

MONTEREY

Base from U.S. Geological Survey
Monterey, 1968
Universal Transverse Mercator projection

SEASIDE

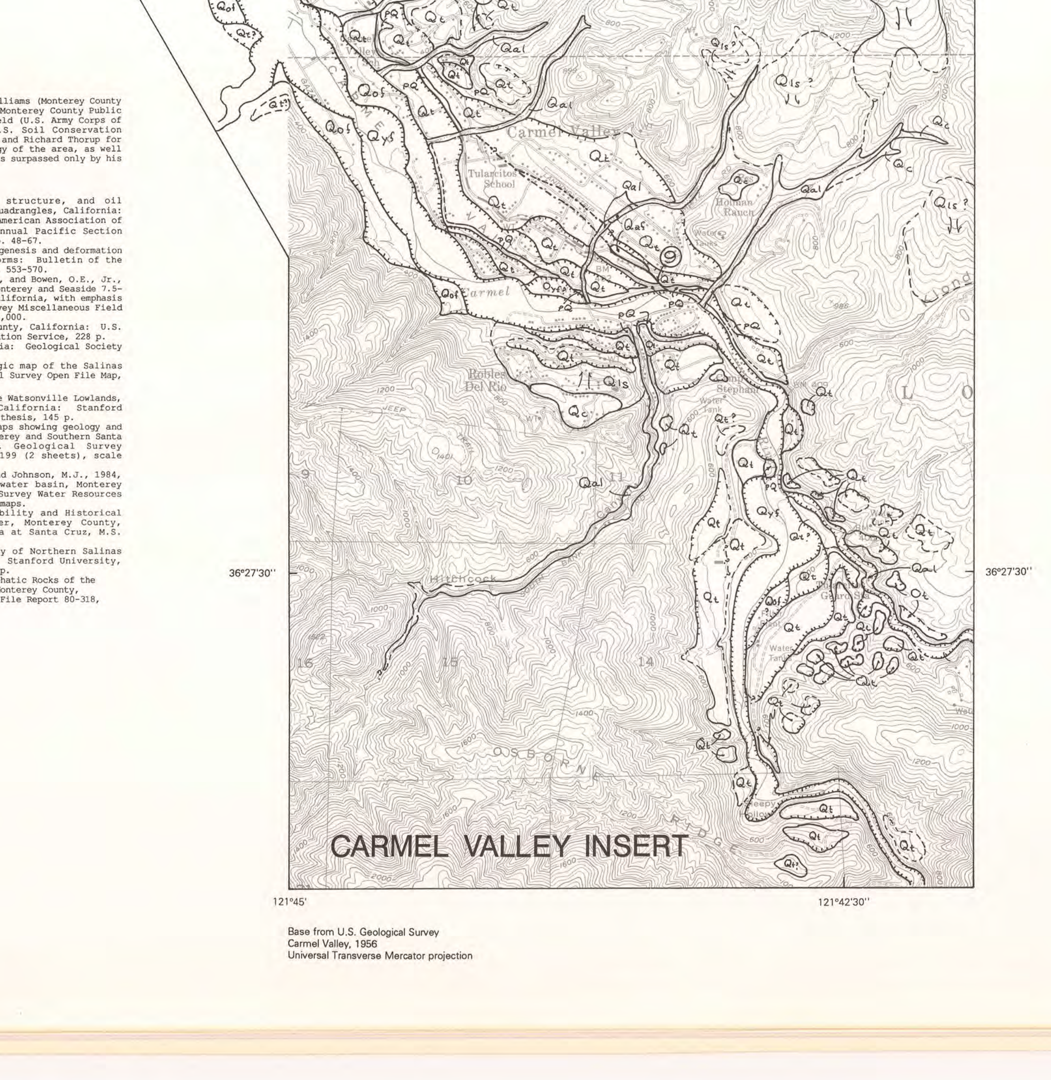
Base from U.S. Geological Survey
Seaside, 1968
Universal Transverse Mercator projection

TRUE NORTH
MAGNETIC NORTH
15½°
APPROXIMATE MEAN DECLINATION, 1990

SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DASHED OR DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

CALIF
AREA OF MAP



Base from U.S. Geological Survey
Carmel Valley, 1956
Universal Transverse Mercator projection

SPRECKELS

Base from U.S. Geological Survey
Spreckles, 1968
Universal Transverse Mercator projection

Geology mapped in 1980-85

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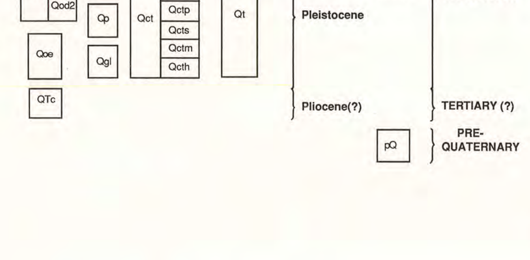
GEOLOGIC MAPS

MAPS SHOWING GEOLOGY AND LIQUEFACTION SUSCEPTIBILITY OF QUATERNARY DEPOSITS IN THE MONTEREY, SEASIDE, SPRECKELS, AND CARMEL VALLEY QUADRANGLES, MONTEREY COUNTY, CALIFORNIA

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1990

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CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qbs Beach sand deposits (Holocene)--Unconsolidated, well-sorted, medium- to coarse-grained sand. Local layers of pebbles and cobbles. Thin discontinuous lenses of silt relatively common in back-beach areas. Thickness variable, in part due to seasonal changes in wave energy; commonly less than 6 m thick. May interfinger with either well-sorted dune sand or, where adjacent to coastal cliffs, poorly sorted colluvial deposits. Iron-and magnesium-rich heavy minerals locally form placers as much as 60 cm thick. High porosity and permeability. High susceptibility to coastal flooding, moderate to high liquefaction susceptibility

Qd Dune sand deposits (Holocene)--Unconsolidated, well-sorted, fine-to medium-grained sand, deposited as linear strip of coastal dunes. May be as much as 25 m thick. High porosity and permeability; well drained. Soils poorly developed or absent. Accelerated erosion likely in areas where vegetation disturbed or removed. Low susceptibility to flooding. Moderate to high liquefaction susceptibility depending on depth to the water table

Qb Basin deposits (Holocene)--Unconsolidated, plastic clay and silty clay containing much organic material. Locally contain interbedded thin layers of silt and silty sand. Deposited in a variety of environments including estuaries, lagoons, tidal flats, marsh-filled sloughs, flood basins, and lakes. Thickness highly variable; may be as much as 30 m thick underlying some sloughs. High susceptibility to flooding. Moderate to high liquefaction susceptibility where cohesionless sediments present, except where water table is more than 10 m below the surface. Highly expansive soils develop on these deposits

Qal Alluvial deposits, undivided (Holocene)--Unconsolidated, heterogeneous, moderately sorted silt and sand with discontinuous lenses of clay and silty clay. Locally includes large amounts of gravel. May include deposits equivalent to both the younger and older flood-plain deposits (Qyf and Qof, respectively) in areas where these were not differentiated. Thickness highly variable; may be more than 30 m thick near the coast. Variable permeability and porosity. Depth to water table highly variable. High susceptibility to flooding in areas where not incised by present stream. Liquefaction susceptibility moderate to high where water table is close to surface

Qf Alluvial fan deposits (Holocene)--Unconsolidated, moderately to poorly sorted sand, silt and gravel, with layers of silty clay. Generally coarsest nearest the mountain front. Thickness uncertain, but locally may be greater than 20 m. Present streams entrenched along entire fan. Depth to water table variable, especially where large amounts of ground water pumping occurs; perched water tables may be locally present. Relatively low susceptibility to flooding. Possible area for ground-water recharge. Sediments capped by well-drained, immature soils. Mostly low liquefaction susceptibility except locally where water saturated and well-sorted sand and silt are present

Qyf Younger flood-plain deposits (Holocene)--Unconsolidated, relatively fine-grained, heterogeneous deposits of sand and silt, commonly including relatively thin, discontinuous layers of clay. Gravel content variable and is locally abundant within channel and lower point bar deposits, especially in the Carmel Valley. Thickness generally less than 6 m. Moderate permeability and porosity. Depth to water table commonly less than 2m. Relatively high susceptibility to flooding except in areas protected by artificial levees. Gravel-rich zones may be areas of ground-water recharge. High to very high liquefaction susceptibility. Where deposited as veneer of levee deposits over older flood-plain deposits, mapped separately as unit Qyf(a), such as in Carmel by the Sea

Qc Colluvium (Holocene)--Unconsolidated, heterogeneous deposits of moderately to poorly sorted silt, sand, and gravel, deposited by slope wash and mass movement. Minor fluvial reworking. Locally includes numerous undivided landslides and small alluvial fans. Contacts generally gradational. Locally grades into alluvial deposits. Generally more than 2 m thick. Moderately well-drained and permeable. Mostly moderate to low liquefaction potential but can be moderate to high locally. Slope stability relatively low; small landslides common where water is close to surface

Qcf Channel-fill deposits (Holocene)--Unconsolidated, highly plastic, poorly sorted clay, silty clay, and silt overlying moderately well-sorted silt and sand. Deposited in abandoned channels within both the younger and older flood-plain deposits (Qyf and Qof, respectively). Thickness of fill generally less than 3 m, but many of these areas have been artificially filled with material that is poorly compacted and prone to subsidence. Expansive soils are common. These areas are poorly drained, and ground water is generally within 3 m of the surface. Liquefaction susceptibility of underlying channel deposits is generally high

Qaf Artificial fill (Holocene)--Heterogeneous mixture of artificially deposited fill material ranging from well-compacted sand and silt to poorly compacted sediment high in organic content; only locally delineated. Liquefaction susceptibility ranges from high to low, depending on degree of compaction

Qfd Flandrian dune deposits (Holocene) of Cooper (1967)--Unconsolidated, well-sorted sand as much as to 30 m thick, deposited in a belt of parabolic dunes up to 700 m wide. The dunes are presently stabilized, but accelerated erosion may occur where the vegetation is disturbed. Their physical characteristics are similar to those of younger dune sand. Liquefaction potential ranges from moderate to low, depending on the depth to the water table. Unit age is early (?) Holocene

Qof Older flood-plain deposits (Holocene)--Unconsolidated, relatively fine-grained, heterogeneous deposits of sand and silt, commonly including relatively thin layers of clay. Grain size of levee deposits decreases away from abandoned channel-fill deposits. These deposits are locally over 50 m thick where they fill buried valleys beneath the Salinas and Carmel River valleys; the lower part of this valley fill is highly gravelliferous and constitutes a major ground-water aquifer in the region. Rivers are presently entrenched as much as 6 m below the surface of these deposits except near the coast. Depth to water table is variable, but is generally 3-10 m except where lowered by extensive ground water pumping (e.g. middle reach of Carmel Valley). Flooding is relatively uncommon except near the coast. Moderately well-drained, immature soils are developed in the sediments. Moderate susceptibility for liquefaction except where depth to water table is greater than 10 m

Qls Landslide deposits (Quaternary)--Heterogeneous mixture of deposits ranging from large block slides in indurated bedrock to debris flows in semiconsolidated sand and shale; only locally delineated. Younger landslides have a relatively high probability of failure during or after an earthquake, but the susceptibility for liquefaction is relatively low

Qod Older coastal dunes, undivided (Pleistocene)--Weakly consolidated, well-sorted, fine-to medium-grained sand deposited in an extensive coastal dune field in the Fort Ord area. Thickness ranges from 2 to 25 m. High porosity and permeability except at surface where moderate degree of soil development results in decreased porosity and permeability. Generally well drained. Low susceptibility for liquefaction may be moderate. Unit age is late Pleistocene. Locally divided into:

Qod_1 - Younger dune deposits, Locally equivalent to the Eolian Deposits of Sunset Beach, as mapped by Dupre' and Tinsley (1980). Unit age is middle (?) Wisconsinan

Qod_2 - Older Dune Deposits (Early ? Wisconsinan), locally equivalent to Eolian Deposits of Manresa Beach, of Dupre' and Tinsley (1980). Unit age is middle (?) Wisconsinan

Note: Some geologic units are covered with a thin veneer of eolian deposits. In some areas, this has been indicated by a subscript (e) following the symbol for the geologic unit overlain by the dune deposits

Qch Alluvial fan deposits of Chualar (Pleistocene)--Weakly consolidated, moderately to poorly sorted sand, silt, and gravel deposited as a series of alluvial fans flanking the Salinas Valley, south of the town of Spreckels. Depth to water table generally greater than 10 m because of ground-water pumping. Characterized by well-drained, medially developed soils. Relatively low susceptibility for flooding and liquefaction. Unit age is late Pleistocene

Qct Coastal terrace deposits, undivided (Pleistocene)--Semiconsolidated, moderately well-sorted marine sand containing thin, discontinuous gravel-rich layers. May be overlain by poorly sorted fluvial and colluvial silt, sand, and gravel. Thickness variable; generally less than 6 m thick. May be relatively well indurated in upper part of weathered zone; capped by maximally developed soils, some with duripans. Moderate to low porosity and permeability. Local perched water tables in areas where marine sand overlies relatively impervious deposits. Low to very low susceptibility to flooding and for liquefaction. Locally divided into:

Qctl Lighthouse coastal terrace -- partly equivalent to Santa Cruz coastal terrace of Bradley and Griggs (1976). Age is Sangamonian

Qcto Ocean View coastal terrace -- may be equivalent of older part of Santa Cruz coastal terrace, or as old as the Western coastal terrace of Bradley and Griggs (1976). Age is Sangamonian (?)

Qctp Peninsula College coastal terrace

Qcts Silvan coastal terrace

Qctm Monte Vista coastal terrace

Qcth Huckleberry coastal terrace -- in part equivalent to unit Qoa (older alluvium and terrace graved and sand) mapped by Clark and others (1974)

Note: Much of what was mapped as the (Miocene) Los Laureles Sandstone Member of Bowen (1965) of the Monterey Formation by Clark and others (1974) on the Monterey Peninsula actually consists of Quaternary coastal terrace deposits (this map) based on morphology, mineralogy, and stratigraphic relationships. Nonetheless, some areas, especially in the vicinity of Carmel Village, exist where the distinction between these two units is unclear

Qt Terrace deposits, undivided (Pleistocene)--Weakly consolidated to semiconsolidated, moderately to poorly sorted silt, silty clay, sand, and gravels, mostly deposited in a fluvial environment. Thickness highly variable, locally as much as 20 m thick. Deposits capped by moderately to fully well-developed soils, some with duripans; expansive soils are locally present. Low to very low susceptibility to flooding and for liquefaction

Qp Alluvial fan deposits of Placentia (Pleistocene)--Semiconsolidated, moderately to poorly sorted sand, silt, and gravel; gravel content increases toward the head of the fan. Similar to the alluvial fan deposits of Chualar, except capped by more well-developed soils. Generally low susceptibility to flooding; very low liquefaction susceptibitily. Unit age is middle (?) Pleistocene

Qoe Older eolian deposits (Pleistocene)--Moderately well-sorted sand as much as 60 m thick that contains no intervening fluvial deposits. Largely equivalent to the Aromas Sand as mapped by Dupre' and Tinsley (1980). 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. Porosity and permeability, as well as degree of consolidation, are thus a function of the relative position within the weathering profile. Perched water tables may be present where eolian deposits overlie less permeable fluvial deposits; springs may develop in these areas, and slumps and landslides may develop as well. Severe erosion may occur in this unit when the weathering zone and its protective duripan are breached and the relatively unconsolidated sands are exposed, as evidenced by the extensive colluvial slopes that mantle much of the outcrop area

Qgl Alluvial fan deposits of Gloria (Pleistocene)--Moderately consolidated, deeply weathered, moderately to poorly sorted sand, silt and gravel, capped with moderately well drained, maximally developed soils with duripans. Low susceptibility to flooding and very low susceptibility for liquefaction. Unit age is middle to early (?) Pleistocene

QTc Continental deposits, undivided (Pleistocene and Pliocene?)--Semiconsolidated, relatively fine grained, oxidized sand and silt; locally includes some deposits of marine origin (locally mapped as QTm). Equivalent to the Paso Robles Formation as mapped by Clark and others (1974). Moderate permeability and porosity. Erosion problems in areas where poorly consolidated parts of unit are exposed. Very low susceptibility for flooding and liquefaction

pQ Sedimentary, igneous, and metamorphic rocks, undivided (pre-Quaternary)--Characterized by very low susceptibility for liquefaction

Geologic contact--Dashed where approximately located,dotted where concealed, queried where doubtful

Thrust fault--Sawteeth on upthrown side

Inner edge of terrace deposits--May be shoreline angle of coastal terrace deposit or valley margin of fluvial terrace deposit; dashed where approximately located; barbs on terrace side of scarp

Linear scarp of uncertain origin, possibly structurally controlled

Landslide deposit--Arrows show general direction of movement

(1) Site of possible Quaternary deformation--Described in text

INTRODUCTION

This map shows the distribution of the Quaternary deposits in the southern Monterey Bay region, California, and is intended to provide a better understanding of the processes and events by which the present landscape was formed, as well as to supply information about the possible effects and potential hazards of these processes as they relate to land use. The geologic units have been defined and delineated on the basis of their relative age, morphology, and depositional environment. Each unit as defined has a relatively restricted assemblage of physical properties; where these properties vary, many do so in a systematic and predictable way. The description of each geologic unit includes a brief summary of selected physical properties of the deposits, their variability, relation to other geologic units, and relative susceptibility to certain geologic hazards such as liquefaction and flooding.

The map is not a substitute for investigation of a specific site. Rather it should be used to determine what problems may occur in any particular area. The map can also supply basic data for derivative maps that evaluate and categorize each geologic unit with respect to one or more of its physical properties, commonly in the context of a specific land use or geologic hazard. The liquefaction susceptibility map (sheet 2) is one such example--similar maps could delineate areas of potential flooding, show sand and gravel resources, or locate favorable sites for ground-water recharge or solid-waste disposal.

SOURCES OF DATA

The distribution of pre-Quaternary deposits, as well as some Pleistocene sediments (such as landslide deposits) is based in large part on geologic maps by Bowen (1965), Dibblee (1973), Dupre' (1975), Tinsley (1975), Dupre' and Tinsley (1980), Clark and others (1974), and Younse (1980). Maps of the Soil Conservation Service (Cook, 1978) as well as by Kondolf (1983), were porticularly useful in aiding in the delineation of Holocene fluvial deposits (for example, younger flood-plain deposits, older flood-plain deposits, and basin deposits) as well as mapping and correlating alluvial fan deposits (for example, alluvial fan deposits of Chualar, alluvial fan deposits of Placentia, and alluvial fan deposits of Gloria). These data were combined with the interpretation of various sets of aerial photography (1939-84), topographic maps, well logs and engineering borings, and field checked by examining natural and man-made exposures supplemented by shallow borings using a hand auger.

AGE OF DEPOSITS

The absolute age of the Quaternary deposits in the Monterey Bay region has yet to be well established. The relative age of the deposits is based in part on stratigraphic and geomorphic relationships. The relative degree of soils development (based on work by Tinsley, 1975) was extremely useful. I have attempted to use the following time-stratigraphic units where possible: 1) Holocene (10,000 yr B.P. to present); 2) late Pleistocene 125,000 yr B.P. to 10,000 yr B.P.); 3) middle Pleistocene (700,000 yr B.P. to 125,000 yr B.P.); and early Pleistocene (1.8 m.y. B.P. to 700,000 yr B.P.).

STRUCTURAL GEOLOGY

It was not the purpose of this project to map the structural geology in the area. Readers interested in that aspect of the regional geology are refered to maps by Clark and others (1974), and Younse (1980). Nonetheless, evidence of Quaternary tectonism was noticed during the course of this study that was not indicated in previous mapping, ranging from differentially uplifted and tilted coastal terrace deposits rimming the Monterey Peninsula, to thrust faulted terrace deposits in the foothills south of Monterey. The implications of possible Quaternary faulting are of such interest that these areas are noted on the maps by numbers. These sites are described below.

Seaside Quadrangle

1 Terrace gravels (too small to be mapped) which appear to be faulted against the Monterey Formation within the Berwick fault zone (Clark and others, 1974; Younse, 1980); fault trends approximately N. 30° W.

2 Thrust faulted terrace deposits with estimated 15-20 m of throw (up to the south); terrace deposits tilted at approximately N. 65° W., dipping 28°E.; possible extension of the Navy fault zone (Clark and others, 1974).

3 Terrace deposits with approximately 2 m of offset along a narrow fault zone (down to the east), trending approximately N.50° W., dipping 70° NE

Monterey Quadrangle

4 Thrust faulted terrace deposits (extension of thrust fault at location 2), with estimated throw of 10-15 meters. Beds strike approximately N. 80° W. and dipping 35°N.

5 Edge of terrace coincides with near vertical fault zone in the Monterey Formation, trending N. 15-20°W.

6 Edge of terrace coincident with sheared fault zone (strike approximately N. 25° W., dip 55°E.), Cypress Point fault of Clark and others (1974), however no obvious offsets of the terrace deposits.

7 Possible fault in terrace deposits; sheared zone within deposits trends N. 45° W., dipping 60°NE.

8 Possible faulted terrace gravels; strike of beds approximately N. 50° W., dipping 18°W.

Carmel Valley Quadrangle

9 Faulted terrace deposits; fault zone trends approximately N. 50° W., possibly a trace of the Tularcitos fault zone.

10 Faulted terrace deposits, fault zone trends approximately N. 30°-35° W.

ACKNOWLEDGMENTS

This project was initiated as part of a regional study of the earthquake hazards of the San Francisco Bay region and is part of the National Program for Earthquake Hazard Reduction of the U.S. Geological Survey. Earl E. Brabb established this project, provided base maps, aerial photographs and other materials, as well as funded most of the field work. Supplementary funding to complete the project was provided by the Monterey County Planning Department, under the supervision of Catherine M. Stein-West. Field work was done during the summers of 1980, 1981, 1982, and 1985. I was assisted in the field by Jerry Wagstaff and Bill O'Brien (University of Houston graduate students). Many people and corporations (such as the Pebble Beach Company) generously provided access to their properties in the course of mapping. In addition, numerous people have given their time and provided access to unpublished well logs and engineering reports; they include John Williams (Monterey County Flood Control District), Frederick Madison (Monterey County Public Works Department), Joe Cochran and Harold Field (U.S. Army Corps of Engineers, Fort Ord), and Ron Edwards (U.S. Soil Conservation Service). Lastly, I wish to thank Joe Clark and Richard Thorup for sharing their insights on the regional geology of the area, as well as John Kinsley, whose knowledge of the area is surpassed only by his hospitality.

REFERENCES

Bowen, O.E., Jr., 1965, Stratigraphy, structure, and oil possibilities in Monterey and Salinas quadrangles, California: in A Symposium of Papers presented at American Association of Petroleum Geologists Meeting, 40th Annual Pacific Section convention, Bakersfield, Calif., 1965, p. 48-67.
Bradley, W.C., and Griggs, G.B., 1976, Form, genesis and deformation of central California wave-cut platforms: Bulletin of the Geological Society of America, v. 83, p. 553-570.
Clark, J.C., Dibblee, T.W., Jr., Greene, H.G., and Bowen, O.E., Jr., 1974, Preliminary geologic map of the Monterey and Seaside 7.5-minute Quadrangles. Monterey County, California, with emphasis on active faults. U.S. Geological Survey Miscellaneous Field Studies Map MF-577, 2 sheets; scale 1:24,000.
Cook, T.D., 1978, Soil survey of Monterey County, California: U.S. Department of Agriculture, Soil Conservation Service, 228 p.
Cooper, W.S., 1967, Coastal dunes of California: Geological Society of America Memoir 104, 131 p.
Dibblee, T.W., Jr., (compiler) 1973, Geologic map of the Salinas Quadrangle, California: U.S. Geological Survey Open File Map, scale 1:62,500.
Dupre', W.R., 1975, Quaternary History of the Watsonville Lowlands, North-Central Monterey Bay Region, California: Stanford University, Stanford, California, Ph.D. thesis, 145 p.
Dupre', 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.
Kappla, G.W., Mitten, H.T., Durbin, T.J., and Johnson, M.J., 1984, Analysis of the Carmel Valley groundwater basin, Monterey County, California: U.S. Geological Survey Water Resources Investigation Report 83-4280, 45 p. and maps.
Kondolf, G.M., 1983, Recent Channel Instability and Historical Channel Changes of the Carmel River, Monterey County, California: University of California at Santa Cruz, M.S. Thesis, 140 p.
Tinsley, J.C. III, 1975, Quaternary Geology of Northern Salinas Valley, Monterey County, California: Stanford University, Stanford, California, Ph.D. thesis, 195 p.
Younse, G.A., 1980, The Stratigraphy and Phosphatic Rocks of the Robinson Canyon - Laureles Grade Area, Monterey County, California: U.S. Geological Survey Open File Report 80-318, 127p.

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