PRELIMINARY GEOLOGIC MAP OF THE RED BLUFF 100,000 QUADRANGLE, CALIFORNIA

by M. C. Blake, Jr.,

D. S. Harwood,

E. J. Helley,

W. P. Irwin,

A. S. Jayko,

D. L. Jones*

1984

U.S. Geological Survey

OPEN-FILE MAP

OF 84-105

This report is preliminary and
has not been edited or reviewed
for conformity with Geological
Survey standards or nomenclature.

*Alphabetical listing

INTRODUCTION

The Red Bluff quadrangle includes portions of the Klamath Mountains, Coast Ranges, Great Valley and Cascade Range geologic provinces. The stratigraphic and structural relations observed from this map provide a key to understanding how rocks of these provinces were formed and subsequently assembled.

The Red Bluff quadrangle is the first of nine 1:100,000 maps along a transect extending from Cape Mendocino to the Nevada border (Fig. 1), currently being mapped and compiled by geologists of the U.S. Geological Survey, Menlo Park. For the purposes of this study Irwin was responsible for mapping and compiling the Klamath Mountains province; Blake and Jayko the Coast Ranges; Jones the pre-Cenozoic rocks of the Great Valley; Helley for the late Cenozoic deposits of the Great Valley province; and Harwood the Cenozoic rocks of the Cascade province.

GEOLOGY

Klamath Mountains

The northwestern part of the Red Bluff 1,100,000 scale metric sheet is occupied by a metamorphic-plutonic basement complex of Jurassic and older rocks within the Klamath Mountains geologic province. Along the eastern limit of their exposure, the Klamath rocks are unconformably overlapped by easterly dipping Cretaceous strata of the Great Valley sequence. Erosional outliers of Cretaceous strata are preserved on Klamath basement rocks at several places. Klamath basement rocks are faulted against dominantly South Fork Mountain Schist of the Coast Range province along the southern limit of the province.

The Klamath Mountains province is divided into several tectonostratigraphic terranes (Irwin, 1972, 1977; Blake and others, 1982). These terranes generally trend northwesterly, and are separated by major faults (Fig. 2). The terranes consist of rocks typical of oceanic crust and island arcs that have accreted to the North American continent prior to Cretaceous time. Progressive accretion of crustal material is indicated by (1) the progressive westward (oceanward) decrease in ages of the ophiolitic parts of the terranes, (2) a similar westward younging of ages of the island arc components, and (3) a general westerly younging of ages of metamorphic rocks that formed adjacent to the boundary faults as a result of the tectonic accretionary process.

The east to west succession of Klamath terranes are: the Eastern Klamath, Trinity, Central Metamorphic, North Fork, Hayfork, Rattlesnake Creek, and Western Klamath (Smith River subterrane).

The Eastern Klamath terrane is represented in the Red Bluff map area by only a small, about one square mile, structural outlier of Bragdon Formation and by a narrow southern extension of the Trinity ultramafic sheet. The outlier of Bragdon is inferred to have been thrust over the Central Metamorphic terrane, along a fault that locally contains small slivers of serpentinite derived from the Trinity terrane. The Trinity terrane in the map area consists entirely of serpentinized ultramafic rock. While considered by some to be the basal ophiolite of the Eastern Klamath terrane, we prefer to keep it a separate terrane until proven otherwise. The Central Metamorphic terrane includes two formations that have not been subdivided in this map area, the Abrams Mica Schist and Salmon Hornblende Schist.

The ophiolitic rocks of the North Fork terrane are highly attenuated in the Red Bluff map area compared to more northerly reaches of the terrane where they form a belt up to several kilometers wide. The North Fork terrane is generally more coherent than the Eastern Hayfork, includes the North Fork ophiolite where well-developed, and contains limestone with schwagerinid fusulinid fauna, rather than the Tethyan fusulinid fauna of the Eastern Hayfork terrane. However, they are locally difficult to tell apart. The North Fork terrane has been mapped only in a reconnaissance fashion south of the Trinity-Shasta County line.

The Hayfork terrane in the map area was subdivided into two subterranes, the Eastern Hayfork and Western Hayfork, by Wright (1982).

The Eastern Hayfork terrane is a melange and broken formation that occupies a zone about 9 km wide along the southwest side of the North Fork terrane. The Western Hayfork subterrane consists mostly of Hayfork Bally Meta-andesite, which is an inferred remnant of volcanic arc sequence of Early or Middle Jurassic age and which was intruded by approximately 170 m.y. old plutons. The plutons and the volcanic strata are considered co-genetic.

The Rattlesnake Creek terrane is an ophiolitic melange which occurs along the southwest side of the Western Hayfork terrane. Isotopic data and paleontologic suggest that the ophiolite formed during the Late Triassic (200 m.y.).

The Western Klamath terrane has beén divided into several subterranes (Blake and others, 1982); that portion of it within the Red Bluff sheet is known as the Smith River subterrane.

Rocks of the Smith River subterrane are found along the southern margin of the province. They consist of Galice Formation (?) plus small bodies of volcanic rocks that resemble the Rogue Formation of northwest California and southwest Oregon. In addition to the outcrops along the southern margin of the Klamath Mountains province, rocks of this subterrane occur farther south as small fault-bound slices along the boundary between the Coast Ranges and the Great Valley. The significance of these slices will be discussed later.

In the Red Bluff quadrangle the Great Valley Sequence has been subdivided into Cretaceous overlap assemblage and sedimentary rocks of the Elder Creek terrane. The Cretaceous overlap unconformably overlies the Klamath basement rock and conformably overlies the Elder Creek terrane. The oldest known fossil from the overlap assemblage in the Red Bluff sheet is Hauterivian age; however, slightly older fossils of late Valanginian age are known from the Glade Creek outlier about 20 km to the west (Jones and Irwin, 1971). These strata clearly mark the end of the Nevadan orogeny. They were, themselves, however, involved in several subsequent tectonic events as described in the following sections.

Coast Ranges

The Franciscan rocks of the Coast Ranges have been divided into two terranes, Pickett Peak and Yolla Bolly. Within the structurally higher Pickett Peak terrane there are two distinctive units, the South Fork Mountain Schist and Valentine Spring Metagraywacke believed to have formed during the same metamorphic event but now separated by the Log Springs thrust fault. The Yolla Bolly terrane has been subdivided into four informal thrust-bound units based on differences in lithology and metamorphic grade.

The structurally highest unit is the Taliaferro Metamorphic Complex (Suppe, 1973). It consists of jadeite-bearing metagraywacke (T-2B), metachert, and metavolcanic rocks, the latter containing obvious blue amphiboles. The structural state varies from coherent in the north to melange near the Ovenlid where the rocks are structurally mixed with those of the underlying Chicago Rock broken formation. The upper contact is a sharply-defined contact with the overlying Valentine Spring Formation. It has been mapped as the Sulphur Creek thrust fault (Worrall, 1981) on the basis of both metamorphic and structural discontinuities.

The Chicago Rock melange also varies from relatively coherent broken formation to rather chaotic melange, containing abundant blocks of both greenstone and chert as well as rare knockers of blueschist and scarce intrusive serpentinite. The upper contact with the Valentine Spring Formation is, in most places, the Sulphur Creek thrust fault, but in the southern part of the map area, a tectonic slice of Taliaferro is present between these two units.

The metagraywacke of Hammerhorn Ridge contains more coherent graywacke and chert and lens volcanic rocks than any of the other four units of the Yolla Bolly terrane. The upper contact is placed at the top of the coherent sequence and is inferred to be a thrust fault (Slides Glade thrust, Worrall, 1981) although the thrusting is probably distributed throughout the overlying Chicago Rock melange.

The lowest, Devils Hole Ridge broken formation is somwhat similar to Chicago Rock melange but is usually more coherent and contains fewer blocks of greenstone and chert. West of the Red Bluff 1:100,000 sheet, however, it is extremely difficult to differentiate these two units except where the metagraywacke of Hammerhorn Ridge intervenes. The upper contact of Devils Hole Ridge broken formation is locallv marked by sheared serpentinite and the contact was mapped in the field at the base of the coherent Hammerhorn Ridge unit. The presence of Lower Cretaceous Buchias below Upper Jurassic radiolarians in the overlying metagraywacke-chert sequence requires a thrust fault. It must be emphasized that none of the units of the Yolla Bolly terrane are as stratally disrupted as the central terrane melange that lies to the west of the Red Bluff sheet.

Rocks of these two terranes were formerly thought to have been metamorphosed during the same Cretaceous event (Blake and others, 1967). However, recent work (Jayko, 1983) indicates that: 1.) a progressive eastward increase in textural and metamorphic grade occurs in each terrane, 2.) rocks of the Pickett Peak terrane contain early deformational-metamorphic structures not seen in the rocks of the Yolla Bolly terrane, and 3.) there is a major thrust fault separating the two terranes (Sulphur Creek fault of Worrall, 1981). Although the exact timing of the two metamorphic events is not clear, the regional geologic relationships and available radiometric and fossil data suggest that both occurred during the Cretaceous.

Pre-Cenozoic rocks of the Great Valley

Along the west side of the Sacramento Valley south of the Cold Fork fault zone, Upper Jurassic and Lower Cretaceous strata of the Great Valley sequence are exposed on the steeply dipping western limb of a large syncline. Within the Red Bluff sheet, these strata are in fault contact with ultramafic rocks of the Coast Range ophiolite, however, a few kilometers to the south, exposed along the South Fork of Elder Creek is a depositional contact between the basal Upper Jurassic sedimentary rocks and underlying mafic breccia marking the top of the ophiolite. The ophiolite is thought to represent oceanic crust upon which the Upper Jurassic stata were deposited. The ophiolite and overlying Jurassic and Early Cretaceous sedimentary rocks have collectively been named the Elder Creek terrane (Blake and others, 1982).

Although previously considered to be contiguous with the Cretaceous overlap assemblage, to the north, the oldest sedimentary rocks of the Elder Creek terrane were clearly not part of the overlap assemblage but were deposited during the Nevadan Orogeny. This fact was first noted by Jones and others (1969) and was further discussed by Suppe (1972) who proposed that the "oceanic" Great Valley sequence was presumably allochthonous with respect to North America and that a major fault (subduction zone) lies hidden beneath the Cretaceous cover of the Great Valley. Because of renewed movement on all of the fault zones and a lack of sedimentological studies tied to the stratigraphy, it is impossible at this time to know exactly when stratal continuity commenced. A regional unconformity near the base of the Turonian occurs to the south near Wilbur Springs (McLaughlin and others, 1980). Keeping in mind the many uncertainties, we have mapped the contact of the overlap assemblage on the Elder Creek terrane at this position.

Great Valley and Northern Sierran Foothills

The eastern two-thirds of the Red Bluff quadrangle displays low-rolling topography sloping toward the Sacramento River, the largest drainage system in northern California. This part of the map is covered by late Cenozoic sedimentary and volcanic rocks that rest with marked unconformity on Upper Cretaceous rocks of the Great Valley sequence and locally on the Shasta Bally batholith about 6.5 km northwest of Cloverdale.

The western part of the Sacramento Valley is underlain by Pliocene continental deposits of the Tehama Formation and the eastern part is underlain by coeval volcanic rocks of the Tuscan Formation. The Nomlaki Tuff Member, which occurs locally at or near the base of both formations, blanketed much of the northern valley about 3.4 m.y. ago; approximately beginning at the major Neogene uplift and erosion of the Coast Ranges. Continental deposits of the Tehama accumulated at the foot of the emerging Coast Ranges as coalescing alluvial fans. To the east, lahars and minor flows, composed of basalt and basaltic andesite flowed westward from several volcanic centers near Lassen Peak at the southern end of the Cascade Range. Rocks of the Tehama and Tuscan formations interfinger in a zone several kilometers wide near the present channel of the Sacramento River, which we have taken arbitrarily as the formational boundary.

The Tehama and Tuscan are bevelled and capped by the Red Bluff Formation, a thin unit of bright red gravel with a red sandy matrix. The Red Bluff generally forms the highest part of the valley landscape on the west side of the Sacramento River, where it occurs as remanants of a highly dissected and eroded geomorphic surface. We interpret the Red Bluff as a sedimentary cover on a pediment surface because 1) the Red Bluff is apparently deposited on a cut surface of low relief that extends regionally across various older rock types, 2) the deposits are thin and are locally derived, and 3) the pediment and its deposits probably formed during a period of lateral planation by high gradient tributary stream due to impeded drainage which raised local base level. Well-developed, non-calcic brown soils (Xeralfs) of the Redding and Corning Soil Series characterize the Red Bluff.

On the west side of the valley all units younger than the Red Bluff occur in nested terraces usually tens of meters below the pediment surface. This depositional scheme is partially developed on the east side of the valley, but, locally, younger alluvial deposits and volcanic rocks extend over the Red Bluff surface (Helley and others, 1981). Four Pleistocene terrace deposits have been recognized on the west side of the Sacramento Valley and have been correlated by absolute ages, soil stratigraphy, geomorphic expression, and superposition with the Riverbank and Modesto formations of the San Joaquin Valley (Marchand and Allwardt, 1981). Each formation is divided informally into an upper and lower member. Original alluvial material on the terraces on the west side of the valley are lithologically virtually identical, but each deposit has a characteristic elevation, degree of dissection, and soil-profile development; each characteristic is chiefly a function of age. The terrace deposits on the east side of the valley are lithologically indistinguishable from each other, but their volcanic character readily distinguishes them from west-side deposits. Correlation of east-side terraces is based on the same criteria used on the west-side terrace deposits. The greatest elevation difference within the Pleistocene deposits exists between the top of the Red Bluff and the highest terrace of the Riverbank Formation, the oldest Pleistocene terrace. Streams throughout the Sacramento Valley incised their valleys tens of meters between the deposition of the Red Bluff and the deposition of the older Riverbank, suggesting a major regional lowering of base level. Younger terraces such as the lower and upper Riverbank and the lower and upper Modesto terraces differ in elevation by only a few meters.

Terrace deposits of Riverbank age are well developed and best preserved in the Sacramento River valley near Anderson, Balls Ferry and along Cottonwood Creek including its tributaries, South Fork, Dry Creek and Red Bank Gulch. Riverbank age deposits are also present along the west side of the Sacramento River south of the city of Red Bluff along Pine Creek, Reeds Creek, Red Bank Creek, Oat Creek and Elder Creek. The terrace deposits along these streams merge eastward to form a broad terrace plain along the right bank of the Sacramento River from Red Bluff south to the border of the quadrangle and beyond.

The deposits of Modesto age are best preserved in the same areas as those of Riverbank age. Clearly the Riverbank and Modesto deposits were laid down by the same water courses that exist today. The major volume of Holocene deposits is accumulating along the Sacramento River and the tributaries commonly contain significantly smaller volumes of material in open non-vegetated sediment-filled channels eroded into Modesto, Riverbank, and older deposits.

In contrast to the west side of the valley, the east side displays fewer terraces and more erosional morphology.

TECTONIC HISTORY

The oldest tectonic event recorded in the rocks of the Red Bluff sheet is the metamorphism of the Abrams Mica Schist and the Salmon Hornblende Schist. The metamorphism is thought to have taken place when the Central Metamorphic terrane was overridden by the Trinity terrane during the Devonian.

Accretion of the North Fork terrane to the Central Metamorphic terrane occurred during Middle or Late Jurassic time, as the youngest rocks of the North Fork terrane are Early or Middle Jurassic in age (Irwin and others, 1982).

The Eastern and Western Hayfork terranes were sutured together probably during the Middle or Late Jurassic along a fault that probably predates the suturing with the North Fork. Suturing of the Rattlesnake Creek and Western Hayfork terrane probably occurred during Middle or Late Jurassic.

Near Greasewood Hills, in the southwestern portion of the Red Bluff 1:100,000 quadrangle, rocks of the Klamath Mountains including the overlap assemblage, Great Valley, and Coast Range provinces come together in what has been called the Yolla Bolly junction (Blake and Jones, 1977; 1981). The tectonic history that led to the formation of this junction is still not clearly understood despite the fact that rock distribution and age are fairly well known. Perhaps the greatest uncertainty is how, when, and where the Pickett Peak terrane was formed. Despite these uncertainties, the tectonic events that led to the formation of the Yolla Bolly junction probably involved:

(1) Obduction of the Coast Range ophiolite and lower Great Valley sequence (Elder Creek terrane) onto the late Jurassic volcanic arc represented by the Smith River terrane. This is suggested by the previously mentioned slices of Smith River subterrane along the western margin of the Coast Range ophiolite, here, and at least as far south as Thomes Creek in the Willows 1:100,000 sheet. The timing of this event could be as old as Nevadan (Late Jurassic 150 m.y.) or as young as Early Cretaceous.

(2) Left-lateral strike-slip faulting roughly coinciding with the present Sulphur Spring and Oak Flat faults in order to juxtapose the terranes of the Klamath Mountains province against the Elder Creek terrane.

(3) Accretion of the Pickett Peak and Yolla Bolly terranes beneath the combined Klamath-Elder Creek terranes (probably two events) accompanied by tear-faulting within the upper plate rocks (Cold Fork and Elder Creek fault zones).

(4) Formation of the high-angle reverse fault that forms the present eastern and northern boundary of the Coast Range province. The time of initiation of this faulting, which was responsible for the uplift of the previously accreted Franciscan rocks, is not clear, but the uplift may have commenced approximately when Nomlaki Tuff was erupted (3.4 m.y.) since abundant Franciscan detritus first appears above that horizon in the Tehama

Formation. Faulting probably continued throughout the time of deposition of the Red Bluff Formation and may even be active today since an earthquake swarm of more than ten events occurred near this fault between March 22 through April 4, 1982 (Jeff Howard, California Department of Water Resources, written commun., 1983).

Structural Analysis of the Sacramento Valley

Pliocene and younger deposits in the eastern part of the map area also show evidence of significant late Cenozoic deformation. The northwest-trending zone of short fault segments located southeast of Red Bluff marks the northern half of the Chico monocline (Harwood and others, 1981). The monocline is a southwest facing flexure draped over a steeply east-dipping, high-angle reverse fault that offsets basement rocks about 400 m up-to-the east (Harwood and Helley, 1982; in press). The monocline formed between 1.0 and 2.5 m.y. ago under essentially east-west directed compressive stress that steeply thrust up the Sierran block east of the valley (Harwood, 1983). Although evidence for lateral movement during formation of the monocline is scarce, limited slickenside data suggest minor left-lateral slip.

From Red Bluff to the northern end of the valley, late Cenozoic structural features strike east-northeast, nearly orthogonal to the Chico monocline and other north-trending structures located south of the map area (Harwood and Helley, 1982). The change from north- and northwest-striking structures to east-northeast-trending structures occurs at the Red Bluff fault, which trends about N.40°E. diagonally across the valley subsurface passing directly beneath the city of Red Bluff. Southwest of Red Bluff, the fault has no surface expression but northeast of the city the Pliocene volcanic rocks of the Tuscan Formation are warped into a broad northeast-trending anticline along the extended trend of the Red Bluff fault. As far as can be determined from data available to us, the Red Bluff fault appears to have normal, down-to-the-south displacement with the base of the Pliocene rocks offset by folding or faulting, or both, about 140 m (465 ft). Griscom (1973) inferred major right-lateral slip on the Red Bluff fault from tentative correlation of offset magnetic and gravity anomalies associated with basement rocks beneath the northern part of the valley. There is no indication of major late Cenozoic lateral movement, but earlier strike-slip displacement cannot be ruled out with available data.

About 25 km north of Red Bluff, rocks east of the Sacramento River are offset up-to-the-north along the Battle Creek fault. Displacement on the fault and the height of the prominent fault scarp along Battle Creek increases significantly toward the east (Harwood and others, 1980). West of the Sacramento River the straight channel and valley of Cottonwood Creek is on strike with the Battle Creek fault and probably coincides in part with the western extension of the fault. The most likely projection of the Battle Creek fault is down the South Fork of Cottonwood Creek where many linear features are found within and bordering Quaternary terraces (Helley and others, 1981).

Although the Battle Creek fault offsets a number of older volcanic flows and the scarp is buried or draped by younger volcanic units, the movement history and slip rate of the fault are not well known. Many of the volcanic units are high alumina basalts, extremely low in K_2O, and cannot be dated accurately by the K/Ar method. If the volcanic fanglomerate, offset by the fault near the confluence of Battle Creek and the Sacramento River, correlates with the Red Bluff Formation as proposed here, major down-to-the-south, normal faulting occurred less than 1 million years ago. The westward course of the Rockland ash, which erupted east of the map area about 0.45 m.y. ago (Meyer and others, 1980), appears to have been directed in part by the Battle Creek fault scarp. Thus the major movement on the fault appears to have occurred between 0.45 and about 1.0 m.y. ago (see Table 1).

Between the Battle Creek and Red Bluff faults, the major meanders of the Sacramento River are controlled by southwest plunging folds referred to as the Inks Creek fold system (Helley and others, 1981). The trace of the anticline in the fold system extends northeastward from the river, east of Juniper Point, and merges with the Battle Creek fault at about the quadrangle boundary. The synclinal trace passes through Table Mountain and Inks Creek. West of the river, between Table Mountain and Hooker the Pliocene Tehama Formation is arched into a broad dome clearly shown by the drainage pattern of Hooker Creek and Blue Tent Creek. Deformation that produced the Inks Creek and the Hooker dome began shortly before eruption of the Rockland ash bed which rests unconformably across the eroded contact between Red Bluff Formation and the Tehama at Round Mountain about 2 km south of Juniper Point. Early phases of folding probably accompanied early movement on the Battle Creek fault. Subsequent folding and doming produced the incised meanders of the Sacramento River and deformed Quaternary terrace deposits on the north side of Hooker dome that may be as young as 250,000 years.

The kinematic relations, if any, between late Cenozoic structures in the northern part of the valley and those in the provinces to the west are unknown. It is interesting to speculate, however, that the east-northeast-trending Battle Creek fault extends southwest under the South Fork of Cottonwood Creek to join the Oak Flat and Sulfur Springs faults at the Yolla Bolly junction. Certainly, late Cenozoic movement on the Battle Creek fault has been predominantly south-side down normal faulting, but little evidence is available on pre-late Cenozoic movement. It is possible that the northeast-trending Bear Creek, Battle Creek and Red Bluff faults reflect a broad zone of early and pre-Neogene left-lateral displacement that accommodated any differential movement between the Klamath Mountains-Oregon Coast Range and the Sierra Nevada during early Cenozoic clockwise rotations (Magill and Cox, 1981).

References Listed

Bailey, E. H., and Jones,m D. L., 1973, Preliminary lithologic map, Colyear Springs quadrangle, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-516, scale 1:48,000.

Blake, M. C., Jr., 1965, Structure and petrology of low-grade metamorphic rocks, blueschist facies, Yolla Bolly area, northern California: Stanford University unpublished Ph.D. thesis, 91 p.

Blake, M. C., Jr., Howell, D. G., and Jones, D. L., 1982, Preliminary Tectonostratigraphic terrane map of California, scale 1:750,000: U.S. Geological Survey Open-File Report 82-593.

Blake, M. C., Jr., Irwin, W. P., and Coleman, R. G., 1967, Upside-down metamorphic zonation, blueschist facies, along a regional thrust in California and Oregon: U.S. Geological Survey Professional Paper 575C, p. 1-9.

Blake, M. C., Jr., and Jones, D. L., 1977, Plate tectonic history of the Yolla Bolly Junction, northern California: Geological Society of America, Guide for 73rd Annual Cordilleran Section Meeting, Sacramento, California.

Blake, M. C., Jr., and Jones, D. L., 1981, The Franciscan assemblage and related rocks in northern California: a reinterpretation, in the Geodynamic development of California, W. G. Ernst, ed., Prentice-Hall, Inc., p. 307-328.

Creely, R. S., 1965, Geology of the Oroville quadrangle, California: California Division of Mines and Geology Bulletin 184, 86 p.

Evernden, J. F., Savage, D. E., Curtis, G. H., and James, G. T., 1964, Potassium-argon ages and the Cenozoic mammalian chronology of North America: American Journal of Science, v. 262, p. 145-198.

Griscom, Andrew, 1973, Bouguer gravity map of California, Redding Sheet, California Division of Mines and Geology, scale 1:250,000.

Harwood, D. S., 1983, Late Cenozoic east-west compressive tectonism in the Sacramento Valley, California (abs.): Pacific Section, American Association of Petroleum Geologists-Society of Economic Paleontologists and Mineralogists Annual Meeting, Sacramento, California.

Harwood, D. E., Helley, E. J., Barker, J. B., and Griffin, E. A., 1980, Preliminary geologic map of the Battle Creek fault zone, Shasta and Tehama Counties, California: U.S. Geological Survey Open-File Report 80-474, scale 1:24,000.

Harwood, D. S., Helley, E. J., and Doukas, M. P., 1981, Geologic map of the Chico monocline and northeastern part of the Sacramento Valley, California: U.S. Geological Survey Miscellaneous Investigation Series Map I-1238, scale 1:62,500.

Harwood, D. S., and Helley, E. J., 1982, Preliminary structure contour map of the Sacramento Valley, California showing contours of major structural features and depth to basement: U.S. Geological Survey Open-File Report 82-737, scale 1:250,000.

Harwood, D. S., and Helley, E. J., in press, Late Cenozoic tectonism of the Sacramento Valley, California: U.S. Geological Survey Professional Paper ---.

Helley, E. J., Harwood, D. S., Barker, J. A., and Griffen, E. A., 1981, Geologic map of the Battle Creek fault zone, northern Sacramento Valley, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1298, scale 1:62,500.

Huber, D. F., and others, 1983, Geology of six roadless areas in the Redding sheet, California: U.S. Geological Survey Miscellaneous Field Studies Map MF--- (in press).
Irwin, W. P., 1972, Terranes of the western Paleozoic and Triassic belt in the southern Klamath Mountains, California: U.S. Geological Survey Professional Paper 800-C, p. C103-C111.
Irwin, W. P., 1974, Reconnaissance geologic map of the Hayfork quadrangle, Trinity County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-576, scale 1:62,500.
Irwin, W. P., 1977, Review of Paleozoic rocks of the Klamath Mountains, in Paleozoic paleogeography of the western United States: Society of Economic Paleontologists and Mineralogists, Pacific Coast Paleogeography Symposium 1, p. 441-454.
Irwin, W. P., and Galanis, S. P., Jr., 1976, Map showing limestone and selected fossil localities in the Klamath Mountains, California and Oregon: U.S. Geological Survey Miscellaneous Field Studies Map MF-749, scale 1:500,000.
Irwin, W. P., Jones, D. L., and Blome, C. D., 1982, Map showing sampled radiolarian localities in the western Paleozoic and Triassic belt, Klamath Mountains, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1399, scale 1:250,000.
Jayko, A. S., 1983, Deformation in low-grade blueschists of the Eastern Franciscan belt, northern California: Geological Society of America Abstracts with Programs, v. 15, p. 313.
Jones, D. L., Bailey, E. H., and Imlay, R. W., 1969, Structural and stratigraphic significance of the Buchia zones in the Colyear Springs-Paskenta area, California: U.S. Geological Survey Professional Paper 647-A, 21 p.
Jones, D. L., and Irwin, W. P., 1971, Structural implications of an offset Early Cretaceous shoreline in northern California: Geological Society of America Bulletin, v. 82, p. 815-822.
Lanphere, M. A., Irwin, W. P., and Hotz, P. E., 1968, Isotopic age of the Nevadan orogeny and older plutonic and metamorphic events in the Klamath Mountains, California: Geological Society of America Bulletin, v. 79, no. 8, p. 1027-1052.
Macdonald, G. A., 1963, Geology of the Manzanita Lake quadrangle, California: U.S. Geological Survey Geologic Quadrangle Map GQ-248, scale 1:62,500.
Macdonald, G. A., and Lydon, P. A., 1972, Geologic map of the Whitmore quadrangle, California: U.S. Geological Survey Geologic Quadrangle Map GQ-993, scale 1:62,500.
Magill, J. and Cox, Al, 1981, Post-Oligocene tectonic rotation of the Oregon western Cascade Range and the Klamath Mountains: Geology, v. 9, p. 127-131.
Marchand, D. E., and Allwardt, A., 1981, Late Cenozoic stratigraphic units, northeastern San Joaquin Valley, California: U.S. Geological Survey Bulletin 1470, 70 p.
Maytum, J. R., 1967, Areal geology of southeast portion Chanchelulla Peak quadrangle, California: California State University, San Diego, M.S. thesis, 113 p.
McLaughlin, R. J., Ohlin, H. N., Thormahlen, D. J., Miller, J. W., and Carlson, Christing, 1980, Structure of late Mesozoic rocks in the core of the Wilbur Springs antiform, northern Coast Ranges, California: Geological Society of America, Programs with Abstracts, v. 12, p. 119.

Meyer, C. E., Woodward, M. J., Sarna-Wojcicki, A. M., and Naeser, L. W., 1980, Zircon fission-track age of 0.45 million years on ash in the type section of the Merced Formation, west central California: U.S. Geological Survey Open-File Report 80-1071.

Murphy, M. A., Rodda, P. U., and Morton, D. M., 1969, Geology of the Ono quadrangle, Shasta and Tehama Counties, California: California Division of Mines and Geology, 28 p.

Peterson, Gary, 1969, Chanchelulla Peak quadrangle, part of figure 3, in Murphy, M. A., Redda, P. U., and Morton, D. M., 1969, Geology of the Ono quadrangle, Shasta and Tehama Counties, California: California Division of Mines and Geology Bulletin 192, 28 p.

Wilson, T. A., 1961, The geology near Mineral, California: University of California, Berkeley, unpublished M.S. thesis, 94 p.

Worrall, D. M., 1981, Imbricate low-angle faulting in uppermost Franciscan rocks, south Yolla Bolly area, northern California: Geological Society of America Bulletin, v. 92, p. 703-729.

Wright, J. E. 1981, Geology and U-Pb Geochronology of the Western Paleozoic and Triassic Subprovince, Klamath Mountains, northern California: California University, Santa Barbara, Ph.D. thesis, 300 p.

Wright, J. E., 1982, Permo-Triassic accretionary subduction complex, southwestern Klamath Mountains, northern California: Journal of Geophysical Research, v. 87, p. 3805-3818.

DESCRIPTION OF MAP UNITS

KLAMATH MOUNTAINS

Qls LANDSLIDE DEPOSITS

CRETACEOUS OVERLAP ASSEMBLAGE--divided into:

Ks UNDIFFERENTIATED SEDIMENTARY ROCKS (LOWER CRETACEOUS)

Kms MUDSTONE (CRETACEOUS)--Dark gray with minor thin interbeds of siltstone and fine-grained sandstone

Kss SANDSTONE AND CONGLOMERATE (CRETACEOUS)--Fine- to coarse-grained and local pebble to boulder conglomerate

PLUTONIC ROCKS--divided into:

Jsb SHASTA BALLY BATHOLITH (EARLY CRETACEOUS AND(OR) LATE JURASSIC)--Biotite-hornblende quartz diorite, K-Ar isotopic age of about 136 m.y. (Lanphere and others, 1968)

Jbg BASIN GULCH PLUTON (JURASSIC)--Predominantly (biotite) hornblende quartz diorite. U-Pb isotopic age of 170 m.y. (Wright, 1981)

Jgb WALKER POINT AND WILDWOOD PLUTONS (JURASSIC)--Predominantly biotite hornblende gabbro and (biotite) olivine clinopyroxenite (cpx). U-Pb isotopic age of 169 m.y. (Wright, 1981)

Joc OLIPHANT CREEK PLUTON (AGE UNKNOWN)--Predominantly (biotite) hornblende gabbro

Jgr UNNAMED PLUTON (PROBABLY LATE JURASSIC)--Medium- to coarse-grained leucocratic granite

SMITH RIVER SUBTERRANE OF WESTERN KLAMATH TERRANE--In this area, divided into:

srs METASEDIMENTARY ROCKS (PROBABLY LATE JURASSIC)--Metagraywacke and slates

srv METAVOLCANIC ROCKS (PROBABLY LATE JURASSIC)--Volcanic rocks metamorphosed to the lower greenschist facies

RATTLESNAKE CREEK TERRANE--In this area, divided into:

rcm UNDIVIDED MELANGE (AGE UNKNOWN)--Melange includes serpentinite, pillow basalt, chert, tuff, argillite, and limestone (ls)

rcdc DIKE AND SILL COMPLEX (EARLY JURASSIC AND(OR) LATE TRIASSIC)--Diabase, diorite, and quartz keratophyre. U-Pb isotopic age of 207 m.y. (Wright, 1981)

rcp PLUTONIC COMPLEX (EARLY JURASSIC AND(OR) LATE TRIASSIC)--Gabbro, diorite, quartz diorite, and albite granite. U-Pb isotopic age of 193-204 m.y. (Wright, 1981)

rcum ULTRAMAFIC ROCK (AGE UNKNOWN)--Mainly tectonized harzburgite

WESTERN HAYFORK TERRANE (PROBABLY EARLY OR MIDDLE JURASSIC)--In this area, divided into:

wh1 VOLCANIC ROCKS--Predominantly crystal-lithic tuff and tuff breccia of andesitic and basaltic composition

wh2 VOLCANIC AND SEDIMENTARY ROCKS--Predominantly crystal-lithic tuff and black slaty argillite wh3 VOLCANIC ROCKS--Predominantly tuff breccia. wh1, wh2, and wh3 combined are equivalent to the Hayfork Bally Metaandesite of Irwin (1977)

wh4 SEDIMENTARY AND VOLCANIC ROCKS--Volcanogenic sandstone, conglomerate, chert, argillite, quartzose sandstone, and crystal-lithic tuff

wh SEDIMENTARY AND VOLCANIC ROCKS, UNDIVIDED

eh EASTERN HAYFORK TERRANE (AGE UNKNOWN)--Melange and broken formation including argillite, quartzose sandstone, chert, limestone (ls), tuff, and serpentinized ultramafic rock (sp). Limestone locally contains Permian (Tethyan?) foraminifers (Irwin and Galanis, 1976), radiolarians in chert yield both Triassic and Jurassic ages (Irwin, Jones, and Blome, 1982). Unit is generally equivalent to the upper unit of the Hayfork terrane of Irwin (1974)

NORTH FORK TERRANE--In this area, includes:

nfs SEDIMENTARY ROCKS (PERMIAN-JURASSIC)--A melange which includes tuffaceous sedimentary rocks and thin-bedded chert plus argillite, conglomerate, quartzose sandstone, rare limestone, pillow basalt, and serpentinized ultramafic rock (sp). Radiolarians yield Permian, Triassic, and Jurassic ages (Irwin, Jones, and Blome, 1982)

nfum ULTRAMAFIC ROCKS (PERMIAN)--Mainly serpentinized harzburgite

cm CENTRAL METAMORPHIC TERRANE (DEVONIAN METAMORPHIC AGE)--Undivided well-foliated hornblende-epidote-albite-schist, quartz-mica schist, and calc schist: includes Salmon Hornblende Schist and Abrams Mica Schist. Rb-Sr isotopic age of metamorphism is approximately 380 m.y. (Lanphere and others, 1968)

tum TRINITY TERRANE (ORDOVICIAN)--Mostly serpentinized harzburgite

EASTERN KLAMATH TERRANE--In this area includes:

ekb BRAGDON FORMATION (MISSISSIPPIAN)--slaty sandstone, shale and conglomerate

ekc COPLEY GREENSTONE (DEVONIAN)--In this area, metamorphosed to dark green, fine-grained amphibolite and hornfels

COAST RANGES

Qg GLACIAL DEPOSITS

Qls LANDSLIDE DEPOSITS

PICKETT PEAK TERRANE--In this area, divided into:

ppsm SOUTH FORK MOUNTAIN SCHIST (EARLY CRETACEOUS METAMORPHIC AGE)--Intensely crumpled and quartz-veined mica schist, Includes fine-grained, laminated, greenish-bluish metabasalt (mb) plus local metachert (not mapped)

ppv VALENTINE SPRING FORMATION (EARLY CRETACEOUS METAMORPHIC AGE)--Dominantly metagraywačke of textural zone 2B and 3A of Blake and Jones (1977). Includes schistose metavolcanic rock (mv) and rare metachert (not mapped)

YOLLA BOLLY TERRANE--In this area, divided into:

ybt TALIAFERRO METAMORPHIC COMPLEX (EARLY CRETACEOUS? METAMORPHIC AGE)--Includes schistose metagraywacke, crumpled phyllite, metagreenstone (gs) and metachert (cht)

ybc CHICAGO ROCK MELANGE (EARLY CRETACEOUS TO LATE JURASSIC)--Mostly sheared argillite, graywacke, and conglomerate with very abundant blocks of fine-grained greenstone (gs), chert (cht) plus scarce serpentinite (sp) and rare blueschist and amphibolite knockers (unmapped). Radiolarians extracted from chert are Tithonian-Valanginian in age. Terrain commonly characterized by lumpy grass-covered hillsides

ybh METAGRAYWACKE OF HAMMERHORN RIDGE (EARLY CRETACEOUS TO LATE JURASSIC)--Dominantly graywacke with lesser amounts of argillite and conglomerate and abundant interbeds of chert (cht) which yield fossils of Tithonian-Valanginian age. Locally intruded by coarse-grained greenstone (g), includes scarce, fine-grained intrusive and extrusive greenstone bodies (gs), and rare intrusive serpentinite (sp). Forms resistant ridges and is commonly timber covered

ybd DEVILS HOLE RIDGE BROKEN FORMATION (LATE JURASSIC TO EARLY CRETACEOUS)--Dominantly argillite, graywacke and conglomerate with blocks and lenses of fine-grained greenstone (gs) radiolarian chert (cht) and rare intrusive serpentinite (sp)

SACRAMENTO VALLEY-EASTERN FOOTHILLS

t MAN-MADE MATERIALS (HOLOCENE)
dredge tailings and other disturbed ground

ALLUVIAL DEPOSITS--(HOLOCENE) Divided into:

Qsc Stream channels--deposits of open, active stream channels without permanent vegetation. These deposits are being transported under modern hydrologic conditions; consequently they are light colored (tan and gray), unweathered and usually in contact with modern surface waters. Our mapping merely limits the right and left bank boundary. The morphology within is constantly changing. Thickness may reach 25 m on the Sacramento River or be less than a few centimeters in bedrock canyons

Qa Alluvium--Gravel, sand, and silt derived from the Tehama and Tuscan Formations and rocks in the Coast Ranges and Klamath Mountains deposited by present-day stream and river systems. Differentiated from older units chiefly on geomorphic position and position in modern stream channels

Qo Overbank deposits--Sand, silt and minor lenses of gravel deposited by floods and high-water stages on low terraces adjacent to present-day alluvial channels

Qao Mixed alluvial and overbank deposits

Qb BASIN DEPOSITS--Fine-grained silt and clay

Qls LANDSLIDE DEPOSITS--Slumped, chaotic mixtures of underlying bedrock units and colluvium

BASALTIC ROCKS OF INSKIP HILL VOLCANIC CENTER--Divided into:

Qip Basalt flows of Paynes Creek--Thin, black to dark-gray high alumina basalt erupted from Inskip Hill (5 km east of Soap Butte) and flowed primarily westward into the drainage of Paynes Creek reaching the Sacramento River at Chinese Rapids. The flows are marked by small lava tubes, pahoehoe texture, and thin scoria layers on the flanks of Inskip Hill and a general diktytaxitic texture further from the center. Scattered yellow-brown phenocrysts of olivine and less abundant, glassy-green phenocrysts of clinopyroxene are set in a matrix of fine-grained plagioclase and clinopyroxene. Northeast of Dales near the quadrangle boundary, the Paynes Creek flow is about 8 m thick; where it crosses the Manton Road northeast of Dales Lake, it is about 2 m thick. The absolute age of the Paynes Creek flow is unknown but it must be on the order of 10,000 years or less because the flow overlies alluvium assigned to the upper member of the Modesto Formation in a tributary of Inks Creek

Qi Undifferentiated basalt of Inskip Hill and Soap Butte--Several high alumina, olivine basalt flows originating at Inskip Hill and Soap Butte. The thickness of the flows is unknown but their limited distribution suggests they are thin, near-vent deposits

BASALTIC ROCKS OF BLACK BUTTE VOLCANIC CENTER--Divided into:

Qbba Cinder deposits--Black, well-bedded, coarse to fine-grained basaltic cinders forming a dissected ejecta blanket that ranges in thickness from about 10 m in the cinder pit on Ash Creek to about 1.5 m on the south rim of Lack Creek near the northeast corner of the map

Qbb Basalt flow of Black Butte--Black to light gray, high alumina olivine basalt flow that issued from the vent that ultimately built the Black Butte cinder cone (east of map). One branch of the flow moved about 1 km west of the vent into the upper reaches of Rancherio Creek; the other cascaded over the Battle Creek fault scarp, forming a bulbous puddle of blocky lava just north of Darrah Springs fish hatchery (not shown on map). The basalt flow is similar in texture and mineralogy to the Paynes Creek flow from Inskip Hill. Olivine and clinopyroxene phenocrysts are scattered in a diktytaxitic matrix of clinopyroxene and plagioclase; accessory minerals include abundant magnetite in the matrix and minor amounts of euhedral spinel included in the olivine phenocrysts. The basalt contains 17.41% alumina, 0.19% K_2O, and 48.33% SiO_2

Qb Basalt--gray, reddish gray to black glomeroporphyritic to highly vesicular, high alumina basalt exposed on west flank of Tuscan Buttes and in Sevenmile Creek to the southwest. Minor scoria blanket beneath and interbedded with basalt flows at Tuscan Buttes. Morphology of deposits suggest small, local extrusions of basalt along approximately north-trending fissure system after much, if not all, of present relief on the surface of the Tuscan had formed by deformation and extensive erosion

MODESTO FORMATION (Pleistocene)--Divided into:

Qmu Upper member--Gravel, sand, silt, and clay lithologically similar to the lower member but does not have pedogenic B-horizon. Both the upper and lower members probably were deposited by the same stream systems that flow today because they tend to border existing channels and are generally less less than 3 meters thick

Qml Lower member--Alluvium composed of gravel, sand, silt, and clay Soils on the lower member contain a pedogenic B-horizon. Terraces display very fresh dispositional morphology with little if any erosional features. Unit is less than 5 meters thick

RIVERBANK FORMATION (Pleistocene)--Divided into:

Qru Upper member--Gravel, sand, silt, and clay lithologically similar to the Modesto Formation but differentiated from the Modesto by (1) geomorphic position above the Modesto terrace and (2) greater degree of soil formation. Soils of the unit display medial development with strong textures, B-horizons, and local hardpans. The upper member of the Riverbank Formation underlies lower and generally smoother terrace surface deposited in the eroded Red Bluff Formation. It is lithologically very similar to, but more widespread than, the lower member of the Riverbank. The soil profile on the upper member is not as well developed as that on the lower member. Unit is less than 10 meters thick

Qrl Lower member--Gravel, sand, and silt. Lower member is lithologically similar to the Red Bluff Formation, but is slightly finer grained and contains less gravel. The lower member occurs on the higher of two terraces cut and filled into surface of the Red Bluff Formation; it is especially prominent west of the Sacramento River along the north side of Cottonwood Creek and is more eroded than the upper member

Qab HYPERSTHENE ANDESITE OF BROKEOFF MOUNTAIN--Porphyritic hypersthene andesite channeled along the Battle Creek fault zone in the northest part of the quadrangle. The unit is continuous with the andesite of Brokeoff Mountain mapped by Macdonald and Lydon (1972) in the Whitmore quadrangle. The rock is dark gray to black and contains abundant white plagioclase phenocrysts as much as 5 mm in length. Scattered honey-yellow phenocrysts of hypersthene and rare augite are set in a fine-grained matrix of plagioclase microlites and brown glass. The flow is about 6 m thick

Qam ROCKLAND ASH BED--White, loosely aggregated, pumice lapilli ash with scattered coarse pumice fragments as much as 20 cm in diameter. Occurs as scattered erosional remnants of a large ash flow sheet that erupted east of the map area. About 15 km east of the map area, the ash-flow tuff is at least 60 m thick north of Digger Buttes but it is generally less than 5 m thick in the scattered patches to the west. The ash is predominantly fine-grained glass, locally distinctly bedded, but in general massive with scattered pumiceous fragments. The pumiceous fragments are composed primarily of silky white, wispy, vesicular glass that contains scattered crystals of glassy to white feldspar, both plagioclase and sanidine, green hornblende, hypersthene, and minor magnetite. Wilson (1961) determined the refractive index of the glass to be 1.500 ± .001, indicative of a silica content of about 67 percent, and the composition of the glass to be dacite

Qbs_3 Qbs_2 Basalt of Shingletown Ridge--At least three flows of olivine basalt enter the northeast part of the quadrangle from Shingletown

Ridge (see Harwood and others, 1980)

Qbs_1 The flows have been mapped in the Whitmore quadrangle by Macdonald and Lydon (1972) and have been traced eastward to the Red Mountain Lake area in the Manzanita Lake quadrangle by Macdonald (1963). They apparently originated from a series of vents scattered along a fissure system trending north-northwest from the vicinity of Lassen Peak. In the map area the flows overlie the Tuscan Formation and the similar appearing flows of the basalt of Coleman Forebay. Maximum thickness of the individual flow are about 5 m. The basalt is dark gray, fine-grained, diltytaxitic, and locally porphyritic with rounded phenocrysts of brownish-green olivine scattered in an openwork mesh of matrix plagioclase and clinopyroxene. The rock is high-alumina basalt containing 47.6 percent SiO_2, 18,09 percent Al_2O_3 and 0.19 percent K_2O. Chemically, mineralogically, and texturally, the rocks are very similar to the underlying basalt of Coleman Forebay, and both may have originated from the same source area at separate, but perhaps not widely spaced, times

Qeb OLIVINE BASALT OF EAGLE CANYON--Olivine basalt exposed in Battle Creek along the foot of the Battle Creek fault scarp above coarse bouldery volcanic fanglomerate. Wilson (1961, p. 11) grouped the basalt of Eagle Canyon, the fanglomerate and the underlying basalt of Coleman Forebay into his Long Ranch basalt unit. The basalt of Eagle Canyon is dark-gray, diktytaxitic, vesticular olivine basalt about 4 m thick. Its source is unknown

Qba OLIVINE BASALT OF DEVILS HALF ACRE--Gray glomeroporphyritic, vesicular olivine basalt showing well-developed columnar jointing on the north rim of Antelope Creek. Aggregates of strongly zoned plagioclase up to 10 mm in diameter and euhedral to subhedral olivine to 5 mm in diameter set in an ophitic matrix of nearly equal amounts of plagioclase microlites and clinopyroxene. Magnetite scattered in the matrix; knee-shaped twinned high-relief crystals of rutile (?) included in plagioclase microlites. Clear to white opal coats some vesticles and also fracture fillings in plagioclase phenocrysts. Maximum thickness 15 m; source unknown

Qrb RED BLUFF FORMATION (PLEISTOCENE)--Very coarse red (2.5-5YR) gravel with minor amounts of interstratified sand and silt. Red Bluff deposits located west of the Sacramento River derived from the Coast Ranges and Klamath Mountains. Fanglomerate composed of volcanic rocks derived partly from the Tuscan Formation and from andesite flows located east of the quadrangle correlated with the Red Bluff to the west. All other Quaternary alluvial deposits; with the exception of the older gravel deposits, are deposited in channels eroded through the Red Bluff. Maximum thickness 5 m. Overlain by the Rockland Ash Bed (0.45 m.y.) and overlays the basalt of Deer Creek 25 km southeast of Red Bluff (1.1 m.y.; Harwood and others, 1981)

Qcb BASALT OF COLEMAN FOREBAY--Olivine basalt underlying volcanic fanglomerate deposits in several isolated areas extending from Coleman Forebay on the Battle Creek fault escarpment southward to the vicinity of Hog Lake. The map unit may represent several flows. The rock is light rusty-gray weathering, dark-gray, olivine basalt with pronounced diktytaxitic texture and scattered large vesicles and voids that form large rounded pits on the weathered surface. The thickness ranges from about 10 m to 0; its source is unknown

QTog OLDER GRAVEL DEPOSITS--Reddish-tan to yellowish-tan, moderately well indurated coarse gravel and minor coarse sand resting unconformably above a truncated soil profile developed on the Tuscan Formation near the Hogback and in Salt Creek east of Red Bluff. Clasts are well rounded, locally deeply weathered volcanic fragments apparently derived from the Tuscan Formation. At Deer Creek on the Chico monocline, older gravel deposits rest unconformably below olivine basalt of Deer Creek (Harwood and others, 1981). The Red Bluff Formation unconformably overlies the older gravels in Salt Creek (Table 1)

QTa Andesite--Gray, greenish gray, red, and grayish tan, fine-grained, sparsely porphyritic, locally flow-banded andesite preserved as an erosional remnant of larger flow capping Tuscan Buttes. Phenocrysts of basaltic hornblende variably altered to fine dust-like particles of magnetite set in matrix of oriented flow-trained microlites of plagioclase. Interstices filled with very fine-grained plagioclase? or a silica mineral after glass. Flow-banded samples from southeast butte contain cumulate fragments. Maximum thickness 35 m; source unknown

TUSCAN FORMATION (PLIOCENE)--Divided into:

Ttd Unit D--Directed-blast and/or avalanche deposits, juvenile andesitic pyroclastic deposit, and related lahars characterized by large monolithologic masses of gray hornblende andesite, augite-olivine basaltic andesite, black pumice, and smaller fragments of black obsidian and white and gray hornblende-bearing pumice in a grayish-tan pumiceous mudstone matrix. Unit D probably originated as a volcanic avalanche deposit triggered by a major explosive event at its source volcano. Samples of two monolithologic masses of andesite in the avalanche deposit at Inskip Hill (5 km east of quadrangle near Soap Butte) gave whole rock K/Ar ages of 2.49 $\pm$ 0.08 and 2.43 $\pm$ 0.07 m.y. Unit D is distinguished from Unit C by monolithologic rocks masses, black obsidian fragments and white and dove-gray dacitic pumice fragments. It ranges in thickness from about 10 to 50 meters

Tth Tuff of Hogback Road--Discontinuous unit of well-bedded lapilli tuff, pumiceous conglomerate, and sandstone. Contains abundant well-rounded white hornblende-bearing dacitic pumice clasts as much as 3 cm in diameter and lesser amounts of smaller, well-rounded light gray and black andesitic pumice clasts. At the Hogback the tuff layer is 1 m thick; on the south side of Tuscan Buttes the unit is about 4 m thick. The tuff rests unconformably on deformed and locally eroded older units in the Tuscan Formation and it appears to be conformably beneath Unit D of the Tuscan

Ttc Unit C--Predominantly lahar composed of angular to subrounded volcanic fragments, as much as 3 m in diameter, in a matrix of gray-tan volcanic mudstone. Composition and texture of fragments and ratio of fragments to matrix are highly variable. Scattered large irregular masses of brick-red and gray, commonly massive to locally flow-banded volcanic breccia occur within the lahars throughout the area. Lahars are generally reversely graded and range in thickness from about 0.5 m to 10 m; upper and lower contacts are sharp. Poorly sorted polymict volcanic conglomerate, sandstone, and siltstone are interlayered with the lahars and increase in abundance toward the west and south. Unit C is at least 75 m thick in the western part of Antelope Creek

Tti Ishi Tuff Member--South of Shasta County the member is a white to light-gray, fine-grained pumiceous airfall tuff commonly reworked and contaminated with variable amounts of volcanic sandstone and silt. Readily distinguished by abundant bronze-colored mica flakes about 1 mm in diameter. Grades laterally into tan pumiceous micaceous siltstone. Maximum thickness in exposures along the Chico monocline about 30 cm. In Shasta County north of the map area, about 4.0 km northeast of Millville on the Whitmore Road the Ishi Tuff Member is a white, faintly bedded, reworked pumiceous sandstone with pumice conglomerate layers. It overlies dark to medium gray moderately welded felsic tuff that contains light and dark gray, quartz-bearing pumice fragments that are commonly oriented but not significantly flattened. Glass from the Millville locality has been correlated by trace element chemistry with glass from the type Ishi Tuff (Harwood and others, 1981). Preliminary K-Ar ages obtained on biotite, hornblende and plagioclase separated from pumice clasts from the Millville locality are widely discordant. Zircons from clasts from the same locality gave a fission-track age of 2.6 m.y. (Table 1) which is currently the best estimate of the age of the Ishi Tuff. Along the Chico monocline the Ishi Tuff separates Units B and C of the Tuscan

Ttb Unit B--Interbedded lahars volcanic conglomerate, volcanic sandstone and siltstone similar to rocks of unit C, but volcanic conglomerate and volcanic sandstone more abundant in unit B. Lahars and alluvial volcaniclastic rocks interbedded in approximately equal proportions, giving a more regularly layered sequence than in the lahar-rich unit C. Maximum thickness of conglomerate layers about 15 m. Unit B is about 130 m thick along the Chico monocline

Tta Unit A--The only exposures of Unit A in the map area are found in Dye Creek Canyon and they consist of interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone, all containing scattered fragments of metamorphic rocks. Metamorphic fragments include white vein quartz, green, gray, and black chert, greenstone, greenish-gray slate, and serpentinite. Metamorphic clasts usually make up less than 1 percent of the rock, the remainder being basaltic and andesitic volcanic fragments. The top of the member is defined by the highest lahar or volcanic conglomerate layer that contains metamorphic fragments

Ttn Nomlaki Tuff Member--White, light-gray, locally reddish-tan to salmon-colored dacitic pumice tuff and pumice lapilli tuff at or very near base of the Tuscan and Tehama Formations. Pumice fragments, as much as 20 cm in diameter, are generally white in the lower part of the member and a mixture of white, light gray, and dark gray in the upper part. Member is generally a massive, nonlayered ash flow well exposed at Tuscan Springs, Antelope Creek, Gas Point on Cottonwood Creek, and several localities south of Gas Point along the west margin of the valley. Maximum thickness 25 m at Tuscan Springs, about 20 m at Antelope Creek, Springs, and 10 m at Gas Point. Lahars containing metamorphic fragments typical of unit A of the Tuscan occur below the Nomlaki Tuff Member in Rock Creek and at the western end of the Lovejoy Basalt exposures in Bidwell Park near Chico, California southeast of the quadrangle (see Harwood and others, 1981). The age of the Nomlaki is given by Evernden and others (1964) as 3.4 m.y. (see Table 1)

Tt TUSCAN FORMATION, UNDIVIDED--Interbedded lahars, volcanic conglomerate, volcanic sandstone, siltstone, and pumiceous tuff

Tte TEHAMA FORMATION (PLIOCENE)--Fluvial deposits of pale-green, gray, and tan sandstone, tuffaceous sandstone, and siltstone with lenses of crossbedded pebble and cobble conglomerate derived from rocks of the Coast Ranges, Klamath Mountains, and the Tuscan Formation. As mapped, includes the Nomlaki Tuff Member at its base. Interfingers with Tuscan Formation in the approximate vicinity of the Sacramento River. Maximum thickness is about 600 m near the city of Red Bluff

Taa BASALTIC ANDESITE OF ANTELOPE CREEK--Dark-gray to greenish-gray, locally altered to brick red and reddish gray, massive, highly fractured, fine-grained, sparsely vesticular basaltic andesite exposed in Antelope Creek and, to a lesser extent, in Salt Creek. Red and reddish-gray scoria layers about 1 m thick alternate with layers of massive gray basaltic andesite of about equal thickness in the western exposures of Antelope Creek and Salt Creek, suggesting that these exposures are near the distal end of the flow. Plagioclase laths as much as 2 mm in length are strongly alined and locally swirled around equidimensional to elongate masses of iddingsite (?), probably pseudomorphous after olivine. No fresh olivine was seen in this rock, which was originally described as a basalt (see Harwood and others, 1981), but which is now known to contain 54.7 percent SiO_2 and thus is located on the generally accepted basalt-andesite boundary

Tc Channel deposits (PLIOCENE AND(OR) MIOCENE)--Tan, yellowish-tan to reddish brown interbedded fluvial conglomerates and sandstone exposed below the Nomlaki Tuff at Tuscan Springs and in some of the deeper canyons along the Chico monocline southeast of the map area. Cobble to pebble conglomerate is the dominant lithology with rounded, commonly disk-shaped clasts showing variable degrees of imbrication. Clasts include greenstone, gray quartzite, red, green and black chert, white vein quartz and lesser amounts of green and gray phyllite. Variable amounts of basalt and basaltic andesite identical to that in the Tuscan Formation are intermixed with metamorphic rock fragments many of which appear to have been reworked from the Cretaceous Chico Formation. Maximum thickness is about 20 m

Kc CHICO FORMATION (UPPER CRETACEOUS)--Tan, yellowish-brown to light-gray fossiliferous marine sandstone with lenticular beds of pebble to fine cobble conglomerate and minor siltstone exposed at Tuscan Springs, Salt Creek, and in Sevenmile Creek south of Tuscan Buttes. Clasts in the conglomerate include rounded to well-rounded red, green, and black chert, white vein quartz, quartzite, granite, and greenstone. Calcite cement and fossil fragments common at Tuscan Springs. Sandstone is composed of fine- to medium-grained angular to subrounded grains of quartz, plagioclase, alkali feldspar, lithic fragments, and detrital chert

ELDER CREEK TERRANE--In this area, divided into:

eco COAST RANGE OPHIOLITE (LATE JURASSIC)--Dismembered ophiolite consisting of sheared serpentinite and small blocks of gabbro and diabase

ecms MUDSTONE (LATE JURASSIC-EARLY CREATACEOUSO--Dark-gray, mainly hackly fractured, with minor tan siltstone and sandstone. Limestone nodules, lenses, and thin beds locally abundant. Forms valleys

ecss SANDSTONE AND CONGLOMERATE (EARLY CRETACEOUS TO LATE JURASSIC)--Fine to coarse-grained sandstone and local conglomerate. Contains minor interbedded mudstone. Forms prominent topographic ridges

Kms MUDSTONE (Middle Cretaceous)--Dark-gray with minor thin interbeds of siltstone and fine-grained sandstone. Disconformably overlies older sedimentary rocks of the Elder Creek terrane

Kss SANDSTONE AND CONGLOMERATE (MIDDLE CRETACEOUS)--Fine- to coarse-grained sandstone and local pebble to boulder conglomerate. Disconformably overlies Elder Creek terrane

EXPLANATION

Strike and dip of beds

Beds inclined; ball where top of beds known from sedimentary structures; beds overturned

Strike and dip of foliation

Foliation in metamorphic rocks; shear fabric in melange; slaty cleavage

Contacts

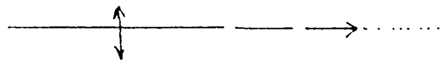
Dashed where approximate, queried where uncertain, and dotted where locally shown as concealed

Faults

Dashed where approximate, queried where uncertain, and dotted where locally shown as concealed

Thrust Faults

Sawteeth are on upper plate



Anticline

?

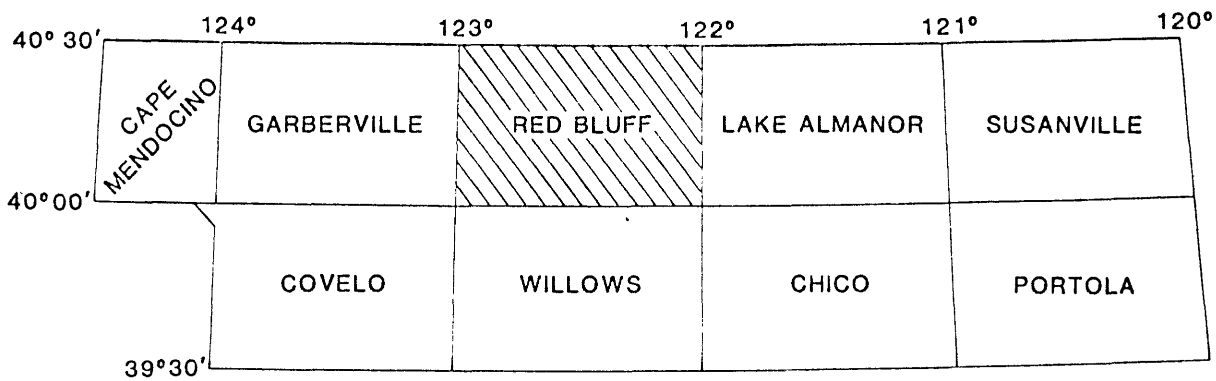
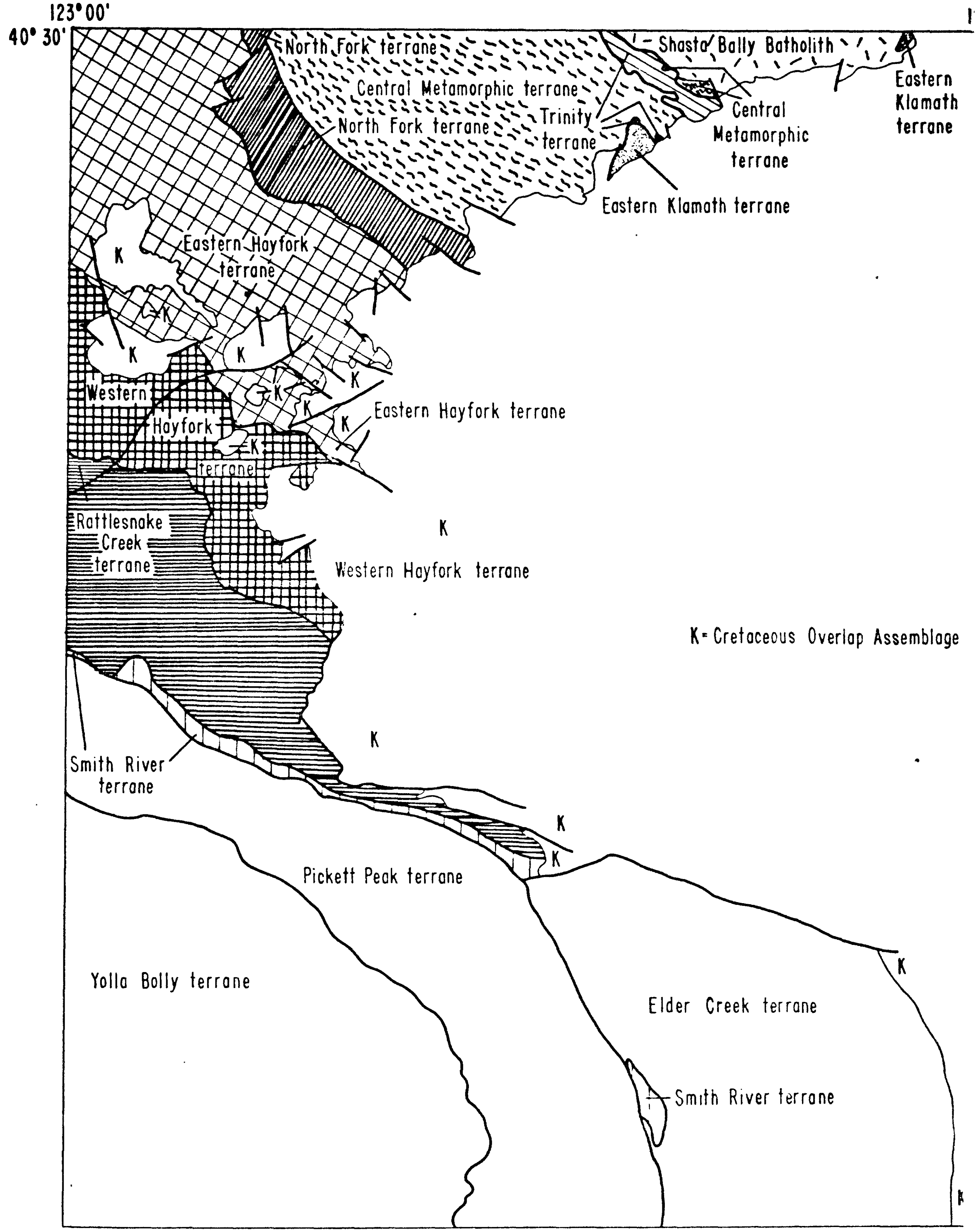
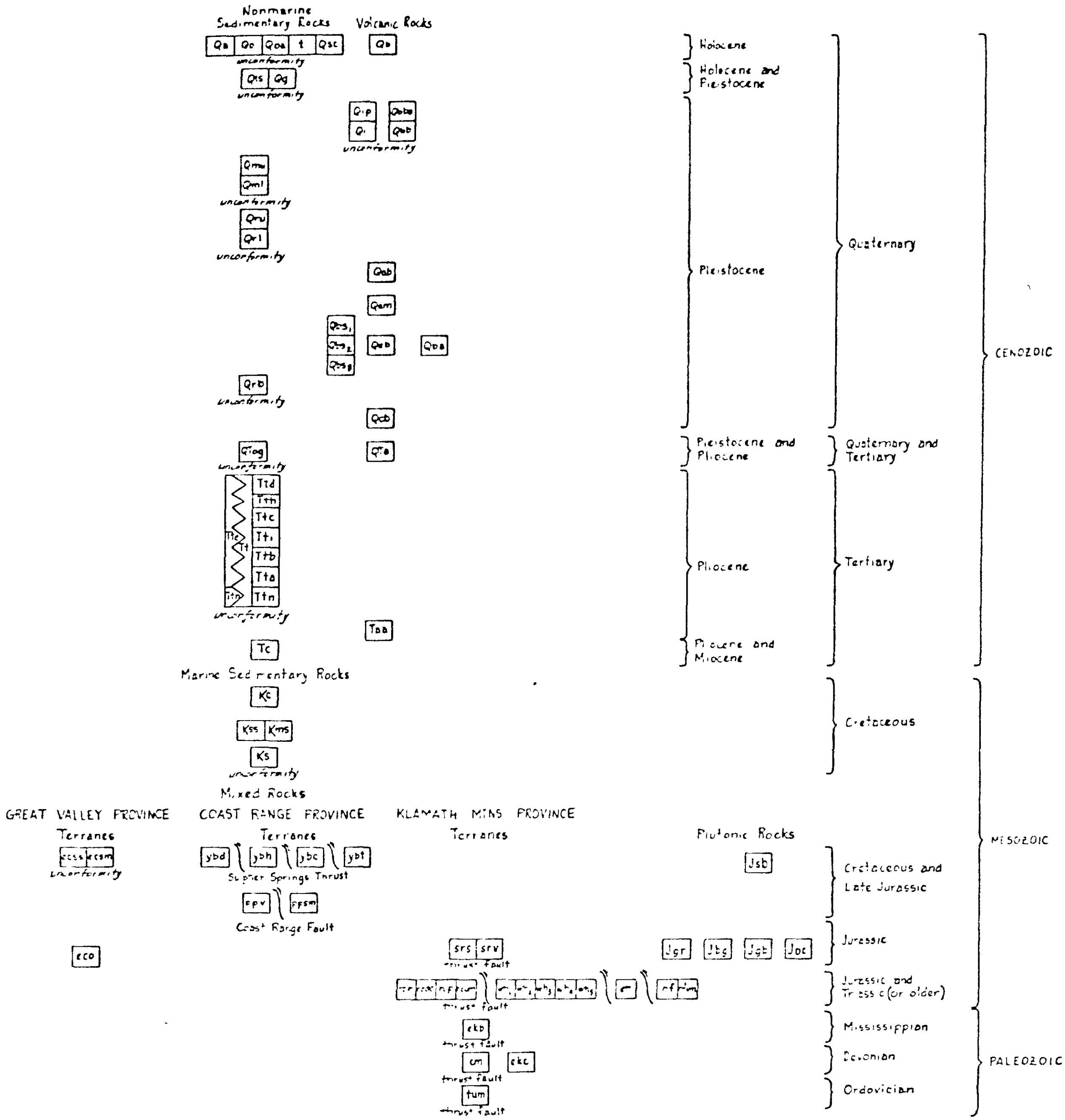


Fig.1--Index map to 1:100 000 scale maps to be completed as part of the northern California transect.


123° 00'
40° 30'
North Fork terrane
Central Metamorphic terrane
North Fork terrane
Trinity terrane
Shasta Bally Batholith
Central Metamorphic terrane
Eastern Klamath terrane
Eastern Klamath terrane
Eastern Hayfork terrane
K
Western Hayfork terrane
Eastern Hayfork terrane
Rattlesnake Creek terrane
Western Hayfork terrane
K= Cretaceous Overlap Assemblage
Smith River terrane
Pickett Peak terrane
Yolla Bolly terrane
Elder Creek terrane
Smith River terrane

CORRELATION OF MAP UNITS



Index to geologic mapping of the Red Bluff 1:100 000 map