PALEOTECTONIC AND PALEOGEOGRAPHIC SIGNIFICANCE OF THE CALAVERAS COMPLEX, WESTERN SIERRA NEVADA, CALIFORNIA

Richard A. Schweickert
Lamont-Doherty Geological Observatory
of Columbia University, Palisades, N.Y. 10964

Jason B. Saleeby
Department of Geology and Geophysics
University of California, Berkeley, California 94720

Othmar T. Tobisch
University of California, Santa Cruz, California
Earth Science Board, Applied Science Building
Santa Cruz, California 95064

William H. Wright, III
Department of Geology, California State College
Sonoma, Rohnert Park, California 94928

ABSTRACT

The Calaveras Complex of the western Sierra Nevada, as defined here, consists of a 375 km long, 35 km wide belt of metasedimentary and metavolcanic rocks, bounded on the west by the Melones fault zone and Kings-Kaweah suture, and on the east by the Sierra Nevada batholith. The Calaveras Complex forms a continuous northwest-trending belt between the Placerville area and the Merced River area. South of the Merced River the belt extends in numerous roof pendants at least as far south as the Tule River.

A sequence of four lithologic units is recognized, each of which is thousands of meters thick. Precise original stratigraphic thicknesses cannot be measured because of intense soft-sediment and post-consolidation deformation. The lowest unit consists of mafic pillow lava, breccia, tuff, and argillite, and may represent layer 2 of oceanic crust. This basal unit is overlain by a predominantly chaotic unit of argillite with variable amounts of chert and siltstone often occurring as clasts in a diamictite. Olistoliths of shallow water limestone are locally an important component of this argillite unit. The overlying chert unit contains abundant large olistoliths of rhythmically bedded chert and locally important limestone olistoliths in a matrix of streaky argillite and diamictite. The highest unit included within the Calaveras Complex contains abundant, well-bedded quartzite with abundant interbedded olistostromes containing quartzite clasts and limestone olistoliths.

Fossils from limestone olistoliths reported here indicate a maximum Permo-Carboniferous age for the upper part of the argillite unit, and a maximum late Permian age for the overlying chert unit. Published fossil data indicate the upper parts of the quartzite unit are late Triassic to early Jurassic.

The argillite and chert units apparently comprise numerous olistostromes that accumulated on oceanic crust in a marginal basin that was broad enough to have been relatively free of clastic detritus derived from the basin margins. Olistostromes apparently were shed from tectonically elevated areas within the marginal basin that were denuded of their pelagic and hemipelagic cover. The quartzite unit may represent an early Mesozoic northwestward progradation of mature continent-derived sand across the western end of the late Paleozoic marginal basin. The marginal basin is considered to have been situated between the Cordilleran miogeocline to the southeast and a volcanic arc terrane to the northwest. The late Paleozoic Havallah sequence of north-central Nevada is believed to have accumulated in the same marginal basin.

The Melones fault zone and Kings-Kaweah suture represent a zone of early Mesozoic tectonic truncation along which the Calaveras Complex is juxtaposed against upper Paleozoic ophiolitic rocks and Jurassic volcanic and epiclastic rocks. Thus, we infer that the Calaveras Complex represents the westernmost exposure of the late Paleozoic marginal basin.

INTRODUCTION

The Calaveras Complex (formerly Calaveras Formation) as defined here is the younger of two Paleozoic metamorphic complexes that lie east of the Melones fault zone in the western Sierra Nevada metamorphic belt (Fig. 1). Even though it has been nearly 90 years since portions of the Calaveras Complex were first mapped by the United States Geological Survey, little or nothing has been published on the age, stratigraphy, or structural development of the complex apart from the broad outlines provided by Turner, Ransome, and Lindgren (see below). The great areal extent and probable Permo-Carboniferous age of the Calaveras underscore the possible significance of the complex, both in regard to its relation to the Cordilleran orogen and its bearing on late Paleozoic plate tectonic evolution of California.

This report synthesizes results of our joint and individual field studies of various parts of the Calaveras carried out since 1958 and still in progress. From detailed mapping of small areas and reconnaissance of larger areas we have arrived at a regionally consistent sequence of lithologic units within the complex and have begun to unravel the complex structure. Descriptions of the various mappable subunits and consideration of their probable origin and paleogeographic significance are the main topics of this paper. Our conclusions are tentative and we are not in unanimous agreement in all cases; we have chosen the simplest possible interpretations of lithologic and paleontologic data and realize that further work will require modification of many of our conclusions.

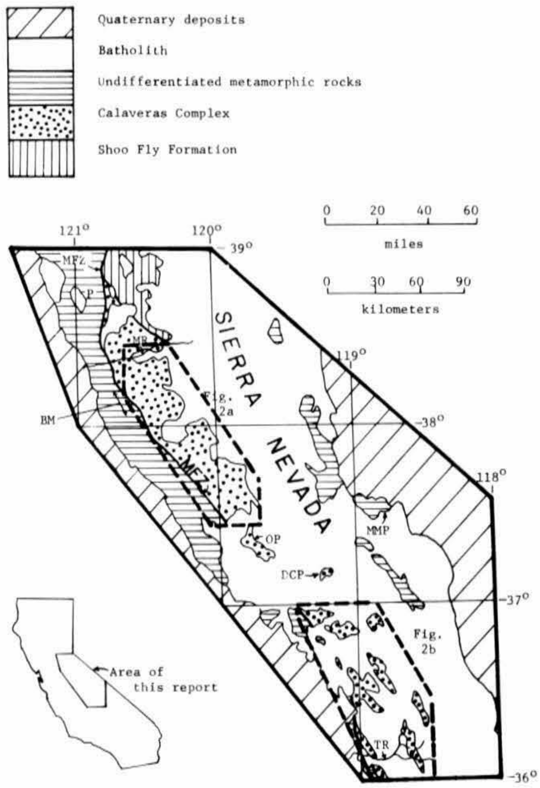

Figure 1. Location map of central Sierra Nevada, showing outline of Figure 2 and extent of Calaveras Complex. MFZ: Melones fault zone; P: Placerville; M: Mariposa; OP: Oakhurst pendant; DCP: Dinkey Creek pendant; MMP: Mt. Morrison pendant; MR: Mokelumne River; TR: Tule River; BM: Bear Mountains

Previous investigations and history of nomenclature

Between 1885 and 1900 most of the region under consideration was mapped by Henry W. Turner, Frederick L. Ransome, and Waldemar Lindgren of the United States Geological Survey. The results of the mapping were published as a series of 1:125,000 scale folios of the United States Geological Survey Geologic Atlas Series (Turner, 1894; Turner and Ransome, 1897, 1898; Lindgren, 1900). Turner also published two lengthy, descriptive articles on the geology (1893b, 1896).

The term "Calaveras Formation" was first introduced into the literature in 1893 by Turner who stated (1893a, p. 309) that the term "includes all of the Paleozoic sedimentary rocks of the Sierra Nevada." Turner (1893b, p. 446) later pointed out, however, that the term was not meant to include either Silurian rocks or the upper Carboniferous Robinson Formation of the northern Sierra Nevada, both of which had been discussed and mapped earlier by Diller (1892). The name "Calaveras" was derived from a belt of fossiliferous Paleozoic rocks in the Bear Mountains (Fig. 1) (Turner, 1893a). The Calaveras Formation, then, by Turner's descriptions (1893a, b), included all of the post-Silurian Paleozoic sedimentary rocks of the bedrock complex of the Sierra Nevada between lat. 37°30' and lat. 39°45'N. Fossils from widely separated localities within the Calaveras Formation were believed to indicate an age range from early Carboniferous to Permian (Turner, 1893b). The all-inclusive nature and great regional extent of the Calaveras prompted Taliaferro (1943, p. 280) to comment that "the name is a catchall for all the Paleozoic rocks of the Sierra Nevada and hence has no stratigraphic significance."

Clark (1954) and Eric and others (1955) published the first detailed geologic maps of parts of the Calaveras (as restricted in this paper) and provided important observations about metamorphism, which had also been mentioned by Knopf (1929) and Taliaferro (1943). Clark (1954, p. 11) referring to the general geology of the Calaveritas quadrangle, noted that "Interpretation of the geologic structure is exceptionally difficult because of the complexity of the area, widespread destruction of bedding by shearing, scarcity of outcrops, and the absence of key horizons in the schist that underlies most of the quadrangle." Baird (1962) presented the first detailed structural analysis of a small area within the Calaveras north of the Stanislaus River. His work revealed the existence of two and possibly three phases of deformation of Calaveras rocks and summarized further data on metamorphism. Clark (1964) presented maps of geologic traverses in Calaveras rocks along the Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Cosumnes Rivers and gave the first detailed regional synthesis of rocks in the Calaveras.

Douglass (1967) reported Permian Tethyan fusulinids from limestone blocks in the belt of rocks west of the Melones fault zone to which Turner (1893a) had originally applied the name Calaveras, and which had become known as the "western belt of the Calaveras Formation" (Clark, 1964). Duffield and Sharp (1976; Sharp and Duffield, 1973) reported tectonic melanges in this western belt. Schweickert and Cowan (1975) noted that chaotic rocks exist as well in the Calaveras Complex (defined below) east of the Melones fault zone. We do not consider that relations between the western belt of the Paleozoic rocks and the Calaveras Complex are well known and therefore argue that fossils contained in the chaotic western belt cannot be used to define the age of the larger eastern belt. This restriction means that the age of the eastern belt is defined only by one fossil locality at Hites Cove (Fig. 2), and Turner (1893a, p. 309) suggested these fossils indicate a Carboniferous age.

PROPOSED REVISIONS AND RESTRICTIONS

The following facts indicate to us the necessity of revising and restricting the use of the term Calaveras Formation.

1) The larger, main belt of "Calaveras" rocks lies east of the Melones fault zone, is more strongly deformed and metamorphosed than, and is tectonically separated from, lenses of fossiliferous Paleozoic rock west of the Melones fault zone (Schweickert and Cowan, 1975; our unpublished data).

2) The Shoo Fly Formation of probable Silurian age (McMath, 1966; Schweickert, 1974) is now known to extend at least as far south as Placerville (Fig. 1) (Clark, 1976; Schweickert, 1977) and thus underlies about half the area originally regarded as Calaveras Formation by Turner (1893a, b).

In this paper we introduce the term Calaveras Complex for metasedimentary and metavolcanic rocks that crop out east of the Melones fault zone and south of Placerville (Fig. 1), where the outcrop belt runs south-southeast from lat. 38°45' to lat. 37°30'N. This usage corresponds to blocks IV and V of Bateman and Clark (1974, p. 84). In addition we include in the Calaveras Complex metamorphic rocks in isolated patches on trend as far south as lat. 36°, studied recently by Saleeby (1975a; Saleeby and Goodin, 1977).

Rocks possibly equivalent to the Calaveras Complex (Bateman and Clark, 1974; Schweickert, 1976) north of lat. 39° and west of the Melones fault zone will not be considered in this report (discussion of some of these rocks farther north is included in D'Allura and others, this volume).

For reasons discussed above we tentatively exclude from the Calaveras Complex the exposures of Paleozoic rock west of the Melones fault zone (formerly known as "western belt") that contain limestones with Permian Tethyan fusulinids, even though the name "Calaveras Formation" was evidently first applied to these rocks (Turner, 1893a). The name "Calaveras" is best retained for the much more extensive belt of rocks we have outlined in preceding paragraphs because such rocks have traditionally been called "Calaveras Formation" by geologists for the past 80 years.

The chaotic nature of most Calaveras rocks (Tobisch, 1960; Schweickert and Cowan, 1975; Schweickert and Wright, 1975a, b; and Saleeby and Goodin, 1977) and uncertainty about the age range of rocks within the Calaveras have led us to term it a "complex". It may eventually be desirable to formally name mappable subunits within the complex, but this is not done in this paper.

Thus defined, the Calaveras Complex forms a terrane between lat. 36° and 38°45'N bounded on the west by the Melones fault zone and the Kings-Kaweah suture (Saleeby, 1975a, b; Saleeby and Goodin, 1977), and on the east by rocks of the Sierra Nevada batholith. At the north end of the belt, east of Placerville, and possibly elsewhere to the south, the Calaveras is in tectonic contact with rocks of the Silurian(?) Shoo Fly Formation (Schweickert, 1977).

GROSS STRATIGRAPHIC AND STRUCTURAL SEQUENCE

Detailed and reconnaissance mapping of Schweickert, Wright, and Tobisch between lat. 37°30' and 38°45' indicate the existence of a sequence of four lithologic units, all of which can be traced for 60 km along the outcrop belt. The units strike northwestward and generally dip steeply northeastward. From oldest to youngest, the units, discussed in terms of their protoliths, are: (1) volcanic-rich sequence of tuff, tuff breccia, pillow breccia, pillow lava and slate, herein called the volcanic unit; (2) argillite unit, made up of chaotic argillite and siltstone with small inclusions of chert throughout, and with lenses of marble in its upper (eastern) part; (3) chert unit, composed largely of chert-rich olistostromes[1] with small chert olistoliths and local coherent chert olistoliths up to 1 km long; (4) quartzite unit, with thick to thin well-bedded and sometimes graded quartz sandstone and shale, minor limestone and interbedded olistostromes with quartzite olistoliths.

Units 1, 2, and 3 have gradational contacts and are closely interrelated units; unit 4 may have been deposited on and may locally interfinger with unit 3, but distinctive augen gneisses and mylonites have been mapped in several areas near the contact between 3 and 4, leaving open the possibility that the contact between units 3 and 4 may be tectonic.

Outcrop widths of these lithologic units are highly variable but are on the order of thousands of meters. Unit 1 may be as much as 10 km wide south of the Merced River, but we have too little structural data from this region to rule out repetition by folding or faulting. Unit 2 is the most areally extensive and, based on structural studies, the broadest of the various units, with perhaps up to 12 km or more of olistostromes. The width of unit 3 ranges from zero northwest of Sonora to perhaps 11 km south of the Merced River. Unit 4's greatest exposed width is about 10 km east of Sonora.

The above figures do not represent measured stratigraphic thicknesses of primary sedimentary units. Rather, the figures are little more than structural thicknesses measured off maps in directions perpendicular to lithologic boundaries or to layering within the units. The units themselves are largely comprised of enormous olistostromes occasionally containing blocks of coherent, bedded rock up to several kilometers long. Lacking distinctive marker horizons within each major unit, it is impossible to state categorically whether large scale tight folds do or do not exist within the various units. Tight, small-scale folds are commonplace. Some may be slump folds and some are tectonic. From field data it appears unlikely that large-scale tight folds exist. A limited number of facing indicators within and between units, such as shapes of pillows in unit 1, occasional graded sandstone or siltstone beds between olistostromes in units 2 and 3, and graded bedding in unit 4 all, without exception, indicate tops eastward. Therefore, the original thicknesses of the various units, although unknown, probably were on the order of thousands of meters.

SPECIFIC DESCRIPTIONS OF THE UNITS

Volcanic unit

Mafic pillow lava, pillow breccia, tuff breccia, and bedded tuff predominate in this unit, but relative abundances of these lithologies are variable. Pillow lavas and most lava fragments in breccias are composed of nonporphyritic basalts. In some areas the pyroclastic rocks form lenticular masses that interfinger with slaty mudstone and diamictite[2]. In general, rocks in this unit are stratigraphically coherent and chaotic olistostromes are of minor importance.

The lower boundary of this unit is marked by the Melones fault zone and thus its full original extent and thickness are not known. We infer that this unit in part represents layer 2 of oceanic crust upon which the dominantly sedimentary units of the Calaveras Complex were deposited.

Argillite unit

This is by far the most extensive unit; it underlies most of the Calaveras Complex north of Sonora and perhaps half of it to the south. The predominant lithologies of this unit are argillite or siliceous argillite with lesser amounts of chert and siltstone. Limestone predominates in some areas such as north of Sonora.

The most notable feature of the rocks of this unit is their chaotic appearance (Fig. 3). We have not found bedded sequences of rock in this unit

---

[1] Olistostromes are sedimentary accumulations of generally rounded, resistant inclusions of different rock types embedded in massive pelitic, sandy, or marly matrices (Abbatte and others, 1970). We infer that they were deposited from submarine slides and debris flows. The inclusions are called olistoliths.

[2] Diamictite is used as a descriptive term in the sense of Flint and others (1960): any lithified, nonsorted or poorly sorted terrigenous sedimentary rock that consists of sand-size and/or larger particles in a muddy matrix; no genetic conditions are implied by the terms diamictite and pebbly mudstone.

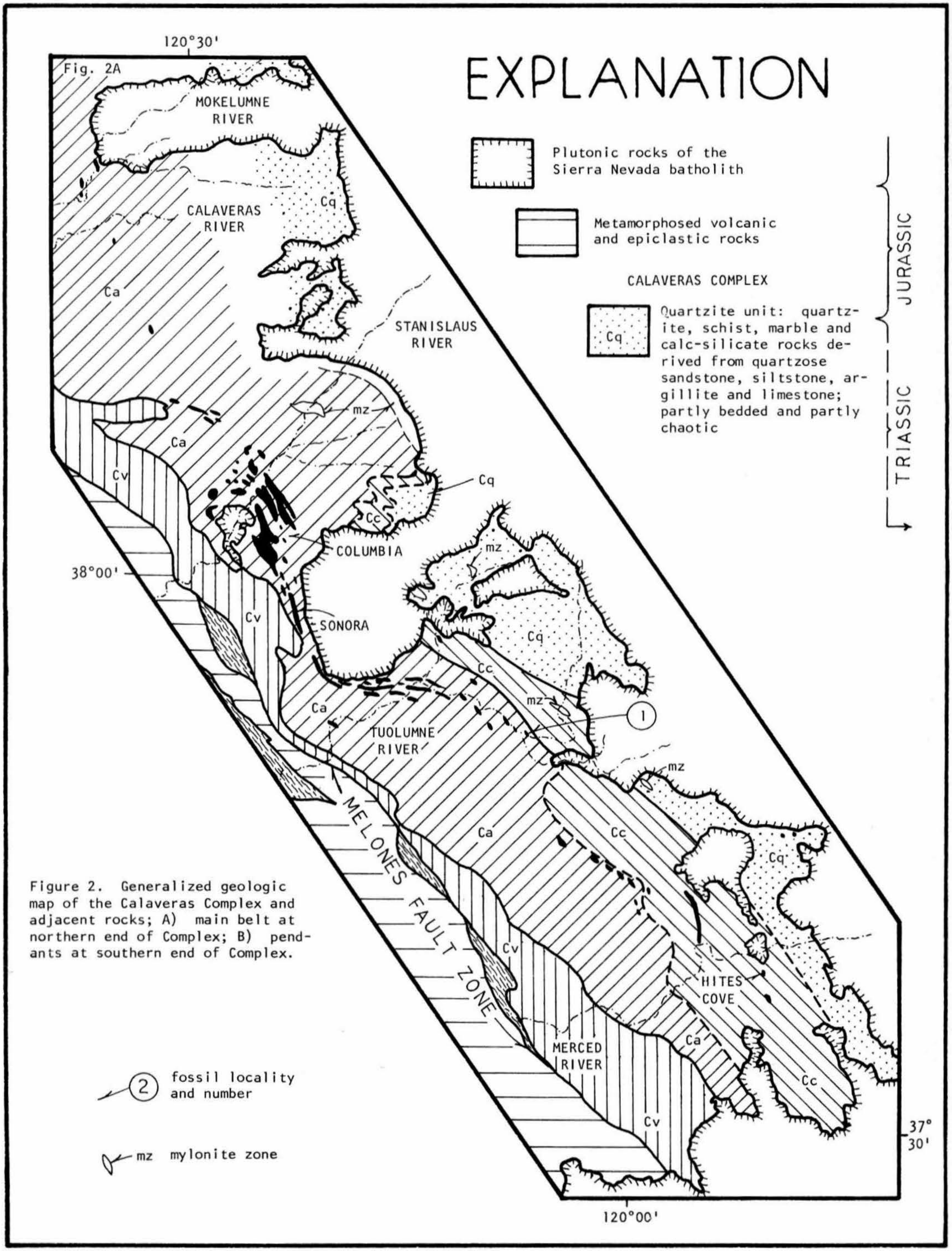

Figure 2. Generalized geologic map of the Calaveras Complex and adjacent rocks; A) main belt at northern end of Complex; B) pendants at southern end of Complex.

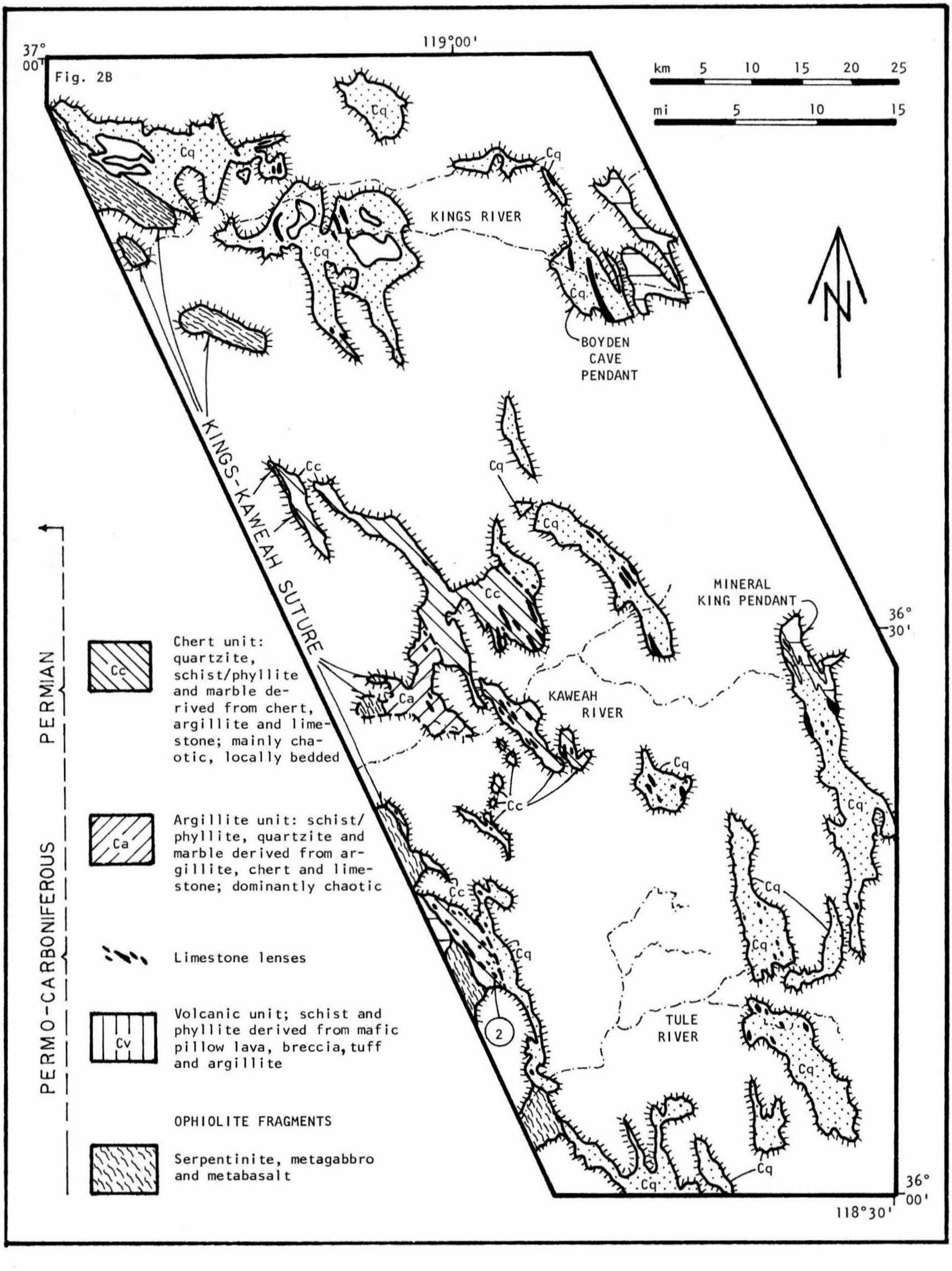
Fig. 2B

37° 00'
119°00'
km 5 10 15 20 25
mi 5 10 15
Cq
KINGS RIVER
BOYDEN CAVE PENDANT
KINGS-KAWEAH SUTURE
Cc
Ca
Cv
KAWEAH RIVER
MINERAL KING PENDANT
36° 30'
TULE RIVER
2
36° 00'
118°30'
PERMO-CARBONIFEROUS
PERMIAN
Chert unit: quartzite, schist/phyllite and marble derived from chert, argillite and limestone; mainly chaotic, locally bedded
Argillite unit: schist/phyllite, quartzite and marble derived from argillite, chert and limestone; dominantly chaotic
Limestone lenses
Volcanic unit; schist and phyllite derived from mafic pillow lava, breccia, tuff and argillite
OPHIOLITE FRAGMENTS
Serpentinite, metagabbro and metabasalt

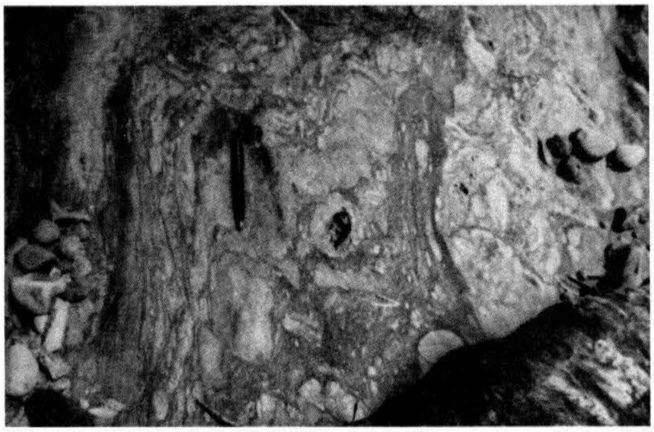

Figure 3. Stream-polished exposure of dark argillite with streaks of gray siltstone. Light colored clasts on left are massive chert. Ballpoint pen is 13 cm long.

Figure 4. Pebbly mudstone or diamictite. Two larger clasts on left are laminated sandstone. Most smaller fragments are chert. Notebook is 13 x 20 cm.

except for thin intervals near the lower contact with the volcanic unit. Argillite and siliceous argillite are generally streaky, with wisps of lighter gray siltstone smeared into the black argillite. Characteristically, lenses, pods, and small fragments of chert are scattered in a streaky argillite matrix. Where chert and limestone fragments are fairly abundant in argillite, the rock is a pebbly mudstone or diamictite (Fig. 4). A gross layering is apparent locally within the chaos and is defined by generally sharp, but sometimes irregular boundaries between olistostromes that differ appreciably in lithologic character, size, and abundance of contained olistoliths. Some olistostromes consist almost entirely of large, semi-continuous masses of chert that range from well-bedded and slump folded, to slightly disaggregated, lenticular fragments of beds that lack continuity, to diamictite in which smaller segments of former chert beds are randomly mingled within streaky argillite. Thicknesses of olistostromes apparently range from a few meters to hundreds of meters, but it has not been possible to measure the thicker ones.

Between the Stanislaus and Tuolumne Rivers, elongate and equant masses of limestone that range from a few centimeters to several kilometers in longest dimension form an important part of the argillite unit. Near and north of the Tuolumne River, these blocks are concentrated in a band about 1-2 km wide mapped by Hart (1969). Heyl and Wiese (1947) mapped the continuation of this zone through Sonora. Near Columbia, the carbonate lenses coalesce into a very large, irregularly shaped mass with dimensions of approximately 8 x 8 km. Baird (1962) presented a detailed map of the part of this body that lies north and west of the Middle Fork of the Stanislaus River. This carbonate mass is interlayered with lenticular bodies of metavolcanic rock which is essentially lacking in other parts of the argillaceous unit except near its base.

Our observations indicate that all carbonate blocks are olistoliths and are generally completely enclosed in streaky argillite. Primary sedimentary structures are rare in the carbonates, but the following features suggest that the carbonates formed in neritic to even supratidal conditions: (1) large, solitary horn corals in an isolated block (fossil locality 1, Fig. 2); (2) crinoid stems and other bioclastic debris in several areas; (3) possible algal structures in local isolated blocks on the Tuolumne River; (4) irregular patches and streaks of dark carbonate in local gray marbles with forms that resemble nodular and laminated anhydrite on the Stanislaus River; (5) local pisolitic limestone south of the Merced River. The close association of mafic metavolcanic rocks and carbonates in the large mass along the Stanislaus River suggests that this large body may have formed on a volcanic seamount. Manganiferous carbonate breccias or diamictites that are locally developed near the south edge of this mass suggest the role of volcanic-hydrothermal circulation locally. We infer that most of the shallow-water limestones were introduced into deeper water environments by slumps or by debris flows.

Previous workers have mapped faults between the volcanic unit and the argillite unit. Careful examination of the contact in a number of localities has shown that a gradational contact exists, although at certain places the contact is sharp. Nowhere have we observed evidence of a fault.

Chert unit

The chert unit contrasts markedly with the underlying argillite unit. It is characterized by thick sequences of well-bedded, rhythmic chert with black argillaceous partings that are intermingled with masses of less well-bedded chert and diamictites that are composed almost exclusively of chert clasts in argillite. Minor limestone pods occur locally, as at Hites Cove and north of the Merced River, and rare tuff and bedded, detrital serpentinite (now talc schist) occur both north and south of the Merced River.

The larger, well-bedded masses of ribbon chert evidently are olistoliths that remained relatively intact during submarine mass movement, but which locally became disarticulated into rubbly zones and diamictites. Spectacular disharmonic open-to-tight folds are widespread within the olistoliths (Fig. 5).

Chert is generally gray to bluish-gray, but local varieties are black and dull green; the latter apparently contains an appreciable component of volcanic ash. Bedding typically averages 3-5 cm in the coherent olistoliths.

Metamorphic recrystallization has obliterated any radiolarians that may have existed. Many of the

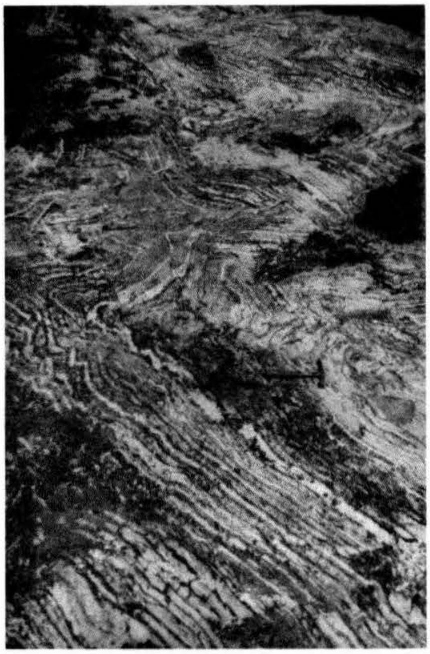

Figure 5. Folded, rhythmically bedded chert. Beds average 7 cm; argillaceous partings average 0.5 cm. Hammer is 30 cm long.

cherts in this unit and in the underlying unit have sugary textures, and in isolated fragments it is often impossible to determine with certainty whether they were originally chert or quartzose siltstone. It appears likely that the abundance of chert in both units, but especially the argillite unit, has been overestimated and that formerly silty rocks may be of appreciable, but undetermined, importance in some areas.

The lower contact of the chert unit is sharply defined in some areas such as near the Tuolumne River and gradational in others. It was drawn where the ratio of chert to argillite in olistostromes was judged to drop markedly. Chert-rich and chert-poor olistostromes are interlayered locally, making placement of the contact somewhat arbitrary.

The map pattern indicates that the chert unit may be thickest south of the Merced River and that it thins and disappears northeast of Sonora. We do not have conclusive evidence as to whether this thinning reflects original geometry and extent of chert-rich olistostromes or whether it results from tectonic truncation at the base of the overlying quartzite unit (discussed below). Coherent slabs of ribbon chert are more abundant and extensive in the unit near the Merced River, and diamictite and disorganized masses of chert are generally more common northward.

Quartzite unit

The most conspicuous lithology of this unit is quartzite or quartz-rich sandstone that forms tabular beds ranging from a few centimeters to 2 m in thickness. Beds are often finely laminated and typically are separated by millimeter to meter-scale interbeds of pelitic material; in many areas pelitic material predominates (Tobisch, 1960). Most beds do not show obvious grain size variation, but locally grading shows consistently that the tops face eastward. Minor lithologies in this unit are limestone, which occurs as lenses a few meters long, and chert or siliceous argillite that locally is difficult to distinguish from fine grained or silty quartzite.

At most scales of observation rocks of this unit appear to be stratigraphically coherent and thus contrast with units 2 and 3. However, in certain areas important interbedded olistostromes have been documented. Where olistoliths consist of large slabs and blocks or quartzite, the affinity of such deposits to the quartzite unit is obvious. Olistostromes lacking large recognizable olistoliths or containing chert fragments cannot always be assigned confidently to this unit. The contact between this unit and the underlying chert unit is generally placed above the highest occurrence of bedded chert. Turner (1896; and Turner and Ransome, 1898) noted that quartzites extend as far north as the Middle Fork Mokelumne River. We have included the quartzites of this area on the regional map (Fig. 2), but we have not verified their distribution.

In a number of areas between the Stanislaus and Tuolumne Rivers cataclastic rocks have been mapped near or along the lower contact of the quartzite unit. These consist of blastomylonitic quartzite and of flaser gneiss or augen gneiss. Such rocks do not form continuous units along strike, and in some cases they occur within the quartzite unit and the chert unit. South of the Tuolumne River, quartzite and chert appear to alternate in the area of the contact. Mylonitic rocks have only been noted as a 100 m x 200 m pod about 1 km east of the contact. Our present data do not allow a firm conclusion about the original nature of the contact because the significance of the cataclastic rocks and their sporadic occurrence has not been resolved. The contact may be sedimentary, tectonic, or some combination of both, and clearly requires further study.

THE CALAVERAS COMPLEX IN ROOF PENDANTS IN THE SOUTHERN SIERRA NEVADA

Mapping by Saleeby and co-workers indicates that the distinctive rocks of the Calaveras Complex (as defined in this paper) underlie most of the small roof pendants in the drainage of the Kings, Kaweah, and Tule Rivers between lat. 36° and $37^{\circ}30'$N (Figs. 1, 2). Such rocks are bounded to the west by the Kings-Kaweah suture, marked by an extensive tectonic melange composed entirely of disrupted ophiolitic rocks of late Paleozoic age (Saleeby, 1975a, b, 1976a). To the south, the "Kernville Series" (Miller and Webb, 1940), which underlies pendants in the Kern River drainage between lat. $35^{\circ}30'$ and 36°N, has gross similarities to the Calaveras Complex. At present there is insufficient data to determine the relation between the Calaveras Complex and the Kernville "Series". If the Kernville is excluded, the minimum extent of rocks assigned to the Calaveras Complex is approximately 375 km, from east of Placerville to the Tule River.

Three of the four lithologic units mapped in the central Sierra Nevada are recognized in the pendants between the Kings and Tule Rivers: (1) the argillite unit; (2) the chert unit; and (3) the quartzite unit. Each of these units is remarkably similar to the corresponding unit exposed to the north. The volcanic unit is not present, except perhaps in the poorly known pendant near Oakhurst (Fig. 1) where we have little data.

The argillite unit is the least extensive and the most poorly exposed of the three units. It has only been mapped near lat. $36^{\circ}30'$, northwest of the Kaweah River. There is a significant amount of chert within this unit, and further work may reveal that it actually belongs to the chert unit or that it represents a particularly thick transition interval between the argillite and chert units.

The chert unit is characterized by the local presence of thin, laterally extensive, well-bedded chert layers that are bounded above and below by chert-argillite diamictite with olistoliths of chert and limestone. These thin chert horizons appear to represent autochthonous pelagic deposits that accumulated between influxes of olistostromes.

The quartzite unit predominates in the region and is characterized by abundant chaotic rocks and the presence of thick, white quartzite and arkose beds and olistoliths. The upper part of the quartzite unit is interbedded with and overlain by Mesozoic metavolcanic rocks (Saleeby and Goodin, 1977). The contacts between the argillite and chert units, and the chert and quartzite units are gradational.

Chaotic rocks of all three units contain diamictite, moderate to large olistoliths, rootless folds, and "ball" structures (Fig. 6). Intact intervals, particularly in the quartzite unit, commonly contain isoclinal and disharmonic folds, and slip surfaces which are most easily explained as slump features.

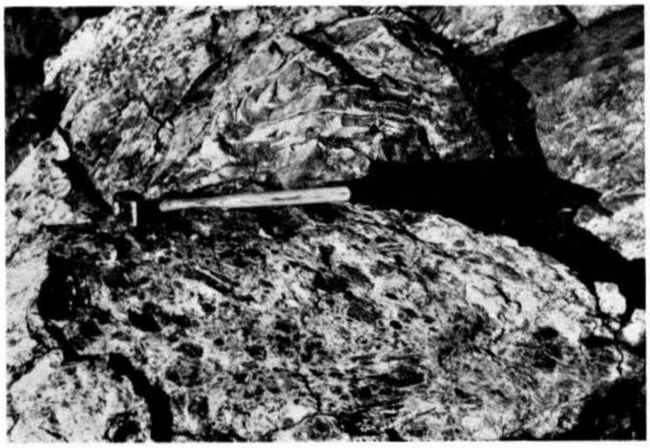

Figure 6a. Soft sediment deformational features from Calaveras Complex of the Kaweah River area. Rootless fold within type I diamictite, chert unit.

Relations with rocks of the Kings sequence

Bateman and Clark (1974) designated metamorphosed strata in the area from the Dinkey Creek pendant to the Mineral King pendant as the Kings sequence. These rocks are shown as part of the quartzite unit on Figure 2. The early Jurassic fossil from the Boyden Cave pendant (Jones and Moore, 1973), and the late Triassic fossils from the Mineral King pendant (Christensen, 1963), are in what appears to be the uppermost part of the quartzite unit described herein; they occur just west of an overlying sequence of Mesozoic metavolcanic rocks (Moore, 1972).

A significant thickness of quartzose clastic rocks in patches separated by granitic rock lies between these late Triassic-early Jurassic rocks and the chert unit which apparently contains Paleozoic limestone olistoliths (see below). These intervening metamorphic rocks are petrologically and structurally identical to the uppermost fossiliferous rocks of the quartzite unit. Therefore, we believe that the rocks of the quartzite unit form a distinctive consanguineous lithologic unit from lat. 38°30' to lat. 36°N; thus rocks designated Kings sequence by Bateman and Clark (1974) are here considered to be the upper part of the quartzite unit of the Calaveras Complex.

NATURE AND ORIGIN OF THE CHAOTIC ROCKS

The most remarkable characteristic of the Calaveras Complex is its overwhelmingly chaotic aspect at nearly all scales of observation, except that of the geologic map (Fig. 2). Except for the volcanic unit in which bedding is generally well-developed, and parts of the quartzite unit, nearly all exposures of the Calaveras show extreme to moderate disruption of primary sedimentary bedding surfaces. In most of the middle units of the Calaveras, the only rocks that retain bedding structures are isolated blocks and slabs of rhythmically bedded ribbon chert, but even these, in many cases, can be shown to have undergone minor degrees of destruction of bedding.

Massive to streaky or laminar argillite and siltstone predominate (Fig. 7). Such rocks are called diamictite where they contain fragments suspended in the argillaceous matrix (Fig. 4). In the argillite and chert units, most fragments are chert; of lesser abundance are lensoidal clasts of sandstone, siltstone, and marble. Diamictites in the quartzite unit chiefly contain quartzite clasts. Recognizable fragments range from a few millimeters to several meters in outcrops. Larger slabs of ribbon chert or limestone range up to several kilometers.

Figure 6b. Fragments of quartzose sandstone beds dispersed within dark argillite.

Several intergradational textural types of chaotic rock have been recognized. These rocks range from those nearly lacking argillite matrix to rocks consisting entirely of argillite. Some units consist entirely of large, semicontinuous masses of folded, bedded chert (Fig. 8). These commonly pass gradually or abruptly into rocks made up of parallel, closely packed slabs and lenses of once-continuous chert beds with little argillaceous matrix (Fig. 9). We refer to these as Type II diamictite. Such rocks commonly grade in turn into matrix-supported pebbly mudstone (or Type I diamictite) with suspended lensoidal to elliptical fragments (Fig. 10). These pass finally into massive or streaky argillite lacking notable clasts (Fig. 7). Some textural types seem to defy description or classification.

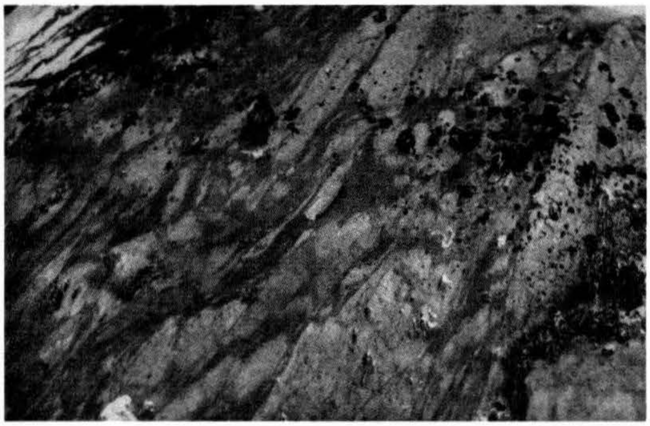

Figure 7a. Dark, streaky argillite with elongate masses of smeared out siltstone. Pocket knife is 8 cm long.

Figure 7b. Laminar streaks of siltstone in argillite. Large fragment of chert to right of pocket knife.

Figure 8. Olistolith of well-bedded chert in central part of photo. On upper right and upper left beds have become disrupted and are termed "Type II diamictite." Pocket knife is 8 cm long.

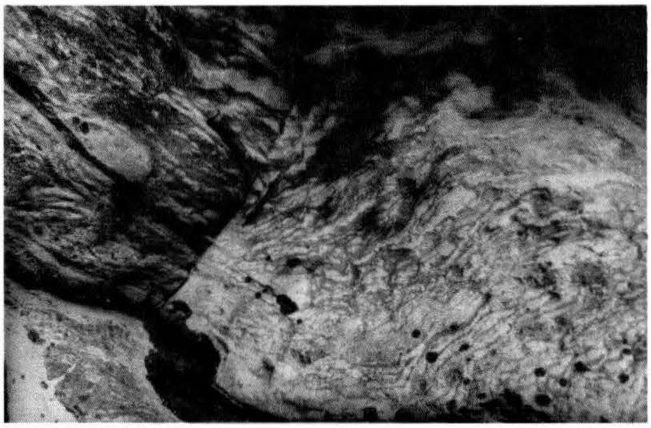

Figure 9. Type II diamictite, consisting of closely packed, subparallel slabs of chert in a dark, argillaceous matrix. Rock hammer is approximately 30 cm long.

Figure 10. Type I diamictite, containing tabular to lenticular clasts of sandstone (s), chert (c), and limestone (l) in black argillaceous matrix. Largest clast is 20 cm long.

On close inspection, a gross lithologic layering is apparent in the chaos. This layering reflects the existence of individual sedimentary slide units or olistoliths. Successive olistostromes commonly possess regular upper and lower boundaries (Fig. 11), and in a few places may be separated by a meter or less of bedded mudstone or sandstone (Fig. 12).

We are convinced from our observations that the chaotic character of Calaveras rocks has resulted primarily from sliding and flowage of unlithified and partially liquefied sediments downslope into a basin. The textural features we have described are identical to those reported by Cox and Pratt (1973) in Paleozoic submarine slide breccias in the southern Klamath Mountains. The central parts of the Calaveras Complex in essence consist of a very thick pile of tabular olistostromes that are grossly lenticular and generally discontinuous on a large scale and which locally were intermixed while still in an unlithified state. Facts on which we base this conclusion include the following (see also Schweickert and Wright, 1975b).

Figure 11. Exposure of several distinct thin chaotic units with planar depositional contacts. Observers are standing on unit composed of Type II diamictite. Dark band is streaky, laminar argillite. Overlying argillite is 2 m of Type II diamictite, overlain on upper left by disharmonically folded, bedded chert.

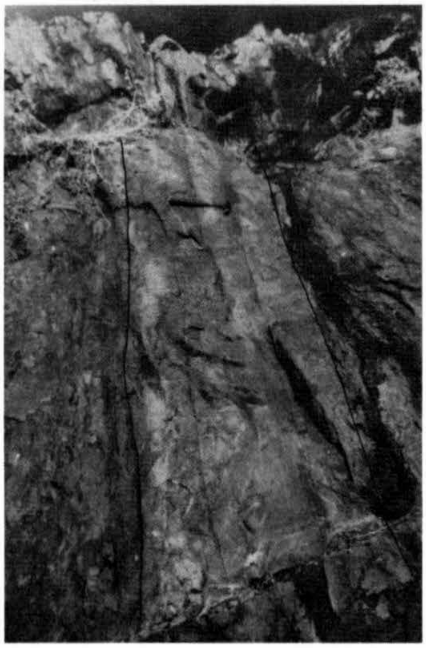

Figure 12. Hammer lies on 1 m thick interval of graded sandstone. Graded bedding indicates that the sandstone was deposited on Type I diamictite on left, and was overlain by streaky argillite and diamictite on right.

1) Primary sedimentary bedding surfaces or laminations are rare in the argillaceous rocks.

2) There is no evidence of widespread brittle shearing with the formation of phacoids or lozenges of resistant lithologies in a sheared matrix. The chaotic rocks we are describing lack the penetrative shear-fracture fabric of tectonic melanges (Cowan, 1974).

3) The complex and irregular interpenetration of light and dark argillite on all scales and the admixtures of bedded and unbedded chert suggest that these rocks initially deformed in an extremely ductile manner, probably prior to lithification.

4) Extensive exposures of pebbly to bouldery mudstone or diamictite and the gradual transitions from streaky argillite to Type I and Type II diamictite (Figs. 8-10) suggest formation by subaqueous debris flows.

5) Rootless folds and chaotic "ball" structures are present in all chaotic units.

6) Limestones of probable shallow water origin are enclosed in an argillaceous matrix and are associated with rhythmic cherts, generally regarded as "deep" water pelagic sediments.

7) Textural features identical to those we have described in 3, 4, and 5 above have been reported from large-scale submarine mass flow deposits in many areas in rocks of various ages including those of Pleistocene and Miocene age off the west coast of Africa and near the Sunda arc (Jacobi, 1977; Arthur and others, 1976; Moore and others, 1976).

It is important to note that compelling evidence exists that the *already chaotic* rocks of the Calaveras Complex underwent at least three phases of hard rock deformation. A regional foliation is defined by the preferred orientation of flattened clasts in diamictite and by the planar preferred orientation of micas in pelitic rocks. A spaced cleavage is recognizable in many exposures of chert both in rhythmic beds and as clasts in Type II diamictite (Fig. 8). It is beyond the scope of this paper to analyze the structure and metamorphism of the Calaveras Complex. Nevertheless, we have observed no evidence of pervasive structural imbrication or thrusting in the chaotic parts of the Calaveras, a structural style that is commonly developed in subduction complexes. Nor is there any indication of blueschist metamorphism. Rather, metamorphic grade is high greenschist to amphibolite facies. In lieu of evidence to the contrary, we conclude that the Calaveras Complex consists of a very thick stack of olistostromes and olistoliths, and that these rest depositionally on a volcanic-rich substrate that probably represents layer two of oceanic crust.

PROBLEMS REGARDING AGE OF THE COMPLEX

Only one fossil locality from within the Calaveras Complex has been reported in the literature. Turner (1893a) reported crinoid stems and *Fusulina cylindrica*, believed indicative of Permian or Carboniferous age, from limestone at Hites Cove (Fig. 2). This collection has been misplaced and later attempts to find more fossils at the locality have not been successful (Clark, 1964).

During our studies, two new fossil localities have been discovered: (1) within the argillite unit near the mouth of the Clavey River (Loc. 1, Fig. 2), and (2) within the chert unit near Yokol Valley south of the Kaweah River (Loc. 2, Fig. 2).

The fossils at locality 1 from a limestone olistolith consist of poorly preserved solitary horn corals. These have been tentatively identified as *Caninia* sp. and indicate Permo-Carboniferous age (C. H. Stevens, personal communication, 1977). These specimens are currently under study. The fossils at locality 2, also from a limestone olistolith 1 km east of the Kings-Kaweah suture, consist of palaeotextulariid foraminifera, small nondescript fusulinids, and large neoschwagerinids, quite likely *Yabeina*. This is a late Permian Tethyan fauna (C. H. Stevens, written communication, 1976).

The exotic nature of the limestone blocks of localities 1 and 2 make it necessary to consider the faunal ages as maximum depositional ages for the Calaveras units in which they occur. Thus, a Permo-Carboniferous maximum age is suggested for the argillite unit and a maximum age of late Permian is apparent for the chert unit if the limestone lens at locality 2 is <u>in situ</u> Calaveras.

Establishing a younger age limit for the Calaveras is problematical, and depends on specific relations of the quartzite unit to the underlying units. The upper part of the quartzite unit here included within the Calaveras Complex is regarded as Lower Jurassic and Upper Triassic on the basis of fossils in the Boyden Cave pendant (Jones and Moore, 1973) and the Mineral King pendant (Christensen, 1963). Unfortunately, these fossiliferous rocks cannot be traced continuously into exposures in other areas.

Kistler and Bateman (1966) argued that the rocks of the Dinkey Creek pendant (Fig. 1), included as part of the quartzite unit here, are lower Paleozoic, because of their lithologic and structural resemblance to lower Paleozoic rocks of the Mt. Morrison pendant (Fig. 1). If a lower Paleozoic age is valid for part of the quartzite unit, a structural break is required between the quartzite unit and underlying units to the west. As mentioned earlier, direct evidence of a structural break between the quartzite and chert units has only been found north of the Merced River, and we are not at present in agreement on its significance.

Alternatively, if there are no major structural or depositional breaks between the Mesozoic fossiliferous rocks and the structurally lower chert and argillite units, more confidently assigned a late Paleozoic age, then some form of continuous sedimentation is implied from perhaps Permo-Carboniferous to Early Jurassic time in the Calaveras Complex. In view of regional evidence for important changes in Permo-Triassic depositional patterns, including major tectonic events such as the Sonoma orogeny and tectonic truncation of the Paleozoic orogen (Silberling and Roberts, 1962; Silberling, 1973; Burchfiel and Davis, 1972, 1975; Schweickert, 1976; Saleeby, in press), continuous deposition into the Early Jurassic, at least in a simple manner, is difficult to envision.

To summarize, available evidence suggests that the Calaveras Complex formed between Permo-Carboniferous and Early Jurassic time, although other interpretations are possible. It must be stressed, however, that no age data exists on the lower part of the argillite unit nor on the basal volcanic unit (Fig. 2). In addition, the chaotic nature of the rocks, the sparsity of fossils, later deformation, and the large amount of granitic rock south of lat. $37^{\circ}30'$ may have obscured significant depositional and/or structural breaks within the complex.

PALEOTECTONIC AND PALEOGEOGRAPHIC MODELS

Silberling (1973), Burchfiel and Davis (1972, 1975), and Churkin (1974) have outlined the late Paleozoic tectonic elements of the southern part of the Cordilleran orogen shown in Figure 13. All identify a northeast-trending volcanic arc extending from northern California to western Idaho that was flanked on the southeast by an oceanic basin of unknown original width. This oceanic basin was considered to be a marginal basin because it separated the island arc from a shallow shelf along the western margin of North America.

There are at least three possible ways of interpreting the Calaveras Complex in the context of the paleogeography outlined above. 1) The Calaveras is an exotic oceanic terrane juxtaposed against the North American continental margin during Mesozoic time. 2) The Calaveras Complex is a subduction complex made up of scrapings of pelagic sediment as an oceanic basin of unknown dimensions was subducted beneath the late Paleozoic volcanic arc. 3) The Calaveras Complex represents deposits that accumulated mainly by subaqueous gravity sliding in a marginal basin situated between the Paleozoic volcanic arc and the continental margin. Alternatives 2 and 3 are similar in several respects; we presently favor 3 although 2 has some points in its favor. In the following sections we consider points for and against each of the three models, and develop more completely a scenario for development of the Calaveras in the third model.

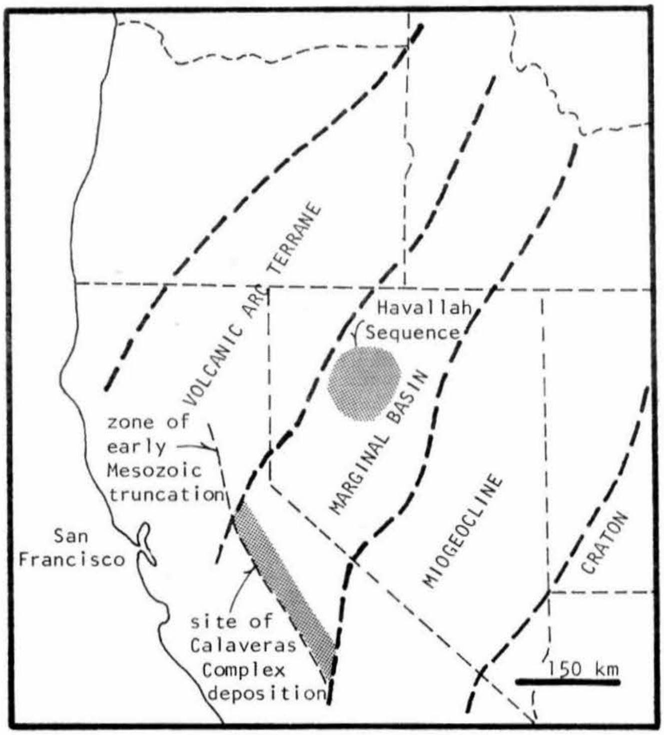

Figure 13. Paleotectonic-paleogeographic map of the southwestern Cordilleran orogen showing site of Calaveras Complex deposition. Location of Paleozoic belts are after Burchfiel and Davis (1972) and Churkin (1974). Zone of early Mesozoic truncation after Schweickert (1976) and Saleeby (in press a, b).

1) Origin as an exotic fragment

The Tethyan fauna from a limestone olistolith considered part of the Calaveras by Saleeby is, in our view, the only evidence in favor of this model. Permian Tethyan faunas occur sporadically in various parts of the western Cordillera and are commonly associated with melange zones (Danner, 1976), but have not been reported from late Paleozoic limestone units of the Cordilleran miogeocline (C. H. Stevens, written communication, 1976). Monger and Ross (1971) and Yancey (1975) have discussed these matters in considerable detail and we will not do so here.

However, as noted earlier, the fossil locality (loc. 2, Fig. 2) is located approximately 1 km east of the presently mapped boundary of the Kings-Kaweah suture. The fact that Permian Tethyan fusulinids have been found elsewhere along this suture belt <u>west</u> of the Melones fault zone (Douglass, 1967) leaves open the possibility this locality is within the Kings-Kaweah suture, and is not <u>in situ</u> Calaveras.

Finally, there is no evidence of a major Mesozoic suture between the Calaveras Complex and rocks to the east in eastern California and western Nevada (Schweickert, 1976), although the Sierra Nevada batholith occupies much of the critical area of interest. We therefore tentatively reject this interpretation, fully realizing that additional work is required before it can safely be lain to rest.

2) Origin as a subduction complex

Important details of the presumed late Paleozoic tectonic and geographic framework of the Cordillera have yet to be worked out. For instance, the polarity of the late Paleozoic island arc has not been convincingly demonstrated. No subduction complex of late Paleozoic age has been identified on either the northern or southern flank of the volcanic arc.

Schweickert (1976) noted that the Calaveras Complex, like inferred marginal basin rocks in north-central Nevada (the Havallah sequence), is presently situated between coeval arc rocks to the north (in the eastern Klamath Mountains and northern Sierra Nevada) and the Cordilleran miogeocline to the south. Lithologic and structural similarities between the Calaveras and the Havallah sequence of north-central Nevada were cited as evidence of former southwestern continuity of the marginal basin to the western Sierra Nevada. Early Mesozoic rocks that we have included in the Calaveras Complex are slightly younger than rocks of the Havallah sequence, but the Paleozoic part of the Calaveras is markedly similar to rocks of the Havallah sequence. Based on the paleogeographic setting and on this physical similarity, we conclude, as did Schweickert (1976), that the argillite and chert units of the Calaveras Complex accumulated in a marginal basin that separated an island arc terrane from the Cordilleran miogeocline, and that this basin was probably the southwestward extension of the basin within which the Havallah sequence accumulated. In both models 2 and 3 the lower volcanic unit is considered to be layer 2 of oceanic crust which was generated within the marginal basin.

The chaotic nature and impressive thickness of rocks of the Calaveras Complex certainly invite the speculation that such rocks (including those of the Havallah sequence) represent a subduction complex formed as the marginal basin was subducted northwestward beneath the late Paleozoic volcanic arc.

If true, a flip in polarity would be implied after the initially NW-facing arc migrated away from the continental margin by back-arc spreading. Pelagic sediments would have been slowly deposited on oceanic crust within the marginal basin. The Calaveras Complex might then have acquired its chaotic structure after a change in polarity as the arc overrode and subducted its own marginal basin crust and scraped off the pelagic sediments. The Sonoma orogeny (Silberling, 1973) could then easily be viewed as the result of an arc-continent collision.

However, the data we have presented on the Calaveras Complex militate against such an interpretation. We have found no evidence of pervasive structural imbrication that could account for the apparently great thickness of the chaotic deposits. Except for local uncertainty regarding the base of the quartzite unit, all contacts we have observed between olistostromes and stratigraphically coherent intervals are depositional contacts. In short, the chaotic deposits of the Calaveras Complex are olistostromes, not tectonic melanges.

Perhaps the olistostromes we have documented formed from debris flows of unlithified pelagic cover that slid off the surfaces of slabs of the marginal basin floor that were uplifted and tectonically accreted into an accretionary wedge during subduction. However, the near absence of ophiolitic debris in olistostromes and the absence of arc-derived volcaniclastic flysch both argue against this possibility.

Finally, regional metamorphism of Calaveras rocks that was synchronous with post-consolidation deformation occurred under upper greenschist to amphibolite facies conditions (our unpublished data).

For these reasons we are forced to conclude either that the Calaveras is not a subduction zone complex or that, if it is, it has important metamorphic and structural differences from generally accepted subduction complexes like the Franciscan Complex of the California Coast Ranges. The only similarities are great areal extent and largely chaotic nature.

3) Origin as a thick pile of olistostromes in an unstable marginal basin

For simplicity, the following discussion assumes there are no major tectonic breaks within the Calaveras; all lithologic units are assumed to be in their original superpositional order.

We envision hemipelagic sedimentation commencing during generation of the marginal basin crust, or alternatively, diffuse spreading and volcanism occurring within a pre-existing basin during hemipelagic sedimentation. In this way the lower volcanic unit was locally intercalated with the argillite unit. The depositional basin remained beyond the reach of significant clastic sedimentation throughout most, if not all, of the Permo-Carboniferous. As deposition continued, siliceous oozes became an increasingly significant component in the sediments relative to the hemipelagic component. This is shown by the transition from the argillite unit to the chert unit.

Local but persistent instability produced repeated failure and downslope movement of liquefied, unlithified sediment that eventually came to rest in the deeper parts of the marginal basin. Evidently some expanses of oceanic crust were stripped of their sedimentary cover, whereas other areas subsided continuously and collected enormous thicknesses of resedimented debris. The olistostromes of the Calaveras Complex accumulated in the subsiding area, whereas regions from which the sediment cover was eroded are not presently exposed and are inferred only on the basis of the olistoliths. In some areas the marginal basin basement was apparently uplifted and exposed adding detrital serpentinites to the olistostrome pile. This suggests that some degree of sediment mobility can be attributed to tectonic unrest. Variations from extensive, coherent slabs of ribbon chert in the southern part of the chert unit to increasingly disrupted and disaggregated chert in the northern parts of the unit suggest that gravity flows moved generally northward during at least part of the late Permian. This general transport pattern would be expected with a northwestward paleoslope from the miogeocline into the marginal basin.

It is tempting to speculate that limestone olistoliths were derived from the miogeocline. However, limestone olistoliths containing a Tethyan fauna, which has not been reported from late Paleozoic limestone units of the Cordilleran miogeocline (C. H. Stevens, written communication, 1976), cannot have such an origin. Again, the significance of the Yokol Valley locality (Fig. 2) is uncertain. If the Tethyan limestone is truly part of the Calaveras, the case for correlation with the Havallah sequence is seriously weakened. Additional work is again indicated.

Probably near the end of the Permian or the beginning of the Triassic, vast quantities of quartzose detritus were deposited in the Calaveras depositional basin by turbidity currents, grain flows, and bottom currents. Much of this material was redeposited as thick olistostromes, some of which contain large limestone olistoliths of unknown age and heritage. The prevalence of olistostromes throughout the complex suggests that the instability of the depositional basin persisted. The influx of quartz-rich detritus is thought to represent a northwestward progradation of mature continent-derived sand across the western end of the marginal basin.

CONCLUSION

Major findings of this paper include the following:

1) Chaotic rocks predominate in the sedimentary parts of the Calaveras Complex.
2) The chaotic rocks lack the penetrative shear-fracture fabric of tectonic melanges, and instead are sedimentary olistostromes showing abundant evidence of soft-sediment deformation.
3) Large masses of shallow-water limestone are olistoliths.
4) The olistostromes accumulated on a mafic volcanic substrate that probably represents layer 2 of oceanic crust.
5) Large-scale mappable lithologic units exist within the olistostrome pile and can be confidently traced for many tens of kilometers in the Sierra Nevada.
6) The uppermost unit of the Calaveras Complex is a distinctive quartzite unit that extends at least 300 km from near the Mokelumne River to the Tule River.

Important, as yet unresolved questions that hamper paleogeographic reconstructions are:

1) What is the age of the quartzite unit and what is the nature of its lower contact?
2) What is the significance of the limestone olistolith bearing a Tethyan fauna at Yokol Valley, and is it part of the Calaveras Complex?

The simplest interpretation that can be drawn from data now available is that the Calaveras Complex accumulated in a tectonically unstable oceanic or marginal basin in which tectonically elevated regions were denuded of their thin pelagic and hemipelagic cover, whereas other regions remained tectonically low and collected immense thicknesses of olistostromes that flowed off the higher regions. The depositional basin in which the Calaveras Complex accumulated fits into the late Paleozoic tectonic and geographic framework proposed for the southwestern Cordilleran orogen by recent workers (Silberling, 1973; Burchfiel and Davis, 1972, 1975; Churkin, 1974). It is significant that the Calaveras Complex contains the southwesternmost exposures of late Paleozoic marginal basin rocks and that the marginal basin thus outlined terminates abruptly at an apparent zone of tectonic truncation defined by the Melones fault zone and the Kings-Kaweah suture (Fig. 13) (Burchfiel and Davis, 1972, 1975; Schweickert, 1976; Saleeby, in press, a).

REFERENCES CITED

Abbatte, E., Bortolotti, V., and Passerini, P., 1970, Olistostromes and olistoliths: Sed. Geology, v. 4, p. 521-557.

Arthur, M. A., Ryan, W.B.F., von Rad, U., McCoy, F., Samthein, M., Weser, O., Lopatin, B. G., Cite, M. B., Lutze, G. F., Cepek, P., Wind, F., Hamilton, N., Mountain, G., Whelan, J., Cornford, C., and Banyra, L., 1976, Large-scale erosion and gravity transport on a passive margin - N.W. Africa - Deep Sea Drilling Project, Leg 47A: Geol. Soc. America Abs. with Programs, v. 8, p. 758-759.

Baird, A. K., 1962, Superposed deformation in the central Sierra Nevada foothills east of the Mother Lode: California Univ. Pubs. Geol. Sci., v. 42, p. 1-70.

Bateman, P. C., and Clark, L. D., 1974, Stratigraphic and structural setting of the Sierra Nevada batholith, California: Pacific Geol., v. 8, p. 79-89.

Burchfiel, B. C., and Davis, G. A., 1972, Structural framework and evolution of the southern part of the Cordilleran orogen, western United States: Am. Jour. Sci., v. 272, p. 97-118.

_____1975, Nature and controls of Cordilleran orogenesis, western United States: extensions of an earlier synthesis: Am. Jour. Sci., v. 275A, p. 363-396.

Christensen, M. N., 1963, Structure of metamorphic rocks at Mineral King, California: California Univ. Pubs. Geol. Sci., v. 42, p. 159-198.

Churkin, M., Jr., 1974, Paleozoic marginal basin-volcanic arc systems in the Cordilleran foldbelt: Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 19, p. 174-192.

Clark, L. D., 1954, Geology of the Calaveritas quadrangle, Calaveras County, California: California Div. Mines and Geol. Spec. Rept. 40, 22 p.

_____1964, Stratigraphy and structure of part of the western Sierra Nevada metamorphic belt, California: U.S. Geol. Survey Prof. Paper 410, 70 p.

_____1976, Stratigraphy of the north half of the western Sierra Nevada metamorphic belt, California: U.S. Geol. Survey Prof. Paper 923, 26 p.

Clark, L. D., Imlay, R. W., McMath, V. E., and Silberling, N. J., 1962, Angular unconformity between Mesozoic and Paleozoic rocks in the northern Sierra Nevada, California: U.S. Geol. Survey Prof. Paper 450B, p. B15-B19.

Cowan, D. S., 1974, Deformation and metamorphism of the Franciscan subduction zone complex northwest of Pacheco Pass, California: Geol. Soc. America Bull., v. 85, p. 1623-1634.

Cox, D. P., and Pratt, W. P., 1973, Submarine chert-argillite slide breccia of Paleozoic age in the southern Klamath Mountains, California: Geol. Soc. America Bull., v. 84, p. 1423-1438.

Danner, W. R., 1976, The Tethyan realm and the Paleozoic Tethyan province of western North America: Geol. Soc. America Abs. with Programs, v. 8, no. 6, p. 827.

Diller, J. S., 1892, Geology of the Taylorsville region of California: Geol. Soc. America Bull., v. 3, p. 370-394.

Douglass, R. C., 1967, Permian Tethyan fusulinids from California: U.S. Geol. Survey Prof. Paper 593A, 13 p.

Duffield, W. A., and Sharp, R. V., 1976, Geology of the Sierra foothills melange and adjacent areas, Amador County, California; U.S. Geol. Survey Prof. Paper 827, 30 p.

Eric, J. H., Stromquist, A. A., and Swinney, C. M., 1955, Geology and mineral deposits of the Angels Camp and Sonora quadrangles, Calaveras and Tuolumne Counties, California: California Div. Mines and Geol. Spec. Rept. 41, 55 p.

Flint, R. F., Sanders, J. E., and Rodgers, J., 1960, Diamictite, a substitute term for symmictite: Geol. Soc. America Bull., v. 71, p. 1809-1810.

Hart, E. W., 1959, Geology and limestone deposits in the southern half of the Standard quadrangle, Tuolumne County, California: California Div. Mines and Geol. Spec. Rept. 58, 25 p.

Heyl, G. R., and Wiese, J. H., 1947, Geology of limestone near Sonora, Tuolumne County, California: California Jour. Mines and Geol., v. 45, p. 509-520.

Jacobi, R. D., 1976, Sediment slides on the northwestern continental margin of Africa: Marine Geol., v. 22, p 157-173.

Jones, D. L., and Moore, J. G., 1973, Lower Jurassic ammonite from the south-central Sierra Nevada, California: U.S. Geol. Survey Jour. Research, v. 1, p. 453-458.

Kistler, R. W., and Bateman, P. C., 1966, Stratigraphy and structure of the Dinkey Creek roof pendant in the central Sierra Nevada, California: U.S. Geol. Survey Prof. Paper 524B, 14 p.

Knopf, A., 1929, The Mother Lode system of California: U.S. Geol. Survey Prof. Paper 157, 88 p.

Lindgren, W., 1900, Colfax folio, California: U.S. Geol. Survey Geol. Atlas of the U.S., folio 66.

McMath, V. E., 1966, Geology of the Taylorsville area, northern Sierra Nevada: California Div. Mines and Geol. Bull. 190, p. 173-183.

Miller, W. J., and Webb, R. W., 1940, Descriptive geology of Kernville quadrangle, California: California Jour. Mines and Geol., p. 344-378.

Monger, J.W.H., and Ross, C. A., 1971, Distribution of fusulinaceaus in the western Canadian cordillera: Canadian Jour. Earth Sci., v. 8, p. 259-278.

Moore, D. G., Curray, J. R., and Emmel, F. V., 1976, Large submarine slide (olistostrome) associated with Sunda arc subduction zone, northeast Indian Ocean: Marine Geology, v. 21, p. 211-226.

Moore, J. G., 1972, Mineral resources of the High Sierra Primitive Area, California: U.S. Geol. Survey Bull. 1371A, 27 p.

Moore, J. G., and Dodge, F.C.W., 1962, Mesozoic age of metamorphic rocks in the Kings River area, southern Sierra Nevada, California: U.S. Geol. Survey Prof. Paper 450B, p. B19-B21.

Saleeby, J. B., 1975a, Structure, petrology and geochronology of the Kings-Kaweah mafic-ultramafic belt - southwestern Sierra Nevada foothills, California: California Univ., Santa Barbara, Ph.D. Thesis, 286 p.

_____1975b, Breaking and mixing of Permian oceanic lithosphere - southwestern Sierra Nevada foothills, California: Geol. Soc. America Abs. with Programs, v. 7, no. 7, p. 1256.

_____1976a, Zircon Pb/U geochronology of the Kings-Kaweah ophiolite belt - southwestern Sierra Nevada foothills, California: Geol. Soc. America Abs. with Programs, v. 8, no. 3, p. 405.

_____in press, a, Fracture zone tectonics, continental margin fragmentation, and emplacement of the Kings-Kaweah ophiolite belt, southwestern Sierra Nevada foothills, California: I.G.C.P., North American ophiolite volume, Oregon State Geol. Dept. Bull.

_____in press, b, Geochronology of the Kings-Kaweah ophiolite belt, southwestern Sierra Nevada foothills, California: Contr. Min. Pet.

Saleeby, J. B., and Goodin, S. E., 1977, Calaveras Formation bounded by the Kings-Kaweah suture - southwestern Sierra Nevada, California: Geol. Soc. America Abs. with Programs, v. 9, no. 4, p. 493-494.

Schweickert, R. A., 1974, Probable late Paleozoic thrust fault near Sierra City, California: Geol. Soc. America Abs. with Programs, v. 6, p. 251.

_____1976, Early Mesozoic rifting and fragmentation of the Cordilleran orogen in the western U.S.A.: Nature, v. 260, p. 586-591.

_____1977, Major pre-Jurassic thrust fault between the Shoo Fly and Calaveras complexes, Sierra Nevada, California: Geol. Soc. America Abs. with Programs, v. 9, no. 4, p. 497.

Schweickert, R. A., and Cowan, D. S., 1975, Early Mesozoic tectonic evolution of the western Sierra Nevada, California: Geol. Soc. America Bull., v. 86, p. 1329-1336.

Schweickert, R. A., and Wright, W. H., III, 1975a, Preliminary evidence of the tectonic history of the Calaveras Formation of the western Sierra Nevada, California: Geol. Soc. America Abs. with Programs, v. 7, p. 371-372.

_____1975b, Structural studies of the Calaveras Formation along the Stanislaus River and their tectonic implications: Geol. Soc. Sacramento, Ann. Field Trip Guidebook, p. 30-45.

Sharp, R. V., and Duffield, W. A., 1973, Reinterpretation of the boundary between the Cosumnes and Logtown Ridge Formations, Amador County, California: Geol. Soc. America Bull., v. 84, p. 3969-3976.

Silberling, N. J., 1973, Geologic events during Permian-Triassic time along the Pacific margin of the United States in The Permian and Triassic Systems and their mutual boundary: Alberta Soc. Petroleum Geologists, Calgary, p. 345-362.

Silberling, N. J., and Roberts, R. J., 1962, Pre-Tertiary stratigraphy and structure of northwestern Nevada: Geol. Soc. America Spec. Paper 72, 58 p.

Taliaferro, N. L., 1943, Manganese deposits of the Sierra Nevada, their genesis and metamorphism: California Div. Mines Bull. 125, p. 277-332.

Tobisch, O. T., 1960, Geology of the Crane Flat-Pilot Peak area, Yosemite district, California: California Univ., Berkeley, M.A. thesis,

Turner, H. W., 1893a, Some recent contributions to the geology of California: American Geologist, v. 11, p. 307-324.

_____1893b, The rocks of the Sierra Nevada: U.S. Geol. Survey, 14th Annual Report, pt. 2, p. 435-495.

_____1894, Jackson folio, California: U.S. Geol. Survey Geol. Atlas of the U.S., folio 11.

_____1896, Further contributions to the geology of the Sierra Nevada: U.S. Geol. Survey, 17th Annual Report, pt. 1, p. 521-762.

Turner, H. W., and Ransome, F. L., 1897, Sonora folio, California: U.S. Geol. Survey Geol. Atlas of the U.S., folio 41.

_____1898, Big Trees folio, California: U.S. Geol. Survey Geol. Atlas of the U.S., folio 51.

Yancey, T. E., 1975, Permian marine biotic provinces in North America: Jour. Paleontology, v. 49, no. 4, p. 758-766.

Thanks to Joan Totton and Coral Dueber for help in typing this article.