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GEOLOGY OF THE ONSHORE PART OF SAN MATEO COUNTY, CALIFORNIA: A DIGITAL DATABASE

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Geologic Explanation

Introduction

This map database represents the integration of previously published and unpublished maps by several workers (see Sources of Data on Sheet 2) and new geologic mapping and field checking by the authors with the previously published geologic map of San Mateo County (Brabb and Pampeyan, 1983). These new data are released in digital form to provide an opportunity for regional planners, local, state, and federal agencies, teachers, consultants, and others interested in geologic data to have the new data long before a traditional paper map is published. The new data includes a new depiction of Quaternary units in the San Francisco Bay plain emphasizing depositional environment, important new observations between the San Andreas and Pilarcitos faults, and a new interpretation of structural and stratigraphic relationships of rock packages (Assemblages).

Stratigraphy

Lithologic associations in San Mateo County are divided into ten assemblages (see Index Map on Sheet 2). As defined in Graymer, Jones, and Brabb (1994), assemblages are large, fault - bounded blocks that contain a unique stratigraphic sequence. The stratigraphic sequence differs from that of neighboring assemblages by containing different rock units, or by different stratigraphic relationship among similar rock units. These stratigraphic differences represent changes in depositional conditions in one or more large depositional basins. The current adjacent location of the different assemblages reflects the juxtaposition of different basins or parts of basins by large offsets along the faults that bound the assemblages.

In general, in San Mateo County the Tertiary strata rest with angular unconformity on three complexly deformed Mesozoic rock complexes. One of these Mesozoic complexes is made up of: the Coast Range ophiolite, which includes serpentinite, gabbro, diabase, and basalt; keratophyre; and overlying Great Valley sequence. This complex represents the accreted and deformed remnants of Jurassic oceanic crust, overlying arc volcanic rocks, and a thick sequence of turbidites. In San Mateo County it is only present in small fault bounded slivers at the base of the Portola Valley Assemblage.

The second Mesozoic complex is the Franciscan complex, which is composed of weakly to strongly metamorphosed graywacke, argillite, limestone, basalt, serpentinite, chert, and other rocks. The rocks of the Franciscan complex in San Mateo County were probably Jurassic oceanic crust and pelagic deposits, overlain by Late Jurassic to Late Cretaceous turbidites. Although Franciscan rocks are dominantly little metamorphosed, high-pressure, low-temperature metamorphic minerals are common in the Franciscan complex (Bailey, Irwin, and Jones, 1964), and the presence of high-grade metamorphic blocks in sheared but relatively unmetamorphosed argillite matrix (Blake and Jones, 1974) reflects the complicated history of the Franciscan. The complex was subducted beneath the Coast Range ophiolite during Late Cretaceous or Early Tertiary time, as shown by the presence of Campanian (Late Cretaceous) fossils in Franciscan sandstone in Marin County. Because of the subduction relationship, the contact between the two Mesozoic complexes is everywhere faulted (Bailey, Irwin, and Jones, 1964), and the Franciscan complex presumably underlies the entire county east of the Pilarcitos fault.

West of the Pilarcitos fault, the Salinian complex, which is composed of granitic plutonic rocks, and inferred gabbroic plutonic rocks at depth, overlain in places by Cretaceous strata, forms the Mesozoic bedrock. In places, small outcrops of pre-plutonic rocks are preserved as well, such as KJv in the Pigeon Point assemblage and m in the Montara Mountain Assemblage. These plutonic rocks are part of a batholith that has been displaced northward by offset on the San Andreas fault system. Estimates of total offset vary, but all are more than a few hundred kilometers.

Two Assemblages in San Mateo County don't contain any of the three types of Mesozoic basement rocks. In the Point San Pedro Assemblage, Tertiary rocks are bounded at the base by a fault. However, large blocks of granitic rock as clasts in the Tertiary strata suggest that the original basement was granitic. In the San Bruno Mountain Assemblage, the rocks are comprised of Mesozoic strata of unknown affinity. The location of the assemblage east of the Pilarcitos fault suggests that these rocks are part of either the Franciscan complex or the Great Valley sequence.

An angular unconformity at the base of the Tertiary strata has been preserved in most of the assemblages. The exceptions are the Point San Pedro Assemblage, which contains no preserved basement, the San Bruno Mountain Assemblage, which contains no Tertiary strata, and the Portola Valley Assemblage, where the base of the Tertiary strata is everywhere faulted.

Paleontology

Hundreds of fossil collections from San Mateo County are described in the references provided in this report, as well as in Brabb (1983).

Radiometric Ages

A compilation of the radiometric ages of rocks in San Mateo and other counties south of latitude 38 degrees is provided by Lindquist and Morganthaler (1991). Additional data are provided by Sarna-Wojcicki (1976, and written communication, 1990), Sarna-Wojcicki and others (1979), Turner (1970), Brabb and Hanna (1981), and Curtis (1989).

Structure

The faults of San Mateo County are characterized by both strike-slip and dip-slip components of displacement. There are three major fault systems that display large right-lateral offsets, the San Andreas, the Pilarcitos, and the San Gregorio fault zones. These fault systems trend roughly N30W. Most of these fault systems include many fault strands in a broad (as much as 10 km wide) zone. Offset is distributed on the various faults in the zones, and the locus of fault movement associated with a fault zone has changed through geologic time (see Graymer, Jones, and Brabb, 1995, and Montgomery and Jones, 1992, for a description of fault zone evolution and distribution of offset on similar active faults in the East Bay region). Both the San Andreas and San Gregorio fault zones have strands which display Holocene offset. The San Andreas fault zone was displaced up to several meters in San Mateo County during the 1906 earthquake. Current estimates of total offset since 8 Ma are about 35 km for the San Andreas fault zone in San Mateo County, 120 km for the Pilarcitos fault zone, and 155 km for the San Gregorio fault zone (Clark and others, 1984, McLaughlin and others, 1996, Dickinson, 1997). Ongoing work by the authors and others has correlated the Coast Range ophiolite (Jgb, Jsv, sp) and Great Valley Sequence (Ka, Ks) rocks at the base of the Portola Valley Assemblage with rocks in the Gualala area more than 150 km north of San Mateo County. These fault systems also form most of the boundaries of the assemblages. The juxtaposition of rocks with different stratigraphic histories across these faults supports the idea of large offsets

In addition to strike-slip faults, some faults in San Mateo County have a major component of reverse or thrust offset. These structures run generally subparallel to the strike-slip faults, and reflect a component of stress perpendicular to the trend of the faults. This fault-normal compression has generated faults that typically have juxtaposed older rocks above younger. Part of the offset on some of these reverse and thrust faults has taken place during Quaternary time, as shown by faulting of QTsc west of Crystal Springs Reservoir.

Folds in San Mateo county can be divided into two categories based on axial trend and style of deformation. The first category includes tight folds and overturned folds with inclined axial planes whose axes trend obliquely to the major strike-slip fault zones (about N60W). These folds were probably caused by the same component of regional stress that formed the strike-slip faults and the thrust and reverse faults of the second category discussed above.

The second category of fold contains tight, upright folds whose axes strike roughly parallel to the major strike-slip faults (about N30W). These folds must have been formed by a component of regional compression perpendicular to the strike-slip faults (Jones and others, 1995).

Preserved folds in San Mateo County for the most part formed in Pliocene or later time, because Pliocene strata (Tp), where present, are involved in the folds. In the Portola Valley Assemblage, major pre-Pliocene Tertiary folding is not indicated, because Pliocene rocks are folded as much as pre-Pliocene Tertiary strata. However, in the Butano Ridge Assemblage, the major angular unconformity at the base of the late Miocene strata indicates a significant period of pre-late-Miocene folding. In the Montara Mountain Assemblage a nonconformity at the base of the middle Miocene strata and an angular unconformity at the base of the Pliocene strata indicate two periods of pre-Pliocene Tertiary uplift and folding. In the Pigeon Point Assemblage, a similar angular unconformity at the base of the Pliocene is present, but pre-Pliocene Tertiary strata are absent, so the evidence of two deformations is not preserved. In the Mindego Hill Assemblage, the base of the Pliocene unconformity is again present, but the middle Miocene strata there are folded as much as the pre-Miocene strata, indicating only one period of pre-Pliocene Tertiary deformation occurred in that Assemblage. In the Woodside Assemblage, Pliocene rocks of the Merced formation just east of the county line are folded as much as earlier Tertiary strata, indicating Tertiary deformation in that Assemblage must be Pliocene or younger. In other Assemblages, late Tertiary folding is not as well expressed, primarily due to the lack of Miocene or Pliocene strata. The Tertiary deformation of the strata in the county is therefore a complex amalgamation of independently deformed blocks that have been brought into proximity only in late Tertiary time. Pre-Tertiary folding undoubtedly occurred, associated with subduction of the Franciscan complex beneath the Coast Range ophiolite and subsequent deformation associated with the unconformity at the base of the Tertiary sequence, as well as offset on strike-slip faults. These folds have for the most part been totally disrupted. The youngest folding must postdate the Pliocene and Pleistocene deposition of QTsc and QTm, as those strata are folded in at least one area, and are steeply inclined throughout the county. Pleistocene strata (Qc) have not been observed to be folded, but are tilted and uplifted in several places. Late Pleistocene and Holocene surficial deposits retain most of their original depositional shape, but Pleistocene alluvium and marine terrace deposits have been uplifted as much as several meters in places throughout the county.

DESCRIPTION OF MAP UNITS

af **Artificial fill (Historic)**--Loose to very well consolidated gravel, sand, silt, clay, rock fragments, organic matter, and man-made debris in various combinations. Thickness is variable and may exceed 30 m in places. Some is compacted and quite firm, but fill made before 1965 is nearly everywhere not compacted and consists simply of dumped materials

alf **Artificial levee fill (Historic)**--Man-made deposit of various materials and ages, forming artificial levees as much as 6.5 m high. Some are compacted and quite firm, but fills 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

Qhasc **Artificial stream channels (Historic)**--Modified stream channels, in most places where streams have been straightened and realigned

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. This straightening is especially prevalent in the lower reaches of streams entering the estuary. 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.

Qhbd **Beach deposits (Holocene)**--Loose clastic deposits composed of sand- to cobble-size fragments in the bay tidal zone. Moderately well-sorted by wave action. Near Little Coyote Point, deposits are composed mostly of oyster shell fragments; west of Coyote Point deposits are composed mostly of rock debris derived from artificial fill (af)

Qhbm **Bay mud (Holocene)**-- Water-saturated estuarine mud, predominantly gray, green and blue clay and silty clay underlying marshlands and tidal mud flats of San Francisco Bay, Pescadero, and Pacifica. The upper surface is covered with cordgrass (*Spartina* sp.) and pickleweed (*Salicornia* sp.). The mud also contains a few lenses of well-sorted, fine sand and silt, a few shelly layers (oysters), and peat. The mud interfingers with and grades into fine-grained deposits at the distal edge of Holocene fans, and was deposited during the post-Wisconsin rise in sea-level, about 12 ka to present (Imbrie and others, 1984). Mud varies in thickness from zero, at landward edge, to as much as 40 m near north County line

Qhb **Basin deposits (Holocene)**--Very fine silty clay to clay deposits occupying flat-floored basins at the distal edge of alluvial fans adjacent to the bay mud (Qhbm). Also contains unconsolidated, locally organic, plastic silt and silty clay deposited in very flat valley floors

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)

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, no longer bordering stream channels, have also been mapped

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

Qyf **Younger (inner) alluvial fan deposits (Holocene)**--Unconsolidated fine- to coarse-grained sand, silt, and gravel, coarser grained at heads of fans and in narrow canyons

Qyfo **Younger (outer) alluvial fan deposits (Holocene)**--Unconsolidated fine sand, silt, and clayey silt

Qcl **Colluvium (Holocene)**--Loose to firm, friable, unsorted sand, silt, clay, gravel, rock debris, and organic material in varying proportions

Qs **Sand dune and beach deposits (Holocene)**--Predominantly loose, medium- to coarse-grained, well-sorted sand but also includes pebbles, cobbles, and silt. Thickness less than 6 m in most places, but in other places may exceed 30 m

Qal **Alluvium (Holocene)**--Unconsolidated gravel, sand, silt, and clay along streams. Less than a few meters thick in most places

Qpaf **Alluvial fan and fluvial deposits (Pleistocene)**--Brown dense gravely and clayey sand or clayey gravel that fines upward to sandy clay. These deposits display variable sorting and are located along most stream channels in the county. 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)**--Deposits consist of crudely-bedded, clast-supported, gravels, cobbles, and boulders with a sandy matrix. Clasts are as much as 35 cm in intermediate diameter. Coarse sand lenses may be locally present. Pleistocene terrace deposits are cut into Pleistocene alluvial fan deposits (Qpaf) a few meters and lie up to several meters above Holocene 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 profile development. They are less permeable than younger deposits, and locally contain fresh-water mollusks and extinct Pleistocene vertebrate fossils.

Qof **Coarse-grained older alluvial fan and stream terrace deposits (Pleistocene)**--Poorly consolidated gravel, sand, and silt, coarser grained at heads of old fans and in narrow canyons

Qmt **Marine terrace deposits (Pleistocene)**--Poorly consolidated and poorly indurated well- to poorly-sorted sand and gravel. Thickness variable but probably less than 30 m

Qc **Colma Formation (Pleistocene)**--Yellowish-gray and gray to yellowish-orange and red-brown, friable to loose, fine- to medium-grained arkosic sand with subordinate amounts of gravel, silt, and clay. Total thickness unknown, but may be as great as 60 m

QTsc **Santa Clara Formation (lower Pleistocene and upper Pliocene)**--Gray to red-brown poorly indurated conglomerate, sandstone, and mudstone in irregular and lenticular beds. Conglomerate consists mainly of subangular to subrounded cobbles in a sandy matrix but locally includes pebbles and boulders. Cobbles and pebbles are mainly chert, greenstone, and graywacke with some schist, serpentinite, and limestone. On Coal Mine Ridge, south of Portola Valley, conglomerate contains boulders of an older conglomerate as long as one meter. Gray to buff claystone and siltstone beds on Coal Mine Ridge contain carbonized wood fragments as large as 60 cm in diameter. Included in Santa Clara Formation are similar coarse-grained clastic deposits near Burlingame. Sarna-Wojcicki (1976) found a tuff bed in Santa Clara Formation near Woodside, and correlated it with a similar tuff in Merced Formation. Later work indicated that the tuff correlates with the 435 ka Rockland ash (Sarna-Wojcicki, oral comm., 1997). Thickness of Santa Clara Formation is variable but reaches a maximum of about 500 m along Coal Mine Ridge

QTm **Merced Formation (lower Pleistocene and upper Pliocene)**--Medium-gray to yellowish gray and yellowish orange, medium- to very fine-grained, poorly indurated to friable sandstone, siltstone, and claystone, with some conglomerate lenses and a few friable beds of white volcanic ash. In many places sandstone is silty, clayey, or conglomeratic. Some of the conglomerate, especially where fossiliferous, is well cemented. Volcanic ash is in beds as much as 2 m thick and consists largely of glass shards. In type section of Merced Formation, the ash was originally reported by Sarna-Wojcicki (1976) to be 1.5$\pm$0.8 m.y. old, but more recent work by Sarna-Wojcicki and others (1991) indicates that the formation contains both the 738$\pm$3 ka Bishop ash and the 435 ka Rockland ash (Sarna-Wojcicki, oral comm., 1997). Merced Formation is about 1525 m thick in the sea cliffs north of Mussel Rock

Tp **Purisima Formation (Pliocene and upper Miocene)**--Predominantly gray and greenish-gray to buff fine-grained sandstone, siltstone, and mudstone, but also includes some porcelaneous shale and mudstone, chert, silty mudstone, and volcanic ash. West of Portola Valley, this unit consists of fine- to medium-grained silty sandstone. Locally divided into:

Tptu **Tunitas Sandstone Member (Pliocene)**--Greenish-gray to light-gray, pale-orange, or greenish-brown, very fine- to medium-grained sandstone with clay matrix. Concretions generally less than 30 cm across are present locally. Tunitas ranges in thickness from 76 m at type section to 122 m elsewhere

Tpl **Lobitos Mudstone Member (Pliocene)**--Dark-gray to light-gray and shades of brown, unbedded, silty mudstone. Lobitos has a maximum thickness of 140 m.

Tpsg **San Gregorio Sandstone Member (Pliocene)**--Greenish-gray to light-brown fine- to coarse-grained sandstone containing calcareous concretions less than 30 cm across. San Gregorio Member ranges in thickness from 45 m at type section to about 140 m elsewhere

Tpp **Pomponio Mudstone Member (Pliocene)** --Gray to white porcelaneous shale and mudstone, in places rhythmically bedded with alternating layers of nonsiliceous mudstone. This unit resembles Monterey Shale, Santa Cruz Mudstone, and Lambert Shale. At its type section in Pomponio Creek the member is 700 m thick

Tpt **Tahana Member (Pliocene and upper Miocene)**--Greenish-gray to white or buff, medium- to very fine-grained lithic sandstone and siltstone, with some silty mudstone. Locally, such as at San Gregorio State Beach, sandstone is tuffaceous and weathers white. Near Memorial Park, this member includes dark-gray porcelaneous mudstone. Pebble conglomerate occurs near base from Memorial Park eastward. Maximum thickness 655 m. A tuff bed in this member west of the San Gregorio fault has been tentatively correlated with the 2.6 Ma Ishi Tuff (Sarna-Wojcicki and others, 1991)

Tsc **Santa Cruz Mudstone (upper Miocene)**--Brown and gray to light-gray, buff, and light-yellow siliceous mudstone with nonsiliceous mudstone and siltstone and minor amounts of sandstone. Santa Cruz Mudstone is more than 1000 m thick

Tsm **Santa Margarita Sandstone (upper Miocene)**--Light-gray to grayish-orange to white, friable, very fine- to very coarse-grained arkosic sandstone. Fine-grained sandstone commonly contains glauconite. A quartz and feldspar pebble conglomerate crops out locally at the base of section. Santa Margarita Sandstone is as thick as 60 m

Tl **Ladera Sandstone (upper(?) and middle Miocene)**--Medium- to light-gray to yellowish-gray and buff, fine-grained, poorly cemented sandstone and siltstone, with minor amounts of coarse-grained sandstone, yellow-brown dolomitic claystone, and white to light-gray porcelaneous shale and porcelanite. Fine-grained sandstone and siltstone comprise more than 90 percent of formation. Coarse-grained sandstone crops out in beds less than a few meters thick in lower half of section; dolomitic claystone and porcelaneous shale beds are less than a meter thick and are scattered through the upper half of the section; porcelanite crops out in thin-bedded lenses less than a few meters thick in the lower part of the section. At and near base of Ladera Sandstone are medium to thick lenticular beds of well-cemented fossiliferous, chert-granule sandstone which interfingers with fine-grained sandstone. About 450 m thick

Tm **Monterey Formation (middle Miocene)**--Grayish-brown and brownish-black to very pale orange and white, porcelaneous shale with chert, porcelaneous mudstone, impure diatomite, calcareous claystone, and with small amounts of siltstone and sandstone near base. Monterey is thinner bedded than the Santa Cruz Mudstone but closely resembles parts of Purisima Formation, especially Pomponio Mudstone Member. Thickness ranges from 120 to 450 m at the surface and up to 600 m in the subsurface west of the San Gregorio fault

Tlo **Lompico Sandstone (middle Miocene)**--Very pale orange, fine to coarse-grained, mostly well-cemented and hard arkosic sandstone. Maximum thickness about 300 m

Tpm **Page Mill Basalt (middle Miocene)**--Interlayered, columnar-jointed basaltic flows and agglomerate. Flows are dark greenish gray to light gray, dense to vesicular, and finely crystalline; agglomerate is light gray to reddish brown. Volcanic rocks are pyritiferous in part. Ranges in thickness from 0 to 15 m. The Page Mill Basalt has yielded a K/Ar age of 14.8$\pm$2.4 Ma (Turner, 1970, recalculated by Fox and others, 1985)).

Tuv **Unnamed Sedimentary and Volcanic Rocks (Miocene and Oligocene)**--Mainly dark-gray, hard mudstone in Año Nuevo area and massive, coarse-grained and pebbly, crossbedded, hard arkosic sandstone in Pescadero Point area. Mapped as

Vaqueros(?) Formation by Hall and others (1959), but rocks do not resemble those of Vaqueros Sandstone in Santa Cruz Mountains. Includes andesite breccia. Intrusive rocks associated with the andesite have yielded a K/Ar age of 22.0 $\pm$ 0.7 Ma (Taylor, 1990). Contains foraminifers and mollusks of Zemorrian (Oligocene) and Saucesian (Miocene) age according to Clark and Brabb (1978). About 135 m thick near Pescadero Point and at least 85 m thick near Año Nuevo

Tls **Lambert Shale and San Lorenzo Formation, Undivided (lower Miocene, Oligocene, and middle and upper Eocene)**--Brown and dark-gray to gray, brown, and red mudstone, siltstone, and shale. Includes some beds of fine- to coarse-grained sandstone. Lambert Shale is generally more siliceous than San Lorenzo Formation, but the two units cannot be distinguished where out of stratigraphic sequence and without fossils

Tla **Lambert Shale (Oligocene and lower Miocene)**--Dark-gray to pinkish-brown, moderately well-cemented mudstone, siltstone, and claystone. Chert crops out in a few places in upper part of section, and sandstone bodies up to 30 m thick, glauconitic sandstone beds, and microcrystalline dolomite are present in places. Lambert Shale is generally more siliceous than San Lorenzo Formation and less siliceous than the Monterey Shale. It resembles Santa Cruz Mudstone and parts of Purisima Formation. Lambert Shale is about 1460 m thick

Tmb **Mindego Basalt and related volcanic rocks (Miocene and/or Oligocene)**--Basaltic volcanic rocks, both extrusive and intrusive. Extrusive rock is primarily dark-gray to orange-brown to greenish-gray flow breccia, but includes lesser amounts of tuffs, pillow lavas, and flows. Extrusive rocks have a maximum thickness of 120 m. Intrusive rock is dark greenish gray to orange brown and medium to coarsely crystalline. It commonly weathers spheroidally, and crops out as roughly tabular bodies up to 180 m thick intruding older sedimentary rocks. Minor amounts of sandstone and mudstone are locally included. The Mindego Basalt has yielded a K/Ar minimum age of 20.2$\pm$1.2 Ma (Turner, 1970, recalculated by Fox and others, 1985))

Tvq **Vaqueros Sandstone (lower Miocene and Oligocene)**--Light-gray to buff, fine- to medium-grained, locally coarse-grained, arkosic sandstone interbedded with olive- and dark-gray to brown mudstone and shale. Sandstone beds are commonly 0.3 to 3 m thick and mudstone and shale beds are as much as 3 m thick. Vaqueros varies from a few meters to as much as 700 m in thickness

Tsl **San Lorenzo Formation (Oligocene and upper and middle Eocene)**--Dark-gray to brown shale, mudstone, and siltstone with local interbeds of sandstone. About 550 m thick. Locally divided into:

Tsr **Rices Mudstone Member (Oligocene and upper Eocene)**--Olive-gray to brown unbedded mudstone and siltstone with some laminated shale. Spheroidal weathering is common, as are elongate carbonate concretions. About 300 m thick

Tst **Twobar Shale Member (middle and upper Eocene)**--Olive-gray to brown laminated shale with some mudstone. Includes a few thin interbeds of very fine-grained sandstone which thicken to as much as 30 m near Big Basin. About 240 m thick

Tb **Butano Sandstone (middle and lower Eocene)**--Light-gray to buff, very fine- to very coarse-grained arkosic sandstone in thin to very thick beds interbedded with dark-gray to brown mudstone and shale. Conglomerate, containing boulders of granitic and metamorphic rocks and well-rounded cobbles and pebbles of quartzite and porphyry, is present locally in lower part of section. Amount of mudstone and shale varies from 10 to 40 percent of volume of formation. About 3000 m thick

Tbs **Shale in Butano Sandstone (lower Eocene)**--Greenish-gray, light-gray, red and reddish-brown clay shale, mudstone, siltstone, and a few thin interbeds of light-gray sandstone. Exposed near the head of Corte Madera Creek. Total thickness is unknown, but at least 200 m of this material is exposed.

Tw **Whiskey Hill Formation (middle and lower Eocene)**--Light-gray to buff coarse-grained arkosic sandstone, with light-gray to buff silty claystone, glauconitic sandstone, and tuffaceous siltstone. Sandstone beds constitute about 30 percent of map unit. Tuffaceous and silty claystone beds are expansive. Locally, sandstone beds are well cemented with calcite. At apparent base of section on north side of Jasper Ridge, just east of Searsville Lake, a thin greenstone-pebble conglomerate is present. In places within this map unit, sandstone and claystone beds are chaotically disturbed. This formation is as much as 900 m thick

Tws **Shale in Whiskey Hill Formation (lower Eocene)**--Brown and reddish brown claystone, mudstone, siltstone and shale. Locally contains lenses of sandstone up to 50 meters thick. Exposed along Highway 84, and along Highway 92, east of Half Moon Bay, where a small patch of red mudstone can be seen in a drainage ditch. Total thickness is unknown, but at least 200 m of this material is exposed along Highway 84.

Tss **Unnamed sandstone, shale, and conglomerate (Paleocene)**--Rhythmically alternating beds of sandstone and shale, with a discontinuous boulder and cobble conglomerate near middle of section and some pebble conglomerate beds near base of section on Montara Mountain. Sandstone is gray to buff, fine- to coarse-grained, and arkosic; the shale is dark gray to brown; conglomerate contains angular boulders of granitic rock as long as 2 m and smaller boulders, cobbles, and rounded pebbles of hornblende gneiss, muscovite gneiss and schist, Franciscan chert, quartzite, limestone, sandstone, and shale. This unit has an estimated total thickness of 1160 m; boulder conglomerate has a maximum thickness of 40 m

Kpp **Pigeon Point Formation (Upper Cretaceous)**--Sandstone and conglomerate, interbedded with siltstone and mudstone and pebbly mudstone. Sandstone is fine- to coarse-grained, arkosic, and gray to greenish gray; mudstone and siltstone are gray or black to buff. Conglomerate contains well-rounded pebbles, cobbles, and boulders of red and gray fine-grained and porphyritic felsic volcanic rocks, granitic rocks, chert, quartzite, dark-colored metamorphic rock, limestone, and clastic sedimentary rocks. The uppermost beds locally contain Cretaceous mollusks and foraminifers. Pigeon Point Formation is estimated to be more than 2600 m thick

Ksh **Unnamed shale (Upper Cretaceous)**--Dark-gray, thin-bedded, nodular shale and silty shale. Unit is exposed only in the bed of San Francisquito Creek, in Menlo Park, where about 15 m of section is visible

Ka **Anchor Bay Conglomerate (Cretaceous)**--Massive sandstone and conglomerate with pebbles and cobbles of diabase, gabbro, and minor granitic rocks; contains abundant shell fragments of a rudistid bivalve similar to *Coraliochama orcutti* of Late Cretaceous (Campanian) age.

Ks **Unnamed sandstone and shale (Cretaceous?)**--Thin-bedded, indurated micaceous sandstone and greenish-gray argillite; age uncertain, but probably Cretaceous based on lithologic similarity to other Cretaceous strata in the Santa Cruz Mountains.

Kgr **Granitic rocks of Montara Mountain**--Very light gray to light brown, medium- to coarsely-crystalline foliated granitic rock, largely quartz diorite with some granite. These rocks are highly fractured and deeply weathered. Foliation is marked by an alignment of dark minerals and dark dioritic inclusions. Tabular bodies of aplite and pegmatite generally parallel foliation. Rocks from this unit have yielded K/Ar ages of 91.6 Ma (Curtis, Everndon, and Lipson, 1958), and 86.2±3.4 Ma (Calif. Div. Mines and Geol., 1965), fission track ages of 84.1±7.8 Ma and 81.7±6.3 Ma (Naeser and Ross, 1976), and most recently Rb/Sr and Ar/Ar ages of 93 ± 2.5 Ma (Kistler and Champion, 1997).

KJv **Unnamed volcanic rocks (Cretaceous or older)**--Dark-gray, dense, finely-crystalline felsic volcanic rock, with quartz and albite phenocrysts. Exposed only west of Pescadero. Thickness unknown

KJs **Unnamed sandstone (Cretaceous or Jurassic)**--Dark-gray to yellowish-brown graywacke interbedded with shale in approximately equal amounts. Unit resembles some Franciscan graywacke (fs) but the bedding is better developed herein. This unit is exposed in San Bruno Mountain, where it is about 1000 m thick

KJf **Franciscan Complex, undivided (Cretaceous and Jurassic)**--Mostly graywacke and shale (fs). May be variably sheared. Partly coeval with Pigeon Point Formation (Kpp), granitic rocks of Montara Mountain (Kgr), unnamed shale (Ksh), unnamed volcanic rocks (KJv), and unnamed sandstone (KJs). Locally divided into:

fs **Sandstone**--Greenish-gray to buff, fine- to coarse-grained sandstone (graywacke), with interbedded siltstone and shale. Siltstone and shale interbeds constitute less than 20 percent of unit, but in places form sequences as much as several tens of meters thick. In many places, shearing has obscured bedding relations; rock in which shale has been sheared to gouge constitutes about 10 percent of unit. Gouge is concentrated in zones that are commonly less than 30 m wide but in places may be as much as 150 m wide. Total thickness of unit is unknown but is probably at least many hundreds of meters

fg **Greenstone**--Dark-green to red altered basaltic rocks, including flows, pillow lavas, breccias, tuff breccias, tuffs, and minor related intrusive rocks, in unknown proportions. Unit includes some Franciscan chert and limestone bodies that are too small to show on map. Greenstone crops out in lenticular bodies varying in thickness from a few meters to many hundreds of meters

fc **Chert**--White, green, red, and orange chert, in places interbedded with reddish-brown shale. Chert and shale commonly are rhythmically banded in thin layers, but chert also crops out in very thick layers. In San Carlos, chert has been altered along faults to tan- to buff-colored clay. Chert and shale crop out in lenticular bodies as much as 75 m thick; chert bodies are commonly associated with Franciscan greenstone.

fl **Limestone**--Light-gray, finely- to coarsely-crystalline limestone. In places limestone is unbedded, in other places it is distinctly bedded between beds of black chert. Limestone crops out in lenticular bodies up to 120 m thick, in most places surrounded by Franciscan greenstone

fm **Metamorphic rocks**--Dusky-blue to brownish-gray blocks of metamorphic rock, commonly glaucophane schist, but some quartz-mica granulite. These rocks are finely to coarsely crystalline and commonly foliated. They almost everywhere crop out as tectonic inclusions in sheared Franciscan rocks (fsr) and serpentinite (sp), and they reach maximum dimensions of several tens of meters though many are too small to show on map

fcg **Conglomerate**--Greenish-gray to buff colored conglomerate, composed of well-rounded pebbles and cobbles in a graywacke matrix, cropping out as layers and lenses in graywacke (fs). Pebbles and cobbles are composed of quartz diorite, arkose, quartzite, chert, graywacke, and minor amounts of shale, serpentinite, and glaucophane schist. Conglomerate bodies range from 0.3 to 200 m in thickness; thinner bodies are not shown on map

fsr **Sheared rock (melange)**--Predominantly graywacke, siltstone, and shale, substantial portions of which have been sheared, but includes hard blocks of all other Franciscan rock types. Total thickness of unit is unknown, but is probably at least several tens of meters

sp **Serpentinite (Cretaceous and/or Jurassic)**--Greenish-gray to bluish-green sheared serpentinite, enclosing variably abundant blocks of unsheared rock. Blocks are commonly less than 3 m in diameter, but range in size from several centimeters to several meters; they consist of greenish-black serpentinite, schist, rodingite, ultramafic rock, and silica-carbonate rock, nearly all of which are too small to be shown on the map

Jsv **Siliceous volcanic rocks and keratophyre (Jurassic?)**--Highly altered intermediate and silicic volcanic and hypabyssal rocks. Feldspars are almost all replaced by albite. Recent biostratigraphic and isotopic analyses yielded a Jurassic age for similar rocks in Alameda and Contra Costa Counties (Jones and Curtis, 1991)

Jgb **Gabbro (Jurassic?)**--Light green-gray, dark-gray weathering, mafic intrusive rock, mostly gabbro but also includes some diabase locally. The age of this unit is unknown, but the unit is probably part of the Jurassic Coast Range Ophiolite

m **Marble and hornfels (Paleozoic?)**--White to gray finely crystalline marble, graphitic marble, and quartz-mica hornfels, in places distinctly bedded, in places foliated. Marble and hornfels crop out as rare isolated bodies as much as 75 m long in granitic rocks of Montara Mountain

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