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:

1. 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).

2. Few of these criteria, however, are adequate for a reliable indication 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 geologic data alone. On the other hand, reconstruction of the full sequence of movements along a fault for some longer period of time requires a complete understanding of the stratigraphic record of the behavior of the fault for that period. Such a record has been 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 knowledge of 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 present 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 faulted rock that is deposited across or intruded into a fault.

The map represents an analysis of geologic information obtained from published and 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 in advance of siting and design. The map has been prepared with the philosophy that portrayal of questionable evidence 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 bibliography of 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 Buchmam-Banks, 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 determination 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 the age limits on the probable 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 variable incompleteness 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.

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 uncommon. 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 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 the materials below the sea floor, and the type of geophysical equipment used determine the quality of the records and the degree of resolution of geological features possible. In addition, although considerable geophysical data of various types have been accumulated by petroleum exploration companies, only a very 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 reconnaissance to broad mapping and that emphasize certain aspects of the geology while ignoring other aspects more pertinent to an evaluation of fault history. Consequently, 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 the 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 lineaments. 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 traces 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 triangle; the inferred age for most 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 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 stratigraphic units.

In addition, routine mapping and interpretation may be limited by the scale at which surficial deposits, stratigraphic and structural relations may be inferred from discontinuities in the
SIGNIFICANCE FOR RECENCY OF FAULTING

<table>
<thead>
<tr>
<th>GEOLOGIC TIME</th>
<th>GEOLOGIC EVIDENCE</th>
<th>CONTROL SYMBOL</th>
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</thead>
<tbody>
<tr>
<td>Present</td>
<td>Oldest preserved unfaulted rock or sediment deposited across or intruded along fault</td>
<td>□</td>
</tr>
<tr>
<td>Present</td>
<td>Youngest preserved faulted rock or sediment</td>
<td>□</td>
</tr>
</tbody>
</table>
| Past          | Youngest preserved fault-produced geomorphic feature | △

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 (T) 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 absence of ground-water 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. 28). 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 controls 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. 22).

**AGE CLASSIFICATION OF FAULTS**

The faults are assigned to eight classes by age of latest displacement. A fault is placed in the appropriate 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 geomorphic 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 except in cases where 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 correlatable 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 controls as indicated by regionally significant unconformities and by widespread correlatable 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 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 5,000 years

**Quaternary** - latest movement within past 2 million years

**Late Pliocene and Quaternary** - 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. 113). 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 faults 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 Elysian. 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 (Hillman 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 last 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 30,000 years in coastal southern California and 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 comm., 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>
<thead>
<tr>
<th>TIME INTERVAL</th>
<th>MAJOR STRATIGRAPHIC UNITS</th>
</tr>
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<tbody>
<tr>
<td>0 to 11,000 years</td>
<td>Soil, younger alluvium, and beach deposits</td>
</tr>
<tr>
<td>11,000 to 500,000 years</td>
<td>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. (500,000 to 5 million years)</td>
</tr>
<tr>
<td>3 million to 5 million years</td>
<td>Upper part of Fernando Fm., Pico Fm., Caragol Sand, Miguel Fm., and San Diego Fm.</td>
</tr>
<tr>
<td>5 million to 12 million years</td>
<td>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>
</tbody>
</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 Kirtland, 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 (Nesnolda, 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 late Pleistocene or younger in 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 Ecken, 1926, 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 late Quaternary 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 displacements 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, in the greater San Diego area. Faults classed as Quaternary in the area north of Agua Tibia Mountain southeast of Temecula displace non-marine sediments of probable early Pleistocene age.

Late Pleistocene and Quaternary

Faulted deposits of late Pleistocene age, or of late Pleistocene and early Holocene age, are the basis for this age class. Upper Pleistocene marine strata are exposed extensively along coastal southern California and intertongue inland with non-marine sediments whose age is less well documented; the non-marine 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 Pleistocene 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 Pleistocene, Quaternary, late Quaternary, Holocene or even historic time; however, no stratigraphic evidence of 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 pre-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 linear age 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 undergone periods of demonstrable 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 movements at many faults. Thus, the fault classes used on the map are not a sufficient basis for identifying all active and inactive faults.

The 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 consequences of seismic shaking or surface faulting on specific engineered structures. That is, the greater the time span used the more 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 Terkes (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 sufficient evidence for activity; that a fault is probably active. A similar degree of engineering conservatism is reflected in the U.S. Atomic Energy Commission's 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 and relatively long periods of quiescence may separate episodes of movement. 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 resurrected to in evaluating fault activity. In the San Diego area, for example, Zony (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 Pleistocene faults are known or inferred to have been quiescent for at least 12 million years; most or all 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 Pleistocene 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 questions represent in duration and rate 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 Pleistocene 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 geologic or seismic monitoring indicates that deformation currently is occurring along them.

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