U.S. GEOLOGICAL SURVEY
OPEN FILE MAP
76-221

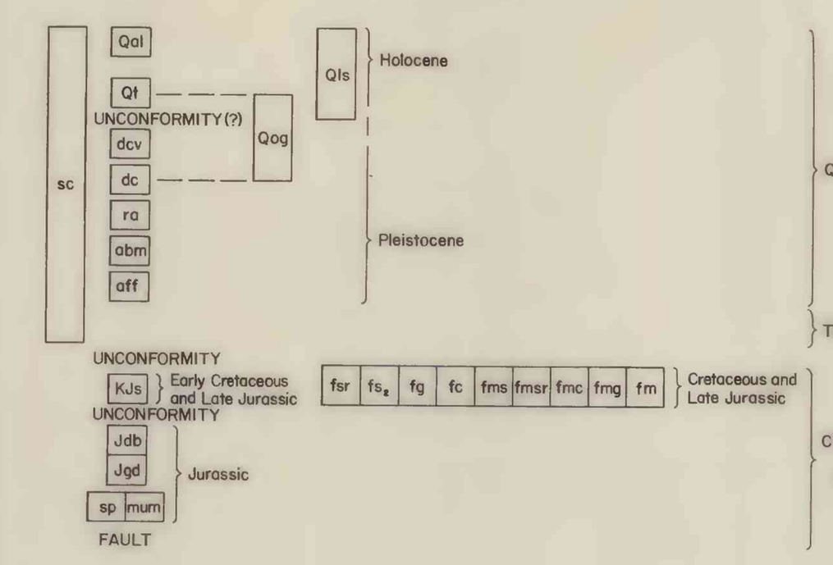
GEOLOGY OF THE COBB MOUNTAIN-FORD FLAT GEOTHERMAL AREA, LAKE COUNTY, CALIFORNIA

By

Fraser E. Goff and Robert J. McLaughlin

1976

CORRELATION OF MAP UNITS



PURPOSE OF REPORT

This report summarizes recently accumulated geologic data which may be of particular concern to economic and environmental interests in this rapidly expanding geothermal area. The accompanying map supersedes published maps of McLaughlin (1974, 1975) and Hearn and others (1975).

GENERAL GEOLOGY AND STRUCTURE

Cobb Mountain is a composite rhyolite and dacite dome built approximately one million years ago during three closely spaced eruptions. It represents an early stage of silicic volcanism in the evolution of the Clear Lake volcanic field. Most of Cobb Mountain was created by a single extrusion of roughly 4.5 km^3 of rhyolite followed somewhat later by less voluminous dacitic eruptions. Boggs Mountain to the northeast is capped by extensive andesite flows which poured out 1.45 million years ago (Hearn and others, 1975).

These young volcanic rocks overlie and intrude complexly deformed metasedimentary and metaigneous Franciscan assemblage rocks of Upper Jurassic and Lower Cretaceous age (McLaughlin, 1974). The Franciscan assemblage is broken by imbricated eastward-dipping thrust faults separating slabs of mélange from more intact slabs of interbedded metagraywacke and lenticular bodies of metachert and metagreenstone. These thrusts, commonly delineated by discontinuous sheets of serpentinite, are thought to have formed in response to Upper Cretaceous and early Tertiary subduction of Franciscan rocks eastward beneath an overriding upper plate of oceanic crust and overlying late Jurassic and Cretaceous strata of the Great Valley sequence (McLaughlin, 1976).

The large northeast-trending body of ultramafic rock and the associated gabbro and diabase on the northeast side of Cobb and Collayomi Valleys represent part of this upper plate of oceanic crust, and the thrust fault forming the lower contact of this ultramafic unit is referred to as the Coast Range thrust (see section B-B').

Superimposed upon the older northeast-dipping thrusts are major steep-dipping northwest-trending faults with significant vertical and strike-slip displacements. These faults and many minor normal faults offset contacts between pre-Tertiary rocks and Pleistocene volcanics.

Collayomi Fault Zone

The Collayomi fault zone on the northeast side of the map area extends for at least 22 km along Cobb Valley and Collayomi Valley (to the southeast of the map area). In the vicinity of Harbin Springs, diabase breccia below the base of late Jurassic-early Cretaceous mudstone (Knoxville Formation?) is right-laterally offset 0.66 km (2,000 ft). Northwest of the map area, andesite dated at 0.4 m.y. (Hearn and others, 1975) has been right-laterally offset 0.4 km (1,300 ft). Other offsets in older alluvium plus the presence of such physiographic features as aligned closed depressions, springs, aligned scarps, and right-laterally offset drainages suggest that the Collayomi fault zone is still active.

Cobb Mountain Fault

The Cobb Mountain fault extends northwestward for 12 km or more cutting across the southwest shoulder of Cobb Mountain. Vertical offsets of 66-100 m occur in the basal rhyolite contact in the southern cliffs of Cobb Mountain and along Gunning Creek which follows the fault trace. The contact pattern across the fault in the SW 1/4 of Sec. 23 along Gunning Creek suggests right-lateral displacement of 185 m (550 ft). West of Cobb Mountain summit (just off the map area) the rhyolite-dacite contact is vertically offset 30 m (100 ft) indicating movement since 1.05 m.y. Serpentinite and tectonic blocks along the zone suggest it may have had a long history of previous movement. No evidence was found, however, to prove Holocene activity although we feel this possibility exists.

INTERPRETATION OF GEOLOGY IN THE VICINITY OF FORD FLAT

The authors prefer to interpret the Ford Flat area as a series of fault blocks down-dropped along northeast-trending normal faults. Previous 1:62,500 scale geologic maps of the region (Brice, 1953; Yates and Hilpert, 1946) interpreted the Ford Flat area to be a large landslide complex composed of Franciscan rocks and rhyolite of Alder Creek chaotically mixed by gravity slides off the southeastern slopes of Cobb Mountain. However, the rumpled topography just northwest of Anderson Springs, formerly thought to be a slide toe, has been formed largely by erosion of metamorphosed Franciscan mélange. In addition we have discovered many outcrops of intact rhyolite flow and flow-breccia overlying well-bedded and sheared Franciscan metagraywacke. In such outcrops, the rhyolite retains uniformly oriented flow banding and/or subhorizontal platy jointing caused by ramping of viscous rhyolite over itself during flowage. Instructive examples are the outcrops exposed in the canyon in the SE 1/4 of Sec. 23, T.11N., R.8W., in which overturned well-bedded metagraywacke is overlain by deeply weathered flow-banded rhyolite whose base is composed of frothy pumice and pumice-breccia, a characteristic of rhyolite flows. Excluding obvious smaller landslides locally abundant in the area, the large rhyolite lobes to the southeast of Cobb Mountain were clearly down-dropped either by normal faulting or by massive blocksliding.

Our preferred interpretation is based on two drill holes just southeast of the northwest limit of the downdropped masses which reveal 160 m of rhyolite over metagraywacke. Projection of the basal rhyolite contact of Cobb Mountain over the downdropped zone implies 200-260 m of vertical displacement. If block-slides are the actual mechanism of displacement rather than faulting, their slippage planes must be too deep-seated to be exposed unless low-dipping shear planes in some of the melange units underlying the rhyolite-graywacke blocks have acted as dislocation surfaces.

Regardless of the interpretation, the rhyolite in the Ford Flat area is an erosional remnant of lava vented on Cobb Mountain that flowed southeastward over a gullied Franciscan terrane. We believe that down-dropping of these flows probably started soon after their eruption (1.14 m.y.) and could represent, in part, post-eruption subsidence related to the large volume of magma extruded.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to Burmah Oil and Gas Company geologists T. Box, J. LaFleur, and R. Wall for providing the shallow borehole data. J. M. Donnelly of the U.S. Geological Survey dated the volcanic rocks by K/Ar at U. C. Berkeley and added helpful advice. B. Carter Hearn, Jr. provided a plentitude of valuable comments.

RESPONSIBILITY FOR MAPPING

Volcanic rocks of Cobb Mountain and adjacent areas were mapped by F. E. Goff, 1974 and 1975; Franciscan and Great Valley sequence rocks were mapped by R. J. McLaughlin in 1974 and 1975, assisted by H. Ohlin, 1975. Volcanic rocks of Boggs Mountain were mapped by J. M. Donnelly, 1975.

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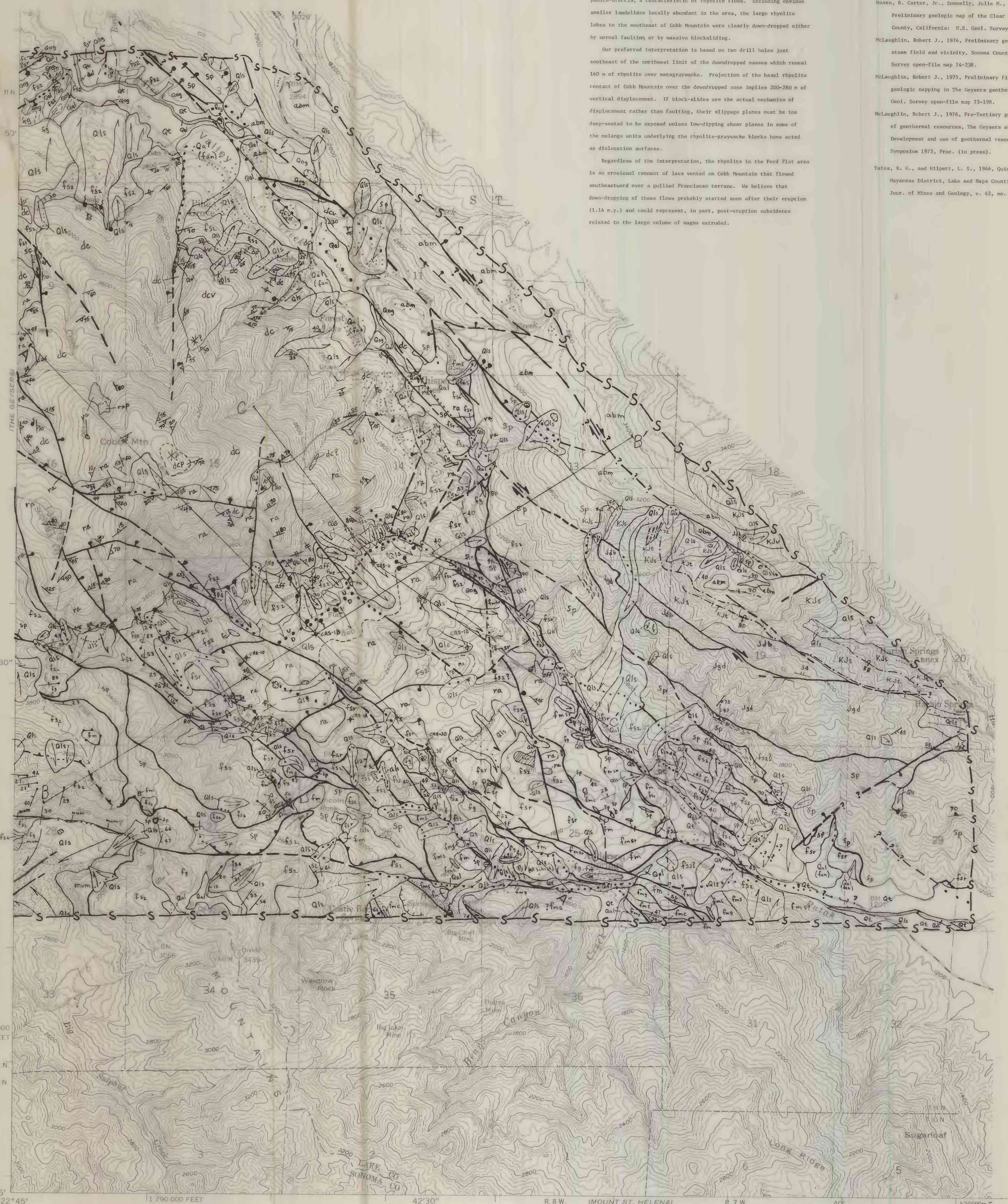


Mapped, edited, and published by the Geological Survey
Control by USGS and USC&GS
Topography from aerial photographs by photogrammetric methods
Aerial photographs taken 1957. Advance field check 1958
Polyconic projection. 1927 North American datum
10,000-foot grid based on California coordinate system, zone 2
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue
Dashed land lines indicate approximate locations
Land lines unsurveyed in parts of Ts. 10 and 12 N – Rs. 7 and 8 W.

APPROXIMATE MEAN DECLINATION, 1958

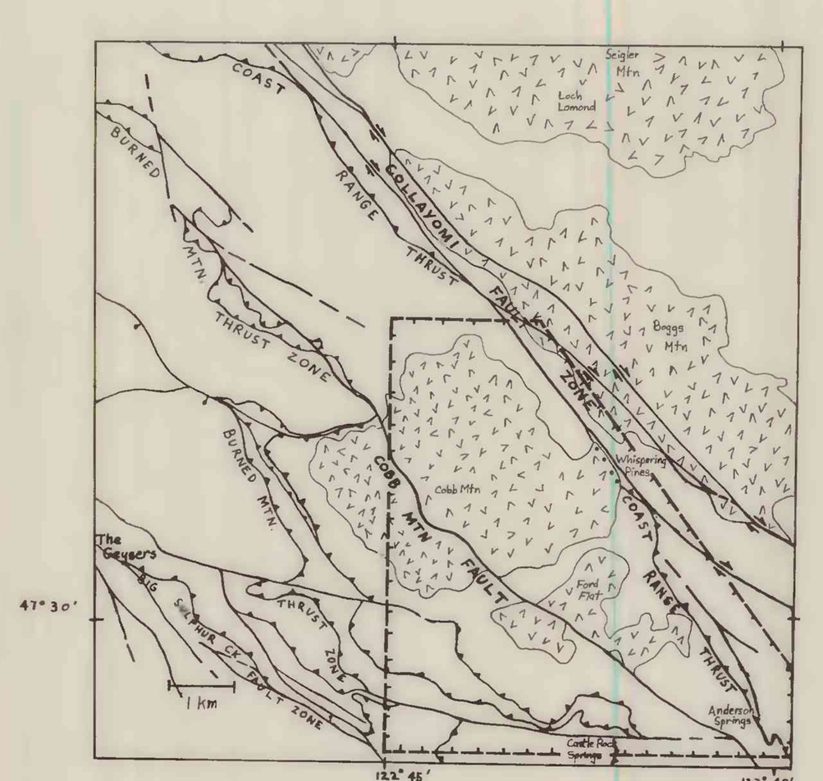
SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

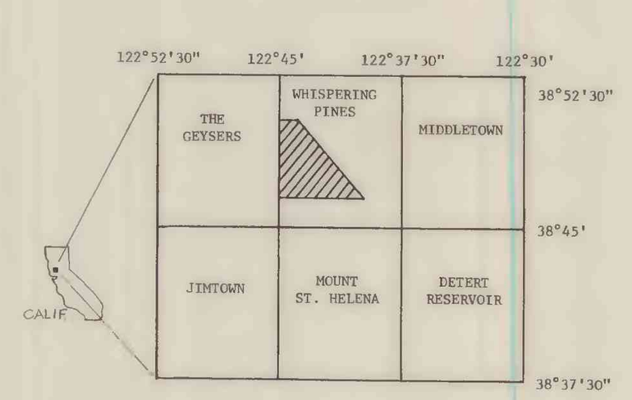
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER 25, COLORADO OR WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION
Medium-duty Light-duty
Unimproved dirt
State Route

WHISPERING PINES, CALIF.
N3845—W12237.5/7.5
1958



Generalized structural map showing Quaternary volcanic rocks (v-pattern) and major fault zones in the Cobb Mountain-Ford Flat area. Data from McLaughlin, 1974; McLaughlin, unpublished; Hearn and others, 1975; Hearn and others, unpublished.



INDEX TO PUBLISHED U.S. GEOLOGICAL SURVEY 7 1/2-MINUTE TOPOGRAPHIC QUADRANGLES, SHOWING LOCATION OF THE MAP AREA

MAP SYMBOLS

Contact — Certain to approximate location, dotted where concealed

Axis of Syncline — Dashed where approximate, dotted where concealed, arrow indicates direction of plunge

Axis of Anticline — Dashed where approximate, dotted where concealed, arrow indicates direction of plunge

Fault — Dashed where approximate, dotted where concealed, queried where uncertain; relative movement indicated by U (up) and D (down), by ball on downthrown side, or by arrows indicating relative lateral displacement; measured direction and amount of dip indicated by arrow and number

Thrust fault — Dashed where approximate, dotted where concealed, queried where uncertain; barbs on upper plate

Attitude of planar structures

Flow structure; Bedding; tops of beds known from sedimentary structures; Bedding; Vertical beds; Overturned beds; Foliation; Strike and dip directions determined from aerial photograph

Closed depression; Hot spring; Spring; Zone of hydrothermally altered rock; Plunge of linear features; Drill hole

Structural symbols used for Pleistocene volcanic rocks

foliation; flow banding and/or sheeting; joints; vents

Landslide deposit — Arrows indicate general direction of movement

Scarp line — May be either fault or landslide related; barbs on downslope side

STRATIGRAPHY

Qal — ALLUVIUM (Holocene) Largely unconsolidated gravel, sand and clay, but locally consists of blocks up to several tens of feet in diameter. Some deposits along faults are hydrothermally altered and cemented by iron oxide, opaline silica, sulfur, calcite, and other spring deposits.

Qls — LANDSLIDE DEPOSITS (Holocene and Pleistocene) Unconsolidated rock and soil debris, that has moved downslope by such processes as surface creep, rotational slumping, or by flowage. Headwall zones of large landslides characteristically contain closed depressions.

Qt — TERRACE DEPOSITS (Holocene and Pleistocene?) Unconsolidated to semiconsolidated older dissected alluvium containing gravel, sand, and clay derived from local bedrock source areas.

Qog — OLDER ALLUVIUM (Holocene and Pleistocene) Dissected older alluvium related to older drainage of Kelsey Creek, may be in part equivalent to older terrace deposits of Putah Creek drainage; unit contains detritus of gravel to clay size and locally thin bedded laminated white silts of probable lacustrine origin. Gravels contain abundant Franciscan detritus and/or debris from Quaternary volcanic rocks of Cobb and Boggs Mountains.

CLEAR LAKE VOLCANICS (Pleistocene)

dcv — DACITE OF COBB VALLEY (Pleistocene) Flank eruption of one major flow and coarse fragmental deposits of light grey to grey, massive to sheeted, sparsely porphyritic dacite; contains 5 percent of 1-3 mm quartz and feldspar, about 2 percent of 1-3 mm orthopyroxene, about 1 percent of 1-5 mm lithic inclusions, in an aphanitic groundmass; source is probably near spine-like outcrop of vesiculated dacite at the highest point of flow; overlies dacite of Cobb Mountain; magnetic polarity reversed; maximum thickness about 100 m (300 ft).

dcp / dc — DACITE OF COBB MOUNTAIN (Pleistocene) Dome and flows (dc) of blocky to massive, locally sheeted, grey to red, coarsely porphyritic biotite dacite which weathers to rubbly rounded outcrops; contains 10 percent total of 2-10 mm plagioclase and sanidine, 5 percent of 1-3 mm quartz, 1 percent of 0.5-1 mm pyroxene, 0.5-1 percent of 0.5-2 mm biotite, 1-2 percent of 1 cm or larger diabasic-textured lithic? inclusions in glassy to aphanitic groundmass; probable vents near summit of Cobb Mountain where the rock is most oxidized, vesicular, and pumiceous (dcp); overlies biotite rhyolite of Alder Creek and is overlain by dacite of Cobb Valley; K/Ar age = 1.05 m.y. on sanidine (Donnelly, 1976, unpublished data); magnetic polarity reversed; maximum thickness about 400 m (1,200 ft).

rap / ra — BIOTITE RHYOLITE OF ALDER CREEK (Pleistocene) Thick flows (ra) of white, pink and grey, vesicular to massive flow-banded crystal-rich rhyolite; contains 2 percent of 1 mm biotite, 0.5 percent of 1 mm pyroxene, 15-30 percent total of 2-5 mm pale pink quartz, white plagioclase, and clear sanidine, in a glassy to aphanitic groundmass; contains sparse diabasic-textured lithic? inclusions up to 10 cm in size; white and grey vitric vesicular blocks occur locally at base and top of unit; rare grey spherulitic rhyolite occurs within 10 m (30 ft) of base in southwestern cliffs; source is within Cobb Mountain, possibly near klinkery pink rhyolite (rap) outcropping beneath the dacite of Cobb Mountain in the NE 1/4 Sec. 16, T.11N., R.8W.; overlies patches of olivine andesite of Ford Flat, Franciscan rocks and serpentine; K/Ar age = 1.14 m.y. on sanidine (Donnelly, 1976, unpublished data); magnetic polarity unique: maximum inferred thickness exposed in the southeast cliffs of Cobb Mountain is about 400 m (1,200 ft).

abm — ANDESITE OF BOGGS MOUNTAIN (Pleistocene) Flows 10-50 m thick of massive, sheeted and vesicular grey to red andesite with distinctive speckled appearance due to abundant plagioclase phenocrysts; contains about 35 percent of 0.25-1 mm plagioclase, about 5 percent of 0.25-1 mm clinopyroxene, 10 percent of 0.25-1 mm orthopyroxene, with about two-thirds of pyroxene occurring in 1-3 mm clots, in a glassy to microcrystalline groundmass of plagioclase, pyroxene and opaques; sources within present outcrop area probably near principle summit in Sec. 2, T.11N., R.8W.; K/Ar age = 1.45±0.04 m.y. on whole-rock (Hearn and others, 1975); magnetic polarity reversed; maximum thickness about 150 m (450 ft).

aff — OLIVINE ANDESITE OF FORD FLAT (Pleistocene) Isolated small areas of black glassy, grey pumiceous, and red oxidized olivine andesite: contains 0.5 percent of 0.5-2 mm olivine, 0.5 percent of 1.3 mm green clinopyroxene, rare 0.5-1 mm black prisms of orthopyroxene(?), 1 percent of 0.5-4 mm plagioclase, and rare 0.5-4 mm quartz, in a slightly vesicular, grey to black glassy groundmass; most occurrences consist of bombs, spatter, and cinders plus 5 percent or less of fragments of Franciscan Assemblage rocks; outcrops below the southern cliffs of Cobb Mountain appear to be gully fillings in an erosion surface which predates biotite rhyolite of Alder Creek; contains interbedded white to light grey finely-laminated lake sediment in the extreme northeast corner of Sec. 22, T.11N., R.8W.; the largest outcrop, on Rte. 175 in Sec. 24, consists of 35 m of a probable mudflow deposit of poorly sorted lapilli and blocks of grey pumiceous olivine andesite and 5-10 percent of blocks of Franciscan graywacke from pebble to small boulder size in a muddy matrix, lobate tongues about 5 m long and 1 m thick suggest that the mudflow moved toward the southeast; andesite cinders locally abundant beneath biotite rhyolite of Alder Creek in occurrences too small to map; source probably concealed beneath Cobb Mountain; maximum exposed thickness is 35 m (105 ft); K/Ar age = 1.60 m.y. on whole rock (Donnelly, 1976, unpublished data).

sc — SILICA CARBONATE ROCK (Late Tertiary and Quaternary) Composed of a mixture of magnesium carbonate minerals, quartz, opal, and chalcedony; formed by hydrothermal alteration of serpentinite; extensively developed in ultramafic rocks associated with thermal springs along major fault zones; and in many areas is the host rock for mercury deposits.

GREAT VALLEY SEQUENCE (Lower Cretaceous-Upper Jurassic)

KJs — KNOXVILLE FORMATION(?) (Late Jurassic (Tithonian)-early Cretaceous (Valanginian)) Olive gray to black, marine mudstone and thin alternating interbeds of hard, dark green siltstone and graywacke sandstone; mudstone is interbedded with sporadic hard gray-weathering impure concretionary carbonate beds that locally contain Tithonian-Valanginian Buchias and palynomorphs, Lower Knoxville beds locally contain three or more 30-foot intervals of hard, grey siliceous tuff (KJt); base of unit locally faulted over diabase and diabase breccia (Jdb), and coarse-grained sedimentary breccia composed chiefly of basaltic volcanic rocks is locally present, interbedded near base.

Jdb — DIABASE AND DIABASE BRECCIA (Late Jurassic) Coarse breccia composed largely of angular fragments of diabase and basalt, and rare chert, locally cut by diabase dikes. On Black Mountain, 18 km to the southwest, similar diabase breccia overlain by Knoxville beds is underlain by basaltic lavas containing chert with radiolaria of late Kimmeridgean age, suggesting a late Kimmeridgean-early Tithonian age for this unit.

Jgd — GABBRO AND DIABASE (Late Jurassic) Fine- to medium-grained layered olivine and orthopyroxene-bearing gabbros displaying cumulate texture, cut by diabase dikes which increase in abundance in the upper part of the unit. Locally abundant dikes of hornblende-albite pegmatite also cut this unit.

ULTRAMAFIC ROCKS

sp — SERPENTINITE (Late Jurassic?) Pervasively sheared harzburgite peridotite, partly to completely altered to chrysotile±clinochrysotile: where present below gabbro and diabase of the Harbin Springs area NE of the Collayomi Valley, serpentinized ultramafic rocks together with overlying mafic rocks are considered to compose an ophiolite complex; elsewhere serpentinite is present along major faults, shear zones, and in the cores of diapiric structures indicating it has been plastically remobilized, possibly along faults of Tertiary and Quaternary age.

mum — METAMORPHOSED ULTRAMAFIC ROCKS (Jurassic?) Foliated ultramafic rocks metamorphosed to antigorite±chlorite± tremolite-actinolite-talc mineral assemblage.

FRANCISCAN ASSEMBLAGE (Upper Cretaceous-Upper Jurassic)

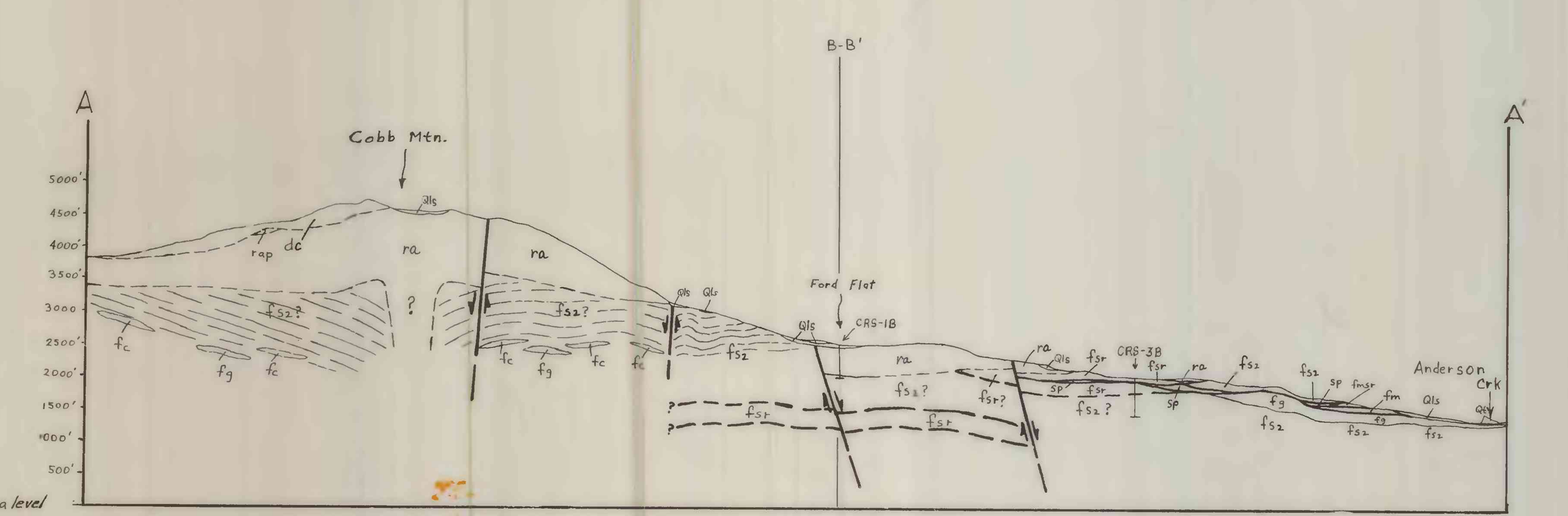
SEDIMENTARY AND TECTONIC MELANGE Mostly graywacke, shale, and conglomerate, with lesser amounts of chert, basaltic rocks, and minor blueschist, occurring chiefly as tectonic blocks and imbricated slabs from less than a foot up to several miles in length, enclosed in a pervasively sheared matrix of black shale and gouged rock. Shale matrix locally is unsheared and well bedded, and may enclose oblate limestone concretions or angular to well-rounded water worn clasts, suggesting that mélange is in part a sedimentary breccia. Components of mélange are differentiated on map as follows:

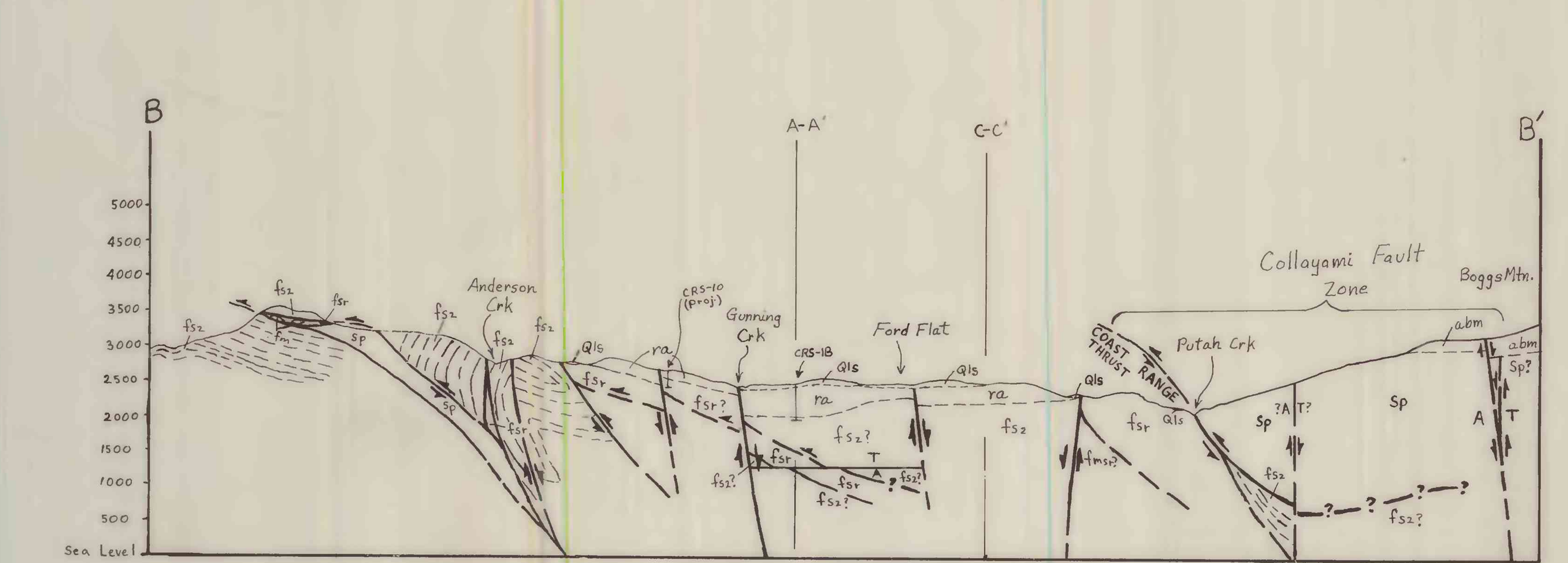
fsr — Sedimentary and tectonic mélange, undifferentiated; chiefly pervasively sheared shale and gouged rock, enclosing tectonically emplaced blocks and resistant masses of rocks too small to be individually shown at map scale.

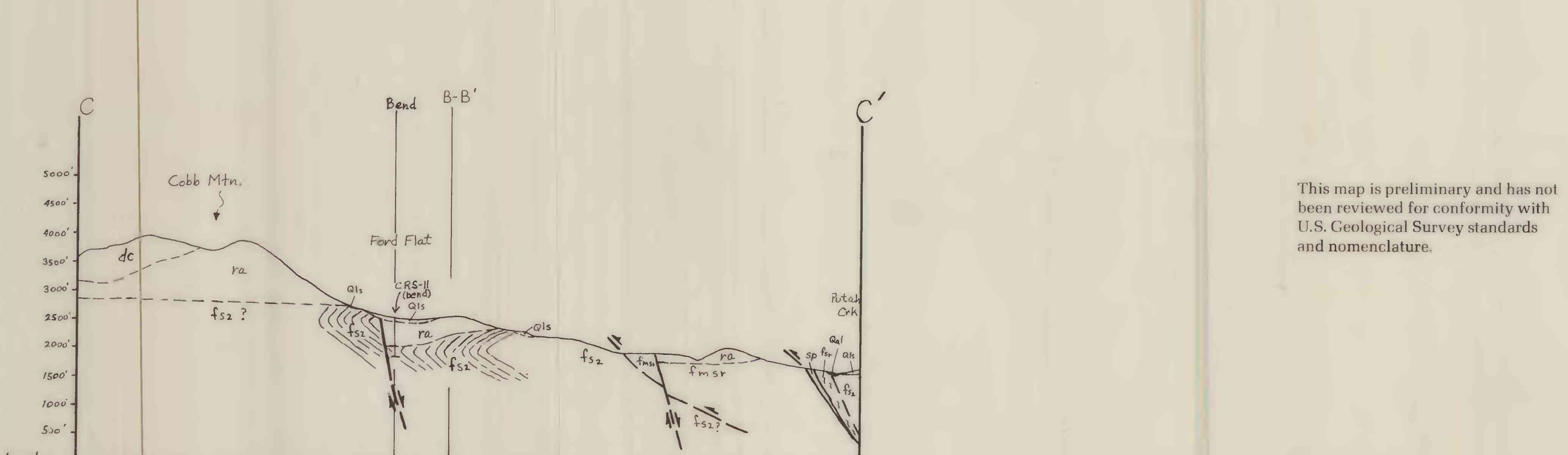
fs_2 — Graywacke and minor interbedded shale and conglomerate with a slight to moderately strong metamorphic fabric (textural zone 1 to 2 of Blake and others, 1967). Graywacke is thin bedded to massive, relatively impervious, and fine to medium grained; it contains a high percentage of mafic volcanic detritus, and locally, concentrations of carbonized plant material are present along bedding planes. Interbedded conglomerate present in some areas has a graywacke matrix and contains abundant well-rounded clasts of mafic and silicic porphyritic volcanic rock, diorite, dark chert, vein quartz, and quartzite, in addition to more angular clasts of basaltic volcanic rock, graywacke, and minor ultramafic rock: elsewhere conglomerate contains angular schist, radiolarian chert, and graywacke detritus identical to corresponding rock types in the Franciscan Assemblage. Graywacke of this unit contains pumpellyite± lawsonite; it is veined with quartz and calcite, and locally it is extensively hydrothermally altered.

fg — Greenstone, slightly to moderately metamorphosed basaltic pillows, pillow breccias, tuffs, and diabase, slightly to extensively sheared and locally extensively hydrothermally altered.

STRUCTURAL SECTIONS







This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey standards and nomenclature.