Open-File Report 85-11 SF

BEDROCK GEOLOGIC MAP OF THE SHOO FLY COMPLEX IN THE JUPITER AREA, STANISLAUS RIVER DRAINAGE, TUOLUMNE COUNTY, CALIFORNIA

by

Charles Merguerian

1985

California Department of Conservation

Division of Mines and Geology

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THE RESOURCES AGENCY

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BEDROCK GEOLOGIC MAP OF THE SHOO FLY COMPLEX IN THE JUPITER AREA, STANISLAUS RIVER DRAINAGE, TUOLUMNE COUNTY, CALIFORNIA

Scale 1:24,000, Four Sheets

Accompanied by 23 page text

3 Figures, 1 Table,

and map explanation

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ABSTRACT

The western flank of the Sierra Nevada range in California is underlain by a diverse assemblage of Paleozoic and Mesozoic metamorphic rocks. The lower Paleozoic Shoo Fly Complex, the oldest of these units, forms an elongate outcrop belt along the eastern margin of the metamorphic belt. The Shoo Fly was first described in the northern Sierra in the early 1900s, but until now little was known about the distribution and structure of the Shoo Fly Complex in the central Sierra except for reconnaissance mapping by R.A. Schweickert in the 1970s. The present study of the Stanislaus river drainage was undertaken to document and describe the lithology, structural geology, and geochemistry of the Shoo Fly Complex and associated rocks.

The Shoo Fly Complex forms a region of mylonitic, epidote-amphibolite grade quartzose and granitoid gneiss, subordinate schist and calcareous rocks, and rare amphibolite in the study area. The Shoo Fly has endured a complicated structural history involving seven superposed deformations at variable crustal depths. The first four of these (D_1-D_4) involved tight to isoclinal folding and shearing under medium grade metamorphic conditions. The last three (D_5-D_7) are marked by open folding and retrograde metamorphism of older fabric elements.

The Shoo Fly is in ductile fault contact with east-dipping argillite, chert, and marble of the upper Paleozoic-lower Mesozoic(?) Calaveras Complex. The Calaveras-Shoo Fly thrust formed during D_3 and is a 1-2 km wide synmetamorphic ductile shear zone. Recognition of D_3 overprinting of the older D_1+D_2 fabrics along the thrust zone indicates that the upper plate Shoo Fly rocks record an earlier and more complex structural history than the lower plate Calaveras rocks. This report provides a detailed record of the geology of the region and places critical constraints on tectonic interpretations of the foothills metamorphic belt.

INTRODUCTION

This is the results of a study of a 22-km long segment of the 330 km long, 6-20 km wide Shoo Fly Complex and the adjacent Calaveras-Shoo Fly thrust. The study area is located in the Sierra Nevada foothills roughly east of the city of Lodi, California. The study was undertaken to improve the understanding of the complex lithology, structure, and deformation related to these geologic phenomena.

The western metamorphic belt of the Sierra Nevada range (Clark, 1964, 1976) is roughly 350 km long, 60 km wide and extends from lat 40°15'N south-southeasterly to lat 37°N. It is overlain by Cretaceous to Cenozoic rocks of the Great Valley sequence to the west and is intruded by the Sierra Nevada batholith to the east. South of lat 39°N, it is composed of three ductile-fault bounded tectonostratigraphic units (Figure 1) which show an eastward increase in age, metamorphic grade, and structural complexity. In these three units, abrupt lithologic, structural, and metamorphic truncations occur at the Melones, Sonora, and Calaveras-Shoo Fly faults (Merguerian and others 1983; Schweickert and others, 1984).

The lower Paleozoic Shoo Fly Complex of the eastern belt underlies a terrane 330 km in length and 6-20 km wide which terminates southward near lat 37°30'N in Mariposa County (Merguerian, 1981ms, 1982) where batholithic rocks cut across trend (Figure 2). Along its strike the Shoo Fly Complex shows a marked southward increase in structural complexity and metamorphic grade. North of lat 39°N it consists of weakly metamorphosed quartzose sandstone, graywacke, slate, chert and limestone (Clark, 1976). South of lat 38°05'N (Figure 2) it is a multiply deformed (seven superposed phases of deformation) and sheared assemblage of quartzite, quartzofeldspathic gneiss, granite, syenite, and gabbroic augen gneiss, garnet schist, calc-silicate rock, marble, and rare amphibolite (Merguerian, 1985).

The Shoo Fly Complex is in ductile fault contact (Figure 2) with the Calaveras Complex along a 1-2 km wide zone of mylonite, intense flattening, imbricated rock units, and transposition with overprinting metamorphism of older fabric elements (Merguerian, 1981, 1983, 1985). The Calaveras Complex, which forms the lower plate of the east-dipping thrust, is a chaotic assemblage of massive argillite and siltstone, massive and rhythmically-bedded-chert, marble, talc-schist, basalt, and rare sandstone layers. The age of the Calaveras remains uncertain, but Permo-Carboniferous fossils from limestone olistoliths (Turner, 1894; Schweickert and others, 1977) indicate a maximum late Paleozoic age for the sequence. The Calaveras was not mapped in detail in the Jupiter area because Schweickert (unpublished data) has mapped extensively in the region. Descriptions of the Calaveras Complex in this region can be found in Schweickert and Wright (1975), and Wright and Schweickert (1977), and Schweickert and others (1977).

Area of this report and methods. The western metamorphic belt of the Sierra Nevada, the focus of gold-seeking prospectors since the mid-1800s, is deeply incised by a system of southwestward-flowing rivers that coalesce ultimately near San Francisco Bay. Eleven months were spent in the field between 1978 and 1981 between the Middle Fork of the Stanislaus River and the South Fork of the Merced River near the southern end of the metamorphic belt (Figure 2). Detailed mapping and structural analysis was carried out in parts of the Stanislaus, Columbia

SE, Crandall Peak, and Twain Harte 7-1/2 minute quadrangles (herein called the "Jupiter area" after a former mining town centered in the study area) (Map Sheets 1-4). The Jupiter area lies between the towns of Murphys, Columbia, Sonora, and Twain Harte and is bounded by Routes 4, 49, and 108, and by the Middle and South Forks of the Stanislaus River. Mapping of the Shoo Fly Complex and the Calaveras-Shoo Fly thrust southeast of Tuolumne City (Figure 2) was accomplished in 2-1/2 months in 1981 with nearly 600 stations measured. Preliminary 1:24,000 scale maps and a report on this southern region (Figure 2) are on file with the California Department of Conservation, Division of Mines and Geology (Merguerian, 1981).

In the Jupiter area detailed mapping was limited to water courses where abundant stream-polished exposure is common. Every outcrop in the rivers and creeks was examined for stratigraphic and structural data (>900 stations) and over 300 samples were collected for petrographic and geochemical analysis. The results of this study are presented elsewhere (Merguerian, 1985). It was not possible to physically trace sub-units of the Shoo Fly Complex across stream channels because the intervening ridges are choked with brush and mantled by a thick clayey paleosol or Tertiary volcanic rocks. The complex fold patterns indicated on the map are based upon lithologic correlation of distinctive sub-units and projection of lithologic contacts between stream channels. This was accomplished by utilizing the geometry and asymmetry of minor fold structures observed in the field. Other interpretations are possible. Some map contacts north and south of the Jupiter area are from Schweickert (unpublished data) and Wagner and others (1981).

STRATIGRAPHY

Paleozoic metamorphic rocks which form parts of the Shoo Fly and Calaveras complexes, crop out in the Jupiter area. The following describes the field occurrence and stratigraphy of metasedimentary and metaigneous units and their sub-units in the Shoo Fly Complex of the Jupiter area.

The Shoo Fly is here subdivided into five mappable units. However, the original stratigraphic relationships between the metasedimentary units is unknown due to extensive folding, shearing, and metamorphism. In order of decreasing areal abundance, the Shoo Fly Complex in the Jupiter area can be subdivided into quartzite and quartzofeldspathic gneiss, granitic, syenitic, and gabbroic gneissic granitoids (augen gneiss), schist, calc-silicate rock and marble, and amphibolite. All metasedimentary units show gradational contacts and are interlayered with one another. The gneissic granitoids are metaigneous rocks that post-date an early S_1 metamorphic fabric in the Shoo Fly (Schweickert and Merguerian, 1980). In many cases interlayered rocks have sharp, structurally imbricated contacts. However, undisrupted sedimentary layering is locally preserved as gradational mineralogic variations between sub-units, thick quartzofeldspathic layers with subordinate schistose layers, and laterally continuous centimeter-scale quartzite layers in schist.

Metamorphic rocks

The major units and their sub-units are listed below in order of decreasing map area. Minerals are listed in order of decreasing relative abundance. Those minerals listed in parentheses are not found in all exposures.

I. Quartzite and quartzofeldspathic gneiss unit (LPzq) -- a heterogeneous sequence of light- to dark-gray to brown- to maroon-weathering, generally gray-colored, massive to thickly-layered and slabby but locally highly-laminated, fine- to coarse-grained quartzite, granoblastic quartz-mica and quartzofeldspathic gneiss, and black vitreous quartzite. The following four sub-units have been recognized:

1. Light- to dark-gray, to white- to cream-colored, massive to well-layered biotite-muscovite-(chlorite)-(plagioclase)-(opaque) quartzite and vitreous biotite-opaque-(muscovite)-(chlorite)-(plagioclase)-(orthoclase)-(calcite) quartzite.
2. Gray, well-layered quartz-plagioclase-biotite-muscovite-(orthoclase)-(chlorite)-(garnet)-(tourmaline)-(zircon) gneiss. Locally the quartz grains have a bluish tint.
3. Gray, well-layered to highly-foliated, quartz-muscovite-biotite-(plagioclase)-(opaque)-(garnet)-(chlorite) gneiss and quartz-plagioclase-orthoclase-biotite-muscovite gneiss.
4. Black to dark-gray, massive to thinly-layered to highly laminated, vitreous non-feldspathic opaque-(muscovite) quartzite with conchoidal fracture and radiating extinction (meta-chert?). Quartz typically comprises over 95% of the rock. Lentils and layers of this sub-unit occur within all metasedimentary units.

Interlayering of lithologies occurs at all scales, and these rocks occur locally within all of the other metasedimentary units of the Shoo Fly Complex. Comingled calc-silicate rock and quartzite are quite common; mixed lithologies occur near contacts with schist. The following lithologies occur in minor amounts throughout the unit: 1) gray weathering, buff-colored quartzite with centimeter-scale dark quartz segregations (identical to those of the schist unit); 2) medium-grained, angular and rounded quartzite-, quartz-, and chert-rich fragmental layers; 3) flattened white- to cream-colored quartz- and chert-pebble conglomerate; 4) laminated gray-weathering quartzite with flattened (up to 1 cm) bluish quartzite pebbles; 5) pyritic schist and massive pyritic quartzite; 6) highly muscovitic zones; and 7) schistose interlayers 1 cm to 1 m thick.

II. Augen gneiss metaplutonic unit (LPzag) -- a compositionally variable assemblage of tan-, white-, and gray-weathering, white to dark-gray, fine- to coarse-grained, massive hypidiomorphic-granular to highly-foliated, granitic, syenitic, and gabbroic orthogneiss typically with feldspar porphyroclasts set in a finer-grained recrystallized matrix. Felsic and alkalic rocks are most abundant although melanocratic internal zonations are common. The augen gneiss bodies range in size from 3 km masses showing complex internal zoning, to centimeter-scale "lit-par-lit" injections, meter-scale sills, and larger lensoidal bodies.

The gneiss bodies contain foliated xenoliths and screens of all of the various lithologies of the Shoo Fly Complex. Scattered apophyses, cross-cutting veins, fine-grained chilled margin facies, and irregular discordant contacts together indicate an igneous origin for these rocks. Mixed zones of gneissic granitoid and metasedimentary rocks of the Shoo Fly Complex are common but cannot be shown at 1:24,000 scale. Within the gneissic granitoids 1m- to 100m-wide zones of foliated augen gneiss and blastomylonite are common. Ultramylonite seams up to 3 cm thick are locally developed. The gneisses, which post-date an early episode of folding and metamorphism in the Shoo Fly (Schweickert and Merguerian, 1980), are described in detail elsewhere (Merguerian, 1985). The following three types have been recognized although transitional lithologies occur:

1. Potash feldspar-quartz-plagioclase-biotite-muscovite-(chlorite)-(hastingsite)-(epidote)-(garnet)-opaque-(apatite)-(allanite)-(zircon) granite gneiss and quartz-plagioclase-muscovite-potash feldspar-(biotite)-(chlorite)-(epidote)-(apatite)-(zircon) granodiorite and diorite gneiss. The potash feldspar commonly occurs as perthite and is locally myrmekitic.
2. Perthite-hastingsite-plagiociase-biotite-(psilomelane)-quartz-(epidote)-(opaque)-allanite)-(sphene)-(zircon) syenite gneiss.
3. Magnesian hornblende-epidote-plagioclase-biotite-(quartz)-(chlorite)-(opaque)-(apatite) gabbro gneiss.

III. <u>Schist unit (LPzs)</u> -- a heterogeneous sequence of brown- to gray-weathering, tan to light-gray to dark-gray to black, well-foliated, medium- to coarse-grained schist, schistose gneiss, and phyllite. The following four sub-units have been recognized:

1. Quartz-muscovite-biotite-plagioclase-(orthoclase)-(chlorite)-(tremolite)-(calcite)-(garnet)-(graphite)-(tourmaline) schist and schistose gneiss.
2. Quartz-plagioclase-muscovite-biotite-(chlorite)-(garnet) schistose gneiss.
3. Biotite-muscovite-quartz-(plagioclase)-(orthoclase)-(garnet)-(chlorite)-(graphite)-(pyrite) schist and phyllite.
4. Muscovite-biotite-quartz-(plagioclase)-biotite-(opaque) schist.

The schistose rocks are interlayered with one another and with 0.5cm to 0.5 m thick layers and lenses of mica-quartzite and quartzofeldspathic gneiss. Complete transitions from mica schist to quartz-mica schistose gneiss to quartz-mica gneiss often occur within individual outcrops. Pods, lentils, and stringers of dark quartz from 2 mm to 2 m long occur in some zones, but they are typically 2 - 5 cm long and quite conspicuous. These quartz bodies are gray-black to bluish-black, flinty, extremely fine-grained and show conchoidal fracture. Minor lithologies in the unit include: dark-gray biotite phyllite, graphitic schist, pyritic schist, layers of angular to wispy quartz pebbles, and local zones of flattened quartz boulder conglomerate. Two outcrops of schist were found with sandy layers 3 - 50 cm thick showing relict detrital textures.

IV. <u>Calc-silicate and marble unit (LPzc)</u> -- a heterogeneous assemblage of calcareous rocks of diverse mineralogy and texture consisting of brown-, tan-, and green-weathering, light- to dark-green to gray-green to whitish well-layered, fine- to medium-grained calc-silicate rock, calcite and dolomite marble, and siliceous marble. The following four sub-units have been recognized:

1. Dark-green to black-green, diopside-biotite-orthoclase-quartz-plagioclase-(chlorite)-

(muscovite)-(calcite)-(epidote)-(apatite)-(sphene)-(zircon) calc-silicate rock.

2. Light-green to dark-green, diopside-quartz-biotite-plagioclase-(calcite)-(apatite)-(zircon) calc-silicate rock.
3. Light-green, quartz-diopside-plagioclase-(tremolite)-(vesuvianite)-(calcite)-(sphene) calc-silicate rock.
4. Whitish to light-green, calcite-(dolomite)-quartz-muscovite-(plagioclase)-biotite-graphite marble.

Outcrops are not common except within larger mappable rock bodies. Where outcrops of marble are extensive, a mini-karstic topographic surface exists. Small occurrences of the calc-silicate and marble that cannot be shown at 1:24,000 map scale are typically interlayered with quartzitic subunits of the quartzite and quartzofeldspathic gneiss. They also are sometimes interlayered with micaceous quartzite within sequences dominantly of quartzite and are associated with schist containing dark quartz pods. These calcareous rocks repeatedly occur near the contact between the quartzite and schist units (Map Sheets 1-4). This may indicate some vestige of stratigraphic continuity in an otherwise thoroughly sheared complex of lithologic units. Mechanical differences between the marble and quartzite creates intricate folding patterns at their contacts that were not recognized in the schist unit.

V. Amphibolite unit (LPza) -- two exposures of green-weathering, green, crudely-foliated amphibolite were found in the study area. They are medium-grained hornblende-plagioclase-biotite-quartz-epidote-opaque amphibolite and amphibolitic gneiss up to 120 m thick, and were found in Eagle and Rose Creeks in the Jupiter area. Elliptical domains 10 to 15 cm across are suggestive of an original volcanic pillow texture.

Age constraints. No fossils have been found in the Shoo Fly Complex of Tuolumne County, and therefore the absolute sedimentary age of the sequence is unknown. The combined effects of multiple deformations under variable metamorphic conditions further obscures any original stratigraphic relationships. Siluro-Ordovician to Pennsylvanian U-Pb and Rb-Sr ages (Sharp and others, 1982) on some gneissic granitoid bodies in the Jupiter area indicate that the Shoo Fly may be of early Paleozoic or older age. The interpreted pre-metamorphic protoliths of the Shoo Fly are nearly identical in lithology to the Shoo Fly of the northern Sierra Nevada (Schweickert and others, 1983, Merguerian, 1985).

The dominance of siliceous lithologies comprising the Shoo Fly Complex of the southern Sierra Nevada suggests derivation from a reworked continental source. Totally non-feldspathic quartzite±mica±opaques with radiating extinction is interpreted as meta-chert. The Shoo Fly evidently represents a thick sequence of sub-feldspathic psammite with subordinate pelite, chert, carbonate rock of variable composition, and rare volcanic rock probably deposited in early Paleozoic time-near the continental margin of western North America.

Igneous rocks

Metamorphic rocks of the Shoo Fly and Calaveras complexes are intruded by numerous late-syntectonic foliated granitoid sills in the vicinity of the Calaveras-Shoo Fly thrust and by post-tectonic felsic and mafic sills and dikes, granitic to mafic-ultramafic plutons, and by the

Sierra Nevada batholith. Tertiary volcaniclastic and volcanic rocks drape many of the prominent ridges. For the most part the igneous rocks were not mapped in detail and the smaller dikes and sills are not shown on the map. Excepting the lithologies described briefly below these rocks are described in Merguerian (1985).

Standard pluton. The Standard pluton (Figure 2) borders the southern edge of Map Sheets 3 and 4 but was not mapped in this study. Field and petrographic studies by W.D. Sharp (unpublished data) and R.A. Schweickert (unpublished data) indicate that the pluton is a steep-walled, internally zoned, medium- to coarse-grained, pyroxene- and hornblende-rich quartz diorite and monzodiorite with subordinate two pyroxene gabbro and ultramafic phases (W.D. Sharp, personal communication, 1983). There are igneous foliations but no through going metamorphic fabrics have been recognized. Sillimanite, found in the contact aureole southeast of the Standard pluton (Kerrick, 1970), and coexisting garnet-biotite-staurolite-sillimanite contact assemblages are found to the north in the present study and are superimposed on older penetrative fabrics in the Shoo Fly. U-Pb data from the Standard pluton yield a 164-170 m.y. middle Jurassic intrusive age (Sharp and Saleeby, 1979; Stern and others, 1981).

Mafic dikes of the Sonora dike swarm. The Shoo Fly and Calaveras complexes and the Standard pluton are multiply-intruded by a swarm of mafic dikes near lat 38°N. Over 1,000 dikes ranging from basalt to andesite have been mapped in the Shoo Fly and Calaveras by C. Merguerian and R.A. Schweickert (unpublished data). In the Shoo Fly, the dikes are sub-parallel to east-west-trending axial surface traces of folds that deform the Calaveras-Shoo Fly thrust.

The dikes occur as solitary sheets and dikelets 3 - 5 cm thick and as dense 25 m-wide zones of profuse multiple injections with anastomosing, chilled margins. Individual dikes within these zones have an average thickness of 1 m and offshoots are common. Three textural types have been recognized:

1. Light-gray to dark-gray spessartite and vogesite lamprophyres with non-oriented subhedral to euhedral phenocrysts of pargasitic amphibole, light-green amphibole, augite, and plagioclase up to 4 mm long. The dikes are generally less than 0.4 m thick.
2. Gray-green to gray-black, dense, dominantly aphyric basalt and andesite dikes which locally possess augite and brown amphibole microphenocrysts and have microgabbro and microdiorite cores when thicknesses exceed 2 m.
3. Dark-gray mottled medium- to coarse-grained, labradorite-phyric pyroxene-free basalt and andesite dikes. The phenocrysts are euhedral to subhedral (up to 4 mm) and the dikes are typically thicker than (1) or (2).

Cross-cutting relationships and chilled margin observations indicate that the dominantly aphyric dikes (2.), which numerically comprise over 35% of the mafic dike swarm, are of median relative age and thickness. They always cross-cut the thicker plagioclase-rich dikes (3.) and are in turn cut by thinner lamprophyre dikes (1.). The geology, geochemistry, and tectonic significance of the Sonora mafic dike swarm is treated elsewhere (Merguerian, 1985). A 157-159 m.y. K-Ar hornblende age for the dikes has been reported by Sharp (1980).

Mesozoic post-tectonic rocks including the Sierra Nevada batholith. Granitic rocks of the Sierra Nevada batholith intrude the Shoo Fly Complex and contact metamorphose its easternmost outcrops. Internal phases within the batholith were not mapped in the present study. The rocks are dominantly medium- to coarse-grained, biotite-hornblende-granite, granodiorite, and quartz monzonite (Bateman and others, 1963).

Along its western border a pronounced biotite and hornblende flow foliation, flow-oriented foliated xenolichs, and reduction in grain size occur. Recrystallization of the Shoo Fly in these areas yields a contact-induced increase in grain size. Elsewhere veins of granitic rock brecciate the Shoo Fly wallrocks. Late Jurassic to late Cretaceous ages have been reported for the batholith by many workers (Bateman and Clark, 1974; Evernden and Kistler, 1970; Stern and others, 1981).

Granitic plutons and dikes of unknown age. There are a number of small plutons in the Jupiter area (Map Sheets 1-4) and to the south (Figure 2) that may be satellitic to the Sierra Nevada batholith or pre-date it entirely. The largest of these are, from north to south, the Knight Creek, Basin Creek, and Hazel Green plutons (Figure 2). Most of these plutons and the batholith crosscut the Calaveras-Shoo Fly thrust.

The Knight Creek pluton is exposed in drainages of Knight and Rose Creeks in the Stanislaus and Columbia SE 7-1/2 minute quadrangles (Map Sheets 1 and 3). It is a medium- to coarse-grained biotite granite with local zones of pegmatite. The pluton crosscuts the Calaveras-Shoo Fly thrust and includes xenoliths of the Sonora mafic dike swarm along its western contact with the Calaveras Complex (R.A. Schweickert, personal communication, 1982).

STRUCTURAL GEOLOGY

The Shoo Fly Complex has endured a long and complicated structural history involving seven superposed deformations occurring at variable crustal depths (Table 1). The first four of these (D_1 – D_4) involved tight to isoclinal folding and local shearing under medium grade metamorphic conditions. The last three (D_5 - D_7) are marked by open folding and retrograde metamorphism of the older fabrics. Early in this evolution, between D_1 and D_2, metasedimentary rocks of the Shoo Fly Complex were discordantly intruded by sills and plutons of granite, syenite, and gabbro which subsequently formed the gneissic granitoid bodies (LPzag), a significant lithologic component of the Shoo Fly in Tuolumne County.

The Calaveras-Shoo Fly thrust formed during D_3 and is a folded syn-metamorphic ductile shear zone that varies in width from 1-2 km and has been traced over 90 km from lat. 38°05’N to 37°30’N. A remarkable along-strike D_3 textural consistency in the Calaveras-Shoo Fly thrust zone includes the formation of: (1) megascopic isoclinal, intrafolial, and rootless F_3 folds with a penetrative axial-planar S_3 mica foliation, spaced ductile shears and widespread transposition; (2) ellipsoidal slivers of foliated Shoo Fly flattened parallel to S_3 and highly elongated parallel to L_3 stretching lineations in sheathing mylonitic envelopes; (3) zones and seams of mylonite, blastomylonite, and ultramylonite; (4) macro- to microscopic strained quartz augen with internal sutures and core and mantle structure, as well as rounded feldspar augen exhibiting marginal granulation, bent twins, corrosion, and cracking with local replacement by muscovite; (5) mylonitic layering defined by adjacent highly strained and polygonized quartz ribbons with abrupt grain-size variations between layers; (6) highly laminated phyllonitic textures in schistose rocks with frayed mica augen surrounded by anastomosing S_3 folia of smaller recrystallized micas and quartzose ribbons; and (7) late-stage D_3 injections of protocataclasite, pseudotachylyte, foliated granitoid sills, and minor folding.

There is a strong contrast in lithology and structural history recognized across the Calaveras-Shoo Fly thrust where metamorphosed chaotic oceanic rocks of the Calaveras Complex are in mylonitic contact with polydeformed metapsammitic rocks of the Shoo Fly (Map Sheets 1-4, Figure 2). The D_1 and D_2 structural fabrics that formed in the Shoo Fly before the development of the D_3 Calaveras-Shoo Fly thrust mark episodes of isoclinal folding and medium-grade metamorphic recrystallization that pre-date juxtaposition with the Calaveras. In addition to the pre-D_3 structural fabrics, the gneissic granitoid bodies have no counterparts in the Calaveras. Figure 3 illustrates these contrasts and shows the near-orthogonal truncation of both S_1 and S_2 of the Shoo Fly against the Calaveras-Shoo Fly thrust.

The recognition of D_3 mylonization of D_1+D_2 fabrics in the Shoo Fly Complex along the Calaveras-Shoo Fly thrust indicates that upper plate Shoo Fly rocks record a more complex and presumably older structural history than the lower plate Calaveras rocks. During the formation of the thrust, the Calaveras Complex experienced its first regional deformation, which was characterized by long-limbed isoclinal folds and the development of a penetrative flattening foliation (Schweickert, 1981). In the thrust zone, syn-metamorphic flattening, disarticulation of layering, and intense silicification of the Calaveras occurs (Merguerian, 1981). Therefore, the oldest regional event shared by the Shoo Fly and Calaveras are D_3 and D_1 respectively, which created penetrative metamorphic fabrics (S_3 and S_1, respectively) that are regionally parallel to the trace of the Calaveras-Shoo Fly thrust (Figure 3).

The thrust and related structural features were folded by east-west-trending F_4 folds which were, in turn, crosscut by a middle Jurassic pluton (Standard pluton) and by mafic dikes of the Sonora swarm (Merguerian, 1985; Sharp and Saleeby, 1979; Stern and others, 1981). The proceeding structural features and igneous bodies are cut by N32°W and N30°E steep to vertical cleavages which are traceable into open, possibly conjugate, F_5, and F_6 folds that formed during the Nevadan orogeny of Late Jurassic time. The youngest N60°W to E-W vertical cleavage (S_7) is probably of upper Cretaceous age (Figure 3, Table 1).

Recognition of the relative structural chronology between various igneous events and regionally developed structural fabrics allows absolute age brackets on the various deformational events to affect the Shoo Fly Complex. Crosscutting isotopically dated intrusives indicate that the protracted deformational and metamorphic history recorded in the Shoo Fly Complex is the result of periodic Phanerozoic orogeny as indicated in Table 1. Available geochronologic data suggest that D_1 and possibly D_2, formed during the Antler orogeny, D_3 and possibly D_4 during the Sonoma orogeny, and D_5 and D_6 during the Nevadan orogeny. The Shoo Fly Complex records numerous episodes of Paleozoic and Mesozoic collisional deformation and igneous activity and therefore provides important constraints on models concerning the Phanerozoic evolution of the Cordilleran orogenic belt.

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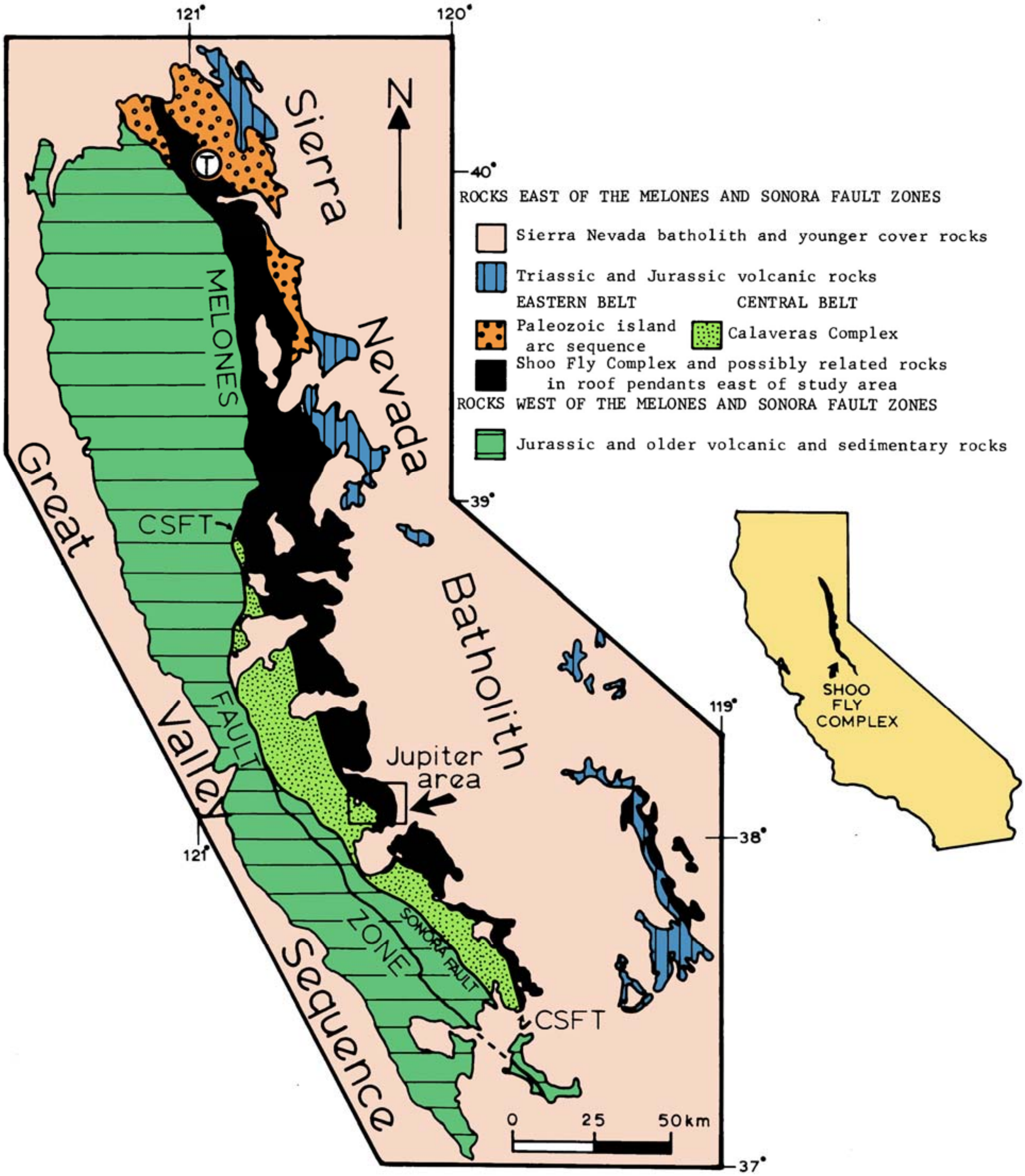


Figure 1. Sketchmap of the Shoo Fly Complex (black) and other tectonostratigraphic units of the Sierra Nevada foothills metamorphic belt. The Calaveras-Shoo Fly thrust (CSFT) extends from lat 39°N southward to lat 37°20’N. (After Schweickert and Merguerian [unpublished data].)

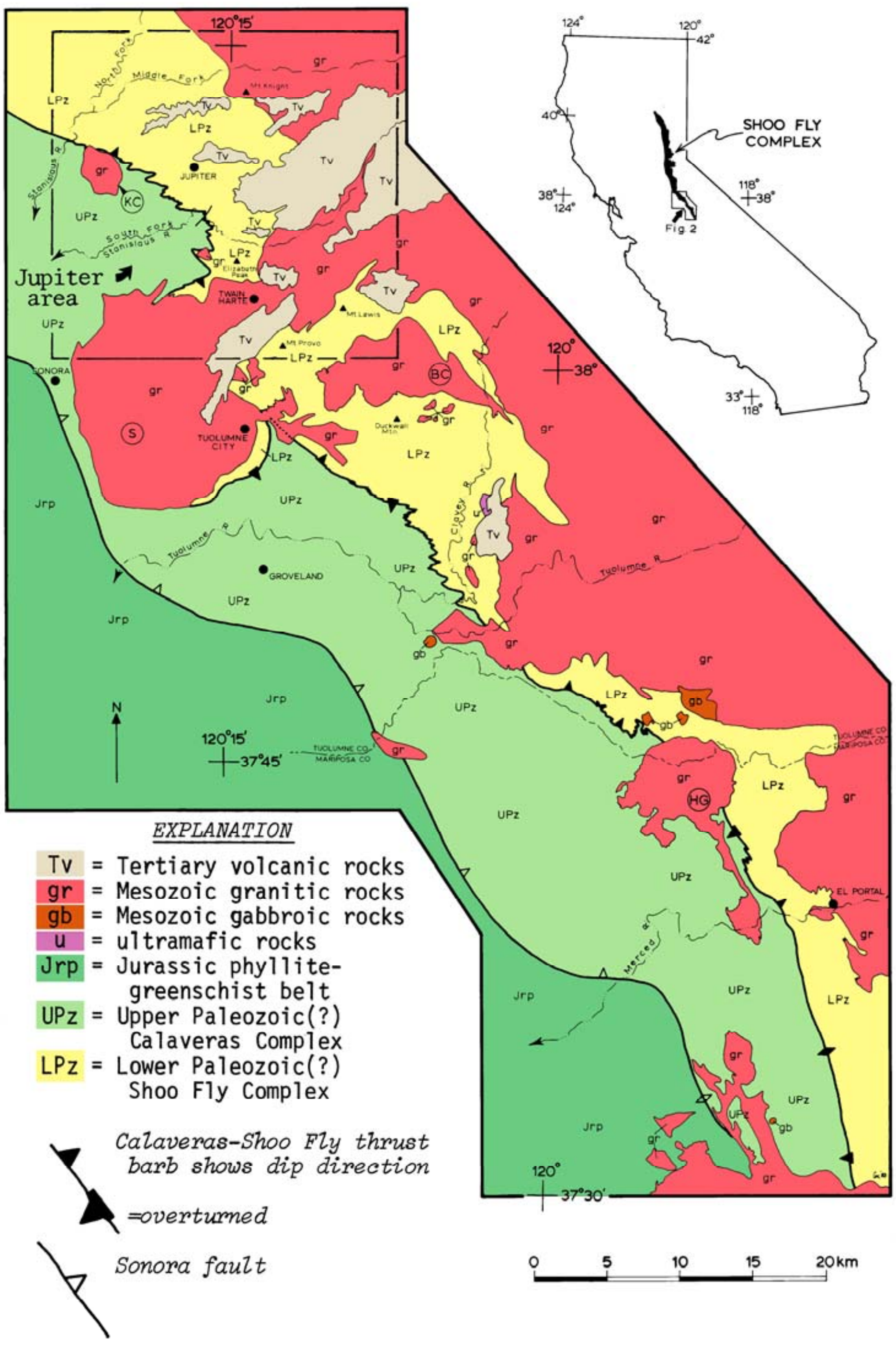


Figure 2. Geologic sketchmap of the Shoo Fly Complex and the Calaveras-Shoo Fly thrust in Tuolumne and Mariposa counties, California. The distribution of the Shoo Fly Complex and geometry of the thrust are outlined from detailed bedrock mapping at 1:24,000 scale accomplished during 1978-1981. Solid circles indicate cities and towns and solid triangles mark geographic localities. Large open circles are plutons: KC=Knight Creek, S=Standard, BC=Basin Creek, and HG=Hazel Green. Some map contacts are from Bowen (1969), Strand and Koenig (1965), Tobisch (1960); Schweickert (unpub. data); Schweickert and Bogen (1983), Turner and Ransome (1897, 1898); and Wagner and others (1981).

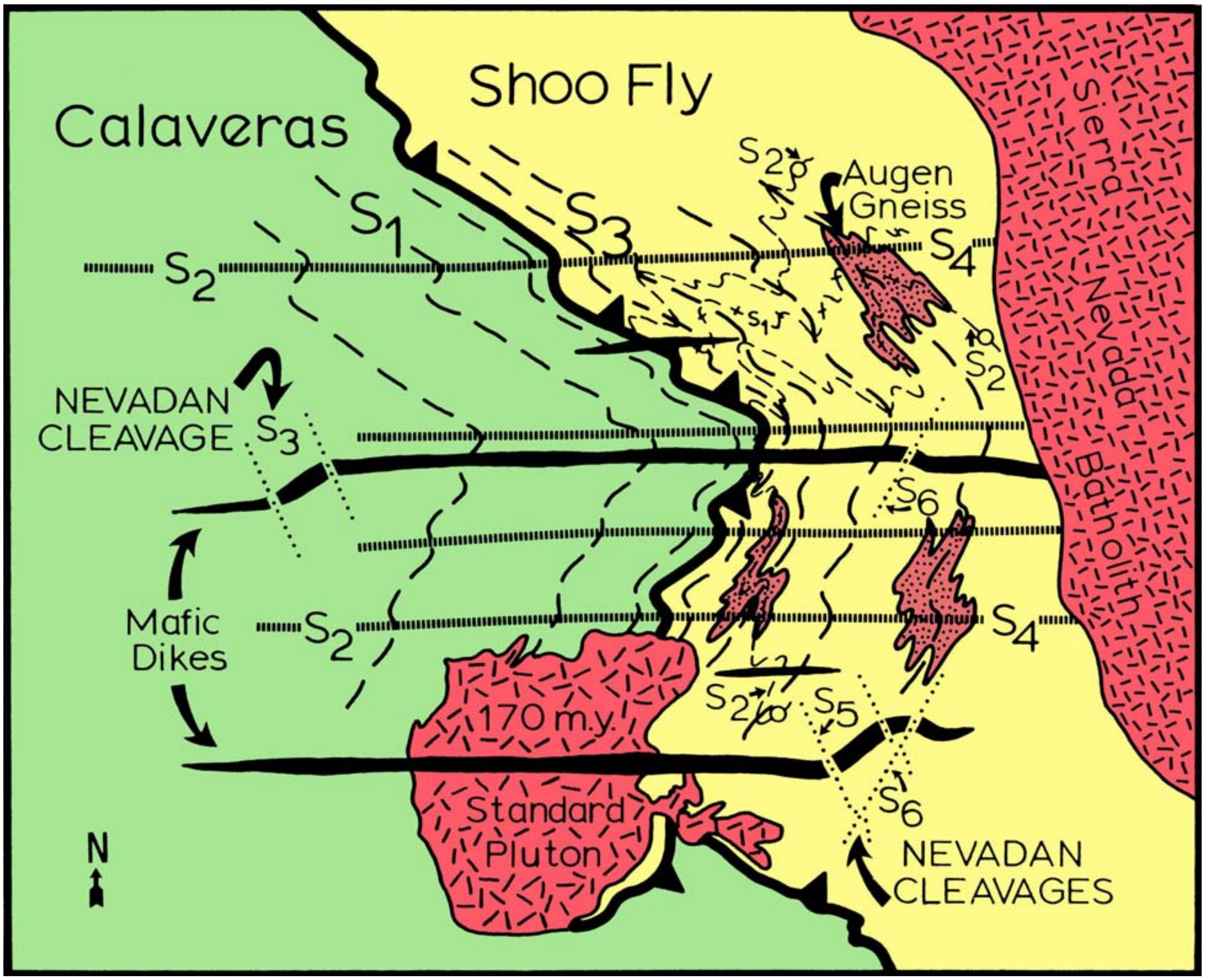


Figure 3. Cartoon depicting the correlation and nomenclature of structural fabrics developed across the Calaveras-Shoo Fly thrust zone. Early folds and metamorphic fabrics in the Shoo Fly (S_1+S_2) are regionally truncated against the thrust and signify a tectonic history for the Shoo Fly that predates D_3 juxtaposition with the Calaveras. The regional parallelism of D_3 Shoo Fly (S_3) and Calaveras (S_1) foliations is due to the fact that D_3 thrusting marks the first in a series of tectonic events shared by both Paleozoic complexes. East-west folding of the thrust (dashed line = Shoo Fly (S_4) and Calaveras (S_2)), is followed by the Middle Jurassic intrusion of the Standard pluton and by injection of mafic dikes (black). These igneous events are closely followed by folds and cleavage (dotted lines) developed during the Nevadan orogeny.

Table 1 - GEOLOGIC HISTORY OF THE JUPITER AREA TUOLUMNE COUNTY, CALIFORNIA

Holocene	Upland are affected by periglacial solifluxion.
Pleistocene	Accelerated uplift and development of trellised, deeply-incised, rejuventated stream system
Mio-Pliocene	I_8 Mudflow breccia ad volcanic flows of the Relief Peak Formation.
Oligo-Miocene	I_7 Rhyolitic ash flows of the Valley Spring Formation.
Eocene	Planation surface developed after post-Cretaceous uplift and erosion. Formation of consequent stream system.
Cretaceous	I_6 Intrusion of Sierra Nevada batholith and possibly other plutons.
Late Cretaceous (?)	D_7 N60°W to E-W, 90° fracture cleavage (S_7) parallel to axial surfaces of open F_7 folds.
Late Jurassic(?)	D_6 N30°E, 90° crenulation cleavage, black residue cleavage (S_6) parallel to axial surfaces of asymmetric open F_6 folds. Retrograde metamorphism.
<u>NEVADAN OROGENY</u> Late Jurassic	D_5 N32°W, 78°NE crenulation cleavage, black residue cleavage (S_5) parallel to axial surfaces of asymmetric open F_5 folds. Retrograde metamorphism.
Middle Jurassic(?)	I_5 Intrusion of the Knight Creek and possibly other plutons
Middle Jurassic	I_4 Intrusion of 159-157 m.y. Sonora dike swarm, sub-parallel to S_4.
Middle Jurassic	I_5 Intrusion of 170-164 m.y. Standard, Parrotts Ferry, and possibly other plutons.
Late Triassic(?)	D_4 N85°W, 90° spaced mica schistosity and crenulation cleavage (S_4) parallel to axial surfaces of isoclinal, tight, and crenulate F_4 folds plunging 47° into S85°E. Biotite-garnet grade metamorphism.
Permo-Triassic (?)	I_2 Intrusion of granitoid dikes and sills. Some foliated sills are late-syntectonic with respect to D_3

<u>SONOMA OROGENY?</u> Permp-Triassic (?)	D_3 Formation of the Calaveras- Shoo Fly thrust zone and intra-Shoo Fly ductile shear zones. Blastomylonitic foliation (S_3) parallel to the axial surfaces of isoclinal and rootless folds (F_3) plunging 42° into S75°E. There is significant tectonic imbrication within 2 km of the fault. The obliterative D_3 thrust fabric becomes a domainal blastomylonite and a mica foliation eastward from the thrust zone formed parallel to the axial surfaces of isoclinal to tight F_3 folds. Epidote-amphibolite grade metamorphism.
<u>ANTLER OROGENY</u>? Middle Paleozoic	D_2 Mica foliation and flattening foliation (+mylonite) (S_2) parallel to axial surfaces of isoclinal and rootless folds (F_2) with variable plunges. Folding and recrystallization of granitoid gneiss – Shoo Fly contacts. Amphibolite grade metamorphism.
Siluro-Ordovician to Permian (?)	I_1 Intrusion of protoliths of the gnessic granitoids as plutons into the Shoo Fly. Compositions range from mainly granite, granodiorite, and syenite to gabbro. Intrustive contacts are discordant, cutting the S_1 metamorphic layering.
<u>ANTLER OROGENY</u>? Pre-Silurian (?)	D_1 Metamorphic layering (S_1) in quartzite and quartz-mica-(feldspar)-gneiss parallel to axial surfaces of intrafolial and long-limbed isoclinal folds (F_1). Biotite grade metamorphism.
Late Precambrian (?) to Early Paleozoic	Deposition as a slope-rise sequence adjacent to the western edge of the North American miogeosyncline.

Table 1. - An interpretive geologic history of the Shoo Fly Complex of Tuolumne County, California. Numbered deformational (D_x) and igneous (I_x) events are listed in order of relative age based upon field relationships and geochronologic age data of Sharp and Saleeby (1979); Sharp (1980); Sharp and others (1982; in press), and Stern and others (1981). The absolute ages of the various D-events will be subject to change as more isotopic data becomes available.

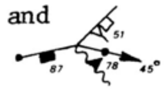
Explanation to Accompany Plate 1 (Merguerian, 1985b)

LITHOLOGIC UNITS

- Pv^p - Mio-Pliocene Relief Peak Formation - andesitic mudflow breccia
- Mv^r - Oligo-Miocene Valley Springs Formation - rhyolite ash flows
- gr - Granitoid rocks of the late Jurassic to late Cretaceous Sierra Nevada batholith and satellitic plutons of unknown age
- gb - Gabbroic plutons of unknown (Mesozoic?) age
- UPz - Upper Paleozoic to lower Mesozoic Calaveras Complex - argillite, chert-argillite, rhythmically bedded and massive chert, marble, talc-schist, rare basalt and sandstone layers
- LPz - Lower Paleozoic Shoo Fly Complex - a heterogeneous assemblage of highly deformed lower amphibolite grade psammitic metasedimentary rocks and post-S_1 discordant metaplutonic rocks. The complex can be subdivided into the following lithologic units which are listed in order of decreasing map area:
  - q - massive to well-laminated orthoquartzite, mica-quartzite, and quartzofeldspathic gneiss
  - ag - granite, syenite, and gabbroic orthogneiss (augen gneiss)
  - s - mica-quartz schist
  - c - calc-silicate rock, marble, and marble schist$\pm$graphite
  - a - amphibolite

STRUCTURAL SYMBOLS

Structural symbols are defined for both the Calaveras Complex and the Shoo Fly Complex. Symbols are often mixed; the point of intersection is the observation point.



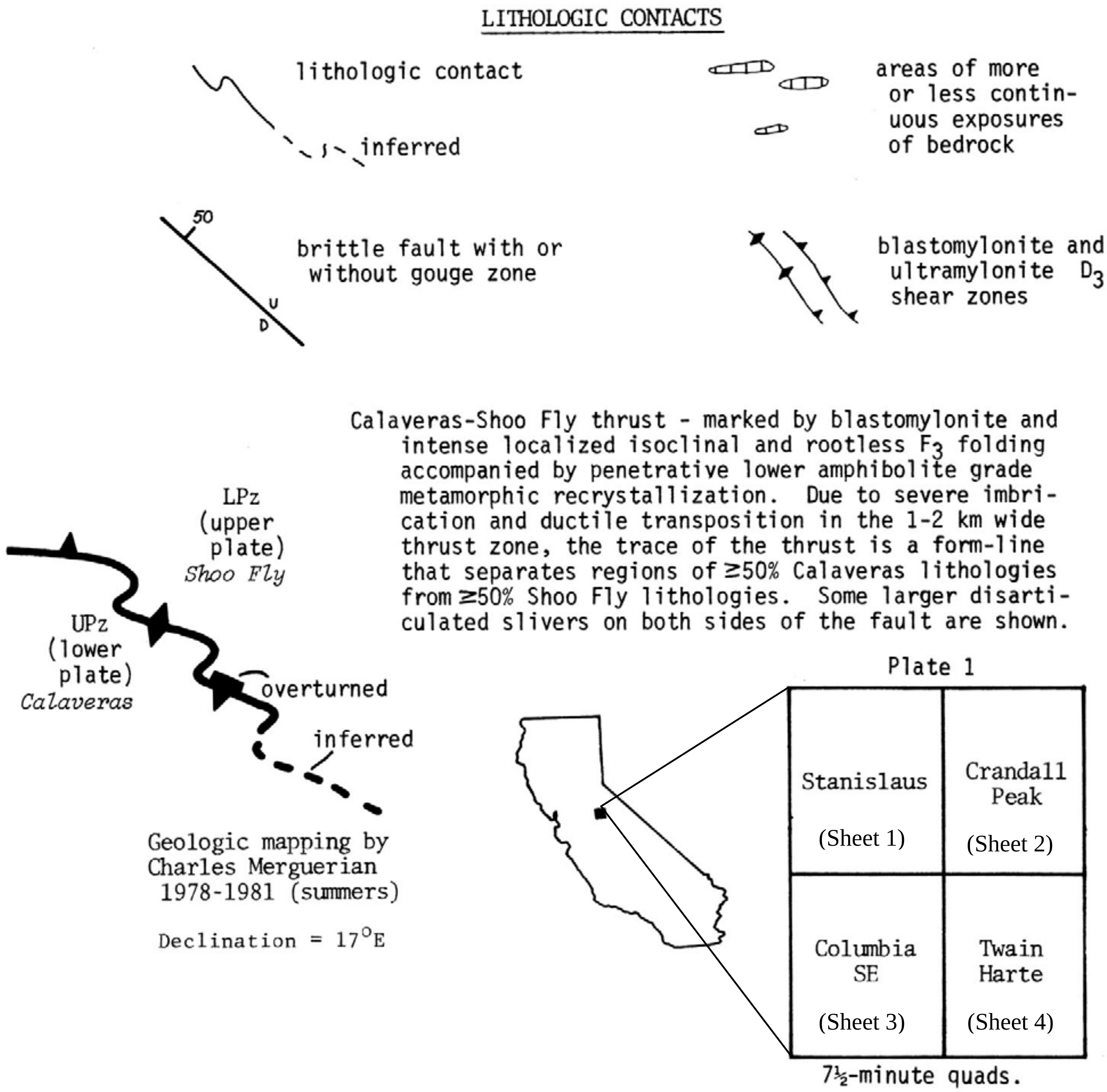
Upper Paleozoic Calaveras Complex

S_0	Bedding
S_1	Flattening foliation
F_1/L_1	Fold axis/mineral streaking
S_2	Slip cleavage and spaced biotite foliation
F_2/L_2	Fold axis/crenulation axis or intersection lineation

Lower Paleozoic Shoo Fly Complex

S_0	Bedding defined by compositional layering indicates metasedimentary origin but extensively transposed in the study area
S_1	Metamorphic layering or mica foliation related to rare F_1 isoclinal folds
F_1/L_1	Fold axis/mineral streaking
S_2	Penetrative lower amphibolite grade mica foliation related to F_2 isoclinal and rootless folds
F_2/L_2	Fold axis/mineral streaking
S_3	Blastomylonitic epidote-amphibolite facies foliation formed axial planar to F_3 isoclinal and rootless folds during formation of the Calaveras - Shoo Fly thrust. Shearing, boudinage, transposition and metamorphic overprinting of older fabric elements (S_1, S_2, etc.) is obliterative within 2 km of the ductile fault creating a wide zone of ductile shear deformation. Away from D_3 shear zones the S_3 foliation is domainal with mica recrystallized axial planar to isoclinal to tight folds
F_3/L_3	Fold axis/elongation lineation
S_4	Spaced schistosity or crenulation cleavage with biotite, muscovite, and quartz growth axial planar to tight to isoclinal folds
F_4/L_4	Fold axis/crenulation or intersection lineation
S_5	N32°W, 78°NE Nevadan cleavage axial planar to crenulate and open F_5 folds
S_6	N30°E, 90° Late Nevadan cleavage axial planar to crenulate and open F_6 folds
S_7	N70°W to E-W, 90° Cretaceous high angle fracture cleavage and local reverse faulting with quartz veining and mineralization. Open F_7 folds are observed, however, $F_{5, 6, 7}$ folds are generally not plotted on Plate 1
S_i	Igneous flow layering

Foliation symbols are square  when axial planar to folds. Down-plunge fold assymetries are shown.



Geological mapping by
Charles Merguerian, 1978-1981 (summers)

Some contacts from:

Schweickert, R.A. (unpublished data)

Wagner, D.L., Jennings, C.W., Bedrossian, T.L., and Bortugno, E.J., 1981, Geologic map of the Sacramento Quadrangle: California Division of Mines and Geology, Regional Geologic Map Series Map No. lA, Scale 1:250,000.

CALIFORNIA GEOLOGY

April 1986

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GEOLOGIC MAPPING

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BEDROCK GEOLOGIC MAP OF THE SHOO FLY COMPLEX IN THE JUPITER AREA, STANISLAUS RIVER DRAINAGE, TUOLUMNE COUNTY, CALIFORNIA. By Charles Merguerian, 1985. Four maps (scale 1:24,000) and 34-page text. $6.00.

This report presents a description of the lithology, structure, and metamorphism of the lower Paleozoic Shoo Fly Complex in the western metamorphic belt of the Sierra Nevada. Structure and deformation are related to the Calaveras-Shoo Fly thrust as observed in the "Jupiter area". The mapped area is covered on the Stanislaus, Crandall Peak, Columbia SE, and Twain Harte 7.5-minute topographic quadrangles (U.S. Geological Survey). The mapped area is bounded by State Highways 4, 49, 108, and by the Middle and South Forks of the Stanislaus River. This report provides a detailed record of the geology of the region and places critical constraints on tectonic interpretations of the foothill metamorphic belt.

This mapping project was completed as part of the author's Ph.D. dissertation, Columbia University. Prior to this investigation the published geologic mapping in this area was done in 1898 (Big Trees, U.S. Geological Survey Folio by Turner and Ransome). Unpublished reconnaissance mapping for the State Map Project was done by DMG geologists in 1979 (Long Barn and Columbia 15-minute quadrangles).

This detailed mapping of the "Jupiter area" presents new data on (1) the stratigraphy of the Shoo Fly Complex and related rocks and (2) the nature and timing of structures and metamorphism of the Shoo Fly Complex and the Calaveras-Shoo Fly thrust.

The report is available for $6.00 from DMG offices in Pleasant Hill and Sacramento. A reference copy will also be available at the Information Section in Sacramento, Pleasant Hill, and Los Angeles offices.

Canyon of the South Fork Stanislaus River. *Photo by Charles Merguerian.*

GORDON K. VAN VLECK, Secretary
THE RESOURCES AGENCY

GEORGE DEUKMEJIAN, Governor
STATE OF CALIFORNIA

CAROL A. THOMAS, Acting Director
DEPARTMENT OF CONSERVATION

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Merguerian, Charles, 1985b, Bedrock geologic map of the Shoo Fly complex in the Jupiter area, Stanislaus River drainage, Tuolumne County, California: California Division of Mines and Geology, Open-file Report 85-11SF, Scale 1:24,000, four sheets, 25 p. text, 3 figures, 1 table, and three-page map explanation. (**Note:** This online version is shorter in total pages (21 p.) as a result of single line paragraph reformatting.)

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