Mendocino Triple Junction:
Eel River Fluvial System Terraces and Tectonics in the Latest and Greatest Quaternary

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Abstract

The Mendocino triple junction, where the overlapping and interfingering southern Cascadia and northern San Andreas plate boundaries exist, is a complicated tectonic region where oblique convergence and dextral shear interact in interesting ways. Northwest-striking, southwest-vergent thrust faults represent anelastic deformation related to Cascadia convergence and east-stepping Pacific-North America dextral shear generates strike-slip faults that either terminate in uplifted terranes and east-west striking reverse faults/folds or as strike-slip faults that penetrate through and past the Humboldt Bay region.

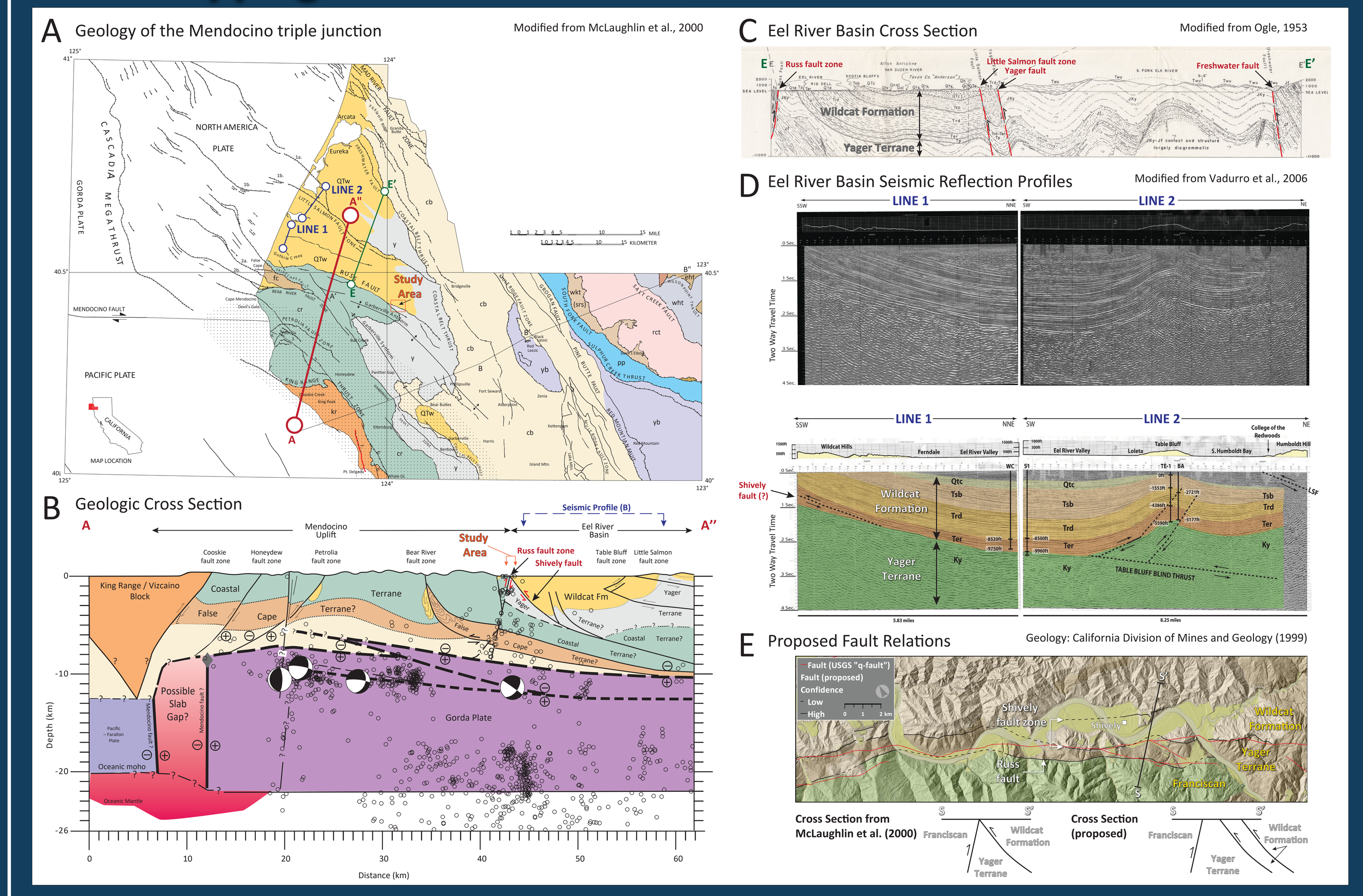
While the Russ fault is mapped as a north-vergent high angle reverse fault, we locate a topographic scarp adjacent to the Russ fault formed by a south-vergent reverse fault that offsets late Pleistocene to Holocene fluvial terrace treads. We hypothesize that this newly discovered fault was accidentally mapped as the Russ fault. We use scarp heights and terrace age estimates derived from regional incision rates to calculate a late Pleistocene slip rate of 1- to 3-mm/yr.

We map fluvial terrace treads in the entire Eel River Watershed to better understand the stratigraphic setting and to provide relative age control for the geomorphic surfaces offset by this and other recently identified faults. This chronostratigraphic framework will form the basis for updated slip-rate calculations made for the scarp-forming fault. We use LiDAR-derived slope rasters to delineate fluvial terrace treads using maximum slopes up to 4°. We calculate the relative elevation for the treads using a relative elevation model that represents the modern floodplain. We also prepare a basin-scale river mile raster so we can plot terrace relative elevations relative to the distance of the river mouth. Terraces north of the mouth of Van Duzen River display syntectonic deformation in the form of a N20E striking syncline, while terrace profiles to the south show increasing relative elevations downstream, suggesting tectonic uplift in the northern Eel basin.

The Mendocino triple junction

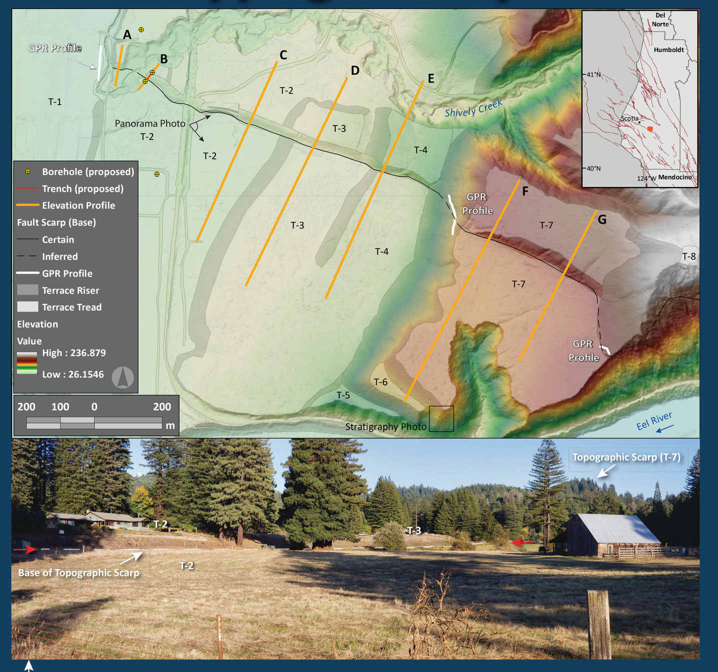
Mendocino triple junction Map. Fault data from USGS Quaternary Active Fault and Fold Database (2019). Faults: BRF, Bear River; BSF, Bartlett Springs; BM/BLF, Bald Mountain/Big Lagoon; CSZ, Cascadia subduction zone; ER, Eaton Roughs; FeF, Ferndale; FrF, Freshwater; GkF Garlock; GvF, Garberville; KRF, 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.

Fault Mapping: Russ fault



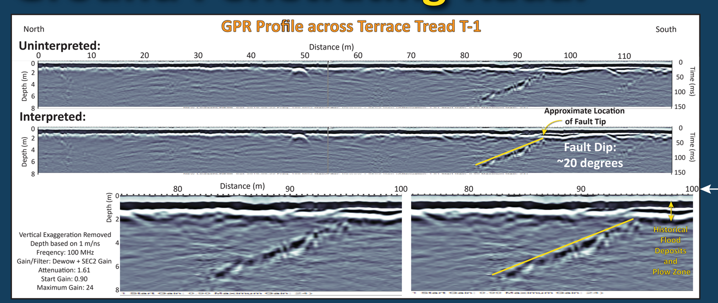
A. Geology map showing cross section locations (modified from McLaughlin et al., 2000) showing major basement rocks in the region. B. Cross section A-A'' shows an hypothetical interpretation of the subsurface. Note the Russ and Shively faults. C. Cross Section E-E' modified from Ogle (1953) shows the stratigraphic structural relations of the Russ fault. D. Eel River seismic reflection profiles Line 1 & 2 show updated stratigraphic-structural relations of the Eel River Basin (modified from Vadurro et al., 2006) and the Shively fault. E. Updated fault mapping proposed for this proposal. The USGS QFFDB Russ fault is shown in red and updated RF and SF mapping in black. Schematic cross-sections S-S' show the structural relations between these faults with opposing vergence in the Shively area.

Fault Mapping: Shively fault



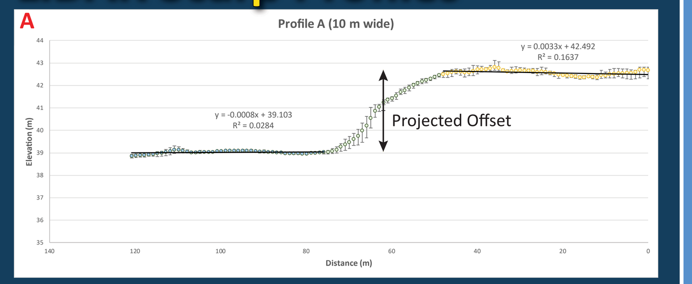
USGS lidar topography as a base map with topographic profiles in orange and proposed trench and borehole sites designated. Terrace treads and GPR profile locations are labeled. Lower panel shows panorama photo of topographic scarp looking east.

Ground Penetrating Radar



Ground Penetrating radar profile across terrace tread T-1. Lower panel shows interpretation of fault dipping to the north at about 20°. Other GPR profiles support 30° fault dip interpretation.

LiDAR Scarp Profiles



1 m resolution lidar 10 meter wide swath topographic profile A. The projected offset shown is used to estimate the vertical separation of terrace treads. Using fault dip constrained by GPR and topographic analyses is used as a contraint for the slip rate estimates.

Slip Rate Estimate

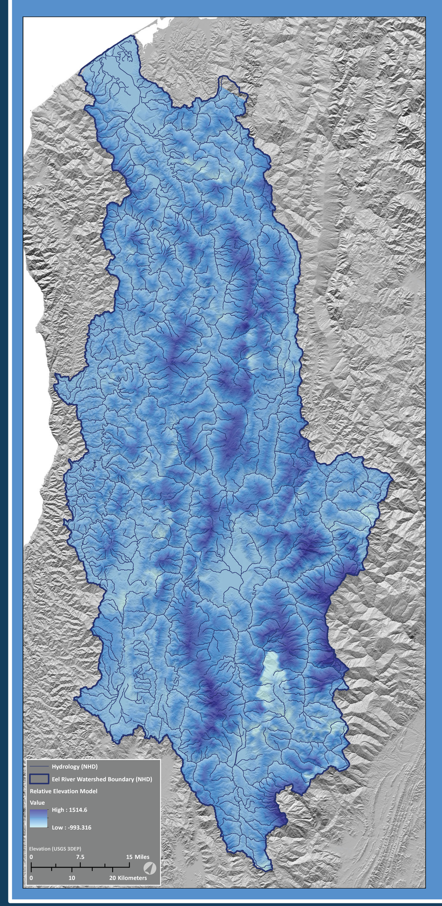
We present our bracketed slip rates using incision rates we calculated using data from Bold (2022). Since the ages have large uncertainties, we don't propagate uncertainty. Using our preferred correlations and a 30° fault dip, slip rates from scarps on terraces T-3, 4, & 7 are 2.7, 3.0, and 1.8 mm/year.

Slip rates bracketed by range of possible correlations between Shively and Hydesville regions.

Shively Terrace[1]	Bold Terrace[2]	Relative Age[3]	Age (years)[4]	Terrace Height[5]	Incision Rate[6]	Scarp Height[7]	Separation Rate[8]	Dip[9] 20	30	40
								Slip Rate[10]		
T3	T3	oldest	5600	17.9	3.2	5.7	1.0	3.0	2.1	1.6
	T2	preferred	4300	17.9	4.2	5.7	1.3	3.9	2.7	2.1
	T1	youngest	2500	17.9	7.1	5.7	2.3	6.7	4.6	3.6
T4	T4	oldest	6900	24.1	3.5	8.5	1.2	3.6	2.5	1.9
	T3	preferred	5600	24.1	4.3	8.5	1.5	4.4	3.0	2.4
	T2	youngest	4300	24.1	5.6	8.5	2.0	5.8	4.0	3.1
T7	T17	oldest	38250	81.9	2.1	19.8	0.5	1.5	1.0	0.8
	T12	preferred	22400	81.9	3.7	19.8	0.9	2.6	1.8	1.4
	T9	youngest	20000	81.9	4.1	19.8	1.0	2.9	2.0	1.5

1. Terrace number, Shively region.
2. Terrace number, Hydesville region (Bold et al., 2022).
3. The Hydesville terrace age relative to the Shively terrace.
4. Bold terrace age. Ages for Bold T-9, 12 & 17 from Bold, et al. (2022).
5. Terrace relative elevation measured from topographic cross section.
6. Incision rate calculated from the age[4] and height[5].
7. Scarp height measured from 10 meter wide swath profile.
8. Separation rate (scarp height divided by terrace age) for the vertical displacement of terrace tread.
9. Range of fault dips assumed for slip rate calculation.
10. Slip rate using the separation rate and the dip angle. Preferred rates in cyan rows with yellow letters.

Relative Elevation Model

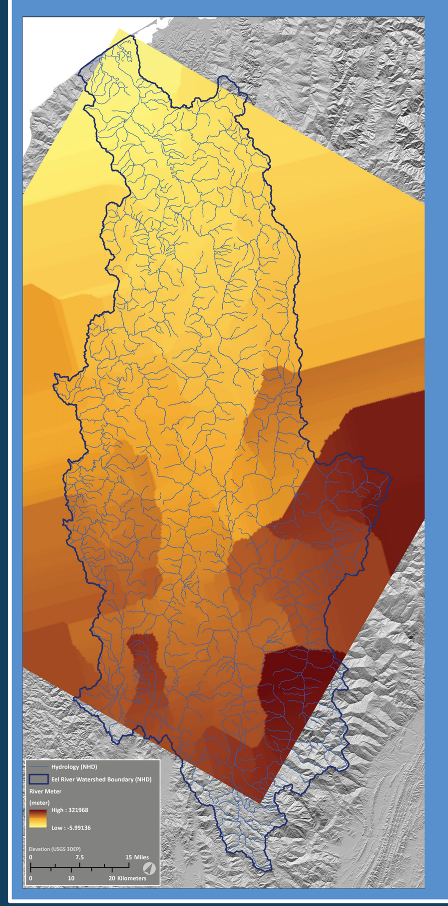


Relative Elevation represents the elevation of landforms relative to the water surface elevation of the modern channel.

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 "Spline" interpolation.

Step 2. Subtract the BLEM from the modern topography (DEM) to calculate the REM.

River Meter Model

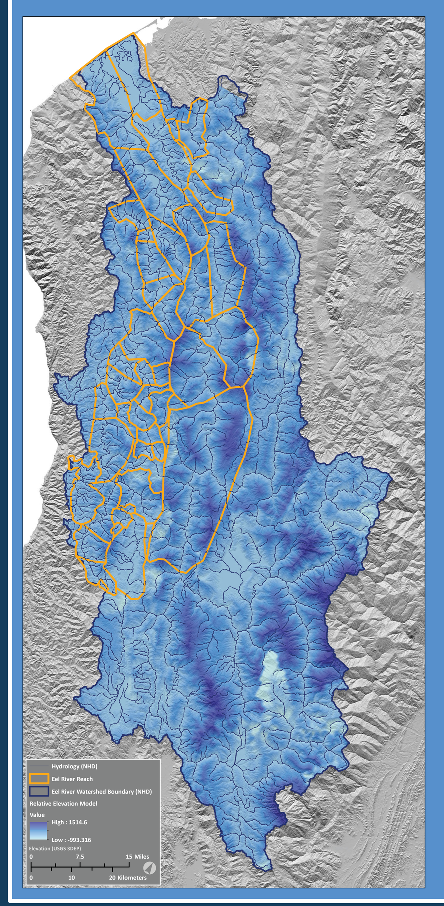


A raster that represents the "river mile" distance from the mouth of the Eel River, in units of meters.

Step 1. Use GIS analysis (using routing) to calculate the distance from the river mouth along the National Hydrographic Dataset hydrology polyline.

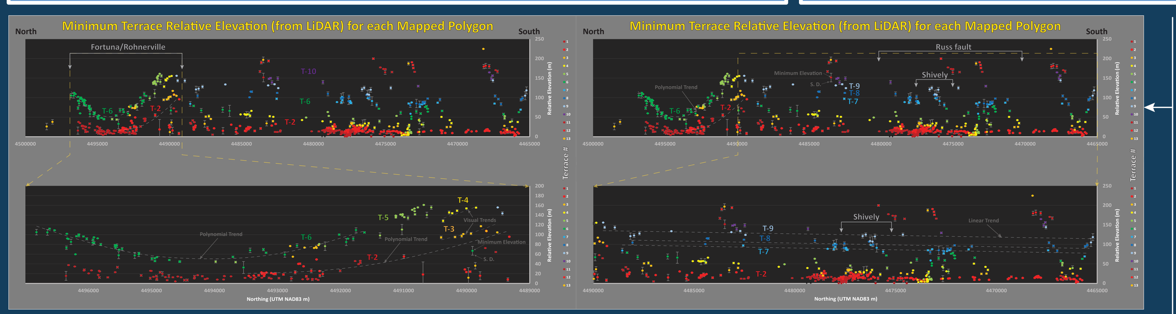
Step 2. Use "Spline" tool to interpolate river meter based on the hydrology route data.

Reaches Used to Stratify T#



Terrace tread numbers (T-#) are initially assigned for terrace flights within each reach.

There may be reasons why terrace flights have different spacing between these reaches. Once all reaches have been interpreted, the next step will be to correlate terraces and apply terrace numbers basin-wide.



Terrace Relative Elevation Long Profiles. Minimum elevation and standard deviation are plotted for each terrace tread polygon symbolized relative to terrace number (see legend). Polynomial, linear, and visual trends are shown as dashed lines. (A) Profile for the entire reach (top) and subset profile for the area near the Fortuna/Rohnerville area. (B) Profile for entire reach (top) and subset profile for the reach between the Van Duzen River confluence and the South Fork Eel River confluence.

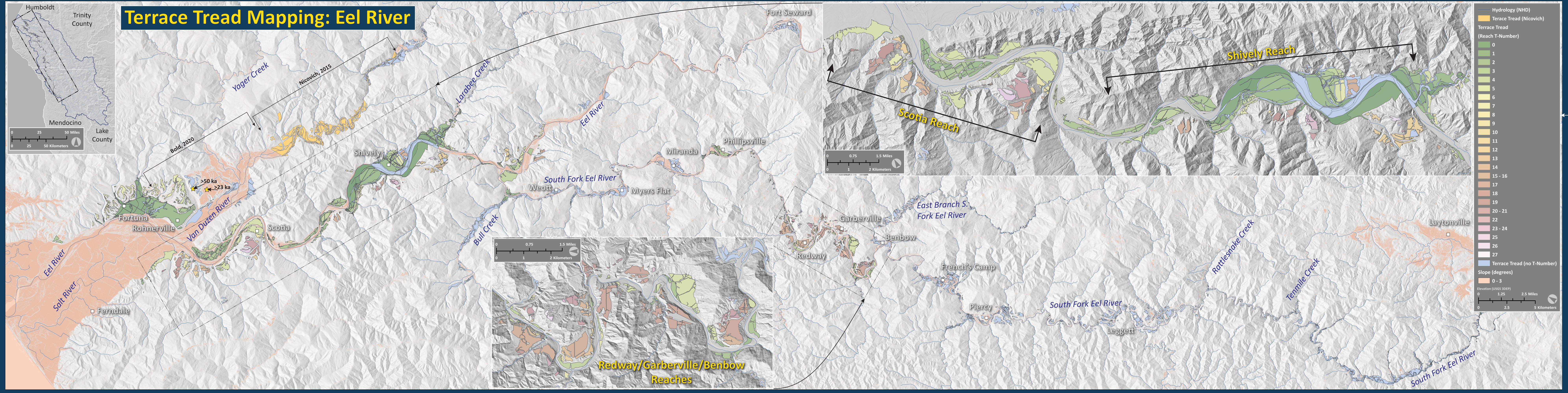
Take Away Points:

- We map at least 27 Quaternary fluvial terraces along the 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 Quaternary slip rate calculation.
- Conduct fault trenching investigation for the fault in Shively.

Terrace Tread Mapping: Eel River



Over 3,000 terrace treads are mapped along the main stem Eel River, the South Fork Eel River, tributaries including the Van Duzen River, the East Branch South Fork Eel, and other rivers and creeks that have Quaternary fluvial terraces.

Terraces are numbered with increasing terrace numbers, from young to old. The youngest terrace (T-0) is the floodplain. Not all treads have been numbered yet.

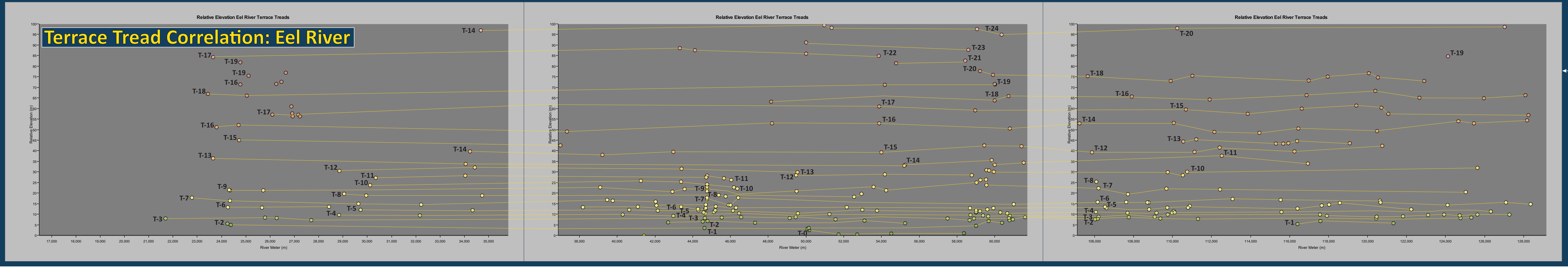
Treads are also classified based on their relative deformation (1 = not deformed, 2 = moderately deformed, 3 = highly deformed with abundant overlying alluvial fan deposition). Highly deformed terraces are not included in the plots below.

Inset maps show terraces in the Scotia and Shively reaches (upper right inset) and the Redway/Garberville and Benbow reaches (lower left center inset).

Terraces in the central Van Duzen River mapped by Sylvia Nicovich (for their Master's Thesis at Humboldt State University, Dept. of Geology) are plotted in orange. These are being remapped (some already have).

Sam Bold mapped river terraces in the lower Van Duzen for their Master's Thesis at Cal Poly Humboldt, Dept. of Geology. These are being remapped.

Terrace Tread Correlation: Eel River



Terrace relative elevations are plotted vs. river meter for three regions:
Left: Scotia Reach
Center: Shively Reach
Right: Redway/Garberville and Benbow Reaches

Relative elevations are based on zonal statistics calculated for each polygon using the REM as a base. This plot includes the minimum elevation from the zonal statistics analysis. However, using the mean relative elevation may be a better proxy to use for correlating the terraces.

Colors represent the terrace number assigned per reach. Terrace numbers are based on the flights within each reach. It is clear that some terraces have incorrect T-#s.

River meter is also calculated using zonal statistics and the river meter raster. These points represent the mean river meter for each terrace polygon.