FRIENDS OF THE PLEISTOCENE PACIFIC CELL FIELD TRIP
NORTHERN WALKER LANE AND NORTHEAST SIERRA NEVADA

October 12-14, 2001.

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INTRODUCTION

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This field trip examines stops related to the neotectonics, paleoseismology, and evolution of the northern Walker Lane, as well as general controls on erosion rates, and topographic evolution of the Sierra Nevada. In addition to showing participants field localities relevant to research on the above topics, the trip should also make it clear to participants that so much research in this area has been conducted at barely a reconnaissance level, leaving many inviting targets for future study. Figure In-1 shows a generalized road map with stop and camp locations (same as the map on the Pacific Cell website, except that the location of Stop 9 has been changed). Figures In-2 and In-3 show the general geology and faults, respectively, of the Sierra Nevada and northern Walker Lane with stop and camp locations. For participants interested in further exploration of this area on their own, there is a full color field trip guide published by the California Division of Mines and Geology (CDMG Special Publication 122) that has trips that include additional neotectonics-related stops in this area (Wakabayashi and Sawyer, 2000; Wagner et al. 2000).

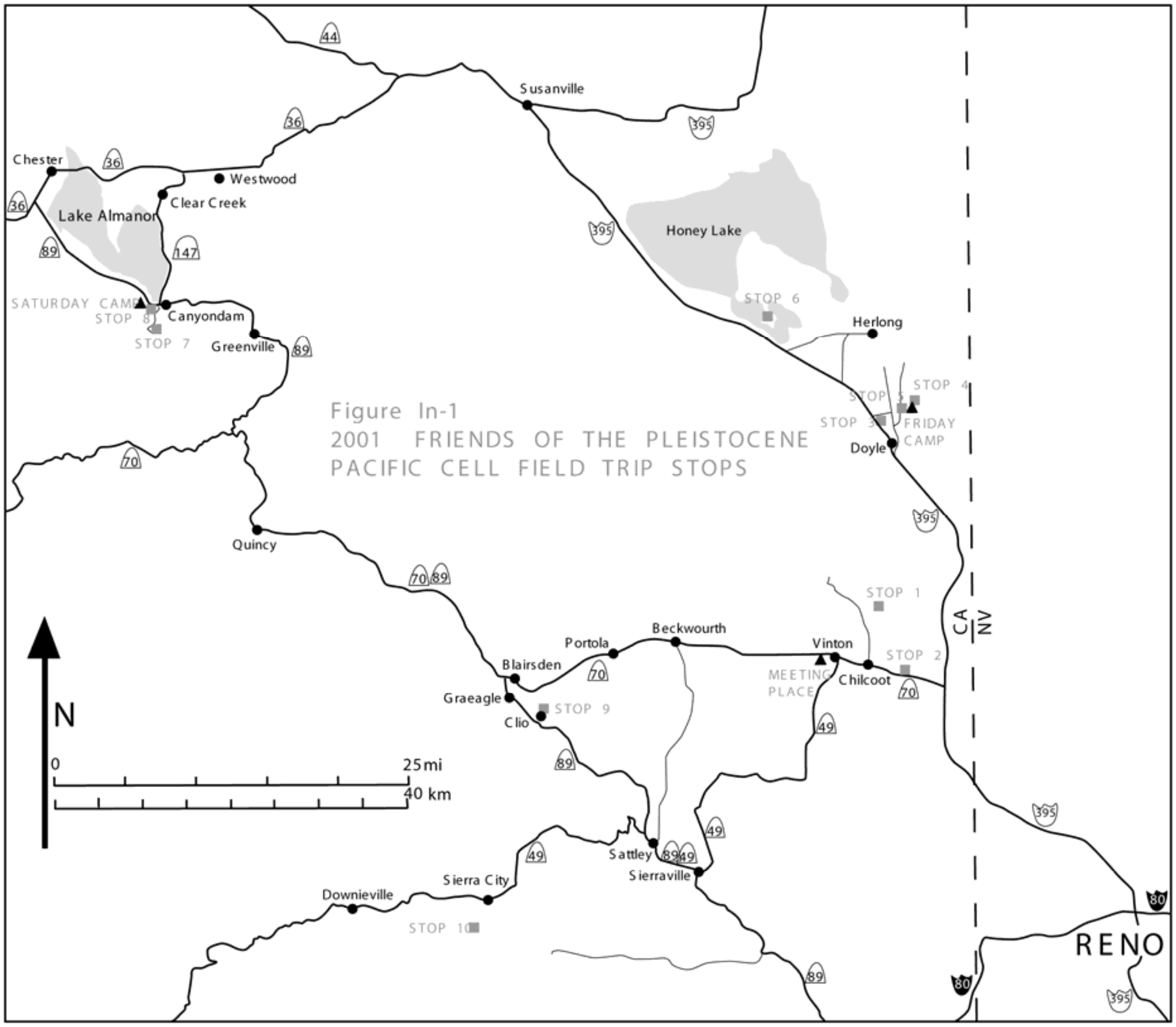


Figure In-1
2001 FRIENDS OF THE PLEISTOCENE
PACIFIC CELL FIELD TRIP STOPS

Tectonic Setting

The Walker Lane is the most active element of the 'eastern branch' of the Pacific-North American plate boundary, a zone of dextral shear separating the Basin and Range province on the east from the Sierra Nevada microplate to the east (Fig. In-2, inset A, B). Collectively the Walker Lane and Basin and

Range accommodate 20-25% of Pacific-North American plate motion; the remaining motion occurs on the San Andreas fault system (e.g., Argus and Gordon, 1991; Dixon et al., 2000). The westernmost part of the Walker Lane is the Sierra Nevada Frontal fault system (Frontal fault system), a zone of dextral, oblique, and down-to-the-east normal faults that bounds the eastern margin of the Sierra Nevada block, and forms the eastern escarpment of the range (Fig. In-2; In-3). The Sierra Nevada is California's most prominent mountain range, extending for over 650 km, with peak elevations that exceed 2000 m over a distance of 500 km, and 3000 m over a distance of 350 km (In-4). The Sierra Nevada is part of the Sierra Nevada microplate, bounded on the west by the California Coast Ranges, and on the east by the Frontal fault system. The Sierra Nevada itself is a west-tilted fault block range, with comparatively little internal deformation and significant variation in topographic expression along strike (e.g., Wakabayashi and Sawyer, 2000; 2001). Note that the eastern boundary of the Sierra Nevada, as defined above, follows the "tectonic" definition of the Sierra Nevada as a comparatively rigid microplate with little internal deformation (implicit in geodetic studies; e.g., Argus and Gordon, 1991, Dixon et al., 1995; 2000; explicit in geologic summaries of Wakabayashi and Sawyer, 2000; 2001). The eastern boundary of the Sierra Nevada is defined as the westermost strand of the Frontal fault system.

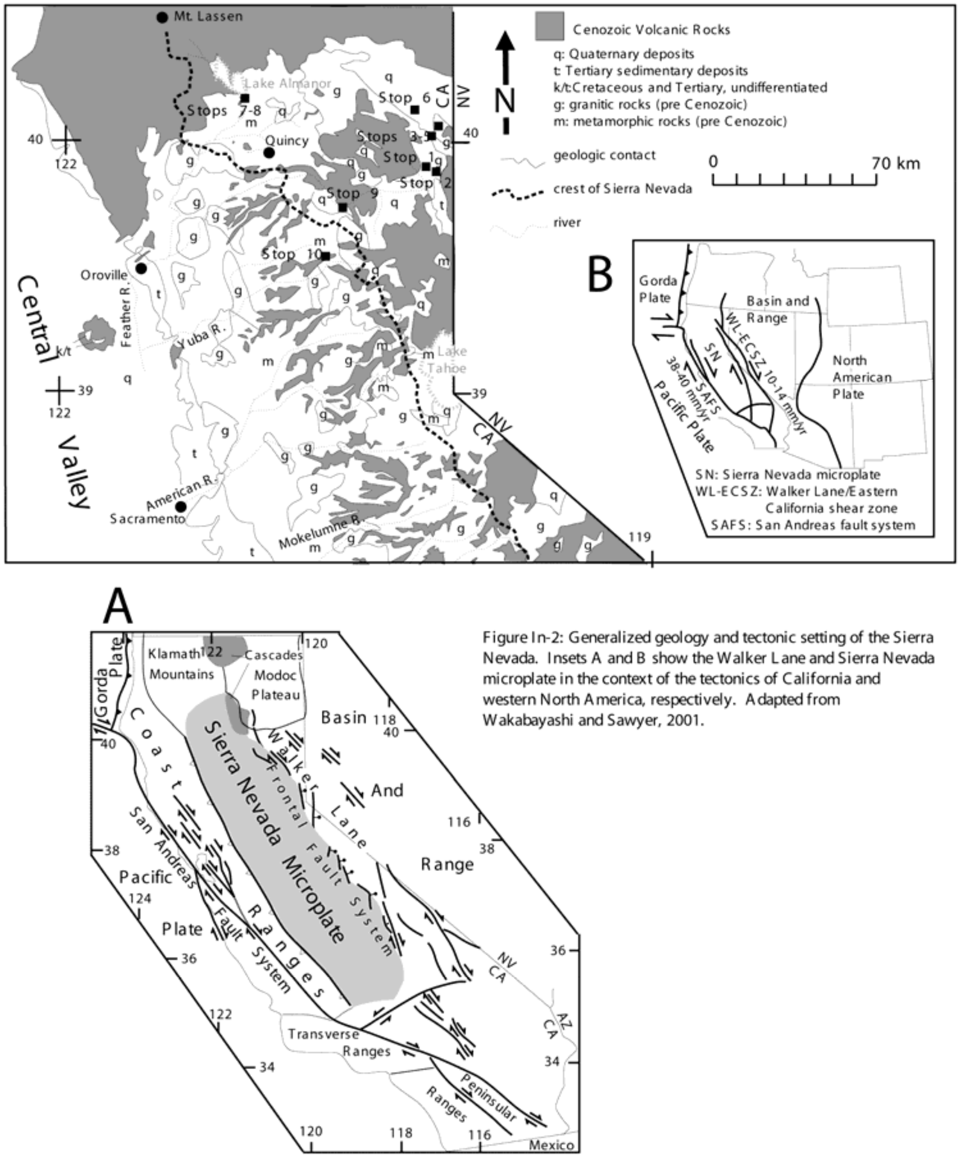
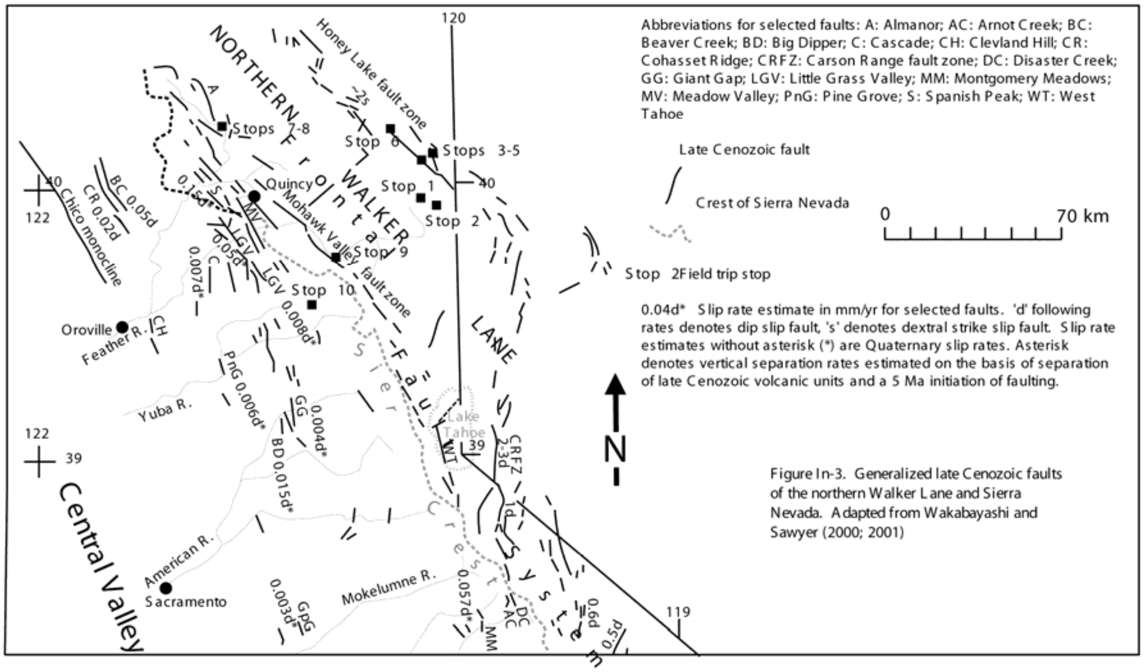


Figure In-2: Generalized geology and tectonic setting of the Sierra Nevada. Insets A and B show the Walker Lane and Sierra Nevada microplate in the context of the tectonics of California and western North America, respectively. Adapted from Wakabayashi and Sawyer, 2001.

Northern Walker Lane faulting appears to be accommodated in two major zones: a western zone known as the Mohawk Valley fault zone an eastern zone called the Honey Lake fault zone. The Walker Lane currently accommodates 10-14 mm/yr of dextral shear in its southern reaches, most of this shear occurring several well-defined fault zones, including the Owens Valley and Fish Lake-Death Valley fault zones (e.g., Dixon et al., 2000). In contrast to the southern and central Walker Lane, comparatively little data exists on the kinematics of the northern Walker Lane, and the distribution of faulting within it, because: (1) geologic slip rate studies are lacking, with the exception of the Honey Lake fault zone (Wills and Borchardt, 1993), and (2) because stations used for geodetically determined slip rates are located well beyond the eastern border of the northern Walker Lane, so it is difficult to assign slip rate to specific fault zones. Dixon et al. (2000) estimated an aggregate slip rate of 7 mm/yr for the northern Walker Lane and assigned 5 mm/yr of this slip rate to the Mohawk Valley fault zone on the basis of subtracting Wills and Borchardt's (1993) ~2 mm/yr slip rate estimate for the Honey Lake fault zone (see Stop 3.), and the geodetically determined slip rate for the Central Nevada Seismic Belt (CNSB) from the velocity between Ely and locations such as Quincy and Oroville; such an approach assumes negligible deformation between the CNSB and the Honey Lake fault zone. Further discussion of the geodetic data bearing on the slip rate of Mohawk Valley fault zone and local geologic features will be presented at Stop 9. There have been no geologic dextral slip rate estimates for the Mohawk Valley fault zone. Long-term (post 5-Ma) vertical separation rates for the Mohawk Valley fault zone have been estimated at 0.1 to 0.24 mm/yr on this dominantly dextral fault zone (Wakabayashi and Sawyer, 2000). Whether or not slip rates are indeed as high as 5 mm/yr for this zone remains to be verified by detailed geologic studies. There are not that many places in the western United States where 5 mm/yr of slip rate is unaccounted for! The Honey Lake and Mohawk Valley fault zones have produced features typical of strike slip fault systems, such as linear scarps, sag ponds and shutter ridges, but it is the subordinate normal faulting (or component of normal slip) that has produced the most noticeable geomorphologic signature in the form of major topographic escarpments and features such as the graben of Mohawk Valley. Piercing points for determining long-term slip displacement and slip rates have not been found across the major fault zones of the northern Walker Lane.



Abbreviations for selected faults: A: Almanor; AC: Arnot Creek; BC: Beaver Creek; BD: Big Dipper; C: Cascade; CH: Clevland Hill; CR: Cohasset Ridge; CRFZ: Carson Range fault zone; DC: Disaster Creek; GG: Giant Gap; LGV: Little Grass Valley; MM: Montgomery Meadows; MV: Meadow Valley; PnG: Pine Grove; S: Spanish Peak; WT: West Tahoe

0.04d* Slip rate estimate in mm/yr for selected faults. 'd' following rates denotes dip slip fault, 's' denotes dextral strike slip fault. Slip rate estimates without asterisk (*) are Quaternary slip rates. Asterisk denotes vertical separation rates estimated on the basis of separation of late Cenozoic volcanic units and a 5 Ma initiation of faulting.

Figure In-3. Generalized late Cenozoic faults of the northern Walker Lane and Sierra Nevada. Adapted from Wakabayashi and Sawyer (2000; 2001)

Both the Mohawk Valley and Honey Lake fault zones appear to have formed comparatively recently in geologic time. The Honey Lake fault zone may have started moving between about 10 and 5

Ma, and the Mohawk Valley fault zone started movement shortly after about 5 Ma; the initiation of movement on these fault zones appears to be related to the progressive encroachment of the Walker Lane into the Sierran microplate (Wakabayashi and Sawyer, 2000; 2001). This encroachment is ongoing in the North Fork Feather River area, where some faults apparently did not start moving until after about 600 ka (Wakabayashi and Sawyer, 2000),(discussed at Stop 7).

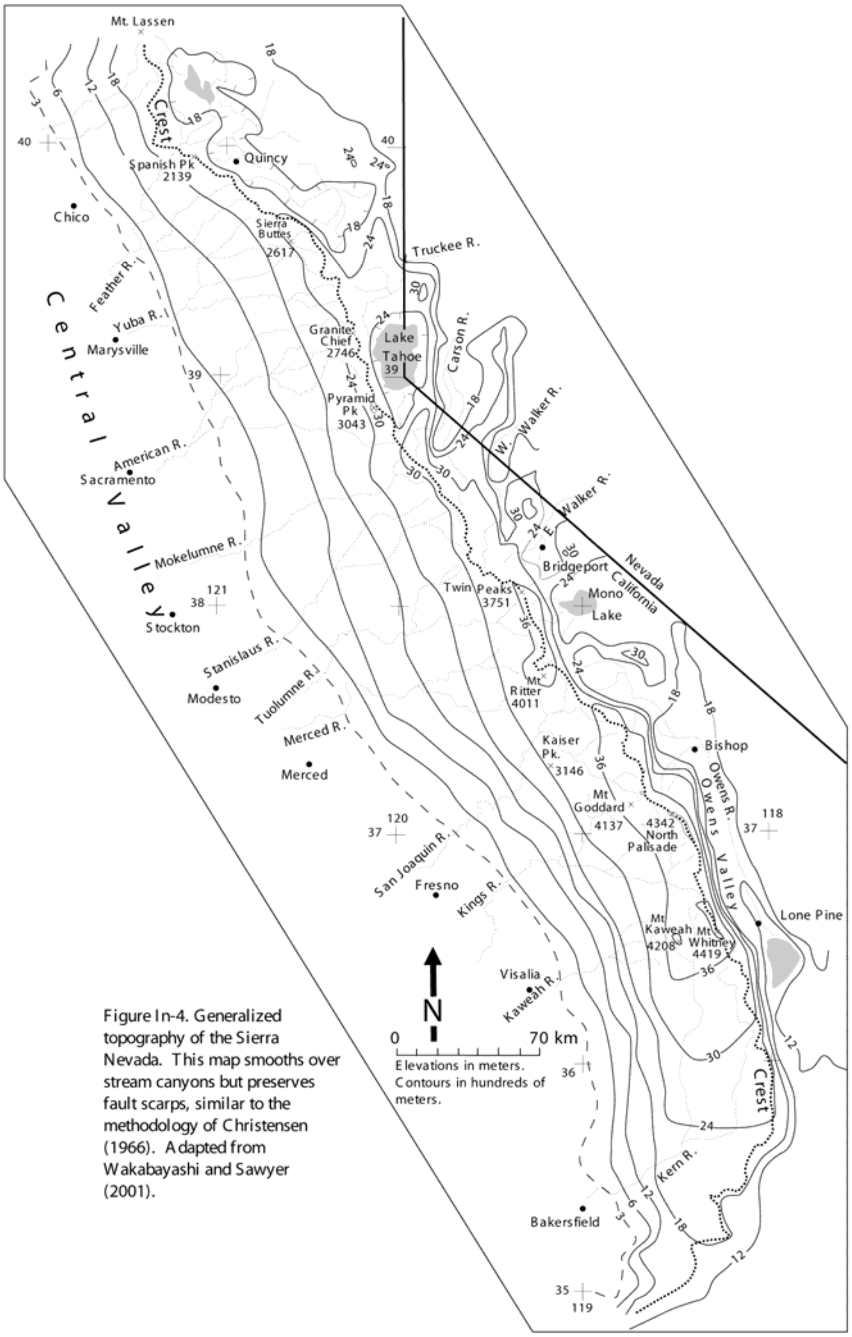


Figure In-4. Generalized topography of the Sierra Nevada. This map smooths over stream canyons but preserves fault scarps, similar to the methodology of Christensen (1966). Adapted from Wakabayashi and Sawyer (2001).

Sierra Nevada: A Geomorphology Field Laboratory

While most of the research on the neotectonics on the Walker Lane has taken place in the last two decades, the Sierra Nevada has served as a field laboratory for examining geomorphic processes and the relationship between tectonics and topographic development for over a century. The Sierra Nevada has long been regarded as a mountain range that attained most of its elevation as a consequence of westward tilting coupled with faulting along the Frontal fault system during the late Cenozoic (e.g., Whitney, 1880;

Ransome, 1898; Lindgren, 1911; Christensen, 1966; Huber, 1981; Unruh, 1991). In contrast to this view, thermochronologic data has been interpreted to suggest that late Cenozoic uplift did not occur and that the Sierra Nevada has been decreasing in elevation since the late Cretaceous (House et al., 1998). Small and Anderson (1995) suggested that the late Cenozoic uplift of the high ridges of the Sierra Nevada may have been climatically rather than tectonically triggered. Thus the Sierra has become the focus of debate on how some types of major mountain ranges form. The debate regarding the long-term topographic evolution of the Sierra Nevada has been discussed in Wakabayashi and Sawyer (2001), who proposed that late Cenozoic surface uplift did indeed occur, probably as a result of a tectonic transition, and that significant elevation was relict from pre-Eocene uplift. Some of the evidence bearing on models of long term development of the Sierra Nevada, particularly with regard to stream incision and development of relief, will be viewed and discussed at Stops 7 and 10.

Theories of landscape development, originally proposed in the Sierra Nevada, such as the stepped topography concept (Wahrhaftig, 1965) have been recently tested by quantification of erosion rates by cosmogenic nuclide dating (Granger et al., 2001) (Stop 1). Quantification of erosion rates in many different settings has allowed evaluation of many surface processes, including the relationship of weathering to parameters such as climate or erosion, and controls on erosion (in addition to the bedrock and boulder armoring effect discussed at Stop1) such as tectonic forcing (Riebe et al. 2000; 2001a, b) (discussed at Stop 4).

Following this introduction is a road log, followed by individual stop descriptions.

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2001 FRIENDS OF THE PLEISTOCENE PACIFIC CELL FALL FIELD TRIP ROAD LOG

Note: As with all road logs, there will be some difference, owing to differences in odometers for various vehicles. It is recommended that the individual segment mileages be considered more than the cumulative ones, as the cumulative mileage 'error' increases as the day goes on.

Thursday, October 11, 2001 Gathering of Friends

Assemble on grounds of Ramelli family homestead, west of the town of Vinton (see Fig. In-1 for generalized main roads in the area). The driveway to meeting place leaves Highway 70 3.0 miles west of Chilcoot (measured from the junction of Highway 70 and the Frenchman Lake road) and 10.7 miles east of the junction of county road A23 and Highway 70. Directly west of the driveway is a white, former one room schoolhouse "Summit School District" that is now an antique shop.

The first night's campsite lies in the northeast part of Sierra Valley, considered by many to be the largest valley within the Sierra Nevada. As discussed in the introduction, we would consider this tectonically-controlled basin to be within the Walker Lane belt, rather than part of the Sierran proper. The valley, which is bisected by several poorly understood northwest-striking faults, may have formed as a pull-apart basin, with right-lateral slip transferring across the valley. The Mohawk Valley fault, which bounds the valley on the southwest, is the subject of STOP 8.

During the Middle Pleistocene, Sierra Valley was occupied by pluvial Lake Beckwourth. Undissected lake sediments form the very flat floor of the valley, although the campsite actually sits on younger sandy alluvium of Little Last Chance Creek that spilled out onto the lake sediments. At the campsite, the lake was about 30 m (100 ft) deep during the most recent lake stand. During an earlier, higher stand (the subject of STOP 2), the lake was more than 90 m (300 ft) deep at this location.

Note that a short stretch of dirt road leading to stop 1 required 4 wheel drive for one of the vehicles in our dry run (but didn't for the other two). Those unsure about the capability of their vehicle may park at the Frenchman Lake road/Highway 70 junction in Chilcoot. Please make your arrangements before we get started on Friday morning.

Friday, October 12, 2001	Mileage from late noted point	Cumulative mileage for day
Start trip. Intersection of driveway from Ramelli homestead and Highway 70. Make a right turn onto Highway 70 and drive eastward on Highway 70.	0.0	0.0
Turn left off of Highway 70 onto the Frenchman Lake road in Chilcoot.	3.0	3.0
Turn right onto an unmarked dirt road. Here, the route traverses a	1.1	4.1

tombolo formed behind the granitic hill to the southwest. The crest of the tombolo, which is covered by a thick layer of eolian sand, is at an elevation of about 1,560 m (5,120 ft). The tombolo formed during the older, higher lake stand, and was likely lowered somewhat by subsequent erosion.		
Bear left at a fork in the road	0.5	4.6
Pass through gate	0.3	4.9
Keep straight at fork	0.5	5.4
STOP 1	1.6	7.0
Retrace route back to Highway 70 Drive southward on dirt road from stop, then turn left (south) onto the Frenchman Lake road	2.9	9.9
Turn left (east) onto Highway 70. The route climbs from the floor of Sierra Valley toward Beckwourth Pass. Beckwourth Pass, named for man who "discovered" it (James Beckwourth), is the lowest pass in the Sierra Nevada. This was a somewhat easier, albeit longer, variant of the mid-1800s emigrant trail.	1.1	11.0
Turn sharply left off of Highway 70 onto road that leads down the slope to some kind of facility (pump station?).	2.3	13.3
STOP 2	0.2	13.5
Drive back to Highway 70 and turn left (east)	0.2	13.7
Turn left (northward) onto Highway 395	3.3	17.0
The channel of Long Valley Creek is to our left (west) for the next 4 miles. The banks of the creek expose Holocene sediments.	7.0	24.0
Junction Doyle Grade (town of Doyle); stay straight on 395	12.5	36.5
Cross Long Valley Creek, stop 3 is just upstream to our right (east)	2.0	38.5
Turn right (east) onto Laver Crossing road, followed by an immediate right onto B&B Way-North Doyle Heights	0.4	38.9
Turn right at driveway, the entrance of which is flanked by two wooden posts	0.4	39.3
Turnaround at end of driveway **STOP 3**	0.2	39.5
Return to B&B road; turn left	0.3	39.8
Return to Laver Crossing road; turn right	0.4	40.2
Turn right onto Hackstaff Road	1.3	41.5
Turn left onto Fort Sage Road	1.2	42.7
Turn right onto an unmarked dirt road that leads up into the Fort Sage Mountains	3.3	46.0
Take left fork (smoothest most prominent track) after crossing dry creekbed	0.3	46.3
Road comes in from left, keep right	0.7	47.0
Road junction; park in this area. Some of the better parking spots come shortly after turning left at this junction, but parking is available both before and beyond this junction off the road to either side. This is the **CAMP FOR FRIDAY** and parking for **STOP 4**	1.0	48.0

Saturday, October 13, 2001	Mileage from late noted point	Cumulative mileage for day
Leave camp drive back to Fort Sage road	0.0	0.0
Bear left at fork	1.0	1.0
Turn left at Fort Sage road	1.0	2.0
Park on the margin of road. This is a very wide road. Park on it rather than off of it, because the shoulder is steep and vehicles may get stuck if they park off the road. **STOP 5**	1.0	3.0
Continue southward on Fort Sage road; turn right onto Hackstaff road	2.3	5.3
Turn left onto Laver Crossing road	1.2	6.5
Turn right (northward) onto Highway 395	1.3	7.8
Pass west-facing scarp of Honey Lake fault on right	0.8	8.6
Turn right onto Garnier Road (A26) toward Herlong	2.4	11.0
Turn left onto Herlong Access Road	3.7	14.7
Turn right onto Pole Line Road	0.4	15.1
Bear left, then follow main branch (both go to same place)	1.7	16.8
Turn left (due west) onto a section line road. follow it with minor detours around low areas	0.3	17.1
Turn left (due south) onto a section line road	5.0	22.1
Turn right onto section line road that bends northerly, then back to the southwest	1.0	23.1
Road junction; best parking is to the left by a corral. To the right is **STOP 6**	2.6	25.7
Turn left (north) on section line road	2.6	28.3
Turn right (east) on section line road	1.0	29.3
Main road turns right on section line; follow it	2.0	31.3
Univ. Nevada facility entrance, go straight, then round low area to right and continue	1.0	32.3
Bear right, several possible tracks cut the corner between section line roads	2.0	34.3
Bear right	0.3	34.6
Turn right (west) onto Herlong Access Road	1.7	36.3
Turn right onto Highway 395	4.2	40.5
Stay straight on Highway 36 toward Susanville (Hwy 395 turns right) you will stay on Highway 36 for the next 29 miles	25.9	66.4
Turn left onto Highway 147. Soon after turning onto Highway 147 you will turn right staying on Highway 147 and descend a short grade to the town of Clear Creek; the grade descends a west-facing fault scarp of the Walker Springs fault in 400 ka Basalt of Westwood.	28.5	95.4
After driving southward along the east shore of Lake Almanor, turn right (west) onto Highway 89	11.0	107.0
Take an immediate left (after about 0.05 miles) onto the Seneca Road	0.1	107.1
We pass a low west-facing scarp of the Eastside fault in 400 ka Basalt of Westwood.	0.1	107.2

Find parking along the Seneca Road. Fortunately it is wide for a fairly long distance. The drop off to the west is extremely abrupt. **STOP 7**	1.9	109.1
Return to Highway 89 and turn left (west)	2.0	111.1
Park along (north side of the road) on Lake Almanor Dam **STOP 8**	0.5	111.6
Continue westward on Highway 89 and turn left onto an unsigned dirt road.	0.6	112.2
Turn left onto another, narrower dirt road	0.1	112.3
Bear left at a fork	0.15	112.45
Turn right via one or two different possible routes into a large bowl with very small trees. Early arrivals should try to dry as far back in the bowl from the entrance point as they can. This is the **SATURDAY NIGHT CAMPING SITE (BUSINESS MEETING SITE)**. Note there is basalt bedrock exposed in the little gullies in this bowl. This is the 400 ka Basalt of Westwood. The steep slope bounding the southwest (upper) side of the bowl is the scarp of the Skinner Flat fault. This fault appears to be dying out to the northwest.	0.15	112.6
Sunday, October 14, 2001	Mileage from late noted point	Cumulative mileage for day
Starting point at exit from camping area onto perimeter dirt road	0.0	0.0
Bear right at fork	0.15	0.15
Turn right onto wide dirt road	0.15	0.3
Turn right (east) onto Highway 89: you will stay on 89 for a long time	0.1	0.4
Entering the Greenville area, we will pass through the town of Greenville. Greenville is situated in Indian Valley, a valley that appears drowned by alluvium as a result of tectonic damming near where Indian Creek flows out of it near its southwest corner. This is one of many tectonically controlled basins along the Mohawk Valley fault zone.	10	10.4
Highway 89 joins Highway 70; turn left and head toward Quincy	11.6	22.0
Entering American Valley, another tectonically controlled basin along the Mohawk Valley fault zone. To the west you can see a bare granite face. This is glaciated escarpment of the Spanish Peak fault, the main strand of the Frontal fault system in this area. The top of the ridge is the crest of the Sierra Nevada and you are viewing the eastern escarpment of the Sierra Nevada. North of American Valley, the Frontal fault system, and the Mohawk Valley fault zone broaden to a distributed zone of deformation some 30-40 km wide, whereas south of American Valley the faulting occupies a narrow zone of about 10 km in width.	8.8	30.8
On the right, at the start of a wide shoulder area, you will see a small	12.5	43.3

hill composed of very dark rock. This is the Lovejoy Basalt, a 16 m.y. old basalt that erupted east of the Honey Lake fault and flowed westward across the Sierra to the western margin of the Central Valley. The eruption of this unit predates movement on the Honey Lake and Mohawk Valley fault zones, and the unit is a good late Cenozoic marker horizon to record deformation, tilting, and rock uplift of the Sierra (see discussion for Stop 10). The Lovejoy Basalt caps ridges on both sides of the Mohawk Valley graben. More information and field trip stops related to the Lovejoy Basalt are found in Wagner et al. (2000; in reference list for introduction). Not long after passing the Lovejoy Basalt exposure the road crosses the curiously low divide between the North Fork and Middle Fork Feather River drainages. We now enter the Middle Fork drainage. We then drive through the little town of Cromberg. Southeast of Cromberg, the route traverses through the gorge that drains Mohawk Valley. Steep, unstable slopes can be seen on both sides of Highway 70. Landslides in this area are one possible mechanism for damming the outlet of Mohawk Valley and raising the level of Lake Beckwourth in Sierra Valley.		
Turn right onto Highway 89	11.3	54.6
We cross over the Middle Fork of the Feather River. The Feather River drainage is unique in that it is the only drainage to cross the entire width of the Sierra Nevada, draining a large area of easternmost California into the Central Valley. For much of the next 3 miles you will be driving across late Quaternary glacial outwash of Gray Eagle and Frazier creeks, two of the largest drainages heading along this part of the Sierran crest.	0.5	55.1
Turn left onto road at Clio (green Clio sign)	3.7	58.8
In 'downtown' Clio, Lower Main street curves 90° and becomes county road A40	0.2	59.0
Turn left onto C road, proceed northward toward railroad tracks	0.4	59.4
Intersection of C Road and railroad tracks. Park on either side of railroad tracks. We'll gather on the southside of the tracks about 100 m east of the crossing with C Road. **STOP 9**	0.3	59.7
return to Highway 89: drive southward on C Road, then turn right onto A40	0.3	60.0
Turn left onto Highway 89. We drive southward on Highway 89, crest over a pass, then eventually descend into Sierra Valley. This part of Sierra Valley is a good location for viewing the shorelines left by the most recent stand of pluvial Lake Beckwourth. Shorelines can be seen to the north along the west side of the valley, and to the east at the base of Hill 5348. Notice that shorelines are not evident from the higher, older lake stand.	0.6	60.6
Join Highway 49, turn left	13.4	74.0
In Sierraville, turn right (southward) onto Highway 89	4.8	78.8

Turn right onto road to Jackson Meadow Reservoir (Forest Road 07)	8.4	87.2
Turn right at an unsigned junction just before crossing dam. After turning you will pass a borrow quarry on your right	16.0	103.2
Keep straight at intersection	2.7	105.9
Keep straight at intersection	1.1	107.0
STOP 10. park at available turnouts on either side of the dirt road	3.4	110.4

STOP 1.

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Introduction for Stops 1 and 4

Chemical weathering and physical erosion jointly regulate soil development, sculpt landscapes, and deliver sediment and solutes to riverine habitats. Chemical weathering also generates nutrients and helps regulate global climate over million year timescales. Thus it is important to quantify long-term rates of weathering and erosion in different environments. Here we present results of a recent test that shows that cosmogenic nuclide techniques can be used to measure long-term, catchment-wide erosion rates (Stop 4; Granger et al., 1996). We used this technique to measure erosion rates at a series of sites in the Diamond and Fort Sage Mountains, and determined that the exposure of slowly eroding, bare rock plays an important role in granitic landscape evolution (Stops 1 and 4; Granger et al., 2001), much as was originally proposed by Wahrhaftig (1965). We also show how long-term chemical weathering rates can be measured by combining physical erosion rates, inferred from cosmogenic nuclides, with dissolution losses, inferred from the rock-to-soil enrichment of insoluble elements (Stop 4; Riebe et al., 2001b). Using this technique, we measured rates of weathering and erosion at a series of granitic Sierra Nevada study sites that span 20-145 cm/yr in average precipitation and 4-15 C in mean annual temperature (Stop 4). Our results show that both physical erosion and chemical weathering rates are insensitive to differences in climate and that long-term rates of chemical weathering and physical erosion are tightly coupled (Riebe et al., 2001 a&b). This result implies that chemical weathering rates may depend on tectonic uplift rates in many mountainous settings.

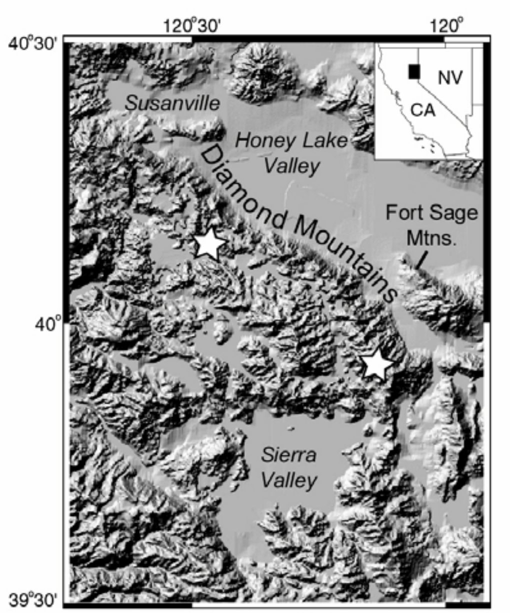


Fig. 1-1. Taken from Granger et al., 2001. Shaded relief map showing Diamond Mtn. study sites. Stars mark Adams Peak to the southeast and Antelope Lake to the northwest. Also shown is the Fort Sage Mtn. site of Granger et al., 1996. The Diamond Mtn. sites are developed in moderately uniform hornblende-biotite granodiorite/tonalite, which is similar to the bedrock of the Fort Sage Mtns (Oldenburg, 1995) Fort Sage sits in the rain shadow and is hotter and drier than the Diamond Mountain Sites.

Description of Stop 1

This is a gently sloped, soil-mantled ridge in the foothills of the Diamond Mountains. Gentler slopes in the area are generally mantled with less boulders and bare rock than their steeper counterparts. A good example of steep, boulder-mantled slopes can be seen on the ridge to the east.

Cosmogenic nuclide measurements from soils and ouctrops two miles North of Stop 1 show that exposed granitic bedrock weathers more slowly than the same rock buried beneath moist soil (Granger et al., 2001). Throughout the area, and at another Diamond Mountains site near Antelope Lake (Fig. 1-1), exposed bedrock and boulders are more abundant on steep slopes (Fig. 1-2) and apparently play an important role in regulating mountain erosion rates (Fig. 1-3). Rapid transport of fine sediment on steep slopes exhumes resistant corestones which accumulate on the surface. The resulting boulder lag apparently shields the underlying bedrock from erosion, even when the bedrock is deeply weathered and friable (Fig. 1-4). Where steep slopes have an abundant boulder lag, they erode as slowly as gentler slopes nearby (Fig. 1-2). On the basis of these observations and counterproof determined at the Fort Sage Mountains (to be discussed at Stop 4), we infer that boulder armoring can modulate hillslope erosion such that erosion rates of summits, steep mountain flanks, and gentle footslopes are indistinguishable, thus permitting local relief and steep mountain slopes to persist for long periods of time.

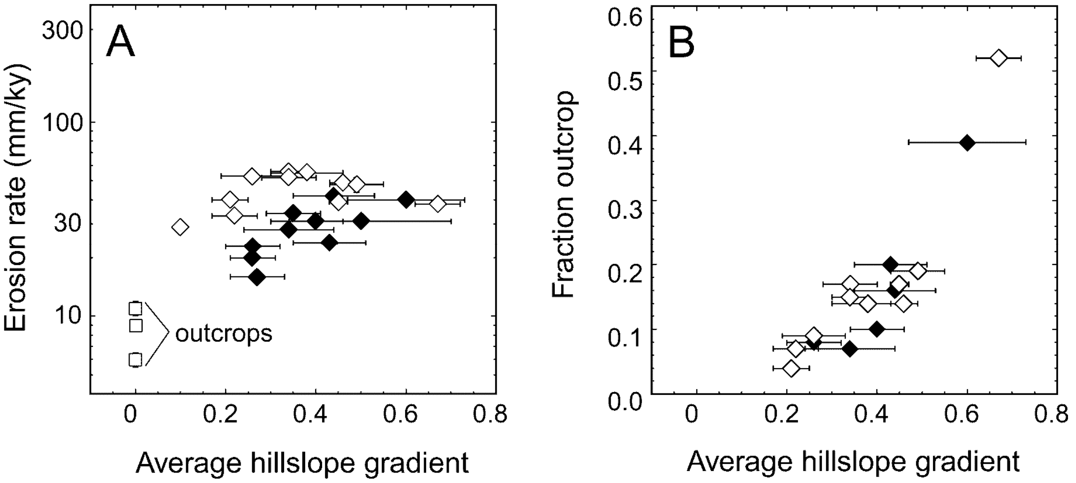
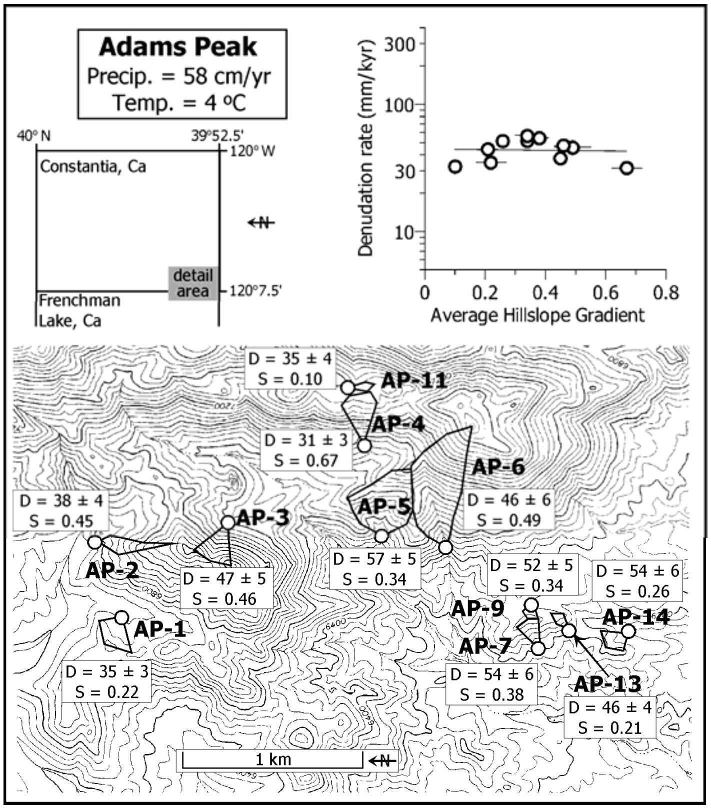
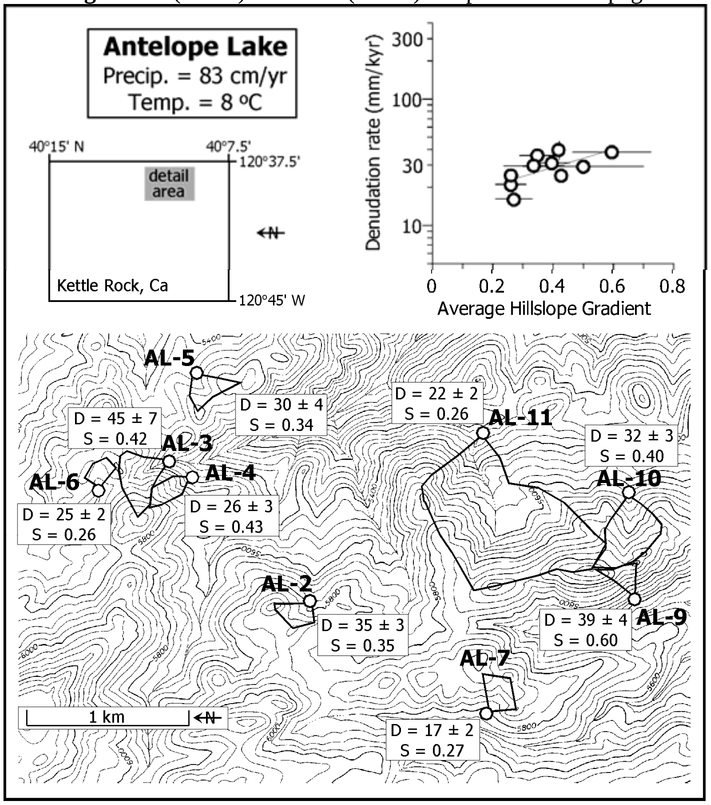


Fig. 1-2. Adapted from Granger et al., 2001. Catchment erosion rates (A) and fraction outcrop (B) plotted against average hillslope gradient for catchments at the Diamond Mountain sites (open diamonds are from Adams Peak, closed diamonds are from Antelope Lake). At both sites at gradients below ~0.4, there is weak correlation between erosion rates and hillslope gradients. More striking is the lack of correlation on steep slopes; for hillslopes with a gradient steeper than 0.45, erosion rates remain constant or even decrease. In contrast, bare rock abundance clearly increases with hillslope gradients. Below gradients of about 0.4, bare rock abundance remains uniformly low, whereas above it, the fraction of boulders and bedrock on the slopes increases rapidly. The steepest slopes are more than half covered with bare rock. The abundance of exposed rock suggests that bare rock weathering may play an important role in this landscape's evolution; it is therefore important to determine bare rock erosion rates. Three samples show that bare rock erosion is significantly slower than catchment averages, at 6-11 mm/ky (labeled "outcrops" in Fig. 2A). Because bare rock erodes more slowly than the catchment average, and because exposed bedrock and boulders comprise an increasing fraction of catchments as they become steeper, we suggest that bare rock exposure retards erosion of steep slopes and limits the range of erosion rate variability.



Figs. 1-3A (above) and 1-**3B** (below). Captions on next page.



Caption for Fig. 1-3 (on the previous page, adapted from Riebe et al., 2000). Map of Adams Peak (Fig. 1-3A) and Antelope Lake (Fig. 1-3B) showing catchment boundaries, names, denudation rates ("D", equivalent to "Erosion rates" of Fig. 1-2), average hillslope gradients ("S" in m/m), and sampling localities (open circles). Maps are taken from USGS 7.5' topographic quadrangles (shown and named at the top of each panel as index maps). Contour interval = 40 ft. Not all study catchments are shown on the maps. Denudation rates are roughly uniform and are weakly correlated with hillslope gradient at these sites. We suggest that baselevel lowering rates are roughly uniform across each site, and that variations in hillslope gradients are largely controlled by differences in erodibility (as modulated by boulder abundance; see Fig. 1-2).

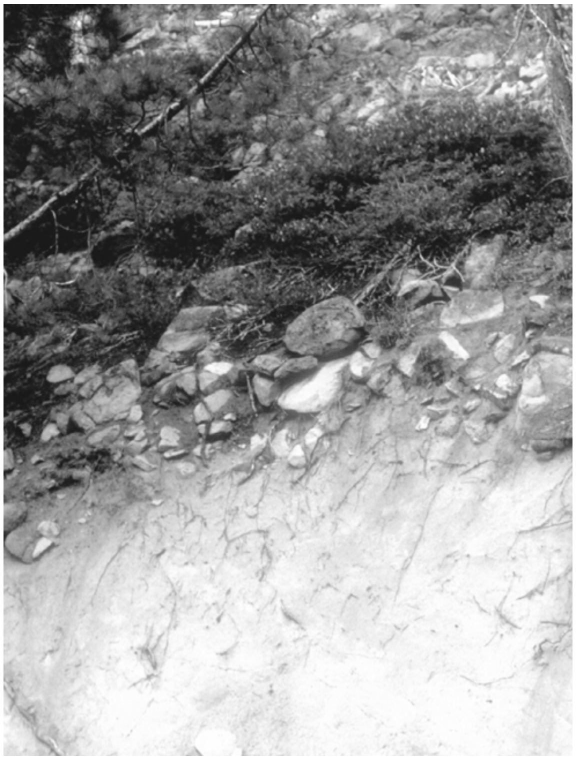


Fig. 1-4. Taken from Granger et al., 2001. Roadcut near Crystal Peak (~15 km northwest of Adams Peak) showing corestone boulders overlying hand-friable saprolite (horizontal field of view is ~5 m). We propose that on steep slopes, prone to rapid sediment transport by rainsplash, sheetwash, and biogenic processes, gruss will be rapidly stripped to expose corestones and bedrock. The exhumed rock will weather much more slowly than the saprolite. Provided that corestones do not roll downhill faster than they are exhumed and that intact bedrock is not exhumed first, a quickly eroding saprolite will accumulate a surface lag of boulders that will shield the underlying saprolite and interrupt rill development during rainstorms. Saprolite beneath such a boulder cover will continue to weather in place, but grussification and sediment transport will be strongly inhibited by the boulder cover. Exposure of slowly weathering boulders and bedrock provides a negative feedback that can modulate hillslope erosion rates. The faster saprolite is stripped, the more corestones and bedrock will be exhumed to slow the erosion.

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STOP 2.

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Spillover Point of Pluvial Lake Beckwourth into the Lahontan Basin, Railroad Tunnel Portal on East Side of Beckwourth Pass.

This stop looks at evidence that a mid-Quaternary pluvial lake in Sierra Valley (Lake Beckwourth) overtopped Beckwourth Pass at least once, spilling into Long Valley Creek and thence into the Lake Lahontan basin (fig. 2-1). This probably short-lived spillover has important biogeographic implications, because it likely transferred fish and other aquatic species from the Feather River, which flows to the Pacific Ocean, into the Lahontan system of the Great Basin.

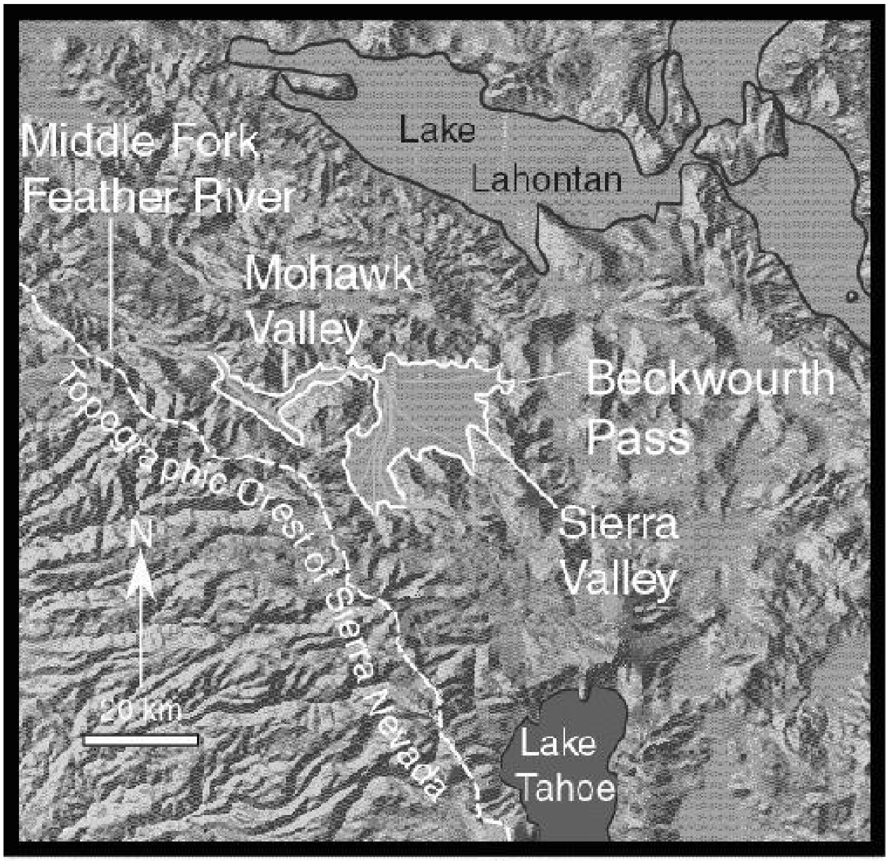

Fig. 2-1. During the Middle Pleistocene, a pluvial lake/marsh system existed in Sierra and Mohawk Valleys. At least once, the lake in Sierra Valley (Lake Beckwourth) rose and overtopped Beckwourth Pass, spilling into the Lahontan basin and causing an exchange of aquatic species.

The existence of a Pleistocene lake in Sierra Valley is indicated by wave-cut platforms, spits, tombolos, rounded beach gravels, and sparsely exposed lake-bed sediments. This pluvial lake was briefly discussed by Van Couvering (1962), who named it Lake Beckwourth, and Durrell (1987), but no one has looked at it in detail. Our reconnaissance studies (Ramelli and Adams, 1999) add something to the picture, but much remains to be done, including surveying of shorelines, establishing better age constraints, and gaining a better understanding of outlet control.

Most recent stand of Lake Beckwourth

The most recent stand of Lake Beckwourth (fig. 2-2) is indicated by moderately preserved shoreline features at and below an elevation of about 1,540 m (5,050 ft). The best preserved of these include: 1) wave-cut benches on the west side of the valley about 10 km (6 mi) south of Beckwourth; 2) wave-cut benches and a tombolo around "Hill 5348" on the south side of Hwy 49 about 7 km (4 mi) west of Loyalton; and 3) broad spits on the east and west sides of "The Buttes" on the north side of Hwy 70 about 10 km (6 mi) west of Vinton. We haven't surveyed the elevations of these features, but the crest of the tombolo on the back side of Hill 5348 is very close to the high shoreline, providing a close approximation of the high stand.

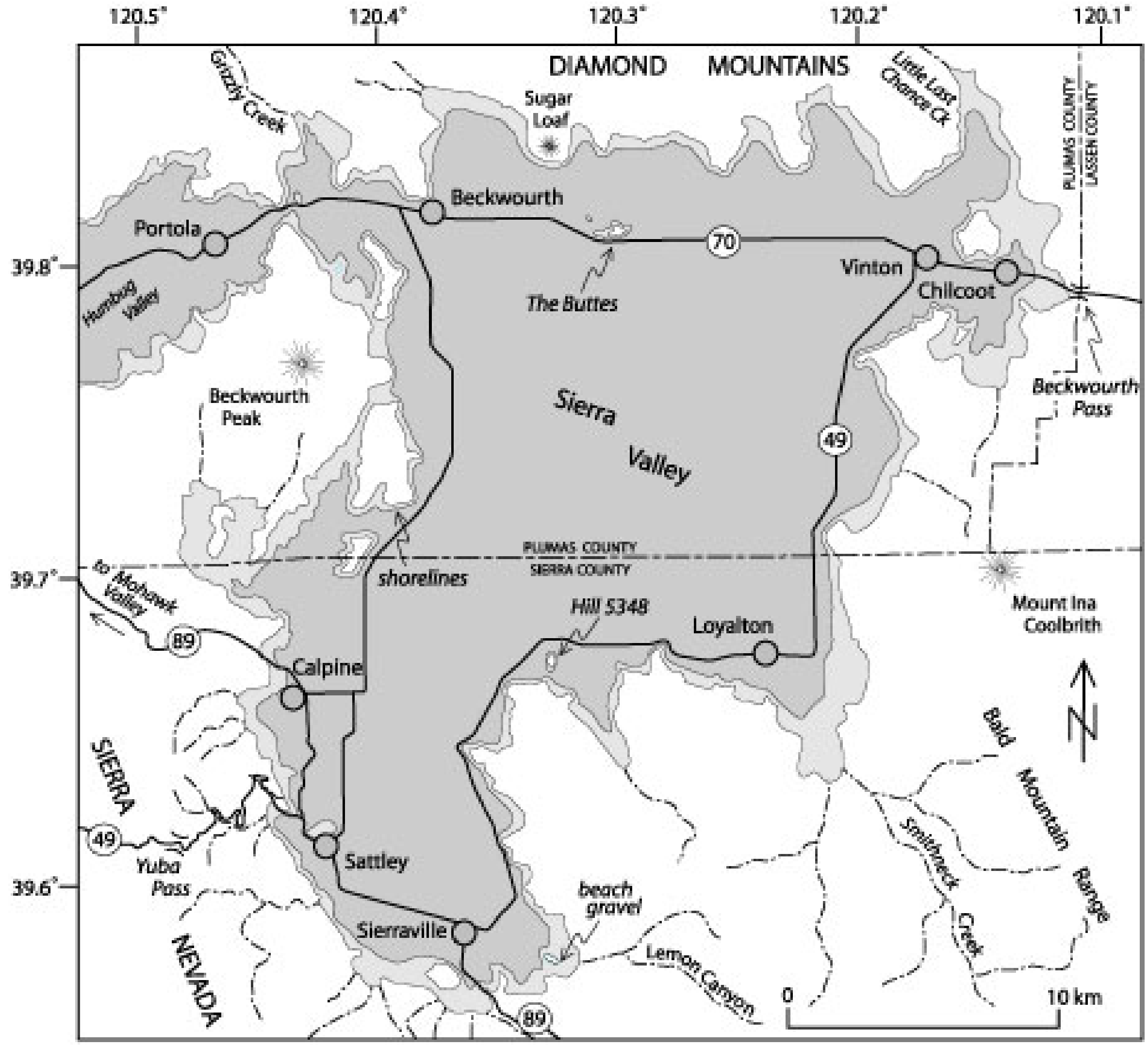

Fig. 2-2. Approximate outlines of two stands of pluvial Lake Beckwourth. The most recent stand (dark shading) reached an elevation of about 1,540 m (est. age about 150 ka). An earlier stand (light shading) reached an elevation of about 1,585 m (est. age greater than 300ka).

Durrell (1987) estimated the maximum elevation of the "Mohawk lake beds" in Mohawk Valley to be about 1,535 m (5,040 ft). This is very similar to the elevation of Lake Beckwourth and suggests the two basins were connected at that time. Durrell (1987) incorrectly interpreted the elevation of Lake Beckwourth to be 1,555 m (5,100 ft), and inferred that a fast-flowing stream connected the two basins. Work by Jim Yount (presented on the 1995 Pacific Cell FOP trip) showed that the Mohawk beds were actually deposited within a marsh environment, rather than being lacustrine in origin as interpreted by Turner (1891), Mathieson (1981), and Durrell (1987). When this marsh existed, Mohawk Valley was drained at its western end by Poplar Creek, on the south side of Big Hill (see Durrell (1987) for a detailed discussion of the Poplar Creek outlet). The Feather River subsequently downcut through highly erodable materials on the north side of Big Hill, establishing a new outlet. Yount (1995) found several tephra layers within the Mohawk beds ranging in age from ~400 ka (Rockland ash) to about 150 ka, after which time the basin apparently became drained due to incision of the Feather River. We infer that this incision resulted in the death of Lake Beckwourth.

Older, higher stand of Lake Beckwourth

In several locations around Sierra Valley, poorly preserved features (e.g., wave-cut benches, tombolos, beach gravels, etc.) are located at elevations up to about 1,585 m (5,200 ft) indicating a higher stand of Lake Beckwourth. The most convincing evidence of this higher stand that we have found so far are rounded beach gravels present on the backside of a small hill to the south of Lemon Canyon Road about 3 km (2 mi) east of Sierraville. The geomorphic indicators of this higher lake stand are much more degraded than those of the most recent stand, indicating an age of substantially greater than 150 ka. Based on the poor preservation of shoreline features, we tentatively estimate the age of this stand to be at least 300 ka, and possibly much greater. Similar to the more recent stand, this high stand also appears to coincide with the maximum elevation of older deposits in Mohawk Valley (Yount, 1995).

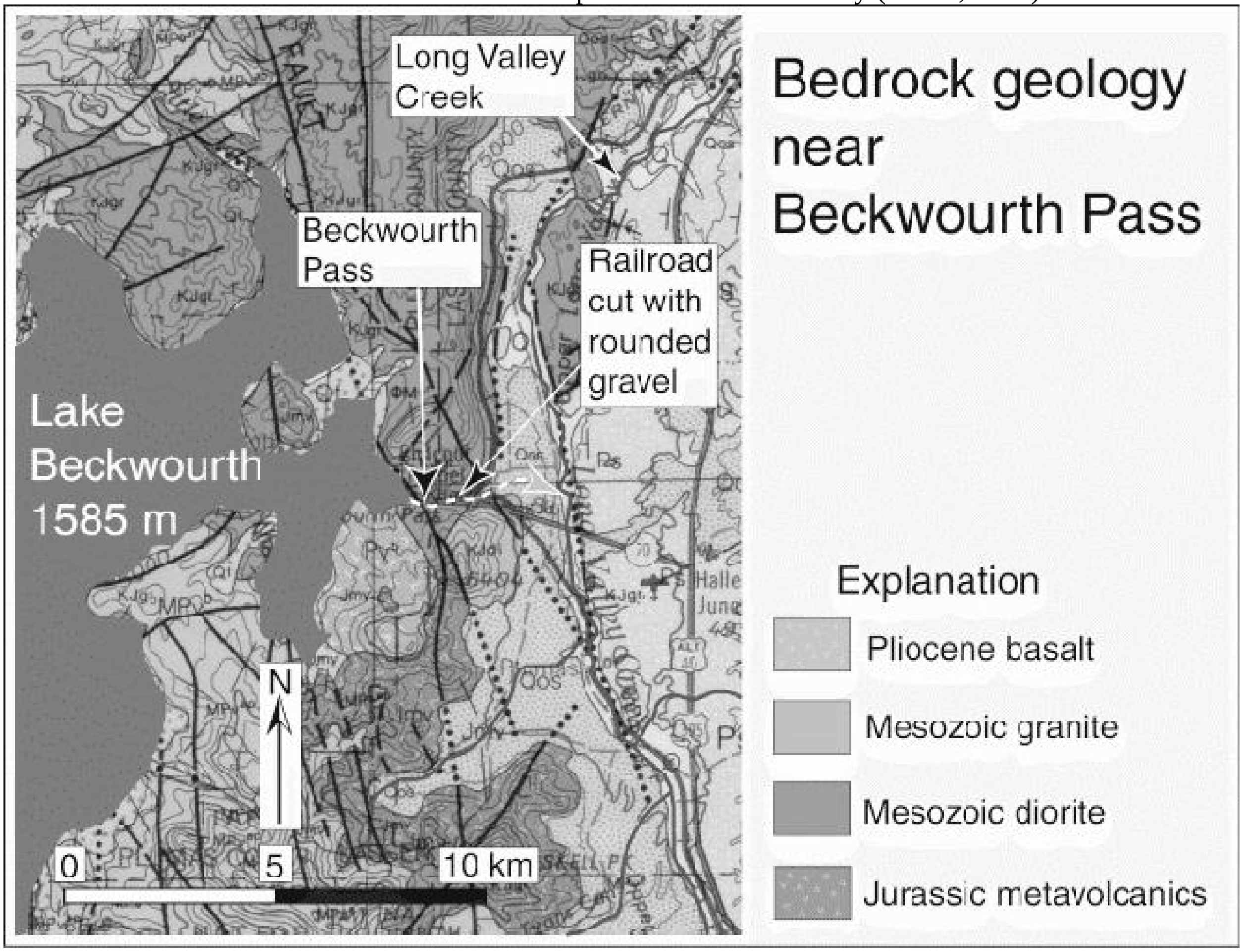

Fig. 2-3. Geologic map of the Beckwourth Pass area. The eastern portal of the railroad tunnel exposes evidence of a Middle Pleistocene spillover of pluvial Lake Beckwourth. Rounded volcanic clasts must have been derived from the west side of the pass.

At an elevation of 1,585 m (5,200 ft), Lake Beckwourth was very close to the 1,590 m (5,220 ft) elevation of Beckwourth Pass. This raised the question of whether the lake ever overtopped Beckwourth Pass, thus spilling into Long Valley and thence into the Lake Lahontan basin, rather than always spilling down the Feather River, which drains to the Pacific Ocean. The alluvial fan on the east side of the pass seems underfit in that it's quite large relative to the area it drains, lending credence to this possibility.

The eastern portal of the railroad tunnel through Beckwourth Pass (STOP 2) exposes fluvial deposits and a gravel lag on granitic bedrock. The gravel lag contains some rounded volcanic clasts that must have been derived from west of the pass, because only granitic and metamorphic rocks are present in the contemporary drainage area (fig. 2-3). The high degree of rounding provides further evidence that these were Lake Beckwourth beach gravels. Rounded volcanic clasts are also sparsely scattered on the surface in the area around the pass. We have found rounded clasts slightly above the pass, indicating the spillover caused at least some downcutting.

Discussion/Speculations

Lacking an outlet, pluvial lakes of the Great Basin (e.g., Lake Lahontan) fluctuate in response to changes in climate. Lake Beckwourth, on the other hand, was likely more controlled by its outlet history, and may not have coincided in time with pluvial lakes of the Great Basin. Similar to Lake Tahoe, Sierra Valley receives considerably more precipitation than does most of the Great Basin, especially along the Sierran front on the southwest side of the valley. Lake Beckwourth likely had a more sustained life, existing during all but the most extreme dry periods.

Shoreline features around Sierra Valley occur at fairly consistent elevations, seemingly precluding large-scale vertical tectonic changes over the time since Lake Beckwourth existed. To the contrary, much of Mohawk Valley may have been relatively downdropped by as much as 60 m (200 ft) over this period of time. This may indicate that late Quaternary tectonic activity has been concentrated along the Mohawk Valley fault system.

Inferred history of Lake Beckwourth

1) Late Tertiary (Plio-Pleistocene?) faulting created structural basins (Sierra, Humbug, and Mohawk Valleys) that received enough runoff that they filled to their respective spillover points, with Sierra Valley spilling into Humbug Valley, Humbug Valley spilling into Mohawk Valley, and Mohawk Valley in turn spilling down the west slope of the Sierra Nevada;

2) Through a combination of incision of the Sierra Valley outlet and sedimentation in Humbug and Mohawk Valleys, the basins became interconnected by a narrow gorge;

3) During the Middle Pleistocene, the lake in Mohawk and Sierra Valleys stabilized at an elevation of about 1,585 m (5,200 ft) for a period long enough to form features that persist until today;

4) The level of Lake Beckwourth then rose -- probably due to some sort of damming mechanism (possibly by a landslide, or possibly by glaciers from the Lakes Basin area extending across Mohawk Valley) -- until it overtopped Beckwourth Pass (>1590 m), thus spilling into the Lahontan Basin and causing an exchange of aquatic species;

5) Some incision of Beckwourth Pass occurred, but the outlet at the west end of Mohawk Valley soon reestablished...this time flowing down Poplar Creek;

6) The Poplar Creek outlet incised to about 1,540 m (5,050 ft) and then stabilized. For an unknown period of time, Lake Beckwourth occupied its most recent stand, with its outlet buffered by a marsh in Humbug and Mohawk Valleys;

7) Headward erosion of the Feather River then chewed through more easily eroded material on the north side of Big Hill, establishing a new outlet that drained Mohawk Valley and resulted in the death of Lake Beckwourth.

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