classifying the Woodlark rift
2. Important rift processes expressed by WR
3. Implementating a research plan.

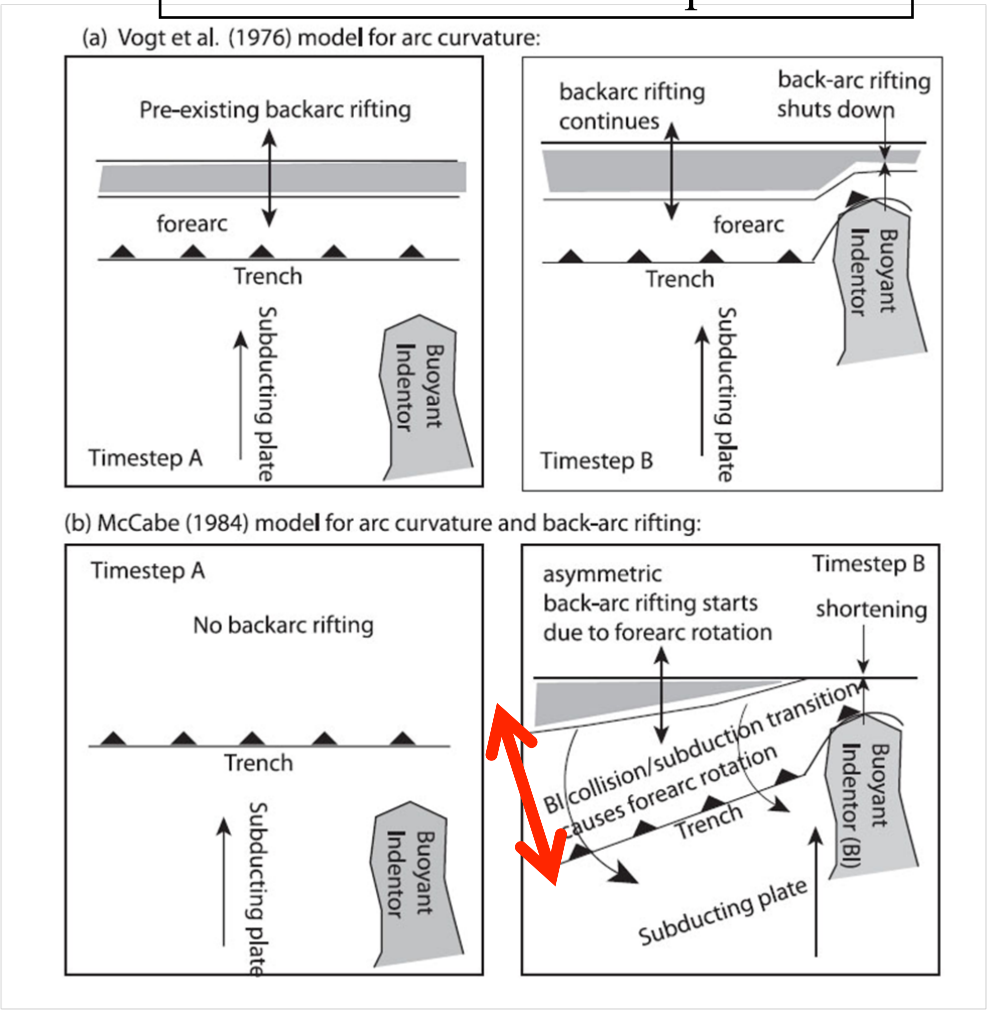
"Dead rifts" front major ocean basins and are deeply buried by 75 modern passive margins (brown lines); intracratonic rifts are either failed rifts (aulacogens) or very slowly evolving (>10 my) and can lack clear driving tectonic forces

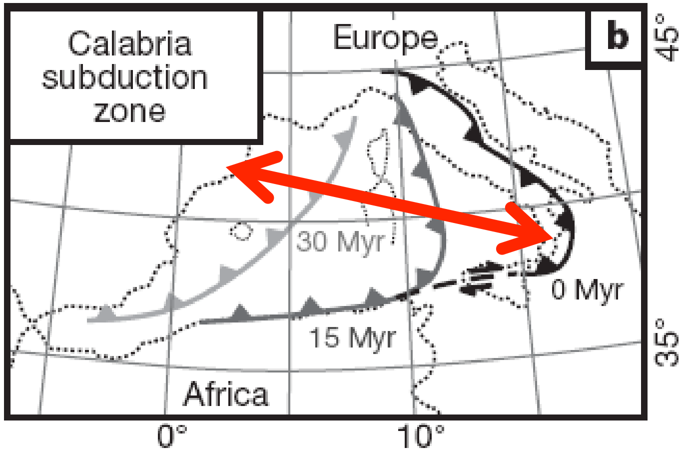


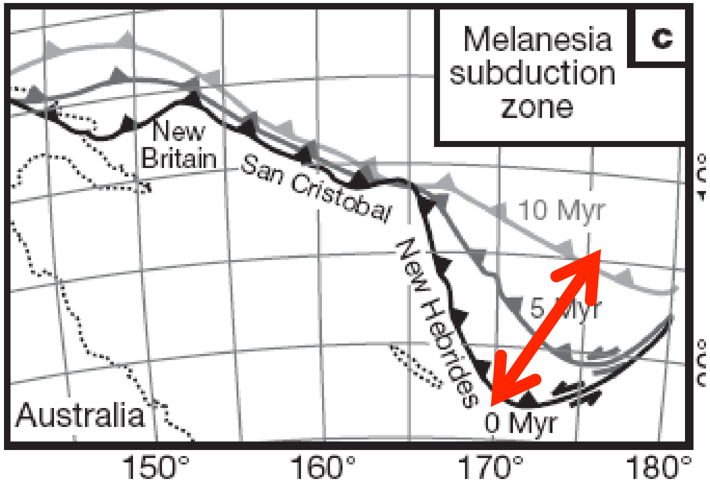
Rifts forming today on active plate margins at fast rates form by 3 processes: ***indent-related***, ***rollback-related***, or ***strike-slip-related***. All three types are more accessible than "dead rifts" beneath passive margins and evolve at faster plate boundary rates than intracratonic rifts

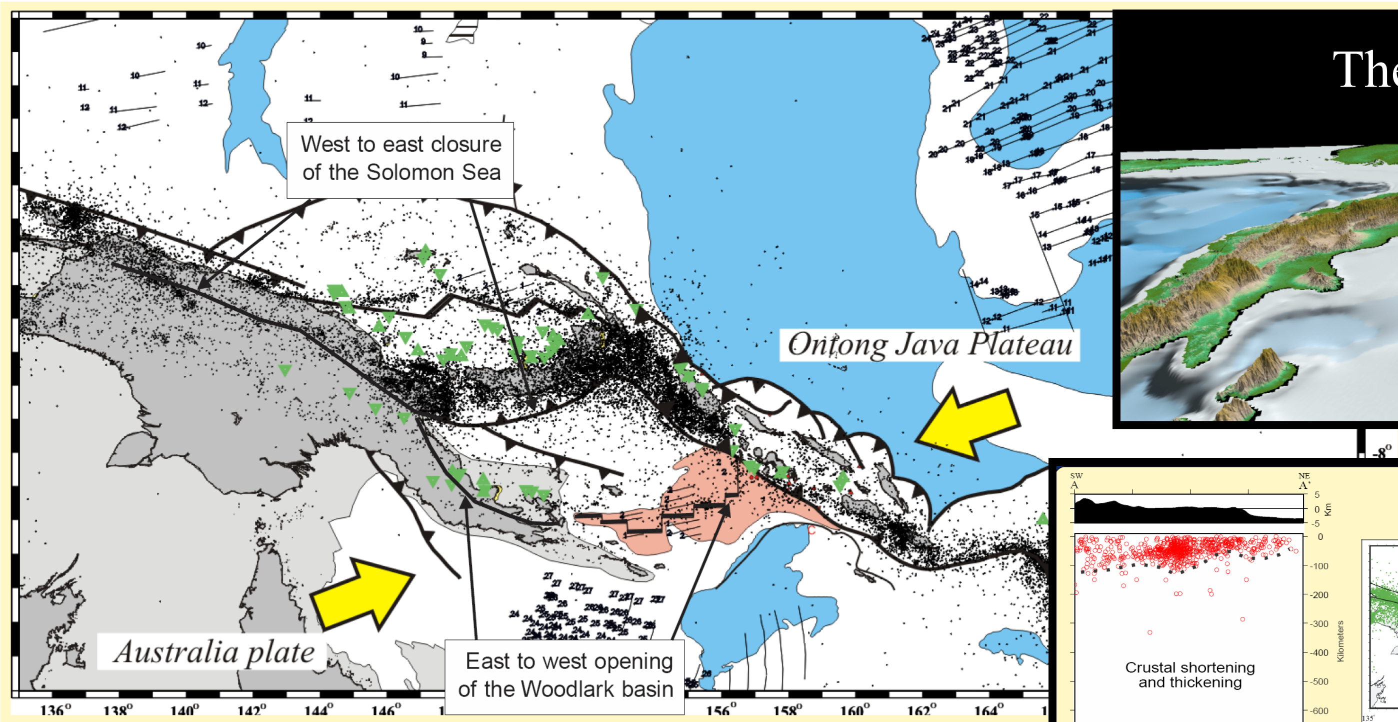
Laura Wallace papers:
crustal-driven indent process

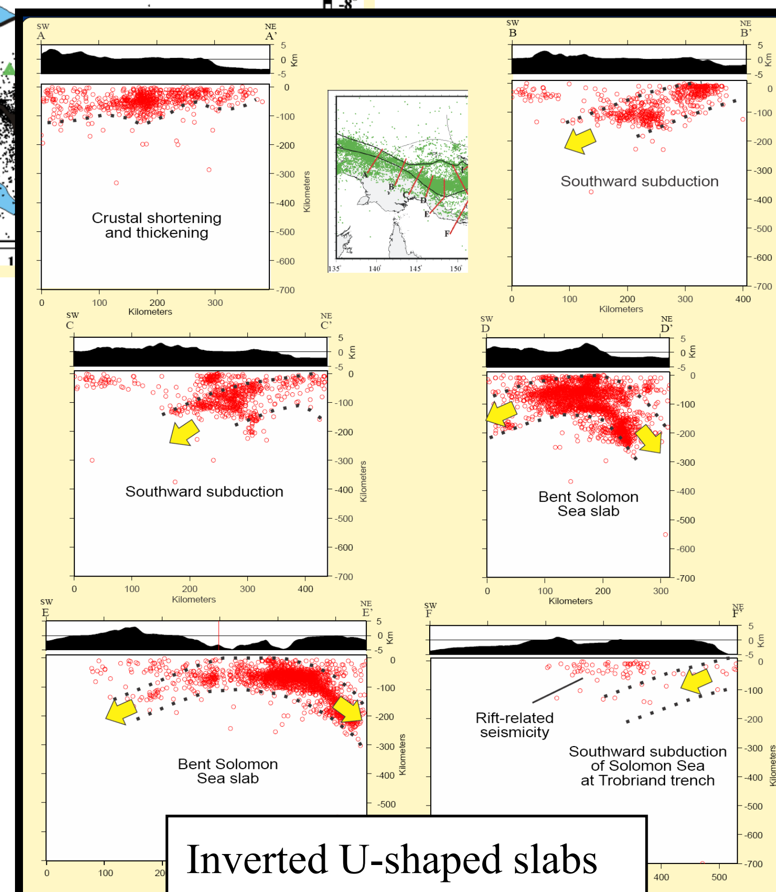
W.P. Schellart papers:
mantle-based process





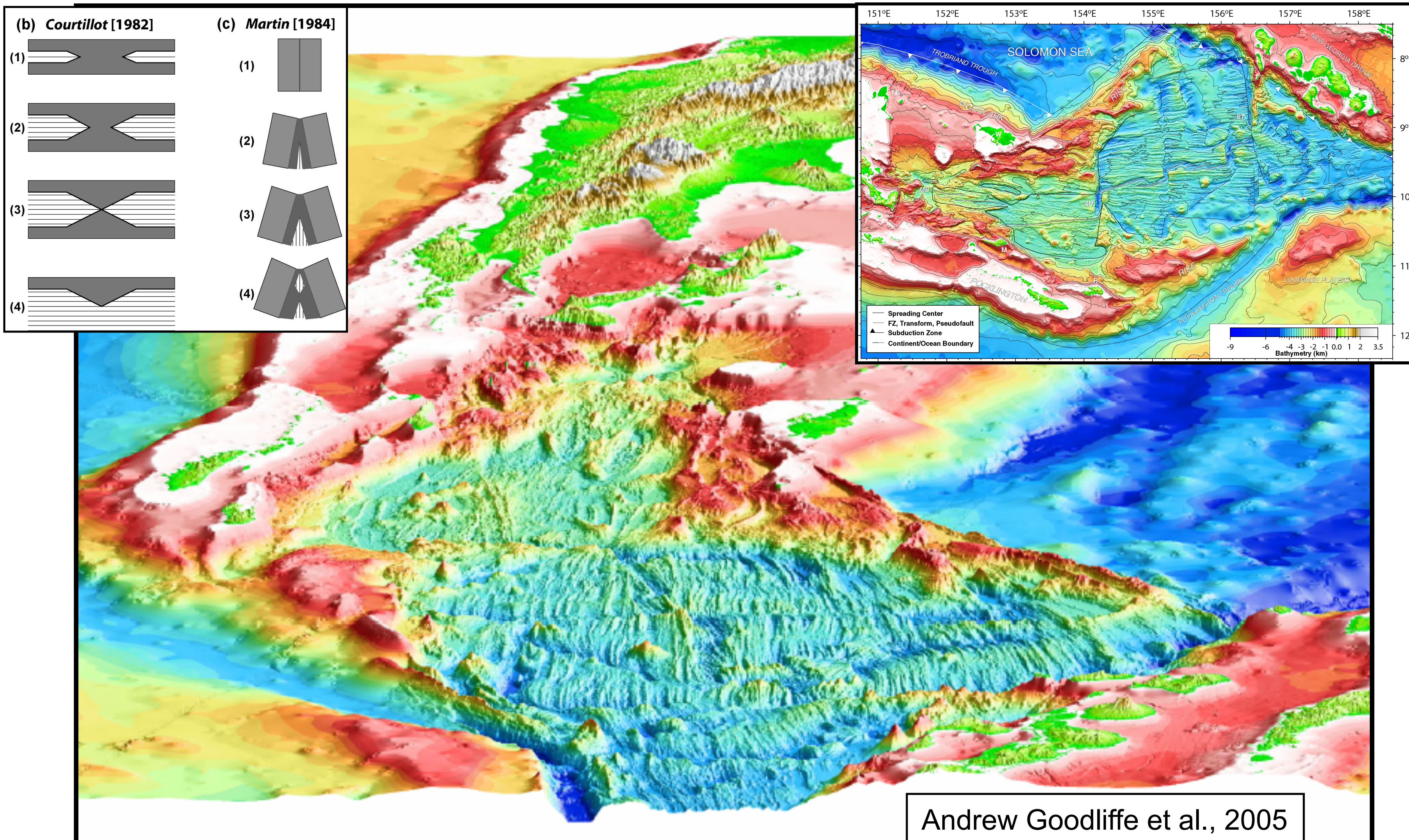






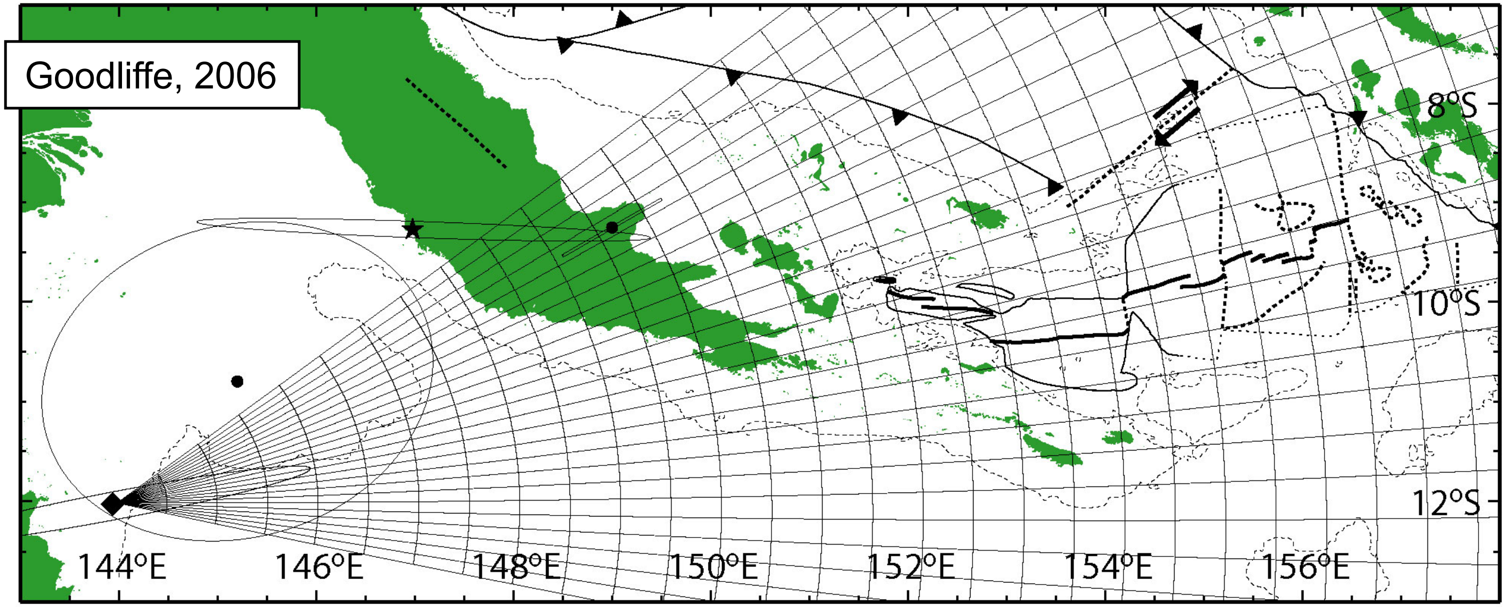
Rifting in Papua New Guinea area is either indent or rollback-related and very rapidly evolving (Australia began colliding with PNG about 30 Ma – middle Oligocene; OJP convergence and Woodlark basin started ~6 Ma, rate of westward propagation of rift tip is 140 km/my.

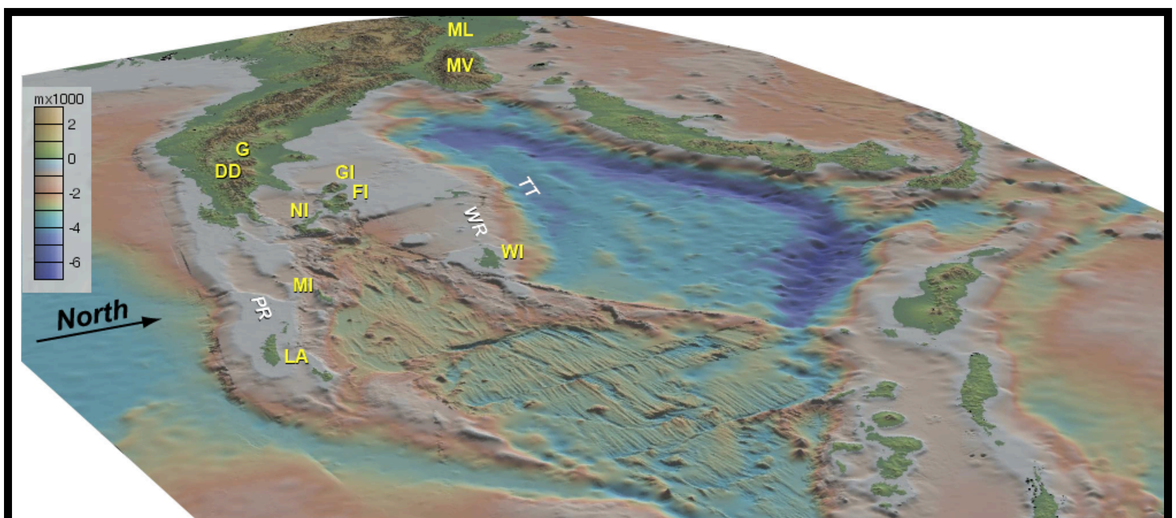
Active oceanic spreading centers propagating into continents are rare and present valuable analogs to the larger ocean basins because of their, diachronous time-space progression: Woodlark, Lena, Afar



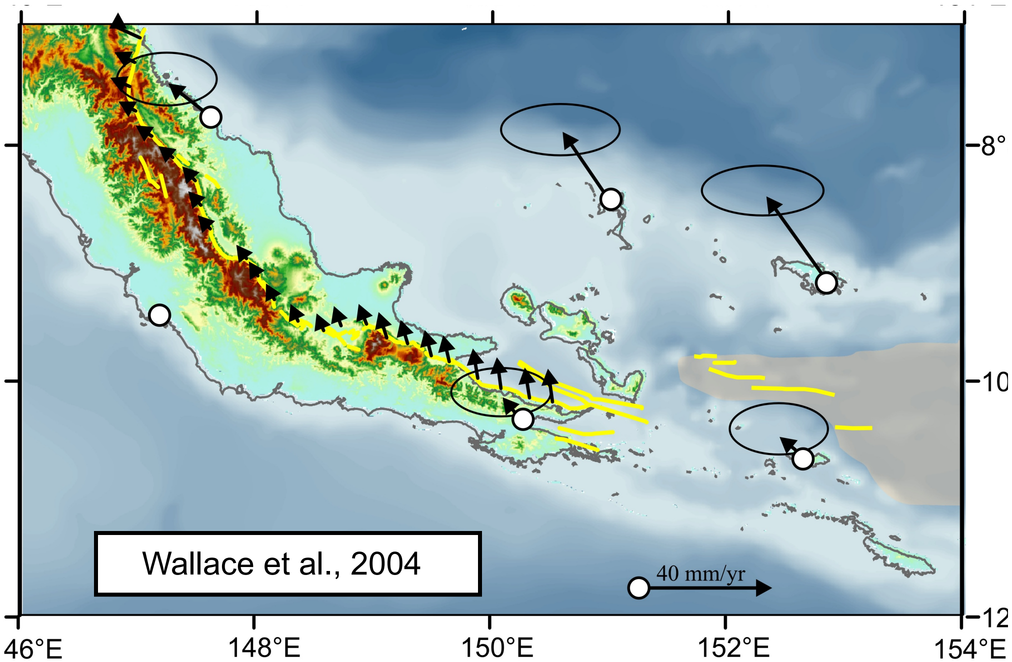
Andrew Goodliffe et al., 2005

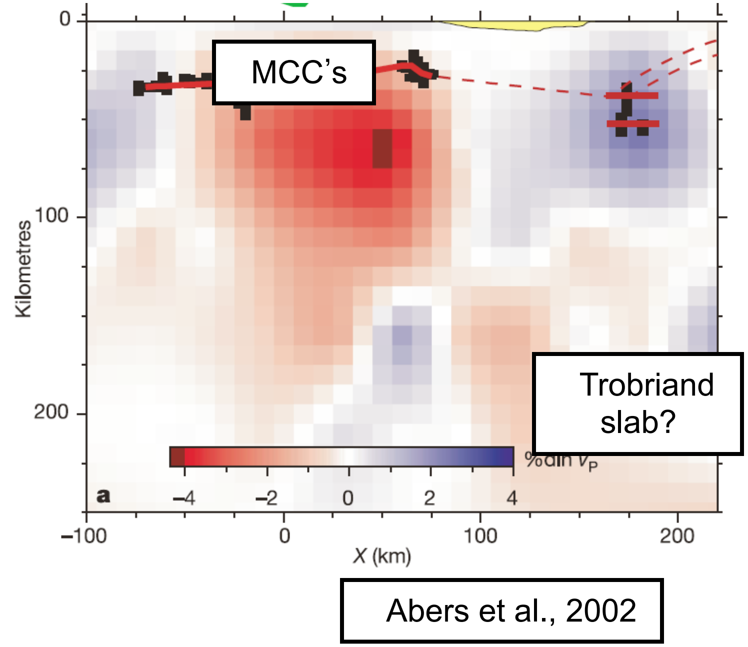
Discrepancy of oceanic spreading vs. continental extension about the pole of opening: where is it taken up? MCC's? Lower crust? Other unknown processes?

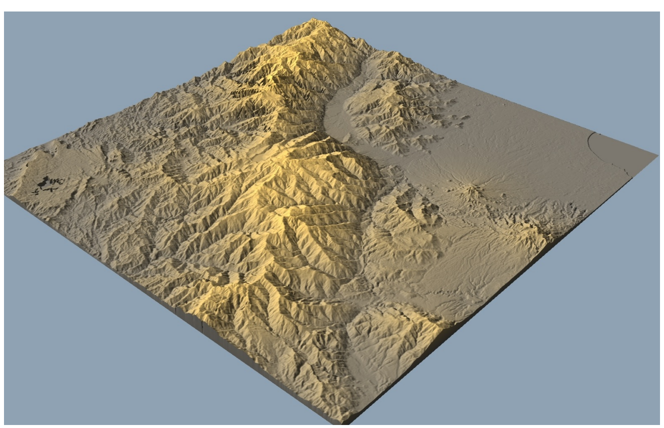


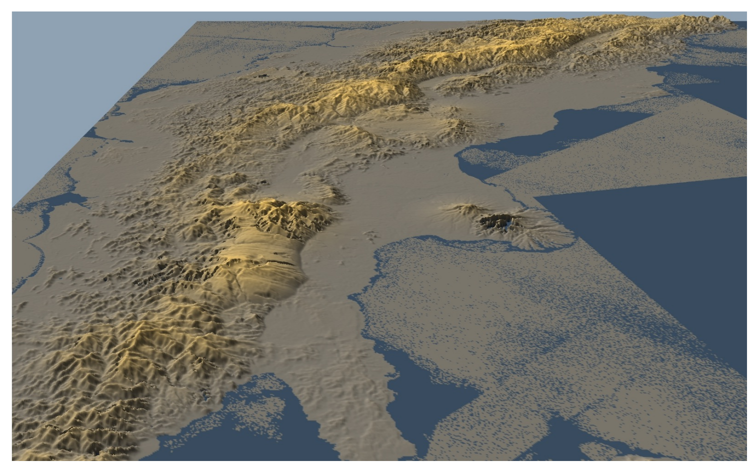


“Forcing parameters” of active plate boundary rifts can be inferred from GPS measurements (crustal) or tomography (mantle). Studies that show links between deformation and magmatism require combining data types from all depths.

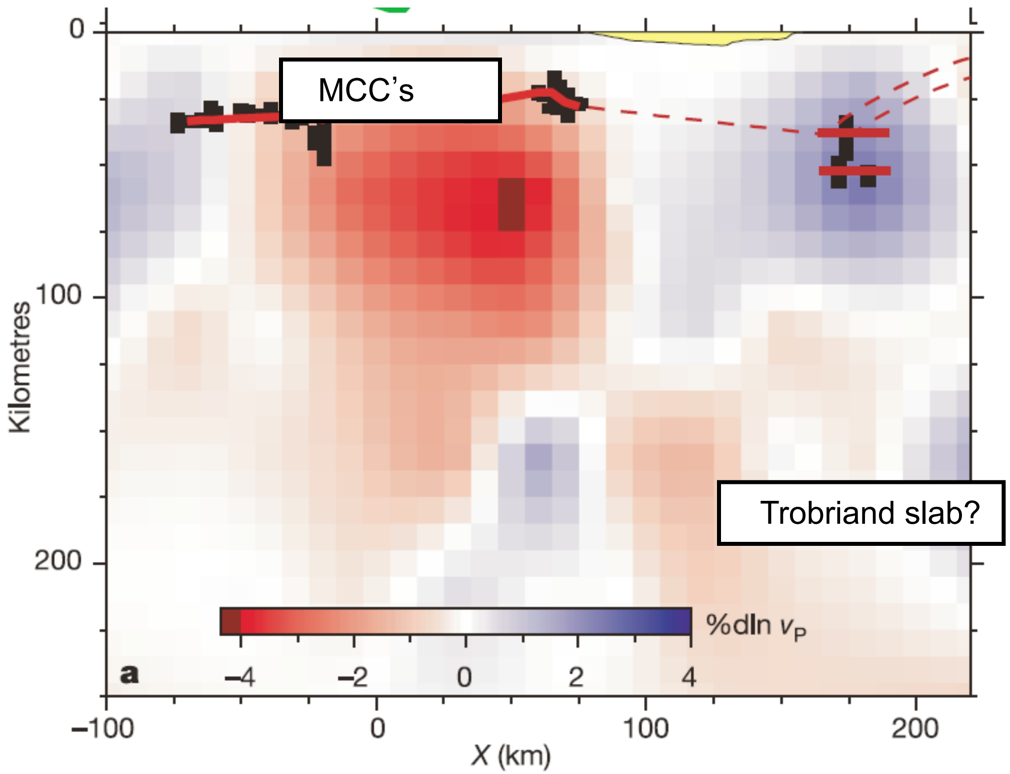




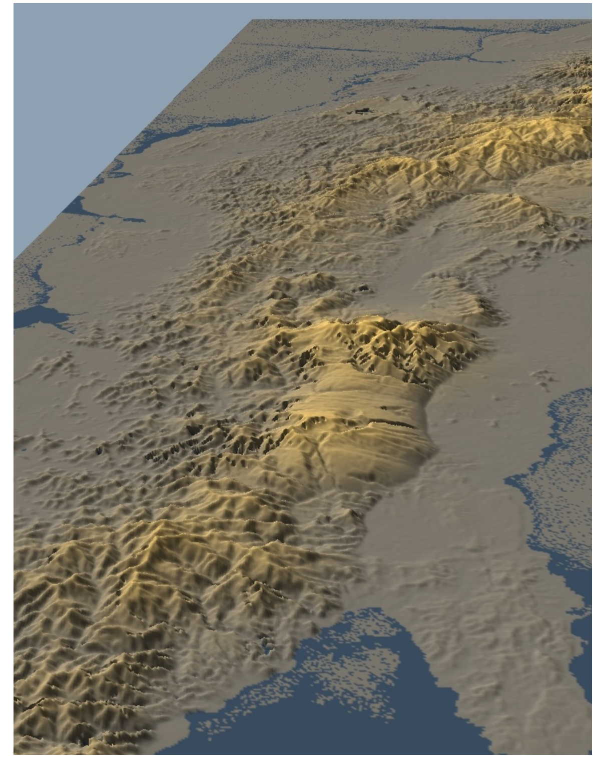




"Few examples of low-angle detachments associated with continental breakup have been described".
Luc Lavier quoting ??.

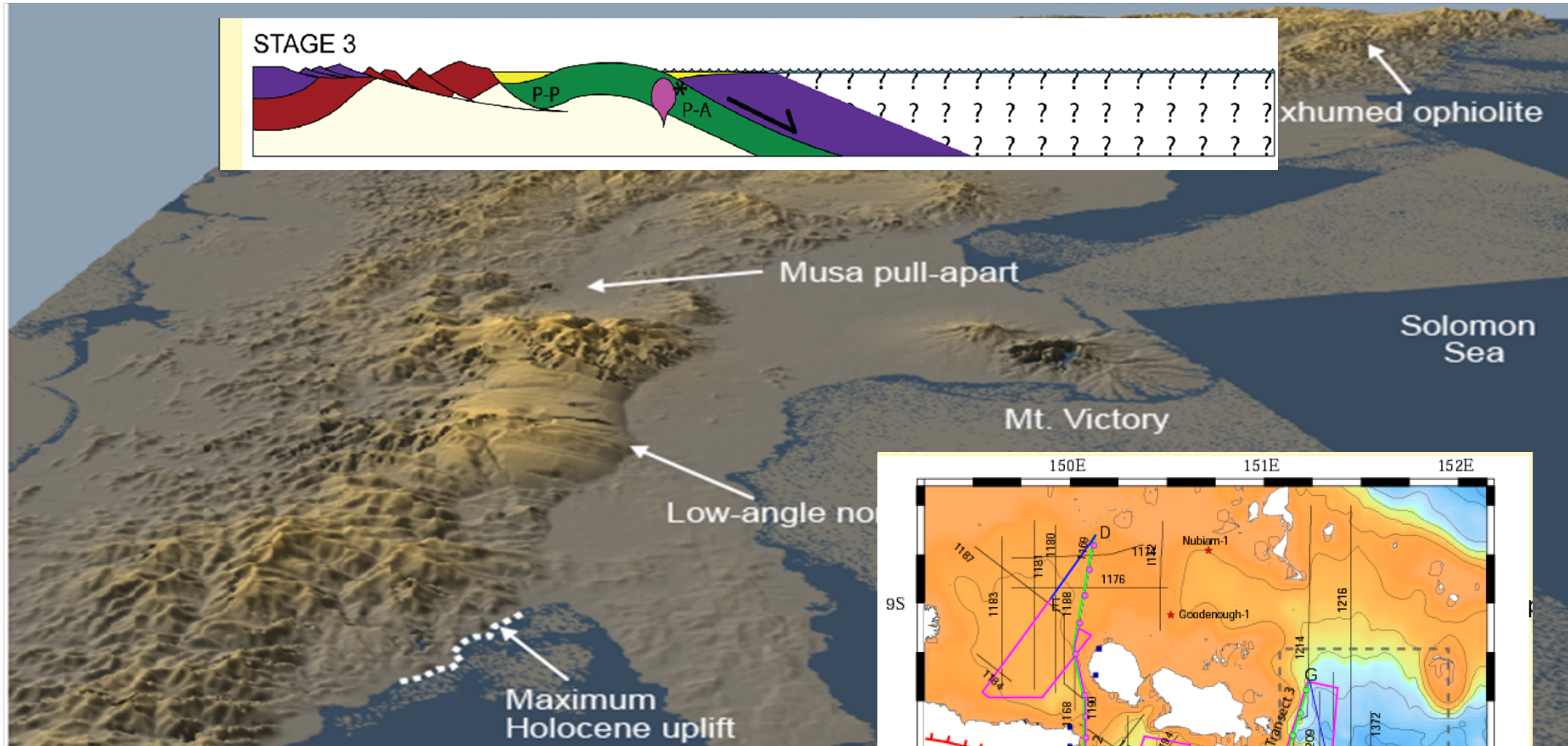


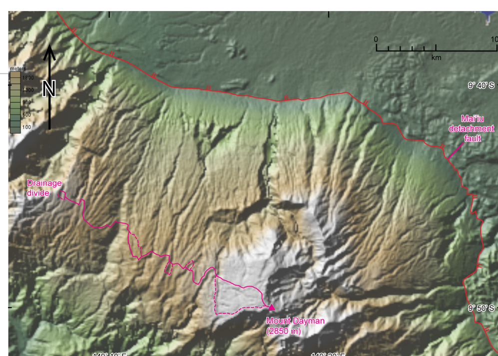
Abers et al., 2002

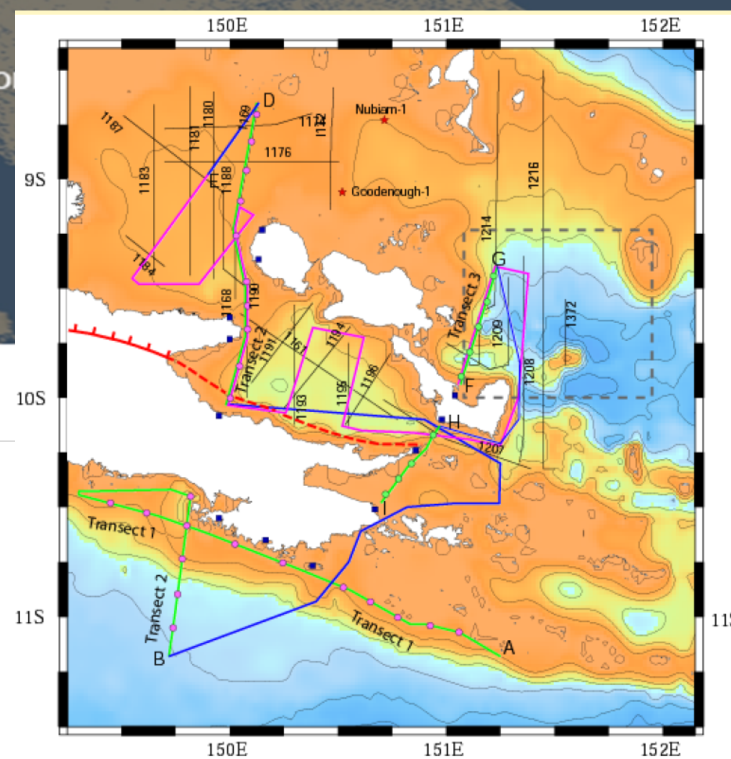


Daczko et al, in press

What controls locations of rifts?
Sites of former arcs or collisional zones? Inherited thrust surfaces?

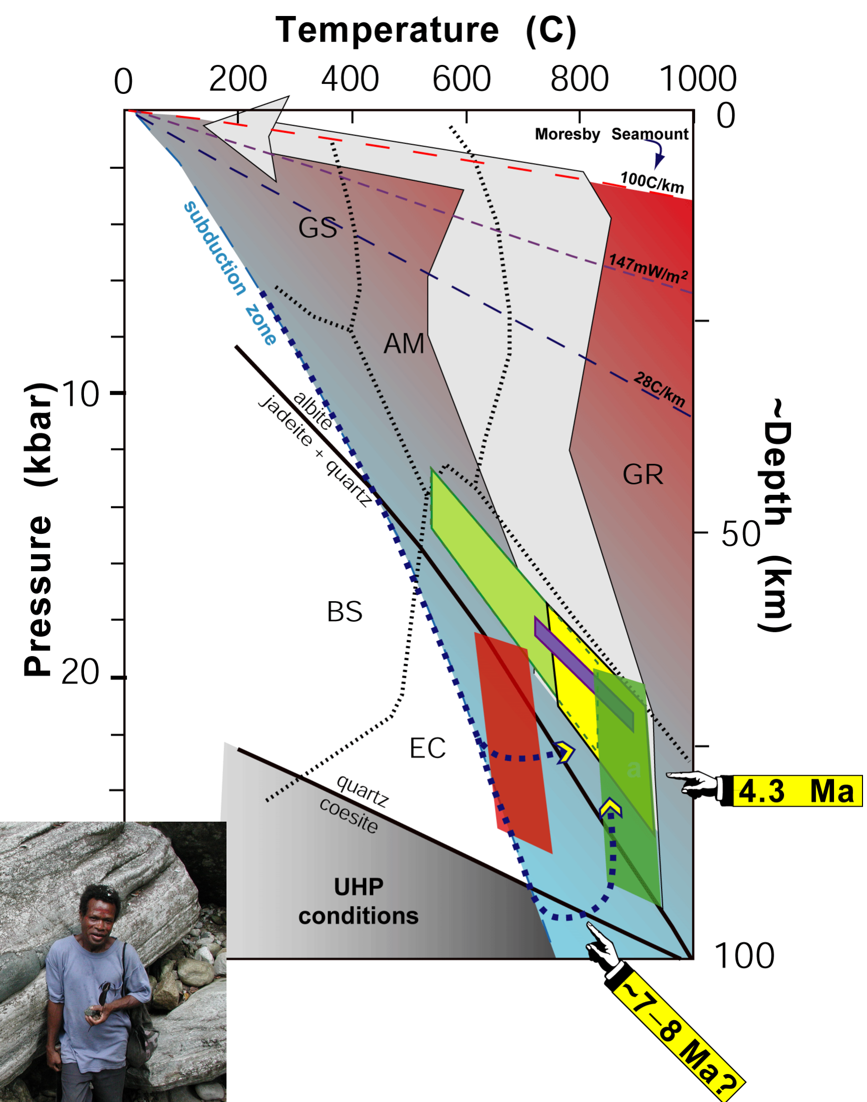




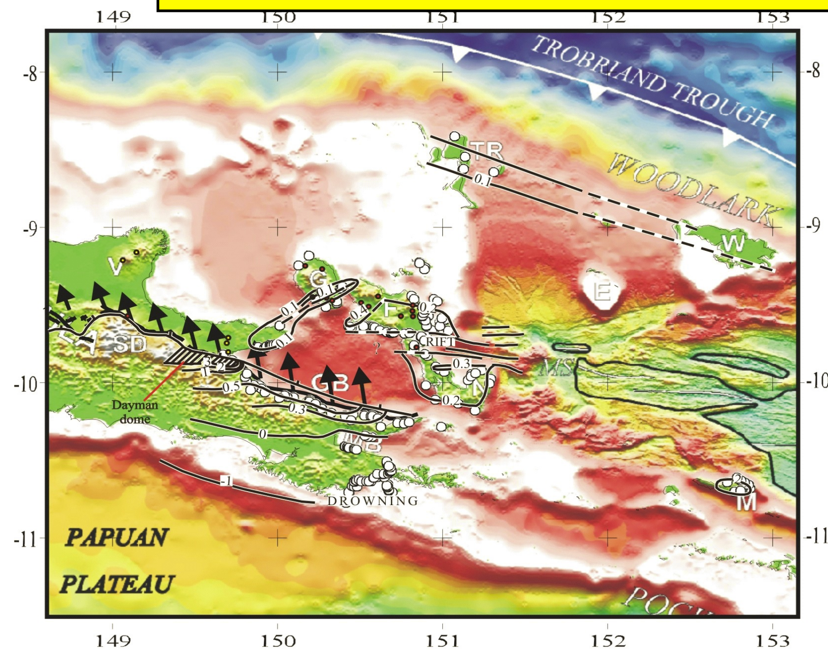


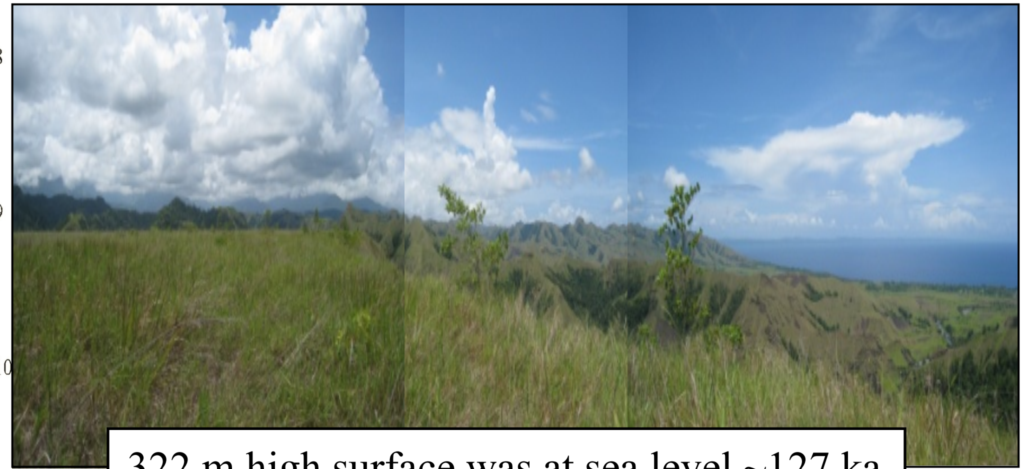
Fast rates from basement rocks: Ferguson MCC uplifting at average rate of 12-17 mm/yr

- **(U)HP rocks have been exhumed from beneath km-scale shear zones at plate tectonic rates (> 1 cm/yr)**
- Average minimum vertical exhumation rates (~12-17 mm/yr)
- 25-51 mm/yr assuming exhumation from beneath 20-30° NNE dipping shear zones
- Compare with:
- 25-40 mm/yr extension rates near rift tip (Abers, 2001)
- 12-40 mm/yr half-spreading rates from magnetic anomalies (Benes et al., 1994) and GPS crustal motion studies (Tregoning et al., 1998)

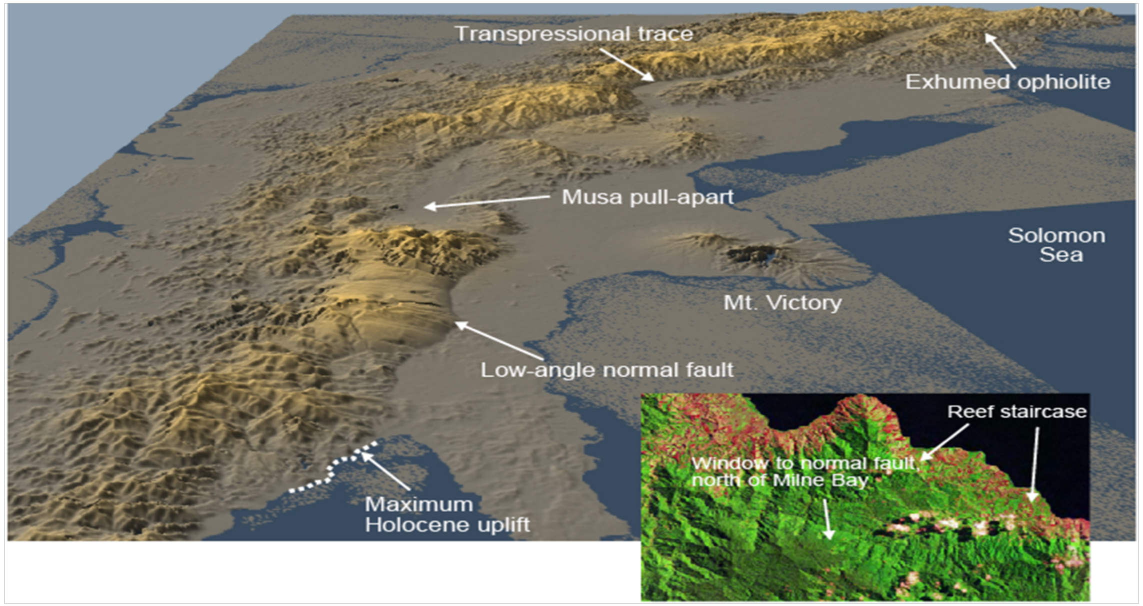


Fast rates from coral reefs: OSFZ footwall block uplifting at 4 mm/yr

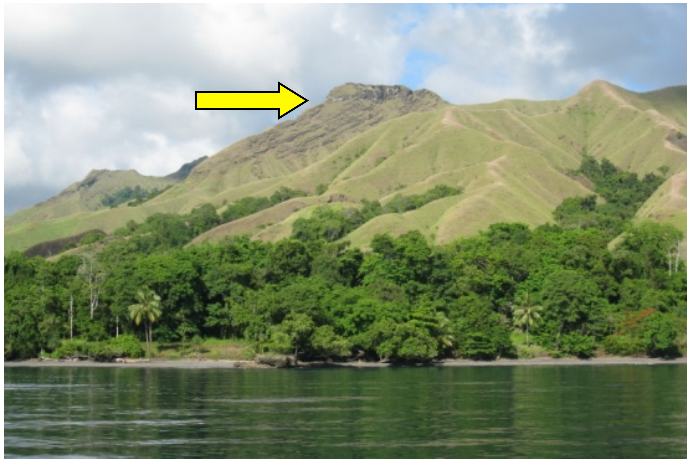




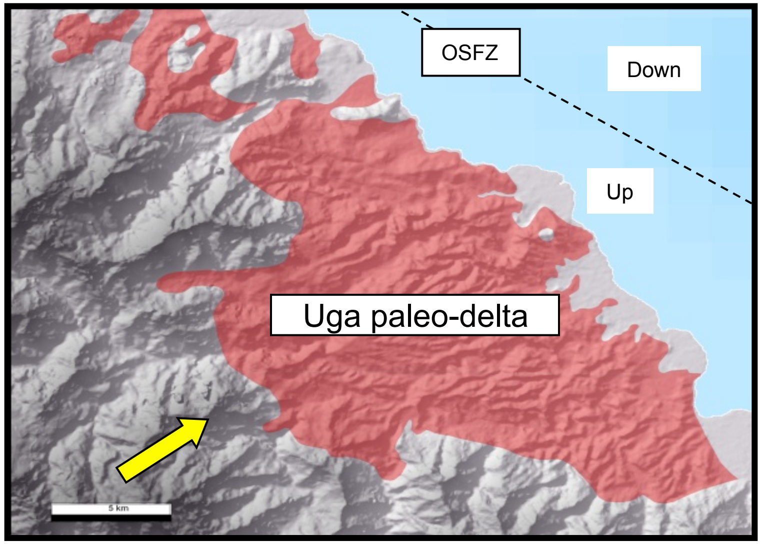
322 m high surface was at sea level ~127 ka



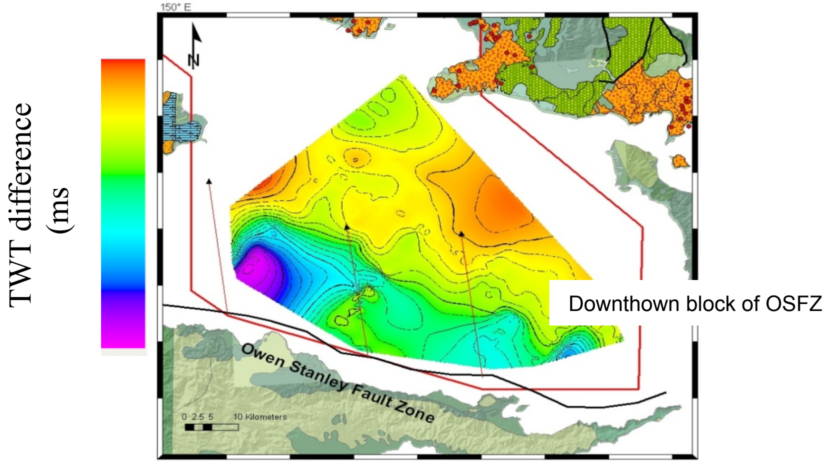
127 Ma coral unconformable on Folded, Pleistocene deltaic sediments

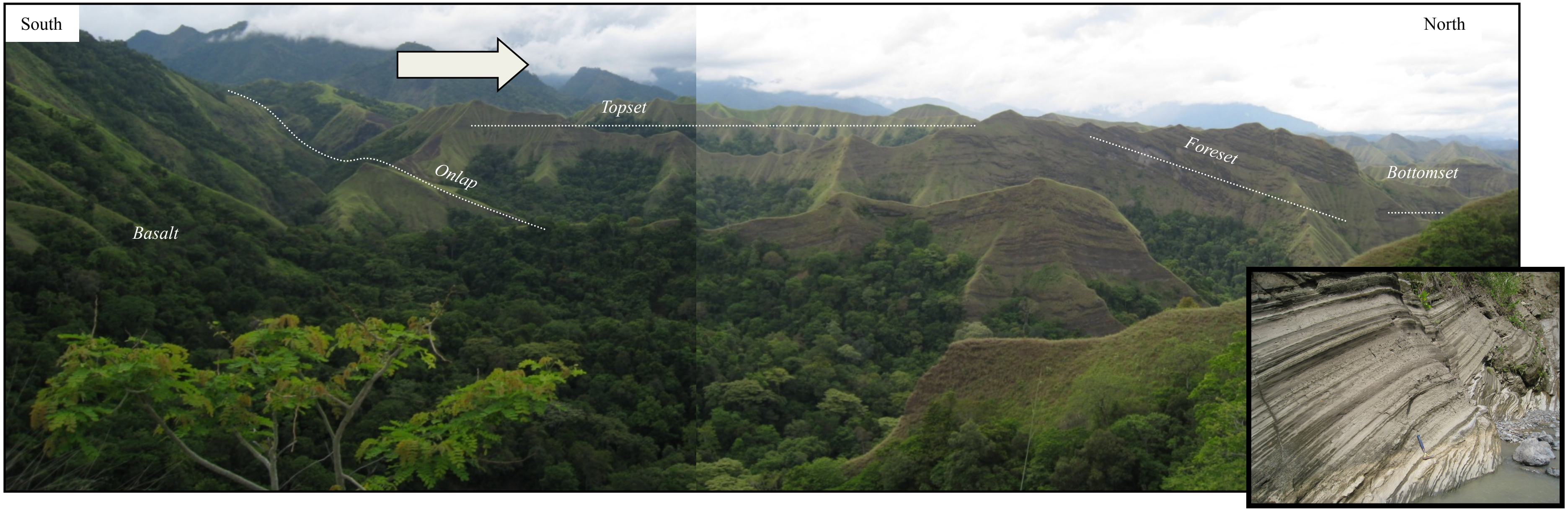


Sediment flux into the rift: Pliocene-Pleistocene Uga delta uplifted on footwall of Owen-Stanley normal fault; thick seen on seismic data on hanging wall block



Pliocene to Plio-Pleistocene Isochron map of Goodenough basin from Fitz, in prep.

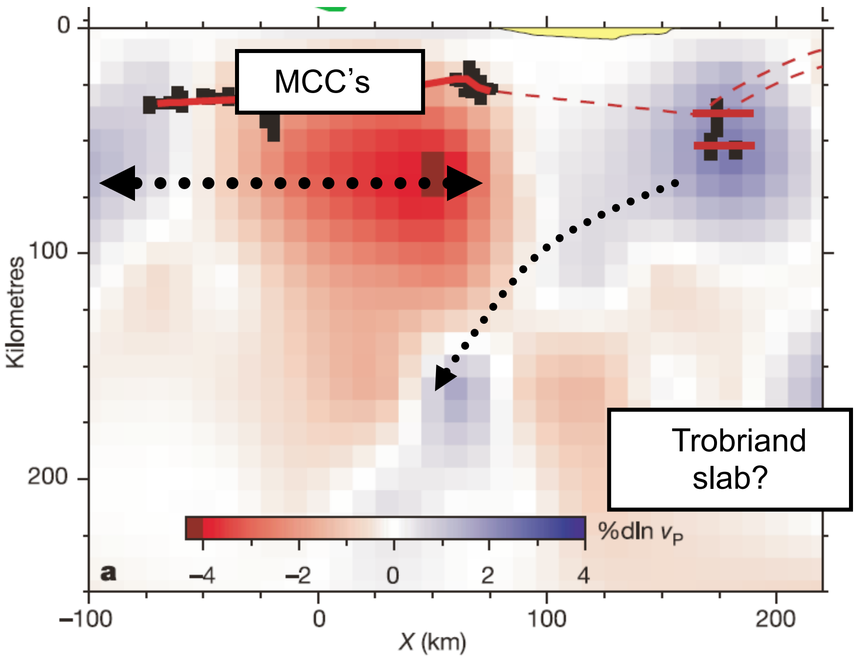




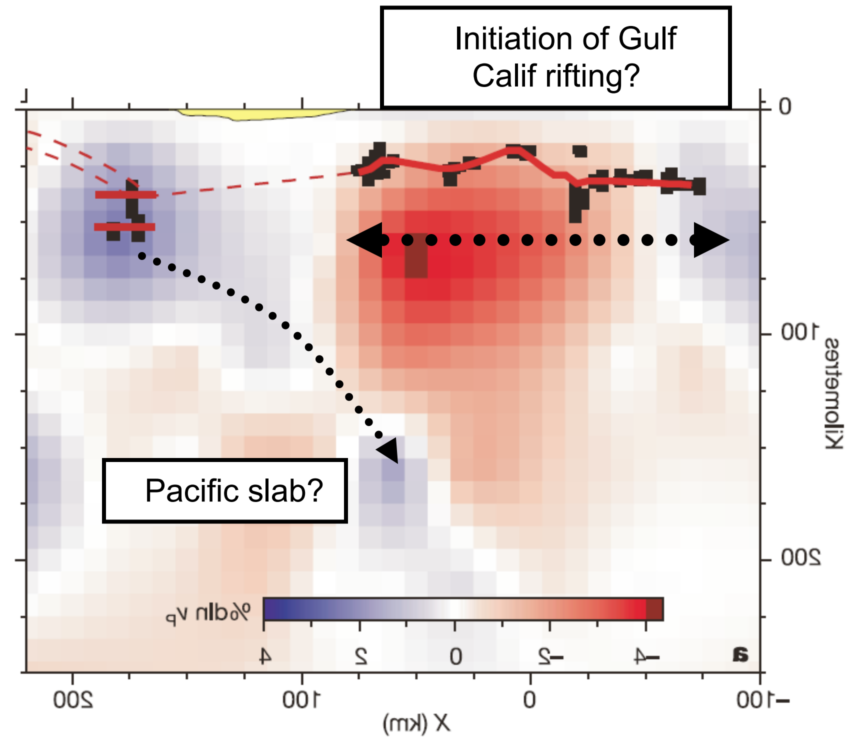
How is lower crust, mantle and deeply subducted slabs return to the surface during the rifting process? Is orogenic collapse triggered by rollback the answer?

Papua New Guinea

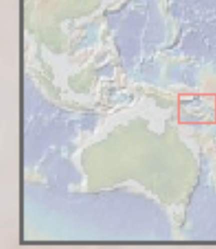
Baja-Gulf of California analog



Abers et al., 2002



Summary
Main points of Woodlark White Paper

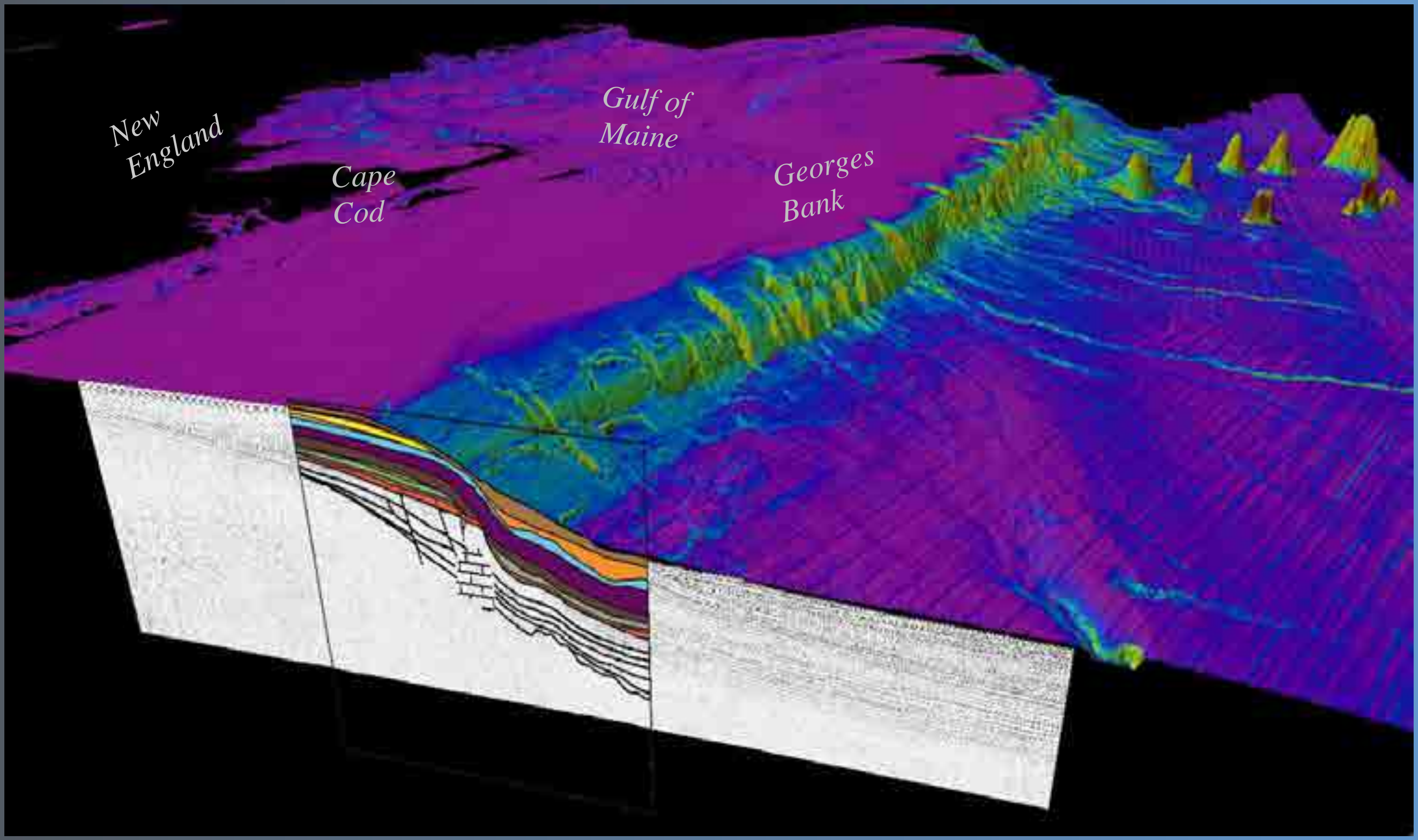


1. Indent, rollback and pull-apart rifts are good targets for systematic studies because they are shallowly buried in most cases, are actively evolving at fast rates, and have clear tectonic forcing functions.
2. Oceanic spreading centers like the WB diachronously propagating into continents are few in number and provide important analogs for understanding the origin of larger ocean basins.
3. Uplift rates of both shallow crustal and HP metamorphic rocks near the WB are extremely fast; one possible mechanism is a belt of mantle to crust extension induced by rollback of the Trobriand slab.
4. What are the processes responsible for the large discrepancy in extension amounts from the WL oceanic basin to adjacent continental crust?

US Atlantic Continental Margin

White Papers:

#7 - Gaherty et al. #9 – Hornbach et al. #12 – Olsen et al.



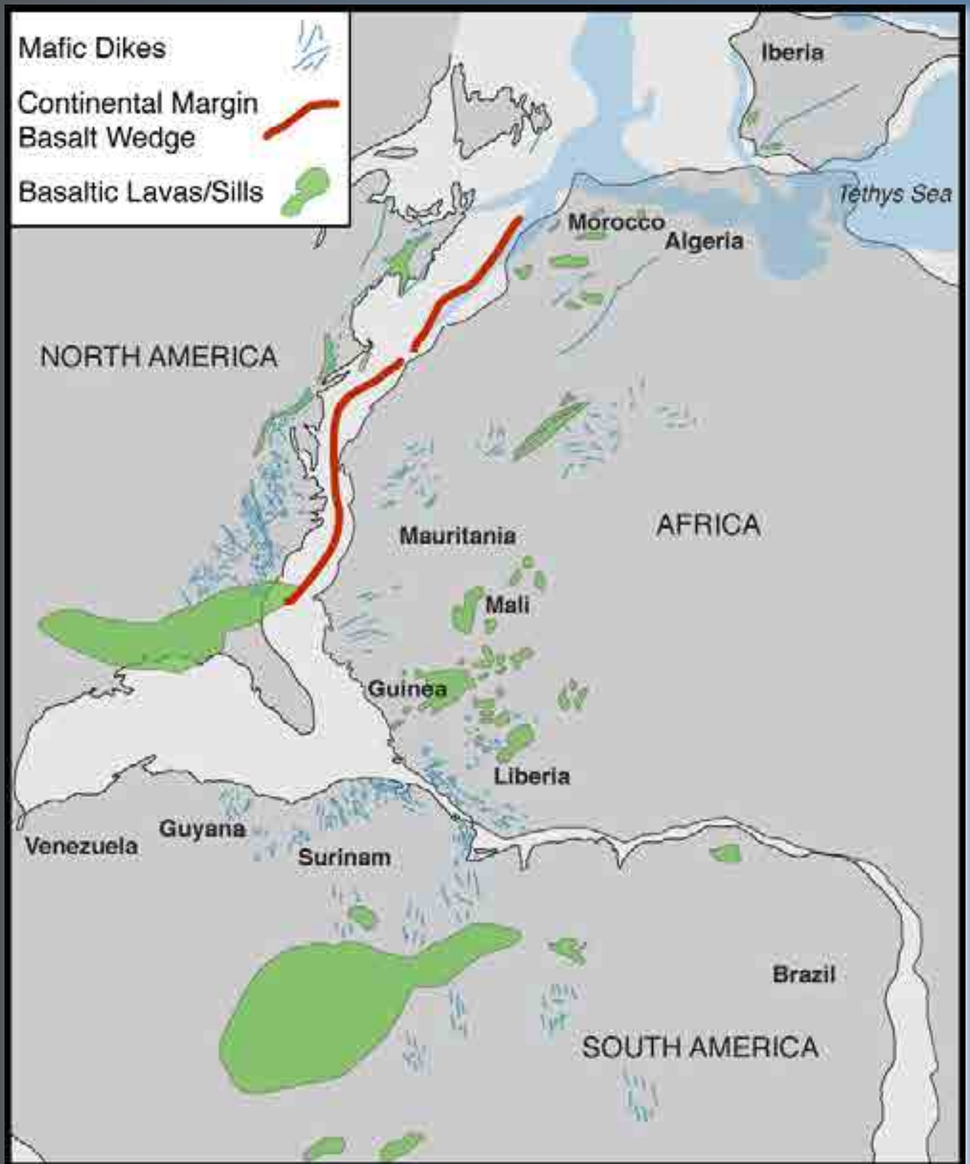
Outline

1. RIE Research Opportunities
   (rift --> breakup --> post-rift)
2. Groundwork and Logistics
3. Synergistic Opportunities

Rift Initiation and Evolution: Compelling Science at a Drifting Margin

1. Distribution of magmatism and deformation in the mantle lithosphere
2. 3D rift structure and segmentation
3. Nature of transitional crust
4. Relationship between failed rift basins and successfully rifted margin
5. Post-rift evolution and growth of a passive margin

Central Atlantic Magmatic Province (CAMP)



McHone (Tectonophysics, 2000)

Rifting began ~230 Ma

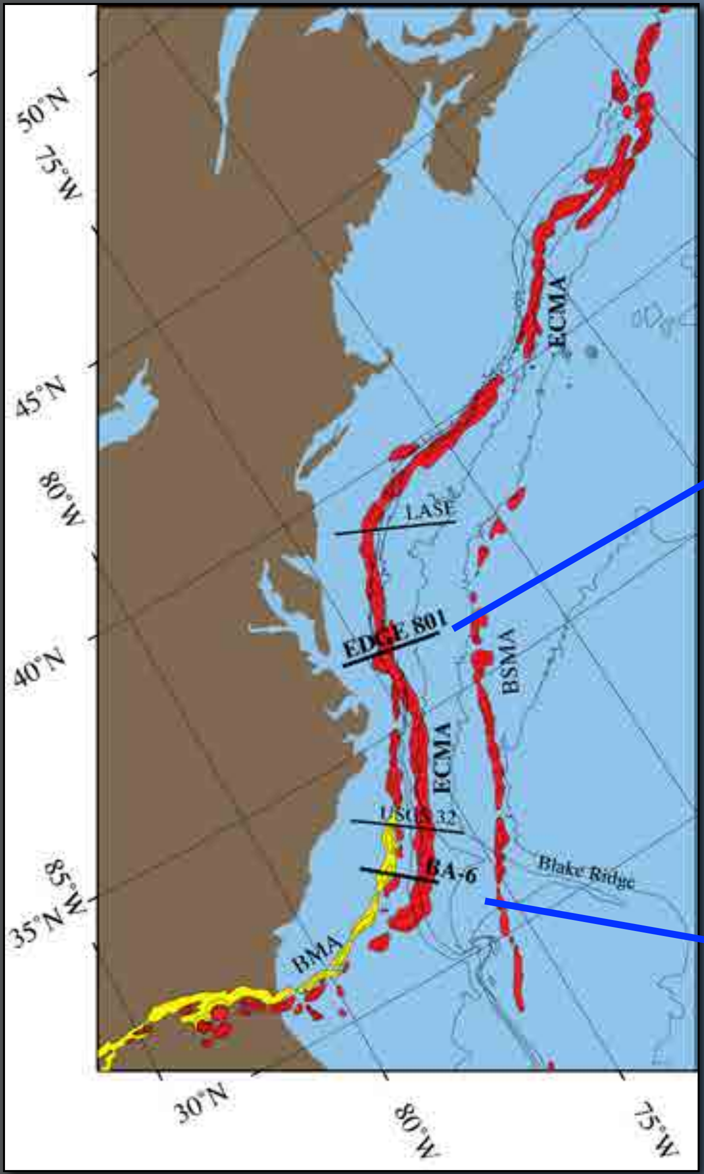
~200 Ma LIP emplaced --> Approximately coincident w/ breakup and mass extinction (end-Triassic)

Relationship between deformation, magmatism and syn-rift sedimentation onshore and offshore is poorly understood (failed versus successful rifting)

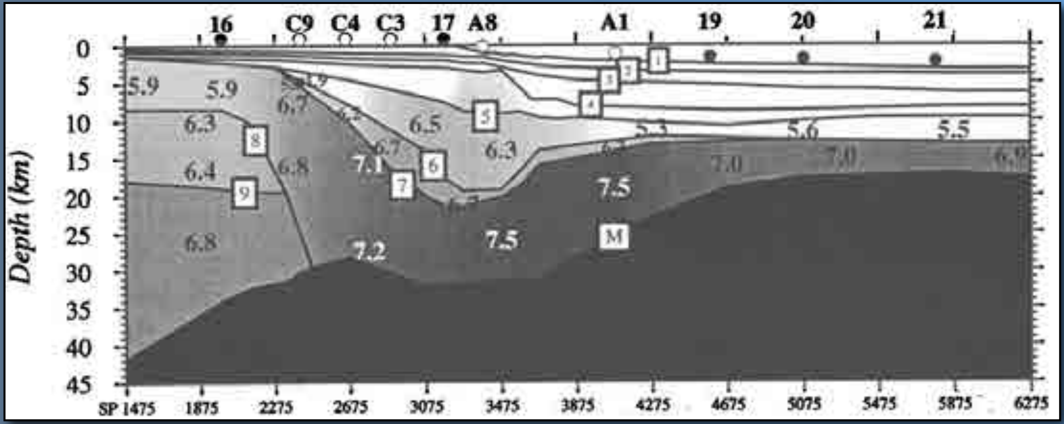
Unknown geodynamic source for magma

See white papers by Gaherty et al. and Olsen et al.

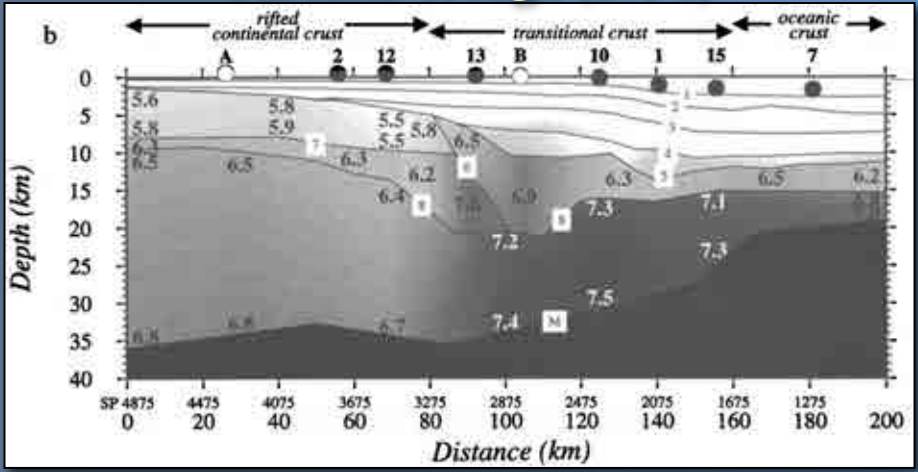
High lower crustal Vp – different melting regime than MOR



Mid-Atlantic (EDGE 801)



Carolina Trough (BA-6)

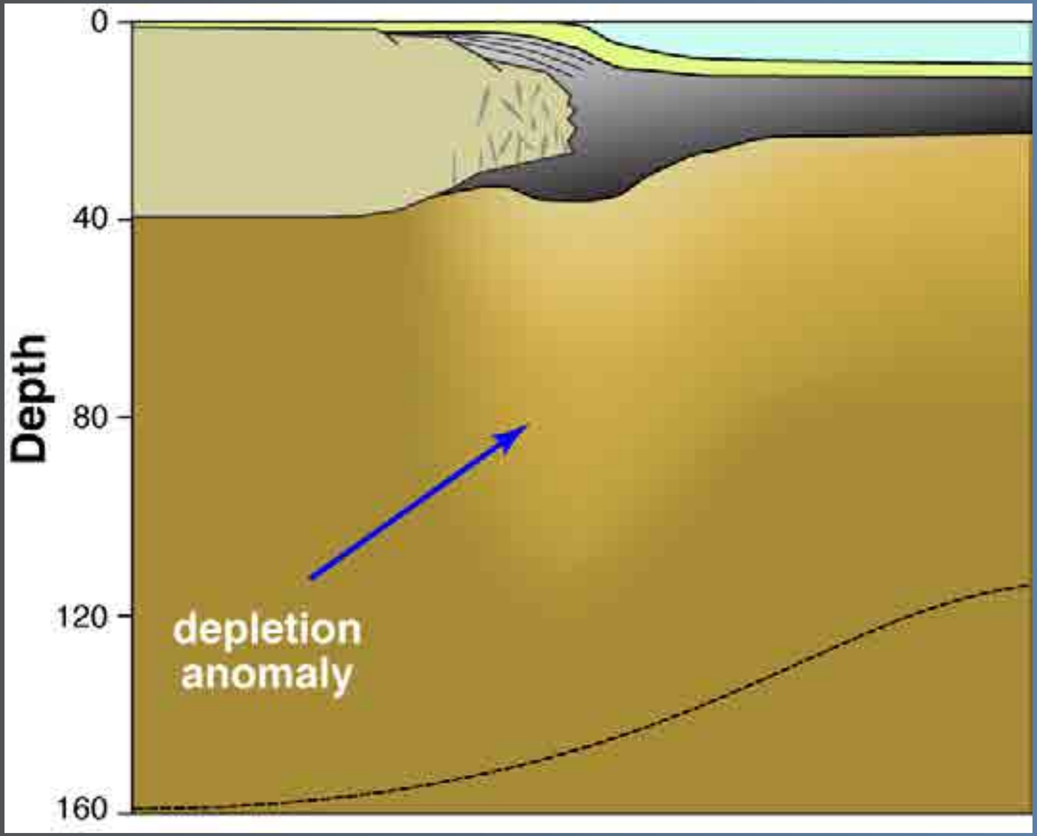


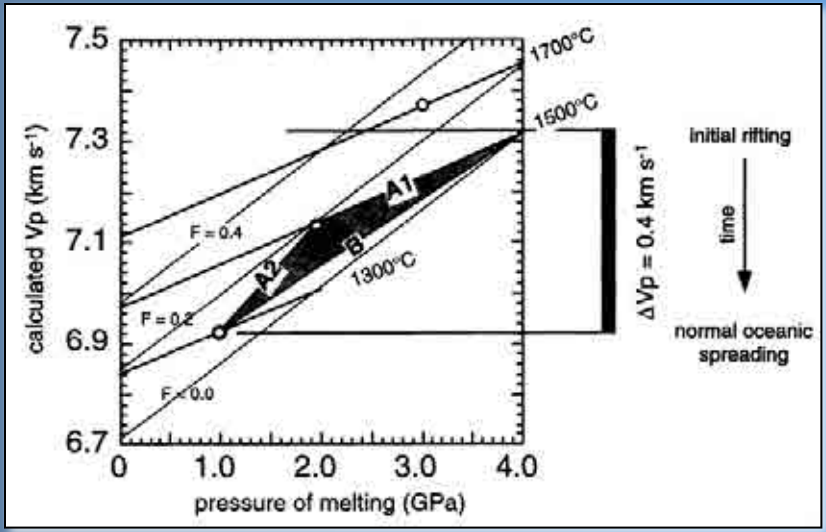
Holbrook et al. (JGR 1994a,b)

Need more constraints on the nature of transitional crust

High Vp > High pressure of melting > Depletion anomaly

New seismic imaging:
- Along-margin architecture
- Mantle source of melt



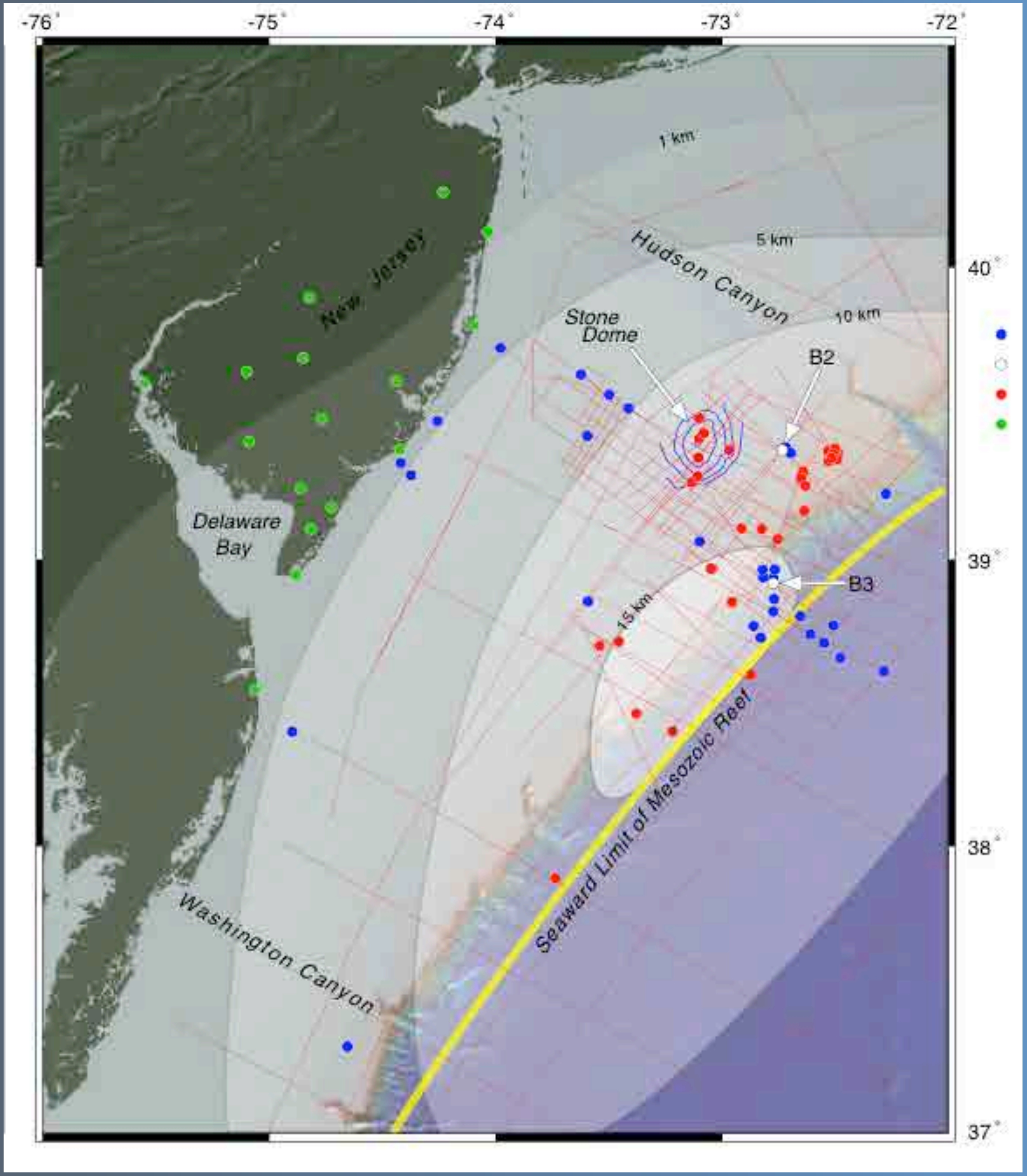


High velocities imply high average pressure of melting

This should leave behind a low density residue of melting that may stabilize the margin.

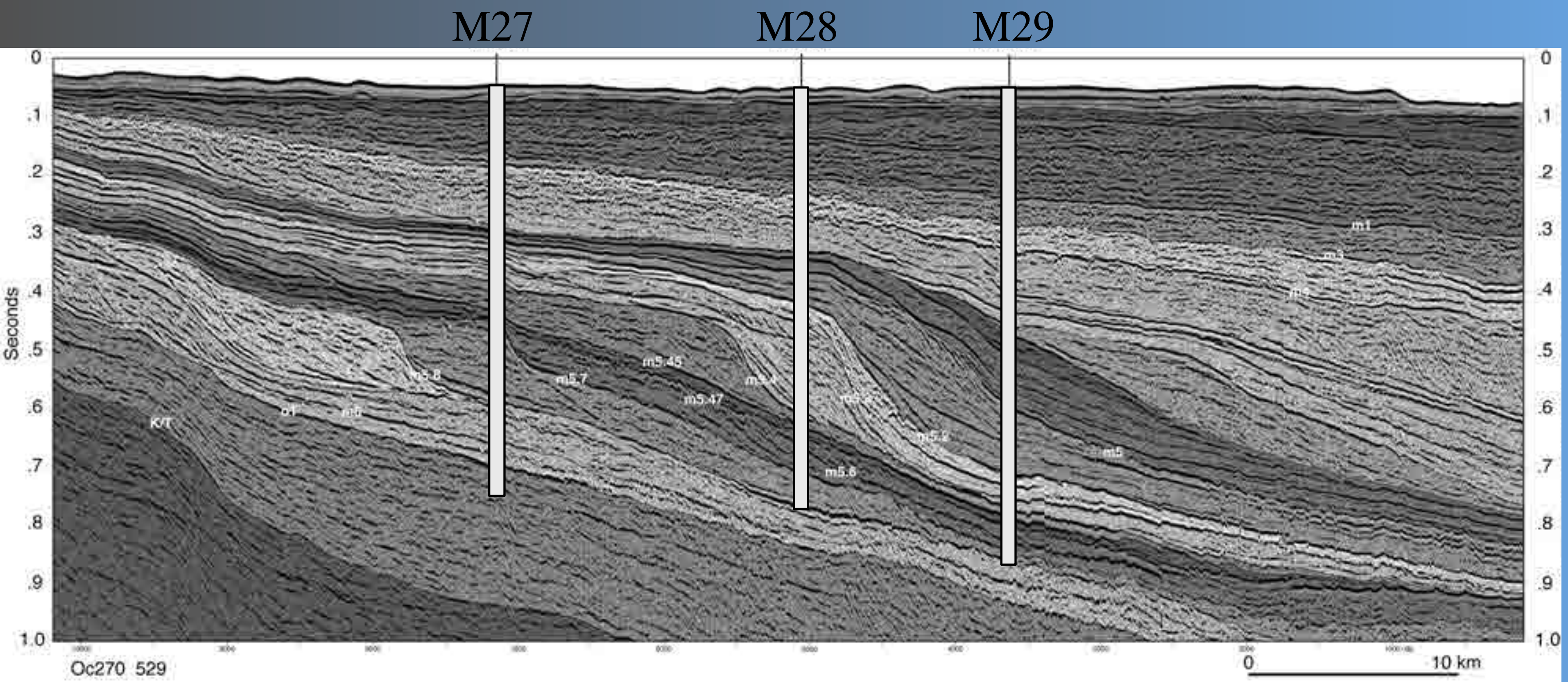
Kelemen and Holbrook (JGR 1994)

Post-rift Evolution



(Figure from Greg Mountain)

How has rift architecture and lithospheric evolution influenced post-rift sediment dispersal and accumulation?



(Figure from Greg Mountain)

3D complexity requires 3D imagery

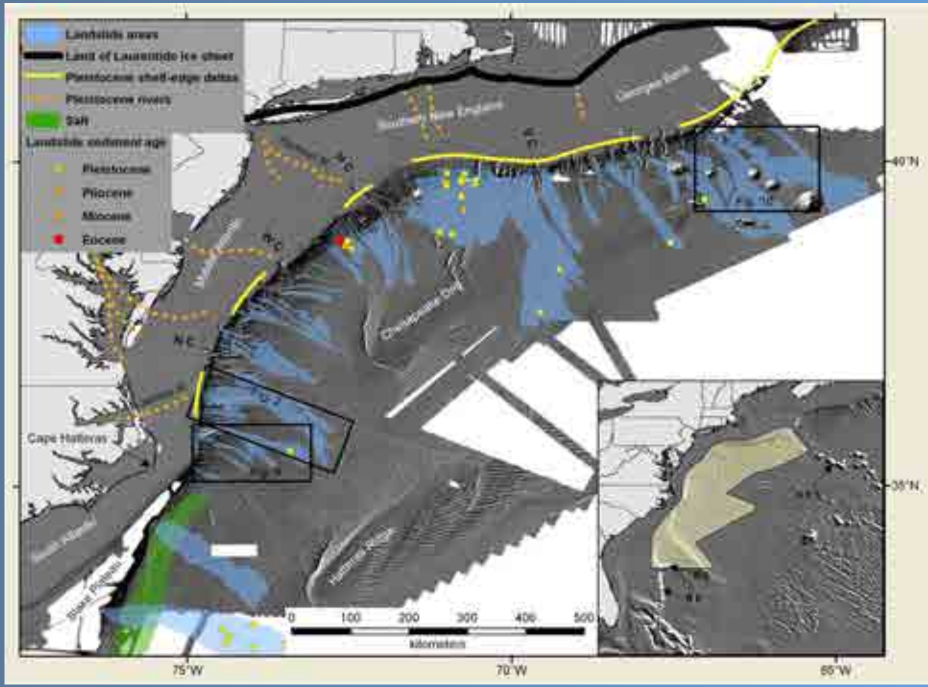
Surficial Processes:

How is today' s morphology influenced by early margin development ?

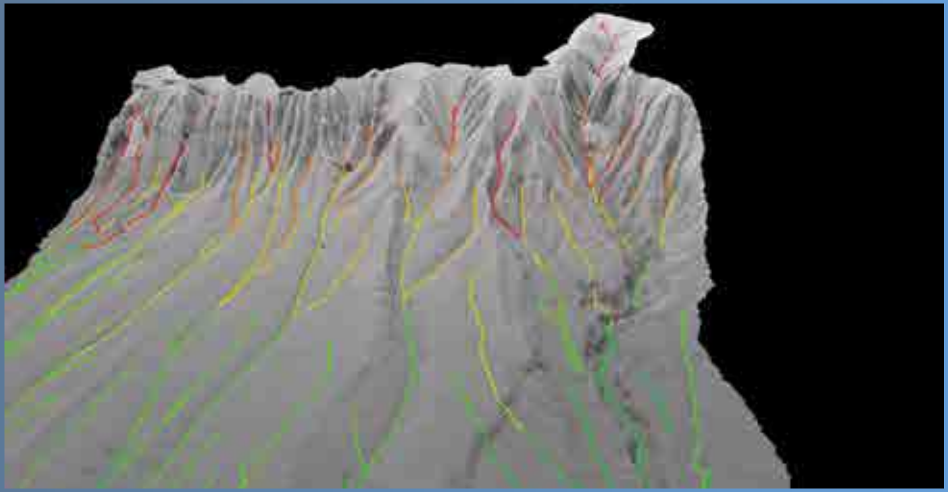
Quantitative geomorphology --> Sediment transport modeling, submarine Canyon formation, turbidity flows

Geohazards --> submarine landslides, slope stability, tsunamis, seismicity

(See white paper by Hornbach et al.)



Twichell et al., (2009)

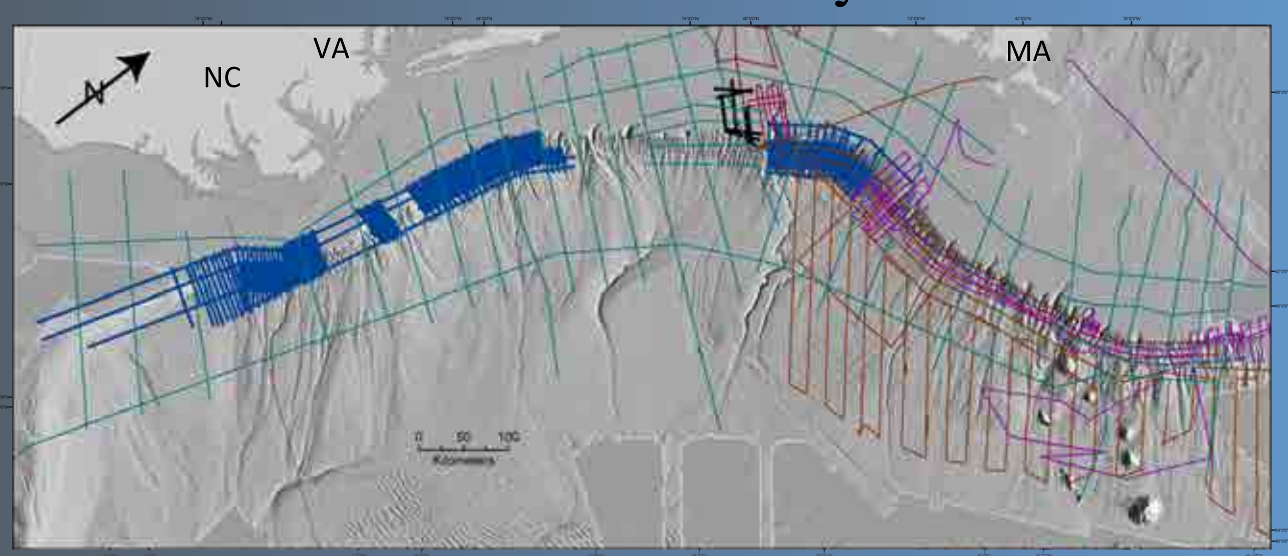


Groundwork and Logistical Considerations

Very heavily studied margin

- •Dozens of hydrocarbon wells, 1-dozen IODP wells, AMCOR wells, many others
- •10's of thousands of line-km of reconnaissance-grade seismic reflection data
- •Onshore seismic, well data, mapping
- •Opportunity to synthesize onshore and offshore data
- •Comprehensive potential field data

Need onshore/offshore synthesis



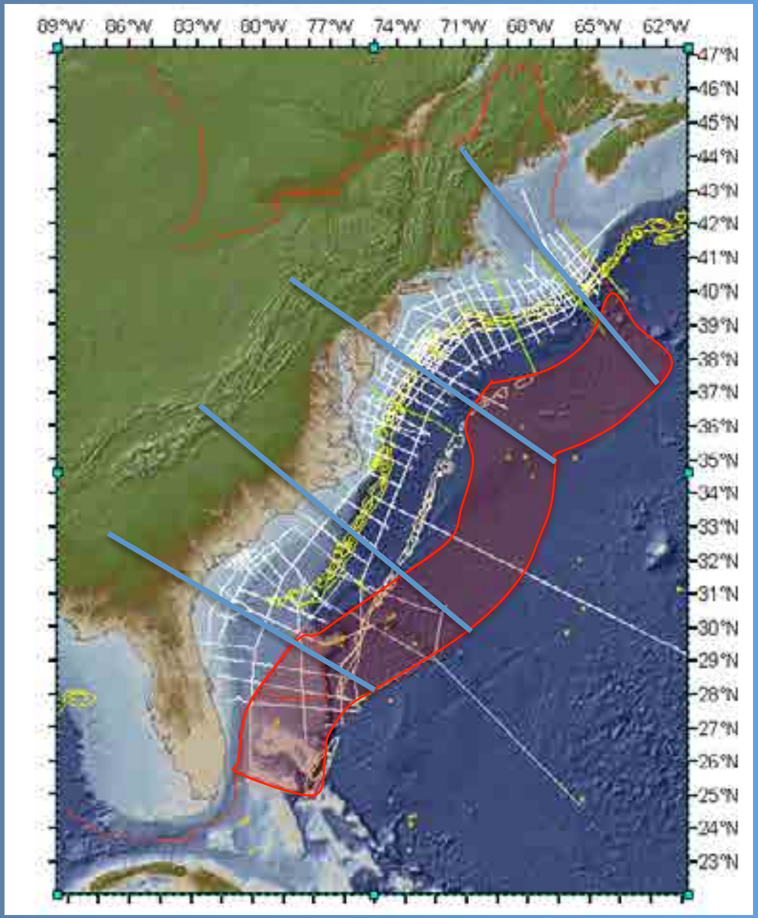
Synergistic Opportunities

Law of the Sea- ECS Project (USGS, NOAA)
-MCS spaced every 60 nautical miles
(beyond 200 nautical mi
-Coincident refraction (select lines)

US Array
Eastern US transportable array 2013

Oil and Gas Exploration
Moratorium may be lifted…

Canadian-Atlantic and Conjugate Margins
International collaboration



Numerous Opportunities for Coordinates Studies

Summary

1. Late-stage rifting, transition to drifting
   - Magmatism (in time and space) and upper mantle deformation
   - Segmentation and along-axis variation
   - Rift localization and formation of transitional crust
   - Breakup unconformity
2. Post-rift evolution
   - Sediment dispersion patterns, passive margin evolution, climate control
   - Geomorphic evolution (progradation, clinoform development, submarine canyon formation)
   - Geohazards (submarine landslides, tsunami generation, seismicity)
3. Synergistic Opportunities
   - US Array
   - Extended Continental Shelf Project (Law of the Sea)
   - Industry and international collaboration
   - International collaboration

Continental Breakup and Formation of Rifted Margins: The Gulf of Mexico as a Natural Laboratory

D. Harry, *Colorado State University*
R. Stern, *University Of Texas At Dallas*
E. Anthony, *University Of Texas At El Paso*
G.R. Keller, *University Of Oklahoma*
I. Norton, *University Of Texas*
J. Van Wijke, *University Of Houston*

Community planning meetings

2008 Geological Society of London Meeting (Houston)
2009 Southcentral GSA (Dallas)

2009 Fall AGU Meeting Town Hall (San Francisco)

Continental Breakup and Formation of Rifted Margins: The Gulf of Mexico as a Natural Laboratory

PART I
Why the Gulf?

Continental Breakup and Formation of Rifted Margins: The Gulf of Mexico as a Natural Laboratory

PART I
Why the Gulf?

PART II
Tectonic Evolution Of The Gulf

Continental Breakup and Formation of Rifted Margins: The Gulf of Mexico as a Natural Laboratory

PART I
Why the Gulf?

PART II
Tectonic Evolution Of The Gulf

PART III
Opportunities & Challenges

Why the Gulf of Mexico?

- This is how continents break apart

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- Inherited Tectonics – 2 Wilson Cycles

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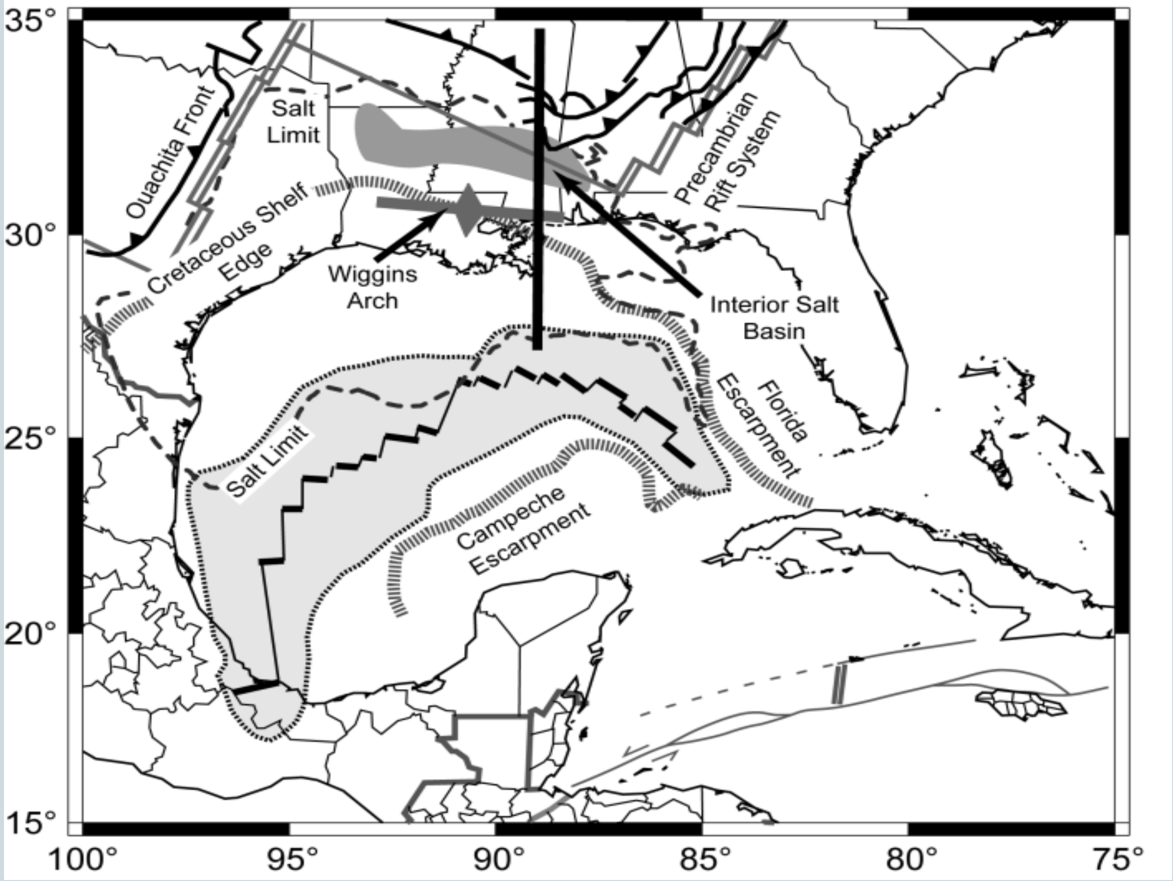
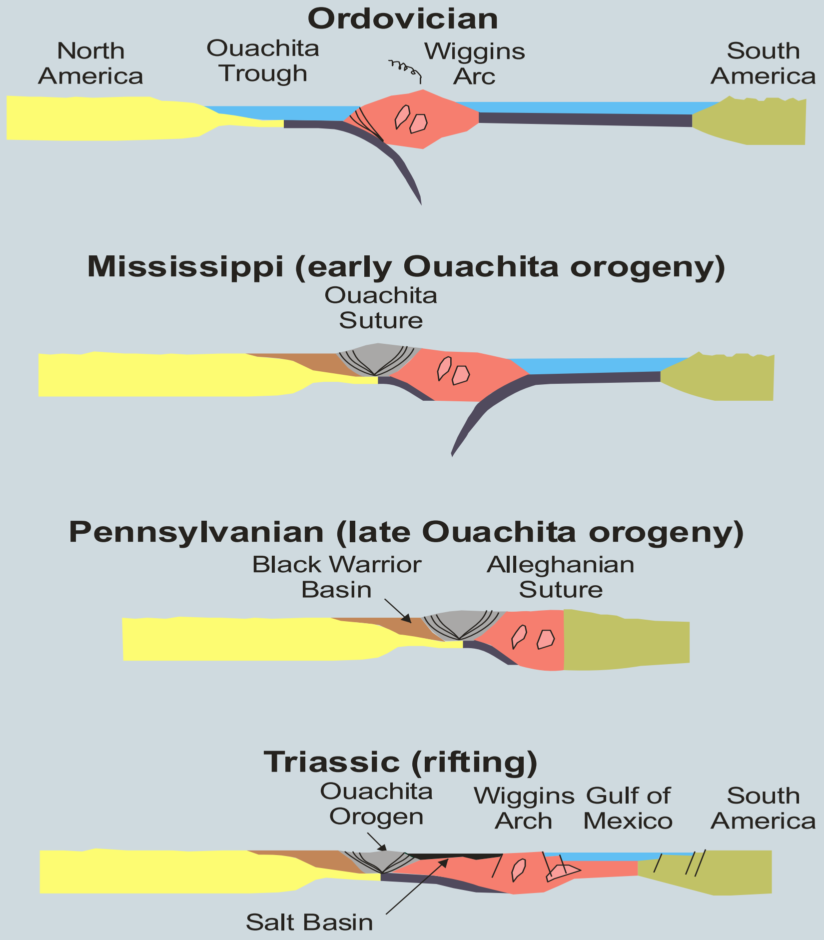
- Reactivated structures and late-stage melting
- Societal Impact – high visibility economic impact
- Science Beyond RIE – a Mesozoic gateway between the Atlantic and Pacific Oceans

Tectonic Evolution

- •Rift initiation ~ 215 Ma (Eagle Mills and La Boca Fms.)
- •Seafloor spreading began ~ 165 Ma (inferred – no direct evidence)
- •Opening ceased ~138 Ma (inferred)
- •Followed Ouachita orogenic trend (sort of)
- •The widest known rifted margin

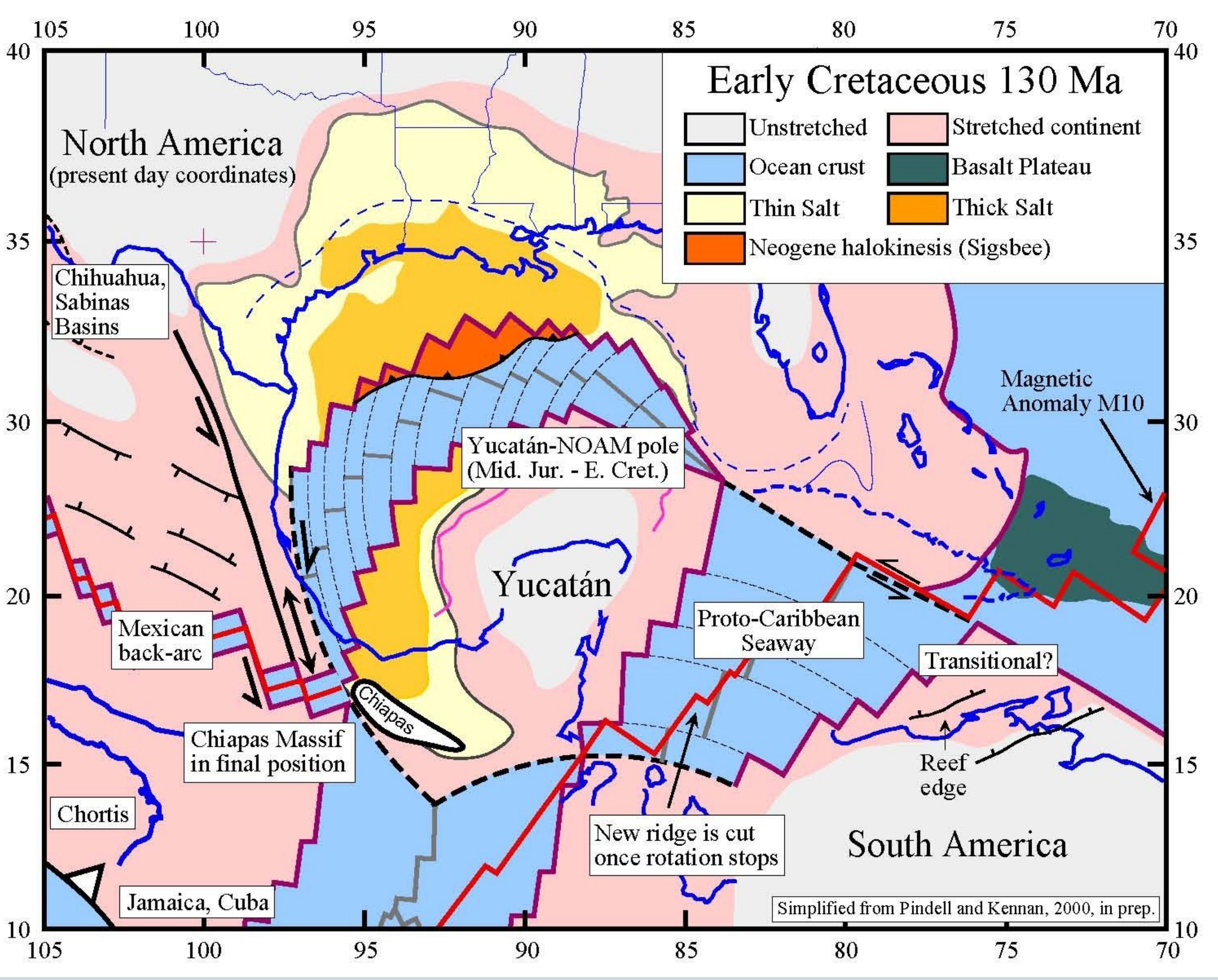


Tectonic Evolution



Tectonic Evolution

- Counterclockwise rotation of Yucatan away from North America
- Transform motion between Yucatan and eastern central Mexico
- Extreme stretching on central North American margin, oblique to trend of Precambrian transform margin and Paleozoic Ouachita orogen



Pindell et al., 2000

Opportunities

- **Tectonic Inheritance** –The Gulf of Mexico provides an opportunity to compare rifting of a “soft” collision orogen in the central and eastern Gulf and a “hard” collision in the western Gulf: thin-skinned vs. thick-skinned.

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- **Rift Segmentation.** What controls whether transitional crust is broad (among the broadest in the world in the central GOM) or narrow (as in the western GOM)? The Gulf offers an opportunity to compare rift vs. transform margins. What controls along strike changes from a magmatic margin (western Gulf) to an amagmatic margin (eastern Gulf).

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- **Mantle Fabrics.** Slightly depleted spinel peridotite mantle. Some evidence of margin-parallel S-wave splitting. A rift relic, or a relic of older orogenic events?
- **Sedimentation, Eustasy, and Coastal Subsidence.** The GOM receives an extraordinary load of sediments from rivers draining central North America. This presents an opportunity to study source to sink depositional systems at a continental scale.

Opportunities

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- **Fluid Evolution and Migration**. The GOM is a factory for generating a wide variety of fluids: CO_2, brines, and hydrocarbons. The GOM provides an opportunity for understanding how these fluids form, migrate, and interact.

Challenges

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- Imaging through salt & separating Salt Tectonics from Rift Tectonics

Tectonic Evolution

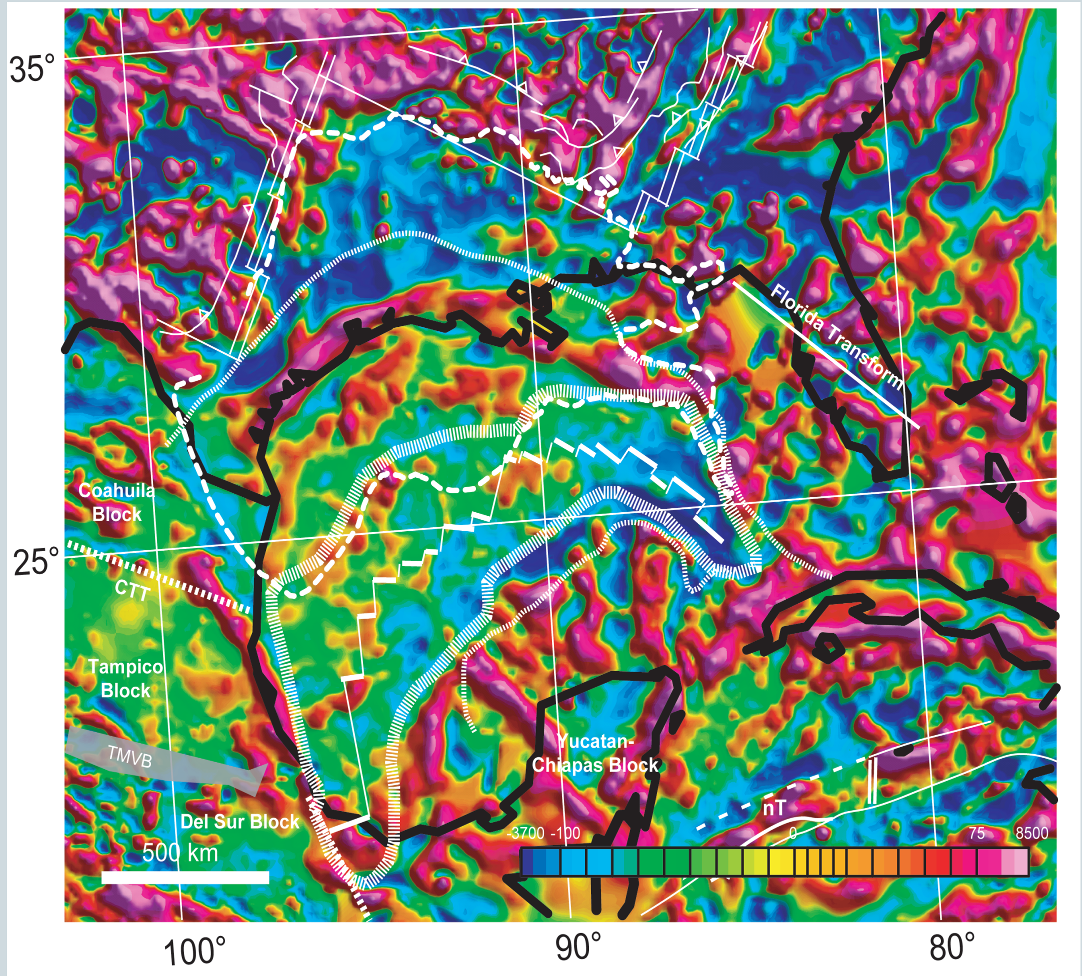
•Rift initiation ~ 215 Ma (Eagle Mills and La Boca Fms.)

•Seafloor spreading began ~ 165 Ma (inferred – no direct evidence)

•Opening ceased ~138 Ma (inferred)

•Followed Ouachita orogenic trend (sort of)

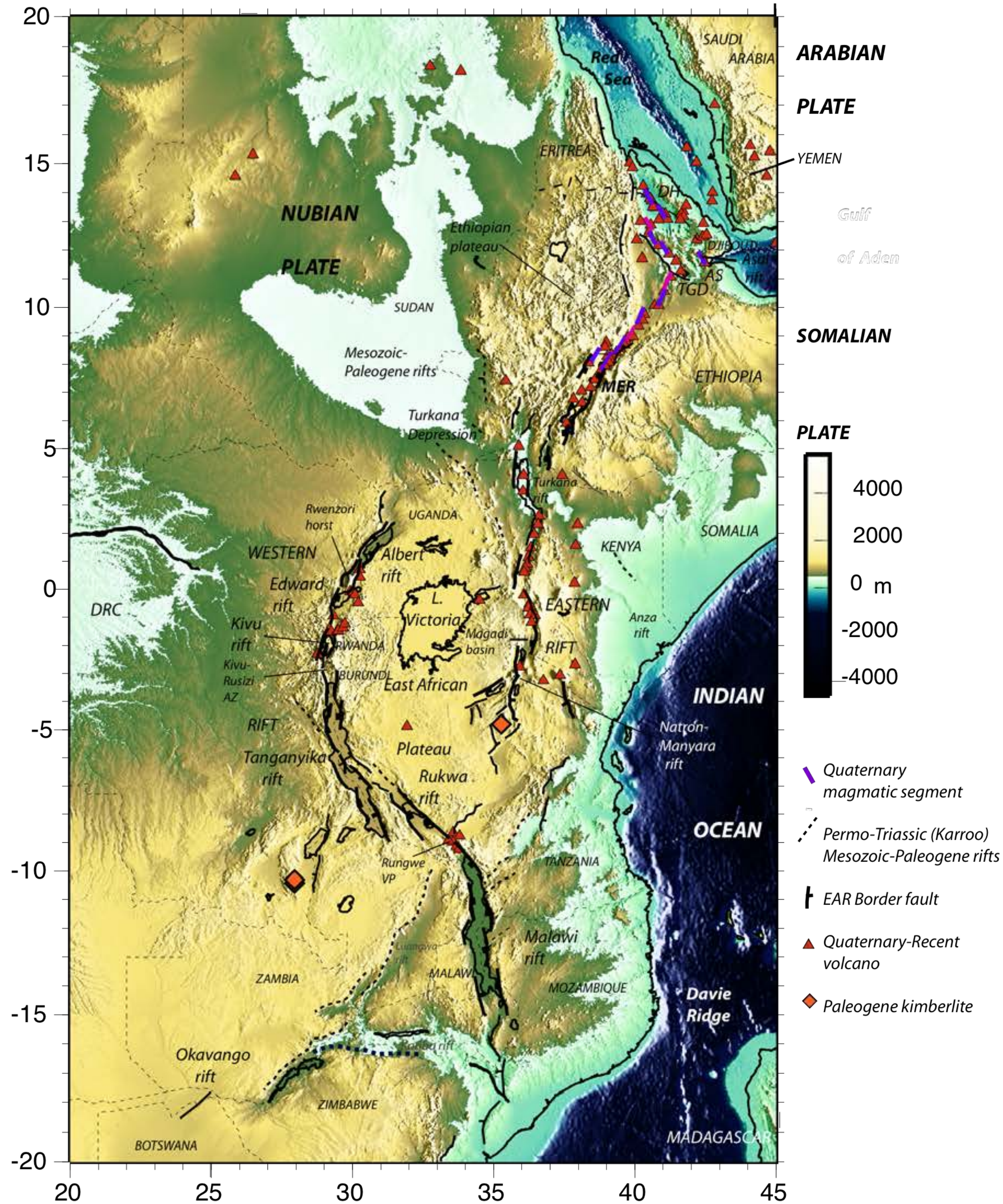
•The widest known rifted margin



The East African Rift System

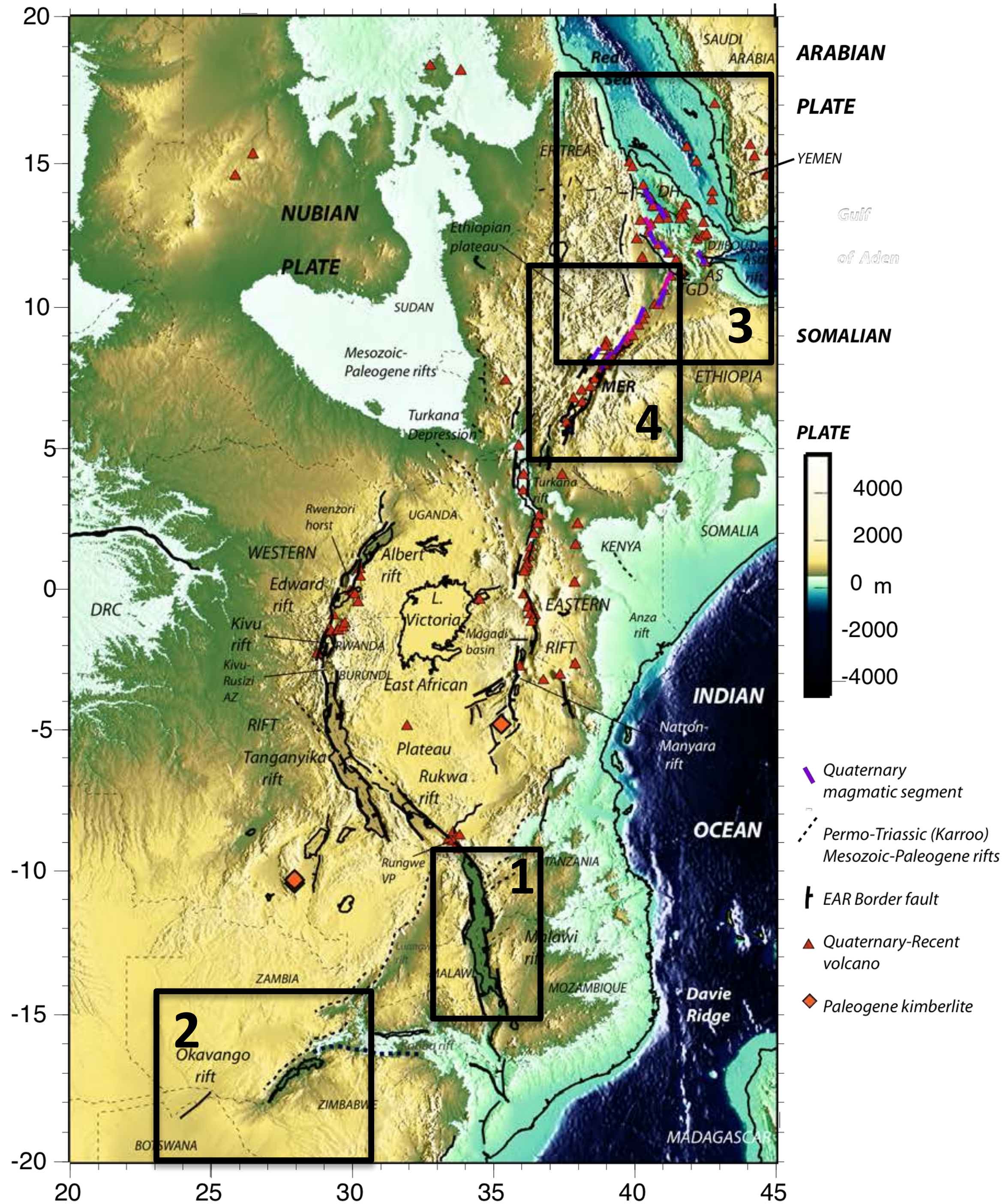
A possible primary or thematic site

Atekwana et al.
Ebinger
Gaherty et al.
Reilinger et al.
Rooney et al.

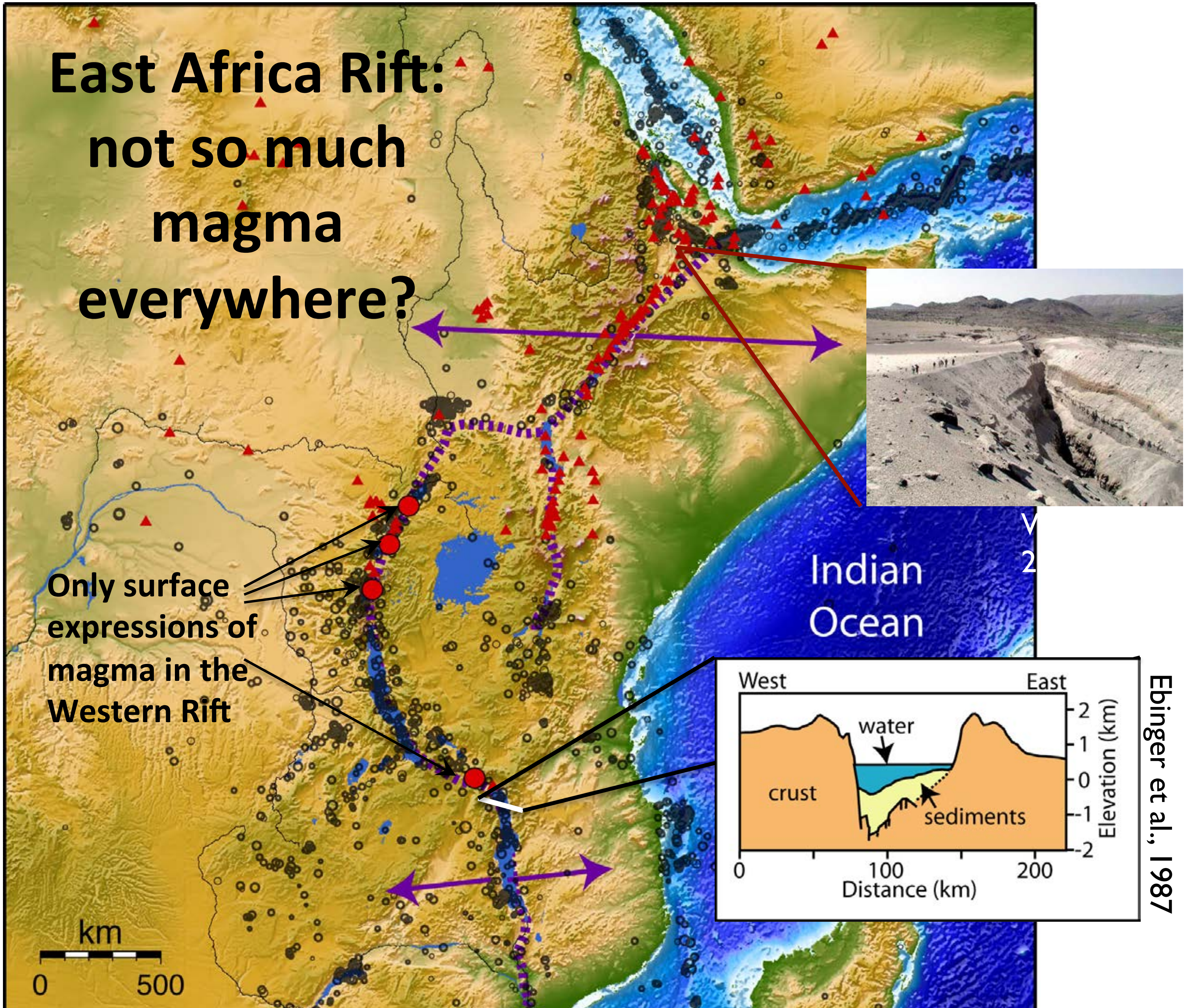


Active continental rift

- Strain rates of 1-6 mm/yr
- Northern end – Afar plume
- Lithospheric blocks (e.g. Tanzanian, Kaapval cratons)
- Pan-African orogeny, older rifting events
- Volcanic, tectonic

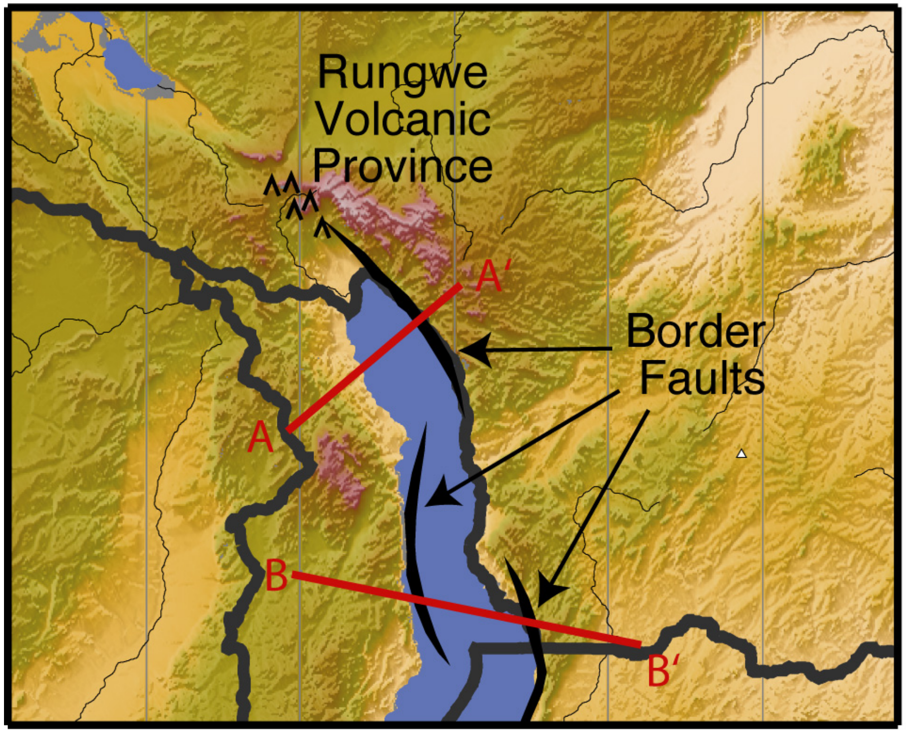


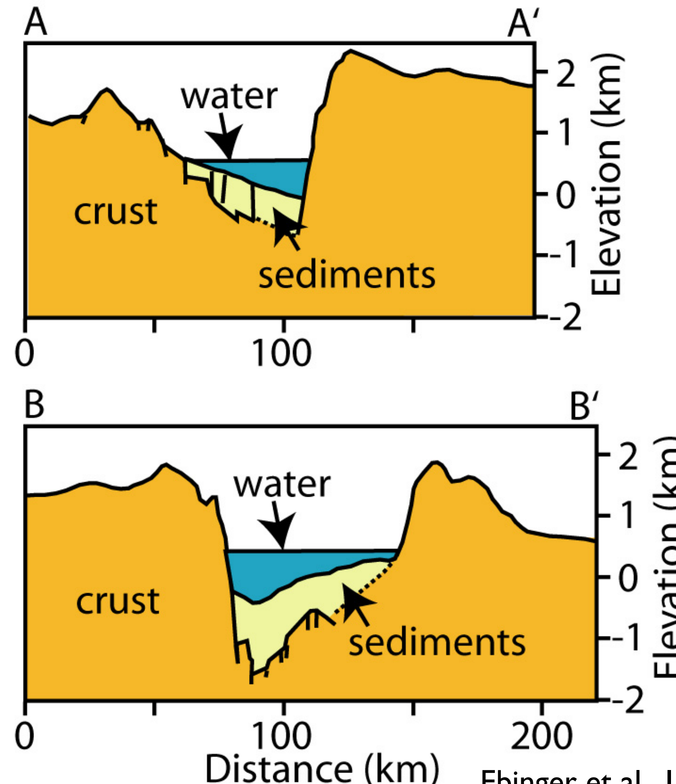
East Africa Rift: not so much magma everywhere?



White paper by Gaherty et al.

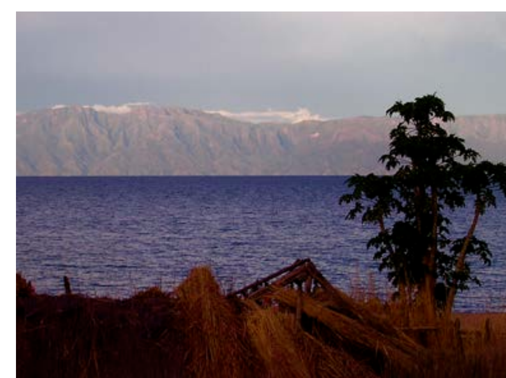
Spatial patterns during early extension: Western Rift, East Africa Rift System





Ebinger et al., 1987

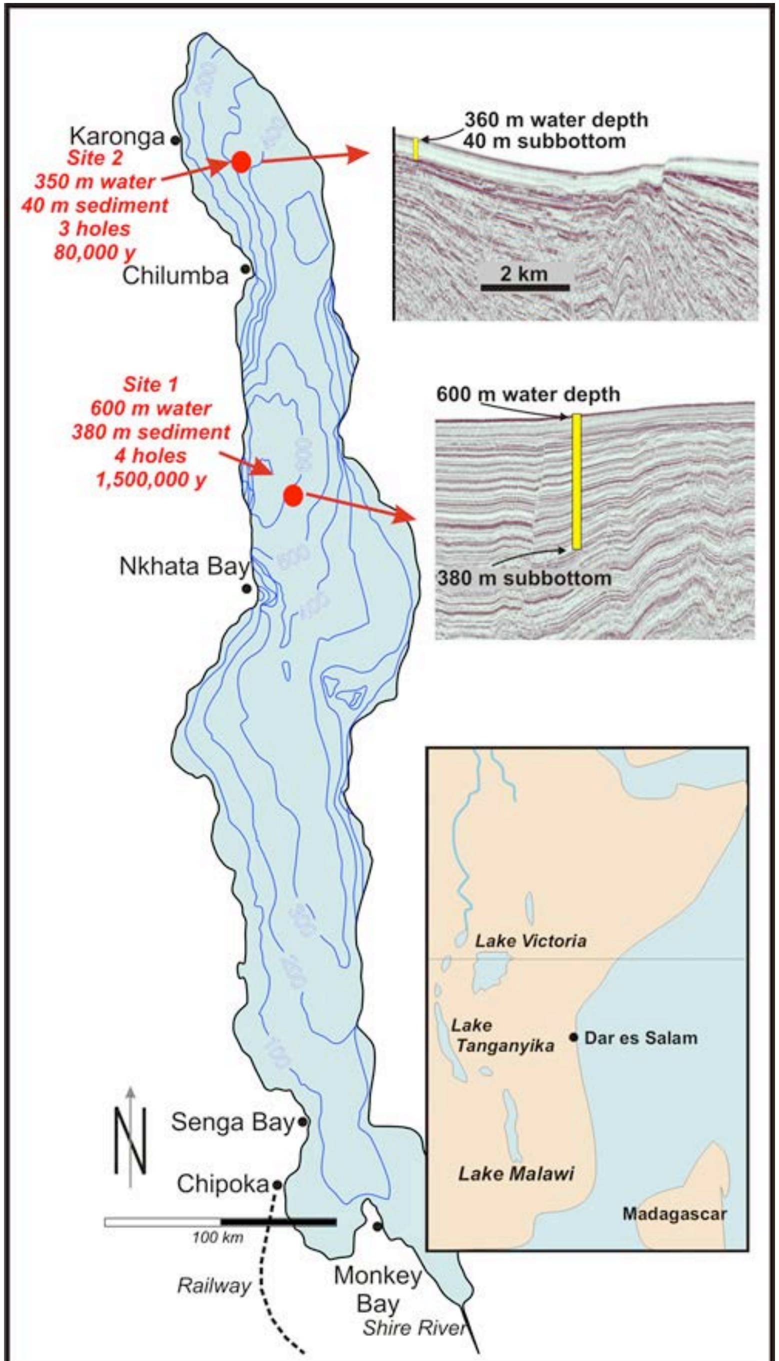
- Pronounced tectonic segmentation at the surface defined by ~100-km-long border faults and accommodation zones



White paper by Gaherty et al.

Western branch:

Sedimentary record in lakes records tectonics and climate change



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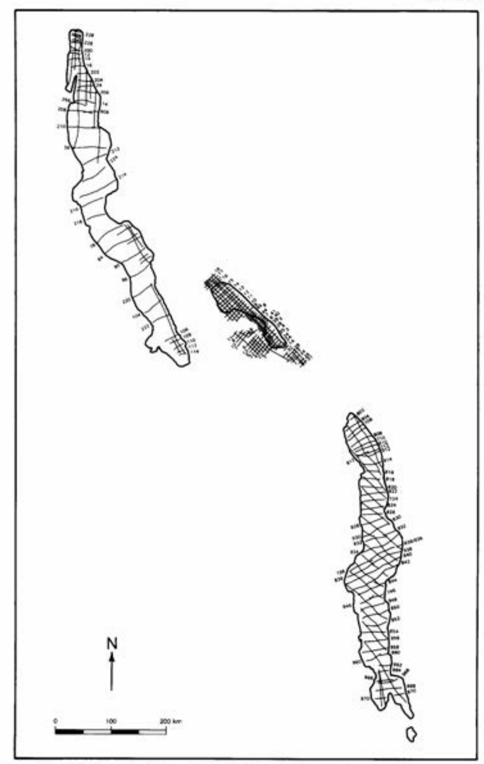
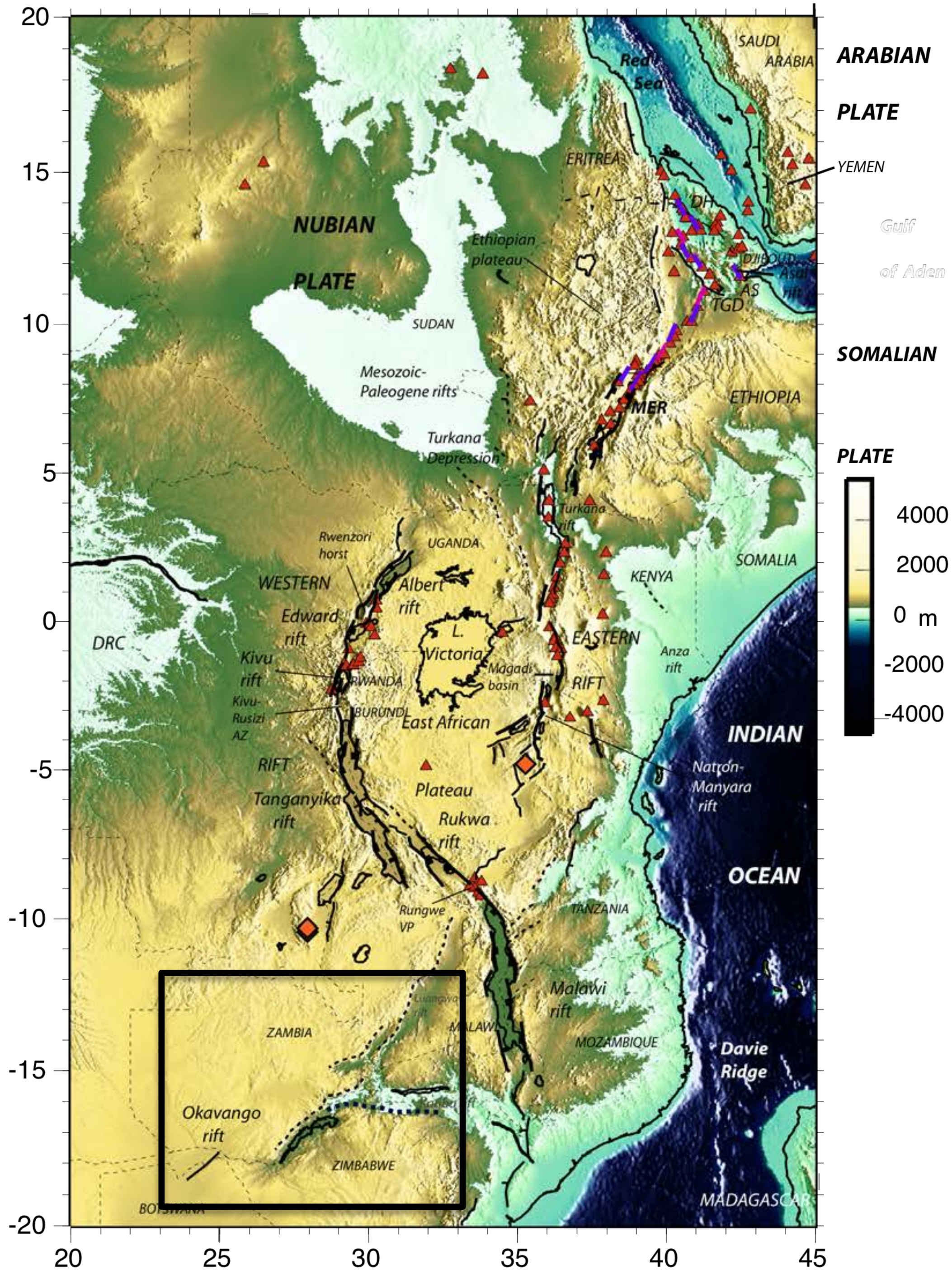
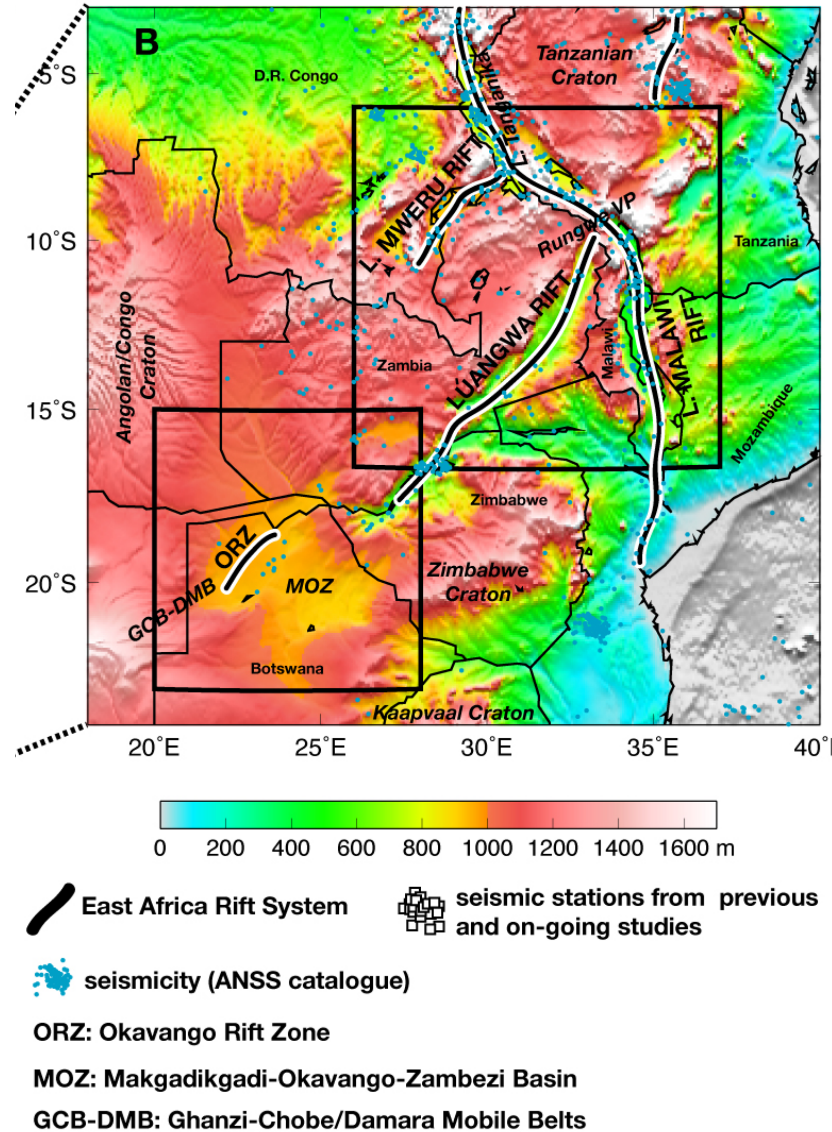


Fig. 2. Map portfolio of the Tanganyika, Rukwa and Malawi Rift Zones. (A) Multifold seismic reflection coverage used in analysis. Lines with numbers refer to line drawings shown in Fig. 3. (B) Permo-Triassic, Cretaceous and Cenozoic sedimentary cover associated with known rift basins. (C) Structure map on acoustic basement. Compiled from Rosendahl (1987), Sholz and Rosendahl (1988), Versfelt and Rosendahl (1989) and Scott et al. (in press). (D) Possible pull-apart geometry linking Kalemie, Rukwa and Livingstone Basins.

Rosendahl et al., 1992





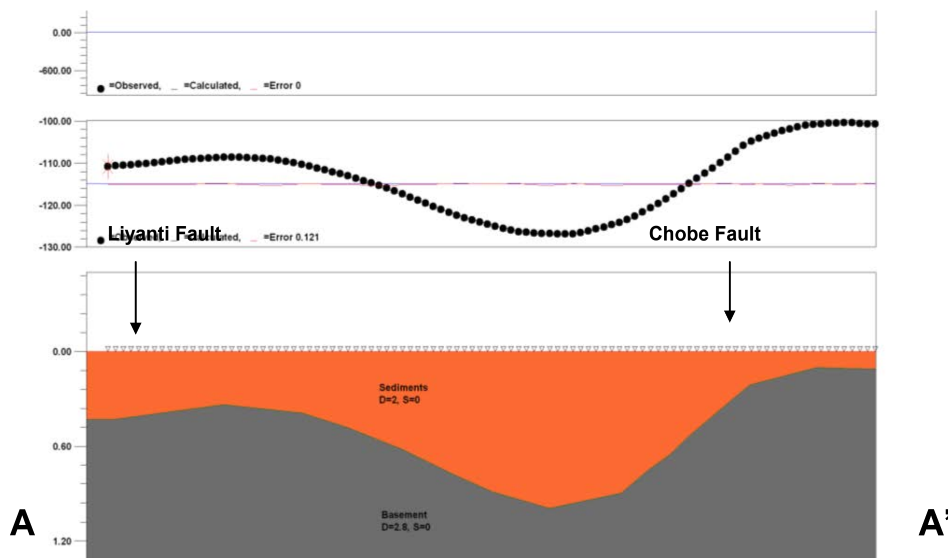
White paper by Atekwana et al.

Fault scarp height comparison

The SWB is geologically less evolved than either the eastern or western branches.

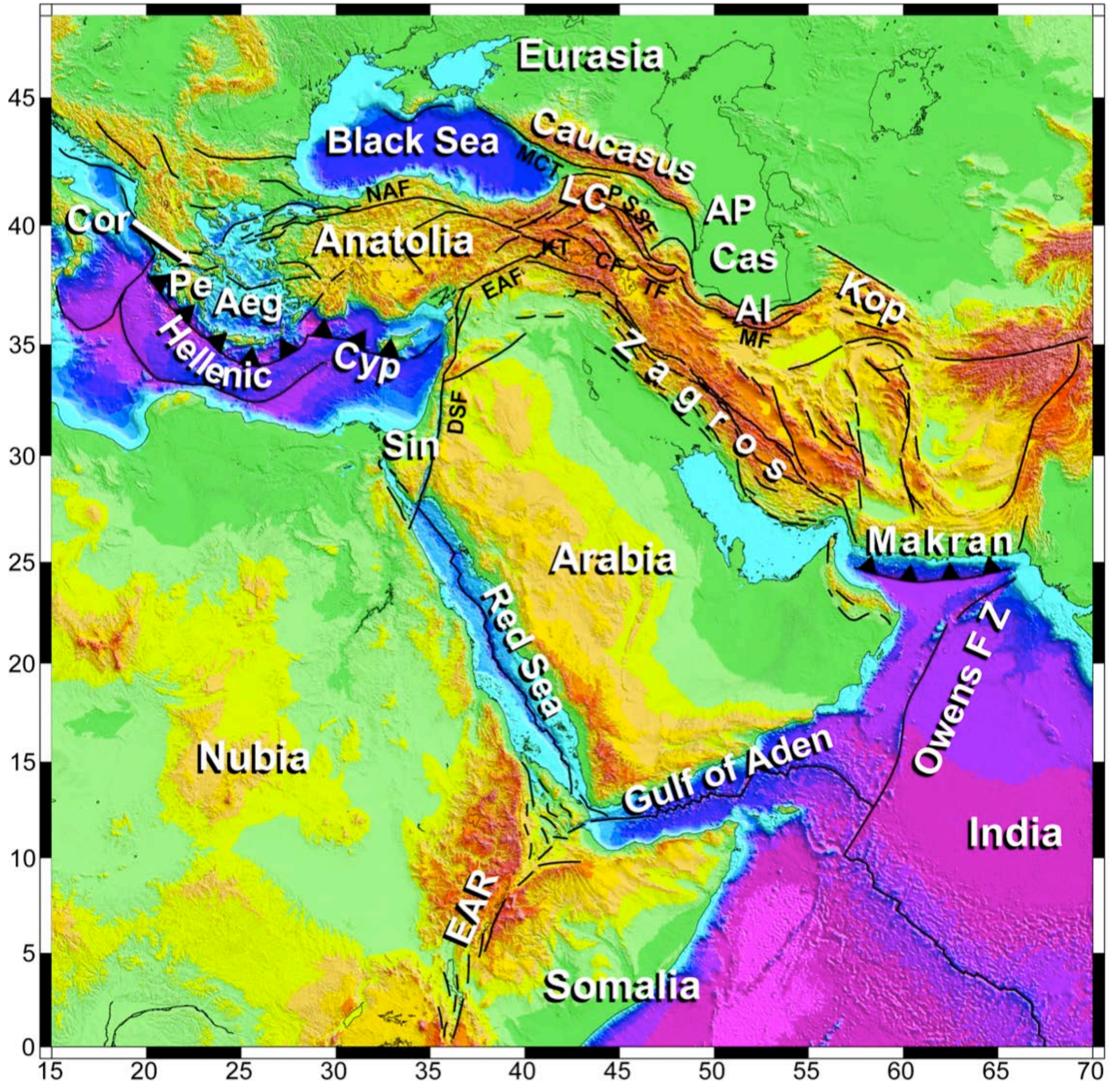
Livingstone Fault > 1 km – L. Malawi

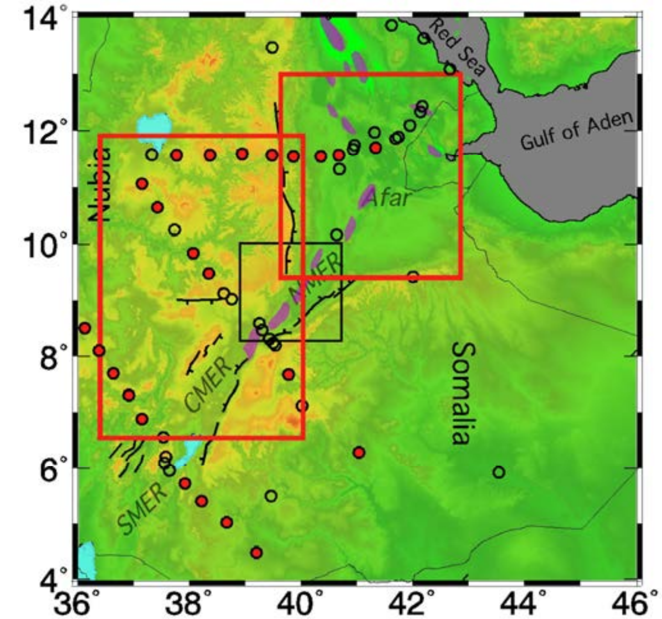
Mweru Fault– 50-200 m – L. Mweru



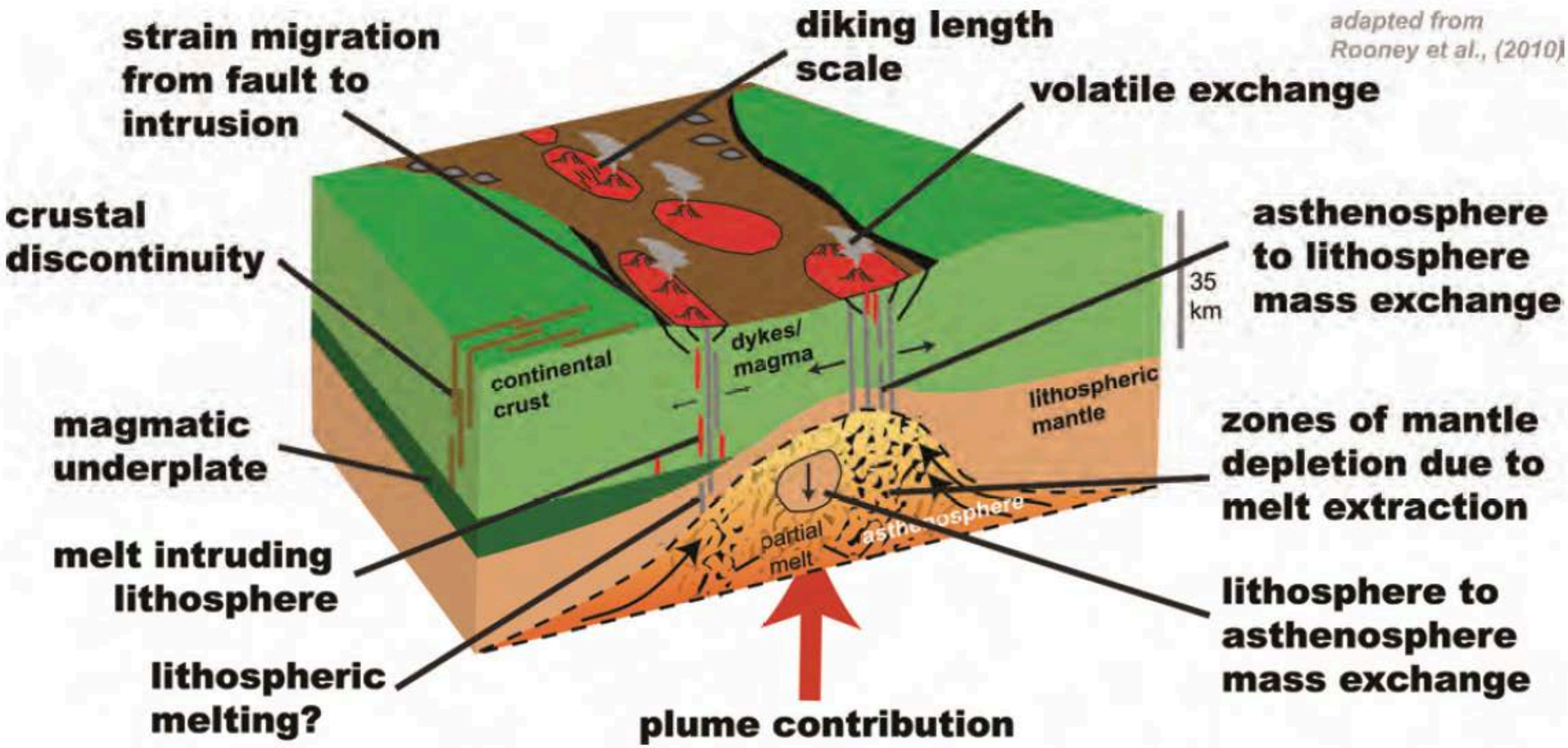
White paper by Atekwana et al.

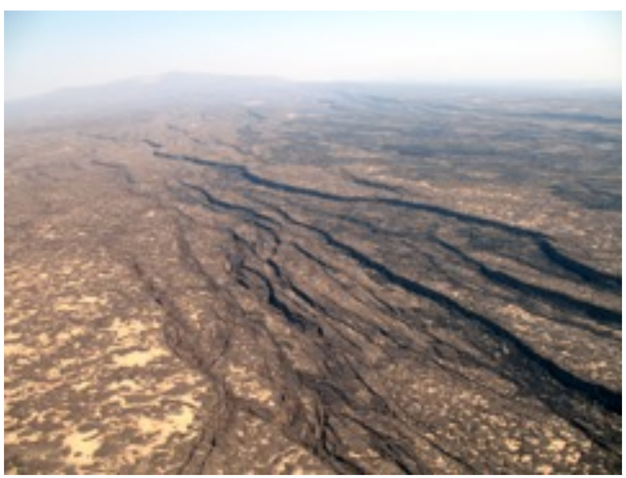
Afar triple junction





White paper by Reilinger et al.



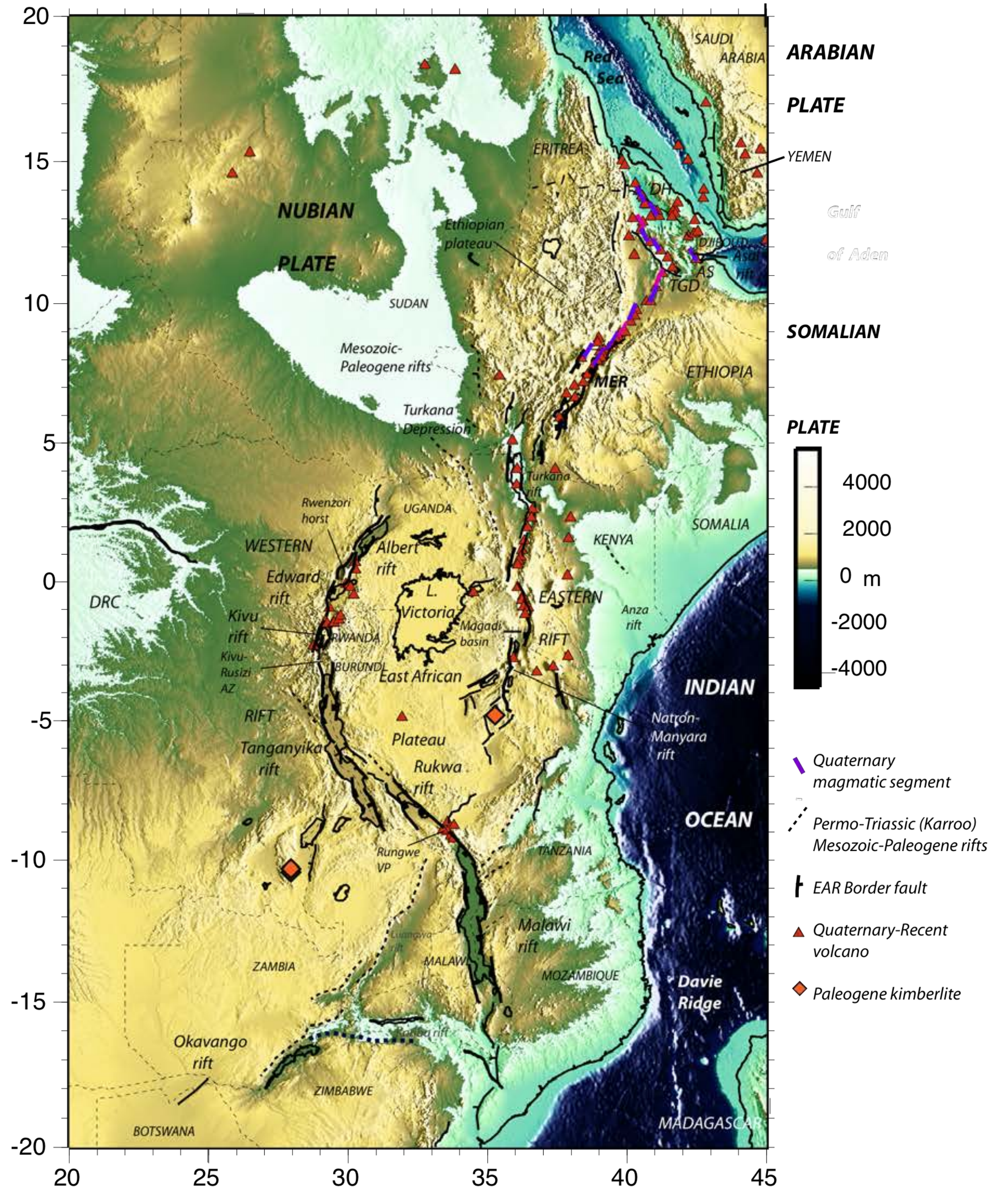

D. Keir

- Opportunity to characterize magma reservoirs at different crustal levels; spatial variability
- Combine geochemistry, geology, and geophysics

White paper by Rooney et al.

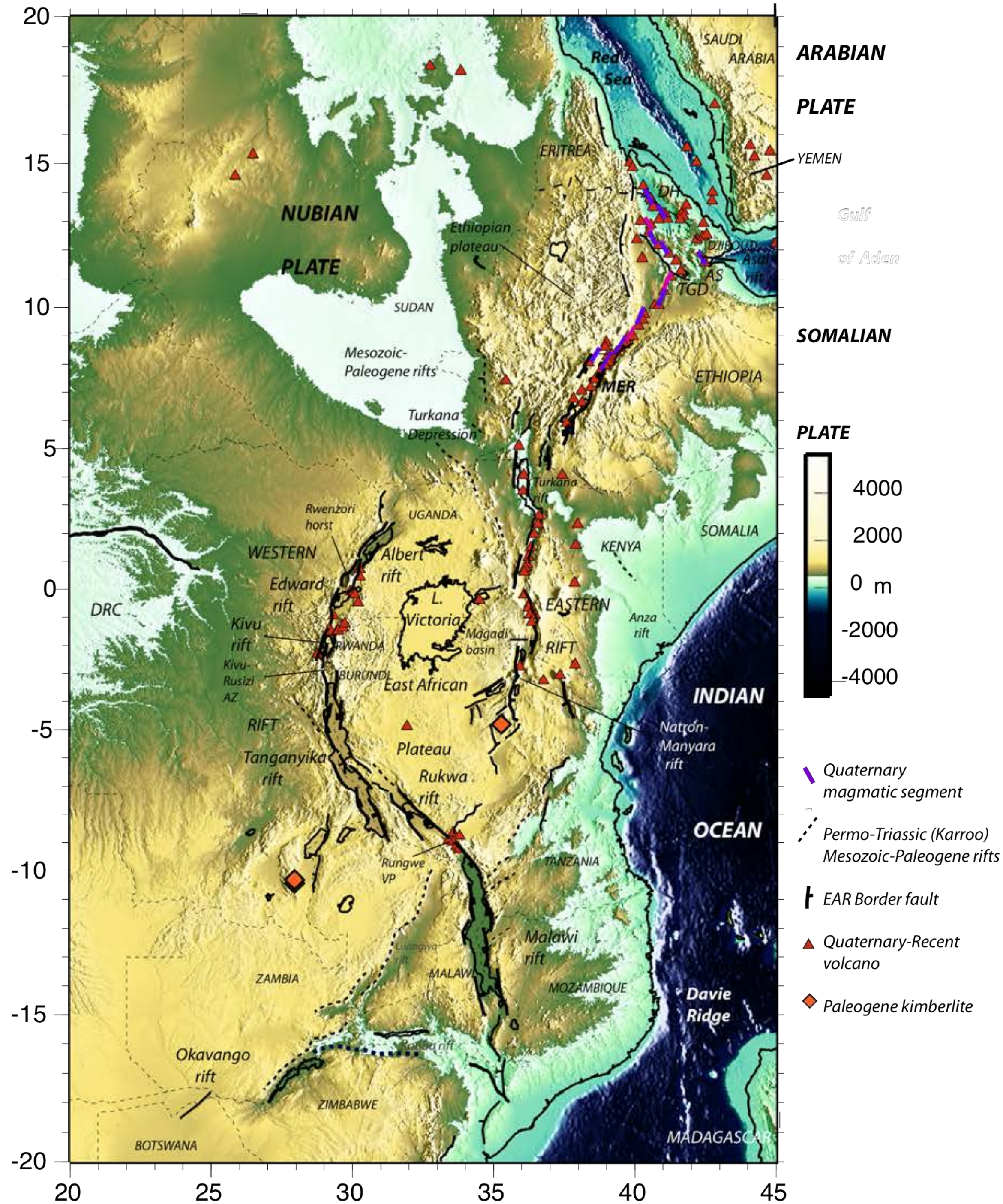
Also: NW branch, Kenya, Eastern Tanzania

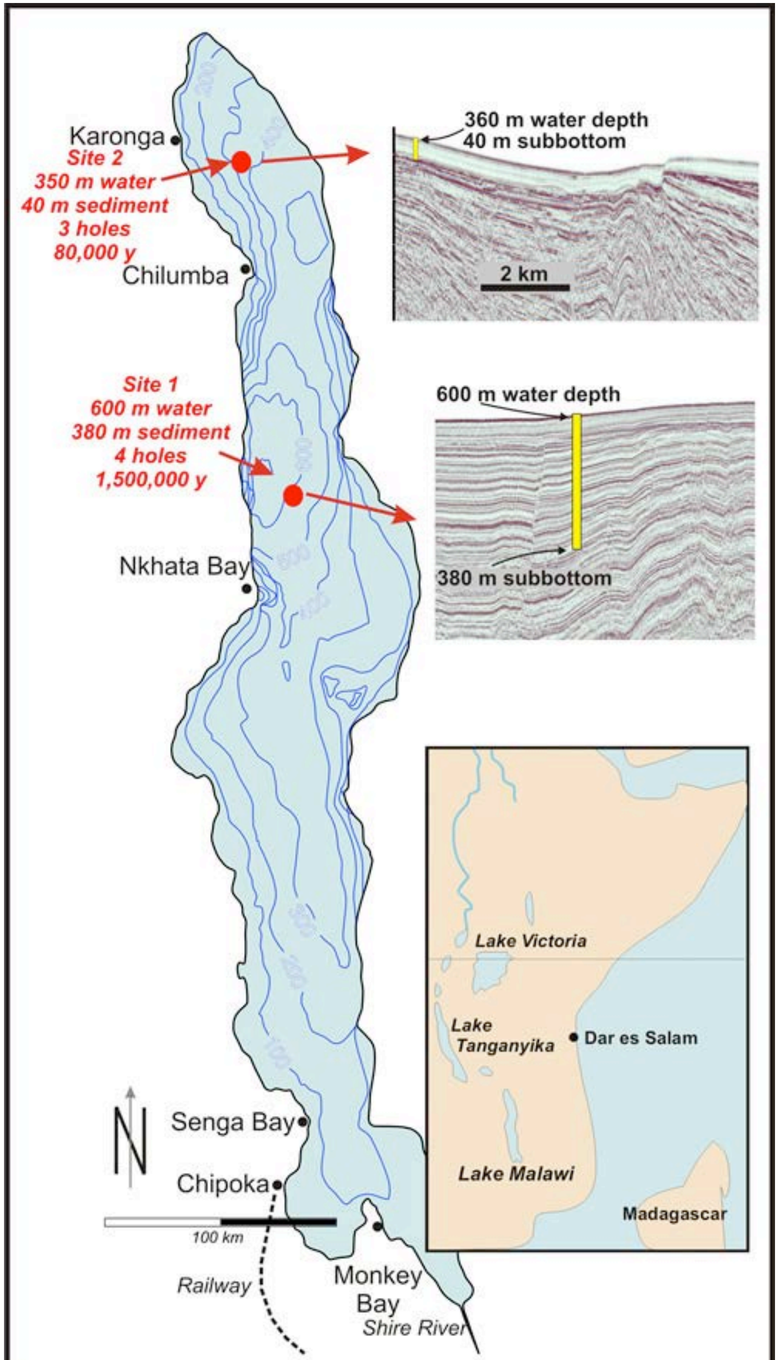
- Nyamulagira, Lake Kivu, etc.
- Resources: Petroleum, geothermal
- Deep earthquakes, sedimentation records
- Intermediate



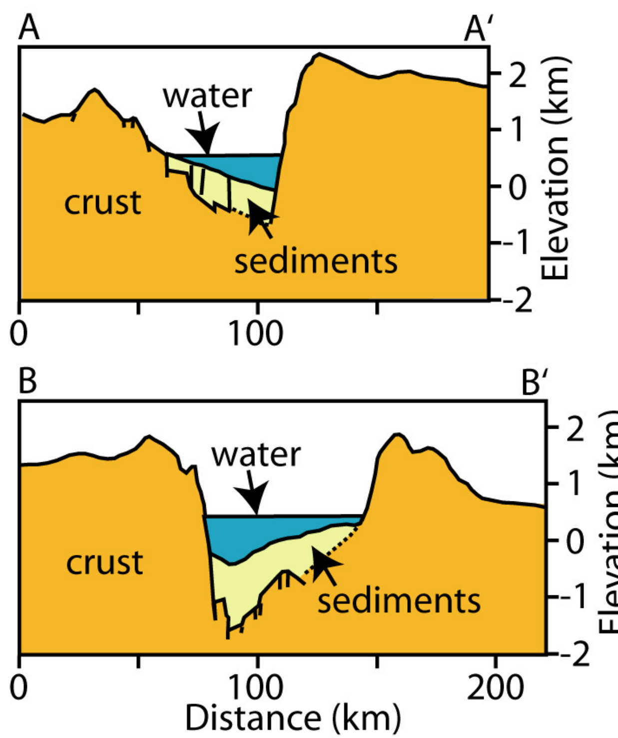
Spatial variability; change in rift maturity

- Spectrum of fault system structures and magmatic influence
- Botswana to Afar
  - Incipient rifts to rift grabens to diking
  - Rift initiation with large faults, no surface volcanism
  - Plume, no plume
- Kenya to Rwanda
- **Comparative studies within one system**



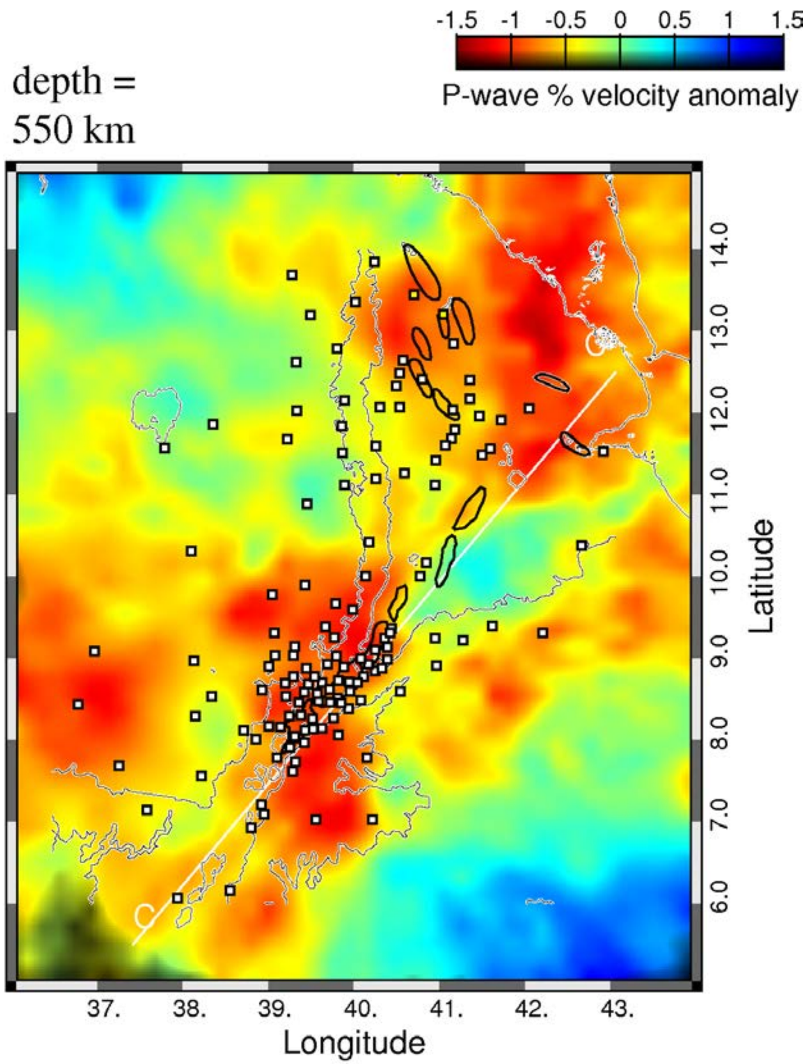


- Fault-bounded basins along the length of the rift
- Sedimentary record of deformation and climate; represent all stages of rift evolution
- Feedbacks between faulting, flank uplift, sedimentation, further deformation



Ebinger et al., 1987

Backbone geophysics: Mantle tomography



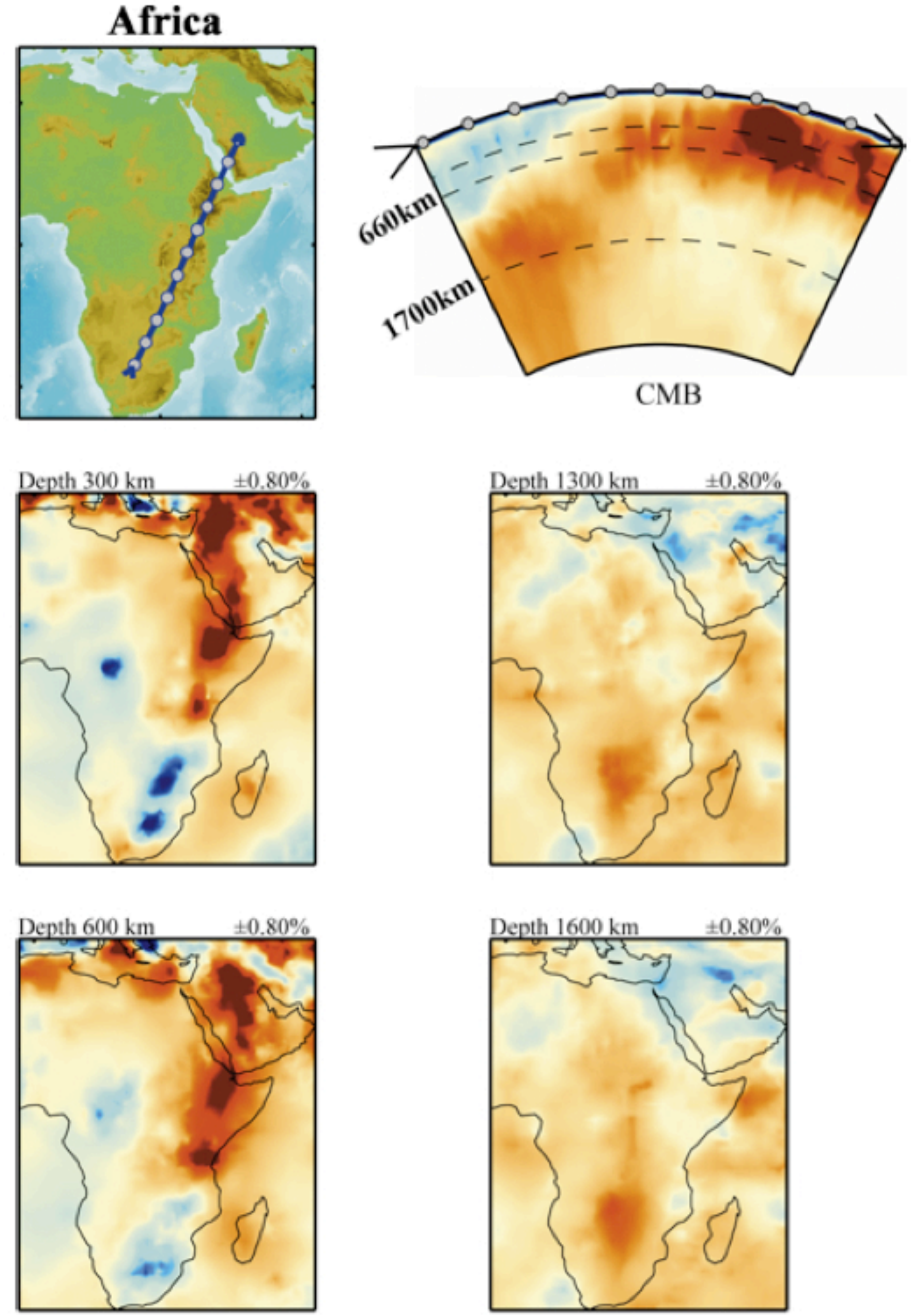
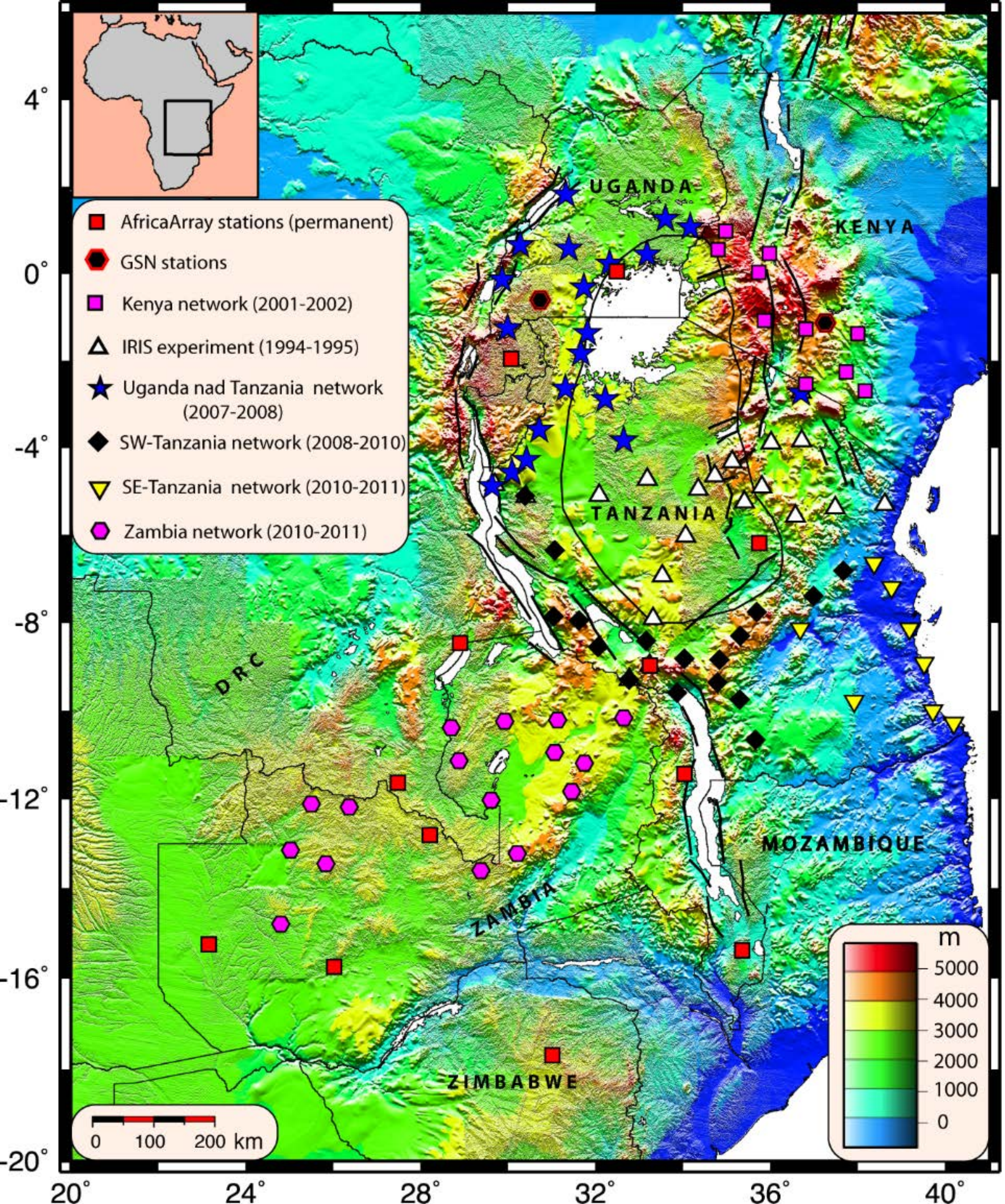


Image from James Hammond, Bristol

Li et al., 2008

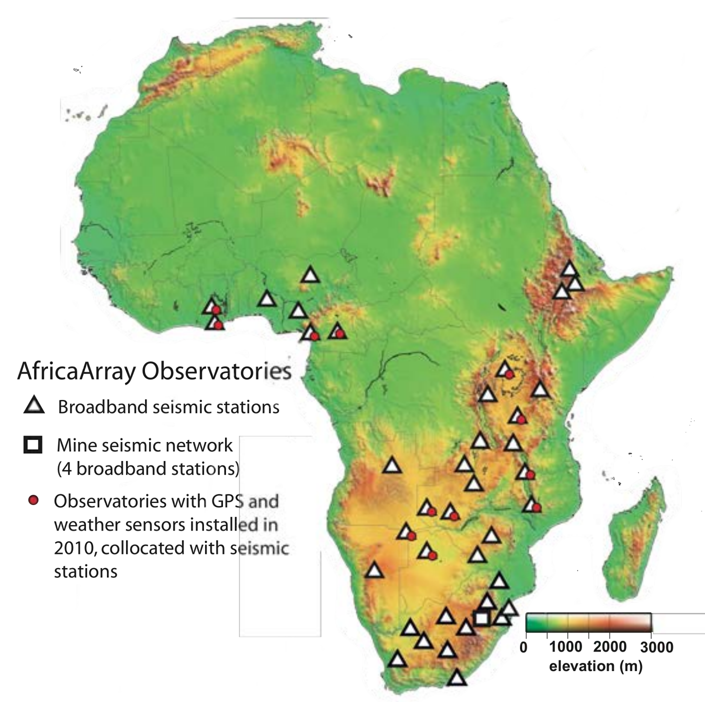
AfricaArray temporary and permanent seismic networks



1) Uganda/NW Tanzania 8/07-12/08

2) Southern Tanzania 1/09-7/108/10-8/11

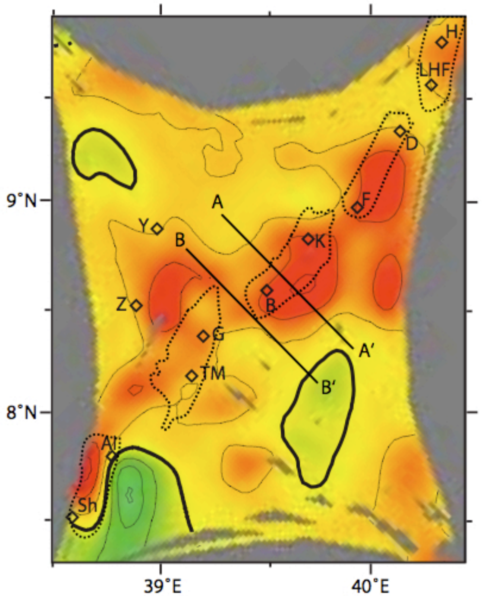
4) SE Tanzania 2/10-3/11

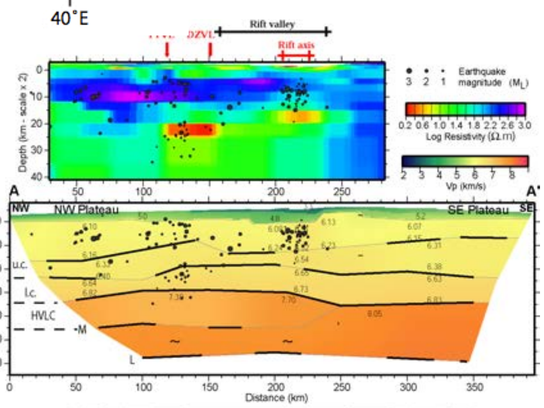


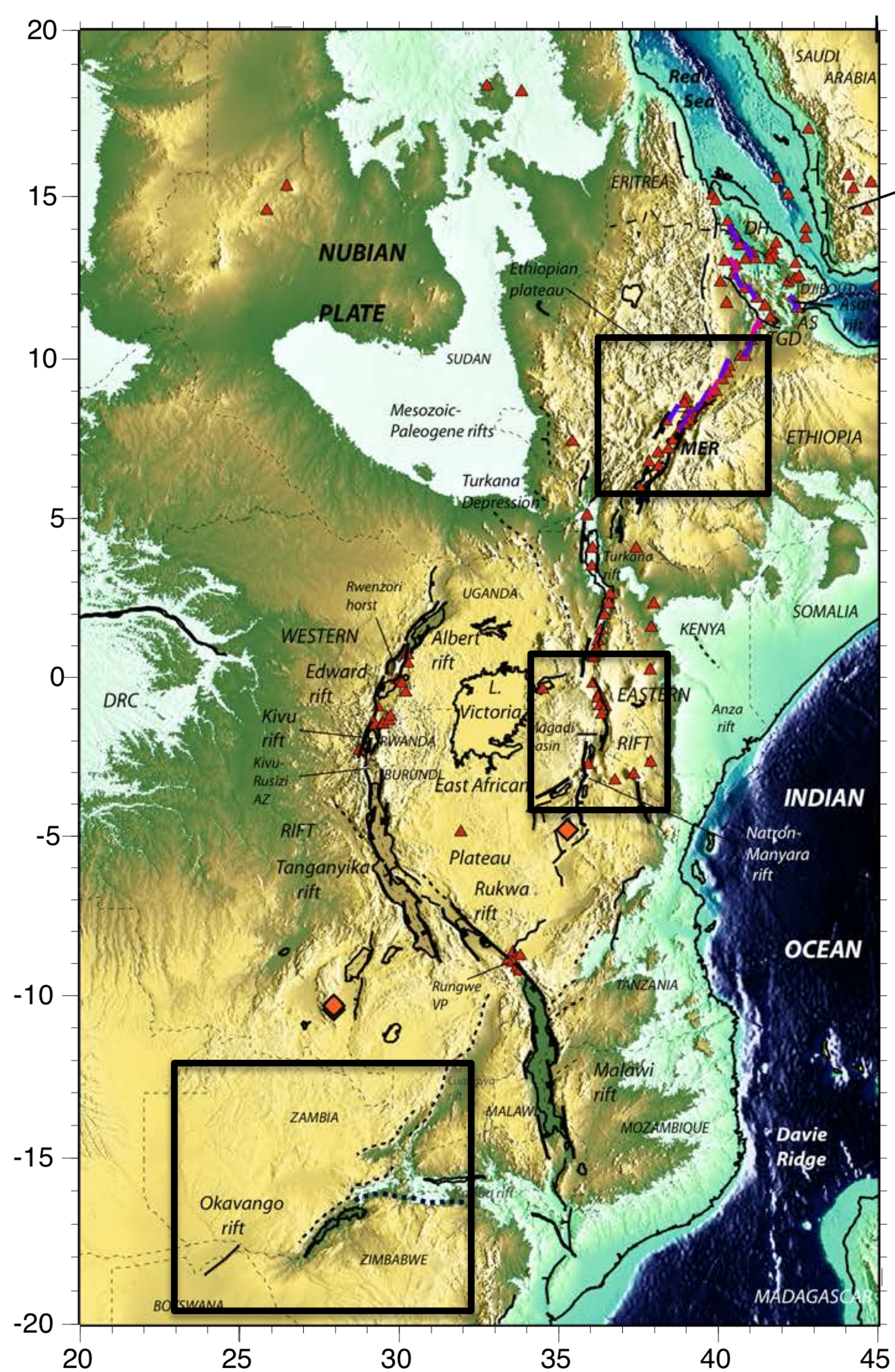
Backbone geophysics: Crustal seismic studies, MT

KRISP – Kenya Rift
EAGLE - Ethiopia
SAMTEX – S. Africa
CD Project – SW Rift*

Gravity, magnetics







Summary – ability to address science objectives of RIE within the EARS

- Where and when do continental rifts initiate?
- How do rift processes and feedbacks evolve in time and space?
- What controls the structural and stratigraphic architecture before and after breakup?
- What are the mechanisms and consequences of fluid and volatile exchange?

Summary – logistics, leveraging

- Amphibious (?)
  - Sub-aerially exposed, but crosses from continental to oceanic crust
- Readiness
  - Significant backbone geophysics, **Africa Array**
  - Existing ancillary studies, *but also a great opportunity for more work (immediate, long-term)*
- Accessibility and safety
- Availability of infrastructure
  - No EarthScope; Africa Array
- Foreign resources and collaboration
  - Strong existing relationships with African scientists at universities, geological surveys, etc.
  - Collaborations with European scientists working in East Africa
- Broader impacts
  - Geohazards – faulting (e.g. Malawi), volcanoes, CO_2 emissions (Kivu)
  - Resources: petroleum, geothermal
  - International field experience and community-building

What can GeoPrisms do for East Africa?

- Bring together loosely-linked groups working on related problems throughout the rift system
  - Develop a strong community; enhance research results; leverage ongoing work

- Bring a new group of scientists, new methods, new enthusiasm
  - Fill gaps in geochron, paleoseismology, fault linkages, magmatic volumes, etc. to test and develop models of rift processes; rift hazards