Geologic and Geomorphic Evidence of Intermontane Deformation and Late Pleistocene Surface Faulting, Great Western Divide, Southern Sierra Nevada

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ABSTRACT

Field reconnaissance in the southern Sierra Nevada suggests the presence of a previously unidentified, potentially active late Pleistocene fault that branches from the active Kern Canyon fault, and extends northwesterly across the Great Western Divide.

The Colby Pass Fault (CPF) has the following characteristics:

- Southern endpoint: intersection with active Kern Canyon fault (KCF) near Kaweah Ridge (lat = 36.527°, long = -118.411°)
- Northern endpoint: postulated near Palmer Mountain south of Kings Canyon (latitude = 36.745°, long = -118.588°)
- Minimum fault length = 30 km
- Possible continuation across Kings Canyon, for total possible length of about 42 km.
- Fault strike = N30W to N40W, fault dip = 70-80SW
- Consists of at least two primary parallel shears bordering zone about 600 m wide
- Prominent geomorphic expression across granitic rocks in the High Sierra
- Parallel with SW-down, pre-late Pleistocene Farewell fault in Little Kern River valley

Several lines of evidence suggest late Pleistocene SW-down displacement
(All of these have alternative, non-tectonic explanations):

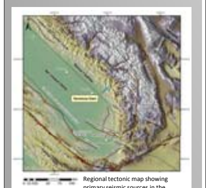
Geomorphic Feature	*Evidence for Pleistocene displacement?*
Scarps and linear troughs on glacial deposits, northern Red Spur Lake plateau	Moderate
An uplifted outlet channel from an unnamed lake along Picket Creek	Moderate
Alluvium ponded against upstream-facing scarps within Kern-Kaweah River valley	Supporting
Displaced moraine crests at mouth of Milestone Basin	Moderate
Higher peak elevations along Great Western Divide north of Colby Pass	Supporting
Higher elevation of a glacial trim-line along walls of Cloud Canyon north of CPF	Supporting
Differences in Cloud Canyon valley morphology north and south of CPF	Supporting
Displaced moraine crests comprising Moraine Ridge	Moderate

Recency of Displacement

- Topographic scarps across smooth-crested, Tahoe-age(?) moraines with SW-down displacement of about 11 m
- Topographic scarps across sharp-crested, Tioga-age(?) moraines with SW-down displacement of about 5.5 m
- Late Pleistocene slip rate of approximately **0.1 to 0.3 mm/yr**

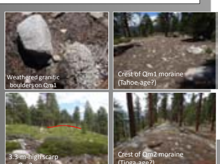
Possibility of late Pleistocene activity along the CPF supports:

- SW-down intermontane normal faulting branches northwestward from active KCF
- Late Quaternary internal tectonic deformation of the southern Sierra Nevada
- Quaternary deformation west of the KCF along north-stepping *en echelon* series of normal faults



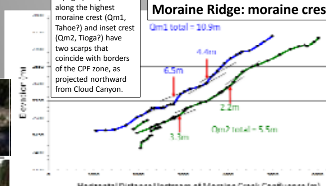
Regional tectonic map showing primary seismic sources in the southern Sierra Nevada region, including fault and background sources (from URS, 2014).

Excerpt from "Map of Limit of Tahoe Glaciation in Sequoia and Kings Canyon National Parks, California" (Moore and Mack, 2008), modified to show generalized locations of the Colby Pass and Kern Canyon faults.

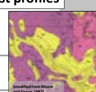


Moraine Ridge: moraine crest profiles

Detailed field topographic profiles along the highest moraine crest (Qm1, Tahoe?) and inset crest (Qm2, Tioga?) have two scarps that coincide with borders of the CPF zone, as projected northward from Cloud Canyon.

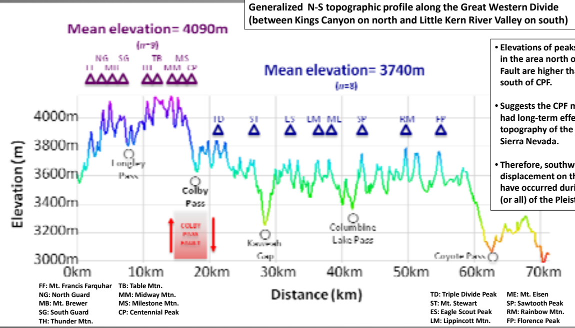


(Profiles completed using hand-held GPS device and may have substantial uncertainty)



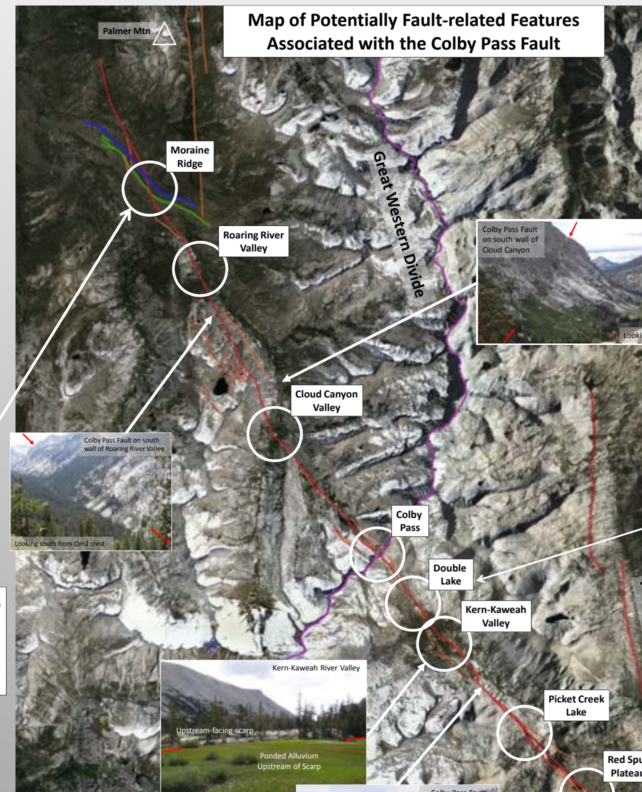
These profiles suggest recurrent late Pleistocene surface rupture along the Colby Pass Fault. Assuming Qm1 is 120 ka and Qm2 is 15 ka, calculated late Pleistocene slip rate ranges from **about 0.10 to about 0.37 mm/yr**

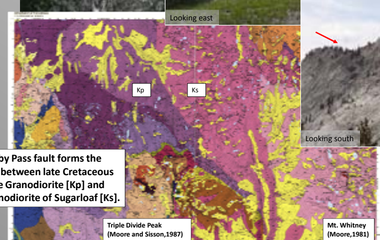
Generalized N-S topographic profile along the Great Western Divide (between Kings Canyon on north and Little Kern River Valley on south)



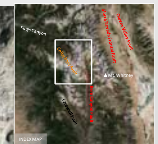
- **Elevations of peaks and passes in the area north of Colby Pass Fault are higher than those south of CPF.**
- **Suggests the CPF may have had long-term effects on the topography of the southern Sierra Nevada.**
- **Therefore, southwest-down displacement on the CPF may have occurred during much (or all) of the Pleistocene.**

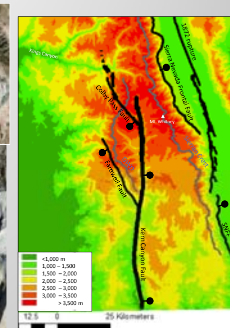
Map of Potentially Fault-related Features Associated with the Colby Pass Fault





The Colby Pass fault forms the contact between late Cretaceous Paradise Granodiorite [Kp] and the Granodiorite of Sugarloaf [Ks].





SUMMARY AND IMPLICATIONS

Seismic Source Characterization, Seismic Hazard, Seismic Risk

- **Late Pleistocene activity** on the Colby Pass Fault is suggested but not confirmed; a probability of activity of 0.8 is warranted (URS, 2014).
- Based on a fault length of 34 km, seismogenic depth of 16±2 km, and range in dip of 60SW to 90, estimated **maximum magnitude is M6.8** (Wells and Coppersmith, 1994).
- Estimated slip rate ranges from 0.07 mm/yr (0.3) to 0.20 (0.4) to 0.3 mm/yr (0.3) (URS, 2014).
- The CPF has had primarily normal (SW-down) faulting; there is no evidence of lateral slip.
- Probabilistic Seismic Hazard Analysis (PSHA) shows that for engineered facilities more than about 30 km from the CPF, the contribution to **strong ground motion hazard is negligible**.
- Therefore, there is **no significant incremental risk** attributable to the CPF.

Regional Tectonics

- The possibility of late Pleistocene activity along the CPF supports multiple recent interpretations that the southern Sierra Nevada is characterized by **localized internal deformation**.
- The CPF suggests internal deformation of the southern Sierra Nevada is manifested primarily as **Late Quaternary normal faulting**, consistent with regional extensional strain.
- The NW-striking normal fault branches northwestward from the active Kern Canyon Fault (KCF), and may **partition strain westward at the northern end of the KCF**.
- The Farewell Fault also strikes NW, branches westward from the KCF, and shows normal faulting during the Neogene, but late Pleistocene activity is not confirmed. Detailed geologic mapping by Kelson et al. (2010) suggests that the Farewell fault exhibits NE-down normal faulting.
- The Colby Pass Fault and the Farewell Fault (if Pleistocene active) collectively may suggest that deformation west of the KCF occurs along a **north-stepping *en echelon* series of normal faults**
- These possible relationships lead to the speculation that the southern Sierra Nevada may be deforming via normal faulting along the borders of several **NW-striking crustal blocks**

Milestone Basin Moraine at Double Lake

- Lateral moraine from Milestone Basin crosses CPF at Double Lake; rounded crest suggests Tahoe age (?)
- Field profiling suggests approximately 10 m SW-down vertical separation
- Assuming age of 120 ka, calculated slip rate on Eastern strand is 10m/120ka = **0.08 mm/yr**

Colby Pass Fault: Southern Intersection with KCF

Picket Creek Lake Paleochannel

- Lake lies within shear zone bordered by two major fault strands.
- Lake is impounded by the SW-facing, 6- to 10-m-high scarp developed in granitic rocks, along the Eastern fault strand
- Drainage outlet is orthogonal to inlet and flows southeast along the Western strand
- Abandoned paleochannel:
  - incised into uplifted granitic rocks
  - contains stranded rounded cobbles and boulders
  - collinear with present NE-trending inlet drainage
  - approximately 4.5 m above outlet elevation (lake level)
- Represents approximately 4.5 m of uplift along Eastern fault strand since occupied
- Assuming drainage developed about 15 ka, calculated **slip rate = 0.3 mm/yr**.