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GEOLOGY OF SOUTHERNMOST SANTA CLARA COUNTY, CALIFORNIA: A DIGITAL DATABASE

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DISCUSSION

INTRODUCTION

The area of study for this report is the southern portion of Santa Clara County that lies within the Monterey 30 by 60 minute quadrangle, consisting of parts of the Watsonville East, Chittenden, San Felipe, Three Sisters, and Mariposa Peak 7.5 minute quadrangles. The study involved combining compilation of previous published and unpublished work in the area with new mapping completed in the first half of 1997.

The study area makes up a transect of the central California Coast Ranges, starting just east of the San Andreas fault and continuing east across the Santa Cruz Mountains, the Santa Clara Valley, and into the heart of the Diablo Range. The area includes five fault-bounded structural blocks, each containing a distinct stratigraphic assemblage, and the Santa Clara Valley which contains a large Quaternary alluvial complex overlying and obscuring bedrock relationships. Several active faults, including the Sargent, Castro, and Calaveras faults, as well as others with an unknown amount of recent activity, including the Carnadero, San Jose, and Madrone Springs faults, cut the study area with a general north-northwest trend.

STRUCTURAL BLOCKS

The study area is divided into five fault-bounded structural blocks, following the division used in Wentworth and others (in review). Each structural block contains a distinct stratigraphic sequence and has undergone a different geologic history. The differences in stratigraphic sequence are major, and suggest that the rocks in each block formed in different depositional basins, and that the rocks in each have been juxtaposed by large scale movement on the block-bounding faults.

The Sierra Azul block in the study area is generally composed of a west-facing, tightly folded and overturned section of Cretaceous and Tertiary strata, unconformably overlain by relatively gently folded Pliocene strata. It is bounded on the west (just out of the study area) by the San Andreas fault zone, and on the east by the Sargent fault zone. The strata are disrupted by a west-vergent reverse fault separating Eocene and Miocene strata, probably related to tight folding within the block.

The New Almaden block in the study area is made up of two Franciscan terranes overlain by Miocene and younger strata. Within the map area, the contact between Franciscan and Miocene rocks is everywhere faulted, but north of the area the same Miocene rock unit lies unconformably on Franciscan rocks (McLaughlin, 1973). The block is bounded on the west by the Sargent fault and on the east by the San Jose fault of Brabb and Hanna (1981), a postulated fault beneath the surficial deposits of Santa Clara Valley. Because this fault is so poorly located, it is not shown on the geologic map (Sheet 1), but the inferred approximate location of the fault is shown on the fault map (Sheet 2).

The presence of the same Pliocene unit in both the Sierra Azul and New Almaden blocks, and the presence of detritus in the Pliocene rocks derived from both blocks, demonstrates that the juxtaposition of the two blocks along the Sargent fault was for the most part complete by the time of Pliocene deposition. However, Pliocene strata are both folded and faulted, so deformation has continued since deposition.

The Silver Creek block in the study area is composed of interbedded Pliocene and younger gravels and volcanic rocks and slivers of serpentinite derived from the Coast Range ophiolite. It is bounded on the west by the San Jose fault of Brabb and Hanna (1981), and on the east by the Calaveras fault. The study area contains only the southern tip of the block, which doesn't include most of the units found in the block farther north. For a complete description of this block in the area to the north, see Wentworth and others (in review).

The Coyote block is bounded on the west by the Calaveras fault and on the east by the Madrone Springs fault. The block in the study area is made up of tightly folded and much faulted Late Cretaceous and Paleogene strata, forming an east dipping, west-vergent imbricate stack.

The Mount Hamilton block is composed of two juxtaposed Franciscan terranes, overlain and intruded by Miocene volcanic rocks of the Quien Sabe volcanic field. It is bounded on the west side by the Madrone Springs fault and on the east (out of the study area) by the Tesla-Ortigalita fault.

GEOLOGIC STRUCTURES

The structures in southernmost Santa Clara County with the largest amount of cumulative offset are the block boundary faults (see Sheet 2). As discussed above, these faults must have undergone large amounts of offset to bring the distinct stratigraphic sequences into juxtaposition. The timing, direction, and amount of offset on most of these faults is poorly understood, but transpressional deformation is suggested by the uplifted terrain, the folded strata, and the structural position of older rocks over younger.

Structural relationships in the study area suggest that the Sargent fault is an east-dipping, west-vergent reverse fault. Overturning of strata west of the fault in the Sierra Azul block and uplifting of Franciscan terrane rocks east of the fault, as well as observed orientation of one strand of the fault (McLaughlin, 1973), support this interpretation. This interpretation of the fault agrees with the interpretation of Allen (1946), but conflicts with that of McLaughlin (1974). The west-dipping, east-vergent thrust fault McLaughlin describes probably does form the boundary between the Sierra Azul and New Almaden blocks north of the complicated faults near Mount Madonna, but not in the study area. As mentioned above, the presence of the same Pliocene unit on both sides of the Sargent fault indicate that most of the offset on the fault was complete by the time of Pliocene deposition. In the area of Sargent Creek, the Pliocene unit is offset by the Sargent fault, however, indicating about 550 meters of right-lateral apparent offset in Pliocene and/or Quaternary time (see map). The Sargent fault also has evidence of Holocene offset along much of its length (McLaughlin, 1974, Hart, 1988), but the section of the Sargent fault that cuts the Pliocene unit is not considered active (Hart, 1988). However, a previously unnamed, northwest-trending cross fault between the Sargent and Castro faults, informally named the Carlyle Hills fault herein, does have evidence of Holocene offset (Hart, 1988), and this fault also forms the northern boundary of the Pliocene strata that lie on both sides of the Sargent fault. These relationships suggest that the offset on the active northern part of the Sargent fault switched from the southern section of the Sargent fault to the Carlyle Hills fault soon after Pliocene deposition.

The San Jose fault of Brabb and Hanna (1981) is inferred by the juxtaposition of the New Almaden and Silver Creek blocks with different stratigraphic sequences on opposite sides of Santa Clara Valley, and by a pronounced aeromagnetic anomaly. The timing, direction, and amount of offset on this fault, even its exact location, is largely unknown. The offset probably mostly predates the Quaternary deposition of surficial deposits in the Santa Clara Valley, judging from the absence of a pronounced lineament or offset of Quaternary units.

The Calaveras fault zone is a major strand of the San Andreas fault system, having as much as 170 km of Miocene or later right-lateral offset, much of which may have been complete by about 3 to 5 Ma (McLaughlin and others, 1996). The Calaveras fault is also the one active fault in the study area that has generated historic large earthquakes. It has an average short-term right-lateral aseismic slip (creep) rate of 1.2 cm/yr. (Evans and others, 1981) and geodetic movement of about 1.5 cm/yr. (Prescott and others, 1981) near Hollister, just south of the study area. The zone of active strands of the Calaveras fault zone in the study area is more than one kilometer wide, and contains at least ten active strands (Hart, 1988). The fault trend changes abruptly just north of San Felipe Lake from north 43∞ west on the northern segment to north 20∞ west on the southern. Dibblee and Rogers (1975) mapped a continuation of the N43W trend to the south as part of the Quien Sabe fault, but this fault has no expression in the Quaternary deposits in or south of the study area. It is possible the Quien Sabe fault is an abandoned (pre-Quaternary) part of the Calaveras fault zone, or that the Quien Sabe fault continues to be active, but is poorly expressed in the surficial deposits.

The Madrone Springs fault is an east-dipping, west vergent reverse fault with an unknown amount of strike-slip offset. Wentworth and others (1997) show the Greenville fault splaying into the Madrone Springs fault near Gilroy Hot Springs, north of the study area. The Greenville fault has about 12 km of right-lateral offset based on offset serpentinite bodies in northernmost Santa Clara and southernmost Alameda Counties, an amount of offset that must be accommodated by the Madrone Springs fault in the area of this report.

In addition to the block bounding faults that are active, there is at least one other active fault in the study area. The Castro fault, within the New Almaden block, is an active (Hart, 1988), high angle reverse-right-lateral fault. The orientation of the fault is shown by the relatively straight fault trend, and the juxtaposition of Mesozoic rocks on the east against Quaternary rocks on the west in Castro Valley.

Additional faults have structural or geomorphic features suggesting that they might be active, but they lack documented offset of Holocene strata. The Carnaderos fault, in the Chittenden quadrangle (see Sheet 2), forms the eastern front of the Santa Cruz Mountains in the study area. The linear nature of the range front, the continuing uplift of the range (Hall and others, 1991), as well as the presence of standing water along the fault near Gavilan College in springtime (sag ponds?) suggest the possibility of continuing activity. Several unnamed fault strands in the northwest part of the Three Sisters quadrangle are marked by remarkably linear valleys and topographic saddles, which could indicate recent activity.

Miocene and older rocks have undergone tight to isoclinal folding in all structural blocks in the area, indicating a major component of compressional deformation in Miocene and younger time. Although the juxtaposition of different strata in different structural blocks makes reconstruction of total compression across the study area impossible, overturned folding within the Sierra Azul block indicates at least 50%, or 4.3 km, of compressional strain normal to the bounding faults in Miocene and younger time. Although the other blocks don't contain Miocene strata in the study area, both the Coyote and Silver Creek blocks have evidence of at least 50% compressional strain normal to the bounding faults in Miocene or younger time north of the study area (Wentworth and others, in review, Jones and others, 1994, Graymer and others, 1995). Assuming that the same minimum of 50% Miocene and younger compression normal to the bounding faults is present in the other two blocks, the study area has undergone at least 32 km of Miocene or younger fault normal compression without considering any compressional deformation on block bounding faults.

Pliocene rocks of the Sierra Azul and New Almaden blocks have also been folded, but in relatively broad, upright folds, indicating that some of the compression had already taken place by the time of Pliocene deposition. Late Pliocene and early Pleistocene strata in the Silver Creek block in the study area are not folded, but are steeply tilted, probably related to folding truncated by the nearby Calaveras fault zone. Pleistocene and Holocene deposits have not been observably folded in the study area, but Pleistocene alluvial fans have been uplifted and remain at a higher level than younger alluvial fans in much of the area, indicating ongoing compression and uplift.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

af **Artificial Fill (Historic)**--Man made deposit of various materials and ages. Some are compacted and quite firm, but fills made before 1965 are nearly everywhere not compacted and consist simply of dumped materials.

alf **Artificial Levee Fill (Historic)**--Man made deposit of various materials and ages, forming artificial levees as much as 20 feet (6.5 meters) high. Some are compacted and quite firm, but levees made before 1965 are almost everywhere not compacted and consist simply of dumped materials. The distribution of levee fill conforms to levees shown on the most recent U.S. Geological Survey 7.5 minute quadrangle maps (San Felipe, 1971, Chittenden, 1993).

Qhasc **Artificial Stream Channels (Historic)**--Modified stream channels, usually where streams have been straightened and realigned, but also including those channels that are confined within artificial dikes and levees.

Qhsc **Stream Channel Deposits (Holocene)**--Poorly to well-sorted sand, silt, silty sand, or sandy gravel with minor cobbles. Cobbles are more common in the mountainous valleys. Many stream channels are presently lined with concrete or rip rap. Engineering works such as diversion dams, drop structures, energy dissipaters and percolation ponds also modify the original channel. Many stream channels have been straightened, and these are labeled Qhasc. The mapped distribution of stream channel deposits is controlled by the depiction of major creeks on the most recent U.S. Geological Survey 7.5 minute quadrangles. Only those deposits related to major creeks are mapped. In some places these deposits are under shallow water for some or all of the year, as a result of reservoir release and annual variation in rainfall.

Qhl **Natural Levee Deposits (Holocene)**--Loose, moderately to well-sorted sandy or clayey silt grading to sandy or silty clay. These deposits are porous and permeable and provide conduits for transport of ground water. Levee deposits border stream channels, usually both banks, and slope away to flatter floodplains and basins. Abandoned levee systems have also been mapped.

Qhfp **Floodplain deposits (Holocene)**--Medium to dark gray, dense, sandy to silty clay. Lenses of coarser material (silt, sand, and pebbles) may be locally present. Flood plain deposits usually occur between levee deposits (Qhl) and basin deposits (Qhb).

Qhb **Basin Deposits (Holocene)**--Very fine silty clay to clay deposits occupying flat-floored basins at the distal edge of alluvial fans.

Qhaf **Alluvial Fan and Fluvial Deposits (Holocene)**--Alluvial fan deposits are brown or tan, medium dense to dense, gravely sand or sandy gravel that generally grades upward, to sandy or silty clay. Near the distal fan edges, the fluvial deposits are typically brown, never reddish, medium dense sand that fines upward to sandy or silty clay. All other alluvial fans and fluvial deposits are confined to narrow valley floors.

Qls **Landslide deposits (Pleistocene and/or Holocene) --** Poorly sorted clay, silt, sand, and gravel. Only a few very large landslides have been mapped. For a more complete map of landslide deposits, see Nilsen and others (1979).

Qpaf **Alluvial Fans and Fluvial Deposits (Pleistocene)**--Brown dense gravely and clayey sand or clayey gravel that fines upward to sandy clay, variously sorted. All Qpaf deposits can be related to modern stream courses. They are distinguished from younger alluvial fans and fluvial deposits by higher topographic position, greater degree of dissection, and stronger soil profile development. They are less permeable than Holocene deposits, and locally contain fresh water mollusks and extinct late Pleistocene vertebrate fossils. They are overlain by Holocene deposits on lower parts of the alluvial plain, and incised by channels that are partly filled with Holocene alluvium on higher parts of the alluvial plain. Maximum thickness is unknown but at least 50 m.

Qpaf1 **Alluvial Terrace Deposits (Pleistocene)**--Qpaf1 and Qpaf2 are the first and second
Qpaf2 Pleistocene alluvial terraces, respectively. Deposits consist of crudely-bedded, clast-supported, gravels, cobbles, and boulders with a sandy matrix. Clasts as much as 35 cm in

diameter are present. Coarse sand lenses may be locally present. Pleistocene terrace deposits are cut into Qpaf alluvial fan deposits a few meters and lie up to several meters above Holocene deposits. These terrace deposits are so similar in lithology and texture as to be almost identical. They are distinguished for mapping purposes on topographic position (the highest is the oldest), degree of dissection, and soil profile development. The highest terrace displays the thickest argillic B horizon and the dark A horizon (Mollic epipedon). Each terrace represents the cutting and filling of previous deposits.

Qpoaf **Older Alluvial Fan deposits (Pleistocene) --** Brown dense gravely and clayey sand or clayey gravel that fines upward to sandy clay. These deposits display various sorting qualities. All Qpoaf deposits can be related to modern stream courses. They are distinguished from younger alluvial fans and fluvial deposits by higher topographic position, greater degree of dissection, and stronger soil profile development. They are less permeable than younger deposits, and locally contain fresh water mollusks and extinct Pleistocene vertebrate fossils.

SIERRA AZUL BLOCK

Tsc, Tscm, Tscn **Conglomerate, sandstone, and siltstone of Sargent Hills (Pliocene) --** Interbedded pebble and cobble conglomerate; massive, brown, coarse- to fine-grained lithic, mica-lithic, and quartz-lithic sandstone; and gray weathering, brown siltstone and silty claystone. Clasts in conglomerate are well rounded to subrounded, up to 20 cm across, and contain: greenstone, greywacke, white weathered siliceous mudstone, laminated chert, red chert and metachert, laminated fine-grained white quartz sandstone, and serpentinite. The detritus could all have been derived from nearby underlying rocks of the Sierra Azul and New Almaden Blocks. Allen (1946) subdivided this unit into a lower marine section (Tscm) and an upper non-marine section (Tscn) based on the presence of macrofossils. This unit is equivalent in part to the Purisima of Allen (1946) and the Etchegoin of Dibblee and Brabb (1978), but is separated from the type section of the former by the San Andreas fault and is too far from the type section of the latter. Note that this unit is part of both the Sierra Azul and New Almaden blocks.

Tps **Siliceous shale and sandstone of Mount Pajaro (Oligocene and/or Miocene) --** Interbedded white weathering, dark brown, hard, laminated, siliceous mudstone; dark brown laminated chert; dark brown micaceous siltstone; white weathering, brown, fine-grained, quartz-mica sandstone, and clean, white, quartz sandstone. Chert was observed only near the top of the unit just south of Hecker Pass. Foraminifers are common in many of the fine-grained outcrops, and Oligocene (Zemorrian) and Miocene (Saucesian and Mohnian) foraminfers have been reported from many localities in this unit (McDougall, written communication, 1997).

Tmss **Sandstone of Mount Madonna (Eocene) --** Interbedded massive, white, fine- to coarse-grained, quartz-mica, quartz-feldspar, and quartz sandstone; distinctly bedded, brown, fine- to coarse-grained, carbonaceous, mica-lithic and lithic wacke; distinctly bedded, brown mudstone and siltstone; and brown weathering, dark gray shale. Glauconite grains are present in one bed of white quartz-mica sandstone. Foraminifers are present in some outcrops of mudstone and shale, and Eocene foraminifers have been reported from more than ten localities in the study area (McDougall, written communication, 1997).

Tws **Shale of Whitehurst Road (Paleocene and/or Eocene) --** Green weathering, gray mudstone; maroon shale; and olive, mica siltstone. Foraminifers are present in some outcrops of this unit, and Paleocene (Bulitian) or Eocene (Penutian) foraminifers have been reported from one outcrop in the study area (McLaughlin, 1971, McDougall, written communication, 1997).

ROCKS WITHIN THE SARGENT FAULT ZONE

Tus **Unnamed sandstone and conglomerate (Miocene) --** Interbedded quartz-feldspar-lithic sandstone and pebble conglomerate. The Miocene age is based on the presence of Miocene macrofossils and foraminifers in the fault lens (McLaughlin, 1973).

Kcg **Unnamed conglomerate (Cretaceous?) --** Highly weathered, sheared, and altered pebble conglomerate and sandstone. Pebbles include intermediate porphyry volcanic rocks. The tentative Cretaceous age is based on lithologic similarity between this unit and other well dated Cretaceous rocks in the Sierra Azul Block (McLaughlin, 1973).

Coast Range Ophiolite (part)

sp **Serpentinite --** Intensely sheared serpentinite and serpentine schist. In places contains blocks of serpentinized harzburgite (bastite) and massive serpentinite.

Franciscan Complex (part)

fm **Melange --** Intensely sheared gray argillite and greywacke, with lenses and blocks of limestone, glaucophane schist, and foliated meta-greywacke.

NEW ALMADEN BLOCK

Tsc, Tscm, Tscn **Conglomerate, sandstone, and siltstone of Sargent Hills (Pliocene) --** Interbedded pebble and cobble conglomerate; massive, brown, coarse- to fine-grained lithic, mica-lithic, and quartz-lithic sandstone; and gray weathering, brown siltstone and silty claystone. Clasts in conglomerate are well rounded to subrounded, up to 20 cm across, and contain: greenstone, greywacke, white weathered siliceous mudstone, laminated chert, red chert and metachert, laminated fine-grained white quartz sandstone, and serpentinite. The detritus could all have been derived from nearby underlying rocks of the Sierra Azul and New Almaden Blocks. Allen (1946) subdivided this unit into a lower marine section (Tscm) and an upper non-marine section (Tscn) based on the presence of macrofossils. This unit is equivalent in part to the Purisima of Allen (1946) and the Etchegoin of Dibblee and Brabb (1978), but is separated from the type section of the former by the San Andreas fault and is too far from the type section of the latter. Note that this unit is part of both the Sierra Azul and New Almaden blocks.

Tms **Monterey Formation (Miocene) --** White weathering, light brown, laminated siltstone and siliceous shale; gray weathering, brown, mica mudstone; and dark brown, laminated, fine-grained, quartz-mica sandstone.

Coast Range Ophiolite (part)

sp **Serpentinite --** Intensely sheared serpentinite and serpentine schist. In places contains blocks of serpentinized harzburgite (bastite) and massive serpentinite.

Franciscan Complex (part)

Permanente Terrane (Cretaceous) -- Divided into:

Kfps **Sandstone (Cretaceous) --** Foliated, fine- to coarse-grained, lithic and mica-lithic wacke with clasts of slate up to 5 mm across, interbedded with gray slate and argillite. Locally contains clasts and lenses of limestone up to 50 cm in length. The age of this unit is based on its position above and inclusion of clasts from the Cretaceous limestone and chert unit (Kfpl).

Kfpl **Limestone and chert (Cretaceous) --** Interbedded, thin bedded gray limestone and black, red, green, and gray radiolarian chert. Beds are mostly less than one-half meter thick. Foraminifera from this unit north of the study area indicate that the limestone formed near the equator during the Early (Barremian) and Late (Turonian) Cretaceous epochs (Wentworth and others, in review).

Kfpg **Greenstone agglomerate (Cretaceous) --** Greenstone from altered basalt, pillow basalt, basalt breccia, and basalt-chert conglomerate. Much of this unit has a distinct clastic texture, indicating original deposition as a volcanoclastic breccia. The matrix of the agglomerate is in large part altered basaltic glass. Geochemical data have yielded an age of 120-135 Ma for this unit (McLaughlin and others, 1991, 1996).

Marin Headlands Terrane (Jurassic and Cretaceous) -- Divided into

Kfms **Sandstone (Cretaceous) --** Distinctly bedded, coarse-grained, lithic wacke with clasts of slate up to 5 mm across, interbedded with gray slate and argillite.

KJfmc **Chert (Jurassic and Cretaceous) --** Thin bedded, red, radiolarian chert. Although no radiolarians have been studied from chert in this study area, radiolaria of Early Jurassic to Early Cretaceous age have been reported from chert of this terrane elsewhere in the New Almaden Block (McLaughlin and others, 1991, Sliter and others, 1993). This chert is correlated with that based on similar lithology and association with greywacke, as well as the absence of limestone associated with chert in the Permanente terrane.

SILVER CREEK BLOCK

QTp **Packwood Gravels of Crittenden (1951) (Pliocene and Pleistocene) --** This rock unit generally consists of gravel to cobble (rare) silty and fine sandy conglomerate, fine silty sandstone, gravely to fine sandy siltstone, and minor olive-green claystone beds. Noteworthy is the presence of numerous nonmarine red beds in the unit. This unit differs from all other gravels in that the clasts are composed almost entirely of detritus derived from conglomerates and sandstone of the Cretaceous part of the Great Valley Sequence. The base of this unit is interbedded with and coeval to the upper part of the 2.6-4 Ma Silver Creek gravels north of the study area (M. Wills and D. Andersen, Cal. State Univ. San Jose, personal comm., 1995). However, the top of the unit postdates and overlaps the Silver Creek thrust, which postdates the deposition of the Silver Creek Gravels.

QTv **Unnamed volcanic rocks (Pliocene and/or Pleistocene) --** Andesite and basalt flows and hypabyssal intrusive rocks, interbedded with and intruded into Packwood Gravels. In the study area this unit outcrops as a fault lens of white andesite north of San Felipe Lake in San Felipe quadrangle.

Coast Range Ophiolite (part)

sp **Serpentinite --** Intensely sheared serpentinite and serpentine schist. In places contains blocks of serpentinized harzburgite (bastite) and massive serpentinite.

COYOTE BLOCK

Tgs **Glauconitic sandstone (Paleocene and/or Eocene) --** Interbedded coarse-grained glauconite sandstone; medium-grained quartz-feldspar-glauconite sandstone; medium- to coarse-grained quartz-mica wacke; dark gray mudstone, in places with glauconite granules and in others with carbonate concretions; and black mudstone with foraminifers. One outcrop of sandstone contains mollusk and snail shell debris, as well as phosphate nodules up to 5 cm across. One outcrop in this unit in the north-central part of San Felipe quadrangle yielded late Paleocene to late Eocene foraminifers (Armstrong and Wagner, 1978).

Kcu **Sandstone, mudstone, and conglomerate (Late Cretaceous) --** Distinctly thin bedded, fine-grained biotite wacke and coarse-grained mica-quartz-feldspar-lithic wacke; massive and thin bedded, fine- to coarse-grained clean quartz-mica-lithic sandstone; brown weathering, dark gray mica siltstone and shale; pebble and cobble bearing lithic-mica-quartz sandstone; dark gray-green mudstone with foraminifers; and dark gray mudstone with carbonate concretions. Plant debris and shale chips are locally abundant in sandstone and siltstone beds. One locality in this unit in the study area west of Ortega Creek north of San Felipe junction has yielded a Late Cretaceous megafossil (Armstrong and Wagner, 1978). Strata in this unit north of the study area have been correlated with the late Campanian “Sacramento” shale based on lithology and presence of late Campanian microfossils.

Coast Range Ophiolite (part)

sp **Serpentinite --** Intensely sheared serpentinite and serpentine schist. In places contains blocks of serpentinized harzburgite (bastite) and massive serpentinite.

MOUNT HAMILTON BLOCK

Quien Sabe Volcanic Field

The Quien Sabe volcanic rocks are a highly differentiated intermediate suite, with composition ranging from basalt to rhyolite, and including both extrusive and hypabyssal intrusive varieties. Only some of the rock types outcrop in the field area (see Drinkwater and others, 1992, for more about the Quien Sabe volcanic field). Silicic rocks (rhyolite to dacite) in the field have yielded radiometric ages of 9.3 to 10.7 Ma, whereas andesite in the north part of the field has been dated at 11.2 to 11.6 Ma (Drinkwater and others, 1992, Nakata and others, 1993).

Tia **Intrusive andesite (late Miocene) --** Hypabyssal andesite plugs. Dark-gray, massive, biotite porphyry andesite.

Tid **Intrusive dacite (late Miocene) --** Hypabyssal dacite plugs. Light brown and greenish brown, biotite and biotite-hornblende porphyry dacite.

Tva **Extrusive andesite (late Miocene) --** Dark gray and brown, aphanitic and biotite porphyry andesite flows and breccia.

Tvb **Extrusive basalt (late Miocene) --** Massive to vesicular or amygduloidal, dark gray, aphanitic basalt flows.

Tud **Undivided dacite (late Miocene) --** Light brown and greenish gray, biotite-hornblende and pyroxene porphyry dacite flows, breccia, domes, plugs, and dikes.

Khu **Unnamed sandstone, shale, and conglomerate (Cretaceous) --** Brown weathering, distinctly thin bedded, coarse- to fine-grained, mica-lithic and mica-quartz-lithic wacke, mica siltstone, and laminated siltstone and shale. Carbonaceous material is present in many outcrops of sandstone and shale. This unit also includes large lenses of pebble to boulder conglomerate and pebbly sandstone. Clasts in conglomerate include dacite, meta-chert, gray chert, mica-lithic sandstone, quartz diorite, green plagioclase porphyry andesite, mudstone, quartz-plagioclase porphyry dacite, and quartzite.

Coast Range Ophiolite (part)

sp **Serpentinite --** Intensely sheared serpentinite and serpentine schist. In places contains blocks of serpentinized harzburgite (bastite) and massive serpentinite.

Franciscan Complex (part)

KJfm **Melange (Late Jurassic and/or Early Cretaceous) --** Sheared black argillite, greywacke sandstone, and minor green tuff, containing blocks and lenses of meta-greywacke, chert (fc), shale, metachert, serpentinite, greenstone, amphibolite, tuff, eclogite, quartz schist, garnet quartzite, greenschist, basalt, marble, conglomerate, and glaucophane schist. Blocks range in size from a few centimeters to several hundred meters in length. Only some of the largest blocks are shown on the map.

KJfy **Yolla Bolly Terrane (Middle to Late Jurassic and Early Cretaceous(?)) --** More or less sheared and metamorphosed mudstone, siltstone, greywacke, conglomerate, chert (fyc), and minor pillow basalt. Mudstone is almost everywhere metamorphosed to slate or chlorite phyllite. Sedimentary structures are well preserved locally. Greywacke ranges from massive, coarse-grained and conglomeratic sandstone to distinctly bedded, medium- and coarse-grained sandstone. Although most Yolla Bolly Terrane greywacke in the study area is little foliated, locally it displays foliation as pronounced as textural zone 2A. The depositional contact of clastic sedimentary rocks on chert is preserved in several locations. Chert, mapped locally (fyc), is mostly thin-bedded, red and green, more or less recrystallized, containing a few well preserved radiolarians locally. Cherts from this terrane north of the study area have yielded Middle to Upper Jurassic radiolaria (Sliter and others, 1993). In some places chert has been altered to white meta-chert. Widely dispersed, small outcrops of basalt are distinctly pillowed, amygduloidal, and lacking phenocrysts. In many locations the basalt has been converted to bright green meta-basalt.

SOURCES OF DATA

Watsonville East quadrangle	New mapping combined with data from McLaughlin (1973) and Dibblee and Brabb (1978). Additional data from Allen (1946), Hart (1988).
Chittenden quadrangle	New mapping combined with data from Dibblee and Brabb (1978) and Allen (1946). Additional data from Hart (1988).
San Felipe quadrangle	New mapping combined data from with Armstrong and Wagner (1978), and Rogers (1993). Additional data from Dibblee and Rodgers (1975).
Three Sisters quadrangle	New mapping combined with unpublished mapping by D.L. Wagner (Cal. Div. of Mines and Geology). Additional data from Dibblee and Rodgers (1975).
Mariposa quadrangle	Drinkwater and others (1992)
Surficial deposits	New mapping combined with data from Helley and Brabb (1971).

REFERENCES CITED

Allen, J.E., 1946, Geology of the San Juan Bautista quadrangle, California: California Division of Mines and Geology Bulletin 133, 111 p.

Armstrong, C.F., and Wagner, D.L., 1978, Environmental geologic analysis of the Diablo Range study area, southern Santa Clara County, California: California Division of Mines and Geology Open-File Report 78-11 SF, 75 p., 3 plates.

Brabb, E.E., and Hanna, W.F., 1981, Maps showing aeromagnetic anomalies, faults, earthquake epicenters, and igneous rocks in the southern San Francisco Bay region, California: U.S. Geological Survey Geophysical Investigations Map GP-932, 6 p., 3 sheets, scale 1:125,000.

Crittenden, M.D., 1951, Geology of the San Jose - Mount Hamilton area, California: California State Division of Mines Bulletin 157, 74 p.

Dibblee, T.W., and Brabb, E.E., 1978, Preliminary geologic map of the Chittenden, Los Gatos, and Watsonville East quadrangles, California: U.S. Geological Survey Open-File Report 78-453, 3 sheets, scale 1:24,000.

Dibblee, T.W., and Rodgers, T.H., 1975, Geologic Map of the Hollister quadrangle, California: U.S. Geological Survey Open-File Report 75-394, 1 sheet, scale 1:62,500.

Drinkwater, J.L., Sorg, D.H., and Russell, P.C., 1992, Geologic map showing ages and mineralization of the Quien Sabe volcanics, Mariposa Peak quadrangle, west-central California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2200, 1 sheet, scale 1:24,000.

Evans, K.F., Burford, R.O., and King, G.C.P., 1981, Propagating episodic creep and the aseismic slip behavior of the Calaveras fault north of Hollister, California: Journal of Geophysical Research, v. 86, p. 3721-3735.

Graymer, R.W., Jones, D.L., and Brabb, E.E., 1995, Geology of the Hayward fault zone:A digital map database**:** U.S. Geological Survey Open-File Report 95-597**.**

Hall, N.T., Lettis, W.R., de Wit, M.W., and Angell, M.M., 1991, Late Quaternary uplift alon the Pajaro River, southern Santa Cruz Mountains, California: Final Technical Report to the U.S. Geological Survey, Contract No. 14-08-0001-G1828.

Hart, E.W., 1988, Fault-rupture hazard zones in California; Alquist-Priolo Special Studies Zones Act of 1972 with index to special studies zones maps: California Division of Mines and Geology Special Publication 42.

Helley, E.J., and Brabb, E.E., 1971, Geologic map of Late Cenozoic deposits, Santa Clara County, California: U.S. Geological Survey Open-File Report, 3 sheets, scale 1:62,500.

Jones, D.L., Graymer, R., Wang, C., McEvilly, T.V., and Lomax, A., 1994, Neogene transpressive evolution of the California Coast Ranges: Tectonics, v. 13, p. 561-574.

McLaughlin, R.J., 1973, Geology of the Sargent fault zone in the vicinity of Mount Madonna, Santa Clara and Santa Cruz Counties, California: California State University, San Jose, M.S. thesis, 131 p., 2 plates.

McLaughlin, R.J., 1974, The Sargent-Berrocal fault zone and its relation to the San Andreas fault system in the southern San Francisco Bay region and Santa Clara Valley, California: Jour. Research U.S. Geological Survey, v. 2, no. 5, p. 593-598.

McLaughlin, R.J., Clark, J.C., Brabb, E.E., and Helley, E.J., 1991, Geologic map and structure sections of the Los Gatos 7 1/2′ quadrangle, Santa Clara and Santa Cruz Counties, California: U.S. Geological Survey Open-File Report 91-593.

McLaughlin, R.J., Sliter, W.V., Sorg, D.H., Russell, P.C., and Sarna-Wojcicki, A.M., 1996, Large-scale right-slip displacement on the East San Francisco Bay Region fault system, California: Implications for location of late Miocene to Pliocene Pacific plate boundary: Tectonics, v. 15, p. 1-18.

Nakata, J.K., Sorg, D.H., Russell, P.C., Meyer, C.E., Wooden, J., Lanphere, M.A., McLaughlin, R.J., Sarna-Wojcicki, A.M., Saburomaru, J.Y., Pringle, M.S., and Drinkwater, J., 1993, New radiometric ages and tephra correlations from the San Jose and the northeastern part of the Monterey 1:100,000 map quadrangles, California: Isochron/West, v. 60, p. 19-32.

Nilsen, T.H., Wright, R.H., Vlasic, T.C., and Spangle, W.E., 1979, Relative slope stability and lands-use planning in the San Francisco Bay Region, California: U.S. Geological Survey Professional Paper 944, 96 p.4

Prescott, W.H., Lisowski, M., and Savage, J.C., 1981, Geodetic measurement of crustal deformation of the San Andreas, Hayward, and Calaveras faults, near San Francisco, California: Journal of Geophysical Research, v. 86, p. 10853-10869.

Rogers, T.H., 1993, Geology of the Hollister and San Felipe quadrangles, San Benito, Santa Clara, and Monterey Counties, California: California Division of Mines and Geology Open-File Report 93-01, 26 p., 3 sheets, scale 1:24,000.

Sliter, W.V., McDougall, K., Murchey, B.L., and Kohnen, E.V., 1993, Mesozoic and Cenozoic microfossils from geologic units within the San Jose 1:100,000 quadrangle, California: U.S. Geological Survey Open-File Report 93-344.

Wentworth, C.M., Blake, M.C., Jr., McLaughlin, R.J., and Graymer, R.W., in review, Preliminary geologic map of the San Jose 30 X 60 minute quadrangle, California: A digital map image: U.S. Geological Survey Open-File Report in review.