Debris flow fan morphology and flow rheology

Today we will work in teams to understand more about the debris flow fans of Owens Valley on the east side of the Sierra Nevada Mountains of California.

The southern Sierra Nevada Mountains are an uplifted range of primarily Cretaceous granitic rocks. Much of the range was occupied by valley glaciers and ice caps during the Pleistocene leaving behind deep glacial valleys perpendicular to the range front and cirques in the high country.

The eastern margin of the Sierra Nevada Mountains is defined by a steeply dipping normal fault with down to the east motion. The downthrown block is buried in many places by more than a thousand meters of sediment shed from the mountains. Both glaciated and non-glaciated basins shed debris flows and built fans.

Along this eastern margin are large fans coalesced into a bajada or piedmont. The fans are studded with large granitic boulders. Outcrops (mostly stream cuts) indicate that the fans were built both from fluvial and debris flow deposits. The large boulders, some meters on a side, were deposited by debris flows.

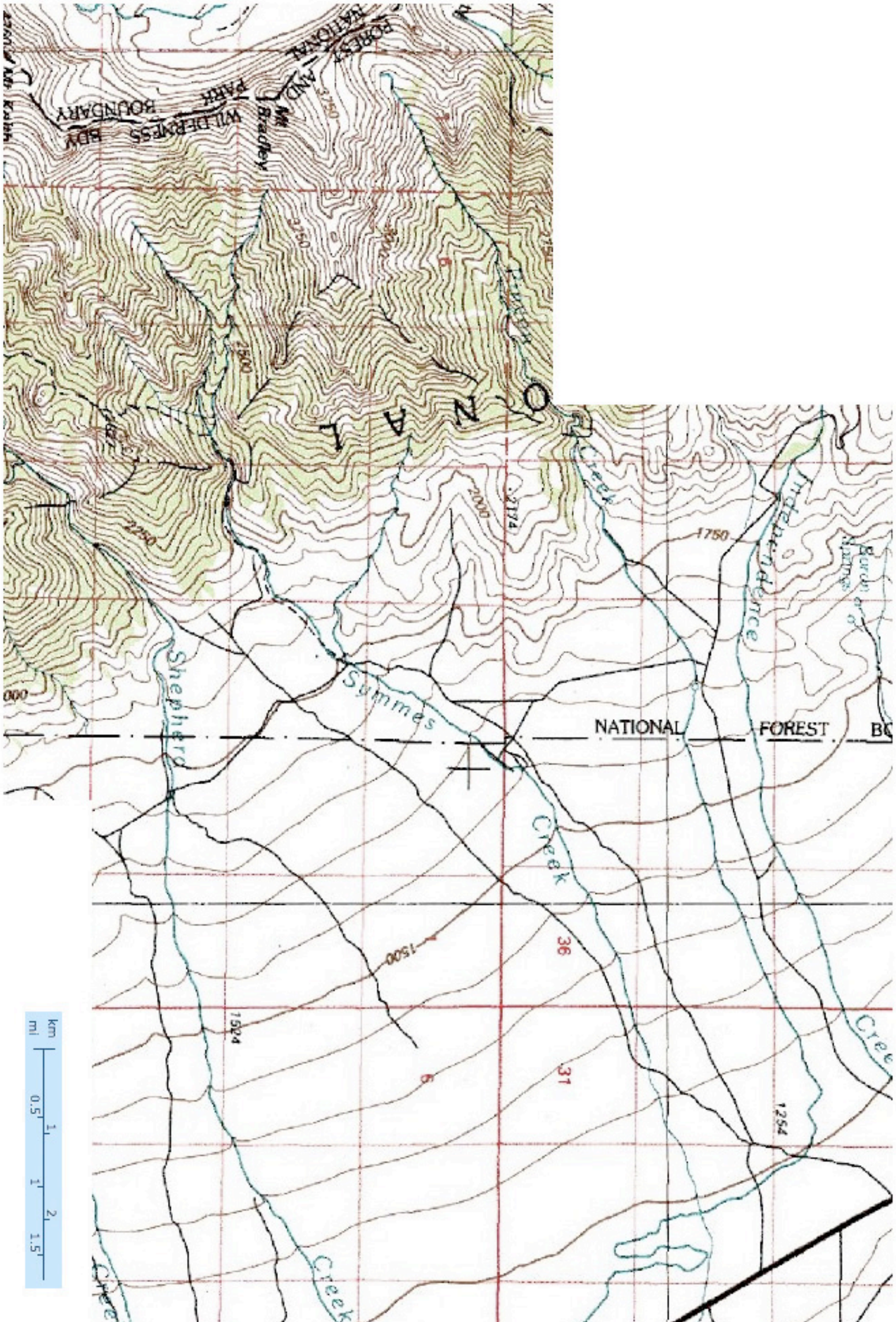
In many places it is possible to map out individual debris flows by finding bouldery snouts and bouldery levees. The thickness of the deposit (*h* in meters) can be estimated from field relations. The local slope (θ) can be deduced from topographic maps and the density (ρ) of the debris flows can be estimated by reconstituting the debris flow material with water. It appears that most Sierra Nevada debris flows had densities of about 2100 kg m^3.

The field data and evidence allow us to understand the rheology or physical characteristics of these debris flows even though thousands of years have passed since they roared down canyons and spilled over fan surfaces. The trick here is simple. Debris flows have a yield strength and when the driving force drops below the yield strength of the flow, the flow stops moving and creates a debris flow deposit; it's those deposits we map. Yield strength appears to vary with grain size and with water content.

As a reminder:

$\boldsymbol{\rho g h \sin \theta}$ = shear stress

shear stress = yield strength when debris flow stops moving.



NATIONAL FOREST
Symmes
Creek
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1254
36
31
km
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1
2
1.5

A large set of debris flow data was gathered by Kelin Whipple while he was a graduate student at the University of Washington working in Owens Valley; he is now at Arizona State University. It is for debris flows on the Symmes Creek Fan (shown on the map above). Below is one of Kelin's data tables which I have typed into excel (it should be posted with other class data on the class web page). *Run out* is the distance the flow traveled away from the fan apex at the mountain front. *Slope* is the slope of the alluvial fan where the flow stopped moving and is in percent (same as the tangent, rise over run, where slope of 100% is equal to a 45 degree angle). Debris flow *thickness* is measured in the field.

run out *km*	slope *percent*	thickness *meters*
0.36	7.9	1.75
1	10.5	1.25
1.25	7.9	0.9
1.78	8.7	1.2
2.06	8.7	0.9
2.11	8	0.75
2.28	11.4	1
2.4	9.6	2.2
2.88	8	2.1
3.05	8	1
3.4	9	1.15
3.48	7	0.3
3.7	4.5	0.5
4.37	6.6	0.85
8.5	1.9	0.45
8.5	1.8	0.6
8.5	2.2	0.6
8.5	5.1	0.6
8.52	1.95	0.35
8.6	3.5	1
8.9	2.35	0.6

Using the data in the table, please do the following **working on your own**.

1. Calculate for each flow, the yield strength in Pascals (Pa), having units of $kg/(m \cdot s^2)$. You should expect yield strengths in the hundreds to thousands of pascals. HINT: Note that at small angles the sin function and tangent function are similar.

2. Make graphs to help you understand the relationship between run out distance of debris flows, fan surface slope, debris flow deposit thickness, and yield strength. Be careful here because some values (yield strength) are calculated from other values and some values are correlated with others (consider for example slope and distance down fan).

3. Using the topographic map, create a long profile of Symmes Creek from the headwaters at the drainage divide to Route 385 (the bold, black diagonal line).

Using the attached map as a base, create a concept sketch that ties debris flow process to form and explains where and why deposition happens. 1. Include and interpret your long profile in your concept sketch. 2. Include relevant graphs on your concept sketch. 3. Plot yield strengths from the table on your concept sketch to better understand the spatial distribution of yield strengths.