

**THE EXTENSION OF THE CALAVERAS - SHOO FLY THRUST TO THE SOUTHERN  
END OF THE SIERRA NEVADA METAMORPHIC BELT, CALIFORNIA**

Preliminary geologic maps of the Tuolumne, Duckwall Mountain, Groveland, Jawbone Ridge, Lake Eleanor NW, and NE 1/4s, Buckhorn Peak, Kinsley, El Portal, and Buckingham Mountain 7 1/2 minute quadrangles, California Division of Mines and Geology, Sacramento, California. Accompanied by 10 p. report plus 5 figures, 1 table, unpublished DMG report.

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## ABSTRACT

THE EXTENSION OF THE CALAVERAS-SHOOFLY THRUST (CSFT) TO THE SOUTHERN END OF THE SIERRA NEVADA METAMORPHIC BELT (SNMB), CALIFORNIA  
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The CSFT has now been mapped within the SNMB as far south as Lat. 37°30'N in Mariposa County, where the belt is engulfed by the Sierra Nevada batholith (SNB). The thrust has been folded and overturned north of the Tuolumne R. by forceful intrusion of the 170 m.y. Standard pluton. It is truncated by granite (SNB) south of Hunter Bend of the Clavey River and re-emerges trending parallel to, but northeast of Pilot Ridge. The CSFT is cut by the Hazel Green pluton and then, with a more southerly trend, extends 16 km beyond the Merced River. The sub-vertical ductile thrust separates polydeformed quartzite, mica-quartz schist ± garnet and graphite, calc-silicate rock, and augen gneiss of the upper plate Lower Paleozoic Shoo Fly Complex on the east from argillite, chert, marble, and talc-schist of the lower plate Calaveras Complex on the west. Within the 250 m-wide CSFT zone, syn-metamorphic imbrication of rock units and intense silicification is common. Slices of the Calaveras occur as flattened and disarticulated meter-scale sheets of recrystallized argillite, massive and rhythmic-bedded chert, quartz sandstone and mylonitic marble intruded locally by syn-tectonic granite. In the Shoo Fly, the CSFT fabric ( $S_3$ ) is marked by the development of blastomylonite with 0.1-1.0 cm-spaced syn-metamorphic shears and attendant isoclinal folding and transposition of pre-thrust penetrative fabrics ( $S_1$  and  $S_2$ ) into  $S_3$ . Since the Shoo Fly, with its distinctive structural style, occurs in the upper plate of the CSFT as far south as Lat. 37°30'N, roof pendants to the east and southeast must be restudied to ascertain the full extent of Lower Paleozoic wallrocks and the tectonic significance of the CSFT.

22 December 1981

## **INTRODUCTION**

The Sierra Nevada range (Figs. 1, 2) has long presented almost insurmountable obstacles to an understanding of the Paleozoic and early Mesozoic tectonic history of the southwestern margin of the Cordillera, largely because the massive Sierra Nevada batholith has obliterated a major part of the evidence and separates sparsely fossiliferous rock sequences in the western and eastern parts of the range. Most previous studies have either been concentrated in small areas where local geologic relations could be established, or have been reconnaissance studies lacking in detail.

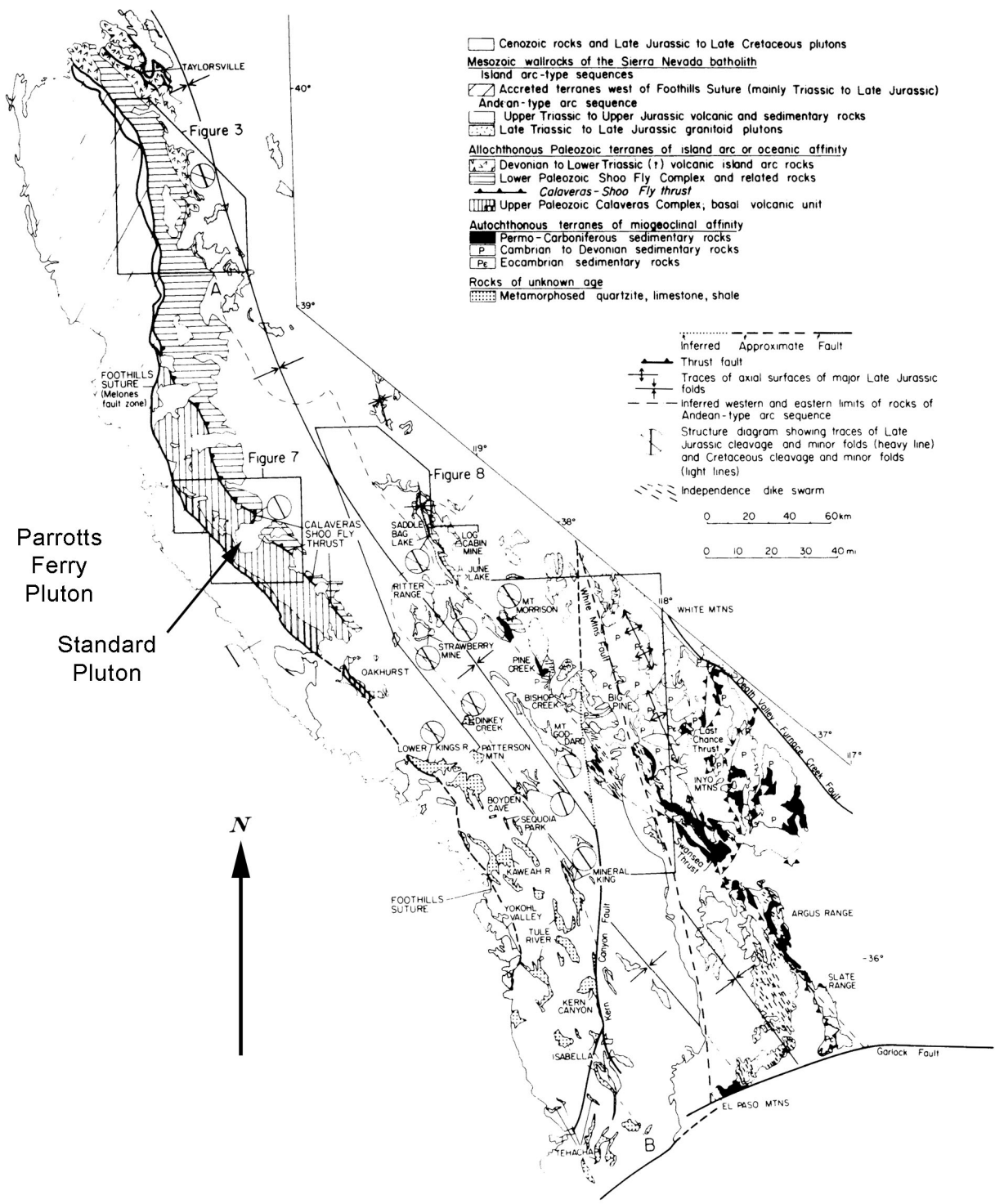
In Tuolumne County, California, recent work (Fig. 3) has established a stratigraphic and structural data base for comparison to other regions and has shown the presence of two sub-parallel belts of rock (the Calaveras and Shoo Fly Complexes) and the presence of a ductile thrust between them.

Detailed and reconnaissance bedrock mapping at a scale of 1:24,000 was conducted in the region southeast of the Standard pluton in July and August, 1981. The work was concentrated on the San Jose and Mariposa Sheets. Figure 4 shows the USGS quadrangles that were mapped and included with this report. The quadrangles mapped were: Tuolumne, Duckwall Mountain, Groveland, Jawbone Ridge, Lake Eleanor (NW, SW, SE), Kinsley, El Portal, and Buckingham Mountain. The last three 7 1/2' quadrangles have been drafted onto a 15" base map (El Portal 15" quadrangle). After some general remarks on the geology of the Shoo Fly Complex I will discuss the geologic discoveries generated by this summer's research.

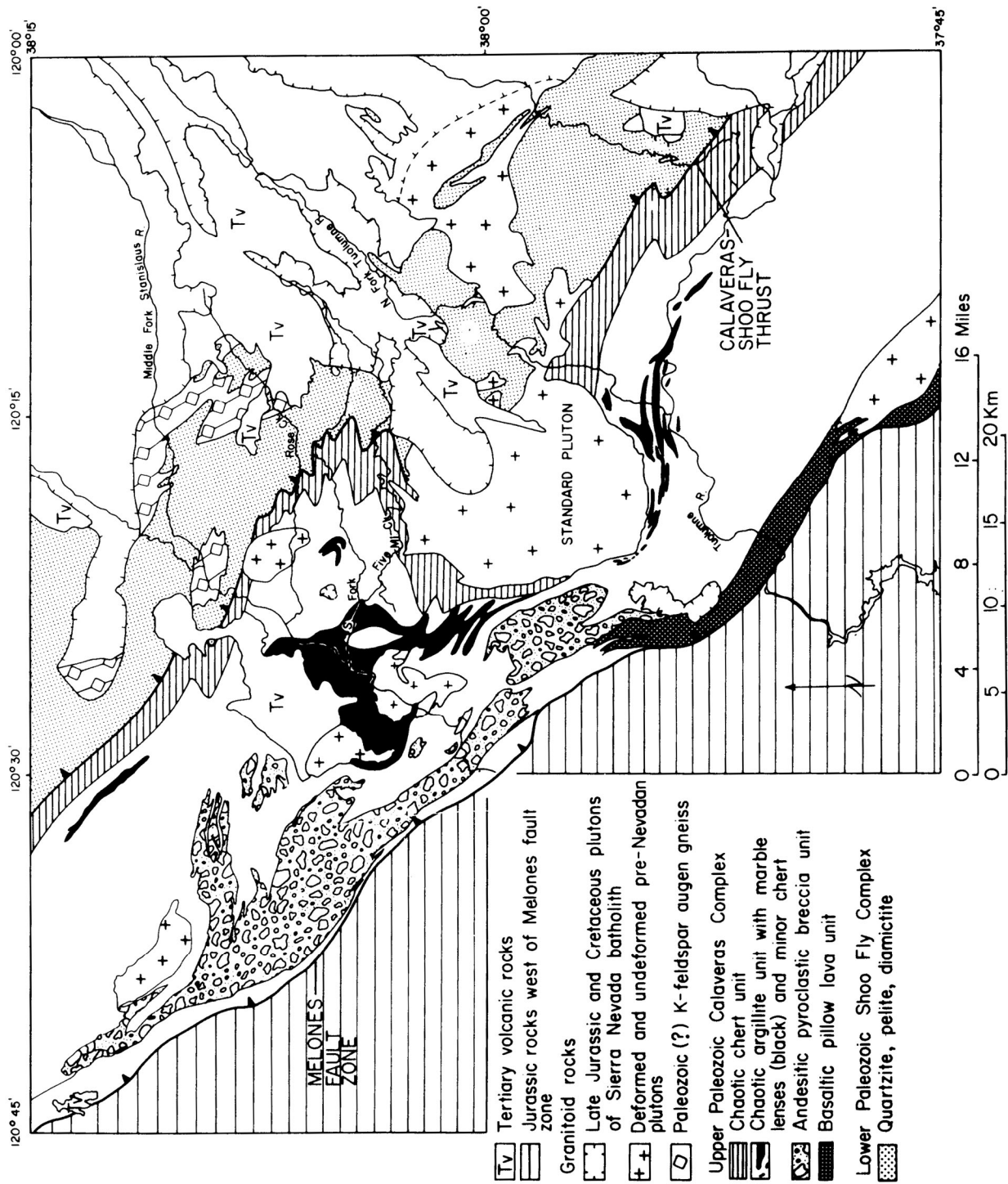
## **PREVIOUS WORK IN THE SHOO FLY**

The Shoo Fly contains at least two generations of structures that pre-date the development of the Calaveras - Shoo Fly Thrust (Merguerian and Schweickert, 1980). Earliest recognizable are a metamorphic layering ( $S_1$ ) and isoclinal folds of bedding that are crosscut by deformed granitoids - augen gneiss. A second generation of structures ( $S_2$ ) created a penetrative foliation in the augen gneiss, isoclinal folds of layering and  $S_1$  in the quartzites, and a strong mylonitic fabric. Both early sets of structures are deformed by third-generation structures ( $S_3$ ) that are related temporally to the Calaveras Shoo Fly Thrust.

Figure 3 is a generalized geologic map of the Shoo Fly in northern Tuolumne County, California showing the widespread occurrence of augen gneiss. Preliminary U-Pb zircon analysis by Jason Saleeby (personal communication) indicates that the augen gneisses may have igneous ages of 400 m.y. and older, and that the gneisses have undergone a major Triassic or older metamorphic event. If true, the first generation structures above are early Paleozoic and the second and/or third structures could be Triassic or older. The structural chronology for the Shoo Fly and Calaveras is shown in Table 1 and is explained in the two-page legend accompanying the maps. Figure 5 is a cartoon that summarizes the structural relations.



**Figure 1** – Tectonic map of the wallrocks of the Sierra Nevada batholith. (Adapted from Schweickert, 1981, Fig 5-1, p. 91.)



**Figure 2** – Generalized geological map of the Calaveras and Shoo Fly Complexes in the central Sierra Nevada, California. (Adapted from Schweickert, 1981, Fig 5-7, p. 104.)

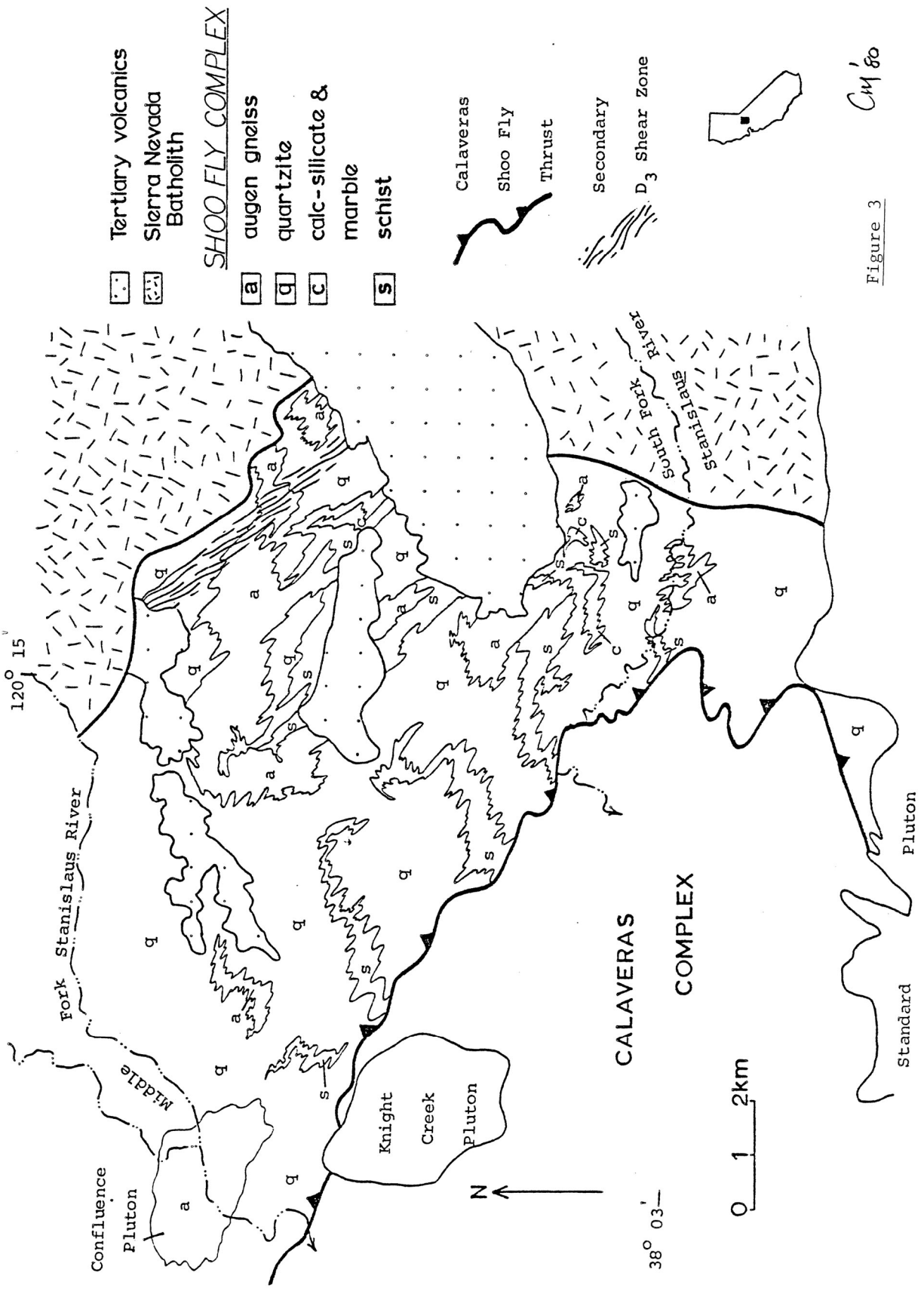
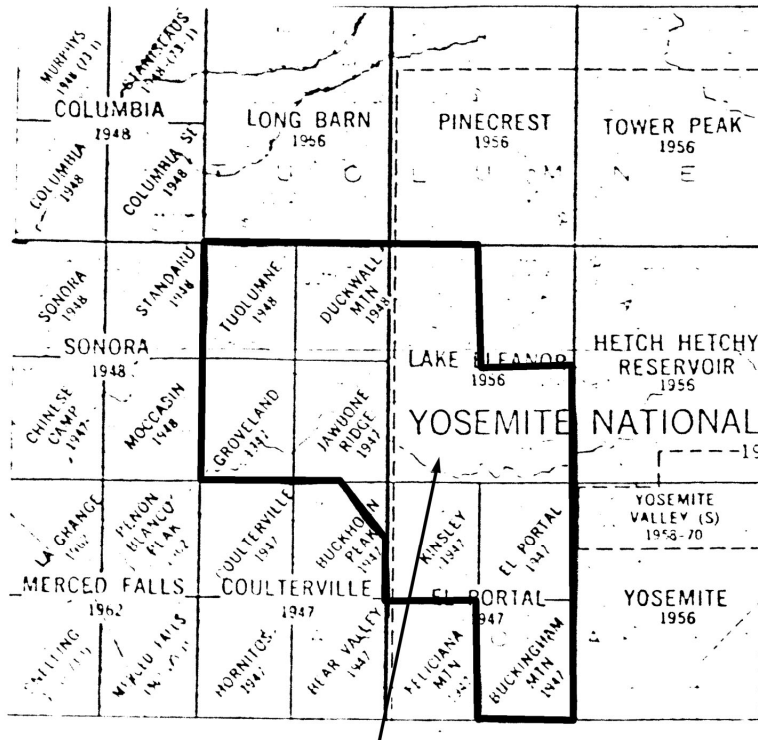


Figure 3  
CM'80



This Report

Figure 4

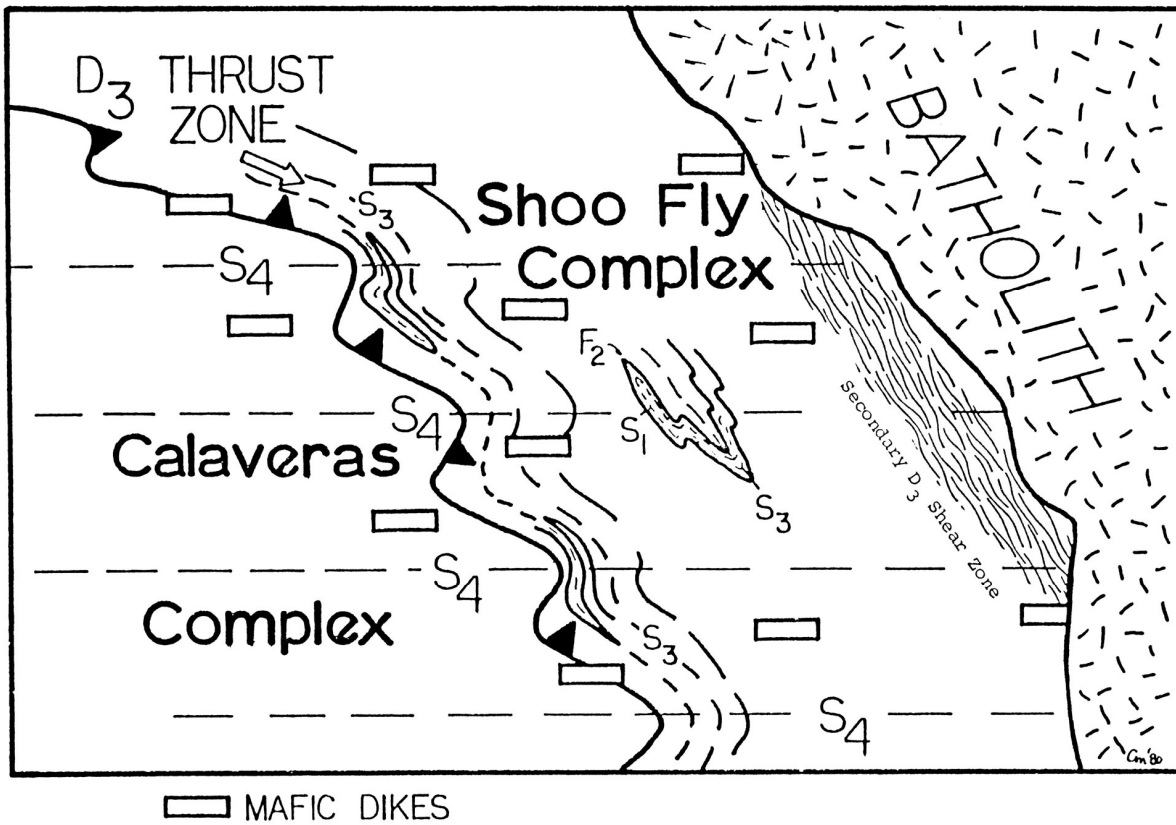


Figure 5 - Cartoon showing structural relations of basement rocks in Tuolumne Co., California

## THE CALAVERAS-SHOO FLY THRUST

The Calaveras-Shoo Fly Thrust is an east-dipping mylonitic thrust zone which separates two distinctive Paleozoic bedrock complexes over its known extent of 175 km in the western Sierra Nevada foothills of California (Fig. 2). The upper plate rocks of the lower Paleozoic Shoo Fly Complex record a longer and more complex deformational history than the lower plate rocks of the upper Paleozoic (?) Calaveras Complex. In particular, the Shoo Fly exhibits two penetrative structural events that formed prior to juxtaposition with the Calaveras (Meguerian, 1981). The thrust formed between early Permian and middle Jurassic time, probably during the Permo-Triassic Sonoma orogeny and represents a deep-seated dislocation between a late Paleozoic island arc massif and its associated subduction complex (Schweickert and Merguerian, in press). A more detailed discussion of the structural history of the Shoo Fly is included in the 1981 RFP Proposal. The key to unraveling the complex geologic history of the southern Sierra Nevada foothills was accomplished by tracing the relevant structural and stratigraphic data southward from Tuolumne County, in accord with my 1981 proposal and subsequent contract. The results of this research is presented, together with maps, below.

**Table 1** - Tentative structural chronology Calaveras and Shoo Fly complexes.

<b>Calaveras Complex</b>	<b>Ages</b>	<b>Shoo Fly Complex</b>
S <sub>5</sub> spaced cleavage (N70°W)	<i>Cretaceous?</i>	S <sub>7</sub> crenulation cleavage (N70°W)
S <sub>4</sub> crenulation cleavage (N20°E)	<i>Late Jurassic?</i>	S <sub>6</sub> crenulation cleavage (N20°E)
S <sub>3</sub> crenulation cleavage (N20°-30°W)	<i>Late Jurassic</i> (Nevadan Orogeny?)	S <sub>5</sub> crenulation cleavage (N20°-30°W)
	++++ Intrusion of Sonora mafic dike swarm +++++	
	++++ Intrusion of Parrotts Ferry pluton (170 m.y. ago) +++++	
S <sub>2</sub> spaced cleavage and mica schistosity (N70°W)	<i>Early Mesozoic</i>	S <sub>4</sub> spaced cleavage and mica schistosity (N70°W)
S <sub>1</sub> flattening foliation and thrusting (C-SF thrust)	<i>Permo-Triassic?</i>	S <sub>3</sub> mylonitic fabric and thrusting (C-SF thrust)
		S <sub>2</sub> mylonitic fabric in quartzite and augen gneiss
		++++ Intrusion of protoliths of augen gneisses +++++ (~280-325 m.y. ago) Pennsylvanian
	<i>pre-Pennsylvanian</i>	S <sub>1</sub> layering and F <sub>1</sub> isoclines (Antler orogenic deformation?)



## **1981 RESEARCH**

The Calaveras-Shoo Fly Thrust is separable into two major segments by the Standard pluton (Fig. 2). I have mapped the region north of the Standard pluton and show the data on Figure 3. The southern area is described below. I am convinced that the Shoo Fly exists as a continuous belt of polydeformed quartzitic gneiss, mica schist, diopsidic marble and augen gneiss as far south as 37°30'N where it is engulfed by granitic rocks of the Sierra Nevada batholith. The Shoo Fly, throughout the 1981 study area (See 1981 RFP), is in ductile thrust contact with the Calaveras to the west and locally the thrust is overturned toward the west. Normally, it is a steep, east-dipping surface of structural discordance. Remarkably, the structural character of both the Calaveras and Shoo Fly are identical in the terranes both north and south of the Standard pluton. Table 1 can therefore be used for the southern area (study area) as well (Merguerian, 1982). What is more, the older fabrics in the Shoo Fly ( $S_1$ ,  $S_2$ ) are truncated at a high angle against the  $D_3$  thrust zone. In addition, all of the various sub-units in the Shoo Fly are in fault contact with the Calaveras which suggests wholesale truncation of stratigraphic horizons in the Shoo Fly. The quadrangle mapping of 1981 is described below. I have tried to concentrate on discussion of geologic relations not shown on prevailing CDMG maps.

### **TUOLUMNE QUADRANGLE**

The Calaveras-Shoo Fly Thrust is encountered southeast of the Standard pluton in sec. 10. It trends southeasterly to sec. 29 but is folded by N70°W-trending  $F_4$  folds. In addition, the thrust is offset in secs. 24 and 19 by a high angle (EW, 50°N) brittle reverse fault that is more than likely a Cretaceous reactivation of a pre-existing  $S_4$  surface. In the western part of the quadrangle, the thrust is folded and overturned, due to forceful intrusion of the Standard pluton. Reconnaissance mapping in the adjacent Standard quadrangle (Fig. 4) indicates the presence of Shoo Fly also overturned with respect to the Calaveras.

### **DUCKWALL MTN. QUADRANGLE**

In this quadrangle the thrust enters and exits in the southwest quarter. It is strongly folded by E-W trending  $F_4$  folds. In sec. 3 small isolated tectonic slivers of the Shoo Fly (garnet-staurolite-mica schist) are surrounded by highly sheared Calaveras chert. These occurrences are the result of imbrication of rock units during  $D_3$  thrust development. The Shoo Fly underlies most of the quadrangle although granitic rocks comprise the eastern portion. In secs. 24 and 25 a large plutonic mass of coarse-textured hornblendite, hornblende pyroxenite and subordinate gabbro are overlain by Tertiary pyroclastic mudflow breccia.

### **GROVELAND QUADRANGLE**

All Calaveras rocks occur in the eastern part of the sheet. Jurassic phyllite occurs in the western half (reconnaissance) and is in ductile fault contact with the Calaveras to the east. Some refinement of Tertiary volcanic contacts are presented. Basically, little mapping was attempted on this sheet.

## **JAWBONE RIDGE QUADRANGLE**

The Shoo Fly underlies the northeast portion of this sheet and the thrust is projected, with little control, into granitic rocks of the batholith in sec. 24 (Tuolumne River). While it is extremely unlikely that the thrust is not folded as shown, the region was inaccessible during the 1981 season. The placement of the thrust in the northern region is constrained by little outcrop data and geologic trends but  $F_4$  digitations were not diagrammatically sketched although they most assuredly exist. The thrust re-emerges northeast of Pilot Ridge (sec. 32) where control is excellent and trends southeasterly to the edge of the sheet. A sliver of mylonitic ferruginous chert (Calaveras) was detected within the Shoo Fly in sec. 33. Early foliations in the Shoo Fly (sec. 33) are isoclinally folded, transposed and truncated at a high angle by the thrust.

## **LAKE ELEANOR NW QUADRANGLE**

Mainly granite with local roof pendants and screens of Shoo Fly.

## **LAKE ELEANOR SW QUADRANGLE**

The thrust enters this quadrangle in sec. 33 and trends southeasterly until it is crosscut by granodiorite of the Hazel Green pluton. The thrust surface is very complex in this region due to the superposition of E-W trending  $F_4$  folds, NW-trending  $F_5$  (Nevadan) folds, and a younger generation of NE-trending crenulate folds ( $F_6$ ). Due to complexities during thrusting (i.e. - isoclinal and shear folding, transposition, development of blastomylonite, and tectonic imbrication of rock units, the thrust trace marks a form-line that separates  $\geq 50\%$  Calaveras lithologies from  $\geq 50\%$  Shoo Fly lithologies to the east. It is possible that in the vicinity of the thrust zone each outcrop is a fault-bounded sliver but I have opted to represent the contact, as a 50% form-line. Gabbroic plutons occur in the Shoo Fly in secs. 1, 6, 5, and 7.

## **LAKE ELEANOR SE QUADRANGLE**

The Shoo Fly is limited to the southern quarter of this sheet, and the Calaveras does not exist. Most of the quadrangle is underlain by granitic rocks of the Sierra Nevada batholith. See Tobisch (1960ms) for more data.

## **EL PORTAL 15' QUADRANGLE**

The El Portal quadrangle is a compilation of mapping done on the Kinsley, El Portal and Buckingham Mountain quadrangles during 1981. In addition, Dr. Richard A. Schweickert has included data from parts of the Felician Mountain quadrangle to complete the 15' sheet.

The thrust emerges from the Hazel Green pluton in sec. 27 and trends southeasterly past the Merced River. Control is good in this segment and post-thrust folding ( $F_4$ ?) can be seen south of sec. 35. The folds are tentatively identified as  $F_4$  folds that have been rotated by local intrusives. At the Merced River, imbrication of the Shoo Fly is obvious as well as intense mylonitization of both the Shoo Fly and Calaveras complexes. The thrust is dashed to the south

of the Merced River due to inaccessibility in 1981 but the thrust is accurately mapped in the extreme southeast part of the quadrangle (secs. 10 and 15) where it is truncated by the batholith.

The Calaveras occupies the central part of the sheet and is in ductile fault contact with Jurassic phyllite and greenstone to the west. Complications exist on Buckingham Mountain as rocks there are highly flattened and are lithically identical to the Shoo Fly occurring to the east. This region needs to be re-examined and will be a focal point for a 1982 RFP to be submitted shortly.

In summary, the extent of the Shoo Fly and the Calaveras-Shoo Fly Thrust has now been mapped as far south as Lat. 37°30'N and shows an identical structural signature as found north of the Standard pluton. The existence of the Shoo Fly in this region poses questions concerning the extent of the Shoo Fly in roof pendants to the east, southeast, and south of the 1981 study area.

Respectfully submitted,  
Charles Merguerian  
22 December 1981

#### **REFERENCES CITED**

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Merguerian, Charles; and Schweickert, R. A., 1980, Superposed mylonitic deformation of the Shoo Fly Complex in Tuolumne County, California (abs.): Geological Society of America Abstracts with Programs, v.12, p. 120.

Schweickert, R. A., 1981, Tectonic evolution of the Sierra Nevada Range, p. 87-131 *in* Ernst, W.G., *ed.*, The geotectonic evolution of California, Rubey volume I: Englewood Cliffs, NJ, Prentice-Hall Inc., 706 p.

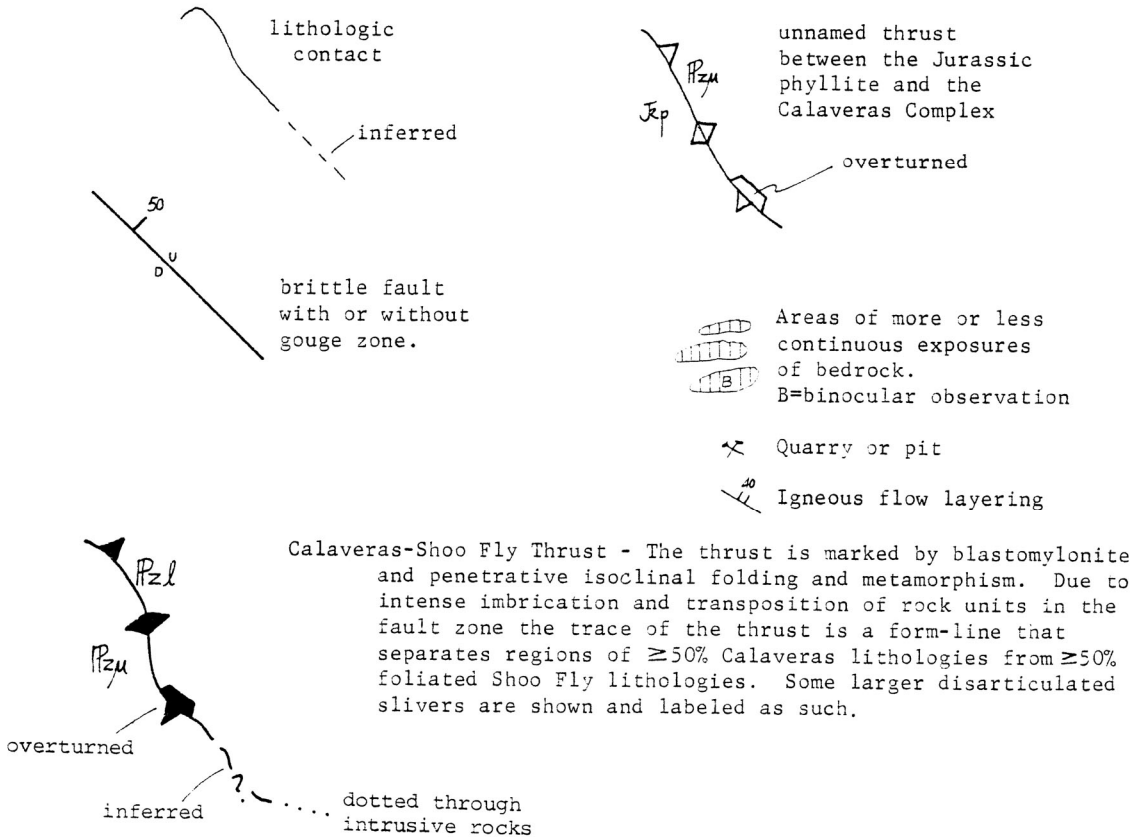
Tobisch, Othmar, 1960ms, Geology of the Crane Flat - Pilot Peak area, Yosemite District, California: University of California Berkeley, M.A. Thesis, 87 p. plus 1:24,000 scale map.

**Note:** Map sheets available from the California Division of Mines and Geology or <http://www.dukelabs.com>. Map explanations are below.

LITHOLOGIC UNITS

- Qg Pleistocene Non-Marine Deposits
- Tg Tertiary Non-Marine Deposits
- PvP Pliocene Mehrten Formation - pyroclastic rocks
- gr Granitic to granodioritic rocks of the Sierra Nevada batholith
- u Ultramafic plutonic rocks
- gb Gabbroic rocks
- Jp Jurassic phyllite
- Jg Jurassic greenstone
- Pzu Upper Paleozoic Calaveras Complex - argillite, chert-argillite, rhythmically-bedded and massive chert, marble (ls), talc-schist, rare sandstone layers, post-tectonic mafic dikes. The Calaveras Complex is in ductile fault contact with both the Jurassic rocks to the west and with the Shoo Fly Complex to the east.
- Pzl Lower Paleozoic Shoo Fly Complex - dominantly mylonitic quartzite and micaceous quartzofeldspathic gneiss and mica-quartz gneiss and schist± garnet and graphite. In addition diopsidic calc-silicate and marble± biotite, graphitic marble and schist. In Tuolumne County, the Shoo Fly also contains numerous bodies of Paleozoic intrusives that now occur as augen gneiss (ag) and many post-tectonic mafic dikes.

LITHOLOGIC CONTACTS




## STRUCTURAL SYMBOLS


The symbols are defined for each lithotectonic belt. Symbols can be mixed. The point of intersection is the observation point.





### Jurassic phyllite and greenstone belt


 S<sub>1</sub> - Dominant phyllitic cleavage and lithologic layering


### Upper Paleozoic Calaveras Complex

 S<sub>0</sub> - Bedding


 S<sub>1</sub> - Flattening foliation


 F<sub>1</sub>, L<sub>1</sub> - Fold axis/stretching lineation


 S<sub>2</sub> - Slip cleavage with recrystallized biotite


 F<sub>2</sub>, L<sub>2</sub> - Fold axis/crenulation or intersection lineation


### Lower Paleozoic Shoo Fly Complex


 S<sub>0</sub> - compositional layering (bedding) proves rocks are meta-sedimentary but of little structural help due to extensive shearing and transposition.


 S<sub>1</sub> or S<sub>2</sub> - Pre-thrust event schistosity or gneissosity with two superposed amphibolite facies folding episodes (F<sub>1</sub>, F<sub>2</sub>). These are often mylonitic. S<sub>1</sub> is rare and is locally noted on the maps.


 F<sub>1</sub>, F<sub>2</sub>, L<sub>1</sub>, L<sub>2</sub> - fold axis / stretching lineation

 S<sub>3</sub> - blastomylonitic amphibolite facies foliation formed during development of the Calaveras - Shoo Fly Thrust. Within 1 km of the ductile fault, shearing, boudinage, transposition and metamorphic overprinting of the older fabrics (S<sub>1</sub> and S<sub>2</sub>) is most complete. Away from the thrust zone the S<sub>3</sub> foliation is a penetrative mica foliation with shearing along S<sub>3</sub> axial surfaces. On the maps the S<sub>3</sub> foliation symbol was only plotted where field relations were unequivocal. The older fabrics are best developed away from the thrust within the main body of the Shoo Fly.

 F<sub>3</sub>, L<sub>3</sub> - Fold axis / stretching lineation

 S<sub>4</sub> - slip cleavage with recrystallized biotite and a local black residue cleavage consisting of biotite ± opaque minerals.

 F<sub>4</sub>, L<sub>4</sub> - Fold axis / crenulation or intersection lineation

 S<sub>5</sub>, S<sub>6</sub>, S<sub>7</sub> - younger slip cleavages

S<sub>5</sub> N32W, 78°NE (Nevadan cleavage with crenulate to open folds (F<sub>5</sub>))

S<sub>6</sub> N30E, 90° (Late Nevadan cleavage with crenulate to open folds (F<sub>6</sub>))

S<sub>7</sub> N70W - EW, 90° (Cretaceous high angle rock cleavage and local reverse faulting with quartz veining and mineralization). Local open folds (F<sub>7</sub>) observed, however, F<sub>5</sub>, 6, or 7 folds are generally not plotted.

Geology mapped in July and August, 1981  
by Charles Merguerian