# The Gorda Deformation Zone

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#### Goals

Better understand Deformation of the So-Called Gorda Plate

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- Look at deformation at a range of depths (crust lithosphere asthenosphere)
- Highlight some of my research

## What Makes The Gorda Interesting?

- The Gorda is the oceanic plate outboard of southern Cascadia subduction zone
- Southern Cascadia is where large megathrust earthquakes are thought to nucleate
- 1/3 of the plate configuration that makes 44°N up the Mendocino triple junction
- Seismically active



Modified from Byrnes et al. (2017)

## **Tectonic History**

- ~10 Ma Pacific plate motion changes
- Ridges begin to reorganize
- ~5 Ma the Blanco transform develops
- ~4 MA Explorer plate breaks off
- The Mendocino transform and Gorda ridge fail to reorient



Atwater and Stock, 1998

# Magnetic Anomalies

- Clear bending of anomalies in Gorda
- Juan de Fuca shows signs of reorganization
  - Formation of new segments
  - Ridge rotation
- Pacific side near Gorda does not show similar signs of reorganization
- Variable spreading rates



# Gorda Is Stagnating

- Gorda motion becomes increasingly independent in the last 3 Ma
- At 0.5 Ma the Pacific controls Gorda motion



#### Seismicity Throughout The Plate



1964 – 1980 Wilson (1989)



Star: M 5.7 (Jay Patton <u>http://earthjay.com/</u>) Historic seismicity (USGS <u>www.earthquake.usgs.gov</u>)



42°0'0"

126°0'0"W

127°0'0"W

125°0'0"W

Chaytor (http://activetectonics.coas.oregonstate.edu/gorda.htm)

## Deformation Accommodated By Left-lateral Faults

- Bathymetry clearly shows ridges associated with faulting
- Ridges appear smoothly deformed, kinked, or undeformed depending on the region
- Moment tensors show dominantly left-lateral strike-slip motion with some normal faulting
- Faults show clear regions of deformation



# Model For Deformation

- Gorda in north-south compression
- Southern section left lateral flexural-slip faulting exploiting old normal faults
- 2<sup>nd</sup> generation strike-slip faulting separate the north and south section
- North is relatively undeformed
- An extensional area reusing normal faults (outer rise bending and/or further accommodation of flexural slip)



Chaytor et al. (2004)

## Deformation Is Driven By Pacific Plate Motion

- Elastic-perfectly plastic model of stress in the JdF
- Transform push is a dominate force
  - Drives the plate northward
  - Reason for N-S stresses in the Gorda
- Circles represent regions of yielding





#### Deformation In The Subducting Plate

- Slab geometry from velocity models and hypocenter locations
- Localized swallowing of the slab east of Gorda
- May be buckling due to Pacific motion





McCrory et al. (2012)

# Heterogeneous Mantle Deformation

- SKS splitting A proxy for mantle flow
- Shear waves split in anisotropic media (deformed olivine rich mantle)
- Pronounced difference in JdF and Gorda splitting directions
- The region of anomalous Gorda measurements correlates with the deformation zone



## Pacific/JdF Motion Shapes Mantle Flow

- Beneath the JdF fast-axes are similar to N absolute plate motion
- Beneath the Gorda fast axes do not match plate motion, instead matching Pacific/JdF relative motion
- A broad zone of mantle reorganization



Bodmer et al. (2015)



# Teleseismic Tomography

a)

4**0**°

- P and S models show slow mantle velocities beneath Gorda
- Low velocity anomalies correlate with deformation region rather than ridge structure
- Inferred to be regions of upwelling and partial melt
- Pacific entrainment draws material away from the stagnant Gorda which is accommodated by upwelling



#### Upwelling Region Extends Under the Plate

- Body and surface wave models show deep low velocities east of the trench which connect to shallow low velocities beneath Gorda
- Infer that the source region for upwelling into the Gorda is from beneath the plate





Bell et al. (2016)

# **Big Picture**

- Multiple lines of evidence suggest the Gorda behaves differently than the adjacent JdF
- Deformation dynamics controls the structure of the Gorda region from the surface to the upper mantle
- The Pacific plates influence on the young and small Gorda is the main driver
- The Gorda is a failing plate, now representing a diffuse boundary between the JdF and Pacific plates

### A Look Into The Future?

- Farallon has broken up several times before
- Old microplates get captured. The triple junction and associated transforms have to readjust
- Likewise stresses within the JdF must readjust



