DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

NATIONAL EARTHQUAKE PREDICTION EVALUATION COUNCIL SPECIAL REPORT I

Workshop on Special Study Areas in Southern California
San Diego, California
February 28-March 2, 1985

compiled by
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Open File Report 86-580

This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey publication standards and stratigraphic nomenclature.

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February 28, 1985

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MATERIALS TO FACILITATE DISCUSSION

Based upon the historical and prehistoric record, three segments of the San Andreas fault in southern California appear to be the most likely to generate a large (M>7) earthquake within the next 50 years. These are labelled 2, 5 and 6 in Figure 1. Figures 2 through 16 and 20 illustrate some of the data upon which these forecasts are based.

Figures 17 through 19 depict evidence for historic slippage on the southern most 100 kilometers of the San Andreas fault. Figure 21 is Stuart's suggestion for future activity on the San Andreas fault.

Clearly, the southern San Andreas and the San Jacinto faults can be divided into segments of differing behavior and perceived risk. Is our understanding adequate, however, for selecting one or more sites for expensive and intensive monitoring?

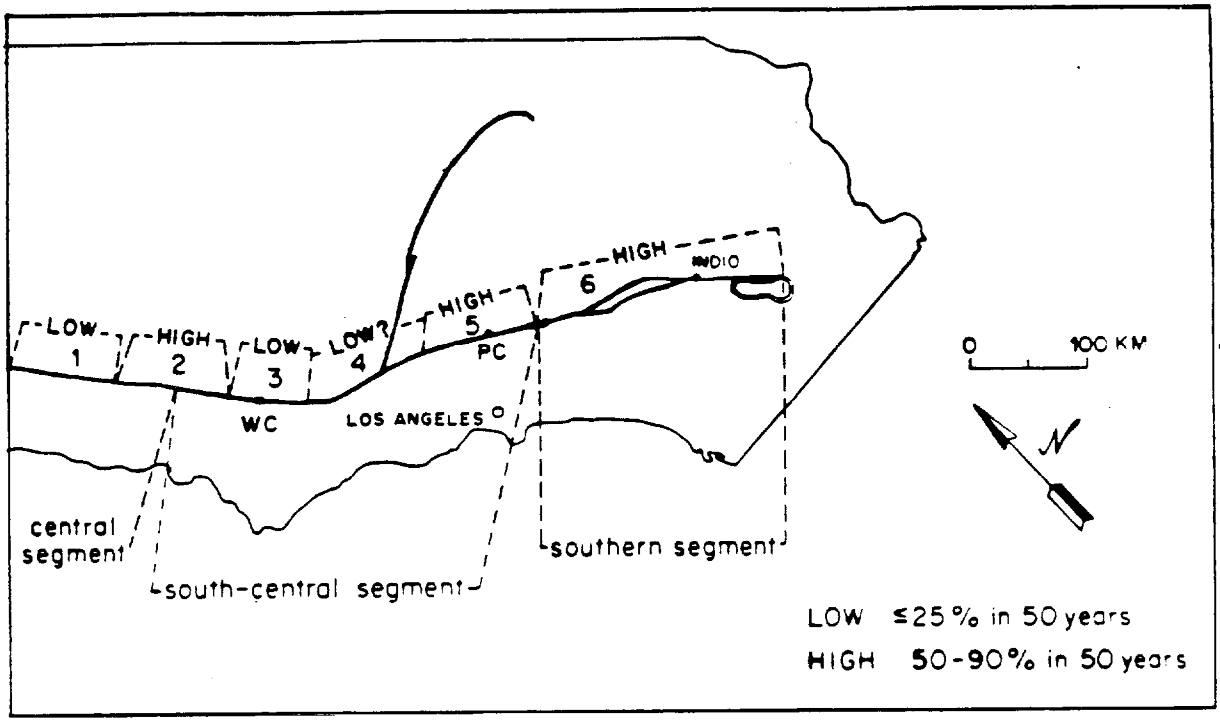


Figure 2. Probabilistic forecasts of large earthquakes along the San Andreas fault in southern California can now be made on the basis of the fault's prehistoric and historic behavior.

Segments labelled 2, 5 and 6 possess the greatest likelihood of rupture within the next 50 years. We plan to concentrate our efforts in 1986 along segments 2 and 6.

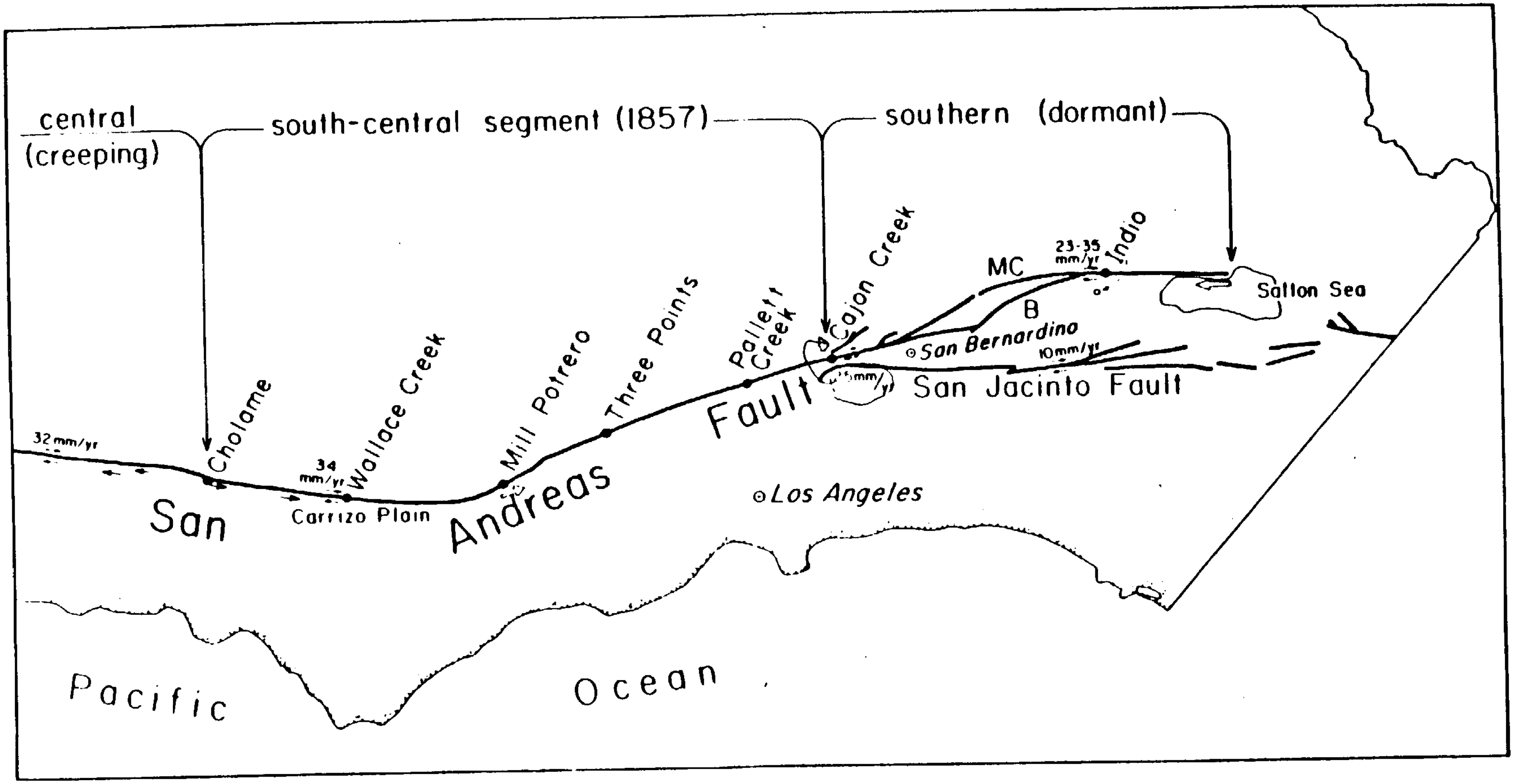


Figure 1. Map of the San Andreas fault in southern California with localities and slip rate values discussed in the proposal. B=Banning fault; MC=Mission Creek fault.

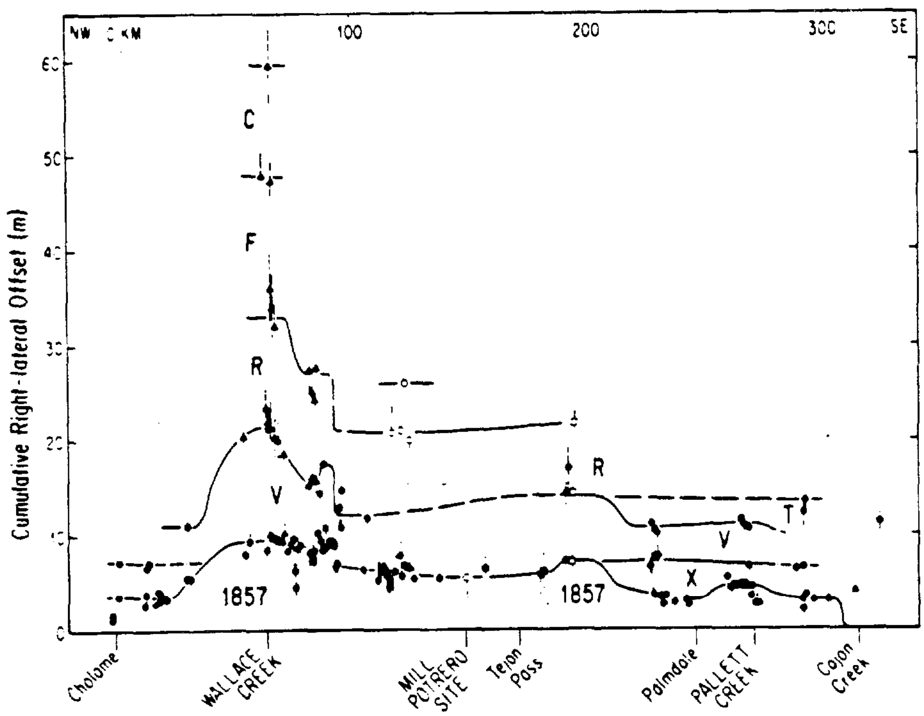


Figure 10. Right-lateral offsets measured along the south-central (1857) segment of the San Andreas fault suggest that slip at each locality is characterized by a particular value. Solid circles are data from Sieh (1978c), with poor-quality data deleted. Open circles are data from Davis (1983). Triangles are new data and remeasurements at sites reported by Sieh (1978c). Open squares are new data. Vertical bars indicate magnitude of imprecision in measurement.

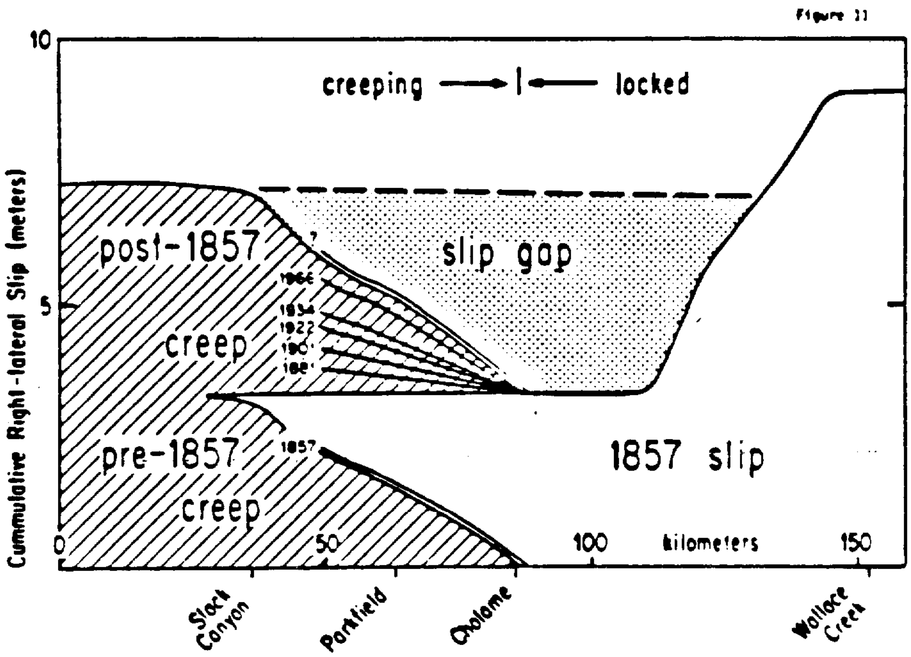


Figure BV-1. A plot of distance along the fault versus cumulative right-lateral slip reveals a historical "slip gap" over a 90-km stretch of the San Andreas fault centered on Cholame. Slip in 1857 amounted to about 3-1/2 m within the gap, whereas at Wallace Creek it was about 9-1/2 m. Assuming strain has been accumulating at 34 mm/yr since 1857, the period between local 1857-size slip events ought to be 240 to 450 years at Wallace Creek, but only 100 years in the "slip gap." Post-1857 creep inferred from modern measurements of creep rate is equal to the accumulated strain to the left (northwest) of Slack Canyon, but is lower between Slack Canyon and Cholame - hence the "slip gap" includes this segment. Pre-1857 slip is assumed to be like post-1857 creep. Location of 1966 rupture is plotted for reference. The slip-gap could generate an M_s = 7 to 7-1/2 earthquake. Figure is from Sieh and Jahns, 1984.

TABLE 2 SMALLEST STREAM OFFSETS NEAR WALLACE CREEK AND PROPOSED INTERVALS BETWEEN GREAT EARTHQUAKES

(1) Stream offsets (m)	(2) Remarks	(3) Produced by	(4) Slip associated with earthquake (m)	(5) Proposed interval between events (yr)
9.5 ± 0.5 (1σ)	Average of 5 measurements	1857 event	9.5 ± 0.5 (1σ)	
				240 to 320§
21.8 ± 1.1	Average of 4 measurements**	1857 plus last prehistoric event	12.3 ± 1.2*	
				300 to 440§
32.8 or 33.5 ± 1.9	Average of 3 measurements**	1857 plus latest 2 prehistoric events	11.0 or 11.7 ± 2.2†	240 to 450§

*21.8 − 9.5 ± $(0.5^2 + 1.1^2)^{1/2}$
†32.8 − 21.8 ± $(1.1^2 + 1.9^2)^{1/2}$ or 33.5 − 21.8 ± $(1.1^2 + 1.9^2)^{1/2}$
§Slip during following earthquake in column 4 divided by average late Holocene slip rate (33.9 ± 2.9 mm/yr)
**These offsets are all between Wallace Creek and Gully D in Figure 1

TABLE 3 SMALLEST STREAM OFFSETS NEAR WALLACE CREEK AND PROPOSED DATES AND CORRELATION OF LATEST FOUR GREAT EARTHQUAKES

(1) Stream offsets (m)	(2) Time required to accumulate offset as elastic strain using average late Holocene slip rate (years)	(3) Proposed dates for latest earthquakes (A.D.)	(4) Possible correlations with events recognized at Pallett Creek	(5) Possible correlations with events recognized at Mill Potrero by Davis (1983)
		1857	Z (1857)	Z (1857)
9.5 ± 0.5 (1σ)	240 to 320			
		1540 to 1630*	V (1550 ± 70)	X (1584 ± 7)
21.8 ± 1.1	560 to 740			
		1120 to 1300†	R (1080 ± 65)	
32.8 or 33.5 ± 1.9	840 to 1140			
		720 to 1020§	F (845 ± 75)	

*1857 − (240 to 320 yr)
†1857 − (560 to 740 yr)
§1857 − (840 to 1140 yr)

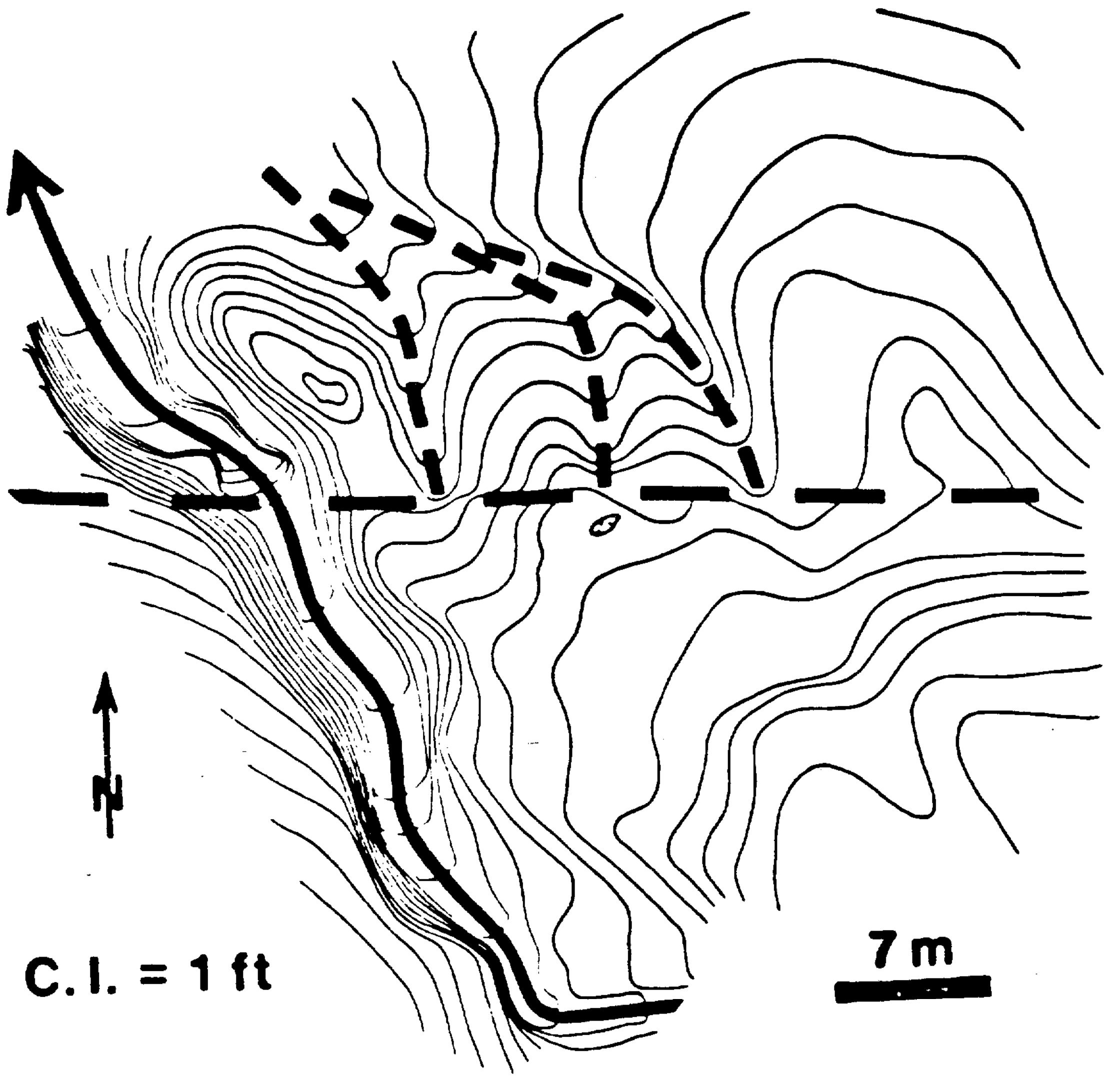


Figure 7. This topographic map shows three offset segments of Cow Spring Creek, From this and related data it appears that right-lateral offsets at the tunnel crossing are characteristically about 7 meters.

TABLE 2. Estimated Dates of Latest 12 Earthquakes at Pallett Creek

Event	Date,[a] A.D.	Remarks
Z	1857	Historically documented.
X	1720 ± 50	Unit 81 date is within period from 140 to 305 years B.P.[b] (i.e., 1730 ± 80 A.D.); event occurs at top of unit, so ~20 years must be added to unit 81 date[c], thus 1750 ± 80 A.D.; historical record precludes event after 1769, thus 1720 ± 50 A.D.
V	1550 ± 70	Weighted average of upper unit 68 (1405–1630 = 1518 ± 112 A.D.) and unit 72 (1485–1660 = 1573 ± 88 A.D.), which bracket the earthquake horizon.
T	1350 ± 50	Unit 61 date is within period from 1280 to 1380 (i.e., 1330 ± 50 A.D.); event occurs at top of unit, so ~20 years must be added to unit 61 date, thus 1350 ± 50 A.D.
R	1080 ± 65	Weighted average of samples PC-223a, PC-28, and PC-207c, which bracket the earthquake horizon.

TABLE 3. Estimated Dates of Earthquakes A Through N, Using Alternate Method

Event	Date, A.D
N	1015 ± 100
I	935 ± 85
F	845 ± 75
D	735 ± 60
C	590 ± 55
B	350 ± 80
A	260 ± 90

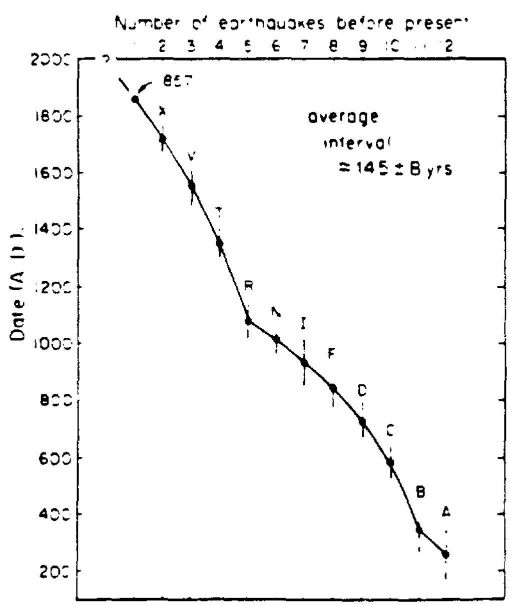


Fig. 16. Revised dates of each earthquake at Pallett Creek

SLIP RATE ON THE SAN ANDREAS FAULT AT CAJON CREEK

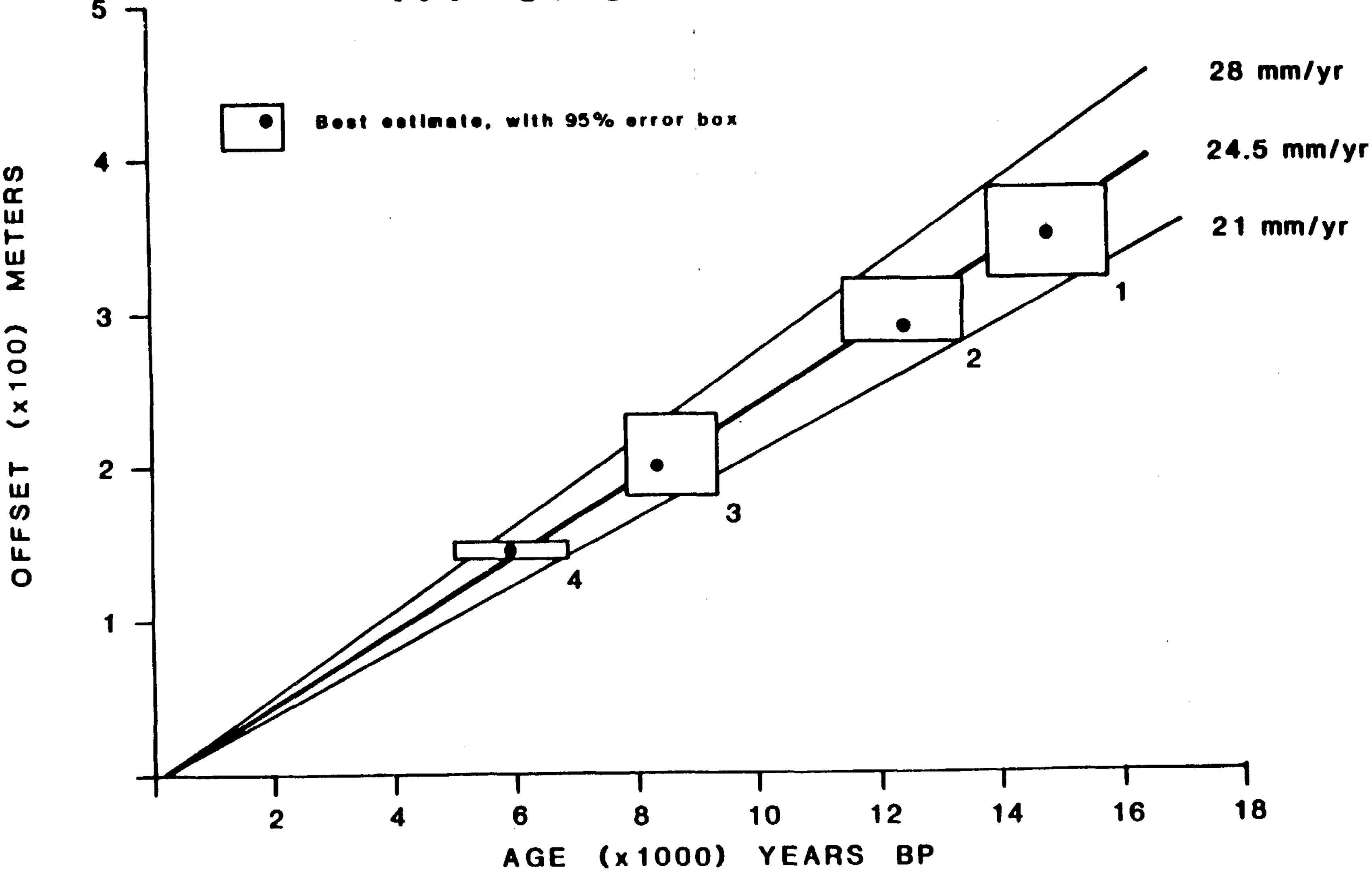


FIGURE 7. Slip rate on the San Andreas fault at Cajon Creek. The points represent our best estimates of the offsets and ages and the boxes represent 95% confidence limits. Each box represents independent offset features, radiocarbon dates and geologic assumptions. The points are not in the center of the boxes due to the asymmetric limits on some of the ages and measurements. The heavy line represents our best estimate of the slip rate at Cajon Creek and the lighter lines are the limits on the rate, constrained to touch each box. The starting point for each line is 170 years ago. This is our best estimate for one-half recurrence intervals after the last earthquake (see text for details).

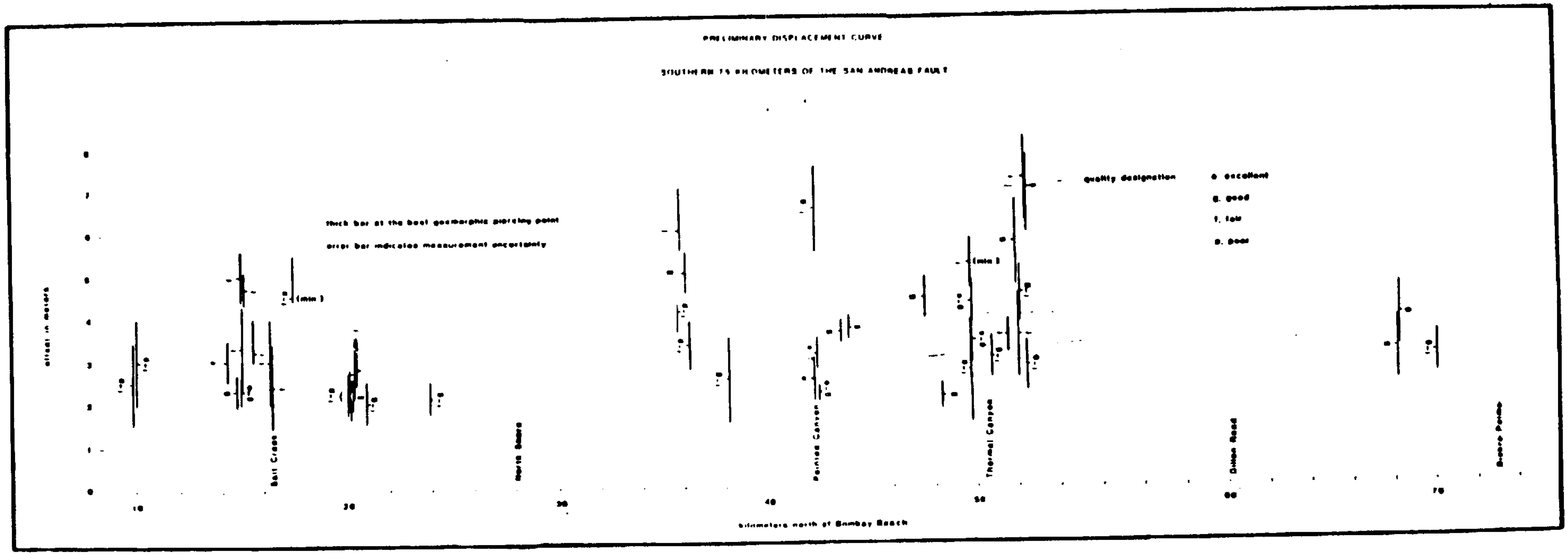

PRELIMINARY DISPLACEMENT CURVE
SOUTHERN 75 KILOMETERS OF THE SAN ANDREAS FAULT
thick bar at the best geomorphic piercing point
error bar indicates measurement uncertainty
quality designation
e. excellent
g. good
f. fair
p. poor
offset in meters
kilometers north of Bombay Beach
Salt Creek
North Shore
Painted Canyon
Thermal Canyon
Dillon Road
10
20
30
40
50
60
70

Figure 3.

10

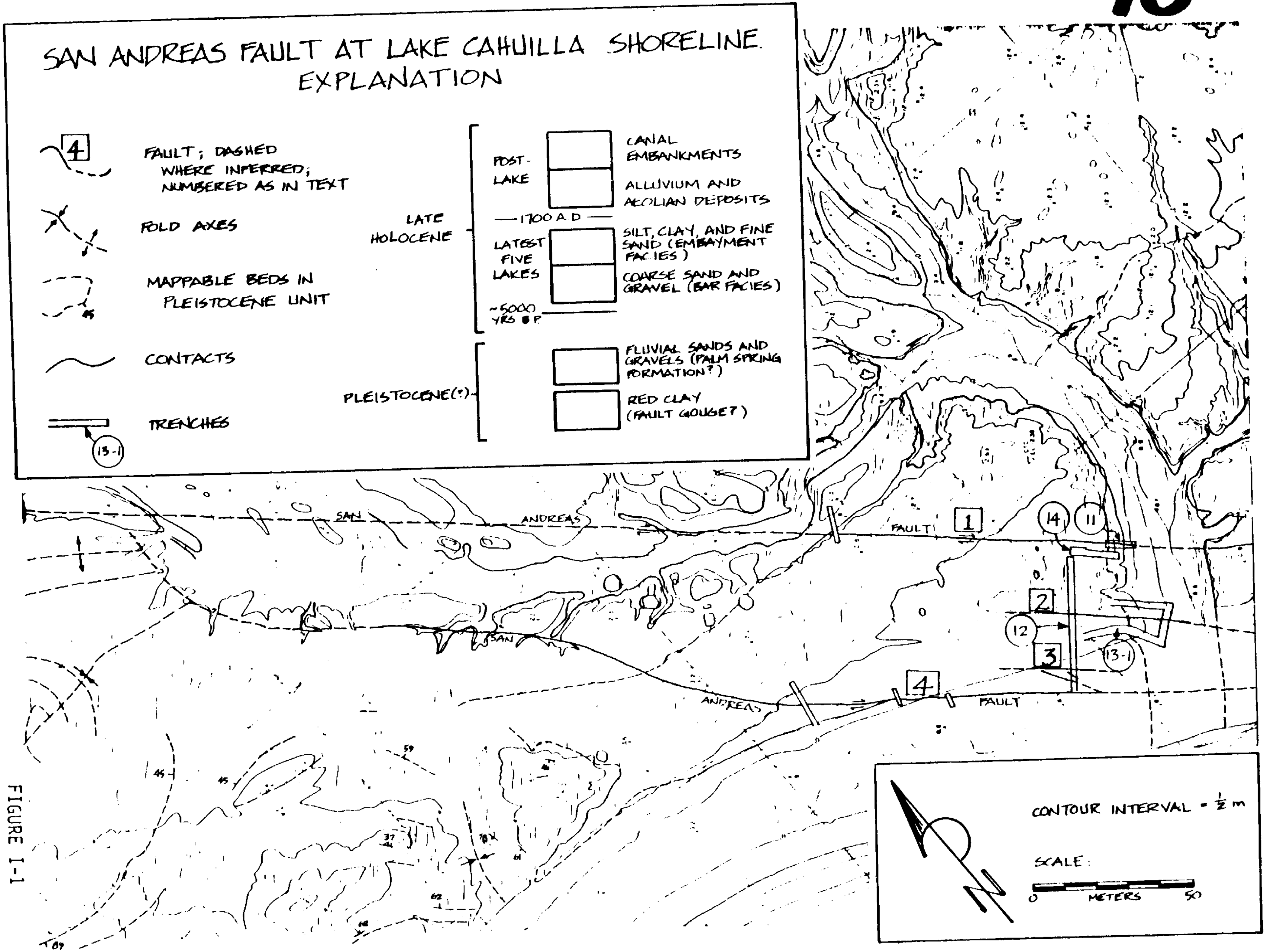

SAN ANDREAS FAULT AT LAKE CAHUILLA SHORELINE
EXPLANATION
FAULT; DASHED WHERE INFERRED; NUMBERED AS IN TEXT
FOLD AXES
MAPPABLE BEDS IN PLEISTOCENE UNIT
CONTACTS
TRENCHES
LATE HOLOCENE
POST-LAKE
CANAL EMBANKMENTS
ALLUVIUM AND AEOLIAN DEPOSITS
1700 A D
LATEST FIVE LAKES
SILT, CLAY, AND FINE SAND (EMBAYMENT FACIES)
COARSE SAND AND GRAVEL (BAR FACIES)
~5000 YRS B P
PLEISTOCENE(?)
FLUVIAL SANDS AND GRAVELS (PALM SPRING FORMATION?)
RED CLAY (FAULT GOUGE?)
SAN ANDREAS FAULT
SAN ANDREAS FAULT
CONTOUR INTERVAL = ½ m
SCALE:
0 METERS 50

FIGURE I-1

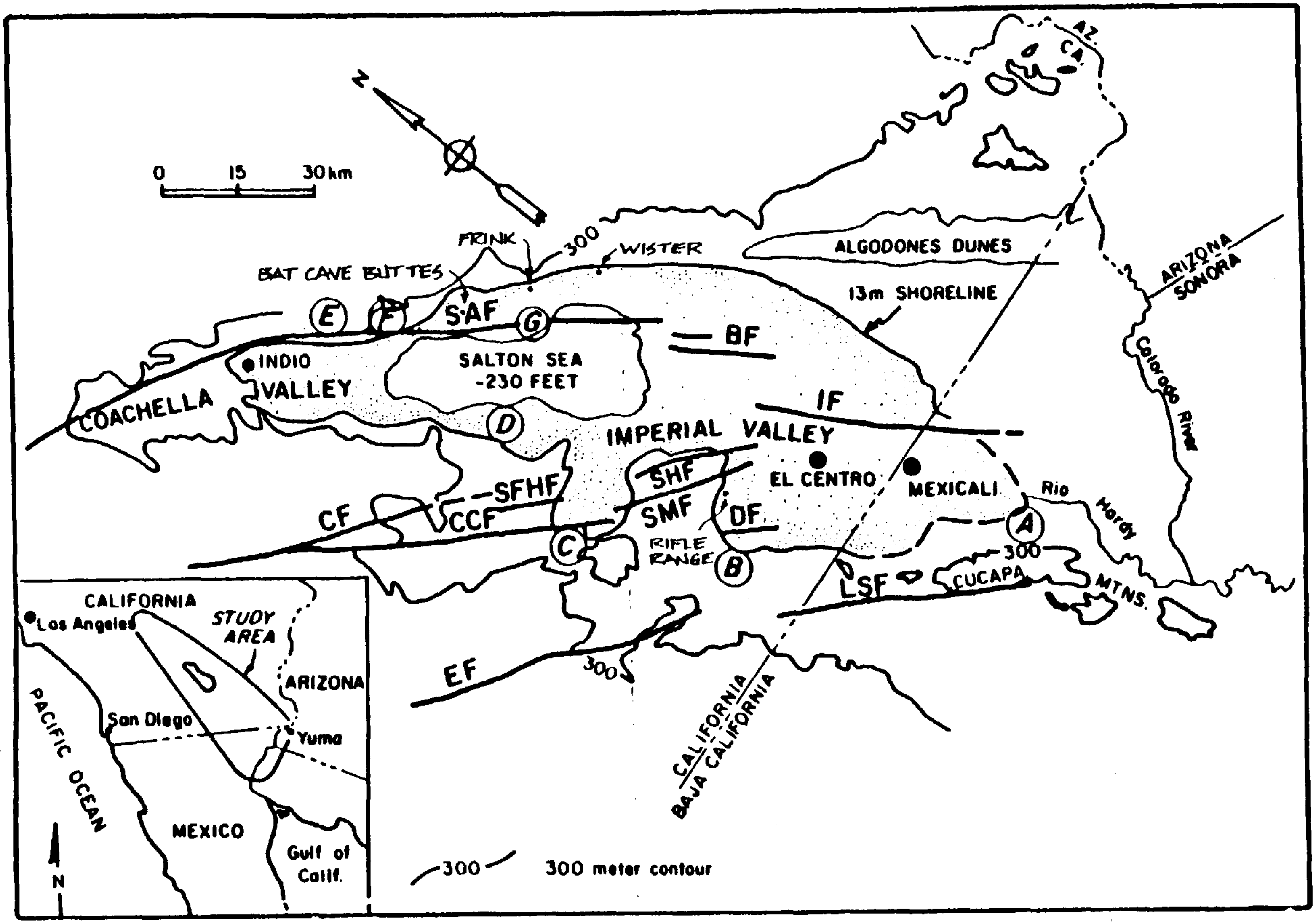


Figure IV-1. Index map of the Imperial and Coachella Valleys showing the major faults and localities mentioned in the text. The faults are named as follows: IF=Imperial fault; BF=Brawley fault; LSF=Laguna Salada fault; SHF=Superstition Hills fault; SMF=Superstition Mountain fault; EF=Elsinore fault; CCF=Coyote Creek fault; CF=Clark fault; SFHF=San Filipe Hills fault; SAF=San Andreas fault. Stipple shows the extent of ancient Lake Cahuilla. The capital letters A through G (clockwise around trough with A at Cerro Prieto) indicate localities mentioned in the text.

Table I-2. Best Estimates for Timing of Lake Cahuilla Activity

Event	Date
Desiccation of latest lake[1]	before 1720
Filling of latest lake[2]	between 1630 and 1700
Penultimate lake full[2]	between 1435 and 1539
Filling of penultimate lake[2]	between 1390 and 1455
Dessication of 3rd lake back[1]	between 1280 and 1420
3rd lake full[2]	between 1210 and 1320 or 1370 and 1385
4th lake full[2]	about 600
Dessication of 5th lake back	before 2550 B.C.

[1] Lake surface below level of Indio Site

[2] Lake surface above level of Indio Site

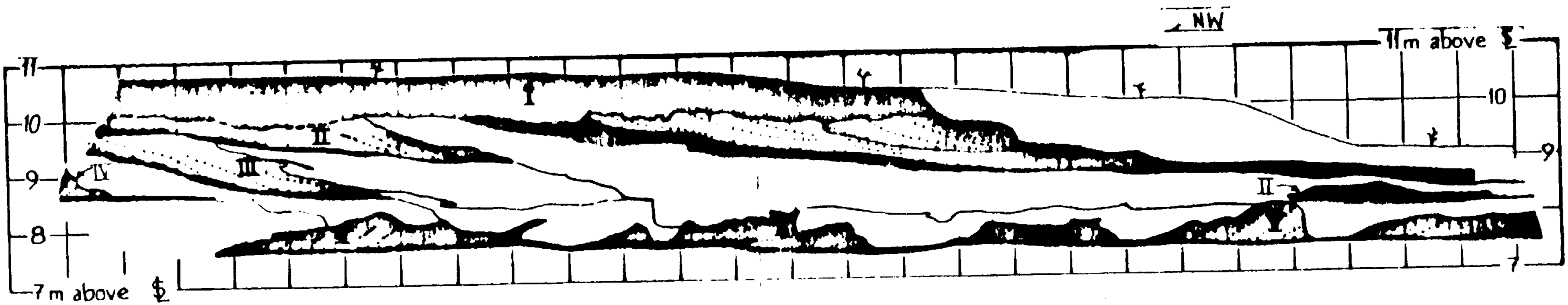


Figure I-2. Highly simplified cartoon of exposed sediments in excavation #13-1 (see Fig. 1-1 for location) within and parallel to San Andreas fault zone east of Indio. Lake deposits are shaded (black: bottomset beds; gray: foreset and topset beds) and labelled I to V (from youngest to oldest). Lake I filled between 1630 and 1700 A.D. Lake II filled between 1390 and 1455 A.D. Lake III filled between 1210 and 1320 A.D. Lake IV filled in about 600 A.D. and Lake V filled prior to 2550 B.C. Unshaded beds are fluvial and aeolian deposits laid down during periods of lake dessication.

B ↓

TRENCH 11, EXPOSURE 6.37

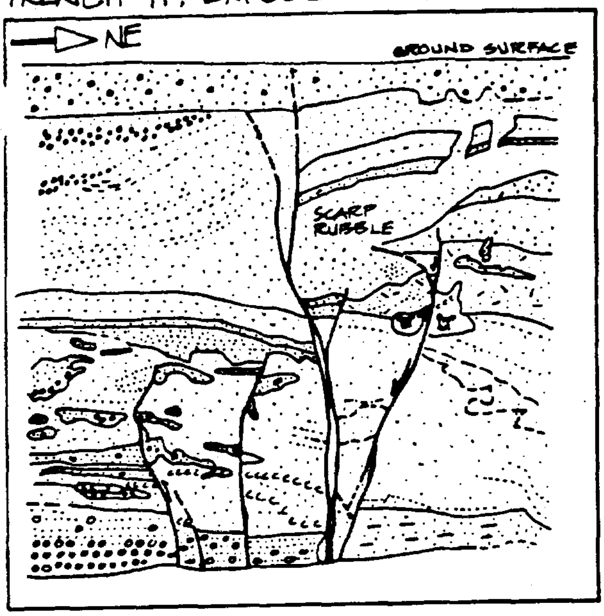


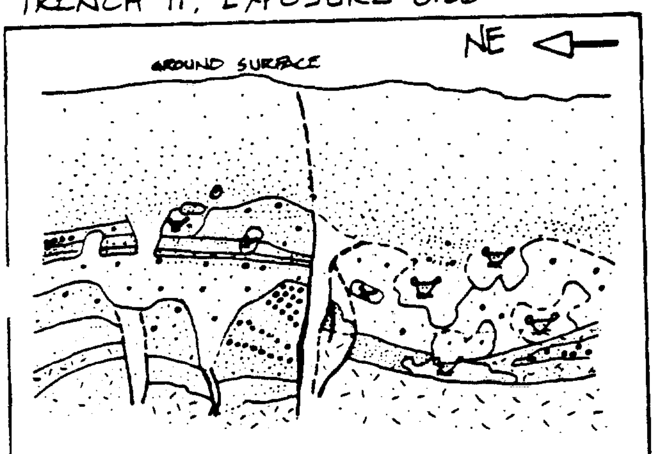
Figure I-4. Various exposures of faulted lake and channel beds at the Indio site.

A. Major disruption of penultimate lake beds in lower left quadrant is buried by unfaulted bottomset beds of latest lake. Fault in center postdates latest lake.

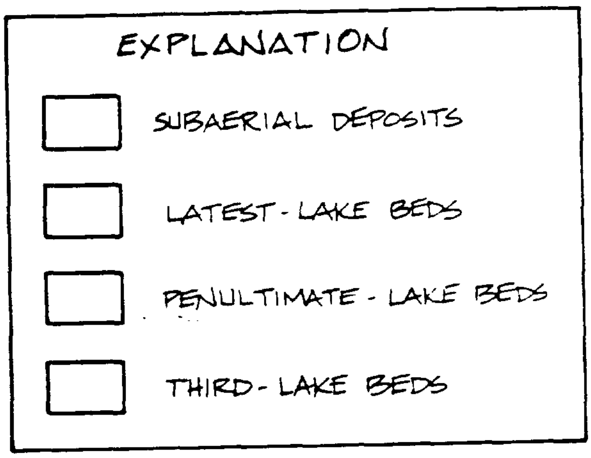
B. Major disruption of channel deposits in lower left quadrant is capped by unfaulted bottomset beds of latest lake. In upper right quadrant, movement on dipping fault resulted in collapse of penultimate lake sands and formation of scarp rubble, which is buried by bottomsets of latest lake. Central fault postdates latest lake beds.

C. Cut parallel and immediately southwest of fault 2 of Figure I-1 displays penultimate and latest lake sediments and superjacent and subjacent channel deposits. See text for discussion.

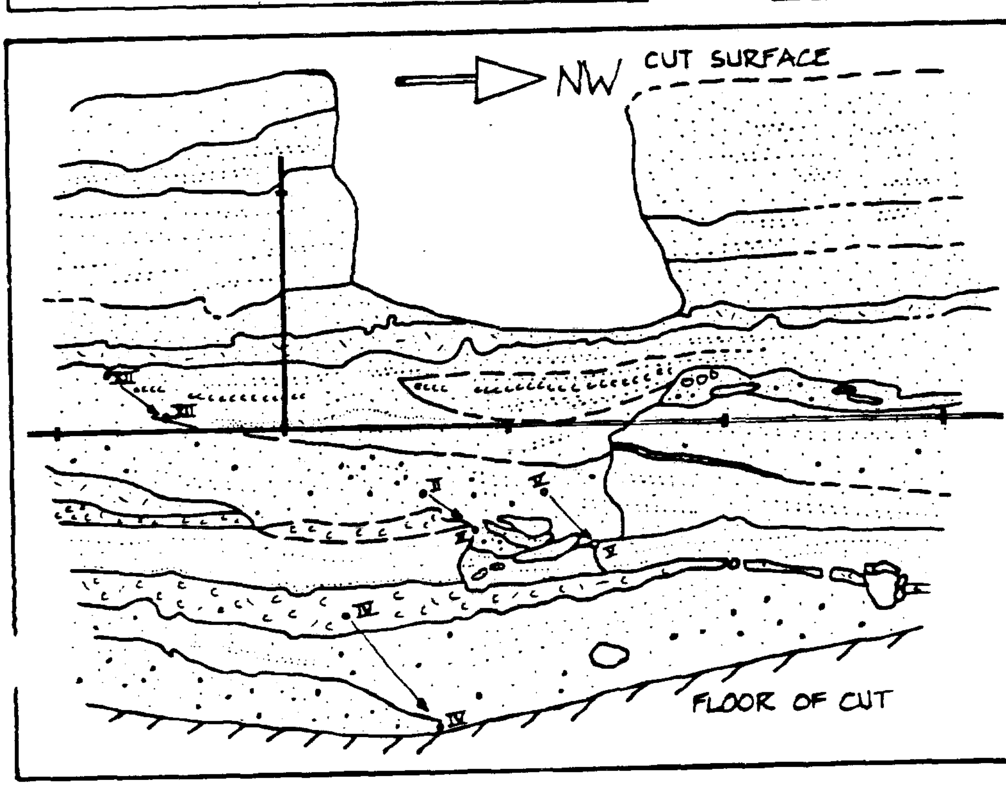
TRENCH 11, EXPOSURE 8.66



A ←



C ↓



PIERCING POINT	HORIZ. SLIP	VERT. SLIP
XII	12 cm	10 cm
II	11 cm	10 cm
V	13 cm	11 cm
IV	21.5 cm	29 cm

TRENCH 13, EXPOSURE 3v

15

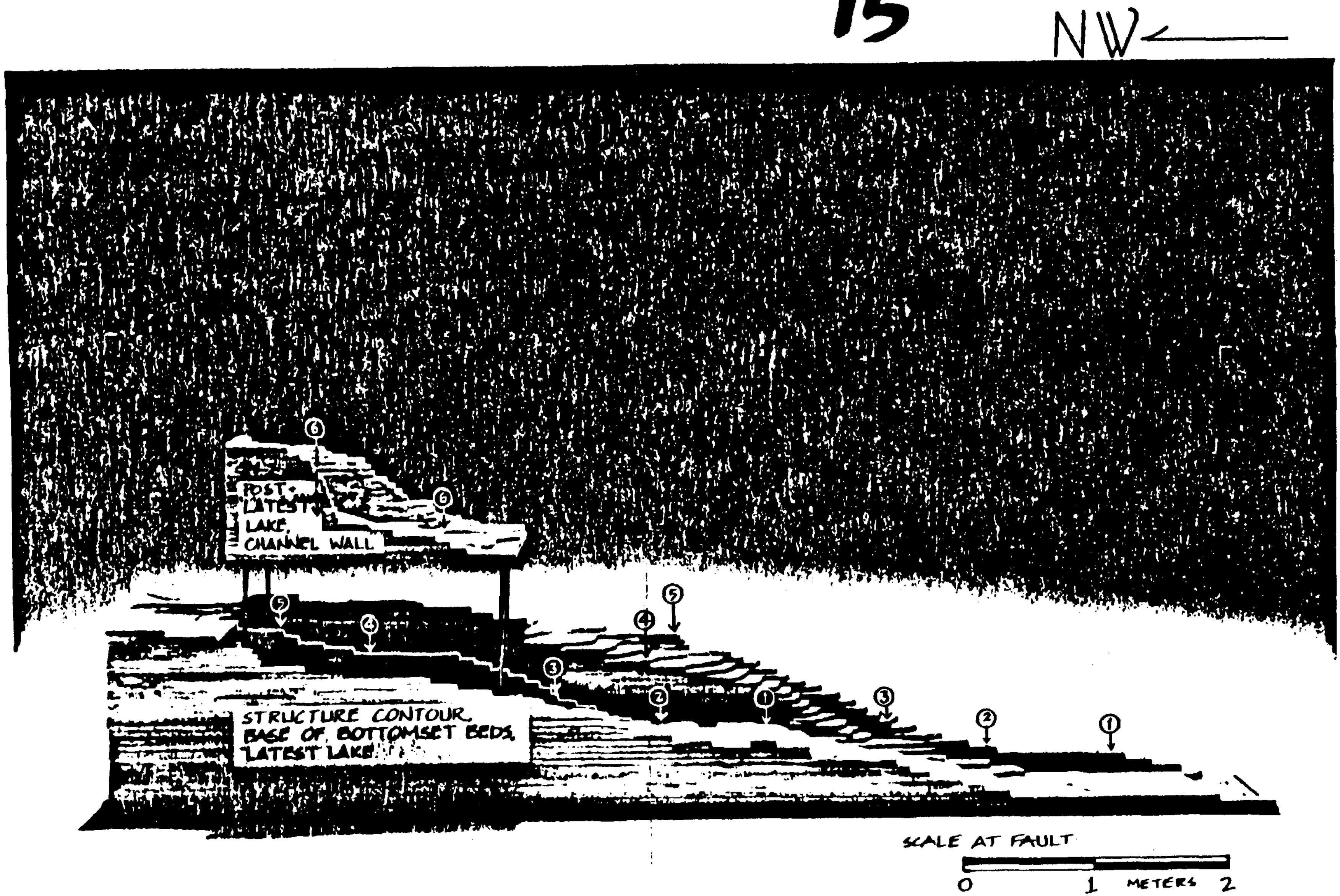


Figure I-5. Balsa models of structure contours drawn on two surfaces offset by fault 1 at site 11 at Indio. Bottomset beds of latest lake are offset about 2.7m, about 1.7m of which occurred during an earthquake in about 1680 A.D. Channel wall of latest lake has been offset about 1 meter since dessication of latest lake. Actual piercing points are not visible in upper model on block nearest viewer because of viewing angle. Circled numbers and arrows indicate offsets.

Table I–3. Offsets Recorded at the Indio Site

FAULT TRACE	1		2		3	4
EVENT	H	V	H	V		
post–1700 A.D.	1m	0.10m	0.03m	0	**	**
~1680 A.D.	1.7m	0.15	0.10	0.12	**	**
~1550 A.D.	yes*	*	0.10	0.18	**	**
~1250 A.D.	*	*	*	*	**	**
~600 A.D.	*	*	*	*	yes**	**

H = horizontal offsets

V = vertical offsets

* indicates data I expect to collect in 1985.

**indicates data I expect to collect in 1986.

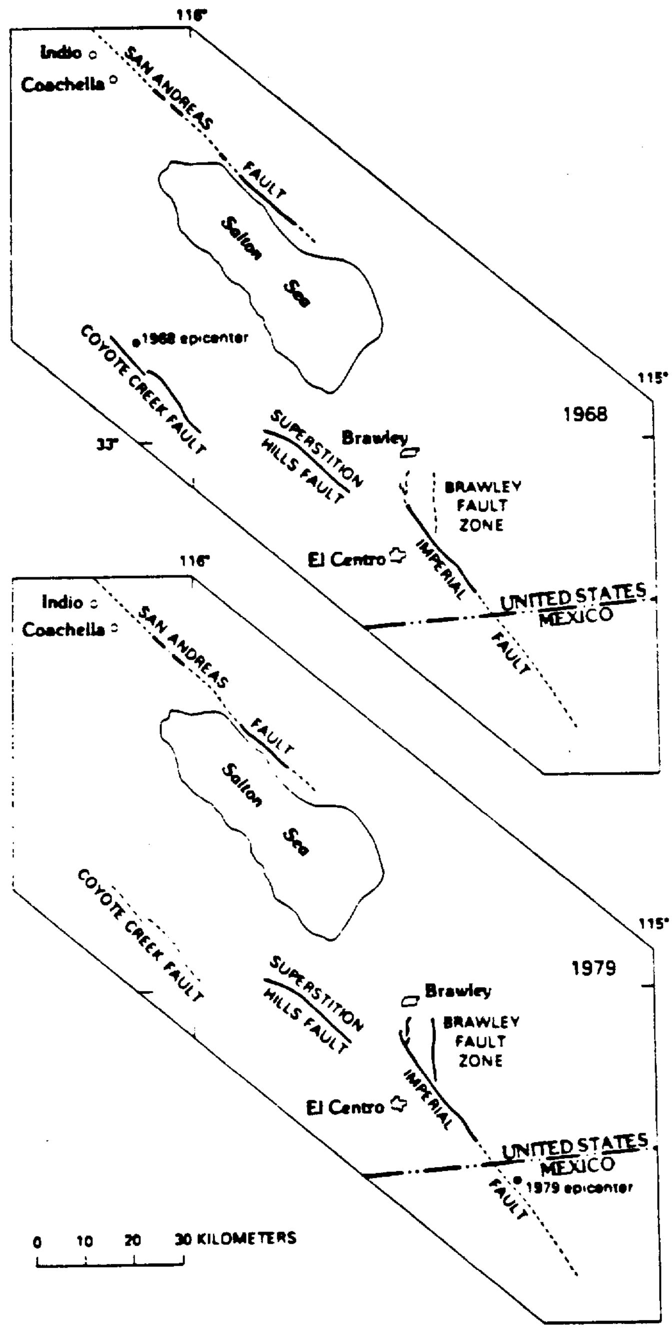
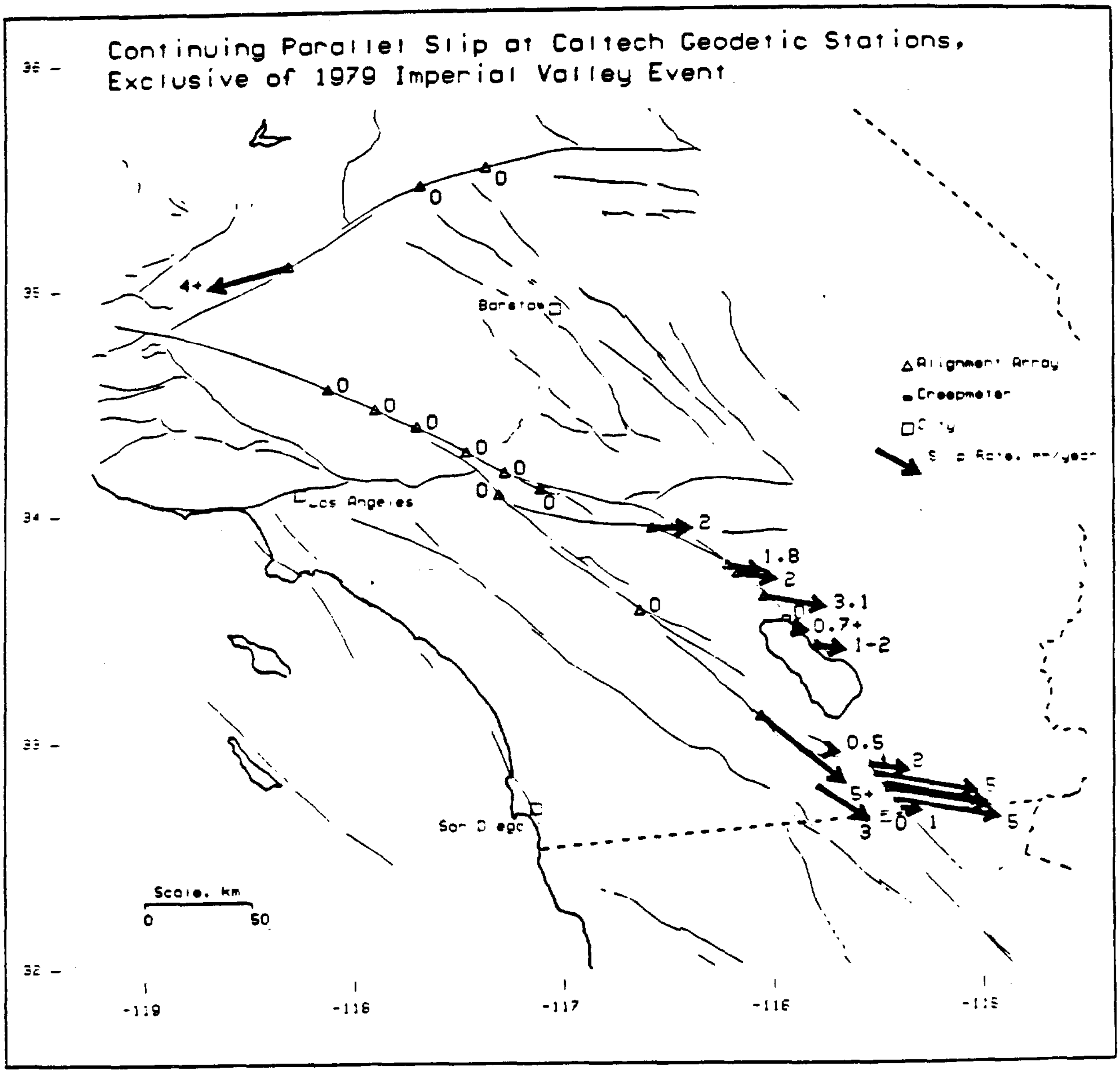
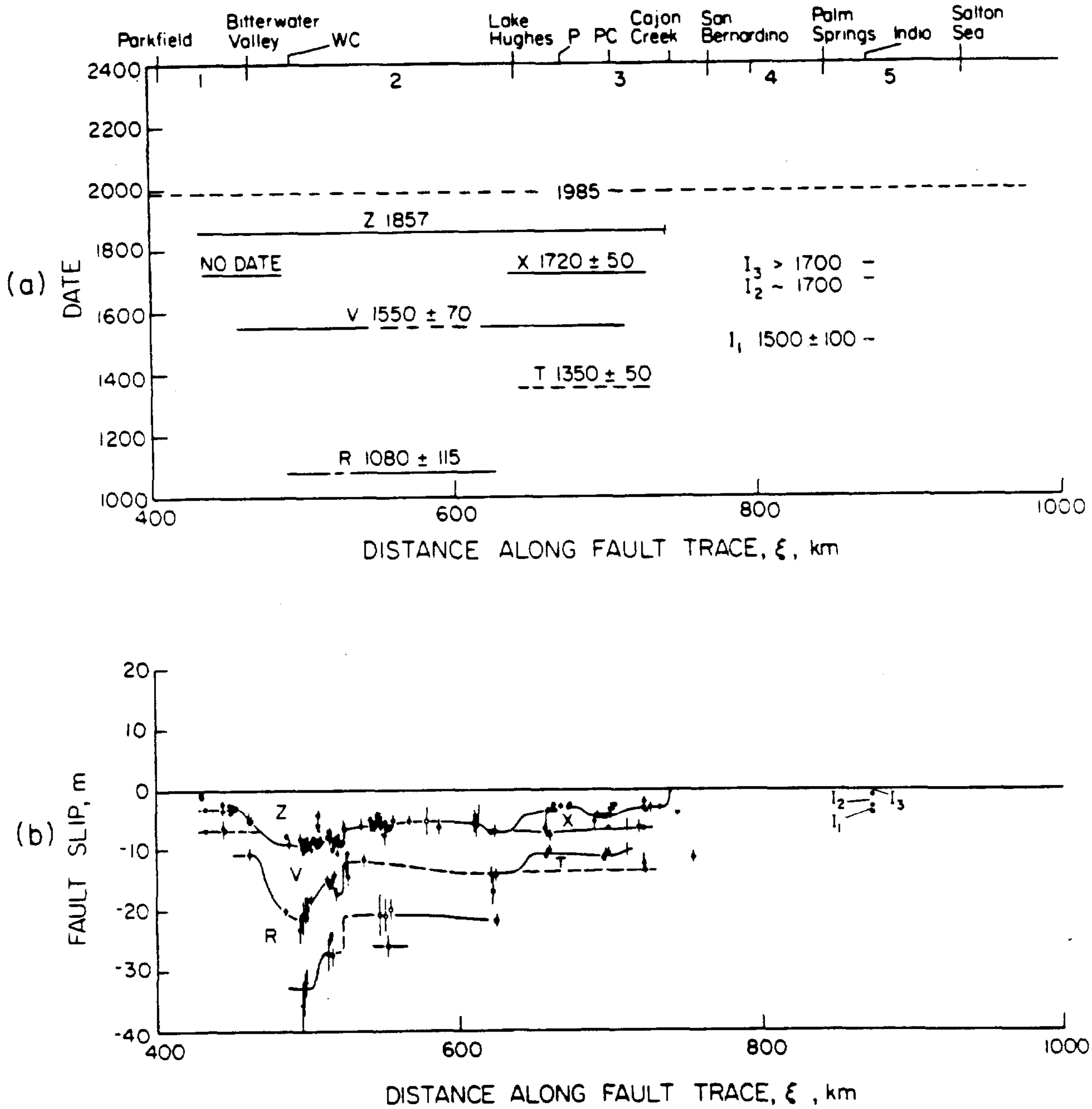


FIGURE 117.—Comparison of slip triggered in 1968 and 1979. In 1968, seismic movement along Coyote Creek fault triggered slip along parts of San Andreas, Superstition Hills, and Imperial faults (heavy lines). In 1979, triggered slip on heavy-lined sections of Superstition Hills and San Andreas faults was associated with seismic rupture on Imperial fault and in Brawley fault zone.



Continuing Parallel Slip at Caltech Geodetic Stations,
Exclusive of 1979 Imperial Valley Event
Alignment Array
Creepmeter
Barstow
Los Angeles
4+
2
1.8
3.1
0.7+
1-2
0.5
5+
3
1
5
Scale, km
0
50
-119
-118
-117
-116
-115

Fig 9


Parkfield
Bitterwater Valley
WC
Lake Hughes
P
PC
Cajon Creek
San Bernardino
Palm Springs
Indio
Salton Sea
1
2
3
4
5
2400
2200
2000
1800
1600
1400
1200
1000
(a)
DATE
1985
Z 1857
NO DATE
X 1720 ± 50
V 1550 ± 70
T 1350 ± 50
R 1080 ± 115
I3 > 1700
I2 ~ 1700
I1 1500 ± 100
400
600
800
1000
DISTANCE ALONG FAULT TRACE, ξ, km
20
10
0
-10
-20
-30
-40
(b)
FAULT SLIP, m
Z
X
V
T
R
I2
I3
I1
400
600
800
1000
DISTANCE ALONG FAULT TRACE, ξ , km

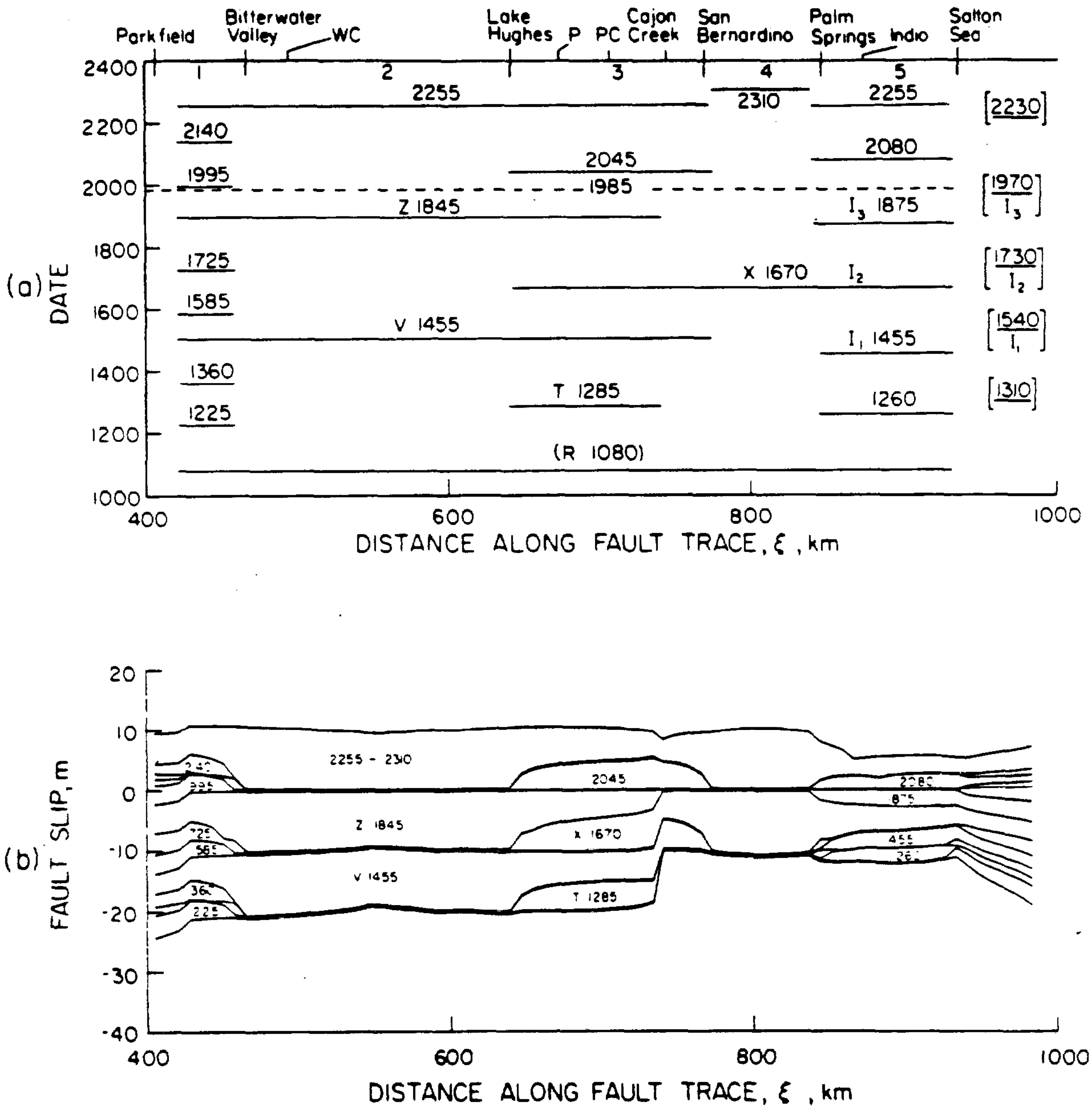

Parkfield
Bitterwater Valley
WC
Lake Hughes
P
PC
Cajon Creek
San Bernardino
Palm Springs
Indio
Salton Sea
1
2
3
4
5
2255
2310
2255
[2230]
2140
2045
2080
1995
1985
[1970 / I_3]
Z 1845
I_3 1875
1725
X 1670
I_2
[1730 / I_2]
1585
V 1455
I_1 1455
[1540 / I_1]
1360
T 1285
1260
[1310]
1225
(R 1080)
(a)
DATE
DISTANCE ALONG FAULT TRACE, ξ, km
2255 - 2310
2045
Z 1845
X 1670
V 1455
T 1285
(b)
FAULT SLIP, m
DISTANCE ALONG FAULT TRACE, ξ, km

Fig.