NRC/PG&E Open Meeting, San Francisco, CA
Diablo Canyon Power Plant
Independent Spent Fuel Storage Installation

■ 8:00	Introduction	NRC Strickland/Grebel
■ 8:10	Overview	Cluff
■ 8:40	Seismicity	McLaren
■ 9:10	Ground Motions	Abrahamson
■ 11:15	Break	
■ 11:30	Public Comments	NRC
■ 11:45	Lunch	

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Independent Spent Fuel Storage Installation

12:30	Slope-Material Properties	White
1:15	Slope Stability	Sun
2:15	Transport Slope stability	White
2:45	Break	
3:00	Cutslope Stability	Bachhuber
3:45	Slope Stability Summary	Team
4:45	Public Comment	NRC
5:00	Adjourn	

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Diablo Canyon Independent Spent Fuel Storage Installation

Geology, Ground Motions, and Geotechnical Studies

Lloyd Cluff
Director
PG&E Geosciences Department

PG&E

April 11, 2002

Project Team

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  Marcia McLaren, Seismology
  Norman A. Abrahamson, Ground Motions
  Robert K. White, Geotechnical Engineering
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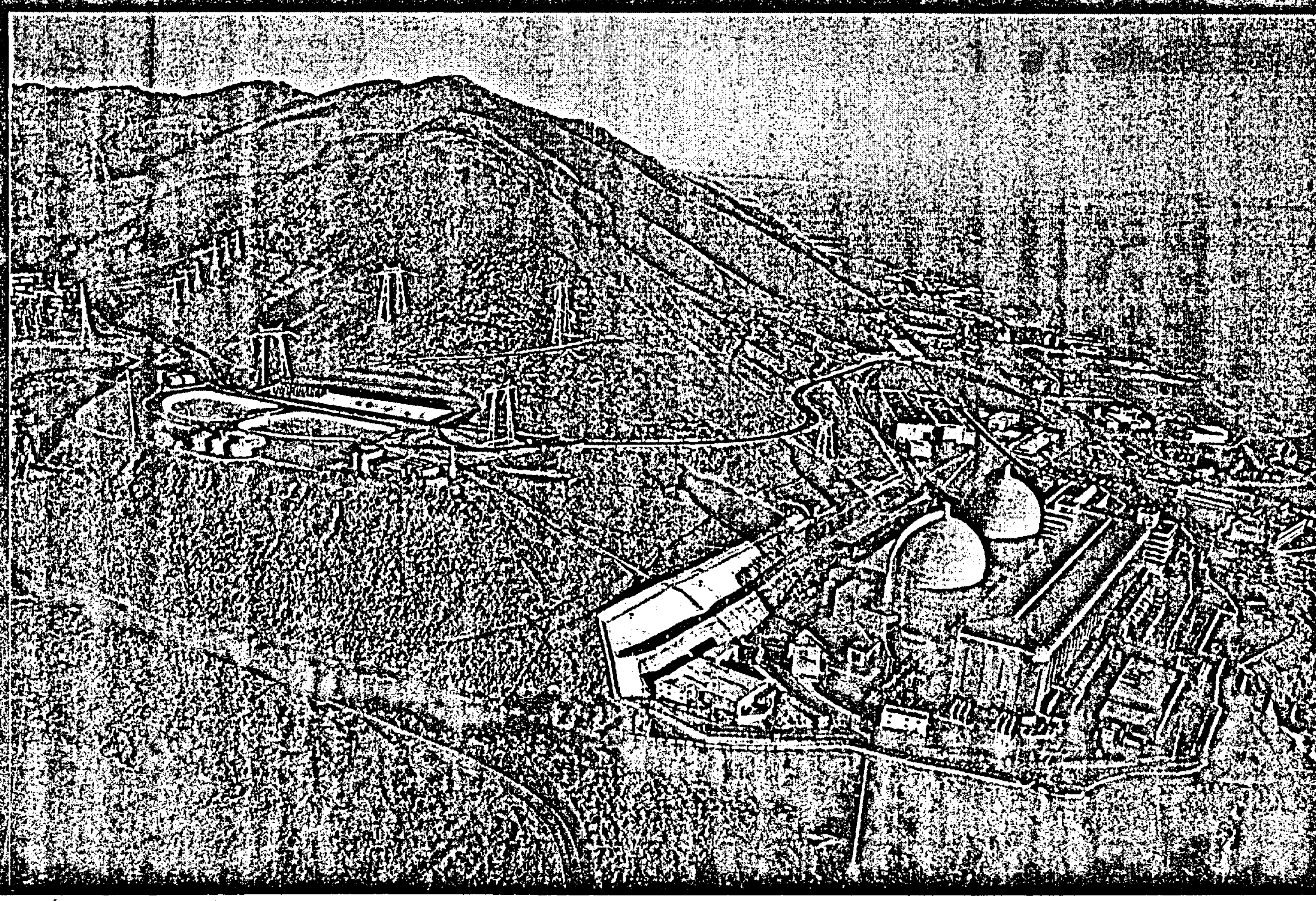
Technical Review Board

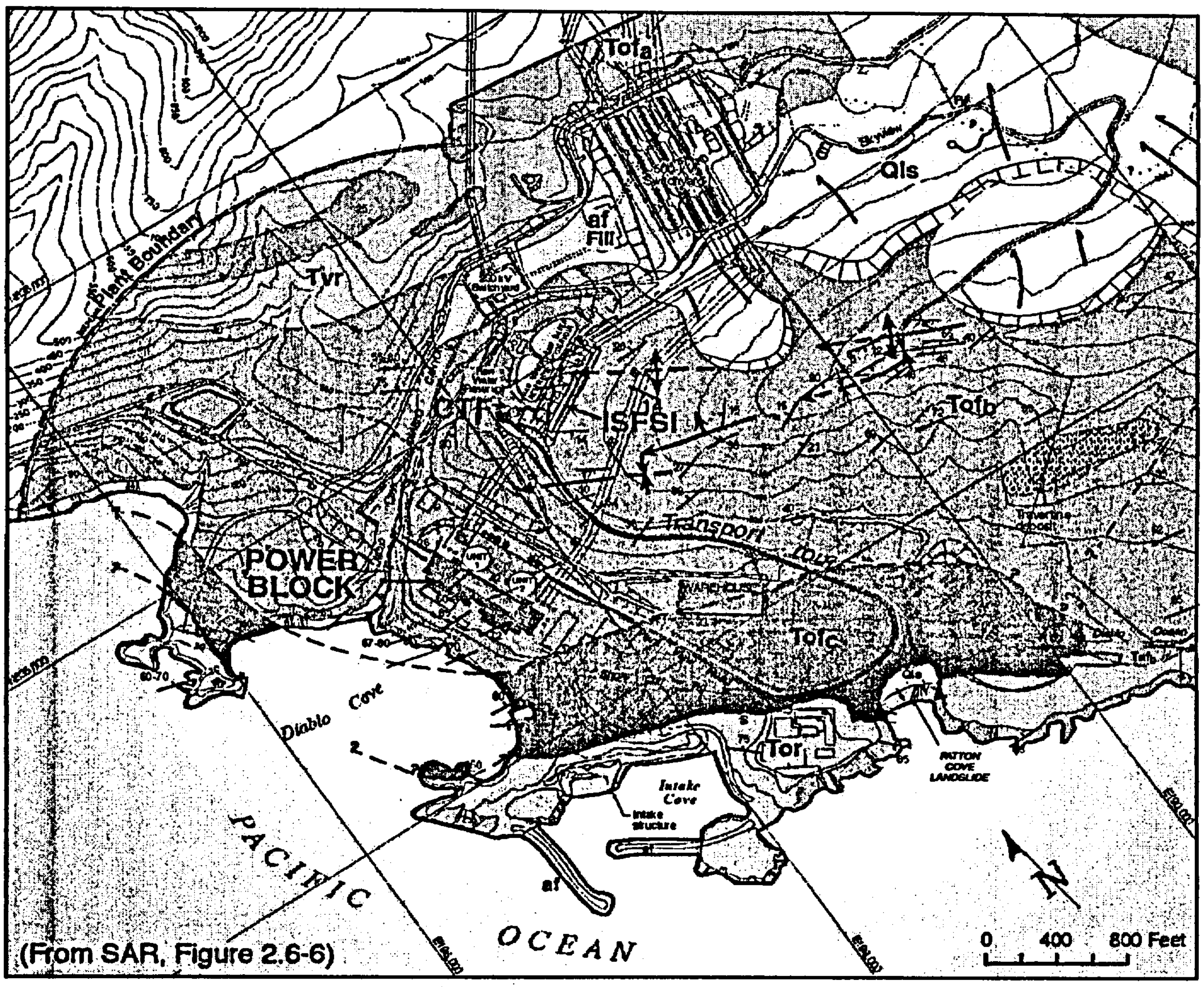
- **Clarence Allen - Geology/Tectonics**
- **Robert Kennedy - Structural Engineering**
- **Bruce Bolt - Seismology/Ground Motions**
- **I. M. Idriss - Geotechnical Engineering/ Ground Motions**

Peer Reviewers and Technical Specialists

- Skip Hendron – Geotechnical Engineering
- Paul Somerville – Seismology
- Dale Marcum – Geotechnical Engineering

ISFSI Site Location





Bedrock in ISFSI Area

Investigations

- Site geology
- Seismicity and seismic geology
- Earthquake ground motions
- Geotechnical engineering

Previous Seismicity and Seismic Geology Studies (LTSP)

- Detailed geologic mapping, trenching, surveying of coastal terraces, and offshore geophysics to locate active faults in region
- Detailed analysis of regional seismicity
- PG&E seismic network established in 1987 to supplement existing USGS regional network
- Hosgri fault confirmed to be the controlling earthquake source for the DCPP

Ground Motions

- Compare earthquake source and distance and ISFSI site conditions with those at DCPP to confirm applicability of DCPP ground motions
- Use DCPP ground motions as basis for developing ISFSI design ground motions, in accordance with 10 CFR 72.102(f)

Ground Motions

- For ISFSI components sensitive to longer-period motions need to develop appropriate response spectra and time histories
- ISFSI long-period (ILP) spectra, taking into account the influence of near-fault effects recorded in recent large earthquakes, such as fault rupture directivity and fling

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Seismicity

Marcia McLaren
Seismologist
PG&E Geosciences Department

PG&E

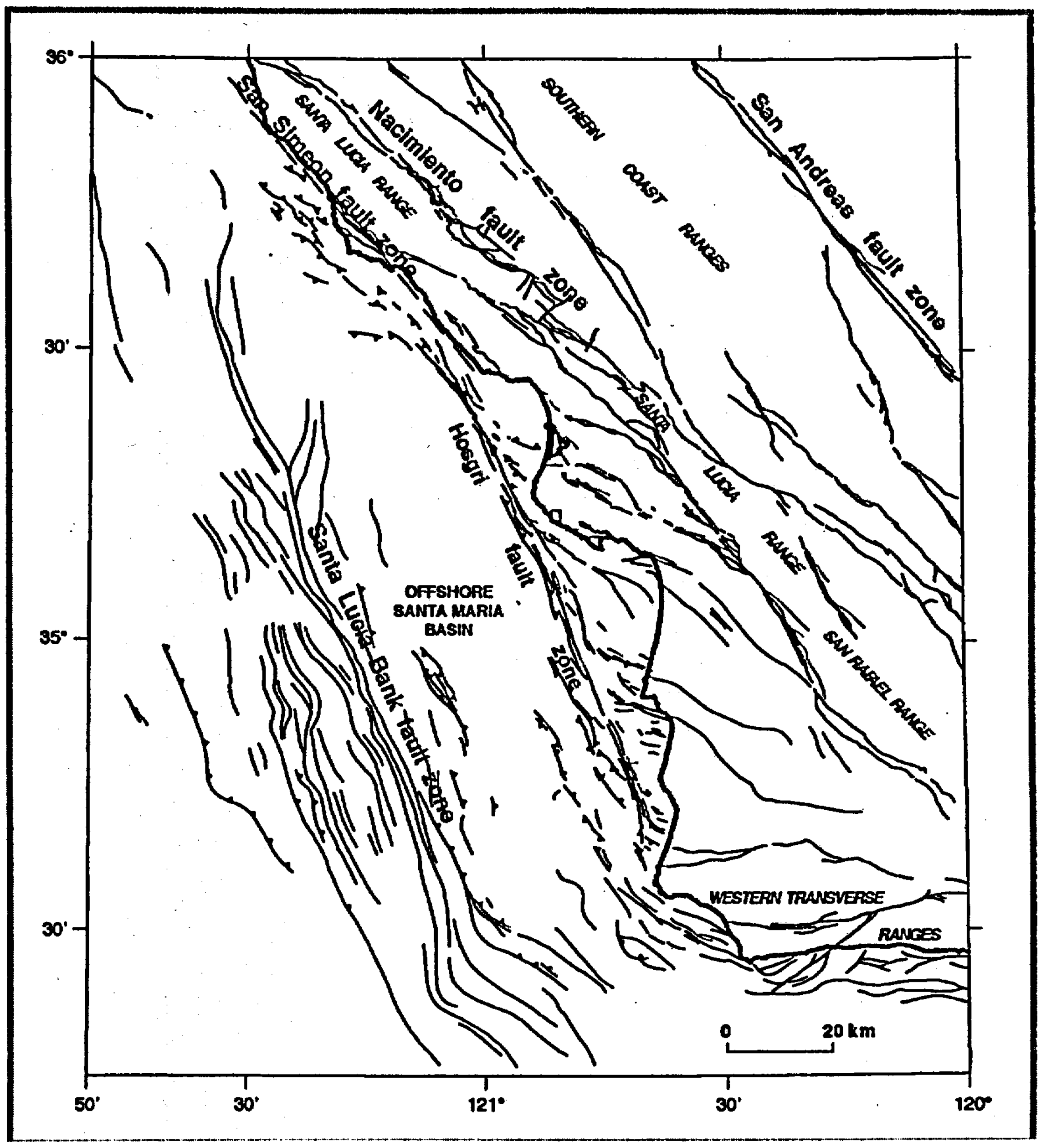
April 11, 2002

Outline

- Tectonic setting
- Seismographic station coverage
- Seismicity patterns and focal mechanisms
- Conclusions

Tectonic setting

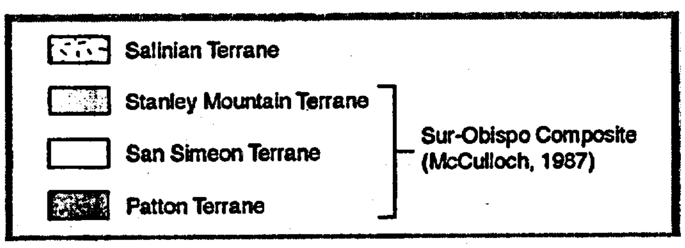
Quaternary faults

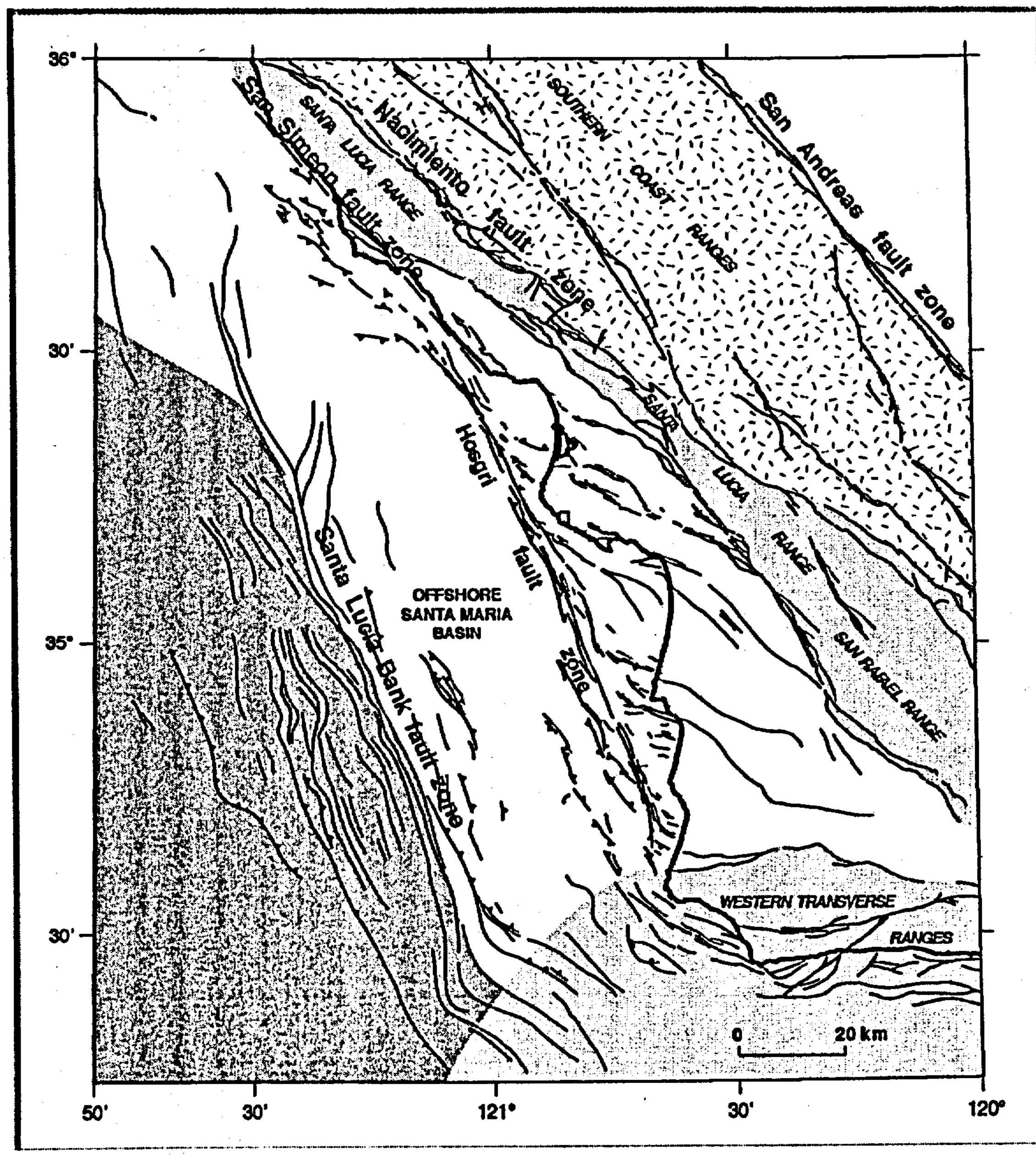


From LTSP (PG&E, 1988)

Tectonic setting

Basement rock terranes

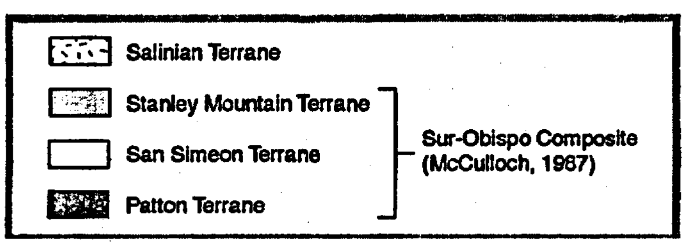


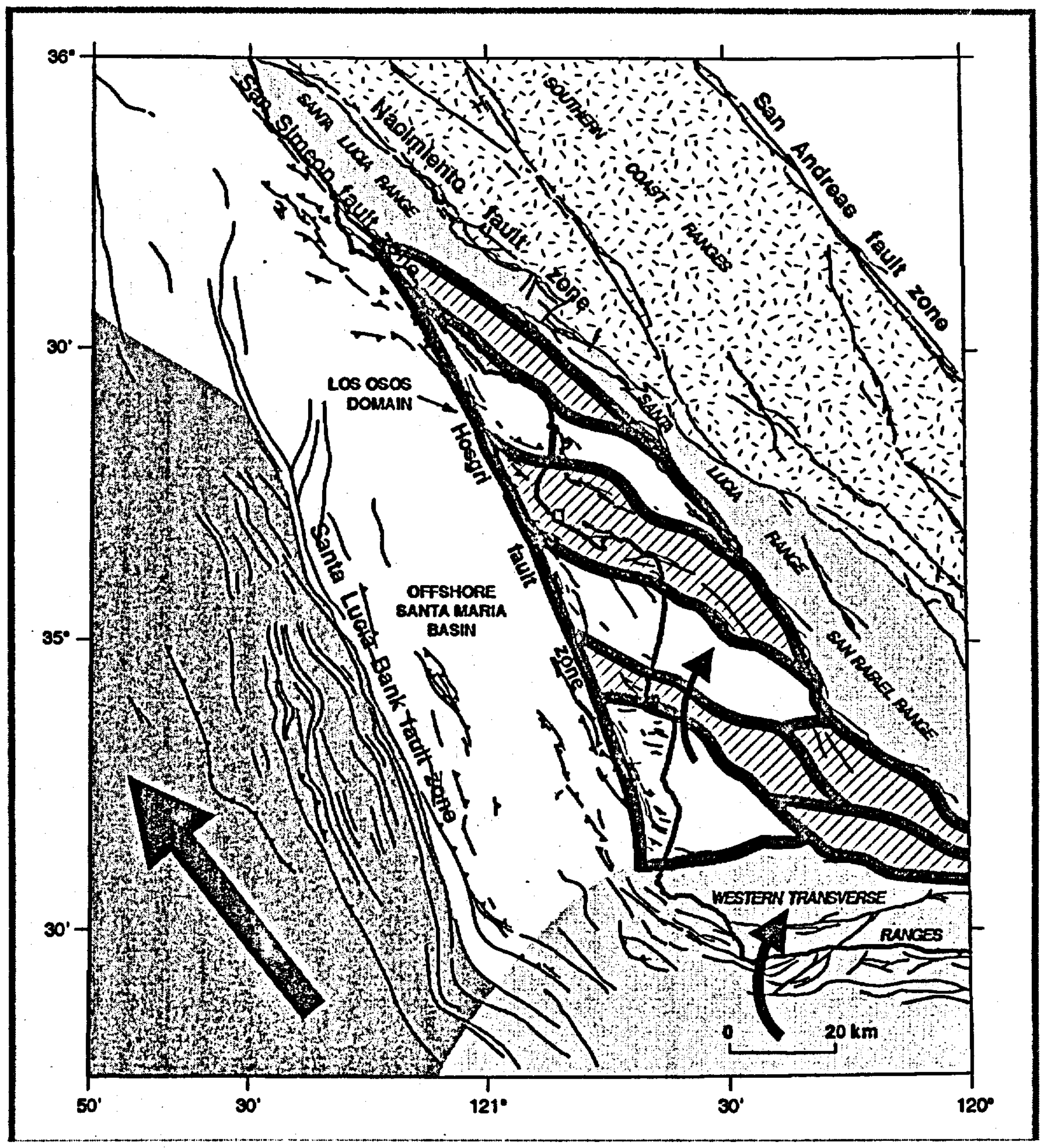


From LTSP (PG&E, 1988)

Tectonic setting

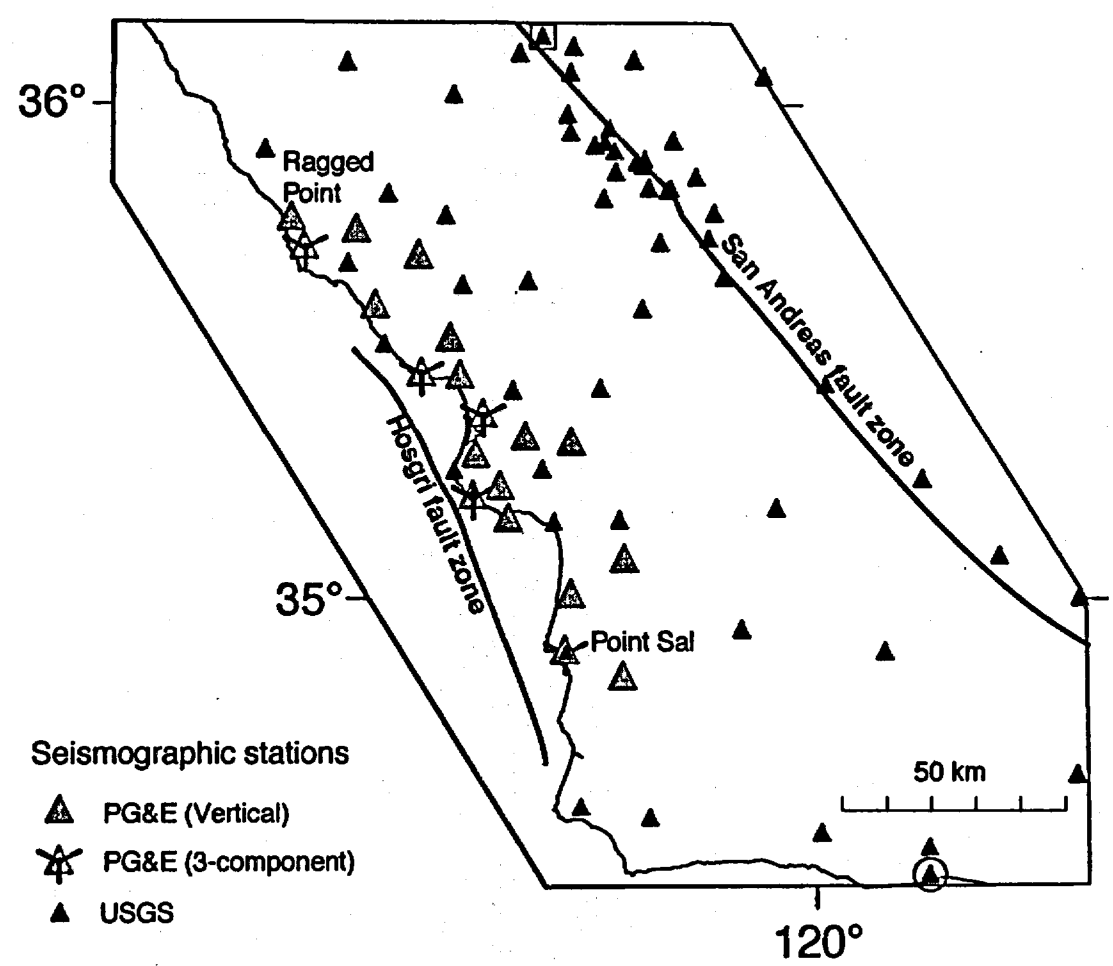
Los Osos domain





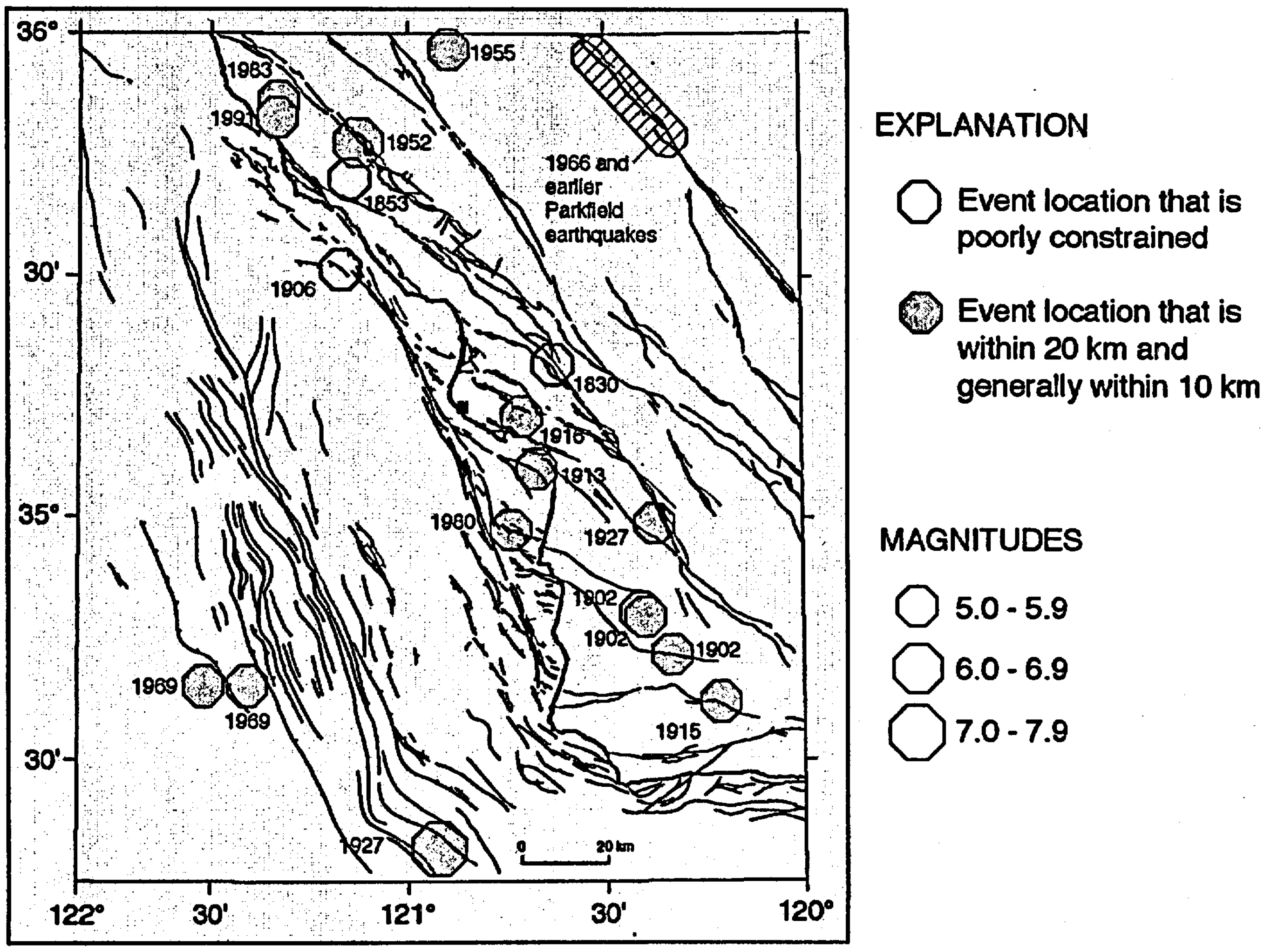
From LTSP (PG&E, 1988)

Seismographic station coverage
1987-present



From LTSP (PG&E, 1988)

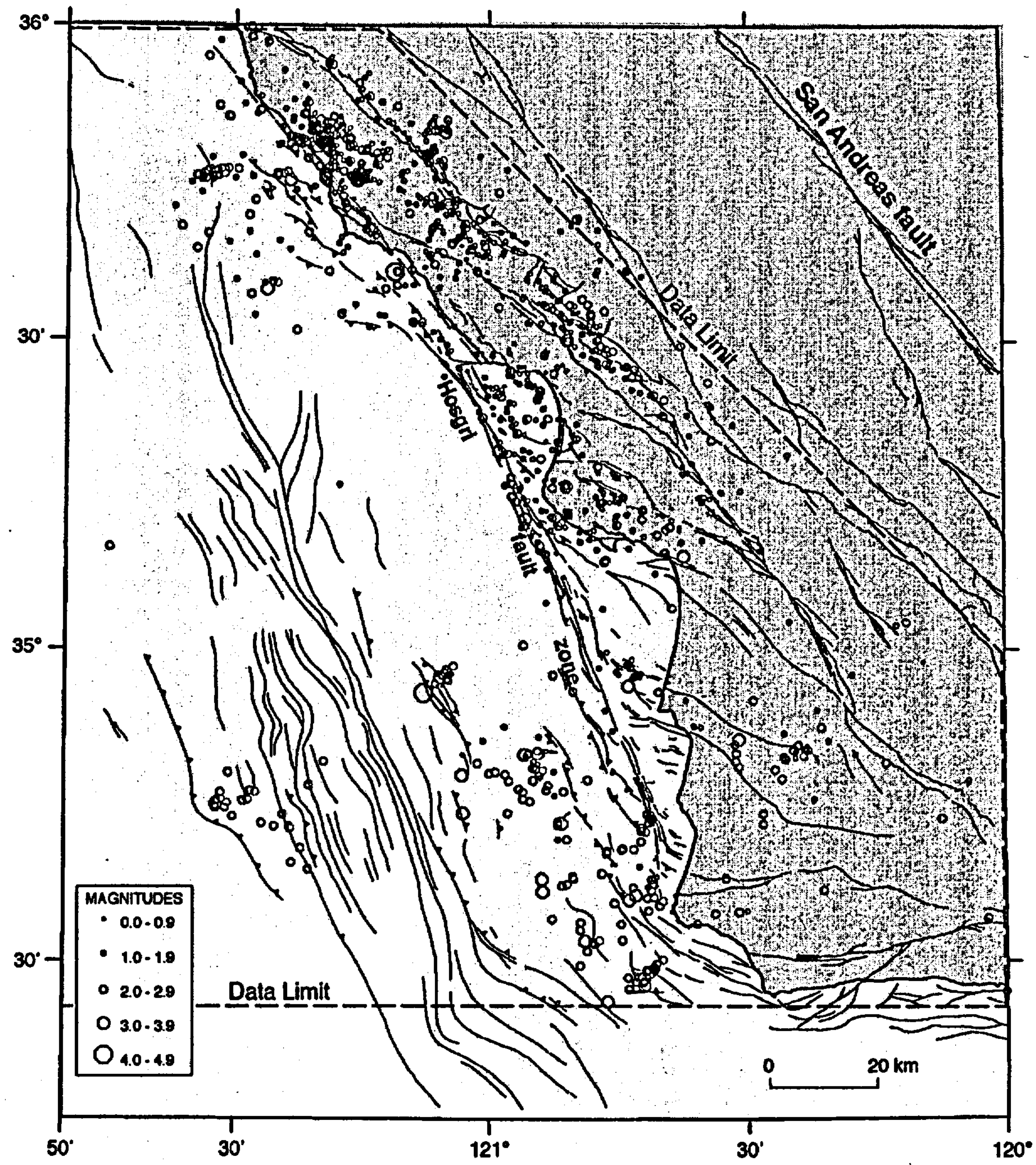
Magnitude 5 and greater earthquakes since 1830



From McLaren and Savage (2001), SAR Figure 2.6-39

Seismicity recorded by the PG&E network

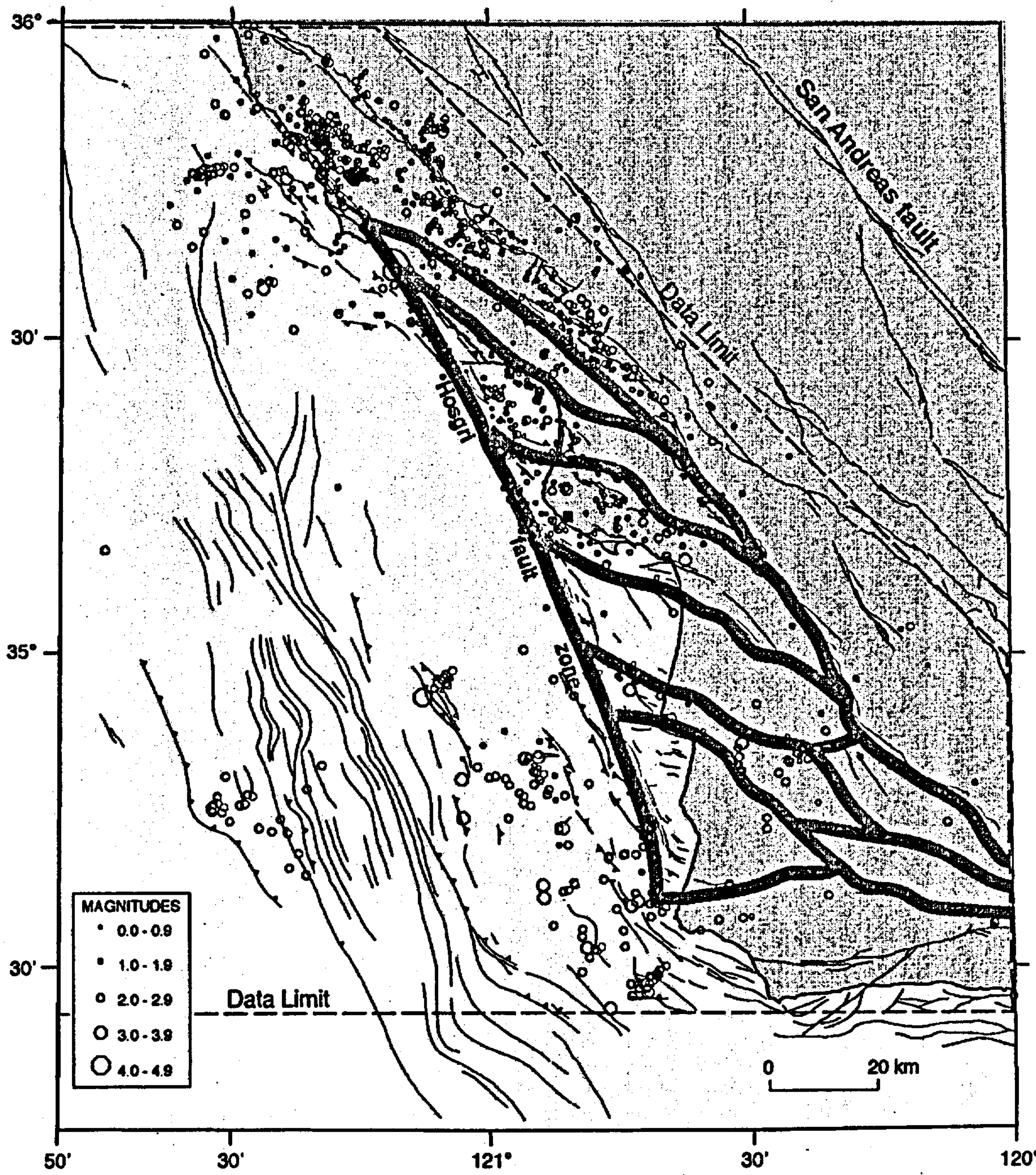
Oct. 1987 through Jan. 1997



From McLaren and Savage (2001), SAR Figure 2.6-40

Seismicity recorded by the PG&E network

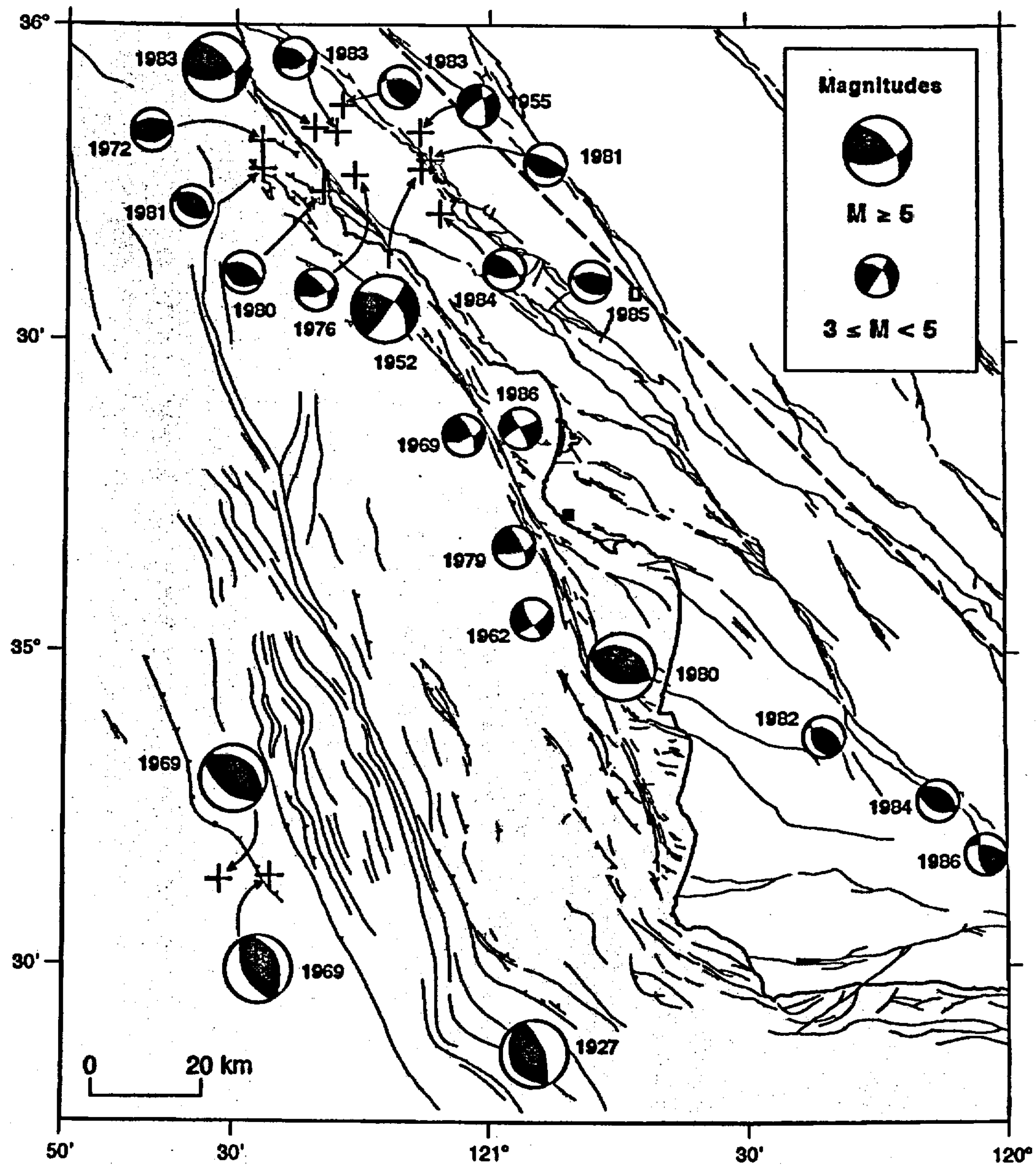
Oct. 1987 through Jan. 1997



From McLaren and Savage (2001)

Focal mechanisms

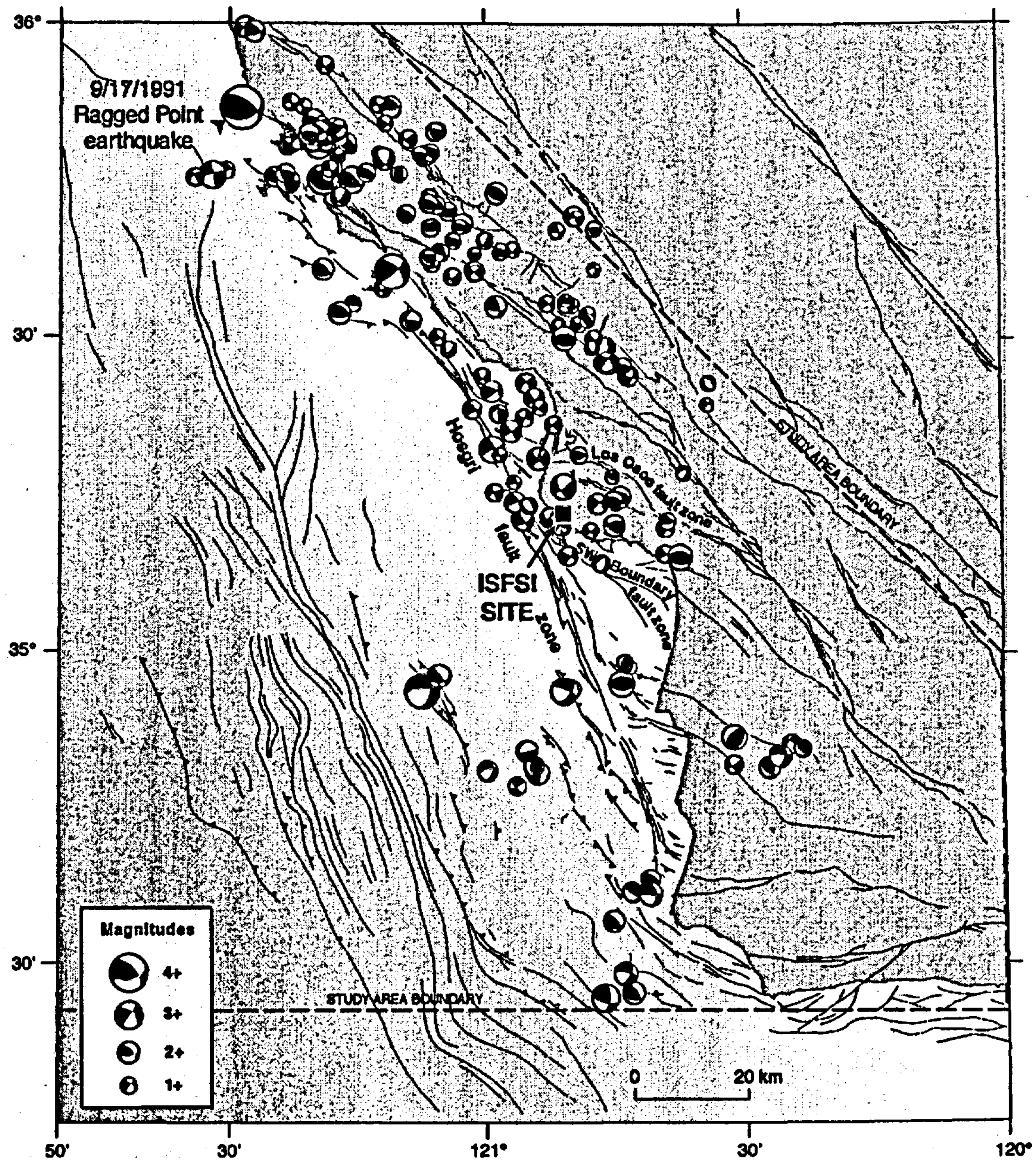
Magnitude 3 and greater earthquakes, 1927-1986



From McLaren and Savage (2001)

Focal mechanisms

Oct. 1987 through Jan. 1997



From McLaren and Savage (2001), SAR Figure 2.6-42

Conclusions

- Seismicity patterns and focal mechanisms of the 1987-1997 earthquakes recorded by the PG&E and USGS networks are consistent with the data presented in the Final Report of the Long Term Seismic Program (PG&E, 1988).

- Focal mechanisms along the Hosgri fault zone show consistent strike-slip motion along northwest trending, nearly vertical fault planes.

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Ground Motions: Lessons from Recent Earthquakes

Norm Abrahamson
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PG&E Geosciences Department

PG&E

April 11, 2002

Outline

- Lessons from recent earthquakes
  - Three large earthquakes in 1999
- Application of those lessons to the ground motions for the ISFSI

Importance of Recent Earthquakes

- LTSP Evaluation Earthquake
  - M=7.2, Dist = 4.5 km
  - Prior to 1999, few empirical recordings were available for this magnitude and distance range
- Recent Earthquakes Have Greatly Increased the Empirical Data Base of Strong Motion Recordings Close to Large Crustal Earthquakes
  - 1999 Kocaeli, Turkey (M=7.4)
  - 1999 Chi-Chi, Taiwan (M=7.6)
  - 1999 Duzce, Turkey (M=7.1)
- Resulting in new models for long period ground motion

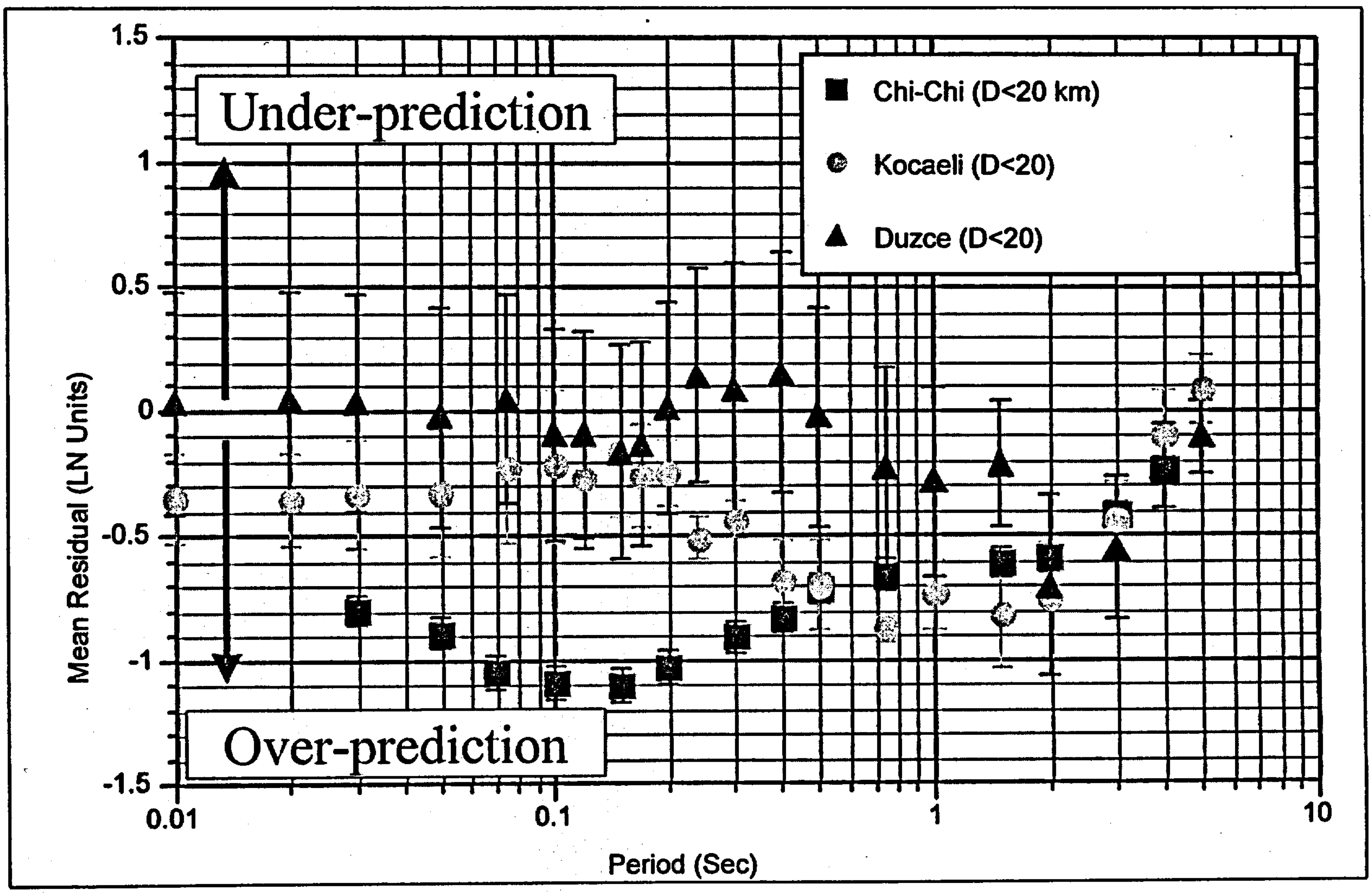
Strong Motion Recordings Close to Large Crustal Earthquakes

	M≥7.0 D≤ 20 km	M≥7.0 D≤ 10 km	M≥7.0 D≤ 5 km
Prior to 1999	9	5	2
1999 Kocaeli	6	3	2
1999 Chi-Chi	63	32	14
1999 Duzce	6	2	1

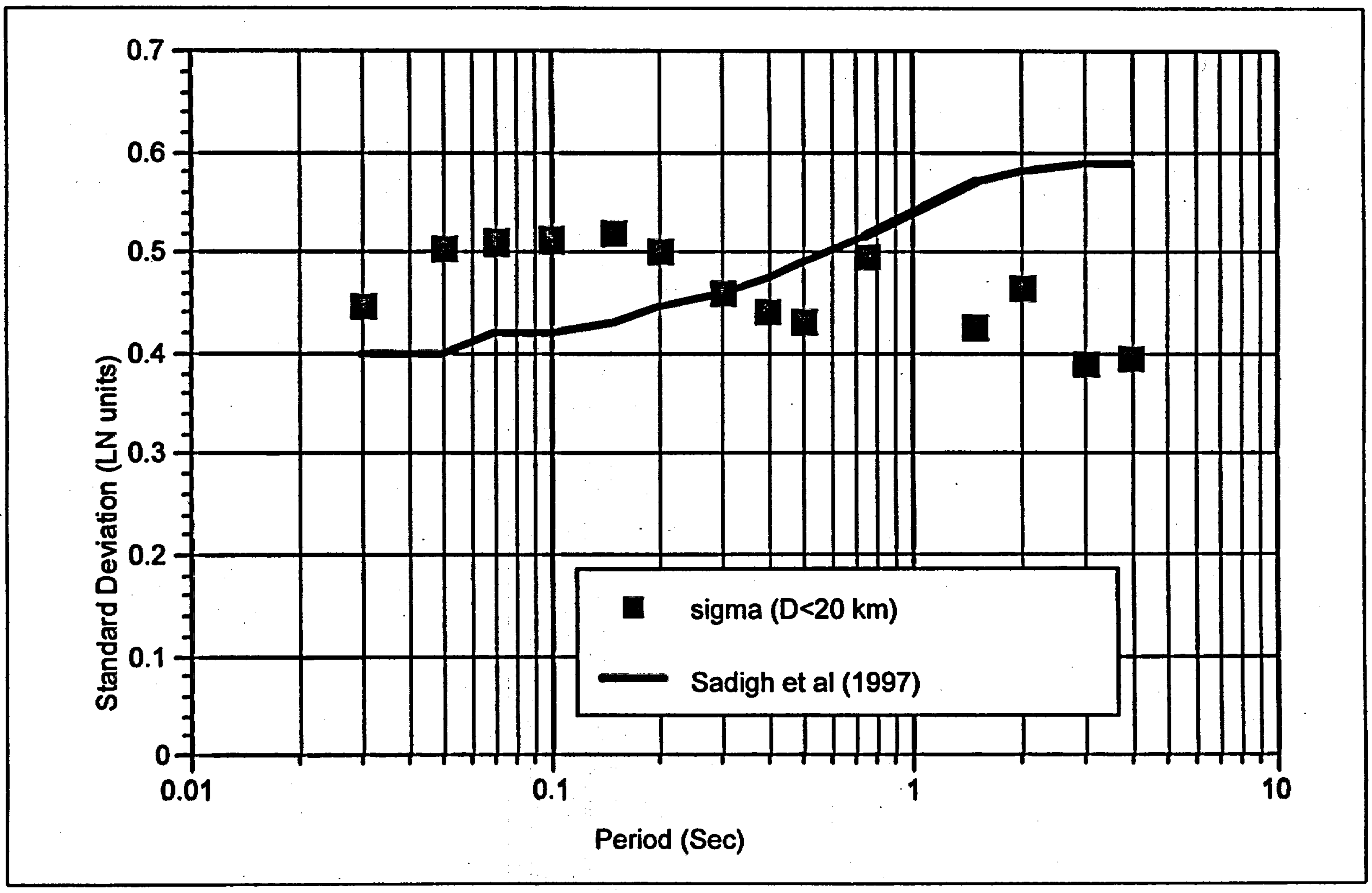
Evaluation of Ground Motions from Recent Earthquakes

- Compare response spectra to predicted values from recent attenuation relations
- Compute residuals (observed - calculated) from Sadigh et al (1997) attenuation relation
  - Mean residual
  - Standard deviation of the residuals

Mean Residuals for Short Distances (D< 20 km)



Ground Motion Variability
(D< 20 km)



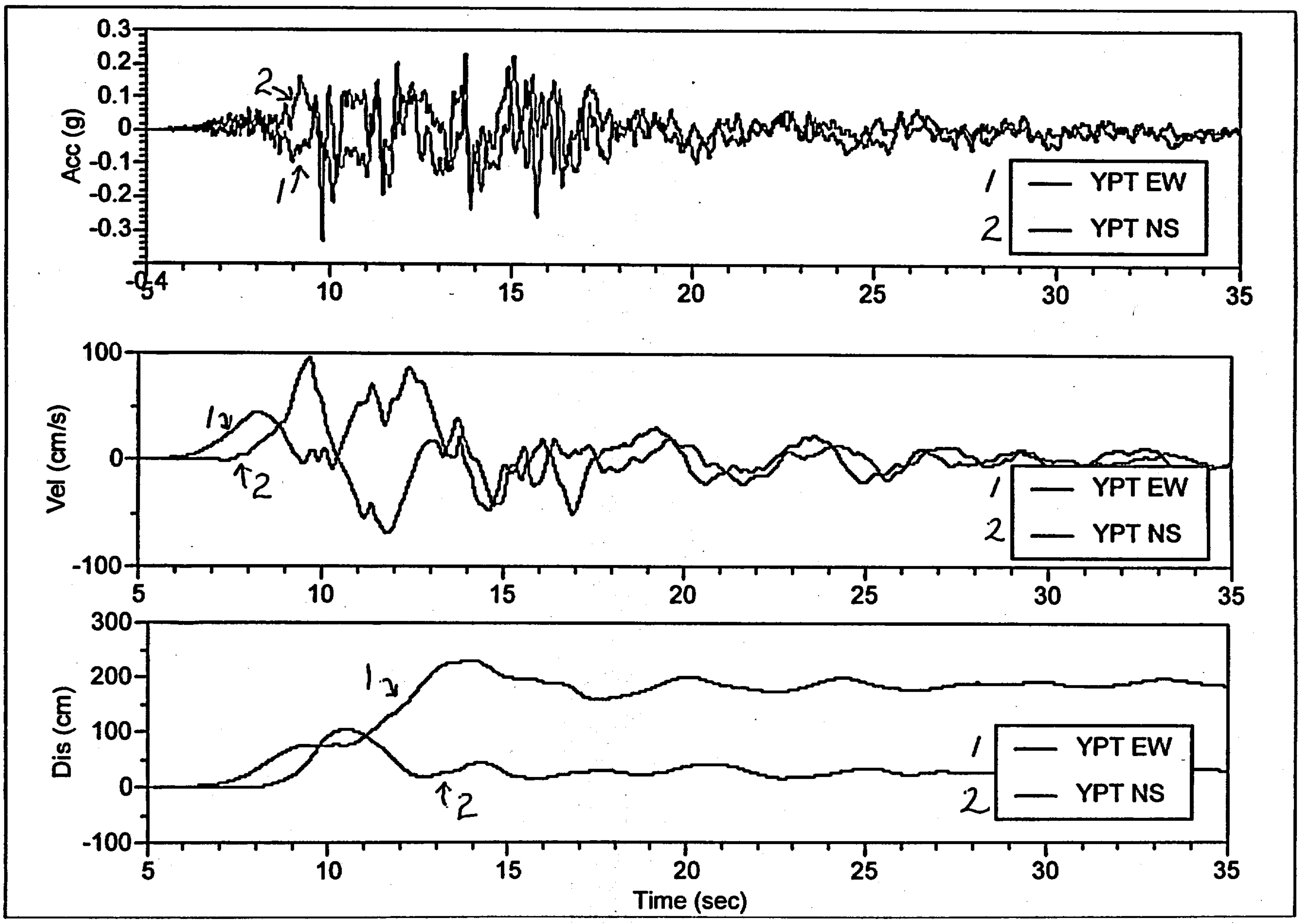
Lessons for Low and Moderate Periods

- Compared to current attenuation relations used in for California earthquakes:
  - Median ground motion lower than expected (T< 2 sec)
  - Variability (standard deviation) of the ground motion is larger than expected at short periods (T<0.2 sec)

Lessons for Long Periods (T>2 seconds)

- Recordings close to the fault showed strong near-fault effects
  - Large velocity pulse
  - Increased long period spectral values
- Two Causes of large velocity pulses
  - Directivity
  - Fling

Example of Near-Fault Effects
(Kocaeli Earthquake)



Causes of Velocity Pulses

- Directivity
  - Related to the direction of the rupture front
    - Forward directivity: rupture toward the site (site away from the epicenter)
    - Backward directivity: rupture away from the site (site near the epicenter)
- Fling
  - Related to the permanent tectonic deformation at the site

Velocity Pulses

- Forward Directivity
  - Two-sided velocity pulse due to constructive interference of SH waves from generated from parts of the rupture located between the site and epicenter
    - Constructive interference occurs if slip direction is aligned with the rupture direction
    - Occurs at sites located close to the fault but away from the epicenter for strike-slip
- Fling
  - One-sided velocity pulse due to tectonic deformation
  - Occurs at sites located near the fault rupture independent of the epicenter location

Observations of Directivity and Fling

Sense of Slip	**Directivity**	**Fling**
Strike-Slip	Fault Normal	Fault Parallel
Dip-Slip	Fault Normal	Fault Normal

Directivity Effects

(Somerville et al, 1997)

Two Effects on Ground Motion Amplitudes

- Changes in the average horizontal component as compared to standard attenuation relations
  - Increase in the amplitude of long period ground motion for rupture toward the site
  - Decrease in the amplitude of long period ground motion for rupture away from the site
- Systematic differences in the ground motions on the two horizontal components
  - Fault normal component is larger than the fault parallel component at long periods

Landers Earthquake (1992)

Directivity

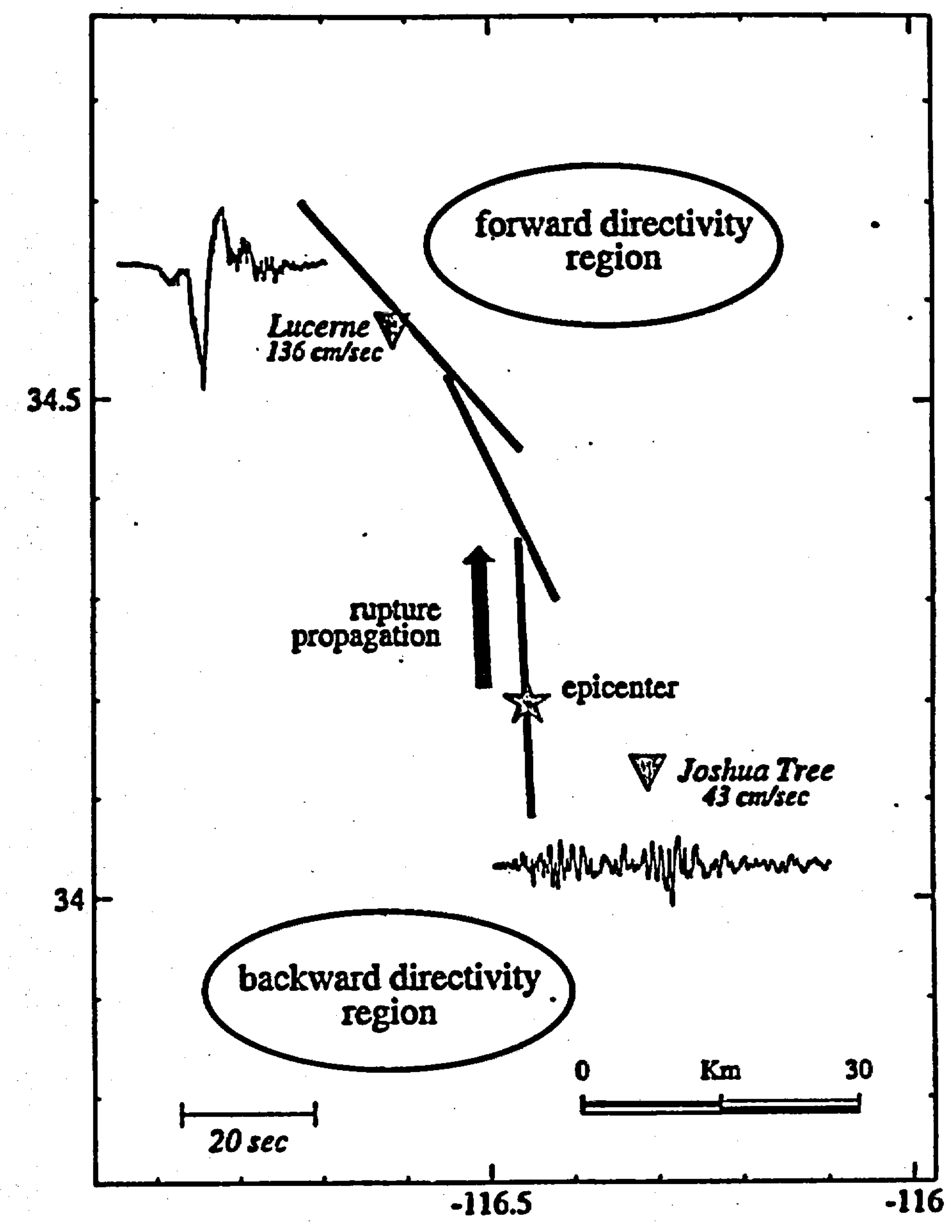
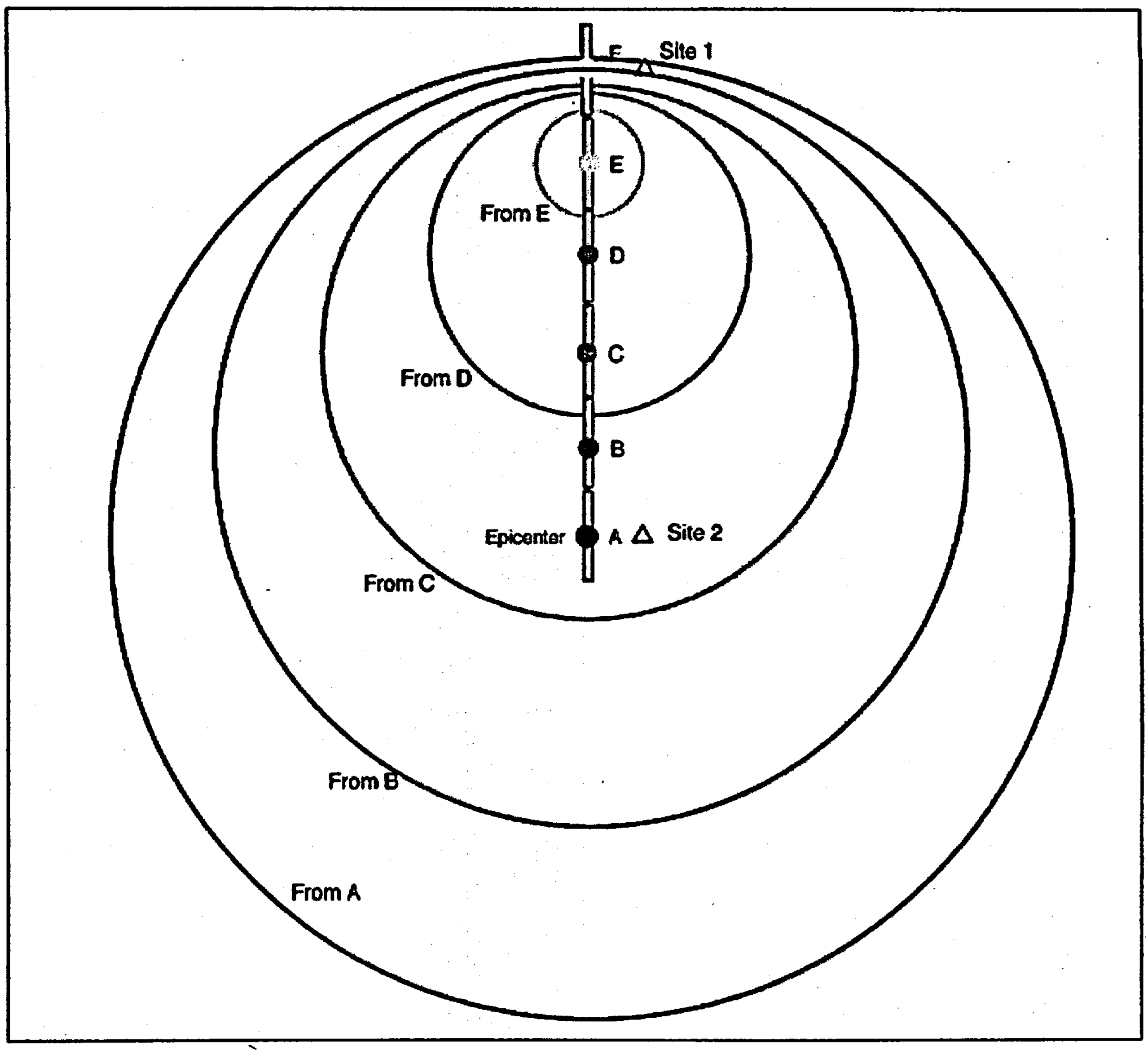


Figure 1. Map of the 1992 Landers earthquake showing the velocity time histories at Lucerene (forward directivity) and Joshua Tree (backward directivity).

Directivity



Model for Directivity Effects

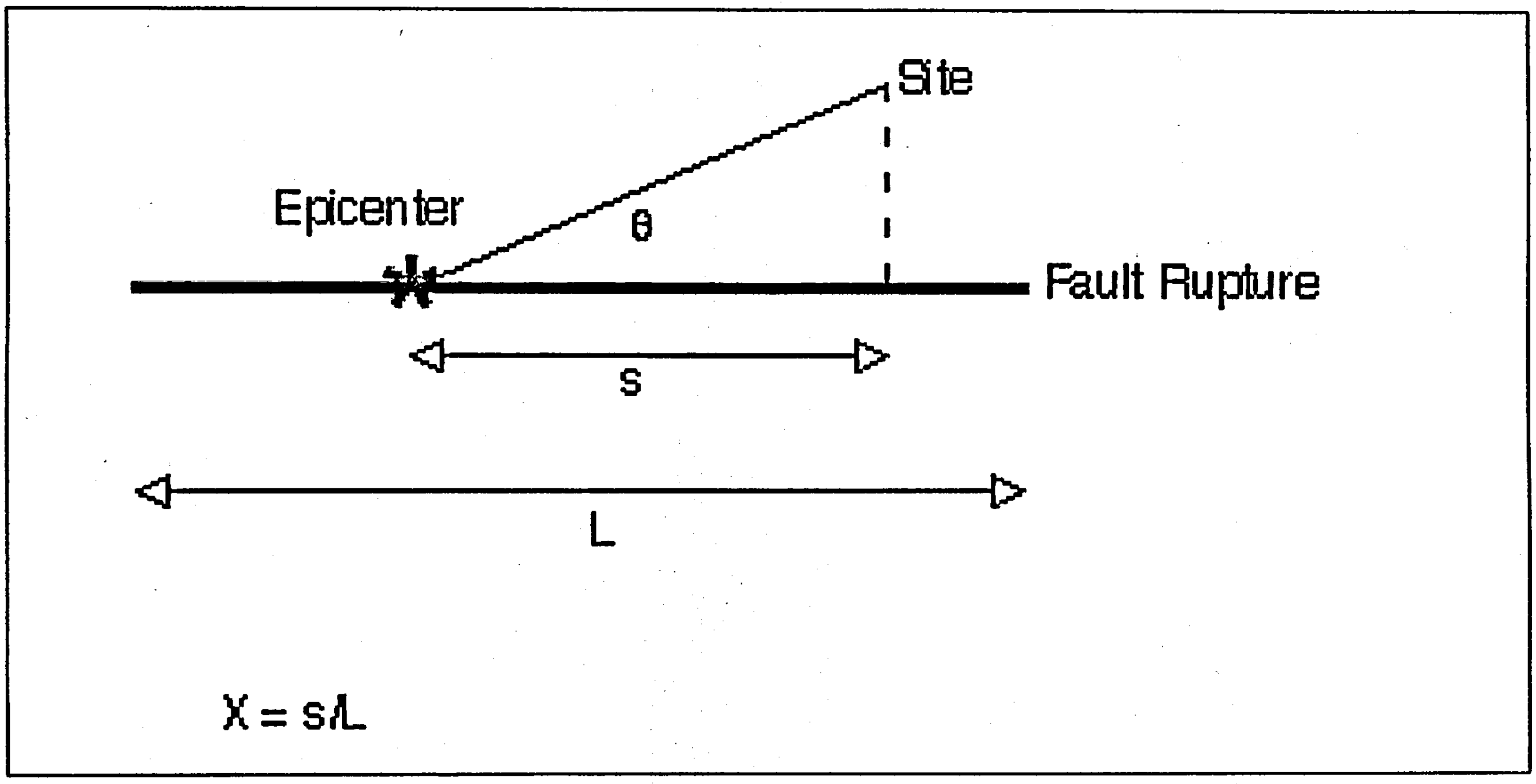
Additional Parameters Required

- Strike-Slip Fault

  X = fraction of fault rupture between the epicenter and the site

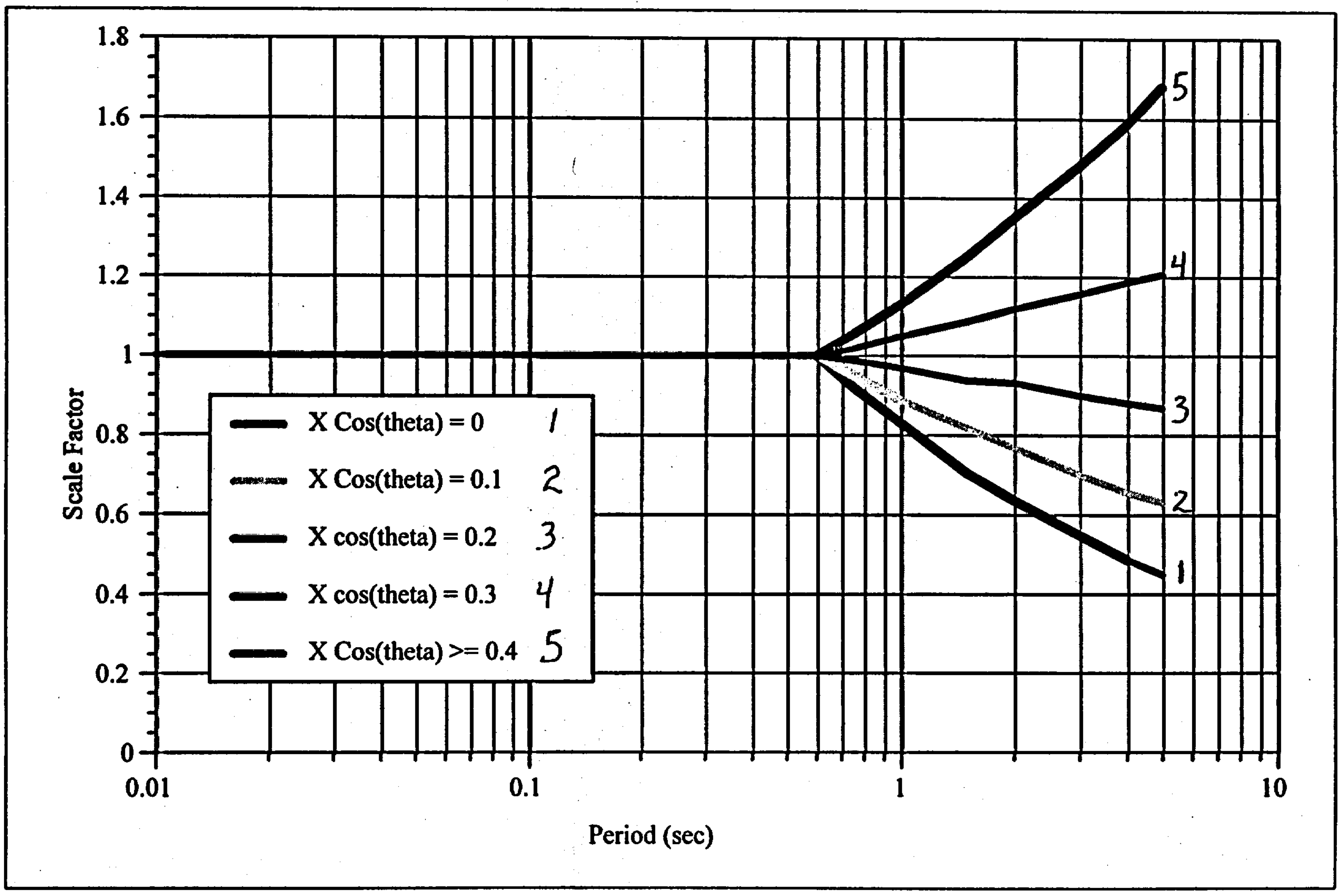
  θ = angle between the fault strike and the epicentral direction from the site

Directivity Parameters for Strike-Slip Faults

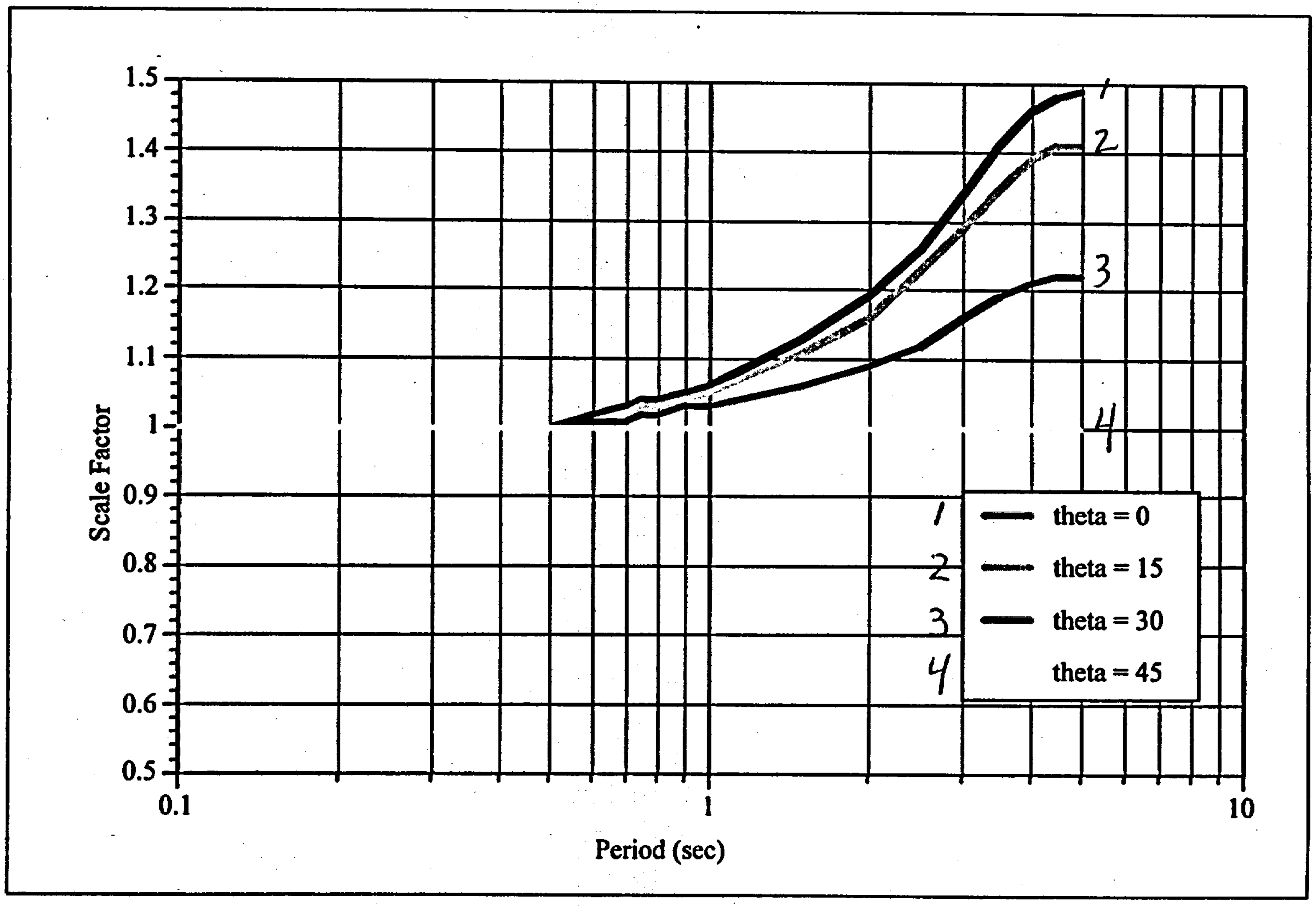


Abrahamson (2000) Directivity Factors

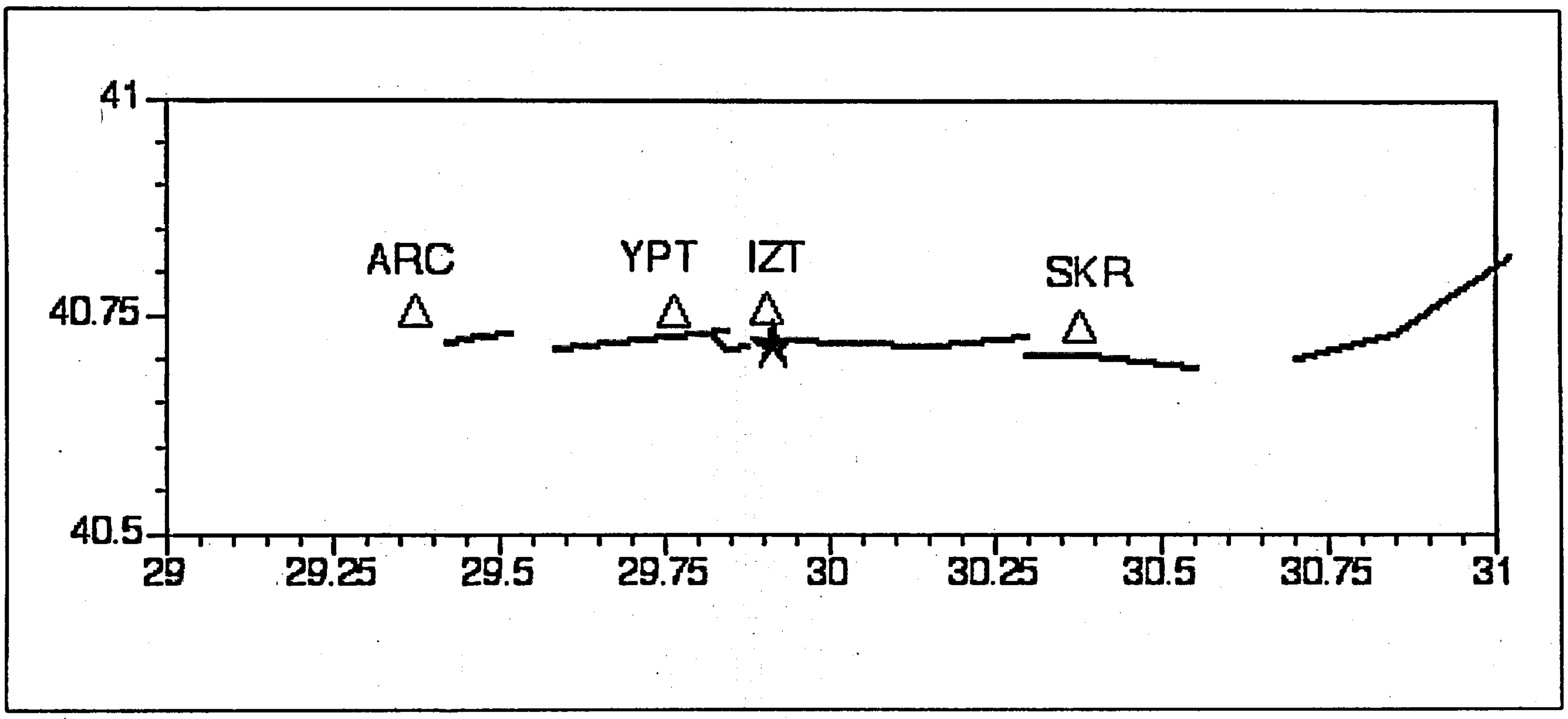
5% damping, Ave Horiz, Strike-Slip



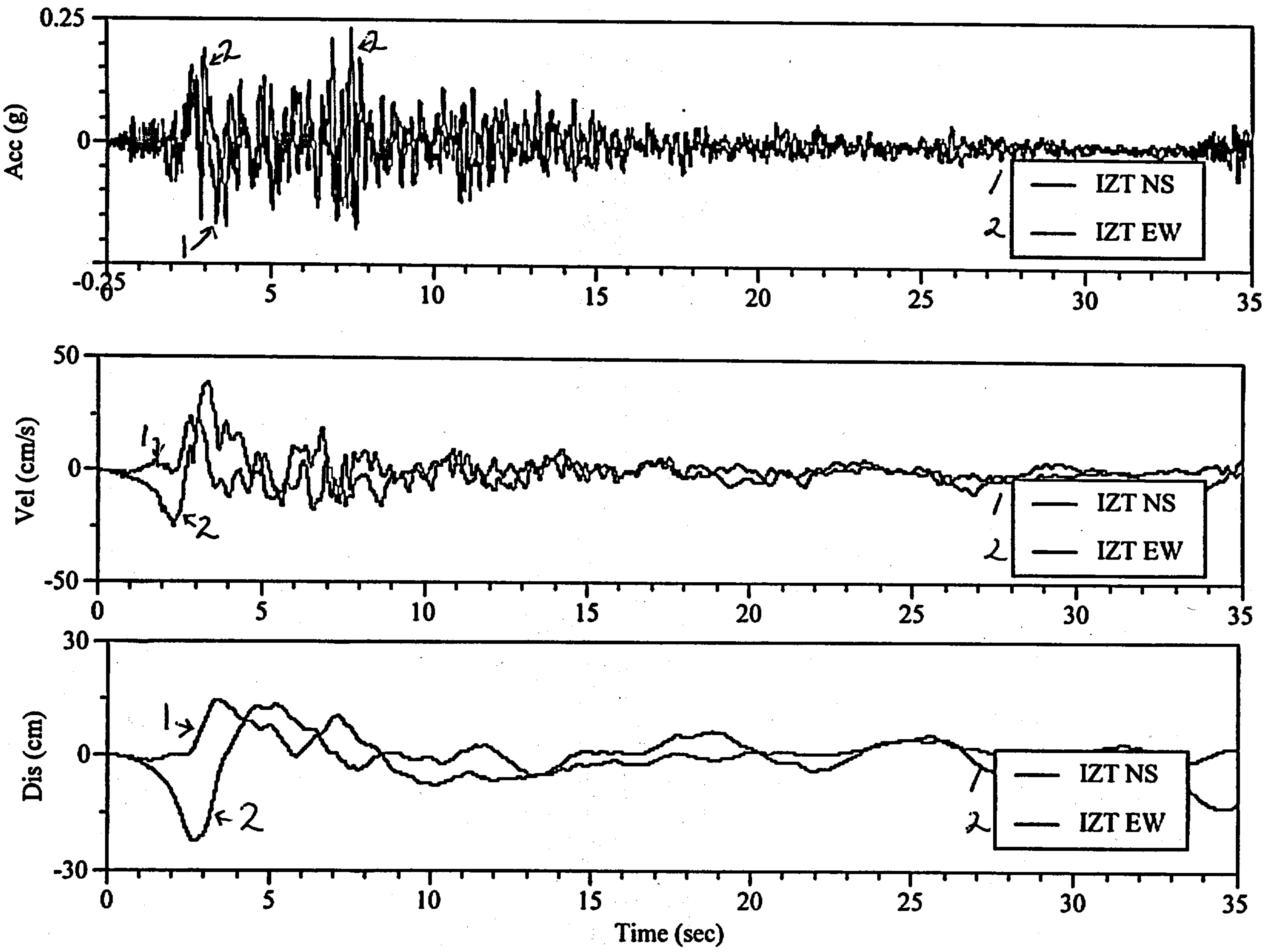
Somerville et al (1997) Scale Factors for FN/Ave Horiz



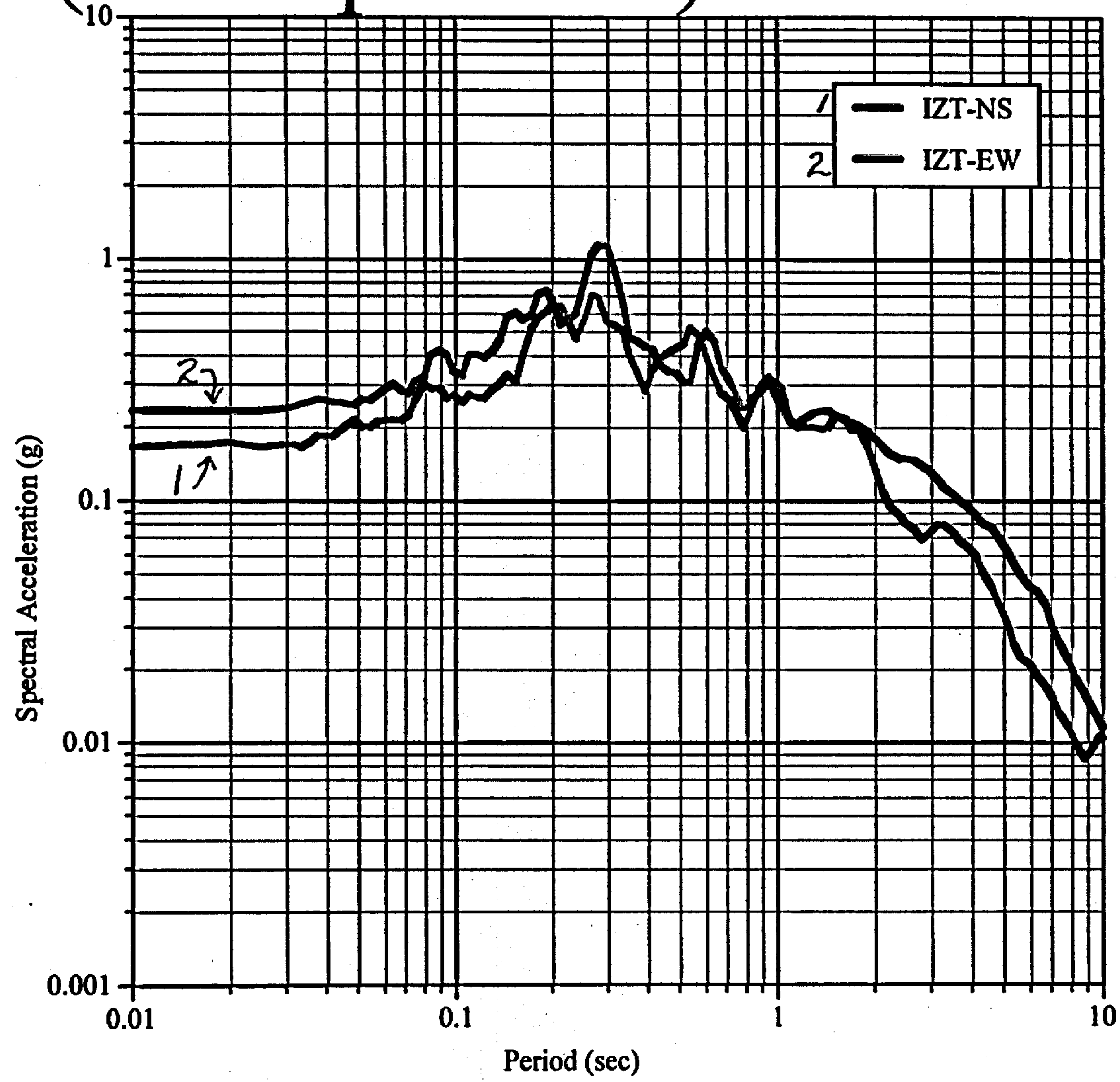
Kocaeli Rupture and Strong Motion Stations



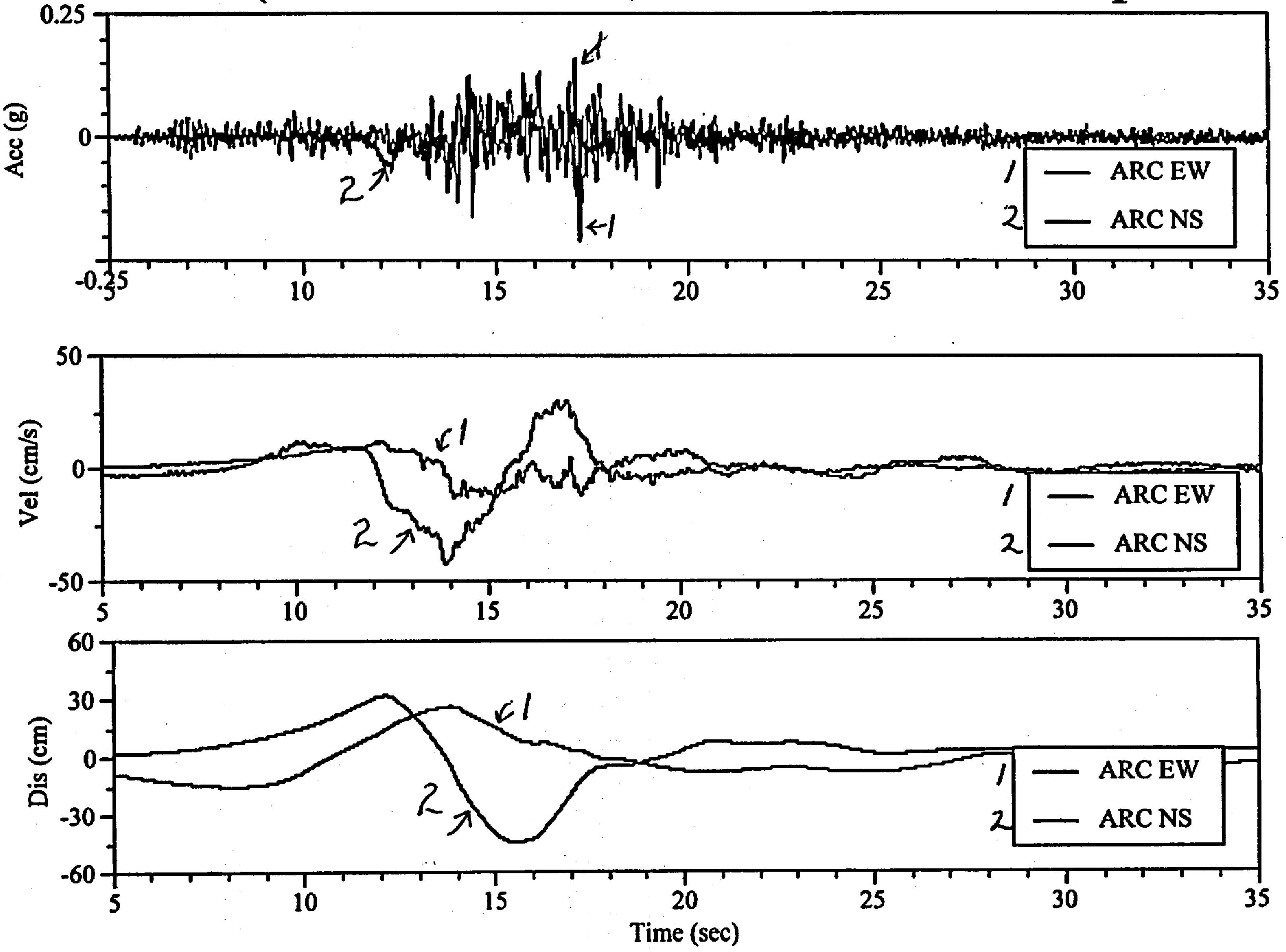
IZT (near epicenter)



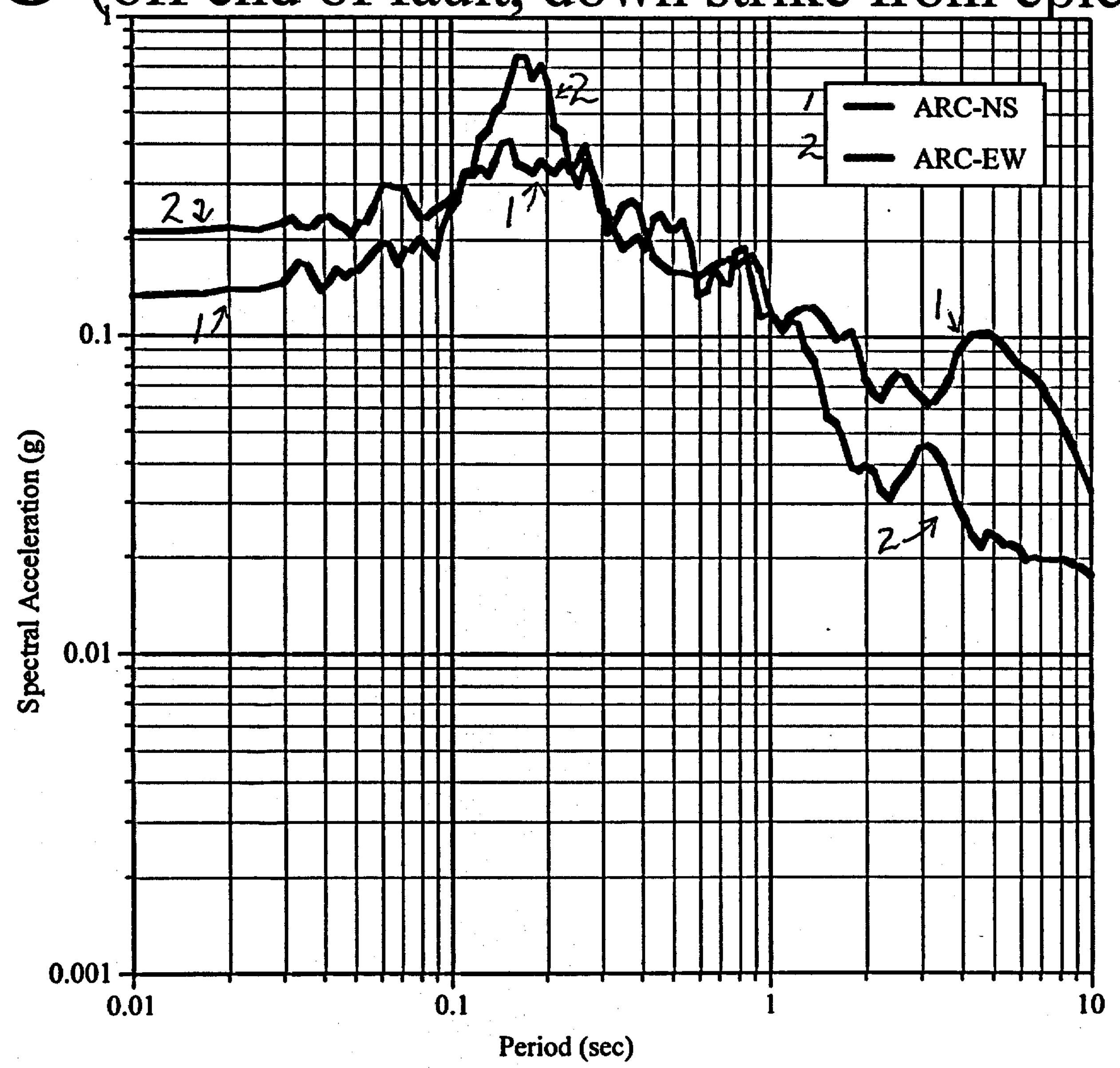
IZT (near epicenter)



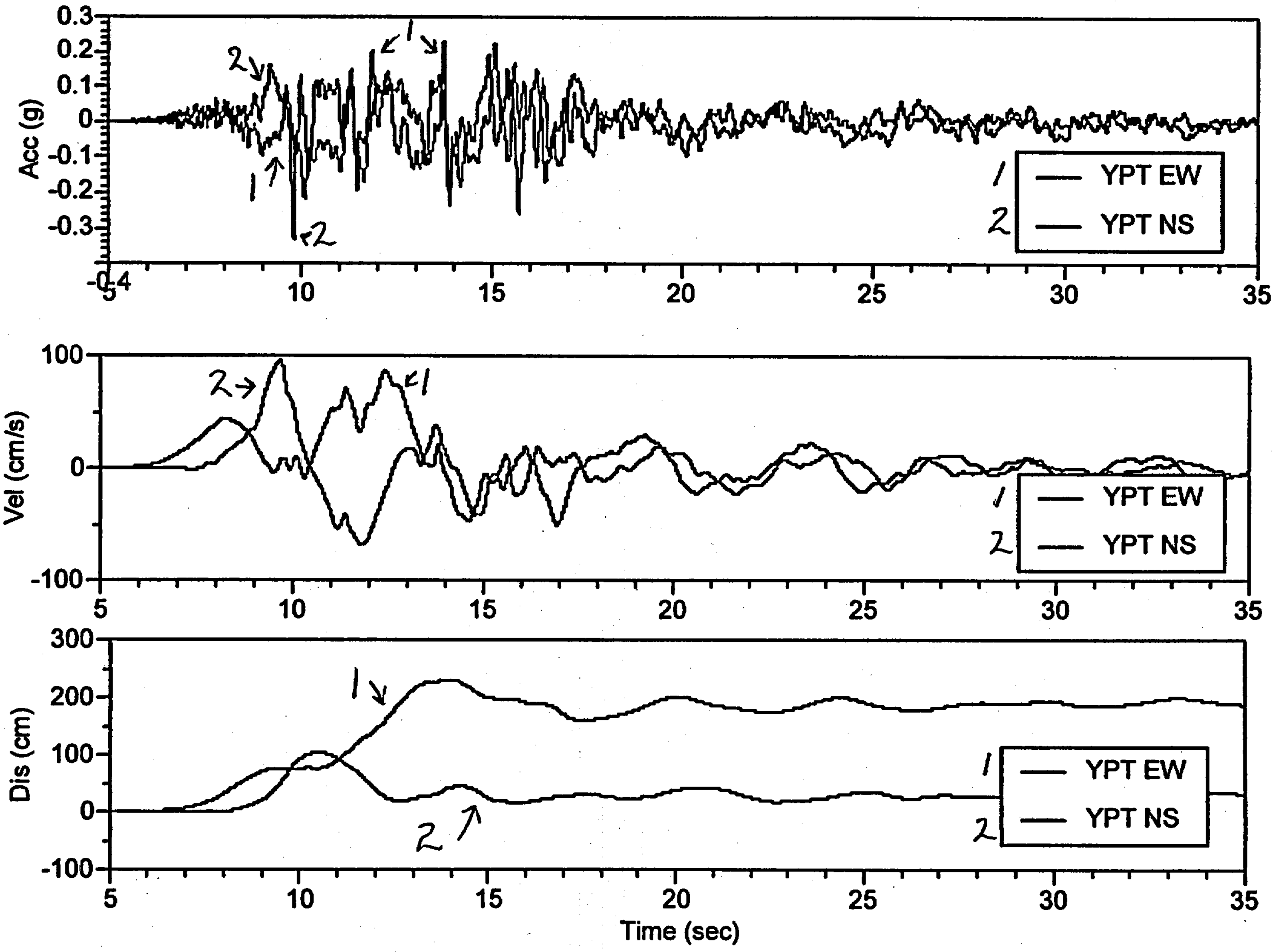
ARC (off end of fault, down strike from epicenter)



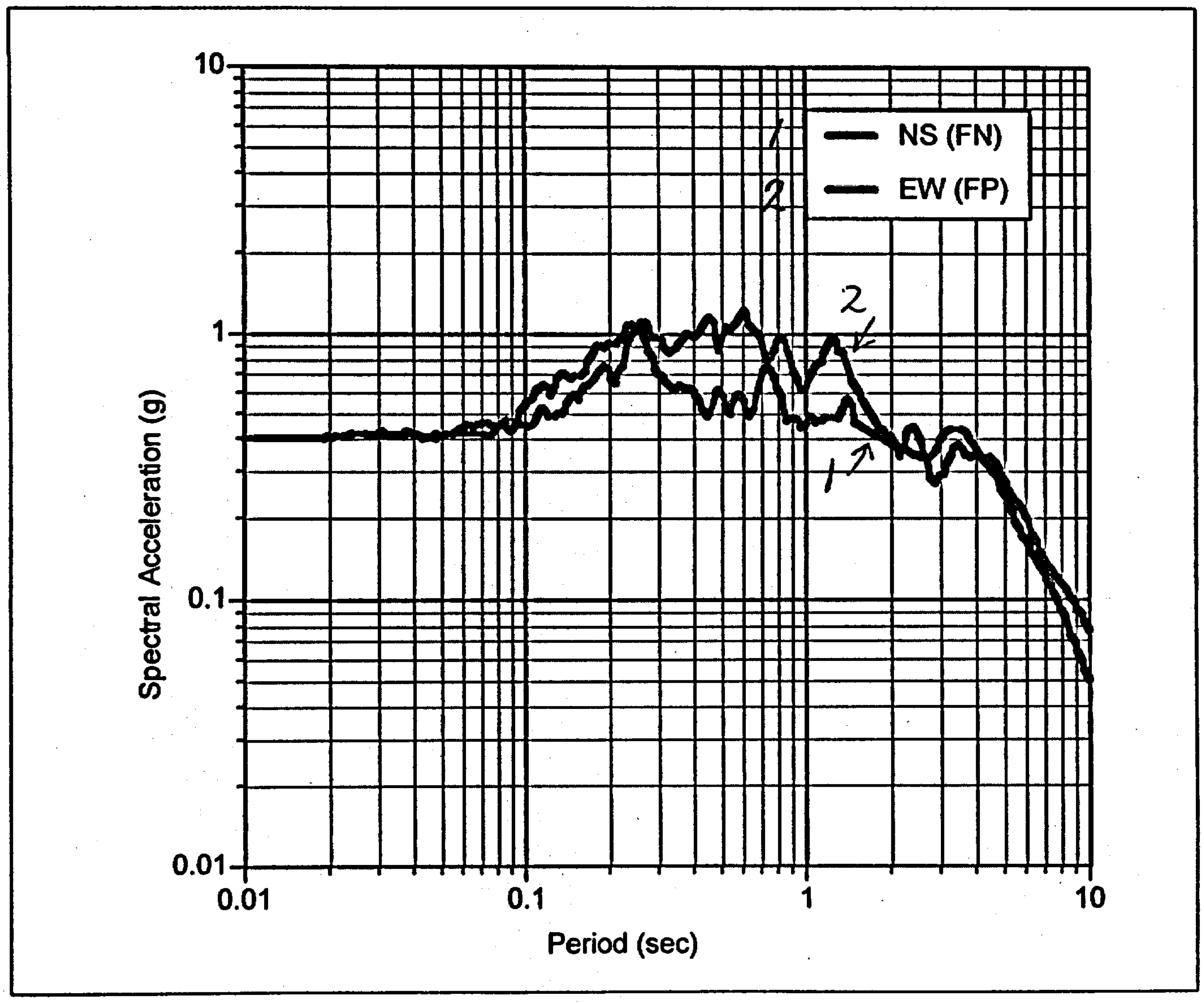
ARC (off end of fault, down strike from epicenter)



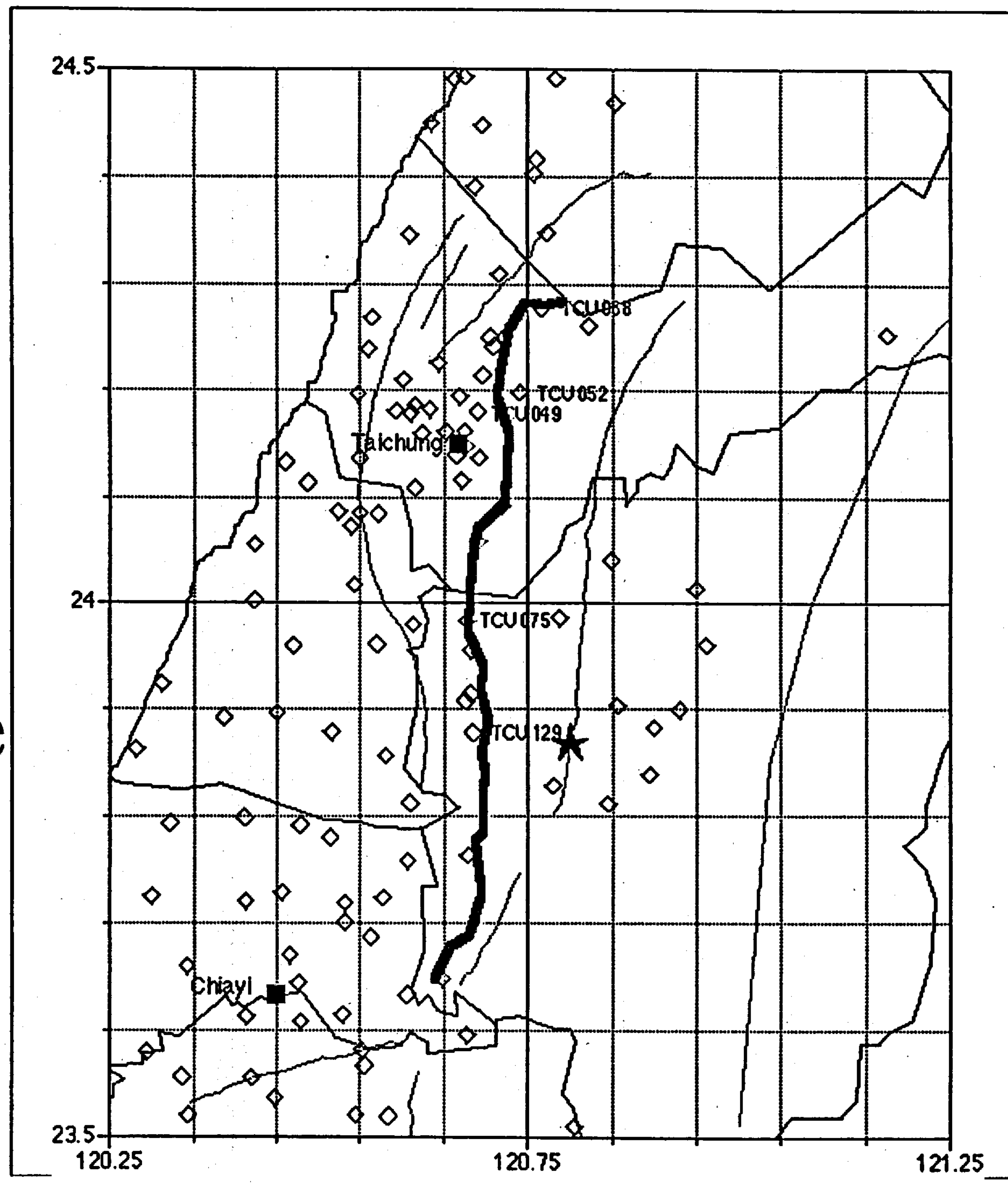
YPT (near fault, down strike from epicenter)



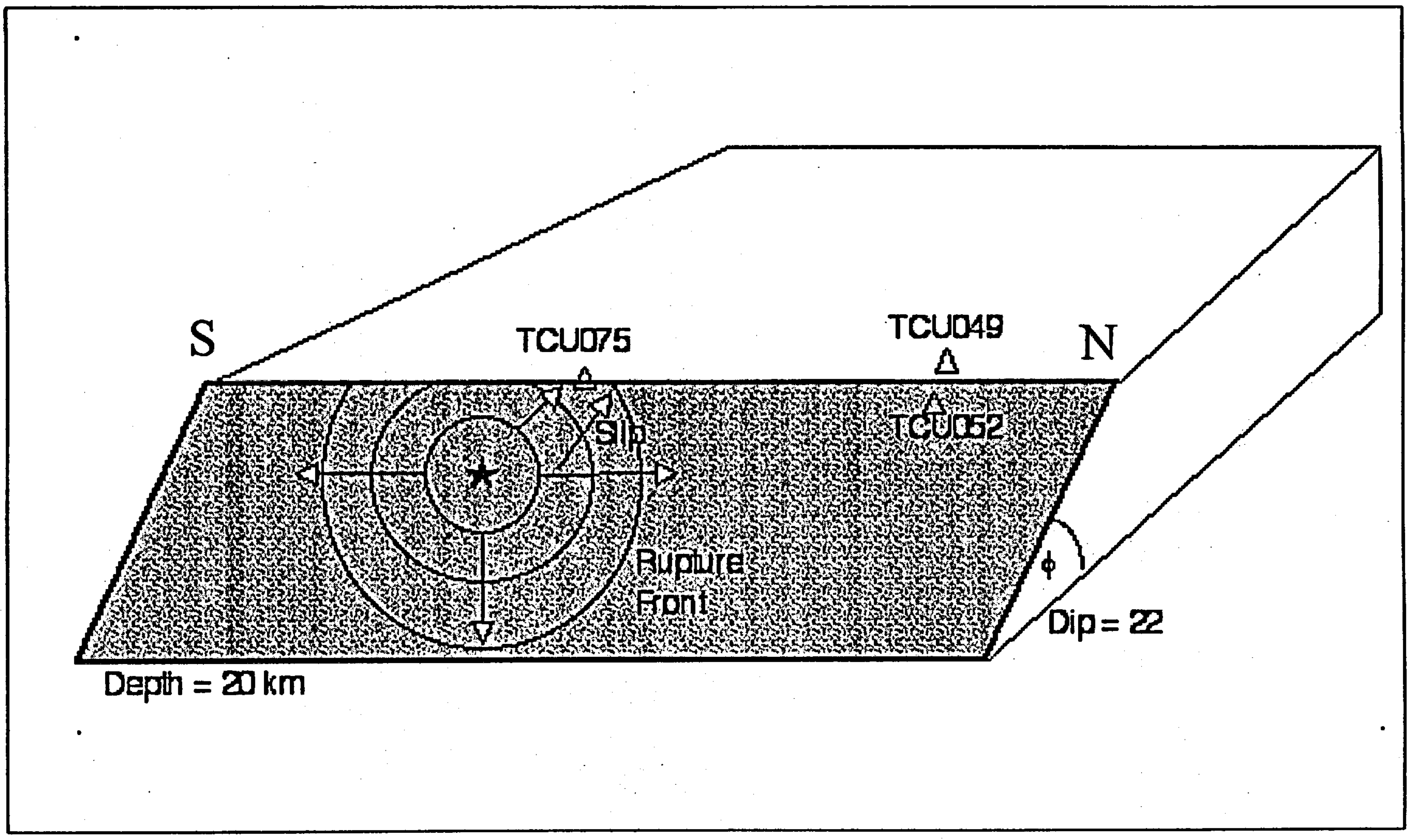
YPT (near fault, down strike from epicenter)



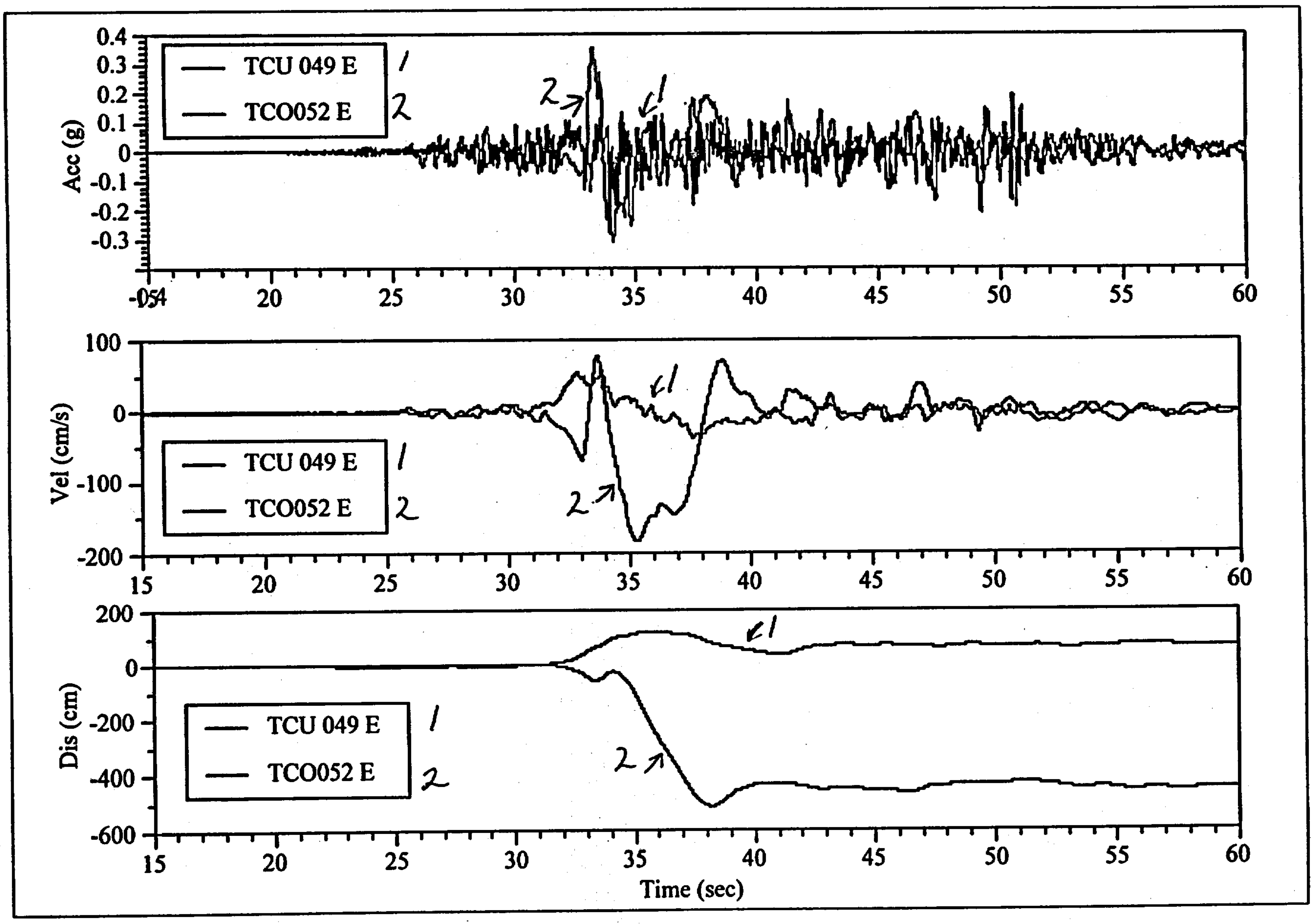
Strong Motion Stations from the Chi-Chi Earthquake



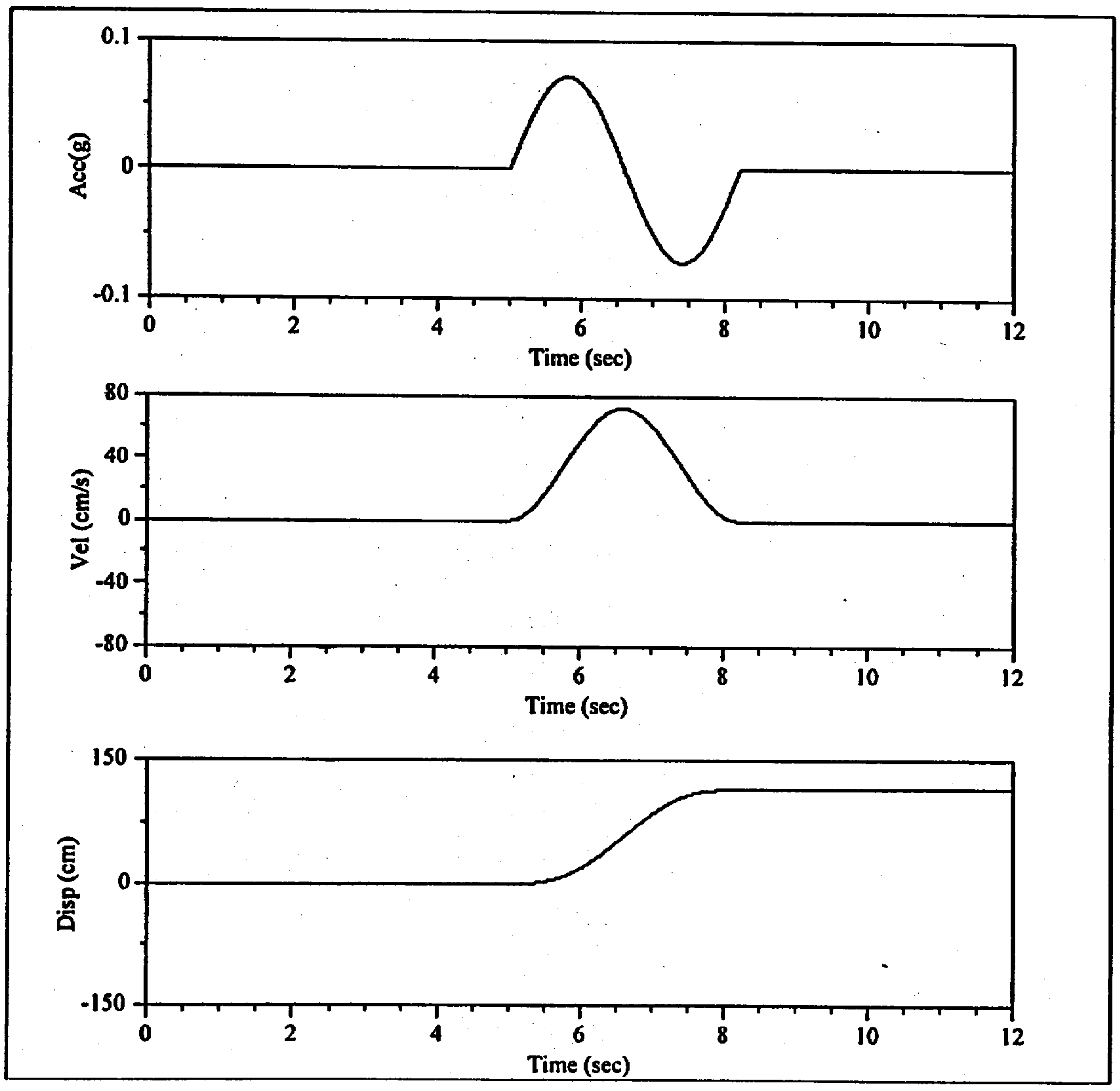
Chi-Chi Earthquake



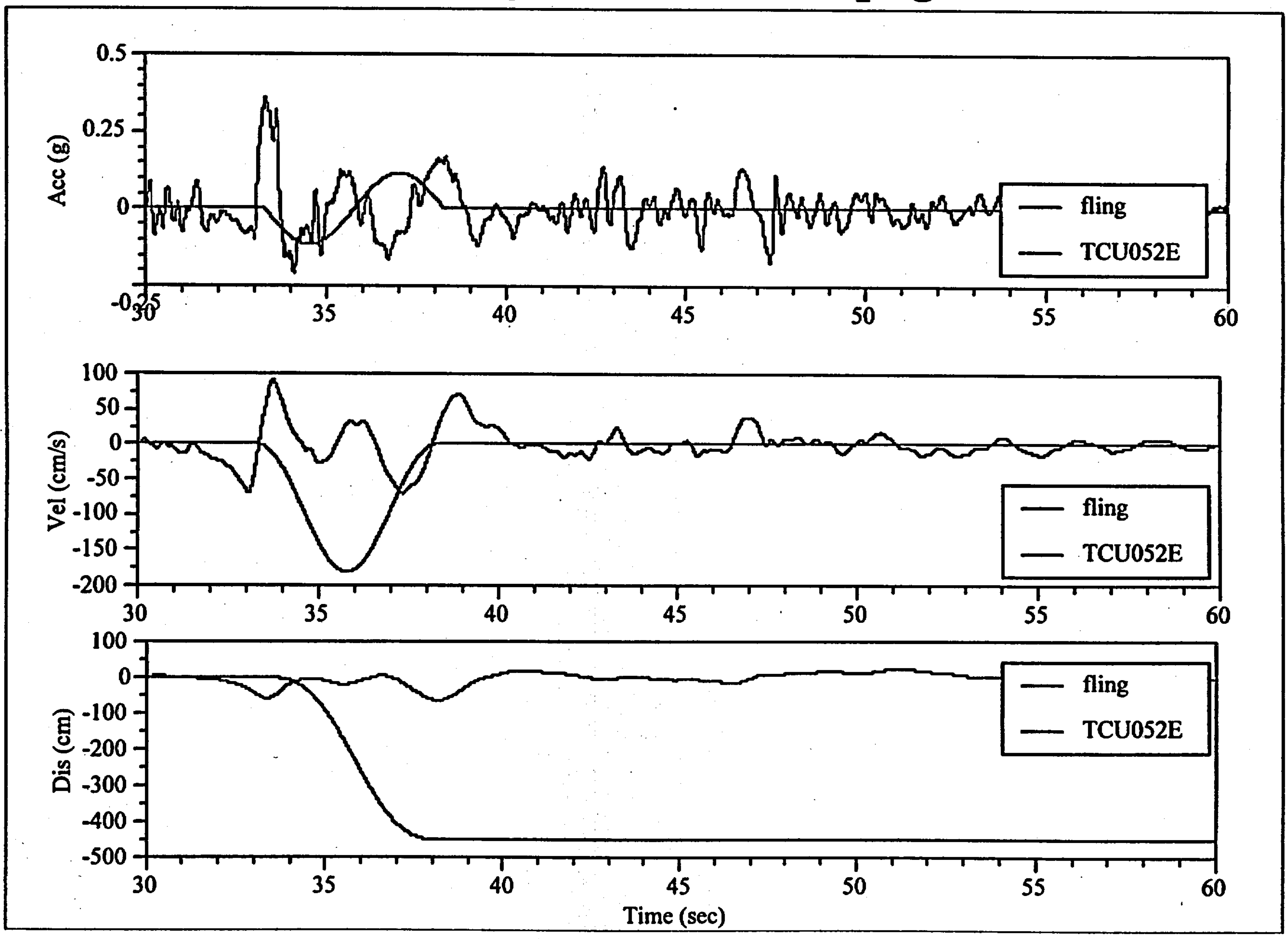
Fling Effects



Time Domain Fling Model



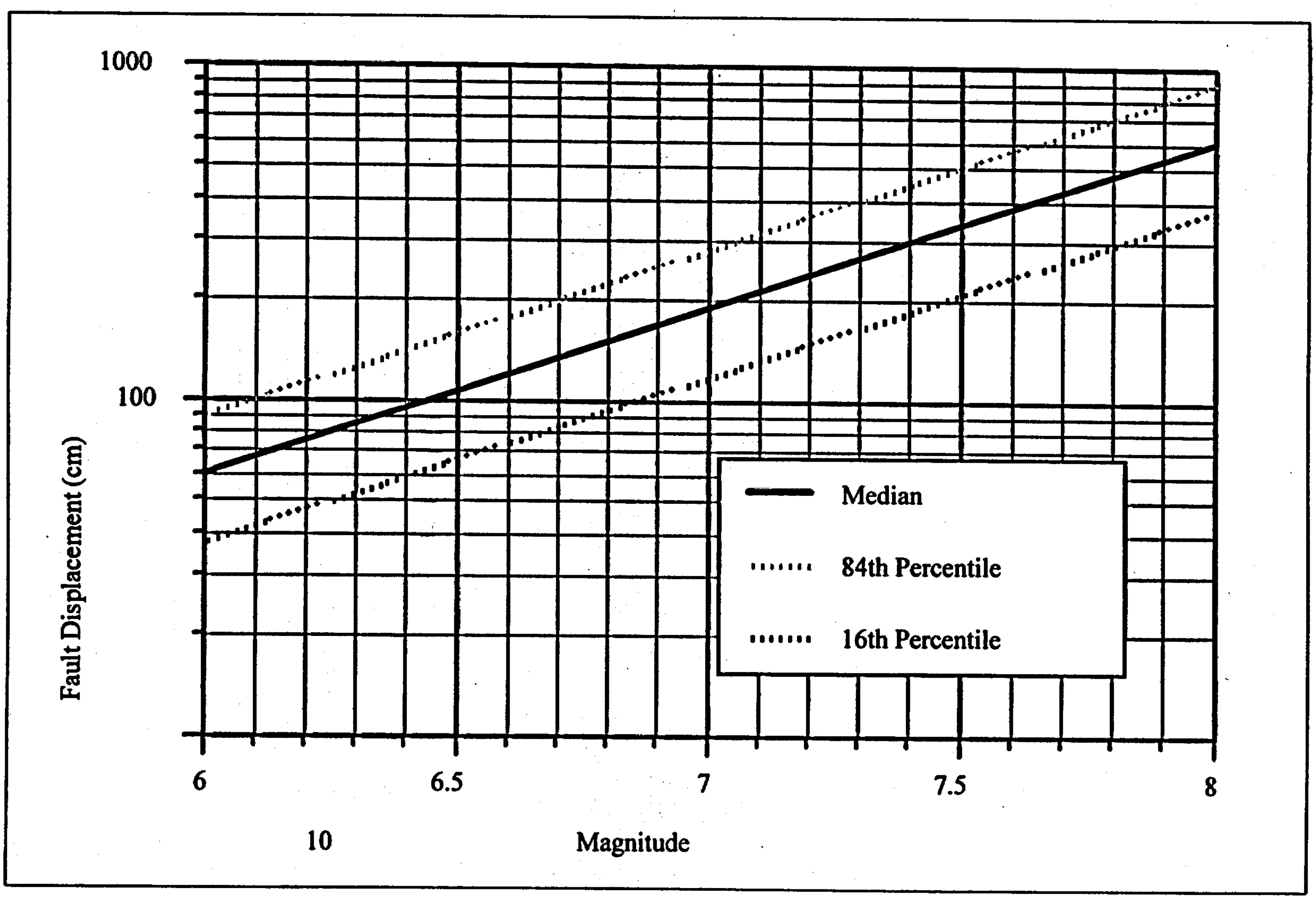
Separation of Fling and Wave Propagation Effects



Parameters Required for Fling

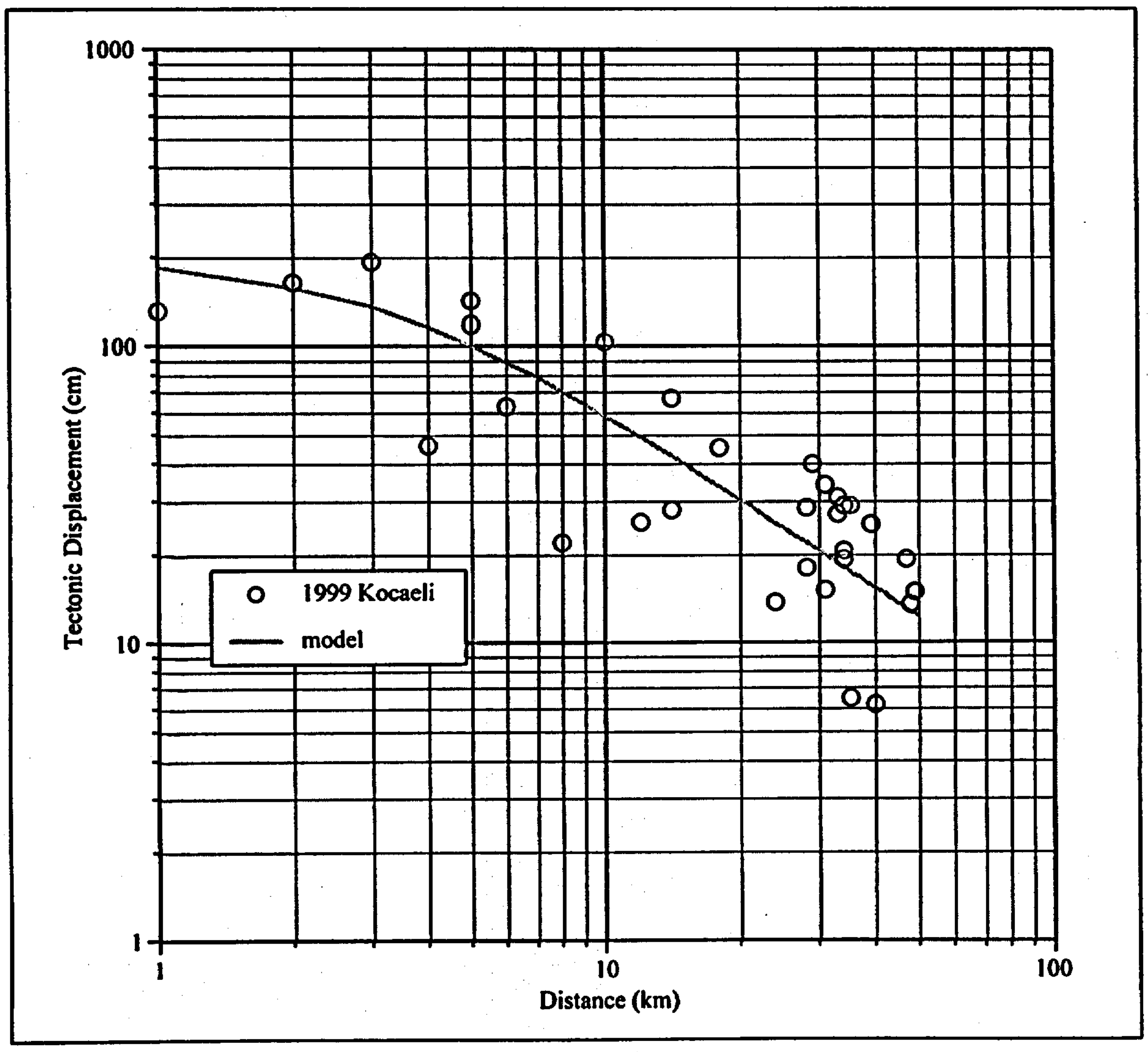
- Amplitude of Fling
  - From fault slip and geodetic data
- Duration (period) of Fling
  - From strong motion data
- Arrival Time of Fling
  - From numerical modeling
  - Relative timing of fling and S-waves

Fault Displacement

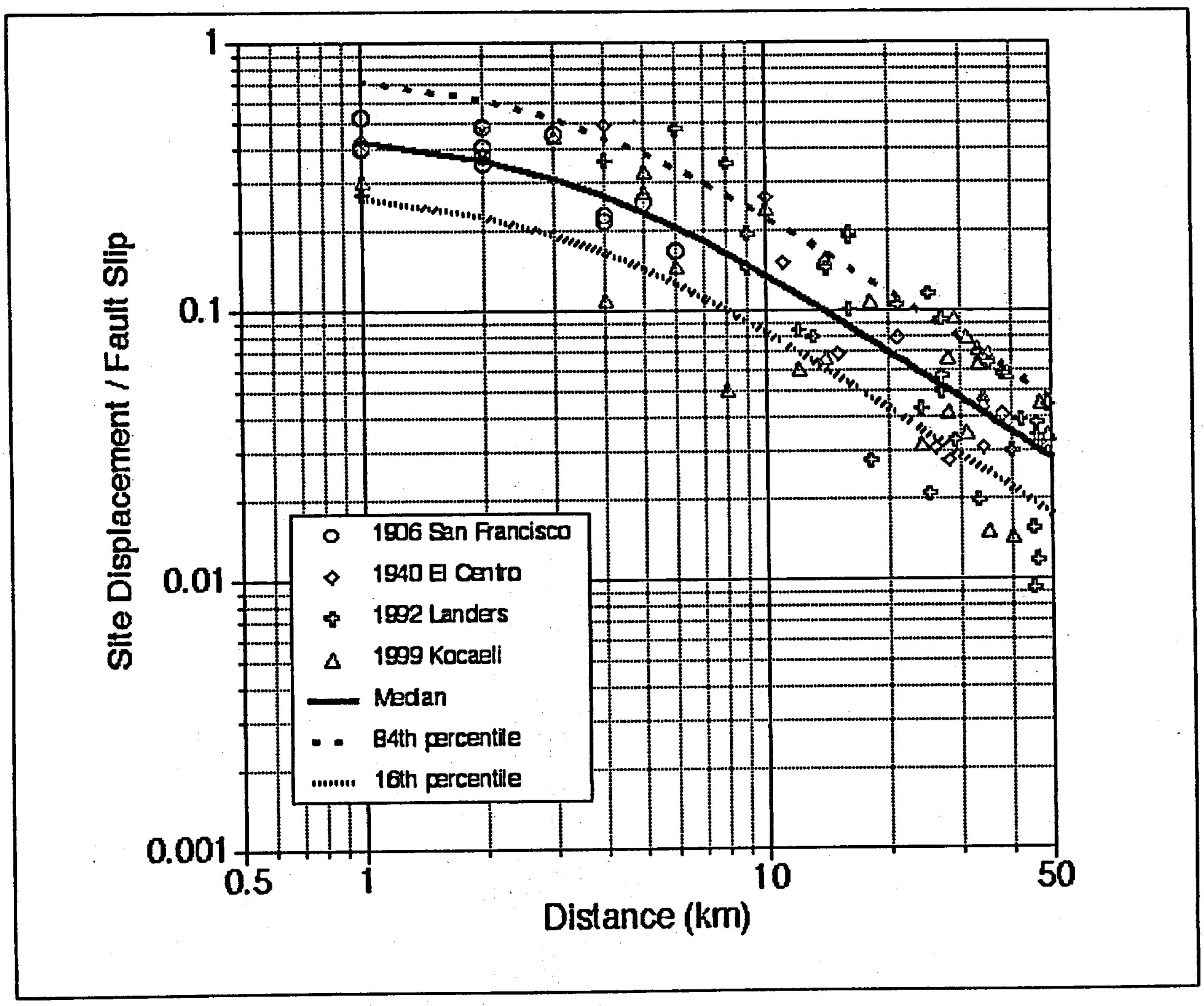


Attenuation of Fling Amplitude

Example from Kocaeli Geodetic Data

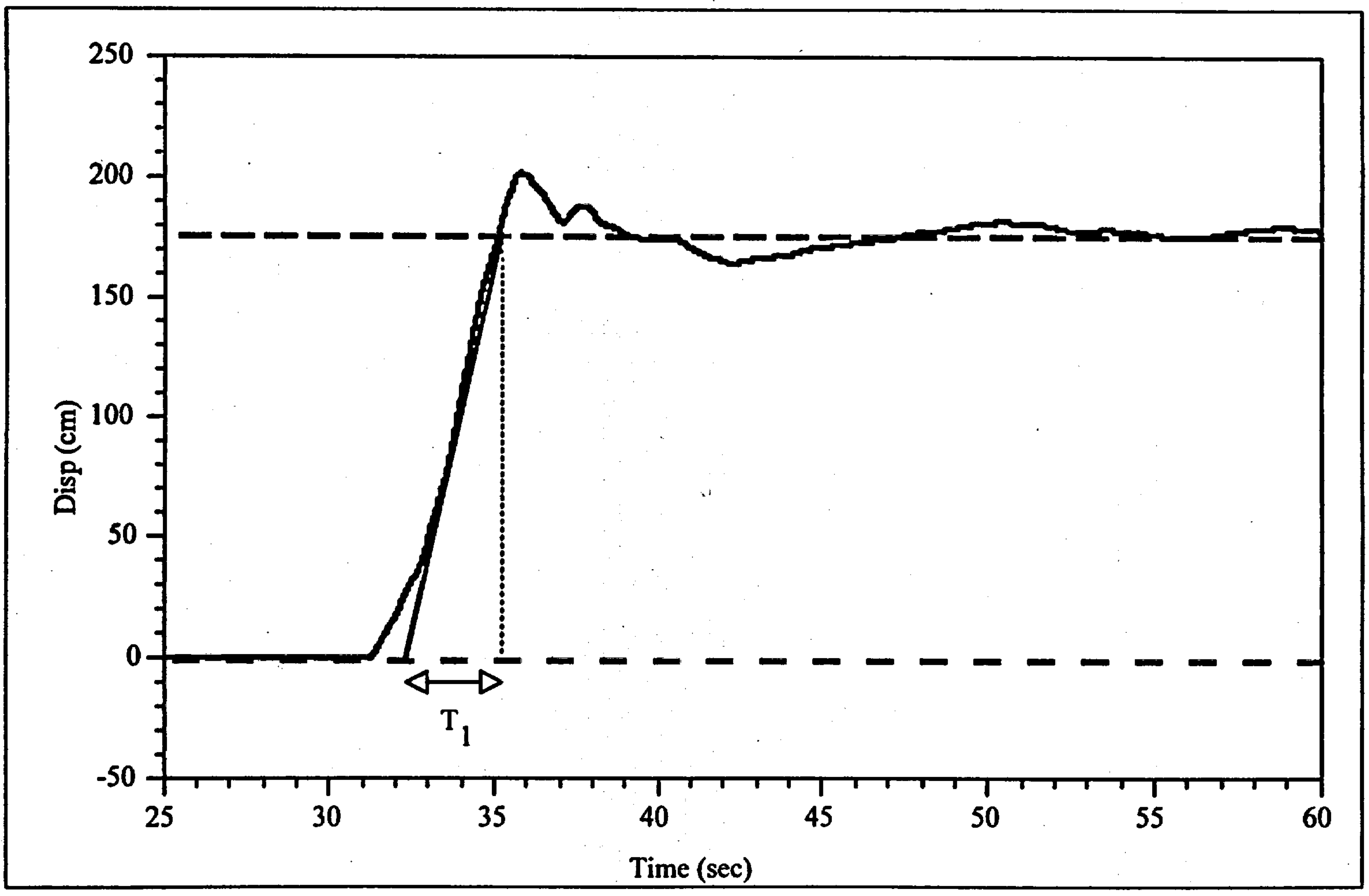


Attenuation of Fling Amplitude

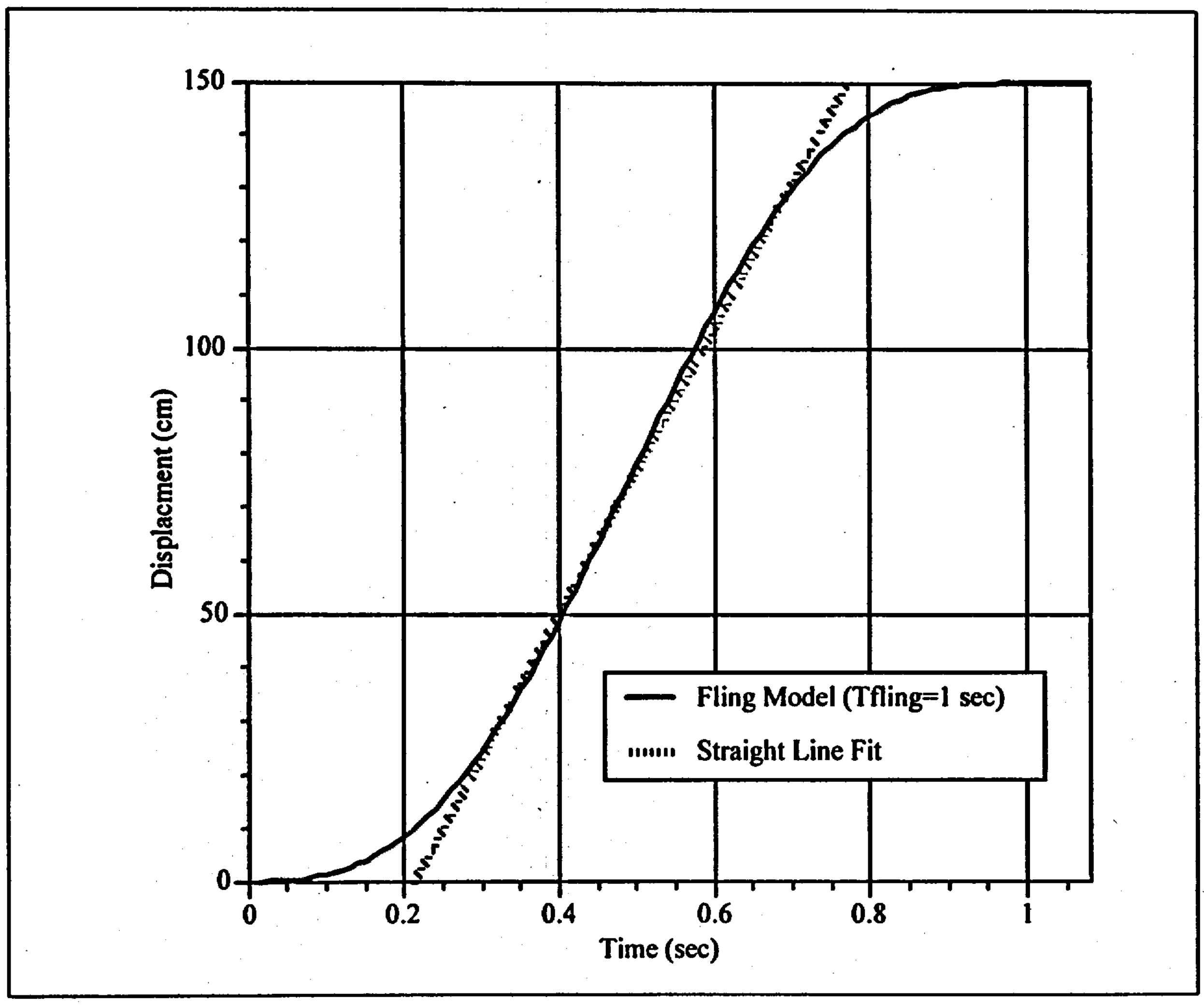


Duration of Fling

Measured from Strong Motion Recordings
(SKR from Kocaeli)

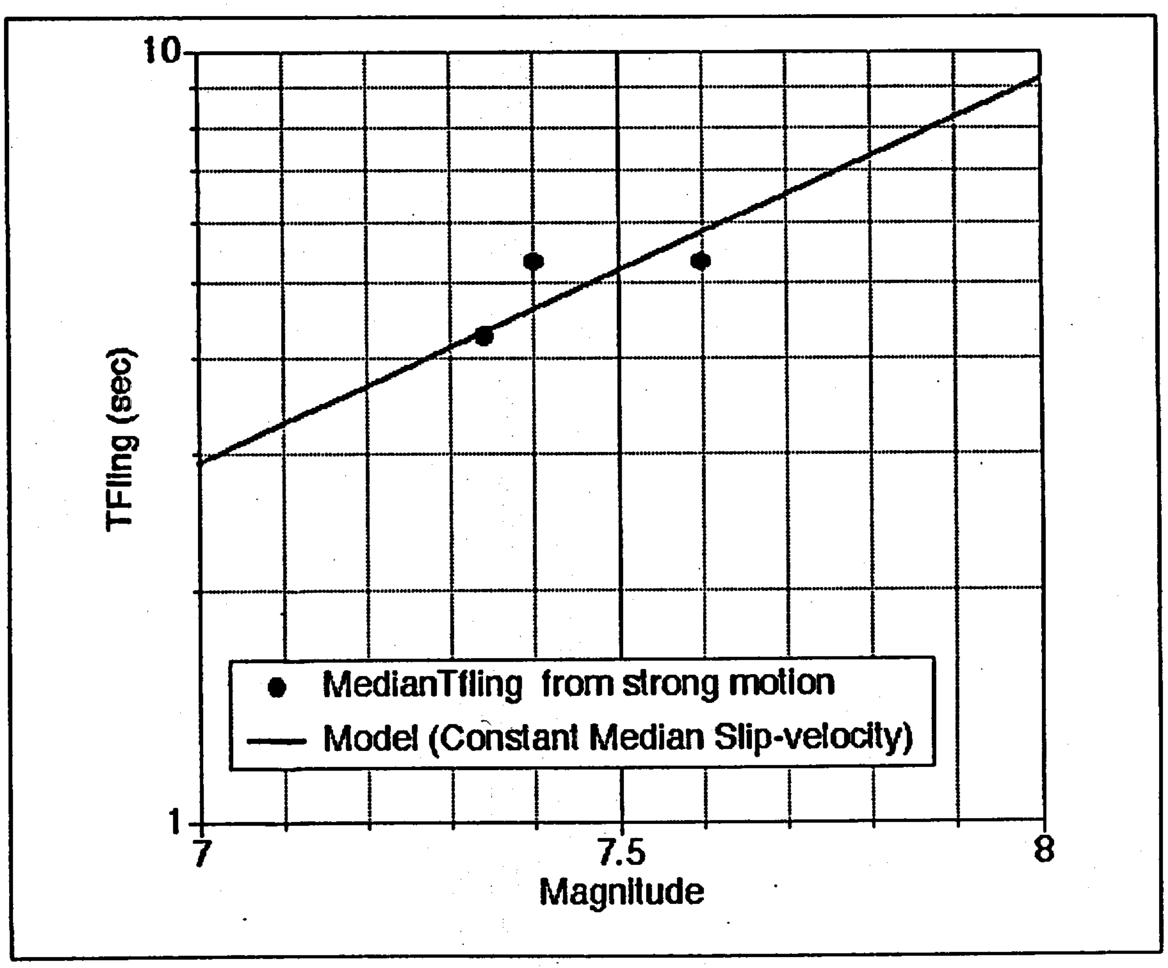


Fling Period



Model for Duration of Fling

(slope fixed by assuming median slip-velocity is independent of magnitude)



Lessons for Long Period Ground Motions

- Near fault ground motions can have large velocity pulses caused by directivity and/or fling
- Forward Directivity Effects
  - Observed in Kocaeli earthquake
    - Consistent with previously derived models
  - Not observed in Chi-Chi earthquake due to shallow depth of hypocenter
- Fling
  - Observed in both Kocaeli and Chi-Chi

Lessons for Long Period Ground Motions

- Directivity
  - Current scaling relations for directivity effects are generally consistent with data from new earthquakes
  - Directivity effects result in narrow band peak in the long period spectrum

Lessons for Long Period Ground Motions

- Fling
  - Commonly used attenuation relations do not include fling
  - Fling effects are not represented in the empirical data prior to 1999
- A separate ground motion model is needed for the fling,
  - Fling effects scale differently with magnitude and distance than ground motion due to wave propagation
- Ground motion from fling effects needs to be combined with the ground motion due to wave propagation

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Ground Motions

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Engineering Seismologist
PG&E Geosciences Department

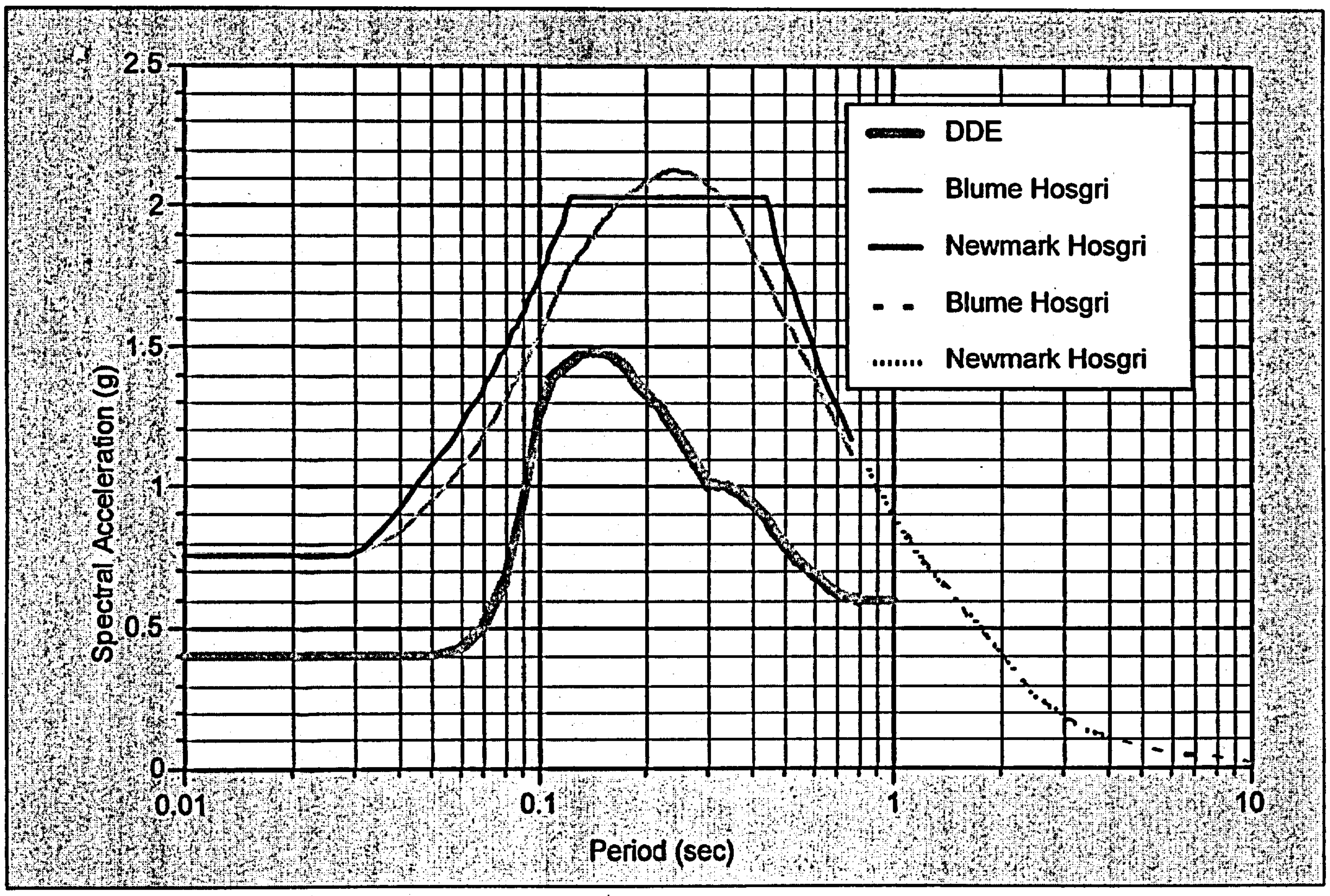
PG&E

April 11, 2002

DCPP Ground Motions

- Design Basis Ground Motions
  - Design Earthquake (DE)
  - Double Design Earthquake (DDE)
  - Hosgri Earthquake (HE)
    - Newmark Hosgri
    - Blume Hosgri
- Margin Evaluations
  - Long Term Seismic Program (LTSP)

Response Spectra (5% damping)

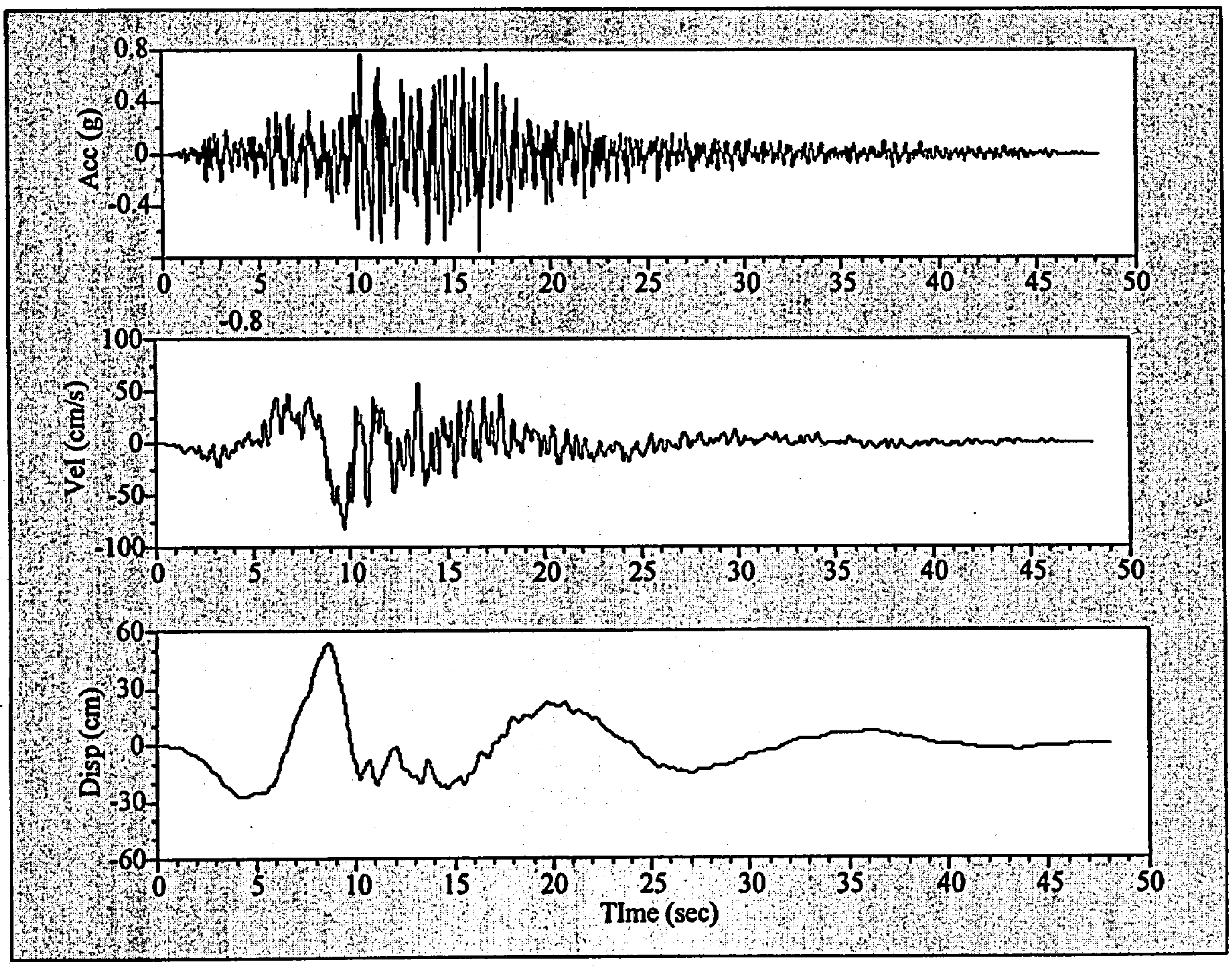


Time Histories for Hosgri Eqk

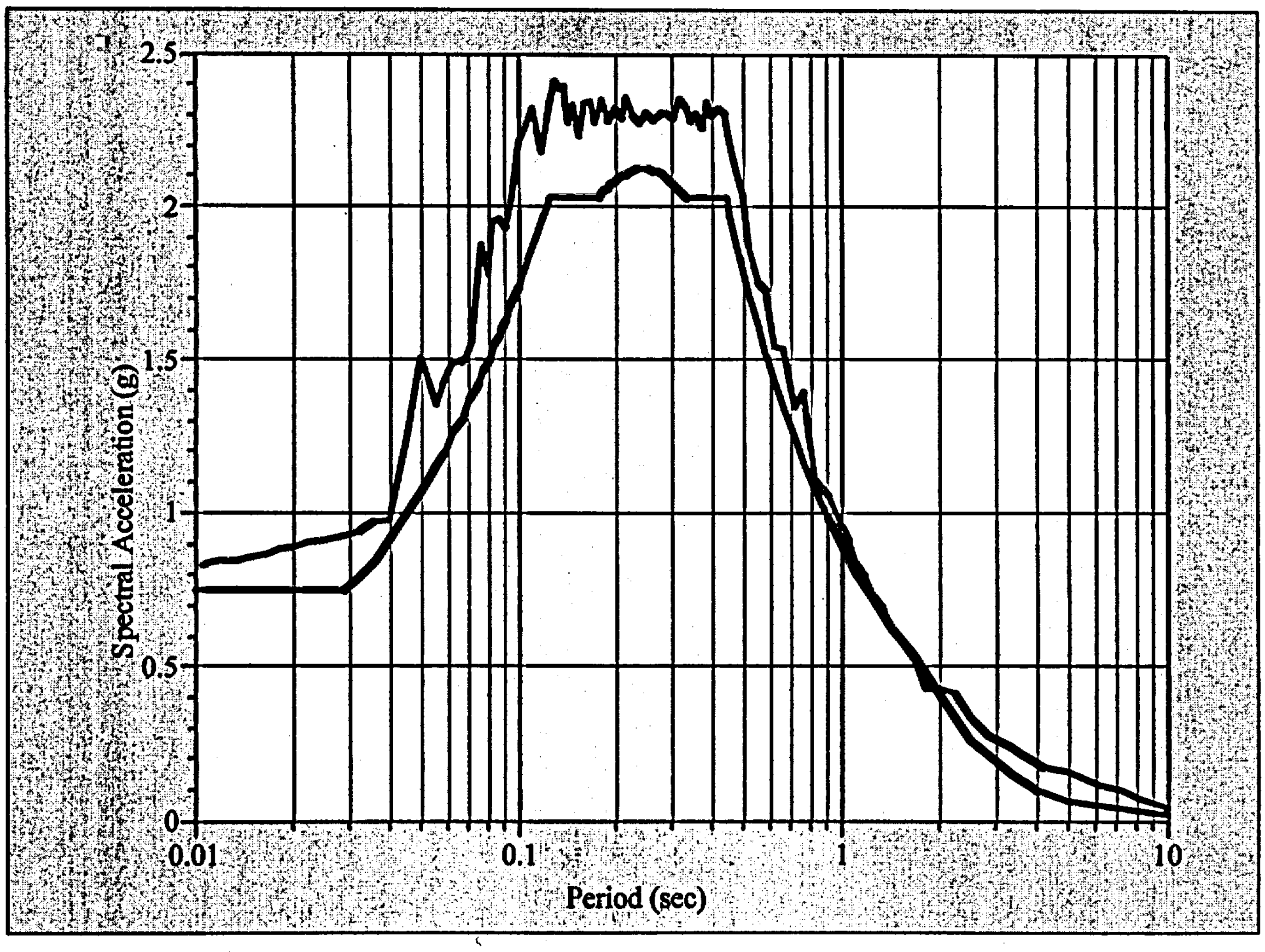
- Approach
  - Develop spectrum compatible time histories
  - Use recorded ground motions as the reference
    - Lucerne recording from the 1992 Landers earthquake

      M = 7.3, Strike-slip, Dist = 1 km
  - Satisfy SRP 3.7.1 requirements for time histories

Example Time History for HE



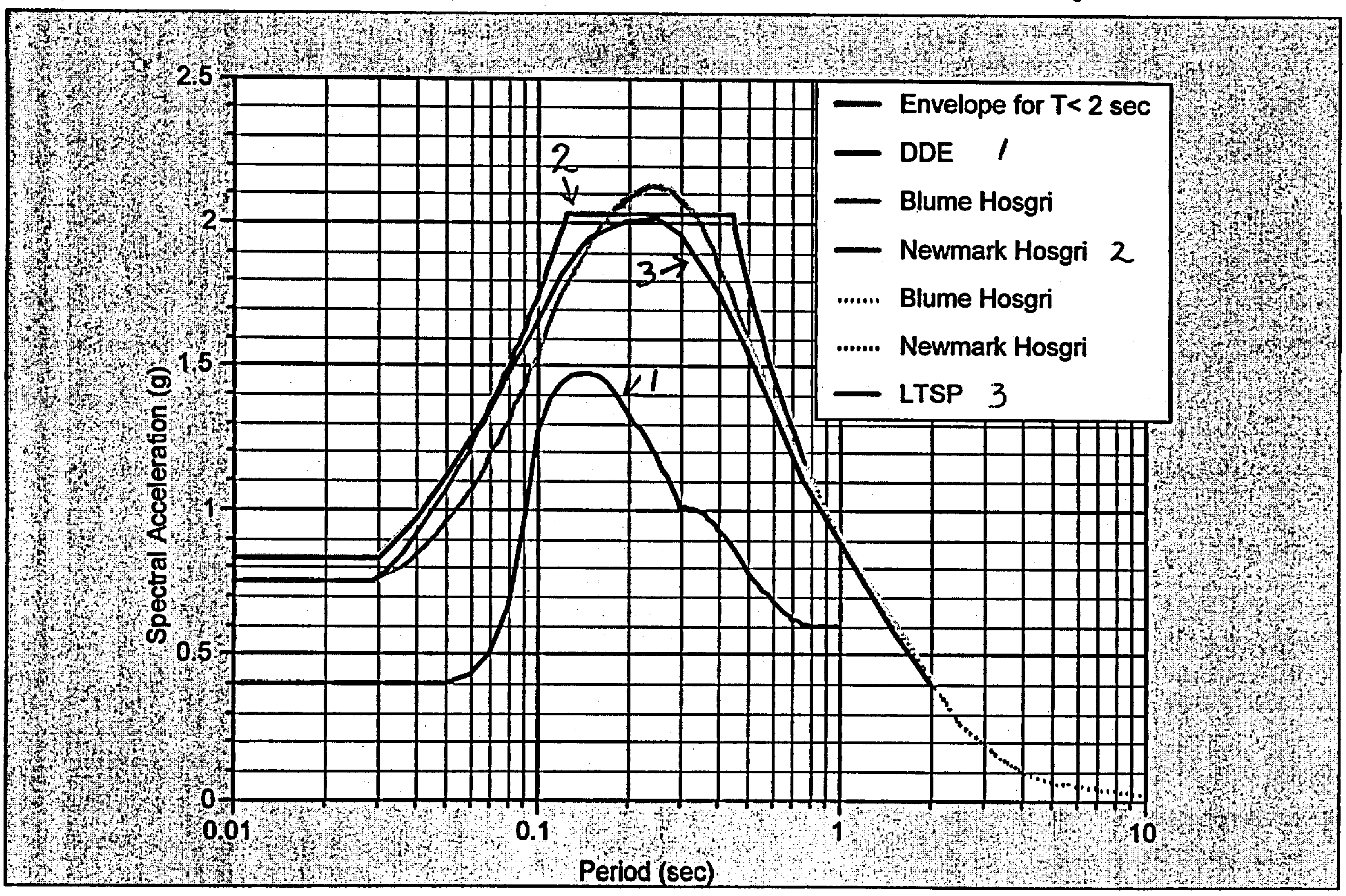
Example Spectrum for HE Time History



Accounting for Lessons from Recent Earthquakes

- No change was made to account for smaller ground motions at short-periods from recent earthquakes
- An ISFSI Long-Period (ILP) spectrum was developed to account for the new information on long period ground motions
  - Envelope of HE and LTSP for T<2 sec
  - Extended to T=10 seconds using attenuation relations developed by PG&E
  - Increased at T> 0.5 sec for directivity effects
- Fling effects were added to the time history
- ILP ground motions were used for ISFSI Part 72 analyses

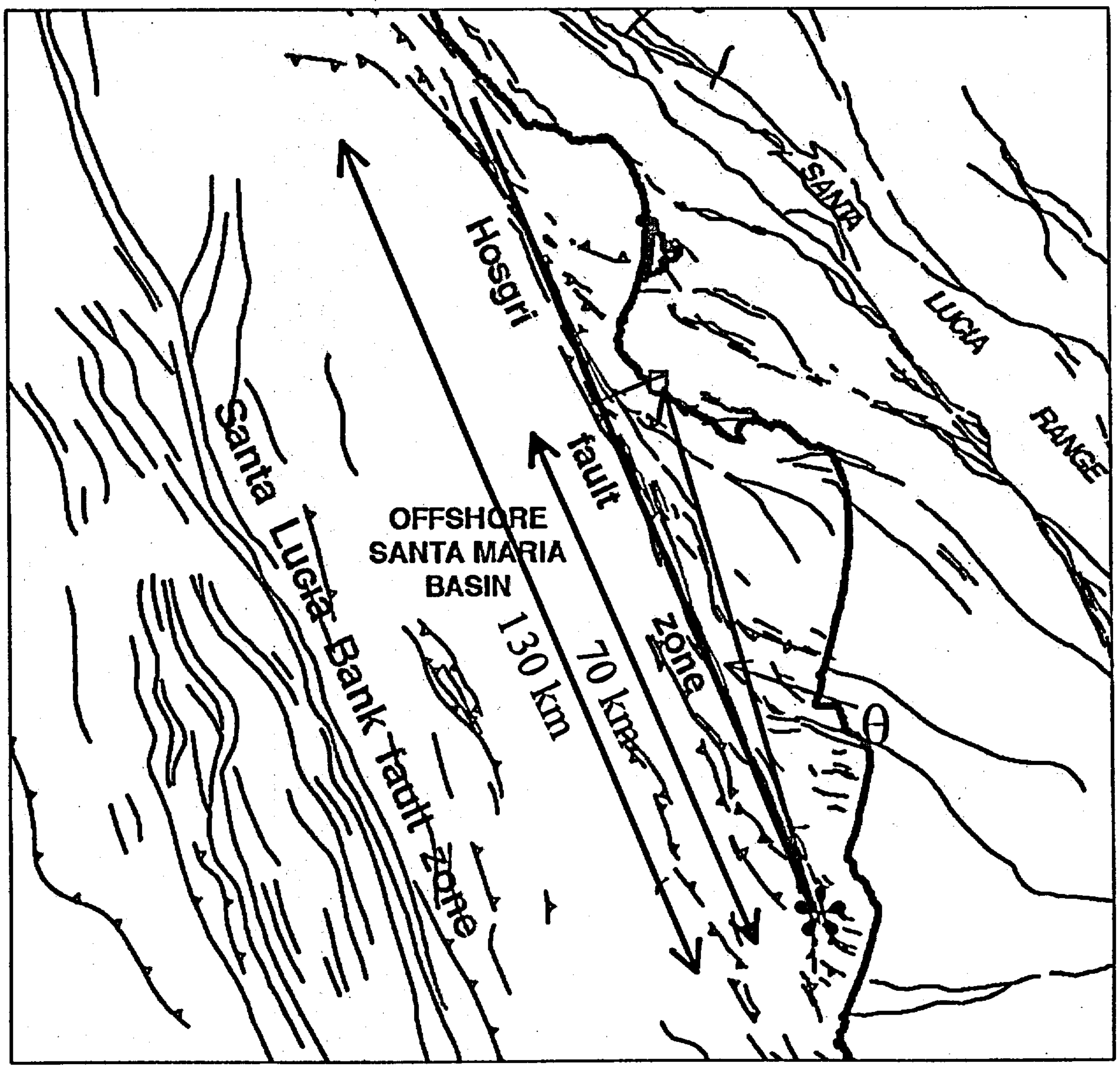
ILP Spectra w/o Directivity



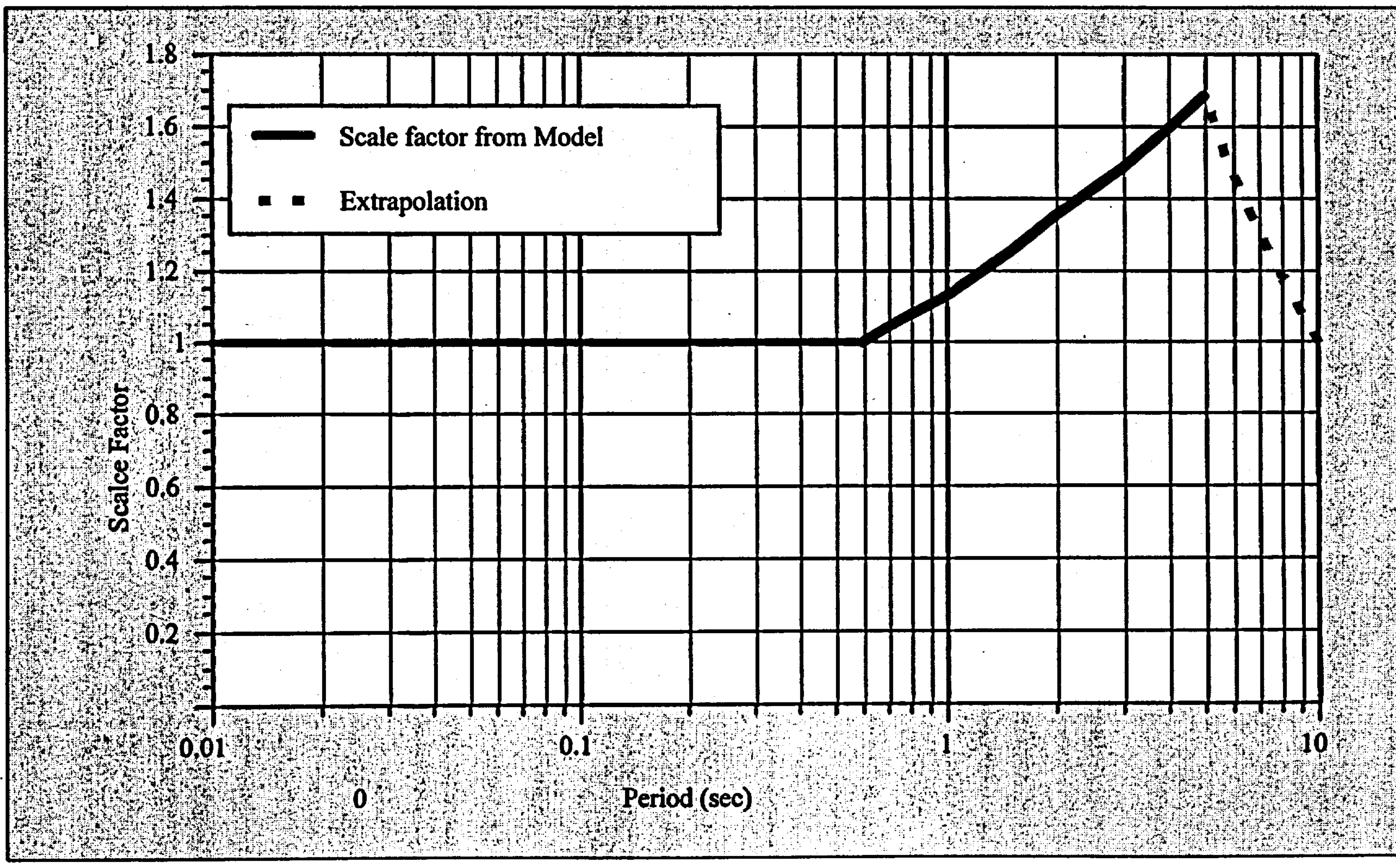
Directivity Parameters

X = 70km/130km
X = 0.64

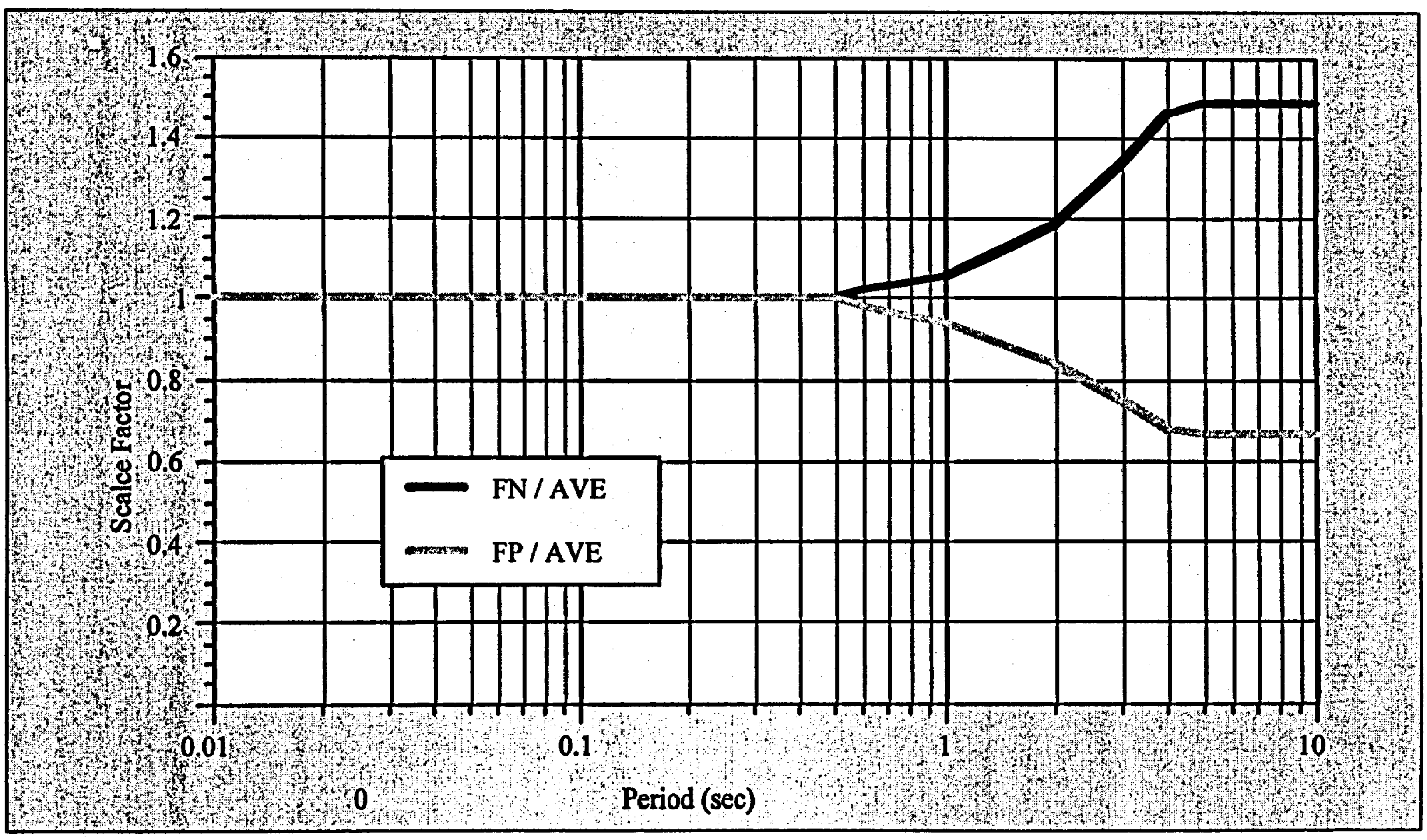
θ = 3 degrees



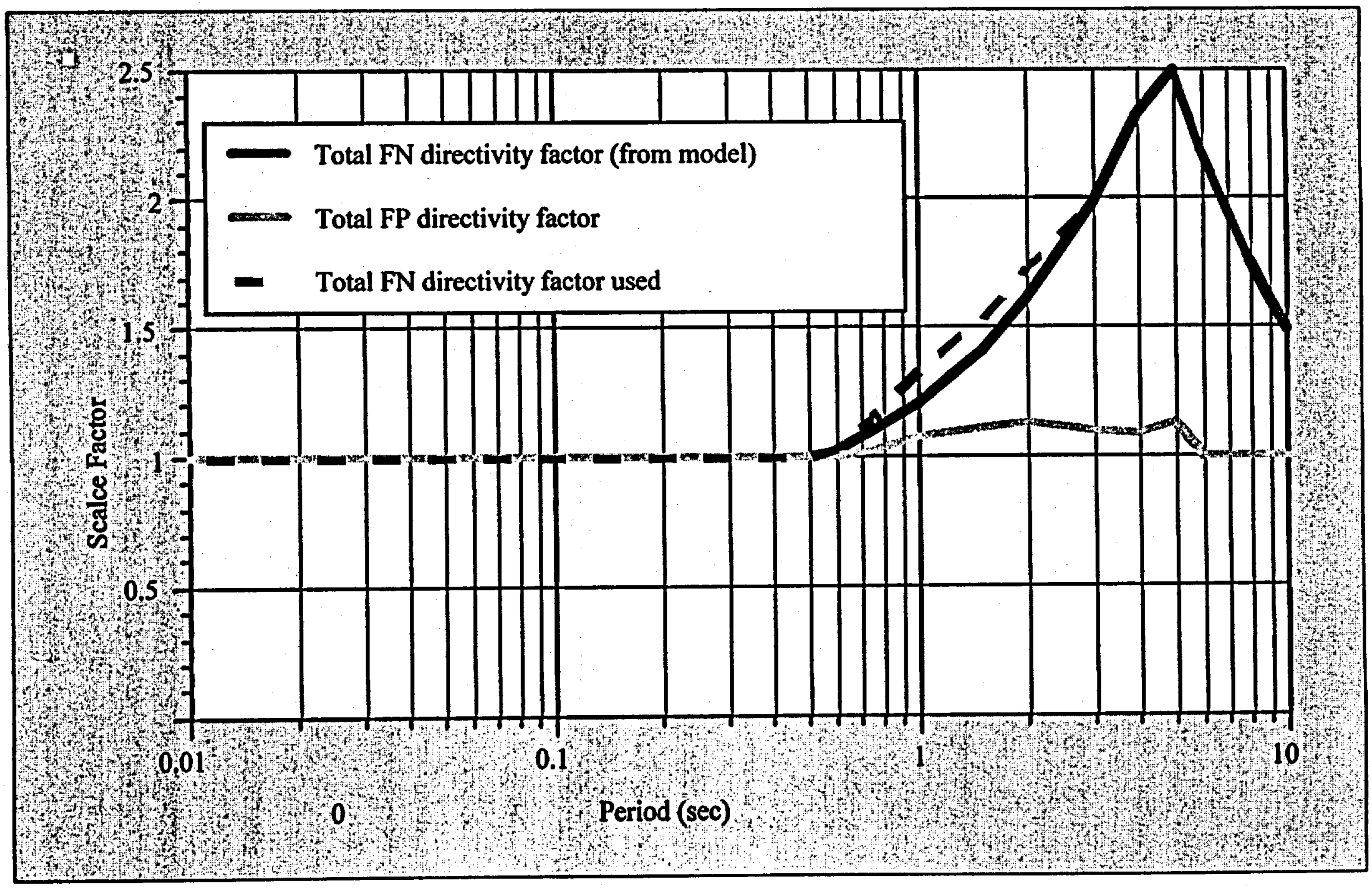
Directivity Effects on the Average Horizontal Component



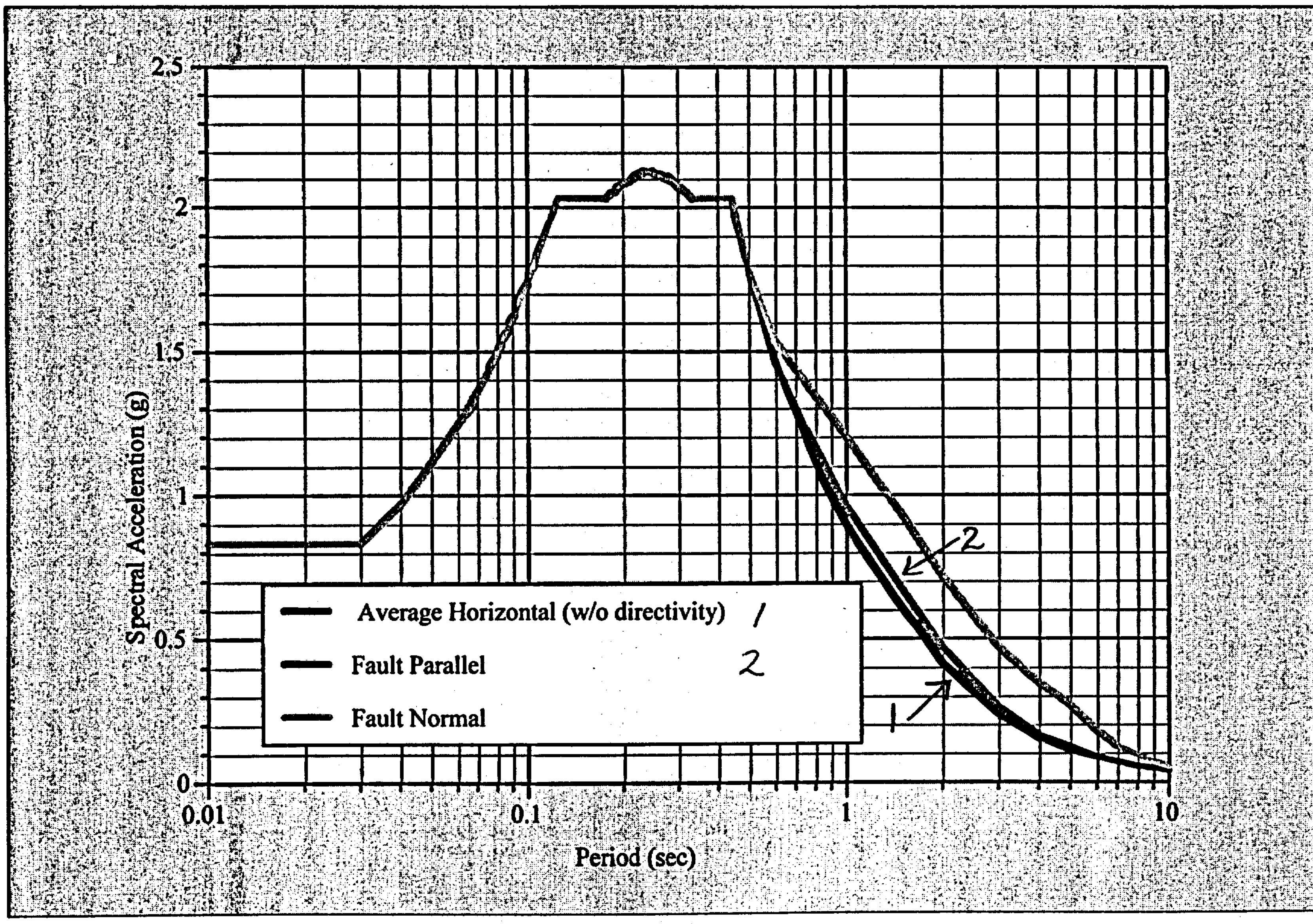
Directivity Effects on FN/Ave and FP/Ave



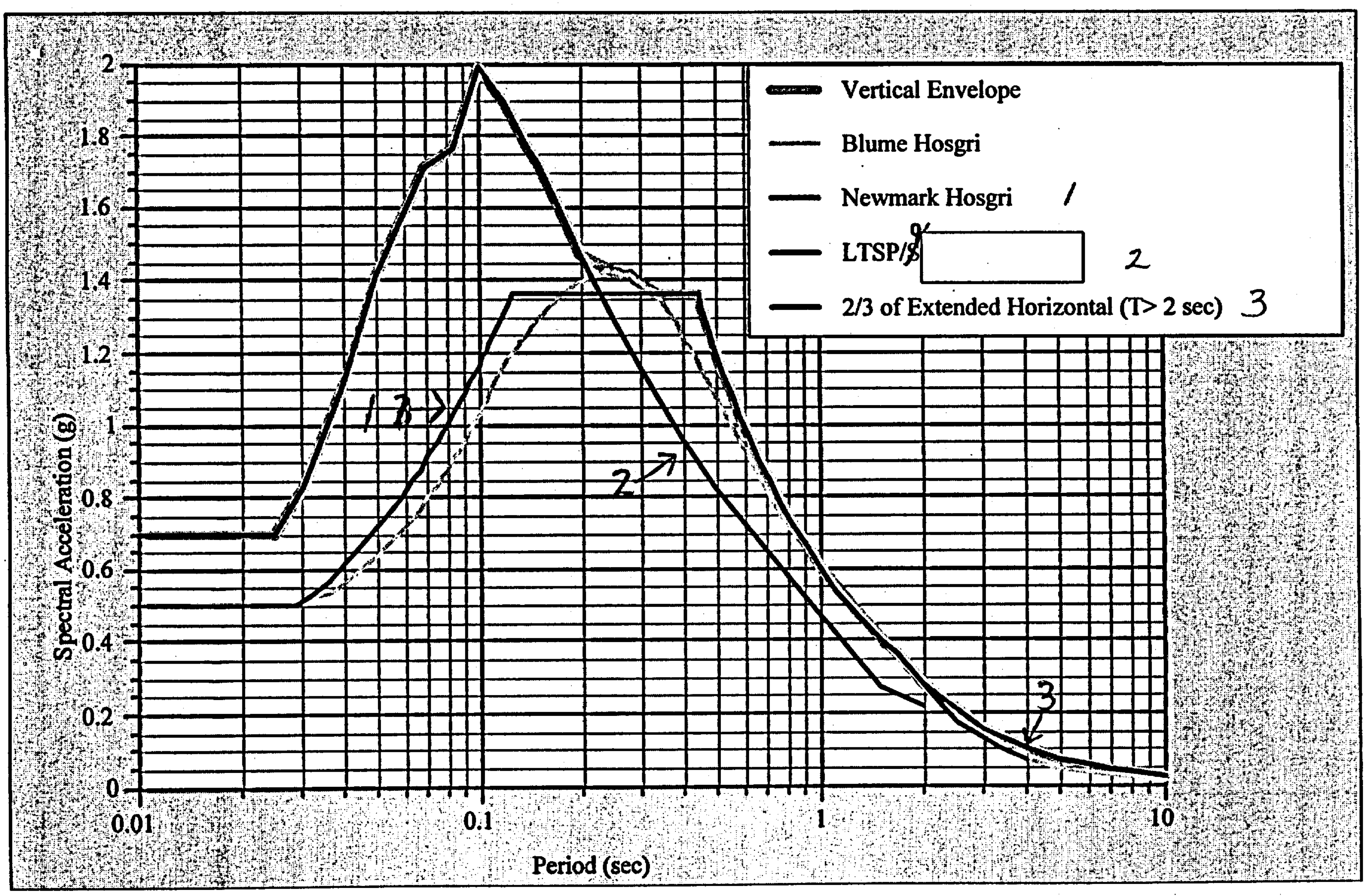
Combined Directivity Effects



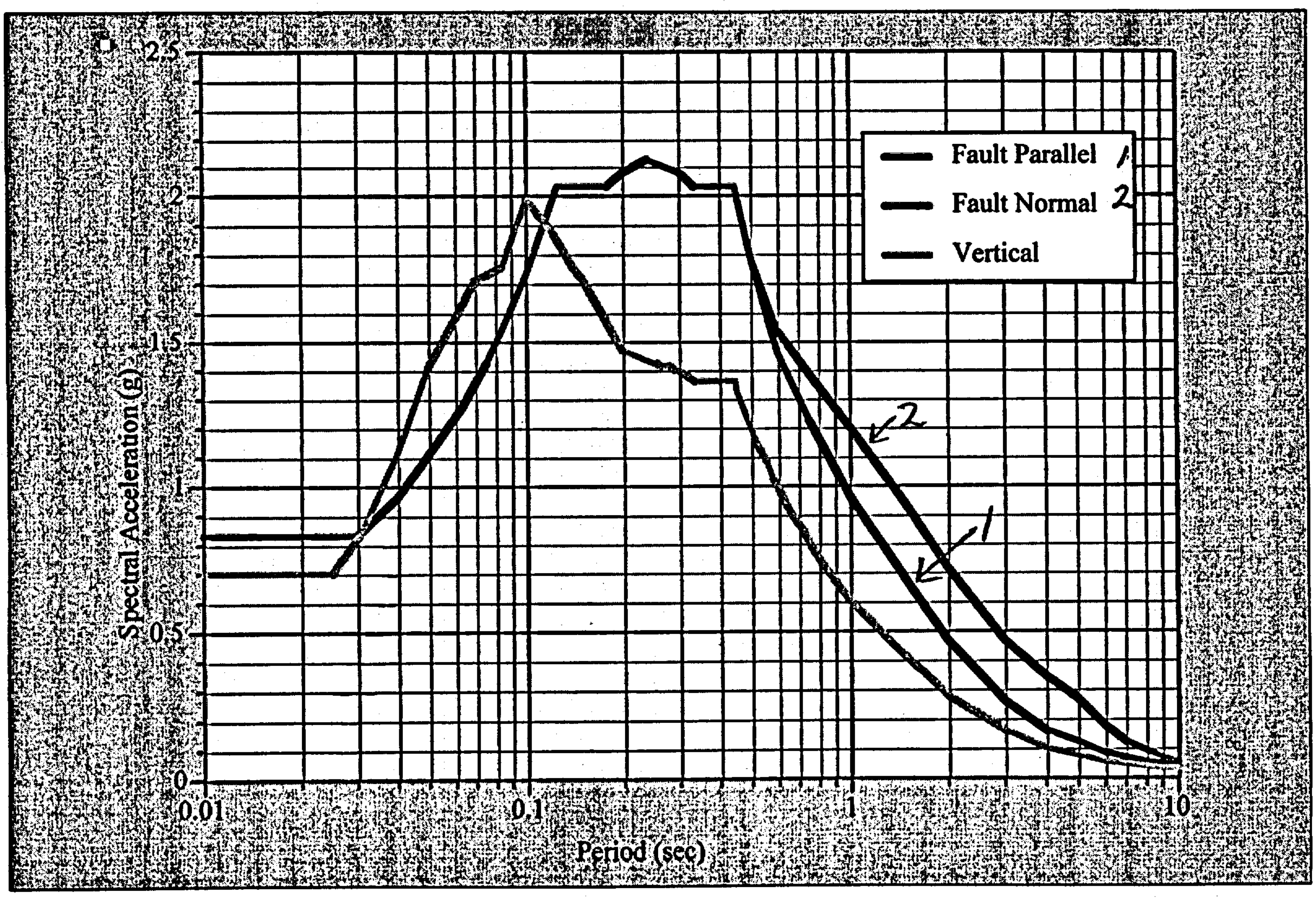
ILP Spectra with Directivity



ILP Spectra: Vertical



ILP Spectra (5% damping)

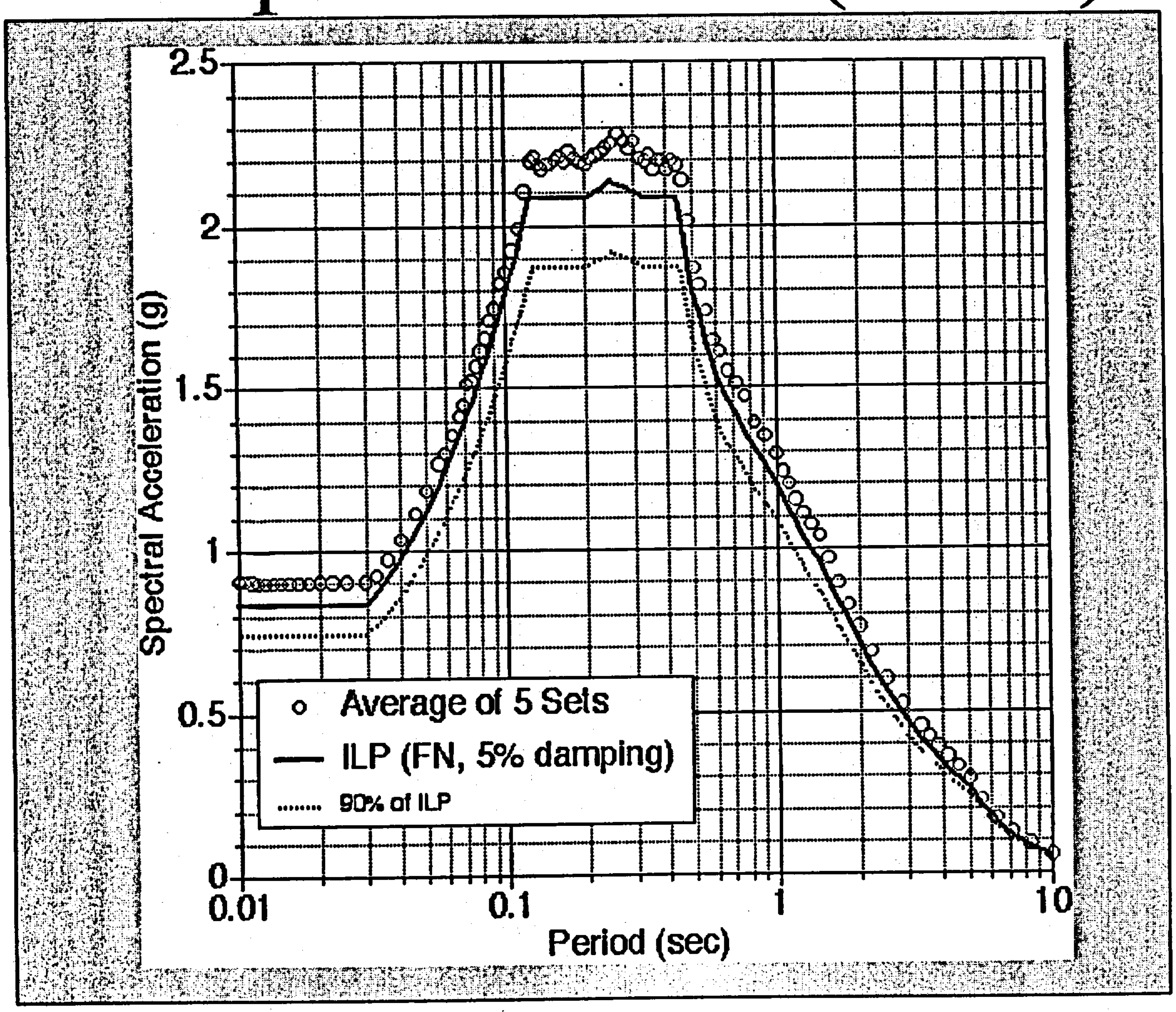


ILP Time Histories

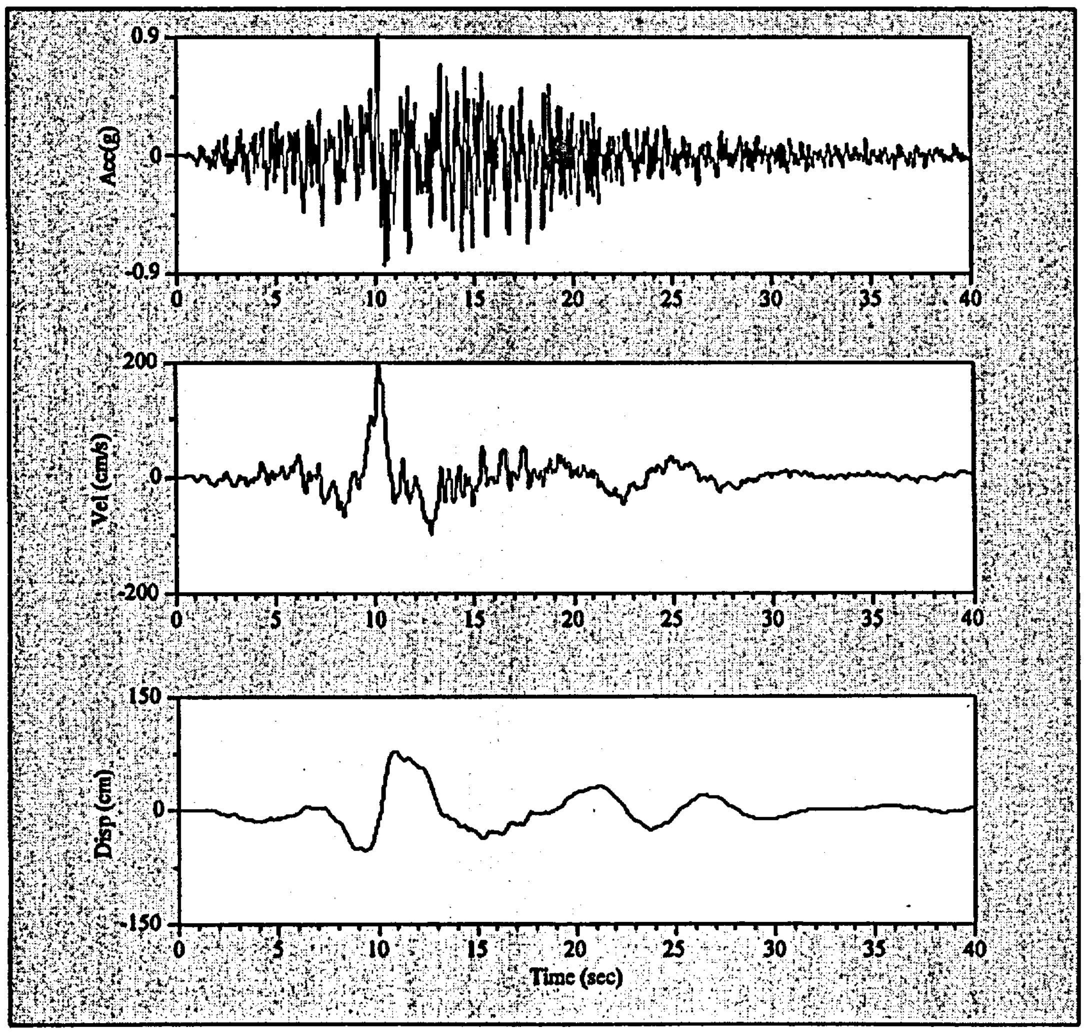
- 5 Sets of 3-component spectrum-compatible time histories were developed (SRP 3.7.1 criteria)
- Time histories are matched to the ILP spectra

Set	Earthquake	Station
1	1992 Landers	Lucerne
2a	1999 Kocaeli	Yarimca
3	1989 Loma Prieta	LGPC
5	1940 Imperial Valley	El Centro
6	1989 Loma Prieta	Saratoga

Mean Spectra of ILP (5 sets)



Example of Time Histories for ILP (Set 1 FN)



Fling

- Use 84th Percentile
  - Two parameters: Displacement at site and Fling period
    - Use 84th percentile displacement
    - Use fling period to give 84th percentile acceleration

Fling Displacement

Median slip on fault = 233 cm

Median disp at site = 59 cm

84th percentile disp at site = 115 cm

Fling Period

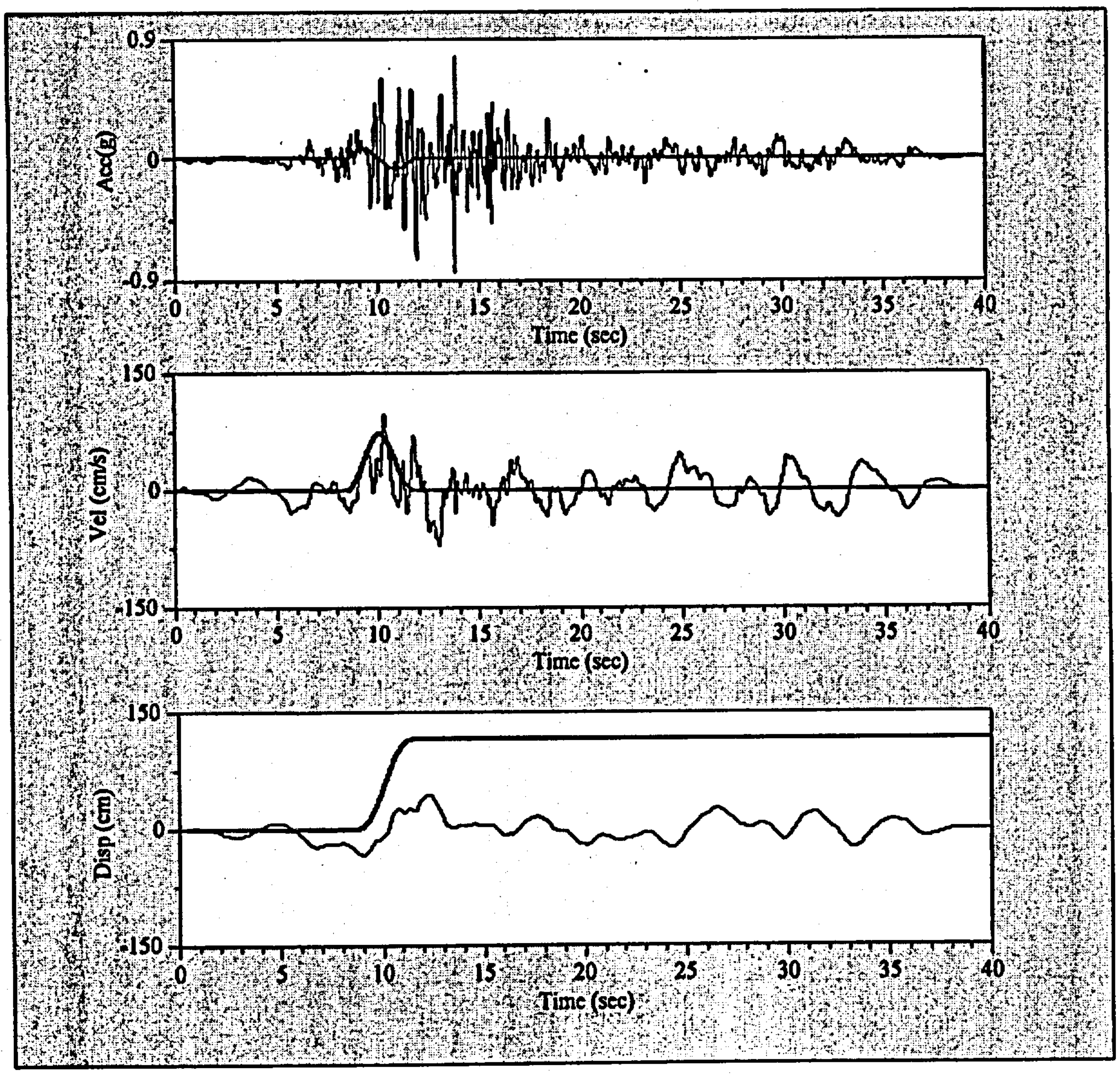
3.2 sec

(84th percentile acc = 0.072g)

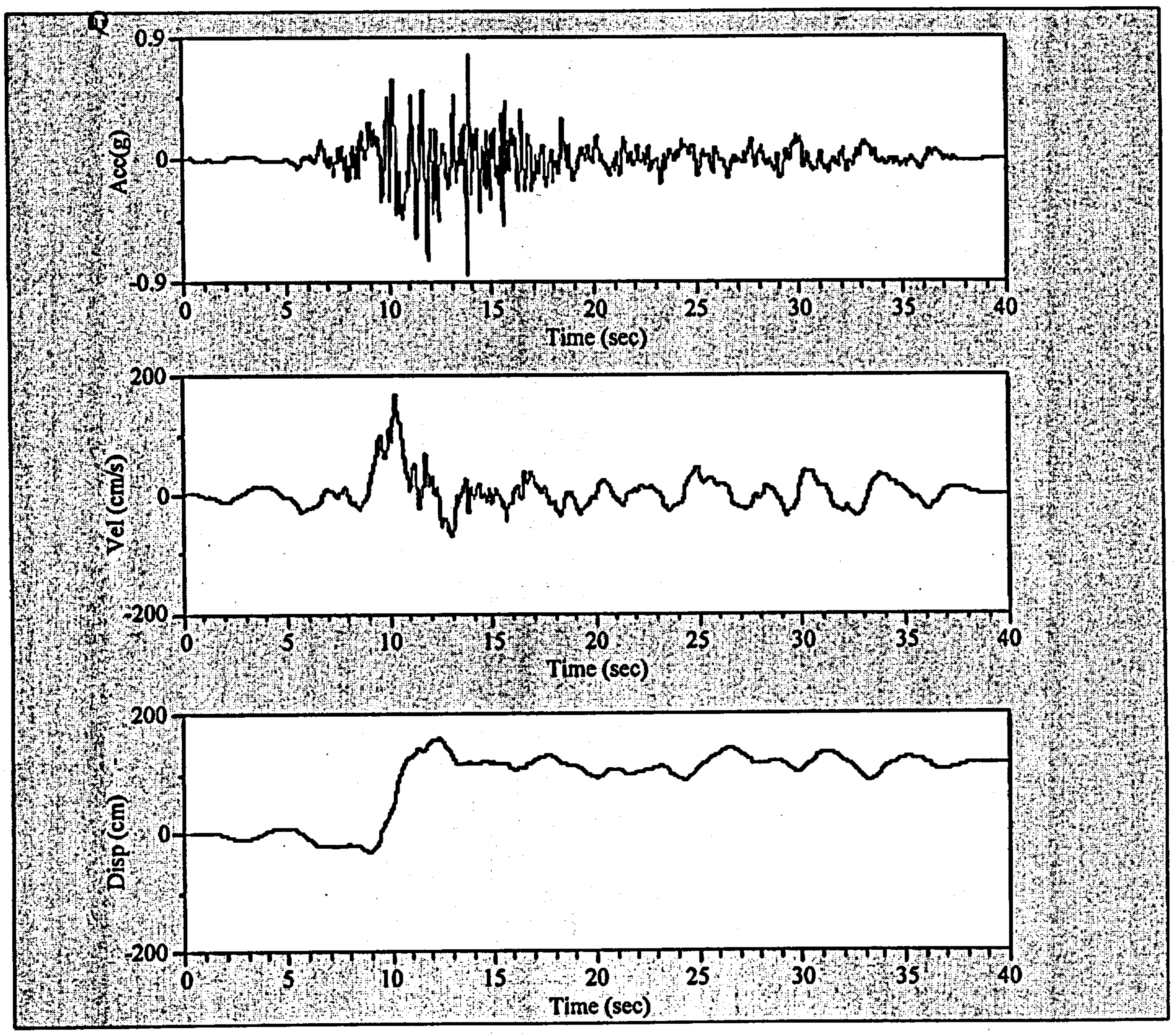
Issues for Combining Fling and Vibratory Ground Motion

- What is the timing between fling and S-waves?
  - For sites close to the fault, fling arrives near the S-wave
- Polarity of fling and S-waves?
  - For design ground motions, require constructive interference of velocity

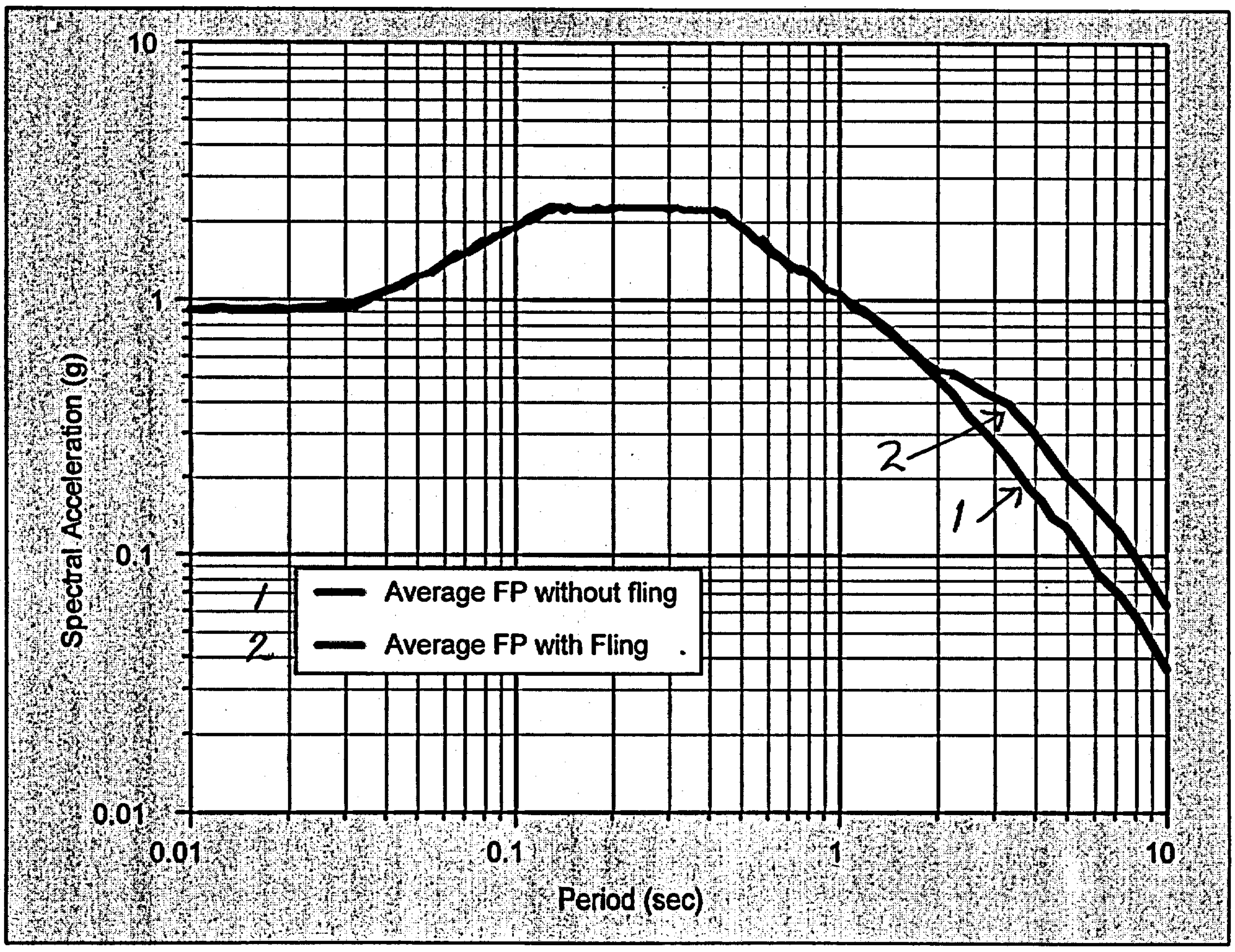
Example Timing of Fling



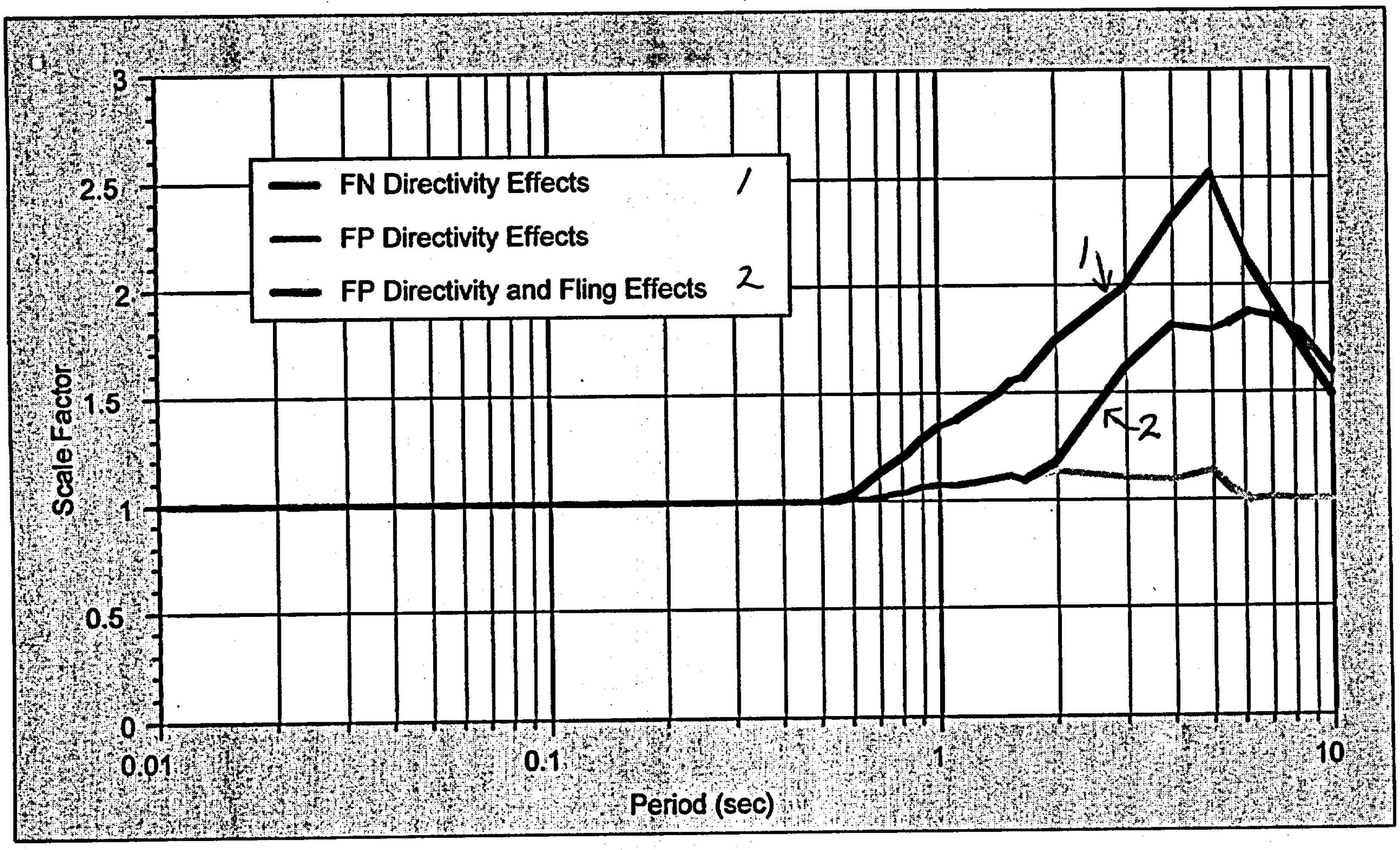
Ground Motion with Fling



Average FP Spectrum Including Fling



Effects of Directivity and Fling



Ground Motion Summary

- Used DCPP design basis ground motions
  - HE, DDE spectra
  - HE time histories
- Applied new research results for directivity and fling
  - ILP spectra and time histories
  - Increase in the long period ground motions
  - Approaches are new and are not standard in earthquake engineering practice

NRC/PG&E Open Meeting, San Francisco, CA
Diablo Canyon Independent Spent Fuel Storage Installation

Geology

William Page
Engineering Geologist
PG&E Geosciences Department

PG&E

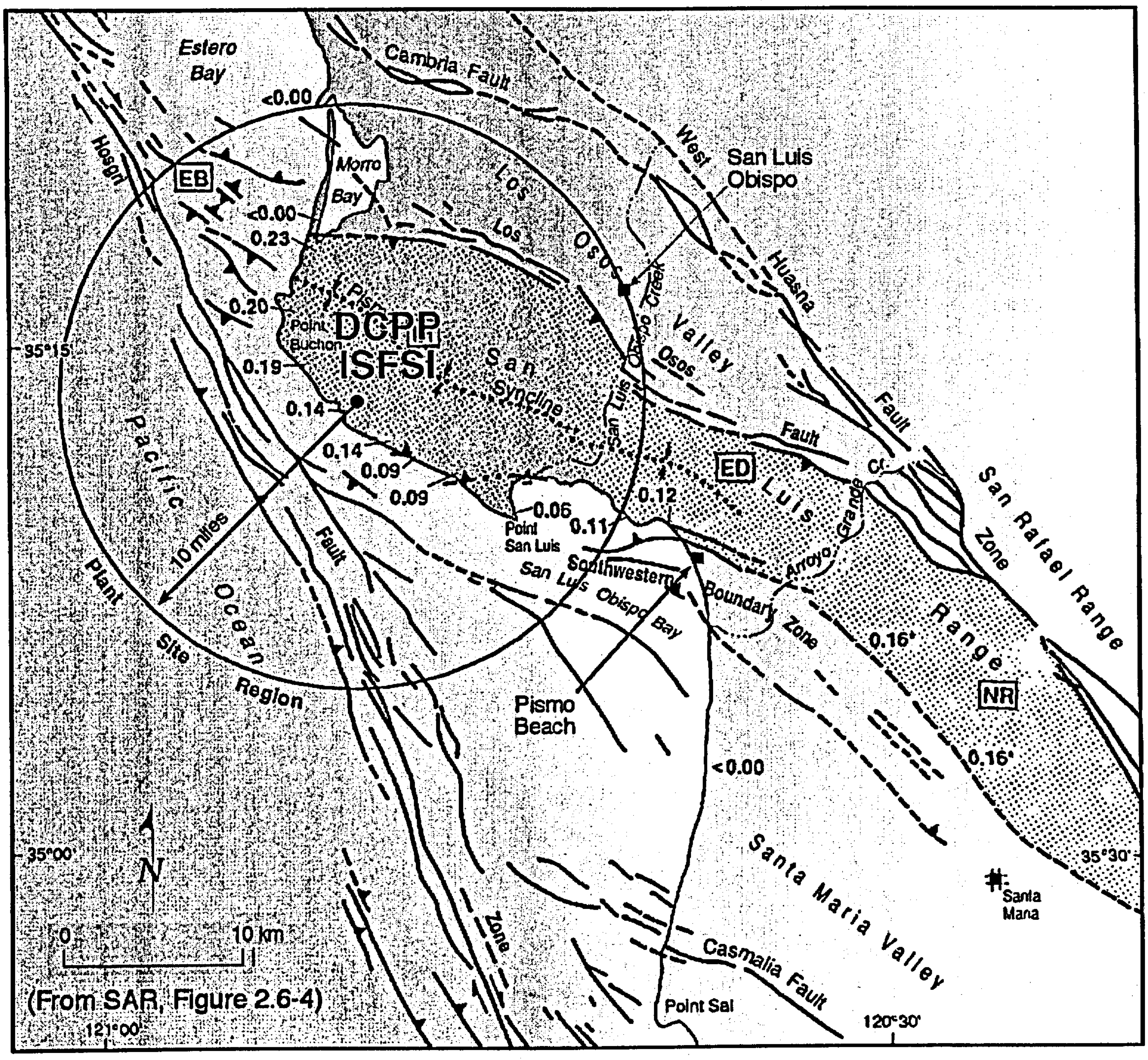
April 11, 2002

Geology Team

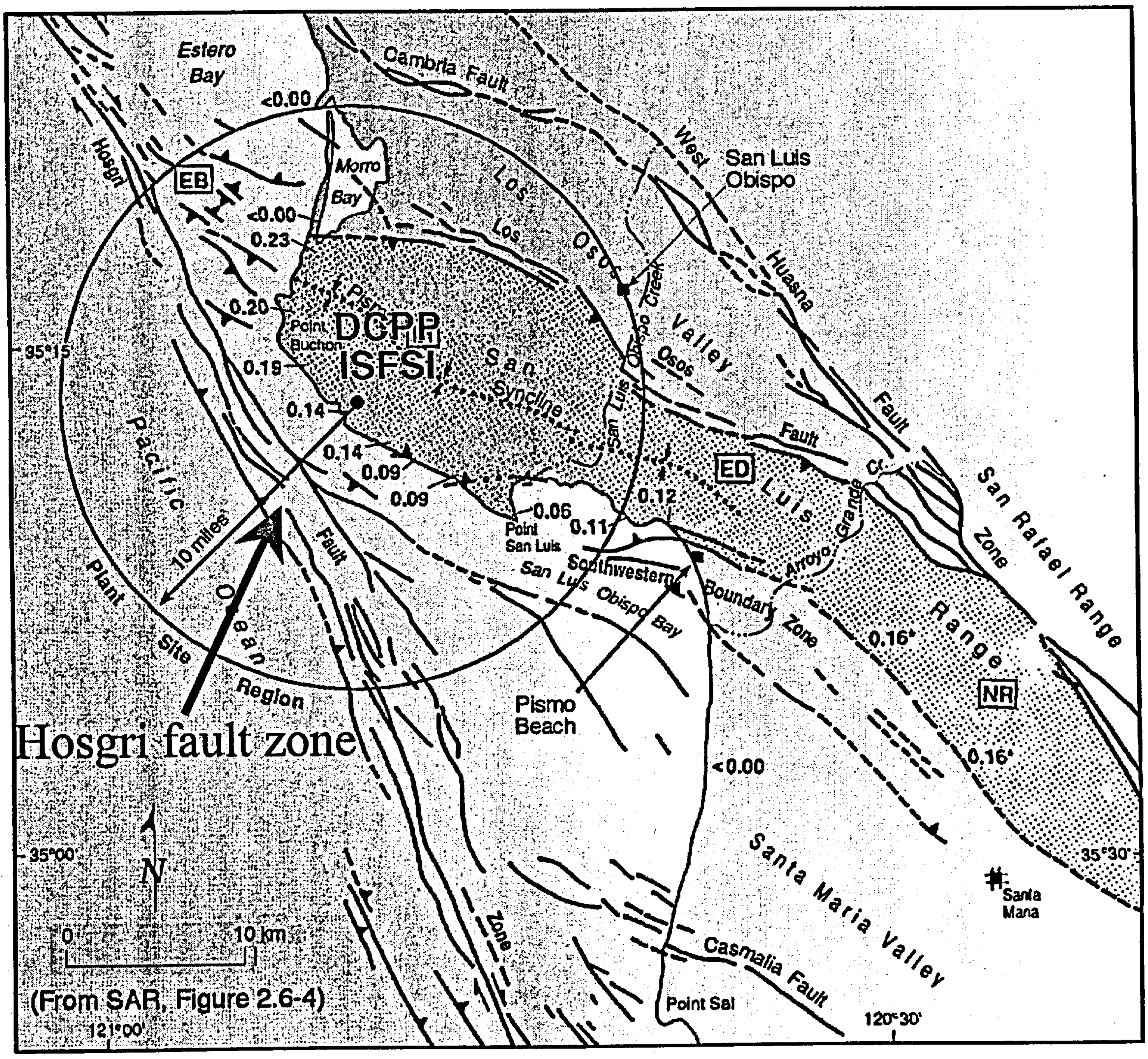
- Bill Page, PG&E Geosciences Dept.
- Jeff Bachhuber, William Lettis & Assoc.
- Charlie Brankman, William Lettis & Assoc.
- Bill Lettis, William Lettis & Assoc.

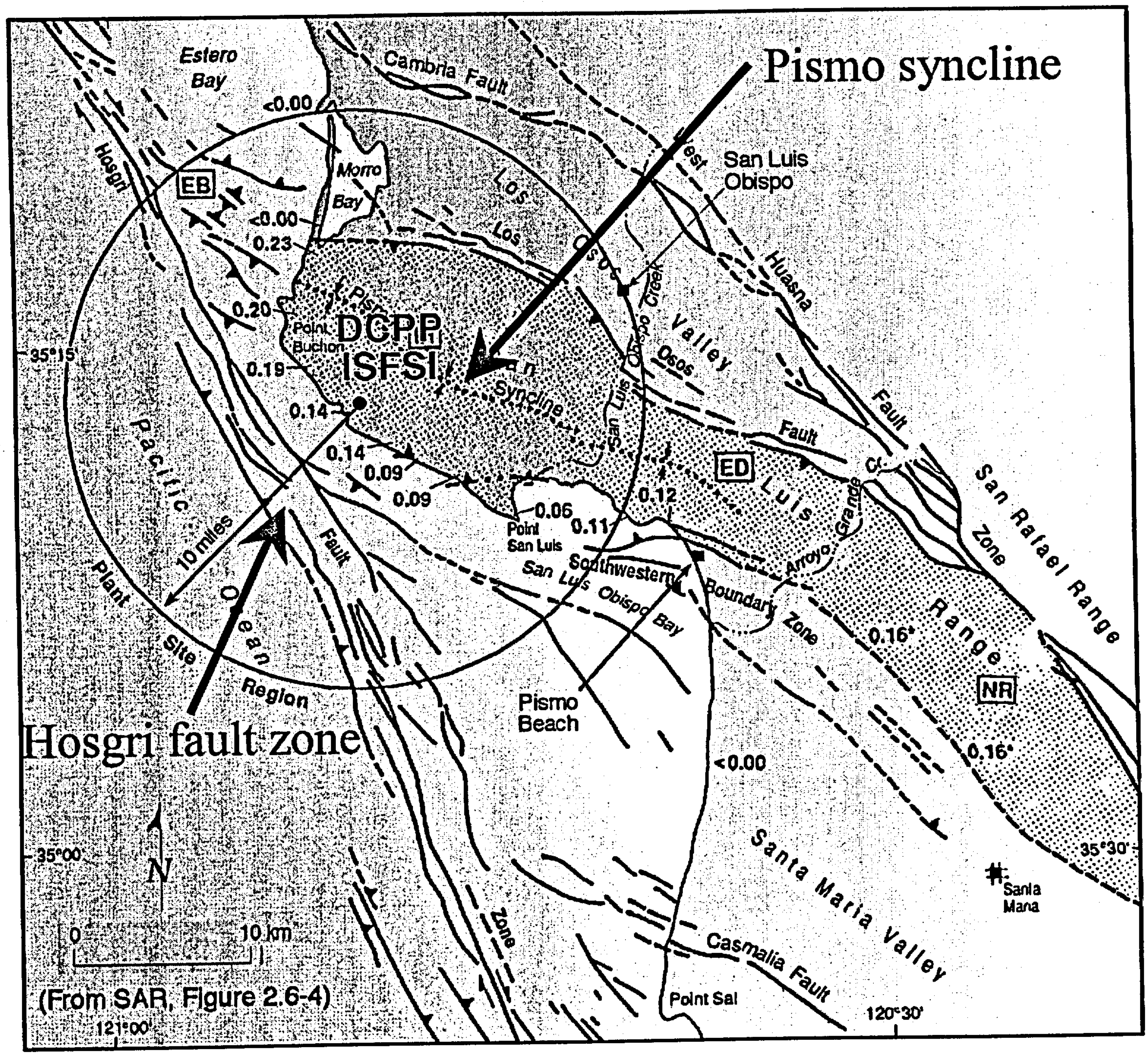
Purpose of Geologic Investigations

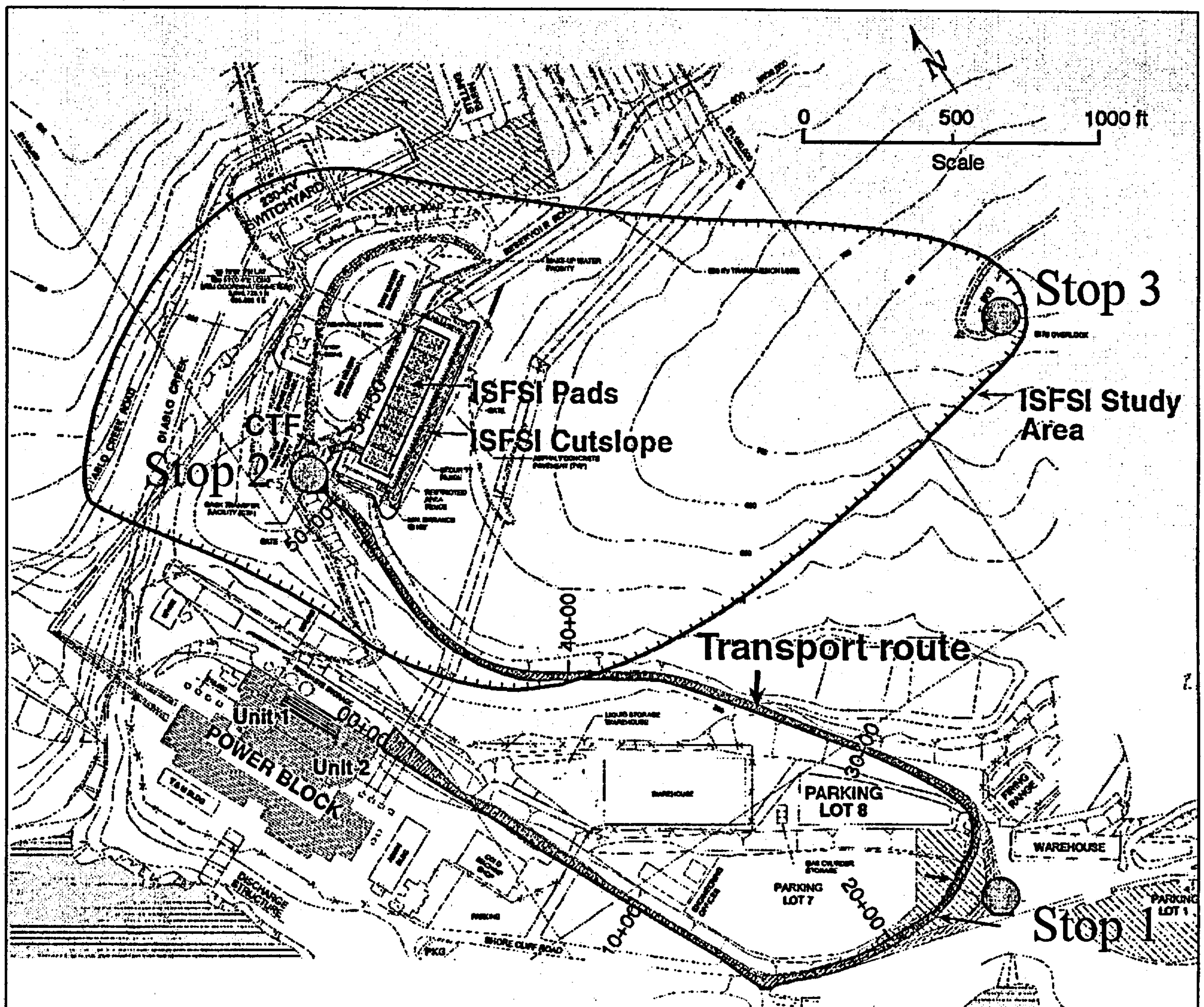
- Foundation conditions
  - Rock characteristics
  - Surficial deposits
- Slope stability
  - Landslides, debris flows
  - Rock characteristics
    - Bedding, joints, faults
    - Clay beds



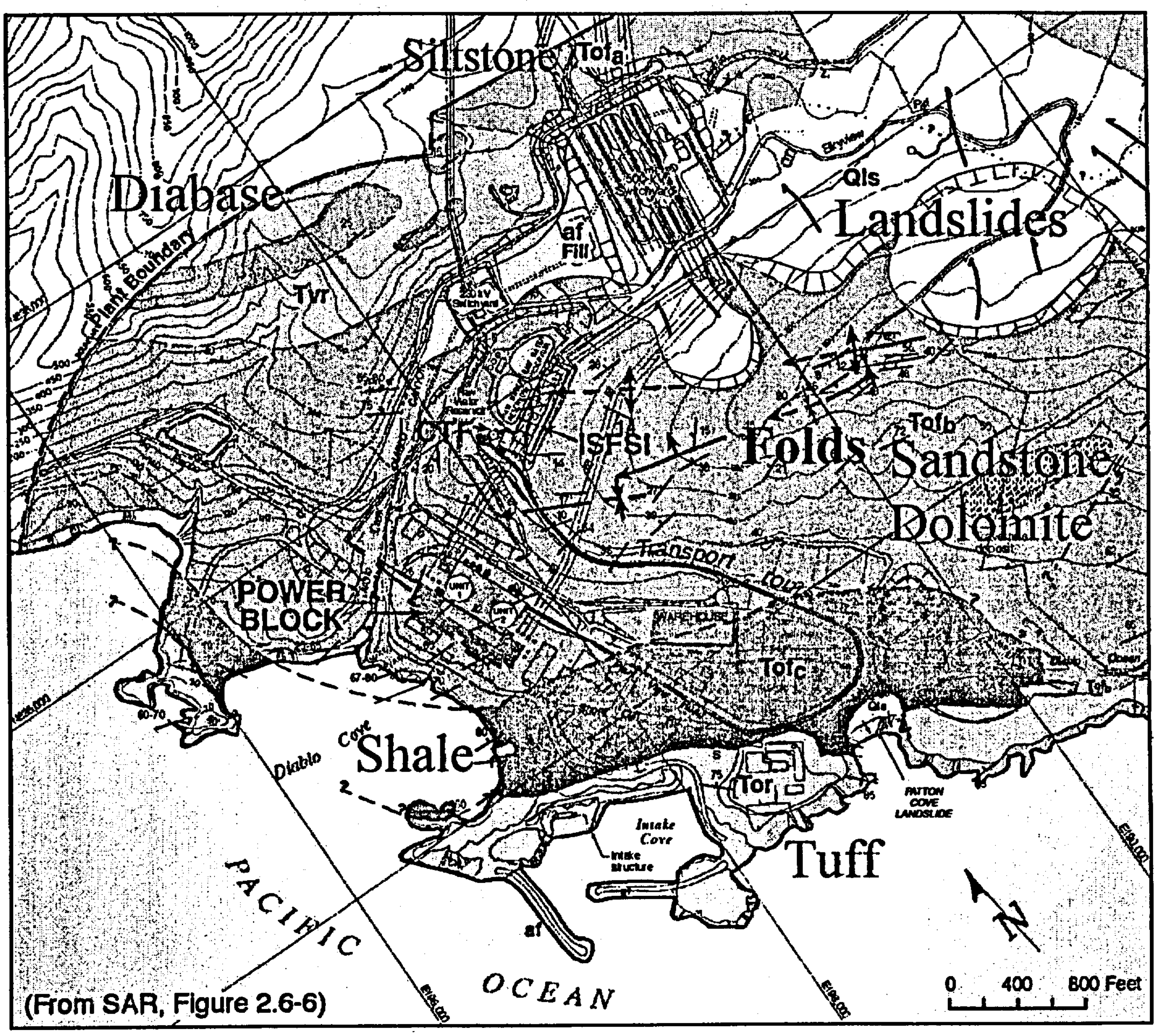
Estero Bay
Cambria Fault
Morro Bay
Los Osos
San Luis Obispo
West Huasna Fault
Hosgri Fault Zone
EB
ED
NR
DCPP ISFSI
Point Buchon
San Luis Obispo Creek
Los Osos Valley
Los Osos Fault
Pismo Syncline
Pacific Ocean
10 miles
Plant Site Region
Point San Luis
Southwestern Boundary Zone
San Luis Obispo Bay
Pismo Beach
San Luis Range
Arroyo Grande Cr.
San Rafael Range Zone
Santa Maria Valley
Santa Maria
Casmalia Fault
Point Sal
<0.00
0.23
0.20
0.19
0.14
0.09
0.06
0.11
0.12
0.16'
35°15'
35°00'
35°30'
121°00'
120°30'
N
0
10 km
(From SAR, Figure 2.6-4)


Estero Bay
Cambria Fault
<0.00
West
San Luis Obispo
Hosgri
EB
Morro Bay
Los
Los Osos
<0.00
0.23
Huasna
0.20
Point Buchon
DCPP
ISFSI
San
Syncline
Valley
Osos
35°15'
0.19
0.14
Fault
Fault
0.14
0.09
ED
San Rafael Range
Zone
Luis
0.09
0.06
0.12
Point San Luis
0.11
Pacific
10 miles
Southwestern
Boundary
Zone
San Luis Obispo Bay
Arroyo Grande
Range
0.16*
NR
Plant
Site
Region
Ocean
Pismo Beach
Hosgri fault zone
<0.00
0.16*
Santa Maria Valley
35°30'
35°00'
N
0
10 km
(From SAR, Figure 2.6-4)
121°00'
Zone
Casmalia Fault
Point Sal
120°30'
Santa Maria

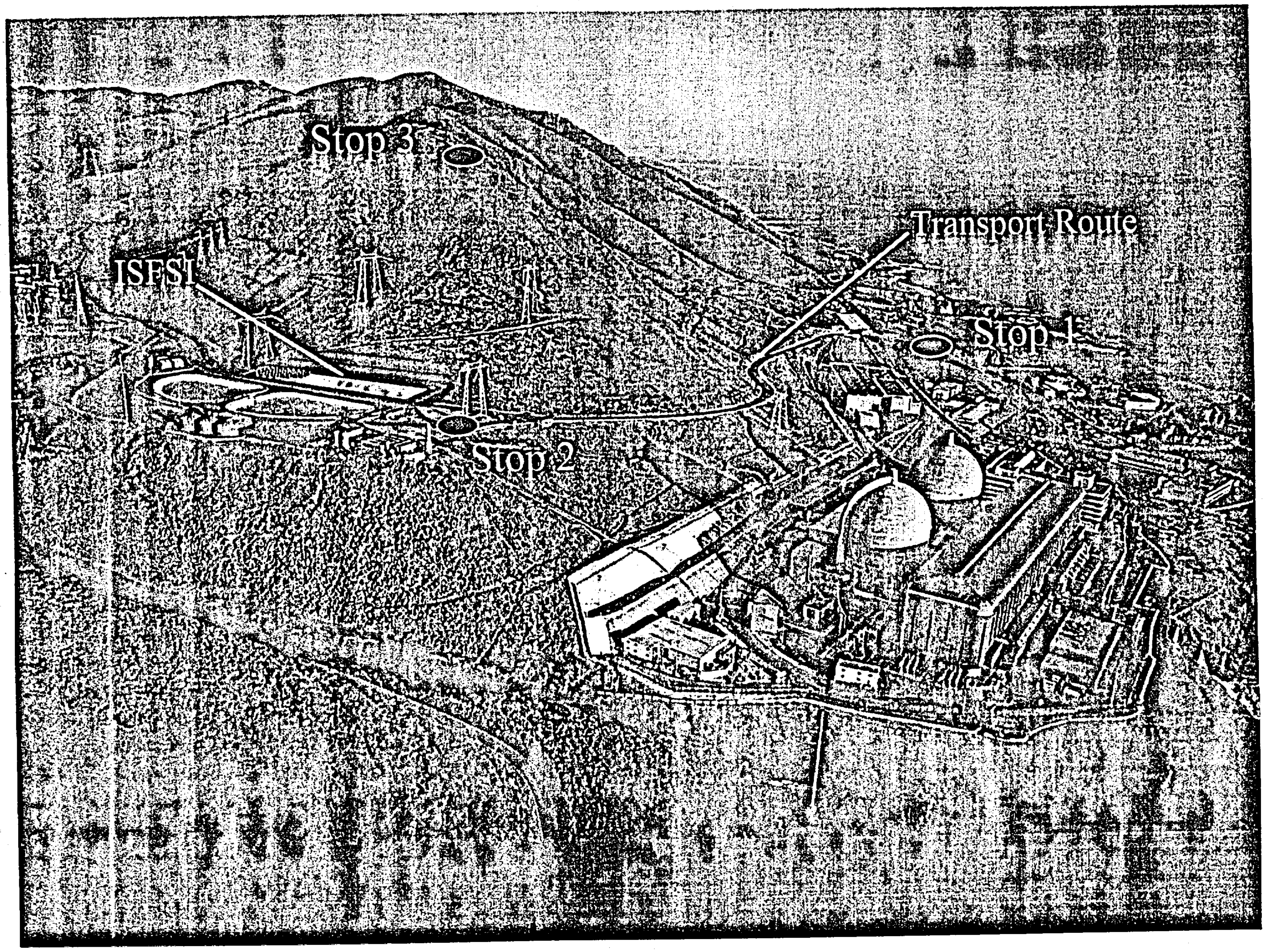

Pismo syncline
Hosgri fault zone
DCPP
ISFSI
Estero Bay
Cambria Fault
Morro Bay
San Luis Obispo
Los Osos Valley
Huasna Fault
Point Buchon
Syncline
San Luis Obispo Creek
ED
EB
NR
San Rafael Range
Zone
Luis Range
Arroyo Grande Cr.
Pacific Ocean
10 miles
Plant Site Region
Hosgri Fault Zone
Point San Luis
Southwestern Boundary Zone
San Luis Obispo Bay
Pismo Beach
Santa Maria Valley
Casmalia Fault
Point Sal
Santa Maria
<0.00
0.23
0.20
0.19
0.14
0.09
0.06
0.11
0.12
0.16*
35°15'
35°00'
35°30'
121°00'
120°30'
N
0
10 km
(From SAR, Figure 2.6-4)

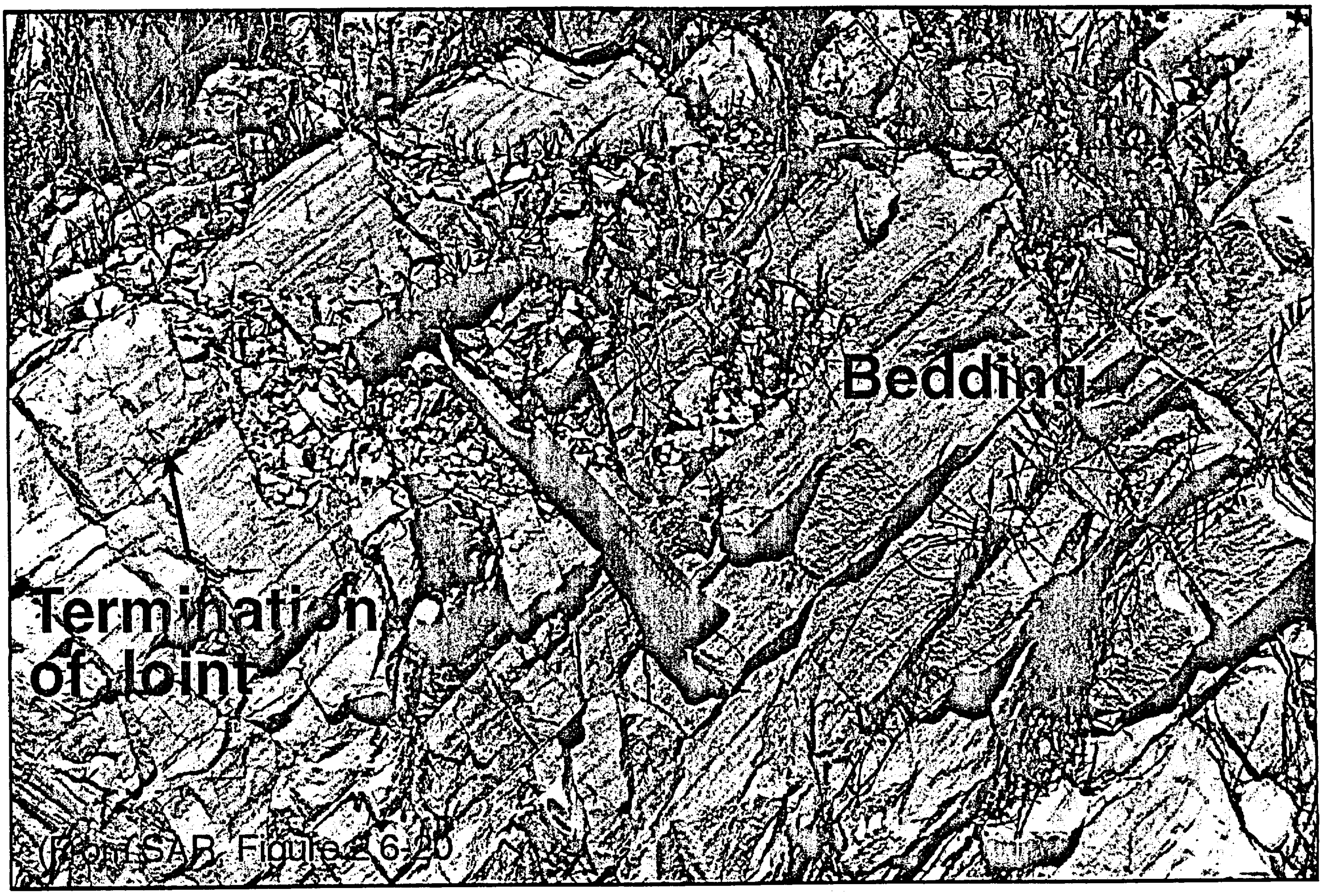


(From SAR, Figure 2.6-1)



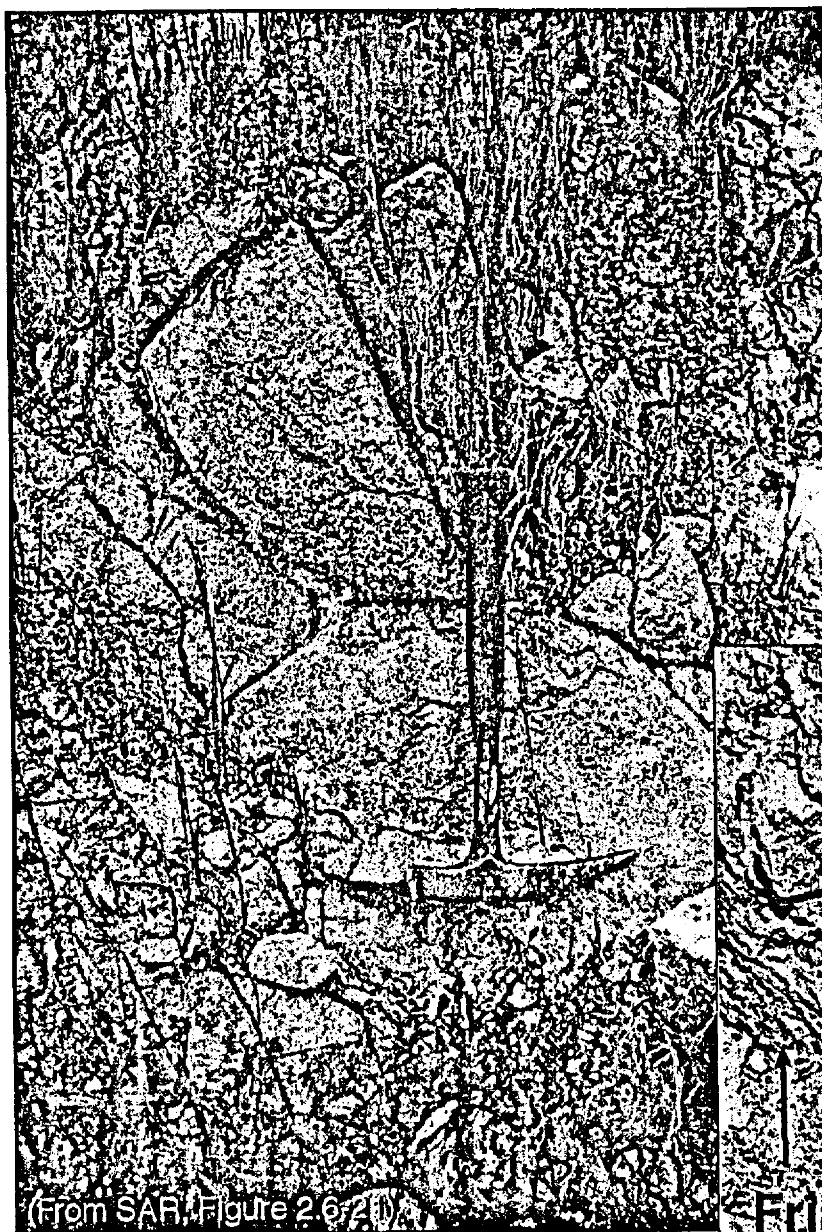
Bedrock in ISFSI Area


Stop 3
Transport Route
ISFSI
Stop 1
Stop 2

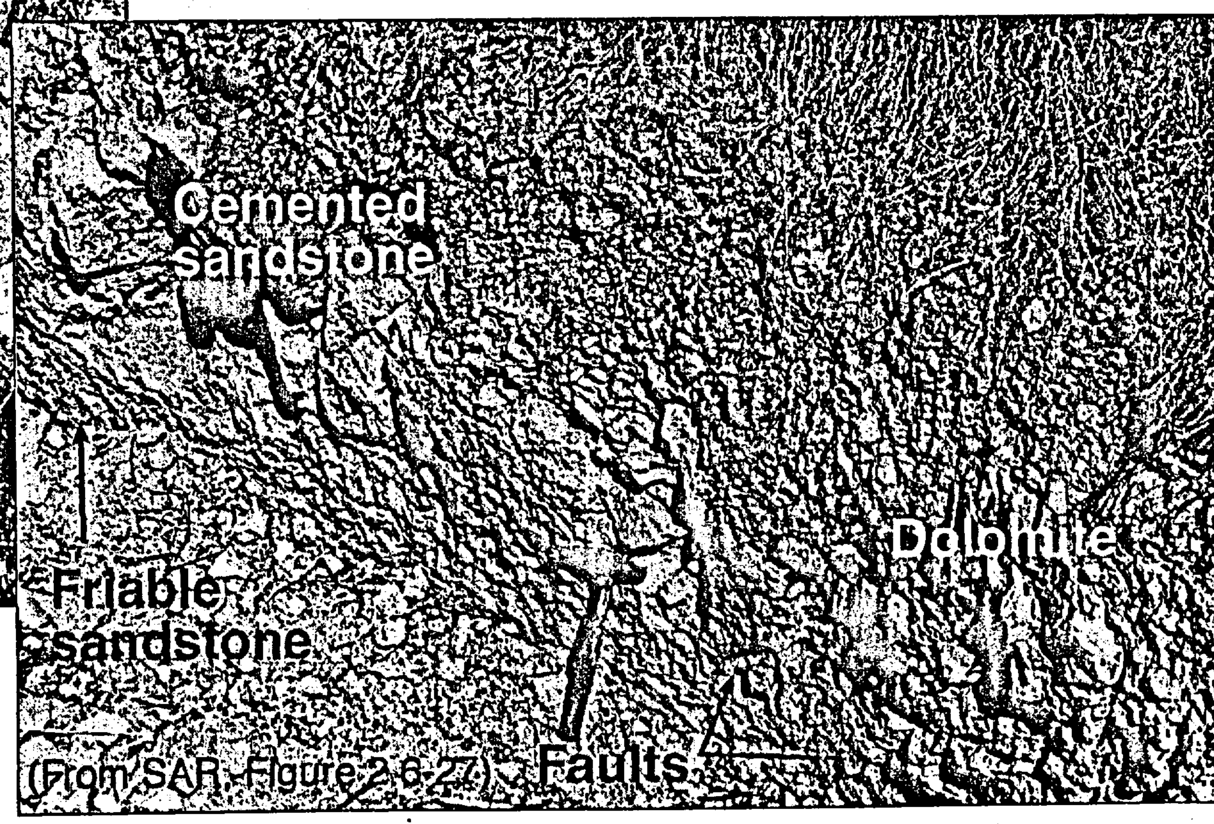


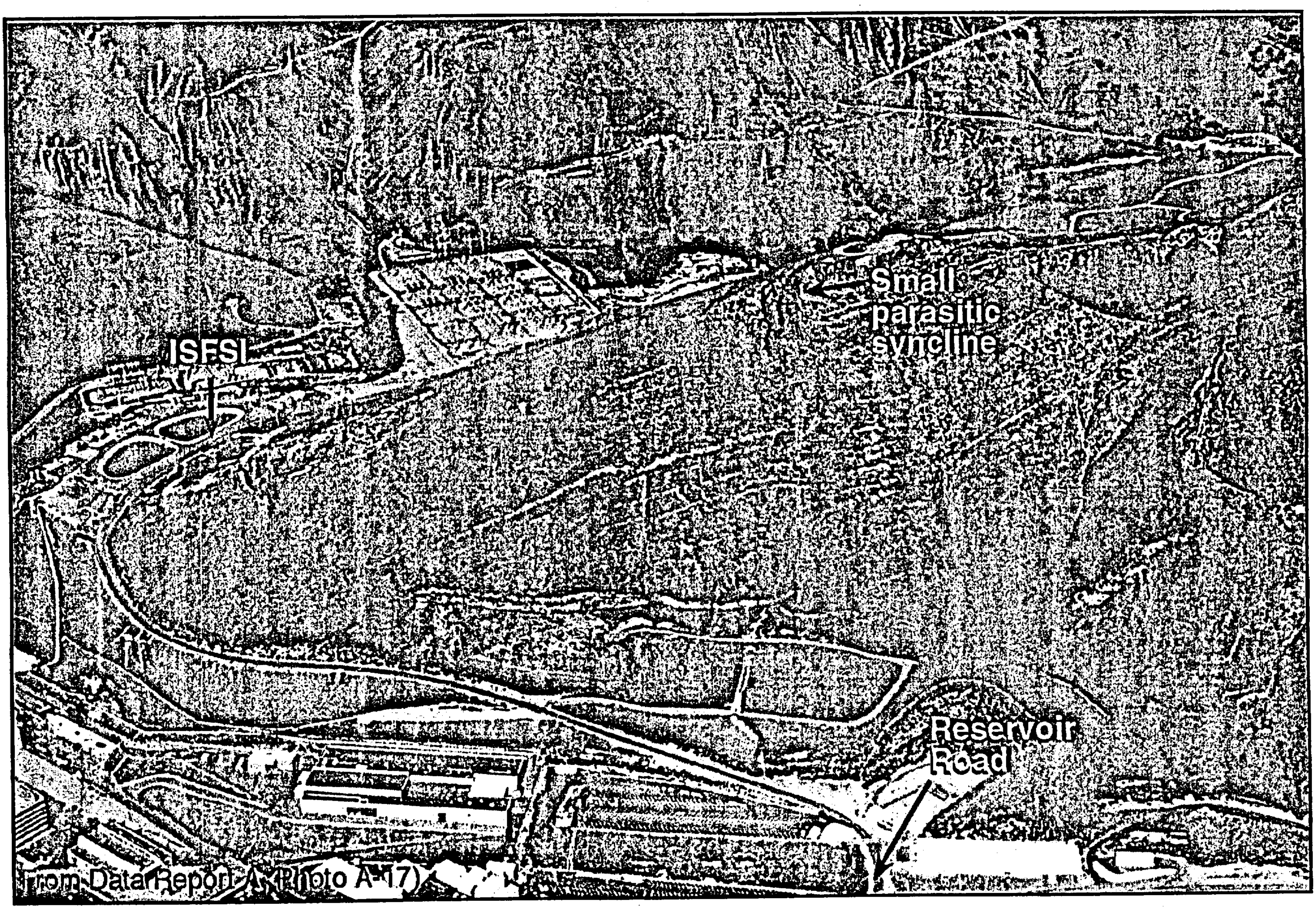
Dolomite Outcrop

Trench T-1

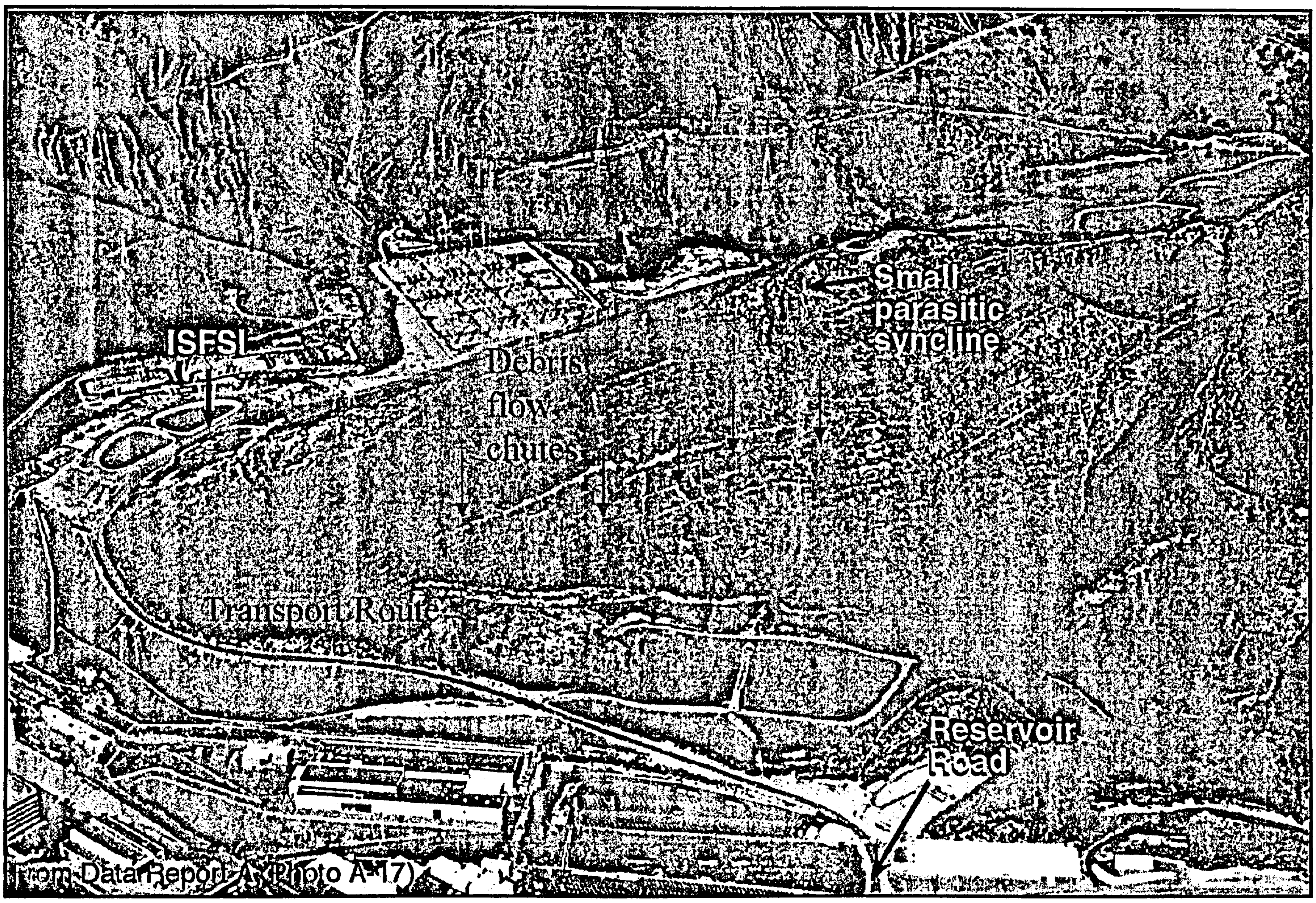


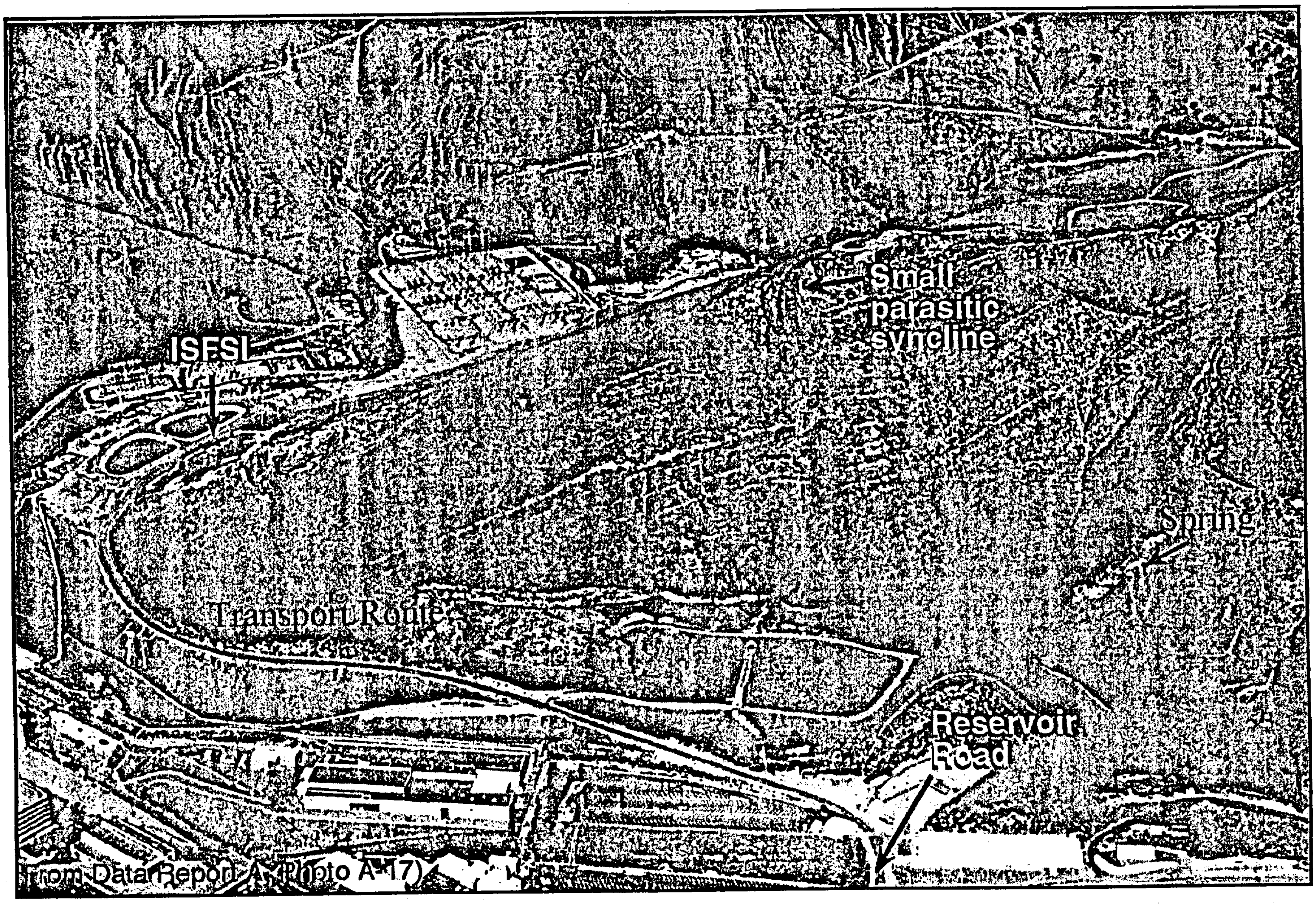
Sandstone outcrop



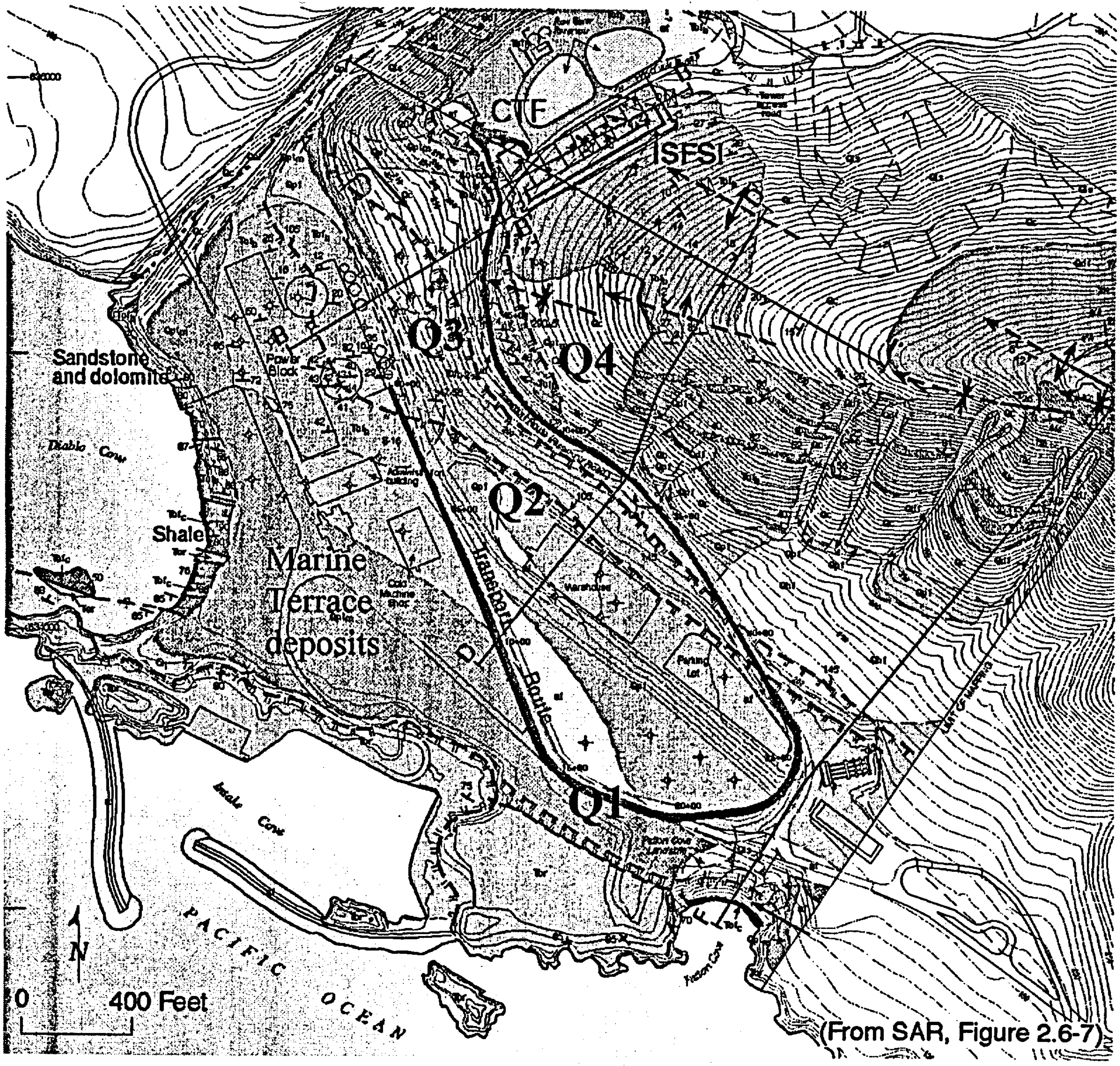


ISFSI
Small parasitic syncline
Reservoir Road
From Data Report A (Photo A-17)


Small parasitic syncline
ISFSI
Debris flow chutes
Transport Route
Reservoir Road
From Data Report A (Photo A-17)



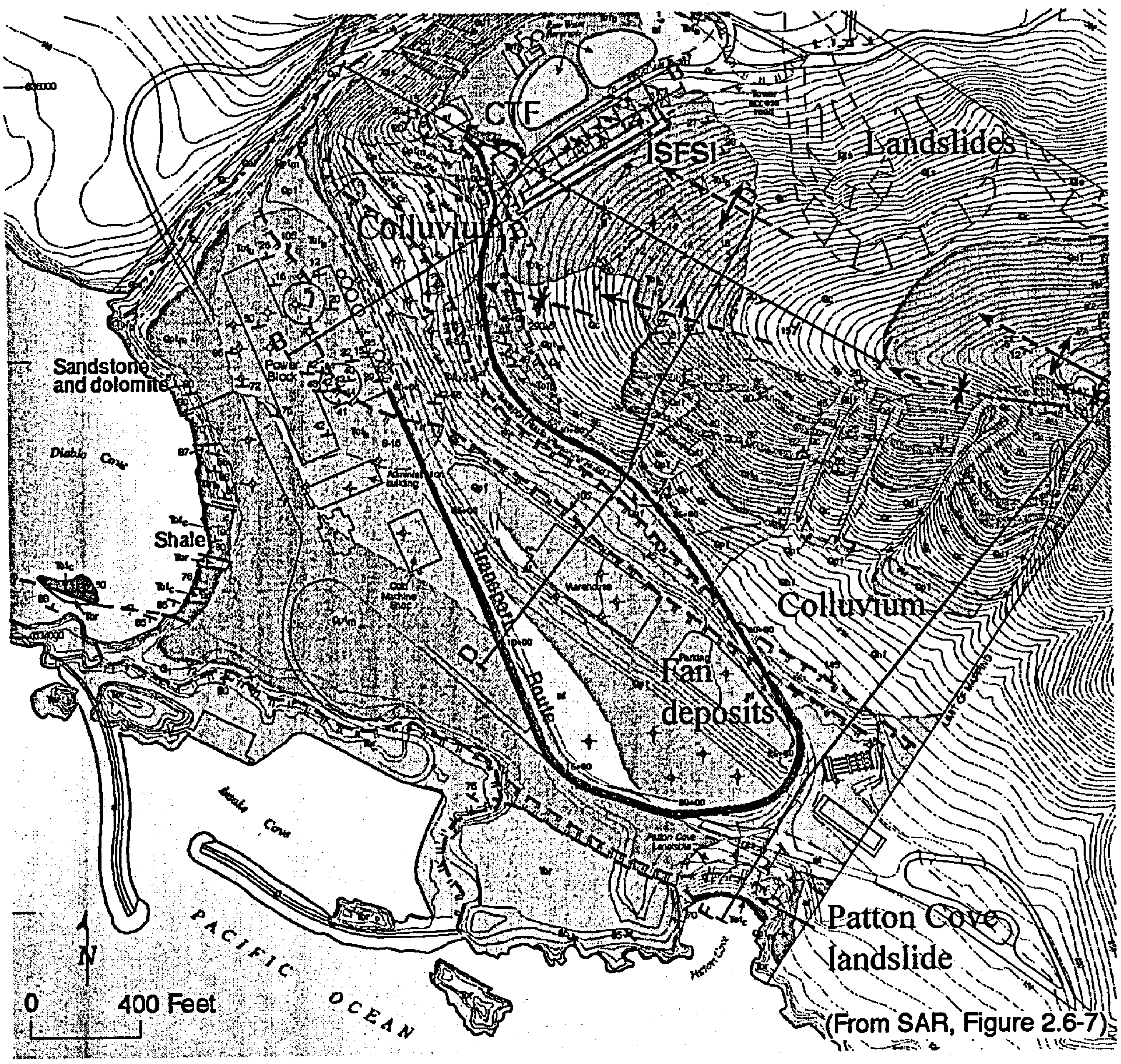
ISFSI
Small parasitic syncline
Spring
Transport Route
Reservoir Road
From Data Report A (Photo A-17)



Surficial Deposits in ISFSI Area

Marine Terraces

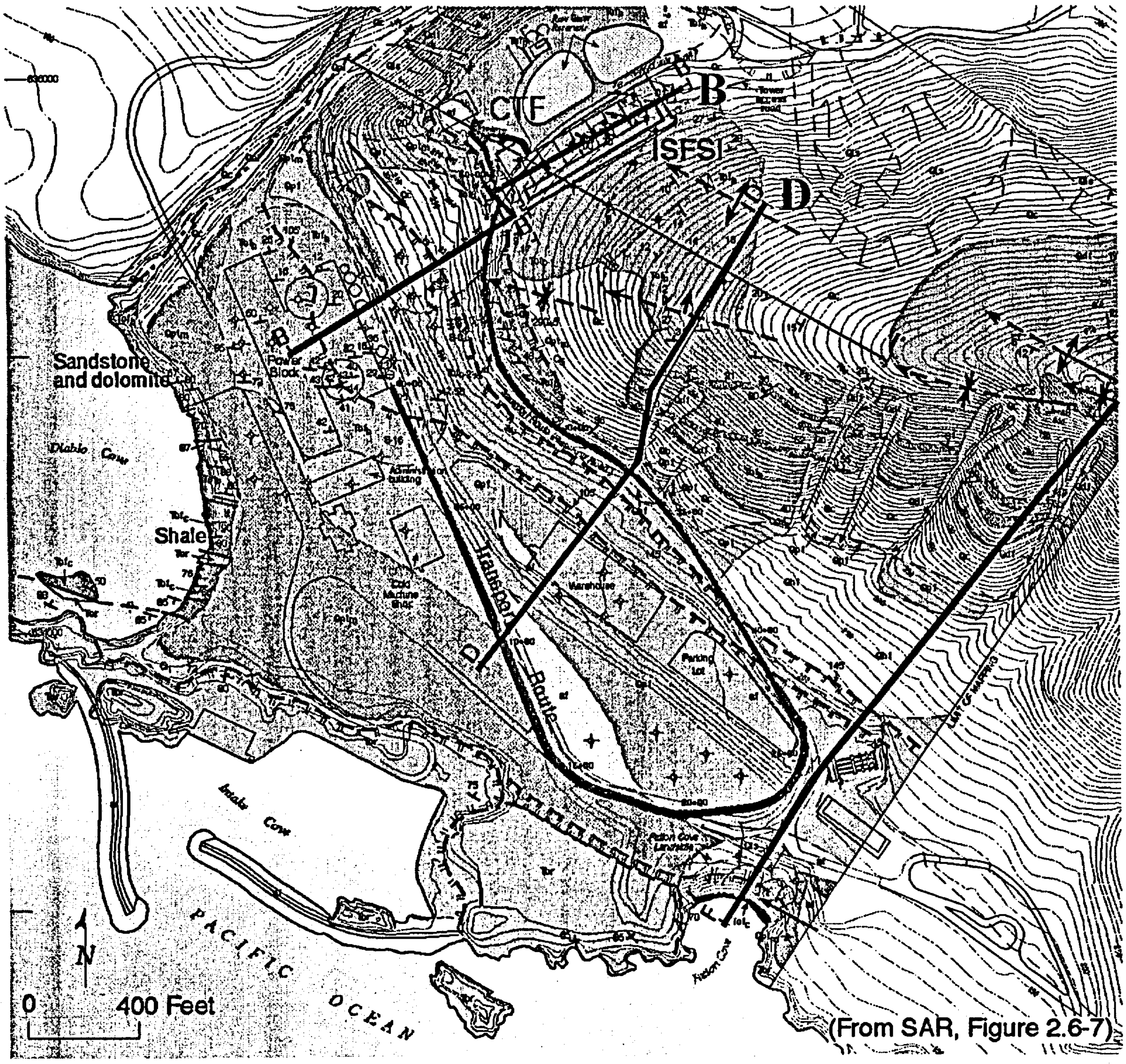
Surficial Deposits in ISFSI Area



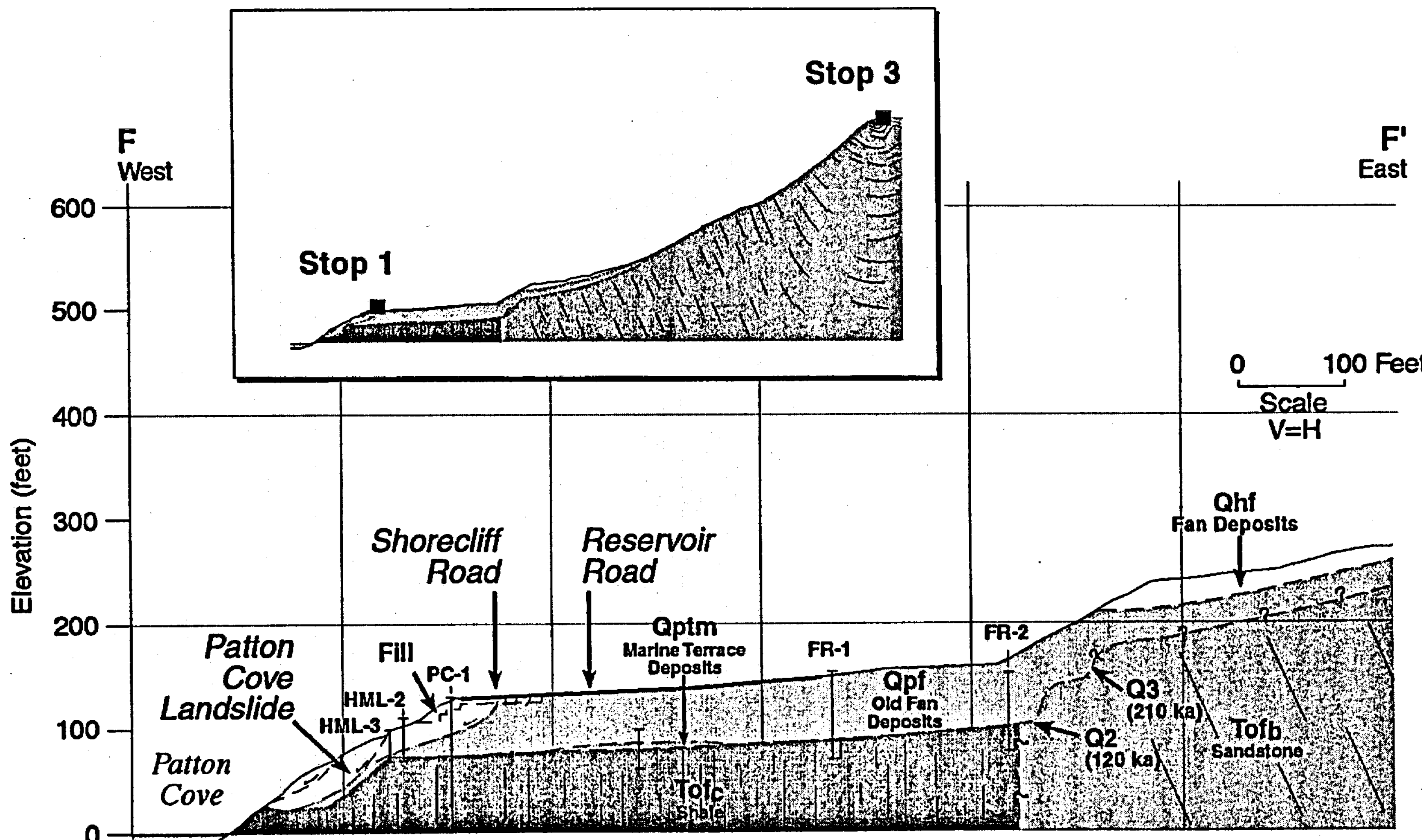
(From SAR, Figure 2.6-7)

Slope Deposits

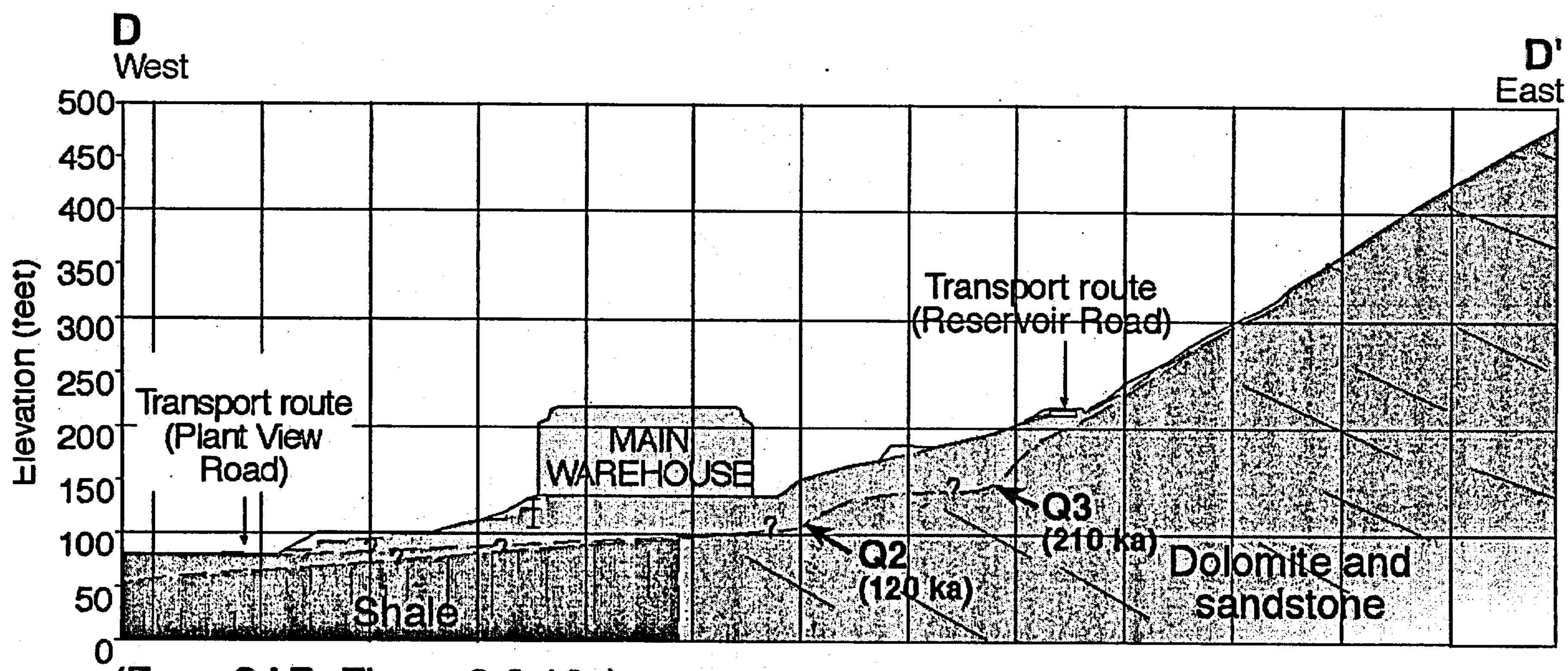
Surficial Deposits in ISFSI Area



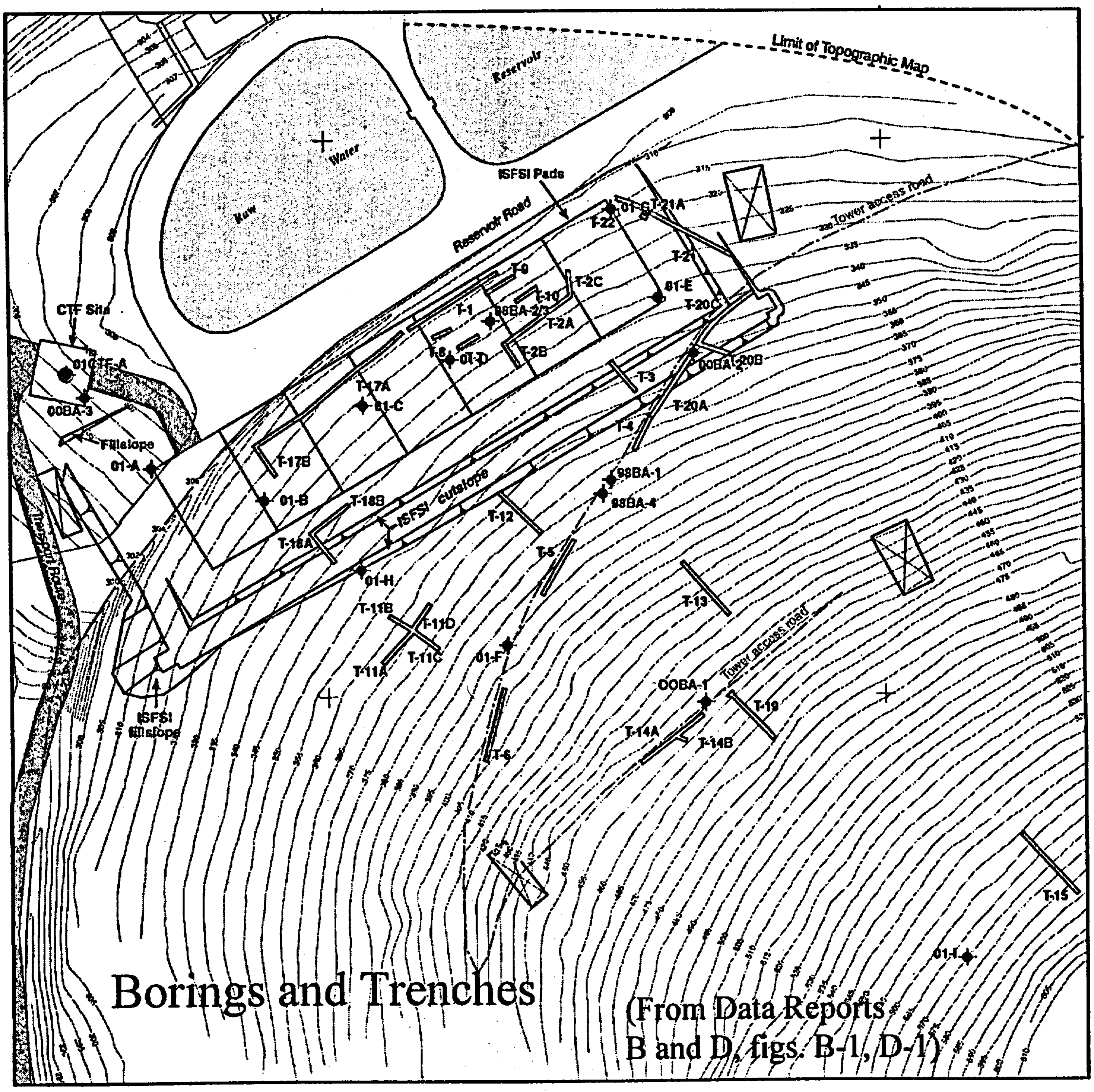
Cross Sections



(From SAR, Figure 2.6-17)

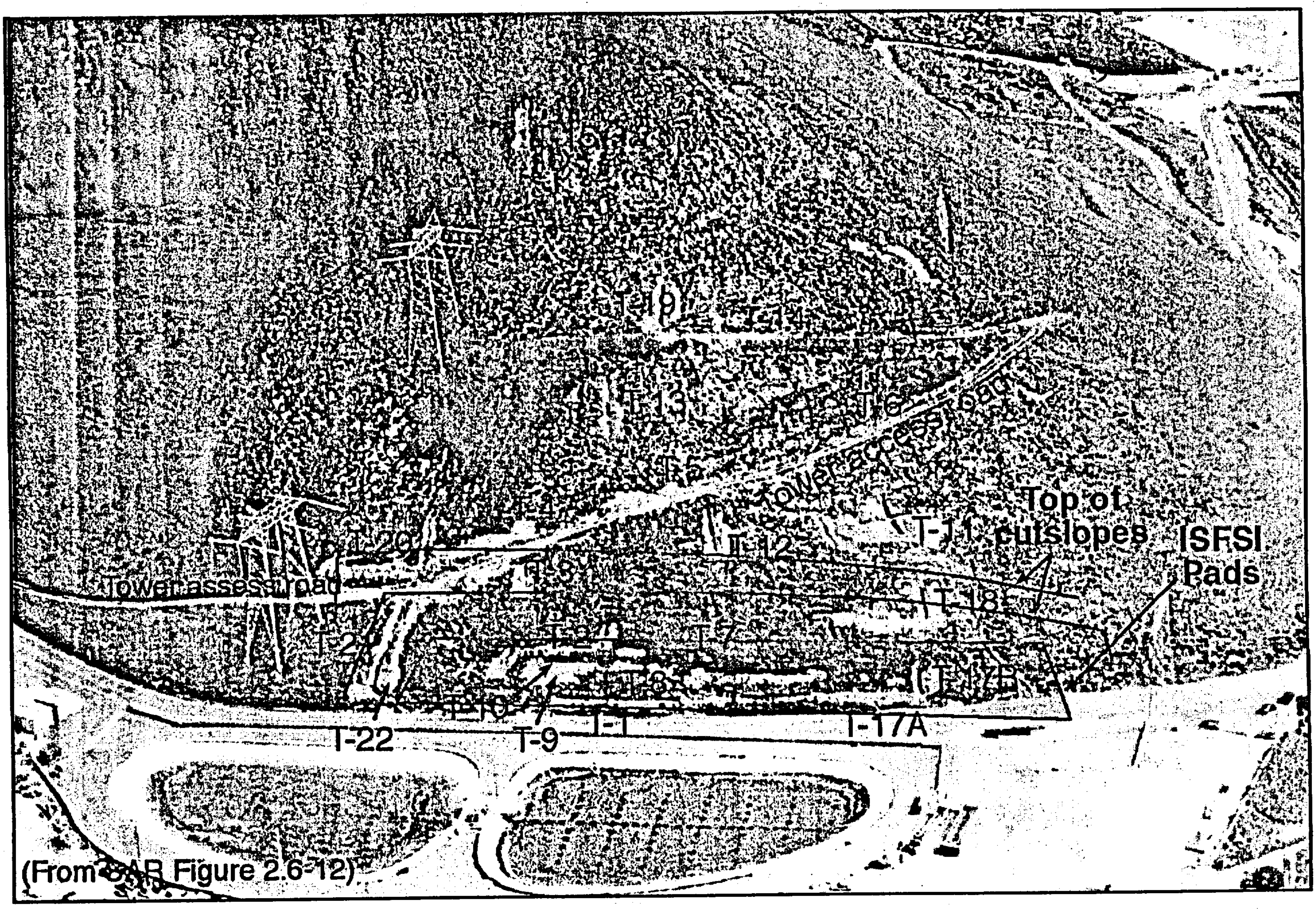


(From SAR, Figure 2.6-16a)

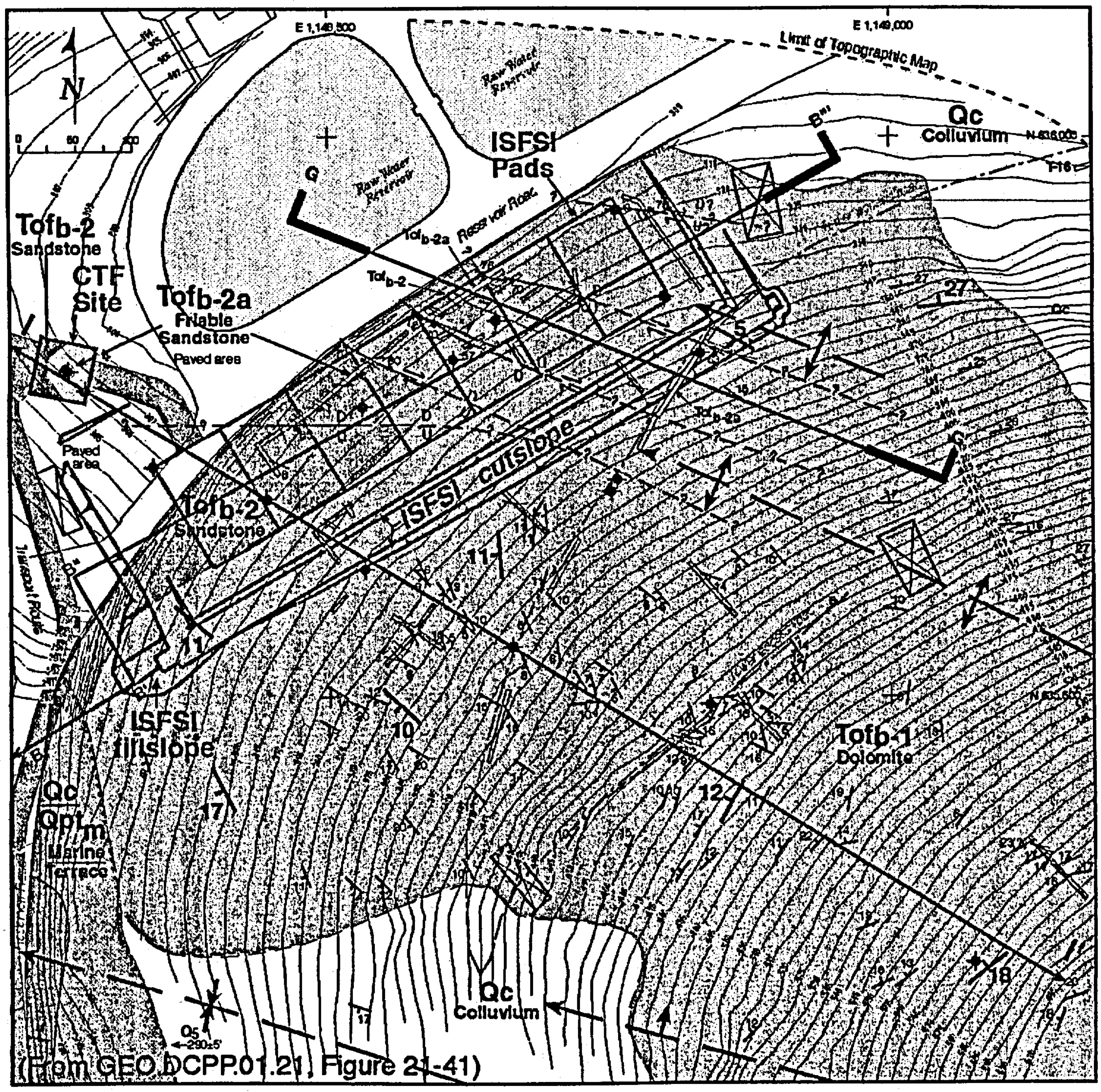


Borings and Trenches

(From Data Reports B and D, figs. B-1, D-1)

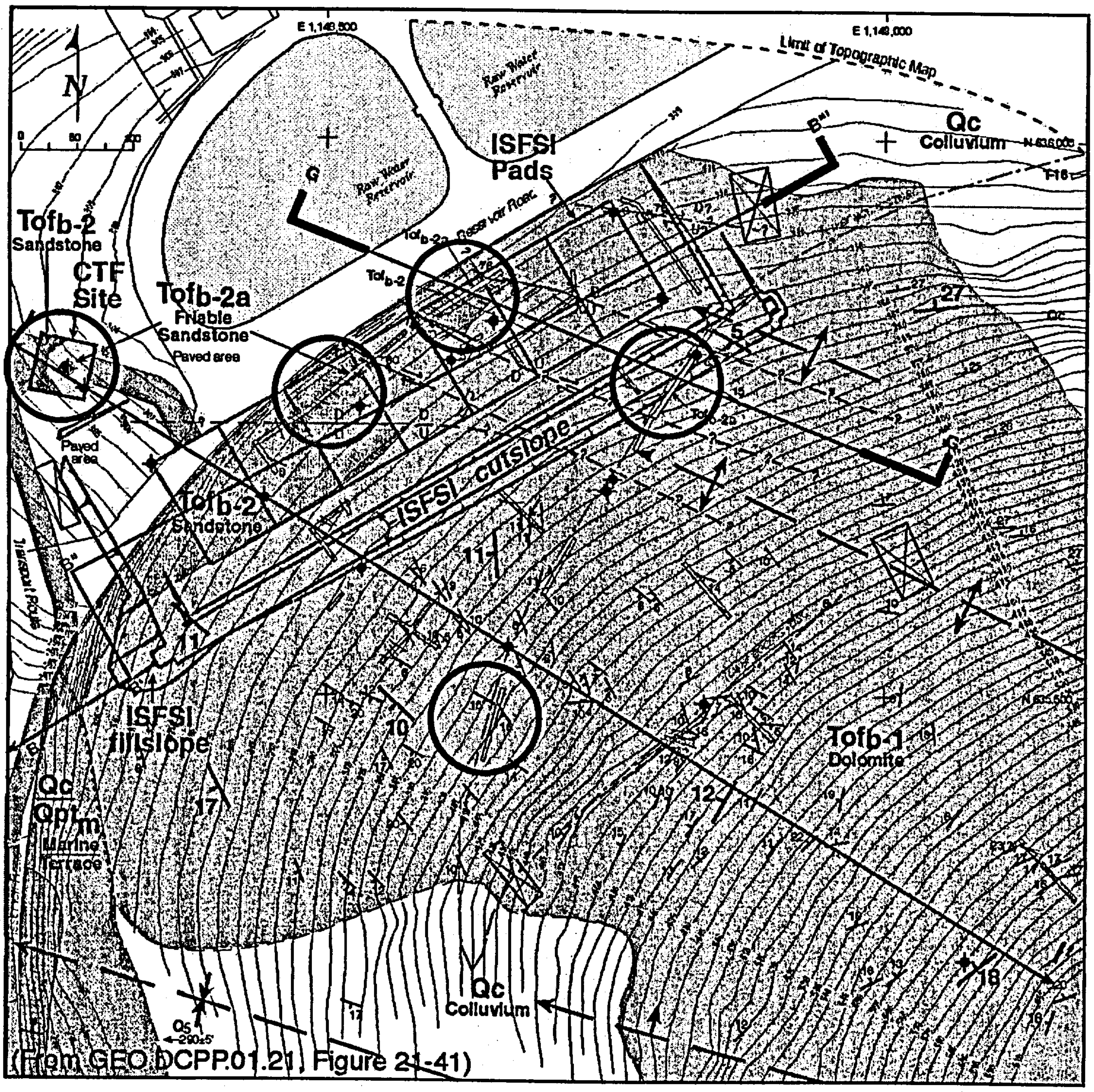


(From SAR Figure 2.6-12)

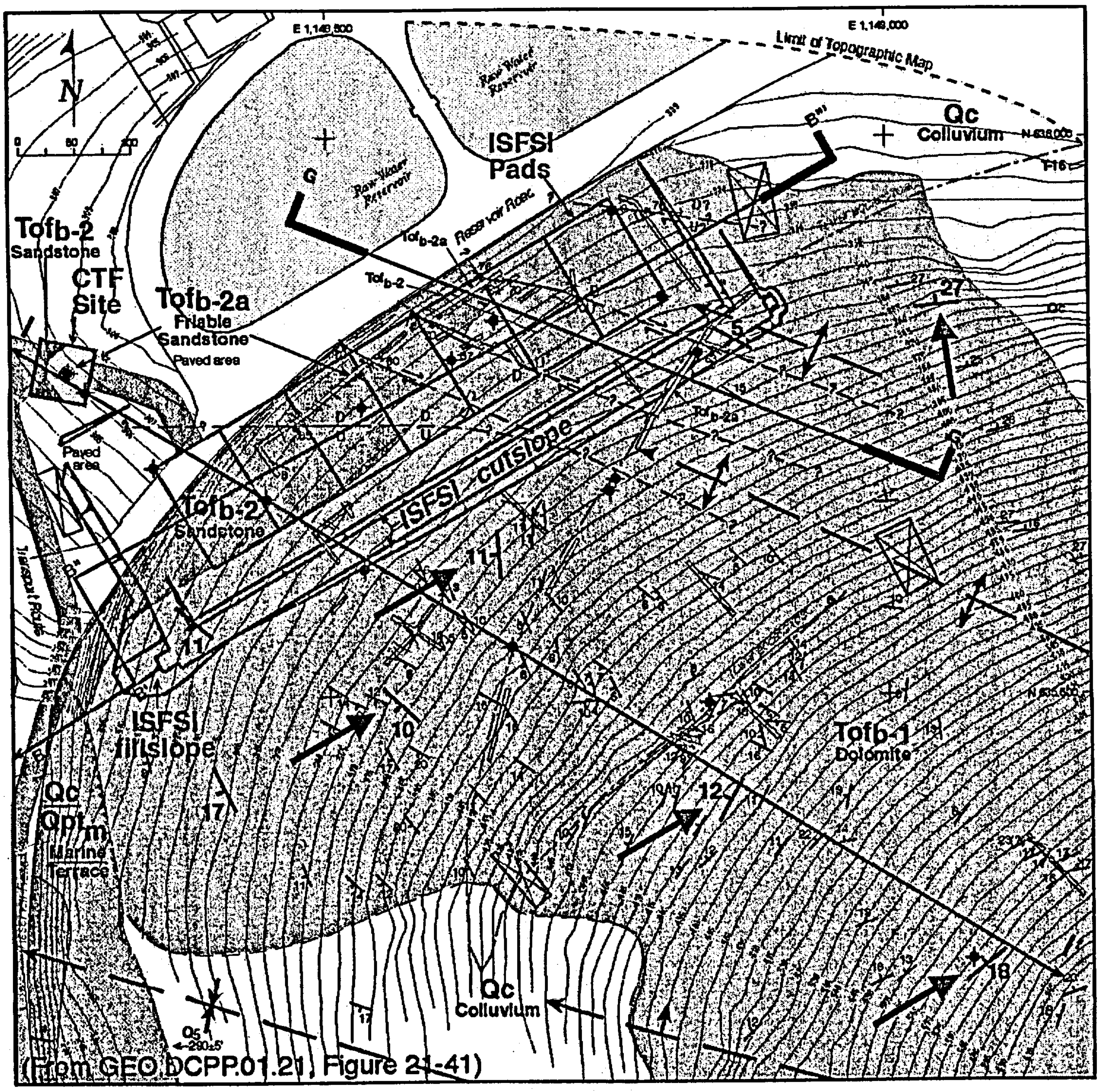


Friable
Rock

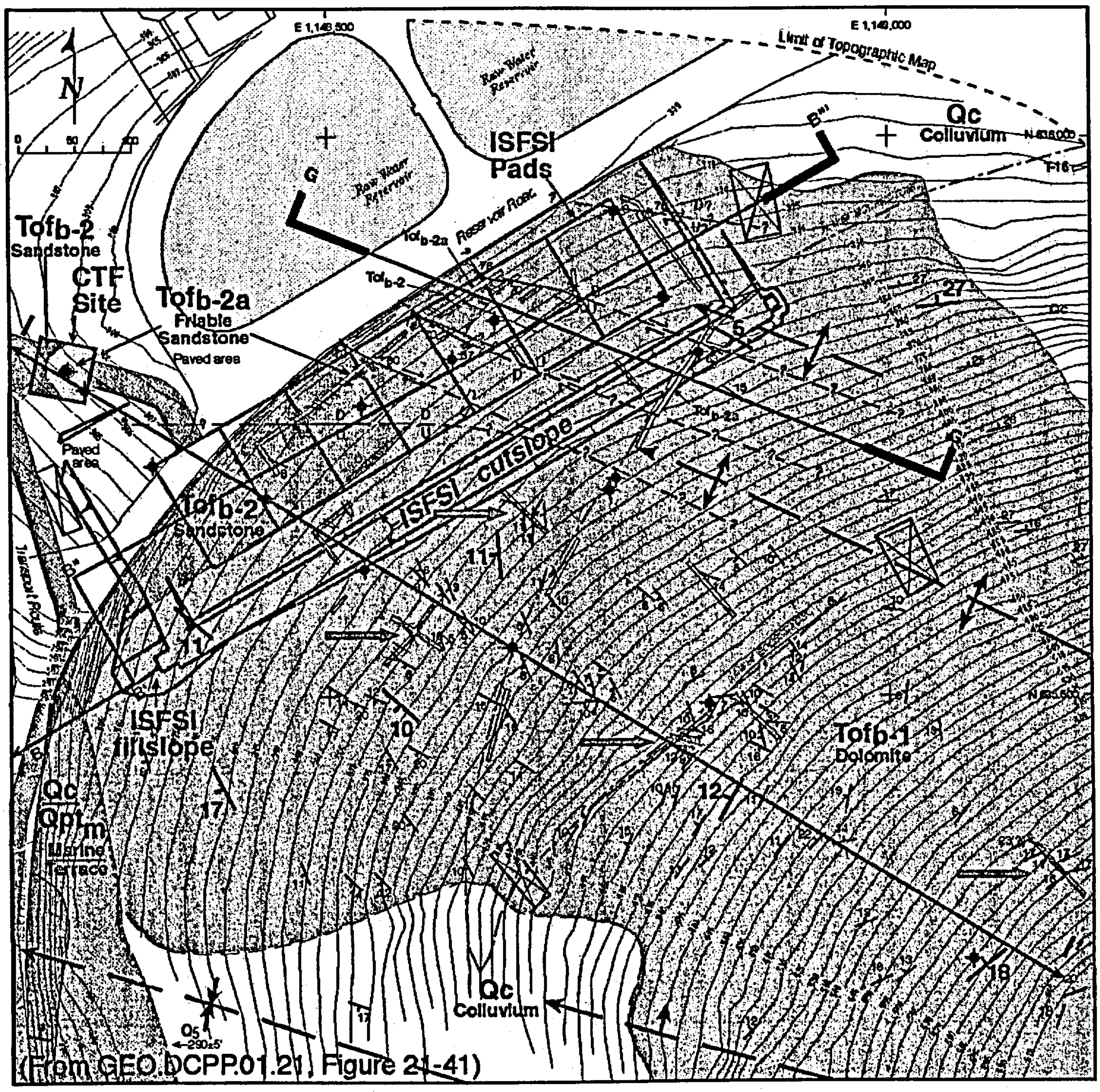
Friable Rock



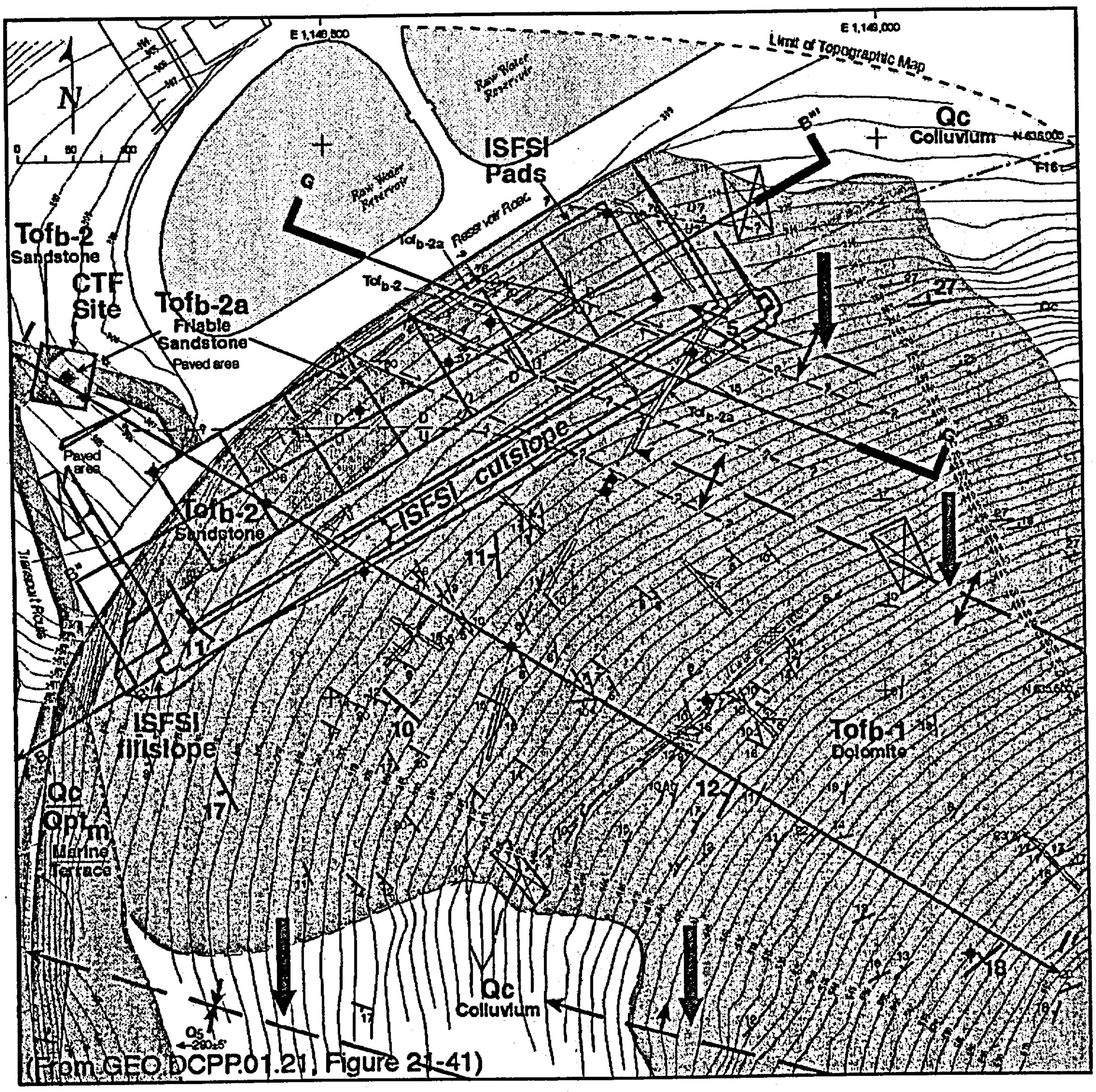
(From GEO.DCPP.01.21, Figure 21-41)


Limit of Topographic Map
Qc
Colluvium
ISFSI
Pads
Tofb-2
Sandstone
CTF
Site
Tofb-2a
Friable
Sandstone
Paved area
Tofb-2
Sandstone
ISFSI cutslope
ISFSI
fillslope
Qc
Qpt m
Marine
Terrace
Tofb-1
Dolomite
Qc
Colluvium
(From GEO.DCPP.01.21, Figure 21-41)

Bedding

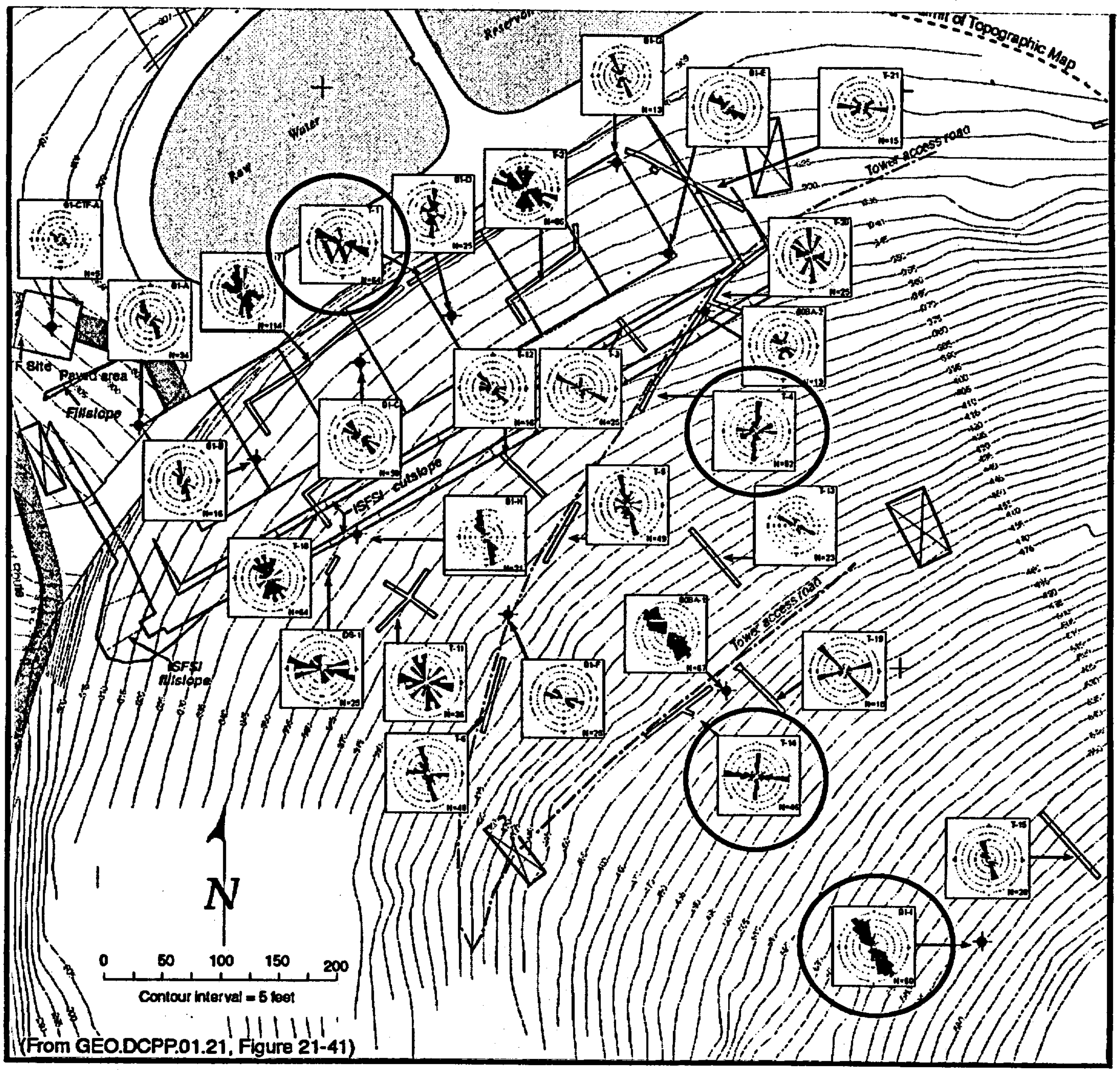

E 1,148,500
E 1,149,000
Limit of Topographic Map
Raw Water Reservoir
Raw Water Reservoir
Qc
Colluvium
ISFSI
Pads
Reservoir Road
Tofb-2
Sandstone
CTF
Site
Tofb-2a
Friable
Sandstone
Paved area
Paved area
Tofb-2
Sandstone
ISFSI cutslope
ISFSI
fillslope
Qc
Qptm
Marine
Terrace
Tofb-1
Dolomite
Qc
Colluvium
(From GEO.DCPP.01.21, Figure 21-41)

Clay beds

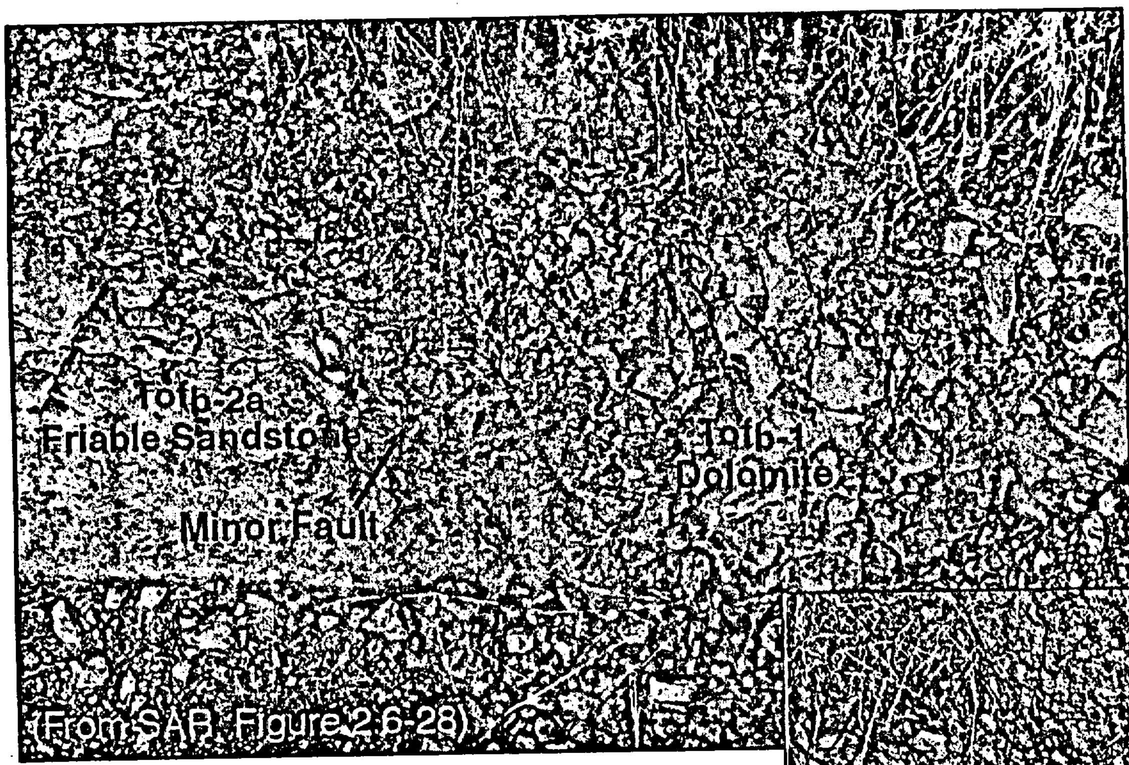


(From GEO.DCPP.01.21, Figure 21-41)

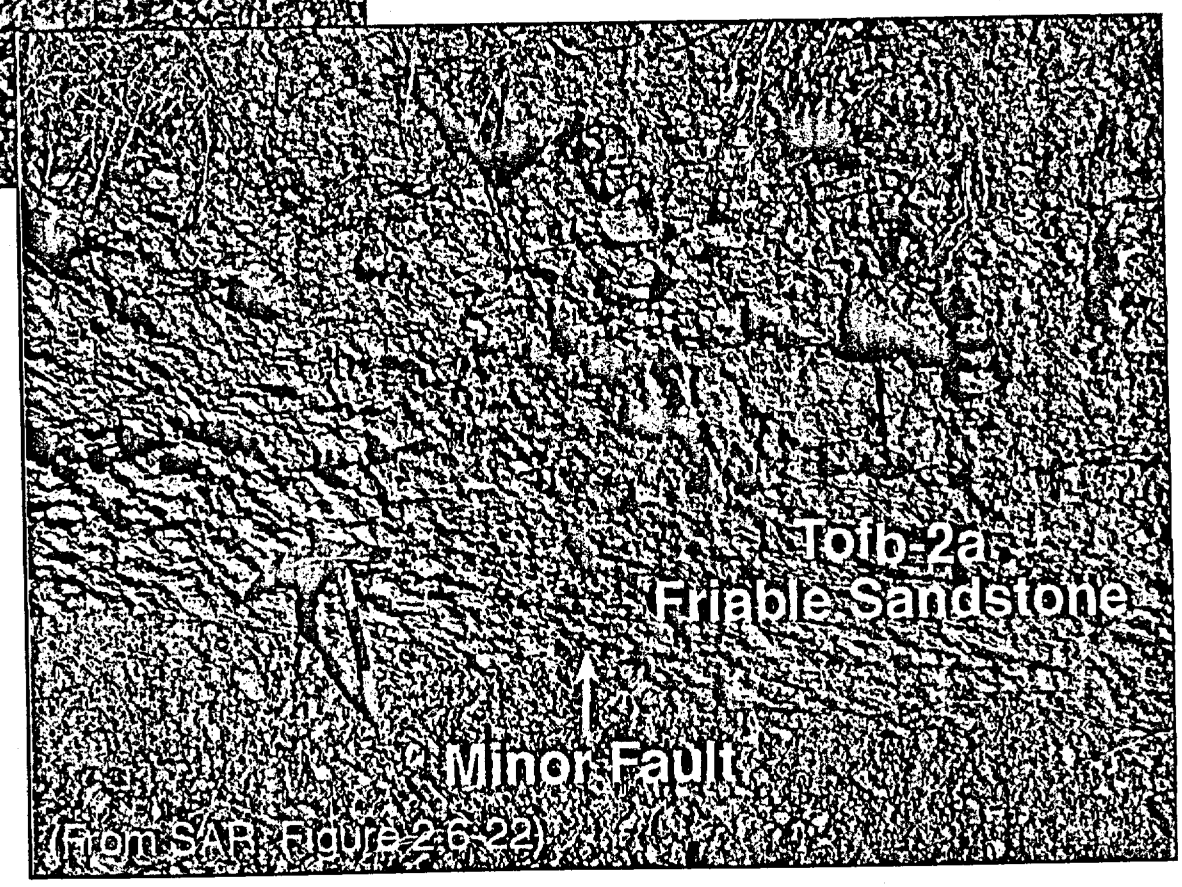
Folds

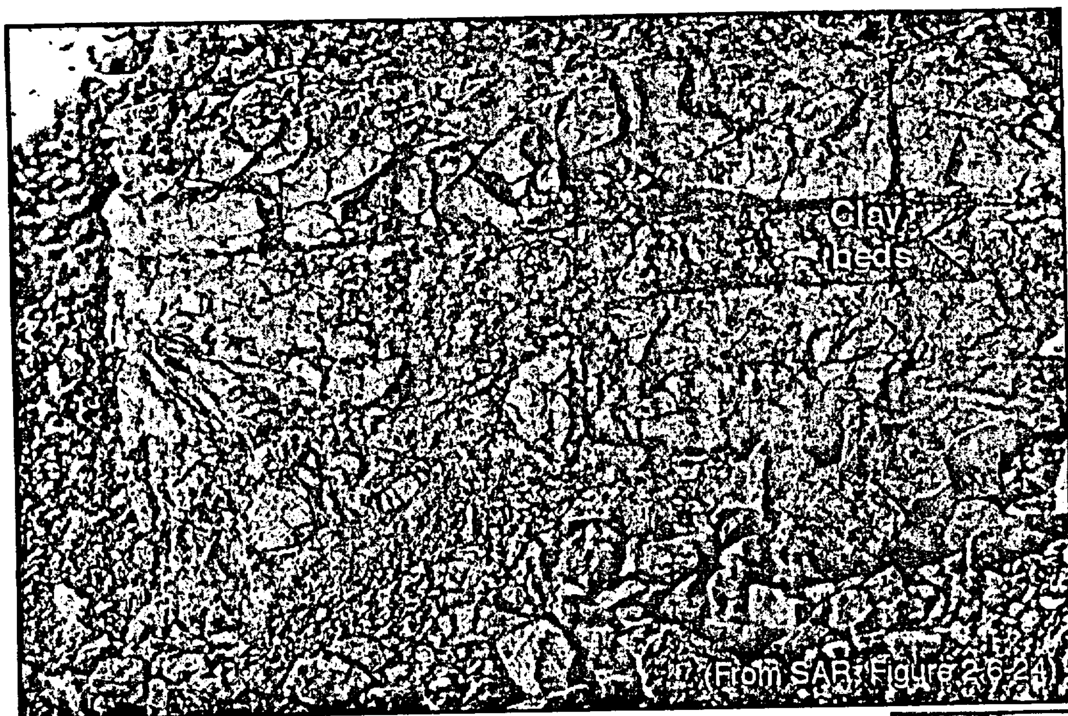


Rose Diagrams for Joints and Faults



Minor Faults
Trench T-1

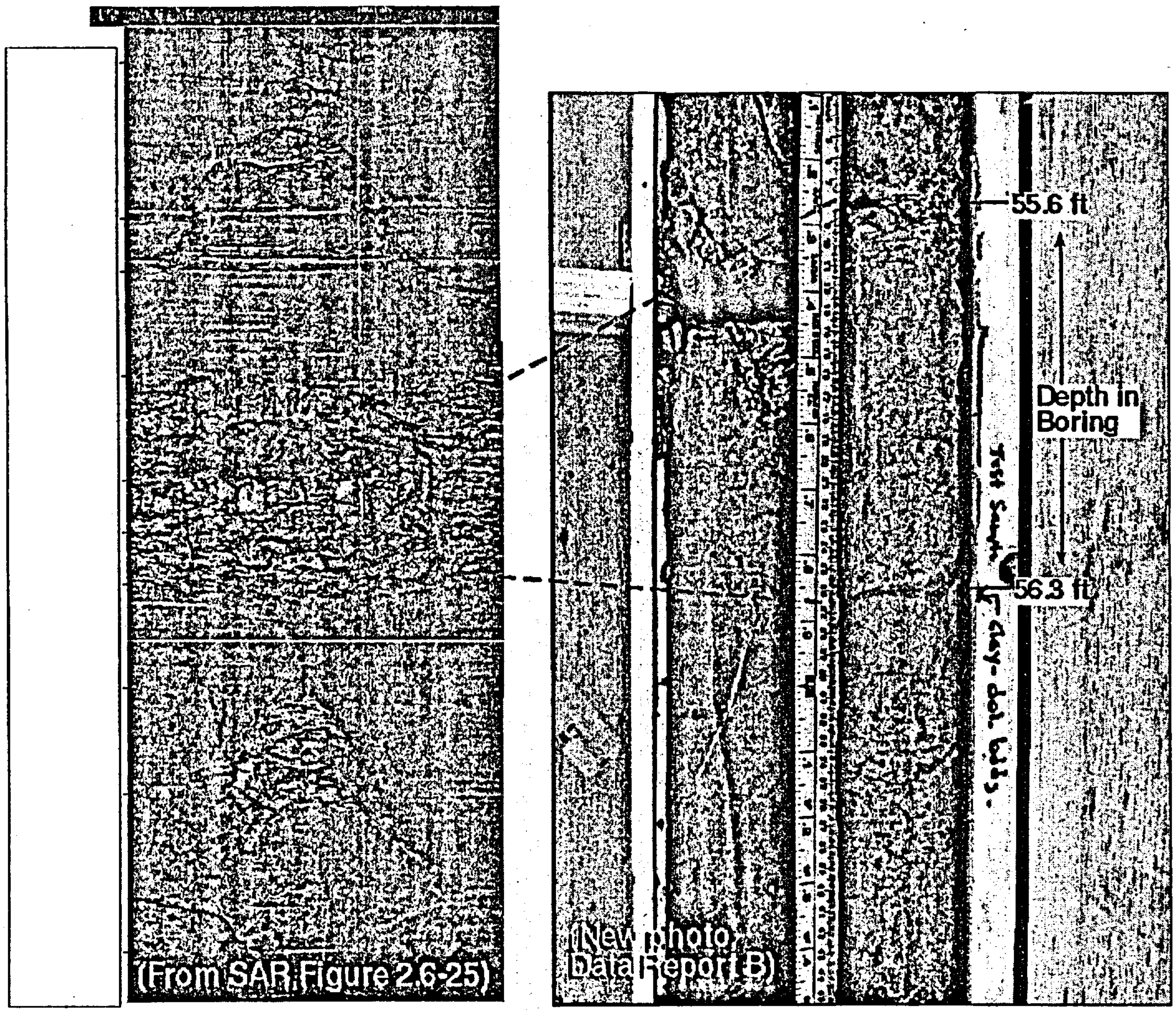




1/16- to 3/4-inch thick clay beds

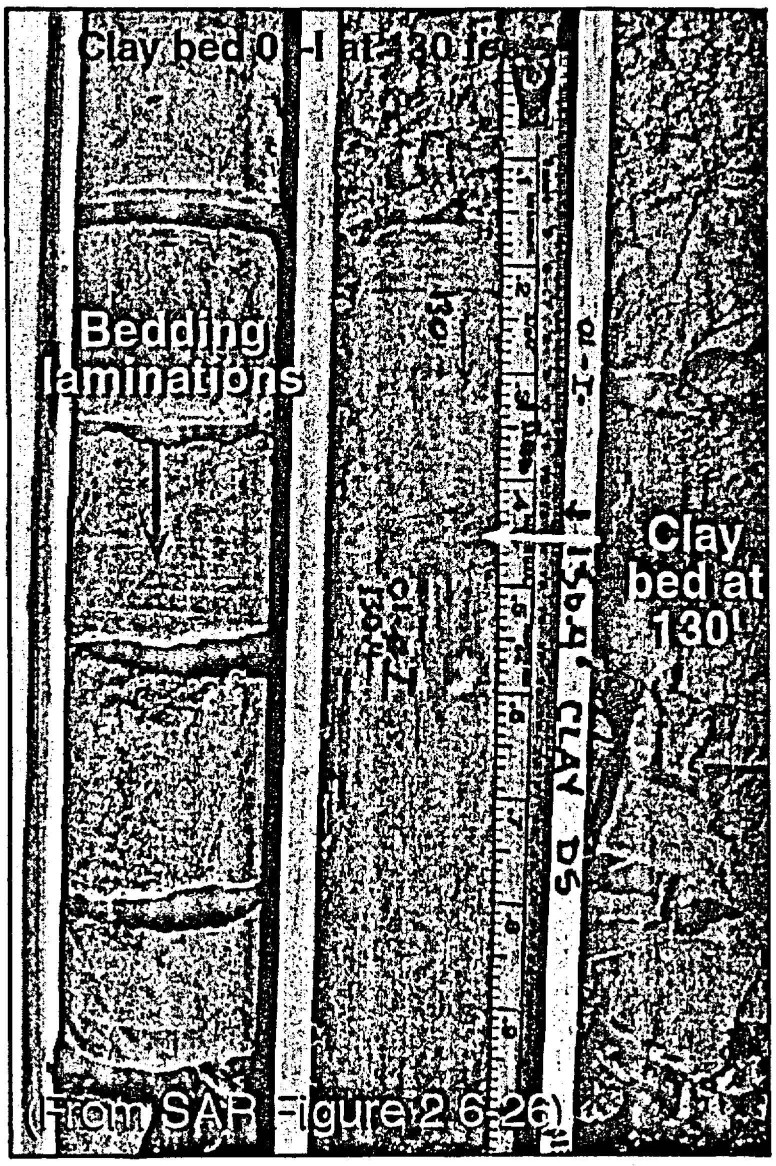
Clay Beds in Trench T-14

1- to 4-inch thick clay beds

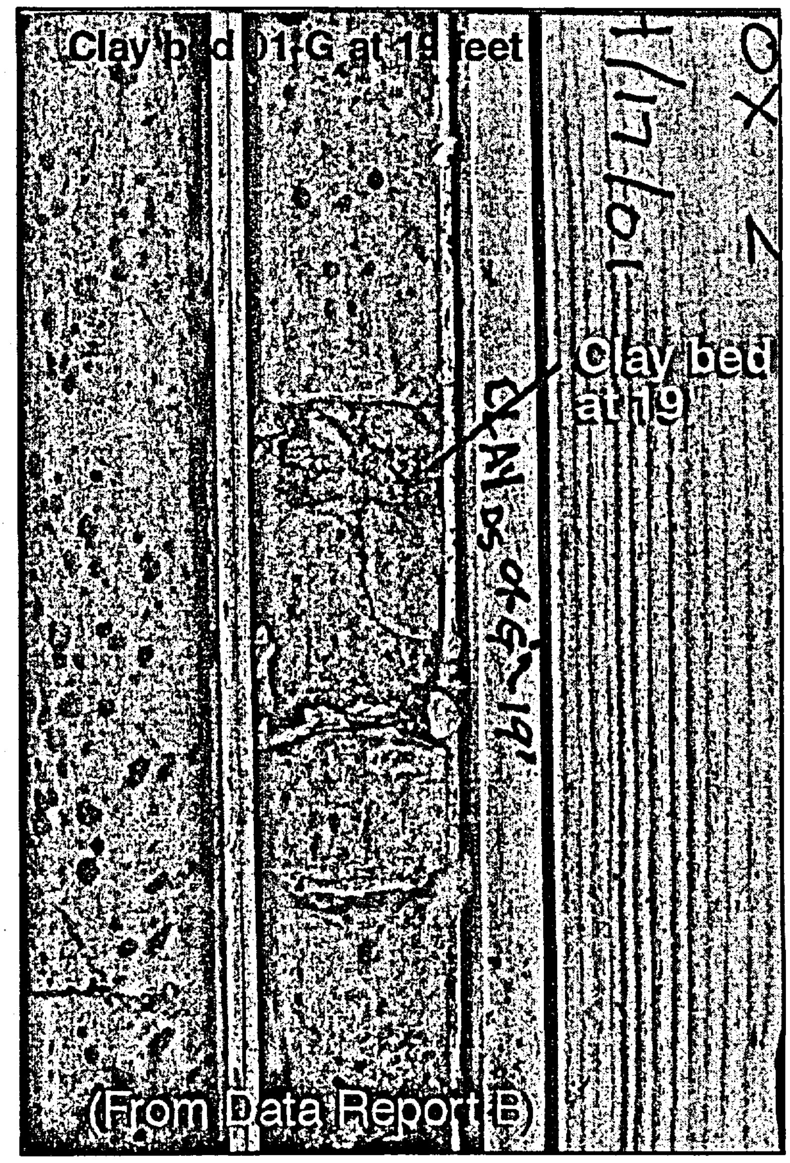


Optical televiewer image Core

Thick Clay Bed in Boring 00BA-1 at 55 Feet

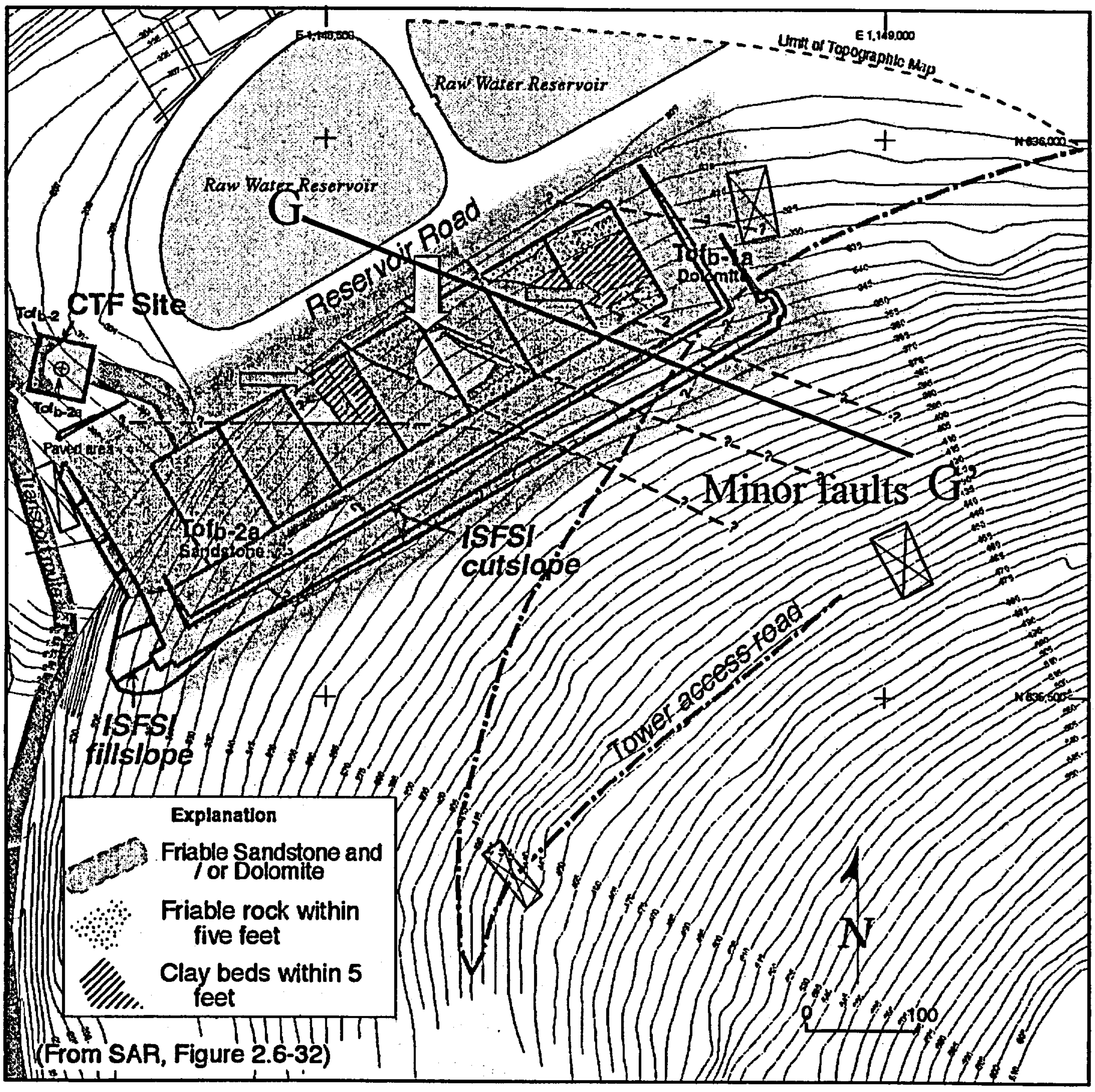


Clay bed 01-I at 130 feet

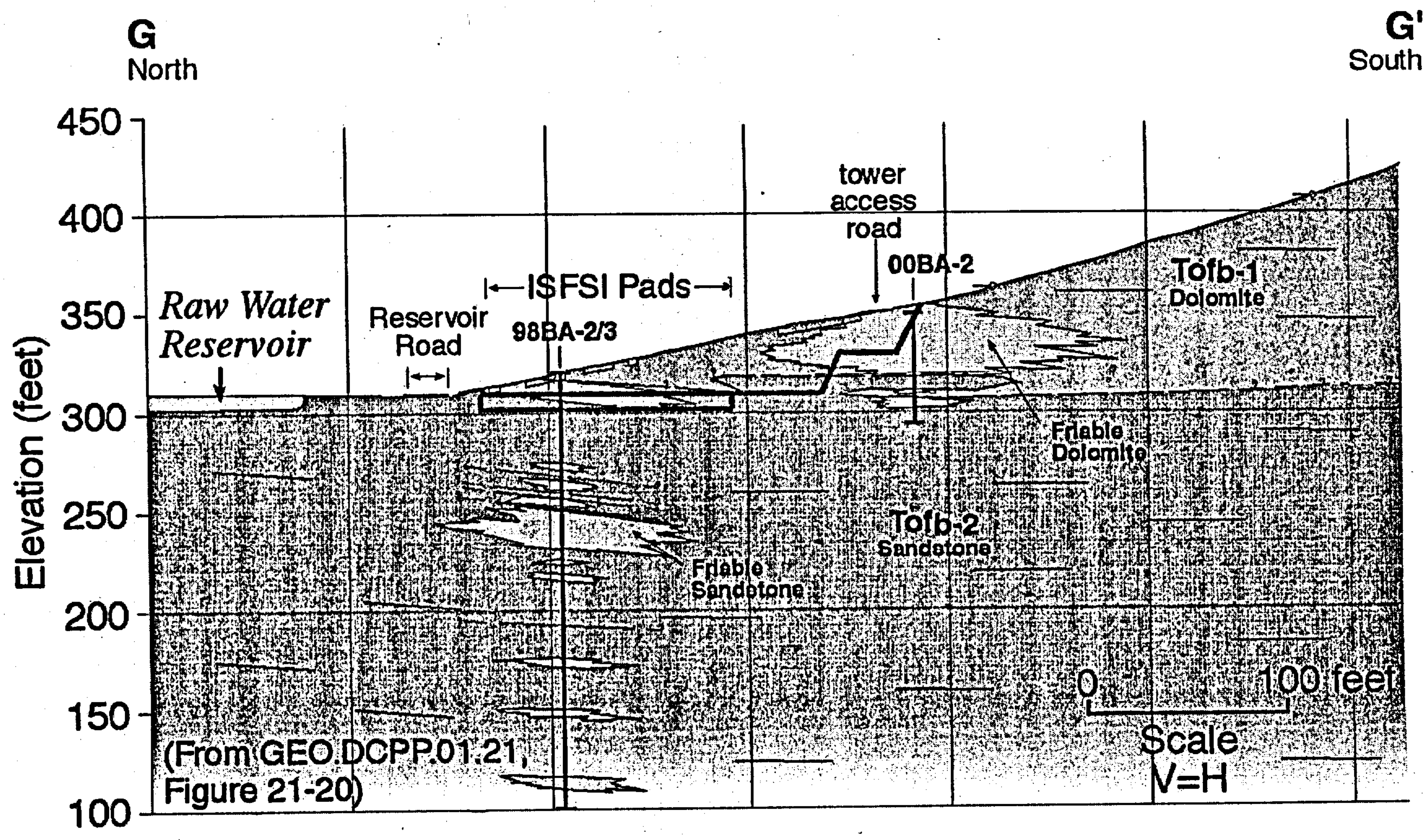


Clay bed 01-G at 19 feet

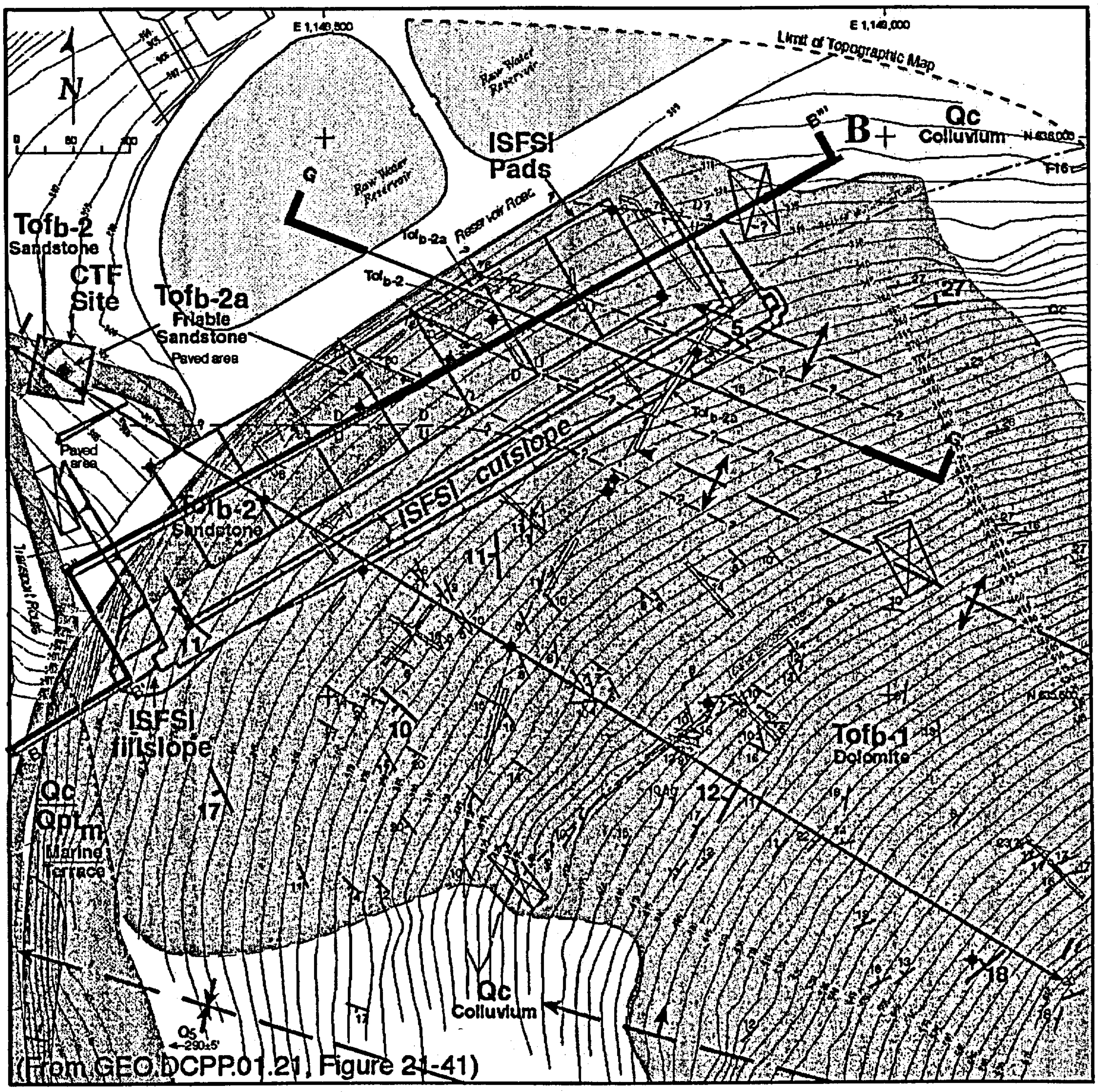
Thin Clay Beds in Boring 01-I and 01-G



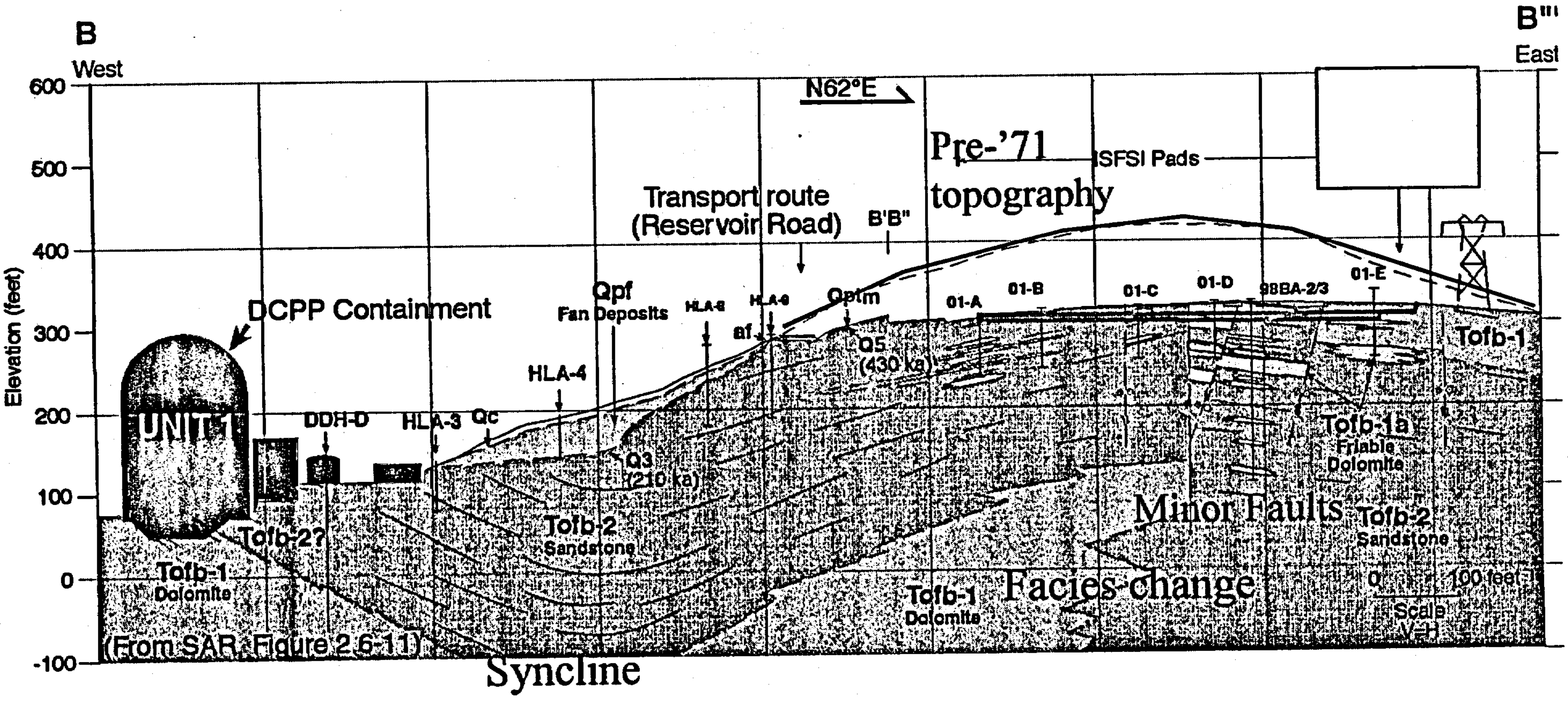
E 1,148,500
E 1,149,000
Limit of Topographic Map
Raw Water Reservoir
Raw Water Reservoir
N 836,000
G
Reservoir Road
Tofb-1a
Dolomite
CTF Site
Tofb-2
Tofb-2a
Paved area
Minor faults
G'
Tofb-2a
Sandstone
ISFSI
cutslope
Tower access road
N 835,500
ISFSI
fillslope
Explanation
Friable Sandstone and / or Dolomite
Friable rock within five feet
Clay beds within 5 feet
N
0
100
(From SAR, Figure 2.6-32)



G
North
G'
South
Elevation (feet)
450
400
350
300
250
200
150
100
Raw Water Reservoir
Reservoir Road
|←ISFSI Pads→|
98BA-2/3
tower access road
00BA-2
Tofb-1
Dolomite
Friable Dolomite
Tofb-2
Sandstone
Friable Sandstone
0
100 feet
Scale
V=H
(From GEO.DCPP.01.21, Figure 21-20)

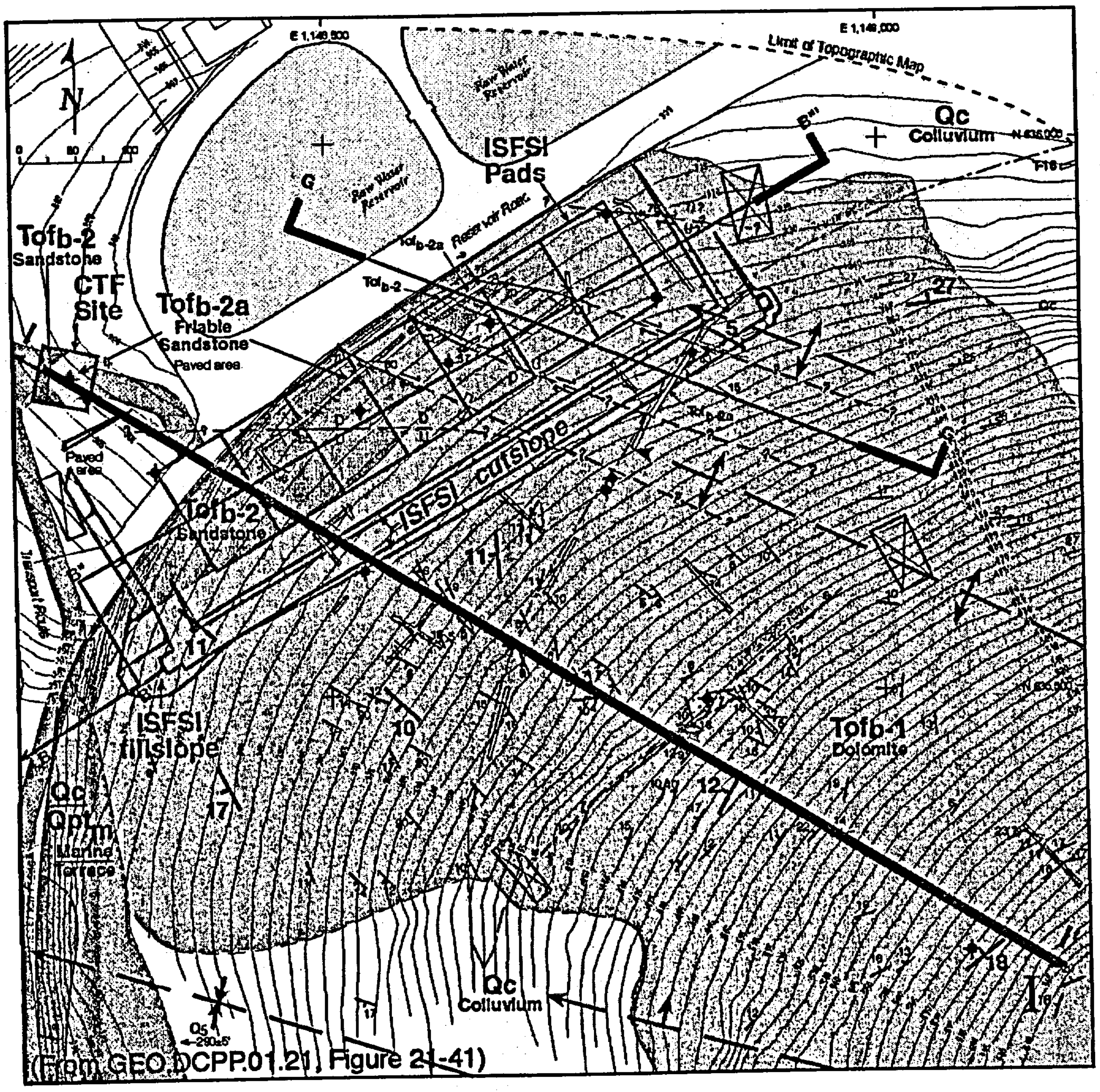


Cross Section B-B

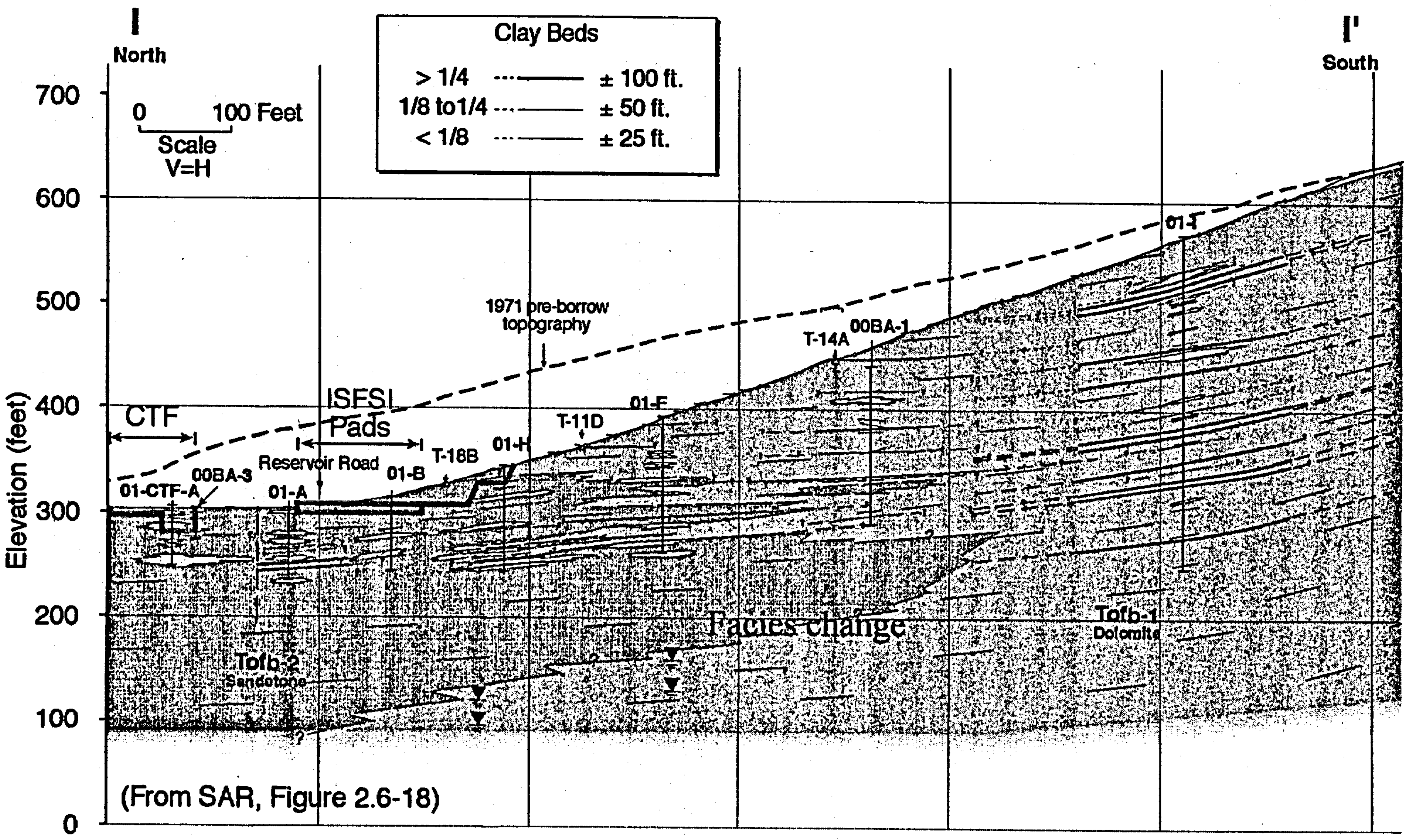

B
West
B'''
East
600
500
400
300
200
100
0
-100
Elevation (feet)
N62°E
Pre-'71
topography
SFSI Pads
Transport route
(Reservoir Road)
B'B"
DCPP Containment
UNIT 1
DDH-D
HLA-3
Qc
HLA-4
Qpf
Fan Deposits
Qptm
Q5
(430 ka)
Q3
(210 ka)
01-A
01-B
01-C
01-D
98BA-2/3
01-E
Tofb-1
Tofb-1a
Friable
Dolomite
Tofb-2
Sandstone
Tofb-2?
Tofb-1
Dolomite
Minor Faults
Facies change
Syncline
(From SAR Figure 2.6-11)
0
100 feet
Scale
V=H

Comparison of Bedrock at ISFSI and Power Block

- Same stratigraphic unit
  - Obispo Formation Tof_b
- Same lithology and density
  - Dolomite and sandstone
- Similar shear wave velocity



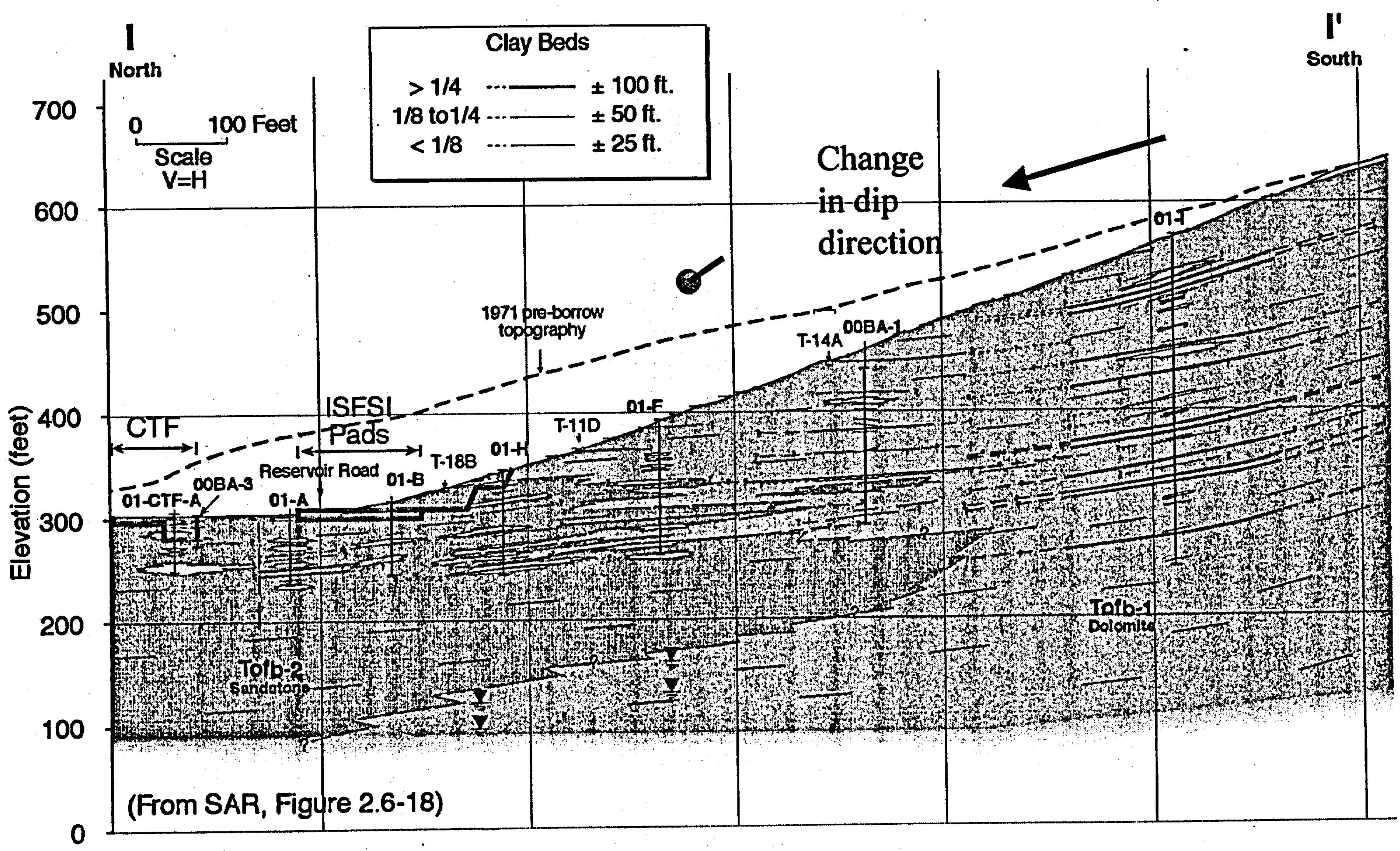
Cross Section I-I



Facies Change

Geologic Constraints for Modeling Potential Large-scale Rock Mass Movements

- Geometry of clay beds
- Clay strength
- Discontinuity of clay beds
- Rock mass discontinuities
- Groundwater

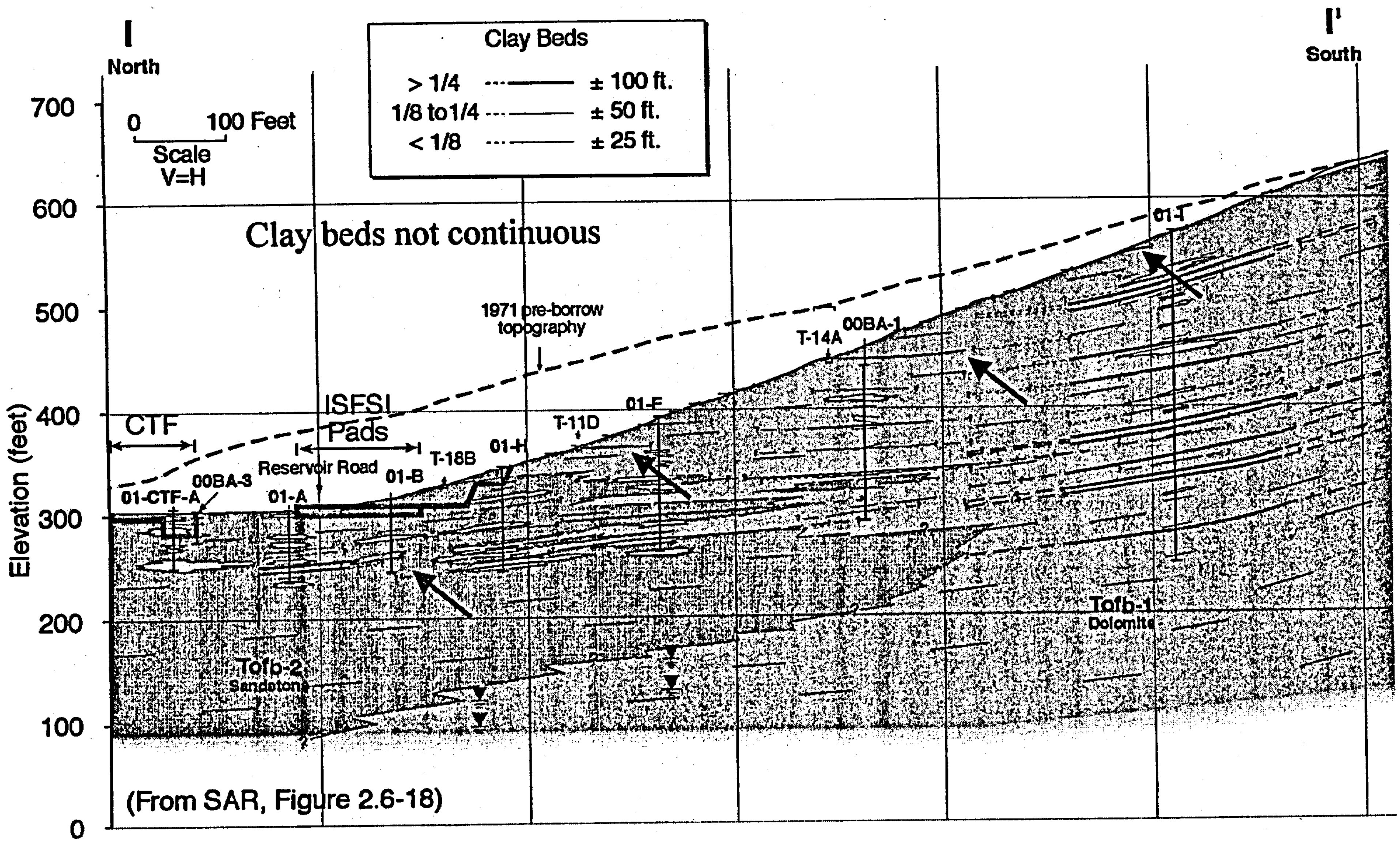


Dip Direction

Geometry of Clay Beds

- Change in dip directions across the structural transitions from monocline to syncline
  - Upper part of slope bedding dips out of slope
    - 10 to 20 degrees
  - Lower part of slope bedding dips to the west; apparent dip is subhorizontal

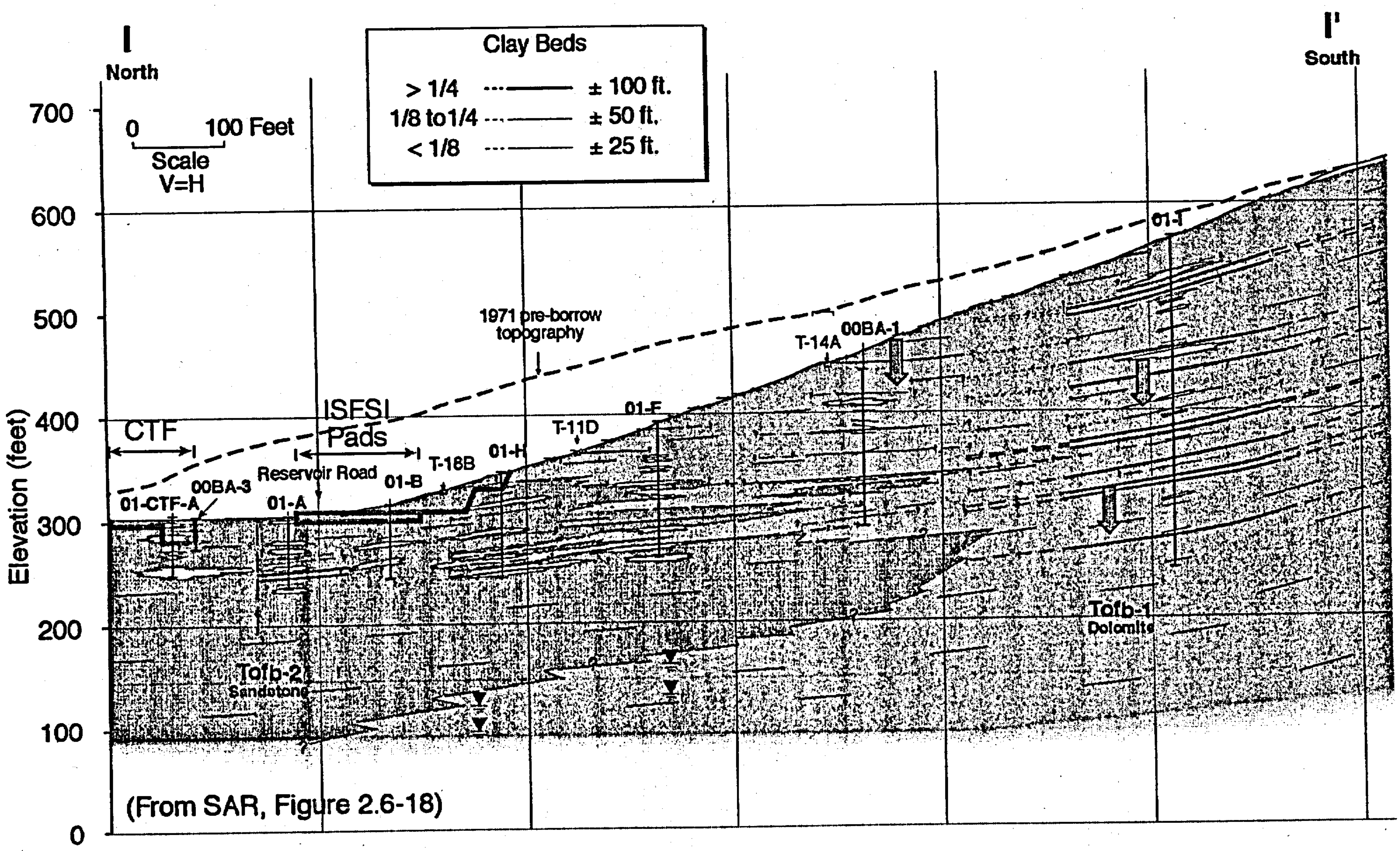
- These structural changes limit size of potential rock mass movements


I
North
I'
South
700
600
500
400
300
200
100
0
Elevation (feet)
0 100 Feet
Scale
V=H
Clay Beds
> 1/4 ± 100 ft.
1/8 to1/4 ± 50 ft.
< 1/8 ± 25 ft.
Clay beds not continuous
1971 pre-borrow topography
CTF
ISFSI Pads
Reservoir Road
01-CTF-A
00BA-3
01-A
01-B
T-18B
01-H
T-11D
01-E
T-14A
00BA-1
01-I
Tofb-2 Sandstone
Tofb-1 Dolomite
(From SAR, Figure 2.6-18)

Clay Beds

Discontinuity of Clay Beds

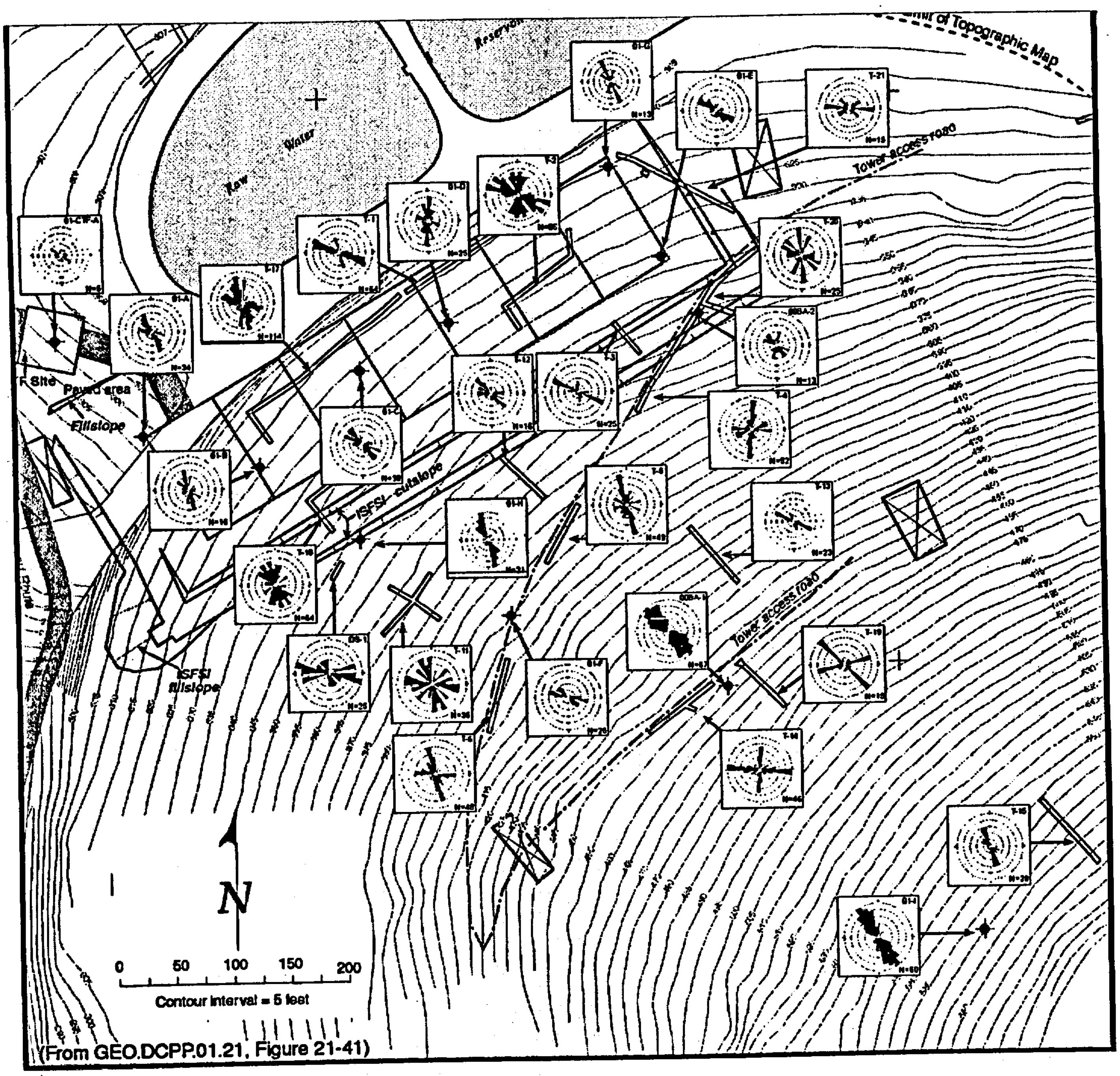
- Clay beds have limited lateral extent
  - Limited correlation between borings and outcrops
  - Clay beds more common in dolomite, do not extend across facies contacts
  - Analysis indicates beds extend a few tens to a few hundreds of feet
- Potential large rock mass movements would step between clay beds along joints and through rock in a "staircase" profile.



Clay Bed Thickness

Clay Strength

- Clay bed thickness varies laterally from a few inches to less than 1/8-inch thick
- Rock to rock contact through the clay bed is typical, increasing effective shear strength
- Clay strength measured in laboratory used in the modeling analysis (presented later)

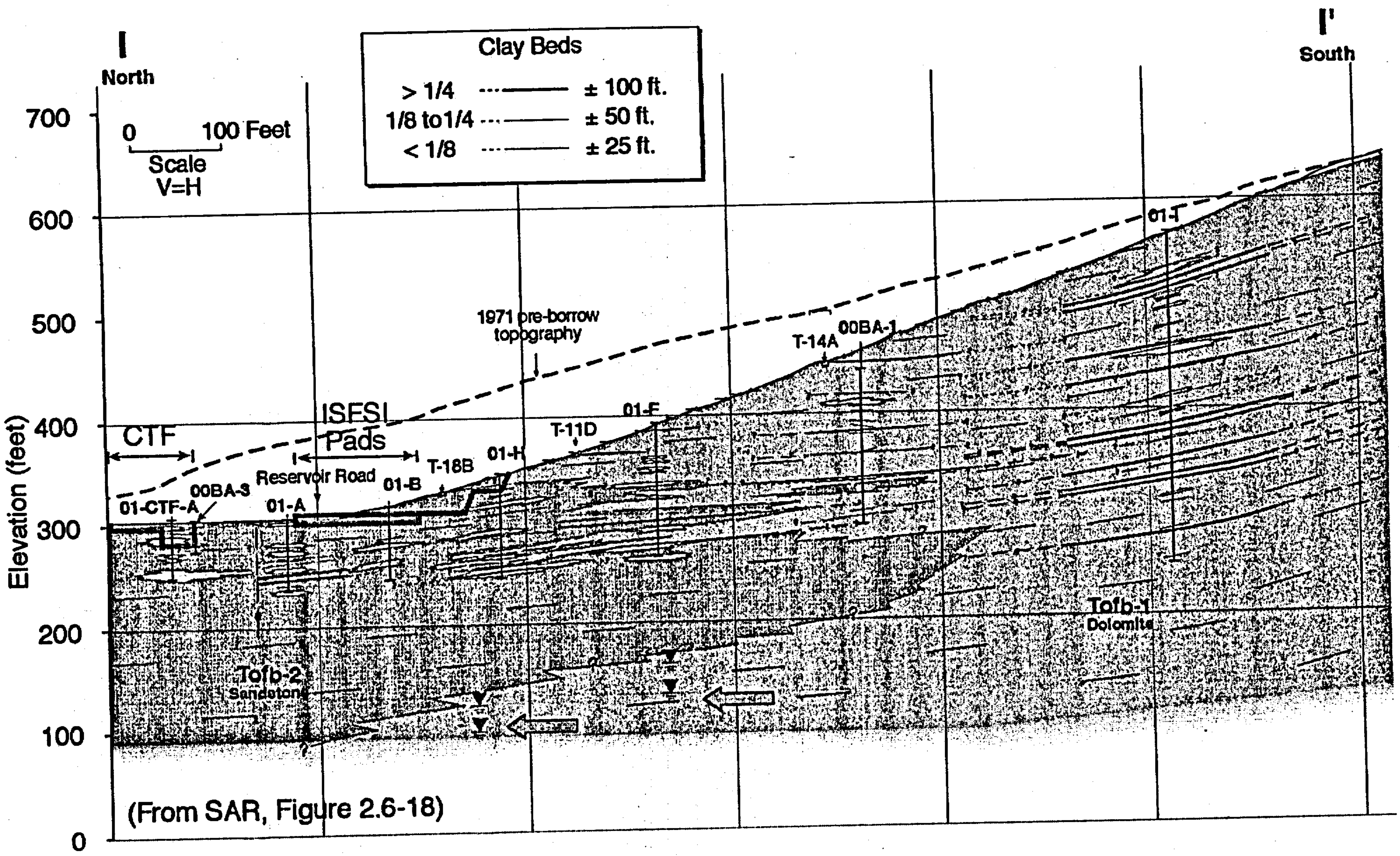


Joints and Faults

Rock Mass Discontinuities

- Joints and minor faults disrupt the continuity of the clay beds causing large-scale rock mass movement to break through rock.

- Faults and joint sets that are subparallel to the potential down slope motion would form the lateral margins of potential rock slides



I
North
I'
South
0
100 Feet
Scale
V=H
Clay Beds
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1/8 to1/4 ± 50 ft.
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Elevation (feet)
CTF
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1971 pre-borrow
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01-CTF-A
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T-11D
01-E
T-14A
00BA-1
01-I
Tofb-2
Sandstone
Tofb-1
Dolomite
(From SAR, Figure 2.6-18)

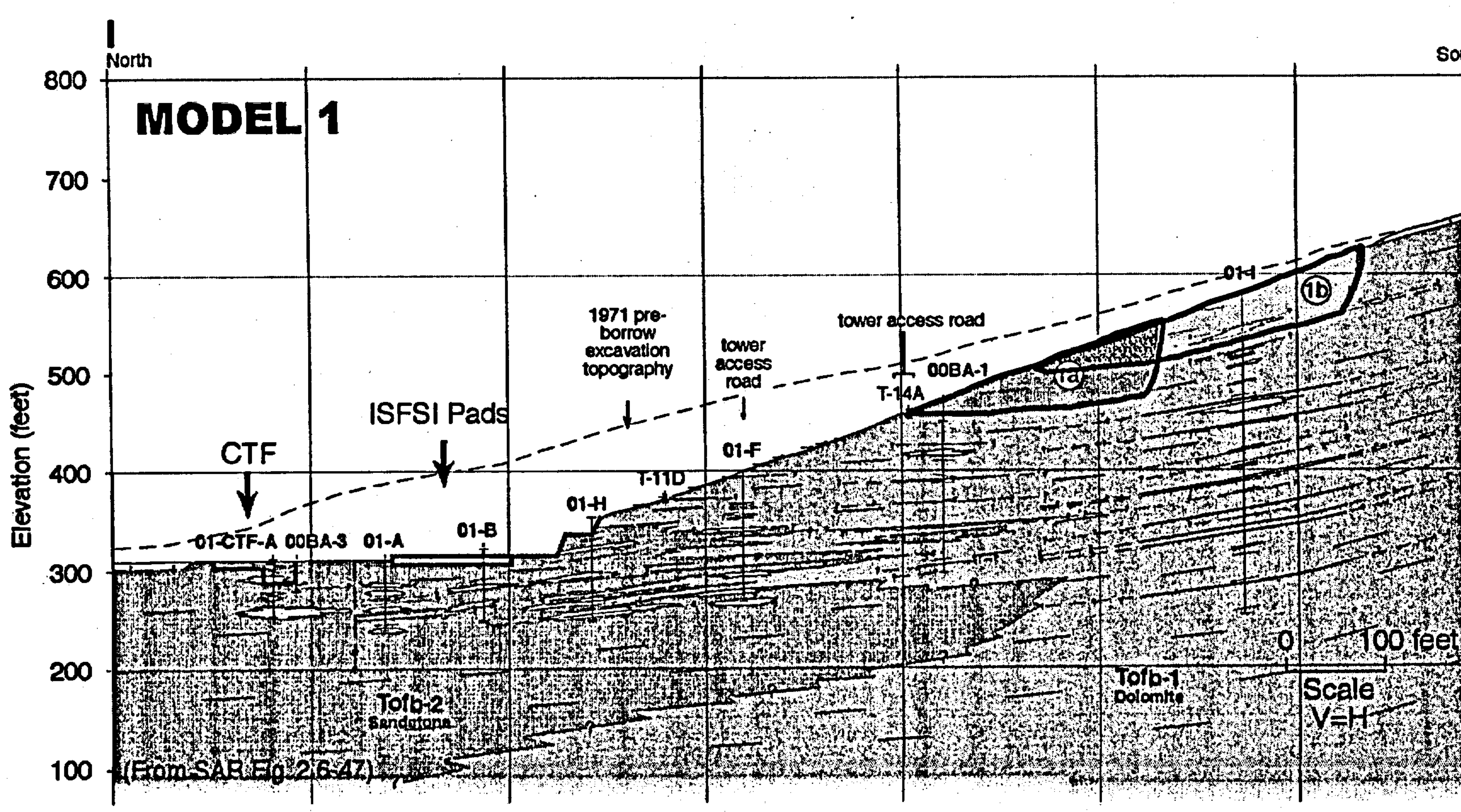
Water Table

Groundwater in ISFSI Area

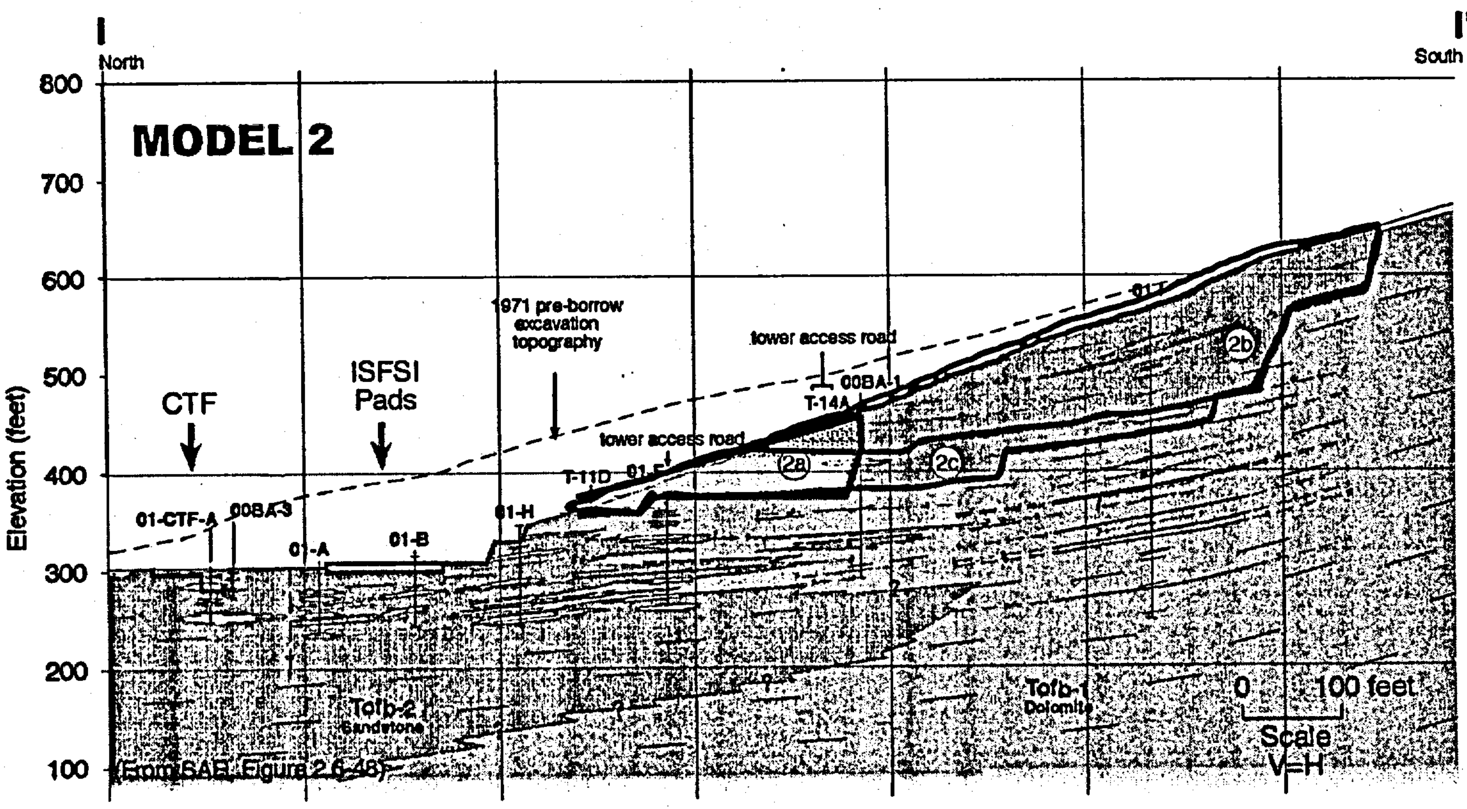
- **Main water table 200 feet below ISFSI**
  - **(100 ft elevation)**
  - **Hence, not an issue for slope stability**

- **Temporary perched ground water**
  - **Top of clay beds in slope above ISFSI**
  - **Assume clay beds are saturated in large rock mass models**
  - **Assume perched water in cutslope rock wedge models**

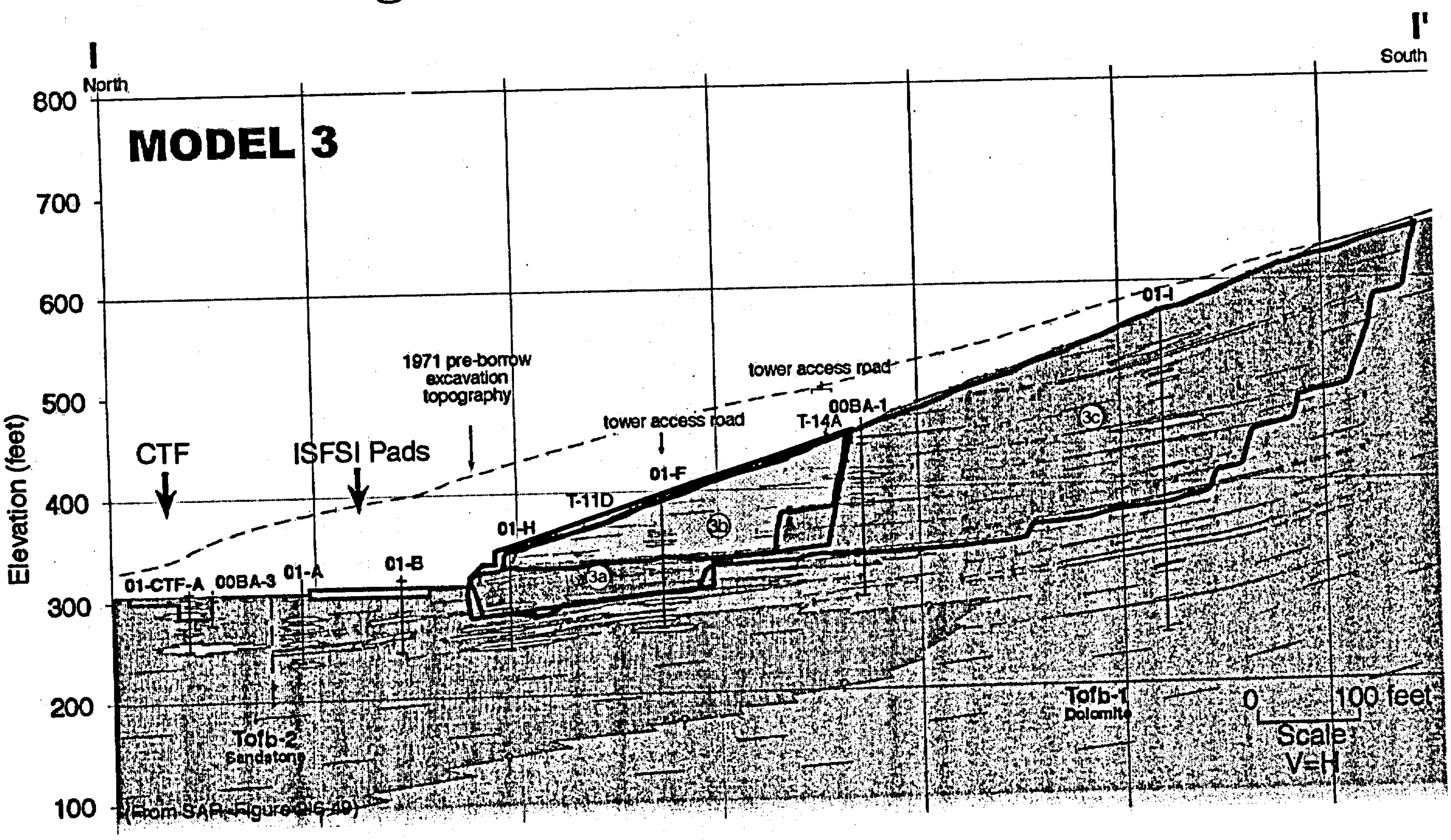
Potential Large-scale Rock Mass Model –Upper Slope

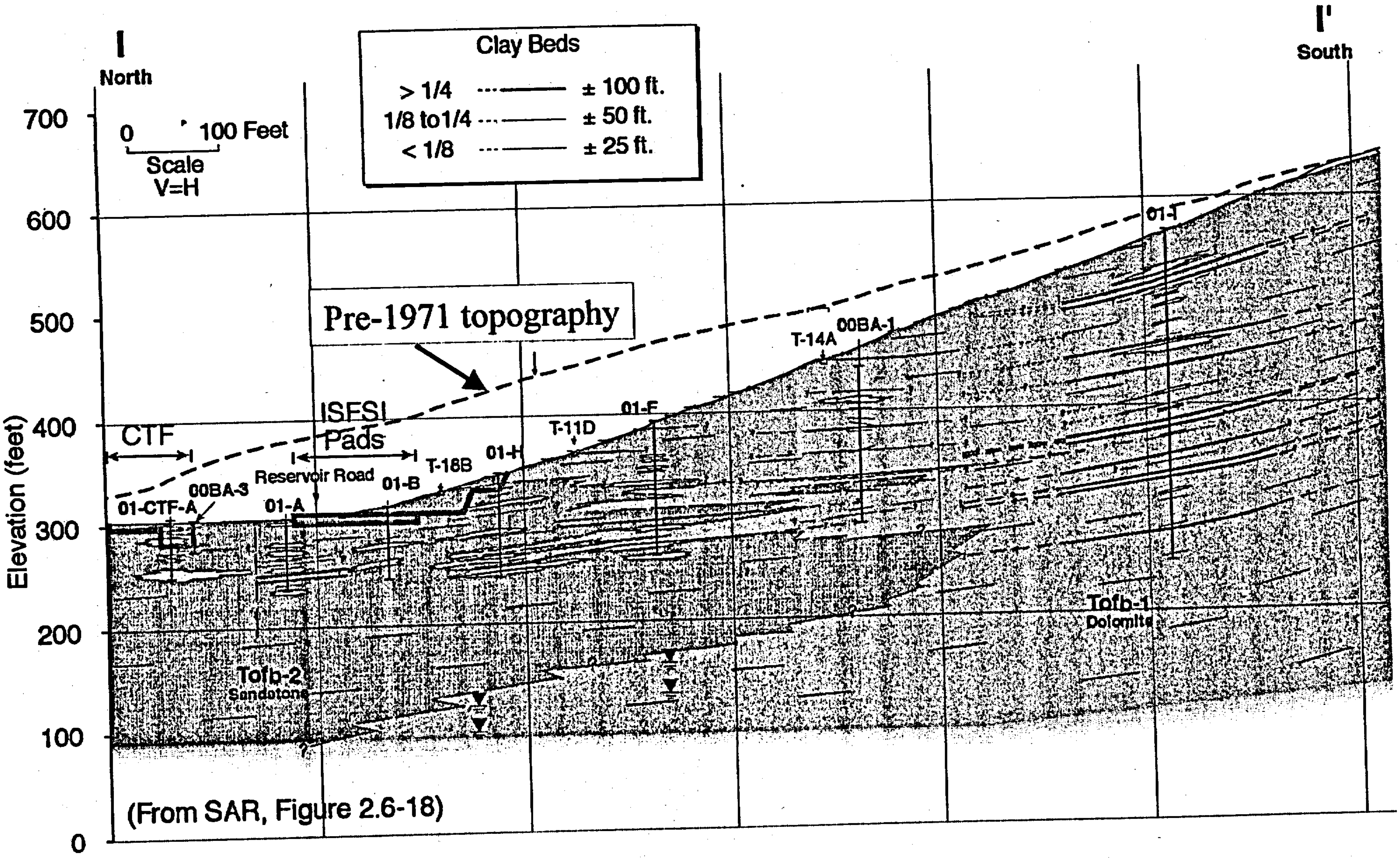


Potential Large-scale Rock Mass Model –Intermediate Slope



Potential Large-scale Rock Mass Model –Lower Slope





Evidence of No Landslides at ISFSI

Evidence of No Landslides at ISFSI

- No evidence on pre-1970 air photos
- No evidence at the borrow site in studies thereof or during excavation
- No evidence of any fissures or fissure fills in trenches for ISFSI
- Topography of ridge 430,000 years old
- Slope has been subjected to numerous large earthquakes in this time period

"Back Calculation"

- Never the less, assume 3 to 4 inches of movement for a "back calculation".
- Results indicate that undrained clay strengths are substantially greater than those from the laboratory tests.

Conclusions

- The ISFSI and CTF sites will be founded on bedrock
  - Sandstone and dolomite
  - Contain zones of friable rock

- The ISFSI will be founded on bedrock that is the same as the DCPP power block.

Conclusions (cont'd)

- The slope above the ISFSI site has stratigraphy and geometry that allows for potential large rock mass movements.
- This is extremely unlikely because
  - no rock slides have occurred in the past 430,000 years
  - modeling ignores several geologic factors that tend to resist down slope movements

Conclusions (cont'd)

- The transport route has variable foundation conditions – rock, dense surficial deposits, and engineered fill.

- Small debris flows could potentially close portions of the transport route during or immediately following intense rainstorms.

Conclusions (cont'd)

- The several minor bedrock faults at the ISFSI site are not capable. Therefore, there is no potential for surface faulting at the ISFSI or CTF sites.