Observing the Structure and Effects of Terrane Accretion at Depth through Patterns of Seismicity in Colombia's Cauca Cluster

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Abstract

The Cauca Cluster of seismicity in western Colombia is the most extensive and persistent collection of intermediate (>60 km) depth earthquakes that cannot be easily associated with a subducting slab. The cluster stretches over an area of ~390 km by ~250 km from 2.5°N to 6°N and from 75.5°W to 77.75°W in a wedge-like zone of seismicity thickening from ~25 km in the west to ~125 km in the east. Prior tomographic results suggest that the lower edge of this feature is contained within the subducting Nazca plate's oceanic lithosphere and corresponds to the Wadati-Benioff zone (WBZ) seen in most slabs, however this cannot explain the full thickness of the cluster. Large earthquakes within the cluster have been reported since at least the 1960s-70s and a great number of smaller events have been reported since the establishment of the Red Sismológica Nacional de Colombia (RSNC)'s regional catalog in 1993. Here, we relocate more than 6,700 events from the RSNC's catalog beginning in 2010 and extending for ~10 years to dissect the Cauca Cluster's structure and relationship to seismicity below 10 km depth. We find that while 40% of this seismicity can be associated with the Nazca plate's WBZ, 35% occurs as features completely or partially within the overlying forearc mantle. These features include: 1) three focused centers of seismicity at ~90, ~100, and ~120 km depth extending ~30 km perpendicular to the WBZ; 2) a feature dipping at an angle shallower than the WBZ between 10 km and ~75 km depth; and 3) a diffuse zone of seismicity extending from the WBZ to ~10 km depth. None of these features extend beneath the active volcanic arc, and as such are limited to the stagnant corner of the mantle wedge. We find that these features are also limited to an area affected by the late Miocene accretion of the Panama-Choco terrane, the top of which we associate with the dipping feature between 10 and 75 km depth. This accretion has likely cooled the deep forearc to a point that allows for seismicity. The occurrence of these mantle wedge earthquakes in an immobile part of the subduction system suggests they are not produced directly by dehydration. They may instead be a result of fracture induced by the upward movement of fluids from the slab or of self-localizing thermal shear runaway triggered by reheating of the cooled forearc along its arc-ward edge.

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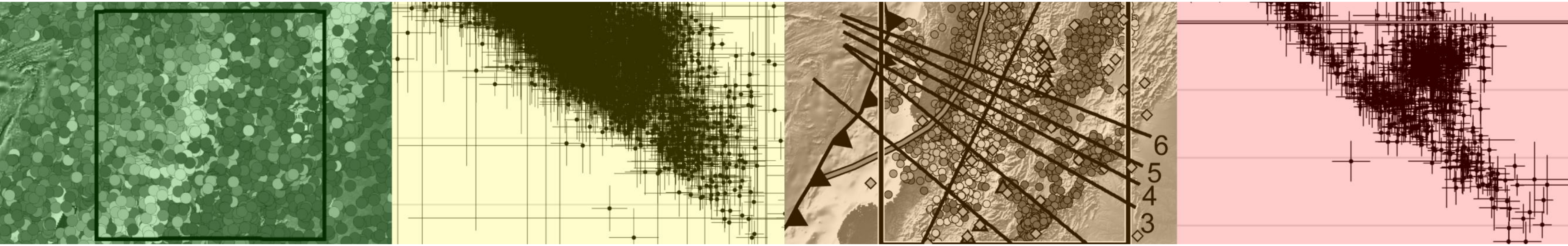

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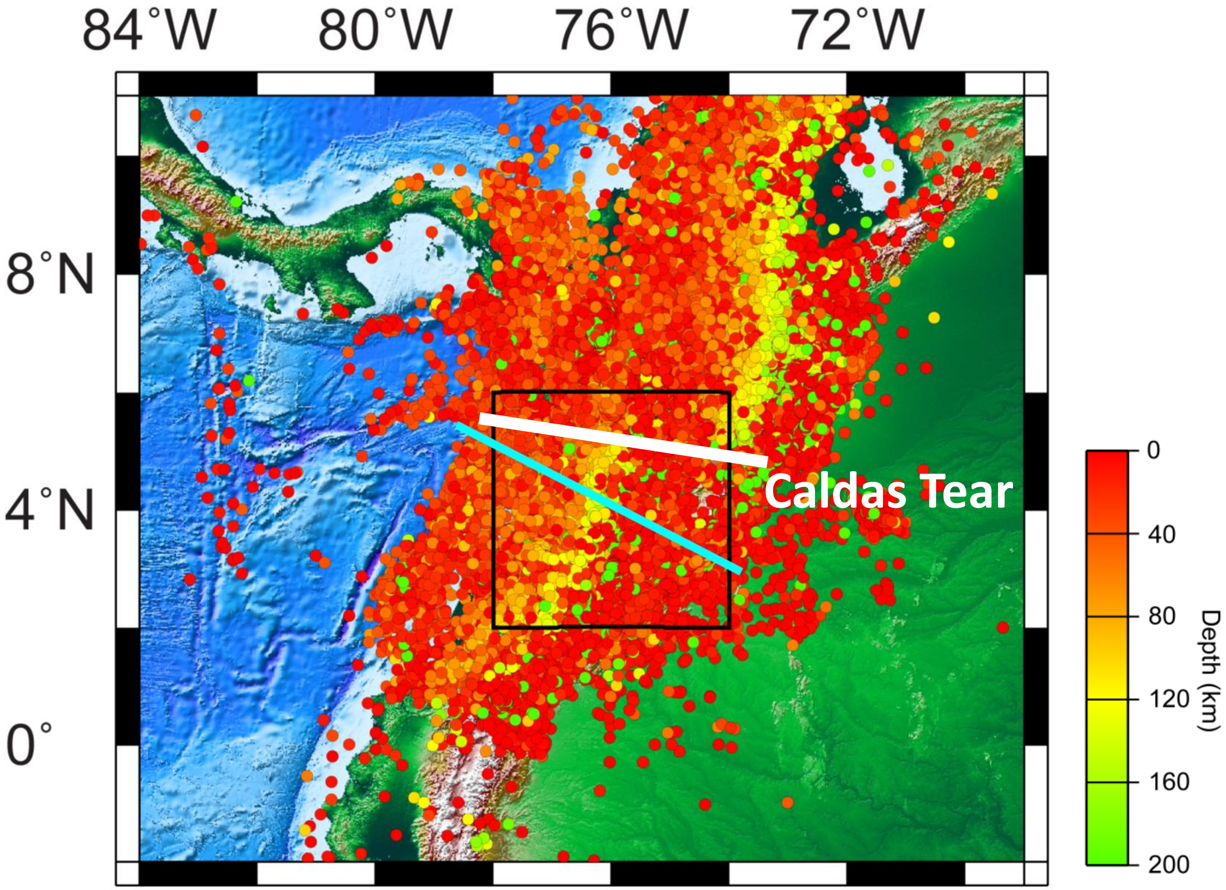
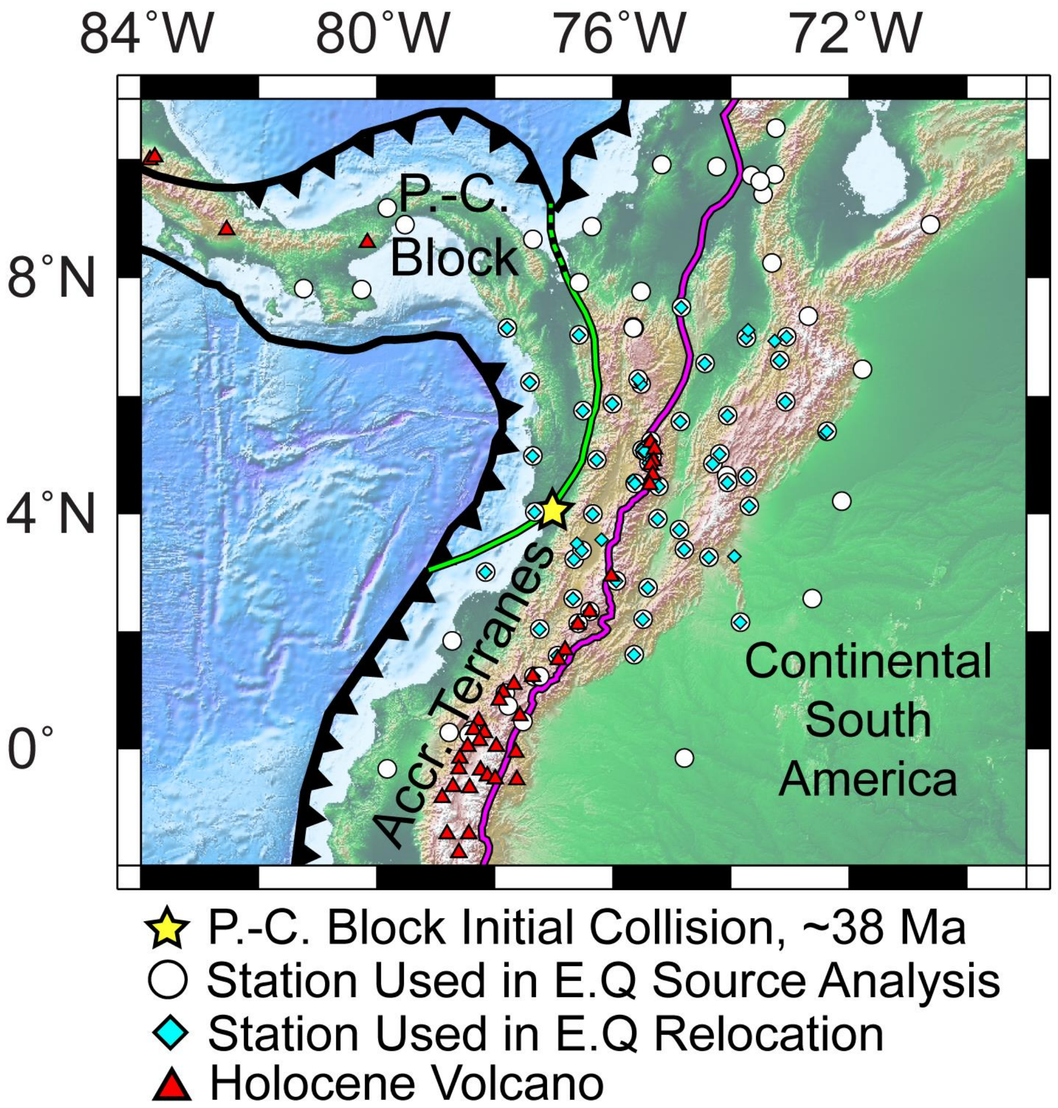
Cauca Region Bounded By Offset in Slab Seismicity, Centered on Clockwise-Rotating Panama-Choco Block Accretion

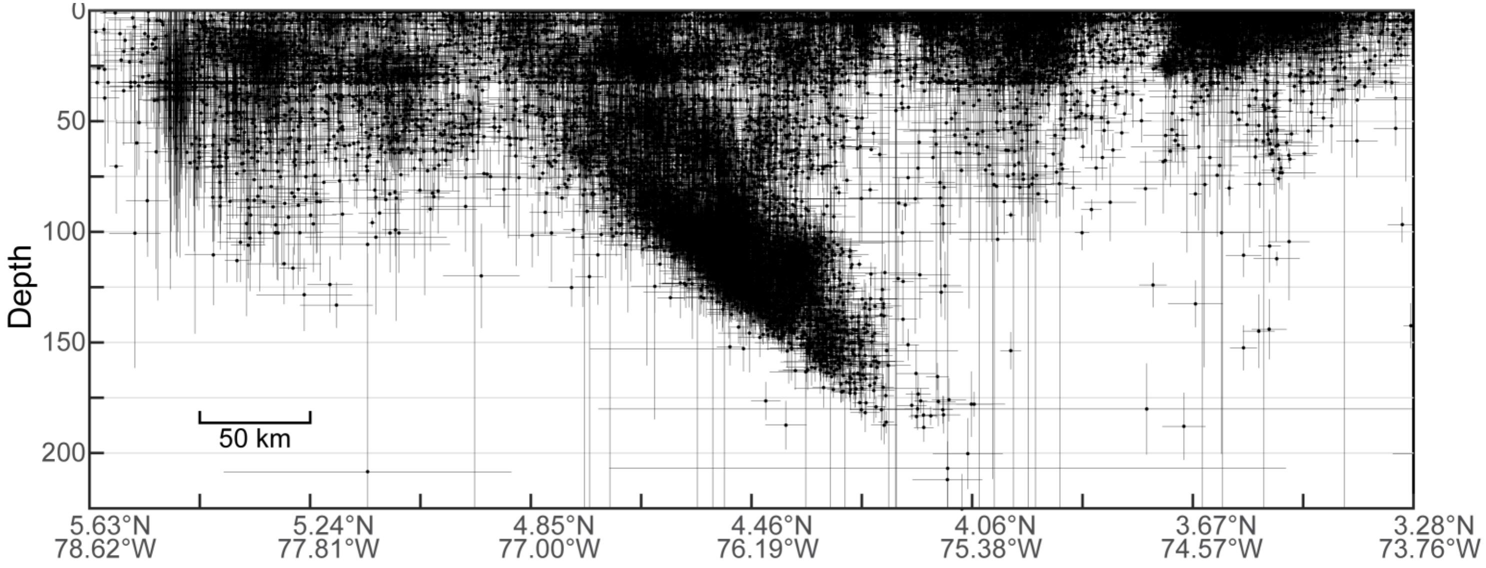


Red Sismológica Nacional de Colombia 2010-2019 EQs

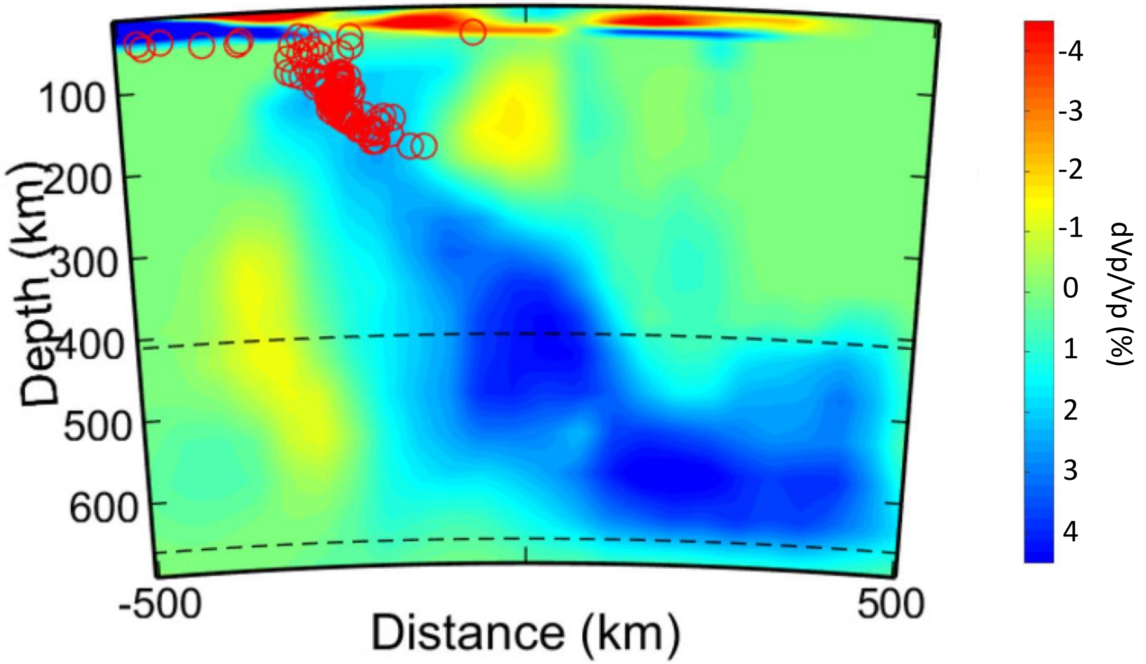


P.-C. Block and suture modified from León et al., 2018; accreted terranes boundary modified from Cochrane et al., 2014; P.-C. Block initial collision point modified from Montes et al., 2019 and Barat et al., 2014; volcanoes from Global Volcanism Program, 2013; Caldas Tear from Vargas and Mann, 2013.

Red Sismológica Nacional de Colombia 2010-2019 Catalog of Cauca Cluster



P-wave Tomography through Cauca Cluster

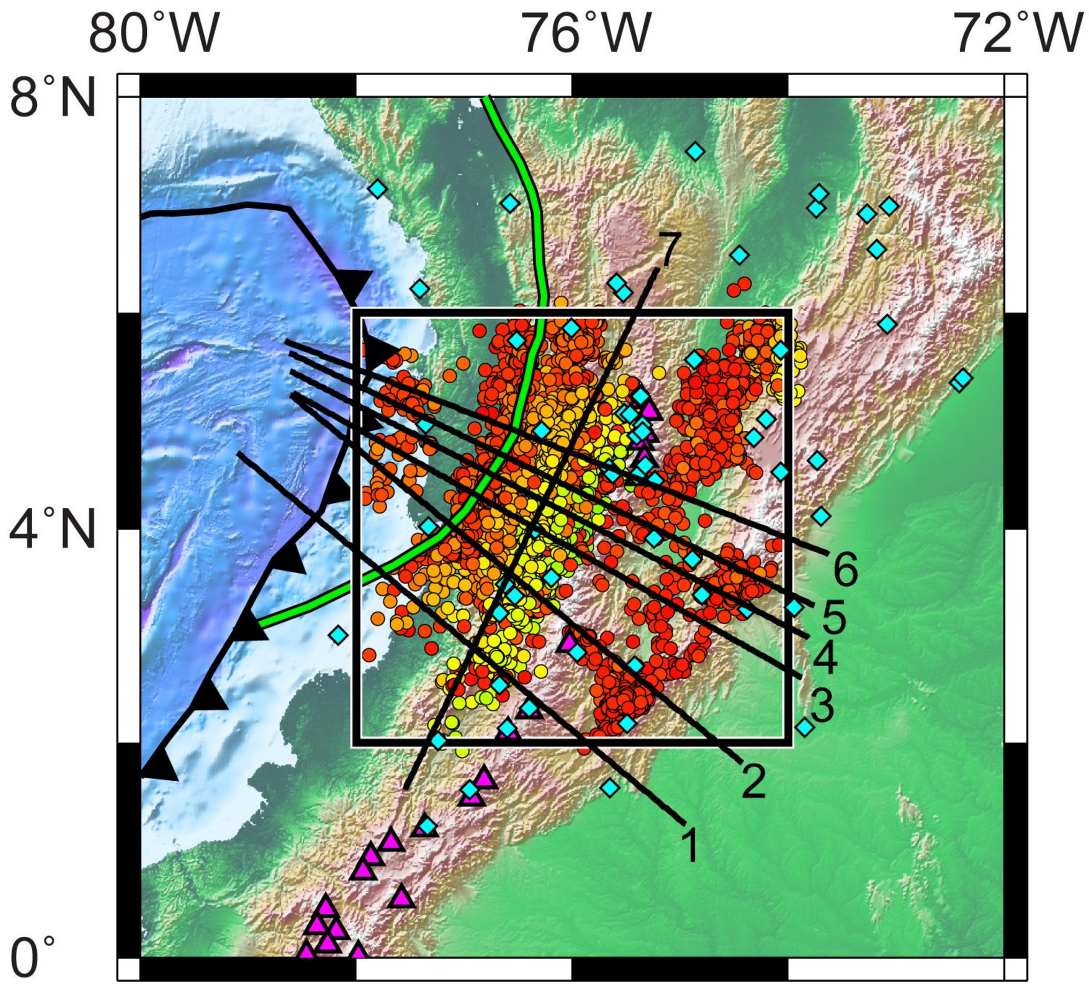


Tomography from Sun et al., 2022

Continuous Slab from Surface to Mantle Transition Zone

- Both Local Seismic Catalog and Regional Tomography Show Continuous Slab Dipping ~40°
- Global and Local Seismic Catalog Show Significant Seismicity in Mantle Above Slab
- No Evidence for Slab Tearing, Contrast with Northern Colombia
- Seismicity Dominated by Small Events, RSNC Catalog Vastly Larger than e.g. NEIC (17,484 vs. 127 events)

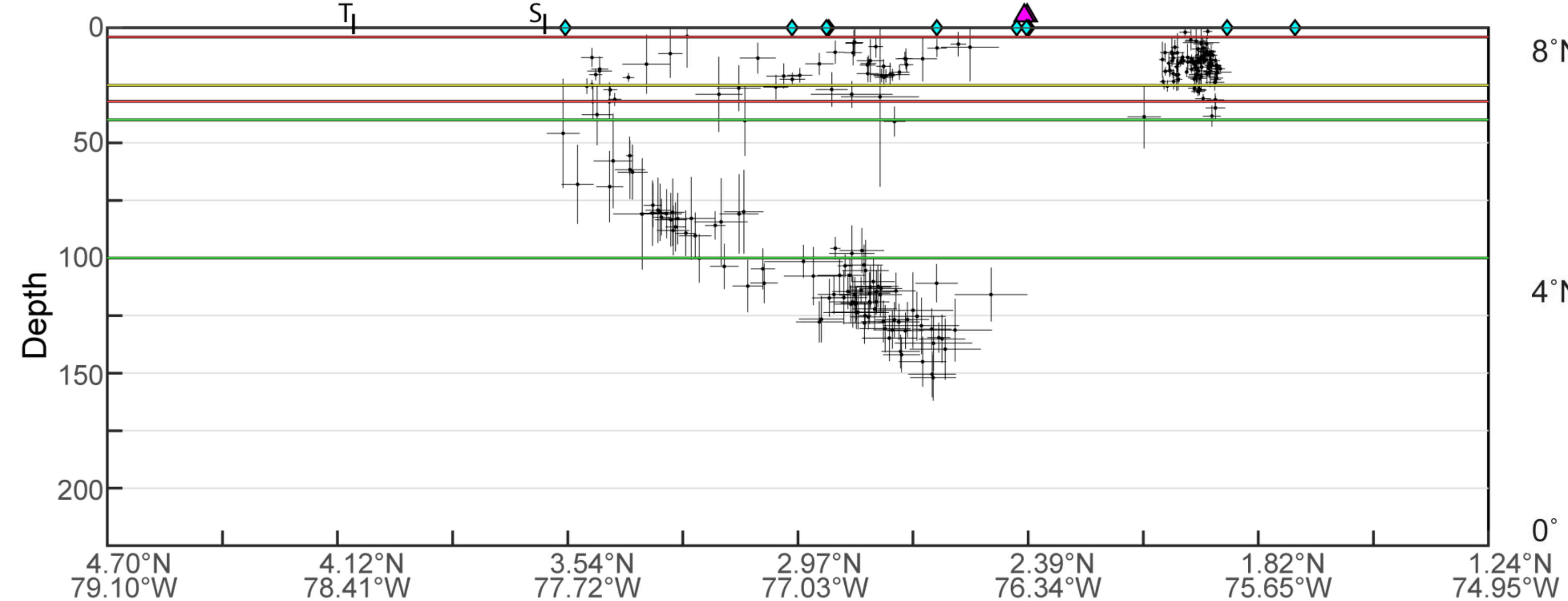
Relative Relocations Highlight Spatial Relationships within Seismicity

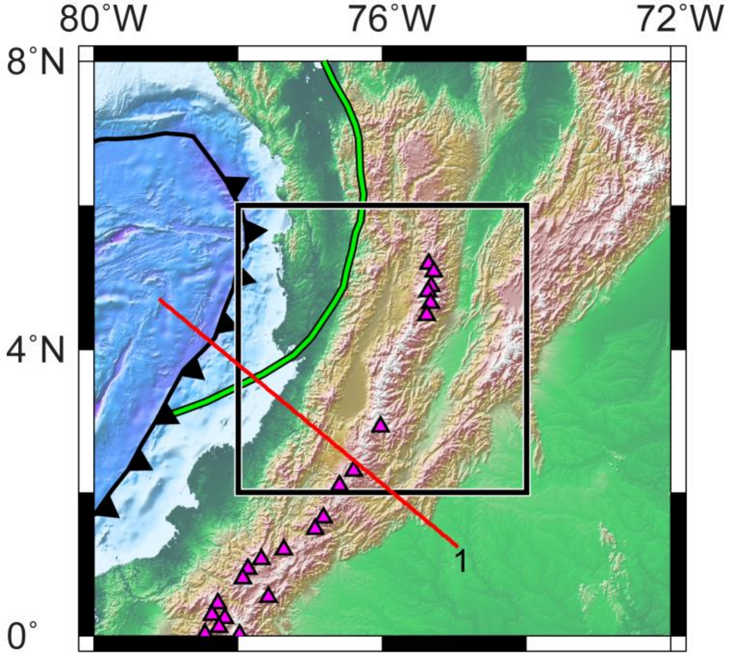


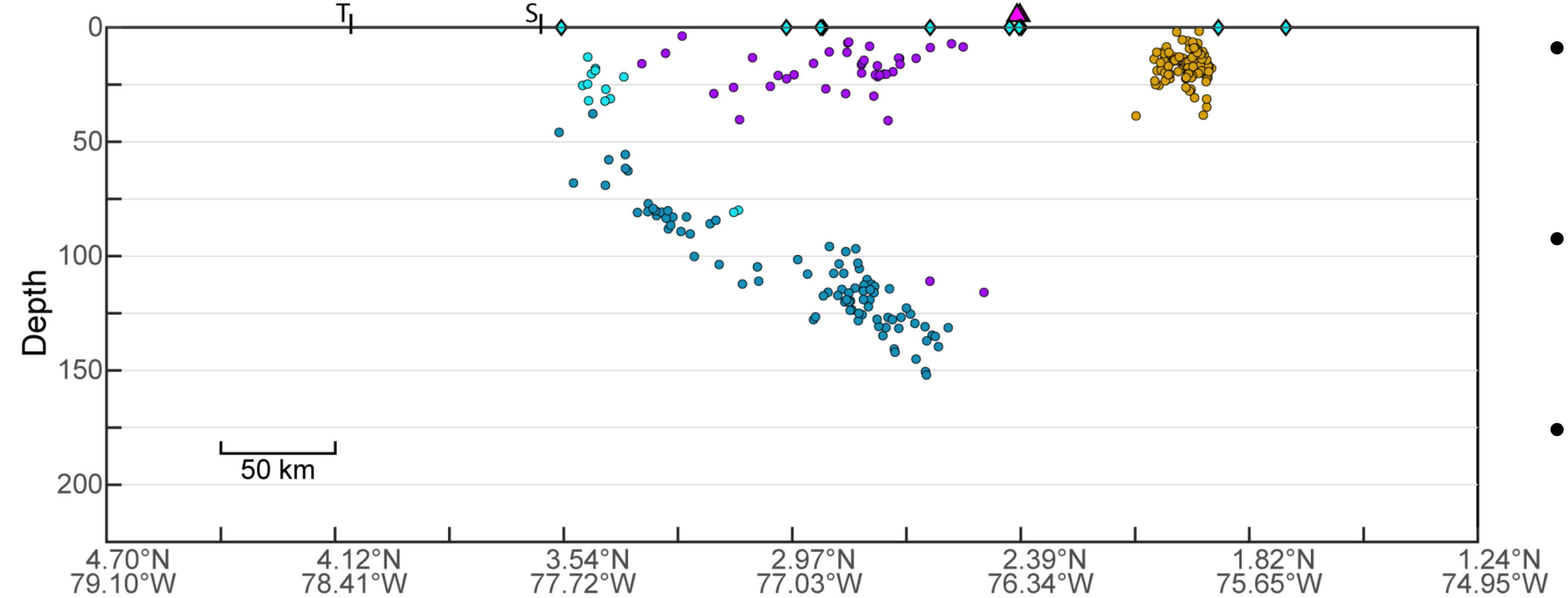
Panama-Choco suture (green) modified from León et al. 2018; Holocene volcanoes from Global Volcanism Program, 2013

- Relative Earthquake Relocation (HypoDD*) Solves for Interconnected "Constellation" of Event Pairs—Need 8+ Observations per Pair
- Relationship of Events in a "Constellation" are Robust, Absolute Location Velocity Model Dependent†
- 11,540 Events >10 km Depth → 7,294 w/ Sufficient Observations → 6,671 Successfully Relocated

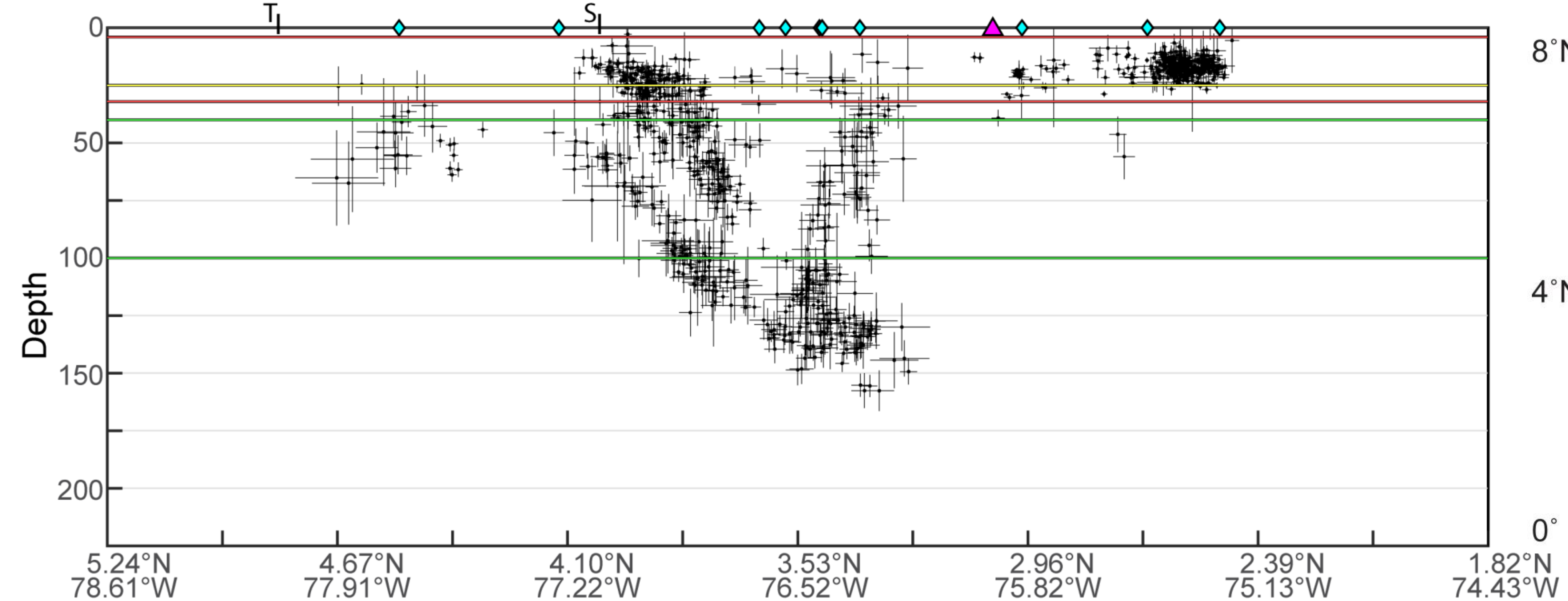
*Waldhauser & Ellsworth (2000); †Model from Ojeda & Havskov (2001)

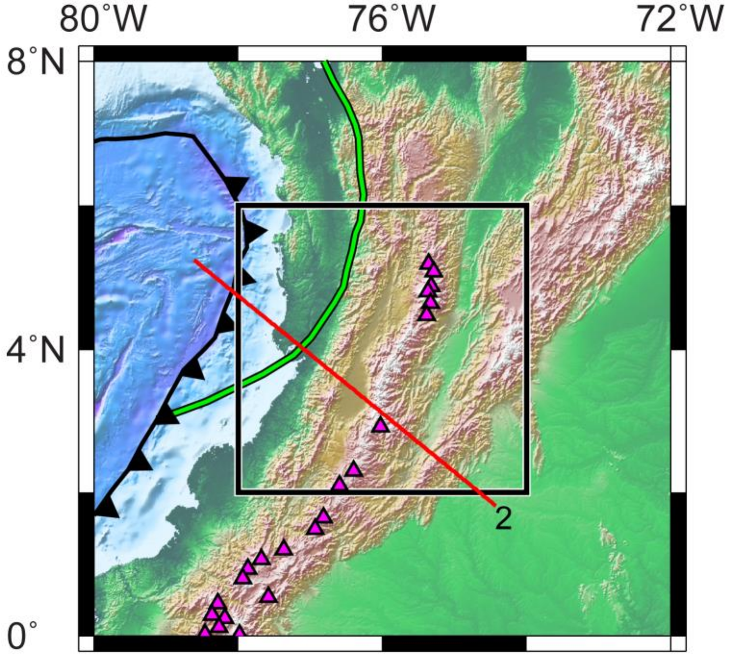


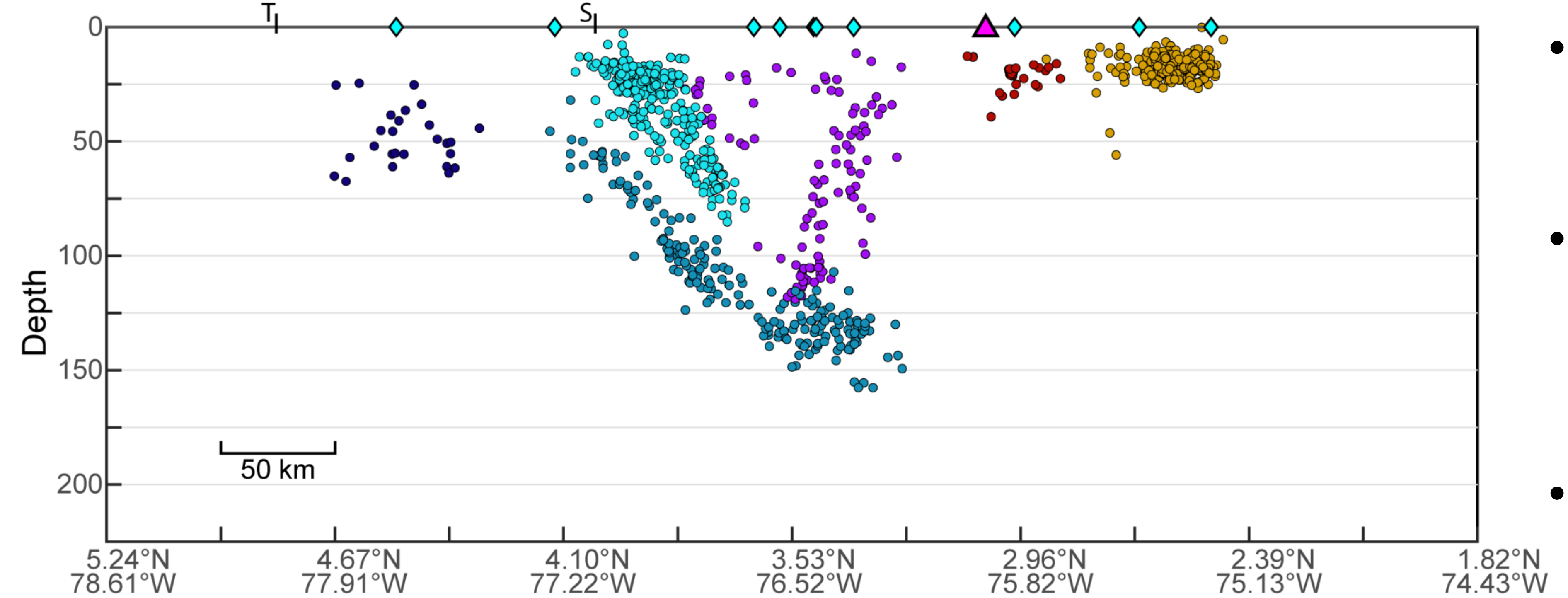




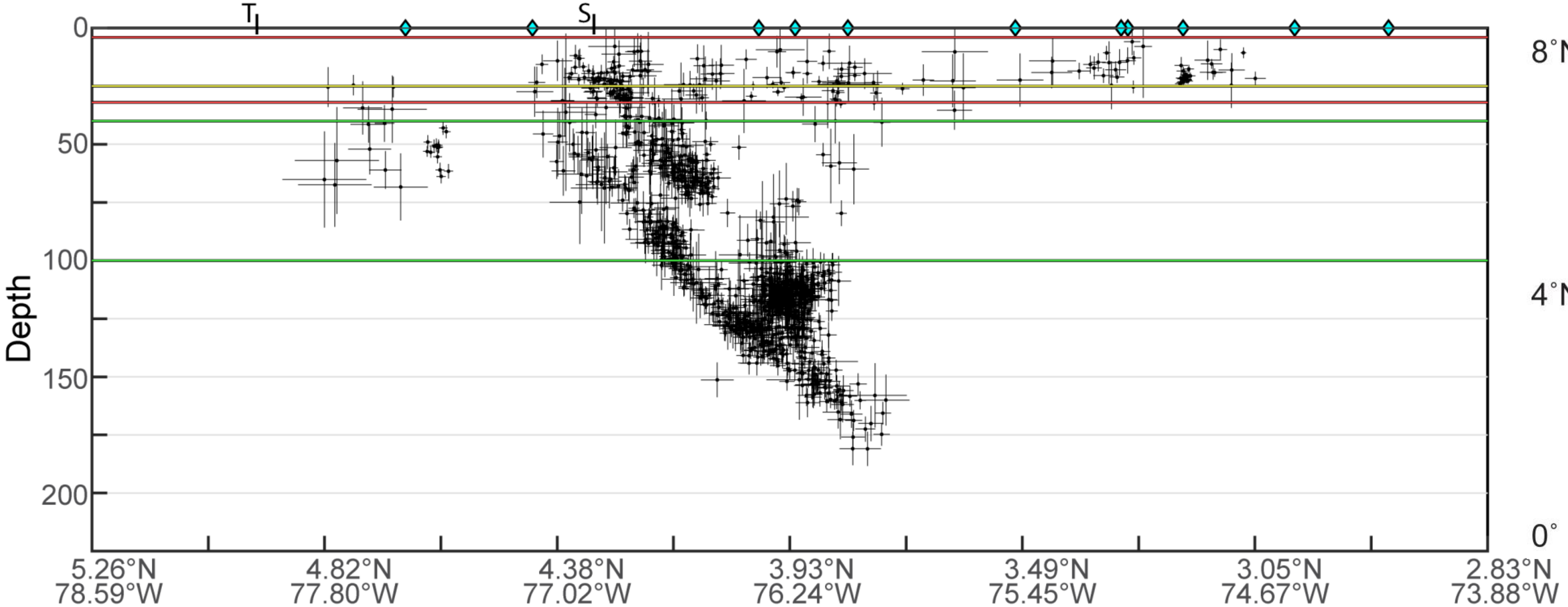
- ~30° Plane of Seismicity, **Slab**
- **Slab** has Little Activity
- **Supra-Slab** Seismicity Limited to 25-30 km depth

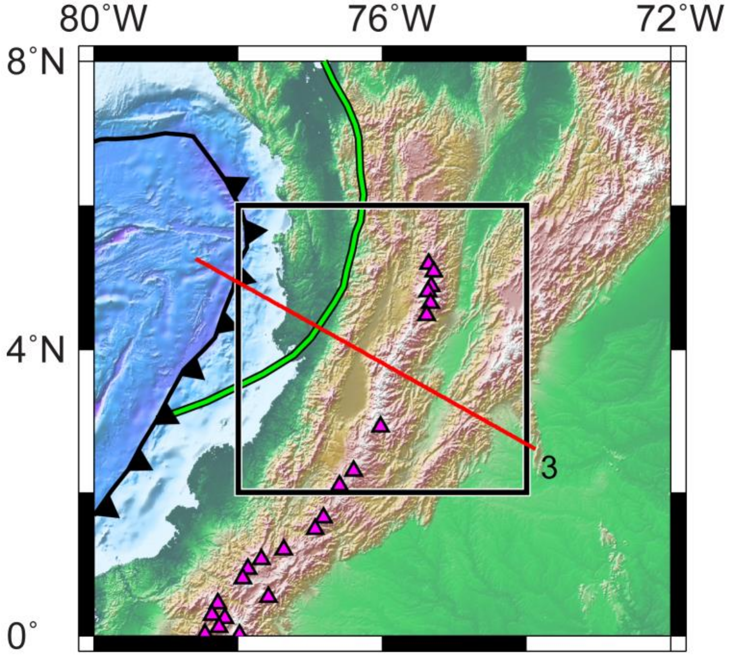


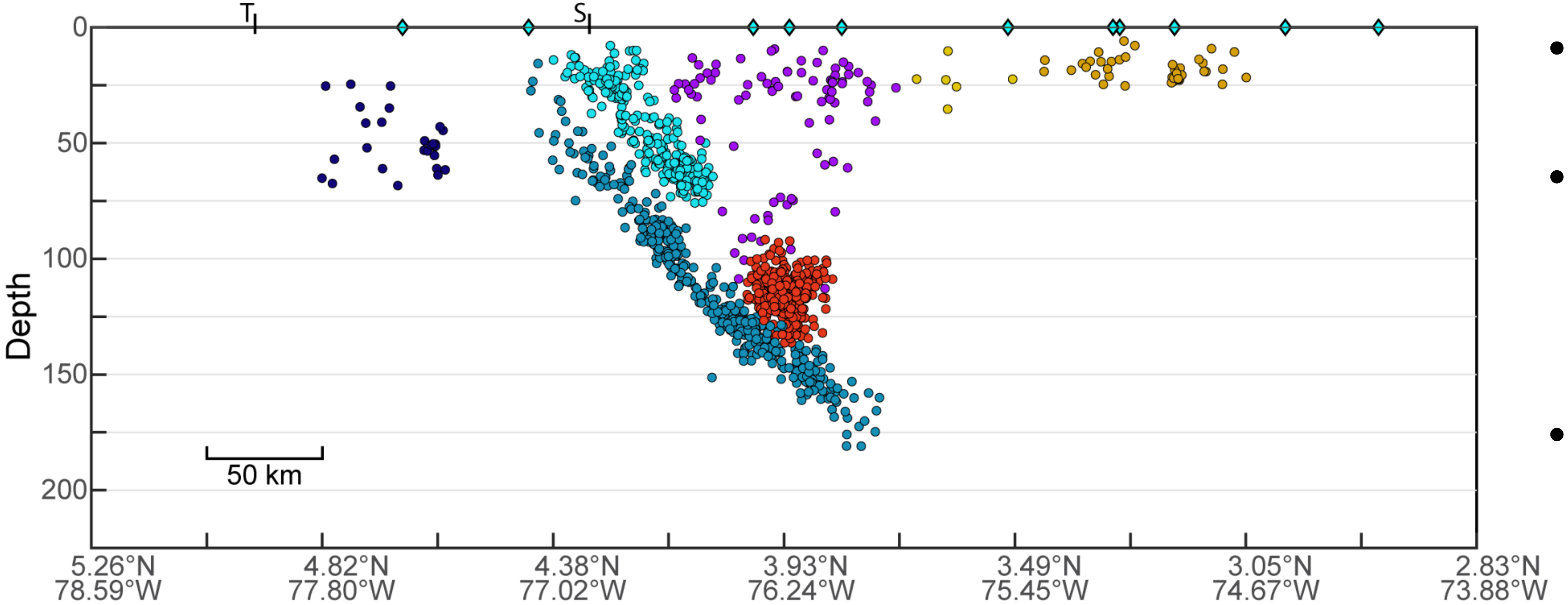




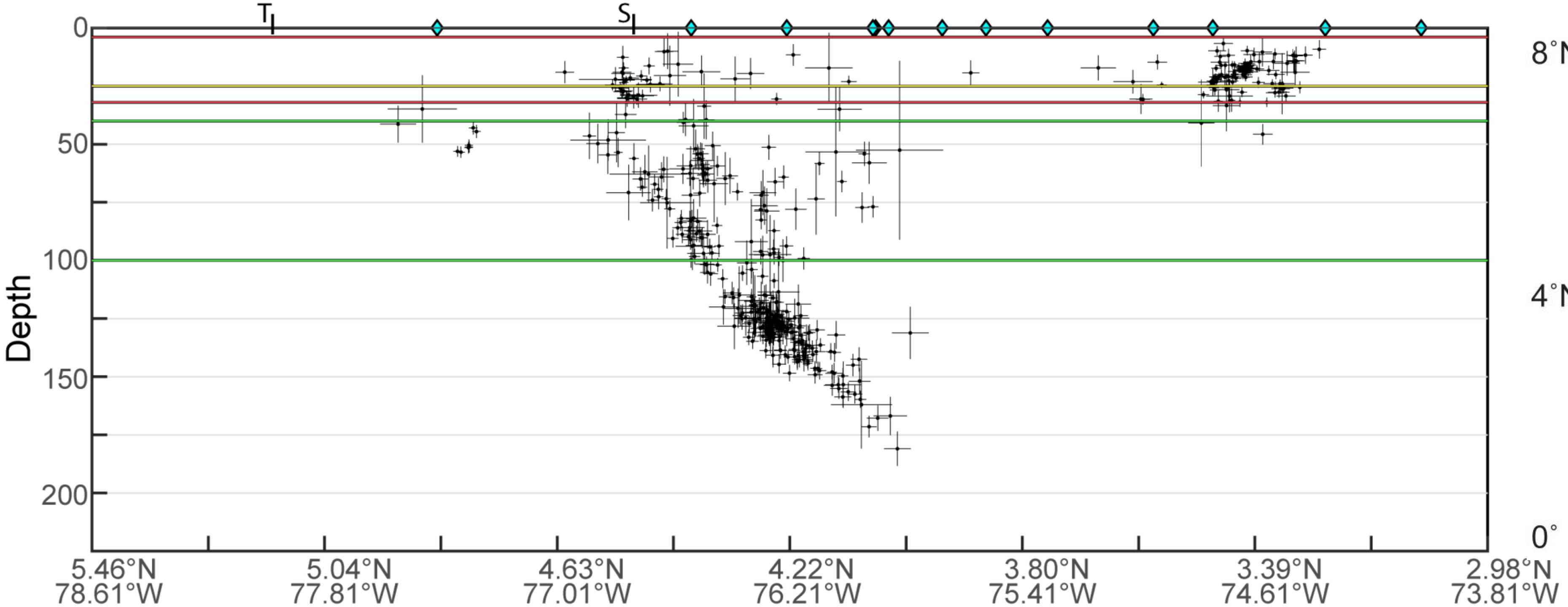
- Cluster West of Volcanoes
- **Supra-Slab Plane** of Seismicity Truncates at Suture
- **Slab** to Crust **Conduit**?

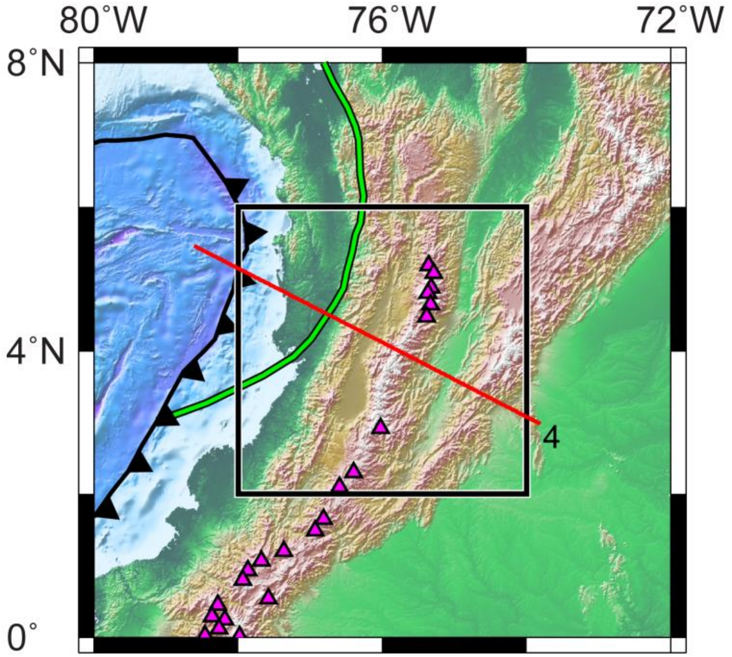


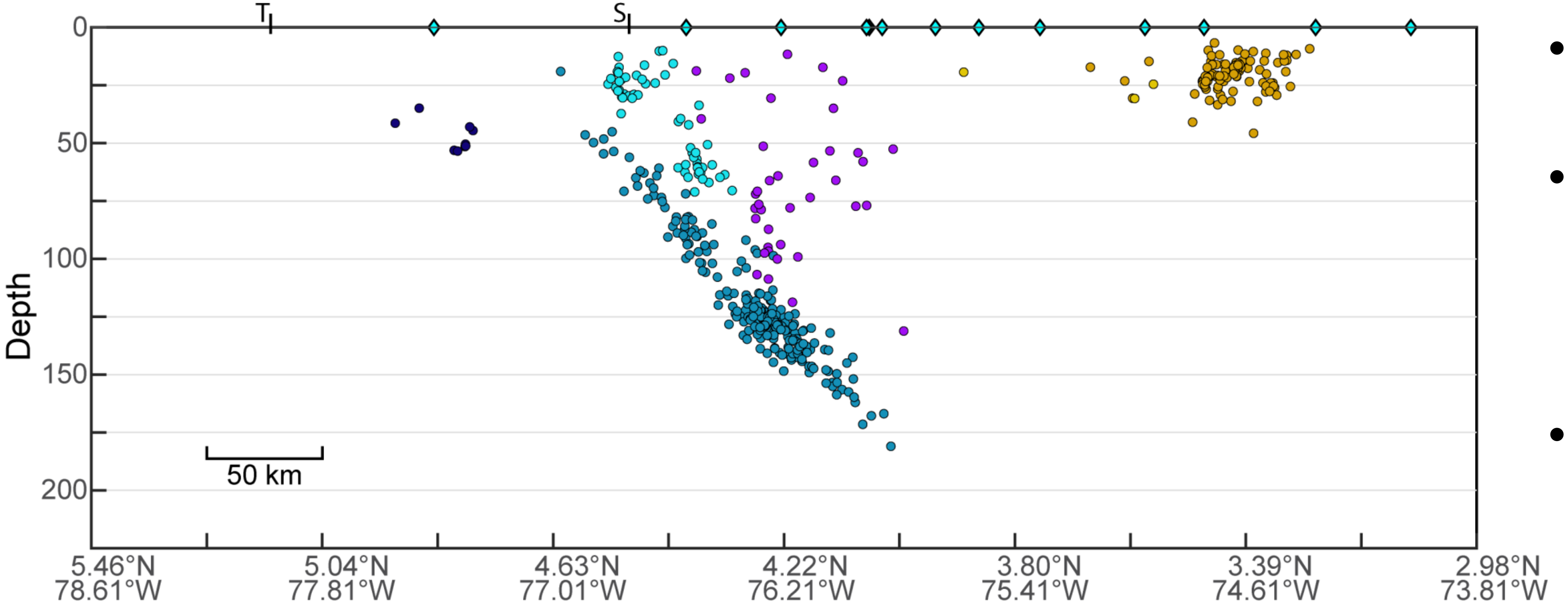




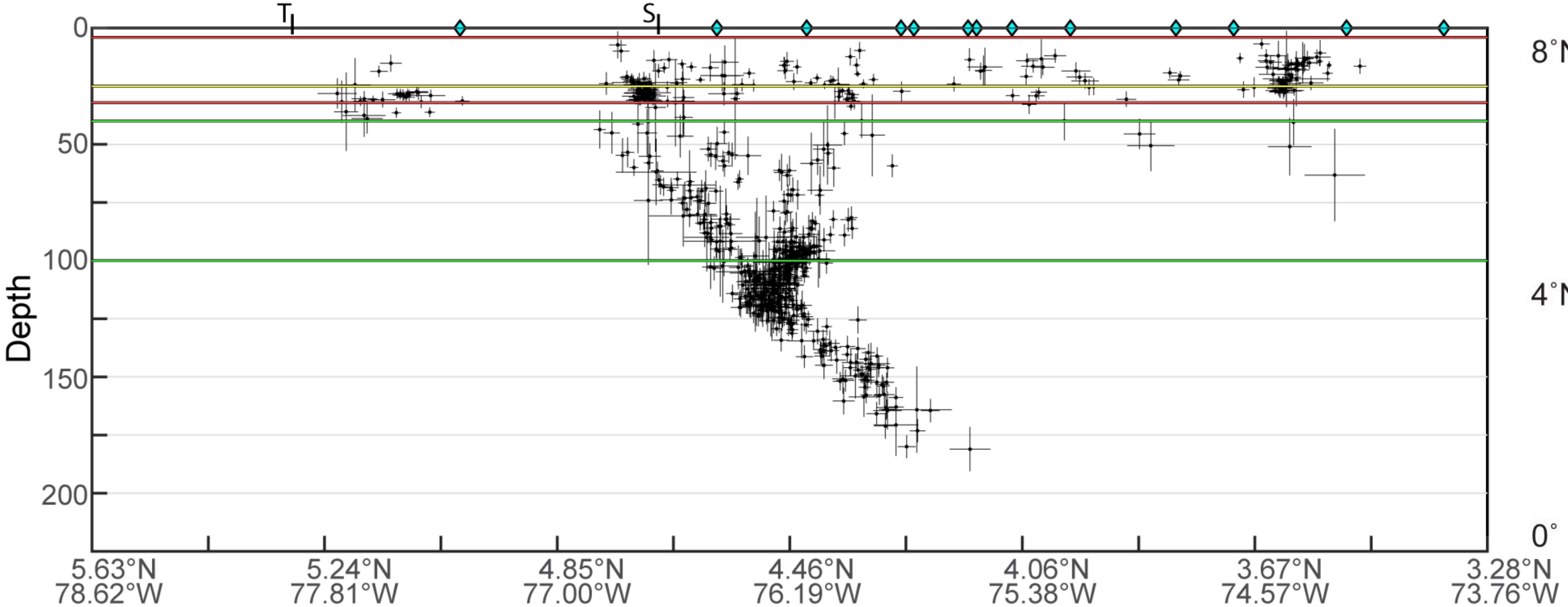
- No Volcanoes
- **Supra-Slab Plane** of Seismicity Truncates at Suture
- 100-125 km Depth "**Ball**" of Seismicity above **Slab**

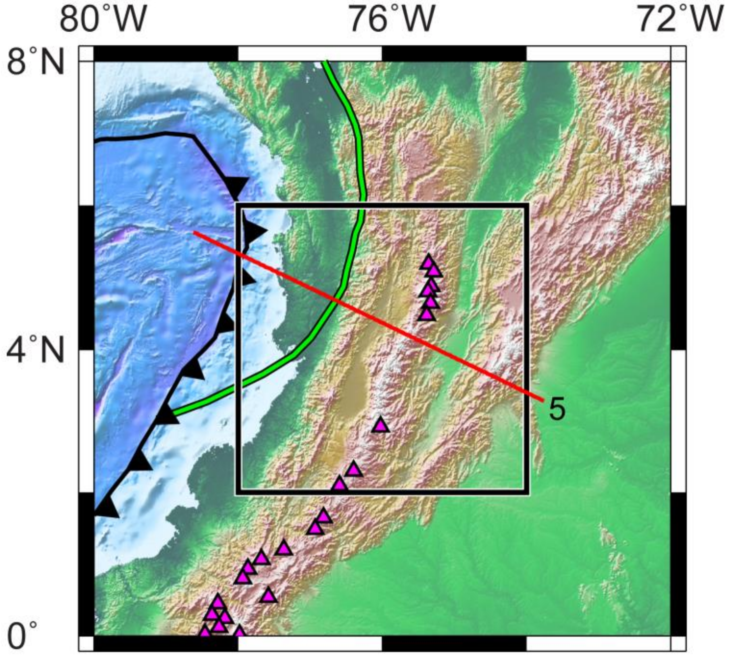


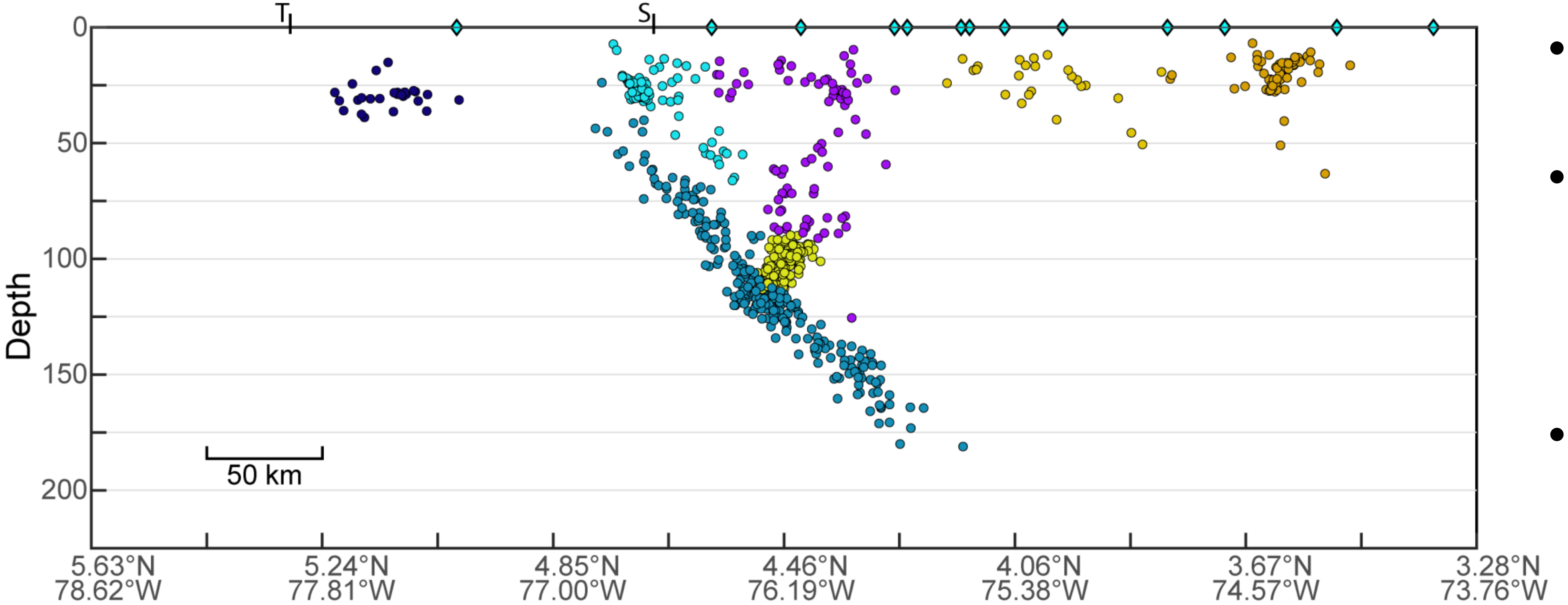




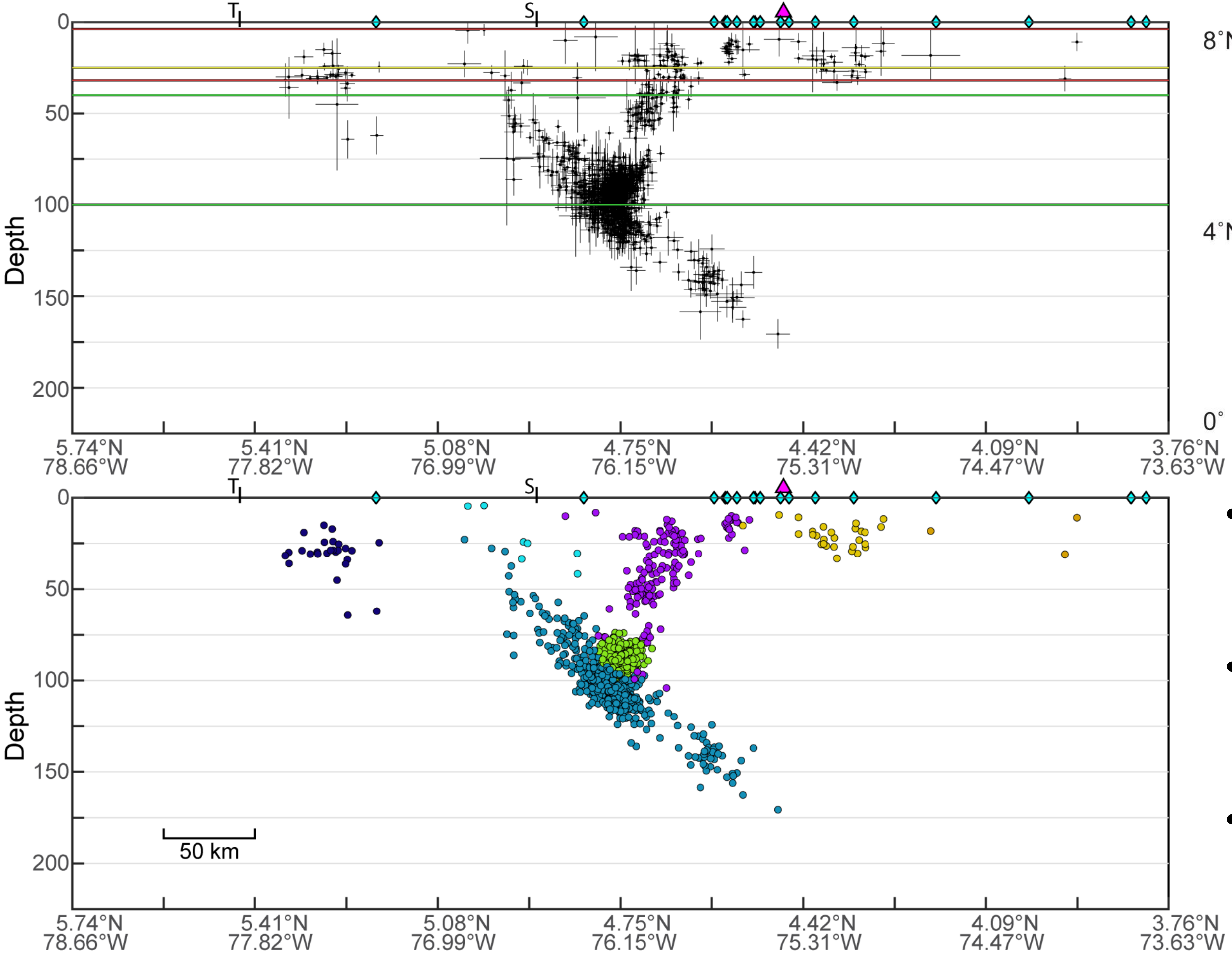
- No Volcanoes
- Weak **Supra-Slab Plane** of Seismicity Truncates at Suture
- No “Ball” of Seismicity above **Slab**

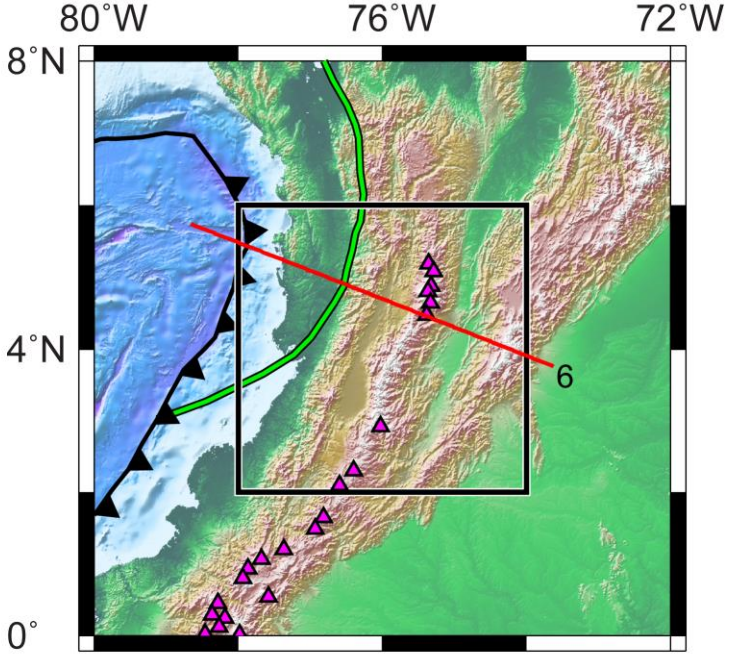




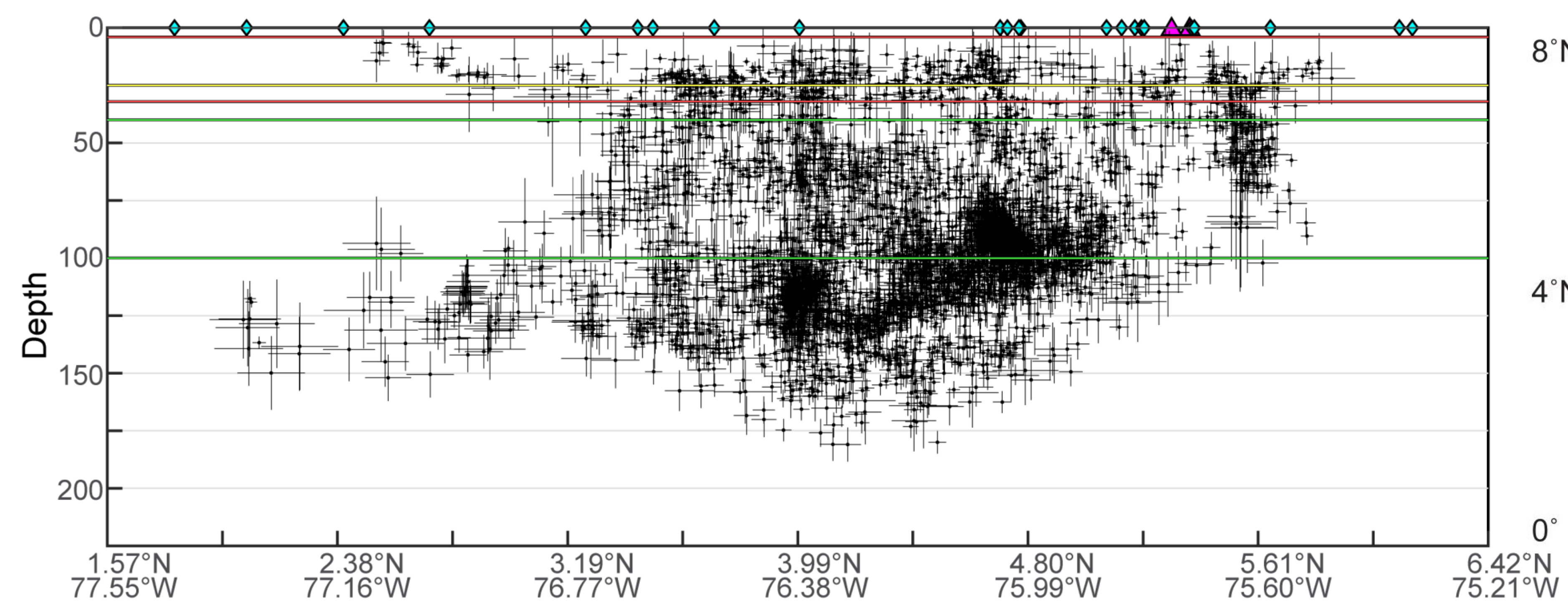


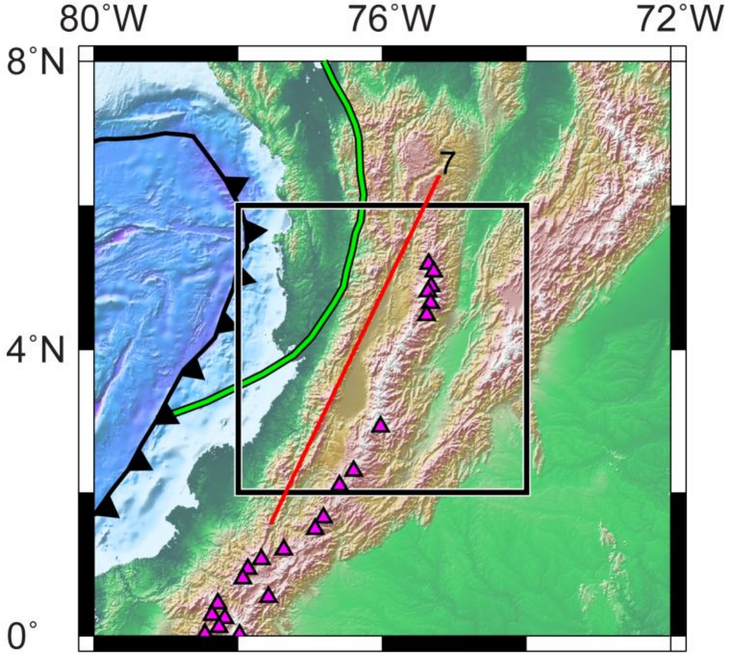
- No Volcanoes
- Weak **Supra-Slab Plane** of Seismicity Truncates at Suture
- 90-110 km "**Ball**" of Seismicity above **Slab**, w/ **Conduit**?

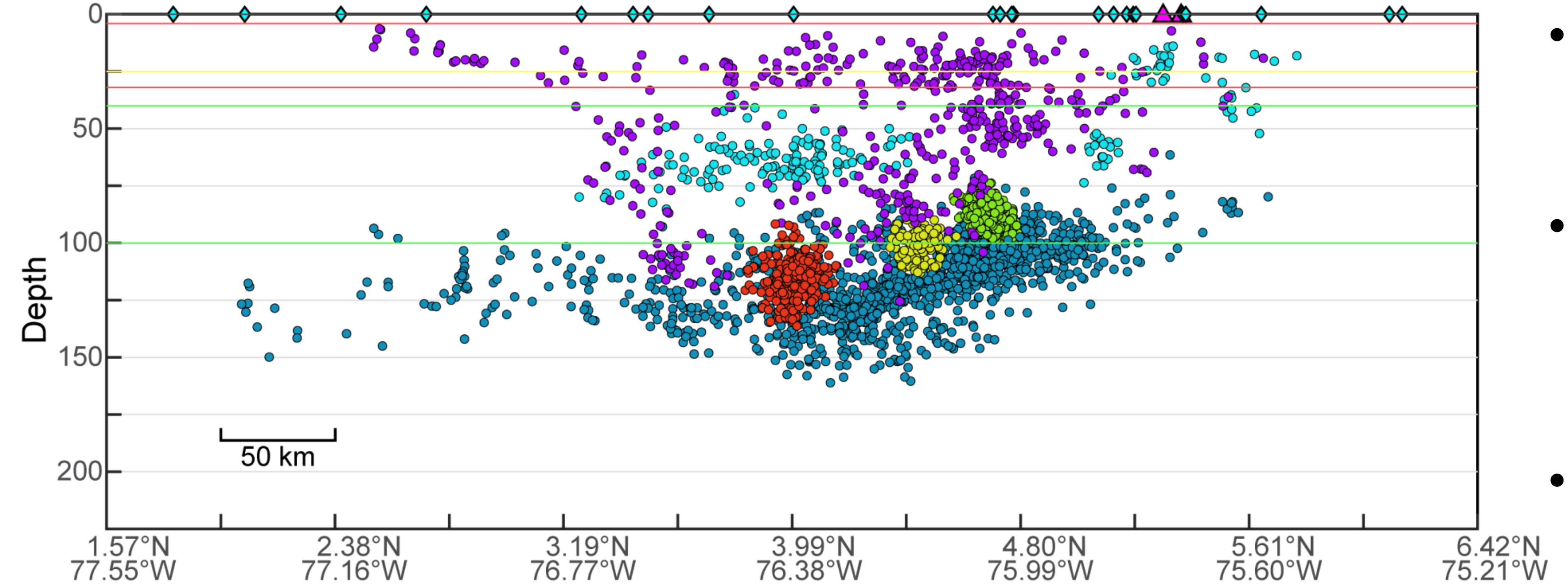




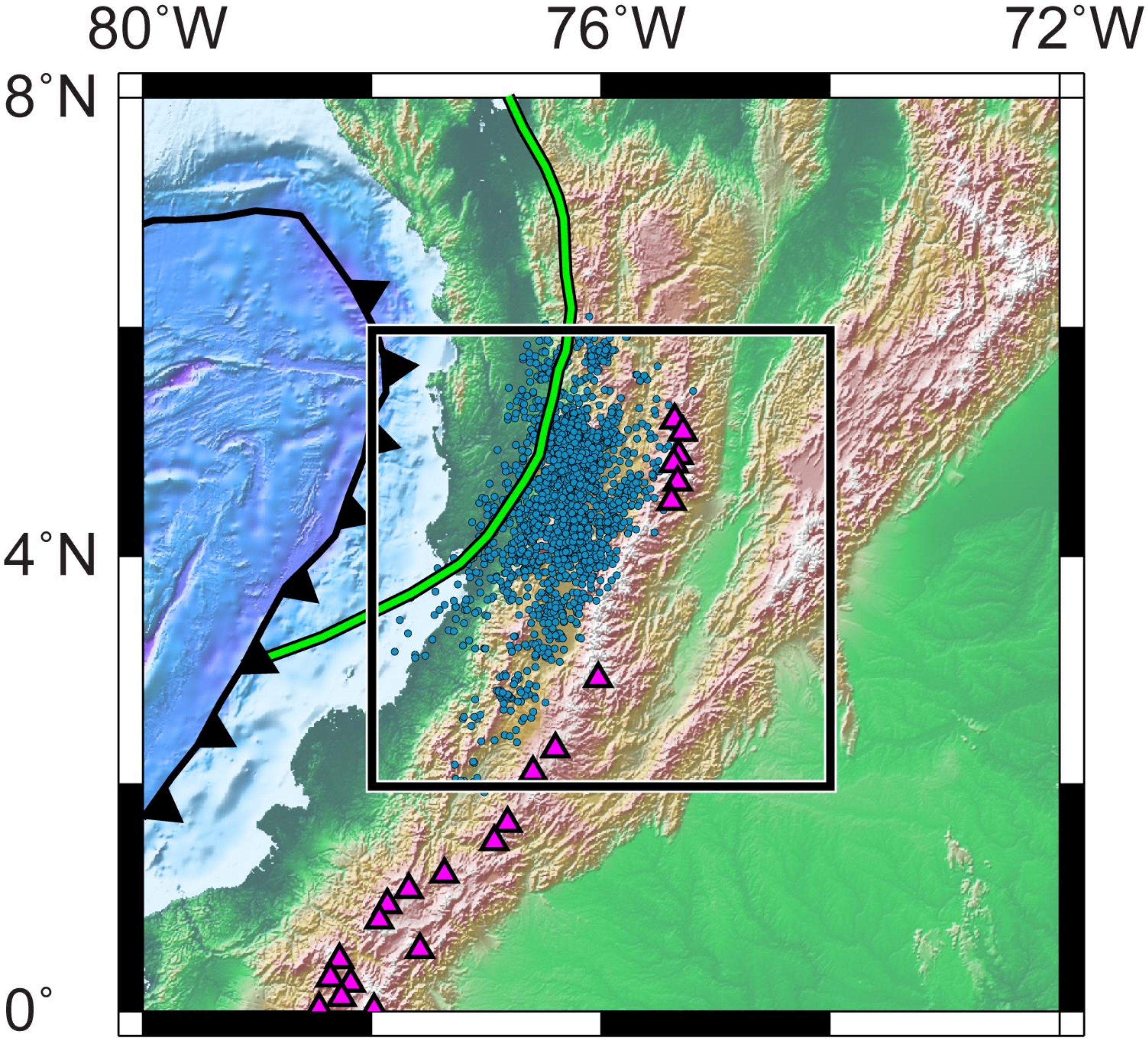
- Cluster West of Volcanoes
- No Supra-Slab Plane of Seismicity
- 75-100 km “Ball” of Seismicity above Slab, w/ Conduit?



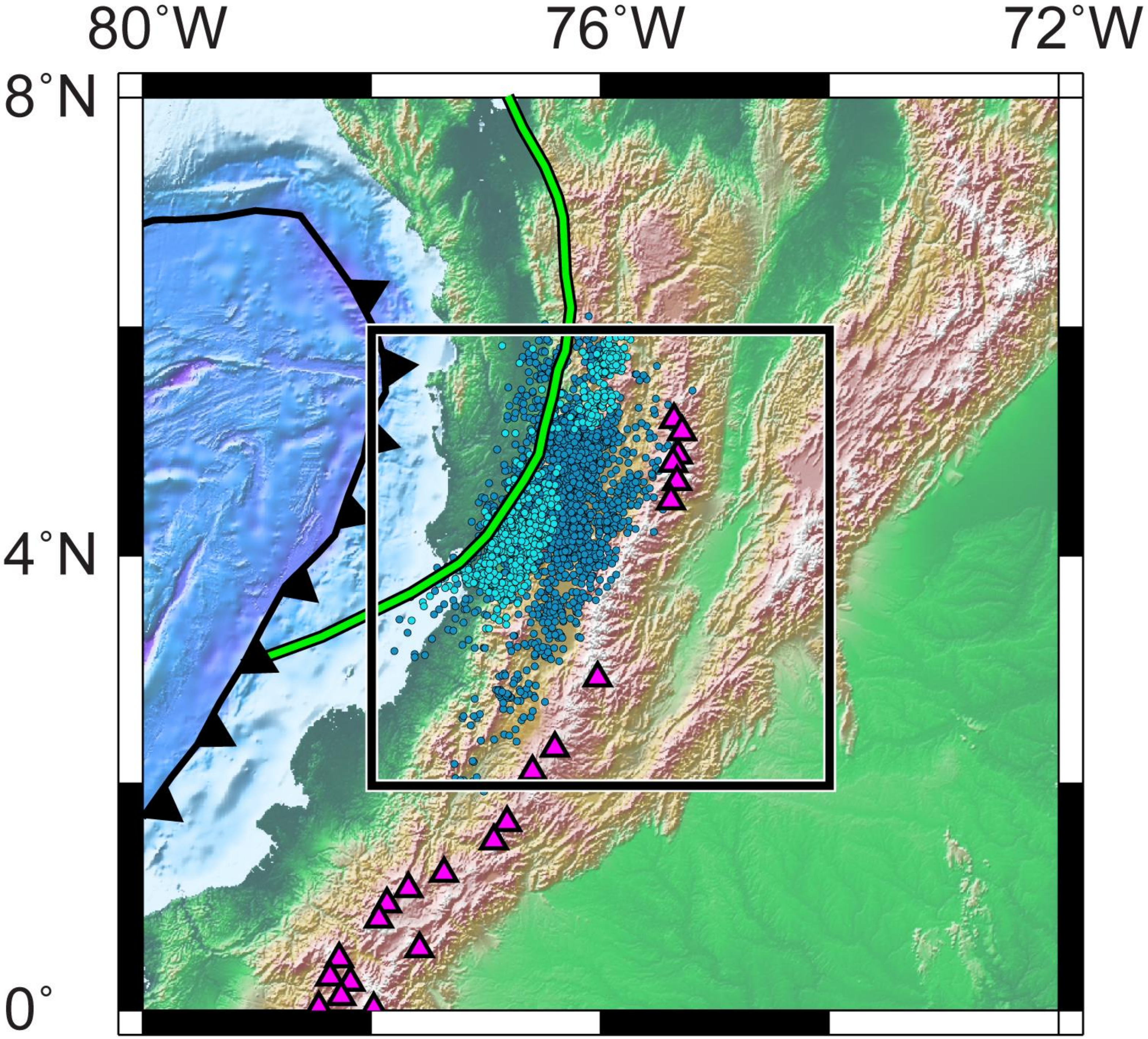




- "Balls" of Seismicity Follow Dip of Slab
- No Supra-Slab Seismicity South of 3.19°N
- Slab to Crust Conduits?



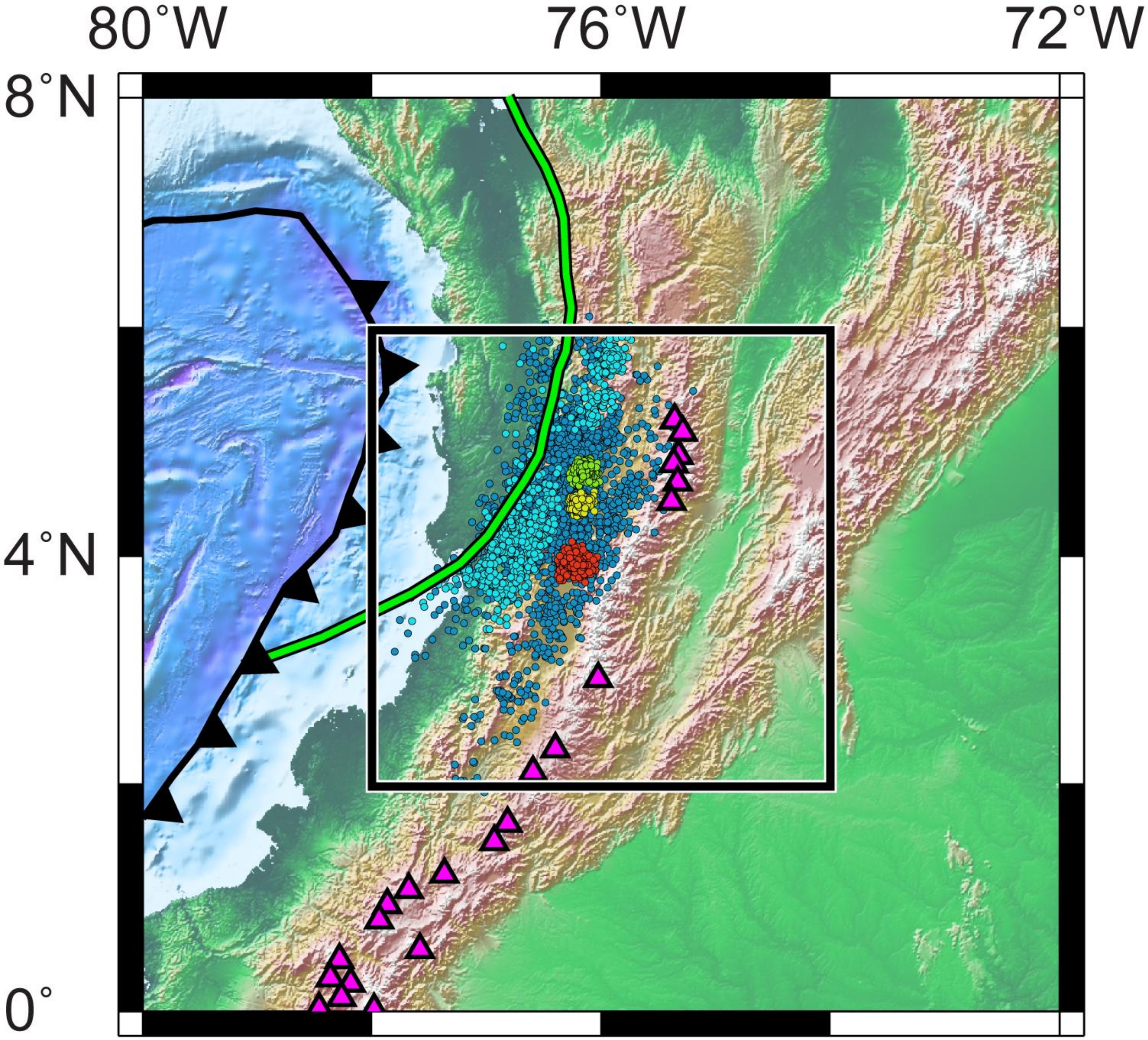
- Slab Seismicity Concentrated within Cluster
- Gap between Trench and Slab Seismicity may be Megathrust Related
- Slab Seismicity Ceases Trench-ward of Volcanic Arc



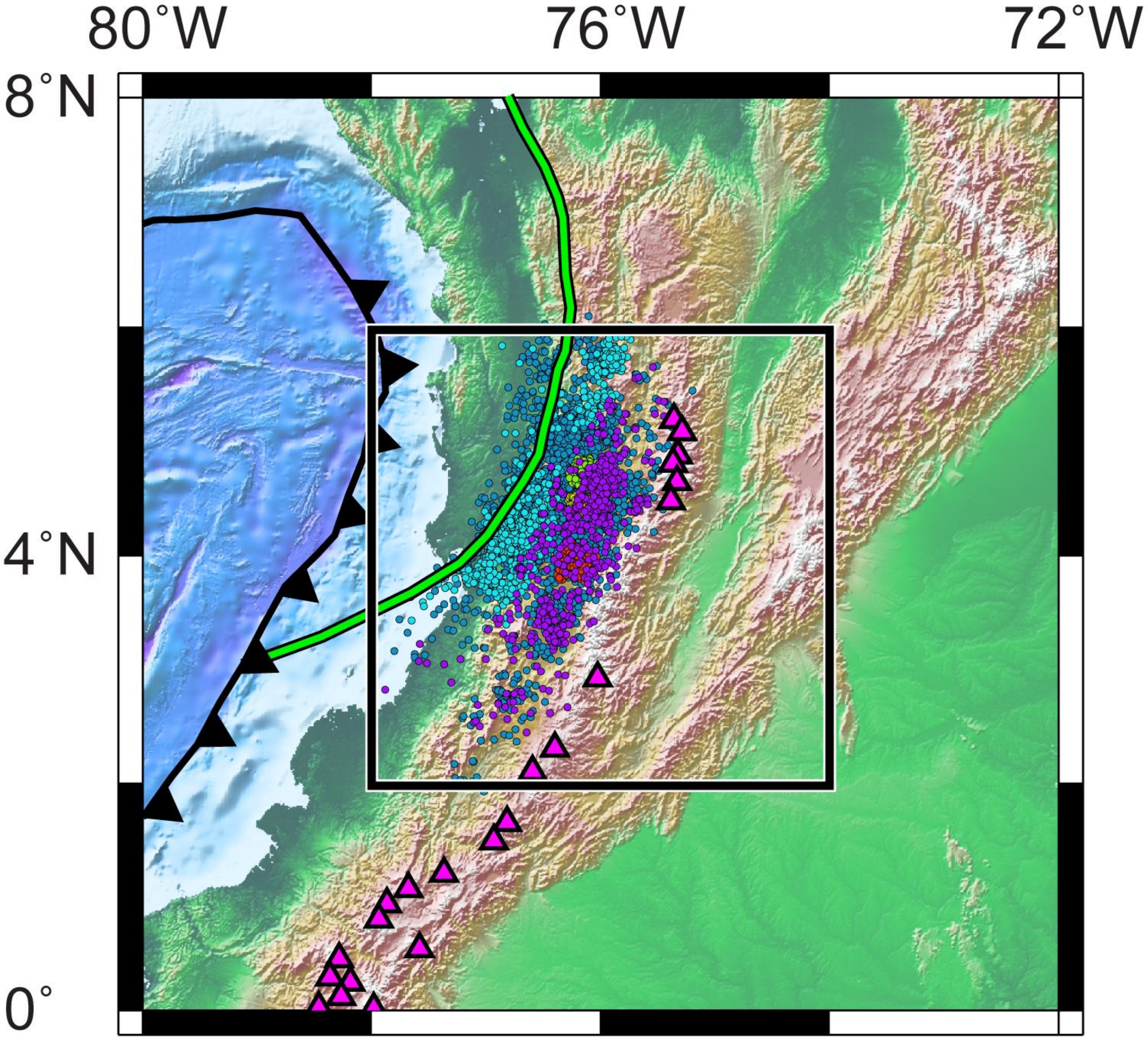
- **Supra-Slab Plane** of Seismicity Consistently Ends at Panama-Choco Suture

- Northern Portion Largely at Crustal Depths, may be Deeper Part of Known Strike-Slip Fault

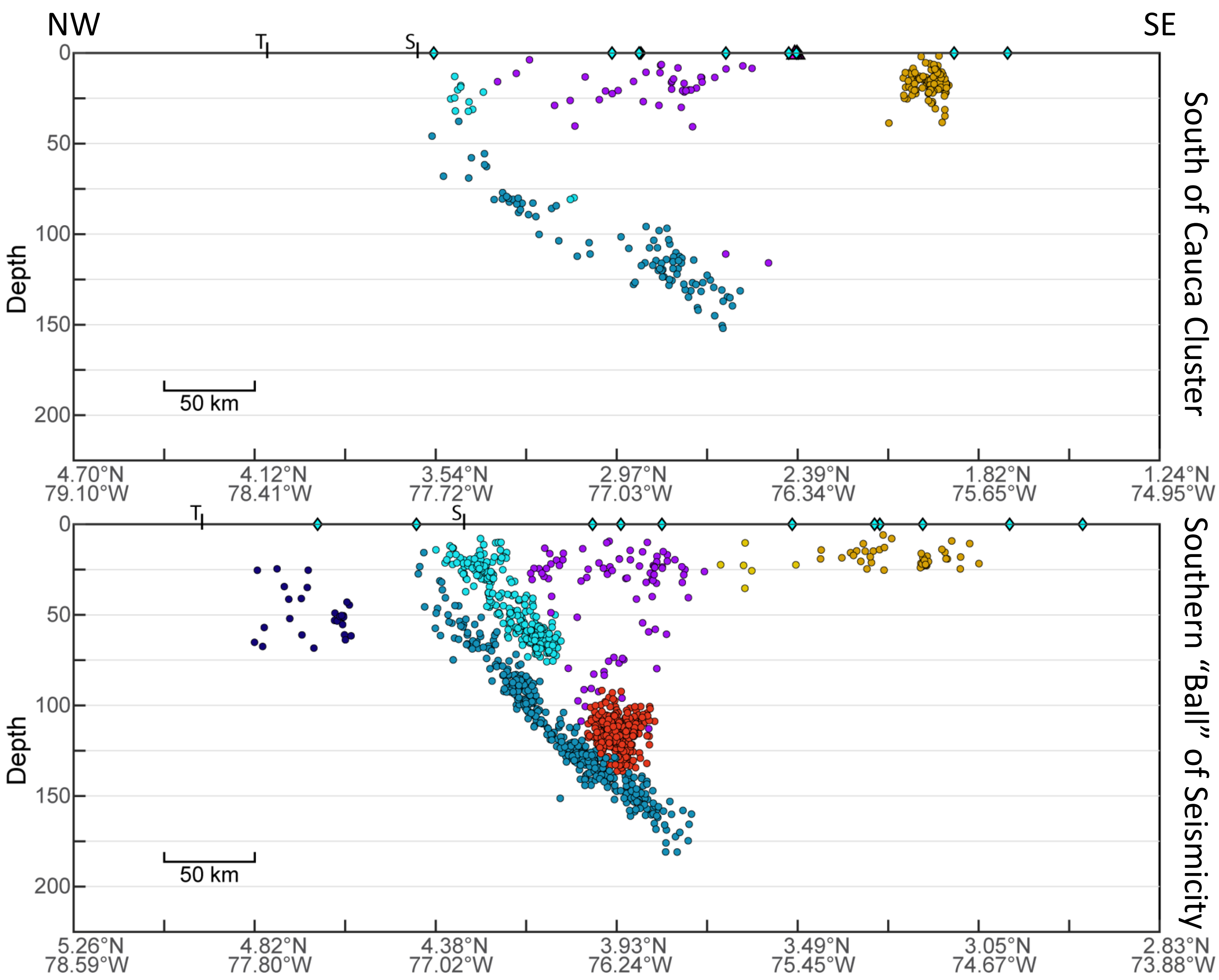
- Southern Part Dips to South-South East



- “Balls” of Seismicity Spatially Separated from Supra-Slab Plane
- “Balls” of Seismicity lie Directly Above Area of Intense Slab Seismicity
- Follow Trend Distinct from Arc Trend, ~100 km from Arc—Not Likely Related to Arc Volcanism



- Remaining Supra-Slab Seismicity Largely Limited to Area Above or Near "Balls"
- Rare South of Cluster
- Majority Well Away from Volcanic Arc, little overlap with Supra-Slab Plane
- Shallower Continuation or Equivalent of "Balls"?



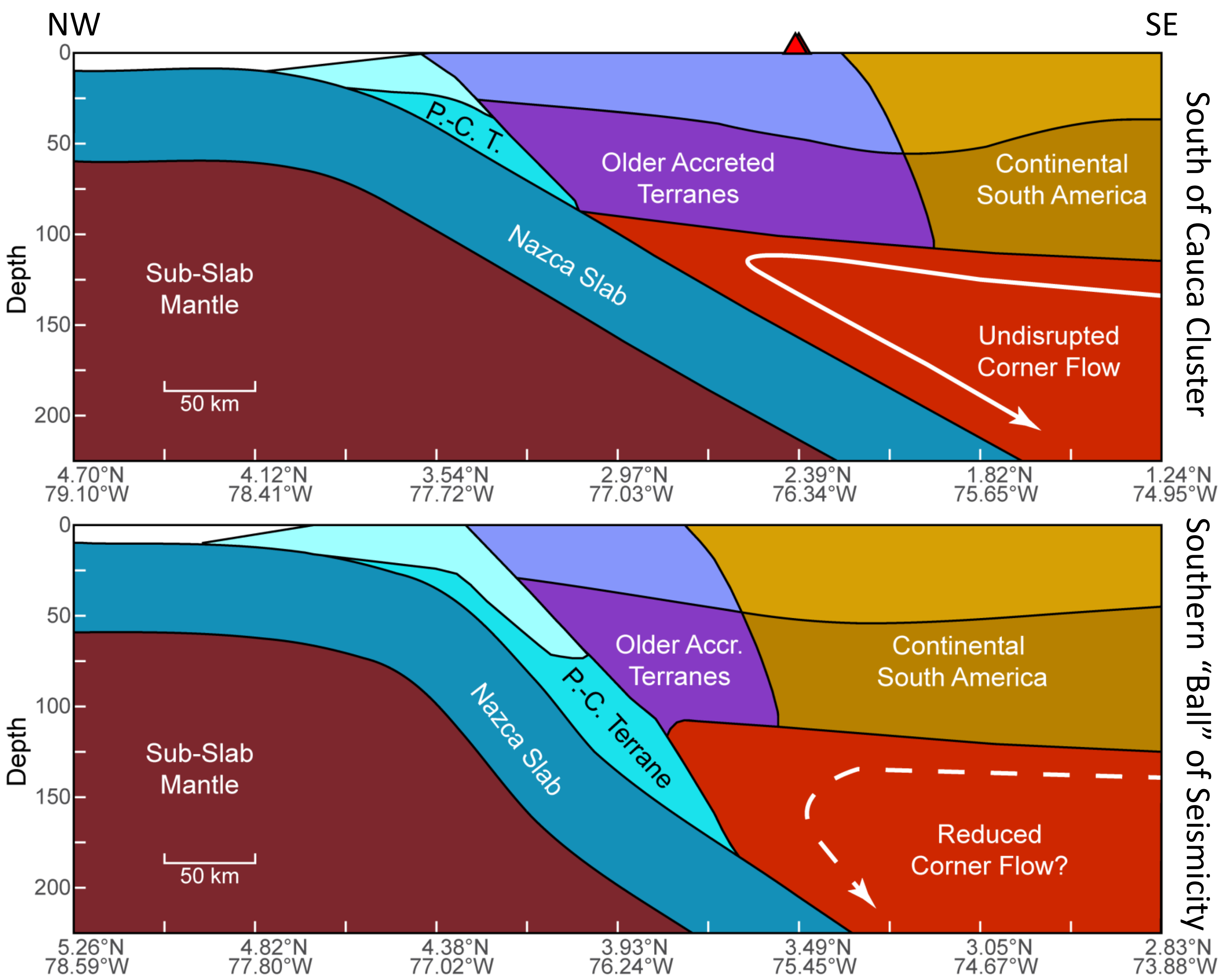
Forearc after Meissnar et al., 1976; crustal thicknesses after Poveda et al., 2015; lithosphere thickness after Blanco et al., 2017; sutures modified from Cochrane et al., 2014 and León et al., 2018

Supra-Slab Plane of Seismicity: Subducted Continuation of Panama-Choco Block

Nazca Slab Deflected, Thermally Shielded by Panama-Choco Block

Other Supra-Slab Seismicity Occurs within Panama-Choco Block & Lithosphere of Accreted Terranes

Panama-Choco Block May Reduce/Disrupt Mantle Wedge Corner Flow—Disrupt Arc



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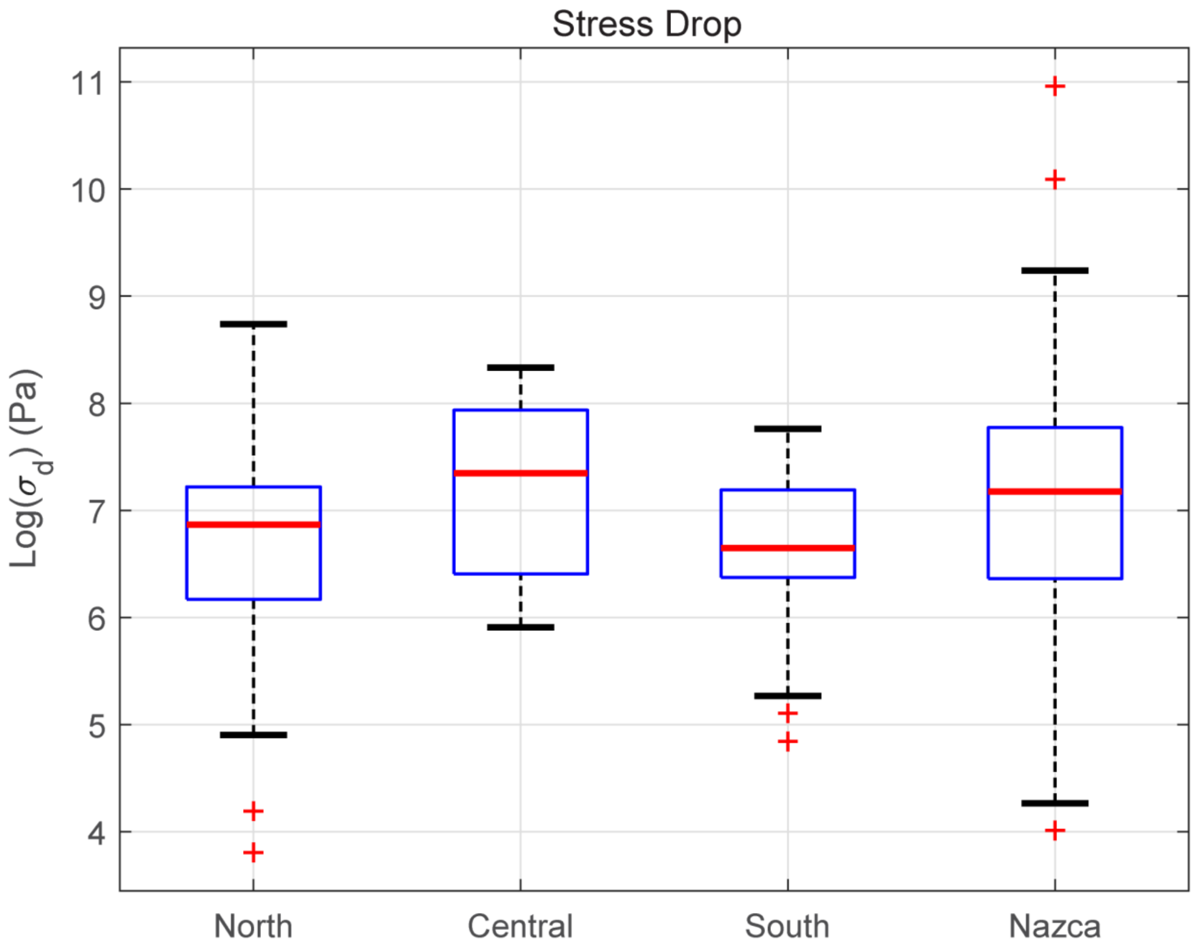
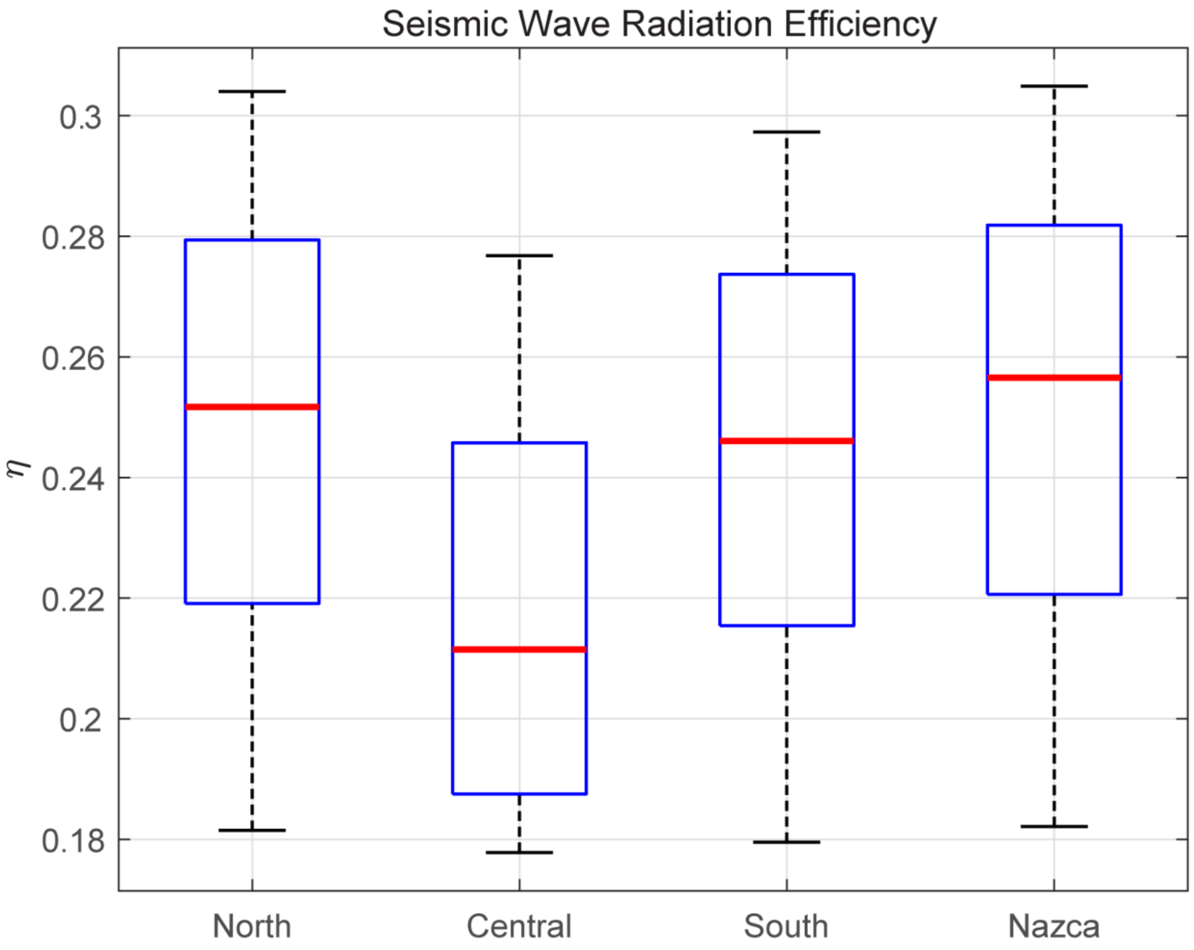
What Drives Cauca Cluster Seismicity?





Moderate to high stress drops and normal radiation efficiencies consistent with fluid related mechanism.

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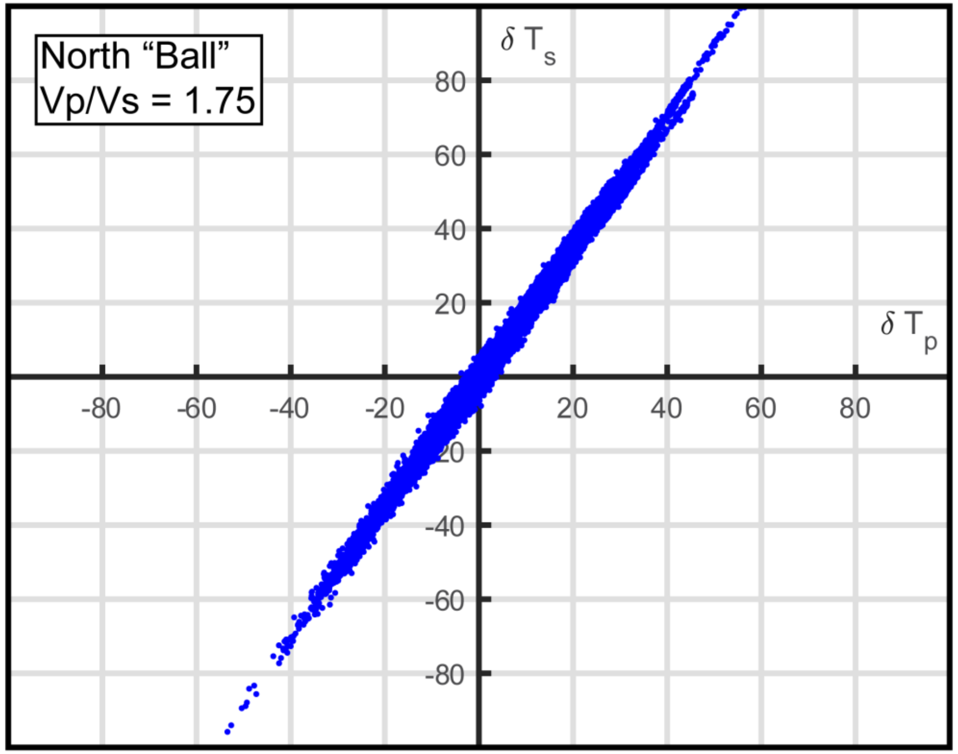
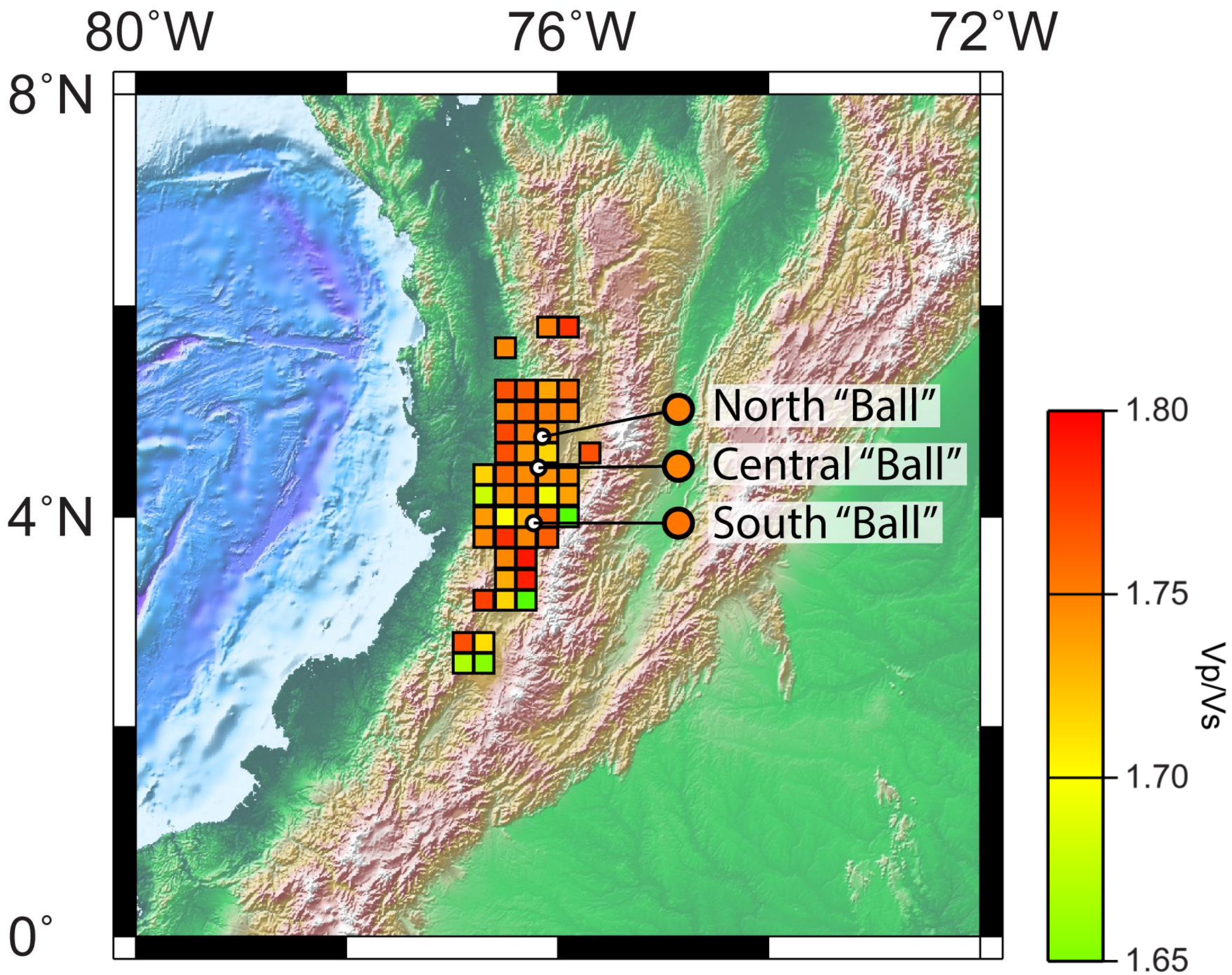
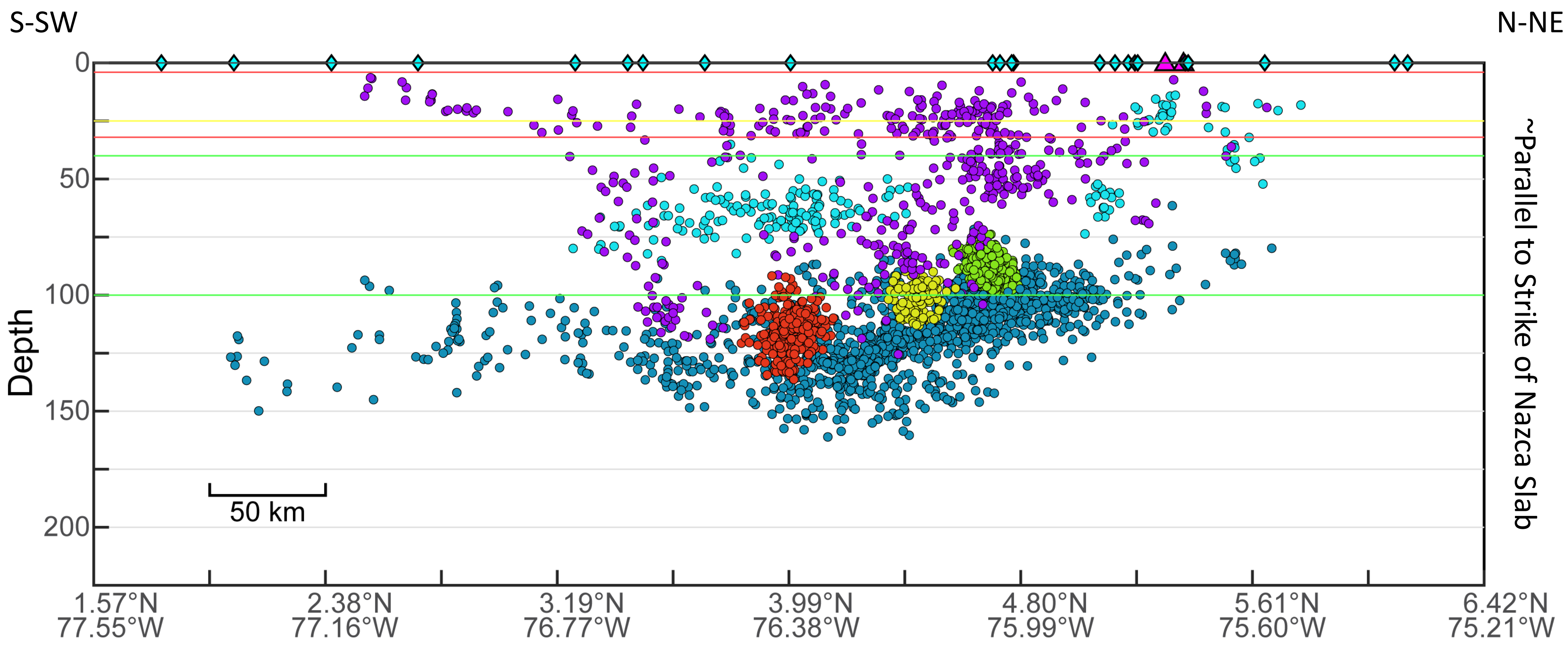


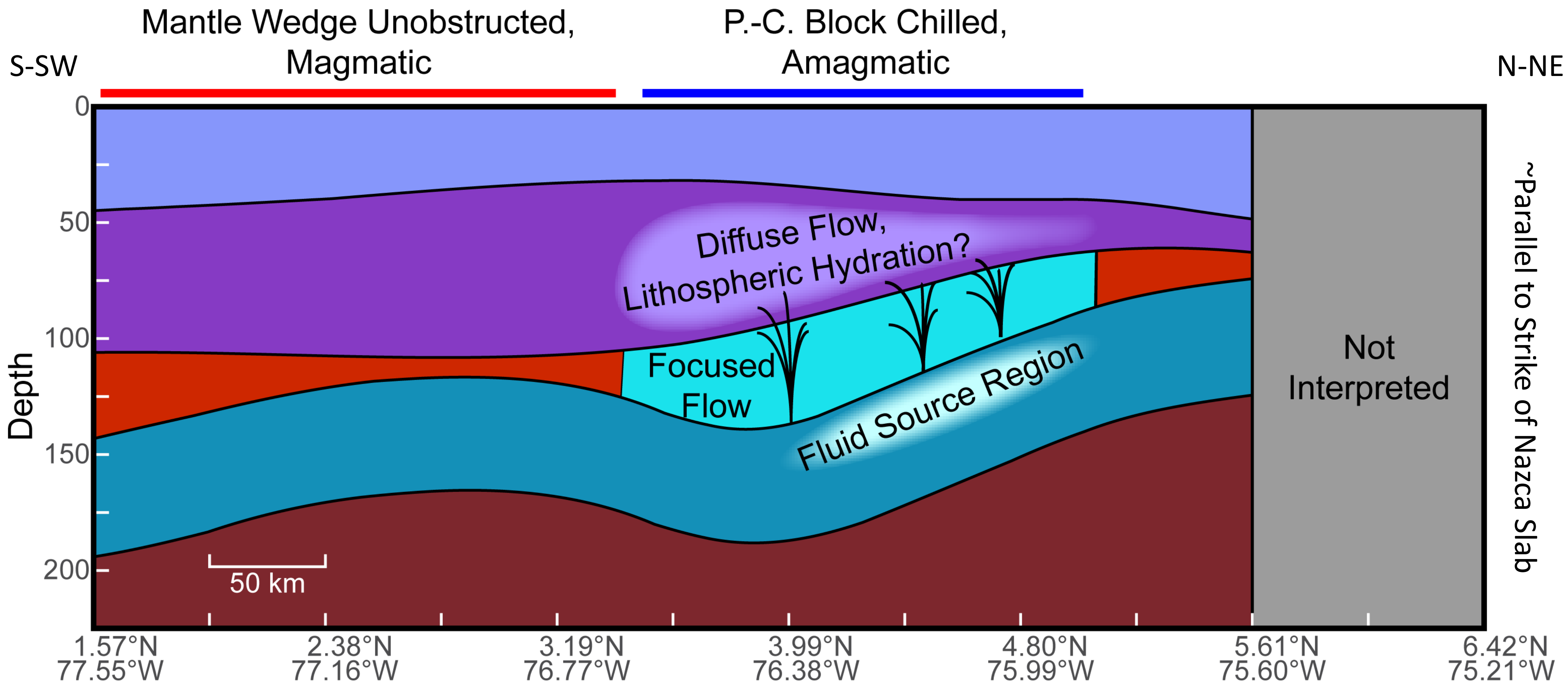
Typical mantle materials at corresponding depths have a Vp/Vs of ~1.70-1.75



Vp/Vs shows little evidence for extensive fluids around earthquake sources, however extensive faulting may allow rapid drainage.



The Cauca Cluster represents a location in which the partial subduction of the now accreted Panama-Choco terrane has disrupted typical mantle wedge processes. Thermal shielding from the terrane and its disruption of mantle wedge corner flow prevent magmatism, while fluids draining from the slab into the overriding plate drive supra-slab seismicity.



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Barat, F., de Lépinay, B.M., Sosson, M., Müller, C., Baumgartner, P.O., and Baumgartner-Mora, C., 2014, Transition from the Farallon Plate subduction to the collision between South and Central America: Geological evolution of the Panama Isthmus: Tectonophysics, v. 622, 145-167, doi:10.1016/j.tecto.2014.03.008.

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