Holocene to Neogene tectonics in central Washington: assessing seismic hazards from the geomorphic, geologic, and paleoseismic record of the Yakima Folds

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Abstract

In the Pacific Northwest, coeval creation of upper crustal blocks and the forearc slab pull-driven tectonic style have created an active and complex tectonic setting. Recent paleoseismologic and stratigraphic studies in the Yakima Fold Province (YFP) of central Washington State have provided new insights into the local and regional tectonic evolution of the area. We revisted and expanded previous low- and high-resolution datasets to investigate the tectonic evolution of the YFP. In particular, we focus on understanding tectonic processes in the central Washington Cascades, where the Yakima fold axes trend west-northwest and provide a unique opportunity to study the interplay of local and far-field tectonics.

1. Background

The Yakima Fold Province (YFP) of central Washington is a 130 km long accommodation zone and potential seismic hazard of central Washington, defined by the Yakima River Canyon, which trends west-northwest. The most prominent structure in the YFP is the Yakima anticline, which represents up to 3000 m of pre-Miocene crustal shortening. This structure is bordered to the west by the Toppenish Ridge and to the east by the Ahtanum Ridge. The Yakima anticline is part of a larger fold system that extends from the Pacific Northwest to the Intermontane plate boundary.

Recent incision rate measurements within the Yakima River Canyon indicate a decrease in the incision rate since the Miocene, suggesting a decrease in tectonic activity in the YFP. Previous work has inferred that rates of YFP tectonism have decreased significantly since the Miocene (Reidel, 2010). The decrease in incision rate is attributed to a combination of factors, including a decrease in the rate of crustal shortening and potential strain rate far inboard of the Cascadia forearc (McCaffrey et al., 2013; Wells and McCaffrey et al., 2013).

2. Stream Profile Inversion

In this study, we use stream profile inversion to determine the relative proportions of the rock type sampled. We estimate the relative proportions of the rock type sampled using the equation (1):

\[ R(x) = \frac{U(x)}{U(x) + E(x)} \]

where \( R(x) \) is the relative proportion of the rock type sampled, \( U(x) \) is the incision rate, and \( E(x) \) is the erosion rate. We find that channel steepness does not significantly vary with time-variant uplift rate.

3. Long-term Geologic Uplift

We include the outlines of mapped Precambrian Thay Seiad Trough (PST) and Eocene Pollock (POL) Faults (Fig. 1). We construct a WE-EW striking cross section to evaluate the time-variant uplift rate. The cross section shows the preserved knick point at the Inyo Mountains, California, JGR Earth Surface, 119, 1651-1681.

4. Paleoseismic Record of Deformation

5. Saddle Mountains Fault

The Saddle Mountains Fault (SMF) is one of the most studied faults in the region, and potential seismic hazard of central Washington, based on its proximity to population centers.

6. Conclusions

Uplift rates, and likely shortening rates, along the Saddle Mountains and Umtanum Ridge Anticlines have increased significantly since the Miocene, with a potential seismogenic slip rate of 2-3 mm/year and cumulative uplift of 600-1000 m.

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Cross section in Fig. 3 depicts the Saddle Mountains Fault and the Umtanum Ridge Anticline. The cross section includes a series of faults, including the Saddle Mountains Fault (SMF), which is the focus of this study. The cross section is based on a series of paleoseismic trenching projects led by the U.S. Geological Survey's Earthquake Hazards Program.