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Geologic map of the Spreckels 7.5-minute quadrangle, Monterey County, California

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Pamphlet to accompany

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GEOLOGIC MAP OF THE SPRECKELS 7.5-MINUTE QUADRANGLE, MONTEREY COUNTY, CALIFORNIA

By

J.C. Clark, E.E. Brabb, and L.I. Rosenberg

INTRODUCTION

General Statement

The Spreckels quadrangle lies at the north end of the Sierra de Salinas and extends from the Salinas Valley on the northeast across Los Laurelles Ridge south to Carmel Valley, an intermontane valley that separates the Santa Lucia Range from the Sierra de Salinas (fig. 1). The Toro Regional Park occupies the east-central part of the quadrangle, whereas the former Fort Ord Military Reservation covers the northwestern part of the area and is the probable locus of future development. Subdivisions largely occupy the older floodplain of Toro Creek and the adjacent foothills, with less dense development along the narrower canyons of Corral de Tierra and San Benancio Gulch to the south. The foothills southwest of the Salinas River are the site of active residential development.

Geologically, the study area has a crystalline basement of Upper Cretaceous granitic rocks of the Salinian block and older metasedimentary rocks of the schist of the Sierra de Salinas of probable Cretaceous age. Resting nonconformably upon these basement rocks is a sedimentary section that ranges in age from middle Miocene to Holocene and has a composite thickness of as much as 1,200 m. One of the purposes of the present study was to investigate the apparent lateral variation of the middle to upper Miocene sections from the typical porcelaneous and diatomaceous Monterey Formation of the Monterey and Seaside quadrangles to the west (Clark and others, 1997) to a thick marine sandstone section in the eastern part of the Spreckels quadrangle.

Liquefaction, which seriously affected the Spreckels area in the 1906 San Francisco earthquake (Lawson, 1908), and landsliding are the two major geological hazards of the area. The landslides consist mainly of older large slides in the southern and younger debris flows in the northern part of the quadrangle.

Methods of Investigation

The geologic map shows the distribution of the crystalline basement rocks, the Tertiary rocks, and the Quaternary deposits together with the geologic structure of the Spreckels quadrangle. The distribution of basement rocks is primarily from Ross (1976a).

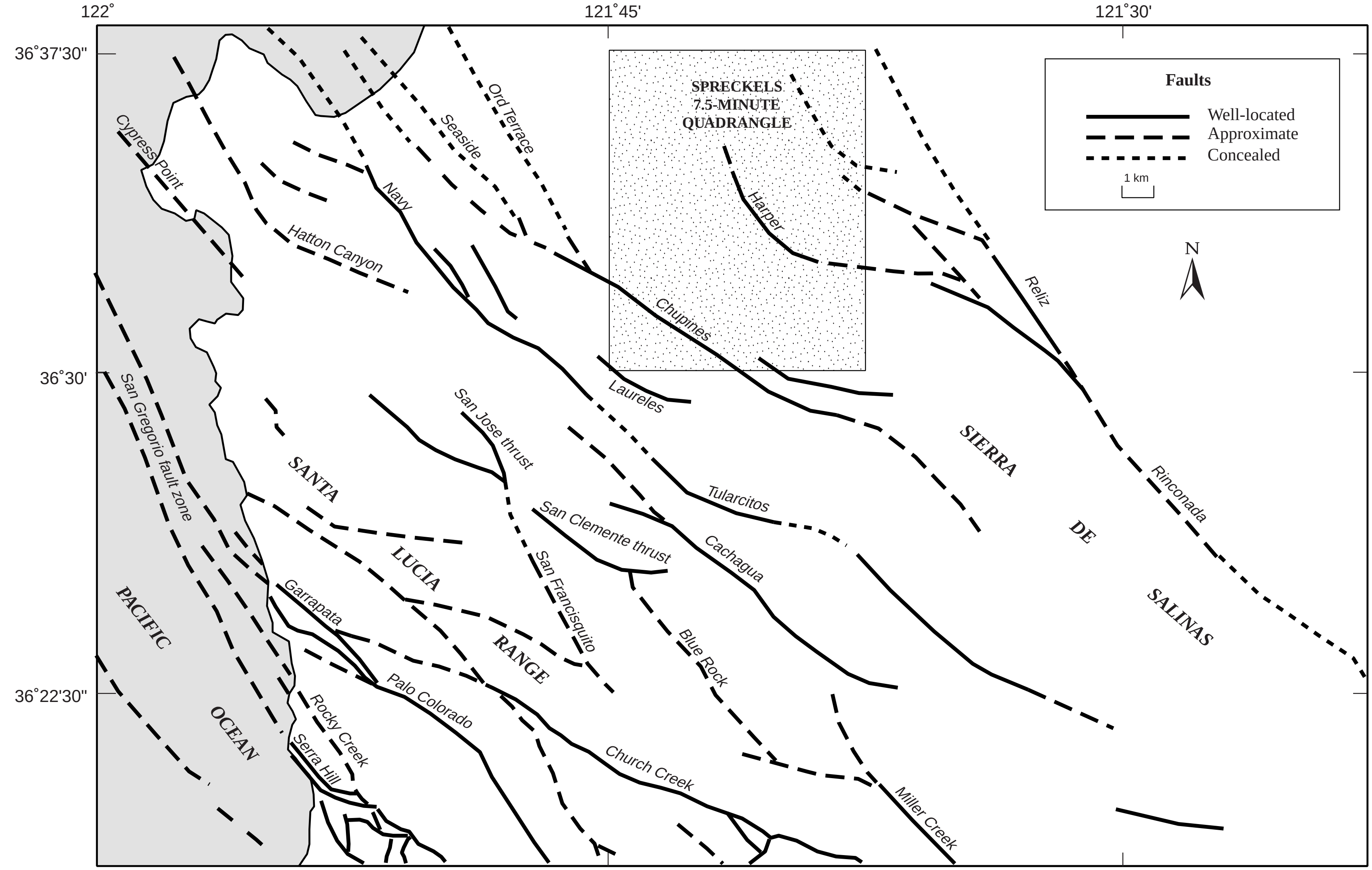
Approximately three weeks of fieldwork in March and May of 1998 by Clark, Brabb, and Rosenberg resulted in local modification of Ross' (1976a) basement rock distribution, in mapping of the Tertiary deposits and of the structure of the area, and in modification of the earlier mapping of the Quaternary deposits by Dupré (1990a) and of an unpublished map compilation by Rosenberg.

The landslide distribution was mapped mainly by Brabb in June 1998 primarily from U.S. Soil Conservation Service (SCS) aerial photos taken on May 14, 1971, mission ABG 1MM, approximate scale 1:20,000 and secondarily from partial coverage of the quadrangle by SCS photos taken on October 25, 1937 and on August 1, 1956; from U.S. Geological Survey Geologic Division color photos taken on July 18, 1974, scale 1:36,000; and from a brief field check during the week of March 16, 1998.

Previous Work

The first comprehensive geologic study of the area was by Herold (1935), whose geologic map (scale 1:62,500) of the Salinas 15-minute quadrangle includes the Spreckels 7.5-minute quadrangle. Cassell's (1949) study of the Monterey Formation includes a map (scale 1:31,250) that extends into the western part of this quadrangle. Bowen (1965, 1969) mapped the geology of the quadrangle at 1:24,000 and described the Tertiary stratigraphy and oil possibilities of the area. Dibblee's (1973) mapping of the Salinas 15-minute quadrangle modified Bowen's earlier mapping. Ross' (1976a) geologic map (scale 1:125,000) of the pre-Cenozoic basement rocks includes the area of this study.

Barron (1976) described the diatoms from the Monterey Formation of the western part of the quadrangle, and Govean and Garrison (1981) described and interpreted the depositional environment of the diatomite beds from this same Monterey section. Dupré (1990a) mapped the distribution and liquefaction susceptibility of the Quaternary deposits. Staal, Gardner & Dunne, Inc. (1991a, 1991b) extensively studied the hydrogeology of the Corral de Tierra region.



Faults modified after Dibblee (1976), Greene (1977), Buchanan-Banks and others (1978), and Clark and Rosenberg (1999).

Figure 1. Regional structure map, northern Santa Lucia Range and Sierra de Salinas, Monterey County, California

Acknowledgements

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Andrei Sarna-Wojcicki (USGS) analyzed and correlated Miocene ash beds from the quadrangle. Charles Powell, II (USGS) identified and interpreted mollusks collected from the quadrangle by Brabb and Clark. He also examined and interpreted mollusks at the California Academy of Science collected by Bowen and at the Museum of Paleontology, University of California, Berkeley that had been collected and reported by Herold (1935). Kristin McDougall (USGS) identified and interpreted Miocene foraminifers. Victoria Langenheim (USGS) and Robert Jachens (USGS) kindly provided unpublished gravity and aeromagnetic data with an interpretation of regional faulting. Special thanks go to Richard R. Thorup for sharing his extensive knowledge of the geology of the quadrangle.

Heather V. Goss (USGS and Environmental Careers Organization) added a structural layer, including strikes and dips and fold axes, to the digital map file, annotated and formatted the map to conform to USGS publication standards, and made corrections to the map after technical reviews. She wrote the metadata for the digital file, formatted the text to conform to USGS publication standards, and changed and added information after technical review.

REGIONAL STRUCTURE

The Spreckels quadrangle is approximately 30 km southwest of the seismically active San Andreas fault zone and about 20 km northeast of the San Gregorio fault zone. These two faults mark the northeastern and southwestern boundaries, respectively, of the Salinian block of granitic and regionally metamorphosed rocks.

Two major intra-Salinian faults, the Tularcitos and the Reliz/Rinconada faults, essentially bound this quadrangle (fig. 1). The active Tularcitos fault passes within 1 km to the southwest of the quadrangle and strikes northwestward to cross the foothills near Monterey as the Navy fault and continues offshore as part of the Monterey Bay fault zone, which in turn is truncated by or more probably merges with the San Gregorio fault, for a minimum length of 74 km. This fault has been assigned a 7.1 M_{max} in a recent probabilistic seismic hazard assessment for the state of California (Petersen and others, 1996).

Although the Reliz/Rinconada fault is not exposed in the Salinas Valley northeast of the quadrangle, recent unpublished aeromagnetic data (Robert Jachens, oral commun., 2000) suggest that this buried fault trends northwestward within 1 km of the northeastern boundary of this quadrangle. As discussed later, the Las Palmas fault that is here mapped as crossing the northeastern part of this area is probably a branch of the Reliz/Rinconada fault. The Reliz/Rinconada fault is as long as 189 km, and although activity on the northern (Reliz) part of the this fault has not been documented, the Rinconada fault has been assigned a 7.3 M_{max} in the recent probabilistic seismic hazard assessment of California (Petersen and others, 1996).

A series of steeply dipping, northwesterly striking faults extends into the Spreckels quadrangle from the south and locally bounds Salinian granitic rocks. At several localities, Pliocene(?)-Pleistocene continental beds are faulted and openly folded, and just to the west of the quadrangle Pleistocene fluvial terrace deposits are offset, thus indicating Quaternary deformation, but clear evidence of Holocene activity has not been documented within the quadrangle.

The Tertiary sedimentary rocks dip northward off of the Salinian granitic rocks and off of the schist of the Sierra de Salinas. These Tertiary rocks are openly folded into a series of northwest-striking anticlines and synclines between faults south of the valley of Toro Creek and east of Calera Canyon. In contrast, an anticline and syncline that extend eastward into the quadrangle in the vicinity of Canyon del Rey strike easterly.

FAULT GEOMETRY AND ACTIVITY

Laureles fault

A segment of the Laureles fault zone crosses the southwestern corner of the quadrangle, where it juxtaposes Cretaceous granodiorite with the unnamed Miocene sandstone. This northwest-striking fault zone extends discontinuously along the foothills on the north side of Carmel Valley for approximately 6.5 km.

Estimates of vertical displacement on the Laureles fault zone range from about 180 m (Fiedler, 1944) to 300 m (Herold, 1935), with the northeastern side relatively upthrown. A segment of the Laureles fault about 1.5 km west of the quadrangle offsets a small patch of Pleistocene fluvial terrace gravel, suggesting that the latest movement on the zone is probably post-middle(?) Pleistocene (Clark and others, 1997).

Chupines fault

Several discontinuous, steeply dipping, northwest-striking faults that extend from Carmel Valley to the Seaside area comprise the Chupines fault zone. Along Calera Canyon, the main strand of this fault separates granodiorite to the southwest from porcelaneous beds of the Monterey Formation to the northeast. There, Herold (1935) reports that shear planes in the granodiorite dip 50°–60° to the southwest. Near the west margin of the quadrangle (sec. 9, T. 16 S., R. 2 E.), vertical to steeply dipping beds of the Monterey diatomite delineate a near-vertical branch of the fault. In a roadcut on Robley Road just west of the quadrangle, a northern branch of the fault juxtaposes Santa Margarita Sandstone to the south against Pliocene(?)-Pleistocene continental deposits to the north along a silica- and caliche-veined, 2-cm-wide fault zone that dips 50° north.

Estimates of minimum vertical displacement on faults of the Chupines fault zone range from about 200 m (Fiedler, 1944) to 300 m (Herold, 1935). Well logs from the Laguna Seca area show Pliocene(?)-Pleistocene continental deposits offset by approximately 150 m (Staal, Gardner & Dunne, Inc., 1988).

Displacement of the continental deposits in the Spreckels quadrangle and to the west indicates Quaternary activity on the Chupines fault zone, and several lines of evidence suggest Holocene activity in the Seaside area. McCulloch and Greene (1989) show a probable offshore extension of the Chupines fault cutting Holocene deposits and the sea floor. Four epicenters plot within 1 km of the mapped surface trace and suggest that the western part of the Chupines fault zone is active (Rosenberg and Clark, 1994).

Corral de Tierra fault

The Corral de Tierra fault strikes northwestward along the lower Corral de Tierra Valley, where it juxtaposes diatomite of the Monterey Formation to the southwest against Santa Margarita Sandstone to the northeast near the Washington Union School and to the southeast. Although the fault plane is not presently exposed, Herold (1935) reports that it dips to the southwest about 40°. As mapped here, the Corral de Tierra fault is as long as 8 km and has a maximum displacement of not more than 60 m (Herold, 1935).

Structural and stratigraphic discordances across the Corral de Tierra Valley indicate that this fault continues to the southeast beneath Quaternary alluvium to the upper Corral de Tierra Valley. In the SE $^{1}/_{4}$ sec. 24, T. 16 S., R. 2 E., a flowing artesian water well (Deberdt well) just south of the mapped trace of the fault suggests that this fault has formed a barrier to groundwater migration in the upper Corral de Tierra Valley (Thorup, 1980). Discordant structural attitudes in the continental deposits about 2 km northwest of the Washington Union School suggest that this fault continues to the northwest beneath Quaternary alluvium and has had Quaternary activity.

Harper fault

In the central part of the quadrangle, the Harper fault juxtaposes the quartz monzonite of Pine Canyon against the Pliocene(?)-Pleistocene continental deposits to the southwest. This fault probably continues to the north beneath the alluvium of Toro Valley, as suggested by a marked structural discordance across this trend.

To the south the Harper fault curves easterly and trends into a fault that separates the schist of the Sierra de Salinas to the south from the quartz monzonite of Pine Canyon and quartzofeldspathic rocks to the north and continues for more than 6 km to the east of the quadrangle (Dibblee, 1973; Ross, 1976a). Dibblee (1973) did not map the continuity of these two faults; however, the interpretation of Ross (1976a), who mapped their continuity is followed here.

Although the Harper fault bounds and locally truncates the continental beds of the Pliocene(?)-Pleistocene age, there is no documented evidence of Holocene activity along this fault.

Las Palmas fault

The Las Palmas fault of this study strikes northwestward along the foothills south of the Salinas River. Its mapped trace is marked by aligned springs, local offset of the Pleistocene-Pliocene(?) continental deposits, and a pronounced gravity gradient, indicating that this fault dips steeply to the southwest beneath the quartz monzonite of Pine Canyon (Victoria Langenheim, USGS, oral commun., 2000). The Las Palmas fault continues to the southeast of the quadrangle for more than 10 km, where Dibblee (1973) maps it as dipping to the southwest and joining the Limekiln fault about 1 km southwest of the Reliz fault. Its parallelism to the Reliz fault and similar sense of displacement suggest that the Las Palmas fault is probably a branch of the Reliz fault.

Trenching of the Las Palmas fault in the foothills south of the Salinas River (Terratech, 1989) revealed that the Las Palmas fault displaces the Pleistocene- Pliocene(?) continental deposits but does not offset the younger alluvial fan deposits of middle(?) to late Pleistocene age. These data and our mapping support Tinsley's (1975, p. 152) conclusion that "A continuous zone of faulting younger than Gloria alluvial fans cannot be shown to exist immediately adjacent to the mountain front of the Sierra de Salinas."

DESCRIPTION OF MAP UNITS

Qaf **Artificial fill (Holocene)--**Artificial (man-made) fill consists of a highly variable mixture of sand, silt, clay, and gravel with varying amounts of organic material. Only the largest deposits are shown and, as a result, areas of artificial fill are under-represented.

Qb **Basin deposits (Holocene)--**Basin deposits consist of unconsolidated plastic clay and silty clay containing much organic material and locally contain interbedded thin layers of silt and silty sand. They are deposited in marsh-filled sloughs, flood basins, and lakes. Their thickness is highly variable and may be as much as 30 m underlying some sloughs.

Qal **Alluvial deposits, undivided (Holocene)--**Alluvial deposits of variable thickness and composition fill the bottoms of the major hillside drainages. These deposits consist of unconsolidated, heterogeneous, moderately sorted silt and sand with discontinuous lenses of clay and silty clay, and locally include large amounts of gravel. They may include deposits equivalent to both the younger and older flood-plain deposits (Qyf and Qof, respectively) in areas where these were not differentiated. Their thickness is highly variable (Dupré, 1990a).

Qyf **Younger flood-plain deposits (Holocene)--**Holocene age younger flood-plain deposits occur in and adjacent to the present Salinas River channel and along Toro Creek. These deposits consist of unconsolidated, relatively fine grained, heterogeneous deposits of sand and silt, commonly including relatively thin, discontinuous layers of clay. The gravel content is variable and is locally abundant within channel and lower point bar deposits. The thickness of the younger flood-plain deposits is generally less than 6 m. They typically are incised within older flood-plain deposits, except south of the Salinas River, where they occur as a veneer of levee deposits over older flood-plain deposits and are mapped separately as unit Qyfa.

Qof **Older flood-plain deposits (Holocene)--**Older flood-plain deposits are stratigraphically between terrace deposits and younger flood-plain deposits and are Holocene in age. Older flood-plain deposits consist of unconsolidated, relatively fine-grained, heterogeneous deposits of sand and silt, commonly including relatively thin layers of clay. The grain size of levee deposits decreases away from abandoned channel-fill deposits. Interpretation of well log data suggests that the older flood-plain deposits are typically less than 18 m thick in the study area, but locally may be as much as 40 m thick.

Qc **Colluvium (Holocene)--**Colluvial deposits are common in the hillside areas, especially in topographic swales. These deposits are as much as tens of meters wide, hundreds of meters long, and as much as 7 meters thick. Colluvium consists of a variable mixture of unconsolidated, heterogeneous, moderately to poorly sorted silt, sand, and gravel deposited by slope wash and mass movement. Some deposits have undergone minor fluvial reworking. Locally they include numerous small landslides and small alluvial fans; contacts with alluvial deposits are generally gradational.

Qcf **Abandoned channel-fill deposits (Holocene)--**Unconsolidated, highly plastic, poorly sorted clay, silty clay, and silt overlie moderately well sorted silt and sand. These deposits occupy abandoned channels within both the younger and older flood-plain deposits. Fill is generally less than 3 m thick, but many of these areas have been artificially filled with material that is poorly compacted and prone to subsidence (Dupré, 1990a).

Qls **Landslide deposits (Quaternary)--**In general, the southern half of the Spreckels quadrangle is characterized by very old, very large (more than 1 km long), and extensively eroded landslides (probably earthflows), whereas the northern half has mainly debris flow scars. The very large landslides are mainly in the Monterey Formation and continental deposits, whereas the debris flow scars are mainly in granitic and metamorphic rocks. The 1998 debris flows observed, however, are mainly in the continental deposits (QTc).

One very large landslide in the continental deposits along the upper part of San Benancio Gulch cut the county road along the gulch and destroyed a house in 1997. This entire landslide complex encompasses nearly 300 acres. The active part of the slide is approximately one acre, with a basal failure plane estimated to range from 21–30 m deep (Cotton and Associates, 1983). This landslide is clearly recognizable on 1971 U.S. Soil Conservation Service aerial photographs but does not appear to have been active at that time. A few small earthflows appear to have been active in 1971. During the winter of 1983, the slide moved approximately 1.2–1.5 m and is presently (1998–1999) moving. Debris flows caused property damage in the San Benancio Canyon area, where in 1997 two homes and seven vehicles were damaged, causing an estimated $1.5 million loss (Tuzon, 1997).

E.W. Hart mapped a very large, older landslide on the south side of Corral de Tierra valley (Bryant, 1985, fig. 2e). The head of the landslide is characterized by a linear group of closed depressions extending for nearly 2.5 km. Bowen (1969) mapped these closed depressions as the southern continuation of the Chupines fault. The anomalous topography on the hillside together with the mapped landslide deposits downslope favors the landslide interpretation. A similar landslide is located approximately 5 km southeast on the northern side of Tularcitos Ridge in Carmel Valley (Curry, 1984). Although there are presently no data to confirm this, an intriguing possibility is that a large earthquake on either the San Gregorio or the Tularcitos fault triggered these two large landslides.

Qt **Terrace deposits, undivided (Pleistocene)--**Elevated fluvial terrace deposits occur as erosional remnants on the north side of Toro Creek and locally south of the Salinas River. These fluvial terrace deposits consist of weakly consolidated to semiconsolidated, moderately to poorly sorted, fine- to coarse-grained silty sand with pebble to cobble gravel. Their thickness is highly variable and locally is as much as 20 m. Their age is Pleistocene.

Qoe **Older eolian deposits (Pleistocene)--**Exposed on the hilltops of the Fort Ord Military Reservation is a series of Pleistocene eolian deposits largely equivalent to the Aromas Sand as mapped by Dupré and Tinsley (1980). The stratigraphic relationship of the older eolian deposits to the underlying continental deposits (QTc) is unclear. In some areas, the older eolian deposits appear to unconformably overlie these continental deposits (QTc) (Bowen, 1965); elsewhere, the two units may be in part facies equivalents (Dupré, 1990b).

The older eolian deposits consist of moderately well sorted sand as much as 60 m thick that contains no intervening fluvial deposits. Several sequences of eolian deposits may be present, each separated by paleosols. The upper 3–6 m of each dune sequence is oxidized and relatively well indurated, and all primary sedimentary structures have been destroyed by weathering; the lower parts of each dune sequence may be relatively unconsolidated below the weathering zone (Dupré, 1990a).

Qch **Alluvial fan deposits of Chualar (Pleistocene)--**Weakly consolidated, moderately to poorly sorted sand, silt, and gravel deposits form a series of alluvial fans flanking the Salinas Valley south of the town of Spreckels that are characterized by well-drained, medially developed soils. Unit age is late Pleistocene (Dupré, 1990a).

Qp **Alluvial fan deposits of Placentia (Pleistocene)--**Dissected alluvial fan deposits south of the town of Spreckels consist of semiconsolidated, moderately to poorly sorted sand, silt, and gravel, with gravel content increasing toward the head of the fan. These deposits are similar to the alluvial fan deposits of Chualar, except are capped by more well-developed soils. Unit age is middle(?) Pleistocene (Dupré, 1990a).

Qgl **Alluvial fan deposits of Gloria (Pleistocene)--**A series of alluvial fans mantle the eastern slope of the Sierra de Salinas. The oldest of these is the Gloria fan and is exposed in the Indian Springs subdivision south of the town of Spreckels. These deposits consist of moderately consolidated, deeply weathered, moderately to poorly sorted sand, silt, and gravel, capped with moderately well drained, maximally developed soils with duripans. Unit age is middle to early(?) Pleistocene (Dupré, 1990a).

QTc **Continental deposits, undivided (Pleistocene-Pliocene(?))--** Unconformable upon the Santa Margarita Sandstone and locally upon the quartz monzonite is a series of nonmarine, semiconsolidated, oxidized, poorly sorted, fine- to coarse-grained, sand beds with common pebble and cobble gravel interbeds. Gravel clasts are angular to subangular and consist of granitic rocks, mica schist, quartzite, and locally Monterey Formation porcelanite and chert. At the base of these deposits in the vicinity of Washington Union School, a distinctive thick, yellowish-gray, ostracod-bearing fresh-water limestone crops out over a 4 km^2 area. Duripan horizons are common in these deposits and weather into prominent ledges, which locally form a barrier to shallow infiltration resulting in debris flows.

The continental deposits form the foothills of San Benancio Canyon and Fort Ord but are absent southwest of the Chupines fault. Herold (1935) estimated these deposits to be as much as 230 m thick along San Benancio Gulch. A deep water well (MPWMD #5) just north of State Route 68 near the western margin of the quadrangle penetrated 335 m of these deposits before reaching the Santa Margarita Sandstone (Staal, Gardner & Dunne, Inc., 1991b).

Herold (1935) correlated these deposits with the Paso Robles Formation of the southern Salinas Valley, a name also applied in later mapping by Bowen (1965) and Dibblee (1973). Because of uncertainty of correlation with the type area to the south, Dupré (1990a) preferred not to use the name “Paso Robles” and called these beds “continental deposits.” His usage is followed here. Stratigraphic relations suggest that these deposits are Pleistocene and possibly Pliocene in part and thus younger than the type Paso Robles Formation.

Tsm **Santa Margarita Sandstone (Miocene)--**Conformably overlying the upper diatomite of the Monterey Formation is a marine, white, very thick-bedded to locally cross-bedded, very fine to coarse-grained arkosic sandstone mapped as the Santa Margarita Sandstone. The Santa Margarita Sandstone is exposed locally northeast of the Chupines fault and is commonly penetrated beneath the continental deposits (QTc) by water wells to the north. The sandstone beds exposed in the foothills south of the Salinas River, while correlative with the upper Miocene Santa Margarita Sandstone, are not easily differentiated from lithologically similar but unnamed middle Miocene sandstone beds with which they accordingly are mapped as Tuss.

The Union WW No. 1 well on the Guidotti Ranch penetrated approximately 150 m of the Santa Margarita Sandstone before reaching diatomite of the Monterey Formation. Its conformable position above the Monterey Formation diatomite together with megafossils collected near the Guidotti Ranch (Herold, 1935; Bowen, 1965) indicates a late Miocene age for the Santa Margarita Sandstone in the Spreckels quadrangle.

Tmd, Tm **Monterey Formation (Miocene)--**Within the quadrangle, there are two mappable units of the Monterey Formation. The lower unit, Tm, (Aguajito Shale Member of Bowen, 1965) is as much as 600 m thick. It is thin-bedded and laminated, light brown to white porcelanite with very thin clay partings between the porcelanite beds and with thin interbeds of waxy-yellow to brown chert. This unit contains a thin pelletal and oölitic phosphorite interbed near its base. Benthic foraminifers are diagnostic of lower middle bathyal depths (Younse, 1980) and of early Mohnian (middle to late Miocene) age.

The upper unit, Tmd, (Canyon del Rey Diatomite Member of Bowen, 1965) is as much as 170 m thick. It is mainly very thick bedded and faintly laminated, very pale orange to white diatomite with thin interbeds and lenses of dark-brown chert and two thick interbeds of light-gray vitric tuff. A sample collected from near the base of this unit south of Canyon del Rey and about 2 km west of the quadrangle yielded benthic foraminifers diagnostic of upper (300–500 m) to upper middle bathyal (500–1,500 m) depths and of an early Mohnian (late Miocene) age (Kristin McDougall, written commun., 1994). Another sample from near the top of this unit east of Laureles Grade is diagnostic of inner neritic (50–100 m) depths and of a Mohnian (late Miocene) age (Kristin McDougall, written commun., 1994), indicating a shallowing of marine conditions during deposition of this upper unit.

Correlation with tuffs from a Trapper Creek, Idaho, section indicates that the two thick vitric tuff interbeds in the diatomite unit (Tmd) that are exposed along Robley Road (SE $^{1}/_{4}$ sec. 9, T. 16 S., R. 2 E.) near the western boundary of the quadrangle are 11.2 Ma and 10.9 Ma (A.M. Sarna-Wojcicki, written commun., 1998), which fall within the early Mohnian (Barron, 1976).

In upper Calera Canyon east of Corral de Tierra, the lower porcelaneous member of the Monterey (Tm) grades eastward to sandy siltstone, which locally yields abundant *Anadara* cf. *A. obispoana* specimens diagnostic of shelfal water depths (C.L. Powell, II, written commun., 1998). Farther east, the siltstone grades into biotitic fine sandstone mapped as Tus. Likewise, the upper diatomite member (Tmd) becomes silty to the east, as exposed along Corral de Tierra Valley, and pinches out farther to the northeast. Thus, in the foothills south of the Salinas River the entire Monterey Formation is replaced by arkosic sandstone that is included within the unit mapped as Tuss.

Tus **Unnamed sandstone (Miocene)--**Nonconformable upon the quartzofeldspathic rocks and the granodiorite of Cachagua in the southwestern part of the quadrangle and upon the schist of the Sierra de Salinas (msc) in the southeastern part of the quadrangle is a sandstone unit mapped as the Los Laureles Sandstone Member of the Monterey Formation by Bowen (1965) to the southwest and as the Los Tularcitos Member of the Chamisal Formation by Bowen (1965) to the southeast. Because both of Bowen’s sandstone units are overlain conformably by the Monterey Formation and could not be differentiated in the field, the term “unnamed sandstone” is used in this report. Dibblee (1973) did not differentiate these units and mapped them as marine sandstone.

This sandstone is typically massive to very thick bedded, moderately to well sorted, medium- to fine-grained biotitic arkose. A granitic coarse sandy cobble conglomerate is developed locally at the base. In the Los Tularcitos area south of Underwood Road, mollusks are locally abundant and include *Anadara obispoana*, “*Chione*” *valentinei*, and few *Pacipecten* cf. *P. andersoni*, which are diagnostic of middle Miocene age and shelfal water deposits (C.L. Powell, II, written commun., 1998). Cassell (1949) reported a thickness of 50 m for this sandstone unit just west of the quadrangle.

Tuss **Unnamed sandstone, undifferentiated (Miocene)--**In the foothills south of Spreckels, lithologically similar arkosic sandstone rests with apparent conformity on the unnamed conglomerate unit (Tuc). There, where the Monterey Formation is absent, the unnamed sandstone is not differentiated from the younger Santa Margarita Sandstone, and both units are mapped as Tuss.

Within this undifferentiated Santa Margarita/unnamed sandstone section, two pinkish-gray ash beds are exposed in a roadcut on the Marks Ranch (NW $^1/_4$ sec. 29, T. 15 S., R. 3 E.). A sample collected from the upper ash bed matches most closely with a dated tephra layer from the Miocene Ammonia Tanks Tuff in the southern Nevada volcanic field with an interpolated age of 11.57 Ma (middle Miocene; A.M. Sarna-Wojcicki, written commun., 1998). Thus, this undifferentiated sandstone unit is in part laterally equivalent to or a facies of the Monterey Formation to the west, as postulated by Bowen (1965). Subsurface data together with surface attitudes indicate a minimum thickness of as much as 520 m for this undifferentiated sandstone section.

Tuc **Unnamed conglomerate (Miocene)--**A well-indurated, sandy cobble conglomerate is nonconformable upon the garnetiferous quartz monzonite of Pine Canyon in the foothills south of Spreckels. Cobble clasts include pink felsite, quartzite, and rare diabase. The general poor sorting and lack of marine fossils or of trace fossils suggest that this unit is nonmarine.

Bowen (1965) included this unit in his Paso Robles Formation, whereas Dibblee (1973) mapped this unit as an unnamed conglomerate of terrestrial origin beneath unnamed upper Miocene sandstone. The apparent conformable relationship of this conglomerate to the overlying Miocene sandstone (Tuss), which includes a middle Miocene ash bed in its lower part, suggests that this unnamed conglomerate is probably of middle Miocene age and thus correlative with the Red Beds of Robinson Canyon southwest of the Tularcitos fault zone in the Monterey and Seaside quadrangles (Clark and others, 1997).

Kgd **Granodiorite of Cachagua of Ross (1976a) (Late Cretaceous)--**The granodiorite of Cachagua is exposed in the southwestern part of the Spreckels quadrangle and is bounded by the Chupines fault on the north and the Laureles fault on the south. Typically it is gray to light pink, medium to coarse grained, with an average modal composition of 49 percent plagioclase, 28 percent quartz, 12 percent biotite, and 11 percent K-feldspar (Ross, 1977, table 11). However, it is a variable unit in both mineral content and texture, and this variability and local resemblance to the adjoining rocks make its differentiation difficult (Ross, 1976a).

Kqm **Garnetiferous quartz monzonite of Pine Canyon of Ross (1976a) (Late Cretaceous)--**Along the north side of the Sierra de Salinas, the garnetiferous quartz monzonite of Pine Canyon, a relatively homogeneous felsic rock with small amounts of small red garnet crystals, crops out over an area of about 20 km^2 (Ross, 1976a). In the foothills south of the Salinas River (north of sec. 29, T. 15 S., R. 3 E.), the Luard Marlini #1 exploratory well reached granite at a depth of 280 m (altitude of 158 m below sea level).

The average modal composition is 36 percent plagioclase, 32 percent quartz, 29 percent K-feldspar, and 3 percent biotite (Ross, 1977, table 15). A combination of two samples from Pine Canyon and one from Toro Regional Park yielded a Rb-Sr age of 79.2±5.0 Ma (Late Cretaceous) and an initial Sr^{87}/Sr^{86} ratio of 0.710 (D.E. Champion, USGS, written commun. to Lawrence Novelli, Toro Regional Park, 1991).

Khqd **Hornblende-biotite quartz diorite and diorite of Corral de Tierra (Late? Cretaceous)--**The hornblende-biotite quartz diorite and diorite of Corral de Tierra consists of two small masses on the north and west margins of the schist of the Sierra de Salinas. The contact of the northern mass with the schist of the Sierra de Salinas is marked by strongly foliated granitic rock containing schist slivers, as well as coarsened schist layers studded with hornblende crystals across a zone about 100 m wide. Although the schist contact is not exposed at the west mass, there are coarsened schist layers nearby containing hornblende crystals, suggesting similar assimilation or granitization (Ross, 1976a). It has an average modal composition of 59 percent plagioclase, 12.5 percent quartz, 16.5 percent hornblende, 12 percent biotite, and <1 percent K-feldspar (Ross, 1977, table 3).

msc **Schist of the Sierra de Salinas of Ross (1976a) (Late? Cretaceous)--**The schist of the Sierra de Salinas is part of a larger mass extending southeastward toward Arroyo Seco (Ross, 1976a) that is in fault contact with the garnetiferous quartz monzonite of Pine Canyon to the north. The schist is gray to reddish brown and well foliated. It consists of approximately 46 percent plagioclase, 33 percent quartz, 18 percent biotite, and 2 percent K-feldspar (Ross, 1976b). Prominent vein quartz and simple pegmatites are common in the schist. The appearance and chemical composition of the schist suggest that it was derived from graywacke with shaly interbeds. Because of its geochemical similarity to the Pelona Schist of probable Mesozoic age in southern California, the schist of the Sierra de Salinas may also be Mesozoic and is probably Late Cretaceous (Ross, 1976a; Jacobson and others, 2000). Herold (1935) estimated a minimum thickness of 1,520 m for this unit in the Spreckels area.

ms **Quartzofeldspathic rocks (pre-Cretaceous)--**Quartzofeldspathic rocks crop out on the east side of Laureles Grade and near the head of Pine Canyon. These rocks consist of dusky blue to dusky yellowish-brown, medium-grained, hornblende-biotite gneiss. These rocks are characteristically well banded with contrasting lithologies that suggest originally thin-bedded sedimentary rocks (Ross, 1976a).

ml **Marble (pre-Cretacous)--**Marble is closely associated with the metamorphic rocks of the Gabilan Range and the northern Santa Lucia Range. In the Sierra de Salinas, the marble consists of isolated lenses within the quartzofeldspathic rocks.

REFERENCES CITED

Barron, J.A., 1976, Marine diatom and silicoflagellate biostratigraphy of the type Delmontian Stage and the type *Bolivina obliqua* Zone, California: U.S. Geological Survey Journal of Research, v. 4, no. 3, p. 339–351.

Bowen, O.E., Jr., 1965, Stratigraphy, structure, and oil possibilities in Monterey and Salinas quadrangles, California, *in* Rennie, E.W. Jr., ed., Symposium of papers presented at the fortieth annual Pacific Section A.A.P.G. convention: American Association of Petroleum Geologists, Pacific Section, Bakersfield, Calif., p. 48–67.

_____1969, Geologic map of the Spreckels 7.5-minute quadrangle: California Division of Mines and Geology unpublished map, scale 1:24,000.

Bryant, W.A., 1985, Faults in the southern Monterey Bay area, Monterey County, California: California Division of Mines and Geology Fault Evaluation Report FER–167, 13 p., 5 map sheets, scale 1:24,000.

Buchanan-Banks, J.M., Pampeyan, E.H., Wagner, H.C., and McCulloch, D.S., 1978, Preliminary map showing recency of faulting in coastal south-central California: U.S. Geological Survey Miscellaneous Field Studies Map MF–910, 11 p., 3 sheets, scale 1:250,000.

Cassell, G.K., 1949, Variation in the Monterey Formation near the type locality: Stanford, Calif., Stanford University, M.S. thesis, 60 p., 4 sheets, scale 1:31,250.

Clark, J.C., Dupré, W.R., and Rosenberg, L.I., 1997, Geologic map of the Monterey and Seaside 7.5-minute quadrangles, Monterey County, California: a digital database: U.S. Geological Survey Open-File Report 97–30, 32 p., 2 sheets, scale 1:24,000.

Clark, J.C., and Rosenberg, L.I., 1999, Southern San Gregorio fault: stepover segmentation vs. through-going tectonics: U.S. Geological Survey, National Earthquake Hazards Reduction Program, Final Technical Report 1434-HQ-98-GR-0007, 50 p., 3 sheets, scale 1:24,000.

Cotton, William, and Associates, 1983, Preliminary geotechnical evaluation, San Benancio Canyon landslide, Monterey County, California: unpublished report to Monterey County Department of Public Works, 3 p.

Curry, R.R., 1984, Observations on Quaternary and recent fault activity, central coastal California: Monterey Peninsula Water Management District open-file report, 11 p.

Dibblee, T.W., Jr., 1973, Geologic map of the Salinas 15-minute quadrangle, Monterey County, California: U.S. Geological Survey Open-File Report 74–1021, scale 1:62,500.

_____1976, The Rinconada and related faults in the southern Coast Ranges, California, and their tectonic significance: U.S. Geological Survey Professional Paper 981, 55 p.

Dupré, W.R., 1990a, Maps showing geology and liquefaction susceptibility of Quaternary deposits in the Monterey, Seaside, Spreckels, and Carmel Valley quadrangles, Monterey County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF–2096, 2 sheets, scale 1:24,000.

_____1990b, Quaternary geology of the Monterey Bay region, California, *in* Garrison, R.E., Greene, H.G., Hicks, K.R., Weber, G.E., and Wright, T.L., eds., Geology and tectonics of the central California coastal region, San Francisco to Monterey: American Association of Petroleum Geologists, Volume and Guidebook GB67, Pacific Section, Bakersfield, Calif., p. 185–191.

Dupré, W.R., and Tinsley, J.C., III, 1980, Maps showing geology and liquefaction potential of northern Monterey and southern Santa Cruz Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF–1199, 2 sheets, scale 1:62,500.

Fiedler, W.M., 1944, Geology of the Jamesburg quadrangle, Monterey County, California: California Division of Mines, California Journal of Mines and Geology, v. 40, no. 2, p. 177–250, 2 sheets, scale 1:62,500.

Govean, F.M., and Garrison, R.E., 1981, Significance of laminated and massive diatomites in the upper part of the Monterey Formation, California, *in* Garrison, R.E., and Douglas, R.G., eds., The Monterey Formation and related siliceous rocks of California: Los Angeles, Calif., Society of Economic Paleontologists and Mineralogists, Pacific Section, p. 181–198.

Greene, H.G., 1977, Geology of the Monterey Bay region: U.S. Geological Survey Open-File Report 77-718, 347 p., 9 sheets.

Herold, C.L., 1935, Preliminary report on the geology of the Salinas quadrangle, California: Berkeley, University of California, M.S. thesis, 143 p., 2 sheets, scale 1:62,500.

Jacobson, C.E., Barth, A.P., and Grove, Marty, 2000, Late Cretaceous protolith age and provenance of the Pelona and Orocopia Schists, southern California: Implications for evolution of the Cordilleran margin: Geology, v. 28, no. 3, p. 219–222.

Lawson, A.C., chairman, 1908, The California earthquake of April 18, 1906: Report of the California State Earthquake Investigation Commission: Washington D.C., Carnegie Institution of Washington, Publication 87, v. 1, 2 parts, 451 p.

McCulloch, D.S., and Greene, H.G., 1989, Geologic map of the central California continental margin, *in* Greene, H.G., and Kennedy, M.P., eds., Geology of the central California continental margin: California Division of Mines and Geology California Continental Margin Geologic Map Series, Map 5A, scale 1:250,000.

Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A., and Schwartz, D.P., 1996, Probabilistic seismic hazard assessment for the State of California: California Division of Mines and Geology Open-File Report 96–08 and U.S. Geological Survey Open-File Report 96-706, 33 p., 2 appendices.

Rosenberg, L.I., and Clark, J.C., 1994, Quaternary faulting of the greater Monterey area, California: U.S. Geological Survey, National Earthquake Hazard Reduction Program, Final Technical Report 1434-94-G-2443, 45 p., 3 appendices, 4 sheets, scale 1: 24,000.

Ross, D.C., 1976a, Reconnaissance geologic map of pre-Cenozoic basement rocks, northern Santa Lucia Range, Monterey County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF–750, 7 p., 2 sheets, scale 1:125,000.

_____1976b, Metagraywacke in the Salinian block, central Coast Ranges, California—and a possible correlative across the San Andreas fault: U.S. Geological Survey Journal of Research, v. 4, no. 6, p. 683–696.

_____1977, Maps showing sample localities and ternary plots and graphs showing modal and chemical data for granitic rocks of the Santa Lucia Range, Salinian block, California Coast Ranges: U.S. Geological Survey Miscellaneous Field Studies Map MF–799, 16 p., 3 plates.

Staal, Gardner & Dunne, Inc., 1988, Phase II hydrogeologic investigation, Laguna Seca subarea, Monterey County, California: unpublished report to Monterey County Environmental Health Department, 33 p., 6 appendices, 8 sheets, scale 1:12,000.

_____1991a, Hydrogeologic update, El Toro area, Monterey County, California: Monterey County Water Resources Agency open-file report, 53 p., 4 appendices.

_____1991b, Laguna Seca Ranch, supplemental hydrogeologic assessment: unpublished letter report to Kimball Small Properties, 7 p.

Terratech, 1989, Supplemental fault investigation, Las Palmas Ranch Development, Monterey County, California: Monterey County Planning and Building Inspection open-file report, 3 p.

Thorup, R.R., 1980, Groundwater evaluation of the Flause property, Corral de Tierra Valley, Monterey County, California: unpublished report to Robert Flause, 19 p.

Tinsley, J.C., III, 1975, Quaternary geology of the northern Salinas Valley, Monterey County, California: Stanford, Calif., Stanford University, Ph.D. dissertation, 195 p., 2 sheets, scale 1:62,500.

Tuzon, Brandy, 1997, Mud ravages San Benancio homes: Salinas, Calif., The Californian, January 29, 1997, p. 1A.

Younse, G.A., 1980, The stratigraphy and phosphoritic rocks of the Robinson Canyon-Laureles Grade area, Monterey County, California: U.S. Geological Survey Open-File Report 80–318, 127 p., 5 sheets.

Digital Publication and Database Description

Introduction

This publication includes, in addition to cartographic and text products, geospatial (GIS) databases and other digital files. These files are published on the Internet through the USGS Publications Group web sites. The database files are particularly useful because they can be combined with any type of other geospatial data for purposes of display and analysis. The other files include digital files that support the databases and digital plot files that can be used to display and print the cartographic and text products included in this publication.

Following is the digital publication and database description. It contains information about the content and format of the digital geospatial databases used to create this digital geologic map publication. **This information is not necessary to use or understand the geologic information in the map and preceding geologic description.** The digital map and database description contains information primarily useful for those who intend to use the geospatial databases. However, it also contains information about how to get digital plot files of the map and geologic pamphlet via the Internet or on magnetic tape, as well as information about how the map sheet and pamphlet were created, and information about getting copies of the map sheet and pamphlet from the U.S. Geological Survey. Therefore, the description is included here.

The digital map database, compiled from previously published and unpublished data, and new mapping by the authors, represents the general distribution of bedrock and surficial deposits in the mapped area. Together with the accompanying text file (skmf.txt, skmf.pdf, or skmf.ps), it provides current information on the geologic structure and stratigraphy of the area covered. The database delineates map units that are identified by general age and lithology following the stratigraphic nomenclature of the U.S. Geological Survey. The scale of the source maps limits the spatial resolution (scale) of the database to 1:24,000 or smaller. The content and character of the database, as well as three methods of obtaining the database, are described below.

For those who do not use digital geologic map databases

For those interested in the geology of the mapped area who do not use an ARC/INFO compatible Geographic Information System (GIS), we have provided two sets of plotfiles containing images of much of the information in the database. Each set contains an image of a geologic map sheet and an explanatory pamphlet. There is a set of images in PostScript format and another in Adobe Acrobat PDF format (see the sections "PostScript plot files" and "PDF plot files" below).

Those interested who have computer capability can access the plot file packages in any of the three ways described below (see the section "Obtaining the digital database and plotfile packages"). However, it should be noted the plot file packages do require gzip and tar utilities to access the plot files. Therefore additional software, available free on the Internet, may be required to use the plot files (see section "Tar files").

Those without computer capability can obtain plots of the map files through USGS plot-on-demand service for digital geologic maps (see section "Obtaining plots from USGS Map On Demand Services") or from an outside vendor (see section "Obtaining plots from an outside vendor").

MF-2349 digital contents

This report consists of three digital packages. The first is the PostScript Plotfile Package, which consists of PostScript plot files of a geologic map sheet and geologic description pamphlet. The second is the PDF Plotfile Package, and contains the same plotfiles as the first package, but in Portable Document Format (PDF). The third is the Digital Database Package, and contains the geologic map database itself and the supporting data, including description of map units, geologic description, and references.

Postscript plotfile package

This package contains the images described here in PostScript format (see below for more information on PostScript plot files):

skmap.ps	A PostScript plotfile containing an image of the geologic map and base map at a scale of 1:24,000, along with a map key including index maps and correlation chart.
skmf.ps	A PostScript plotfile that contains an image of the pamphlet containing detailed unit descriptions and geological information, a description of the digital files associated with the publication, plus references cited.

PDF plotfile package

This package contains the images described here in PDF format (see below for more information on PDF plot files):

skmap.pdf	A PDF file containing an image of the geologic map and base map at a scale of 1:24,000, along with a map key including index maps and correlation chart.
skmf.pdf	A PDF file that contains an image of the pamphlet containing detailed unit descriptions and geological information, a description of the digital files associated with the publication, plus references cited.

Digital database package

The database package includes geologic map database files for the map area. The digital maps, or coverages, along with their associated INFO directory have been converted to uncompressed ARC/INFO export files. ARC export files promote ease of data handling, and are usable by some Geographic Information Systems in addition to ARC/INFO (see below for a discussion of working with export files). The ARC export files and the associated ARC/INFO coverages and directories, as well as the additional digital material included in the database, are described below:

ARC/INFO export file	Resultant Coverage	Description of Coverage
sk-geol.e00	sk-geol/	Polygon and line coverage showing faults, depositional contacts, and rock units in the map area.
sk-strc.e00	sk-strc/	Point and line coverage showing strike and dip information and fold axes.
sk-lnds.e00	sk-lnds/	Point and line coverage showing arrows indicating landslide directions as the locations of wells and springs not included in the topographic base. There are no line attributes associated with this coverage.

The database package also includes the following ARC coverages and files:
ASCII text files, including explanatory text, ARC/INFO key files, PostScript plot files, and an ARC Macro Language file for conversion of ARC export files into ARC coverages:

skmf.ps	A PostScript plotfile that contains an image of the pamphlet containing detailed unit descriptions and geological information, a description of the digital files associated with the publication, plus references cited.
skmf.pdf	A PDF version of skmf.ps.
skmf.txt	A text-only file containing an unformatted version of skmf.ps.
import.aml	ASCII text file in ARC Macro Language to convert ARC export files to ARC coverages in ARC/INFO.
Mf2349d.met	A parsable text-only file of publication level FGDC metadata for this report.

The following supporting directory is not included in the database package, but is produced in the process of reconverting the export files into ARC coverages:

info/	INFO directory containing files supporting the databases.

Tar files

The three data packages described above are stored in tar (UNIX tape archive) files. A tar utility is required to extract the database from the tar file. This utility is included in most UNIX systems, and can be obtained free of charge over the Internet from Internet Literacy's Common Internet File Formats Webpage (http://www.matisse.net/files/formats.html). Both tar files have been compressed, and may be uncompressed with **gzip**, which is available free of charge over the Internet via links from the USGS Public Domain Software page (http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/public.html). When the tar file is uncompressed and the data is extracted from the tar file, a directory is produced that contains the data in the package as described above. The specifics of the tar files are listed below:

Name of compressed tar file	Size of compressed tar file (uncompressed)	Directory produced when extracted from tar file	Data package contained
mf2349a.t.gz	14.1 MB (304 MB)	skps	PostScript Plotfile Package
mf2349b.t.gz	7.6 MB (7.7 MB)	skpdf	PDF Plotfile Package
mf2349c.t.gz	.5 MB (2.1 MB)	skgeo	Digital Database Package

PostScript plot files

For those interested in the geology of the map area who do not use an ARC/INFO compatible GIS system, we have included a separate data package with two PostScript plot files. One contains a color plot of the geologic map database at 1:24,000 scale (skmap.ps). A second PostScript file containing the geologic description and discussion is provided (skmf.ps).

The PostScript image of the geologic map and map explanation is 31 inches high by 29 inches wide, so it requires a large plotter to produce paper copies at the intended scale. In addition, some plotters, such as those with continual paper feed from a roll, are oriented with the long axis in the horizontal direction, so the PostScript image will have to be rotated 90 degrees to fit entirely onto the page. Some plotters and plotter drivers, as well as many graphics software packages, can perform this rotation. The geologic description is on 8.5 by 11 inch pages.

The PostScript plotfiles for maps were produced by the ‘postscript’ command with compression set to zero in ARC/INFO version 7.1.2. The PostScript plotfiles for pamphlets were produced in Microsoft Word 98 using the Destination PostScript File option from the Print command.

PDF plot files

We have also included a second digital package containing PDF versions of the PostScript map sheet and pamphlet described above. Adobe Acrobat PDF (Portable Document Format) files are similar to PostScript plot files in that they contain all the information needed to produce a paper copy of a map or pamphlet and they are platform independent. Their principal advantage is that they require less memory to store and are therefore quicker to download from the Internet. In addition, PDF files allow for printing of portions of a map image on a printer smaller than that required to print the entire map without the purchase of expensive additional software. All PDF files in this report have been created from PostScript plot files using Adobe Acrobat Distiller. In test plots we have found that paper maps created with PDF files contain almost all the detail of maps created with PostScript plot files. We would, however, recommend that those users with the capability to print the large PostScript plot files use them in preference to the PDF files.

To use PDF files, the user must get and install a copy of Adobe Acrobat Reader. This software is available **free** from the Adobe website (http://www.adobe.com). Please follow the instructions given at the website to download and install this software. Once installed, the Acrobat Reader software contains an on-line manual and tutorial.

There are two ways to use Acrobat Reader in conjunction with the Internet. One is to use the PDF reader plug-in with your Internet browser. This allows for interactive viewing of PDF file images within your browser. This is a very handy way to quickly look at PDF files without downloading them to your hard disk. The second way is to download the PDF file to your local hard disk, and then view the file with Acrobat Reader. **We strongly recommend that large map**

images be handled by downloading to your hard disk, because viewing them within an Internet browser tends to be very slow.

To print a smaller portion of a PDF map image using Acrobat Reader, it is necessary to cut out the portion desired using Acrobat Reader and the standard cut and paste tools for your platform, and then to paste the portion of the image into a file generated by another software program that can handle images. Most word processors (such as Microsoft Word) will suffice. The new file can then be printed. Image conversion in the cut and paste process, as well as changes in the scale of the map image, may result in loss of image quality. However, test plots have proven adequate.

Obtaining the digital database and plotfile packages

The digital data can be obtained in any of three ways:

a. From the Western Region Geologic Publication Web Page
b. Anonymous ftp over the Internet
c. Sending a tape with request

To obtain tar files of database or plotfile packages from the USGS web pages

The U.S. Geological Survey now supports a set of graphical pages on the World Wide Web. Digital publications (including this one) can be accessed via these pages. The location of the main Web page for the entire USGS is

http://www.usgs.gov

The Web server for digital publications from the Western Region is

http://geopubs.wr.usgs.gov

Go to

http://geopubs.wr.usgs.gov/map-mf/mf2349

to access this publication. Besides providing easy access to the entire digital database, the Western Region Web page also affords easy access to the PostScript and PDF plot files for those who do not use digital databases (see below).

To obtain tar files of database or plotfile packages by ftp

The files in these reports are stored on the U.S. Geological Survey Western Region FTP server. The Internet ftp address of this server is:

ftp://geopubs.wr.usgs.gov

The user should log in with the user name ‘anonymous’ and then input their e-mail address as the password. This will give the user access to all the publications available via ftp from this server.

The files in this report are stored in the subdirectory:

pub/map-mf/mf2349

To obtain tar files of database or plotfile packages on tape

Database files, PostScript plotfiles, and related files can be obtained by sending a tape with request and return address to:

Spreckels Geologic Database
c/o Database Coordinator
U.S. Geological Survey
345 Middlefield Road, M/S 975

Menlo Park, CA 94025

Do not omit any part of this address!

Copies of either the PostScript or PDF plot-file packages can also be obtained by sending a tape with request and return address to:

Spreckels Geologic Map Plotfiles
c/o Database Coordinator
U.S. Geological Survey
345 Middlefield Road, M/S 975
Menlo Park, CA 94025

Do not omit any part of this address!

NOTE: Be sure to include with your request the exact names, as listed above, of the tar files you require. An MF Report number is not sufficient, unless you are requesting both the database package and plotfile package for the report.

The compressed tar file will be returned on the tape. The acceptable tape types are:

2.3 or 5.0 GB, 8 mm Exabyte tape.

Obtaining plots from a commercial vendor

Those interested in the geologic map, but who use neither a computer nor the Internet, can still obtain the information. We will provide the PostScript or PDF plot files on digital tape for use by commercial vendors who can make large-format plots. Make sure your vendor is capable of reading Exabyte tape types and PostScript or PDF plot files. Many vendors can also download the plotfiles via the Internet. Important information regarding file formats is included in the sections "Tar files," "PostScript plot files," and "PDF plot files" above, so be certain to provide a copy of this document to your vendor.

Obtaining plots from USGS Print-On-Demand Services

The U.S. Geological Survey provides plots such as those described in this report, through Print-On-Demand Services. In order to obtain plots, contact Print-On-Demand Services at:

U.S.G.S. Information Services
Box 25286
Denver, CO 80225

Phone: 1-888-ASK-USGS (1-888-275-8747)
e-mail: ask@usgs.gov

U.S.G.S. Maps on Demand website: http://rmmcweb.cr.usgs.gov/public/mod/index.html

Be sure to include with your request the MF Report number **and** the exact names, as listed in the Database Contents section above, of the plotfiles you require. A MF Report number and its letter alone may not be sufficient, unless you are requesting plots of all the plotfiles for that report.

Digital database format

The databases in this report were compiled in ARC/INFO, a commercial Geographic Information System (Environmental Systems Research Institute, Redlands, California), with version 3.0 of the menu interface ALACARTE (Fitzgibbon and Wentworth, 1991; Fitzgibbon, 1991; Wentworth and Fitzgibbon, 1991). The files are in either GRID (ARC/INFO raster data) format or COVERAGE (ARC/INFO vector data) format. Coverages are stored in uncompressed ARC export format (ARC/INFO version 7.x). ARC/INFO export files (files with the .e00 extension) can be converted into ARC/INFO coverages in ARC/INFO (see below) and can be read by some other Geographic Information Systems, such as MapInfo via ArcLink and ESRI's ArcExplorer (available for Windows (Java) free from ESRI's web site: http://www.esri.com). The digital compilation was done in version 7.1.2 of ARC/INFO with version 3.0 of the menu interface ALACARTE (Fitzgibbon and Wentworth, 1991; Fitzgibbon, 1991; Wentworth and Fitzgibbon, 1991).

Converting ARC export files

ARC export files are converted to ARC coverages using the ARC command IMPORT with the option COVER. To ease conversion and maintain naming conventions, we have included an ASCII text file in ARC Macro Language that will convert all of the export files in the database into coverages and create the associated INFO directory. From the ARC command line type:

```
Arc:  &run import.aml
```

ARC export files can also be read by some other Geographic Information Systems. Please consult your GIS documentation to see if you can use ARC export files and the procedure to import them.

Digital compilation

The geologic map information was digitized from stable originals of the geologic maps at 1:24,000 scale. The author manuscripts (pen on mylar) were scanned using an Altek monochrome scanner with a resolution of 800 dots per inch. The scanned images were vectorized and transformed from scanner coordinates to projection coordinates with digital tics placed by hand at quadrangle corners. The scanned lines were edited interactively by hand using ALACARTE, color boundaries were tagged as appropriate, and scanning artifacts visible at 1:24,000 were removed.

Base map

The base map layer was derived from a 1:2400 scale Digital Raster Graphic (DRG) Topographic Base Map, by the U.S. Geological Survey, Reston, VA. This base map was obtained from the U.S. Geological Survey Geologic Division Bay Area Regional Database Website (http://www.bard.wr.usgs.gov). Please see the website for more detailed information about the original database. Because the base map digital files are already available at the website mentioned above, they are not included in the digital database package.

Faults and landslides

This map is intended to be of general use to engineers and land-use planners. However, its small scale does not provide sufficient detail for site development purposes. In addition, this map does not take the place of fault-rupture hazard zones designated by the California State Geologist (Hart and Bryant, 1997). Similarly, because only some of the landslides in the mapped area are shown, the database cannot be used to completely identify or delineate landslides in the region.

Spatial resolution

Uses of this digital geologic map should not violate the spatial resolution of the data. Although the digital form of the data removes the constraint imposed by the scale of a paper map, the detail and accuracy inherent in map scale are also present in the digital data. The fact that this database was edited at a scale of 1:24,000 means that more detailed information is not present in the dataset. Plotting at scales larger than 1:24,000 will not yield greater real detail, although it may reveal fine-scale irregularities below the intended resolution of the database. Similarly, where this database is used in combination with other data of higher resolution, the resolution of the combined output will be limited by the lower resolution of these data.

Database specifics

What follows is a brief and simple description of the databases included in this report and the data in them. For a comprehensive look at the database structure and content, please see the FGDC Metadata file, mf2349d.met, included in the database package and available separately at the publication web page.

The map databases consist of ARC coverages and supporting INFO files, which are stored in a Universal Transverse Mercator projection (table 1). Digital tics define a 2.5 minute grid of latitude and longitude in the geologic coverages corresponding with quadrangle corners and internal tics.

Table 1. Map Projection File
The map is stored in Universal Transverse Mercator projection. The following is an annotated projection file of the type used in Arc/Info.

PROJECTION UTM	
UNITS METERS	-on the ground
NAD27	-datum
ZONE 10	-UTM zone
SPHEROID CLARKE1866	-Arc/Info default
PARAMETERS	
END	

The content of the geologic database can be described in terms of the lines, points, and areas that compose the map. Each line, point, or area in a map layer or index map database (coverage) is associated with a database entry stored in a feature attribute table. Each database entry contains both a number of items generated by Arc/INFO to describe the geometry of the line, point, or area, and one or more items defined by the authors to describe the geologic information associated with that entry. Each item is defined as to the amount and type of information that can be recorded. Descriptions of the database items use the terms explained in Table 2.

Table 2. Field Definition Terms

ITEM NAME	name of the database field (item)
WIDTH	maximum number of digits or characters stored
OUTPUT	output width
TYPE	B-binary integer, F-binary floating point number, I-ASCII integer, C-ASCII character string
N. DEC.	number of decimal places maintained for floating point numbers

Because some of the database structure is similar for all coverages, some descriptions apply to all coverages in the publication. In that case, the notation <coverage> has been used to indicate the description is valid for any included coverage. The precise description for a particular coverage can be made by substituting the name of the coverage for <coverage>. For example, <coverage>-ID means that the description is the same for every coverage. The specific notation for a single coverage can be derived by replacing <coverage> with the coverage name (ie. SK-GEOL-ID for the coverage sk-geol.)

Lines

The lines (arcs) are recorded as strings of vectors and are described in the arc attribute table (the format of the arc attribute table is shown in table 3). They define the boundaries of the map units, the boundaries of open bodies of water, and the map boundaries. These distinctions, including the geologic identities of the unit boundaries, are recorded in the LTYPE field according to the line types listed in Table 4.

Table 3. Content of the Arc Attribute Tables

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC	
FNODE#	4	5	B		starting node of arc (from node)
TNODE#	4	5	B		ending node of arc (to node)
LPOLY#	4	5	B		polygon to the left of the arc
RPOLY#	4	5	B		polygon to the right of the arc
LENGTH	4	12	F	3	length of arc in meters

<coverage>#	4	5	B	unique internal control number
<coverage>-ID	4	5	B	unique identification number
LTYPE	35	35	C	line type (see table 4)
PLUNGE	35	35	C	plunging fold axis (where applicable)

Table 4. Line Types Recorded in the LTYPE Field

sk-geol	sk-strc
contact, certain	ash bedding (in arc layer for symbol drawing purposes)
contact, approx. located	f.a., anticline, certain
contact, inferred, queried	f.a., anticline, concealed
contact, sed_terrace, approx. located	f.a., anticline, approx. located
contact, sed_terrace, certain	f.a., syncline, certain
fault, approx. located	f.a., syncline, concealed
fault, certain	f.a., syncline, approx. located
fault, concealed	f.a., syncline, approx. located 2
fault, concealed, queried	
map boundary	

The geologic linetypes are ALACARTE line types that correlate with the geologic line symbols in the ALACARTE line set GEOL61.LIN according to the ALACARTE lines lookup table (GEOL61.LUT). For more information on ALACARTE and its linesets, see Wentworth and Fitzgibbon (1991).

Areas

Map units (polygons) are described in the polygon attribute table (the format of the polygon attribute table is shown in table 5). In the geologic coverage (sk-geol), the identities of the map units from compilation sources are recorded in the PTYPE field by map label (table 6). Map units are described more fully in the accompanying text file. In other coverages, various areal information is recorded in the PTYPE field (data source region number, assemblage number, terrane label, quadrangle name). Note that ARC/INFO coverages cannot contain both point and polygon information, so only coverages with polygon information will have a polygon attribute table, and these coverages will not have a point attribute table.

Table 5. Content of the Polygon Attribute Tables

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC	
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
PTYPE	35	35	C		unit label

Table 6. Unit labels (see Description of Map Units section)

Qb
Qal
Qyf
Qcf
Qc
Qc?
Qaf
Qls
Qof
Qch
Qch?

Qt
Qt?
Qp
Qoe
Qgl
Qtc
Qtc?
Tsm
Tuss
Tmd
Tm
Tus
Tuc
Kgd
Kqm
Khqd
msc
ms
ml

Points

Data gathered at a single locality (points) are described in the point attribute table (the format of the point attribute table is shown in table 7). The identities of the points from compilation sources are recorded in the PTTYPE field by map label (table 8). Additional information about the points is stored in additional attribute fields as described below and in Table 9. Note that ARC/INFO coverages cannot contain both point and polygon information, so only coverages with point information will have a point attribute table, and these coverages will not have a polygon attribute table.

Table 7. Content of the Point Attribute Tables

ITEM NAME	WIDTH	OUTPUT	TYPE	N. DEC	
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
PTTYPE	35	35	C		unit label
DIP	3	3	I		dip of bedding or foliation
STRIKE	3	3	I		strike of bedding or foliation

Table 8. Point Types Recorded in the PTTYPE Field

ma-strc
----

ash bedding
bedding
flat bedding
foliation
ot bedding
vert bedding
vert foliation

The geologic point types in the structure coverage are ALACARTE point types that correlate with the geologic point symbols in the ALACARTE point set ALCGEOL.MRK according to the ALACARTE point lookup table. For more information on ALACARTE and its pointsets, see Wentworth and Fitzgibbon (1991).

References Cited

Fitzgibbon, T.T., 1991, ALACARTE installation and system manual (version 3.0): U.S. Geological Survey, Open-File Report 91-587B.

Fitzgibbon, T.T., and Wentworth, C.M., 1991, ALACARTE user interface - AML code and demonstration maps (version 3.0): U.S. Geological Survey, Open-File Report 91-587A.

Hart, E.W., and Bryant, W.A., 1997, Fault-rupture hazard zones in California: California Department of Conservation, Division of Mines and Geology Special Publication 42, 38 p.

Wentworth, C.M., and Fitzgibbon, T.T., 1991, ALACARTE user manual (version 3.0): U.S. Geological Survey, Open-File Report 91-587C.