Oceanic detachments
Formation & associated deformation

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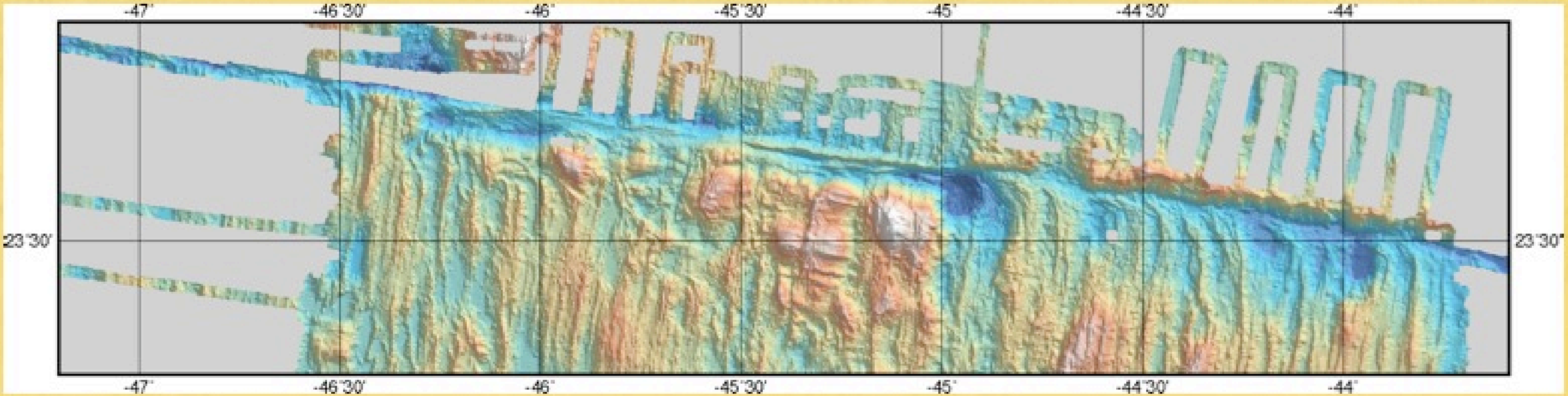


C. J. MacLeod, A. McCaig, M. Cannat
C. Mével, 304-305 IODP Science Party
D. K. Smith & J. Cann

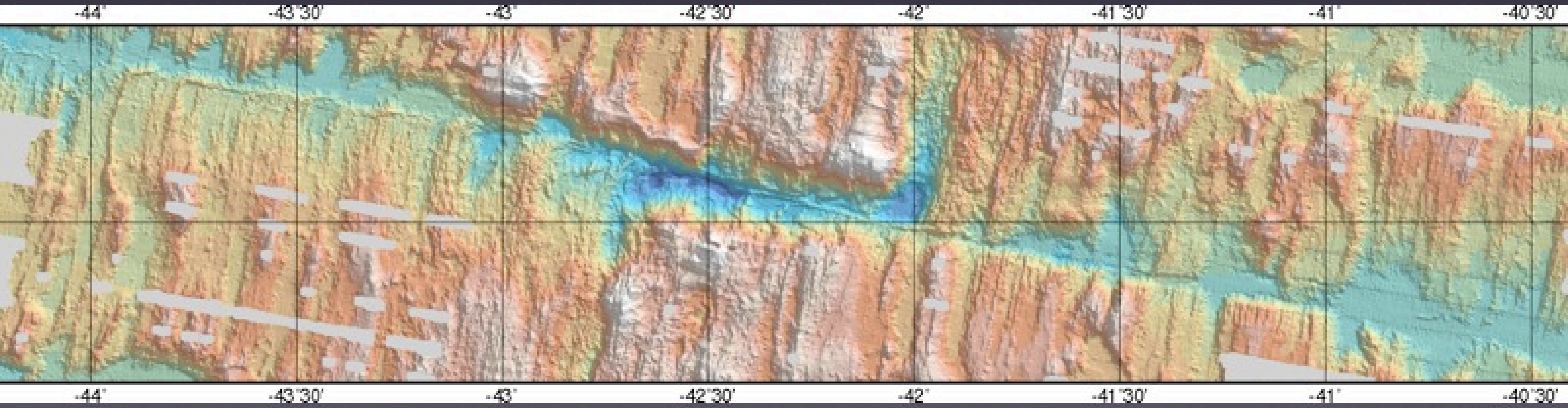
Oceanic detachments

1. Lithospheric construction, structure and tectonism

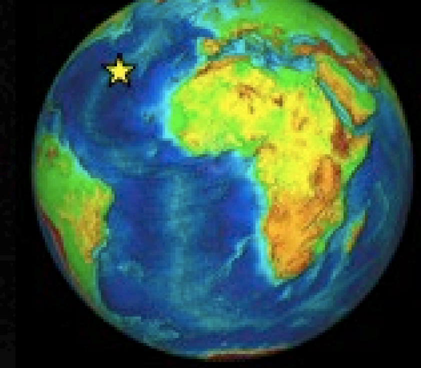
2. Detachments: occurrence & characteristics

3. Deformation & composition
   - *Footwall & fault composition*
   - *Deformation conditions*
   - *Seismicity & active faults*
   - *Models*

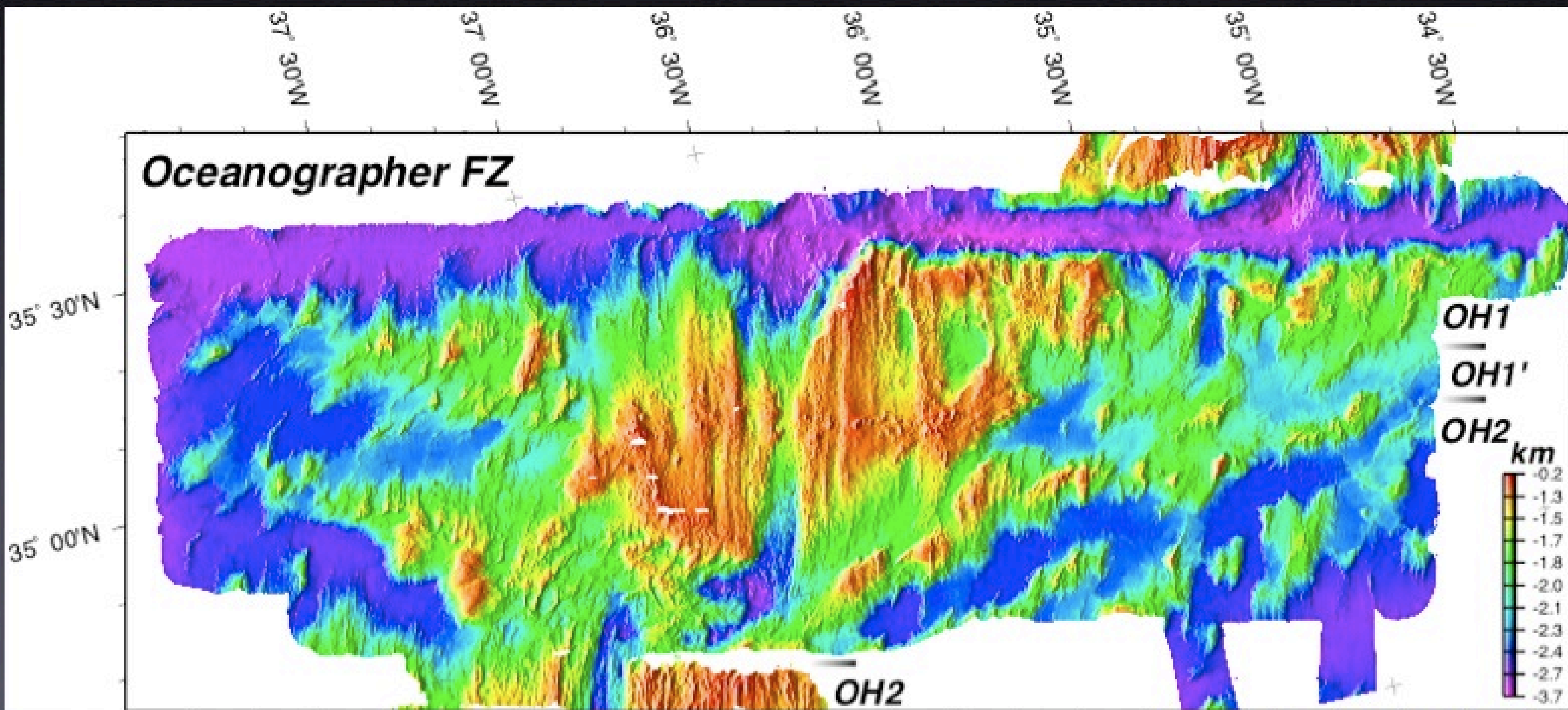
4. Conclusions and perspectives



Seafloor morphology: volcanism + tectonism

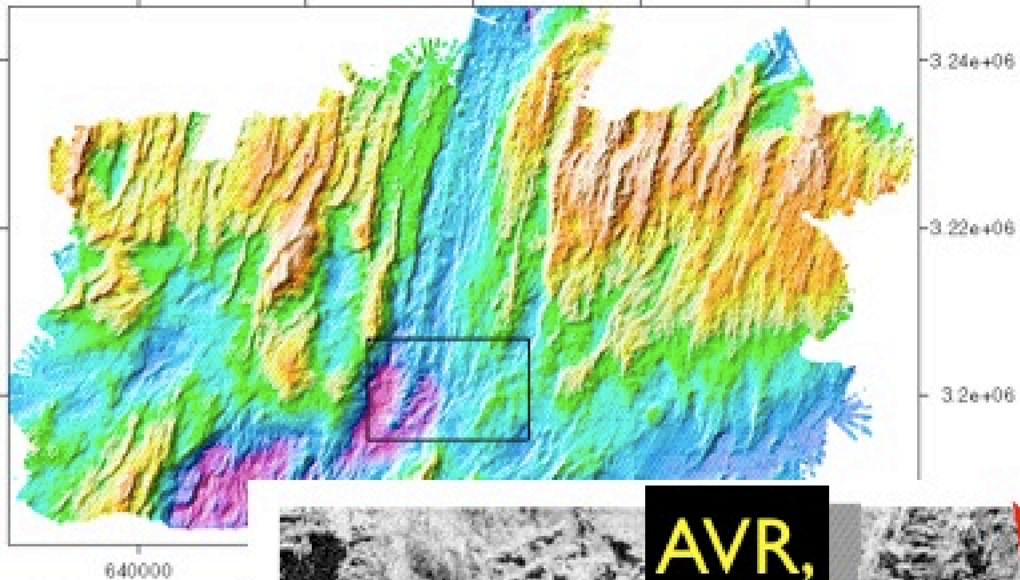


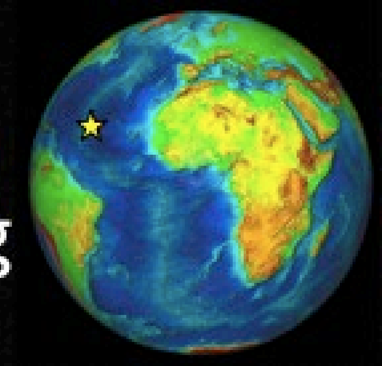
Ridge segmentation
Volcanism limited to axial zone
Interaction of faulting and volcanism
Modification of oceanic crustal structure by extension

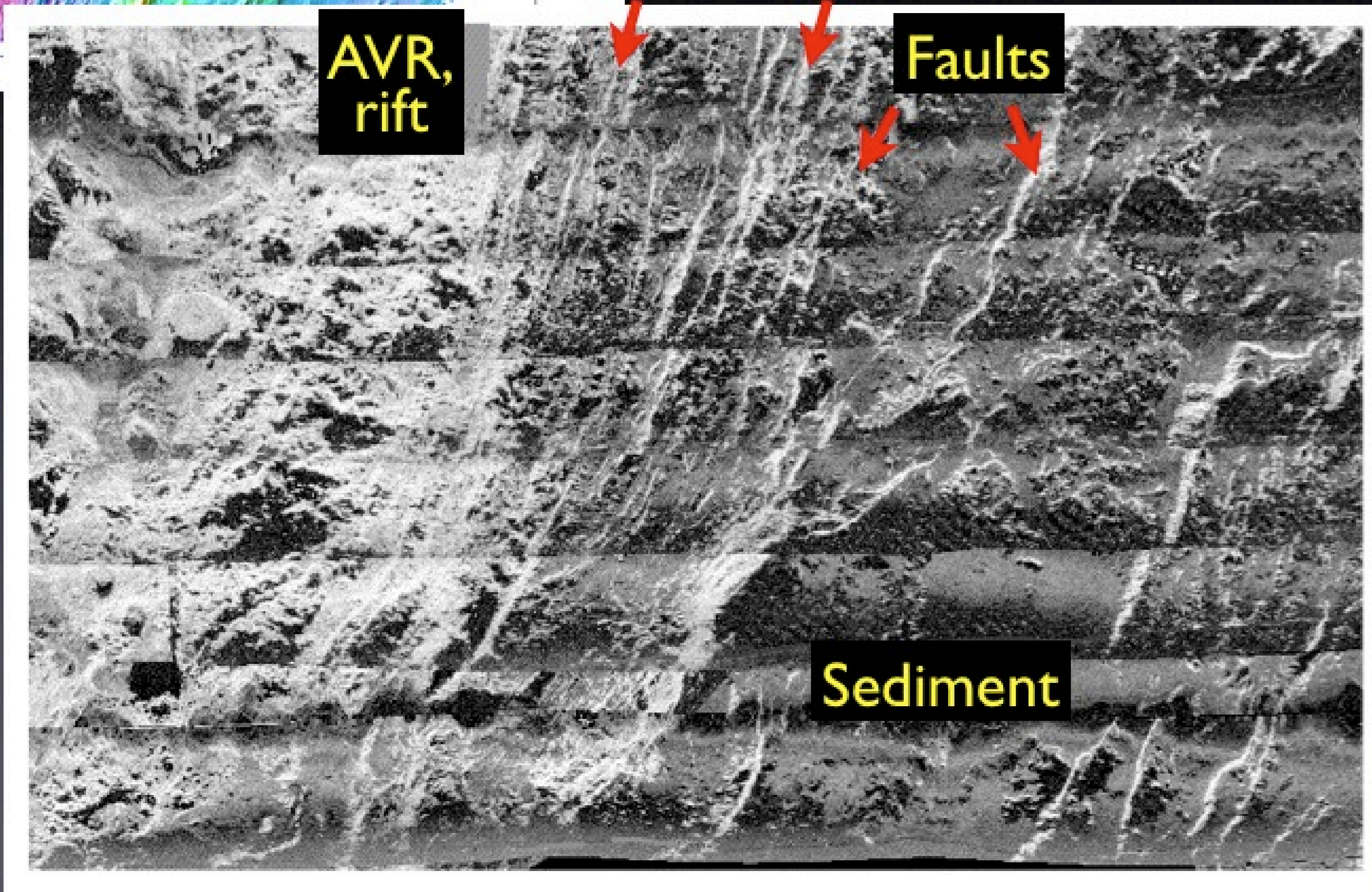


Rabain et al., EPSL, 2001

~10% Strain by high-angle faulting



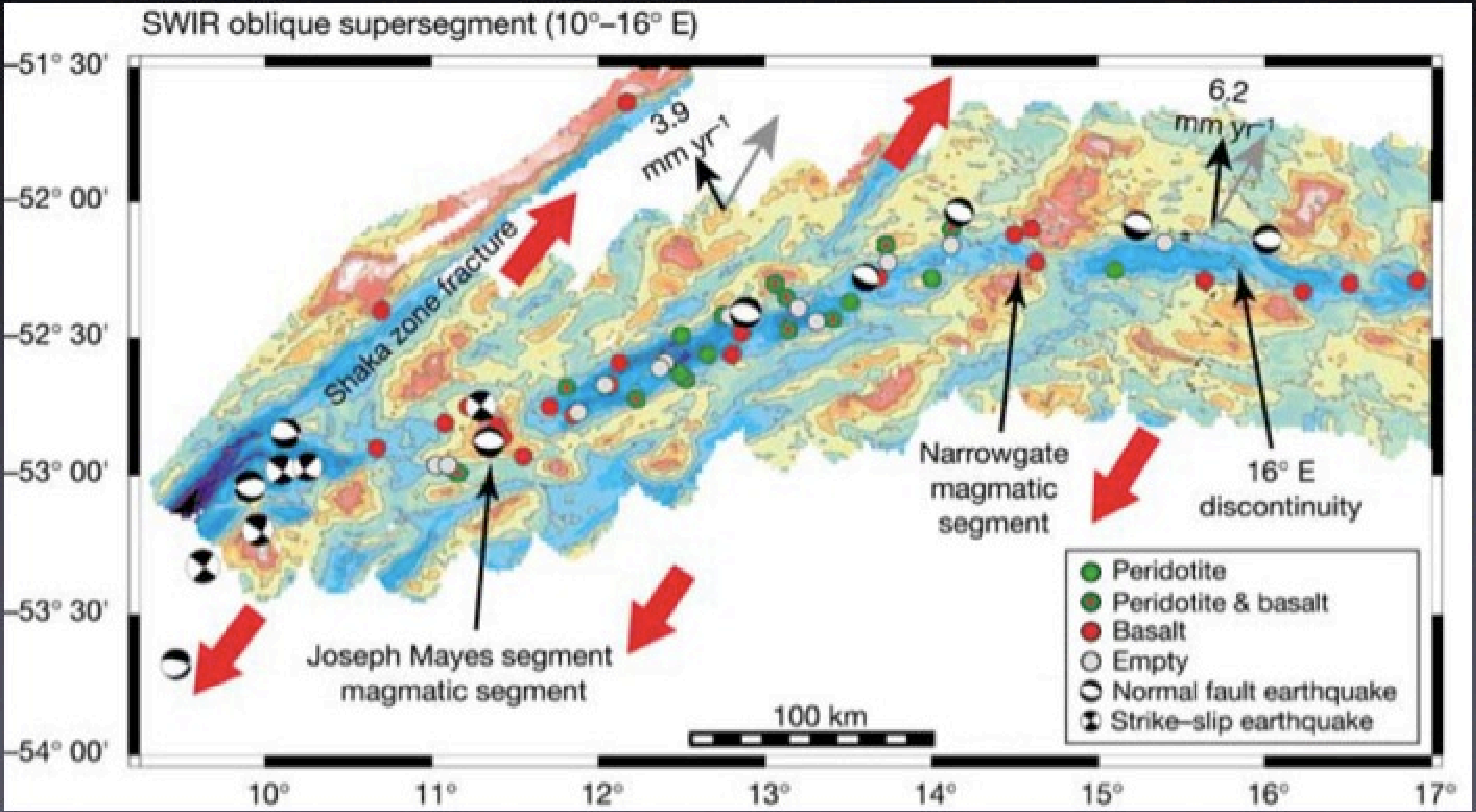




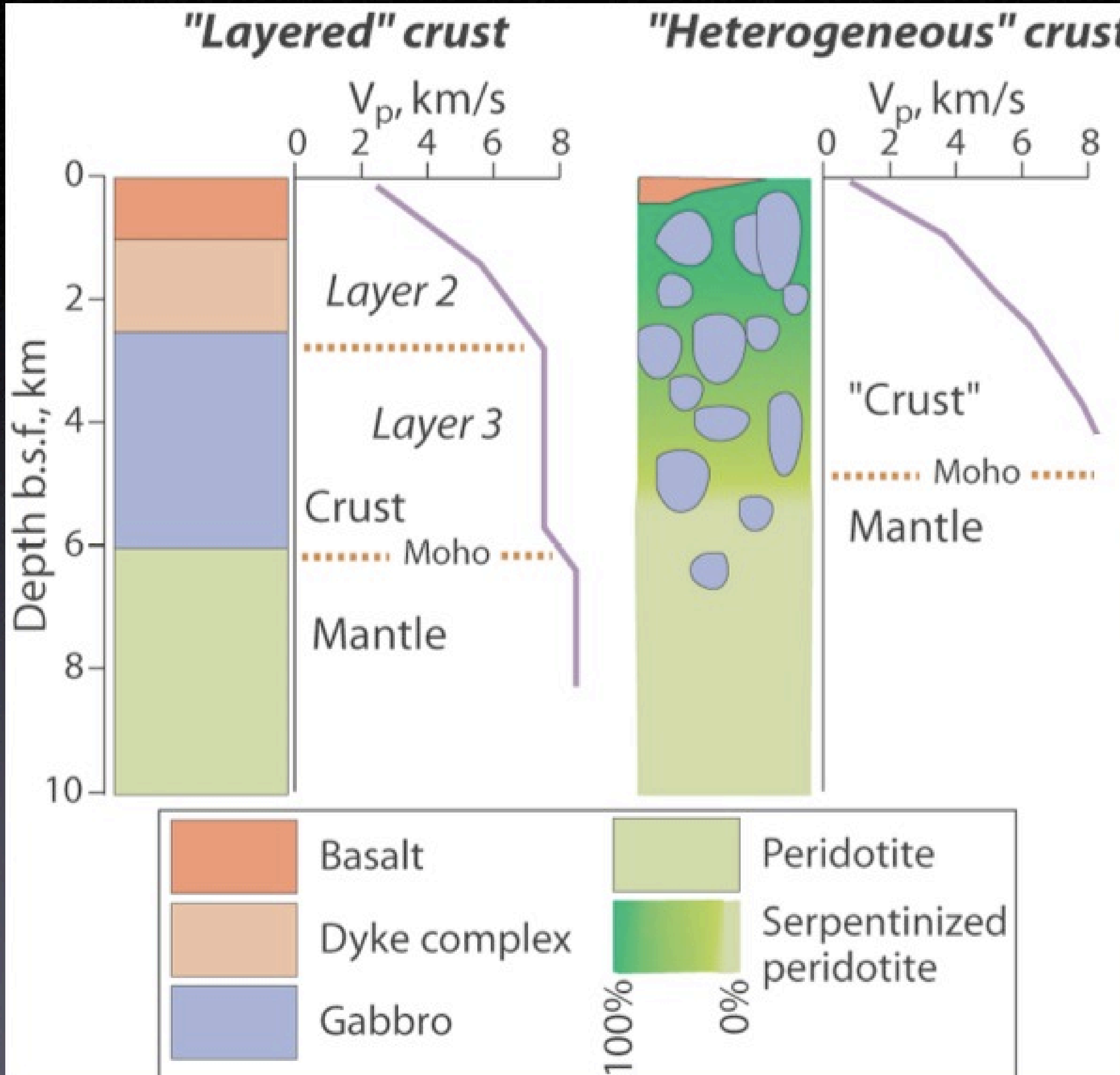
TOBI Sonar, 29°N (CD99)
Sound illumination from W

Searle et al., EPSL, 1998
Escartin et al., JGR, 1999

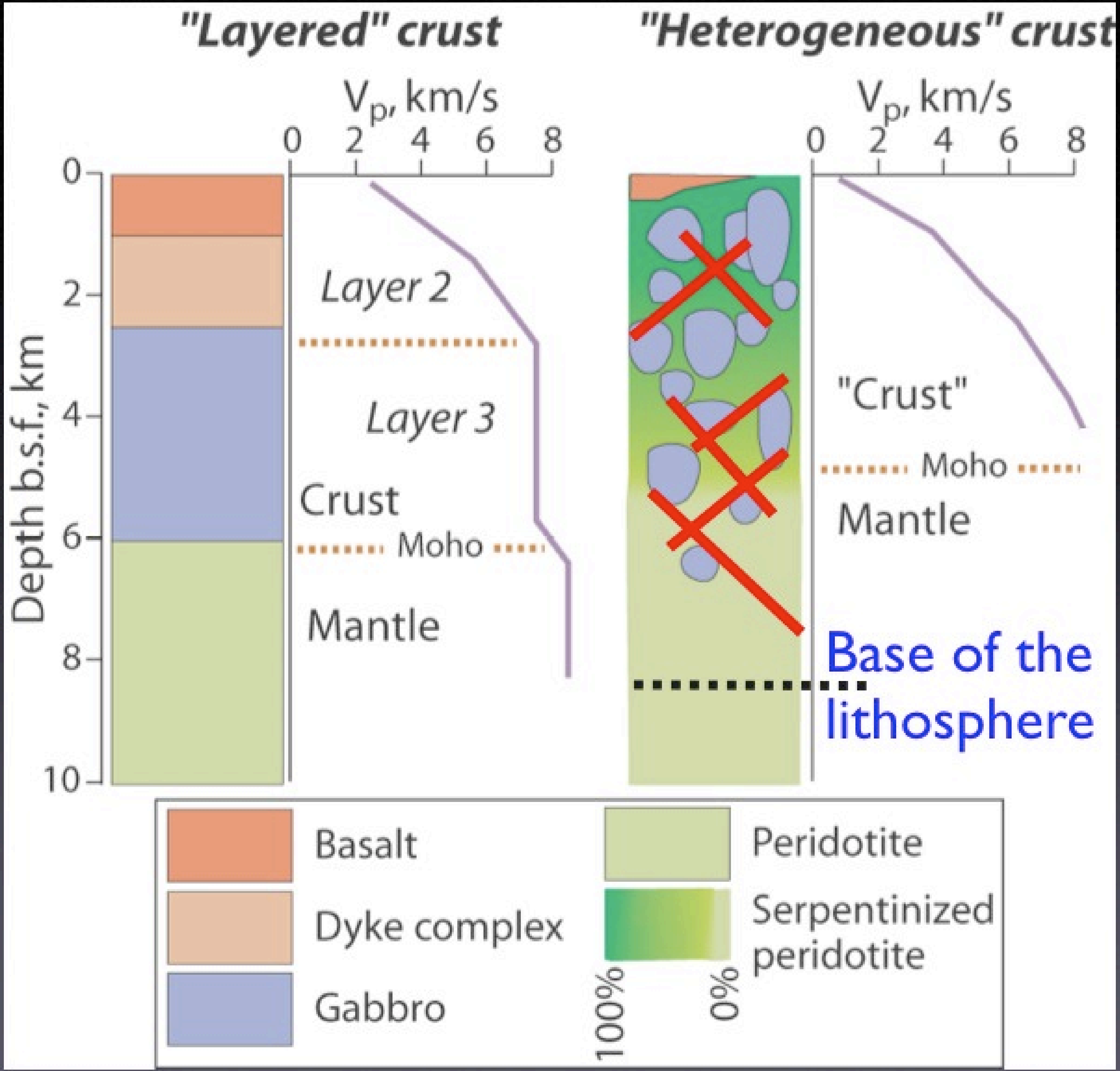
Outcrop of peridotites on-axis (Cannat, et al.):
Heterogeneous lithosphere (gabbro + peridotite)
Tectonic lift from lithospheric base to seafloor
No expression on seafloor morphology
No images of tectonic structure under axis (faults, etc.)



Dick al., Nature, 2003



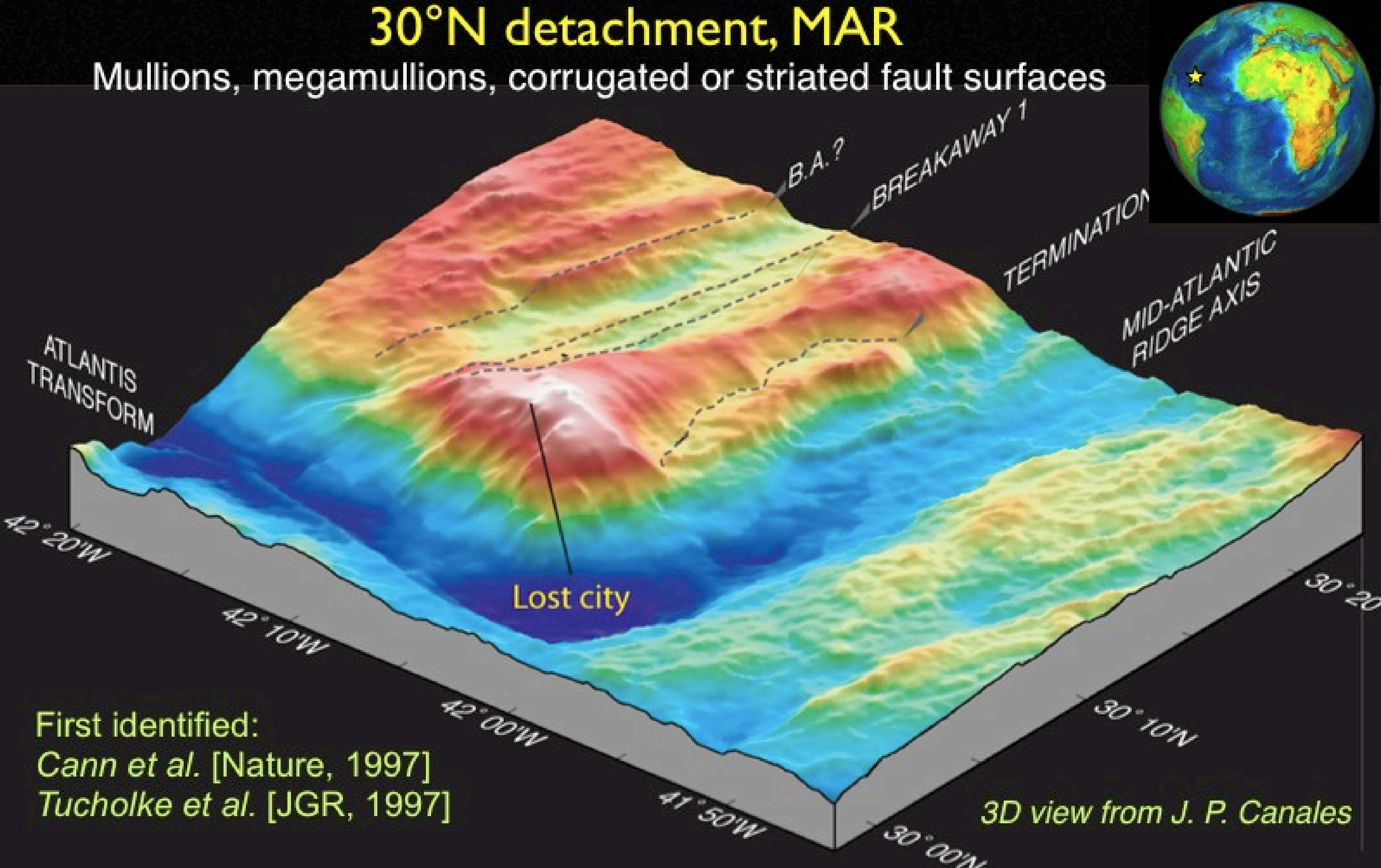
After Cannat [1993; 1995]



After Cannat [1993; 1995]

30°N detachment, MAR

Mullions, megamullions, corrugated or striated fault surfaces



First identified:
Cann et al. [Nature, 1997]
Tucholke et al. [JGR, 1997]

3D view from J. P. Canales

Oceanic low angle faults first identified end of 90's (speculated in '80's)
New mode of tectonic strain accommodations
Analogues to continental core complexes: key to understand their origin

Oceanic detachments

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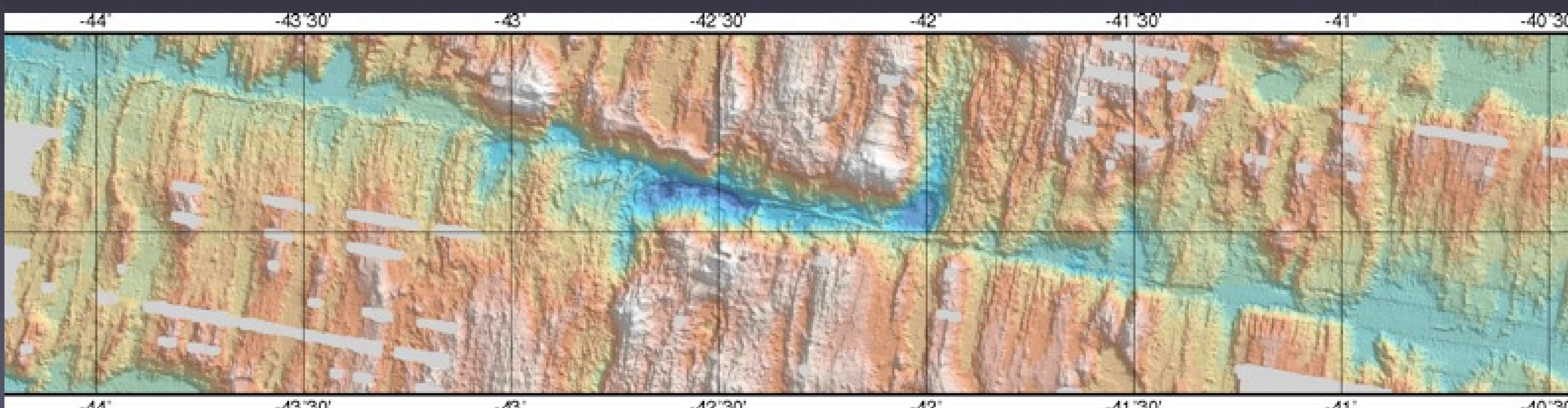
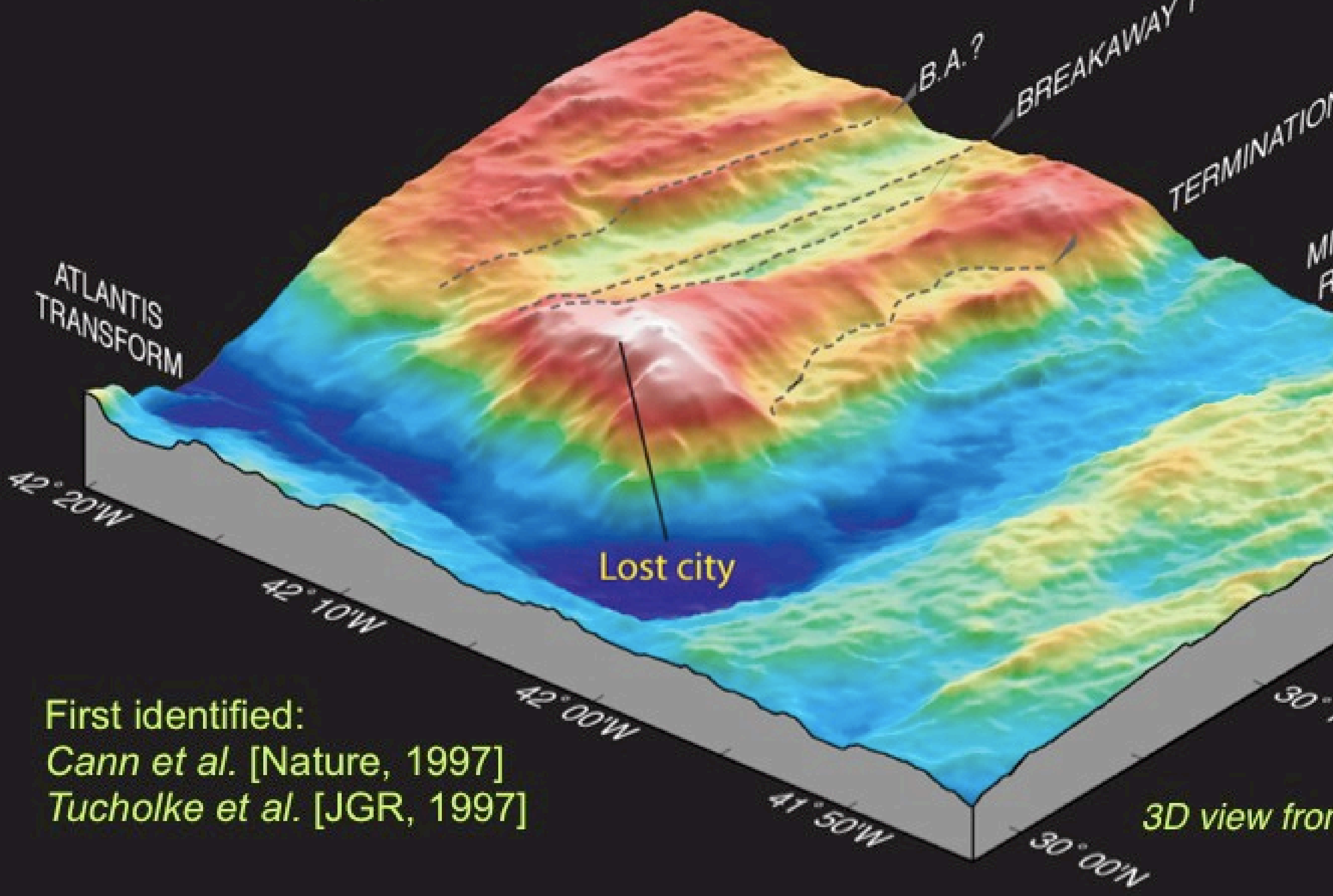
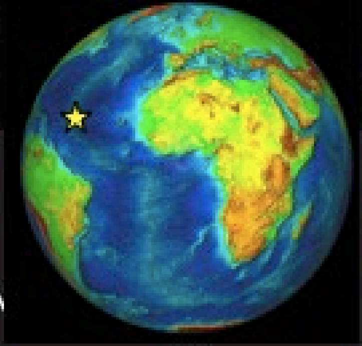


30°N detachment, MAR

Mullions, megamullions, corrugated or striated fault surfaces





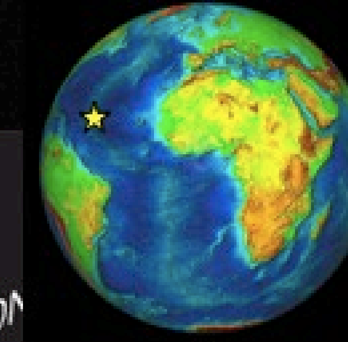
First identified:
Cann et al. [Nature, 1997]
Tucholke et al. [JGR, 1997]

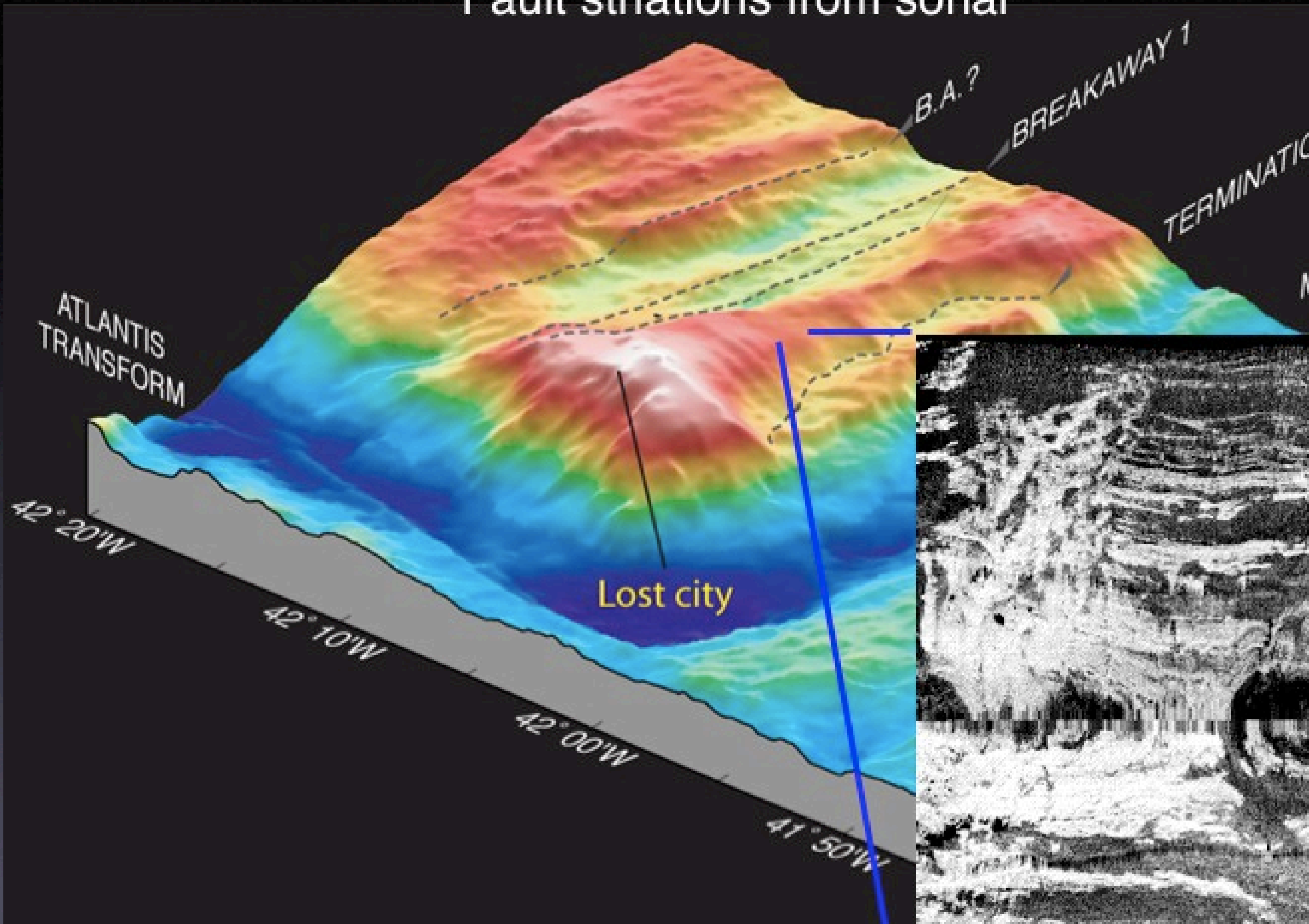
3D view from J. P. Canales

Smooth, domed surfaces, with low angle (<20° at termination)
Corrugations parallel to spreading direction
Gabbro and peridotite outcrops along their surface (limited dredging)

30°N detachment, MAR

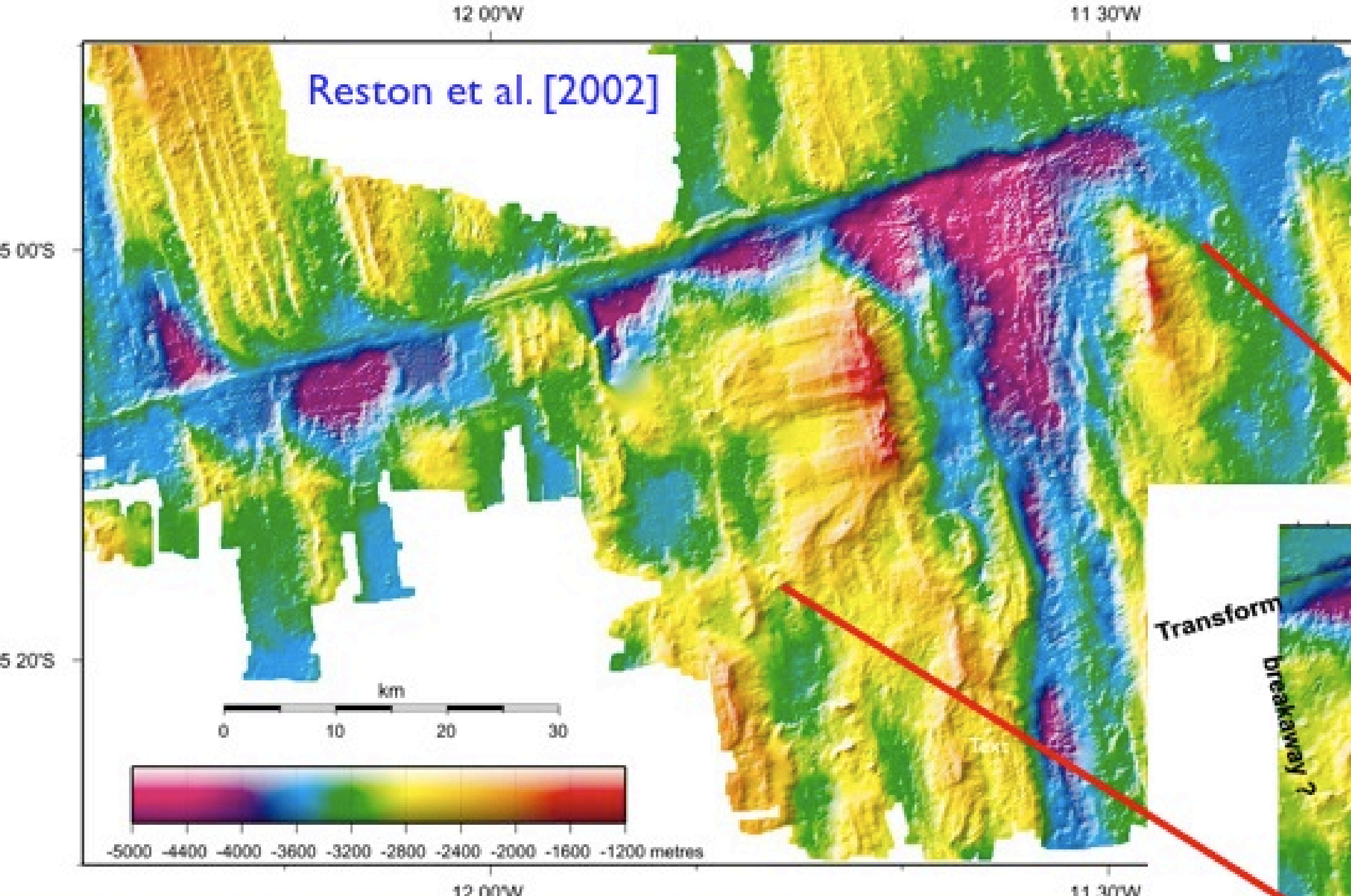
Fault striations from sonar

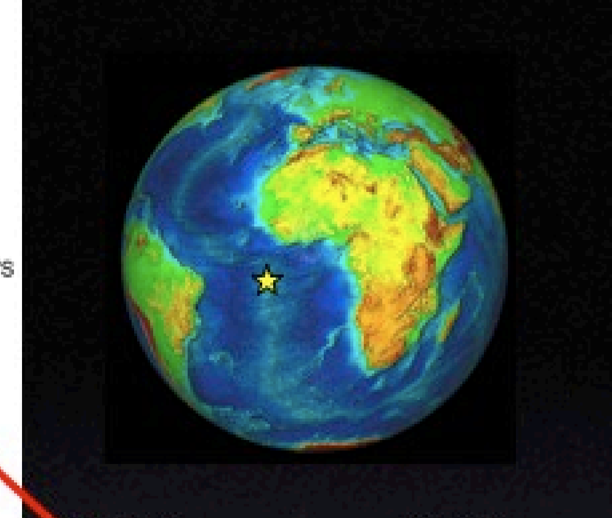


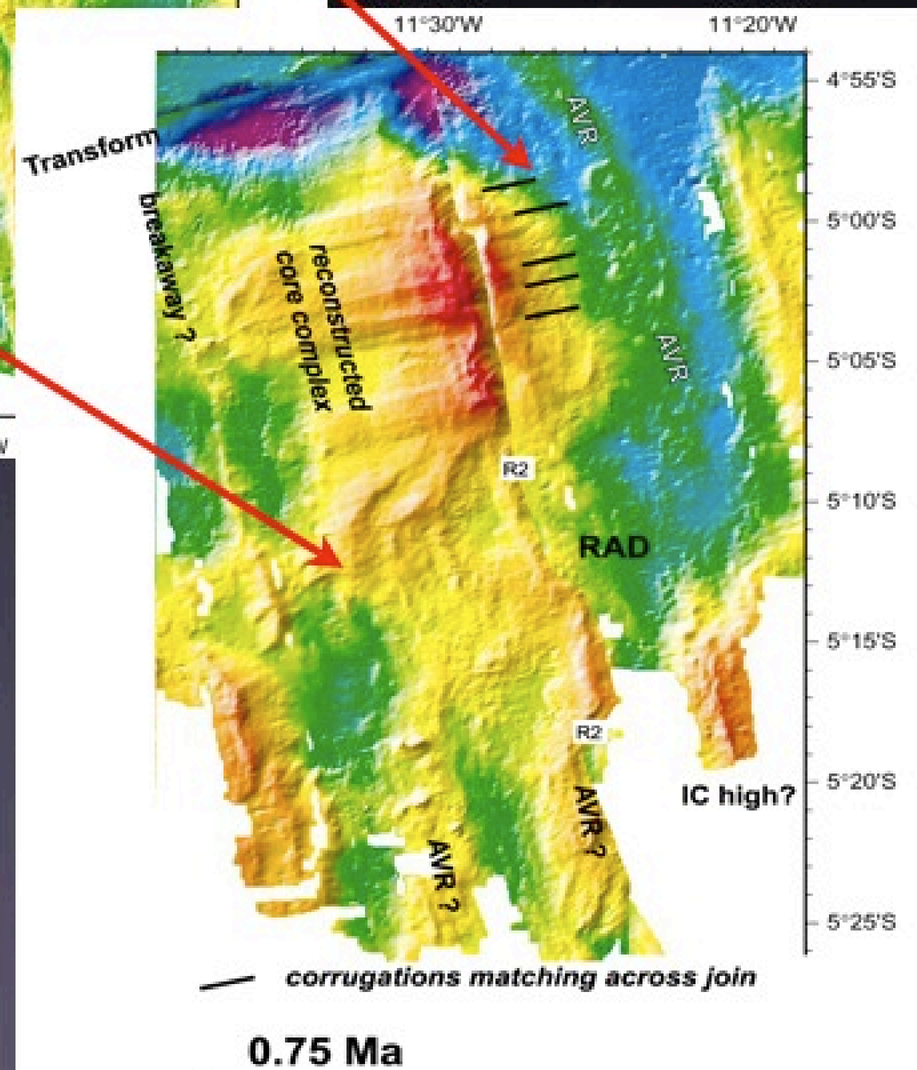


TOBI sonar, ~6x6 km

Cann et al. [1997]







Rifted detachments:
5°S & 35°N, Mid Atlantic Ridge

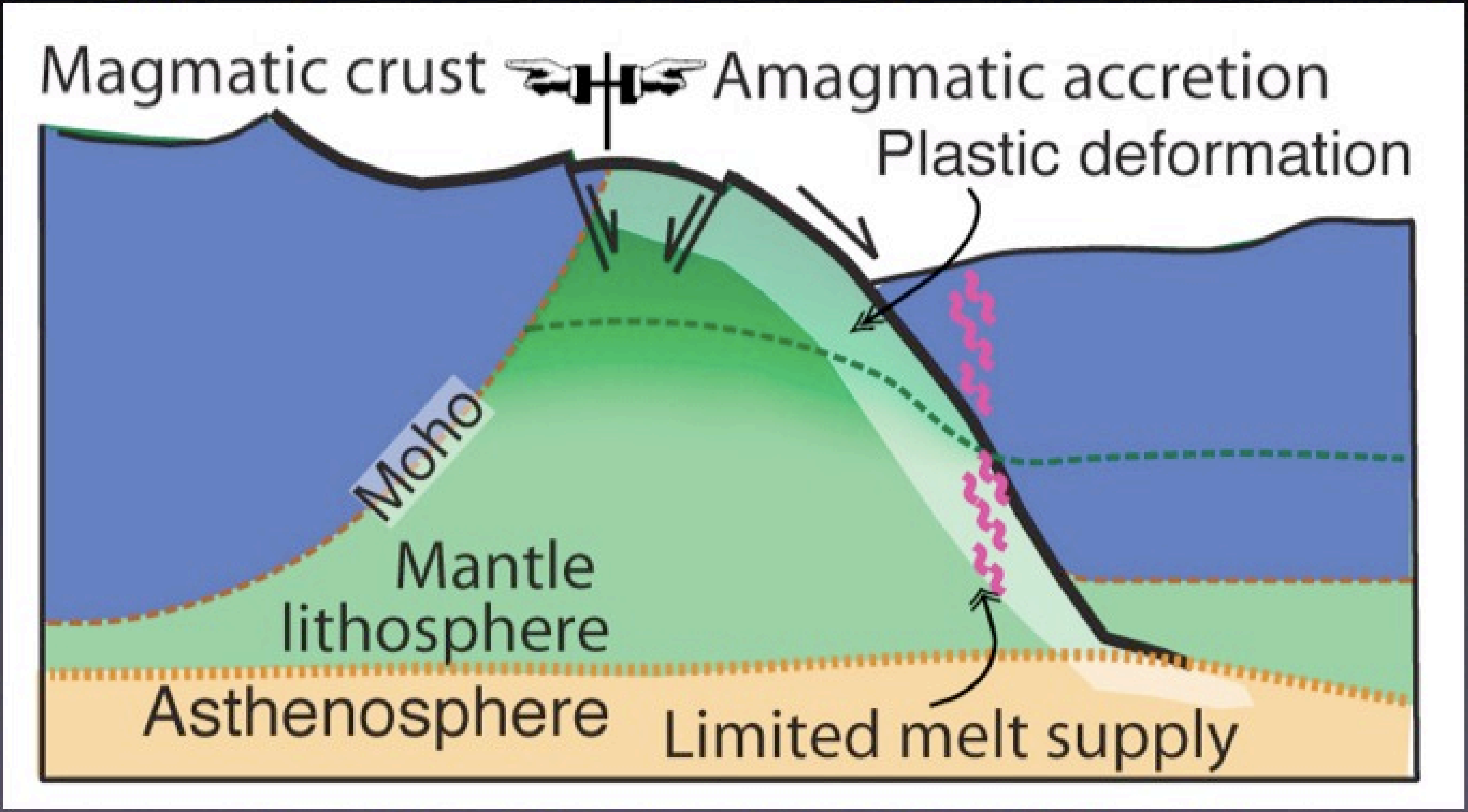
3. Deformation & composition

Fifteen-twenty detachment (MAR, 15°N):

Bridge Drill sampling, dredging’01, ODP 209’03 *geophysics’07*

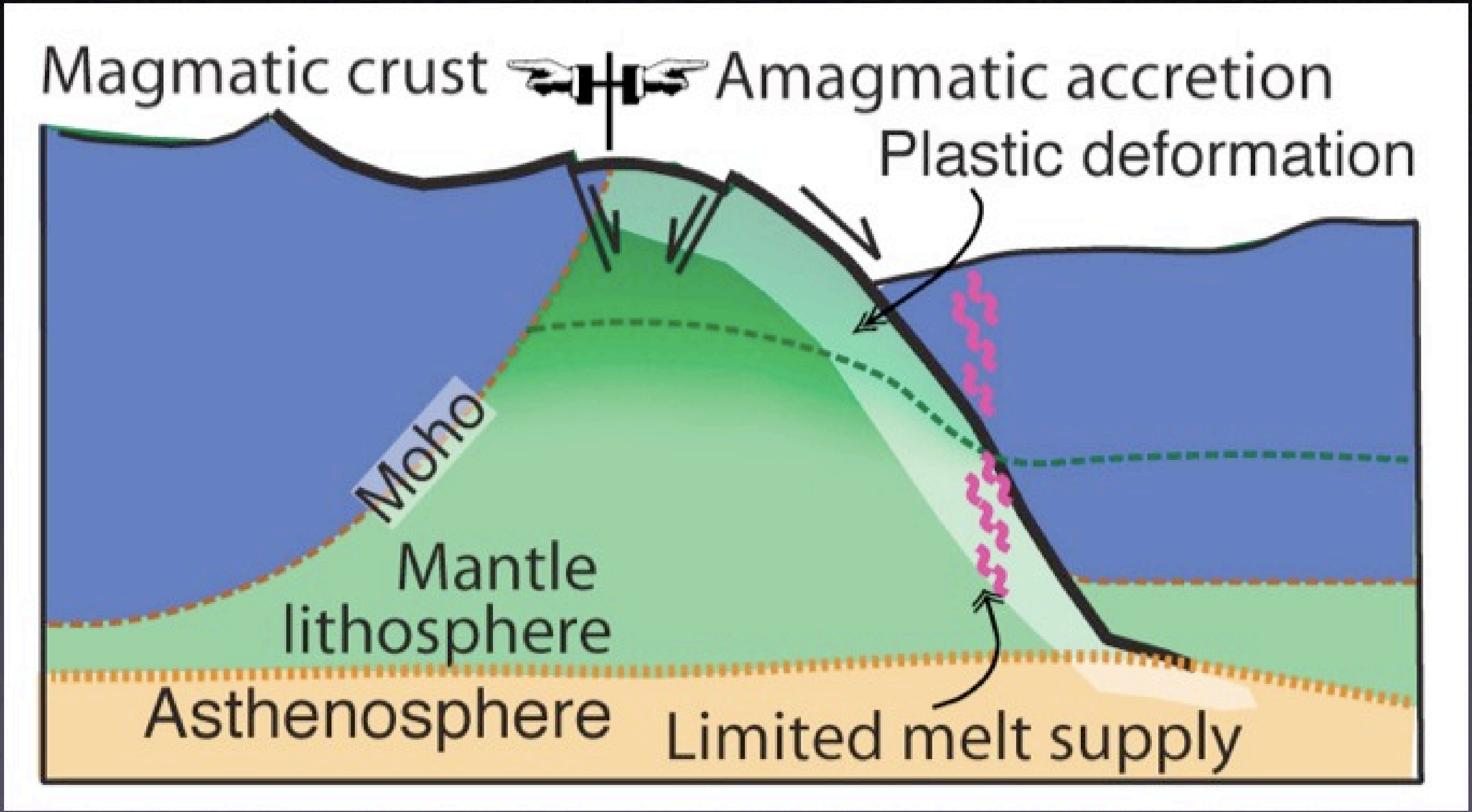
Atlantis (MAR, 30°N):

Geophysics, seismics ‘96-’03, Lost City’09-’05, IODP 304/305, ’04-’05



Interpretation of Tucholke et al.’s [1997; 1999] models;
After continental core complex models

Extension during low-magma supply
Rooting in base of lithosphere - plastic deformation zone
Tectonic window of deep lithospheric levels
Tectonic/passive accretion of mantle to the lithosphere



Interpretation of Tucholke et al.'s [1997; 1999] models;
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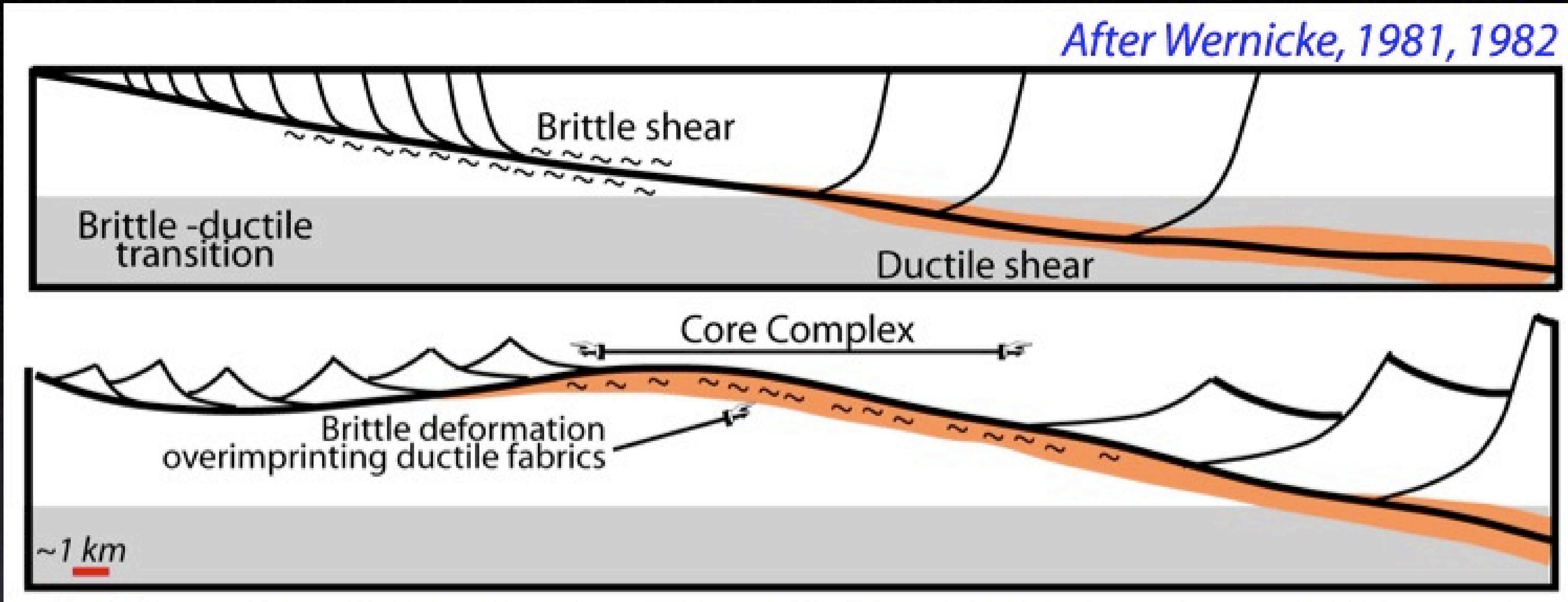


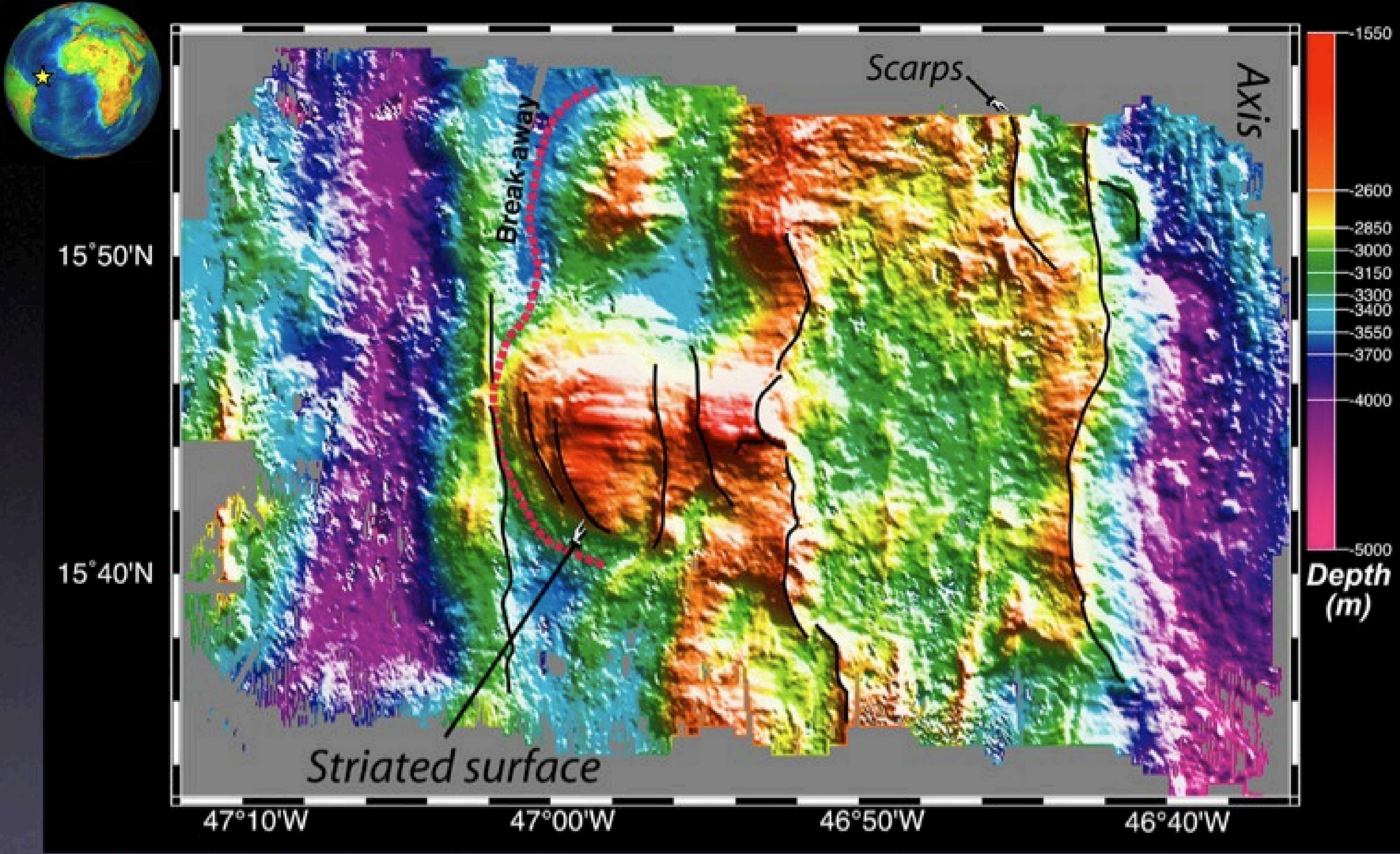
Wernicke [1981;1982]

Rooting in brittle - plastic transition

Deformation zone:

- Wide plastic deformation zone (>100 m)
- Overimprinting of semibrittle and brittle deformation
- Progressive strain localization to thin brittle fault (1 m)

Oceanic detachments: New mode of oceanic lithospheric accretion & possible key to continental detachments



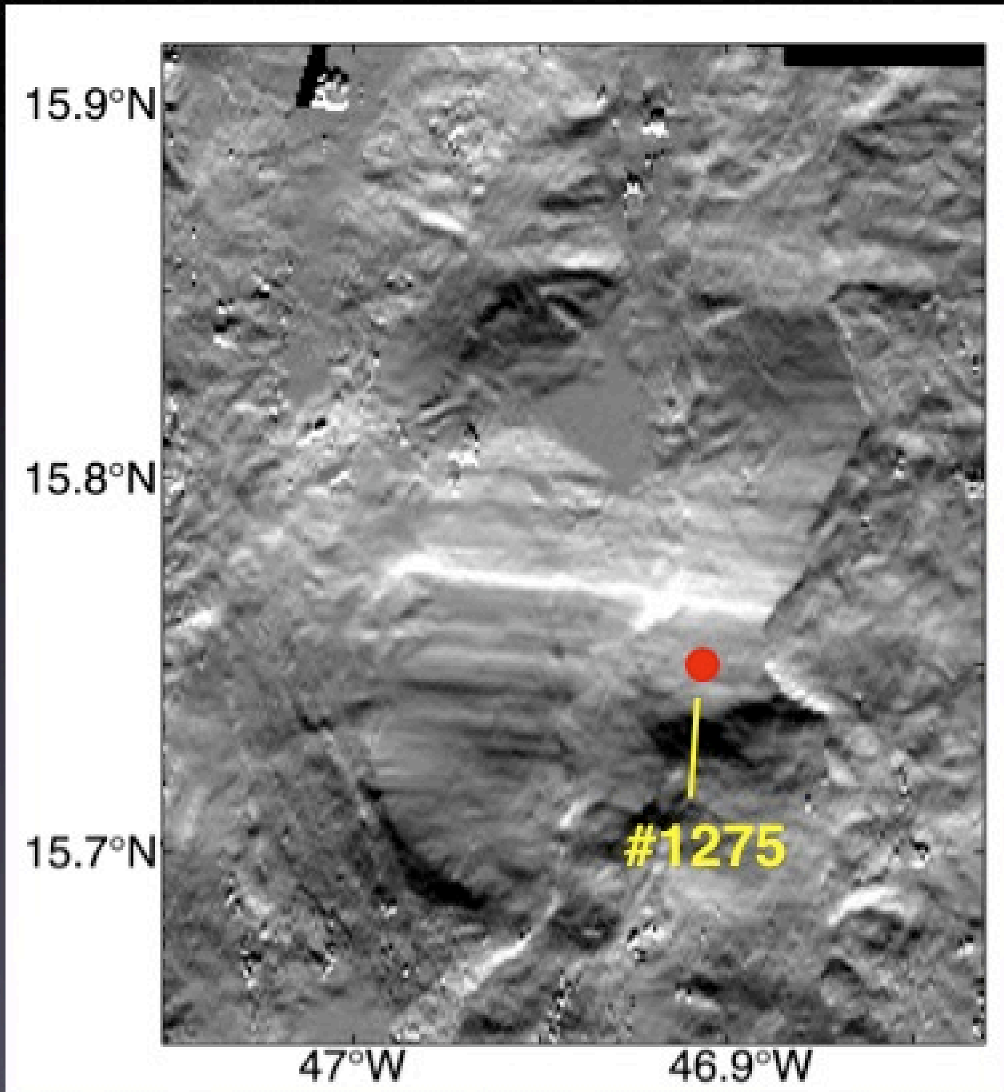
From: MacLeod et al. [2002] & Escartin et al. [2003]

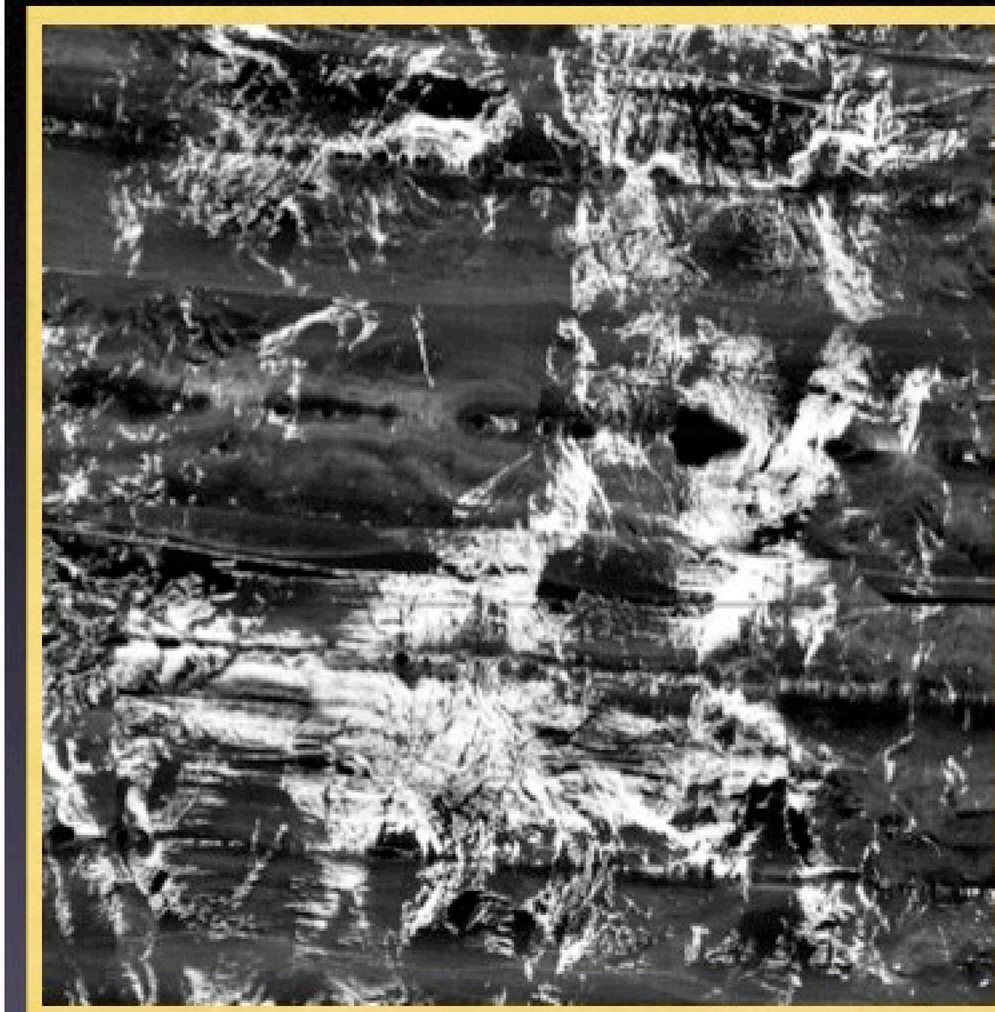
Footwall composition - Geological & geophysical constraints

JR63 BGS Wireline drilling ODP Leg 209 Hole#1275

WHOI TowCam Dives: MODE'98, FARANAUT

Geological constraints:
Striations and fault surface





From: MacLeod et al. [2002] & Escartin et al.

Geological constraints:
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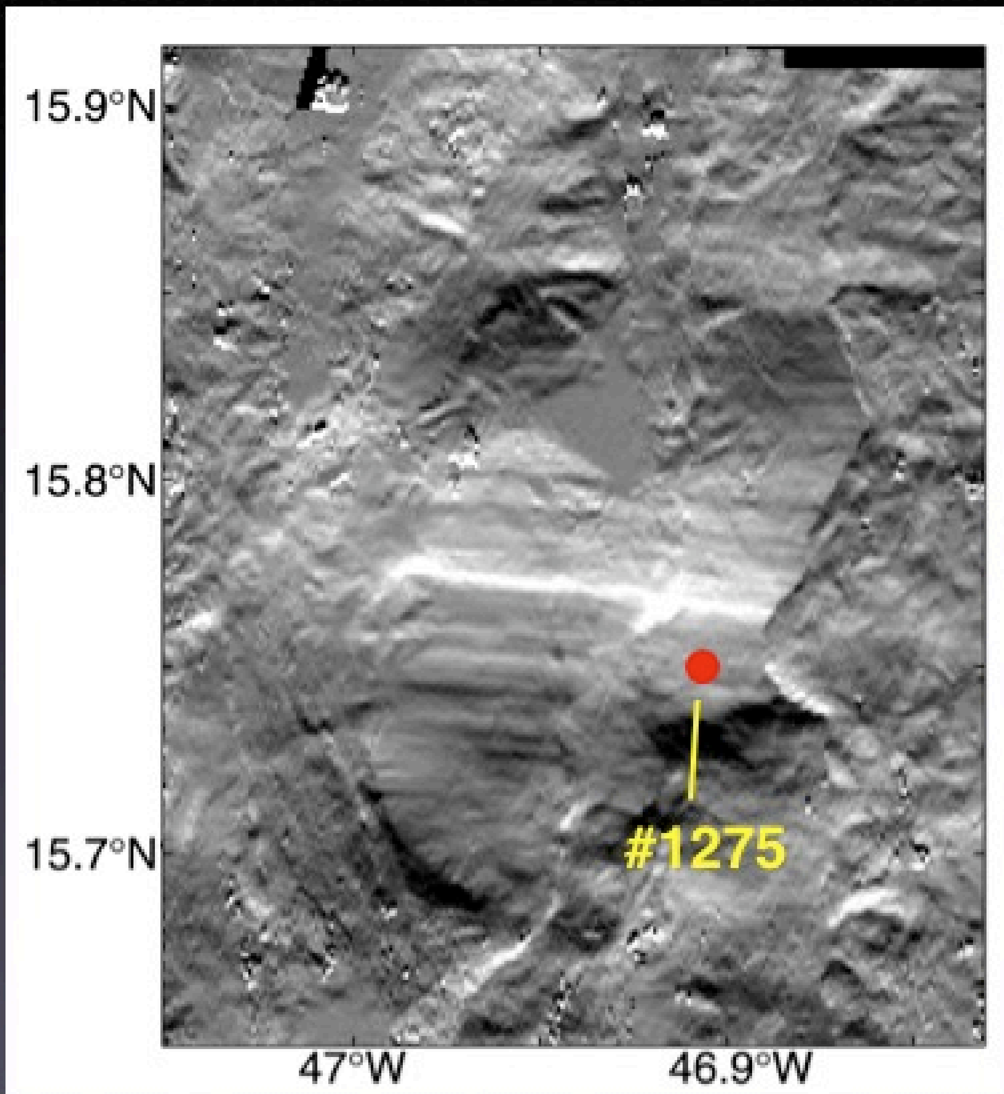
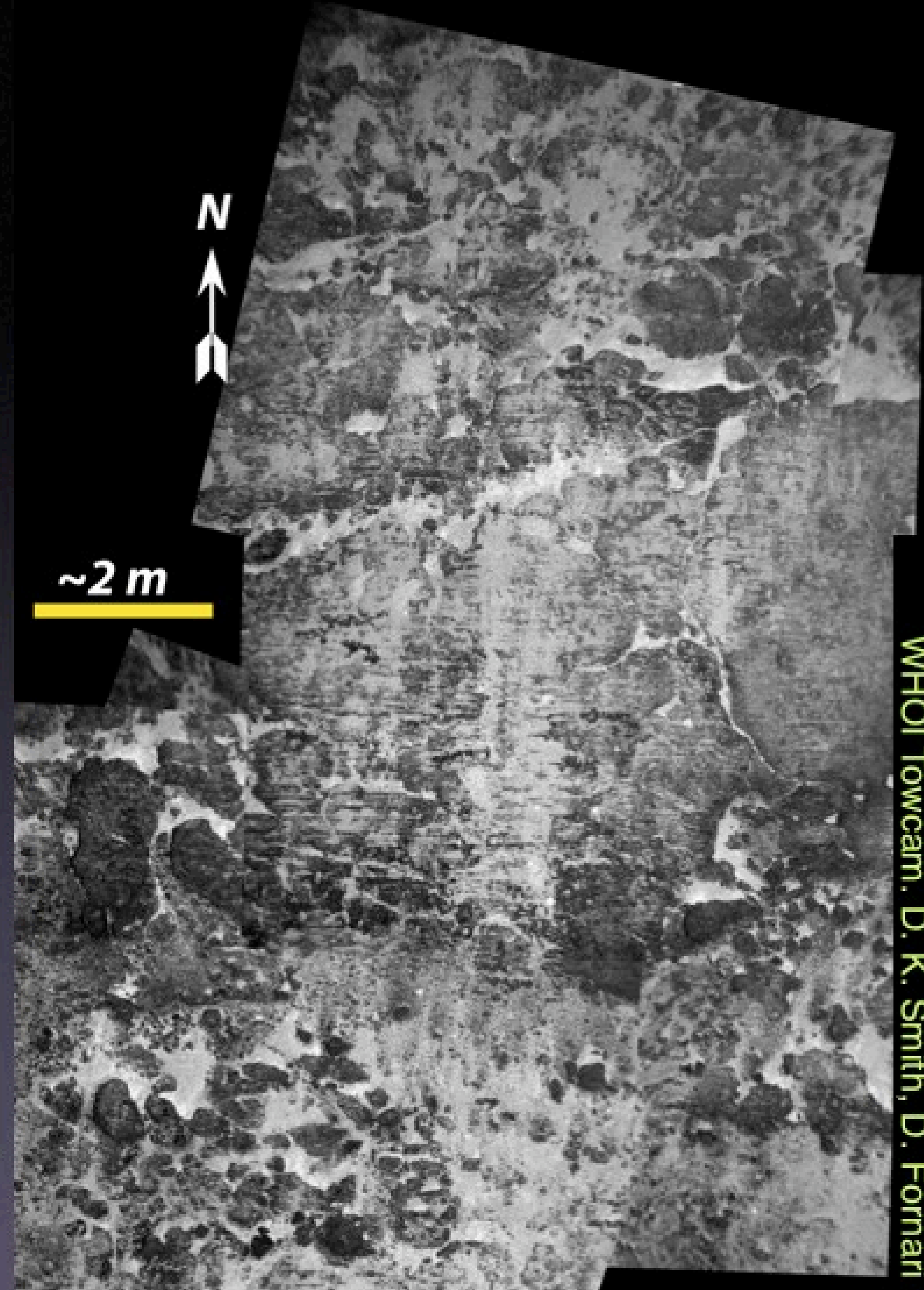
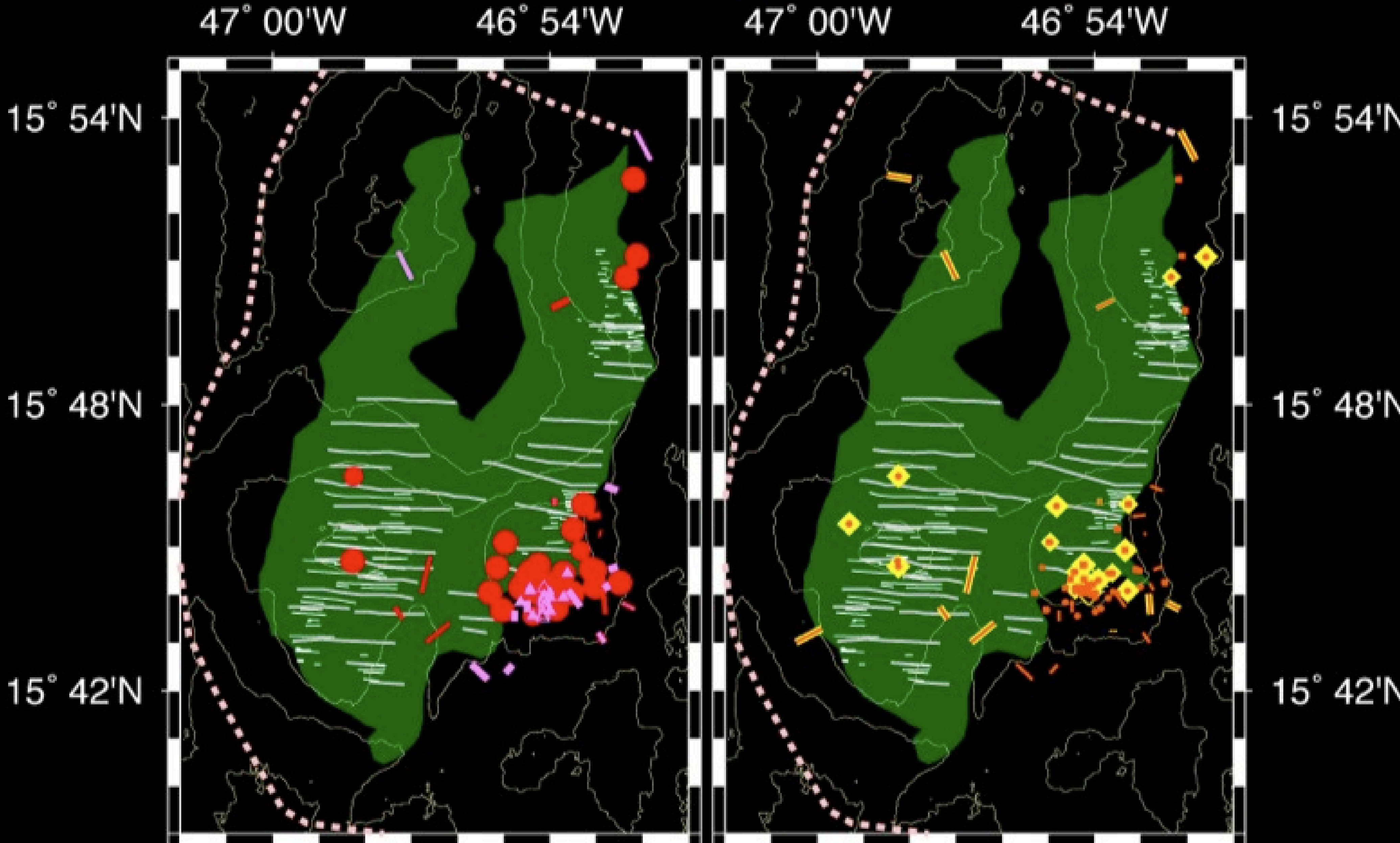




WHOI Towcam. D. K. Smith, D. Fornari

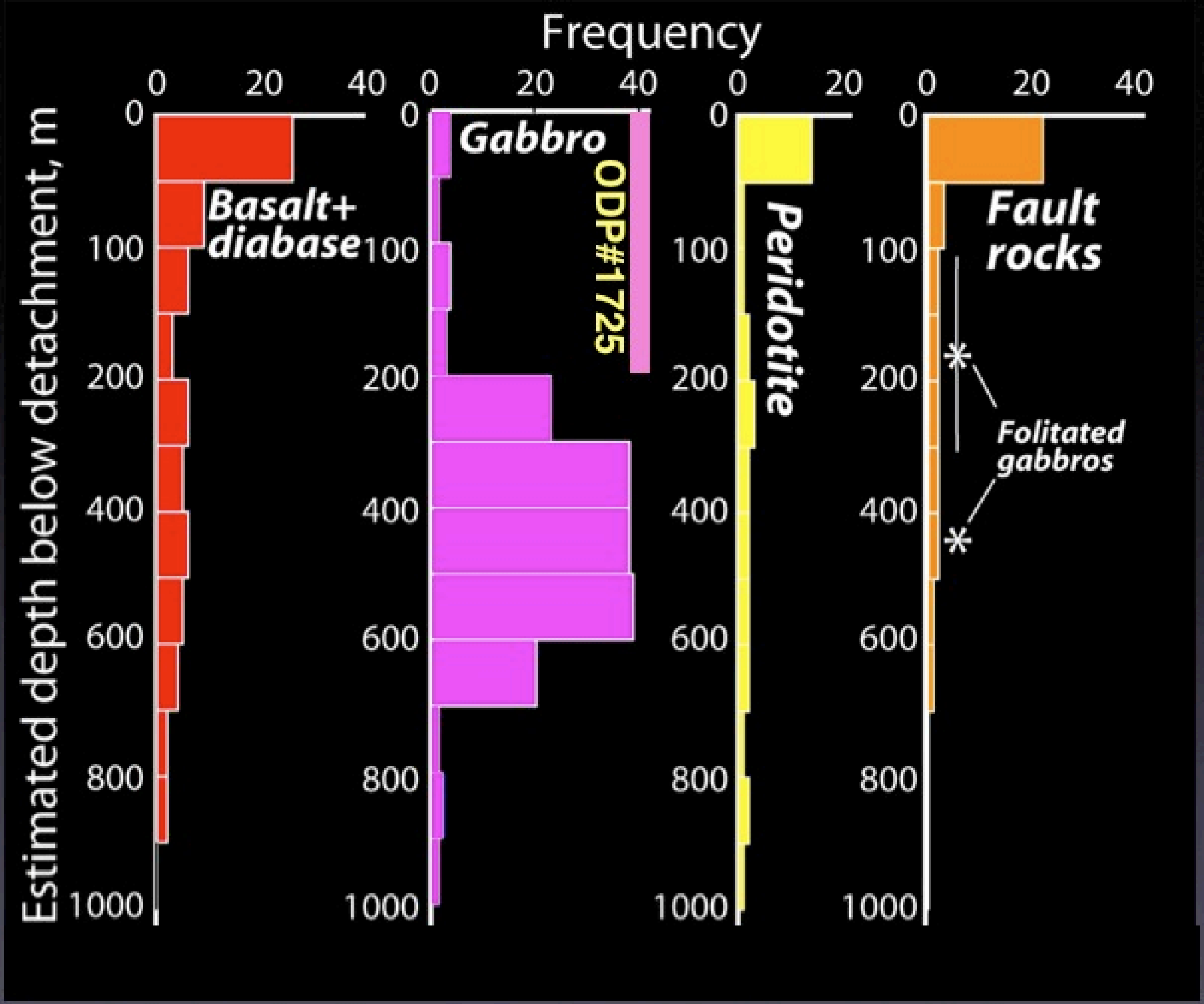
From: MacLeod et al. [2002] & Escartin et al.

Diabase - Gabbro - Peridotite - Fault rocks



No evidence of extrusives (pillow basalts, volcanic cones, etc.)

From: Escartin et al. [2003]



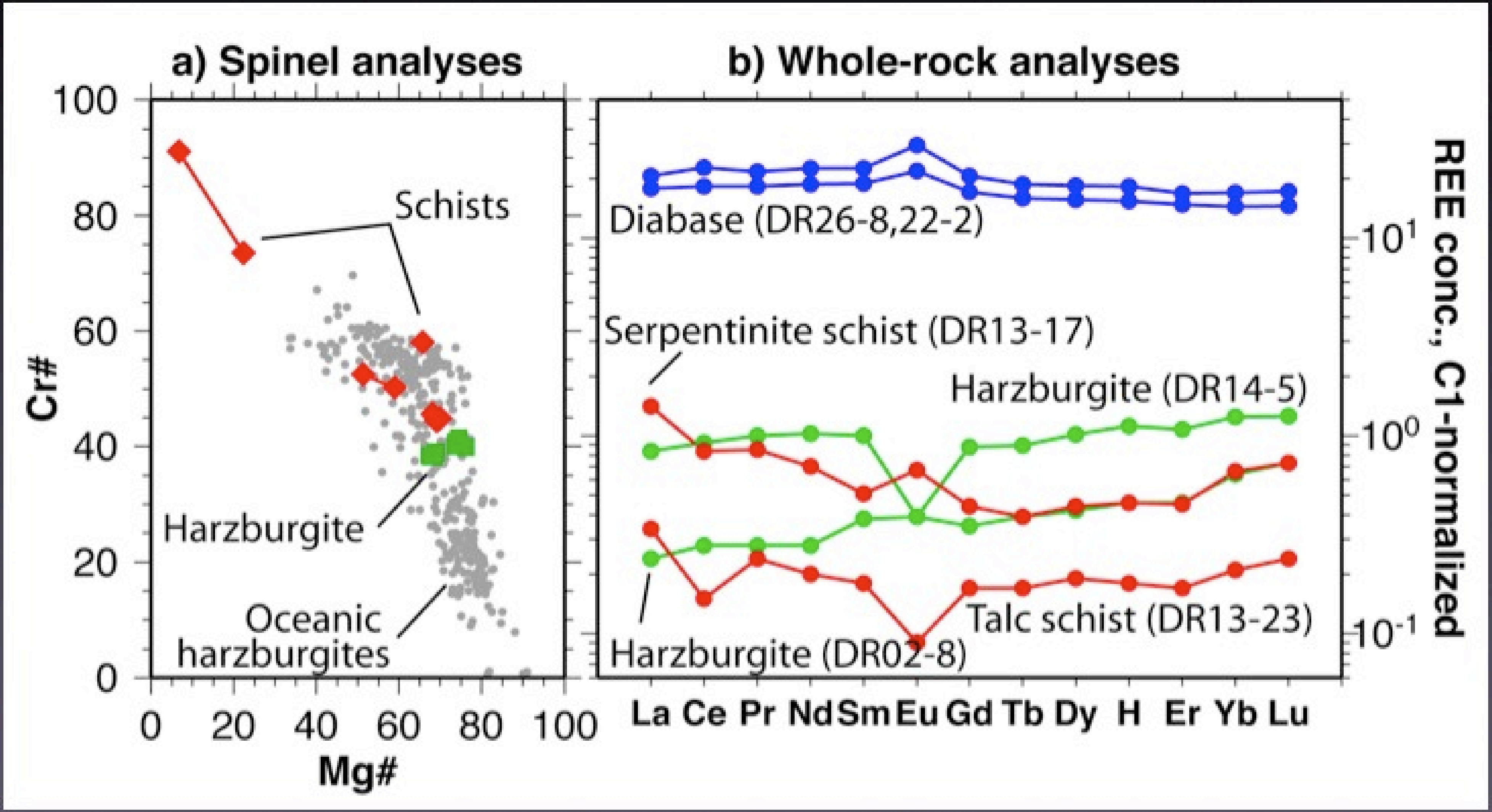
<100 m deformation zone with fault rock

Talc, amphibolite & serpentinite 'schists', Cl-rich

High-T deformation: Scarce, not clearly associated with fault

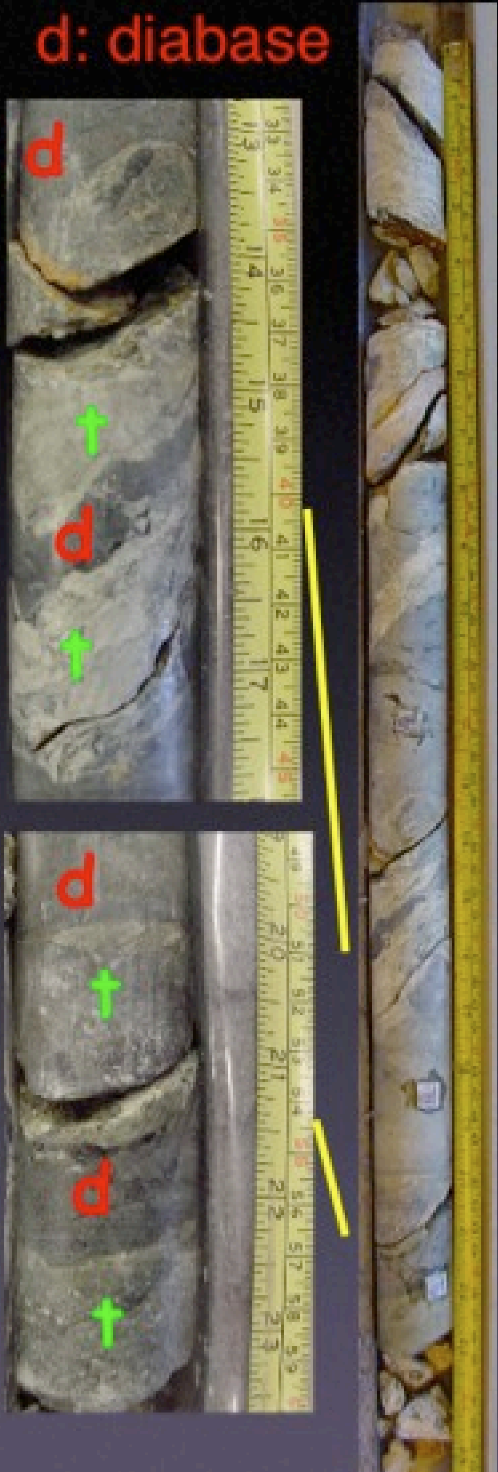
Fault rocks:

- Ultramafic protolith (relict spinels, REE)
- Metasomatism: Si from basalt/gabbro
- Focused fluid flow along fault & deformation



From: Escartin et al. [2003]

d: diabase



t: talc schist

Fault zone & rocks:

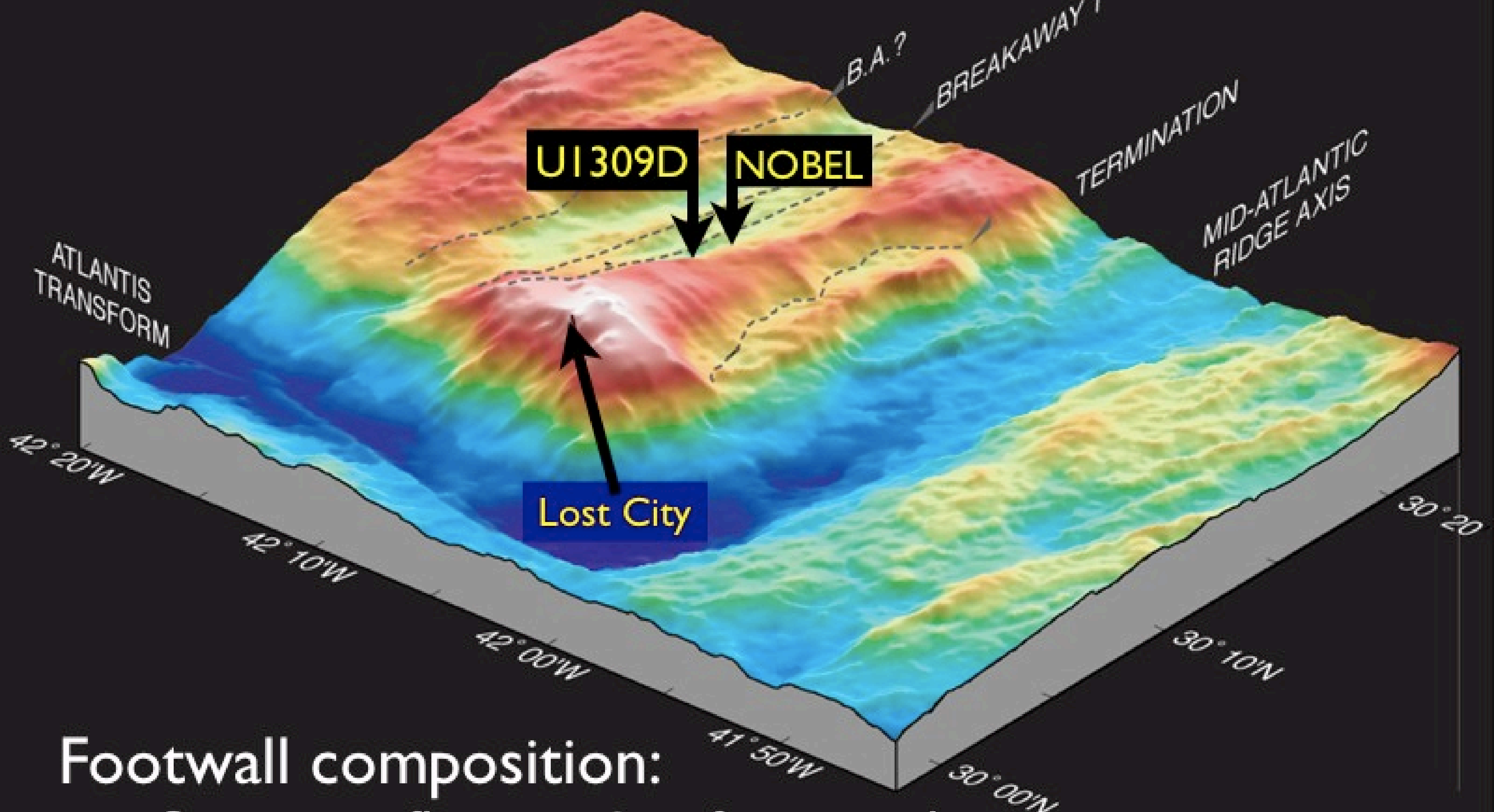
Thin (~100 m) fault zone
Talc & amphibolite derived from peridotite
Fault-parallel foliations

Coeval with magmatism:
- Chill margins against schists
- Magmatic clasts

Green-schist facies (T<400-500°C)

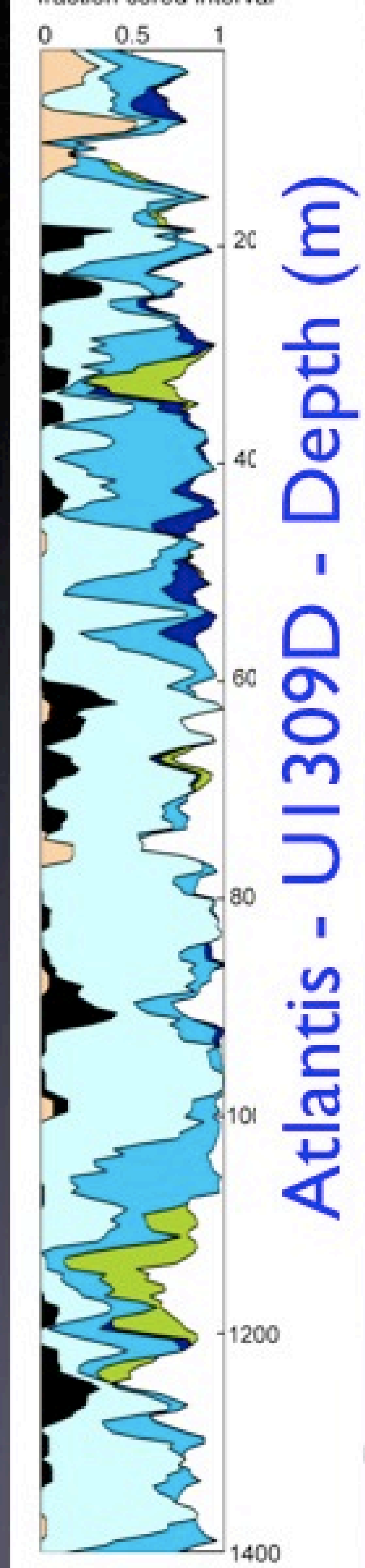
Similar to:
MAR : Atlantis FZ (MAR) Detachment
(Karson, John, Fruh-Green & Co.)
22°N (Tucholke) & 5°S (Reston et al.).
Also reported in Atlantis Bank, SWIR (Dick & Co.)

From: Escartin et al. [2003]



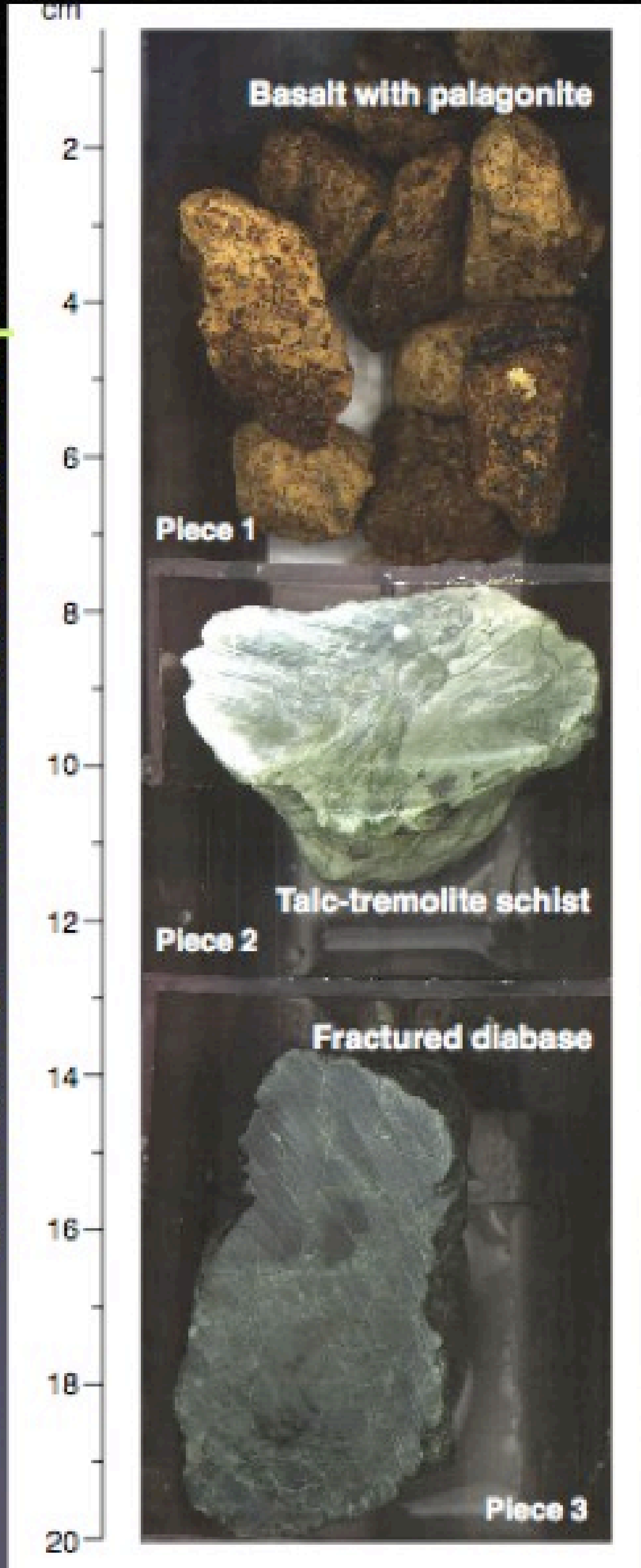
Footwall composition:

- Seismic reflection & refraction data
- IODP Drilling (2 legs, 1.5 km)
- Hydrothermal activity related to serpentinization
- Peridotite sampling along fracture zone wall

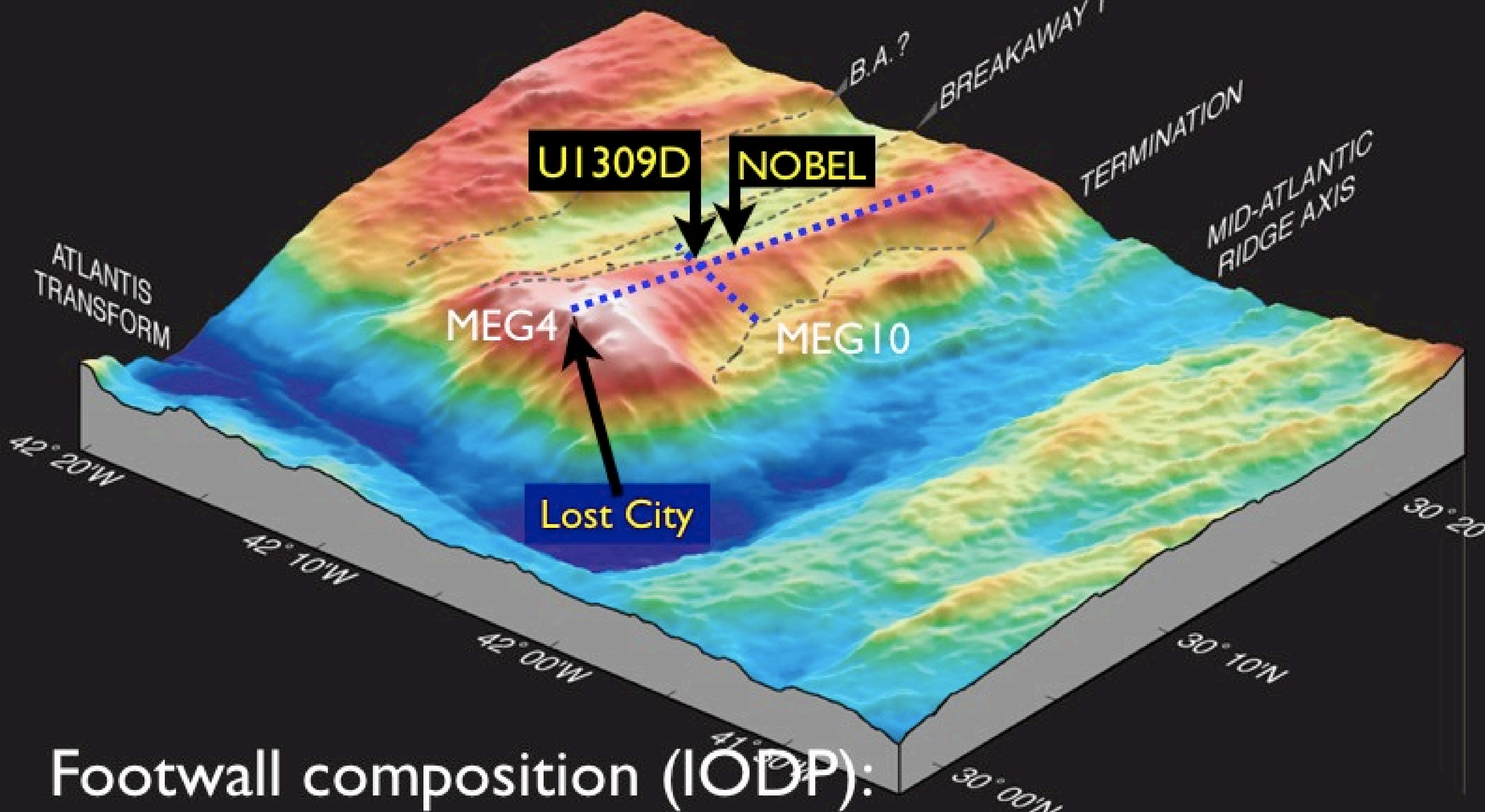


Atlantis - U1309D - Depth (m)

U1309G - Fault rocks at top



Rest: Undeformed gabbro (NO peridotite)

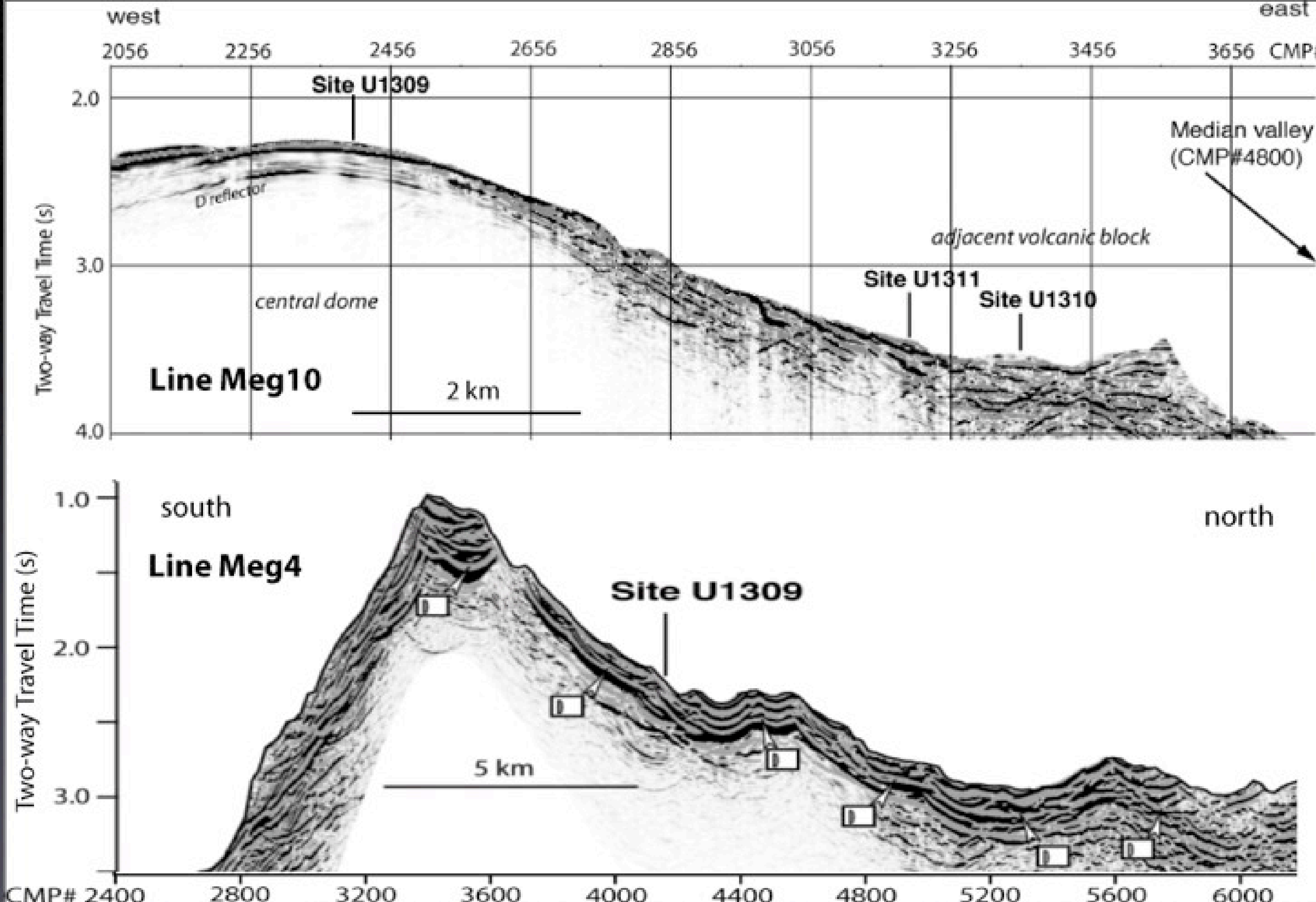


Footwall composition (IODP):

- 100-200 m of fault zone
- 1.5 km of gabbro (!)

Long story short: tested lithospheric heterogeneity

Geological data not concordant with geophysics



Canales et al. [2004]

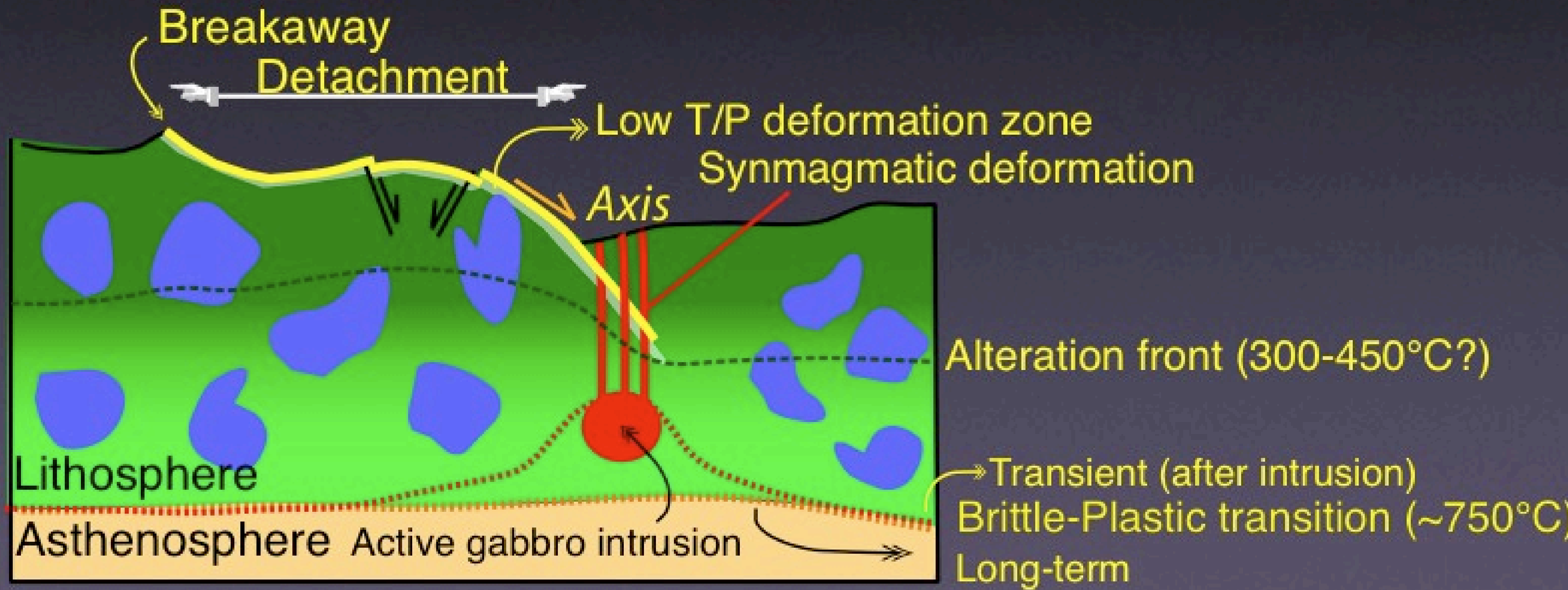
Reflector & velocity gradient at 500 m

Fresh peridotites: Vp>8 km/s at >500m; Lost City site

ODP drilling 2004/05: 1.5 km gabbro

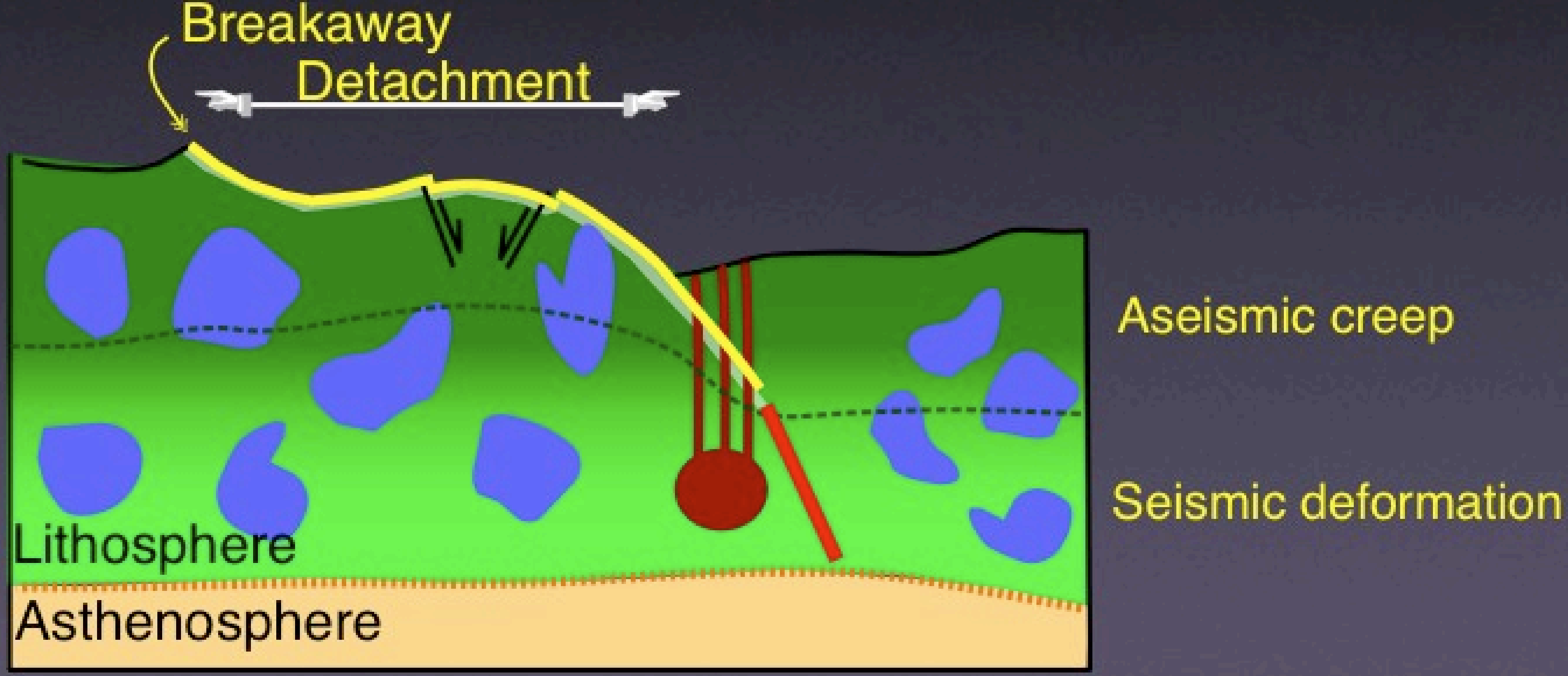
Recap of observations 1/2

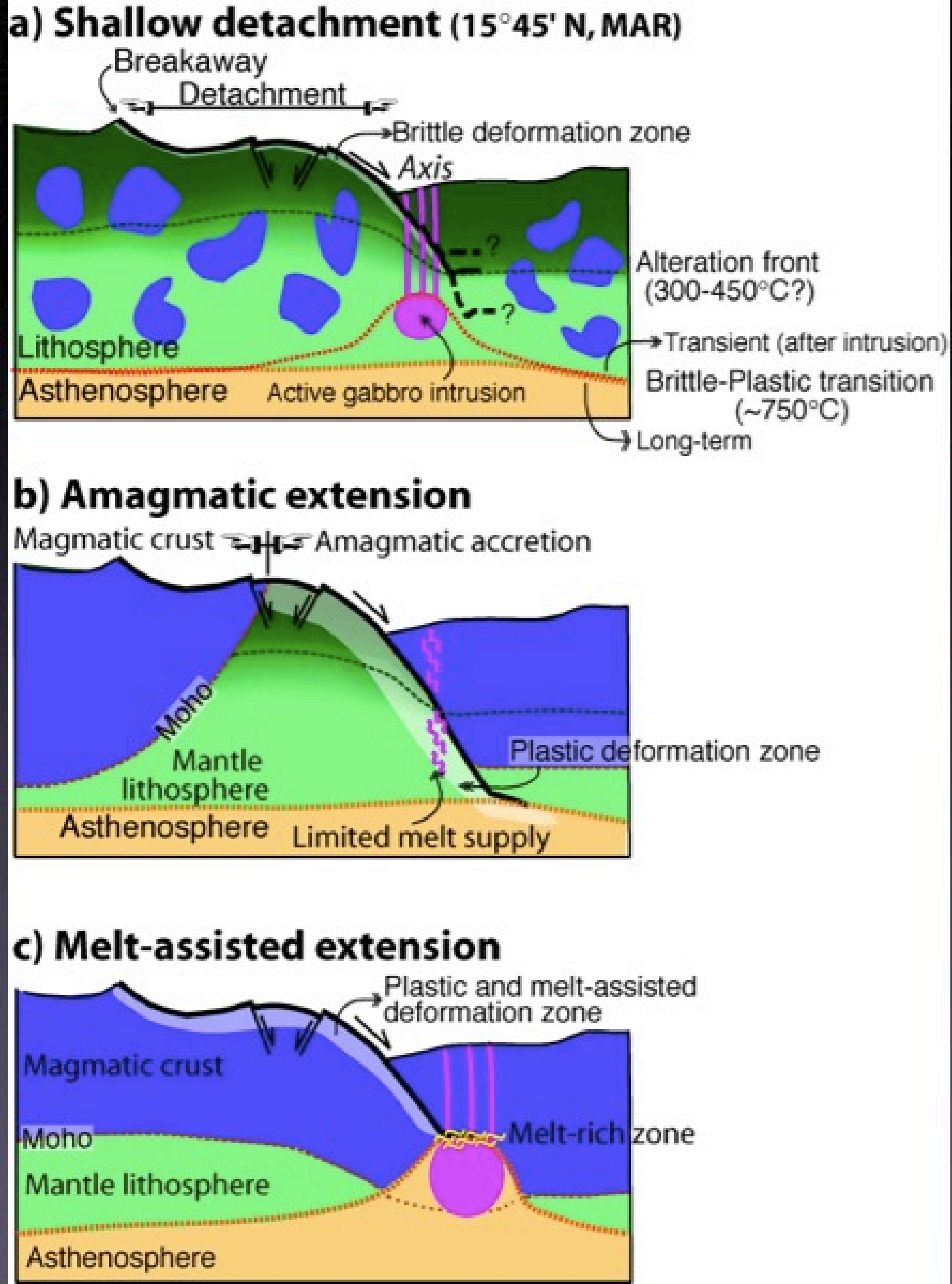
Thin fault zone (~100 m) recording low T/P deformation
Linked fluid flow, magmatism and deformation
No evidence of deep, hight T/P deformation
Long-lived structures (~1-3 Myr)
Shallow fault at surface; geometry at depth unconstrained



Recap of observations 2/2

Seismicity at deep levels (~3-8 km, TAG detachment)
Active surfaces over large portions of the MAR (hydrophone)
Aseismic creep in shallow levels:
- Serpentinites, talc, fluids and other weakening processes
- Limit may correspond to alteration front



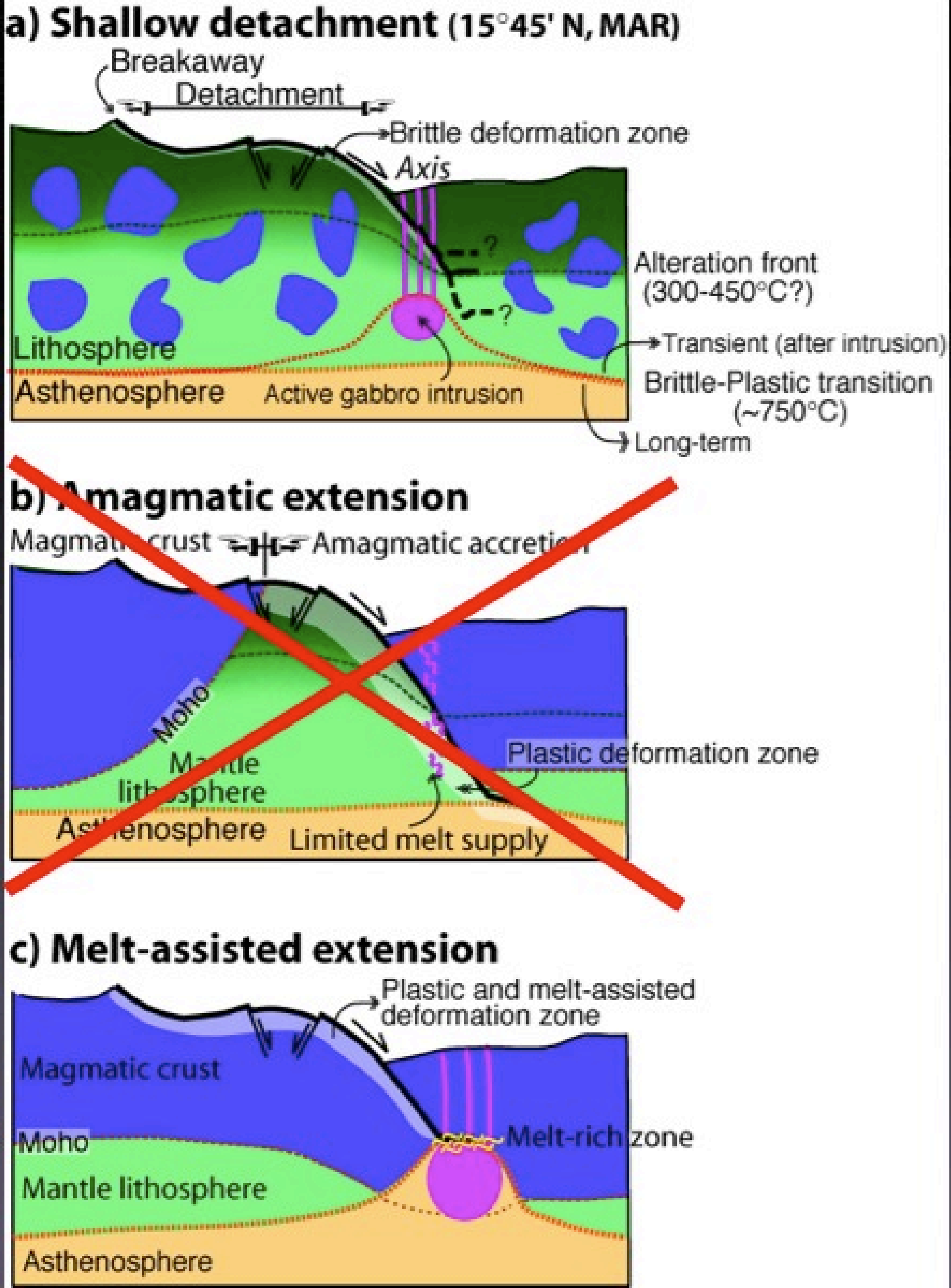


Escartin et al. [2003]

15°45'N, MAR
Atlantis, MAR 30°N
(Kane, MAR 21°N)

Needs modification to include seismic constraints

Atlantis Bank, SWIR



Escartin et al. [2003]

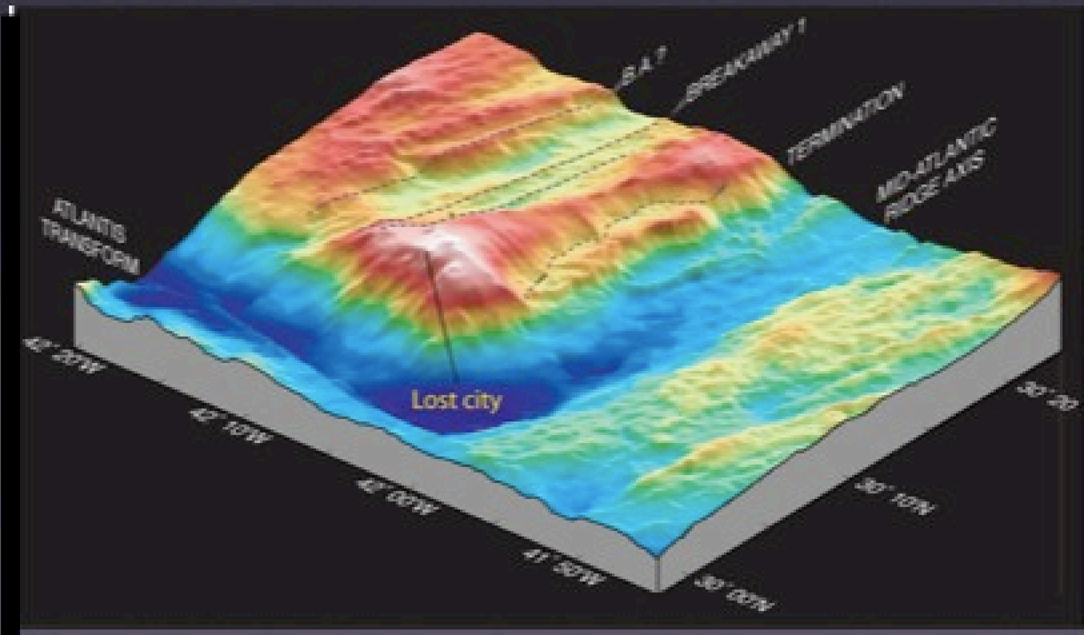
4. Open questions and perspectives

Contribution of detachments to tectonic lithospheric accretion: are they more pervasive than previously thought? - Need reevalutation of existing data, comparison among sites, and integration of new results

Feedback between detachment-related extension & magmatism - Modelling

Geometry at depth: rooting of faults & deformation conditions - Microseismicity (other than TAG), drill holes, and seismic surveys

Why do they form? Indicators of specific magmatic, rheological and/ or tectonic conditions



Rheology of talc (and other alteration products) & fluid interaction
G. Hirth, B. Evans

Tectonic rotations, displacements, and fluid flow (MAR 15°N)
C. MacLeod, J. Carlut, A. McCaig

Nature of seismic reflectors (30°N) J. P. Canales, S. Singh

Seismic activity & reevaluation (13°N) D. K Smith, J. Cann, M. Cannat

Numerical modeling N. Ribe