E. Brooks

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SIERRA NEVADA FIELD TRIP

Geologic Transect of the Northern Sierra Nevada along the North Fork of the Yuba River

by

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A TRANSECT OF THE NORTHERN SIERRA ALONG THE NORTH WBA RIVER

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The northern Sierra Nevada contains some of the best preserved sequences of Paleozoic and Mesozoic sedimentary and volcanic rocks of island-arc affinity in the western U.S. Many questions concerning site(s) or location(s) of origin of these sequences with respect to continental North America are still unresolved, but published studies and studies still in progress are beginning to place constraints on tectonic environments, depositional settings, and sources of detritus of many of the sedimentary units, and nature and mode(s) of volcanism of the volcanic units.

This brief section aims only at introducing the principal units to be studied along the North Yuba River transect, and outlines their structural relations. Many details, and most of the broader questions concerning regional relations of these rocks, will be discussed on the field trip.

Along the field trip route following the North Yuba River, the northern Sierra can be subdivided into two principal terranes separated by a major serpentine-belt fault (see Fig. 1). The more westerly terrane, consisting of a vast, structurally complex collage of Upper Paleozoic and Mesozoic sedimentary and volcanic rocks and slices of ultramafic rocks will not be dealt with directly on this field trip, although we will drive through some of these rocks on Saturday morning before arriving at our first stop. This terrane probably contains scraps of island arcs and chaotic subduction complexes as young as early Mesozoic age. For descriptions of these rocks, see Hietanen (1973, 1976, 1981).

The dividing fault zone, generally called the Melones fault zone, is an important tectonic boundary, as it is marked by slices of Paleozoic ultramafic rocks and, locally, by slices of metamorphic rocks, some indicative of blueschist facies. Our first two stops will be within the Melones fault zone, where we will examine ultramafic rocks and blueschists (see Fig. 3). Although the details are far from clear, the rocks of the Melones fault zone (and portions

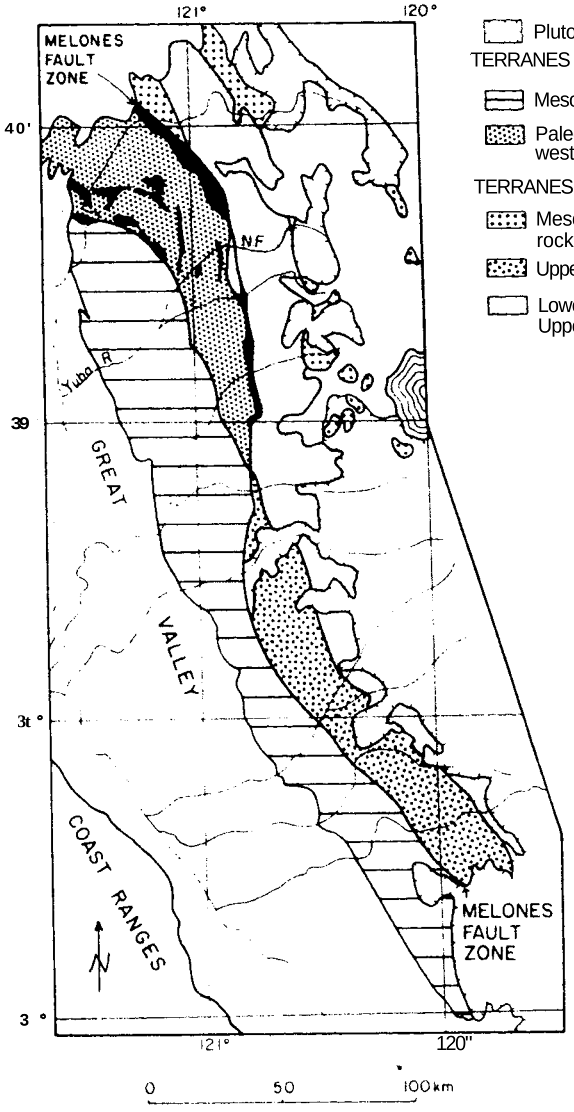


Figure 1 Tectonic sketch map of the northern and western Sierra Nevada showing the extent of the Melones fault zone and the region along the North Fork Yuba River discussed here. N.F.: North Fork Yuba River: unpatterned area along Melones fault is belt in which blueschist rocks occur.

from Schweickert and others, 1900

of the terrane to the west) probably represent part of an early Mesozoic subduction complex developed along or near what was then the western edge of North America. Rocks of a coeval early Mesozoic arc occur along the eastern flank of the Sierra Nevada and in western Nevada,

The eastern terrane of Paleozoic rocks has been labelled the "Plumas" terrane by Churkin and Eberlein (1977) and the "Northern Sierra" terrane by Blake and others (1982). The latter name will be used here.

The Northern Sierra terrane consists of a metasedimentary basement complex, known as the Shoo Fly Complex, which is unconformably overlain by Devonian and younger rocks that comprise two distinct Paleozoic island-arc sequences.

Shoo Fly Complex

Recent mapping by Schweickert in the North Yuba River drainage (Map 1B) indicates that the Shoo Fly consists of an imbricate stack of thrust sheets which were emplaced prior to the Late Devonian. These are outlined below, from lowest to uppermost.

Lang-Halsted Unit, lowest and westernmost (Fig. 2, Maps 1A and 1B), is the most areally extensive unit. It consists of polyphase deformed phyllite and quartzose sandstone with chert and rare marble. Earliest structures are pre-Late Devonian; second structures are probably Late Jurassic in age. Internal stratigraphy is unknown, but locally preserved sedimentary features and the overall lithic succession suggest the original depositional environment may have been continental rise and/or slope. The quartzose sandstones, although poorly sorted, imply continental derivation. Stops 3 and 4 are in the Lang-Halsted unit (see Map 1A).

Culbertson Lake allochthon, thrust over the Lang-Halsted unit (Fig. 2, Map 1B), consists of several stratigraphically intact units that correspond closely with rocks in this allochthon near Bowman Lake (Girty and Schweickert, in press). The lowest unit consists of greenstone and limestone of the Bullpen Lake sequence (Map 1B), which is depositionally overlain by a persistent chert

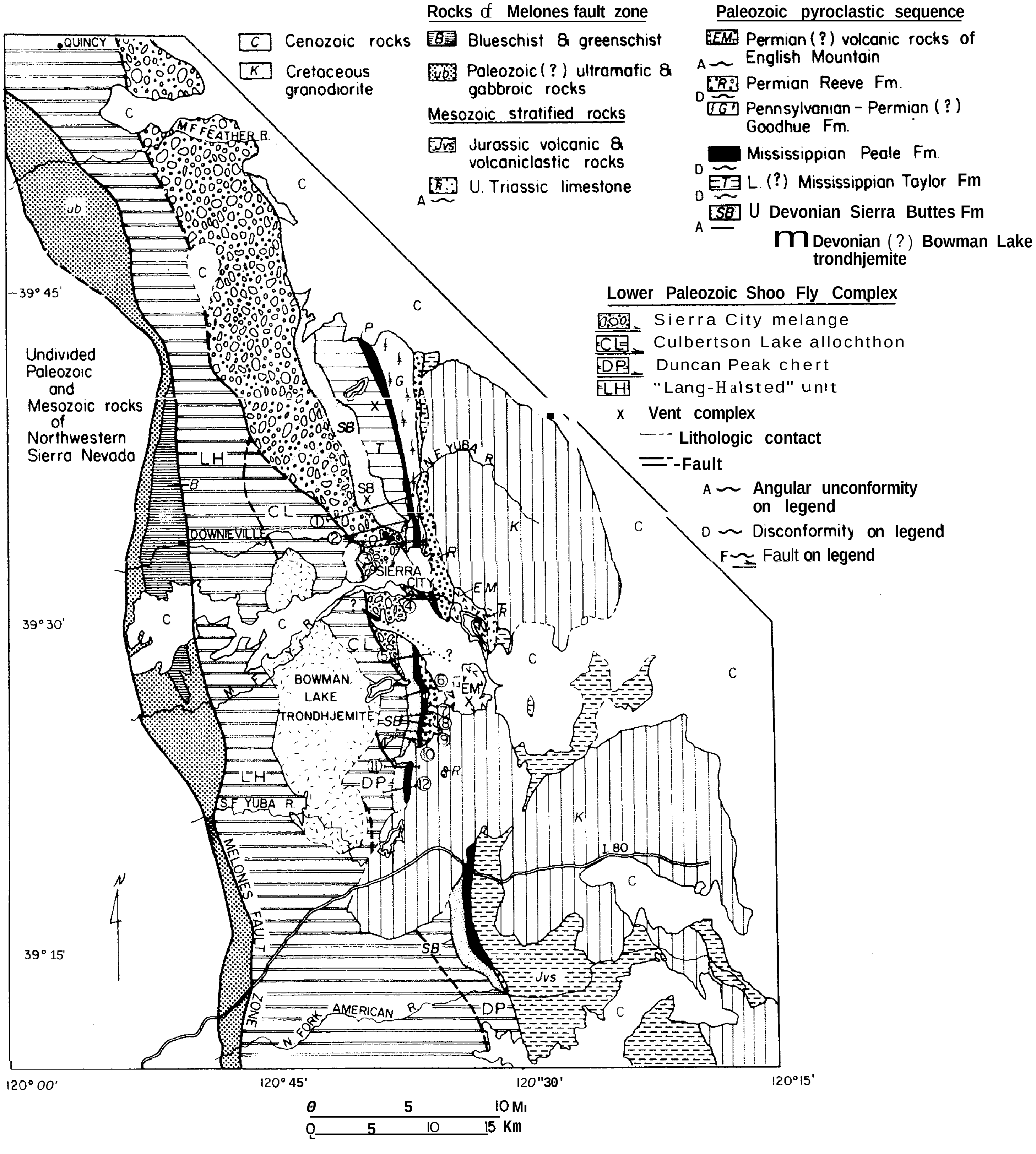


Figure 2. Generalized map of the Sierra Buttes-Bowman Lake region, modified from Schweickert (1981). Mapping by Schweickert, Hanson, Girty, and Bond, 1973-82. Area south of I-80 from Harwood (in press). Field trip stops will be along the North Yuba River in the vicinity of Downieville and Sierra City.

unit that is in turn overlain by a thick sandstone unit. This sandstone unit, part of the Poison Canyon Fm., is characterized by quartzose and feldspathic sandstones and slates of possible midfan depositional facies. The unit may approach 1 km in thickness. Another chert horizon separates this unit from a higher sandstone unit, the Red Hill Fm., which is characterized by quartzose sandstones and slates, again of probable midfan facies (Girty and Schweickert, in press). This unit also may be about 1 km thick. The Red Hill Fm. is overlain by a chert horizon that in turn is succeeded by an unnamed siltstone unit that may have a tuffaceous component. Unidentifiable radiolarians and sponge spicules occur in cherts in the Culbertson Lake allochthon.

Sierra City Melange is an extensive chaotic unit thrust over the Culbertson Lake allochthon (Fig. 2, Map 1B). It contains lenses of sheared serpentinite, gabbro, pillowed and massive basalt, ribbon chert, and small blocks of dolomite in a matrix of sheared slate, sandstone, and chert. Sandstones within the melange contain volcanic and chert fragments as framework grains in addition to quartz and feldspar. Stops 6 and 7 will be in rocks of the Sierra City melange.

The entire Shoo Fly structural stack was assembled and eroded prior to the deposition of rocks of the overlying Paleozoic volcanic sequence. The Shoo Fly can be interpreted as representing part of a pre-Devonian subduction complex (Sierra City melange) which has incorporated large slabs of sediment from continentally-derived deep-sea fans (Culbertson Lake allochthon) and which ultimately scraped up and incorporated part of a continental slope and rise assemblage as the subduction complex approached a continental margin.

Paleozoic arc sequence

The Paleozoic volcanic sequence consists of the following units, from oldest to youngest:

Grizzly Fm., 0 to about 300 m of coarse conglomerate, sandstone, and siliceous argillite of Late Devonian (Frasnian) age. Contains much Shoo Fly detritus and fills in relief on the basal unconformity. This unit does not crop out on the field trip route.

Sierra Buttes Fm., up to 1.5 km of dominantly rhyolitic to dacitic tuff, tuff-breccia, and ash flows, with persistent black phosphatic chert interbeds. Much of section is inflated by extensive hypabyssal intrusive complexes, consisting both of andesitic and rhyolitic to dacitic material (Map 1B). These intrusive masses invaded a thick section of water-rich sediments and developed spectacular pillow-hyaloclastic complexes (Hanson and Schweickert, unpub. data). Fossils near top and base indicate entire section formed during Frasnian and Famennian stages of Late Devonian. Rocks poorly exposed on field trip route, but discussed at Stops 8 and 10.

Taylor Fm., 0 to over 3 km of andesitic tuff-breccia, debris flows, tuffs, and pillow lavas. Poorly stratified. Does not extend south of Middle Yuba River but very thick near Gold Lake (Map 1B). Rocks of the Taylor Fm. will be examined on Sunday.

Peale Fm., about 100 m of rhythmic radiolarian chert which conformably overlies Taylor Fm. Signifies nearly total absence of volcanic activity over a long part of Carboniferous time. Has yielded fossils ranging from lower Mississippian to lower Pennsylvanian age (Harwood, in press). At Stop 9 we will examine roadcuts of Peale rocks.

Goodhue Greenstone, 0 to 1 km of andesitic and basaltic lava and breccia. Apparently overlies Peale conformably. First expression of late Paleozoic arc activity. No fossils. Not exposed on field trip route, but visible in cliffs east of Hwy. 49.

Reeve Fm., 70 to 1000 m of andesitic breccia, tuffs, and flows. Contains distinctive intrusions of plagioclase megacryst porphyry. Conformably overlies Goodhue and disconformably overlies Peale south of North Yuba River. Lower Permian fossils. Not exposed on field trip route.

Unnamed tuffs, 1 to 3 km of fine, tuffaceous siltstone and sandstone with interbeds of coarse volcanic breccia and debris flows. Presumed to be Fermian because overlain by Upper Triassic (?) limestone east of Bowman Lake.

Notes on Structure

All units, from Shoo Fly to Permian (and even Jurassic) volcanic rocks, contain a northwest-trending slaty cleavage and associated minor folds which developed during the Late Jurassic Nevadan orogeny. They also contain late-phase Nevadan folds and cleavages that typically trend about N10-40E.

The Shoo Fly, however, contains abundant evidence of pre-Late Devonian deformation. Thrust faults predate the late Devonian unconformity. Folds and early cleavages in Lang-Halsted unit predate the Devonian (?) Bowman Lake batholith. The Culbertson Lake allochthon rarely contains penetrative early cleavages, but it **does** contain pre-Devonian folds. Chaotic mixing of the Sierra City melange predates the late Devonian unconformity.

References Cited

Blake, M.C., and others, 1982, Preliminary tectonostratigraphic terrane map of California: U.S. Geol. Survey Open-File Report 82-593.

Churkin, M., and Eberlein, G.D., 1977, Ancient borderland terranes of the North American Cordillera: correlation and microplate tectonics: Geol. Soc. America Bull., v. 88, p. 769-786.

Girty, G.H., and Schweickert, R.A., in press, The Culbertson Lake allochthon, a newly identified structural unit within the Shoo Fly Complex, California: Geol. Soc. America Bull. (in press).

Harwood, D.S., in press, Stratigraphy of Upper Paleozoic volcanic rocks and regional unconformities in part of the Northern Sierra terrane, California: Geol. Soc. America Bull. (in press).

Hietanen, A., 1973, Geology of the Pulga and Bucks Lake quadrangles, Butte and Plumas Counties, California: U.S. Geol. Survey Prof. Paper 731, 66 p.

Hietanen, A., 1976, Metamorphism and plutonism around the Middle and South Forks of the Feather River, California: U.S. Geol. Survey Prof. Paper 920, 30 p.

Hietanen, A., 1981, Petrologic and structural studies in the northwestern Sierra Nevada, California: U.S. Geol. Survey Prof. Paper 1226.

Schweickert, R.A., and others, 1980, Lawsonite blueschist in the northern Sierra Nevada, California: Geology, v. 8, p. 27-31.

Schweickert, R.A., 1981, Tectonic evolution of the Sierra Nevada Range, in Ernst, W.G., ed., The geotectonic development of California: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., p. 87-131.

SATURDAY, OCTOBER 9

A TRANSECT ALONG THE NORTH YUBA RIVER

Previous Work along this Traverse

Cebull, S.E., 1972, Sense of displacement along Foothills fault system: New evidence from the Melones fault zone, western Sierra Nevada, California: Geol. Soc. America Bull., v. 83, p. 1185-1190.

Schweickert, R.A., 1976, Lawsonite blueschist within the Melones fault zone, northern Sierra Nevada, California: Geol. Soc. America Abstracts with Programs, v. 8, p. 409.

D'Allura, J.A., Moores, E.M., and Robinson, L., 1977, Paleozoic rocks of the northern Sierra Nevada: their structural and paleogeographic implications, in Stewart, J.H., and others, eds., Paleozoic paleogeography of the western United States: Society of Economic Paleontologists and Mineralogists Pacific Coast Paleogeography Symposium 1, p. 395-408.

Durrell, C., and D'Allura, J.A., 1977, Upper Paleozoic section in eastern Plumas and Sierra Counties, northern Sierra Nevada, California: Geol. Soc. America Bull., v. 88, p. 844-852.

Cebull, S.E., and Russell, L.R., 1979, Role of the Melones fault zone in the structural chronology of the North Yuba River area, western Sierra Nevada, California: Geol. Soc. America Bull., Part I, v. 90, p. 225-227; Part II, v. 90, p. 528-544.

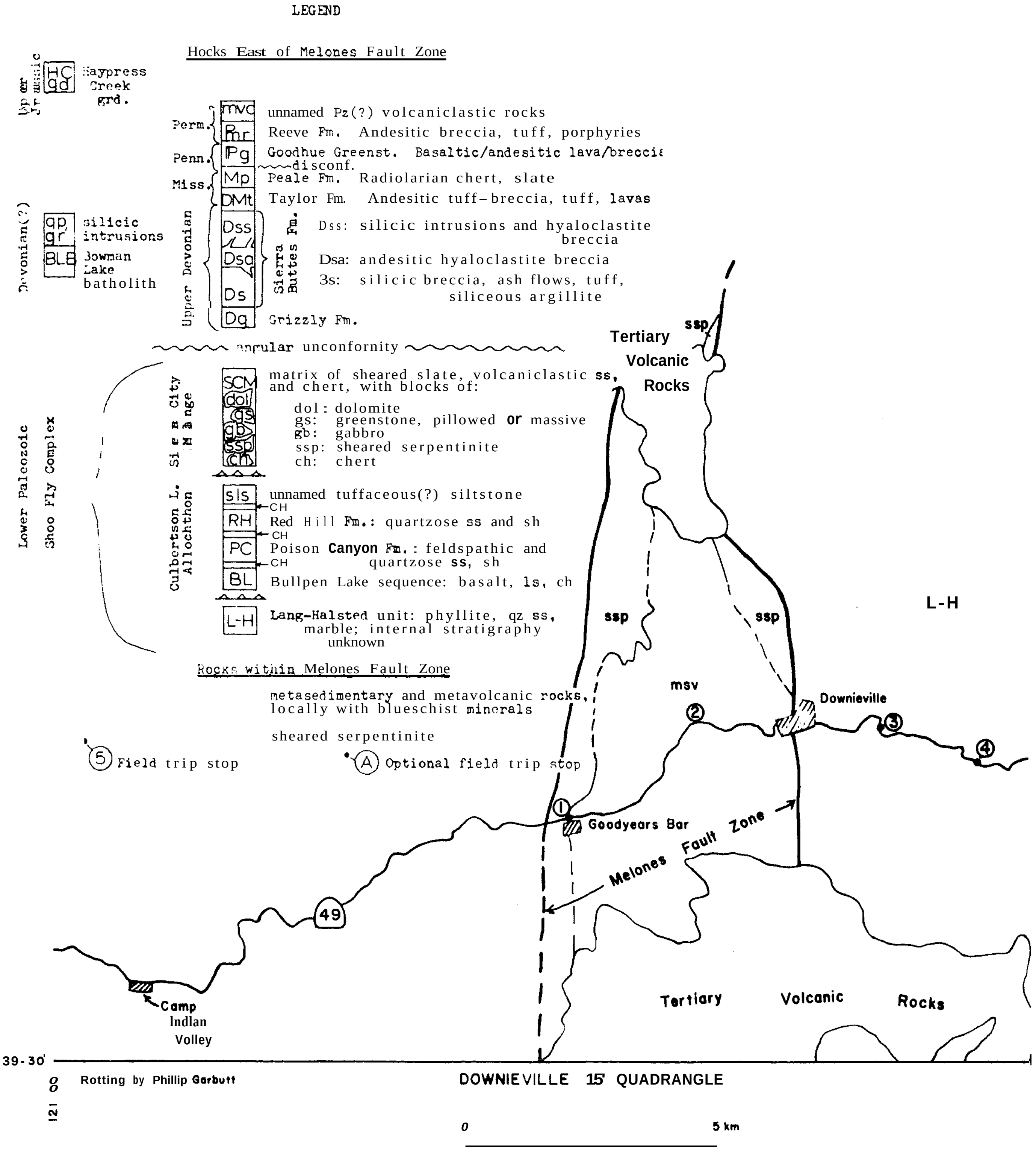
Schweickert, R.A., Armstrong, R.L., and Harakal, J.E., 1980, Lawsonite blueschist in the northern Sierra Nevada, California: Geology, v. 8, p. 27-31.

Schweickert, R.A., 1981, Tectonic evolution of the Sierra Nevada Range, in Ernst, W.G., ed., The geotectonic development of California: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., p. 87-131.

Hietanen, A., 1981, Geology west of the Melones fault between the Feather and North Yuba Rivers, California: U.S. Geol. Survey Prof. Paper 12268, p. A1-A35.

Road Log (Refer to Fig. 3, Maps 1A and 1B)

CUMULATIVE MILEAGE	
0.0	Calif. Hwy. 49 at U.S.F.S. Indian Valley campground, near the SW corner of the Downieville 15' quadrangle. Head eastward at 8:30 AM. For the first 7.0 miles, until our first stop, we traverse rocks mapped and described by Hietanen (1981, **U.S.G.S.** Prof. Paper 1226A). The campground is located within a small quartz diorite pluton of probable Jurassic or Cretaceous age.
0.7	First roadcuts of Triassic (?) phyllite and metachert unit (**Trms** of Hietanen, 1981), invaded by dikes of quartz diorite. Rocks here are mainly black siliceous argillite.
1.9	At sharp bend in road, we pass through a tongue of Franklin Canyon Fm., Permian (?) to Triassic (?) meta-andesite. We quickly pass back into **Trms** unit.
2.5	Convict Flat picnic area.
3.7	Pass through another tongue of Franklin Canyon Fm.
4.7-5.0	We've crossed the Dogwood Peak fault, and are back in more Trms. At mile 5.0, the rocks are chaotic black argillite, containing slabs and pieces of chert beds. The rocks could be called "diamictite".
5.4	At turnoff to Ramshorn campground, we cross Ramshorn fault zone, marked in canyon north of Hwy. 49 by excellent exposures of sheared serpentinite with folded shear fabrics, East of Ramshorn fault are greenschists inferred by Hietanen to be of late Paleozoic age. These are well exposed at mile 6.3. Greenschists are succeed-to east by phyllite, also of supposed late Paleozoic age. Good roadcuts occur at mile 6.8 on left. This unit extends to Goodyear Bar turnoff, our first stop.



LEGEND

Rocks East of Melones Fault Zone

Upper Jurassic: HC gd — Haypress Creek grd.

Devonian(?): gp gr — silicic intrusions; BLB — Bowman Lake batholith

Perm.: mvc — unnamed Pz(?) volcaniclastic rocks

Perm.: Pmr — Reeve Fm. Andesitic breccia, tuff, porphyries

Penn.: Pg — Goodhue Greenst. Basaltic/andesitic lava/breccia

disconf.

Miss.: Mp — Peale Fm. Radiolarian chert, slate

DMt — Taylor Fm. Andesitic tuff-breccia, tuff, lavas

Upper Devonian, Sierra Buttes Fm.:

- Dss: silicic intrusions and hyaloclastite breccia
- Dsa: andesitic hyaloclastite breccia
- Ds: silicic breccia, ash flows, tuff, siliceous argillite

Dg — Grizzly Fm.

angular unconformity

Lower Paleozoic, Shoo Fly Complex:

Sierra City Mélange: SCM — matrix of sheared slate, volcaniclastic ss, and chert, with blocks of:

- dol: dolomite
- gs: greenstone, pillowed or massive
- gb: gabbro
- ssp: sheared serpentinite
- ch: chert

Culbertson L. Allochthon:

- sls — unnamed tuffaceous(?) siltstone
- CH
- RH — Red Hill Fm.: quartzose ss and sh
- CH
- PC — Poison Canyon Fm.: feldspathic and quartzose ss, sh
- CH
- BL — Bullpen Lake sequence: basalt, ls, ch

L-H — Lang-Halsted unit: phyllite, qz ss, marble; internal stratigraphy unknown

Rocks within Melones Fault Zone

metasedimentary and metavolcanic rocks, locally with blueschist minerals

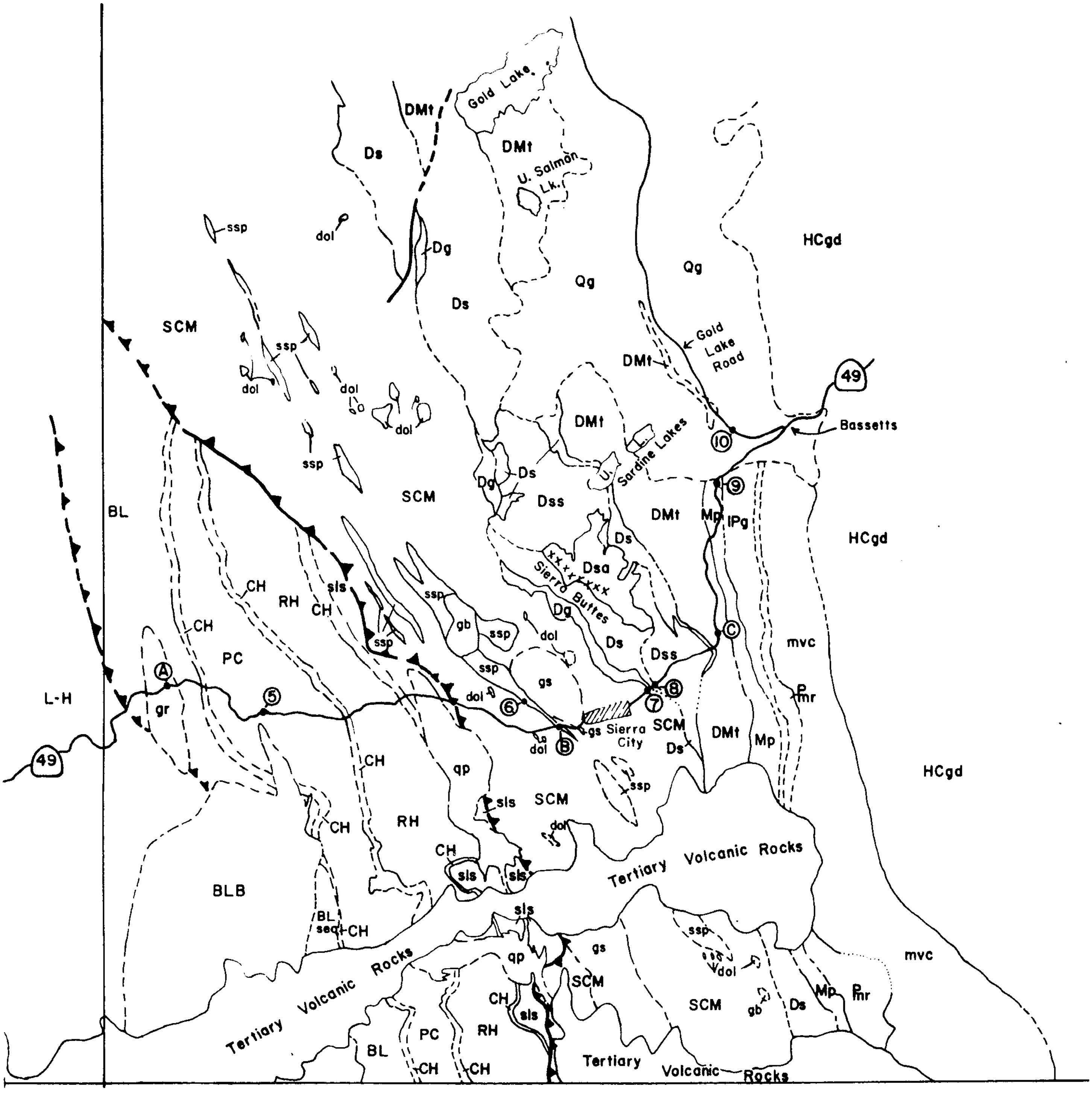
sheared serpentinite

⑤ Field trip stop

Ⓐ Optional field trip stop

Mapping after Hietanen, 1981

MAP 1A



Drafting by Phillip Garbutt

SIERRA CITY 15' QUADRANGLE

0 5 km

Mapping by Schweickert and Hanson. unpub.

MAP 1B

7.1' STOP 1 (Fig. 3, Map 1A)

The trip officially begins here at 9 AM. The long roadcuts provide excellent examples of sheared serpentiaite that marks the western edge of the Melones fault zone (here called the Goodyears Creek fault by Hietanen, 1981). In fact, these rocks typify the structural condition of ultramafic rocks in many fault zones within the Sierra Nevada metamorphic belt. Much of the outcrop is characterized by a nearly penetrative shear-fracture fabric which is statistically subparallel with the walls of the fault zone. In many cases, the shear fabric is folded, and axial surfaces of minor folds are subparallel to the shear foliation. Possibly the shear fabric and folds are all related to a single, protracted period of shear strain.

Occasionally, the shear fabric diverges around polished residual blocks of serpentinized peridotite, and these provide evidence that dunite was the protolith of the ultramafic rocks exposed here.

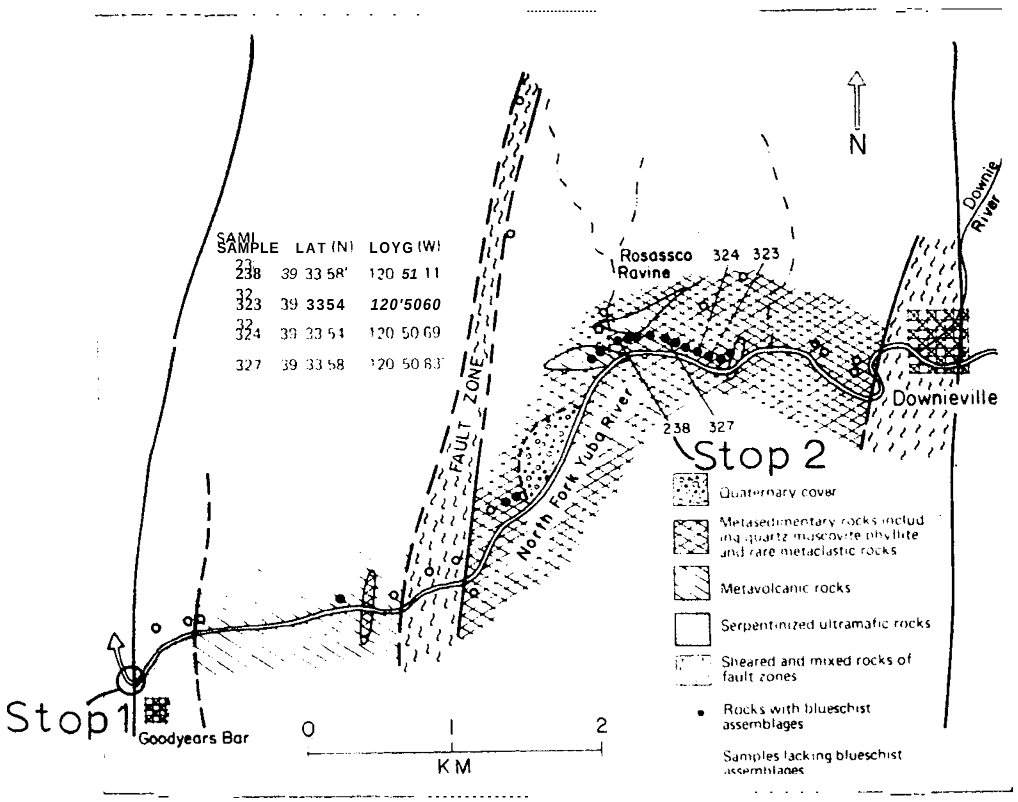
Walking east, note a slice of black, pyritic, slaty argillite within the sheared serpentinite. The rocks in this slice most closely resemble black argillite west of Goodyears Creek; this may thus be a slice of the footwall of the fault zone.

Return to cars. Driving eastward from here, we will begin to traverse metasedimentary and metavolcanic rocks, locally with blueschist assemblages, described by Schweickert and others (1980) and Hietanen (1981); see Figure 3.

7.6 First roadcuts of metasedimentary rocks within the fault zone. These are enclosed in greenstones that only rarely contain blueschist minerals.

7.8–7.9 Metabasaltic breccia, bounded on east by an internal fault zone marked by sheared serpentinite.

7.9–9.3 Chiefly metasedimentary rocks are exposed along here, with sparse lenses of metabasaltic breccia. The metasediments are mainly quartz-muscovite phyllite, with occasional blue amphibole and lawsonite, and probably represent deformed and metamorphosed chert and shale.



SAMPLE	LAT (N)	LOYG (W)
238	39 33 58'	120 51 11
323	39 3354	120'5060
324	39 33 54	120 50 69
327	39 33 58	120 50 83'

Figure 3. Map of Melones fault zone in the vicinity of the North Fork Yuba River. Numbers designate dated samples (see Table I). Most samples were taken from roadcuts along State Highway 49.

from **Schweickert** and others, 1900

9.3 Entering a large mass of metabasaltic breccia in which we will make our second stop,

9.4 STOP 2 (Fig. 3, Map 1A)

Rosassco Ravine. Pull off on right side of road, if possible. PLEASE BE CAREFUL OF TRAFFIC AT ALL TIMES! This is locality 238 of Schweickert and others (1980). Walk eastward along roadcuts to observe basaltic breccia and interlayered (and infolded) quartz-muscovite phyllite (metachert). Also note bizarre disharmonic folding of layering in phyllite. There are at least two visible generations of isoclinal folds and two or more generations of later folds in these rocks. As noted by Schweickert and others (1980), deformation of these rocks was strongly inhomogeneous; only the quartz-muscovite phyllite shows evidence of all phases of deformation. In contrast, the basaltic breccia scarcely shows any penetrative fabric whatsoever, Yet the two rock types are clearly infolded, especially in second-generation folds.

Relationships between metamorphic minerals and structural fabrics: (See Schweickert and others, 1980, p. 29-30.) Petrographic and structural studies of the metamorphic rocks indicate that crystallization of blueschist minerals occurred before a "main phase" isoclinal folding event (here called D_2) and possibly accompanied an earlier deformational event (perhaps represented by earlier visible isoclines in outcrop). Most rocks have suffered retrograde metamorphism and now contain chlorite. Typical prograde mineral assemblages originally were as follows:

quartz-muscovite phyllite: quartz±muscovite±albite±sphene±glaucophane±lawsonite.

metavolcanic rocks:

Basaltic lava and lava fragments: albite+epidote+leucoxene.

Fracture fillings and matrix between fragments: crossite+lawsonite+prehnite.

Hietanen (1981) reported the presence of pumpellyite in addition to the above minerals,

rare metaclastic rocks: quartz+glaucophane+lawsonite+albite +muscovite.
The "main phase" isoclinal folding resulted in bent, broken, and rotated grains of muscovite, chlorite, blue amphibole, and lawsonite. There appears to have been very little growth of minerals during D_2. Quartz+albite±calcite veinlets formed parallel to S_2 and are crumpled by later folds (F_3).

Later folds crenulate or crumple S_2 layering and are extremely disharmonic. Stilpnomelane generally grew parallel to S_3 crenulation cleavages. Late albite porphyroblasts locally grew across all preexisting structures (S_2, veins, S_3).

K-Ar geochronology

In view of the complex history of post-metamorphic deformation, the K-Ar ages reported by Schweickert and others (1980) can only be considered minimum ages for metamorphism. These results, both on muscovite concentrates and on whole-rock samples, suggest that the blueschist metamorphic event was pre-174 m.y.a. (mid Jurassic) and possibly pre-190 m.y.a. Later deformations like D_3, etc. probably were post-174 m.y.a., and have been related to the Late Jurassic Nevadan orogeny,

Return to cars and proceed eastward,

9.5 Roadcuts of highly contorted quartz-muscovite phyllite.

10.0 Another mass of basaltic breccia on the left.

10.1 Coyoteville.

10.6 Good exposure of quartz-muscovite phyllite at sharp lefthand bend in road. Good view of Downieville ahead, at the confluence of the Downie and North Yuba Rivers.

10.7 Columnar-jointed Tertiary andesite intrusion on the left.

10.9 Downieville city limit. Outcrops of melange-like metasedimentary rocks in roadcut on left. Downieville is currently the center of a vigorous gold-mining industry, with considerable placer mining along the Downie River and its tributaries north of town, and along the North Yuba between here and Sierra City, 12 miles east.

11.0 At intersection in the middle of town, turn right and follow Hwy. 49 across the Downie River (CAUTION: ONE-LANE BRIDGE!). We are now driving approximately on the fault that marks the east edge of the Melones fault zone, according to Hietanen (1981). From here eastward for the next 15.6 miles we will be traversing the lower Paleozoic Shoo Fly Complex (Maps 1A and 1B), which makes up the metasedimentary basement beneath two Paleozoic volcanic arc sequences, one Late Devonian to Mississippian, the other Late Pennsylvanian (?) to Permian,

11.1 First roadcuts of Shoo Fly phyllite.

12.2 **STOP 3** (Map 1A)

On south-trending stretch of road, CAREFULLY PULL OFF and park on left (east) side of road, Ahead is a blind curve, so please LISTEN AND WATCH FOR TRAFFIC before attempting to cross highway. This stop is a good place to develop a feeling for structure in the western, structurally lowest part of the Shoo Fly Complex at this latitude (Lang-Halsted unit,). Walk down to river and examine polished outcrops next to river. The obvious, tight, north-plunging folds deform lithologic layering in siliceous phyllite. The folds have s-asymmetry when viewed down-plunge. Close inspection reveals that an early cleavage parallel to layering is also folded by the asymmetric folds. In at least one location, early isoclinal fold closures occur within the layering, and thus possess axial surfaces that are folded by the asymmetric folds, These relations indicate that the lithologic layering is really a structural surface which has formed as a result of transposition of bedding into parallelism with axial surfaces of early isoclines. The "early" cleavage is apparently axial planar to the early isoclines. Because of the two phases of intense folding in these rocks, it has not been possible to determine a stratigraphic "sequence" or facing direction in this part of the Shoo Fly. Instead, the phyllite rocks of this part of the Shoo Fly are characterized by prominent phyllitic cleavage which may in fact be S_1xS_2, and, occasionally, by lithologic layering, which shows little continuity or predictability along strike.

Ages of structures are not known with certainty here. However, detailed structural mapping from here to more easterly, and less intensely deformed, regions, suggests that the D_2 structures are "Nevadan" (Late Jurassic), and the earlier isoclines may be pre-Devonian. This evidence will be discussed more fully at optional stop A (mile 17.4).

13.8 STOP 4 (Map 1A)

Pull off on right, just before turnoff to Sierra Shangrila. Walk down to stream-polished rock bench next to river. This stop provides a good example of poorly-sorted quartzose sandstone which occurs in the Lang-Halsted unit. Commonly, quartz grains have a bluish cast. Note transposed lithologic layering in thick sandstone "beds" with thin black slaty or phyllitic partings. Many isoclinal fold closures occur in these thin partings between sandstone layers. Layering here appears to be a composite of S_0, S_1, and S_2. Locally, a spaced cleavage oriented 015, 90 refracts through sandstone layers; this may be a "late Nevadan" structure. S_1 (probably pre-Late Devonian) and S_2 (probably main-phase Nevadan cleavage) are subparallel here. Note how quartz-filled gashes are confined to sandstone and do not extend into more ductile slaty layers.

Continue eastward on Hwy. 49.

16.1 Enter Sierra City 15' quadrangle.

16.8 Cross a thrust fault along which rocks of Culbertson Lake allochthon have been thrust upon the Lang-Halsted unit. The lowest part of the Culbertson Lake allochthon here consists of marble and greenschist of the Bullpen Lake sequence. This unit has been defined principally from exposures south of Bowman Lake, about 11 miles southeast of here (Girty and Schweickert, in press).

16.9 Union Flat U.S.F.S. campground.

17.1 Outcrops of metatuff and marble of Bullpen Lake sequence.

17.2 Outcrops of an isolated mass of Devonian (?) trondhjemite and leucogranite, similar (and probably related) to the Devonian (?) Bowman Lake batholith, exposed on the steep ridge 1 mile southeast.

17.4 <u>OPTIONAL STOP A</u> (Map 1B)

If time and interest permit, it is possible to pull off here to examine leucogranite of this small satellitic body which seems related to the Bowman Lake batholith. This small body and the much larger batholith intrude the thrust which separates the Culbertson Lake allochthon from the Lang-Halsted unit (Map 1B). Petrographic and field data indicate that the Bowman Lake batholith and similar satellitic bodies may be comagmatic in part with the Upper Devonian Sierra Buttes Fm., implying the batholith and its satellites are also Devonian. Earliest structures in the Shoo Fly western unit predate the batholith; probable Nevadan structures are developed within the intrusion. This provides important age constraints on ages of structures in the western part of the Shoo Fly.

17.6 More outcrops of greenstone and marble of Bullpen Lake sequence.

18.1 We've now crosses a thin chert horizon that separates the Bullpen Lake sequence from overlying quartz-rich sandstone and slate of the Bowman Lake sequence. This is the lowest unit in the Bowman Lake sequence, called the Poison Canyon Fm., and consists of feldspathic and quartzose sandstone and slate (Girty and Schweickert, in press). It is named for exposures near Bowman Lake, 11 miles south.

18.3 Ladies Canyon Creek. This canyon was reportedly so named because several brothels were located in the canyon in the early days, 19.0 **STOP 5** (Map 1B)

Park carefully on right. Between Ladies Canyon and here we have crossed several tight "Nevadan" folds that deform bedding and an early, bedding-parallel cleavage that is rather faint. Bedding/cleavage relations are well illustrated here. Bedding in 2 to 6 cm thick sandstone beds is oriented about 320, 75NE. A slaty cleavage oriented 320, 85SW refracts markedly through the sandstone beds. This is the characteristic main-phase Nevada cleavage.

The sandstone beds are highly cross-laminated, with tops to the northeast. In contrast with the Lang-Halsted unit, rocks in the Culbertson Lake allochthon still possess relict sedimentary structures. These thinly bedded, cross-laminated sandstones may conceivably represent overbank deposits developed marginal to a turbidite fan channel.

20.3 Looking up canyon, we have a good view of the southwest face of the Sierra Buttes. These peaks are underlain by metavolcanic rocks of the Upper Devonian Sierra Buttes Formation, which, together with the underlying Grizzly Formation, unconformably overlie the rocks of the Shoo Fly Complex.

20.8 Pass through the outcrops of a persistent chert unit that caps the Bowman Lake sequence and is overlain by unnamed tuffaceous siltstone.

21.2 Here, we pass through a mass of intrusive quartz porphyry that is part of a major intrusive complex related to the Sierra Buttes Fm. and the Bowman Lake batholith. The complex continues south through Keystone Ravine, across the Middle Yuba River, to the vicinity of Bowman Lake, a distance of 9 miles.

21.6 Loganville. These buildings lie on the approximate trace of the thrust along which the overlying rocks of the Sierra City melange were thrust over rocks of the Culbertson Lake allochthon. The melange forms the highest structural unit within the Shoo Fly Complex at this latitude, and extends from Bowman Lake, 8 miles south, to Lake Almanor, 70 miles north of here.

23.0 OPTIONAL STOP B

Lens of serpentinite-matrix melange containing blocks of diabase and gabbro, 0.1 mi. west of Sierra City limit.

23.6 Turn left at white building ("Sierra-Plumas Realty"), ½ block east of Post Office. Proceed uphill on paved street.

23.7 Bear left up paved road to garbage dump.

24.8 STOP 6

Sierra City garbage dump. From this vantage point, we can view several key features of the Sierra City melange. The blocky knob on the ridge N30W from here is a 1 km-across tectonic block of metagabbro enclosed in sheared serpentinite. The rocky, brushy hill to the northeast is a tectonic block of massive greenstone, about 1.5 km across. We can also see the approximate basal contact of the Grizzly Fm. where it rests on the melange on the highest ridge to the north. Return to Hwy. 49 in Sierra City.

26.0 Continue east on Hwy. 49.

26.5 Junction of road to Wild Plum U.S.F.S. campground. Continue east 0.1 mile.

26.6 STOP 7

This stop is very near the (unexposed) contact with Grizzly Fm. above; rocks here are typical chaotic sandstone-melange or broken formation. Sandstones in this unit typically contain, in addition to quartz and feldspar, appreciable chert and volcanic rock fragments (Girty and Schweickert, unpublished data), suggesting derivation from arc and/or uplifted subduction complex.

26.7 Outcrops of intrusive felsite and quartz porphyry of Sierra Buttes Fm., which cut out the Grizzly Fm. here.

26.8 STOP 8

Basal part of Sierra Buttes Fm. Cleaved black phosphatic siliceous argillite is intruded by subvertical diabase dikes. These rocks are overlain by silicic ash-flow tuff and tuff-breccia beds up to *3* m thick. Some contain collapsed pumice fragments.

26.9 Road to Kentucky Mine on left.

27.1 Intrusive quartz porphyry in roadcuts, part of a large hypabyssal complex within Sierra Buttes Formation.

27.4 Cross Pacific Crest Trail.

27.6 Outcrops of andesitic breccia in lower part of Taylor Fm. Bare patches in middle of slope ahead (to east) are underlain by rhythmically bedded cherts of the Mississippian to Lower Pennsylvanian Peale Fm. The Upper Devonian to Lower Mississippian Taylor Fm. here is about 1300 ft. thick between the Sierra Buttes and the Peale.

27.9 **OPTIONAL STOP C**

Roadcuts of unstratified andesitic tuff-breccia of Taylor Fm. Overlying Peale Fm. again underlies bare slopes to east. We are now heading about parallel to the strike. The Taylor comprises a vast thickness, in some places possibly over 10,000 feet, of andesitic lava and breccia (Durrell and D'Allura, 1977). These rocks are fairly typical of the Taylor. We will spend considerable time tomorrow looking at Taylor also.

29.1 Lavezzola Spring. Bold outcrops above brushy slopes across river are pillow lava of Goodhue Greenstone, which overlies the Peale.

29.2 Outcrops of Peale cherts in roadcuts on left.

29.5 Bridge across Salmon Creek. *Our* next stop will be to view roadcuts in Peale Fm. just north of the bridge, but it will be necessary to drive past the outcrop, park, and walk back.

29.7 Outcrop of Peale to be visited at stop 9.

29.8 **STOP 9**

Pull off on dirt road to right and walk back about 0.1 mi. to outcrop. This is an excellent exposure of typical white to light green ribbon chert of Mississippian to lower Pennsylvanian Peale Formation. This unit signifies a major hiatus in volcanic activity, and separates two distinct arc sequences: an older one consisting of the Upper Devonian Grizzly and Sierra Buttes Fms. and the Upper Devonian–Lower Mississippian Taylor Fm., and a younger arc sequence consisting of the Pennsylvanian (?) to Permian Goodhue Greenstone, the Lower Permian Reeve Fm., and overlying, unnamed Permian (?) volcaniclastic rocks. The asymmetric folds with NE–striking axial surfaces are late–phase Nevadan folds; main–phase Nevadan folds can be made out in part of the outcrop as tight, subisoclinal closures. Both fold sets occur in the Lower Jurassic Sailor Canyon Fm. 9 mi. southeast, and are cut by the 150 m.y. Haypress Creek granodiorite to the east (Map 1B), dating both phases as late Jurassic (Nevadan). Walk back to cars. Continue east on Hwy. 49.

30.9 Turn left on Gold Lake Road at Bassetts Station.

31.6 **STOP 10**

Pull off on left side of road. Good view of east face of Sierra Buttes. Here we will point out salient features of the Sierra Buttes and Taylor Formations, Also note superposition of a younger lateral moraine, related to a glacier that flowed out of Sardine Lakes, upon south–trending lateral moraine developed by an older glacier that flowed down Salmon Creek. To south, across the Yuba River, we again see dark cliffs formed by the Goodhue Greenstone.

32.1 Outcrops of Taylor meta–andesite.

32.3 Turn left across Salmon Creek toward Sardine Lake.

32.8 Turn left into Sardine Lake U.S.F.S. campground, where we will spend the night.

SUNDAY, OCTOBER 10

CIRCUIT OF UPPER SALMON AND HORSE LAKES, GOLD LAKE 7½' QUAD.

MILE 0.0 - Leave Sardine Lake Campground, turn right (east) on Sardine Lake Road

MILE 0.5 - Turn left (north) toward Gold Lake on Gold Lake Road

MILE 3.2 - Turn left (west) on Salmon Lake Road, drive across several recessional moraines associated with the most recent post-Sangamon advance of the Salmon Creek Canyon Glacier (Mathieson, 1981)

MILE 4.2 - Park at Salmon Lake trailhead

Walk south on a narrow, rough fisherman's path along the east side of Upper Salmon Lake (refer to Map 2 for route of walking tour). Note glacial striae trending S50E at the lake outlet; striae are developed on plagioclase-phyric, pumice-rich lapilli-tuff* of the Taylor Formation.

Continue southwesterly around the south end of Upper Salmon Lake; where the path becomes tangent to the overhead powerline, note that the Taylor lapilli-tuff underfoot contains widely scattered blocks, some amygdaloidal (quartz and chlorite amygdules). Similar lapilli-tuff and tuff-breccia underlie the knob you have just passed on your left (to the south); at least 95 m of such rocks are exposed there, without obvious depositional break. How did these materials originate, and how did they accumulate in such great thicknesses?

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* I use the classification of R.V. Fisher (1966) for mixture terms and grade size limits (ash < 2 mm, lapilli 2-64 mm, blocks > 64 mm).

Leave the path and angle southwestward uphill to a clinopyroxene- and plagioclase-phyric dike* that trends N80W. Walk westerly along the dike until it intersects pillow lava present near the base of the Taylor Formation.

STOP 1 (See Map 2)

These discrete, unconnected, ellipsoidal pillows are embedded in relatively voluminous tuffaceous matrix. The small plagioclase glomerocrysts are characteristic of Taylor pillow lavas, which were originally basalts and basaltic andesites**. Concentrations of immobile trace elements show that these lavas belong to the tholeiitic rock association of island arcs (Brooks and Coles, 1980).

Note the zoned margins of pillows; the reddening is due to outward increase in the amount of metamorphic chlorite or actinolite, and the pale rim is epidote-rich. Occasionally, an outermost chlorite-rich rim is preserved. Also note the occasional broken pillow.

Walk west to Stop 2 (see Map 2).

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* The relict mode of a chemically analysed sample of this dike is: matrix, 70%; plagioclase, 27%; clinopyroxene, 3%. The sample, however, now consists (except for a little relict clinopyroxene) of the greenschist-facies assemblage epidote+white mica+chlorite+actinolite+quartz+sphene. The rock is apparently a metabasalt (SiO_2 = 49.5%) but has an unusually high Al_2O_3 content (24.0%) (other oxide contents are: CaO, 8.0%; MgO, 4.0%; FeO*, 8.8%; Na_2O, 1.5%; K_2O, 1.9%; TiO_2, 0.6%). Such dikes were formerly thought to feed lavas stratigraphically higher in the Taylor Formation, but details of the trace-element chemistry do not make such correlations easy.

** A chemically analysed sample collected nearby, which represents the core of a pillow, originally had 12.5% plagioclase glomerocrysts and 0.5% pyroxene phenocrysts(?). It now consists of albite +quartz+epidote+chlorite+calcite+white mica+pyrite. The rock was evidently originally a basaltic andesite, and the oxide abundances are: SiO_2, 55.0%; Al_2O_3, 20.3%; CaO, 3.9%; MgO, 4.1%; FeO*, 9.1%; Na_2O, 4.2%; K_2O, n.d.; TiO_2, 0.4%.

STOP 2

Taylor pillow lava is here overlain by bedded (N10W, 30E) tuffs (the finest grades weather white), which are in turn surmounted by lapilli-tuff containing pillow fragments and china-white lumps of pumice (look for tiny round quartz amygdules with the hand lens). The Taylor pillowed flows have flat bases, steep flanks, and highly irregular upper surfaces (Brooks and Garbutt, 1972). The vitric-lithic tuffs were deposited contemporaneously with the pillows, thereby comprising much of their matrixes. When pillows were not being generated, tuffs with tabular stratification continued to be deposited, from turbidity currents (evidence for this depositional mechanism will be demonstrated at Stop 3). The interbedded lapilli-tuffs and tuff-breccias containing pillow fragments and pumice lapilli ("broken-pillow breccias") are interpreted as debris-flow deposits; debris flows evidently were initiated by slumping of the steep flanks of pillowed flows.

Noteworthy in this outcrop are: 1) the differential compaction of tuff where it overlies large pillows (the facing direction is everywhere easterly); 2) pillows broken in situ and veined by tuff; 3) the pinching out of the bedded tuff sequence against the pillow lava; 4) trace fossils in the bedded tuffs; 5) channeling in bedded tuff immediately beneath the debris flow; and 6) pillow fragments in the debris flow, some with quartz amygdules elongated perpendicular to pillow margins, some with pale, epidote-rich rims.

A slab lying on the ground nearby also shows a fossil debris flow, but it is directly in contact with pillow lava.

Walk northeasterly downhill to Stop 3.

STOP 3

Thinly stratified tuffs are here characterized by A-B-C Bouma sequences, and are accordingly thought to be tuffaceous turbidites. The coarsest, "massive" A division of a turbidite bed is followed upward by the plane-parallel-laminated B division, which is in turn succeeded by the finest (white-weathered), rippled C division. Crests of ripples are commonly truncated at the base of the next higher turbidite. Trace fossils are again found, in the C divisions of turbidites.

Interbedded (N20W, 25NE) with the tuffaceous turbidites are relatively thin (e.g., approx. 90 cm) beds of lapilli-tuff containing pillow fragments. A fallen slab shows two such debris-flow deposits, separated by a little stratified tuff. Note differential compaction above pillow fragments and minor loadcasting at the base of the overlying debris-flow deposit.

Walk WNW to join the trail to Horse Lake. Leave the trail south of Horse Lake and walk westerly into the mouth of a narrow, straight canyon bearing approximately N60E. Clamber upstream to Stop 4. We have walked across the poorly exposed Elwell Formation and arrived at the top of the Sierra Buttes Formation.

STOP 4 (Refer to Maps 2 and 3)

Well bedded (N25W, 20NE), generally fine-grained, quartz-rich volcaniclastic rocks at the top of the Sierra Buttes Formation, probably turbidites and debris-flow deposits (the latter containing scattered blocks of metadacite). Are these rocks epiclastic or pyroclastic?

Continue upstream to Stop 5.

STOP 5

Mesoscopically folded, laminated, carbonaceous chert interbedded with fine-grained, thinly stratified volcaniclastic rocks. Note the cleavage, which is commonly axial planar to mesoscopic folds in carbonaceous chert (such folds are thought to be tectonic, and to have formed during the Nevadan orogeny). The anticlinal hinge trends S20E toward you (angle of plunge is approx. 40°).

Examine the interesting bedding features ("flame structure", etc.) in the very fine-grained, quartz-rich turbidites overlying the chert in the southeast wall of the stream canyon. The top of the wall is held up by a relatively thick turbidite(?) bed whose structureless base (Bouma A division?) consists of pumice-rich lapilli-tuff (microvesicular long-tube pumice, instead of the pumice with round vesicles seen in the Taylor Formation).

Long-tube pumice is more evident in the "subaqueous pyroclastic flows" (i.e., pyroclastic debris flows) present up the slope south of the stream canyon. Some debris-flow deposits are structureless, some are subtly bedded (the pumice has been sorted into repetitive thin layers). Red-weathered, ragged, elongated (in the plane of bedding), often laminated fragments of long-tube pumice up to 10-12 cm long are present. The metadacitic pumice bears small plagioclase and quartz phenocrysts.

STOP 6

Thick (about 18 m), approximately vertical dike of aphanitic Elwell meta-andesite cutting bedded (N5E, 40E) Sierra Buttes rocks. Note approximately vertical platy parting in the dike, which is characteristic of the margins of Elwell dikes and sills. The knife edge-sharp, straight dike contacts trend N15-40W. This dike is sill-like lower in the Sierra Buttes Formation, where it intrudes the carbonaceous chert seen at Stop 5 (see Map 3). A linear swarm of thin red-weathered dikes oriented N5E, 85W, cuts laminated Sierra Buttes rocks nearby.

Rare-earth-element abundances of Elwell sills and related pillow lavas indicate that these rocks, too, belong to the tholeiitic rock association of island arcs (Brooks, Wood, and Garbutt, in press). The Elwell magma was andesitic; the mean of nine partial chemical analyses is: SiO_2, 58.1%; Al_2O_3, 13.7%; CaO, 4.1%; MgO, 3.0%; FeO*, 11.0%; Na_2O, 3.4%; K_2O, 0.6%; TiO_2, 1.0%; MnO, 0.1%. Most sills now consist of the greenschist-facies assemblage albite +quartz+epidote+actinolite+chlorite+Ti-rich mineral±calcite±stilpnomelane±white mica.

STOP 7

The thick Elwell dike has turned on its side to become sill-like again at a higher stratigraphic level (at the horizon of the Elwell Formation-- see Map 3). The sill, which has columnar structure, overlies several cm of very fine-grained, quartz-rich sandstone interlaminated with phosphatic chert (white phosphatic nodules are set in dark gray, carbonaceous, radiolarian chert).

The whole is underlain by another sill of quite a different kind, being choked with large, unaltered, light green clinopyroxene phenocrysts. Sills of this type, which are like those thought to be ankaramitic by some, occur voluminously in and near the stratigraphic horizon of the Elwell Formation. They reach thicknesses of at least 34.5 m, and are metabasaltic (the partial analysis of a sample collected 2.5 miles to the northwest, near Round Lake, is: SiO_2, 48.7%; Al_2O_3, 15.7%; CaO, 8.3%; MgO, 6.9%; FeO*, 10.2%; Na_2O, 1.6%; K_2O, 1.5%; TiO_2, 0.4%). These rocks typically contain very large amounts of Cr, doubtless incorporated in the voluminous clinopyroxene phenocrysts (Brooks and Coles, 1980). The relict modes of three samples contain from 12 to 35% clinopyroxene phenocrysts and from 0 to 16% plagioclase phenocrysts.

Walk downhill to the southeast and rejoin the trail; Elwell sill rock along the way contains exceptionally abundant large chlorite- and quartz-filled amygdules. Walk northeasterly toward Horse Lake.

STOP 8

Doubtless the same Elwell sill as that examined at Stop 7, here with spectacularly displayed columnar structure. Look for the poorly *exposed* phosphatic chert that concordantly underlies the sill. The sill rock here is unusual in that it contains scattered small phenocrysts of plagioclase and clinopyroxene (probably augite); nearly all Elwell magma was phenocryst-free. The sill rock also contains unusually abundant gray quartz megacrysts that greatly resemble large quartz phenocrysts which choke some rock units in the underlying Sierra Buttes Formation. Are these crystals xenocrysts or phenocrysts? The hand lens shows that they are here commonly deeply embayed and highly irregular.

The top of the sill is missing, having been removed by a highly erosive epiclastic debris flow charged with large clasts of Sierra Buttes quartz porphyry, black chert, Elwell sill rock, etc. (such debris-flow deposits make up the basal member of the Taylor Formation). The contact between the sill and debris flow is very sharp and highly irregular; it intersects vesicles flattened in the plane of the sill during its emplacement. Look for steeply dipping chert veins in the sill adjoining the contact; still-fluid "chert" injected columnar joints as they opened during shrinkage of the solidifying sill. Note that many sand-sized grains in the matrix of the debris flow consist of smoky quartz eroded from the Sierra Buttes Formation.

Rejoin the trail and walk northeasterly toward Horse Lake. Leave the trail south of Horse Lake, skirt the west side of the lake, and climb Hill 6717 north of the lake (see Map 2).

STOP 9 (Refer to Map 4)

Much of the top of this hill consists of Elwell sill rock and peperite (see Map 4 for the details). Here, invading Elwell magma encountered relatively very wet "chert" (phosphatic radiolarian ooze), so that it was quenched drastically enough to produce peperite--block- to ash-sized fragments of aphanitic andesite supported by a black chert matrix. Search among the finer andesitic fragments for those that are bounded by characteristic conchoidal fractures. The fractures represent thermal-contraction cracks developed in rapidly freezing glassy lava. A few notable properties of the Horse Lake peperites and related rocks are: 1) large chert xenoliths enclosed in sill rock without intervening peperite that represent chert which was lithified when intruded; 2) relatively well-sorted and fine-grained peperite, the chert matrix of which contains chert fragments and phosphatic nodules, both broken and unbroken (How do the phosphatic nodules form? How are they broken?); 3) peperite containing small pillows deformed during dispersal of the peperite by steam explosions; and 4) the actual passage of sill rock into peperite where it adjoins originally wet "chert". An exhaustive description of the character and modes of origin of these and other Elwell peperites is in press (Brooks, Wood, and Garbutt).

Rejoin the trail just after crossing the outlet of Horse Lake and stay on it around the north side of Upper Salmon Lake until you have returned to the parking area.

REFERENCES CITED

Brooks, E.R., and Coles, D.G., 1980, Use of immobile trace elements to determine original tectonic setting of eruption of metabasalts, northern Sierra Nevada, California: Geological Society of America Bulletin, Part I, v. 91, p. 665-671.

Brooks, E.R., and Garbutt, P.L., 1972, Broken-pillow breccia in the northern Sierra Nevada, Sierra County, California: Geological Society of America Abstracts with Programs, v. 4, p. 131-132.

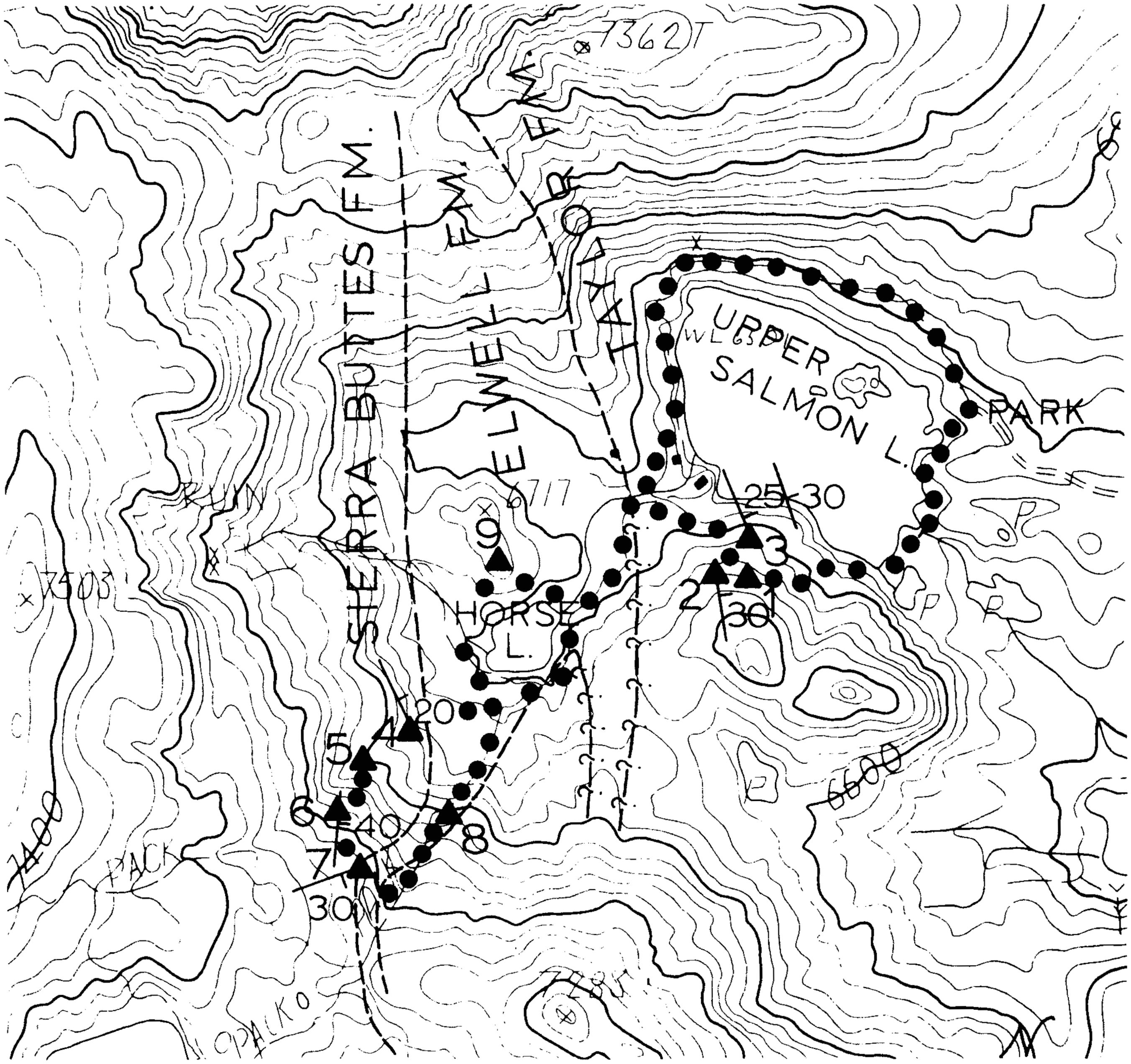
Brooks, E.R., Wood, M.M., and Garbutt, P.L., 1982, Origin and metamorphism of peperite and associated rocks in the Devonian Elwell Formation, northern Sierra Nevada, California: Geological Society of America Bulletin, v. 93 (in press).

Fisher, R.V., 1966, Rocks composed of volcanic fragments and their classification: Earth-Science Reviews, v. 1, p. 287-298.

Mathieson, S.A., 1981, Pre- and post-Sangamon glacial history of a portion of Sierra and Plumas Counties, California (M.S. thesis): Hayward, California State University, 258 p.

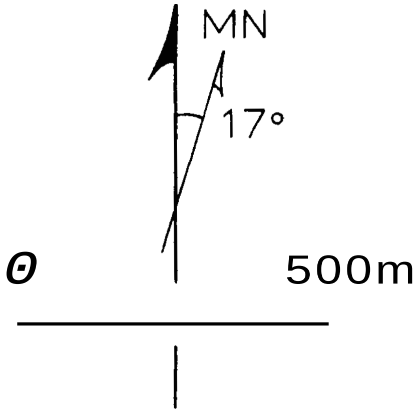
MAP 2. UPPER SALMON LAKE AREA

Base from preliminary Gold Lake, Calif., 7½' Quad.



2▲ Number and location of field trip stop

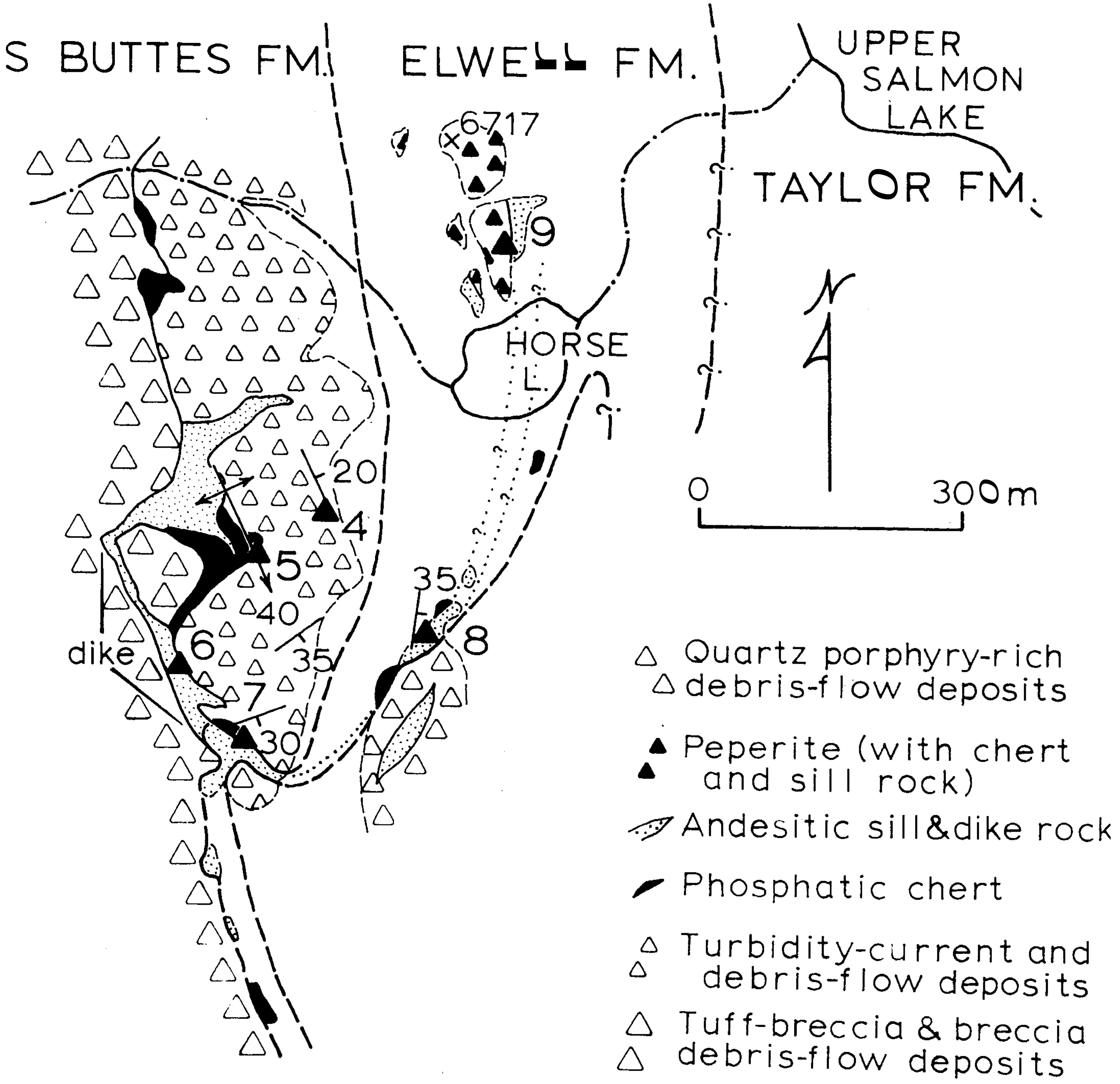
●●●● Route of field trip



MAP 3

OUTCROP MAP OF HORSE LAKE AREA

After Michael M. Wood, 1980



MAP 4. OUTCROP MAP OF HILL 6717

After Christine Naschak, 1980