U.S. DEPARTMENT OF THE INTERIOR

U. S. GEOLOGICAL SURVEY

Geologic Map and Structure Sections of the Los Gatos 7-1/2' Quadrangle, Santa Clara and Santa Cruz Counties, California

by

R. J. McLaughlin*[1], J. C. Clark*[2], E. E. Brabb*[1], and E. J. Helley*[1]

Open-file Report
91-593

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

*1 U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025
*2 Indiana University of Pennsylvania, Indiana, PA 15705; supported in 1990 by the U.S. Geological Survey, Department of the Interior, under award number 14-08-0001-G1826

1991

GEOLOGIC MAP AND STRUCTURE SECTIONS OF THE LOS GATOS 7-1/2' QUADRANGLE, SANTA CLARA AND SANTA CRUZ COUNTIES, CALIFORNIA

by

R. J. McLaughlin, J. C. Clark, E. E. Brabb, and E. J. Helley

DESCRIPTION OF ROCK UNITS

SURFICIAL DEPOSITS OF SANTA CLARA VALLEY

D MINE DUMP DEPOSITS--Unconsolidated tailings, largely from inactive mercury mines in the New Almaden Mining District in northern part of Los Gatos Quadrangle

PP PERCOLATION PONDS--Sediment deposits associated with ponded water diverted from Guadalupe Creek, for purpose of recharging Santa Clara Valley aquifers.

Qhsc STREAM CHANNEL DEPOSITS (HOLOCENE)--Poorly- to well-sorted sandy silt, silty sand, and sand or sandy gravel with minor cobbles.

$Qhaf_1$ ALLUVIAL FAN DEPOSITS (HOLOCENE)--Brown, poorly-sorted, dense, sandy or gravelly clay. Deposits may have debris flow origin, possibly representing the most recent deposition of Qhaf deposits. Deposits are found both incised into, and conformably on top of older deposits.

Qhaf ALLUVIAL FAN DEPOSITS (HOLOCENE)--Brown, medium dense, gravelly sand and clayey gravel that grades upward to sandy or silty clay. Sediments near the heads of these fans are locally brown or tan, medium dense to dense, gravelly sand or sandy gravel that grades upward to sandy or silty clay. These alluvial fan deposits interfinger, or merge with Holocene basin deposits on distal fan edges. In some areas, alluvial fan deposits cover Holocene terrace surfaces which also merge with Holocene basin deposits.

$Qpaf_1$ ALLUVIAL FAN DEPOSITS (PLEISTOCENE)--Crudely-bedded, clast supported, tan to reddish-brown clayey gravels and cobbles with a sandy matrix. These deposits typically were deposited by one or more of the drainages that have incised into them in modern time. Distal edges of these fans are overlapped by Holocene basin deposits. The heads of these fans may be overlapped and partially incised by Holocene alluvial fan deposits (Qhaf, $Qhaf_1$).

Qpaf ALLUVIAL FAN DEPOSITS (PLEISTOCENE)--Tan to reddish brown, dense, gravelly and clayey sand or clayey gravel that grades upward to sandy clay. These deposits may have been transported by streams which largely predated, and are obscured by, the modern drainage system.

SURFICIAL DEPOSITS OF UPLAND AREAS SOUTH OF SANTA CLARA VALLEY

Qal — UNDIFFERENTIATED ALLUVIUM (HOLOCENE AND UPPER PLEISTOCENE)--Unconsolidated gravel, sand, and silt deposited by modern streams.

Qt — UNDIFFERENTIATED ALLUVIAL TERRACE DEPOSITS (HOLOCENE AND PLEISTOCENE)--Unconsolidated to weakly consolidated, fluvial, bouldery to pebbly gravel, sand, and silt, dissected and elevated above present base level, along mountainous streams having no well-defined flood plains.

Qf — UNDIFFERENTIATED ALLUVIAL FAN DEPOSITS (HOLOCENE AND PLEISTOCENE)--Unconsolidated to weakly consolidated, fluvial, bouldery to pebbly gravel, sand, and silt, in fan-shaped depositional lobes at the mouths of mountainous streams and their tributaries. Older fan deposits are dissected and uplifted. Some alluvial fan deposits grade laterally into alluvial terrace deposits (Qt) and alluvium (Qal).

Qls — LANDSLIDE DEPOSITS (HOLOCENE AND PLEISTOCENE)--Unconsolidated rock debris, colluvium, and intact masses of rock, displaced downslope by gravity. Note that although many landslides are delineated, they were not systematically mapped. Thus, more landslides are probably present than are depicted on the geologic map. See Keefer (in press, 1991), Spittler and Harp (1990), and Spittler and others (1990) for distribution of landslides activated during October 17, 1989 earthquake. See also Ponti and Wells (in press, 1991); Cotton and others (1990); and Hart and others (1990) for additional information concerning relationship of landslides to surface deformation during October 17, 1989 earthquake. Additional landslide information may be found in report by Cooper-Clark and Associates (1975), and in Wieczorek and others (1988). Numerous giant landslides are present along the San Andreas fault zone southwest of Lexington Reservoir and in the upland area to the east. Several of these giant landslides include large, intact masses of rock that are rotationally displaced downslope. The stratigraphy within intact rotational landslides was mapped locally. Several ancient giant landslides west of Lexington Reservoir have headwalls upslope, as much as two miles (3.2 km) to the southwest, in the adjacent Castle Rock Ridge Quadrangle. These ancient landslides are cut by active traces of the San Andreas fault and locally are overlain by younger terrace, fan and stream deposits. Ancient and younger landslides may be stable or partially to totally unstable and subject to additional or renewed downslope movement, especially in areas that have experienced repeated shaking from moderate to strong earthquakes associated with the San Andreas and other associated active faults.

ROCK UNITS SOUTHWEST OF SAN ANDREAS FAULT

Tp — PURISIMA FORMATION (PLIOCENE)--Thick-bedded to massive, medium-gray, fine-grained lithic sandstone with pelecypods and irregular echinoids diagnostic of inner neritic depths. Unit is present as fault-bounded slivers along the San Andreas fault. The Purisima Formation is extensive in adjacent Laurel and Loma Prieta Quadrangles to south and southeast.

Tv VAQUEROS SANDSTONE AND DIABASE (LOWER MIOCENE AND OLIGOCENE)--Thick-bedded to massive, yellowish-gray weathering, fine- to medium-grained arkosic sandstone with thin interbeds of dark-brown mudstone. Includes a thick glauconitic sandstone in lower part. As much as 1,500 feet (460 m) of Vaqueros is preserved along the Summit syncline. A complete section in the Laurel Quadrangle to the south is as thick as 2,700 feet (820 m)(Clark and others, 1989). Mudstone interbeds include fish scales and fish bone fragments and benthic foraminifers diagnostic of bathyal depths and of a Zemorrian (Oligocene) age (J. E. Eke, written commun., 1958; R. S. Boettcher, written commun., 1990). Unit locally includes:

Tvb? Altered diabase and basalt. Occurs locally along Aldercroft Creek near western quadrangle border; also is well exposed in coherent landslide block in State Highway 17 road cut west of Lexington School. Basalt in Highway 17 landslide exposure intrudes inverted contact between Vaqueros Sandstone and overlying carbonaceous mudstone assigned to San Lorenzo Formation. Basalt here has interstitial texture, with abundant chlorite and actinolite, and minor interstitial epidote-clinozoisite. Plagioclase is oligoclase (An 18-23) by

Michel-Levy method of maximum extinction angles, suggesting sodic alteration, and is conspicuously zoned. Includes questionably identified remnant grains of corroded olivine and clinopyroxene. Contains minor inclusions of foliated quartzite, arkosic metasandstone and felsic igneous rock with minute euhedral biotite grains. Upper and lower basalt contacts in State Highway 17 road cut are baked. Unit may be correlative with the Mindego Basalt to the northwest of early Zemorrian to early Saucesian age (Clark, 1968), and (or) with basalt flows to the south in the Laurel Quadrangle, and to the southwest in the Felton Quadrangle, where they are as much as 200 feet (60 m) thick (Clark, 1981). Plagioclase from the basalt in Felton Quadrangle was dated by potassium-argon methods at 23.7±0.7 Ma (Turner, 1970; age recalculated by Fox and others, 1985, using currently accepted IUGS constants).

Tsl

SAN LORENZO FORMATION (OLIGOCENE AND UPPER EOCENE)--Dark brown to gray, carbonaceous shale and mudstone, and minor interbedded arkosic sandstone, locally divided into:

Tsr

Rices Mudstone Member - nodular dark-brown mudstone with spheroidal carbonate concretions as much as 0.5 m in diameter. Includes very thick glauconitic sandstone bed at base and medium to thick, yellowish-gray, very-fine-grained arkosic sandstone interbeds in upper part. Rices is as much as 2,300 feet (700 m) thick. Mudstone includes fish scales and fragments, *Delectopecten*, pyritized diatoms and radiolarians, and benthic foraminifers diagnostic of upper bathyal (150-500 m) depths and of early Zemorrian (Oligocene) age (K. McDougall, written commun., 1990). Beds of Refugian (Oligocene and (or) late Eocene) age may also be present.

Tst

Twobar Shale Member - thin-bedded and laminated, olive-gray shale to medium-bedded, dark-brown mudstone. From 350 feet (107 m) to as much as 500 feet (152 m) thick along Mountain Charlie Gulch. Contains fish scales, sponge spicules, and stratigraphically undiagnostic arenaceous foraminifers. In the Laurel Quadrangle to the south, bathyal benthic foraminifers from the Twobar are assignable to the Narizian Stage of the Eocene (Clark and others, 1989).

Tb

BUTANO SANDSTONE (UPPER AND MIDDLE EOCENE)--Massive to thick-bedded, yellowish-gray to light-brown weathering, medium- to coarse-grained, arkosic sandstone and thin-bedded and laminated, fine-grained biotitic arkosic sandstone with thin to thick interbeds of dark-brown shale. As much as 2,800 feet (850 m) of Butano crops out south of the Butano fault. These beds are interpreted by Nilsen (1983/1984) to have been laid down by northward-flowing currents as middle-fan channel and interchannel deposits of a submarine fan. Shale interbeds include large arenaceous foraminifers and along Burns Creek yield benthic species of late Narizian (Eocene) age (Fairchild and others, 1969). Unit locally includes:

Tbm? Light-brown interbedded fine- to very-fine-grained sandstone and siltstone that was trenched near the Loma Prieta School (Johnson and Associates, 1989). Sandstone and siltstone is tentatively correlated with similar sandstone and siltstone (Tbm) of the Laurel Quadrangle to the south (Clark and others, 1989).

db DIABASE OF MORRELL CUTOFF ROAD (LOWER MIOCENE, OLIGOCENE, OR JURASSIC)--Altered coarse-grained titanaugite-bearing diabase. Unit is poorly exposed along Morrell Cutoff Road beneath landslide debris, at boundary with Laurel Quadrangle, where diabase is faulted against mudstone of Butano Sandstone and Rices Mudstone member of San Lorenzo Formation. Pyroxene in diabase is partly replaced by uralitic amphibole, and plagioclase has probably undergone sodic alteration (composition is An20-23 by Michel-Levy method of maximum extinction angles). Rock is locally veined with laumontite, and may contain pumpellyite. Diabase is compositionally similar to some undated diabase and gabbro in the Laurel and Loma Prieta Quadrangles (mapped as unit db by McLaughlin and others, 1988; and Clark and others, 1989). Rocks of gabbroic composition are also exposed at Logan, near San Juan Bautista southwest of the San Andreas fault, where they have been dated at about 156 Ma (Jurassic) by K-Ar method (Ross, 1970), and at 161-165 Ma (Jurassic) by Pb-U technique (Johnson and O'Neil, 1988). However, the gabbro of Logan is closely associated with banded amphibolite, and pyroxenes reported from the gabbro are hypersthene and augite, not titanaugite (Ross, 1970). Alternatively, the diabase of Morrell Cutoff Road might be correlative with altered basalt and diabase (Tvb?) of early Miocene or Oligocene age exposed near the western edge of Los Gatos Quadrangle, and to Tvb of the Laurel Quadrangle (Clark and others, 1989). The low $^{87}Sr/^{86}Sr$ value of .70439 for the diabase of Morrell Cutoff Road suggests derivation from oceanic source rocks (see also Clark and others, 1991).

ROCK UNITS NORTHEAST OF SAN ANDREAS FAULT

QTsc SANTA CLARA FORMATION (PLIOCENE AND PLEISTOCENE)--Unsorted to poorly sorted coarse fluvial gravel and fanglomerate, equivalent to Stevens Creek lithofacies of the Santa Clara Formation of Cummings (1968), locally with intercalations of poorly sorted pebbly arkosic sandstone and grit. Clast content of gravels consists predominantly of graywacke, and minor basalt, diabase, red to green metachert, and vein quartz, derived from adjacent uplands of the Franciscan Complex. Northwest of Los Gatos, the lower part of the Santa Clara Formation consists of moderately well-sorted, sandy, pebble gravel with large-scale low-angle and trough-shaped cross bedding, and minor mottled mudstone and claystone, deposited in a braided stream and associated floodplain overbank setting (Arastradero lithofacies of Cummings, 1968). The mudstone and claystone, together with minor lenses of laminated lacustrine mudstone of the Arastradero lithofacies locally contain fresh water gastropods, pelecypods, and plant and vertebrate remains of Late Pliocene (Blancan) age (Sorg and McLaughlin, 1975; Adam and others, 1982). The clast content of gravels in the Arastadero lithofacies is characterized by abundant reworked well-rounded pebbles of black chert, silicic porphyritic volcanic rocks, and laminated chert (Vanderhurst and others, 1982). The Santa Clara Formation in the Los Gatos Quadrangle is locally divided into:

QTsc2 — Uplifted, dissected, and tilted gravels, possibly younger than and unconformable upon QTsc1. Alternatively, this unit is coeval with QTsc1 and structural differences merely reflect variation in intensity of deformation within the quadrangle.

QTsc1 — Uplifted, dissected, and (or) steeply dipping gravels, commonly deformed by high-amplitude folding and faulting.

QTlx — LAMINATED MUDSTONE OF LEXINGTON RESERVOIR (PLIOCENE AND PLEISTOCENE?)--Laminated, thin bedded, gray to light-brown, locally carbonaceous mudstone; friable, thin bedded, graded arkosic siltstone; and minor gritty arkosic sandstone, exposed in Los Gatos Creek Canyon and its tributaries along the west side of Lexington Reservoir. West of Highway 17, mudstone depositionally overlies the Franciscan Complex, and is overlain by, and grades laterally into, gravel of the Santa Clara Formation. Unit locally contains fresh water ostracodes, pelecypods, and gastropods, and probably is correlative with less extensive laminated mudstone lenses mapped elsewhere as part of the Santa Clara Formation (i.e. Sorg and McLaughlin, 1975). Mudstone is interpreted to have been deposited in a moderately large lake formed by damming of the ancestral course of Los Gatos Creek by landsliding and (or) by strike-slip movement and uplift along the adjacent San Andreas fault.

Tmm MONTEREY SHALE (MIDDLE MIOCENE)--Flaggy, yellowish-white weathering, hard brown mudstone, porcelanite, and cherty porcelanite. Mudstone and porcelaneous rocks commonly contain molds of foraminifers and scarce fish parts. As much as 1,400 feet (425 m) of Monterey Shale is exposed north of and along the Berrocal fault zone, where it depositionally overlies the Temblor Sandstone or older rocks. The Monterey Shale is middle Miocene (Luisian, CN3 or CN4) and was deposited at upper bathyal depths (500-1,500 m) based on nannofossils and benthic foraminifers from identical rocks in Los Altos Hills near Foothill College (D. Bukry, written commun., 1988). The Monterey Shale of the Los Gatos Quadrangle is equivalent to the Monterey Formation of Bailey and Everhart (1964).

Tmt TEMBLOR SANDSTONE (OLIGOCENE TO MIDDLE MIOCENE)--Up to 700 feet (213 m) of brown to buff weathering, friable to compact, massive to thick bedded, subfeldspathic to arkosic sandstone, with minor mudstone and unsorted calcite-cemented conglomerate in lower part, and dacitic tuff in upper part of unit. Basal conglomerate locally unconformably overlies the Franciscan Complex and rocks of the Coast Range ophiolite. The conglomerate contains both angular and rounded clasts derived from the Franciscan Complex (radiolarian chert, metachert, metasandstone, and mafic igneous rocks) and also clasts derived from early Tertiary to Jurassic rocks of the Loma Prieta-Sierra Azul area and the Santa Teresa Hills (rounded quartz pebbles, arkosic wacke, sandy limestone containing Eocene foraminifers, including *Discocyclina* sp., and serpentinite) (Blondeau and Brabb, 1983). Reef-like accumulations of oysters, barnacles, bryozoa, sparse shark teeth, and pectens, are locally abundant at the base of the Temblor Sandstone, notably along Hicks Road west of the town of New Almaden (Bailey and Everhart, 1964). The megafauna indicates deposition in a moderately shallow marine setting and an Oligocene or early Miocene age for the lower part of the Temblor Sandstone. The upper beds of the Temblor Sandstone near New Almaden are tuffaceous and grade upward into:

Tmv Dacitic tuff, tuff breccia, and intrusive rocks. As much as 200 feet (61 meters) of dacitic tuff and tuff breccia (Bailey and Everhart, 1964). Plagioclase from the dacite tuff sampled 1200' E., 450' N. of the southeast corner, sec. 19, T 8 S, R 1 E, yielded a K-Ar date of 15.6±0.2 Ma (D. Sorg and P. Russell, written commun., 1990). The tuff is reported by Bailey and Everhart to be hydrothermally altered and to contain mercury mineralization locally, indicating that the hydrothermal system responsible for mercury mineralization post-dated the Miocene volcanism.

Te2 MARINE SANDSTONE AND SHALE OF LOMA CHIQUITA RIDGE (EOCENE)--As much as 3,300 feet (1,000 m) of thick bedded to massive, pebbly, quartzofeldspathic sandstone with minor disseminated glauconite, and rhythmically interbedded micaceous sandstone and carbonaceous shale. Unit is deeply weathered and hydrothermally altered, with extensive secondary silica cement and quartz veining. The most extensive exposures are in Loma Prieta Quadrangle to the southeast along Loma Chiquita Ridge. An early to late Eocene age for this unit is indicated by molds of *Turritella buwaldana* (W. Elder, written commun., 1990) in the middle part of the section east of Elsman Reservoir (0.4 mi E., .35 mi N. of SW corner of sec. 19, T 9 S., R. 1 E.), and also an occurrence of *Parvamussium stanfordensis* in the upper part of the unit (McLaughlin and others, 1988) in Loma Prieta Quadrangle. An early Eocene benthic foraminiferal fauna (correlative with planktic foraminiferal faunas of zone P6b or younger; (K. McDougall, written commun., 1989) was collected from a road cut east of Elsman Reservoir (.35 mi N., .05 mi E. of SW corner of sec. 19, T. 9 S., R. 1 E.). Large discocyclinid foraminifers have also been found in thin sections of sandstone from near this area. Sedimentary structures and benthic foraminifers suggest an upper middle bathyal slope depositional setting for this unit.

Te_1 MOTTLED MARINE MUDSTONE AND SANDSTONE OF MOUNT CHUAL (LOWER EOCENE)--As much as 700 feet (213 m) of olive green and mottled red and green foraminiferal mudstone and minor quartzofeldspathic sandstone, locally with minor conglomerate, coarse quartzose glauconitic grit, and (or) carbonate-cemented bioclastic grit near or at the base of the unit. Benthic and planktic foraminifer and nannofossil localities in mottled mudstone overlying the lower carbonate-cemented bioclastic grit south of the Aldercroft-Sierra Azul-Soda Spring faults are indicative of an early Eocene (Penutian, planktic zones P-8 to P-9 and nannoplankton zone CP11) age for the mudstone, and deposition in a lower bathyal to abyssal (1500-2000 m) setting (K. McDougall written commun., 1990 and 1991). Base of unit is here considered to be a low-angle attenuation fault. Mottled mudstone is poorly exposed, and tectonically thinned by basal and structurally higher attenuation faults between San Andreas and Aldercroft-Sierra Azul-Soda Spring faults. Locally, this unit also includes:

Tel Limestone. In the northeastern part of Los Gatos Quadrangle, the basal beds of this unit include a large body of bioclastic limestone which contains large discocyclinid foraminifers and planktic and benthic foraminifers indicative of an early Eocene (planktic zone P6 to P7) age (Bailey and Everhart, 1964; Blondeau and Brabb, 1983; K. McDougall, oral commun., 1990).

SANDSTONE, SHALE, AND CONGLOMERATE OF SIERRA AZUL (UPPER CRETACEOUS)--

Kus Sandstone and shale. As much as 1,600 feet (488 m) of lithic, feldspathic to arkosic wacke and dark-green to black, hard, locally concretionary argillite. Sandstone is orange-brown weathering, gray to green, biotitic, thin to thick bedded, fine- to medium-grained, and locally is pebbly to conglomeratic. Sandstone and argillite are mostly rhythmically interbedded, exhibiting thinning-upward bedding cycles, load features, planar laminations at tops of beds, and rare graded beds. Upper part of the section is largely massive, medium- to fine-grained sandstone and dark-green to black, hard, silty to micaceous argillite, locally with spheroidal carbonate concretions and lenses. In Loma Prieta Quadrangle and along the southwest side of Elsman Reservoir in Los Gatos Quadrangle, rocks in the upper part of section contain ammonites, gastropods, *Dentalium* sp., *Isocrinus* sp., fish parts, and rare crabs (*Archaeopus* sp.) of probable late Campanian age. This fossil assemblage was probably deposited in a shelf setting, transported west-southwestward down-slope and re-deposited in a deeper, submarine fan setting (Elder, 1991; McLaughlin and others, 1991). The uppermost beds of this unit in Loma Prieta Quadrangle include a thickening-upward cycle of 25 cm to 1 m-thick beds of feldspathic sandstone that locally exhibit trough-shaped cross-bedding. In most places the formation is veined extensively with quartz + calcite ± laumontite.

Kuc

Conglomerate. Unsorted, polymict, rounded, and pebbly to bouldery conglomerate forming a lens up to 2,300 feet (700 m) thick in Los Gatos Quadrangle, that thickens to as much as 3,300 feet (1,000 m) in Laurel Quadrangle, and then thins southeastward to less than 500 feet (152 m) in Loma Prieta Quadrangle. Thinner, less continuous lenses of conglomerate are present locally in the overlying section of sandstone and argillite. Clast counts (Simoni, 1974) show that the conglomerate consists predominantly of well-rounded clasts of intermediate to silicic, porphyritic volcanic extrusive and hypabyssal intrusive rocks (andesite, dacite, rhyolite) (55 percent). These volcanic clasts are followed in order of abundance by clasts of granitic rocks, including aplite (16 percent), mafic igneous rocks, including basalt and diabase (13 percent), and minor slate or phyllite (6 percent), sandstone (5 percent), vein quartz (3 percent), and quartzite (1 percent). Calcite-cemented conglomerate with abundant oysters and other epifaunal bivalves, *Dentalium* sp., bryozoa, and calcispongea, of late Campanian age (Elder, 1990) occurs near the top of the main conglomerate lens or as thin lenses within the overlying sandstone and argillite section. The rounded clasts and fossil assemblage of the conglomerate have been transported downslope from a near-shore depositional setting, to a deeper submarine fan environment.

KJs

SHALE AND SANDSTONE OF LOWER GREAT VALLEY SEQUENCE (LOWER CRETACEOUS AND UPPER JURASSIC)--Thin-bedded, cherty, dark-green to black shale, commonly sheared and folded, and minor interbedded arkosic lithic wacke. A thin quartz-veined greenish-gray, tan-weathering, radiolarian-bearing tuff is locally interbedded in the lower part of the shale. Tabular to nodular, dark-gray to brown calcareous concretions are also found locally. Calcareous interbeds and cherty nodular shales locally contain rare ammonites and pelecypods (mostly *Buchia*), which indicate a Late Jurassic (Tithonian) to Early Cretaceous (Valanginian) age for this unit (McLaughlin and others, 1991). The unit varies in thickness from about 300 feet (91 m) to 600 feet (183 m) and is bounded above and below by bedding-parallel attenuation faults and, locally, by later thrust faults.

Jt — ALTERED TUFF OF MOUNT UMUNHUM (JURASSIC?)--Thin bedded, deeply weathered, hydrothermally altered, and laumontized tuffaceous volcanic rocks exposed locally on southwest side of Mount Umunhum. Volcanic rocks appear to range from basalt to dacite, but are extensively altered to chlorite and uralitic amphibole, and are veined with quartz and epidote. Tuff is cut by fine-grained dioritic to microgabbroic dikes and sills and entire unit is extensively sheared. Unit is less than 100 feet (30 m) thick and is bounded by faults, interpreted to be attenuation faults, which cut flows at low angles.

Jdb — DIABASE BRECCIA OF MOUNT UMUNHUM JURASSIC?)--Up to 200 feet (60 m) of breccia composed of angular clasts of diabasic to dioritic composition, derived from underlying dikes and sills of the Coast

Range ophiolite, exposed locally on southwest flank of Mount Umunhum. Breccia appears to form a thin fault-bounded sheet below, and sub-concordant with, altered tuff (Jt) and shale and sandstone of lower Great Valley sequence (KJs). Unit is extensively sheared, suggesting that brecciation may have occurred during attenuation faulting and be entirely tectonic. However, the composition and texture of this breccia, and its position between the Coast Range ophiolite and strata of the lower Great Valley sequence, are similar to stratigraphic position of diabase breccia at the base of the Great Valley sequence in the northern Coast Ranges which is interpreted as talus debris shed from the Coast Range ophiolite along submarine fault scarps during Jurassic uplift and unroofing of the ophiolite. (McLaughlin and others, 1988; Robertson, 1990).

COAST RANGE OPHIOLITE (UPPER TO MIDDLE (?) JURASSIC)--

Jov Volcanic rocks. Spilitized, locally vesicular pillow lava and flow breccia, as much as 1,000 feet (300 m) thick, altered commonly to epidote-actinolite-prehnite-pumpllyite-chlorite assemblage. Volcanic rocks typically have SiO_2 content greater than 52 percent and thus are basaltic andesites (LeBas and Streckeisen, 1991). $^{87}Sr/^{86}Sr$ values for these volcanic rocks range from .7040 to .7044, suggesting a relatively primitive magma source of oceanic character (R. Kistler, written commun., 1990).

Jodi Fine-to coarse-grained dikes and sills. A section as much as 4,000 feet (1,200 m) thick of diabase or microgabbro and diorite, with textures that range from ophitic to intergranular, and with silica contents greater than 52 percent. Some dikes contain abundant dark inclusions of diabase. Unit includes late dikelets of hornblende-albite pegmatite locally. The dikes and sills have geochemistry and $^{87}Sr/^{86}Sr$ ratios (.7041 to .7045; R. Kistler, written commun., 1990) similar to the overlying extrusive rocks. These rocks are clinopyroxene-bearing and extensively altered to epidote-actinolite and prehnite-pumpellyite-chlorite assemblages.

Jodb — Diabase. Dark green, orange-brown weathering, with ophitic to intergranular texture, locally mapped where dike rocks over large area are significantly darker colored and less felsic than Jodi.

Jog — Gabbro. Medium- to very coarse-grained gabbro with cumulate texture. Includes coarse orthopyroxene- and clinopyroxene-olivine-plagioclase cumulate gabbro, in segregations and layers up to 200 feet (61 m) thick, which occur within cumulate ultramafic section, and as much as 500 feet (152 m) of compositionally layered olivine-clinopyroxene-hornblende cumulate gabbro that discontinuously overlies the ultramafic cumulates. Clinopyroxene in gabbro locally is extensively replaced by uralitic green amphibole. Upper part of gabbro cumulate section is locally cut by dikes of non-cumulate diabase or microgabbroic to dioritic rock. Gabbro cumulate rocks overlying ultramafic section are bounded above and below by attenuation faults. $^{87}Sr/^{86}Sr$ values for the cumulate gabbros vary from .7037 to .7048 (R. Kistler, written commun., 1990).

Jou

Ultramafic cumulate rocks. Very coarse- to fine-grained pyroxenitic to dunitic ultramafic cumulate rocks with intercumulus plagioclase. In places cumulate ultramafic rocks are interlayered with cumulate gabbro (Jog), and locally ultramafics are cut by fine- to coarse-grained gabbro and minor plagioclase-clinopyroxene-hornblende pegmatite dikes and dikelets, which are commonly altered to rodingite. Ultramafic cumulate rocks are partially serpentinized, and bounded above by attenuation faults. Lower contact with underlying Franciscan Complex is interpreted to be the regional Coast Range fault, which is highly modified by Late Mesozoic(?) to middle Tertiary attenuation faulting, and by Miocene and younger reverse-slip faults. The younger (i.e. the Sargent, Hooker Gulch, Aldercroft, and Sierra Azul-Soda Spring) faults cut and locally are alined with the older Coast Range fault. $^{87}Sr/^{86}Sr$ values for the cumulate ultramafic rocks range from .7024 to .7042 (R. Kistler, written commun., 1990). Locally these rocks are hydrothermally altered to silica carbonate rock (sc).

Jos

Serpentinite. Undifferentiated partially to highly serpentinized ultramafic rocks. South of Aldercroft-Soda Spring fault system rocks mapped as part of this unit commonly contain relict interstitial plagioclase and are here considered to be cumulates. However, structurally lower serpentinized ultramafic rocks incorporated into terranes of the Franciscan Complex to the northeast consist largely of dunite and harzburgite that generally lacks interstitial plagioclase and cumulate textures. In places these ultramafic rocks are extensively altered hydrothermally to silica carbonate rock (sc) which is the principal host rock for mercury mineralization in the now inactive New Almaden mining district.

CENTRAL BELT OF THE FRANCISCAN COMPLEX (LOWER EOCENE? TO UPPER CRETACEOUS)--Melange, composed predominantly of resistant blocks of different sizes, lithologies, metamorphic grades, and ages, enclosed in a less resistant matrix of penetratively sheared black argillite, green tuff, and lithic sandstone with abundant chert and volcanic detritus. Age of melange is considered to be the time of tectonic mixing, which was no earlier than the time of latest deposition of pelagic limestone and chert (ca. 90 Ma). Tectonic mixing also followed or was coeval with the deposition of overlying sedimentary rocks that now are penetratively deformed and are part of the Central belt (90 Ma or younger). Mixing was prior to unroofing of the Central belt and reworking of detritus derived from these Franciscan rocks into younger, unmetamorphosed slope deposits (Early Eocene). Argillite matrix of the melange characteristically exhibits a boudinage fabric. In some areas a fissile slaty fabric is also evident. The matrix rocks commonly contain incipient pumpellyite ± phengitic white mica ± prehnite. Some of the matrix rocks having a pronounced slaty parting (textural zone 2 of Blake and others, 1967) contain an incipient pumpellyite ± lawsonite + phengitic white mica metamorphic assemblage. The Central belt of the Franciscan Complex in the Los Gatos Quadrangle is subdivided into two major tectonostratigraphic terranes:

PERMANENTE TERRANE (UPPER AND LOWER CRETACEOUS)--

Consists of:

flp

Limestone. White, pink, greenish-gray, and dark brown to black, bituminous, foraminiferal, and locally oolitic limestone. Limestone was deposited in shallow to deep water, open-ocean, seamount or oceanic plateau setting, at equatorial latitudes (Sliter and others, 1991). Limestone commonly includes interlayered nodules, lenses, and layers of dark gray to black replacement chert. Lower part of limestone section typically is tuffaceous to cherty with fissile partings. Locally, limestone may be overlain by red radiolarian chert. Foraminifers and sparse megafossils from limestone in Los Gatos Quadrangle are late Early Cretaceous (Aptian) to Late Cretaceous (Turonian) in age (Sliter and others, 1991).

fcp

Chert. Black, green, or red chert, locally containing radiolaria of Early Cretaceous (Berriasian (?) to Aptian) age (Sliter and others, 1991).

fvp

Basalt. Basalt flows, basaltic tuff breccia, and thin bedded andesitic tuff, altered to prehnite-pumpellyite-chlorite assemblage. Basalt is locally pillowed. The basaltic rocks are geochemically similar to volcanic rocks of oceanic seamounts and plateaus (high Ti relative to V, FeO/MgO and Cr, and high P_2O_5). Stratigraphically higher andesitic tuff is geochemically arc-like and locally contains undated radiolaria. Basaltic rocks commonly contain prominent ilmenite and sphene, and clinopyroxene generally is augite or titanaugite. Flow rocks of Permanente terrane in adjacent Santa Teresa Hills Quadrangle along

Uvas Reservoir shoreline locally contain abundant large inclusions of olivine orthopyroxene cumulate rock. $^{87}Sr/^{86}Sr$ values for the basaltic rocks range from .7039 to .7040, whereas andesitic tuffs from the Uvas Reservoir area have $^{87}Sr/^{86}Sr$ values ranging from .7043 to .7100. Collectively, the range in $^{87}Sr/^{86}Sr$ values for the volcanic section of the Permanente terrane yield an Early Cretaceous initial $^{87}Sr/^{86}Sr$ isochron age of 135 to 120 Ma (R. Kistler, written commun., 1990) which tentatively has been interpreted as the approximate age of the volcanic section (Sliter and others, 1991).

fsrp

Melange. Composed predominantly of penetratively sheared argillite and minor, sheared lithic metasandstone with less than 1 percent detrital K-feldspar (textural zone 1 of Blake and others, 1967) mixed with undivided blocks of basaltic volcanic rocks, limestone, chert, serpentinite, and rarer blocks of glaucophane-bearing metavolcanic and metasedimentary rocks, hornblende-bearing metamorphic rocks (amphibolite), and glaucophane schist. Tectonic mixing of materials into this melange unit and its subsequent metamorphism to pumpellyite- and lawsonite-bearing assemblages occurred between the Late Cretaceous (Turonian) and early Eocene.

BALD MOUNTAIN-EL SOMBROSO TERRANE (LOWER JURASSIC TO UPPER CRETACEOUS)--Consists of:

fsm

Metasandstone. Broken formation to well bedded, and complexly folded metasandstone. Ranges in composition from lithic metasandstone with abundant chert and felsic to mafic volcanic detritus, celadonitic volcanic glass and fine-grained chloritic schist or phyllitic rock fragments; to quartzo-feldspathic, with angular quartz detritus, fragments of phyllite and mica schist, common biotite, muscovite, epidote-clinozoisite, and minor detrital zircon and sphene. Metasandstone contains less than 1 percent detrital k-feldspar. Different slabs of the metasandstone are variously reconstituted to upper textural zone 1 to upper textural zone 2 of Blake and others, 1967. Metasandstone commonly contains incipient metamorphic pumpellyite. More recrystallized metasandstones locally contain pumpellyite ± incipient lawsonite or lawsonite ± pumpellyite. Slabs of quartzo-feldspathic lawsonitic metasandstone are probably equivalent to parts of the Eastern belt of the Franciscan Complex (i.e. Yolla Bolly terrane of Blake and others, 1988). Metasandstone locally contains prominent laminar concentrations of carbonaceous debris and coal fragments. In several places metasandstone is extensively hydrothermally altered to quartz ± chlorite ± clays ± epidote, and silicified. Depositional age of lithic metasandstone is here considered to be late Early Cretaceous (Hauterivian) or younger, based on occurrence of chert detritus of that age in the metasandstone (see fcm, below); its metamorphism to lawsonite and pumpellyite-bearing assemblages was therefore also younger than Hauterivian. Deposition and metamorphism of quartzofeldspathic metasandstone could be considerably younger or older than lithic metasandstone, since original stratigraphic relationship to more lithic component, is unknown. The metamorphism of similar quartzofeldspathic metasandstone in the Eastern belt of the Franciscan Complex in the Diablo Range (Mattinson and Echeverria, 1980) is dated on the basis of a U/Pb sphene age at 92 Ma.

fcm

Radiolarian chert. Red to green radiolarian chert, occurring in mappable large to small blocks, or as part of composite blocks and slabs tens of meters up to several kilometers long, within melange of Bald Mountain-El Sombroso terrane. Chert depositionally overlies basaltic rocks locally. Stratigraphic relationship of chert with metaclastic rocks is everywhere obscured by shearing. Radiolaria from a large lens of red chert enclosed by melange near Bald Mountain along west edge of adjacent Santa Teresa Hills Quadrangle range in age from Early Jurassic (MH-1, late Pliensbachian to middle Toarcian) to Middle Jurassic (MH-3, Bajocian) (Murchey and Hagstrum, 1991; Hagstrum and Murchey, 1991). Within Los Gatos Quadrangle, radiolarian faunas from numerous blocks of chert and composite blocks of chert and basalt in melange range in age from Early Jurassic (MH-2, middle and late Toarcian) to late Middle or early Late Jurassic (MH-4, Callovian or Oxfordian) (B. Murchey, oral commun., 1991; Y. Isozaki, written commun., 1991; I. Hattori, written commun., 1990). In addition, radiolarian faunas of Late Jurassic to Early Cretaceous (MH-5, late Tithonian to Hauterivian) age also occur in the argillite matrix of melange as angular to subround olistolithic clasts of meter length down to pebble size, and as detritus in bedded lithic metasandstone of terrane. Elsewhere in the Coast Ranges, chert sections in the

Geysers and Marin Headlands terranes of the Franciscan Complex, include radiolarian faunas as young as early Late Cretaceous (MH-7, Cenomanian) (McLaughlin and Pessagno, 1978; Murchey, 1984; Murchey and Jones, 1984; McLaughlin and Ohlin, 1984).

fvm Basalt. Basalt flows, massive to pillowed, locally vesicular in upper part, and minor tuff and pillow breccia. Basalt is extensively spilitized and metamorphosed to prehnite-pumpellyite and low blueschist grade mineral assemblages. Locally, thin lenses and pods of thermally metamorphosed interpillow pelagic deposits, including recrystallized limestone altered to calc-silicate mineral assemblages (i.e. epidote, pumpellyite, calcite-aragonite, and hematite), and hydrothermal chert (orbicular jasper) are present. Correlative basaltic rocks from the Marin headlands area are geochemically MORB-like, in general higher in vanadium (V=350-550 ppm) and lower in ratio of zirconium/ytrium ($Zr/Y \leq 4$) than oceanic plateau and seamount-related rocks of the Permanente terrane of this area ($V \leq 350$ ppm; $Zr/Y \geq 5$) (Shervais, 1982; Shervais and Kimbrough, 1987; and McLaughlin, unpublished data, 1991). Age of basaltic rocks of Bald Mountain-El Sombroso terrane is Early Jurassic (Pliensbachian) or older, based on oldest radiolarian-bearing cherts that stratigraphically overlie basaltic rocks.

fsrm Melange. Composed predominantly of penetratively sheared argillite and minor sheared lithic metasandstone, which encloses, and may include unmapped blocks of other components of Bald Mountain-El

Sombroso terrane. Melange of the Bald Mountain-El Sombroso terrane is different from that of the Permanente terrane (fsrp) in three major respects: 1) Melange of the Bald Mountain-El Sombroso terrane includes abundant Jurassic radiolarian chert, which occurs as large to small blocks, and as detritus in pebbly to bouldery mudstones or in coarse lithic metasandstone of melange matrix; 2) Pelagic Permanente-like limestone is absent from the melange; and 3) a prominent platy (axial plane?) cleavage is superimposed on the penetrative shear fabric of the argillitic matrix of the Bald Mountain-El Sombroso terrane melange in most of the area. Lithic metasandstone of this melange usually contains conspicuous chert, felsite, and mafic volcanic detritus, but metasandstone also may include fine-grained mica schist, phyllite, and quartzite detritus and coaly carbonaceous debris. Argillite and metasandstone of melange matrix contain minor but conspicuous pumpellyite and chlorite ± white mica ± trace to minor amounts of incipient lawsonite. The depositional age and the age of metamorphism of the argillic rocks of the melange matrix, like the metasandstone of this unit, are considered to be late Early Cretaceous (Hauterivian) or younger, based on radiolarian faunas of Early Cretaceous (MH-5, late Tithonian to Hauterivian) age (B. Murchey, oral commun., 1991) from chert detritus in pebbly to bouldery argillite of the matrix, and the platy fabric of the matrix rocks.

ROCKS OF UNCERTAIN ORIGIN AND AGE FOUND IN MELANGES OF BOTH PERMANENTE AND BALD MOUNTAIN-EL SOMBROSO TERRANES--

fmv — Glaucophane-bearing metavolcanic and metasedimentary rocks

fmh — Hornblende-bearing metamorphic rocks (amphibolite)

fm — Glaucophane schist

Jos — Serpentinite. Mildly to highly serpentinized peridotite, partly derived from Coast Range ophiolite and partly from other oceanic source rocks, tectonically interleaved in melange of Permanente and Bald Mountain-El Sombroso terranes. Serpentinite incorporated into these terranes is predominantly of non-cumulate origin, and locally is extensively altered to silica-carbonate rock (sc), a major host for mercury mineralization in New Almaden area.

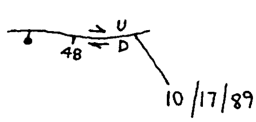
MAP SYMBOLS

Contact, dashed where approximate, dotted where concealed

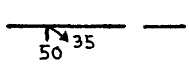
Fault, dashed where approximate, dotted where concealed, queried where uncertain. Ball and bar denote down-thrown block, or U and D denote up and down-thrown blocks. Direction and amount of dip of fault plane shown locally. Horizontal arrows denote relative horizontal movement

Fault at low-angle to bedding, interpreted as low-angle normal fault, double-bars on down-dropped side

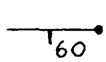
Thrust fault, barbs on upper plate



Surface cracks, mapped locally, associated with 1989 Loma Prieta earthquake. Where known, sense of slip indicated by symbols used for faults. See Ponti and Wells (1991, in press) for crack data in main area of surface deformation along San Andreas fault zone.

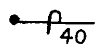


Surface trace and amount of dip of fault, and plunge of lineation on fault plane

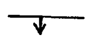


Bedding. Ball denotes that facing direction is known from sedimentary structures

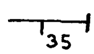
Vertical bedding. Ball denotes facing direction is known from sedimentary structures



Overturned bedding, ball denotes that facing direction is known from sedimentary structures



Bedding, strike and dip direction approximated from air photos, from long distance sighting, or averaged in area where strike or dip highly variable.

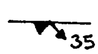


Bedding attitude, taken from trench excavation

Shear foliation or cleavage

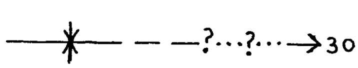
Inclined

Vertical

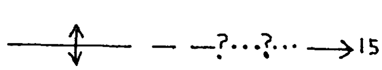


Shear foliation or cleavage showing plunge of lineation on shear (cleavage) surface

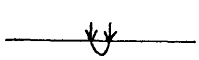
Folds



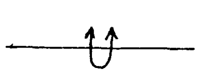
Synclinal axis, showing direction and amount of plunge, dashed where approximate, dotted where concealed, queried where uncertain



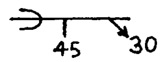
Anticlinal axis, showing direction and amount of plunge, dashed where approximate, dotted where concealed, queried where uncertain



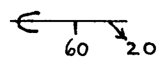
Overturned syncline



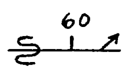
Overturned anticline



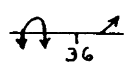
Outcrop-scale anticlinal fold, showing dip of axial plane, and amount and direction of plunge



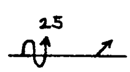
Outcrop-scale synclinal fold, showing dip of axial plane, and amount and direction of plunge



Isoclinal folds showing dip of axial planes and plunge direction



Outcrop-scale overturned anticline, showing dip of axial plane and plunge direction



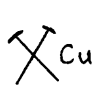
Overturned isoclinal folds, showing dip of axial plane and plunge direction

Drill hole

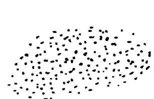
Mine dump

Mine adit

Mine shaft



Mineral prospect, with commodity indicated where known

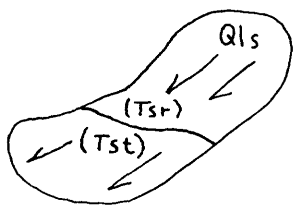


Area of hydrothermal alteration

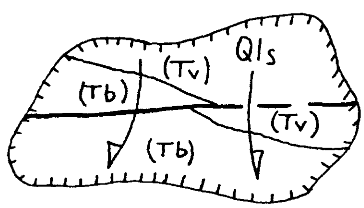
g···g···g···g

Glauconitic marker bed

Closed depression



Landslide, arrows indicate direction of movement, stratigraphy and structure within intact landslide blocks shown locally, with rock unit designations in parentheses, movement downslope minor to considerable



Large landslide, consisting of one or more blocks of intact rock. Movement predominantly rotational with relatively minor downslope displacement from a prominent headwall scarp. Arrows indicate direction of movement; stratigraphy and structure of intact blocks delineated where mapped, with rock unit designations in parentheses.

Topographic escarpment. Line above barbs denotes top of escarpment

Subsurface course of abandoned railroad tunnel southwest of Wright

REFERENCES CITED IN ROCK DESCRIPTIONS

Adam, D.P., McLaughlin, R.J., Sorg, D.H., Adams, D.B., Forester, R.M., and Repenning, C.A., 1982, An animal and plant-fossil assemblage from the Santa Clara Formation (Pliocene and Pleistocene), Saratoga, California: *in* Ingersoll, R.V., and Woodburne, M.O., eds, Cenozoic nonmarine deposits of California and Arizona: *Society of Economic Paleontologists and Mineralogists, Pacific Section,* p. 105-110.

Bailey, E.H., and Everhart, D.L., 1964, Geology and quicksilver deposits of the New Almaden District, Santa Clara County, California: *U.S. Geological Survey Professional Paper 360,* 206 p.

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 575-C,* p. C1-C9.

Blake, M.C., Jr., Jayko, A.S., McLaughlin, R.J., and Underwood, M.B., 1988, Metamorphic and tectonic evolution of the Franciscan Complex, northern California *in* Ernst, W.G., ed., Metamorphism and crustal evolution of the western United States, *Rubey Vol VII,* p. 1035-1060, Prentice Hall, Englewood Cliffs, NJ.

Blondeau, A., and Brabb, E.E., 1983, Large foraminifers of Eocene age from the Coast Ranges of California, *in* Brabb, E.E., ed., Studies in Tertiary stratigraphy of the California Coast Ranges, *U.S. Geological Survey Professional Paper 1213,* p. 41-48.

Clark, J.C., 1968, Correlation of the Santa Cruz Mountains Tertiary--implications for San Andreas history, *in* Dickinson, W.R., and Grantz, Arthur, eds., Proceedings of Conference on geologic problems of San Andreas fault system: *Stanford University Publications in the Geological Sciences*, v. 11, p. 166-180.

_____ 1981, Stratigraphy, paleontology, and geology of the central Santa Cruz Mountains, California Coast Ranges: U.*S. Geological Survey Professional Paper 1168,* 51 p., 2 map sheets and sections, scale 1:24,000.

Clark, J.C., Brabb, E.E., and McLaughlin, R.J., 1989, Geologic map and structure sections of the Laurel 7-1/2' Quadrangle, Santa Clara and Santa Cruz Counties, California: *U.S. Geological Survey Open-File Map 89-676,* 30 p., 2 sheets, scale 1:24,000.

Clark, J.C., McLaughlin, R.J., Kistler, R.W., Champion, D.E., and Franck, C.R., 1991, Basement structure southwest of the San Andreas fault, Loma Prieta, Laurel, and Los Gatos Quadrangles, California [abs.]: *Geological Society of America Abstracts with Programs,* v. 23, no. 2, p. 13.

Cooper-Clark and Associates, 1975, Preliminary map of landslide deposits in Santa Cruz County, California: *in* Seismic Safety Element: Publication of Santa Cruz County Planning Department, Santa Cruz, California, scale 1:62,500.

Cotton, W.R., Fowler, W.L., and Van Velsor, J.E., 1990, Coseismic bedding plane faults and ground fissures associated with the Loma Prieta earthquake of October 17, 1989, in *The Loma Prieta (Santa Cruz Mountains), California earthquake of October 17, 1989,* McNutt, S.R., and Sydnor, R.H., eds., *California. Division of Mines and Geology Special. Publication, 104,* p. 95-103.

Cummings, J.C., 1968, The Santa Clara Formation and possible post-Pliocene slip on the San Andreas fault in central California, *in* Dickinson, W.R., and Grant, Arthur, *eds.*, *Proceedings of Conference on geologic problems of San Andreas fault system: Stanford University Publications in Geological Sciences*, v. XI, p. 191-207.

Elder, W.P., 1991, An unusual Late Cretaceous fauna from an oyster-rich interval in the Santa Cruz Mountains of California: *U.S. Geological Survey Bulletin 1934.*

Fairchild, W.W., Wesendunk, P.R., and Weaver, D.W., 1969, Eocene and Oligocene foraminifera from the Santa Cruz Mountains, California: *California University Publications in Geological Sciences*, v. 81, p. 1-145.

Fox, K.F., Jr., Fleck, R.J., Curtis, G.H., and Meyer, C.E., 1985, Implications of the northwestwardly younger age of the volcanic rocks of west central California: *Geological Society of America Bulletin*, v. 96, p. 647-654.

Hagstrum, J.T., and Murchey, B.L., 1991, Paleomagnetism of lower Jurassic chert within the Franciscan Complex, northern California, indicates deposition at paleoequator and accretion near 7° north paleolatitude [abs.]: *Geological Society of America Abstracts with Programs*, v. 23, p. 33.

Hart, E.W., Bryant, W.A., Wills, C.J., and Treiman, J.A.,1990, The search for fault rupture and significance of ridgetop fissures, Santa Cruz Mountains, California, in The Loma Prieta (Santa Cruz Mountains), California earthquake of October 17, 1989, McNutt, S.R., and Sydnor, R.H., eds., *California Division of Mines and Geology Special Publication 104*, 104, p. 83-94.

Johnson, C.M., and O'Neil, J.R., 1988, Constraints on Pre-Tertiary movement on the San Andreas fault system (SAF): Stable and radiogenic isotope and trace element data from

Jurassic gabbros [abs.]: *Geological Society of America Abstracts with Programs,* v. 20, p. A381.

Johnson, R.E., and Associates, 1989, Fault investigation report, Loma Prieta Elementary School, Santa Clara County, California: *Loma Prieta School District Open-File Report,* 50 p.

Keefer, D.K., in press, Geologic hazards in the Summit Ridge area of the Santa Cruz Mountains, Santa Cruz County, California, evaluated in response to the October 17, 1989, Loma Prieta Earthquake: Report of the Technical Advisory Group: *U.S. Geological Survey Open-File Report*.

Le Bas, M.J., and Streckeisen, A.L., 1991, The I.U.G.S. systematics of igneous rocks: *Journal of the Geological Society of London,* v. 148, p. 825-833.

Mattinson, J.M., and Echeverria, L.M., 1980, Ortigalita Peak gabbro, Franciscan Complex-U-Pb date of intrusion and high-pressure-low temperature metamorphism: *Geology*, v.8, p. 589-593.

McLaughlin, R.J., and Pessagno, E.A., 1978, Significance of age relations above and below Upper Jurassic ophiolite in The Geysers-Clear Lake region, California: *U.S. Geological Survey Journal of Research*, v. 6, p. 715-726.

McLaughlin, R.J., and Ohlin, H.N., 1984, Tectonostratigraphic framework of the Geysers-Clear Lake Region, California: *in* Blake, M.C., Jr., ed., Franciscan Geology of northern California, *Society of Economic Paleontologists and Mineralogists, Pacific Section*, v. 43, p. 221-254.

McLaughlin, R.J., Blake, M.C., Jr., Griscom, A., Blome, C.D., and Murchey, B., 1988, Tectonics of formation, translation, and dispersal of the Coast Range ophiolite of California: *Tectonics*, v. 7, no. 5, p. 1023-1056.

McLaughlin, R.J., Clark, J.C., and Brabb, E.E., 1988, Geologic map and structure sections of the Loma Prieta 7-1/2' Quadrangle, Santa Clara and Santa Cruz Counties, California: *U.S. Geological Survey Open-File Map 88-752*, 2 sheets, scale 1:24,000.

McLaughlin, R.J., Elder, W.P., and McDougall, Kristin, 1991, Tectonic Framework of the Loma Prieta area, *in* Sloan, Doris, and Wagner, D.L., eds., Geologic excursions in northern California: San Francisco to the Sierra Nevada: *California Division of Mines and Geology Special Publication 109*, p. 45-54.

Murchey, Benita, 1984, Biostratigraphy and lithostratigraphy of chert in the Franciscan Complex, Marin headlands, California: *in* Blake, M.C., Jr., ed., Franciscan Geology of northern California, *Society of Economic Paleontologists and Mineralogists, Pacific Section,* v. 43, p. 51-70.

Murchey, B.L., and Jones, D.L., 1984, Age and significance of chert in the Franciscan Complex, in the San Francisco Bay Region: *in* Blake, M.C., Jr., ed., Franciscan Geology of northern California, *Society of Economic Paleontologists and Mineralogists, Pacific Section,* v. 43, p. 23-30.

Murchey, B.L., and Hagstrum, J.T., 1991, Developments in Jurassic stratigraphy of the Franciscan Complex, California: expanded and recalibrated radiolarian zonation coupled with potential for magnetostratigraphy [abs.]: *Geological Society of America, Abstracts with Programs*, v. 23, no. 2, p. 82.

Nilsen, T.H., 1983/1984, Submarine-fan facies associations of the Eocene Butano Sandstone, Santa Cruz Mountains, California: *Geo-Marine Letters*, v. 3, p. 167-171.

Ponti, D.J., and Wells, R.E., in press, Off-fault ground ruptures in the Santa Cruz Mountains, California: Ridge-top spreading vs. tectonic extension during the 1989 Loma Prieta earthquake: *Seismological Society of America Bulletin.*

Robertson, A.H.F., 1990, Sedimentology and tectonic implications of ophiolite-derived clastics overlying the Jurassic Coast Range ophiolite, northern California: *American Journal of Science*, v. 290, p. 109-163.

Ross, D.C., 1970, Quartz gabbro and anorthositic gabbro: markers of offset along the San Andreas fault in the California Coast Ranges: *Geological Society of America Bulletin*, v. 81, p. 3647-3662.

Ross, D.C., 1978, The Salinian block--A Mesozoic granite orphan in the California Coast Ranges, *in* Howell, D.G., and McDougall, K.A., eds., Mesozoic paleogeography of the Western United States, *Society of Economic Paleontologists and Mineralogists, Pacific Section, Pacific Coast Paleogeography Symposium 2*, p. 509-522.

Shervais, J.W. and Kimbrough, D.L., 1987, Alkaline and transitional subalkaline metabasalts in the Franciscan Complex melange, *Geological Society of America Special Paper 215*, 167-182.

Shervais, J.W., 1982, Ti-V plots and the origin of modern and ophiolitic lavas, *Earth and Planetary Science Letters*, v. 59; p. 101-118.

Simoni, T.R., Jr., 1974, Geology of the Loma Prieta area, Santa Clara and Santa Cruz Counties, California: California State University, San Jose, M.S. thesis, 75 p., with map and structure sections, scale 1:12,000.

Sliter, W.V., Murchey, B.L., McLaughlin, R.J., and Kistler, R.W., 1991, Permanente terrane: History of Early Cretaceous Seamount Formation in the eastern Pacific [abs.]: *Geological Society of America Abstracts With Programs*, v. 23, no. 2, p. 98.

Sorg, D.H., and McLaughlin, R.J., 1975, Geology of the Sargent-Berrocal fault zone between Los Gatos and Los Altos Hills, California: *U.S. Geological Survey Miscellaneous Field Investigations Map MF-643, scale 1:24,000.*

Spittler, T.E. and Harp, E.L. (Compilers), 1990, Preliminary map of landslide features and coseismic fissures triggered by the Loma Prieta earthquake of October 17, 1989: *California Division of Mines and Geology, Open-File Report 90-6*, scale 1:48,000.

Spittler, T.E., Harp, E.L., Keefer, D.K., Wilson, R.C., and Sydnor, R.H., 1990, Landslide features and other coseismic fissures triggered by the Loma Prieta earthquake, central Santa Cruz Mountains, California, in the Loma Prieta (Santa Cruz Mountains), California earthquake of October 17, 1989: McNutt, S.R., and Sydnor, R.H., eds., *California Division of Mines and Geology Special Publication 104*, p. 59-66.

Turner, D.L., 1970, Potassium-argon dating of Pacific Coast Miocene foraminiferal stages, *in* Bandy, O.L., ed., Radiometric dating and paleontologic zonation: *Geological Society of America Special Paper 124*, p. 91-129.

Vanderhurst, W.C., Cummings, J.C., and Anderson, D.W., 1982, The Santa Clara Formation as a record of Late Cenozoic uplift of the Santa Cruz Mountains, Santa Clara County, California: *in* Ingersoll, R.V., and Woodburne, M.O., eds., Cenozoic nonmarine deposits of California and Arizona: *Society of Economic Paleontologists and Mineralogists, Pacific Section,* p. 23-32.

Wieczorek, G.W., Harp, E.L., Mark, R.K., and Bhattacharyya, A.K., 1988, Debris flows and other landslides in San Mateo, Santa Cruz, Contra Costa, Alameda, Napa, Solano, Sonoma, Lake, and Yolo Counties, and factors influencing debris-flow deposition, *in* Ellen, S.D., and Wieczorek, G.W., eds., Landslides, floods, and marine effects of the storm of January 3-5, 1982, in the San Francisco Bay region, California: *U.S. Geological Survey Professional Paper 1434*, p. 133-161.

INDEX TO SOURCES OF DATA USED IN MAP COMPILATION

1. Bailey, E.H., and Everhart, D.C., 1964, Geology and quicksilver deposits of the New Almaden District, Santa Clara County, California: *U.S. Geological Survey Professional Paper 360,* 206 p.

2. Brabb, E.E., field work, 1969.

3. Clark, J.C., and Brabb, E.E., field work 1990-91.

4. Clark, J.C., and McLaughlin, R.J., field work, 1990-91.

5. Dibblee, T.W., Jr., and Brabb, E.E., 1978, Preliminary geologic map of the Los Gatos Quadrangle, Santa Clara and Santa Cruz Counties, California: *U.S. Geological Survey Open-File Report 78-453,* scale 1:24,000.

6. Helley, E.J., photogeology and field checking, 1989-91.

7. Johnson, R.E., and Associates, 1989, Fault investigation report, Loma Prieta Elementary School, Santa Clara County, California: *Loma Prieta School District Open-File Report,* 50 p.

8. Keefer, D.K., in press, Geologic Hazards in the Summit Ridge area of the Santa Cruz Mountains, Santa Cruz County, California, evaluated in response to the October 17, 1989, Loma Prieta Earthquake: Report of the technical Advisory Group: *U.S. Geological Survey Open-File Report.*

9. McLaughlin, R.J., field work, 1989-91.

10. McLaughlin, R.J., and Harden, J.W., Site visit to Shannon fault trenched by Emcon Associates, 1989.

11. McLaughlin, R.J., Loma Prieta earthquake investigation, surface deformation data, 1989.

12. Ponti, D.J., and Wells, R.E., in press. Off-fault ground ruptures in the Santa Cruz Mountains, California: Ridge-top spreading vs. tectonic extension during the 1989 Loma Prieta earthquake: Bulletin, *Seismological Society of America.*

13. Sarna-Wojcicki, A.M., Pampeyan, E.H., and Hall, N.T., 1975, Map showing recently active breaks along the San Andreas fault between the central Santa Cruz Mountains and the northern Gabilan Range, California: *U.S. Geological Survey Miscellaneous Field Investigations Map MF-650,* scale 1:24,000.

14. Sorg, D.H., and McLaughlin, R.J, 1975, Geologic Map of the Sargent-Berrocal fault zone between Los Gatos and Los Altos Hills, Santa Clara County, California: *U.S. Geological Survey Miscellaneous Field Investigations Map MF-643,* scale 1:24,000.

INDEX TO SOURCES OF DATA, 1989 LOMA PRIETA EARTHQUAKE SURFACE DEFORMATION

1. Haugerud, R.A., and Ellen, S.D., 1990, Coseismic ground deformation along the northeast margin of the Santa Cruz Mountains, *in* Schwartz, D.P. and Ponti, D.J., eds., Field guide to neotectonics of the San Andreas fault system, Santa Cruz Mountains, in light of the 1989 Loma Prieta earthquake: *U.S. Geological Survey Open-File Report 90-274*, p. 32-36.

2. Keefer, D.K., in press, Geologic hazards in the Summit Ridge area of the Santa Cruz Mountains, Santa Cruz County, California, evaluated in response to the October 17, 1989, Loma Prieta earthquake: Report of the technical advisory group: *U.S. Geological Survey Open-File Report*.

3. McLaughlin, R.J., Surface deformation data, 1989.

4. Ponti, D.J., and Wells, R.E., in press, Off fault ground ruptures in the Santa Cruz Mountains, California: Ridge-top spreading vs. tectonic extension during the 1989 Loma Prieta earthquake: *Seismological Society of America Bulletin.*

5. Sorg, D.H., Surface deformation data, 1989.

ACKNOWLEDGMENTS

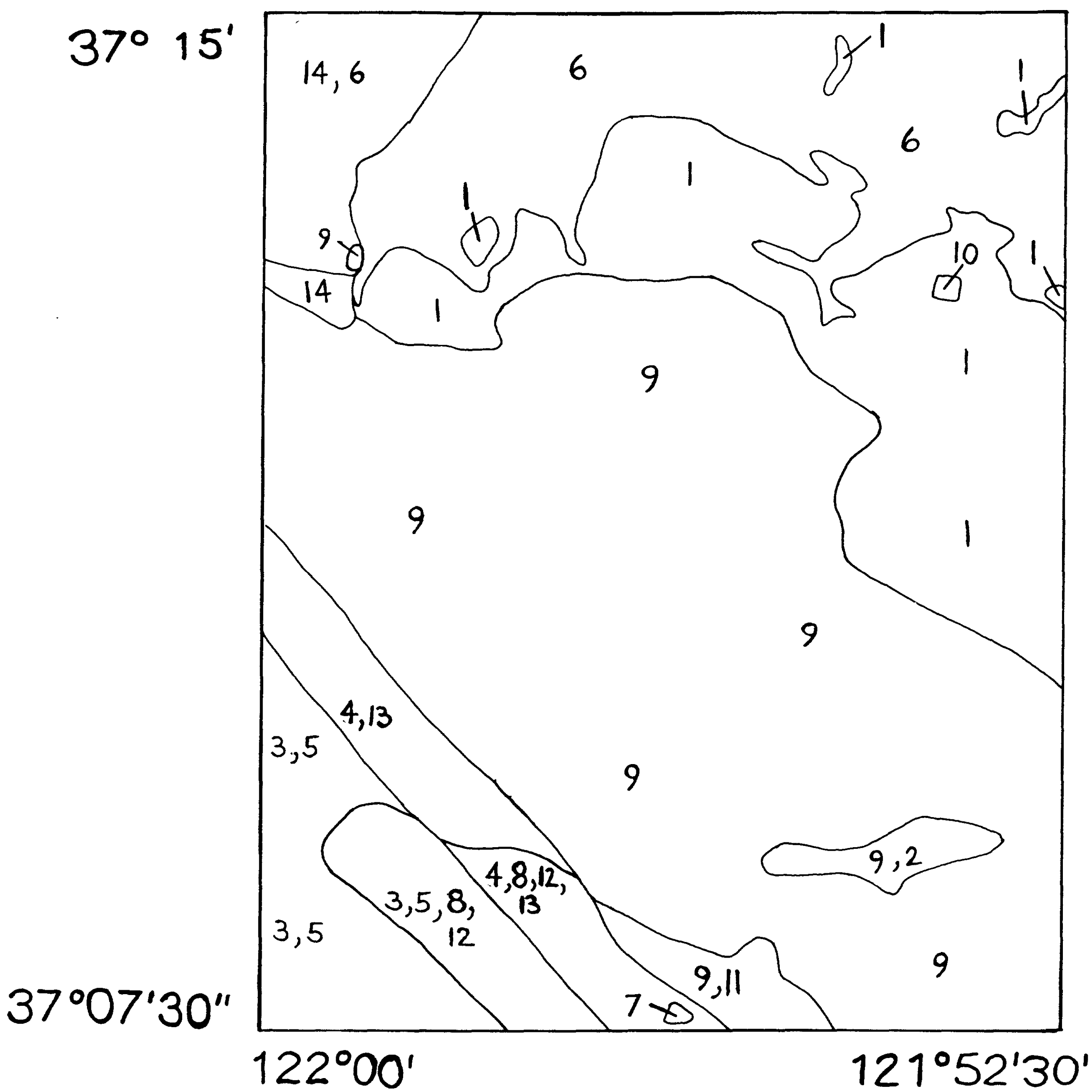
Numerous residents and property owners in the Los Gatos Quadrangle have aided us in this investigation by allowing access to their property and by providing us with gate keys and (or) information about the condition and location of access roads. We especially thank the following individuals for their interest and cooperation: Mr. J. P. Barrett, Mr. M. McQueen, Mr. R. Estrada, Mr. and Mrs. R. Brennan, Mrs. V. C. Barrick, Mrs. L. R. Kephart, and the Viebaum and Leeson families. We thank the Mid-Peninsula open-space district and its staff, and the San Jose Water Company for their continuing cooperation in our investigations in the area surrounding Mount Thayer, Mount Umunhum, and Lexington Reservoir. McLaughlin also thanks the staff of the California Division of Forestry, Burrell Station, for the lodging and hospitality provided to him from 1988-1990, while mapping in the Los Gatos and adjacent quadrangles. The able field assistance and geotechnical support of P. Showalter, C. Franck, E. Lehmer, and K. Fraracci, are herein gratefully acknowledged. The text for this report was typed and formatted by Louise King.

CREDITS FOR PALEONTOLOGIC DATA

Mesozoic and lower Tertiary invertebrate fossils	-	W.P. Elder[*1], D.L. Jones[*2]
Mesozoic foraminifers	-	W.V. Sliter[*1]
Mesozoic radiolaria	-	B. Murchey[*1], Y. Isozaki[*3], I. Hattori[*4]
Tertiary foraminifers		
Benthic	-	K. McDougall[*1], R.L. Pierce (deceased)[*1]
Planktic	-	R.Z. Poore[*1]
Planktic and benthic in thin section	-	W.V. Sliter[*1]
Tertiary nannofossils	-	D. Bukry[*1]
Tertiary fish scales	-	R.L. Pierce (deceased)[*1]

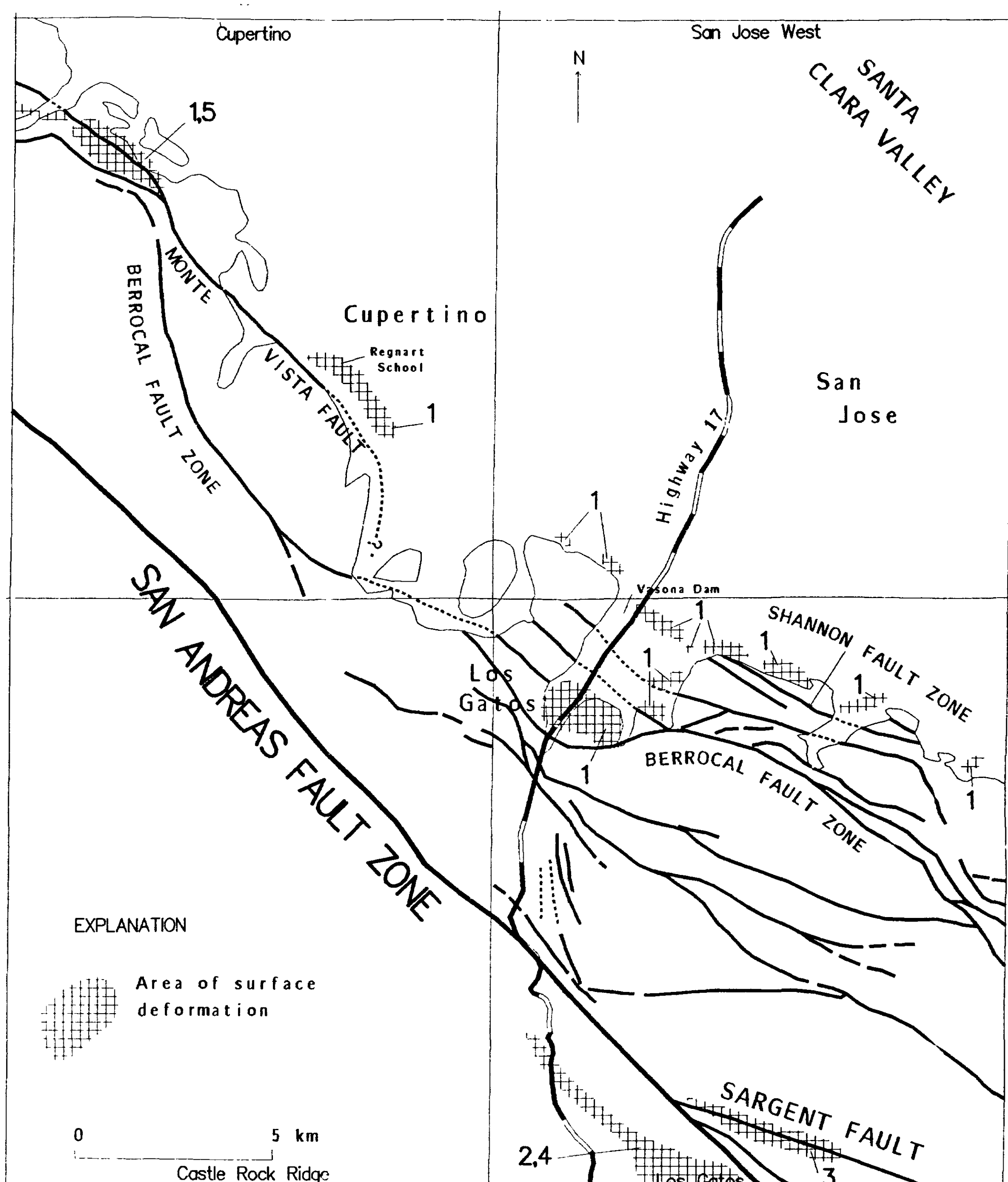
*1 U.S. Geological Survey
*2 University of California at Berkeley
*3 Yamaguchi University, Yamaguchi, 753, Japan
*4 Fukui University, Fukui, 910 Japan

FIGURE 1. INDEX TO SOURCES OF DATA USED IN COMPILATION



FIQURE 2.

37° 22'30"



37° 15'00"

37° 7'30"

122°7'30"　　122°00'00"　　121° 52'30"

Fig 2. Index map showing areas of major surface deformation during October 17, 1989 Loma Prieta earthquake (adapted in-part from Haugerud and Ellen, 1990)

CORRELATION OF MAP UNITS