GEOLOGIC MAP OF THE DUNCAN PEAK AND SOUTHERN PART OF THE CISCO GROVE 7-1/2' QUADRANGLES, PLACER AND NEVADA COUNTIES, CALIFORNIA

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LOCATION AND ACCESS

This map covers an area of 123 km^2 on the west slope of the Sierra Nevada, an uplifted and west-tilted range in eastern California (fig. 1). The area is located 20 km west of Donner Pass, which lies on the east escarpment of the range, and about 80 km east of the Great Valley Province. Interstate Highway 80 is the major route over the range at this latitude and secondary roads, which spur off from this highway, provide access to the northern part of the area. None of the secondary roads crosses the deep canyon cut by the North Fork of the American River, however, and access to the southern part of the area is provided by logging roads that spur off from the Foresthill Divide Road that extends east from Auburn to the Donner Pass area (fig. 1).

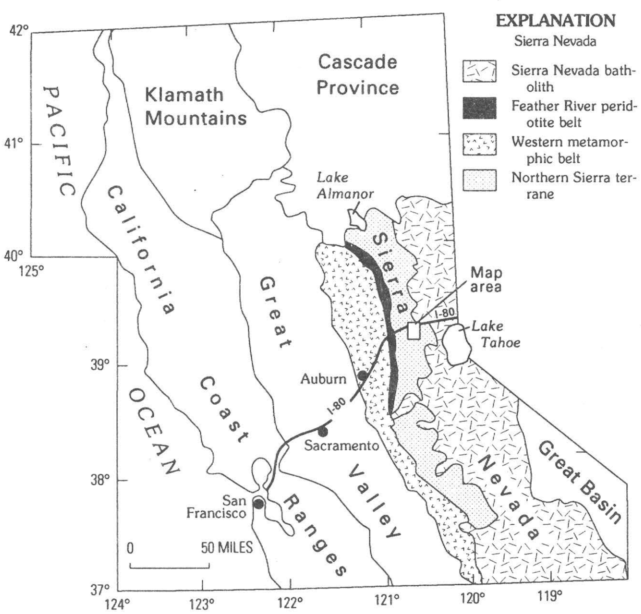

Figure 1. Index map showing location of map area relative to major physiographic/geologic areas in California.

GEOLOGIC SETTING

Metamorphosed Paleozoic and Mesozoic sedimentary and volcanic rocks underlie most of the map area. They are part of a belt of rocks, referred to as the northern Sierra terrane (Coney and others, 1980), that extends 120 km north to Lake Almanor where it is buried by Tertiary and Quaternary volcanic rocks of the Cascade Province (fig. 1). The fault-bounded Feather River peridotite belt lies about 15 km west of the map area (fig. 1) and marks a major tectonic boundary separating rocks of the northern Sierra terrane from Paleozoic and Mesozoic rocks to the west that were accreted to the northern Sierra terrane during the Mesozoic (Day and others, 1985). A variety of plutonic rocks, ranging in age from Middle Jurassic to Early Cretaceous, intrude the metamorphic rocks in the map area. The metamorphic and plutonic rocks are unconformably overlain by erosional remnants of Tertiary volcanic rocks and scattered Quaternary glacial deposits.

Metasedimentary and metavolcanic rocks in the northern Sierra terrane have been divided into sequences that are separated by regional unconformities. The oldest sequence consists of the lower Paleozoic Shoo Fly Complex, which is made up of four regionally extensive thrust blocks referred to as the (ascending) (1) Lang sequence (2) Duncan Peak allochthon (3) Culbertson Lake allochthon and (4) Sierra City melange (Schweickert and others, 1984b). The thrust blocks are composed of imbricate thrust slices that were juxtaposed prior to the Late Devonian. The Shoo Fly Complex is unconformably overlain by Upper Devonian to Middle Pennsylvanian volcanic and basinal rocks, referred to collectively and informally as the Taylorsville sequence. Rocks of the Permian volcanic sequence range in age from late Early to early Late Permian (Harwood, 1988; 1992) and rest disconformably on the Taylorsville sequence. Upper Triassic conglomerate and limestone and Upper Triassic and Lower Jurassic(?) volcaniclastic rocks and conglomerate form a southward transgressive overlap assemblage at the base of the Mesozoic sequence. These rocks are overlain by Lower and Middle Jurassic volcaniclastic rocks of the Sailor Canyon Formation that are overlain, in turn, by Middle Jurassic volcanic rocks of the Tuttle Lake Formation.

Structures in the four major sequences of rocks and the unconformities that separate them indicate that the northern Sierra terrane was deformed periodically between the middle Paleozoic and the early Mesozoic. The thrust blocks of the Shoo Fly Complex, which probably represent an accretionary wedge (Schweickert and others, 1984b) were amalgamated, uplifted, and eroded prior to deposition of the Upper Devonian rocks in the Taylorsville sequence. The region was differentially uplifted and eroded again between the Middle Pennsylvanian and the late Early Permian. No compressive structures have been recognized that might relate to this episode of deformation and Harwood (1988) suggested that the region may have been thermally uplifted and extended in response to the initial phases of mid-Permian volcanism. Late Permian and (or) Early Triassic deformation locally produced east-northeast-trending folds in the Paleozoic rocks in the map area and broadly uplifted the region to the north. Following deposition of the Mesozoic sequence, the region was deformed, metamorphosed to greenschist grade, and tilted eastward approximately 90° about a north-north-west-trending axis during the Late Jurassic.

Mafic and ultramafic rocks of the (informal) Emigrant Gap mafic complex of James (1971) intrude the metamorphic rocks in the northwestern part of the map area. Snoke and others (1982) suggested that the Emigrant Gap mafic complex and similar bodies in the Sierra Nevada and Klamath Mountains may represent local magma systems related to the wide-spread Middle Jurassic volcanic rocks in these mountain belts. Numerous dikes, ranging from gabbro to quartz porphyry, extend eastward from the Emigrant Gap mafic complex and probably represent parts of a feeder system for volcanic rocks of the Tuttle Lake Formation. The Emigrant Gap mafic complex and the dikes were intruded after to eastward rotation of the region in the Middle Jurassic. Plutonic rocks of the Sierra Nevada batholith intruded the metamorphic rocks and the Emigrant Gap mafic complex after they were rotated to their present, near-vertical attitudes.

Following intrusion of the Sierra Nevada batholith, Tertiary volcanic rocks, which were erupted first from centers east of the range and later from centers along the Sierran crest, blanketed the west slope of the Sierra Nevada. Due to late Cenozoic uplift and erosion of the range, however, the Tertiary volcanic rocks are preserved only in ancient river channels and as scattered remnants on the higher interfluves. Quaternary till and glacial outwash are present in the major drainages and till covers some uplands in the map area.

STRATIGRAPHY

SHOO FLY COMPLEX

Two of the four regional thrust blocks of the Shoo Fly Complex occur in the map area. The Lang sequence, which makes up the lowest regional thrust block, is divided locally into the Antoine Canyon Formation, the Big Valley Bluff Formation, the Screwauger Breccia, and the Barney Cavanah Ridge Formation. The structurally overlying Duncan Peak allochthon is divided into three informal lithologic units composed of chert, chert and argillite, and chert breccia. Although these specific units have not been mapped separately outside of the map area, the Lang sequence, characterized by various facies of quartzose turbidites, and the Duncan Peak allochthon, composed primarily of ribbon chert, are recognized as the lower two regional thrust blocks in the northern Sierra terrane (Schweickert and others, 1984b).

Few fossils have been found in the Shoo Fly Complex, and its age and tectonic history are not known in detail. Because the Shoo Fly is a tectonic complex, the depositional age or age range of each thrust block must be determined independently. Furthermore, the depositional ages of the thrust blocks set only maximum limits on the age of tectonic amalgamation of the Shoo Fly Complex.

Available data indicate that the depositional age of the Shoo Fly Complex ranges from Ordovician(?) to Devonian(?). Because the Shoo Fly is intruded by Late Devonian rocks of the Bowman Lake batholith (Hanson and others, 1988) and unconformably overlain by Upper Devonian (Frasnian and Famennian) epiclastic and volcanic rocks (Hanson and Schweickert, 1986), the least upper bound on both the depositional and tectonic age of the Shoo Fly is Late Devonian. Conodonts from a lense of limestone interbedded with quartzose turbidites in the Lang sequence are indicative of a late Middle to Late Ordovician age (Harwood and others, 1988) and currently provide the oldest depositional age for rocks in the Shoo Fly Complex. Detrital zircons from volcanic-lithic sandstone beds in the Culbertson Lake allochthon yielded a U/Pb age of 509 Ma (Girty and Wardlaw, 1984), which indicates a Late Cambrian or Early Ordovician provenance age for those rocks; but the matrix is undated. Quartzose sandstone from the Sierra City melange has yielded detrital zircons with a U/Pb age of about 2.0 Ga. (Girty and Wardlaw, 1985). Conodonts indicative of a Late Ordovician age and North American affinity (Hannah and Moores, 1986) were recovered from a limestone block in the Sierra City melange, and a second block of limestone produced megafossils of Late Ordovician age and North American affinities (Potter and others, 1990). Zircons from a felsic tuff interbedded with the matrix of the Sierra City melange give a U/Pb age of late Early Silurian (423+5-10 Ma) (Saleeby and others, 1987), which is the youngest depositional age yet obtained for the Shoo Fly Complex. Furthermore, this zircon age indicates that at least the upper thrust blocks of the Shoo Fly Complex were juxtaposed between the late Early Silurian and the Late Devonian.

Lang sequence

The Lang sequence is composed primarily of quartz sandstone-pelite turbidites. It consists of four map units that are differentiated on the basis of bedding characteristics, sandstone-pelite ratios, and degree of internal deformation. Quartz sandstone beds have been metamorphosed to quartzite in the Shoo Fly Complex.

Antoine Canyon Formation: The name "Antoine Canyon Formation" is given here to thick-bedded, parallel-laminated, generally fine grained quartzite with minor thin beds of black pelite that make up the lowest unit of the Lang sequence in this area. Exposures in Antoine Canyon (sec. 13, T. 15 N., R. 12 E., Duncan Peak 7-1/2' quadrangle), from which the unit name is derived, are designated as the type locality, and similar stream-polished exposures in Manilia Canyon and the lower reaches of Screwauger Canyon (sec. 18, T. 15 N., R. 3 E., Duncan Peak 7-1/2' quadrangle) are designated as reference localities. Harwood (1988) referred informally to the formation as the amalgamated quartzite unit.

Quartzite beds, which range in thickness from a few centimeters to several meters, are characteristically parallel laminated and poorly graded. Thin tabular pelite inclusions and flame structures are common in the quartzite beds. Pelite layers a few millimeters to several centimeters thicker locally separate the thicker quartzite beds and the pelite beds are commonly interrupted by erosional channels filled with coarse-grained quartzite or quartz-granule conglomerate that grade abruptly into fine-grained quartzite. Quartzite beds commonly rest directly on quartzite beds (amalgamated) without intervening pelite beds. Zones of thin-bedded (2-5 cm) quartzite and pelite occur sporadically in the thick-bedded quartzite sequence. Commonly, these quartzite-pelite zones contain slumped and intermixed lenses of quartzite and pelite, or tightly appressed intrafolial slump folds, or both.

The Antoine Canyon Formation is at least 2,700 m thick at the type locality, but the total thickness is unknown because its base is not exposed. The formation is overlain locally by the Screwauger Breccia and by the Big Valley Bluff Formation in much of the map area. Its age is considered to be Ordovician(?) to Devonian(?).

Screwauger Breccia: The name "Screwauger Breccia" is given here to a chaotic unit composed primarily of broken thin beds of quartzite in a black pelite matrix. Mappable blocks of gray ribbon chert, fine- to coarse-grained massive orthoquartzite, and quartz-feldspar granule conglomerate occur sporadically in the unit. Exposures on the southwest slope of Duncan Peak and in the adjacent upper reaches of Screwauger Canyon (secs. 9, 10, 15, 16, T. 15 N., R. 13 E., Duncan Peak 7-1/2' quadrangle), from which the unit name is derived, are designated as the type locality.

The unit is composed of disrupted material and is devoid of normal-bedded sequences and internal stratigraphic continuity. Fragments of quartzite beds, 2 to 30 cm thick and as long as 3 m, are engulfed in black pelite that contains abundant smaller fragments of quartzite. Some quartzite fragments are graded, and most contain thin parallel laminations that are broken and offset in small steps by closely spaced fractures oriented perpendicular to the strike of the laminations. Some of the larger quartzite fragments contain tightly appressed to isoclinal folds, but these are rare, and the dominant style of deformation that produced the breccia appears to have been layer-parallel extension of semiconsolidated quartz-rich turbidites.

In addition to disrupted quartzite beds, the unit also contains blocks of light-gray, fine- to coarse-grained, vitreous orthoquartzite several meters to tens of meters on a side. These blocks contain abundant fractures healed by white vein quartz, but recognizable bedforms are rare. In this respect, the orthoquartzite blocks are unlike quartzite beds in either the Antoine Canyon or Big Valley Bluff Formations. The origin of the orthoquartzite blocks is unknown, but they must have been deposited in a different environment than those of the disrupted quartzite beds found in the breccia. Blocks of light-gray ribbon chert, equal in size or larger than the orthoquartzite blocks, are scattered throughout the Screwauger Breccia. They are lithologically similar to chert in the Duncan Peak allochthon and probably were incorporated in the breccia during tectonic amalgamation. Chert-rich breccia, composed of angular chert fragments, as much as 2 cm in length, mixed with variable amounts of black pelite and coarse-grained quartz, forms irregularly shaped, wispy, and lenticular masses that were incorporated into the Screwauger Breccia as it formed. Quartz-granule conglomerate interbedded with quartzite and minor pelite form the largest blocks in the breccia. The origin of these blocks is unknown, but they may have formed in the same environment as the blocks of orthoquartzite, or they may be large slump blocks derived from the Big Valley Bluff Formation.

The total thickness of the Screwauger Breccia is unknown, but its maximum exposed thickness is at least 300 m. The Screwauger Breccia has the characteristics of a type I melange described by Cowan (1985) and it is interpreted to be a slump deposit formed at the time when the Lang sequence and Duncan Peak allochthon were structurally juxtaposed. Its age is considered to be Ordovician(?) to Devonian(?).

Big Valley Bluff Formation: The name "Big Valley Bluff Formation" is given here to interbedded quartzite, pelite, and quartz-feldspar granule conglomerate (grit) that constitutes most of the Lang sequence in this area. Characteristic exposures occur at Big Valley Bluff (sec. 25, T. 16 N., R. 12 E., Duncan Peak 7-1/2' quadrangle), from which the unit name is derived, and these exposures as well as those on the north rim of the canyon of the North Fork of the American River west and east of Big Valley Bluff are designated as the type locality. Exposures along the Foresthill Divide Road between Tadpole Campground and Ford Point (secs. 5 and 6, T. 15 N., R. 13 E., Duncan Peak 7-1/2' quadrangle) form an easily accessible reference section for the unit.

Gray quartzite and green, gray, and black pelite commonly form graded turbidite beds that range in thickness from about 10 cm to 2 m. Coarse-grained quartz sand or grit at the base of the quartzite grades into medium- to fine-grained sand at the top, where it locally interfingers with pelite. Parallel laminations, pelite inclusions, and sole markings are scarce. Quartzite-pelite ratios range from 2:1 to 4:1. Massive grit beds, from 1 to 3 m thick, are composed of poly- and monocrystalline quartz, alkali feldspar, sparse plagioclase, and locally abundant coarse-grained, detrital muscovite. Fine-grained muscovite and chlorite form the matrix of the grit beds, which are most commonly grain supported. Thick grit beds occur in the turbidites. Amalgamated packets of grit beds, as thick as 20 m, define local channel deposits in the formation. Lenses of gray ribbon chert a few meters thick define broken horizons in the turbidites. A lens or block of white and tan marble occurs at the confluence of Earl Gray Creek and the North Fork of the American River and represents the only calcareous rocks found in the formation.

The total thickness of the Big Valley Bluff Formation is unknown because of intense folding, but its maximum structural thickness is about 7,000 m. The formation overlies both the Antoine Canyon Formation and the Screwauger Breccia in the southern part of the area, and it is overlain by the Barney Cavanah Ridge Formation and the chert unit of the Duncan Peak allochthon. Its age is considered to be Ordovician(?) to Devonian(?) based on the occurrence of late Middle to Late Ordovician conodonts from a lens of limestone interbedded with quartz-pelite turbidites north of the map area (Harwood and others, 1988; Harwood, 1992) and on its position unconformably below Upper Devonian rocks.

Barney Cavanah Ridge Formation: The name "Barney Cavanah Ridge Formation" is given here to a unit composed primarily of hematite-rich purple slate and thin-bedded quartzite that contains zones of broken quartzite and pelite with blocks of chert, quartz-granule conglomerate, and massive orthoquartzite, which are lithologically similar to blocks in the Screwauger Breccia. Exposures on the west slope of Barney Cavanah Ridge (secs. 16 and 21, T. 15 N., R. 13 E., Duncan Peak 7-1/2' quadrangle), from which the unit name is derived, are designated as the type locality. Exposures on the west slope of the knob containing the VABM Lawton (sec. 14, T. 16 N., R. 12 E.) are designated as a reference locality. These rocks were referred to informally as the Lawton terrane by Schweickert and others (1984b) and as the melange of Deep Canyon by Harwood (1988).

About half of the formation is composed of variegated purple and green slate that contains intensely folded but coherent thin beds of white-weathering, gray-green, fine-grained quartzite and quartz-rich siltstone. Arenite-pelite ratios in the well-bedded part of the formation range from 1:4 to 1:10. The remainder of the formation is composed of chaotic mixtures of purple and dark-gray slate, disrupted thin quartzite beds, and large blocks of chert, orthoquartzite, and quartz-granule conglomerate.

In the coherent part of the formation, the purple slate is locally bioturbated and the thin quartzite beds show a variety of internal structures ranging from graded turbidites with lode casts to planar sandstone beds with trough cross-bedding and cross-laminated flazer bedding. In chaotic zones, which range in thickness from a few meters to several hundred meters, disrupted thin quartzite beds are commonly slump folded. Beds in the chert blocks, and to a lesser extent, beds in the orthoquartzite blocks are folded, and these folds are discordant to folds in the chaotic matrix. Bed forms in much of the formation indicate their deposition by turbidity flows, but trough cross beds in parts of the formation suggest their deposition in a relatively shallow water environment that was subjected to periodic storm-wave erosion and deposition. The restricted distribution of this formation and local bed forms within the formation suggest that it formed during episodes of tectonic instability related to thrusting of the Duncan Peak allochthon over the Lang sequence. The occurrence of chert, quartzite, and grit blocks suggest it may be related depositionally to the Screwauger Breccia, but it is not as pervasively disrupted.

The maximum exposed thickness of the Barney Cavanah Ridge Formation is 1,500 m, but the total depositional thickness is unknown due to the locally chaotic nature of the rocks. The unit is structurally overlain by chert and chert-argillite units of the Duncan Peak allochthon. Its age is considered to be Ordovician(?) to Devonian(?).

Duncan Peak allochthon

The Duncan Peak allochthon is composed of gray ribbon chert, black chert and siliceous argillite, and minor chert breccia. These lithologic units occur as thin, fault-bounded slices that are locally interleaved with tectonic slivers of quartzite-pelite turbidites of the Big Valley Bluff Formation. The chert and chert and argillite units are characterized by numerous isoclinal folds and the chert breccia unit is marked by a penetrative fabric oriented parallel to the trace of the bounding thrust faults. Thrusting of the allochthon occurred prior to the Late Devonian because Upper Devonian volcaniclastic rocks of the Sierra Buttes Formation unconformably truncate the axial traces of early isoclinal folds, thrust faults, and fault-bounded slices of chert and the Big Valley Bluff Formation south of Sugar Pine Point.

Chert: Gray ribbon chert with thin partings of black siliceous argillite is the most widespread and characteristic rock type in the Duncan Peak allochthon. Radiolarians are visible locally in the chert beds, but extracted radiolarians are not age diagnostic.

Chert and argillite: Excellent exposures of interbedded black chert and siliceous argillite occur in New York Canyon and on the glaciated slope southwest of Mears Meadow. Bedding in this unit ranges in thickness from 1 to 10 cm, with chert and siliceous argillite alternating in regular intervals. In New York Canyon, siliceous argillite with only minor amounts of black chert forms much of the unit. Lenticular masses of the gray ribbon chert unit are structurally intercalated with the siliceous argillite along northwest-trending faults. The chert and argillite unit is intensely deformed adjacent to these faults. Southwest of Mears Meadow, the chert and argillite unit is isoclinally folded.

Chert breccia: The best exposures of the chert breccia unit occur at the north end of Barney Cavanah Ridge just west of Little Bald Mountain. White and black chert fragments, as long as 0.5 cm, make up about 80 percent of the breccia and black pelite chips make up 10 to 20 percent of the breccia. The fragments are set in a sparse granular to pelitic matrix composed of rounded quartz grains, chlorite, and fine-grained sericite. The chert breccia unit is lithologically similar to chert breccia lenses in the Screwauger Breccia.

TAYLORSVILLE SEQUENCE

Harwood (1988) gave the informal name, Taylorsville sequence, to the Upper Devonian through lower Upper Permian rocks in the northern Sierra terrane. As additional paleontologic data became available to more clearly define the regional disconformity between the Permian and older rocks, the name, Taylorsville sequence, was restricted to the Upper Devonian through Middle Pennsylvanian rocks and the Permian rocks were referred to collectively and informally as the Permian volcanic sequence (Harwood, 1992). This subdivision emphasizes the fact that the Paleozoic volcanic rocks in the northern Sierra terrane were deposited in two relatively brief episodes, the first during the Late Devonian and Early Mississippian and the second in the mid-Permian. During the intervening period of volcanic quiescence, which lasted nearly 100 m.y., the northern Sierra terrane collected deep-water, siliceous pelagic sediments.

In the map area, the Taylorsville sequence consists of the Sierra Buttes, Taylor, and Peale Formations. The lower member of the Sierra Buttes Formation consists of coarse-grained submarine debris flows composed of angular felsic volcanic fragments and variable amounts of black chert intraclasts. This map unit is lithologically similar to member C of the Sierra Buttes Formation described by Hanson and Schweickert (1986) and probably correlates with the stratigraphically higher parts of the formation exposed in the vent-proximal area near Sierra Buttes. The lower member of the Sierra Buttes is conformably overlain by an upper member composed of fine-grained, generally thin bedded tuff and tuffaceous siltstone that does not occur north of Interstate Highway 80. Thin lenses of chert-rich granule conglomerate are interbedded with the fine-grained volcaniclastic deposits. The upper member represents distal volcaniclastic rocks deposited on the fringe of a submarine volcanic apron. Chert and quartzite-rich debris was derived from the Shoo Fly Complex.

The Sierra Buttes Formation is conformably overlain by andesitic crystal-lithic turbidites of the Taylor Formation (Harwood , 1983). Stratigraphic relations in the Sierra Buttes and Taylor Formations are particularly well exposed in the glaciated outcrops on the north slope of Monumental Ridge.

On the south slope of Monumental Ridge, the Taylor Formation is overlain by volcaniclastic rocks of the lower member of the Peale Formation that is composed predominantly of fine-grained, thin-bedded tuff and tuffaceous siltstone interbedded with black slate and scattered lenses of chert-granule conglomerate. Chert-rich debris was derived from locally uplifted areas of the Shoo Fly Complex within the volcanic arc (Harwood and others, 1991). Coarse-grained volcaniclastic debris-flow deposits, which contain sparse jasper and alkali feldspar-phyric volcanic clasts, occur in the lower part of the member and are prominently exposed near the southeast shore of SP Lakes. Near Sugar Pine Point, andesitic turbidites of the Taylor Formation pinch out and, to the southeast, the lower member of the Peale Formation rests on the upper member of the Sierra Buttes Formation. Without the intervening Taylor Formation, it is difficult to separate these units.

The chert member of the Peale Formation conformably overlies the lower member and is composed of green and gray ribbon chert. Rusty-weathering black argillite and chert occur in the chert member southeast of SP Lakes.

Rocks in the Taylorsville sequence range in age from Late Devonian to Middle Pennsylvanian. Most of the fossil data that support age determinations for units in the Taylorsville sequence come from scattered localities north of the map area (Hannah and Moores, 1986; Hanson and Schweickert, 1986; Harwood, 1988; 1992; Harwood and Murchey, 1990). However, radiolarians indicative of a Late Mississippian and Early Pennsylvanian age occur in the chert member of the Peale Formation west of Big Valley (table 1, loc. 1).

PERMIAN VOLCANIC SEQUENCE

In the map area, the Permian volcanic sequence consists only of the Reeve Formation, but to the north, it is composed of the Arlington, Goodhue, and Reeve Formations as well as the Robinson Formation of McMath (1958, 1966). Paleontologic data indicate that these formations are equivalent lithofacies deposited from the late Wolfcampian or early Leonardian to the early Guadalupian (Harwood, 1988; 1992). The Arlington Formation consists of chert-rich conglomerate, pebbly mudstone, breccia, volcaniclastic sandstone and slate. The Goodhue Formation locally overlies the Arlington Formation and consists primarily of basaltic breccia and pillowed flows. The Reeve Formation overlies the Goodhue in the northern part of the northern Sierra terrane and consists of andesitic tuff breccia and flows. Locally, the lower part of the Reeve Formation contains chert-rich conglomerate, volcaniclastic sandstone, and tuffaceous slate typical of the Arlington Formation.

In the map area, the Reeve Formation is composed primarily of thin-bedded, fine-grained tuff and tuffaceous siltstone. Coarse-grained volcaniclastic sandstone beds as thick as 2 m are locally interbedded with the tuffaceous siltstone. Locally, the sandstone beds are calcareous and contain crinoidal debris and indeterminate shell fragments. West of Big Valley, a debris-flow deposit composed predominantly of white plagioclase and volcanic-lithic fragments contains scattered brachiopod fragments indicative of a late Early Permian age (table 1, loc. 2) (Harwood, 1983). East and northeast of SP Lakes, chert-rich conglomerate occurs at the base of the Reeve Formation.

Mesozoic sequence

The Mesozoic sequence is composed of Upper Triassic conglomerate and limestone, Upper Triassic and Lower Jurassic(?) tuff, volcaniclastic sandstone and conglomerate, Lower and Middle Jurassic volcaniclastic sandstone, tuff, and slate of the Sailor Canyon Formation, and Middle Jurassic andesitic volcanic rocks of the Tuttle Lake Formation. In the northern part of the map area, Upper Triassic rocks rest disconformably on the Permian Reeve Formation, but they progressively overlap older Paleozoic rocks toward the south and rest with profound angular unconformity on the Shoo Fly Complex at the North Fork of the American River. Lindgren (1900) first recognized the unconformity at the American River, but the stratigraphic relations he proposed for rocks above and below the unconformity were revised by Clark and others (1962) and Harwood (1983). This report provides additional information on the regional distribution and lithologic variations of the basal Mesozoic rocks and their relation to structures in the underlying Paleozoic rocks that have important bearing on Late Permian to Late Triassic deformation in this part of the Sierra Nevada.

Four discontinuous units have been mapped above the Mesozoic unconformity and below the well-dated Lower Jurassic rocks of the Sailor Canyon Formation. These basal Mesozoic units are lithologically heterogeneous and their contacts are gradational. The only direct paleontologic data on the age of the basal Mesozoic units comes from conodonts in the limestone unit at the North Fork of the American River that are indicative of a Late Triassic (late Carnian through Norian) age (table 1, loc. 3). The conglomerate unit that gradationally underlies the limestone unit is assumed to be Late Triassic in age, and no older than Carnian. The tuff and conglomerate unit that gradationally overlies the limestone is inferred to be Late Triassic and Early Jurassic(?) in age, but it can be no younger than Sinemurian, the age of the oldest fossils in the Sailor Canyon Formation (Clark and others, 1962; Imlay 1968).

Table 1. Fossil localities in Duncan Peak and southern part of Cisco Grove 7-1/2' quadrangles, Calif.

Locality	Map unit	Fossils	Fossil age	Reference
1	Peale Formation, chert member	*Scharfenbergia tailleurense*	Late Mississippian to Early or Middle Pennsylvanian	B.L. Murchey, written commun., 1990
2	Reeve Formation	*Chonetinetes* sp., *Megousia* sp., *Neospirifera* sp., *Aviculopecten* sp., *Cyrotorostra*? sp. indent., gastropod? indnt., crinoid columnals	Mid-Permian (Roadianor Wordian)	Harwood, 1983
3	Reeve Formation, Limestone block	Echinoderm debris	Possible late Early to Middle Devonian	J.T. Dutro, Jr., written commun., 1988 (see Harwood, 1992)
4	Reeve Formation	Trace fossils: *Planolites*, *Muensteria*, *Scalarituba*, *Helminthoida*	Indeterminate	C.K. Chamberlain written commun. to D.A. Davis, 1986
5	Unnamed limestone	*Epigondollela* cf. *E.* abneptis (Huckriede)	Late Triassic (late Karnian through Norian)	A.G. Harris, written commun., 1981 (see Harwood, 1983)
6	Sailor Canyon Formation	? *Paltechioceras* spp.	Early Jurassic (late Sinemurian)	D.G. Taylor, written commun., 1988
7	Sailor Canyon Formation	*Reynesoceras* cf. R. *ragozzoni* Hauer), *Arieticeras* sp., *Ostrea*? sp.	Early Jurassic (Pliensbachian)	J.W. Miller, written commun., 1987
8	Sailor Canyon Formation	*Weyla*	Early Jurassic (Sinemurian to Pleinsbachian)	N.J. Silberling, written commun. to D.A. Davis, 1986
9	Sailor Canyon Formation	Hildoceratid or Arietidid ammonite	Early Jurassic	N.J. Silberling, written commun. to D. Stuart Alexander, 1967
10	Sailor Canyon Formation	Hildoceratid ammonites, highly deformed	Early Jurassic	J.W. Miller, written commun., 1987
11	Sailor Canyon Formation	*Dactylioceras* sp	Early Jurassic	Clark and others, 1962; Imlay, 1968
12	Sailor Canyon Formation	*Orthildaites*? sp., *Hildaites* sp. *Dactylioceras* cf. D. *directum* (Buckman), *Protogrammon* oceras? sp.	Late Early Jurassic (early Toarcian)	Clark and others, 1962
13	Sailor Canyon Formation	Deformed ammonite	Early Jurassic(?)	D.G. Taylor, written commun., 1988

Conglomerate: From the North Fork of the American River to the north border of the map area, the lowest Mesozoic unit is conglomerate that varies significantly in composition along strike. At the American River, the unit is clast-supported, chert-pebble conglomerate composed predominantly of rounded, gray and black chert clasts derived from the Duncan Peak allochthon. Felsic volcanic and quartzite clasts, derived from the Sierra Buttes Formation and the Shoo Fly Complex, respectively, make up less than five percent of the unit. From Little Granite Creek to Sugar Pine Point, the conglomerate is composed predominantly of green, gray, and black chert clasts (90 percent) with the remainder being scattered quartzite, granitoid, felsic volcanic, and limestone clasts. Rounded granitoid boulders, as large as 0.5 m in diameter occur sporadically in this part of the conglomerate and were apparently derived from the small intrusive body (PTRgd?) directly below the conglomerate. On the north slope of Big Valley, well-rounded clasts of tuff and tuffaceous siltstone, derived from the underlying Reeve Formation, make up more than 95 percent of the conglomerate unit and are associated with scattered quartzite and chert clasts derived from the Shoo Fly Complex. In this locality, the beds are massive, as thick as 2 m, and clast supported. Coarse-grained quartz sand occurs locally in the interstices between the volcanic clasts. From the vicinity of Cisco north to Fordyce Road, the lower part of the conglomerate unit consists of massive debris-flow deposits composed of angular to subrounded chert and limestone clasts, as much as 10 cm in length, supported in a recrystallized calcareous siltstone or tuffaceous matrix composed of actinolite, plagioclase, biotite, quartz, and small chert fragments. Chert-rich pebble conglomerate and trough cross-bedded chert- and quartz-rich sandstone overlies the debris-flow deposits and locally forms the lowest Mesozoic unit north of Fordyce Road.

Limestone: On the north wall of the American River Canyon, chert-pebble conglomerate grades up into thin-bedded, gray limestone that contains beds of metamorphosed calcareous siltstone, as thick as 6 cm, and scattered lenses of chert-granule conglomerate. The upper part of the unit is massive, gray and white limestone that contains scattered *Heterastridium* (Clark and others, 1962) and small crinoid fragments. In Little Granite Creek, the unit is composed of limestone breccia and massive gray calcarenite. The breccia consists of blocks of light- and dark-gray, massive and stylolitic limestone, as long as 0.5 m, set in a matrix of gray calcarenite or tan-weathering, calcareous siltstone that contains abundant shell fragments.

Tuff and conglomerate: Green and gray metamorphosed tuff, lapilli tuff, and tuffaceous siltstone with scattered lenses of calcareous, chert-rich granule conglomerate and sparse limestone fragments form the bulk of this unit in the map area. The unit generally is composed of beds, from 3 to 30 cm thick, of fine-grained, tabular, non-graded, tuff and tuffaceous siltstone. Granule conglomerate lenses have sharp, locally erosive lower contacts and are commonly matrix-supported and indistinctly graded. Massive lapilli tuff composed of subrounded, porous weathering, plagioclase-phyric andesitic(?) fragments, as much as 2 cm in diameter, occurs in scattered outcrops along the trail northeast of Little Granite Creek. The volcanic debris was not eroded from Paleozoic units but , rather, it is juvenile, early Mesozoic tephra, derived from an unknown source, that was reworked and mixed with calcarenite, calcareous mudstone, and chert-rich epiclastic debris in a shallow-water environment. Fine-grained, thin-bedded, green tuff gradationally overlaps the Upper Triassic limestone unit at the North Fork of the American River and rests unconformably on various lithologic units in the Duncan Peak allochthon to the south. In New York Canyon, sparse thin lenses of chert-pebble conglomerate and gray limestone occur at and near the base of the unit. Southeast of the map area, gray tuff interfingers with chert-pebble conglomerate and coarse-grained, chert-rich sandstone derived from the Shoo Fly Complex.

The basal Mesozoic units are interpreted to represent a shallow-water marine transgressive sequence that lapped southward onto an eroding positive area during the Late Triassic. North of Sugar Pine Point, Upper Triassic rocks rest disconformably on mid-Permian rocks, but, to the south, stratigraphically higher units in the transgressive sequence unconformably truncate progressively older Paleozoic units. These map relations indicate Late Permian to Late Triassic deformation that varied from broad uplift of the Paleozoic basement in the northern part of the map area to compressive folding accompanied by pronounced local uplift and erosion of the basement in the south. Depositional patterns in the basal Mesozoic rocks were strongly influenced by Permian to Triassic structures in the basement rocks.

From the south slope of Monumental Ridge to the North Fork of the American River, the basal Upper Triassic conglomerate is a littoral deposit dominated by clasts derived from local substrates. West of Big Valley, for example, the basal conglomerate is essentially monolithologic and composed of volcaniclastic siltstone clasts derived from the underlying Reeve Formation. South of Sugar Pine Point, where units of the Taylorsville sequence change strike to the east and define the north limb of Permian to Triassic anticline, the basal conglomerate is distinctly polymict and contains clasts derived from various local units in the basement. The abundance of chert clasts derived from the Shoo Fly Complex increases southward from Sugar Pine Point.

On the north wall of the American River canyon, the basal conglomerate unit thins and pinches out gradationally into the overlying Upper Triassic limestone unit. This gradational change from epiclastic to carbonate deposition occurs where rocks of the Taylorsville sequence trend eastward and rest unconformably on the Shoo Fly Complex. The Upper Triassic limestone unit apparently formed as a narrow reef or platform at an erosional knick point in the Late Triassic topography that was controlled by the change in basement lithologies. The Shoo Fly Complex apparently was more resistant to erosion than the Taylorsville sequence, and it formed the core of an uplifted anticline south of the American River.

Limestone breccia exposed in Little Granite Creek formed on the distal slope of the limestone reef or platform. The chert- and limestone-clast debris-flow deposits, which make up much of the basal conglomerate unit between Cisco and Fordyce Road, also may have formed originally on the distal slope of the limestone reef and slumped northward into deeper water. This interpretation is speculative, however, because no chert- and limestone-clast debris has been found in the limited exposures at the north end of the limestone unit.

The tuff and conglomerate unit gradationally overlaps the limestone unit and rests unconformably on the Shoo Fly Complex south of the North Fork of the American River. Because eustatic sea level was falling in the Late Triassic (Haq and others, 1987), southward transgression of the basal Mesozoic units was probably related to erosion and eventual subsidence of the positive area underlain by the Shoo Fly Complex south of the American River.

Although the composition of the basal Mesozoic units varies significantly along strike, all of the units contain bed forms indicative of shallow-water deposition and all contain variable amounts of epiclastic debris derived from local rocks below the Triassic unconformity. These characteristics of the basal Mesozoic rocks are not found in the overlying Sailor Canyon Formation, which implies that major changes in source terranes and depositional environments occurred in the region during the Early Jurassic.

Sailor Canyon Formation: The Sailor Canyon Formation is composed of pyritic black slate, feldspathic sandstone, gray tuff and tuffaceous siltstone, scattered thin beds of calcarenite, and a variety of debris-flow deposits including mappable lenses of diamictite in its upper part. A section measured along the railroad right-of-way east of Cisco, shown in figure 2, is representative of the formation in the northern part of the map area.

The lower 100 m of the formation in the measured section consists primarily of rusty-weathering, pyritic, carbonaceous, black slate that contains tabular, parallel laminated, very fine grained to fine-grained, feldspathic sandstone beds that range in thickness from 10 mm to 6 cm. Impressions of ammonites, associated with pelecypod impressions, occur at scattered localities and are indicative of Sinemurian and Pliensbachian ages (table 1, locs. 6-11). The black slate and feldspathic sandstone grade up into a thick interval of parallel-layered, gray tuff, tuffaceous siltstone, and black slate. Tuffaceous beds, which are not graded and only locally contain thin, parallel laminations, range in thickness from 2 to 20 cm in the lower part and from 10 to 50 cm in the upper part of the interval. Calcarenite beds, averaging 20 cm in thickness but attaining 1 m in thickness, occur in local zones in the tuffaceous rocks, but only one zone has sufficient lateral continuity to be mapped as a discontinuous horizon. The calcarenite in this horizon is associated with medium-grained, graded, feldspathic sandstone. The upper part of the measured section is composed of interbedded black slate and feldspathic sandstone that contain scattered lenses of conglomerate and pebbly mudstone composed of rounded volcanic, chert, limestone, and quartzite clasts and sparse angular rip-up clasts of black slate and feldspathic quartzite. The lower contact of the diamictite layers is erosive.

From the vicinity of the North Fork of the American River southeastward, the Sailor Canyon Formation is composed of distinctly graded, feldspathic sandstone

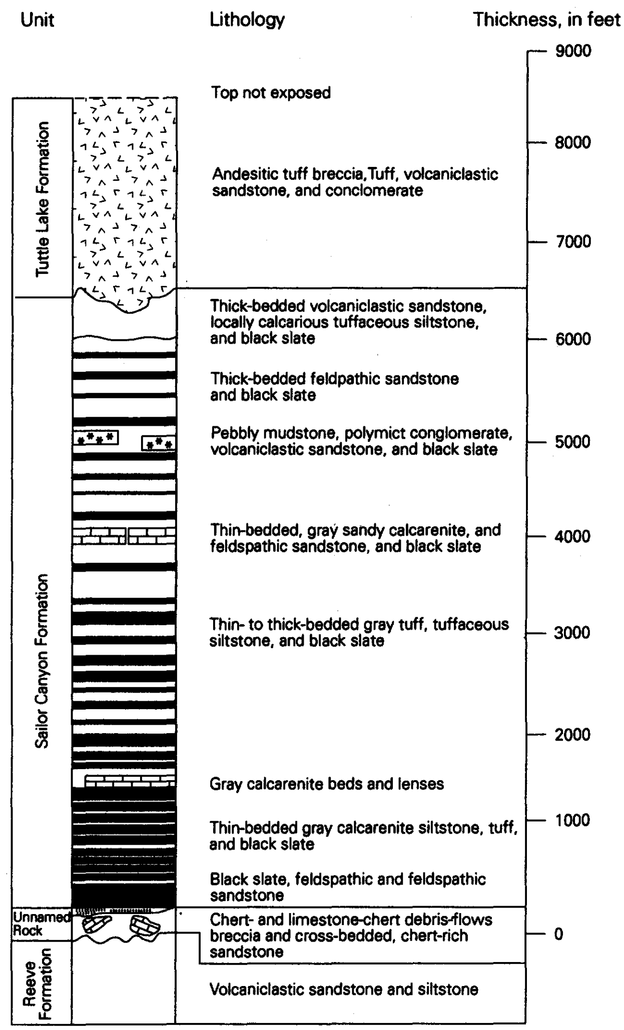

Figure 2. Measured section through the Sailor Canyon Formation along S.P. Railroad between Cisco and Big Bend, Calif.

and black slate turbidites. Gray tuff and tuffaceous siltstone beds occur at scattered intervals in the turbidites. Massive pebbly mudstone layers, as much as 15 m thick, occur in the upper part of the formation. In contrast to the disseminated occurrence of conglomerate and pebbly mudstone lenses in the northern part of the map area, conglomerate and pebbly mudstone occur in a fairly narrow stratigraphic interval in the Royal Gorge 7-1/2' quadrangle to the southeast. Thin, commonly parallel laminated beds of gray tuffaceous siltstone are interbedded with black slate within 20 m of the top of the Sailor Canyon Formation and mark the gradational boundary into the overlying Tuttle Lake Formation.

Tuttle Lake Formation: The Tuttle Lake Formation is composed of metamorphosed tuff breccia, tuff, and minor volcaniclastic sandstone and conglomerate. Clinopyroxene-rich gabbro dikes and plagioclase-porphyry dikes intrude the tuff breccia and are locally abundant in the lower part of the formation. Fragments in the tuff breccia are dominantly clinopyroxene-phyric andesite or basaltic andesite but plagioclase-rich and plagioclase-clinopyroxene andesite fragments are locally prominent. Layering is not common or easily recognized in the tuff breccia except where epidote-rich clasts, which make up as much as 30 percent of the fragments in some exposures, are abundant and help define layers in the tuff breccia as thick as 10 m.

In the north-central part of the map area, the contact between the Tuttle Lake and Sailor Canyon Formations is an erosional unconformity but, to the southeast, the contact is conformable and gradational over a zone as much as 20 m thick. Ammonites recently discovered in the gradational contact zone in the adjacent Royal Gorge quadrangle are indicative of a Middle Jurassic age, no older than Early Bajocian and no younger than Bathonian. These fossils indicate that initial volcanism of the Tuttle Lake Formation was younger, by several ammonite zones, than previously determined on the basis of *Tmetoceras* (Imlay, 1968), which is indicative of an Aalenian age (D.G. Taylor, written commun., 1991). A possible Bathonian age, around 170 Ma, for the beginning of andesitic volcanism in the Tuttle Lake Formation is compatible with local geologic relations.

Northwest of Tuttle Lake, the base of the Tuttle Lake Formation defines an ancient channel eroded into the Sailor Canyon Formation. Beds in the Sailor Canyon Formation are truncated by the base of the Tuttle Lake Formation. Furthermore, at least two large slump blocks of interbedded black slate and feldspathic sandstone typical of the Sailor Canyon Formation, occur in the lower part of the Tuttle Lake Formation near the thalwig of the ancient channel. The channel is presently located east of the Emigrant Gap mafric complex and we conclude that it formed in the Middle Jurassic during forceful intrusion of early phases of the Emigrant Gap mafic complex when strata of the Sailor Canyon Formation and underlying units were essentially horizontal.

STRUCTURE

Metamorphic rocks in the area contain a variety of superposed structures that can be related to episodes of Paleozoic and Mesozoic deformation by their relation to the regional unconformities and a few dated plutons. Our tectonic interpretations are based on the assumption that each regional unconformity was essentially horizontal when the overlying rock sequence was deposited. This assumption may be misleading, particularly for the basal Mesozoic sequence, which lapped southward onto a local positive area, but we know of no other way to approximate the original geometry of the structures in the older rocks. The following structural analysis progresses in inverse chronological order, and the kinematic interpretations of older deformational events are less certain than those of younger events.

MESOZOIC DEFORMATION

Structures in the Mesozoic rocks have traditionally been related to the Late Jurassic Nevadan orogeny (Schweickert and others, 1984a) but new isotopic studies indicate that major Mesozoic deformation in this area occurred in the Middle Jurassic. Wracher and others (1991) reported U/Pb ages ranging from 171.5 to 162.9 Ma from dioritic and granodioritic rocks north of the Emigrant Gap mafic complex. These plutonic rocks were finally intruded into the Tuttle Lake and Sailor Canyon Formations and the underlying Paleozoic rocks after the county rocks had been rotated to their present, near vertical, attitude about a north-northwest trending axis. Major block rotation of the Mesozoic and Paleozoic rocks in this area occurred during a short time interval in the Middle Jurassic, certainly after deposition of the youngest dated strata in Sailor Canyon Formation (Bathonian) but prior to about 163 Ma. Snoke and others (1982) reported a U/Pb age of 163 Ma on zircon from two-pyroxene diorite that James (1971) interpreted to be late-stage magma of the Emigrant Gap mafic complex It appears, therefore, that the Emigrant Gap mafic complex and the granitic rocks just to the north were emplaced contemporaneously.

Structures in the Emigrant Gap mafic complex indicate that the ultramafic rocks were emplaced as crystal mushes that were differentiated from the enclosing mafic magma by magmatic flow (James, 1971). Structures in the wall rocks indicate forceful emplacement of the complex. The country rocks east of the complex are intensely sheared in a zone as much as 300 m wide. North- northeast-trending, vertical, plagioclase- and quartz-porphyry dikes, which contain smeared-out fragments of mafic and ultramafic rocks, are abundant in the shear zone. The dikes extend east of the shear zone, where they strike northeast and are significantly less deformed. The chert member of the Peale Formation in the shear zone is locally folded and offset by several closely spaced faults that show sinistral displacements of a few tens of meters. The faults are intruded by abundant, sheared, plagioclase- and quartz-porphyry dikes and sparse gabbro dikes. Adjacent to the Emigrant Gap mafic complex on Monumental Ridge, the contact between the Sierra Buttes Formation and the Shoo Fly Complex, as well as units in the Shoo Fly, are folded into a northeast-trending, northeast-plunging anticline. James (1971) first recognized this anticline and ancillary folds and related them to emplacement of the Emigrant Gap mafic complex. The contact between the Sierra Buttes Formation and the Shoo Fly Complex on Monumental Ridge is a steeply east-dipping thrust fault that bifurcates to the south, where the upper thrust locally places the Sierra Buttes Formation over the Taylor Formation. Southeast of Monumental Ridge, a gabbro dike intrudes the inferred trace of the thrust fault that separates the Sierra Buttes Formation from the Shoo Fly Complex to the north. Thrusting of the Sierra Buttes Formation apparently occurred early in the emplacement history of the Emigrant Gap mafic complex because the thrust fault at the base of the Sierra Buttes Formation is folded by the northeast-trending anticline at the margin of the complex.

Rocks in the Shoo Fly Complex adjacent to the west margin of the Emigrant Gap mafic complex also are intensely sheared and folded (Schweickert and others, 1984b). Plagioclase-porphyry dikes, like those found east of the complex, intrude the Shoo Fly and contain a strongly developed gneissic foliation in the shear zone. Folds adjacent to the west margin of the complex trend and plunge northeast but, unlike folds adjacent to the east margin, these folds show dextral asymmetry (Schweickert and others, 1984b; Wracher and others, 1991).

Prior to block rotation of the region and emplacement of the Emigrant Gap mafic complex and related granitic plutons, the Sailor Canyon Formation was locally uplifted and eroded in the northern part of the map area. There, the Tuttle Lake Formation rests disconformably on the Sailor Canyon Formation but farther south the contact is conformable and gradational. Local uplift and erosion of the Sailor Canyon Formation may have been related to initial deep magmatism that gave rise to the Emigrant Gap mafic complex and related granitic plutons.

Structures in the upper Paleozoic rocks: Upper Paleozoic rocks in the map area show evidence of two episodes of deformation. The older episode occurred between the Middle Pennsylvanian and the late Early Permian and the younger episode occurred between the early Late Permian and the Late Triassic.

Throughout the northern Sierra terrane, upper Lower Permian volcanic and volcaniclastic rocks rest disconformably on older rocks (Schweickert, 1981; Harwood, 1988, 1992). Evidence for the disconformity comes primarily from paleontologic data, which indicate that the youngest age of the chert member of the Peale Formation is Middle Pennsylvanian (Desmoinesian) and the oldest age of the overlying Permian rocks is late Wolfcampian or early Leonardian (Harwood, 1992). The age of the youngest and oldest strata on opposite sides of the disconformity, however, varies throughout the northern Sierra terrane (Harwood, 1988; 1992). In the map area, radiolarians near the top of the chert member are indicative of a Late Mississippian to Early Pennsylvanian age, whereas megafossils in the lower part of the overlying Reeve Formation are indicative of a mid-Permian (Roadian or Wordian) age (Harwood, 1983). No compressive structures have been identified with this episode of deformation and Harwood (1988) suggested that the regional disconformity may reflect widespread uplift and erosion related to crustal heating at the onset of Permian volcanism.

Evidence of Late Permian to Late Triassic deformation varies from a regional disconformity in the northern part of the region to a pronounced angular unconformity between Paleozoic and Upper Triassic rocks in the southeastern part of the map area. These regional stratigraphic relations indicate that an abrupt change in deformation occurred within the map area. North of Sugar Pine Point, Upper Triassic rocks rest disconformably on the Permian Reeve Formation and reflect the stratigraphic relations characteristic of the region to the north. South of Sugar Pine Point, however, successively younger Triassic rocks rest unconformably on progressively older Paleozoic rocks indicating that the Paleozoic basement rocks were folded in this area prior to uplift and erosion. The orientation of Late Permian to Late Triassic folds is difficult to determine, but their trend is inferred to have been approximately east-northeast based on the trend of the Sierra Buttes Formation at the North Fork of the American River.

Structures in the Shoo Fly Complex

The Duncan Peak allochthon overlies the Lang sequence and forms the structurally highest part of the Shoo Fly Complex in the map area. Imbricate thrust slices of chert in the allochthon are interlayered with thrust slices of the Big Valley Bluff Formation at Mears Meadow, south of Sugar Pine Point, and at the west wall of New York Canyon. South of Sugar Pine Point , the imbricate thrust slices and the axial surfaces of isoclinal folds related to the thrusting are unconformably overlain by the Sierra Buttes Formation indicating that these structures formed prior to the Late Devonian.

In the southern part of the map area, east- and northeast-trending folds are defined by map units in the Shoo Fly Complex. The Antoine Canyon Formation, which is the stratigraphically lowest local unit in the Shoo Fly, forms the cores of two northeast-trending anticlines. West of New York Canyon, the Barney Cavanah Ridge Formation lies in the core of a southeast-trending syncline. These folds are truncated on the east by imbricate thrust slices of the Duncan Peak allochthon, which suggests that they may have formed prior to the Late Devonian.

The anticlines cored by the Antoine Canyon Formation are unusual in that primary sedimentary structures, such as graded beds, do not consistently reflect the structure defined by the stratigraphic units. For example, graded beds in the Antoine Canyon Formation face outward around the nose of the anticline west of Duncan Peak and establish the stratigraphic position of the Antoine Canyon Formation below the Screwauger Breccia. In the central and western parts of this anticline, however, graded beds in the Antoine Canyon Formation face to the north as do graded beds in the Big Valley Bluff Formation, both north and south of the belt of the Antoine Canyon Formation.

The observed relations between primary sedimentary structures and the map pattern of stratigraphic units may have been produced by one period of deformation that was coeval with deposition of the Screwauger Breccia. The chaotic nature of the Screwauger Breccia indicates that it is a major slump deposit, probably a type I melange as defined by Cowan (1985), and its contact with the Antoine Canyon Formation is a soft-sediment tectonic contact. Because the trend of broken segments of beds in the Screwauger Breccia conforms to the trend of bedding in the overlying Big Valley Bluff Formation, it is concluded that the Screwauger Breccia was deposited when older strata in the Shoo Fly Complex were being deformed. Early deformation apparently exposed the Antoine Canyon Formation to the sea floor where it was partly overlapped by the Screwauger Breccia. Ensuing deformation folded the contact between the Screwauger Breccia and the Antoine Canyon Formation and eventually juxtaposed the Antoine Canyon Formation with the Big Valley Bluff Formation along soft-sediment tectonic contacts.

Although the deformational history described above is favored, it is possible that the map pattern was produced by Late Permian to Late Triassic deformation superposed on pre-Late Devonian deformation. The abundance of soft-sediment deformation and the lack of brittle deformation within and along the boundaries of map units in the Shoo Fly Complex argues against widely separated periods of deformation. Futhermore, the imbricate thrust slices of the Duncan Peak allochthon, though deformed, do not reflect the structures in the Lang sequence or the pre-Late Triassic deformation in the Taylorsville sequence shown at the North Fork of the American River. Therefore, it is concluded that the northeast-trending structures in the Lang sequence formed during a period of complex, pre-Late Devonian deformation that was coeval with deposition of the Screwauger Breccia in a tectonically active, probably subduction-related, accretionary-wedge environment.

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