UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD

PROBABLISTIC SEISMIC AND VOLCANIC HAZARD ESTIMATION

MARCH 8-9, 1994
SAN FRANCISCO

RECENT PROGRESS IN GEOLOGIC AND SEISMIC INVESTIGATIONS AT YUCCA MOUNTAIN, NV

JOHN W. WHITNEY
U. S. GEOLOGICAL SURVEY

NWTRB QUESTIONS & DISCUSSION POINTS

1- DISCUSS RECENT FINDINGS IN TECTONICS ('92-'94)

2- INVESTIGATIONS & RESULTS THAT HAVE THE MOST AND LEAST IMPACT ON THE SEISMIC HAZARD ASSESSMENT. WHY?

3- FUTURE INVESTIGATIONS THAT WILL HAVE THE MOST AND LEAST IMPACT ON SEISMIC HAZARD ASSESSMENT. WHY?

4- DISCUSS PRECLOSURE & POST CLOSURE, SURFACE & UNDERGROUND, GROUND MOTION & FAULT DISPLACEMENT ASPECTS

IMPORTANT FINDINGS FOR SEISMIC HAZARD ASSESSMENT AT YUCCA MOUNTAIN

1- QUATERNARY FAULT MAP OF YUCCA MOUNTAIN

2- MAP OF QUATERNARY FAULTS WITHIN 100KM OF YUCCA MOUNTAIN

3- FAULT BEHAVIOR STUDIES COMPLETED OR NEARLY COMPLETE ON THE FOLLOWING FAULTS:

- -- BOW RIDGE
- -- SOLITARIO CANYON
- -- WINDY WASH (PLUS LONG-TERM OFFSET RATE)
- -- PAINTBRUSH CANYON
- -- STAGECOACH ROAD
- -- BARE MOUNTAIN
- -- DEATH VALLEY-FURNACE CREEK

4- MIDWAY VALLEY STUDY COMPLETED

5- 10-YEAR GPS SURVEY COMPLETED

6- ANALYSIS OF THE LITTLE SKULL EARTHQUAKE AND AFTERSHOCK SEQUENCES

7- INITIAL ASSESSMENT OF RELEVANT EARTHQUAKE SOURCES

8- PRELIMINARY PSHA OF THE ESF AT YUCCA MTN

9- PRELIMINARY TECTONIC MODEL OF YUCCA MTN

MOST IMPORTANT FUTURE STUDIES FOR SEISMIC HAZARD ASSESSMENTS AT YUCCA MOUNTAIN

1- SEISMIC REFLECTION PROFILES ACROSS BARE MTN, CRATER FLAT, YUCCA MTN, AND FORTYMILE WASH

2- DETAILED MAPPING OF FAULTS WITHIN PROPOSED REPOSITORY BLOCK (SURFACE & UNDERGROUND)

3- ANALYSIS OF FAULT MOVEMENT HISTORY ON THE GHOST DANCE AND SUNDANCE FAULTS

4- REFINE AGES OF PALEOSEISMIC EVENTS

5- COMPLETE PALEOSEISMIC INVESTIGATIONS OF RELEVANT EARTHQUAKE SOURCES

6- GROUND MOTION MODELLING OF RELEVANT EARTHQUAKE SOURCES

7- REFINE KNOWLEDGE OF FAULT GEOMETRIES

8- ASSESS POSSIBLE CONNECTIONS BETWEEN QUATERNARY FAULTS AT YUCCA MTN

9- IMPROVED EARTHQUAKE LOCATIONS

10- HISTORIC EARTHQUAKE CATALOG

11- LOCAL SITE EFFECTS ON GROUND MOTIONS

12- REFINE TECTONIC MODEL(S) OF YUCCA MTN

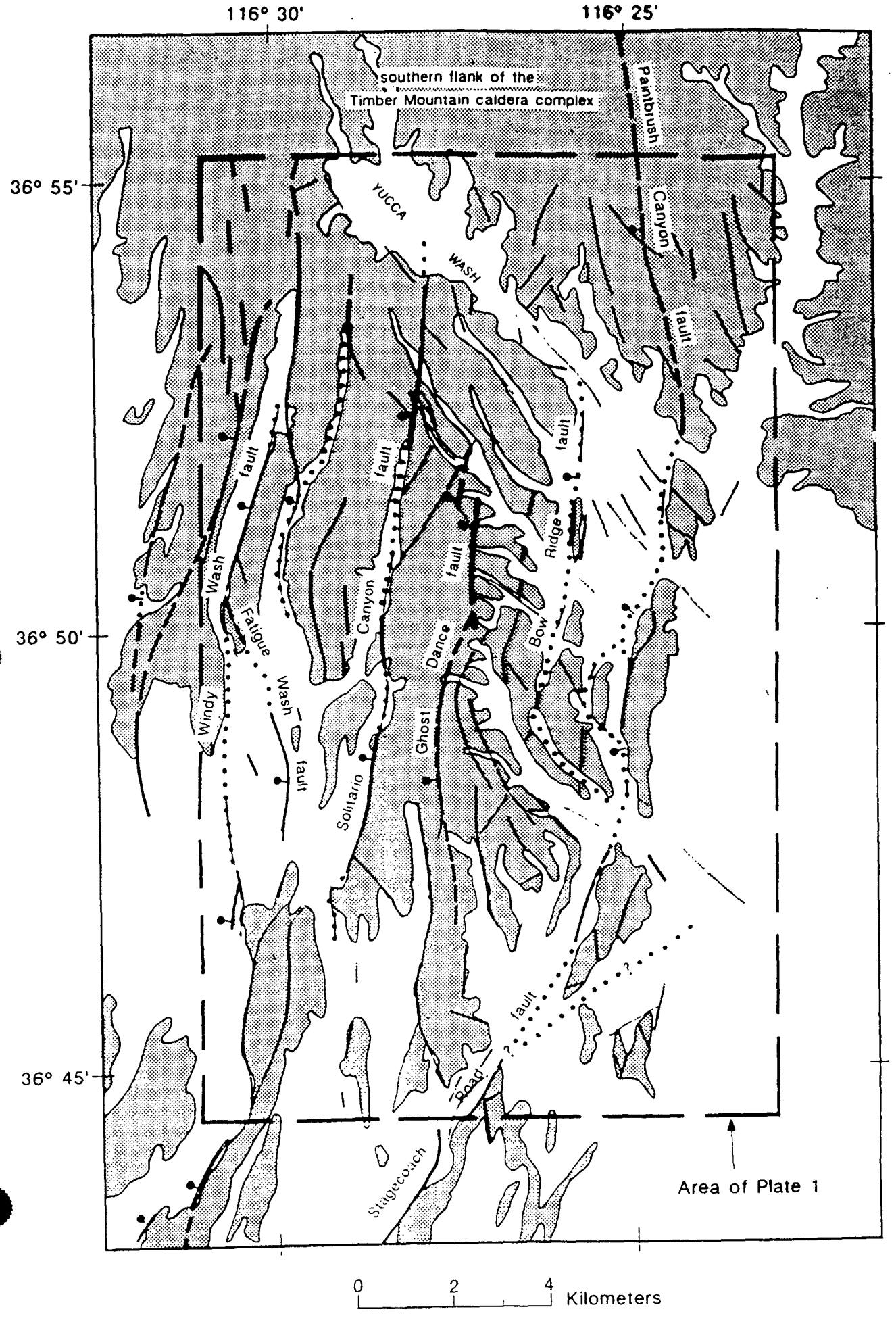
SITE CHARACTERIZATION STUDIES THAT HAVE THE LEAST IMPACT ON SEISMIC HAZARD ASSESSMENTS

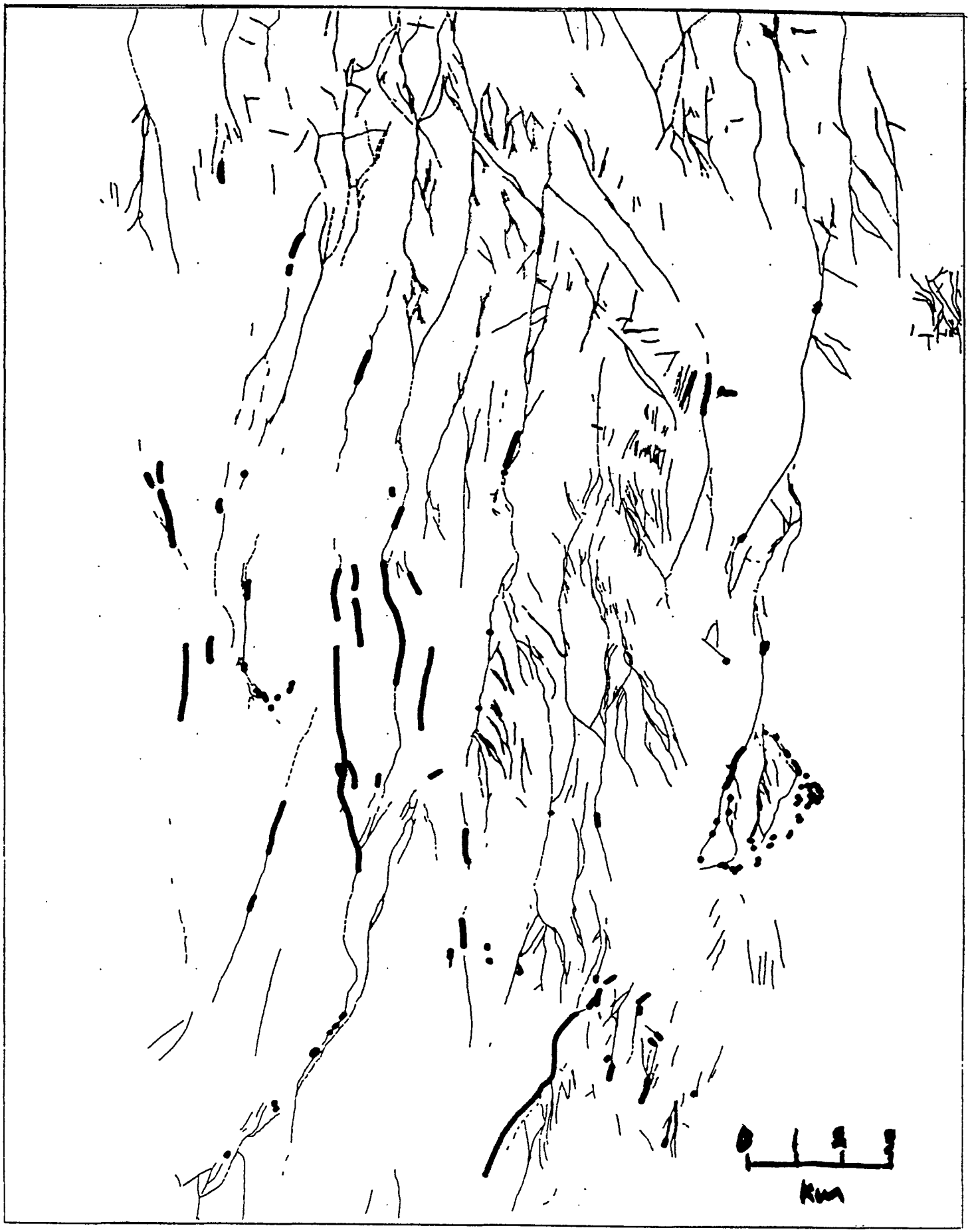
1- TECTONIC GEOMORPHOLOGY

2- FOLDING IN MIOCENE ROCKS

3- LATERAL CRUSTAL MOVEMENT

4- TECTONIC EFFECTS ON THE WATER TABLE, PERCOLATION FLUX RATES, FRACTURE PERMEABILTY, & ROCK GEOCHEMICAL STUDIES


116° 30'
116° 25'
36° 55'
36° 50'
36° 45'
southern flank of the
Timber Mountain caldera complex
Paintbrush
Canyon
fault
YUCCA
WASH
fault
fault
fault
Ridge
Bow
Dance
Ghost
Canyon
Fatigue
Wash
Windy
Wash
fault
Solitario
fault
?
?
Road
Stagecoach
Area of Plate 1
0
2
4
Kilometers

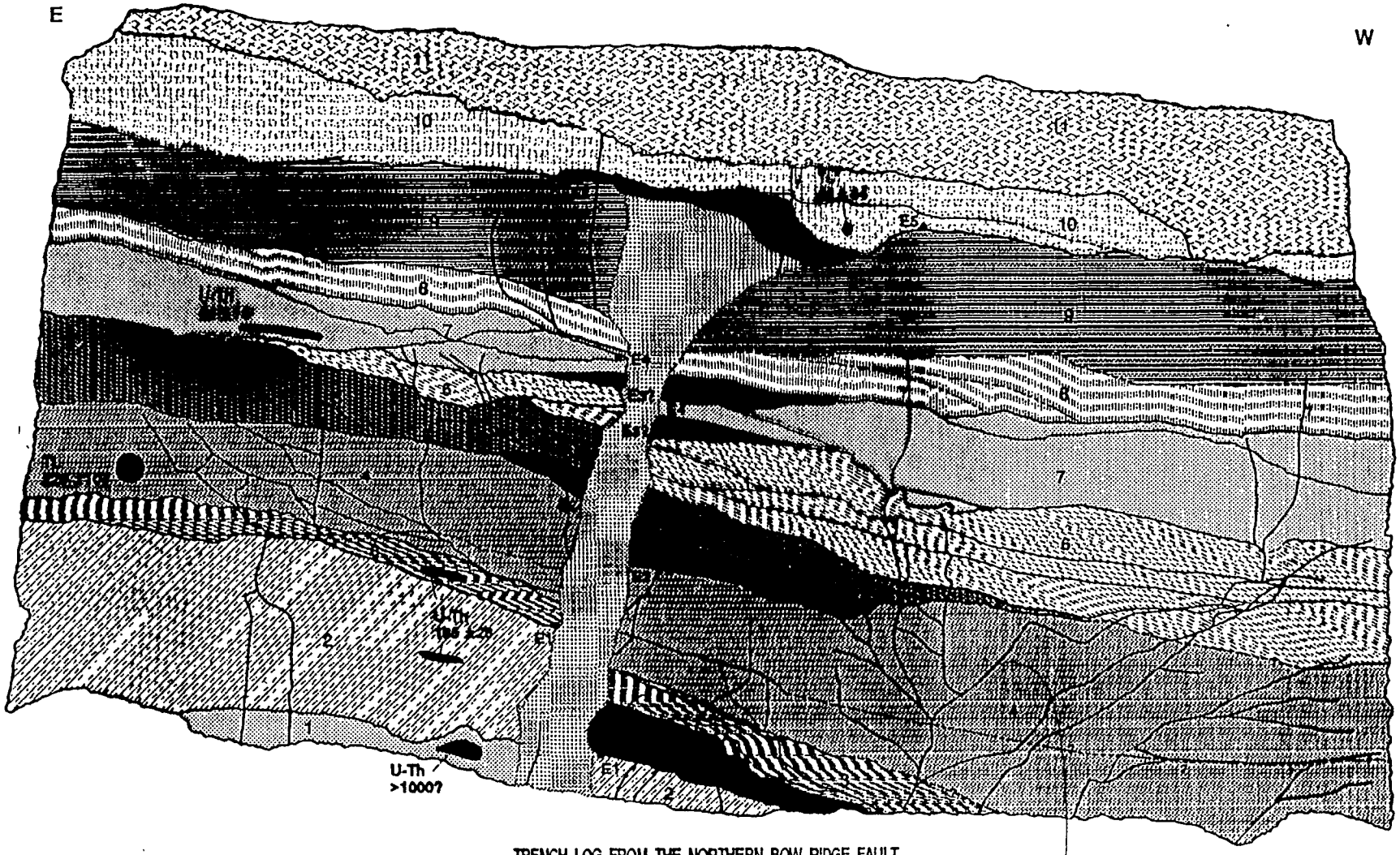


A FAULT MAP OF THE YUCCA MOUNTAIN AREA, NYE COUNTY, NEVADA

TRENCH SITES BY FAULTS

FAULT	SITE	TRENCHES
Paintbrush Canyon	3	6
Bow Ridge	1	2
Stagecoach Road	2	3
Solitario Canyon	7	7
Fatigue Wash	1	1
Windy Wash	1	3
Ghostdance/Sundance	3	3
Pagony Wash	1	1

USGS-YMP DOE/TPR 2/94



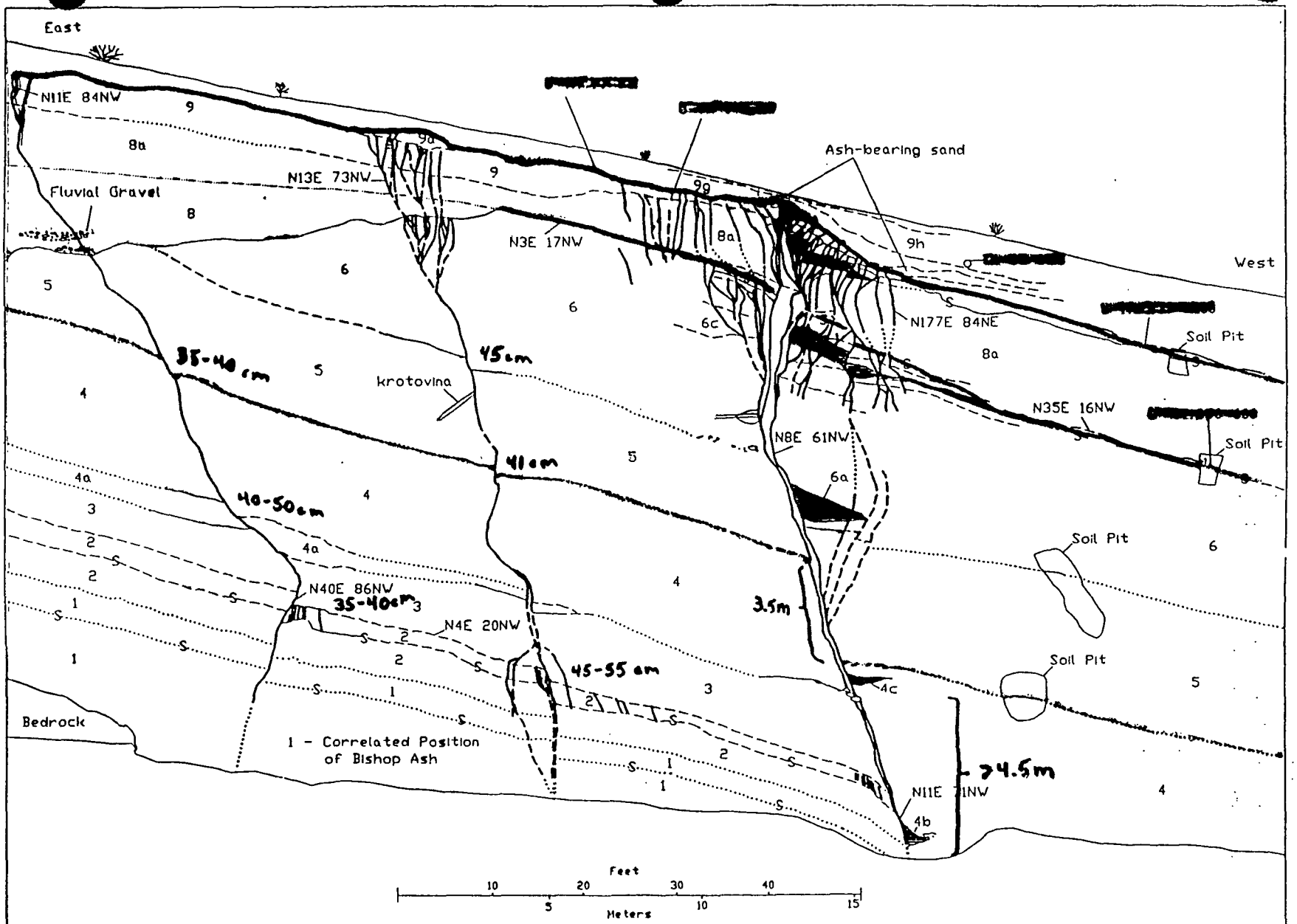
TRENCH LOG FROM THE NORTHERN BOW RIDGE FAULT
TRENCH 14D, INNER (SOUTH) WALL, NORTH BRANCH

Horizontal and Vertical Scale are Equal

0 0.5 1

Meters

EG&G YMP-94-019.0



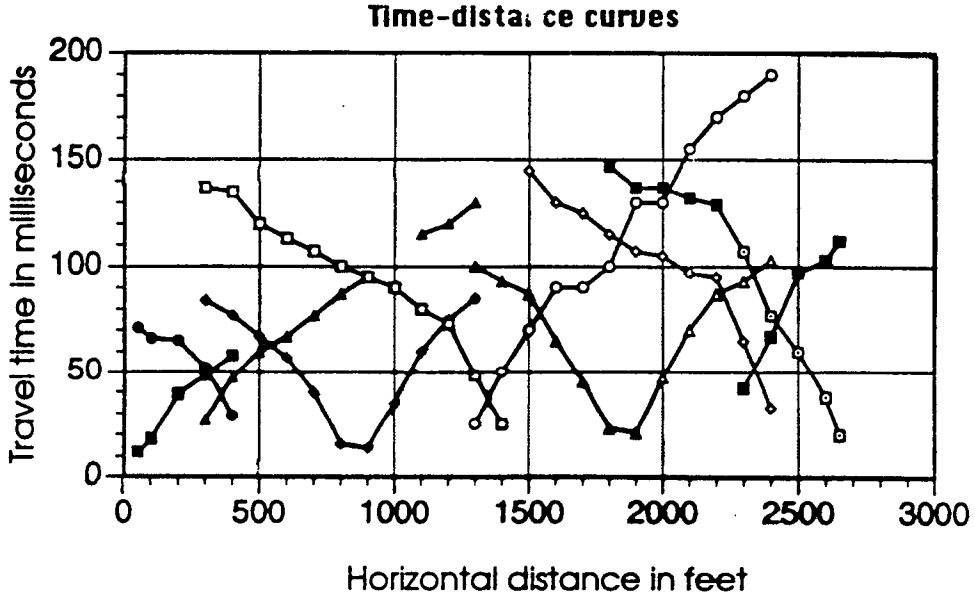
PRELIMINARY LOG OF A NATURAL EXPOSURE OF THE PAINTBRUSH CANYON FAULT AT BUSTED BUTTE WALL 4, NYE COUNTY, NEVADA

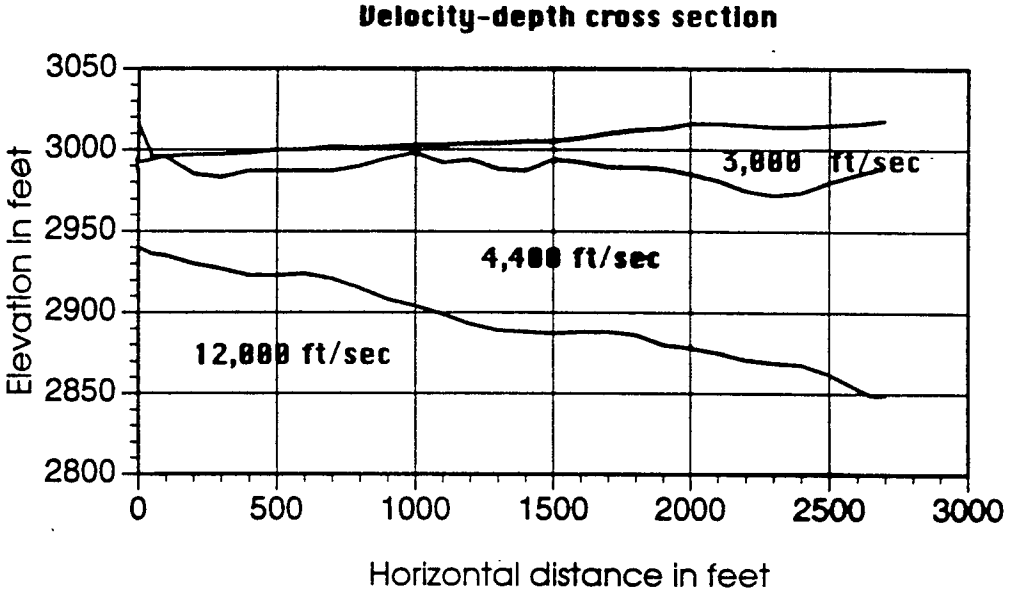
PALEOSEISMIC DATA

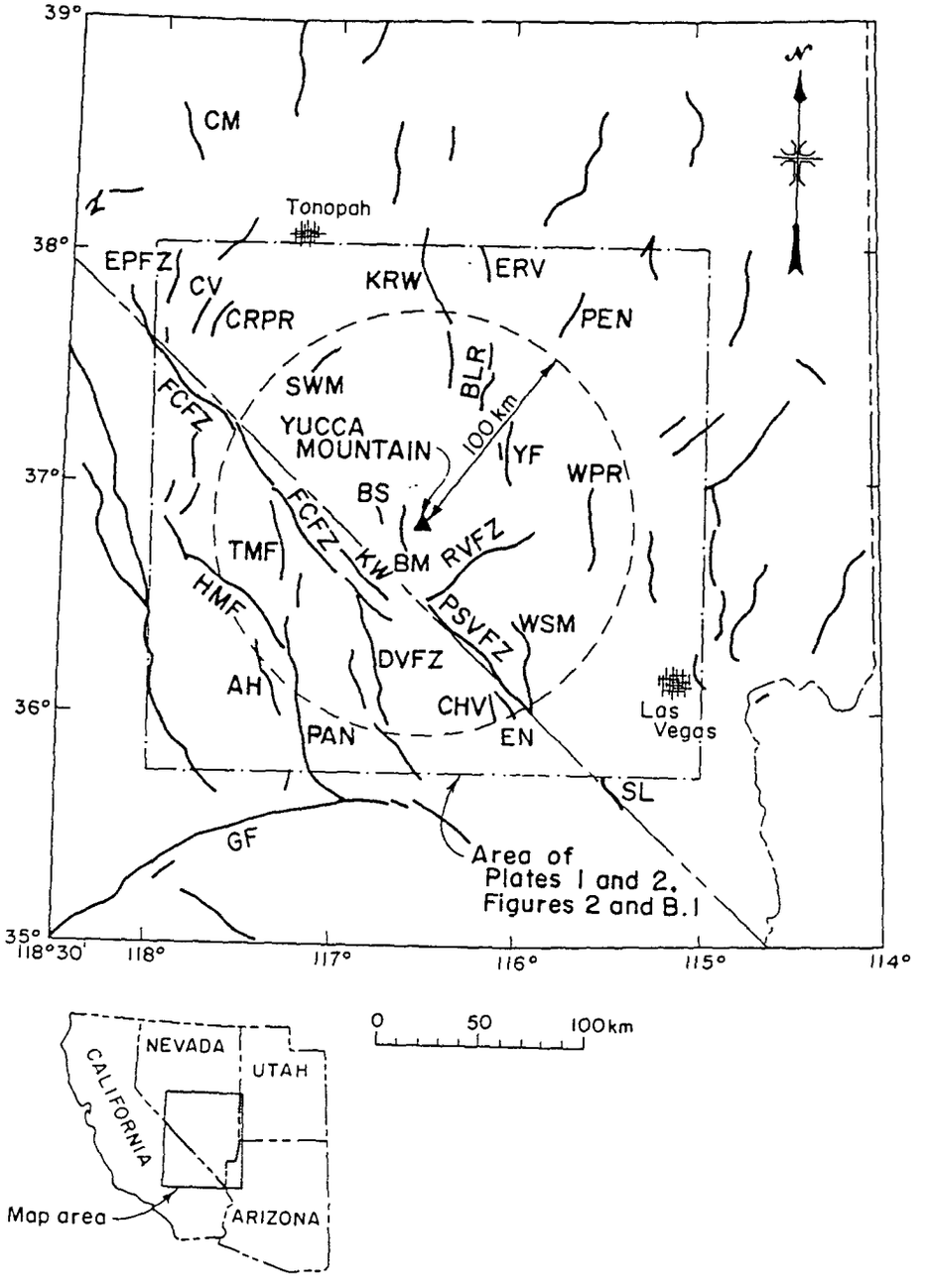
PRELIMINARY RESULTS

- Fault Lengths: 5 - 20 km
- Number of Events: 2 - 5 (past 100 ka)
- Displacment Sizes / Event: 10-100 cm
- Recurrence Intervals: 20 ka - 100 ka
- Slip Rates: 0.001 - 0.02 mm/yr

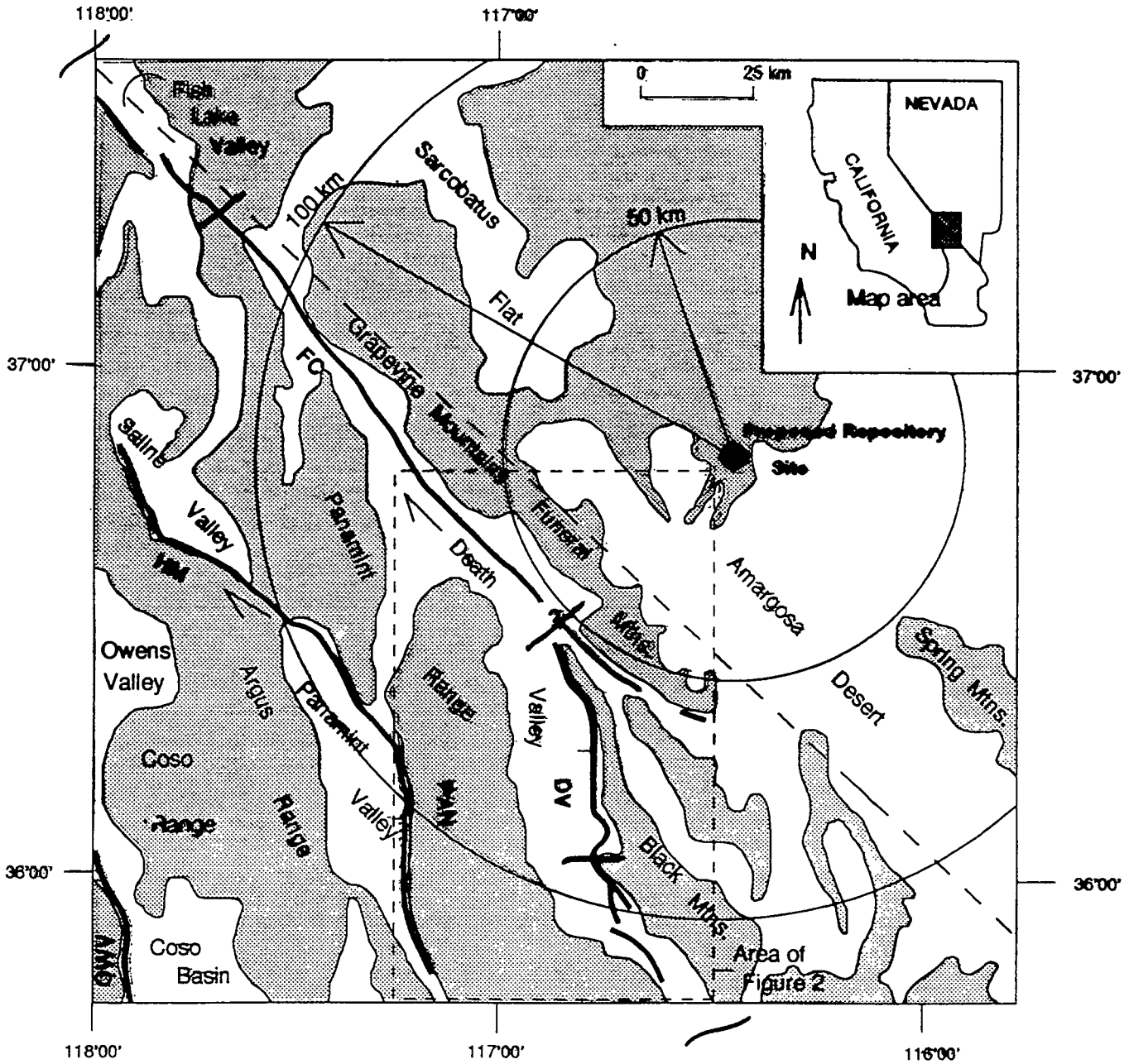
SEISMIC LINE PERPENDICULAR TO WINDY WASH FAULT







Major known and suspected Quaternary faults in southern Nevada and southeastern California in the regional surrounding Yucca Mountain.

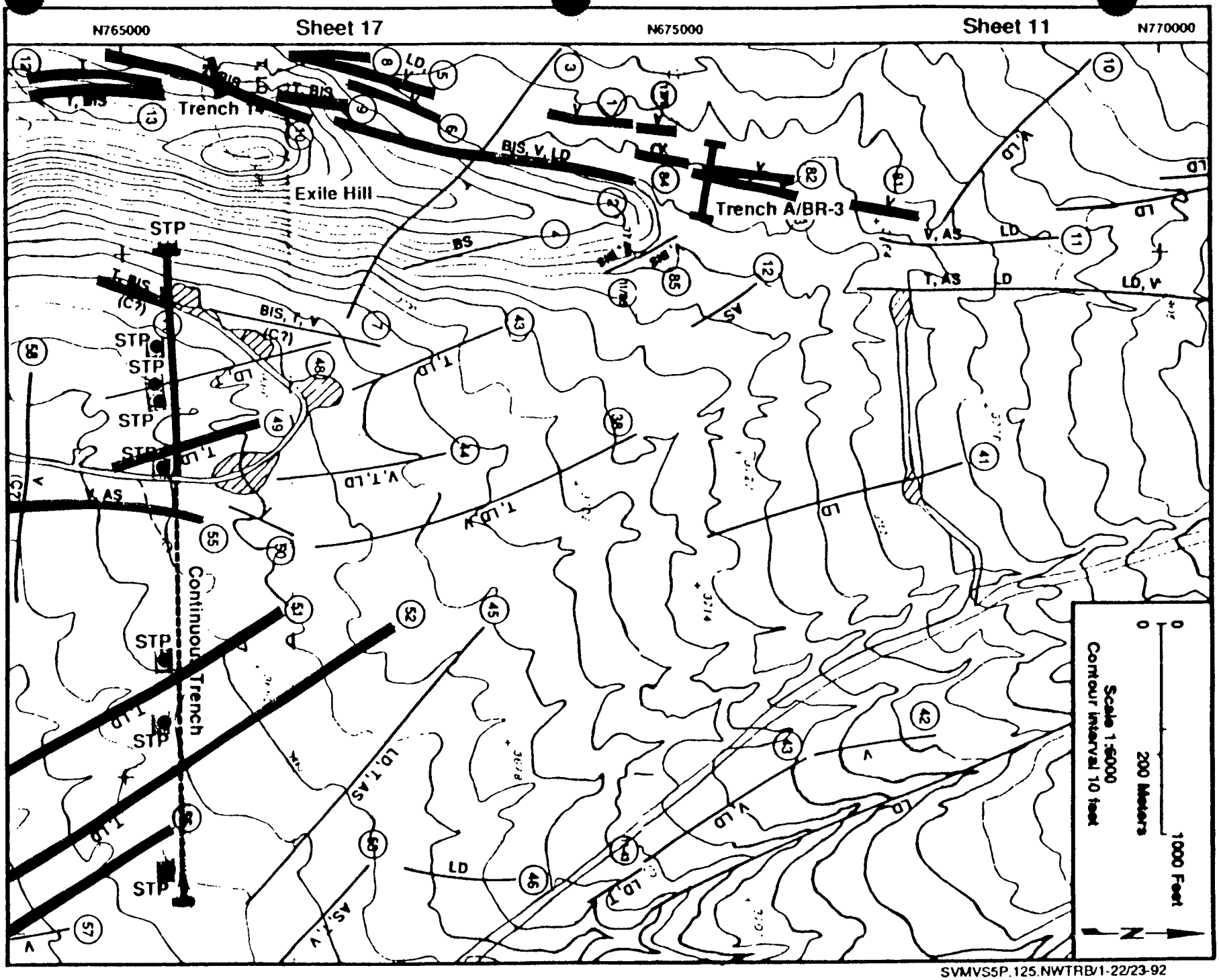

118°00'
117°00'
0
25 km
NEVADA
CALIFORNIA
N
Map area
37°00'
Fish Lake Valley
Sarcobatus Flat
100 km
50 km
Grapevine Mountains
Proposed Repository Site
Saline Valley
Panamint Valley
Death Valley
Funeral Mts.
Amargosa Desert
Owens Valley
Argus Range
Coso Range
Panamint Range
Valley
Black Mts.
Spring Mts.
Coso Basin
Area of Figure 2
36°00'
116°00'

Data for the Bare Mountain fault (about 14 km west of site)

Source	Estimated age of youngest event (ka)	Recurrence interval (10^3 yrs)	Slip rate (mm/yr)
Published estimates ----------	<9	≥20–>150	0.19
Our preliminary estimates ------	>10 to 100?	>100	0.015

Data for the Death Valley — Furnace Creek fault system (about 50 km west of the site)

Source	Estimated age of youngest event (ka)	Recurrence interval (10^3 yrs)	Slip rate (mm/yr)
Published estimates ----------	≤0.2	1.7–3.7	0.2–2.5
Our preliminary estimates ------	≤0.2	0.5–2	4–8



SVMVS5P.125.NWTRB/1-22/23-92

RESULTS OF MIDWAY VALLEY STUDY

GEOLOGIC MAPPING & SUBSURFACE INVESTIGATIONS WERE CONDUCTED AT SITE OF PROSPECTIVE SURFACE FACILITIES.

TWO ZONES OF FRACTURES (N15E) OCCUR IN MIDDLE QUATERNARY DEPOSITS. NO VERTICAL SEPARATION CAN BE DISCERNED WITHIN A RESOLUTION OF <5 CM NO EVIDENCE OF LATERAL SEPARATION.

FRACTURES DO NOT EXTEND INTO OVERLYING LATE PLEISTOCENE OR HOLOCENE DEPOSITS.

NO SIGNIFICANT FAULTS ($>$ 5 CM DISPLACEMENT DURING LAST 100,000 YEARS) HAVE BEEN FOUND AT REFERENCE CONCEPTUAL SITE.

DATA FROM THIS STUDY PROVIDE CALIBRATION INFORMATION ON INTRABLOCK FAULTS (MAY BE SIMILAR TO GHOST DANCE FAULT).

Preliminary Magnitude and Recurrence Parameters for Known and Suspected Quaternary Faults in the Yucca Mountain Region

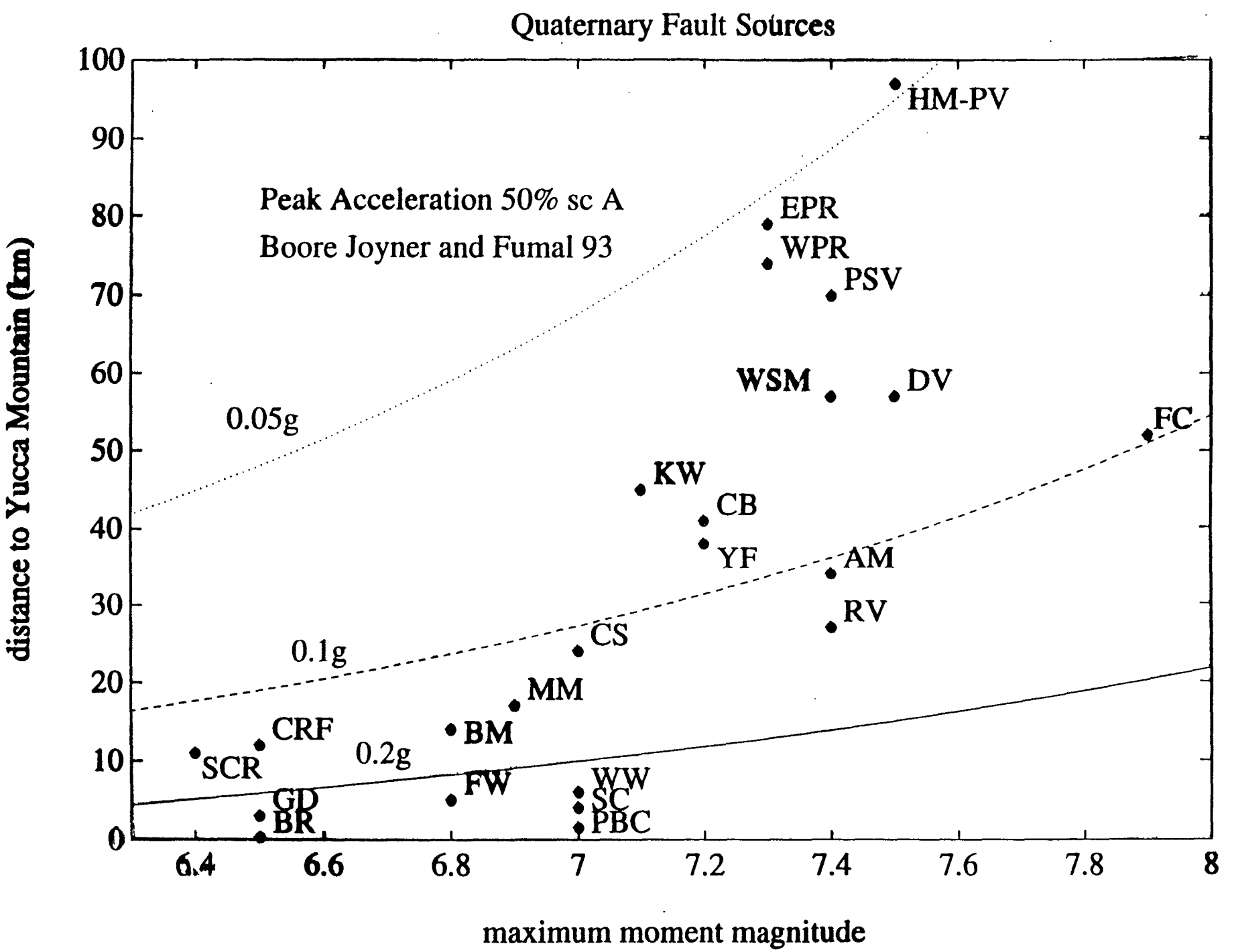
Fault Name	Closest Approach to ESF (km)	Total Length (km)	Maximum Magnitude (Mw)	Fault Slip Rate (mm/yr)	Average Recurrence Interval (ka)
Bow Ridge	0.3	4 - 10	6.5	0.001 - 0.003	40 - 80
Paintbrush	1.5	20 - 26	7.0	0.01 - 0.02	30 - 100
Ghostdance	3	3 - 9	6.5	(10^{-4} - 10^{-3})	(700 - 7000)
Solitario	4	13 - 22	7.0	0.001 - 0.02	20 - 100
Fatigue Wash	5	10 - 16	6.8	0.005 - 0.02	40 - 100
Windy Wash	6	14 - 24	7.0	0.005 - 0.03	40 - 100
Stagecoach	11	6 - 10	6.4	0.005 - 0.02	20 - 60
Crater Flat	12	3 - 9	6.5	(10^{-3} - 10^{-2})	(70 - 700)
Bare Mountain	14	10 - 16	6.6	0.001 - 0.02	20 - 100
Mine Mountain	17	13 - 20	6.9	(10^{-4} - 10^{-3})	(1500 - 15000)

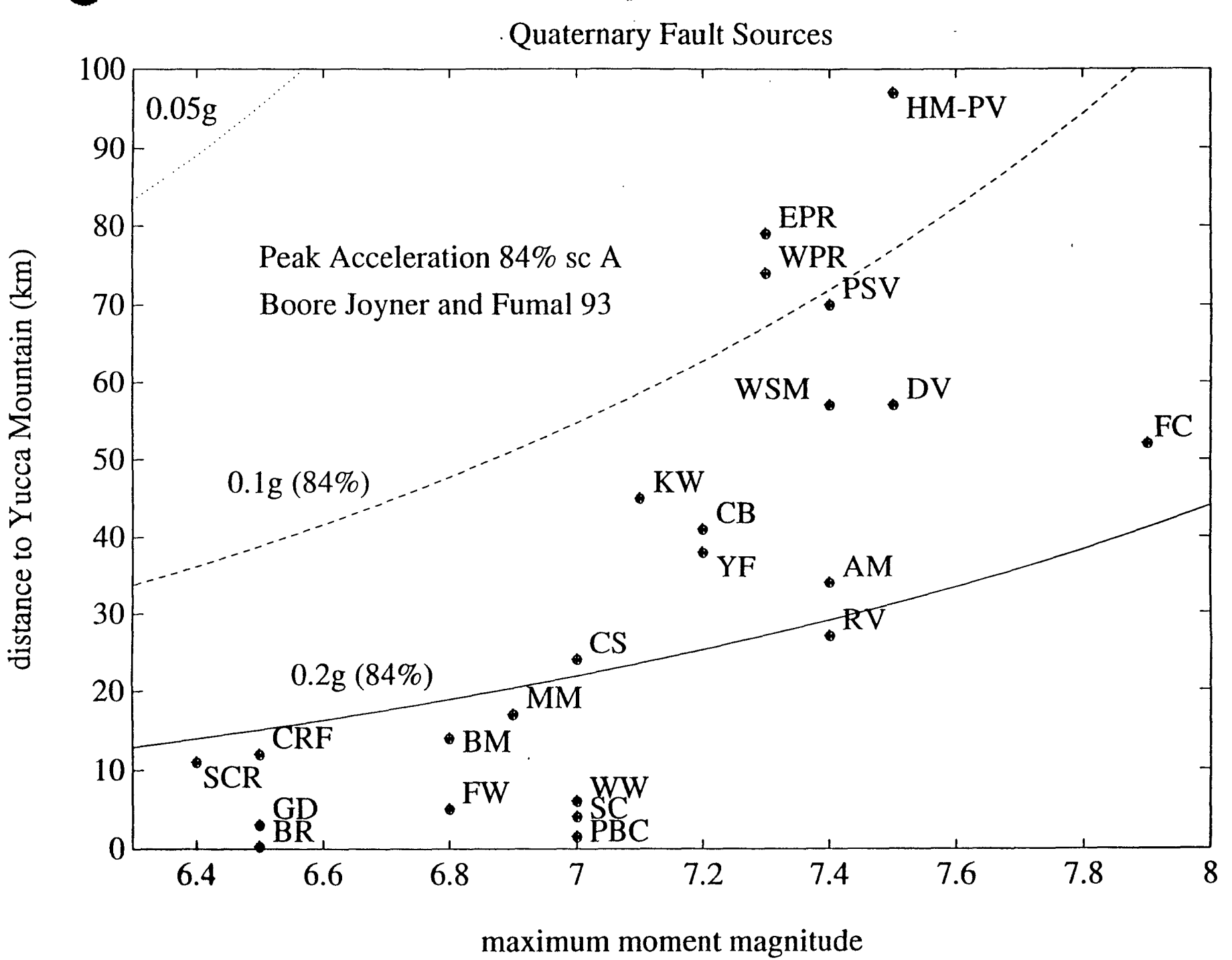
Preliminary Magnitude and Recurrence Table (continued)

Fault Name	Closest Approach to ESF (km)	Total Length (km)	Maximum Magnitude (Mw)	Fault Slip Rate (mm/yr)	Average Recurrence Interval (ka)
Cane Spring	24	15 - 27	7.0	(10^{-4} - 10^{-3})	(1800 - 18000)
Rock Valley	27	19 - 65	7.4	0.003 - 0.02	30 - 150
Ash Meadows	34	48 - 60	7.4	0.005 - 0.02	20 - 100
Yucca	38	22 - 35	7.2	0.008 - 0.02	20 - 130
Carpetbag	41	17 - 35	7.2	(10^{-4} - 10^{-3})	(2600 - 26000)
Keane Wonder	45	25 - 29	7.1	(10^{-3} - 10^{-2})	(2200 - 22000)
Furnace Creek	52	190	7.9	(2 - 4+)	(1 - 5)
Belted Range	55	38 - 54	7.4	?	(eP - lP)
Death Valley	57	75	7.5	(2 - 4+)	(1 - 4)
Kawich Range	57	? - 84	7.6	?	(QT - eP)

Preliminary Magnitude and Recurrence Table (continued)

Fault Name	Closest Approach to ESF (km)	Total Length (km)	Maximum Magnitude (Mw)	Fault Slip Rate (mm/yr)	Average Recurrence Interval (ka)
West Springs Mountain	57	60	7.4	0.06 - 0.1	(20 - 100)
Pahrump - Stewart Valley	70	70	7.4	(10^{-2} - 10^{-1})	(40 - 400)
West Pintwater	74	45	7.3	(10^{-3} - 10^{-2})	(300 - 3000)
East Pintwater	79	45	7.3	(10^{-3} - 10^{-2})	(300 - 3000)
Hunter Mountain	97	80	7.5	(1.5 - 3.5)	(1 - 4)
Panamint Valley	97	80	7.5	1.5 - 3.5	1 - 4


Quaternary Fault Sources
Peak Acceleration 50% sc A
Boore Joyner and Fumal 93
0.05g
0.1g
0.2g
HM-PV
EPR
WPR
PSV
WSM
DV
FC
KW
CB
YF
AM
RV
CS
MM
BM
CRF
SCR
FW
WW
SC
PBC
GD
BR
distance to Yucca Mountain (km)
maximum moment magnitude
100
90
80
70
60
50
40
30
20
10
0
6.4
6.6
6.8
7
7.2
7.4
7.6
7.8
8


Quaternary Fault Sources
0.05g
0.1g (84%)
0.2g (84%)
Peak Acceleration 84% sc A
Boore Joyner and Fumal 93
HM-PV
EPR
WPR
PSV
WSM
DV
FC
KW
CB
YF
AM
RV
CS
MM
CRF
BM
SCR
FW
WW
SC
GD
BR
PBC
distance to Yucca Mountain (km)
maximum moment magnitude
100
90
80
70
60
50
40
30
20
10
0
6.4
6.6
6.8
7
7.2
7.4
7.6
7.8
8

Relevant Seismic Sources

Can potentially generate 0.1 g or greater peak acceleration at YM

50th percentile (median in lognormal distribution)

Bow Ridge	Paintbrush Canyon	Ghostdance*
Solitario Canyon	Fatigue Wash	Windy Wash
Stagecoach Road	Crater Flat*	Bare Mountain
Mine Mountain*	Cane Spring*	Rock Valley
Ash Meadows	Yucca Fault	Furnace Creek*
(Carpetbag)*	(Keane Wonder)*	

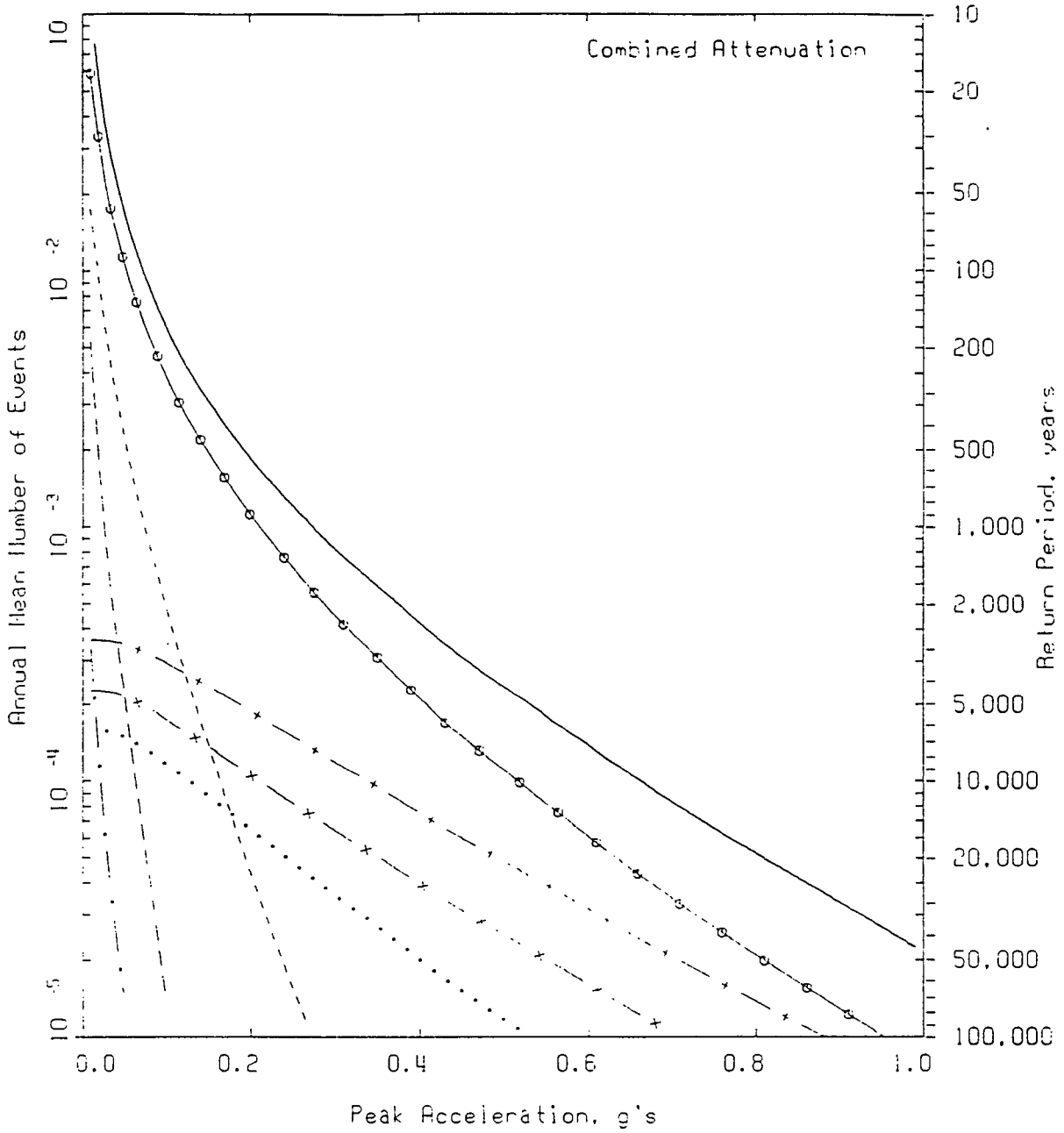
84th percentile (one sigma in lognormal distribution)

Death Valley	West Springs Mountain
Pahrump-Stewart Valley	(West Pintwater Range)*

* Faults that lack documented information pertaining to Quaternary activity, geometry, maximum length, slip rate, and recurrence interval.

Is peak acceleration an adequate measure of damage potential?

- Better to use spectral velocity that spans frequency bands of engineering significance



LEGEND

- Total of All Sources
- Fatigue Wash
- Furnace Creek
- Hunter Mountain
- Pahrump-Stewart Valley
- Paintbrush
- Solitario Canyon
- Background

7/16/93 ANNUAL2.RP_

Project No. 5001A	Nuclear Waste Repository Yucca Mountain, Nevada	PEAK GROUND ACCELERATION COMBINED ATTENUATION	Figure 7
Woodward-Clyde Consultants			

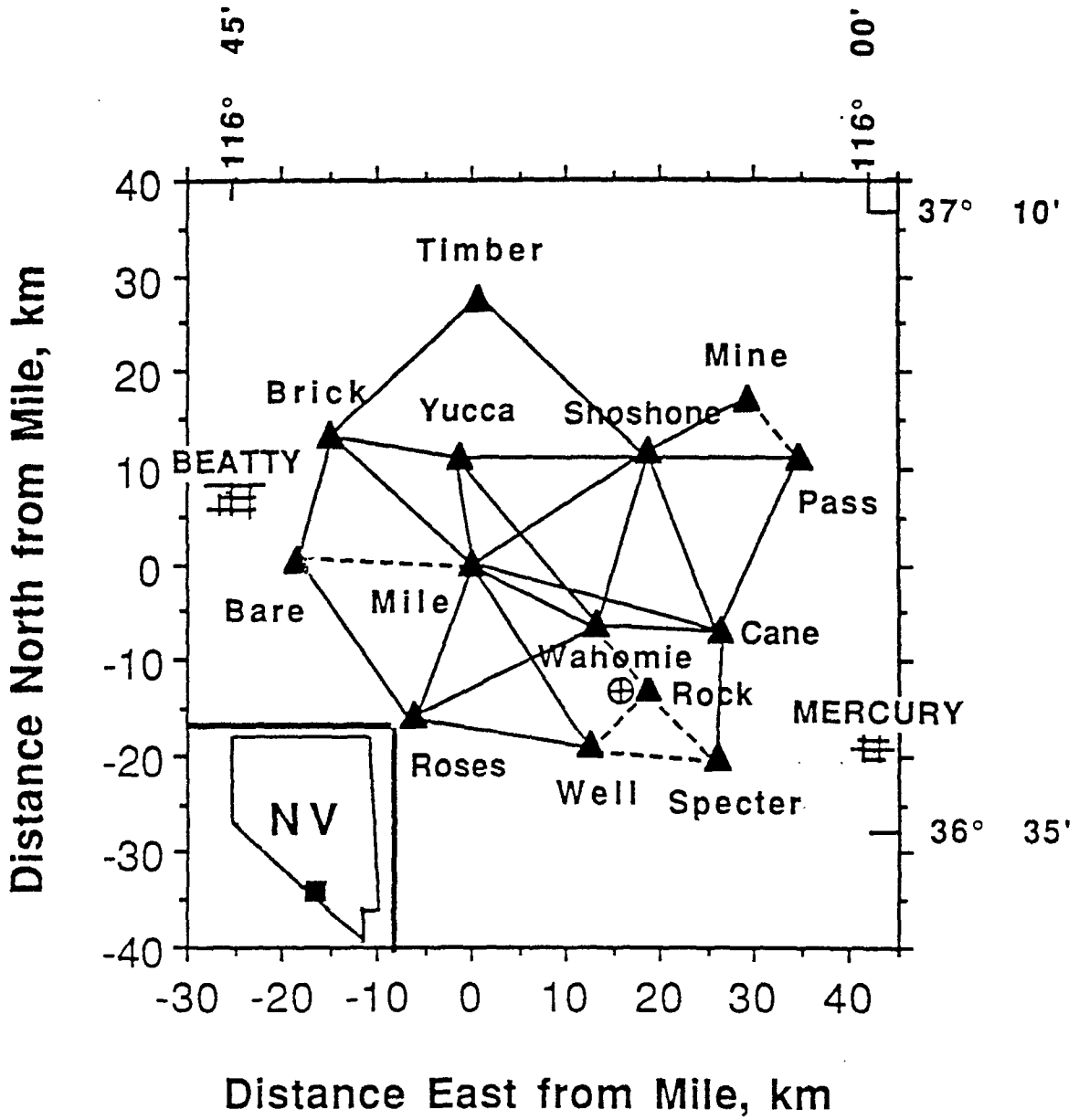


TABLE 2. Tensor Strain Rates (μstrain/yr) Referred to a Coordinate System with the 1 Axis Directed East and the 2 Axis North

Network	$\dot{\epsilon}_{11}$	$\dot{\epsilon}_{12}$	$\dot{\epsilon}_{22}$
All lines	0.010 ± 0.020	-0.002 ± 0.008	-0.009 ± 0.021
14 Geodolite	0.009 ± 0.022	-0.005 ± 0.011	-0.011 ± 0.023
12 Others	0.012 ± 0.023	0.003 ± 0.012	-0.008 ± 0.024

Southern Great Basin Earthquakes 1978–LSM Mainshock

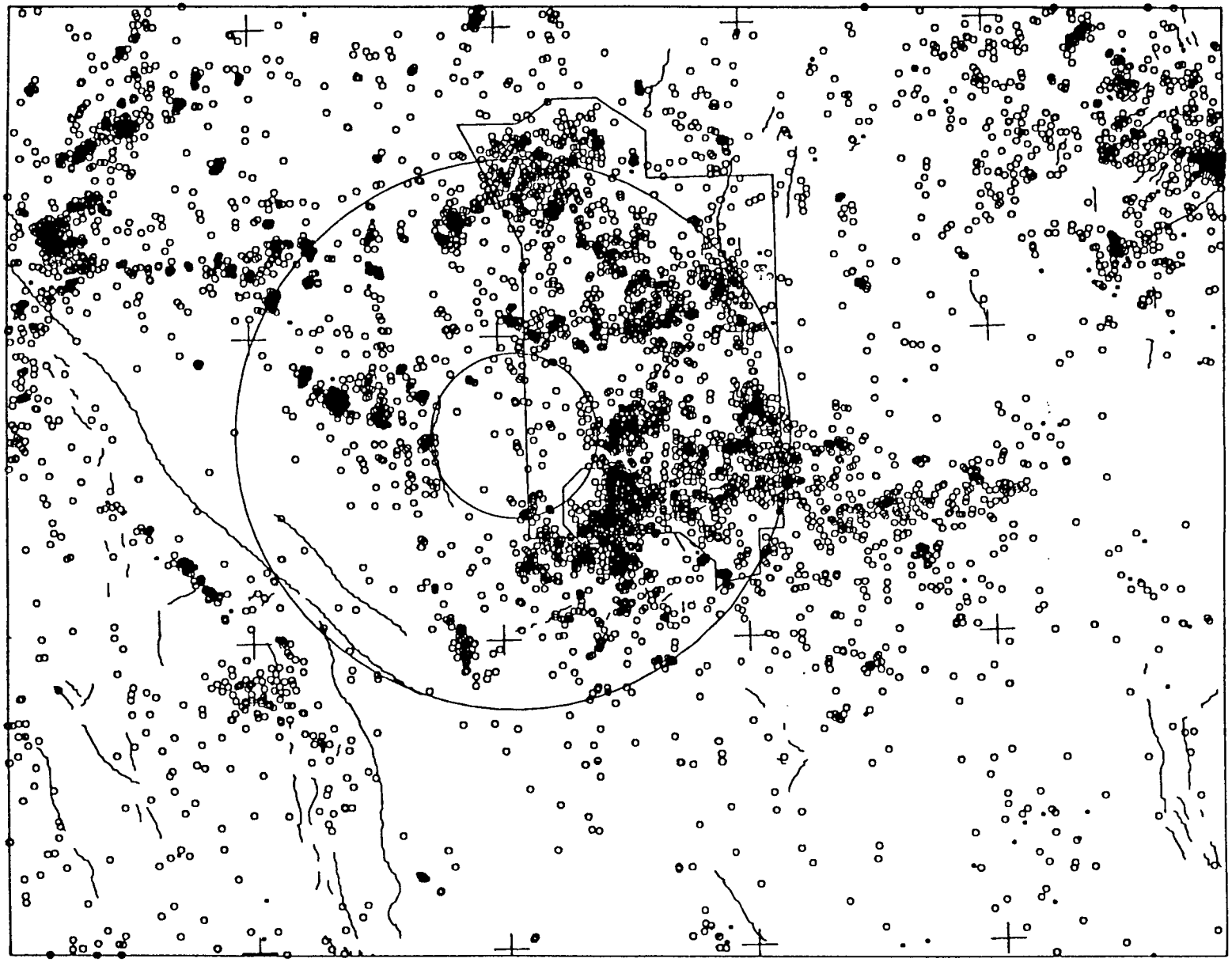


Figure 2

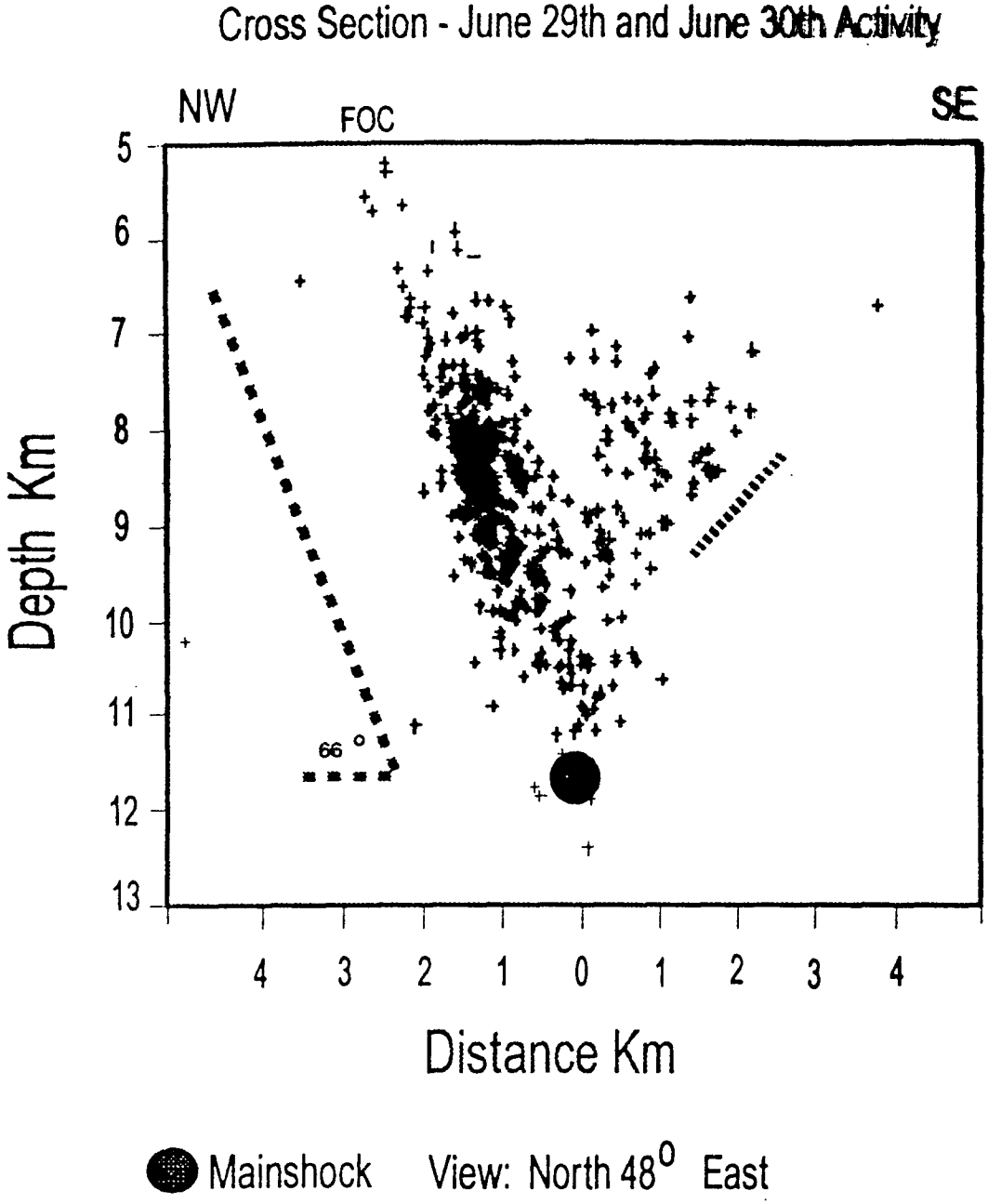

Cross Section - June 29th and June 30th Activity
NW
FOC
SE
Depth Km
5
6
7
8
9
10
11
12
13
66 °
4
3
2
1
0
1
2
3
4
Distance Km
Mainshock
View: North 48° East
Interpreted Southeast Dip of Main Shock Fault Plane
Base of Conjugate Normal Surface Dipping Northwest

Figure 9b

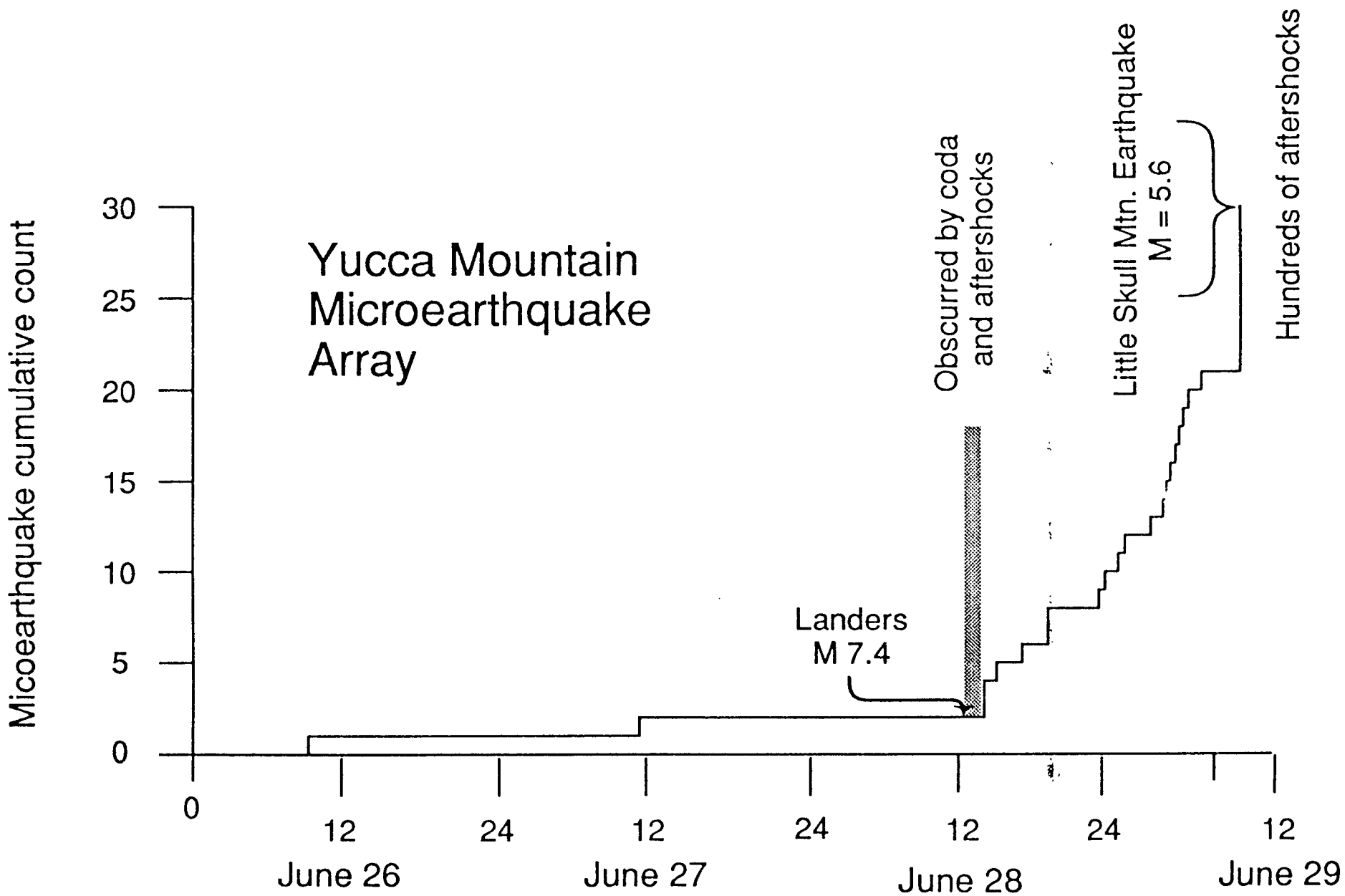
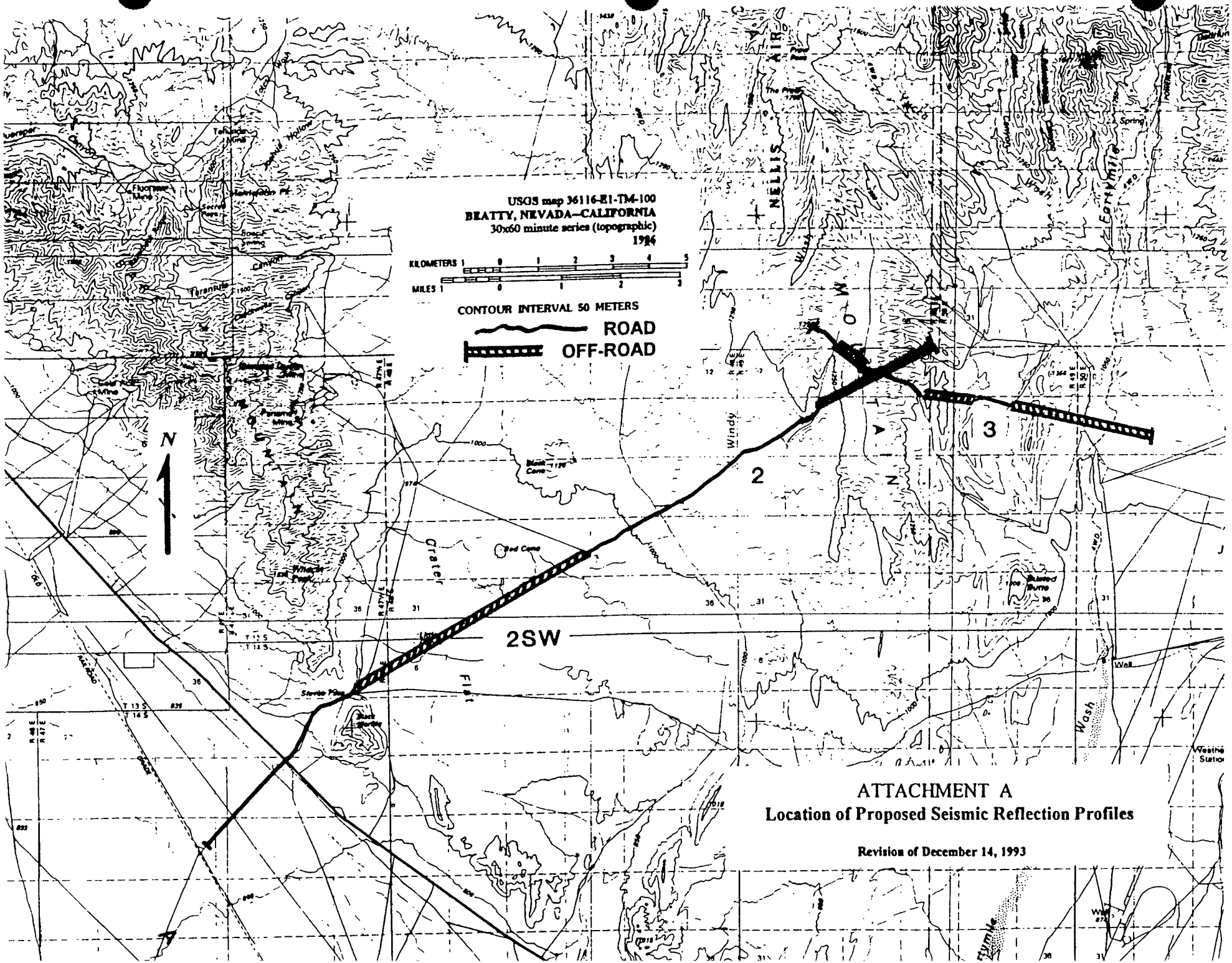

Yucca Mountain
Microearthquake
Array
Micoearthquake cumulative count
30
25
20
15
10
5
0
0
12
24
12
24
12
24
12
June 26
June 27
June 28
June 29
Landers
M 7.4
Obscurred by coda
and aftershocks
Little Skull Mtn. Earthquake
M = 5.6
Hundreds of aftershocks

Figure 5

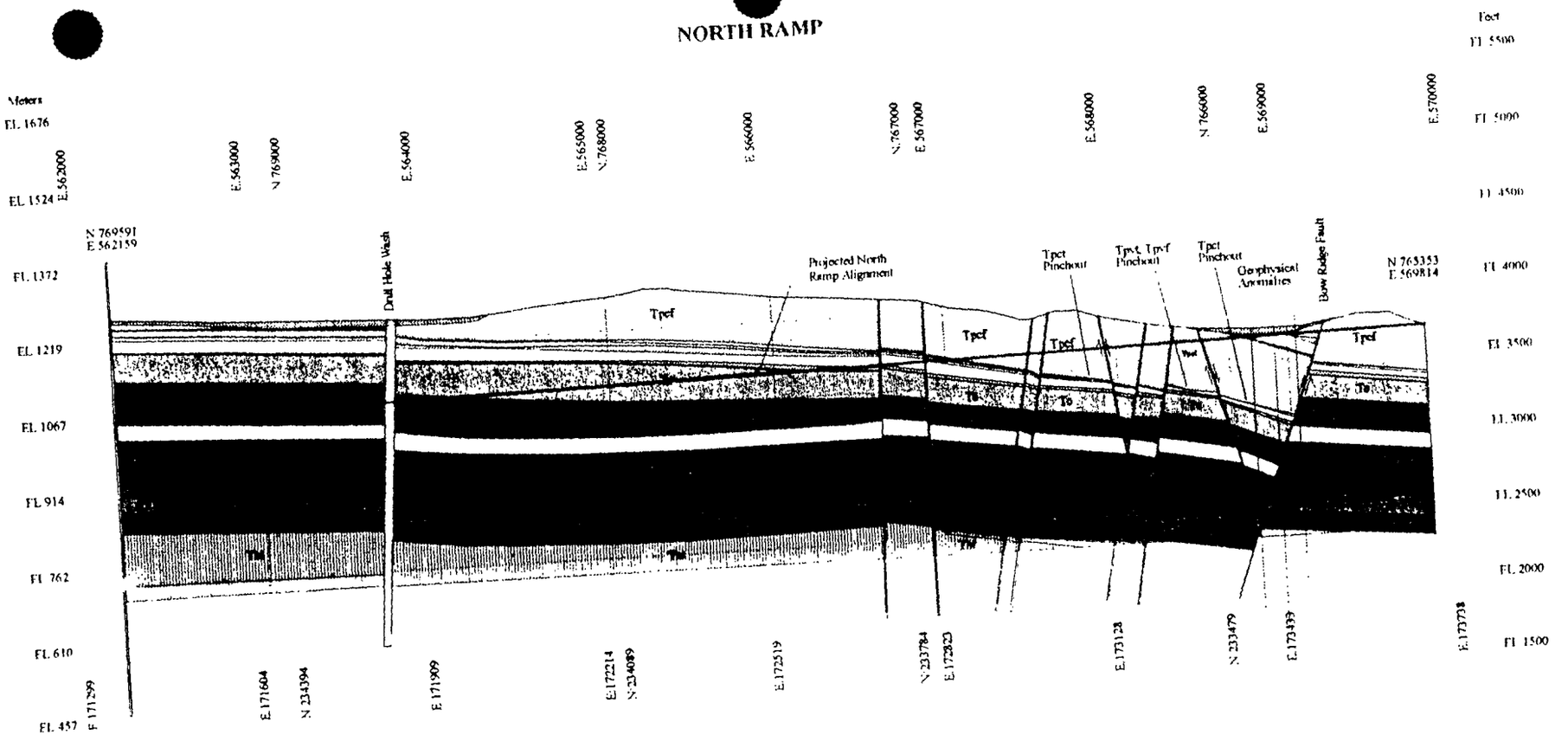


ATTACHMENT A

Location of Proposed Seismic Reflection Profiles

Revision of December 14, 1993

NORTH RAMP



EXPLANATION OF SYMBOLS

- Qac Alluvium
- Tmrf Rainier Mesa Ash-flow Tuff
- Tmrt Rainier Mesa Bedded Tuff
- Tx Tuff "X" Ash-flow Tuff
- Txt Tuff "X" Bedded Tuff
- Tpcf Tiva Canyon Ash Flow Tuff
- Tpct Tiva Canyon Bedded Tuff
- Tpyf Yucca Mountain Ash Flow Tuff
- Tpyt Yucca Mountain Bedded Tuff
- Tppf Pah Canyon Ash Flow Tuff
- Tppt Pah Canyon Bedded Tuff

Topopah Spring Tuff Subdivisions

- Tc Caprock
- Tpul Upper Lithophysal
- Tpmn Middle Nonlithophysal
- Tpll Lower Lithophysal
- Tpln Lower Nonlithophysal
- Tv Vitrophyre
- Tppt Topopah Spring Bedded Tuff
- Thf Calico Hills Lava Flow
- Tht Calico Hills Bedded Tuff
- Tcpf Crow Pass Ash Flow Tuff

PRELIMINARY, UNREVIEWED DATA

HOW COMPLETE IS THE DATABASE FOR SEISMIC HAZARD ASSESSMENT AT YUCCA MOUNTAIN?

SITE ACTIVITY	PERCENT COMPLETE
GEOLOGIC MAPPING	85
SITE FAULT CHARCTERISTICS	85
REGIONAL FAULTS	40
GEOPHYSICS: FAULT LOCATION	95
SUBSURFACE GEOMETRY	65
TECTONIC MODELS	55
MODERN DEFORMATION: GPS	75
GEODETIC	95
HISTORIC LEVELS	100
IN SITU STRESS	80
HISTORIC EARTHQUAKES	100
MODERN SEISMIC ACTIVITY	95
SITE EFFECTS ON GROUND MOTION	70
RELEVANT EARTHQUAKE SOURCES	45
GROUND MOTION MODELLING	05
PSHA	15

Data collected and interpreted by 10/01/94