Onshore and offshore paleoseismic evidence from 41 Cascadia earthquakes strongly suggest that segmentation plays a significant role in Cascadia, and may have multiple sources. Southern segments may be controlled by obvious structural boundaries such as the Blancone Fracture zone, and two subducting pseudo faults. Along the northern margin, where segmentation is not apparent, significant basement structure is masked by thicker sediment supply, supporting a primary control by sediment thickness on the subducting plate. In Cascadia, massive submarine fans are accreting to the along the northern margin in their northern regions, with incoming sections of 3-4 km thickness that taper southward. These thick sections smooth the plate interface with respect to structures in both the downgoing and upper plates, likely promoting long ruptures. We suspect, supported by paleoseismic data, that northern Cascadia and northern Sumatra may be prone to large ruptures due to the masking of other structures by large influxes of sediment on the subducting plate.

One segment boundary in Cascadia appears not to be related to sediment supply, but may linked to a narrowing of the locked interface in map view. The Cascadia forearc is composed of an Eocene-Pliocene accretionary complex, outboard of which lies a Blancone-Holocene wedge of low taper, mixed verge, and high pore fluid pressure. The young wedge is widest off Washington and northernmost Oregon, tapering both north and south. Mixed verge, open folds, mud volcanoes and backstop parallel trends indicate poor coupling of the young wedge that is easily mapped from surface data. The long-term average downdip limit of significant coupling appears to be consistent with thermal, geodetic, and structural evidence of a transition from arc normal to arc parallel contraction. An average boundary consistent with these disparate data suggest significant heterogeneity in along-strike width and or magnitude of coupling. A seaward swing of the downdip locked zone, combined with a landward position of the updip limit may create a “pinchout” in central Oregon, where we observe a paleoseismic segment boundary.

**ABSTRACT**

Cascadia Segmentation: Sediment Supply, Structural Influences, and a (possible) Pinchout of the Locked Interface

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**INTRODUCTION**

Core Locations

**Synchronous Earthquake Triggering**

The synchronicity test demonstrates earthquake origin by eliminating other possible landlump triggers for the northern margin (Adams, 1999; Sniffen et al., 2003). But this does not test earthquake origin for the remainder of the margin, which we have previously linked based on the identical number of events above the Mazama Ash datum (13) and the Holocene Paleoseismic boundary (18).

Direct correlation, shown at right, links the northern and southern margin. The correlation is based on the characteristics of the sandy coarse pulses, and is reflected in magnetic susceptibility, gamma density and K-Ar imagery. We find that by using multiple cores at each site we can overcome the inevitable mismatches, even between cores at the same site and make a positive correlation based on these data.

**CASCADIA EVENT CORRELATION**

Direct correlation, shown at right, links the northern and southern margin. The correlation is based on the characteristics of the sandy coarse pulses, and is reflected in magnetic susceptibility, gamma density and K-Ar imagery. We find that by using multiple cores at each site we can overcome the inevitable mismatches, even between cores at the same site and make a positive correlation based on these data.

**EVIDENCE FOR SEGMENTED RUPTURES:**

Small Mud Turbidites

Fine-grained turbidites. The panels to the left show four turbidite sequences from the Rogue Apron that include fine-grained silt of sandy composition. These small mud turbidites (connected by red dashed lines and subevent descriptions using lower-case letters) were originally observed as small-amplitude deviations in magnetic susceptibility (black-brown traces) and gamma density (light blue traces) and logged as “dark” in visual logs. High-resolution Computed Tomography (CT) scans of the cores reveal that these areas are denser than the surrounding material, but are less dense than the subevent described using lower-case letters. These small mud turbidites have been observed in the upper Cascadia sedimentary column and have a typically fine-grained correction. These small mud turbidites can be observed through biogenic sediment (i.e., biodebris) of the small turbidites. This event is represented by the biodebris (not shown). Bolan and Sanger Lake data are from Briles et al., 2008.

The persistent presence of similar or identical numbers of small mud turbidites between core sites, and between Rogue and Hydrate Ridge (Panel to Right) suggests a connection, and we have tentatively correlated events between these two sites. The core sites are presented in arbitrary gray scale. Many of these small mud turbidites have been observed in the upper Cascadia sedimentary column and have a typically fine-grained correction. These small mud turbidites can be observed through biogenic sediment (i.e., biodebris) of the small turbidites. This event is represented by the biodebris (not shown). Bolan and Sanger Lake data are from Briles et al., 2008.

**RUPTURE MODES**

Holocene rupture lengths of Cascade great earthquakes from marine and onshore paleoseismology. Four panels showing rupture modes inferred from turbidite stratigraphic/HCl correlation, supported onshore radiocarbon data. A. Full or nearly full rupture, represented by most sites by 15. B. Mid Southern rupture, represented by 2-3 events. C. Southern rupture from central Oregon southward represented by 8-10 events. Correlation to Inland Sites The recent discovery that inland lakes contain records of Cascadia subduction zone earthquakes will provide additional information which will improve our ability to fine-tune estimates of event timing and identification of small events. Southern Oregon sites including Sanger Lake, CA, Botan Lake, OR and Upper Sanger Lake, OR are currently being correlated to Bradley Lake, OR and our southern Cascadia marine sites: Rogue, Smith and Klamath to create an east-west transect (Morey et al., in prep).

Magnetic susceptibility from Sanger Lake, CA sediments (red traces) show a remarkable similarity to the gamma density and magnetic susceptibility at our southern sites: Rogue, Smith and Klamath. Independent radiocarbon dates from plant material in the lake sediments supports the relationships observed in the physical property data. Nearby Botan Lake, OR magnetic susceptibility data also show similar variability (not shown). Bolan Lake, OR magnetic susceptibility data also show similar variability (not shown).
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TURBIDITE EVIDENCE FOR SEGMENTATION

TWO SEGMENTATION MECHANISMS

1. Pinchout from convergence of up and downdip limits

- Three indicators of downdip limits have a common feature, and seaward swing in northern Oregon.
- Likely plate boundary focal solutions (near coast) are compatible with this model.
- Initial thrust ridge (Western Geco Line 552a, USGS, 2009).

2. Sediment supply and basement structure

- B: Subduction of lower plate features along the southern Cascadia margin.
  - Blanco Fracture Zone and two pseudofaults extend toward the base of the Cascadia subducting Juan de Fuca plate, shown by white dashed lines. The structures themselves, and an underlying ~1 km step up in basement level on the Gorda plate, may play a role in the apparent paleoseismic segment boundary near Cape Blanco and the Rogue Canyon.
  - Sediment supply and basement structure.

Space time diagram for the Cascadia margin showing Holocene marine radiocarbon data and stratigraphic correlations.

Filled symbols are marine 14C ages, smaller-filled symbols are hemipelagic calculated ages. Marine data plotted as ±2-sigma midpoints and ±2-sigma ranges. Dashed lines show stratigraphic correlation of the turbidite data, which shows deviations from the preferred age range where correlation overrules an individual 14C age. Up arrows shown for marine data where side-slip erosion suggests a maximum age. Marine error ranges are RMS 2-sigma propagated errors. Smaller southern Cascadia events shown with thinner dashed lines. Green bars are best fitting offshore-coupling age trends for Cascadia earthquakes. Land data plotted as published, with some sites revised as discussed in text. Preferred among land sites given to recent publications using well constrained ages. Down arrows indicate minimum ages as published (land only). Two sided arrows shown where maximum and minimum ages averaged (land sites only). From Goldfinger et al., 2010.

Correlation of isolated sites, Hydrate Ridge and Rogue Apron.

These two sites are completely isolated from each other and are separated by 220 km along strike. Hydrate Ridge (HR) basin is also surrounded on three sides by high ridges, further isolating the site from onshore sediment sources. Finally, the HR site has no river or canyon sources of sediment along the coast. These two core sets correlate very well based on geophysical “wedge matching” and numerous 14C ages. Many of the smaller events shown below appear to correlate between these two sites. Through they pass fewer tests of seismic origin than the larger events, their persistent correlation between these two sites suggests that they too are earthquakes generated. Hydrate Ridge and adjacent 0-4GC-TC core have been “flattened” to all turbidite horizons in Rogue Apron core 31 PC.

Hydrate Ridge Basin West Rogue Apron

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LEFT: Sedimentary section thickness on the incoming Juan de Fuca plate.

Three indicators of downdip limits have a common feature, and seaward swing in northern Oregon.

Panel at left shows Goldfinger up and downdip limits (Priest et al., 2009) and leveling and tide gauge estimate (Yellow line, Burgette et al., 2009).

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C: Migrated multichannel reflection profile showing subducting pseudofault B beneath a landward vergent initial thrust ridge (Western Geco Line 552a, USGS, 2009).

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