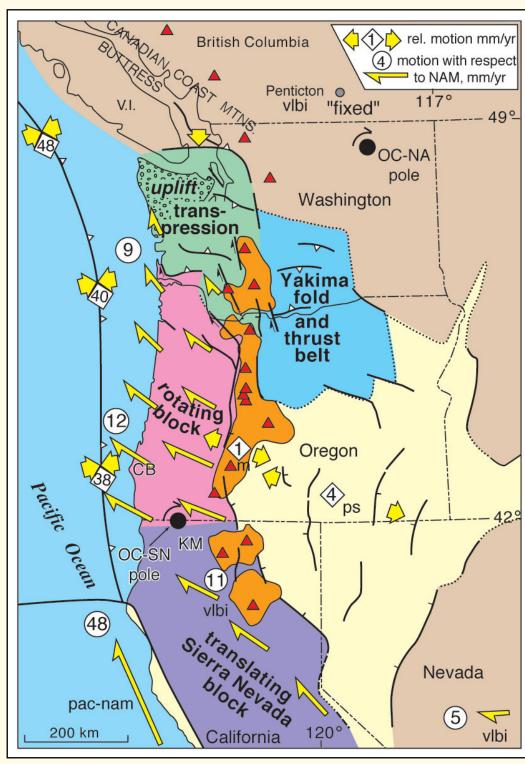
The Doty Fault: What is its place in modern crustal deformation of southwest Washington?

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Tectonic Setting

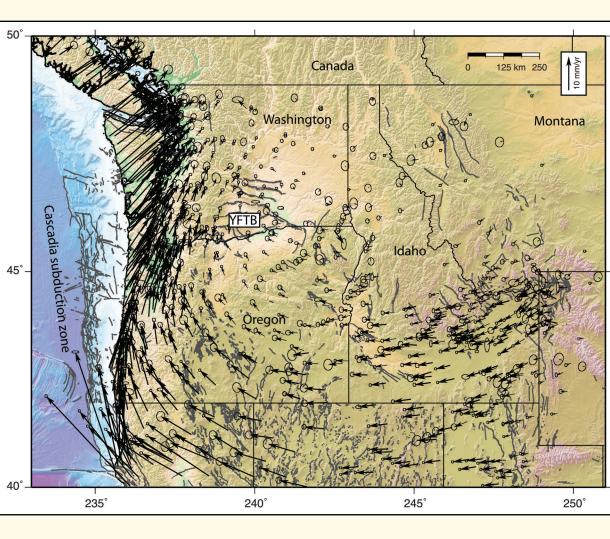


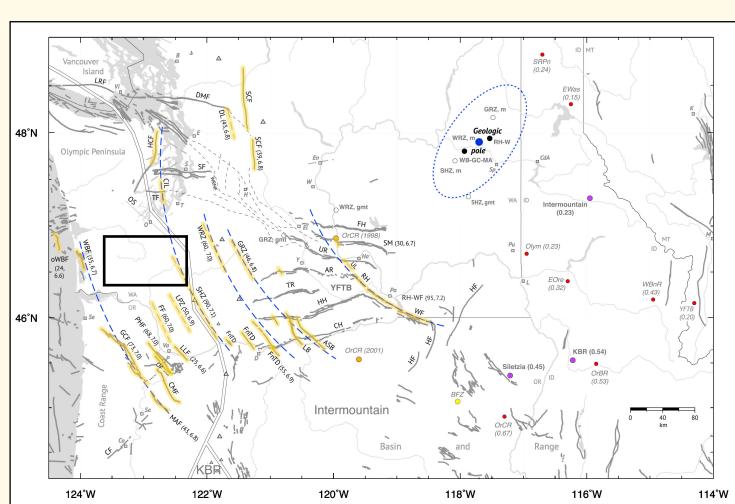
► GPS data constrain more precise models of present-day crustal movement (McCaffrey and others, 2016). GPS velocities show the effect of both crustal rotation around a pole in eastern WA-northern ID and elastic deformation due to locking along the subduction interface

supports independen **McCaffre**

(2013) places the southern edge of the "Taco" block, which is locked roughly along the Doty fault. This block boundary accommodates < 1 mm/yr shortening and 1–2 mm/yr left-lateral

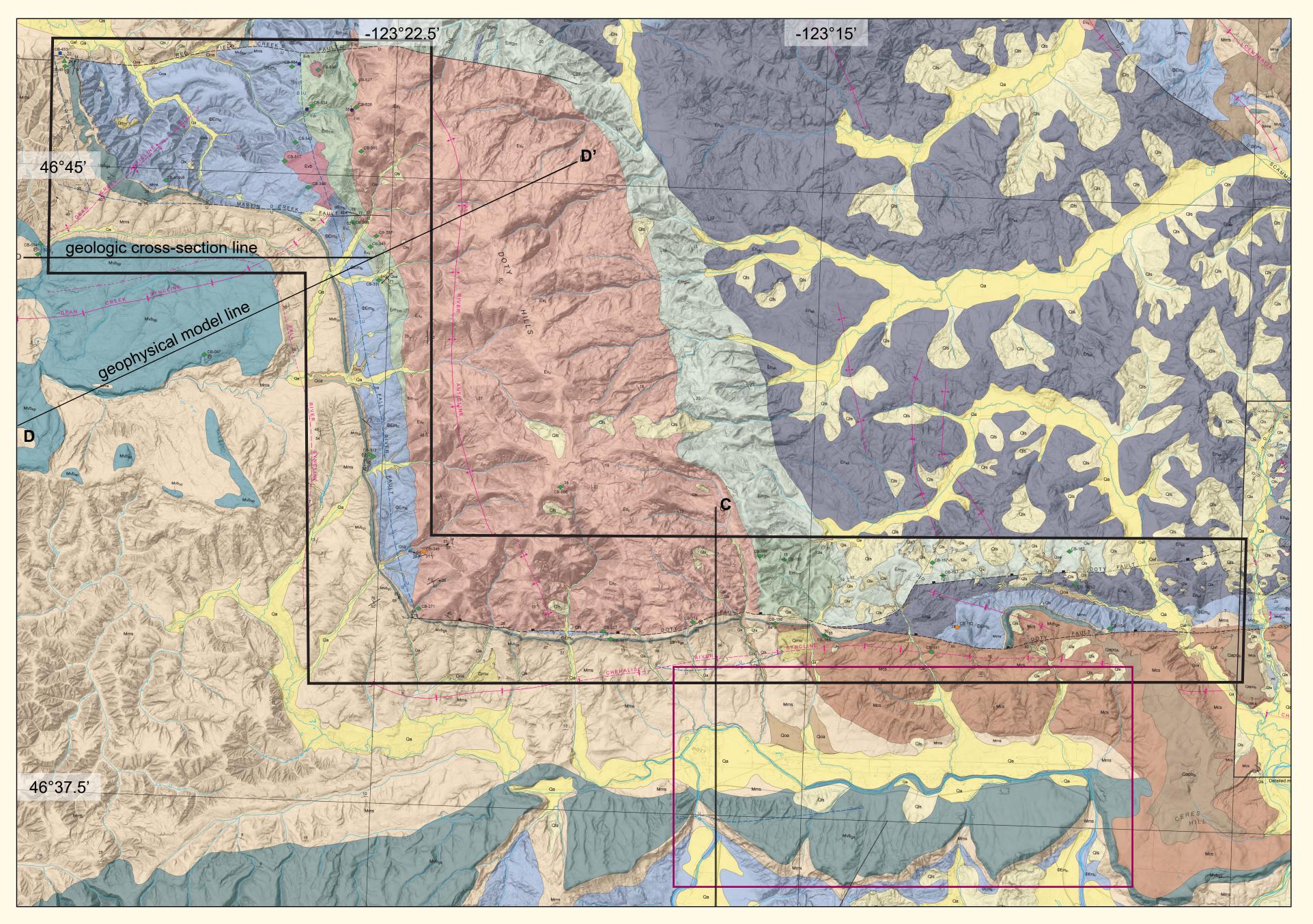
■ Block rotation model for the Pacific Northwest from Wells and others (1998). Rotational motions are constrained by very long baseline interferometry, paleoseismology, magmatic arc spreading, and Pacific—North America motions. The western Oregon block (pink) rotates about the OC-NA pole. A weaker western Washington block (green) accommodates north-south shortening between Siletzia and the slower-moving Canadian Coast Mountains. The limits of the deforming western Washington block are not well known. The Doty fault is one of several east-trending compressional structures in western Washington that could currently be accommodating N-S compression.





▲ Broadly, faults and seismic lineaments (yellow) paralleling concentric circles around a rotational pole in eastern WA show right-lateral transform displacement. Faults subperpendicular to the rotation direction (gray) show predominantly compressional offset (Brocher and others, 2017). The location of our study area in southwest WA (black box) is a zone of missing data.

1) Geological Mapping



Detailed geologic mapping (inside black outline) confirms general geometries and contact relationships defined by Pease and Hoover (1957). The Doty fault does not appear to continue west of its previously mapped extent, and bedding attitudes seem to indicate a structure stepping north and west. New interpretations increase the length and significance of the Martin Creek fault. Magenta box shows the location of the lidar image, right, in Section 4.

Major Geologic Units

Qa Quaternary alluvium Miocene Columbia River

Miocene continental

Miocene marine sandstone Oligocene-Miocene Lincoln Creek Formation (sedimentary)

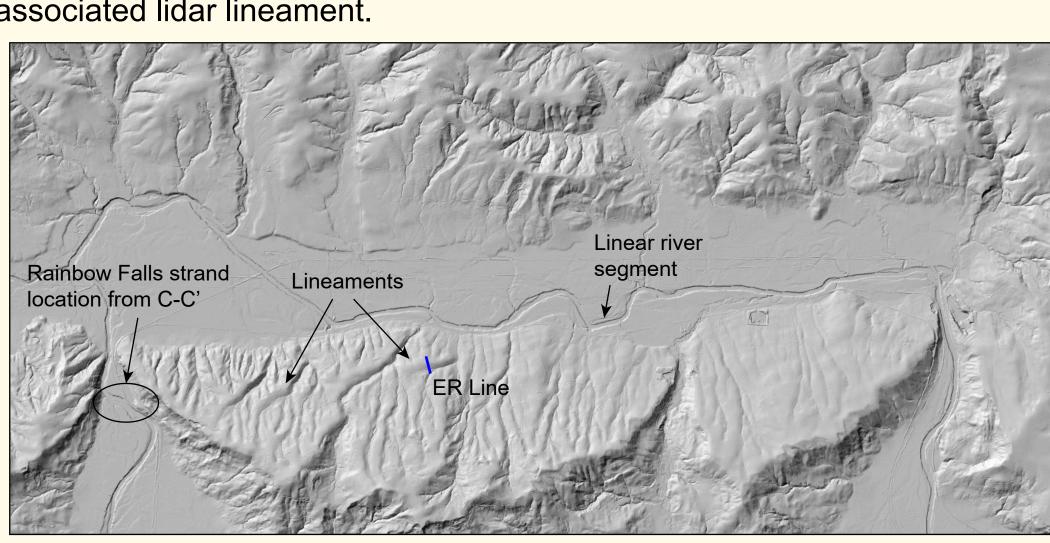
Eocene Skookumchuck Formation (sedimentary)

Eocene McIntosh Formation (sedimentary)

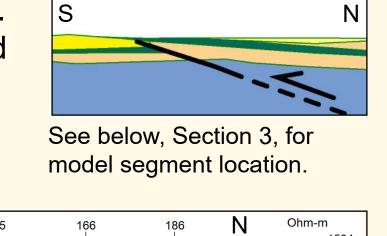
Eocene Crescent Formation

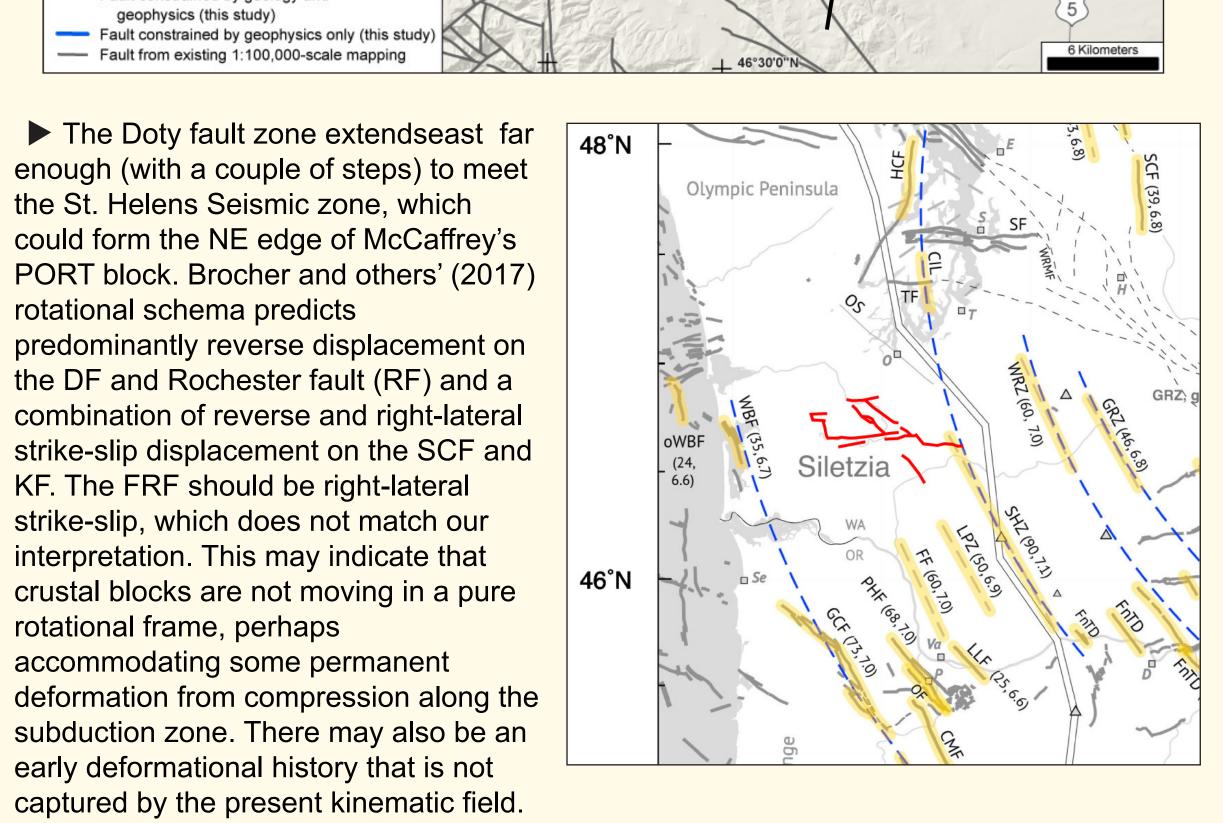
4) Recent Fault Activity?

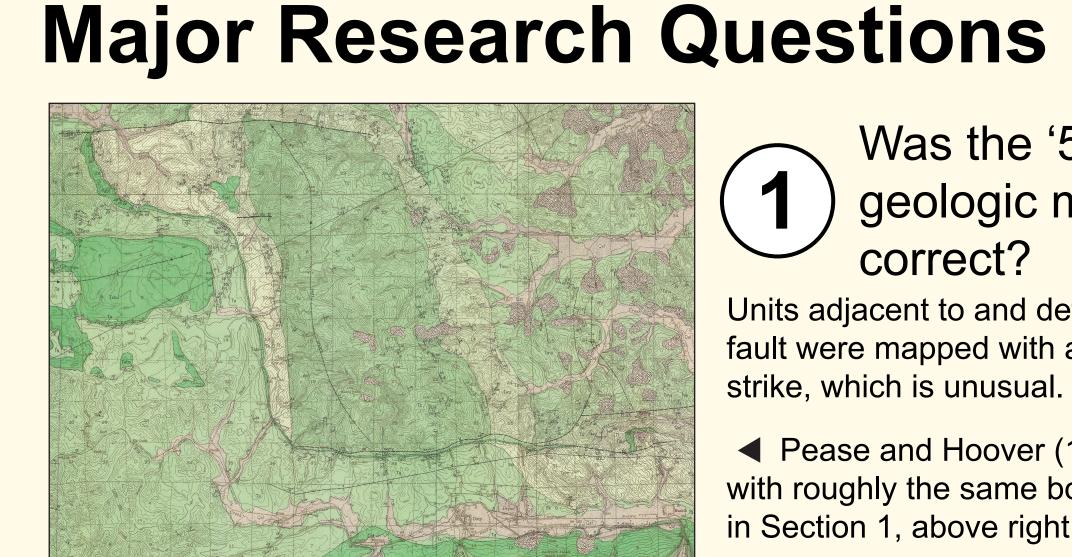
▼ Lidar image along Doty fault zone segment (see boxes left and right for location). Unlike the Puget Lowland around Seattle, clear fault scarps are not apparent in the Doty fault region. Though this may indicate these faults have been inactive in the Quaternary, any scarps that form could have low preservation potential due to lack of compact near-surface substrate combined with a low displacement rate. Near-surface materials are instead highly weathered, loose regolith in most places. There are few locations with preserved Quaternary deposits at all. One location with preserved Q is along the Chehalis River, crossing model profile C-C' (circle below) and the Rainbow Falls Doty fault strand. This strand also has the clearest associated lidar lineament



▼ ER image along lidar lineament shown above. Resistive Columbia River Basalt (CRB) is exposed at the surface and seems to be duplicated below, matching the gravity/magnetics model (shown here in the opposite orientation for comparison).







Was the '50s-era 1) geologic mapping correct?

Units adjacent to and deformed by the Doty fault were mapped with a 90° change in strike, which is unusual.

◆ Pease and Hoover (1957) geologic map with roughly the same bounds as that shown in Section 1, above right.

How does the Doty fault connect to the regional fault network?

Prior mapping did not show the Doty fault endpoints connecting to any other faults.

4) Is the Doty fault active?

No clear scarps are visible in lidar data for the region. This may indicate the Doty and other local faults are inactive. However, lack of consolidated glacial deposits and a thick carapace of highly weathered regolith may lead to poor preservation. Other approaches are needed to clearly answer this question.

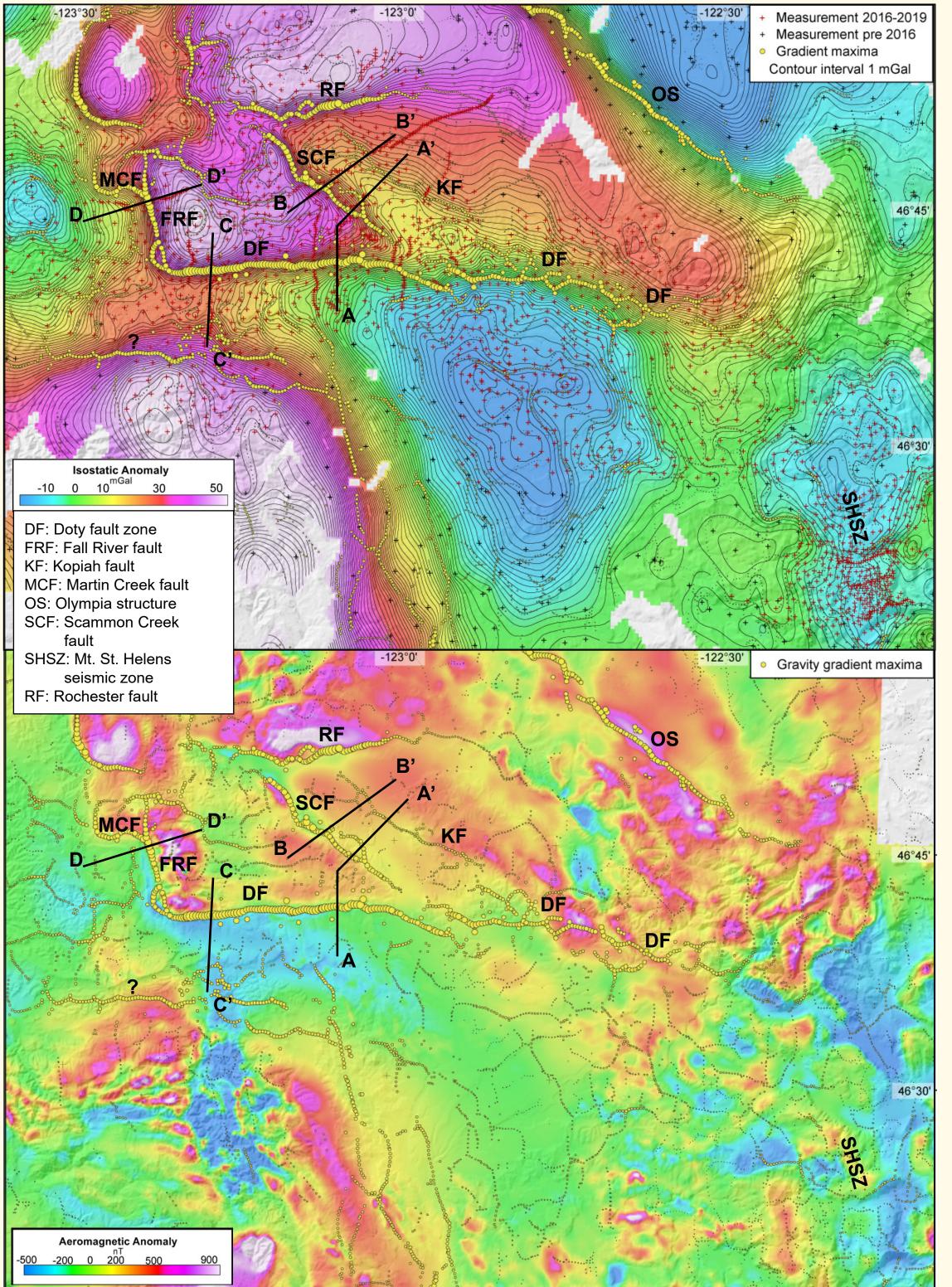
Is the Doty fault really a zone?

Previous research suggested the Doty is a reverse fault. This work will test this hypothesis to confirm its kinematic relationship to crustal deformation. This research will also determine if the fault is really a zone with multiple strands.

What is the Doty fault's 5) role in regional crustal deformation kinematics?

To understand full hazard potential, defining current driving forces, whether from forearc rotation or subduction, is important.

(2) Fault Extent



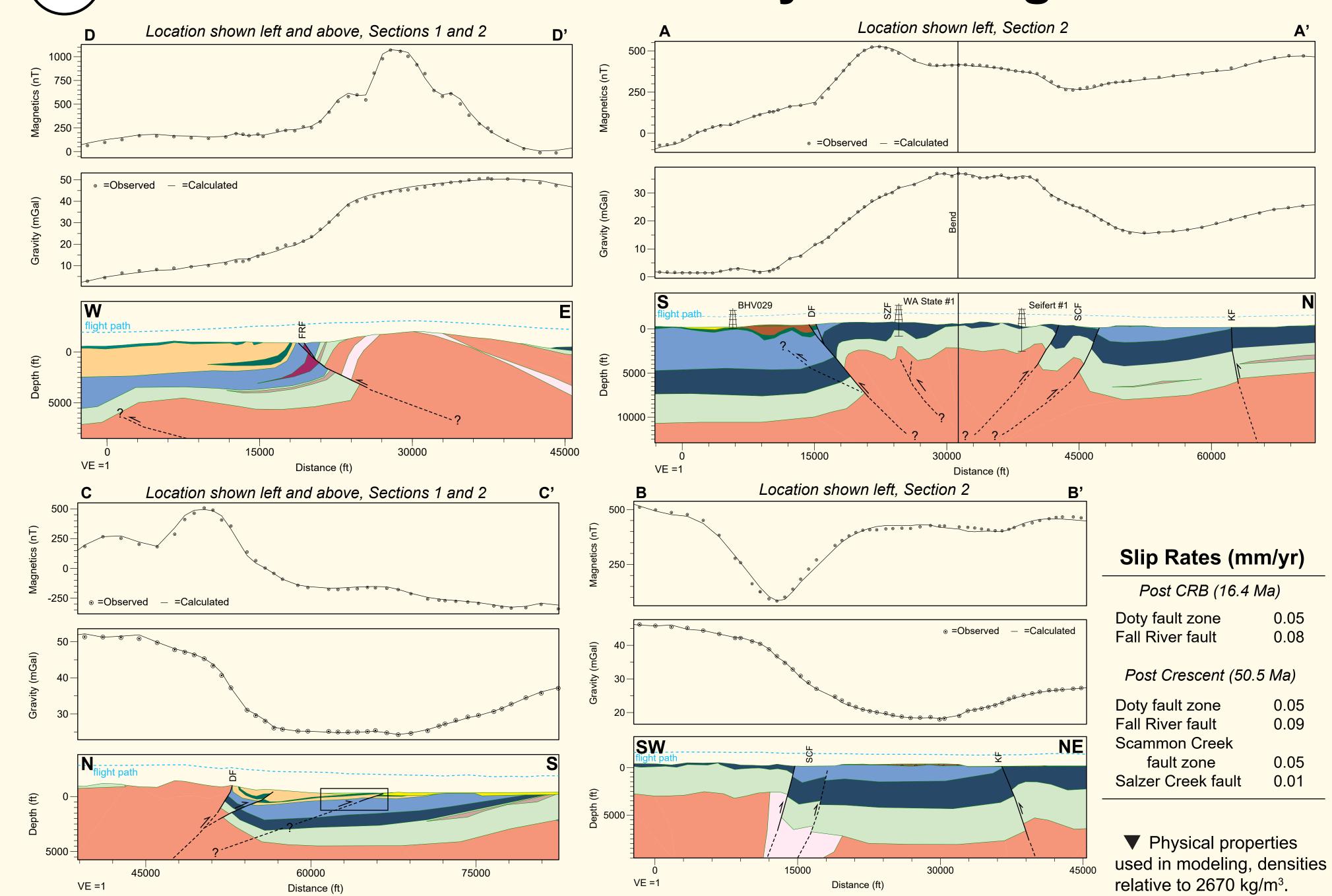
▲ High-resolution aeromagnetic data (Blakely and others, 2016) largely confirm lineament locations identified from gravity and support modeling (right). Both gravity and magnetic datasets confirm the Doty fault does not extend west of its geologically mapped extent.

■ More than 2000 new gravity measurements in the last 3 years have made gravity a key tool for identifying faults through lineament analysis and modeling (right). Completed work confirms a minimum length of 41 km for the Doty fault and data collection in the summer of 2019 extends its associated gradient to 69 km total (roughly the same length as the Seattle fault), nearly meeting the St. Helens seismic zone (SHSZ).

The crust of southwestern

Washington is composed predominantly of basalts of the Crescent Formation, the local Siletzia member unit. Eocene to Miocene onshore and coastal sedimentary partly strata blanket the basalt. Fault offsets juxtaposing these two lithologies provide an excellent target for gravity and geomagnetic mapping because of their contrasting density and magnetic properties. Crescent Formation is magnetic (~45 SI) and dense (~2830 kg/m³) and sedimentary units are nonmagnetic (~0 SI) and less dense (~2150 kg/m^3).

3) Subsurface Fault Geometry Modeling



Modeling of subsurface geometries in cross section constrained by surface geology, wells, aeromagnetic, ground magnetic, and isostatic gravity anomalies confirms fault dip and strongly suggests multiple strands for several of the faults. Some faults could be blind. Sedimentary stratigraphy consistently thins over the uplifted blocks suggesting a long history of faulting and/or folding since the Eocene. Most faults have significant vertical throw (≤ 3.4 km) and steady-slip rates between Eocene and Miocene, but at a fraction of the Seattle fault's rate (~0.9 mm/yr; Johnson and others, 2016). Box on C–C' is shown in Section 4, above.

Qapo_{lh} – Logan Hill Formation $\Delta \rho = -470 \text{ to } -660 \qquad \chi = 0$ Mcs – Continental sandstone $\Delta \rho = -660$ $\chi = 0$ Mvb_(sp/qs) − Columbia River Basalts x = -70 to 30 x = 15 to 80Mms – Marine sandstone $\Delta \rho = -470$ $\chi = 0$ Evb – Basalt of uncertain affinity ΦEm_{lc} – Lincoln Creek Formation $\Delta \rho = -400 \text{ to } -430 \qquad \chi = 0 \text{ to } 10$ En_{sk} – Skookumchuck Formation Ev_n/Ev_n? – Northcraft Formation and unknown magnetic rocks $\Delta \rho = -70$ $\chi = 35$ Em_{1m} – Upper McIntosh Formation $\Delta \rho = -220 \text{ to } -240 \qquad \chi = 0 \text{ to } 3$ Em_{2m} – Lower McIntosh Formation $\Delta \rho = -220 \text{ to } -240 \qquad \chi = 0 \text{ to } 3$ Ev_{c (R)} – Reversely magnetized Crescent Formation 0.5 or 0 Ev_c – Normally magnetized Crescent Formation

Conclusions & Continuing Work

(5) Kinematic Relationships

▼ If the Doty fault zone (DF) and nearby faults accommodate most of the relative motion

between the TACO and PORT blocks of McCaffrey and others (2013; two arrows below),

we expect major reverse and minor left-lateral displacement on the DF, major right-lateral

displacement on the Scammon Creek (SCF) and Kopiah faults (KF), which broadly fits our

and minor reverse displacement on the Fall River fault (FRF), and significant reverse

interpretation below. Box shows location of lidar in Section 4. All faults here are shown

simplified in red on the map below with additions from 2019 data collection.

The '50s-era mapping was correct! Our work confirms unusual (?) right-angle intersections for faults and folds in the region.

The western end of the Doty fault connects to a NW-stepping (2) set of faults. The east end appears to step slightly south to connect to the St. Helens seismic zone.

The Doty fault and many others in the area are zones of closely The Doty fault and many others in the area are zones of spaced fault strands, some likely blind. All have some component of reverse and transform displacement.

Recent activity is unclear. Further geophysical imaging (4) (planned, April 2020), including ER, active seismic, and GPR may resolve this.

Relative displacement on the faults studied is broadly (5) consistent with two proposed regional frameworks for deformation. The Fall River fault displacement doesn't entirely fit and indicates that our understanding is incomplete.

Acknowledgments

rotational schema predicts

rotational frame, perhaps

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