Quaternary Stratigraphy of the Eel River and Van Duzen Fluvial Systems: Geochronology to Support Tectonic Interpretations and Slip Rate Calculations for Late Pleistocene Active Faults

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Abstract

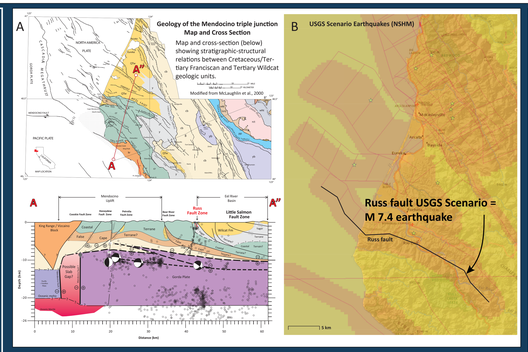
The Mendocino triple junction (MTJ) in California has overlapping tectonic regimes; the San Andreas fault (SAF) to the south and Cascadia megathrust to the north. Late Pleistocene northward migration of the MTJ juxtaposes north-south convergence from Pacific-North America (PAC-NAM) plate motion at the northern on-shore termination of the SAF with E-W compression from the Juan de Fuca-North America relative plate motion. Active N-NW striking faults, like those in the N30W striking Mad River fault zone near Arcata, CA, represent deformation related Cascadia convergence. Structures striking ~E-W, like the Table Bluff fault south of Eureka, CA, represent deformation related to PAC-NAM N-S convergence. Slip in this area is transferred from the termination of the SAF and strain is partitioned onto structures to the east. These crustal faults contribute to regional seismic hazard and may comprise one-third of the tectonic strain in coastal northern California.

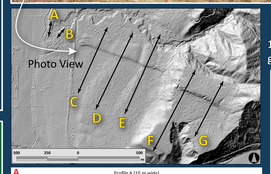
We locate a topographic scarp adjacent to the Russ fault zone that may represent Holocene slip on a west striking reverse fault offsetting late Pleistocene to Holocene fluvial terraces. We identify this structure as the Lahsâséte fault. The south facing scarp crosses multiple terraces. Scarp heights increase on progressively older terraces. Using regionally derived incision rates as a proxy for terrace age, we use topographic swath profiles to measure scarp heights and calculate a late Pleistocene slip rate of about 0.75 mm/yr.

To better understand the stratigraphic setting and to provide relative age control for the geomorphic surfaces offset by the fault, we conduct a terrace mapping campaign. This chronostratigraphic framework will form the basis for updated slip-rate calculations made for the scarp forming Lahsâséte fault. We use LiDAR derived slope rasters to delineate fluvial terrace treads using maximum slopes up to 10°. We calculate the relative elevation for the treads using a constructed digital elevation model that represents the modern floodplain. Using the distribution of relative elevations for each tread, and the vertical spacing between these treads, we correlate terraces along the lower Eel and lower Van Duzen rivers. Once we acquire additional numerical ages, we will be able to calculate relative ages for the other terraces using incision rates.

Cascadia subduction zone

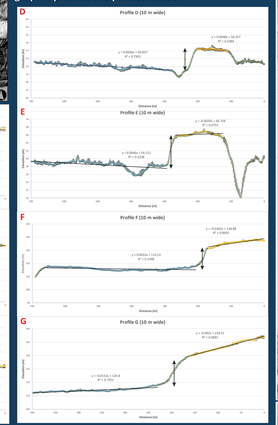
Plate configuration for the Cascadia subduction zone (CSZ). Juan de Fuca and Gorda plates are subducting northeastwardly oblique beneath the North America plate at ~36 mm/yr in the Humboldt Bay region. Paleoseismic core sites (marine and terrestrial) are plotted as circles.

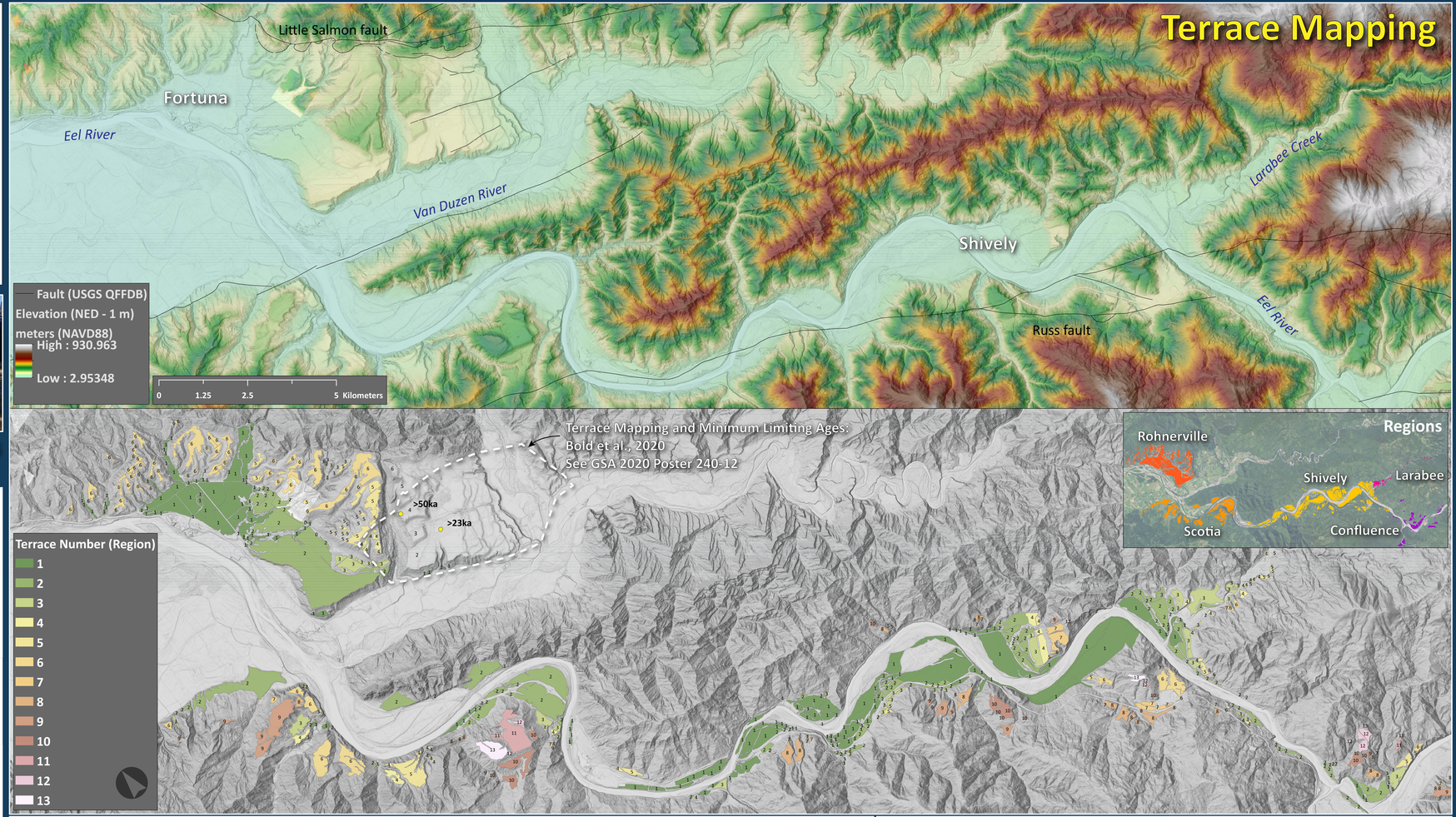




LiDAR Scarp Profiles

1 m resolution LiDAR 10 meter wide swath topographic profiles are plotted below.





The Mendocino triple junction

Mendocino triple junction Map. Fault data from USGS Quaternary Active Fault and Fold Database (2019). Faults: BRF, Bear River; BSF, Bartlett Springs; BM/BLF, Bald Mountain/Big Lagoon; CSZ, Cascadia subduction zone; ER, Eaton Roughs; FeF, Ferndale; FrF, Freshwater; GkF Garlock; GvF, Garberville; KRF, King Range; LM/GF, Lost Man/Garlock; LSF, Little Salmon; MCF, Mendocino Canyon; MaF Maacama; MeF Mendocino; MRFZ, Mad River; PF, Petrolia; PSGF, Point St. George, RF, Russ in red; TBF, Table Bluff; TF, Trinidad; YF, Yager. Arrows designate direction of fault motion.

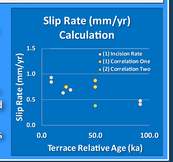
Terrace Ages and Slip Rate Calculations

Vertical separation and fault slip rate calculations using two methods to establish terrace ages: (1) incision rate and (2) preliminary correlation with terraces along Van Duzen River with ^{10}Be minimum limiting exposure ages (Bold et al., 2020).

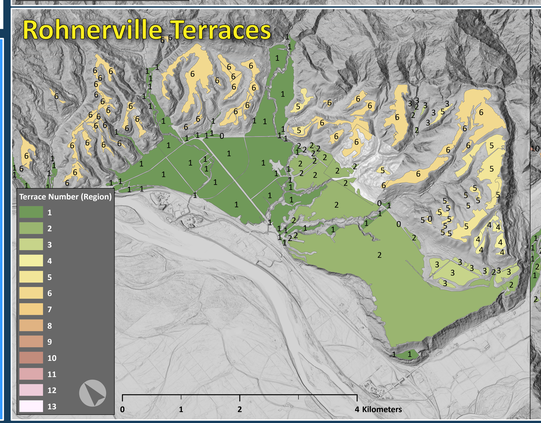
Terrace	Age (ky)[1]	±	Age (ky)[2]	Age (ky)[3]	Profile	Scarp Height	Vertical Separation Rate (mm/yr)[1]	Vertical Separation Rate (mm/yr)[2]	Vertical Separation Rate (mm/yr)[3]	Slip Rate (mm/yr)[1]	Slip Rate (mm/yr)[2]	Slip Rate (mm/yr)[3]
T-2	9.5	0.4			A	3.6	0.4			0.8		
T-2	9.5	0.4			B2	4.0	0.4			0.9		
T-2	9.5	0.4			C	7.4	0.8			1.7		
T-3	20.1	0.9			D	5.7	0.3			0.6		
T-4	27.1	1.2	23	50	E	8.5	0.3	0.3	0.2	0.7	0.7	0.4
T-7	92.0	4.1	50		F	16.9	0.2	0.3		0.4	0.7	
T-7	92.0	4.1	50		G	19.8	0.2	0.4		0.5	0.9	
						Mean	0.4	0.4		0.8	0.8	
						Standard Dev.	0.2	0.0		0.4	0.1	

1. Age based on incision rates calculated by Stallman and Kelsey (2004) for late Pleistocene fluvial terraces in the North Fork Elk River (35 km from Shively).
2. Age based on correlation option 1 using ages and mapped terraces from Bold et al. (2020).
3. Age based on correlation option 2 using ages and mapped terraces from Bold et al. (2020).

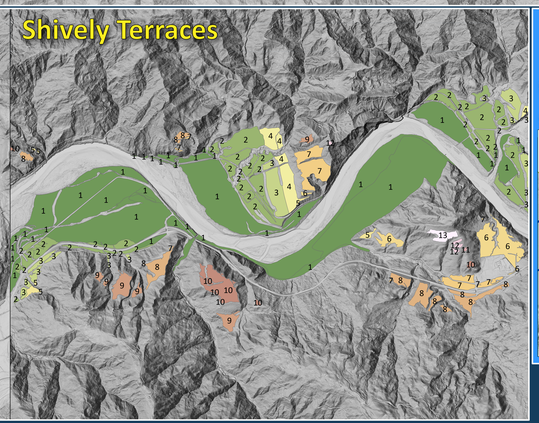
Terrace Ages are either calculated by:
(1) applying an incision rate to the Relative Elevation of the terrace
or
(2) using correlations between terraces mapped in Rohnerville and Shively. Minimum limited ^{10}Be exposure ages (collected and analyzed by Kim Blisniuk and Melanie Michalak) form the basis for these ages. Scarp height, fault dip, and terrace age form the basis for slip rate calculated.



Rohnerville Terraces



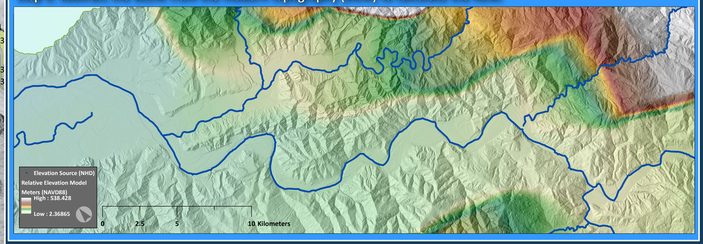
Shively Terraces



Relative Elevation Model

Relative Elevation represents the elevation of landforms relative to the water surface elevation of the modern channel.

Step 1. Use modern active channel to create a "baselevel" elevation model (BLEM) that extends the active channel elevation beneath adjacent terraces and hillsides. This example uses inverse distance weighted interpolation.
Step 2. Subtract the BLEM from the modern topography (DEM) to calculate the REM.



Take Away Points:

- We map at least 13 major Quaternary Quat. fluvial terraces in the lower Eel River.
- Our terrace correlation is a work in progress.
  - Challenge: tectonic deformation confounds vertical spacing of terrace treads

Future Work:

- Obtain numerical ages for terraces in Shively to help with late Quat. slip rate calculation.
- Conduct fault trenching investigation for the fault in Shively.