UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PRELIMINARY REPORT ON RECENCY OF FAULTING IN THE GREATER SAN DIEGO AREA, CALIFORNIA

by

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Introduction

Maps summarizing data on recency of faulting along individual faults provide a consistent and easily applied framework for assessing the future behavior of faults, and hence are useful for land planning and engineering purposes. The most recent displacement of a fault commonly is the best criterion of activity in a region because data on seismicity, strain accumulation, and repetitive movements are not widely or consistently available.

This report was prepared to permit early release of part of the results of a more comprehensive study of coastal California being prepared by the Geological Survey on behalf of the U.S. Atomic Energy Commission. Figure 1, a map showing recency of faulting in the greater San Diego area, represents an analysis of available geologic information (both published and unpublished) supplemented by limited field reconnaissance. On the basis of stratigraphic or topographic evidence, a fault is assigned to that age class which most closely brackets the time span containing its youngest known or inferred movement. The geologic limits on the age of latest displacement of a fault are represented by symbols that depict the age of youngest faulted rocks, the inferred age of fault-produced topography, and the age of oldest unfaulted rocks deposited across the fault.

The map represents a minimum statement on faulting in the greater San Diego area. Many other faults exist, but are covered by alluvial or terrace deposits or are presently unrecognized because of insufficient investigation of the geology. Future geologic studies undoubtedly will identify many of these faults and may disclose evidence which could change the classifications of faults shown on Figure 1.

The map will permit the identification and early investigation of known or inferred faults which could be of significance to engineering development. It cannot be used directly as a hazards map nor is it intended to designate any particular fault as being either active or inactive. As pointed out by Wentworth, Ziony, and Buchanan (1970, p. 9), not enough is known of the behavior of faults to assure recognition of all active faults by present geophysical or geologic criteria. Thus, selection of the particular criteria used to identify active faults must be influenced by the consequences of possible fault displacement on the engineering works involved. For example, in the greater San Diego area it may be appropriate to consider faults with proved or reasonably possible Quaternary movements as active for purposes of siting dams and other structures that require high safety factors, whereas many such faults might not be considered active for less critical land uses. Determination of which faults should be considered active therefore requires a balancing of confidence of activity against consequences. Such risk judgements are outside the purview of this report.

Most technical terms used in this report are defined in the glossary of the American Geological Institute (Howell and Weller, 1960).

Faulting in the greater San Diego area

The geologic structure of the greater San Diego area is dominated by a series of discontinuous north- to northwest-striking faults (Figure 1) that characteristically are steeply dipping and have normal separation[1/]. Some of these faults, such as the Rose Canyon and the La Nacion, have surface traces

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[1/] Separation is the distance measured between two parts of a marker stratum disrupted by a fault. The hanging wall of a fault with normal separation has been depressed relative to the footwall.

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more than 15 miles in length and display vertical separations of hundreds of feet. A subordinate system of east- to northeast-striking faults, which have much smaller separations, is most extensively exposed northeast of La Jolla and on the Point Loma peninsula.

Rose Canyon fault zone

The Rose Canyon fault zone, probably the most widely known geologic structural feature of San Diego, forms a belt of fractures about a mile wide. The zone onshore can be traced southeastward along the western margins of the Lindavista and San Diego mesas from near La Jolla to downtown San Diego, a distance of more than 10 miles. Because the zone projects southeastward under San Diego Bay, a continuation to the Mexican Border and possibly beyond has been suggested by Wiegand (1970) and by Moore and Kennedy (1970). North of La Jolla, an offshore extension of the fault zone has been recognized by Moore (1972). Recent investigations (Ziony and others, unpublished data) suggest that the Rose Canyon zone is part of a much larger northwest-trending zone of deformation, which extends southeastward at least 150 miles from near Santa Monica, California, into Baja California, Mexico. At its northwestern end, in the Los Angeles basin, this long deformational belt includes the tectonically active Newport-Inglewood zone, possible locus of the 1933 Long Beach earthquake (magnitude 6.3).

Cretaceous and Tertiary strata of the San Diego region generally are only slightly to moderately tilted, but near the Rose Canyon fault zone these rocks dip steeply and are sheared and faulted. Although some strands of the Rose Canyon zone are overlain by unfaulted lower Pleistocene Lindavista Formation, other strands displace this marine terrace unit. About 450 feet of vertical separation of the Lindavista Formation can be recognized across the zone east of La Jolla (Peterson, 1970, p. 125). Younger stratigraphic control consists of Holocene alluvium which overlaps the zone in many places. The upper Pleistocene Bay Point Formation, the youngest extensive marine terrace unit, is not seen in contact with the fault zone; however, warping of the Bay Point Formation in the La Jolla area (Peterson, 1970, p. 126) could be related to late Pleistocene or younger activity along the Rose Canyon zone. The abrupt, steep northeastern slope of Soledad Mountain could be a result of late Pleistocene faulting.

The most recent displacement along the Rose Canyon fault zone must post-date the Lindavista Formation, whose age lies within the 3 million-500,000 years B.P. range (see chart on page 12). Because the age of the basal alluvium is not known, and could be as young as a few hundred years or less in places, faulting as recently as early Holocene time cannot definitely be precluded. Subbottom acoustic-reflection profiles offshore from Del Mar show faulted sediment that has been inferred to be of Holocene age (Moore, 1972). However, sag depressions and sharply defined scarps, possible evidence for Holocene offsets, do not occur along the Rose Canyon zone; Wiegand (1970, p. 111 and 112) ascribed certain topographic features south of San Diego to Holocene faulting along a projected Rose Canyon fault, but such features are better explained by nontectonic origins.

La Nacion fault and related faults

The La Nacion fault extends for some 16 miles southward from near La Mesa along the east side of National City and Chula Vista. The structure was first recognized and named by geologists of Woodward-Gizienski and Associates, and numerous trenches and borings have been made to investigate it. The fault dips 60° to 70° toward the west and locally consists of two or more strands several tens of feet apart. The western block appears downthrown; for much of its length, the La Nacion fault separates the upper Pliocene San Diego Formation on the west from Eocene strata on the east.

The youngest geologic unit definitely displaced by the fault is the Lindavista Formation, which is offset vertically as much as 200 feet in several places. Offsets of basal Holocene deposits along the fault are cited (Artim and Pinckney, in press), but our field investigations did not confirm such displacements. As observed at the surface, the alluvium of stream valleys extends unbroken across the fault trace without exception. More importantly, topographic features (such as sag depressions or well-defined scarps) commonly associated with Holocene faulting elsewhere in coastal California have not been observed along the La Nacion fault.

Shorter north-trending faults with traces as long as 2 miles crop out between San Diego Bay and the La Nacion fault. Many of these structures have displaced the Lindavista Formation, with vertical separations of a few feet to as much as 100 feet. The existence and recency of movement of other faults are inferred from topographic lineaments or subdued scarps of probable late Pleistocene age developed on the terrace underlain by the Lindavista Formation.

A group of north-trending faults which probably belong to the same system as the La Nacion fault were mapped just north of the Mexican Border west of San Ysidro. Most of the faults offset strata as young as the Lindavista Formation, and some have topographic features suggestive of late Pleistocene faulting; all are overlain by Holocene alluvium. The structures project into, and presumably are an extension of, a similarly oriented Quaternary fault system described by Minch (1967) about 15 miles southward in northwestern Baja California.

Other north- to northwest-striking faults

Other short faults with northwest strikes are exposed elsewhere in the San Diego area. Some are overlain by the Lindavista Formation, but others, such as on the Point Loma peninsula, offset those strata. Stratigraphic evidence on recency of movement along faults in crystalline basement near El Cajon is lacking, except that these are overlain by Holocene alluvium.

Faults having Quaternary displacements have been postulated for Soledad Valley (south of Del Mar) and Murphy Canyon (south of Miramar) on the basis of topographic anomalies (Ligon, 1969; Peterson, 1970).

Subdued northwest-trending scarps on the otherwise nearly level mesa east of San Ysidro are inferred in this report to be the scarps of faults that have displaced the Lindavista Formation, which caps the mesa.

East- to northeast-striking faults

Faults of this system are exposed chiefly on the Point Loma peninsula and northeast of La Jolla. Displacements along most of these structures are restricted within Cretaceous and Eocene strata and are significantly smaller than those associated with north- to northwest-trending faults. Most east- to northeast-striking faults are overlain by, and therefore are demonstrably older than, undisturbed strata of the Lindavista Formation. Locally, such as south of Del Mar, faults of the system have displaced this lower Pleistocene unit a few feet. The most recent movement along the northeast-striking faults that do cut the Lindavista Formation on the Point Loma peninsula predates the overlapping Bay Point Formation of late Pleistocene age.

Summary

Many faults in the greater San Diego area have proved or reasonably possible displacements younger than the Lindavista Formation (between about 3 million and 500,000 years old; see chart on page 12), or have fault-produced topography of probable late Pleistocene age. The Rose Canyon fault zone and similar north- to northwest-striking faults are part of a linear zone of deformation which extends at least 150 miles along the southern California coast and which includes the tectonically active Newport-Inglewood zone.

The ages of latest displacement for nearly half of the exposed faults in the greater San Diego area are limited by overlying unfaulted strata of either the Bay Point Formation (between 130,000 and 70,000 years old) or the older Lindavista Formation. Minimum age control on recency of faulting along the rest of the faults is provided only by undisturbed Holocene alluvium; displacements during Holocene time (the last 11,000 years) cannot definitely be precluded because the basal alluvium at many places could be only a few hundred years old or less. However, sag depressions and sharply defined scarps commonly associated with Holocene faulting elsewhere in coastal California have not been recognized.

References cited

Artim, E. R., and Pinckney, C. J., 1973, La Nacion fault system, San Diego, California: Geol. Soc. America Bull., (in press).

Howell, J. V., and Weller, J. M., eds., 1960, Glossary of geology and related sciences, with supplement, 2d ed.: Am. Geol. Inst., Wash., D.C., 397 p.

Ligon, L., 1969, A drainage anomaly south of Del Mar, California: San Diego State College, Geology Department, senior report.

Minch, J. A., 1967, Stratigraphy and structure of the Tijuana-Rosarito Beach area, northwestern Baja California, Mexico: Geol. Soc. America Bull., v. 78, p. 1155-1177.

Moore, G. W., and Kennedy, M. P., 1970, Coastal geology of the California-Baja California border area: Am. Assoc. Petroleum Geologists, Pacific Sec., Fall 1970 Guidebook, p. 4-9.

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.

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.

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.

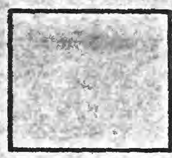
Wiegand, J. W., 1970, Evidence of a San Diego Bay-Tijuana fault: Assoc. Eng. Geologists Bull., v. 7, p. 107-121.

Figure 1- Map showing recency of faulting in the greater San Diego area

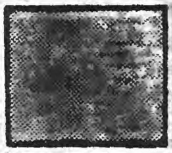
Explanation for Figure 1

MAP UNITS

(onshore area only)



Chiefly pre-Quaternary bedrock at or within 50 feet of ground surface.

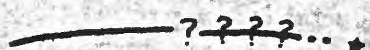


Chiefly alluvial or terrace deposits generally more than 50 feet thick.

RECENCY OF FAULTING

Known or inferred faults are delineated by line symbols for location. Each fault is classed into one of three categories which indicate precision of age of the most recent displacement. Shape symbols superposed on line symbols indicate location of stratigraphic or topographic control for age of the most recent movement.

Line Symbols



Fault

Dotted where inferred beneath covering deposits; queried where existence, continuation, or connection uncertain. ★ indicates short fault with Quaternary displacement.

Age Classes

Three age classes within which the most recent known or inferred displacement has occurred are shown by letter symbol. Faults are assigned to a class chiefly on the basis of stratigraphic or topographic evidence that most closely brackets the age of the most recent displacement. The youngest reasonable age is assumed for deposits whose age is uncertain or in dispute. The age range of each class is shown in the chart on page 12.

Symbol	Class
Q	Quaternary
P	Late Pliocene and Quaternary
U, Um	Unknown

The classes overlap; each extends farther back into geologic time than the preceding one, and therefore represents a longer period within which the most recent fault displacement <u>may</u> have occurred. The "unknown" class represents faults for which information on late Cenozoic history is incomplete because of absence of faulted rocks younger than Cretaceous or Eocene; except for those "unknown" faults with minimum age control (Um), faults classed as "unknown" could have moved as recently as those of any other class.

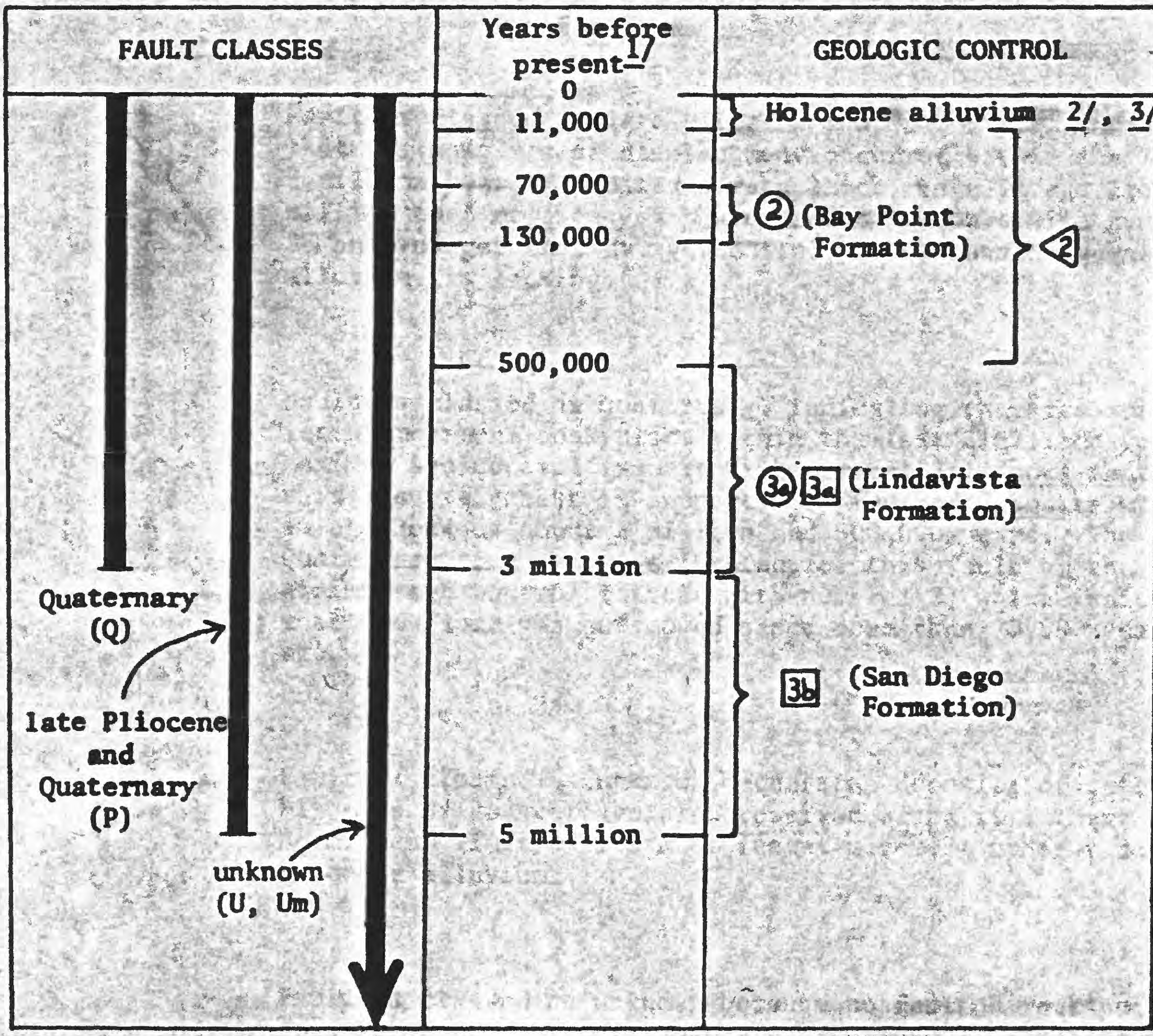
Control Symbols

These symbols show geologic limits on the age of the most recent fault movement and are located on the fault near the point of control. Shape of symbol indicates type of control. Numerals within symbols are keyed to the time range which contains age of geologic control (see chart on following page).

3a 3b	(open square)	Maximum age limited by age of youngest rock displaced by fault
2	(open triangle)	Maximum age limited by probable age of faulted topography (poorly defined lineaments and rounded fault scarps are considered of late Pleistocene age)
2 3a	(open circle)	Minimum age limited by age of oldest rock which is deposited across fault
(no control symbol on fault)		Age inferred, chiefly from spatial relations to other faults

Chart showing possible age ranges of fault classes

and of geologic control for the greater San Diego area

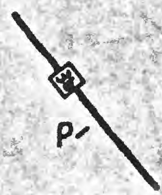


1/ Ages in years are approximate and are based in part on radiometric ages from strata in the Los Angeles basin believed to be correlative. Column is not to scale.

2/ Holocene control is not shown by symbols on map. Where present, Holocene alluvium is deposited across faults; no faults exposed in the San Diego area are known to displace alluvium.

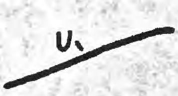
3/ A geologic unit may actually represent only a part of the whole duration of the time range assigned to it. The base of a unit may be younger than the beginning of the time range, and the top may be older than the end of that range. For example, the basal alluvium at many places could be only a few hundred years old or less.

<u>Examples</u>

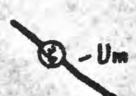


Fault is classed as late Pliocene and Quaternary, indicating that its most recent displacement occurred within the last 5 million years. Faulted strata which range in age from 5 million to 3 million years are present (square with numeral 3b) but younger minimum age control, other than Holocene alluvium, is lacking.

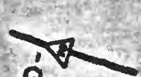
Fault is classed as Quaternary, indicating that its most recent movement took place within the last 3 million years. Maximum age control (square with numeral 3a) shows that this age assignment is supported by faulted deposits with an age between about 3 million and 500,000 years. The Quaternary time range is limited for this fault by the minimum age control (circle with numeral 2) which indicates that the fault has not moved since more than 70,000 years ago.



Fault is classed as unknown because no deposits of late Pliocene or younger age are preserved along it. There is no minimum limit on its most recent movement other than Holocene alluvium.



Fault is classed as unknown because no faulted rocks of late Pliocene or younger age are preserved. Latest movement along it predates, and is limited by, unfaulted deposits between 3 million and 500,000 years old (circle with numeral 3a).



Fault is classed as Quaternary. Maximum age control is provided by fault-produced topography (triangle with numeral 2) inferred to be late Pleistocene in age. Younger age control, other than Holocene alluvium, is lacking.

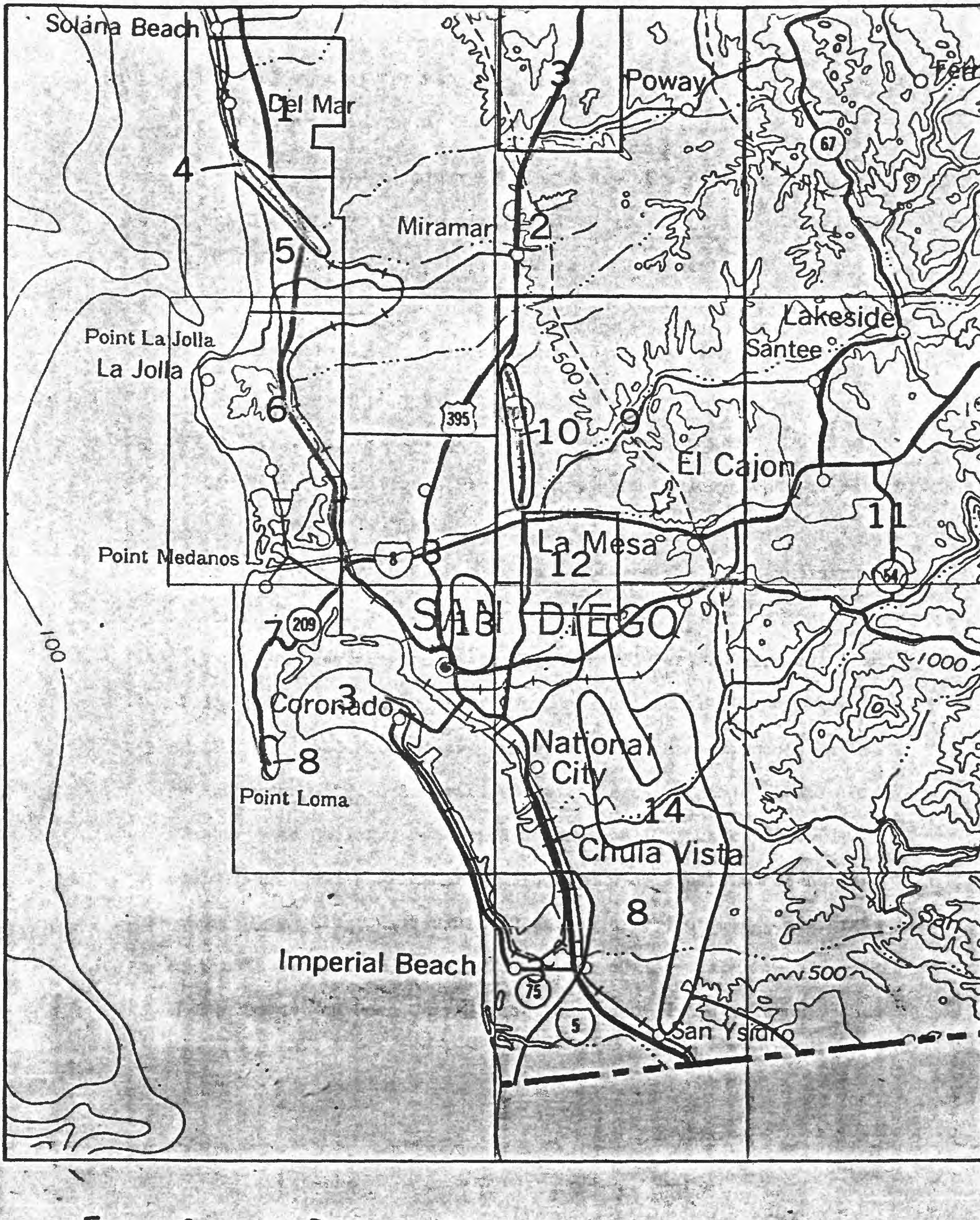


Figure 2- Diagram of map sources

List of sources for map showing recency of faulting

(numbers keyed to diagram of map sources, fig. 2)

1. Kennedy, M. P., 1968, Preliminary geologic map of a portion of northwestern San Diego City, California (Detailed area 2 of 5): California Div. of Mines and Geology, Open File Release 68-1, scale 1:9,600.

2. Kennedy, M. P., Geologic maps of the Del Mar, Poway, and La Jolla quadrangles: California Div. of Mines and Geology, work in progress, 1972, scale 1:24,000.

3. Kennedy, M. P., 1967, Preliminary report, engineering geology of the City of San Diego: California Div. of Mines and Geology, open file report, map scale 1:24,000.

   Quaternary control on Rose Canyon fault zone from field reconnaissance by J. I. Ziony.

4. Ligon, L., 1969, A drainage anomaly south of Del Mar, California: San Diego State College, Geology Department, senior report.

5. Kennedy, M. P., 1968, Preliminary geologic map of a portion of northwestern San Diego City, California (Detailed area 3 of 5): California Div. of Mines and Geology, Open File Release 68-10, scale 1:9,600.

6. Kennedy, M. P., 1969, Preliminary geologic map of a portion of northwestern San Diego City, California (Detailed area 4 of 5): California Div. of Mines and Geology, Open File Release 69-13, scale 1:9,600.

   Quaternary control on Rose Canyon fault zone from field reconnaissance by J. I. Ziony.

Kennedy, M. P., 1969, Preliminary geologic map of a portion of northwestern San Diego City, California (Detailed area 5 of 5): California Div. of Mines and Geology, Open File Release 69-14, scale 1:9,600. Quaternary faulting in part from Woodward-Gizienski and Associates, San Diego, unpublished mapping.

Field reconnaissance by J. I. Ziony.

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Goldstein, G. F., 1956, The geology of the Sweitzer formation at San Diego, California: California Univ. at Los Angeles, M. A. thesis, map scale 1:31,680.

Woodward-Gizienski and Associates, San Diego, unpublished mapping at various scales.