

Seismogenic, Electrically Conductive, and Fluid Zones at Continental Plate Boundaries in New Zealand, Himalaya, and California

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A. INTRODUCTION

Evidence that fluid-related processes well-removed from the actual seismogenic crust may be critically important in the earthquake cycle has been bolstered by recent discoveries that nonvolcanic, episodic tremors originating 10s of km below correlate with increased seismic activity above. We explore the idea that fluid occurrence *below* the seismogenic zone plays an active role in the rupture process by examining how fluids spatially relate to seismicity at continental plate boundaries. To address this question we co-plot three-dimensional distributions of earthquake hypocenters projected onto magnetotelluric (MT) electrical resistivity cross-sections. Although MT is unique in its ability to detect conductive zones in the deep crust with very low fractions (<1%) of fluids, detection requires an *interconnected* network of fluid-filled porosity. Interconnection is facilitated by shearing, micro- and macrofracturing, and/or grain-edge wetting.

● Underlying Assumption

Magnetotelluric-detected crustal conductive zones are dominantly caused by interconnected fluid (aqueous or partial melt).

● Underlying Question

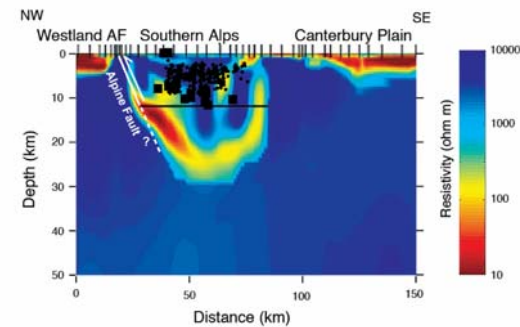
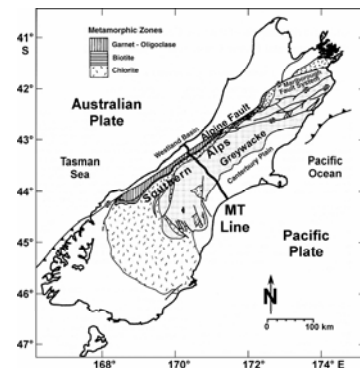
How do fluid zones *below* the brittle-ductile transition relate to seismicity at active plate boundaries, e.g., in New Zealand and Himalaya?



MT field site in Southern Alps, New Zealand.

B. PLATE BOUNDARY AREAS RELATION BETWEEN CONDUCTIVE AND SEISMOGENIC ZONES

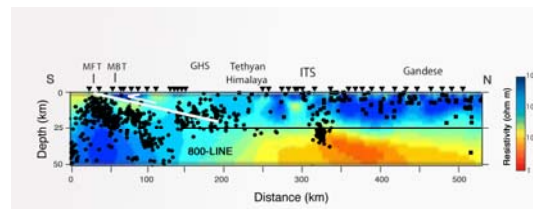
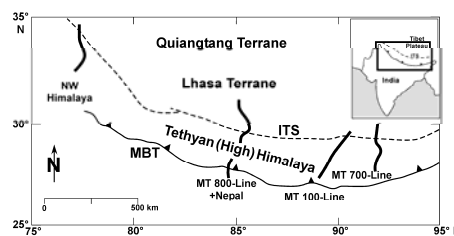
New Zealand Southern Alps



Location of MT line across the South Island of New Zealand.

Electrical resistivity model of New Zealand MT line and nearby earthquake hypocenters (black squares and dots). Horizontal black line at 12 km depth marks brittle-ductile transition. Warmer (e.g., red, orange) colors are zones of low resistivity (high conductivity) (Wannamaker et al., 2002, JGR).

Himalaya



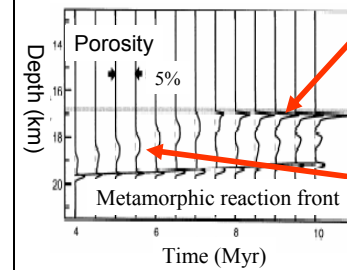
Location of MT profiles crossing the Himalaya Indus-Tsangpo suture (ITS).

Electrical resistivity model of Himalaya MT 800-line and surrounding earthquake hypocenters (black squares and dots). Horizontal black line at 25 km depth marks brittle-ductile transition. Warmer (e.g., red, orange) colors are zones of low resistivity (high conductivity) (Unsworth et al. 2005, Nature).

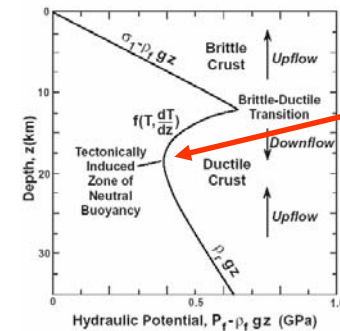
● Key Observation

Conductive zones beneath the Southern Alps of New Zealand and the Himalaya are distinctly *below* the seismogenic zones.

C. FLUID TRAPPING AT OR BELOW THE BRITTLE-DUCTILE TRANSITION



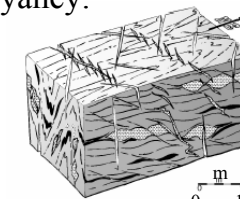
High-porosity water sills formed by arrest of upward propagating porosity waves at heterogeneities below the brittle-ductile transition (Connolly, 1997, JGR).



Zones of tectonically induced neutral buoyancy (fluid stagnation) below the brittle-ductile transition (Connolly and Podladchikov 2004, JGR; Hobbs et al., 2004, EPS).

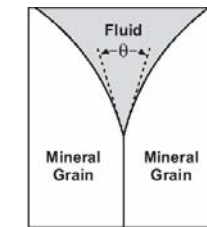
D. CONCLUSIONS

- Fluid reservoirs form *below* the brittle-ductile transition where upward migrating fluids are trapped at heterogeneities, e.g., ductile shear zones, or at regions of neutral buoyancy.



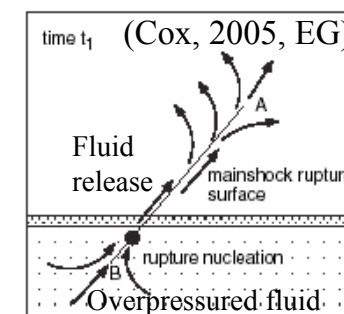
Fracture connectivity

(Famin et al., 2005, Tectonics).



Grain-edge connectivity.

- Fracture and/or grain-edge fluid connectivity can produce low resistivity (high conductivity) zones detected by MT in the ductile crust at <1% fluid levels.
- Fluid-rich regions promote high pore pressures, continued deformation, and permeability enhancing reactions characteristic of ductile shear zones and mylonites.
- Localized, unstable aseismic flow in fluid-rich regions can trigger earthquakes above, e.g., by fluid expulsion or stress loading.



- Continuously generated, overpressured, fluids in New Zealand and Himalaya could generate large earthquakes upon rapid release whereas untrapped fluids distributed through the entire crust in the Parkfield area of the San Andreas fault may facilitate lesser magnitude, more frequent seismicity.