PRELIMINARY MAP SHOWING RECENCY OF FAULTING IN COASTAL SOUTHERN CALIFORNIA*

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INTRODUCTION

Seismic shaking and surface faulting can severely damage engineered structures unless adequate precautions are taken in siting and design. The information on which such precautions must be based includes identification and delineation of those faults that are active, that is, capable of generating earthquakes and rupturing the ground. This report is directed toward the identification of active faults in coastal southern California by summarizing what is presently known about the location of faults and the recency of displacement along them.

The capability for movement along a fault is a product of its present tectonic environment and cannot be directly determined. However, several criteria related to the past history of a fault have been used to assess whether or not it is active: historic surface faulting or creep movement; historic seismicity; instrumentally determined strain accumulation; repeated episodes of displacement in the recent geologic past as deduced from the stratigraphic record; and geologically young displacement inferred from geomorphic features (Louderback, 1950; Allen and others, 1965; Albee and Smith, 1966; Bonilla, 1970). Few of these criteria, however, are adequate for a systematic appraisal of the activity of faults throughout a region. On the one hand, the time span of recorded history is too short to permit all active faults to be identified using historic surface displacements, seismicity, or geodetic measurements. On the other hand, reconstruction of the full sequence of movements along a fault for some longer period of time requires a complete and well-understood stratigraphic record of the behavior of the fault for that period. Such a record has been partly compiled for only a few faults in the world, and many faults simply lack the necessary preserved record.

An available alternative that provides useful information for many faults is the age of the most recent movement along a fault. An approximation of the recency of movement can be made for each fault from known stratigraphic or geomorphic relations, and the relative ages of the most recent movement along different faults compared. This comparison provides the best available means of examining all faults in a region and determining which should be tentatively considered active for particular land uses (Ziony and others, 1974). The existing geologic information is sufficient basis for considering some faults active or inactive, whereas evidence along other faults may be inconclusive, and additional investigation may be required. For many faults, history of movement in the recent geologic past is not available at all; the possible activity of these faults cannot be established unless seismicity or strain measurements indicate current deformation.

NATURE AND PURPOSE OF MAP

This preliminary map depicts the location of presently known or inferred faults in the coastal southern California region between Point Arguello and the Mexican border, including the Channel Islands and parts of the Continental Borderland (map sheets 1 and 2). It systematically portrays what is currently known about the recency of displacement along each fault. On the basis of stratigraphic or geomorphic evidence, each fault is assigned to the age class that most closely brackets the time span containing its youngest movement as interpreted from the geologic record. The geologic limits on the age of latest faulting are indicated by symbols that show the age of youngest preserved faulted rock or sediment, the inferred age of fault-produced geomorphic features, and the age of the oldest preserved unfaulted rock that is deposited across or intruded into a fault.

The map represents an analysis of geologic information obtained from published or publicly available unpublished material, supplemented by limited field investigations of selected faults. More faults exist than are portrayed, but these are hidden beneath surficial deposits, or by water, or are presently unrecognized because of insufficient investigation of the geology. Future geologic studies undoubtedly will identify many more faults and may also disclose evidence requiring change in classification of the recency of movement along some faults now shown on the map.

For engineering purposes, it is desirable to be alerted to possible geologic problems so that their presence can be investigated in advance of siting and design. The map has been prepared with the philosophy that portrayal of questionable evidence of faulting should lead to its investigation, whereas omission might lead to the inference that no problems exist. Thus, some questionable data have been included on the map so long as they had some basis and were reasonable. Individual faults and connections between faults have been shown where reasonable, even though conclusive evidence for their existence may be lacking. Similarly, the ages assigned to stratigraphic units used in evaluation of control on age of latest fault movement are as young as is consistent with presently available data. This procedure, which possibly leads to assignment of too young an age to some units and thus to exaggeration of the recency of some fault displacements, avoids the falsely comforting alternative of overestimating the age of some displacements.

A source diagram (map sheet 3) indicates the various sources used in compiling each part of the map, and the list of sources at the end of the text contains the complete bibliographic citation for each reference. Published reports are available in or through most geologic libraries. Unpublished theses can be consulted at the respective schools. Other unpublished data are on file at the California Division of Mines and Geology, Ferry Building, San Francisco, California, or in the library of the U.S. Geological Survey, Menlo Park, California.

The report is a product of a project conducted on behalf of the U.S. Atomic Energy Commission to prepare small-scale maps of coastal California showing geologic factors of concern to the siting and design of nuclear power reactors. Earlier products of this project (Wentworth and others, 1970; Ziony and Buchanan, 1972; and Ziony, 1973) summarize information on the Los Angeles and San Diego areas, respectively, and describe the philosophy and graphic techniques upon which these maps are based. The present map integrates these earlier studies, somewhat modified, with data for the balance of coastal southern California. Although it is directed primarily toward the needs of critical engineered structures such as nuclear reactors, the map should be valuable also for regional land-use planning. The map, which was prepared primarily to permit the identification and investigation of faults that may be of significance to engineering development because of their potential for movement, should not be used directly as a hazards map nor in place of detailed studies for a specific site.

LIMITATIONS OF MAP

Limitations of the map must be recognized so that it will be used with appropriate caution. Several factors affect the reliability of the information shown: the nature of the geologic record and its availability to observation; the quality of the age designation of stratigraphic units that provide limits on the age of latest faulting; and the purposes for which the original data sources were prepared. Because of variations in these factors, the reliability of information on fault location and recency of displacement differs from place to place. Diagrams on map sheets 1 and 2 show the probable reliability of different parts of the map in terms of the likelihood that additions or modifications might result from further investigations.

The chief limitation of the map is the variably incomplete nature of the geologic record in coastal southern California and hence, for many areas, an incomplete understanding of those geologic relations that can bracket the time of latest faulting. In areas where the geology is relatively simple and a nearly complete late Cenozoic stratigraphic sequence is preserved, an adequate appraisal of the geologic limits on the age of latest faulting is possible. In other places, however, much or all of the late Cenozoic sequence may not be preserved or was never deposited, so that assessment of fault activity by analysis of the geologic evidence is uncertain or impossible.

*Work done on behalf of U.S. Atomic Energy Commission.

Even where a fairly complete stratigraphic sequence is preserved, lack of exposures may restrict evaluation of the relations between stratigraphic units and fault movements. Many of the rock and sediment units in coastal southern California are relatively soft and commonly are covered with soil or vegetation, so that natural exposures are rare. Evidence for recency of faulting thus may be found only by trenching or drilling, or by inference from geophysical data. In addition, routine mapping and interpretation may not reveal displacements of less than several tens of feet, although a few feet or even inches of offset in young materials are important in determining minimum limits on the age of the latest faulting.

Because direct observations are extremely limited for the offshore area, data on both location and age of faulting generally are least reliable for this part of the map. Geologic information here has been derived chiefly from interpretation of geophysical data such as subbottom acoustic-reflection profiles (for a review of the method, see Moore, 1969, p. 97-111). The presence of faults and their relation to stratigraphic units are inferred by analysis of the geometric configurations between major discontinuities in the velocity of sound waves as indicated on these records. Factors such as depth to the sea floor, the character of materials below the sea floor, and the type of geophysical equipment used determine the quality of the records and the degree of resolution of geologic features possible. In addition, although considerable geophysical data of various types have been accumulated by petroleum exploration companies, only a relatively small number of their profiles were available for the present study. As a result, there is a paucity of available data points as compared with the onshore region. Therefore, the offshore location, extent, and trend of faults are known with much less certainty than those onshore. Topographic lineaments indicated by bathymetric maps (National Oceanic and Atmospheric Adm., 1967) provide the only basis for inferring the existence of possible offshore faults over much of the region.

Uncertainty or imprecision of the age of rock or sediment units introduces uncertainty in the limits on the most recent faulting. Fossils, which are the most common basis for dating earth materials, may be lacking, so that the age of a unit must be inferred from its stratigraphic relation to adjacent units. Even where the age of a deposit is reliably known, the unit may not actually represent the whole time range indicated by the geologic age to which it is assigned. For example, the base of a unit designated Pleistocene may be younger than the beginning of Pleistocene time or the top may be older than the end of that time span. In addition, the whole age range of a unit commonly is not represented at a single locality.

The different objectives of the authors of the source materials have resulted in source maps that range in scale from detailed to reconnaissance and that emphasize certain aspects of the geology while ignoring other aspects more pertinent to an evaluation of fault history. Commonly, the relations between Quaternary deposits and faults--relations that are critical to the understanding of recency of faulting--have not been recorded in geologic mapping directed toward other purposes.

Finally, use of the map is limited by its scale of 1:250,000. At this scale, a mile on the ground is represented by about a quarter of an inch on the map, necessitating the generalization of detail, length, and spacing of fault traces. Faults whose traces are shorter, or are closer together, than about 1,500 feet are not differentiated, except for significant young faults represented by star-shaped symbols. The map scale limits accuracy of location of features to about plus or minus 1,000 feet.

MAP SYMBOLS

Line symbols on the map show the location, extent, and relative certainty of existence of faults. Letters tied to these line symbols distinguish various age classes that reflect the latest known or inferred movement of each fault. The location, type, and age of stratigraphic or geomorphic control that are used to limit the age of these displacements are shown by open symbols, containing numbers, superposed on the fault traces. Patterned areas onshore represent areas in which surficial deposits generally exceed 50 feet in thickness; unpatterned onshore parts of the map designate bedrock units that are exposed or lie beneath a relatively thin cover of surficial deposits.

Line symbols for faults

A solid line on land represents the trace of a fault that displaces the rock or sediment adjacent to it at the ground surface, whereas a dotted line represents the trace of a fault that is buried beneath a significant thickness of rock or sediment and therefore does not extend to the ground surface. If the existence of a fault is uncertain, a solid line with superposed queries is used. A query at the end of a fault trace indicates probable but unknown continuation of the fault for a significant distance beyond that point. Faults that are too short to show as a line at the map scale but that are significant because of relatively young movement are represented by a star.

Offshore faults inferred from apparent stratigraphic discontinuities in acoustic profiles are indicated by dashed lines. Some of these faults may be overlain by significant amounts of young sediment on the sea floor, but the available acoustic data commonly do not permit resolution of relations at or near the sea floor. Fault trends shown on the map are approximate and are based on inferred connections between relatively widely spaced ship-track crossings of interpreted faults. Because of probable undocumented extensions, the ends of all submarine fault traces are queried.

Offshore topographic lineaments inferred from 1:250,000-scale bathymetric maps are shown by bands of closely spaced dots that indicate the approximate location and extent of such features. These lineaments may reflect faults or fault zones, but the available data are insufficient to verify this. The lineaments are included on the map to draw attention to the need for further investigation of their role in the regional tectonic pattern.

Symbols for geologic control

The geologic control on which the age of latest faulting is based is shown by shape symbols placed on the fault trace at or near the point where the controlling geologic relations occur. The youngest displaced rock or sediment unit along a fault is indicated by an open square, and the age of that unit is represented by the number within the square keyed to the time-range chart in the explanation (sheet 1). Similarly, the oldest geologic unit that overlies or intrudes a fault without displacement is shown by an open circle containing a number keyed to the same chart. Geomorphic features indicative of geologically recent faulting are shown by an open triangle; the inferred age of the geomorphic features is shown by the number inside the symbol.

DETERMINATION OF AGE OF LATEST FAULTING

The precise age of latest faulting is known only for those few faults that have undergone surface movement in historic time; for many of these, the time of the most recent surface rupture can be documented to the year, day, or even minute. Such precision, however, is not possible for the vast majority of faults. The age for most faults must be inferred from geologic evidence that provides limits only on the span of geologic time during which the latest movement occurred; this span may be thousands or millions of years long. The length of the time span that can be defined for each fault depends on the completeness and preservation of the available geologic record. Figure 1 shows the relations between the age of the most recent faulting and the geologic relations that can restrict the time span.

Stratigraphic relations are the chief source of information for bracketing the age of latest faulting. Relations between a fault and adjacent rock or sediment units ideally can define maximum and minimum limits within which the latest faulting occurred (fig. 2A): the latest faulting must postdate the youngest faulted rock or sediment and must predate the oldest unfaulted rock or sediment unit that is deposited across or intruded into the fault. How closely the time of latest movement can be assessed depends on the closeness in age of the bracketing stratigraphic units. In areas of surficial deposits, stratigraphic and structural relations may be inferred from discontinuities in the

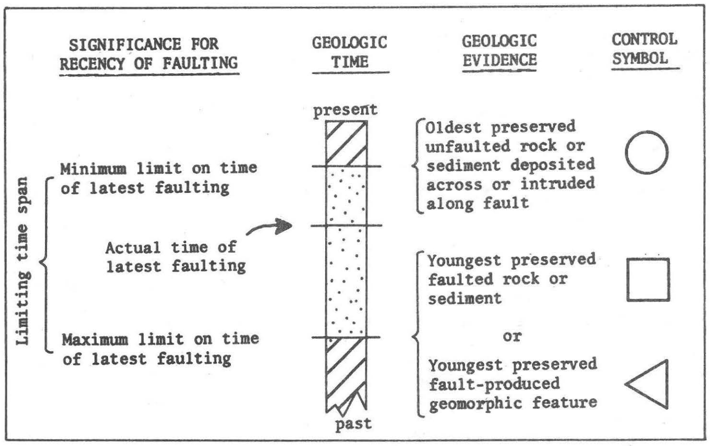

Figure 1.--Basis for determining recency of faulting: available geologic limits on time of latest faulting, and symbols used to show that control on map.

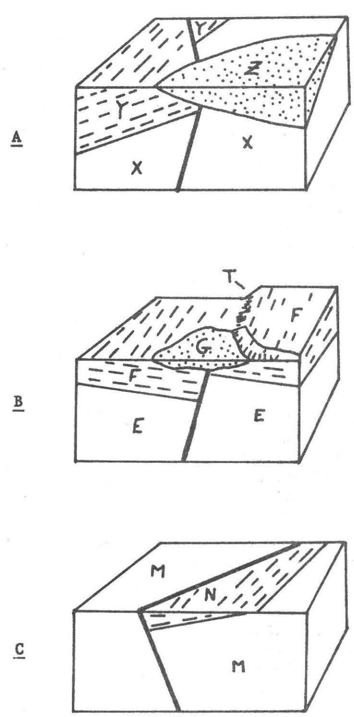

Figure 2.--Geologic relations that limit the time of latest faulting. A, Youngest faulted unit (Y) provides maximum limit. Oldest unfaulted unit (Z) provides minimum limit. The closer the ages of Z and Y, the shorter the time span containing the latest faulting event. B, Inferred age of fault-produced geomorphic feature (T) provides maximum limit. Minimum control given by youngest unfaulted stratigraphic unit (G). C, Age of youngest faulted unit (N) provides maximum limit. No minimum control is preserved; thus, age of latest fault movement may extend to present time.

flow or level of ground water in the deposits. For instance, the presence of groundwater barriers, impediments, or cascades within water-bearing Pleistocene valley fill may indicate faulting of at least the lower part of that material.

Certain geomorphic features can supplement stratigraphy as a means of determining the age of latest faulting (fig. 2B). Displacement of the ground surface by faulting commonly produces features such as scarps, closed depressions, or offset stream courses. These features are short-lived parts of the landscape, and their presence indicates relatively recent fault movement. The age of such geomorphic features thus determines the maximum limit on the age of latest faulting, because the faulting can be no older than the age of the fault-produced feature. Criteria can be selected whereby different geomorphic features suggest different ages of the most recent ground displacement (see footnotes to age-range chart in map explanation). Such age inferences, however, are particularly uncertain because the rate at which fault-produced surface features are destroyed depends on such variables as material hardness, climate, and the activities of man.

The time range of latest movement can be most closely restricted for faults where the age difference between the youngest faulted rock and the oldest unfaulted rock is small. Commonly, however, the record of thousands or even millions of years of earth history may be lacking because of nondeposition, erosion, or excavation of stratigraphic units. Thus, the time span between the maximum and minimum stratigraphic control may be quite large, bracketing a long period of geologic time during which the most recent movement of a fault could have occurred. An added difficulty is that for many faults, the preserved stratigraphic record, except for surficial deposits which may be only a few hundred years old, provides no minimum limit on the time of latest faulting (fig. 2C).

AGE CLASSIFICATION OF FAULTS

The faults are assigned to eight classes by age of latest displacement. A fault is placed in the appropriate age class chiefly on the basis of the youngest known stratigraphic or geomorphic evidence of faulting preserved along it, which is indicated on the map by the control symbols. This classification emphasizes the possible youthfulness of a fault. Faults lacking positive evidence of late Cenozoic movement are assigned to the Unknown class unless geometric and spatial relations with other faults whose history is better understood indicate that they should be assigned to another class. The age range of a particular fault in a class may be restricted by the presence of unfaulted deposits that provide a minimum limit on the age of the most recent faulting.

The entire length of a fault is assigned to a single age class consistent with the evidence of youngest movement along its length, unless minimum control indicates that one part of a fault cannot have moved as recently as another part. Some faults of the Newport-Inglewood zone in the Los Angeles basin, for example, locally displace upper Pleistocene terrace deposits but elsewhere along their traces are overlain by correlative deposits that apparently are unfaulted.

The age categories are based on time-stratigraphic boundaries within late Cenozoic time (approximately the last 12 million years of earth history) because older history probably has little bearing on current fault activity in coastal southern California. Classes selected are derived from the available stratigraphic record as indicated by regionally significant unconformities and by widespread correlative deposits. An approximate geologic time scale (fig. 3), presents age designations and their approximate limits in years as commonly used by geologists for strata in southern California and as referred to in the text and map explanation. Figure 4 summarizes the selected time intervals of the late Cenozoic to which individual stratigraphic units are assigned for purposes of the map; each stratigraphic unit is placed in a single time interval that contains the youngest known age compatible with available geologic evidence.

The classes used to represent recency of faulting are:

- Historic - latest movement within period of reliable observations of surface faulting (since 1900)
- Holocene - latest movement within past 11,000 years
- Late Quaternary - latest movement within past 500,000 years
- Quaternary - latest movement within past 3 million years
- Late Pliocene and Quaternary - latest movement within past 5 million years
- Late Cenozoic - latest movement within past 12 million years
- Pre-late Cenozoic - latest movement before about 12 million years ago
- Unknown - history of movement in past 12 million years indeterminate

Historic

Faults of the historic class have had recognized displacements since 1900. The historical record of earthquakes in southern California begins with exploration by the Spanish in 1769 and necessarily is incomplete because of the gradual and uneven population growth of the region. Until the present century, reliable accounts of surface faulting in this region were unavailable, and it is only within the past several decades that field investigations of major earthquakes have been of sufficient scope to assure that any associated surface faulting was recognized. Unrecognized ground displacements during the past 200 years, therefore, are possible for many faults in the map area.

The most recent occurrence of faulting in the map area was associated with the February 9, 1971 San Fernando earthquake, when a complex zone of surface breakage about 15 km long was formed across the northern San Fernando Valley (U.S. Geological Survey, 1971; Barrows and others, 1971). A generalized pattern that is representative of the 1971 ruptures is shown on the map. A few of these ruptures that could have origins other than faulting are indicated by a query preceding the date.

Historic surface faulting has been reported near Culver City in the Baldwin Hills (Castle and Yerkes, 1969) and near Buena Park in the Coyote Hills (Yerkes, 1972, p. C31). The Baldwin Hills displacements occurred along preexisting tectonic faults; however, because of their close spatial and temporal association with subsiding ground above oil fields, the latest offsets could have resulted from fluid extraction rather than from tectonic forces. The dates shown on the map for recency of movement along these fractures are approximate and represent the most recent movements that can be documented in the literature. Movements may be currently taking place along these or other faults associated with areas of ground subsidence.

Engel (1959, p. 52) cites evidence for historic surface ruptures along the trace of a fault north of Elsinore. These breaks reportedly formed at the time of the 1918 San Jacinto earthquake. Confirmation that these displacements were caused by faulting requires further investigation.

The historic seismic record (Hileman and others, 1973; Allen and others, 1965; and California Department of Water Resources, 1964) may aid in the identification of faults that have moved during historic time. However, this seismic record has not been used to identify historically active faults in the present study. Instrumentally determined seismicity is available for southern California only for the period since about 1932. In the absence of accompanying surface rupture, it is difficult to attribute specific earthquakes to specific faults without special instrumental studies because most epicentral locations based on the permanent seismograph network have precision of only about 5 to 15 kilometers, which equals or exceeds the spacing between many faults.

Holocene

The Holocene age class represents faults that are known or inferred to have moved within the past 11,000 years. Unrecognized historic displacement is possible along such faults.

The stratigraphic record that provides the basis for assigning faults to this class consists chiefly of alluvial and flood-plain sediments deposited when the rise in sea level at the close of the Pleistocene Epoch approached present sea level. The base of these deposits is the only available stratigraphic boundary of any great extent formed within the past 50,000 years in coastal southern California; it is the only widespread common basis for evaluating fault movements during that

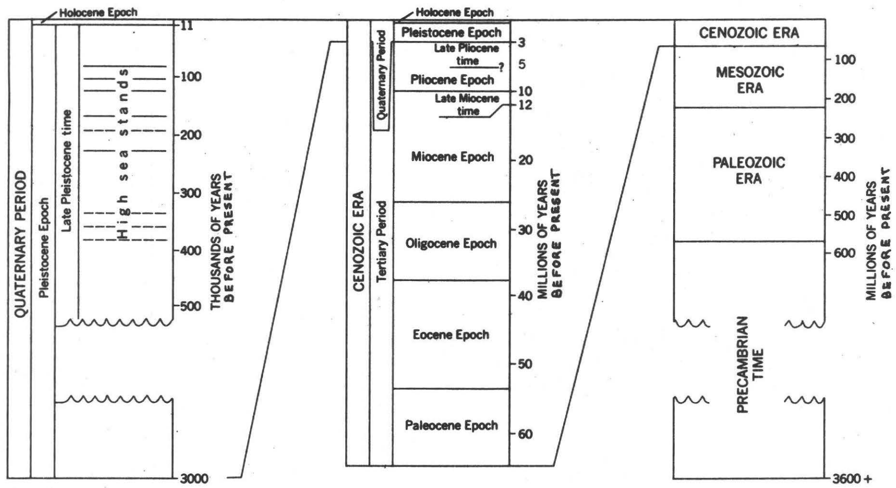

Figure 3.--Approximate provincial geologic time scale for coastal southern California. The tentative eustatic high stands of sea level (solid line, control from radiometric dates; dashed lines, inferred from Barbados terraces and solar radiation curve) represent the most likely times of sediment accumulation during late Pleistocene time. The boundaries of late Miocene time shown are those most consistent with current California usage. The beginning of late Pliocene time is uncertain and is arbitrarily placed at 5 million years. Time scale chiefly after Geologic Names Committee of U.S. Geological Survey (written commun., 1972) except as follows: Holocene-Pleistocene boundary from Morrison (1969); high sea stands from Mesolella and others (1969); beginning of Pleistocene time from Obradovich (1968); Pliocene-Miocene boundary from Ingle (1967); and beginning of late Miocene time from Turner (1968).

<table>
<tr><th>TIME INTERVAL YEARS BEFORE PRESENT</th><th colspan="3">MAJOR STRATIGRAPHIC UNITS</th></tr>
<tr><td>0 to 11,000 years</td><td colspan="3">Soil, younger alluvium, and beach deposits</td></tr>
<tr><td>11,000 to 500,000 years</td><td colspan="3">Older alluvium, marine terrace deposits exclusive of Lindavista Fm., Orcutt Sand, San Dimas Fm. of Eckis (1928), Duarte Cgl., Coyote Hills Fm., La Habra Fm., and Pauba Fm. of Mann (1955)</td></tr>
<tr><td>500,000 to 3 million years</td><td>Lindavista Fm., Santa Barbara Fm., Potato Harbor Fm. of Weaver and Meyer (1969), Casitas Fm., Temecula Arkose of Mann (1955), and San Pedro Fm.</td><td rowspan="2">500,000 to 5 million years</td><td rowspan="2">Paso Robles Fm. and Saugus Fm.</td></tr>
<tr><td>3 million to 5 million years</td><td>Upper part of Fernando Fm., Pico Fm., Careaga Sand, Niguel Fm., and San Diego Fm.</td></tr>
<tr><td>5 million to 12 million years</td><td colspan="3">Sisquoc Fm., so-called Repetto Fm., lower part of Fernando Fm., Towsley Fm., Mint Canyon Fm., Modelo Fm., Puente Fm., Monterey Fm., and Santa Margarita Fm.</td></tr>
</table>

Figure 4.--Time-stratigraphic chart for late Cenozoic deposits of coastal southern California. The late Cenozoic time span is divided into intervals and each stratigraphic unit is assigned to a single interval that contains youngest known age compatible with existing evidence. Time intervals correspond to those in map explanation on sheet 1. The time span of a particular stratigraphic unit does not necessarily coincide with the entire time interval.

time. The base of the Holocene alluvial sediments, which have been dated precisely in only a few places in coastal southern California, may range in age from about 11,000 years to only a few hundred years or less for modern alluvium.

Fault-produced geomorphic features provide the other main source of age information for the Holocene class. In the present study, the following features in association with a fault trace are considered criteria for inferring displacements during the last 11,000 years: sag ponds or sag depressions, offset stream courses in Holocene deposits, linear scarps in Holocene deposits, and linear submarine scarps in sea floor sediments above wave base. These features are susceptible to rapid degradation, and their presence thus strongly suggests very young fault movements.

Late Quaternary

Faults that are known or inferred to have moved in the past 500,000 years are included in the late Quaternary category. Unrecognized Holocene or even historic displacements are possible for faults so classed unless contrary minimum stratigraphic control, such as unfaulted basal Holocene sediments, exists.

Marine terrace and nonmarine alluvial deposits of late Pleistocene age constitute the main stratigraphic basis for defining this class. Good control on the age of most of these deposits is not yet available: fossils are either scarce, difficult to find, or not useful for subdividing the late Pleistocene; most of the deposits are too old for radiometric dating using carbon-14; and volcanic horizons that can be dated radiometrically by the potassium-argon method are generally absent. The usefulness of the uranium-series dates from mollusks in marine terrace deposits of southern California (summarized by Szabo and Vedder, 1971, and Birkeland, 1972) has been thrown into serious question by stratigraphic inconsistencies in the data and analyses of world-wide results by Kaufman and others (1971).

At least the lower emergent marine terraces in southern California probably can be correlated in a general way with similarly located terraces on Barbados in the Caribbean Sea, on the basis of persistent coastal emergence in both areas and formation of the terraces by eustatic high sea stands. The lower terraces on Barbados range in age from about 80,000 to 230,000 years, on the basis of uranium-series dating of corals (Mesolella and others, 1969; and see fig. 3), and the lower southern California terraces probably have a similar age range. However, this general equivalence does not provide sufficient basis for correlating individual terraces within the two groups.

With few exceptions, the older alluvium that flanks the mountains and underlies many of the basins and plains of southern California is not accurately or even approximately dated, although it is presumed to be largely of late Pleistocene age on the basis of its stratigraphic relations. Evidence of linear barriers or impediments to movement of ground water within such deposits has been used in this report to infer faulting of the sediments in the subsurface. Some stratigraphic units (for example, San Dimas Formation of Eckis, 1928, and Duarte Conglomerate) that are commonly assigned an early Pleistocene age in the literature are here considered to be late Pleistocene because the younger age is reasonable and the implications for age of latest faulting are important.

Fault-produced geomorphic features are another source of age information for determining late Quaternary faulting. The following are considered criteria for inferring faulting during late Quaternary time: offset stream courses in Pleistocene or older deposits, linear scarps in Pleistocene deposits, markedly linear steep mountain fronts associated with adjacent concealed fault traces, and linear submarine scarps in sea-floor sediments below wave base.

Quaternary

The Quaternary class consists of faults that have offset rocks as young as early Pleistocene in age. Some faults of the class could have been active in late Quaternary, Holocene, or historic time, but no evidence of such displacement is known, and geomorphic evidence of younger surface faulting is lacking.

Stratigraphic control is provided by faulted marine strata of early Pleistocene age preserved in the western parts of the Los Angeles and Ventura basins and nearby offshore areas, and in the greater San Diego area. Faults classed as Quaternary in the area north of Agua Tibia Mountain southeast of Temecula displace nonmarine sediments of probable early Pleistocene age.

Late Pliocene and Quaternary

Faulted deposits of late Pliocene age, or of late Pliocene and early Pleistocene age, are the basis for this age class. Upper Pliocene marine strata are exposed extensively along coastal southern California and intertongue inland with nonmarine sediments whose age is less well documented; the nonmarine deposits represent a time range that may extend into early Pleistocene time.

Unless younger unfaulted deposits are present to restrict the range of latest displacement, faults designated late Pliocene and Quaternary could have moved more recently than early Pleistocene time, although stratigraphic or geomorphic evidence of such younger faulting is not found along their traces.

Late Cenozoic

Late Cenozoic faults displace deposits of late Miocene and early Pliocene age. Those faults that lack minimum age control may have moved in late Pliocene, Quaternary, late Quaternary, Holocene or even historic time; however, no stratigraphic evidence of such displacement is preserved nor are fault-produced geomorphic features evident.

The base of the late Miocene deposits in much of the Los Angeles basin is an unconformity. This, combined with the locally distinct lithology of the deposits and their wide distribution, makes the boundary most useful for assessing the movement history of faults in coastal southern California.

Pre-late Cenozoic

A small number of faults, chiefly in the Santa Monica Mountains, the San Joaquin Hills, and Catalina Island, are categorized as pre-late Cenozoic because available evidence suggests that they probably have undergone no displacement since middle Miocene time or earlier. Minimum control for the class is provided by the unfaulted base of the late Miocene and locally older strata described above, and by middle Miocene intrusive rocks that have been emplaced along many of these faults. Because the generally poor exposures of rocks in coastal California may obscure field evidence of possible faulting of intrusive rock, absence of late Cenozoic fault movement is assured only where control from unfaulted overlying late Miocene strata is available.

Unknown

Faults for which late Cenozoic histories are incomplete because of the absence of displaced late Miocene or younger strata are placed in the unknown class. Such faults occur chiefly in terranes where late Cenozoic rocks were eroded or never formed and the youngest preserved rocks thus are middle Miocene or older.

The latest movement on faults in this class could have occurred at any time since the age of the youngest pre-late Miocene faulted rocks and may extend to the present time unless restricted by overlying unfaulted deposits. However, no geomorphic evidence of surface faulting is recognized along these faults. A minimum limit on time of latest faulting for some faults in this class is provided along the coast by unfaulted late Pleistocene marine terrace sediments and, in the San Diego area, by undisturbed lower Pleistocene strata overlying the faults. The age of the most recent displacement of faults in this class may range through tens or even hundreds of millions of years. For example, the maximum limit on recency of movement along faults in crystalline basement terranes of southern California is provided by the age of the displaced rocks. These rocks are as old as Mesozoic in the Santa Monica Mountains, Channel Islands, and the Santa Ynez Mountains; in parts of the San Gabriel Mountains some of the basement rocks are as old as Precambrian.

DESIGNATION OF FAULTS AS ACTIVE

Information about recency of faulting is useful in designating particular faults as active for specific land uses. Designation of a fault as active can be based on the assumption that the more recent the faulting, the more likely that the fault will undergo intermittent displacement in the geologically near future. Conversely, renewed movement is presumed less likely to occur along faults that have progressively longer periods of demonstrated quiescence. Assessment that a fault is or is not active cannot always be made with certainty, however, because the frequency of movement along active faults is not completely understood and because the geologic record commonly does not provide sufficient control on the time of latest movement for many faults. Thus, the fault classes used on the map are not a sufficient basis for identifying all active and inactive faults.

The manner and frequency of displacement differs from fault to fault. Some faults have released strain at the ground surface relatively slowly through creep events that extend over days or years, whereas others have slipped several feet or more almost instantaneously. Little is known about the range in frequency of movement along active faults, but at least one historically active fault, the White Creek fault of New Zealand, seems to have been dormant for about 20,000 years before its 1929 movement (Richter, 1958, p. 546; G. J. Lensen, 1970, oral commun. to M. G. Bonilla). Some faults have had sporadic movement through many millions of years and relatively long periods of quiescence may separate episodes of movement. Furthermore, intervals of recurrence may differ substantially from place to place along a single fault or fault zone (Wallace, 1970).

Because of the apparent great range in frequency of movement, there is no agreement at present on the length of geologic time pertinent to evaluation of the near-future behavior of faults. Selection of the time span used to designate faults as active from age of latest movement thus has been influenced by the potential consequence of seismic shaking or surface faulting on specific engineered structures. That is, the greater the risk incurred if an active fault is not recognized, the longer the time span that must be considered, in order to include more of the possibly active faults. Displacement during Holocene time (the past 11,000 years) is a generally accepted criterion of activity for many land uses; this time span is probably inadequate, however, to assure recognition of all active faults because historic offsets have occurred along faults, such as the White Wolf fault of California, that had no previously recognized evidence of Holocene faulting. Wentworth and Yerkes (1971) concluded, in the context of the 1971 San Fernando earthquake, that evidence of displacement during late Quaternary time (the past several hundred thousand years) should be considered evidence that a fault is probably active. A similar degree of engineering conservatism is reflected in the U.S. Atomic Energy Commission requirement that faults with movements during the past 500,000 years be considered active for siting and design of nuclear power facilities (U.S. Atomic Energy Commission, 1973; and Coulter and others, 1974).

Our present opinion is that at least the past few hundred thousand years are important in assessing the present activity of a fault. Furthermore, because the geologic record of this period of time is not available for many faults in coastal southern California (owing to nondeposition or removal of significant stratigraphic units), evidence of movement during successively older segments of late Cenozoic time must be resorted to in evaluating fault activity. In the San Diego area, for example, Ziony (1973) suggested that faults offsetting lower Pleistocene strata should be considered active for purposes of siting engineered structures that require high safety factors because these faults commonly have no significant late Quaternary age control to preclude younger movement.

Faults classed as historic, Holocene, or late Quaternary exhibit positive stratigraphic or geomorphic evidence of movement within the past several hundred thousand years and can reasonably be designated as active, depending on the safety factor required.

On the other hand, a fault can probably be considered inactive if positive evidence of quiescence is available. Pre-late Cenozoic faults are known or inferred to have been quiescent for at least 12 million years; most of them originated in response to stress systems that apparently have been superseded, and where the minimum control is good, these faults can be considered inactive. Similarly, faults overlain by undisturbed strata of early Pleistocene or late Pliocene age have not undergone movement for as much as 3 million to 5 million years and seem to be inactive under the present state of stress. Minimum age control based on unfaulted late Pleistocene or Holocene strata, however, cannot be considered sufficient basis for inferring that a fault is inactive. These deposits represent time spans of several thousand to a few hundred thousand years, which are relatively short when compared with the length of geologic time and the probable range in duration and rates of tectonic processes. Some faults limited only by late Pleistocene or Holocene deposits may be infrequently operating active faults, but are not recognized as such because knowledge of recurrence intervals is incomplete.

For the majority of faults in coastal southern California, the geologic record is insufficient to designate possible activity from recency of faulting. Faults without minimum age control that are classed as Quaternary, late Pliocene and Quaternary, late Cenozoic, or unknown lack positive evidence that either supports or refutes young displacement. Movement as recent as the present cannot be precluded along many of these faults, although the apparent absence of recognized geomorphic evidence of surface faulting, which commonly is associated with late Quaternary faulting, suggests that they may not have been in operation during the past several hundred thousand years. For these faults, further assessment of activity cannot be made unless geodetic or seismic monitoring indicates that deformation currently is occurring along them.

REFERENCES

Albee, A. L., and Smith, J. L., 1966, Earthquake characteristics and fault activity in southern California, in Lung, Richard, and Proctor, Richard, eds., Engineering geology in southern California: Assoc. Eng. Geologists Spec. Pub., p. 9-33.

Allen, C. R., St. Amand, Pierre, Richter, C. F., and Nordquist, J. M., 1965, Relationship between seismicity and geologic structure in the southern California region: Seismol. Soc. America Bull., v. 55, no. 4, p. 753-797.

Barrows, A. G., Kahle, J. E., Weber, F. H., Jr., and Saul, R. B., 1971, Map of surface breaks resulting from the San Fernando, California, earthquake of February 9, 1971: California Div. Mines and Geology, Prelim. Rept. 11, pl. 1, scale 1:24,000.

Birkeland, P. W., 1972, Late Quaternary eustatic sea-level changes along the Malibu Coast, Los Angeles County, California: Jour. Geology, v. 80, p. 432-448.

Bonilla, M. G., 1970, Surface faulting and related effects, in Wiegel, R. L., ed., Earthquake engineering: Englewood Cliffs, New Jersey, Prentice-Hall, p. 47-74.

California Dept. Water Resources, 1964, Crustal strain and fault movement investigation; Faults and earthquake epicenters in California: California Dept. Water Resources Bull. No. 116-2, 96 p.

Castle, R. O., and Yerkes, R. F., 1969, Recent surface movements in the Baldwin Hills, Los Angeles County, California; A study of surface deformation associated with oil-field operations: U.S. Geol. Survey open-file rept., 185 p.

Coulter, H. W., Waldron, H. H., and Devine, J. F., 1974, Seismic and geologic siting considerations for nuclear facilities: Fifth World Conf. on Earthquake Eng., Rome, Italy, June 1973, Proc., (in press).

Eckis, Rollin, 1928, Alluvial fans of the Cucamonga district, southern California: Jour. Geology, v. 36, no. 3, p. 225-247.

Engel, Rene, 1959, Geology of the Lake Elsinore quadrangle, California: California Div. Mines and Geology Bull. 146, p. 9-58.

Hileman, J. A., Allen, C. R., and Nordquist, J. M., 1973, Seismicity of the southern California region, 1 January 1932-31 December 1972: California Institute of Technology, Seismol. Lab. Contr. No. 2385, 486 p.

Ingle, J. C., 1967, Foraminiferal biofacies variation and the Miocene-Pliocene boundary in southern California: Am. Paleontology Bull., v. 52, no. 236, p. 209-394.

Kaufman, A., Broecker, W. S., Ku, T.-L., and Thurber, D. L., 1971, The status of U-series methods of mollusk dating: Geochim. et Cosmochim. Acta, v. 35, no. 11, p. 1155-1183.

Louderback, G. D., 1950, Faults and engineering geology, in Paige, Sidney, chm., Application of geology to engineering practice: Geol. Soc. America, Berkey Volume, p. 125-150.
Mann, J. F., Jr., 1955, Geology of a portion of the Elsinore fault zone, California: California Div. Mines and Geology Spec. Rept. 43, 22 p.
Mesolella, K. J., Matthews, R. K., Broecker, W. S., and Thurber, D. L., 1969, The astronomical theory of climatic change: Barbados data: Jour. Geology, v. 77, p. 250-274.
Moore, D. G., 1969, Reflection profiling studies of the California continental borderland: Structure and Quaternary turbidite basins: Geol. Soc. America Spec. Paper 107, 142 p.
Morrison, R. G., 1969, The Pleistocene-Holocene boundary: An evaluation of the various criteria used for determining it on a provincial basis, and suggestions for establishing it world-wide: Geologie en Mijnbouw, v. 48, no. 4, p. 363-371.
National Oceanic and Atmospheric Administration, 1967, Bathymetric maps, Cape San Martin to Point Conception 1306N-20, Southwest of Santa Rosa Island 1306N-19, Huntington Beach to Punta Sal si Puedes 1206N-16, and Santa Barbara to Huntington Beach 1206N-15: U.S. Dept. Commerce, Natl. Oceanic Atmospheric Adm., scale 1:250,000.
Obradovich, J. D., 1968, The potential use of glauconite for late-Cenozoic geochronology, in Morrison, R. B., and Wright, H. E., Jr., eds., Means of correlation of Quaternary successions: Internat. Assoc. Quaternary Research 7th Cong., U.S.A., 1965, Proc., v. 8; Salt Lake City, Utah Univ. Press, p. 267-279.
Richter, C. F., 1958, Elementary seismology: San Francisco, W. H. Freeman & Co., 768 p.
Szabo, B. J., and Vedder, J. G., 1971, Uranium-series dating of some Pleistocene marine deposits in southern California: Earth and Planetary Science Letters, v. 11, no. 4, p. 283-290.
Turner, D. L., 1968, Potassium argon dates concerning the Tertiary foraminiferal time scale and San Andreas fault displacement: California Univ., Berkeley, Ph.D. thesis, 99 p.
U.S. Atomic Energy Commission, 1973, Seismic and geologic siting criteria for nuclear power plants: Federal Register, v. 38, no. 218, p. 31279-31285.
U.S. Geological Survey Staff, 1971, Surface faulting in The San Fernando, California, earthquake of February 9, 1971: U.S. Geol. Survey Prof. Paper 733, p. 55-76.
Wallace, R. E., 1970, Earthquake recurrence intervals on the San Andreas fault: Geol. Soc. America Bull., v. 81, no. 10, p. 2875-2890.
Weaver, D. W., and Meyer, G. L., 1969, Stratigraphy of northeastern Santa Cruz Island, in Weaver, D. W., Geology of the Northern Channel Islands: Am. Assoc. Petroleum Geologists and Soc. Econ. Paleontologists and Mineralogists, Pacific Sections, Spec. Pub., p. 95-104.
Wentworth, C. M., and Yerkes, R. F., 1971, Geologic setting and activity of faults in the San Fernando area, California, in The San Fernando, California, earthquake of February 9, 1971: U.S. Geol. Survey Prof. Paper 733, p. 6-16.
Wentworth, C. M., Ziony, J. I., and Buchanan, J. M., 1970, Preliminary geologic environmental map of the greater Los Angeles area, California: U.S. Geol. Survey TID-25363, 41 p., table, 1:250,000 scale map; issued by U.S. Atomic Energy Comm.
Yerkes, R. F., 1972, Geology and oil resources of the western Puente Hills area, southern California: U.S. Geol. Survey Prof. Paper 420-C, 63 p.
Ziony, J. I., 1973, Recency of faulting in the greater San Diego area, California, in Ross, A., and Dowlen, R. J., eds., Studies on the geology and geologic hazards of the greater San Diego area, California: San Diego Assoc. Geologists and Assoc. Eng. Geologists, Guidebook for field trip, May 1973, p. 68-75.
Ziony, J. I., and Buchanan, J. M., 1972, Preliminary report on recency of faulting in the greater San Diego area, California: U.S. Geol. Survey open-file rept., 16 p.
Ziony, J. I., Wentworth, C. M., and Buchanan, J. M., 1974, Recency of faulting: a widely applicable criterion for assessing the activity of faults: Fifth World Conf. on Earthquake Eng., Rome, Italy, June 1973, Proc., (in press).

LIST OF MAP SOURCES

References followed by single asterisk (*) are on file with the California Division of Mines and Geology, Ferry Building, San Francisco. Those followed by double asterisk (**) are on file in the U.S. Geological Survey Library, Menlo Park, California.

1. Evenson, R. E., and Miller, G. A., 1963, Geology and ground-water features of Point Arguello naval missile facility, Santa Barbara County, California: U.S. Geol. Survey Water-Supply Paper 1619-F, 35 p., pl. 1, map scale 1:31,680.
2. Woodring, W. P., and Bramlette, M. N., 1950, Geology and paleontology of the Santa Maria district, California: U.S. Geol. Survey Prof. Paper 222, 142 p., pl. 1, map scale 1:24,000.
3. Dibblee, T. W., Jr., 1950, Geology of southwestern Santa Barbara County, California: California Div. Mines and Geol. Bull. 150, 95 p., pl. 1 and 2, map scale 1:62,500.
4. Roubanis, A. S., 1963, Geology of the Santa Ynez fault, Gaviota Pass-Point Conception area, Santa Barbara County, California: California Univ., Los Angeles, M. A. thesis, map scale 1:24,000.
5. J. I. Ziony, field reconnaissance.
6. Upson, J. E., and Thomasson, H. G., Jr., 1951, Geology and water resources of the Santa Ynez River basin, Santa Barbara County, California: U.S. Geol. Survey Water-Supply Paper 1107, 194 p., pl. 2 and 3, map scale 1:48,000.
7. A. G. Sylvester, 1971, oral communication.
8. Vedder, J. G., Gower, H. D., Clifton, H. E., and Durham, D. L., 1967, Reconnaissance geologic map of the central San Rafael Mountains and vicinity, Santa Barbara County, California: U.S. Geol. Survey Misc. Geol. Inv. Map I-487, scale 1:48,000 (map by authors and T. W. Dibblee and E. E. Brabb).
9. Dibblee, T. W., Jr., 1966, Geology of the central Santa Ynez Mountains, Santa Barbara County, California: California Div. Mines and Geol. Bull. 186, 99 p., pl. 1, map scale 1:31,680, pl. 3, map scale 1:62,500.
10. Dibblee, T. W., Jr., 1966, as in reference 9.
    Page, B. M., Marks, J. G., and Walker, G. W., 1951, Stratigraphy and structure of mountains northeast of Santa Barbara, California: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 8, p. 1727-1780.
    J. I. Ziony, as in reference 5.
11. Vedder, J. G., Dibblee, T. W., Jr., and Brown, R. D., Jr., 1971, Geologic map of the upper Mono Creek-Pine Mountain area, California: U.S. Geol. Survey open-file map, scale 1:48,000.
    Dibblee, T. W., Jr., and Fisher, R. V., (unpub.), Geology of the Wheeler Springs and Old Man Mountain quadrangles, California: map scale 1:31,680.
12. Gross, D. J., 1958, Geology of the Ortega area, Ventura County, California: California Univ., Los Angeles, M. A. thesis, map scale 1:14,100.
13. Jestes, E. C., 1963, A stratigraphic study of some Eocene sandstones, northeastern Ventura basin, California: California Univ., Los Angeles, PhD. thesis, map scale 1:42,500.
14. Hagen, D. W., 1957, Geology of the Wheeler Springs area: California Univ., Los Angeles, M.A. thesis, map scale 1:21,180.
15. Badger, R. L., 1957, Geology of the western Lion Canyon quadrangle, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:14,000.
16. Jestes, E. C., 1963, as in reference 13.
    Stanford Geological Survey, 1968, Geology of the Sespe Creek-Piedra Blanca Creek area, Ventura County, California: Stanford Geological Survey, map scale 1:24,000. **
17. Dibblee, T. W., (unpub.), Geologic map of Lion Canyon and Topotopa Mountains quadrangles: U.S. Geol. Survey, scale 1:62,500.
18. Dibblee, T. W., (unpub.), Geologic map of Devils Heart Peak quadrangle: U.S. Geol. Survey, scale 1:31,680.
19. Crowell, J. C., (unpub), mapping at various scales.
    Crowell, J. C., McClure, D. V., Kienle, C. F., and Edwards, L. N., 1967, Geologic map of the eastern end of the Santa Ynez fault zone: California Univ., Santa Barbara, unpub. field studies, scale 1:250,000.
20. Coudray, R. M., and Richards, J. W., 1968, Geologic map of the Goleta basin <u>in</u> Goleta Watershed Report: Santa Barbara Soil Conservation District, and Flood Control and Water Conservation District, Goleta Watershed Comprehensive Soil and Water Conservation Planning Project, June 1968, pl. 1, map scale 1:48,000. **
    J. I. Ziony, as in reference 5.
21. Upson, J. E., 1951, Geology and ground-water resources of the south-coast basins of Santa Barbara County, California: U.S. Geol. Survey Water-Supply Paper 1108, 144 p., pl. 1 and 2, maps scale 1:31,680.
22. Lian, H. M., 1954, Geology of the Carpinteria district, Santa Barbara County: California Div. Mines and Geol. Bull. 170, map sheet no. 25, scale 1:63,360.
23. Muir, K. S., 1968, Ground-water reconnaissance of the Santa Barbara-Montecito area, Santa Barbara County, California: U.S. Geol. Survey Water-Supply Paper 1859-A, 28 p., pl. 1, map scale 1:24,000.
24. Dibblee, T. W., (unpub.), Geologic map of Ventura quadrangle: U.S. Geol. Survey, scale 1:62,500.
25. Chauvel, J. P., 1958, The geology of the Arroyo Parida fault, Santa Barbara and Ventura Counties, California: California Univ., Los Angeles, M.A. thesis, map scale 1:24,000.
26. Dutton, W. G., 1962, The geology of the Casitas Pass region, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:18,000.
27. J. I. Ziony, as in reference 5.
    Geotechnical Consultants, Inc., Ventura, unpub. mapping at 1:600.
28. Turner, J. M., 1971, Ventura County water resources management study-Geohydrology of the Ventura River system: Ground water hydrology: Ventura County Dept. Public Works, Flood Control District, prelim. rept., May 1971, 31 p., pl. 2A and 2B, map scale 1:24,000. **
29. Bush, G. L., 1956, Geology of upper Ojai Valley: California Univ., Los Angeles, M. A. thesis, map scale 1:12,000.
30. Bertholf, H. W., 1967, Geology and oil resources of the Timber Canyon area, Ventura County, California: California Univ., Los Angeles, M.S. thesis, map scale 1:12,000.
31. McCullough, T. R., 1957, The geology of the Timber Canyon area, Santa Paula Peak quadrangle, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:18,000.
32. Eschner, Stanford, 1969, Geology of the central part of the Fillmore quadrangle, Ventura County, California: Am. Assoc. Petroleum Geologists, Pacific Coast section, field trip June 6, 1969, guidebook, 49 p., geologic road guide, map scale 1:24,000.
33. Bailey, T. L., (unpub.), Geology of a portion of Ventura basin, Los Angeles and Ventura Counties, California: consulting geologist, Ventura, Calif., map scale 1:24,000.
34. Robinson, B. B., 1956, Geology of the Holser Canyon area, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:11,725.
35. Pollard, D. L., 1958, Geology of the Halsey Canyon area, Los Angeles County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
36. Dibblee, T. W., (unpub.), Geologic map of the Santa Susana quadrangle: U.S. Geol. Survey, scale 1:62,500.
37. Jestes, E. C., 1958, Geology of the Wiley Canyon area, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
    Brown, R. S., 1959, The geology of the Grimes Canyon area, Moorpark and Fillmore quadrangles, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.

38. Bain, R. J., 1954, Geology of the Eureka Canyon area, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:9,600.
39. Martin, D. R., 1958, Geology of the western part of the Santa Susana Mountains, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
40. Winterer, E. L., and Durham, D. L., 1962, Geology of southeastern Ventura basin, Los Angeles County, California: U.S. Geol. Survey Prof. Paper 334-H, p. 275-366, pl. 44, map scale 1:24,000.
41. Saul, R. B., (unpub.), Geologic map of the SW¼ of the Mint Canyon quadrangle: California Div. Mines and Geol., work in progress, scale 1:9,600.
42. Oakeshott, G. B., 1958, Geology and mineral deposits of San Fernando quadrangle, Los Angeles County, California: California Div. Mines and Geol. Bull. 172, 147 p., map scale 1:62,500.
R. F. Yerkes, 1973, written communication.
43. Lung, Richard, 1958, Geology of the South Mountain area, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
Bailey, T. L., (unpub.), as in reference 33.
Yeats, R. S., 1965, Pliocene seaknoll at South Mountain, Ventura basin, California: Am. Assoc. Petroleum Geologists Bull., v. 49, no. 5, p. 526-546.
44. Van Camp, Q. W., 1959, Geology of the Big Mountain area, Santa Susana and Simi quadrangles, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
45. Hetherington, G. E., 1957, Geology of the south Tapo Canyon area, Santa Susana quadrangle, Ventura County, California: California Univ., Los Angeles, M. A. thesis, map scale 1:12,000.
Bailey, T. L., (unpub.), as in reference 33.
46. Bishop, W. C., 1950, Geology of the southern flank of Santa Susana Mountains, county line to Limekiln Canyon, Los Angeles County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
47. Saul, R. B., (unpub.), Geologic map of the SE¼ of the Oat Mountain quadrangle: California Div. Mines and Geol., work in progress, 1968, scale 1:9,600.
48. Merifield, P. M., 1958, Geology of a portion of the southwestern San Gabriel Mountains, San Fernando and Oat Mountain quadrangles, Los Angeles County, California: California Univ., Los Angeles, M.A. thesis, map scale approx. 1:12,000.
Metropolitan Water District of Southern California, 1968a, Preliminary geologic map and section along the 5.6-mile San Fernando tunnel: Los Angeles, Metropolitan Water District Southern California, L-1078, scale 1:12,000.*
Metropolitan Water District of Southern California, 1968b, Preliminary geologic map and sections along the 4.4-mile Sunland Tunnels: Los Angeles, Metropolitan Water District Southern California, B-20262, scale 1:12,000.*
U.S. Geological Survey Staff, 1971, Surface faulting, in The San Fernando, California, earthquake of February 9, 1971: U.S. Geol. Survey Prof. Paper 733, p. 55-76, fig. 2, map scale 1:24,000.
Barrows, A. G., Kahle, J. E., Weber, F. H., Jr., and Saul, R. B., 1971, Map of surface breaks resulting from the San Fernando, California, earthquake of February 9, 1971: California Div. Mines and Geol., Prelim. Rept. 11, pl. 1, scale 1:24,000.
Proctor, R. J., Crook, R., Jr., McKeown, M. H., and Moresco, R. L., 1972, Relation of known faults to surface ruptures, 1971 San Fernando earthquake, southern California: Geol. Soc. America Bull., v. 83, no. 6, p.1601-1618.
49. Dibblee, T. W., (unpub.), Geologic map of Condor Peak quadrangle: U.S. Geol. Survey, scale 1:24,000.
50. J. I. Ziony, as in reference 5.
Putnam, W. C., 1942, Geomorphology of the Ventura region, California: Geol. Soc. America Bull., v. 53, no. 5, p. 691-754.
Bailey, T. L., 1943, Late Pleistocene Coast Range orogenesis in southern California: Geol. Soc. America Bull., v. 54, no. 10, p. 1549-1568.
Geotechnical Consultants, Inc., Ventura, unpub. mapping at 1:24,000.
51. Fault configuration from Turner, J. M., 1970, Effective base of fresh water Ventura-Calleguas investigation: Ventura County Dept. of Public Works, Flood Control District, map scale 1:63,360.** Pleistocene control from California State Water Resources Board, 1953 (1956), Ventura County investigation: California State Water Res. Board Bull. 12, v. 2, pl. 12-B, section K-K', and Hardoin, J. L., 1961, McGrath area of West Montalvo oil field in California oil fields, Summary of operations: California Div. Oil and Gas, v. 47, no. 2, p. 43-53, Pl. V.
52. Pasta, Dave, 1958, Geology of the Las Posas-Camarillo Hills area, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:24,000.
53. Sage, Orrin G., Jr., 1971, Geology of the eastern portion of the "Chico" formation, Simi Hills, California: California Univ., Santa Barbara, M.A. thesis, map scale 1:18,000.
54. J. I. Ziony and C. M. Wentworth, field reconnaissance.
55. Johnston, R. L., 1938, The geology of a portion of the western Verdugo Mountains: California Univ., Los Angeles, M.A. thesis, map scale approx. 1:12,000.
56. Saul, R. B., and Jennings, C. W., (unpub.), Geologic map of north part of Burbank quadrangle: California Div. Mines and Geol., 1969, scale 1:24,000.*
57. Metropolitan Water District of Southern California, 1968c, Preliminary geologic map and section along the 6.9-mile Verdugo Tunnel: Los Angeles Metropolitan Water District Southern California, L-1079, scale 1:12,000.*
California State Water Rights Board Referee, 1962, as in reference 65.
58. Metropolitan Water District of Southern California, 1968d, Preliminary geologic map and sections along the La Crescenta Tunnel: Los Angeles, Metropolitan Water District Southern California, L-1084, scale 1:12,000.*
59. Dibblee, T. W., (unpub.), Geologic map of the Pasadena quadrangle: U.S. Geol. Survey, scale 1:24,000.
Metropolitan Water District of Southern California, 1967b, as in reference 67.
60. Page, R. W., 1963, Geology and ground-water appraisal of the Naval Air Missile Test Center area Point Mugu, California: U.S. Geol. Survey Water-Supply Paper 1619-S, 40 p., pl. 1, map scale 1:31,680.
61. Gamble, J. H., 1957, Geology of the Point Mugu and Camarillo quadrangles, Ventura County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
62. Renke, D. F., 1957, Geology of a part of Newbury Park quadrangle, Ventura County, California: California Univ. Los Angeles, M.A. thesis, map scale, 1:24,000.
63. Hamilton, D. H., 1962, Geology of the proposed Joel McCrea reservoir site and vicinity, Ventura County, California: Stanford Univ., M.S. thesis, map scale 1:2,000.
64. Wentworth, C. M., Bonilla, M. G., and Buchanan, J. M., 1969, Seismic environment of the Burro Flats site, Ventura County, California: U.S. Geol. Survey open-file rept., 1973, 35 p., fig. 2, map scale 1:24,000.
Conrad, S. D., 1949, Geology of the eastern portion of the Simi Hills, Los Angeles and Ventura Counties, California: California Univ., Los Angeles, M.A. thesis, map scale approx. 1:34,000.
J. I. Ziony, as in reference 5.
65. California State Water Rights Board Referee, 1962, Report of referee, the city of Los Angeles, a municipal corporation, plaintiff, vs. city of San Fernando, a municipal corporation, et al., defendants: State Water Rights Board Referee, No. 650079, v. 1, 258 p., pl. 4, map scale 1:160,000 and pl. 30 map scale 1:125,000.
66. Frankian, R. T., and Associates, 1968, Report of geologic and soil investigation Verdugo Mountains development and conservation study, Glendale, California: R. T. Frankian and Associates, Job. No. 6233, seven chaps.*

67. Metropolitan Water District of Southern California, 1967b, Preliminary geologic map and section along the 2.8 mile Flintridge Tunnel: Los Angeles, Metropolitan Water District Southern California, B-20263, map scale 1:12,000.*
68. Metropolitan Water District of Southern California, 1967c, Preliminary geologic map and section along the 4.0 mile Altadena Tunnel: Los Angeles, Metropolitan Water District Southern California, B-20264, map scale 1:12,000.*
69. Jennings, C. W., and Strand, R. G., 1969, Geologic map of California, Olaf P. Jenkins edition, Los Angeles sheet: California Div. Mines and Geol., scale 1:250,000.
70. Sonneman, H. S., (unpub.), [Geologic map of Santa Monica Mountains and Simi Hills], scale 1:48,000.*
71. Weber, F. H.. Jr., (unpub.), Preliminary geologic map of part of the Thousand Oaks quadrangle: California Div. Mines and Geol., work in progress, 1968, scale 1:9,600.
MacIvor, K. A., 1955, Geology of the Thousand Oaks area, Los Angeles and Ventura Counties, California: California Univ., Los Angeles, M.A. thesis, map scale, 1:24,000.
72. Kew, W. S. W., 1924, Geology and oil resources of a part of Los Angeles and Ventura Counties, California: U.S. Geol. Survey Bull. 753, 202 p., pl. 1, map scale 1:62,500.
73. Brown, G. E., 1957, Geology of parts of the Calabasas and Thousand Oaks quadrangles, Los Angeles and Ventura Counties, California: California Univ., Los Angeles, M.A. thesis, map scale 1:18,000.
74. Soper, E. K., 1938, Geology of the central Santa Monica Mountains, Los Angeles County: California Div. Mines 34th Rept. State Mineralogist, v. 34, no. 2, p. 131-180, pl. 1, map scale approx. 1:36,000.
75. Hoots, H. W., 1931, Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California: U.S. Geol. Survey Prof. Paper 165-C, p. 83-134, pl. 16, map scale 1:24,000.
76. Brady, T. J., 1957, Geology of part of the central Santa Monica Mountains east of Topanga Canyon, Los Angeles County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
77. Harding, T. P., 1952, Geology of the eastern Santa Monica Mountains between Dry Canyon and Franklin Canyon: California Univ., Los Angeles, M.A. thesis, map scale approx. 1:10,000.
78. Hardey, G. W., 1958, Stratigraphy of the Topanga formation in the eastern Santa Monica Mountains: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
79. Modified from Neuerburg, G. J., 1953, Geology of the Griffith Park area, Los Angeles County, California: California Div. Mines and Geol. Spec. Rept. 33, 29 p., pl. 1, map scale 1:20,000, based on fieldwork of C. M. Wentworth, J. M. Buchanan, and J. I. Ziony.
80. Lamar, D. L., 1970, Geology of the Elysian Park-Repetto Hills area, Los Angeles County, California: California Div. Mines and Geol. Spec. Rept. 101, 45 p., pl. 1, map scale 1:24,000.
81. Byer, J. W., 1968, Manuscript geologic map of city of Glendale: Glendale, Public Works Div., Eng. Sec., Glendale, Calif., scale 1:24,000.*
82. California Division Water Resources, 1943, Raymond Basin area, city of Pasadena vs. city of Alhambra: California Div. Water Resources, Report of Referee, North Pasadena No. C-1323, 2 v., 392 p., pl. 6, map scale 1:70,000.
83. Metropolitan Water District of Southern California, 1966, Preliminary geologic map and section along the 4.4 mile Santa Anita Tunnel No. 1: Los Angeles, Metropolitan Water District Southern California, B-20265, scale 1:12,000.*
84. Metropolitan Water District of Southern California, 1966, as in reference 83.
Morton, D. M., (unpub.), as in reference 85.
85. Morton, D. M., (unpub.), Geologic map of the SE¼ of the Mt. Wilson quadrangle: California Div. Mines and Geol., work in progress, 1968, scale 1:12,000.
86. Streitz, Robert, 1964, Preliminary geologic map of the SW¼ Glendora quadrangle, Los Angeles County, California: California Div. Mines and Geol. open-file map, scale 1:9,600.
Streitz, Robert, 1966, Preliminary geologic map of the SE¼ Glendora quadrangle, Los Angeles County California: California Div. Mines and Geol. open-file map, scale 1:9,600.
Faults from: Rogers, T. H., 1969, Geologic map of California, Olaf P. Jenkins edition, San Bernardino sheet: California Div. Mines and Geol., scale 1:250,000.
87. Azmon, Emanuel, 1956, Geology of Point Mugu quadrangle: California Univ., Los Angeles, M.A. thesis, map scale 1:24,000.
88. Sonneman, H. S., 1956, Geology of the Boney Mountain area, Santa Monica Mountains, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
89. Guynes, G. E., 1959, Geology of the Triunfo Pass area, Los Angeles and Ventura Counties, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
90. Campbell, R. H., Yerkes, R. F., and Wentworth, C. M., 1966, Detachment faults in the central Santa Monica Mountains, California: U.S. Geol. Survey Prof. Paper 550-C, 11 p.
Campbell, R. H., 1968, Preliminary geologic map of part of the Triunfo Pass and Point Dume quadrangles, Los Angeles County, California: U.S. Geol. Survey open-file map, scale 1:12,000.
Yerkes, R. F., Campbell, R. H., Blackerby, B. A., Wentworth, C. M., Birkeland, P. W., and Schoellhamer, J. E., 1971, Preliminary geologic map of the Malibu Beach quadrangle, Los Angeles County, California: U.S. Geol. Survey open-file rept., scale 1:12,000.
Yerkes, R. F., Campbell, R. H., Schoellhamer, J. E., and Wentworth, C. M., 1964, Preliminary geologic map and sections of southwest part of Topanga quadrangle, Los Angeles County, California: U.S. Geol. Survey open-file map, scale 1:12,000.
Campbell, R. H., Blackerby, B. A., Yerkes, R. F., Schoellhamer, J. E., Birkeland, P. W., and Wentworth, C. M., 1968, Preliminary geologic map of the Pt. Dume quadrangle, Los Angeles County, California: U.S. Geol. Survey open-file map, scale 1:12,000.
Yerkes, R. F., and Wentworth, C. M., 1965, Structure, Quaternary history, and general geology of the Corral Canyon area, Los Angeles County, California: U.S. Geol. Survey open-file rept. 864, 214 p.
Unpublished U.S. Geol. Survey mapping in progress.
91. Roohi, Mansoor, 1969, Topanga formation in the Malibu Lake area, Los Angeles County: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
92. McGill, J. T., 1948, Geology of a portion of the Las Flores and Dry Canyon quadrangles, Los Angeles County, California: California Univ., Los Angeles, M.A. thesis, map scale approx. 1:26,500.
93. Durrell, Cordell, 1954, Geology of the Santa Monica Mountains, Los Angeles and Ventura counties: California Div. Mines Bull. 170, map sheet no. 8, scale 1:125,000.
94. Carter, N. L., 1958, Geology of the Fernwood-Topanga Park area, Santa Monica Mountains, California: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.
95. Champeny, J. D., 1961, Paleocene and Upper Cretaceous stratigraphy of Santa Ynez Canyon and adjacent areas, Santa Monica Mountains, California: California Univ., Los Angeles, M.A. thesis, map scale 1:24,000. Supplemented near coastline by J. T. McGill, 1969, written commun.
96. Hoots, H. W., 1931, as in reference 75, and J. T., McGill, 1969, written commun.
97. Metropolitan Water District of Southern California, 1967a, Preliminary geologic map and section, Sepulveda Tunnel area: Los Angeles Metropolitan Water District Southern California, Rept. no. 853, L-1082, scale 1:12,000.*
98. Traxler, J. D., 1948, Geology of the east central Santa Monica Mountains: California Univ., Los Angeles, M.A. thesis, map scale 1:24,000.
99. Neuerburg, G. J., 1951, Petrology of the pre-Cretaceous rocks of the Santa Monica Mountains, California: California Univ., Los Angeles, PhD. thesis, map scale approx. 1:4,800.
Terpening, J. N., 1951, Geology of part of the eastern Santa Monica Mountains: California Univ., Los Angeles, M.A. thesis, map scale 1:12,000.

100. Castle, R. O., 1960a, Surficial geology of the Beverly Hills and Venice quadrangles, California: U.S. Geol. Survey open-file rept., scale 1:24,000.
California Dept. Water Resources, 1961, as in reference 107.
Zielbauer, E. J., and Burnham, W. L., 1959, West coast basin barrier project geologic investigation-Manhattan Beach to Palos Verdes Hills California: Los Angeles County Flood Control Dist. unnumbered rept., 22 p., 19 pls.

101. Location of trace of Hollywood fault based on exposed segments at either end; the surface projection of the northernmost fault (labeled Hollywood-Malibu coast) shown on Knapp, R. R., chm., 1962, Cenozoic correlation section across Los Angeles basin from Beverly Hills to Newport, California: Am. Assoc. Petroleum Geologists, Los Angeles Basin subcomm. of Pacific Section Cross-Section Comm., scale approx. 1:62,500; and fieldwork along the eastern third of the trace by C. M. Wentworth, J. I. Ziony, and J. M. Buchanan.

102. Buwalda, J. P., 1940, Geologic map of Raymond Basin: Pasadena Water Dept., unpub. manuscript, scale 1:2,000*; and fieldwork by J. M. Buchanan.
Payne, C. M., and Wilson, K. L., 1974, Age dating recent movement on the Raymond Fault, Los Angeles County, California [abs.]: Geol. Soc. America Abs. with Programs, Cordilleran Sec., v. 6, no. 3, p. 234.

103. Poland, J. F., Garrett, A. A., and Sinnott, Allen, 1959, Geology, hydrology, and chemical character of ground waters in the Torrance-Santa Monica area, California: U.S. Geol. Survey Water-Supply Paper 1461, 425 p., pl. 2, map scale approx. 1:31,680.

104. Taber, Stephen, 1920, The Inglewood earthquake in southern California, June 21, 1920: Seismol. Soc. America Bull., v. 10, no. 3, p. 129-145.

105. U.S. Geological Survey, 1902b, Santa Monica quadrangle: U.S. Geol. Survey, topographic map, scale 1:62,500.
Castle, R. O., 1960b, as in reference 106.

106. Castle, R. O., 1960b, Geologic map of the Baldwin Hills area, California: U.S. Geol. Survey open-file rept., Dec. 27, 1960, scale 1:12,000.
Castle, R. O., and Yerkes, R. F., 1969, Recent surface movements in the Baldwin Hills, Los Angeles County, California: A study of surface deformation associated with oil-field operations: U.S. Geol. Survey open-file rept. No. 1328, 185 p.

107. California Dept. Water Resources, 1961, Planned utilization of the ground water basins of the coastal plain of Los Angeles County; ground water geology: California Dept. Water Resources Bull. 104, App. A, 181 p., pl. 3a and 3b, map scale approx. 1:125,000.

108. Quarles, Miller, Jr., 1941, as in reference 109, modified by fieldwork of C. M. Wentworth, J. I. Ziony, and J. M. Buchanan.

109. Quarles, Miller, Jr., 1941, Geology of the Repetto and Montebello Hills: California Inst. Technology, M.S. thesis, map scale 1:24,000.

110. California Dept. Water Resources, 1966a, Planned utilization of ground water basins--San Gabriel Valley, Geohydrology: California Dept. Water Resources Bull. 104-2, app. A, 230 p., pl. 9A and 9B, map scale 1:125,000.

111. Shelton, J. S., 1955, as in reference 113, and Morton, D. M., (unpub.), as in reference 85.

112. Shelton, J. S., 1955, as in reference 113. Faults modified in part after Metropolitan Water District of Southern California, 1965, Preliminary geologic map and section along the 6.2 mile Glendora Tunnel: Los Angeles, Metropolitan Water District Southern California, L-1076, scale 1:12,000.*

113. Shelton, J. S., 1955, Glendora volcanic rocks, Los Angeles basin, California: Geol. Soc. America Bull., v. 66, p. 45-90, pl. 1, map scale 1:24,000.

114. Daviess, S. N., and Woodford, A. O., 1949, Geology of the northwestern Puente Hills, Los Angeles County, California: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 83, sheet 1 of 2, scale 1:12,000. Modified in part by fieldwork of C. M. Wentworth, J. I. Ziony, and J. M. Buchanan.

115. Schoellhamer, J. E., Vedder, J. G., and Yerkes, R. F., 1954a, Geology of the Los Angeles basin, pl. 1 of chap. 2 in Jahns, R. H., ed., Geology of southern California: California Div. Mines and Geol. Bull. 170, map scale approx. 1:96,000. Faults at eastern margin from Woodford, A. O., Shelton, J. S., and Moran, T. G., 1944, Generalized geologic map of the Puente and San Jose Hills, California: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 23, scale 1:62,500.

116. Taber, Stephen, 1920, as in reference 104.
U.S. Geological Survey, 1896, Redondo quadrangle: U.S. Geol. Survey, topographic map, scale 1:62,500.

117. Poland, J. F., and others, 1959, as in reference 103.
Grinsfelder, S., 1943, Dominquez oil field, in Geologic formations and economic development of the oil and gas fields of California: California Div. Mines Bull. 118, p. 318-319.

118. Yerkes, R. F., 1972, Geology and oil resources of the western Puente Hills area, southern California: U.S. Geol. Survey Prof. Paper 420-C, 63 p., pl. 1, map scale 1:24,000.

119. Durham, D. L., and Yerkes, R. F., 1964, Geology and oil resources of the eastern Puente Hills area, southern California: U.S. Geol. Survey Prof. Paper 420-B, 62 p., pl. 1, map scale 1:24,000.

120. Garrett, A. A., and Thomasson, H. G., Jr., 1949, Ground-water outflow from the Chino basin, California, and the controlling geologic and hydrologic conditions: U.S. Geol. Survey (in cooperation with San Bernardino County), 143 p., pl. 115, map scale 1:48,000.

121. Poland, J. F., and others, 1956, as in reference 134.
Castle, R. O., 1966, as in reference 128.
Zielbauer, E. J., Kues, H. A., Burnham, W. L., and Keene, A. G., 1962, Coastal basins barrier and replenishment investigation; Domingeuz Gap barrier project geologic investigation: Los Angeles County Flood Control District, Los Angeles, 29 p., pl. 1, map scale approx. 1:36,000.

122. Schoellhamer, J. E., and others, 1954a, as in reference 115.

123. Schoellhamer, J. E., Kinney, D. M., Yerkes, R. F., and Vedder, J. G., 1954b, Geologic map of the northern Santa Ana Mountains, Orange and Riverside Counties, California: U.S. Geol. Survey Oil and Gas Inv. Map OM-154, scale 1:24,000.

124. Yerkes, R. F., 1957, Volcanic rocks of the El Modeno area, Orange County, California: U.S. Geol. Survey Prof. Paper 274-L, p. 313-334.

125. Gray, C. H., Jr., 1961, Geology of the Corona South quadrangle and the Santa Ana Narrows area, Riverside, Orange, and San Bernardino Counties, California: California Div. Mines and Geol. Bull. 178, p. 7-58, pl. 1, map scale 1:24,000.
J. J. French and L. C. Dutcher, 1969, U.S. Geol. Survey, oral commun.

126. Cleveland, G. B., 1962, Preliminary geologic map of the Palos Verdes Hills, Los Angeles County, California: California Div. Mines and Geol. open-file map, scale 1:12,000.

127. Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., 1946, Geology and paleontology of Palos Verdes Hills, California: U.S. Geol. Survey Prof. Paper 207, 145 p., pl. 1, map scale 1:24,000.
Yerkes, R. F., McCulloh, T. H., Schoellhamer, J. E., and Vedder, J. G., 1965, Geology of the Los Angeles basin, California-an introduction: U.S. Geol. Survey Prof. Paper 420-A, 57 p., fig. 2.

128. Castle, R. O., 1966, Preliminary study of the geology at two proposed sites for a nuclear-powered desalting plant near Sunset Beach and Pelican Point, Orange County, California: U.S. Geol. Survey open-file rept. to U.S. Atomic Energy Comm., January 1966, 73 p.
U.S. Geological Survey, 1902a, Downey quadrangle: U.S. Geol. Survey, topographic map, scale 1:62,500.

129. Poland, J. F., and others, 1956, as in reference 134.
Zielbauer, E. J., Burnham, W. L., and Keene, A. G., 1961, Coastal basins barrier and replenishment investigation; Alamitos barrier project geologic investigation: Los Angeles County Flood Control District, Los Angeles, 28 p.

Eastern Quaternary fault from California Division of Oil and Gas, 1961, California oil and gas fields maps and data sheets, part 2 Los Angeles-Ventura basins and central coastal regions: California Div. Oil and Gas, p. 666, and p. 10-11 of Zielbauer and others, 1961, as above.

130. California Dept. Water Resources, 1968, Sea-water intrusion; Bolsa-Sunset area, Orange County: California Dept. Water Resources Bull. 63-2, 167 p., pl. 2, map scale 1:125,000.

131. Poland, J. F., and others, 1956, as in reference 134.
Weaver, D. K., and Wilhelm, V. H., 1943, Huntington Beach oil field, in Geologic formations and economic development of the oil and gas fields of California: California Div. Mines Bull. 118, p. 329-331.

132. Poland, J. F., and others, 1956, as in reference 134; and Castle, R. O., 1966, as in reference 128.

133. California Dept. Water Resources, 1966b, Santa Ana Gap salinity barrier, Orange County: California Dept. Water Resources Bull. 147-1, 178 p., pl. 4A, map scale 1:24,000.

134. Poland, J. F., Piper, A. M., and others, 1956, Ground-water geology of the coastal zone, Long Beach-Santa Ana area, California: U.S. Geol. Survey Water-Supply Paper 1109, 162 p., pl. 3, map scale 1:31,680.

135. Vedder, J. G., Yerkes, R. F., and Schoellhamer, J. E., 1957, Geologic map of the San Joaquin Hills-San Juan Capistrano area, Orange County, California: U.S. Geol. Survey Oil and Gas Inv. Map OM-193, scale 1:24,000; fault at west margin from Poland, J. F., and others, 1956, as in reference 134.
J. G. Vedder, 1973, written communication.

136. Carson, M. V., 1967, Geology of the Santiago Peak quadrangle, Orange and Riverside Counties, California: Univ. Southern California, M.S. thesis, map scale 1:24,000.

137. Morton, P. K., 1970, Geology of the NE¼ and NW¼ Cañada Gobernadora quadrangle, Orange County, California: California Div. Mines and Geol., Prelim. Rept. 10, map scale 1:12,000.
Converse, Davis, and Assoc., 1970, Geologic report on the probability of ground displacement on faults in the vicinity of the San Onofre nuclear power plant site, Units 2 and 3, San Diego County, California in Atomic Energy Comm., Preliminary Safety Analysis Rept., v. 2, app. 2A, p. 22.

138. Rogers, B. H., 1959, Geologic map and sections of the southern Temescal Valley region: California Div. Mines and Geol. Bull. 146, pl. 5, scale approx. 1:17,500.

139. Jahns, R. H., 1954, Northern part of the Peninsular Range province in Jahns, R. H., ed., Geology of southern California: California Div. Mines and Geol. Bull. 170, Guidebook No. 5, map no. 7, scale 1:96,000.

140. Engel, René, 1959, Geology of the Lake Elsinore quadrangle, California: California Div. Mines and Geol. Bull. 146, p. 9-58, pl. 1, map scale 1:62,500.

141. Morton, P. K., 1968, Preliminary geologic map of the SW¼ of the Canada Gobernadora quadrangle Orange County, California: California Div. Mines and Geol. open-file release 68-5, scale 1:9,600.

142. Roth, J. C., 1958, Geology of a portion of the southern Santa Ana Mountains, Orange County, California: California Univ., Los Angeles, M.A. thesis, map scale 1:14,400.

143. Barrows, A. G., (unpub.), Elsinore fault zone project: California Div. Mines and Geol., work in progress, unpub. materials.

144. Mann, J. F., Jr., 1955, Geology of a portion of the Elsinore fault zone, California: California Div. Mines and Geol. Spec. Rept. 43, 22 p., pl. 1, map scale approx. 1:12,250.

145. California Department Water Resources, 1956, Santa Margarita River investigation: California Dept. Water Resources Bull. No. 57, v. II, 380 p.,
J. I. Ziony, as in reference 5.

146. Blanc, R. P., and Cleveland, G. B., 1968, Natural slope stability as related to geology, San Clemente area, Orange and San Diego Counties, California: California Div. Mines and Geol. Spec. Rept. 98, map scale 1:12,000.

147. Ball, A. R., 1961, Geology of the northern and western parts of the San Clemente quadrangle, Orange County, California: Univ. Southern California, M.A. thesis, map scale 1:24,000.

148. Boss, R. F., Olmsted, F. H., Riley, F. S., and Worts, G. F., Jr., 1958, Map of Camp Pendleton, California, showing geology and location of wells: U.S. Geol. Survey open-file map, scale 1:37,000.

149. Rogers, T. H., 1966, Geologic map of California, Olaf P. Jenkins edition, Santa Ana sheet: California Div. Mines and Geol., scale 1:250,000.

150. Larsen, E. S., Jr., 1951, Crystalline rocks of the Corona, Elsinore, and San Luis Rey quadrangles, southern California: California Div. Mines and Geol. Bull. 159, p. 7-50, pl. 1, map scale 1:125,000.

151. Hanley, J. B.,(unpub.), Geologic mapping in the Palomar Mountain and Ramona quadrangles, 1946-1948, scale 1:24,000.

152. Irwin, W. P., Greene, R. C., and Thurber, H. K., 1970, Mineral resources of the Agua Tibia primitive area, California: U.S. Geol. Survey Bull. 1319-A, 19 p., pl. 1, map scale 1:48,000.
Howes, T. B., 1955, A brief study of the geology and ground water conditions in the Pauma Valley area, San Diego County, California: California Inst. Technology, M.S. thesis, map scale 1:24,000.
J. I. Ziony, as in reference 5.

153. Jahns, R. H., and Wright, L. A., 1951, Gem-and lithium-bearing pegmatites of the Pala district, San Diego County, California: California Div. Mines Spec. Rept. 7-A, pl. 1, map scale 1:20,000.

154. Kennedy M. P., (unpub.), Geologic maps of the San Luis Rey and Encinitas quadrangles: California Div. Mines and Geol., work in progress, 1972, scale 1:24,000.

155. Gastil, R. G., (unpub.), San Diego State College mapping at 1:24,000.
Geologic map of California, 1966, as in reference 149.

156. Merriam, R. H., 1946, Igneous and metamorphic rocks of the southwestern part of the Ramona quadrangle, San Diego County, California: Geol. Soc. America Bull., v. 57, no. 3, p. 223-260, pl. 1, map scale 1:165,000.
Merriam, R. H., 1951, Groundwater in the bedrock in western San Diego County, California: California Div. Mines and Geol. Bull. 159, p. 117-128, pl. 7, map scale 1:400,000.
Merriam, R. H., 1954a, Northern part of the Peninsular Range province, in Jahns, R. H., ed., Geology of southern California: California Div. Mines and Geol. Bull. 170, Geol. Guide No. 5, p. 43, map 10, scale 1:203,000.
Merriam, R. H., 1954b, A typical portion of the southern California batholith, San Diego County, in Jahns, R. H., ed., Geology in southern California: California Div. Mines and Geol. Bull. 170, map sheet no. 22, scale 1:62,500.
Weber, F. H., Jr., 1963, as in reference 169.

157. Kennedy, M. P., 1967, Preliminary report, engineering geology of the city of San Diego, California: California Div. Mines and Geol. open-file rept., map scale 1:24,000.
Kennedy, M. P., (in press), Geologic map of the Escondido quadrangle: California Div. Mines and Geol., scale 1:24,000, (in press).

158. Kennedy, M. P., 1968a, Preliminary geologic map of a portion of northwestern San Diego City, California (detailed area 2 of 5): California Div. Mines and Geol. open-file release 68-1, scale 1:9,600.

159. Ligon, Lee, 1969, A drainage anomaly south of Del Mar, California: San Diego State College, senior rept., map scale 1:31,680.

160. Kennedy, M. P., 1968b, Preliminary geologic map of a portion of northwestern San Diego City, California (detailed area 3 of 5): California Div. Mines and Geol. open-file release 68-10, scale 1:9,600.
Kennedy, M. P., (in press), Geologic map of the Del Mar quadrangle: California Div. Mines and Geol., scale 1:24,000, (in press).

161. Kennedy, M. P., 1969a, Preliminary geologic map of a portion of northwestern San Diego City, California (detailed area 4 of 5): California Div. Mines and Geol. open-file release 69-12, scale 1:9,600.
Kennedy, M. P., (in press), Geologic map of the La Jolla quadrangle: California Div. Mines and Geol., scale 1:24,000, (in press).
J. I. Ziony, as in reference 5.
162. Kennedy, M. P., 1969b, Preliminary geologic map of a portion of northwestern San Diego City, California (detailed area 5 of 5): California Div. Mines and Geol. open-file release 69-14, scale 1:9,600.
Woodward-Gizienski Assoc., (unpub.), as in reference 168.
Kern, J. P., 1973, Late Quaternary deformation of the Nestor terrace on the east side of Point Loma, San Diego, California, in Studies on the geology and geologic hazards of the greater San Diego area, California: San Diego Assoc. of Geologists and the Assoc. of Engineering Geologists, guidebook, May 1973, p. 43-45; and J. M. Buchanan-Banks, field reconnaissance.
163. Kennedy, M. P., 1967, as in reference 157.
Kennedy, M. P., (in press), Geologic maps of the Point Loma and La Jolla quadrangles: California Div. Mines and Geol., scale 1:24,000, (in press).
J. I. Ziony, as in reference 5.
164. Goldstein, Gilbert, 1965, The Geology of the Sweitzer Formation of San Diego, California: California Univ., Los Angeles, M.A. thesis, map scale 1:31,680.
165. Peterson, G. L., 1970, Quaternary deformation patterns of the San Diego area, southwestern California: Am. Assoc. Petroleum Geologists, Pacific Sec., Fall 1970 Guidebook, p. 120-126.
166. Kennedy, M. P., and Peterson, G. L., (unpub.), Geologic map of the La Mesa quadrangle: California Div. Mines and Geol., work in progress, 1972, scale 1:24,000.
167. Brown, J. W., 1967, The Poway conglomerate and younger units southwest of San Diego State College: San Diego State College, senior thesis, map scale 1:12,000.
168. Woodward-Gizienski and Associates, San Diego, unpub. mapping at various scales.
169. Weber, F. H., Jr., 1963, Geology and mineral resources of San Diego County, California: California Div. Mines and Geol. County Rept. 3, 309 p., pl. 1, map scale 1:125,000.
170. Wolf, S. C., (unpub.), U.S. Geol. Survey, map scale 1:125,000.
171. Wolf, S. C., and Wagner, H. C., (unpub.), U.S. Geol. Survey, map scale 1:62,500.
Inferred from National Oceanic and Atmospheric Adm., 1967a, as in reference 172.
172. National Oceanic and Atmospheric Administration, 1967a, Bathymetric map, Cape San Martin to Point Conception 1306N-20: U.S. Dept. Commerce, Natl. Oceanic Atmospheric Adm., scale 1:250,000.
173. Wolf, S. C., (unpub.), U.S. Geol. Survey, unpub. data.
Holocene control on faults southeast of Santa Barbara from Hamilton, R. M., Yerkes, R. F., Brown, R.D., Jr., Burford, R.O., and DeNoyer, J.M., 1969, Seismicity and associated effects, Santa Barbara region, in Geology, petroleum development, and seismicity of the Santa Barbara Channel region, California: U.S. Geol. Survey Prof. Paper 679, p. 47-68.
National Oceanic and Atmospheric Adm., 1967a and 1967c, as in reference 172 and 182.
174. Weaver, D. W., and Doerner, D. P., 1969, Geologic map of San Miguel Island, in Weaver, D. W., Geology of the northern Channel Islands: Am. Assoc. Petroleum Geologists and Soc. Econ. Paleontologists and Mineralogists, Pacific Sections, Spec. Pub., scale 1:24,000.
175. Sonneman, Howard, 1969, Geology of Santa Rosa Island, in Weaver, D. W., Geology of the northern Channel Islands: Am. Assoc. Petroleum Geologists and Soc. Econ. Paleontologists and Mineralogists, Pacific Sections, Spec. Pub., map scale 1:24,000, as modified and extended by D. Weaver, D. Doerner, and F. Avila and other anonymous authors.
176. Faulted late Quaternary deposits from Dibblee, T. W., and Cross, R. K., (unpub.), U.S. Geol. Survey, unpub. map scale approx. 1:40,000, and inferred by J. I. Ziony from Sonneman, 1969, as in reference 175. Late Quaternary geomorphic control from U.S. Geological Survey, 1943, Santa Rosa Island West, Santa Rosa Island North, and Santa Rosa Island East, 7½' topographic quadrangles; and from Kew, W.S.W., 1927, Geologic sketch of Santa Rosa Island, Santa Barbara County, California: Geol. Soc. America Bull., v. 38, no. 4, p. 645-653.
177. California University, Santa Barbara, Geological Survey, 1964-1965, Geology of Santa Cruz Island, in Weaver, D. W., 1969, Geology of the northern Channel Islands: Am. Assoc. Petroleum Geologists and Soc. Econ. Paleontologists, Pacific Section, Spec. Pub., map scale 1:24,000.
178. Faulted late Quaternary deposits from Rand, W. W., 1931, Preliminary report of the geology of Santa Cruz Island, Santa Barbara County, California: California Jour. Mines and Geol., v. 27, no. 2, p. 214-219. Late Quaternary geomorphic control from Bremner, C.S.J., 1932, Geology of Santa Cruz Island, Santa Barbara County, California: Santa Barbara Museum of Natural History, Occasional Papers no. 1, 33 p.; and inferred from U.S. Geological Survey, 1943, Santa Cruz Island A, Santa Cruz Island B, and Santa Cruz Island C, 7½' topographic quadrangles, by J. I. Ziony.
179. Greene, H. G., Wolf, S. C., and Blom, K. G., (unpub.), U.S. Geol. Survey, unpublished map scale 1:62,500, modified locally by J. I. Ziony.
National Oceanic and Atmospheric Adm., 1967c, as in reference 182.
180. Scholl, D. W., 1959, Geology and surrounding recent marine sediments of Anacapa Island: Univ. Southern California, M.S. thesis, map scale 1:20,000.
181. National Oceanic and Atmospheric Administration, 1967b, Bathymetric maps, southwest of Santa Rosa Island 1306N-19: U.S. Dept. Commerce, Natl. Oceanic Atmospheric Adm., scale 1:250,000.
182. Inferred from National Oceanic and Atmospheric Administration, 1967c, Bathymetric map, Santa Barbara to Huntington Beach 1206N-15: U.S. Dept. Commerce, Natl. Oceanic Atmospheric Adm., scale 1:250,000.
183. Junger, Arne, Wagner, H. C., and Moore, G. W., (unpub.), U.S. Geol. Survey unpublished data.
National Oceanic and Atmospheric Adm., 1967c, as in reference 182.
184. Yerkes, R. F., Gorsline, D. S., and Rusnak, G. A., 1967, Origin of Redondo submarine canyon, southern California, in Geological Survey Research 1967: U.S. Geol. Survey Prof. Paper 575-C, p. C97-C105, fig. 1, map scale approx. 1:160,000; modified by H. C. Wagner and Arne Junger from unpub. U.S. Geol. Survey data.
185. Kemnitzer, L. E., 1933, Geology of San Nicholas and Santa Barbara Islands, southern California: California Inst. Technology, M.S. thesis, map scale 1:10,000.
186. Vedder, J. G., and Norris, R. M., 1963, Geology of San Nicolas Island, California: U.S. Geol. Survey Prof. Paper 369, 65 p., pl. 3, map scale 1:12,000.
187. Bailey, E. H., 1941, Mineralogy, petrology and geology of Santa Catalina Island, California: Stanford Univ., Ph.D. thesis, map scale 1:63,360.
Bailey, E. H., 1954, Road log for Santa Catalina Island, Geol. Soc. America field trip, October 31, 1954: Geol. Soc. America, map scale 1:182,000.
188. Wagner, H. C., and Junger, Arne, (unpub.), U.S. Geol. Survey, unpublished data; and modified from Western Geophysical Company, 1972, Final report, Southern California Edison Company San Onofre offshore investigations: U.S. Atomic Energy Comm., Prelim. Safety Analysis Rept., San Onofre Nuclear Generating Station, Units 2 and 3, Docket nos. 50-361 and 50-362, Amendment no. 11, app. 2E, map scale approx. 1:240,000.

189. Moore, G. W., 1972, Offshore extension of the Rose Canyon fault, San Diego, California, _in_ Geological Survey Research 1972: U.S. Geol. Survey Prof. Paper 800-C, p. C113-C116, fig. 1, map scale approx. 1:260,000; modified by H. C. Wagner from unpublished U.S. Geol. Survey data.
190. Olmsted, F. H., 1958, Geologic reconnaissance of San Clemente Island, California: U.S Geol. Survey, Bull. 1071-B, p. 55-68, pl. 1, map scale 1:31,680.
191. Merifield, P. M., Lamar, D. L., and Stout, M. L., 1971, Geology of central San Clemente Island, California: Geol. Soc. America Bull., v. 82, p. 1989-1994, fig. 2, map scale approx. 1:105,000.
192. Inferred from National Oceanic and Atmospheric Administration, 1967d, Bathymetric map, Huntington Beach to Punta Sal si Puedes 1206N-16 : U.S. Dept. Commerce, Natl. Oceanic Atmospheric Adm., scale 1:250,000
193. Moore, D. G., 1957, Acoustic sounding of Quaternary marine sediments off Point Loma, California: U.S. Navy Electronics Laboratory Rept. 815, 16 p., fig. 10, map scale approx. 1:85,000.
194. G. W. Moore,and M. P. Kennedy, written communication.

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