Earthquake localization at the intersection of oceanic mantle structures with subduction zones

– the 2010 offshore Maule (Chile), 2010 Ryūkyū, & 2011 Tōhoku (Japan) earthquakes

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Regional structures in the lithospheric mantle to deep crust in continental intraplate interiors may act as stress guides, localizing earthquakes in the overlying brittle crust ***e.g. Western Quebec - Adirondack seismic zone.***

Could this also be the case for subduction zone earthquakes?

Research aims to:
- **test whether previously unmapped upper mantle to deep crustal structures in oceanic lithosphere may play a role in localizing earthquake epicentres, especially at their intersection with subduction zones?**
- **determine effects of shear tractions at the base of the lithosphere.**

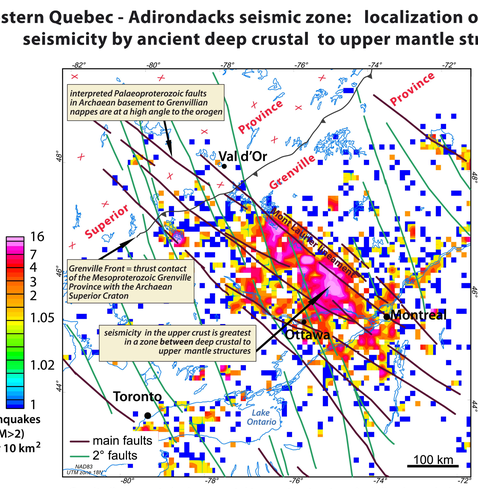
The Western Quebec - Adirondacks seismic zone: localization of intracontinental seismicity by ancient deep crustal to upper mantle structures

Location map

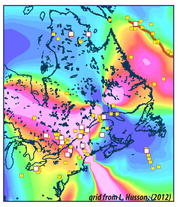
Several NW-SE striking, transverse structures identified from Bouguer gravity data in the Mesoproterozoic Grenville Province correspond to features in a 100 km depth slice of P-wave seismic tomographic data (Model MITP08):

- *interpreted as faults in Archaean lower crust & sub-crustal lithospheric mantle beneath the Grenville orogen formed during Palaeoproterozoic rifting between the Superior & Wyoming cratons,*
- *faults were reactivated during deposition of Grenville Group sediments & localize synsedimentary Zn deposits,*
- *deep faults were reactivated during Grenvillian orogenesis, influencing deformation in upper level nappes, & localize syntectonic IOCG (iron oxide-Cu-Au) deposits & other mineral occurrences.*

Do deep structures in oceanic lithosphere intersecting subduction zones similarly influence seismicity?

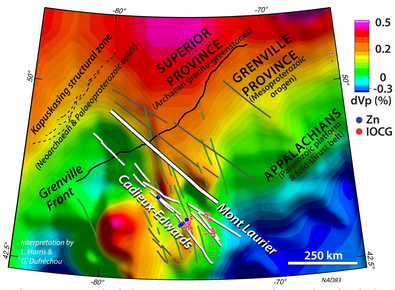


Gravity lineaments (= deep crustal to mantle structures) define boundaries to areas of greatest seismicity: structures act as stress guides



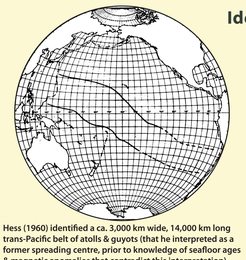
Horizontal divergence of shear tractions at the base of the lithosphere due to the underlying mantle flow, NE North America

grid from L. Husson, (2012)



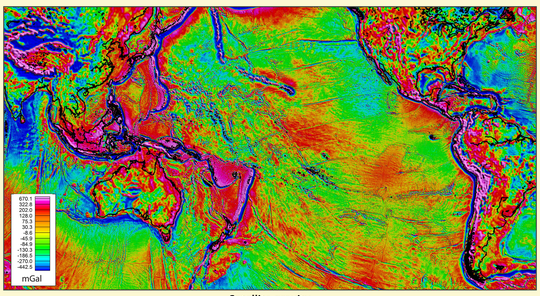
Gravity lineaments on shaded MITP08 seismic tomographic 100 km depth slice
- *several NW- & NNW-striking lineaments represents lithospheric-scale structures*

Identification of deep crustal to upper mantle, trans-Pacific structures from satellite gravity



Hess (1960) identified a ca. 3,000 km wide, 14,000 km long trans-Pacific belt of atolls & guyots (that he interpreted as a former spreading centre, prior to knowledge of seafloor ages & magnetic anomalies that contradict this interpretation).

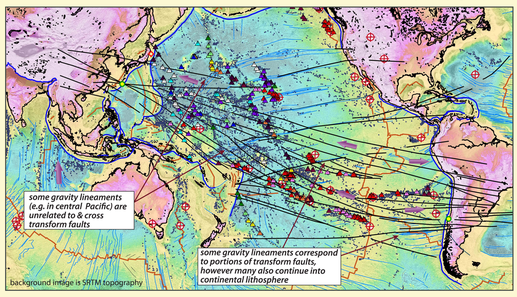
Trans-Pacific deep crustal to upper mantle lineaments are interpreted from enhanced long wavelength satellite gravity data. Many gravity lineaments correspond to mapped transform faults & fracture zones in the oceanic crust, however some lineaments & portions of other lineaments, are highly oblique to mapped structures, suggesting decoupling between oceanic crust and mantle. Gravity lineaments offset or parallel velocity domain boundaries in seismic tomographic images of the mantle and separate or terminate zones of earthquake epicentres of different depths in maps of historical earthquake data. Seismic tomography also suggests the possibility for continental mantle "rafts" within the Pacific Ocean, similar to those previously interpreted in the Atlantic Ocean by Begg et al. (2009). Some gravity lineaments are interpreted as margins of these continental fragments.

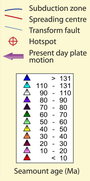


Satellite gravity

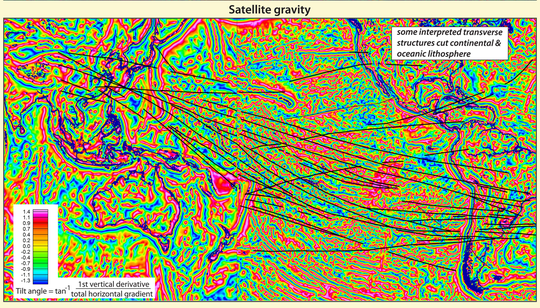
Transverse deep crustal & upper mantle structures may localize seamounts & hotspot-related volcanism

- Subduction of seamounts is suggested as a factor contibuting to seismicity at subduction zones. Can the interpreted structures also influence seismicity where they intersect with subduction zones, or are these structures responsible for effects attributed to seamount subduction?
- Many seamounts occur along interpreted deep, trans-Pacific structures. Even where hot-spot related, volcanism may be controlled by the deep transverse structures. Some seamounts form échelon arrays along transverse structures due to transcurrent displacement along underlying, deep structures (Utkin, 2006).





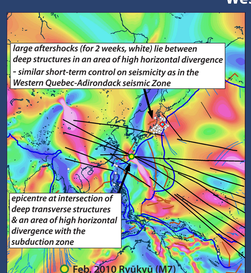
Relationship between gravity lineaments & tectonic features



Tilt angle of long wavelength component highlights linear features = deep crustal to mantle structures

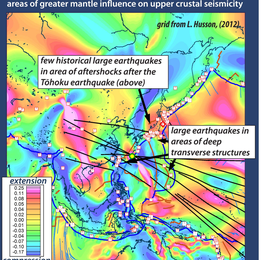
Impact of deep crustal to upper mantle structures on seismicity

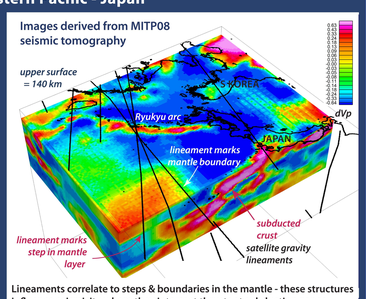
Western Pacific - Japan



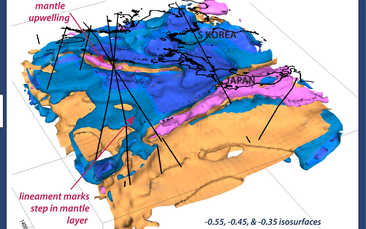
Horizontal divergence of shear tractions at the base of the lithosphere due to the underlying mantle flow = areas of greater mantle influence on upper crustal seismicity

grid from L. Husson, (2012).



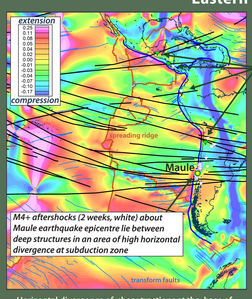


Lineaments correlate to steps & boundaries in the mantle - these structures influence seismicity where they intersect thrusts at subduction zones:
- *flexure/irregularities in thrusts at their intersection*
- *act as 'stress guides'; may limit domains of seismicity (e.g. aftershocks)*



Transverse deep crustal & upper mantle structures & mantle flow shear tractions play a role in localizing seismicity
- *significant aftershocks may be localized in areas of high horizontal divergence bounded by deep structures, transverse to main, active faults*
- *help establish areas of greater impact of large aftershocks after a major earthquake: additional factors to be considered in earthquake risk assessment*

Eastern Pacific - South America



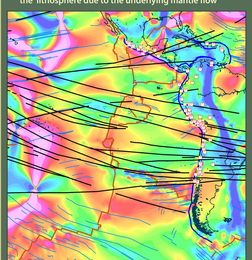
M4+ earthquakes in the week before (green) & 2 weeks after the2010 M8.8 Maule earthquake (white) lie on interpreted transverse faults where they intersect subduction zones in areas of high horizontal divergence

The 27 Feb. 2010 (M 8.8) offshore Maule (Bio Bio) earthquake, Chile, followed the 26 Feb. 2010 (M7) Ryukyu islands earthquake on the opposite side of the Pacific, but within the same interpreted deep crustal /upper mantle transverse fault zone

- coincidence or distant triggering?
- both earthquakes occurred in areas of complex mantle geometry that may have influenced local stresses &/or locking along active faults
- could mantle flow result in stress build up where transverse structures intersect subduction zones?

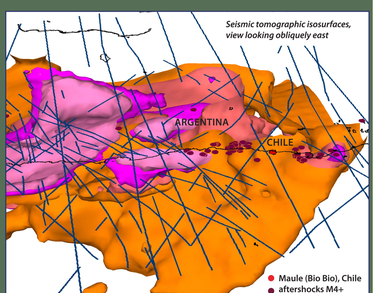
Further statistical analysis of subduction zone earthquakes on either side of the Pacific & their relationship to the interpreted transverse structures is required

Horizontal divergence of shear tractions at the base of the lithosphere due to the underlying mantle flow



Historical M 8+ earthquakes

some earthquakes lie on or cluster about interpreted faults originating in the mantle



Epicentres cluster above mantle discontinuities

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