EV ALUATING THE SLIP HISTORY OF CRUSTAL FAULTS UNDERLYING VICTORIA, BRITISH COLUMBIA

KRISTIN MORELL, University of Victoria, Victoria, British Columbia, Canada
THOMAS GARDNER, Trinity University, San Antonio, TX

INTRODUCTION

Because subduction zone megathrusts tend to produce the largest and most damaging earthquakes, significant attention has been focused on improving our understanding of the seismic cycle associated with the Cascadia megathrust fault in Canada (e.g. Dragert, 2001; Goldfinger et al., 2003; Wang et al., 2013). This improved knowledge has led to significant advancements in the identification and mitigation of seismic risk for the populated regions of the Pacific Northwest (Halchuk et al., 2015), which include the Canadian cities of Vancouver and Victoria, British Columbia (Fig. 1). Although the seismic hazard associated with the Cascadia megathrust is reasonably well understood, the active crustal faults that must overlie it remain poorly identified, especially in western Canada where active crustal faults have only just begun to be formally recognized (Fig. 1) (Morell et al., 2017).

We undertook a month-long field campaign stationed out of the town of Port Renfrew, British Columbia focused on evaluating the potential Quaternary activity and active kinematics of the Leech River and San Juan Fault systems. These two major crustal fault systems underlie the populated regions surrounding the capital city of Victoria, British Columbia on Vancouver Island (Figs. 1 and 2) and, until recently (Morell et al., 2017), were thought to be last active in the Eocene (MacLeod et al., 1977; Johnston and Acton, 2003). Student projects involved geologic mapping, kinematic analyses, and stratigraphic work along a ~45 km long region where the San Juan and Leech River fault systems intersect the Pacific coast in British Columbia.
therefore considered capable of producing great earthquakes (McCaffrey et al., 2013). Radiocarbon
dating of now-submerged forests suggest that the last
great earthquake to have afflicted the region occurred
approximately 300 years ago (Atwater, 1987; Atwater
and Yamaguchi, 1991). The nature of seismicity
within the crust above the megathrust is not as well
defined, however, particularly in northern Cascadia
where the recent Cordilleran glaciation has removed
most sediments older in age than late Quaternary
(Clague et al., 1982). But, emerging research suggests
that prominent ancient terrane-bounding faults that
criss-cross Vancouver Island could be reactivated in
the current plate tectonic setting and could be capable
of producing large seismic events (Morell et al.,
2017).

TERRANE-BOUNDING FAULTS OF VANCOUVER ISLAND

The geologic architecture of Vancouver Island is
described as a series of amalgamated terranes that
accreted to North America starting in the Cretaceous
(Muller, 1977). The Wrengellia terrane, which makes
up the majority of Vancouver Island, is bound by the
east-west striking San Juan and Survey Mountain
Faults, which separate Wrangellia from the Mesozoic
Pacific Rim Terrane near the southern tip of the island
(Fig. 2) (Massey et al., 2005). The Pacific Rim

Terrane is confined to the south by the Leech River
Fault, a prominent east-west striking fault with a deep
topographic valley that separates the Pacific Rim
Terrane from the Crescent Terrane (Fig. 2) (Muller,
1977; Massey et al., 2005). The kinematics and
slip history of all of these terrane-bounding faults
on Vancouver Island are poorly constrained, with
suggestions that they could be either thrusts (Muller,
1977; Clowes et al., 1987) or strike-slip faults with
variable slip sense (Fairchild and Cowan, 1982;
Johnson, 1984; Yorath et al., 1985; Clowes et al.,
1987; Groome et al., 2003). Most past research has
suggested that the Leech River and San Juan Faults
was last active in the Eocene or older (MacLeod et al.,
1977). However, new observations suggest that there
are active strands of the Leech River fault system
(Morell et al., 2017).

RECENT GLACIAL HISTORY OF VANCOUVER ISLAND

Almost all of the Quaternary sediments now preserved
on Vancouver Island are related to the last glaciation
which occurred in the late Pleistocene (Clague et al.,
1982). At its maximum approximately 22,000 years
ago, the Cordilleran ice sheet extended across all of
Vancouver Island and the ice was more than 2000 m
thick in the Georgia Strait (James et al., 2000, 2009).
When deglaciation occurred ~14 ka, relative local
sea level fell as much as ~100 meters in the region of
southwestern BC (Clague et al., 1982; Shugar et al.,
2014), leaving behind an abundance of post-glacial
sediments across the Vancouver Island landscape. A
large majority of this local sea level fall is attributed to
isostatic rebound of the crust following ice retreat; The
crust was depressed due to ice loading by more than
150 meters (James et al., 2000, 2009).

STUDENT PROJECTS AND RESULTS

Carlee Akam (University of Victoria) used the
distribution and elevation of late Eocene to Oligocene
marine sediments of the Carmanah Group to test for
changes in vertical tectonism since deposition of these
units. Carlee found the Carmanah Group to be more
extensive and at higher elevations than previously
recognized, especially in the San Juan Fault. Her
results imply a significant amount of Oligocene to
Recent vertical tectonism that has been previously unrecognized, and could be caused either by slip along crustal faults or, net uplift associated with interseismic cycles of the Cascadia subduction zone.

John Borah (Colorado College) and Nolan Lescalleet (Union College) both conducted kinematic analyses of the San Juan Fault via analysis of slickenlines, fault orientations, and thin section microstructure. Nolan and John’s work found that the San Juan Fault is a sub-vertical fault zone as much as 0.5-1 km wide that contains numerous mesoscale faults within this larger fault zone. Their kinematic analyses show that the San Juan Fault is dominated by a left-lateral slip history, with only a minor dextral component. This left-lateral slip history may be related to active bending of the Olympic orocline and Olympic peninsula, and/or subduction zone strain accumulation.

Brendan Powers (Trinity University) conducted a detailed study of a heavily deformed glacial-marine sediment package exposed in a quarry that lies across the San Juan fault. Brendan found that rather than being related to displacement along the San Juan fault, the deformation exposed in this quarry is instead related to post-glacial processes and collapse of the Cordilleran ice sheet.

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