Golden Gate Region Gas Department

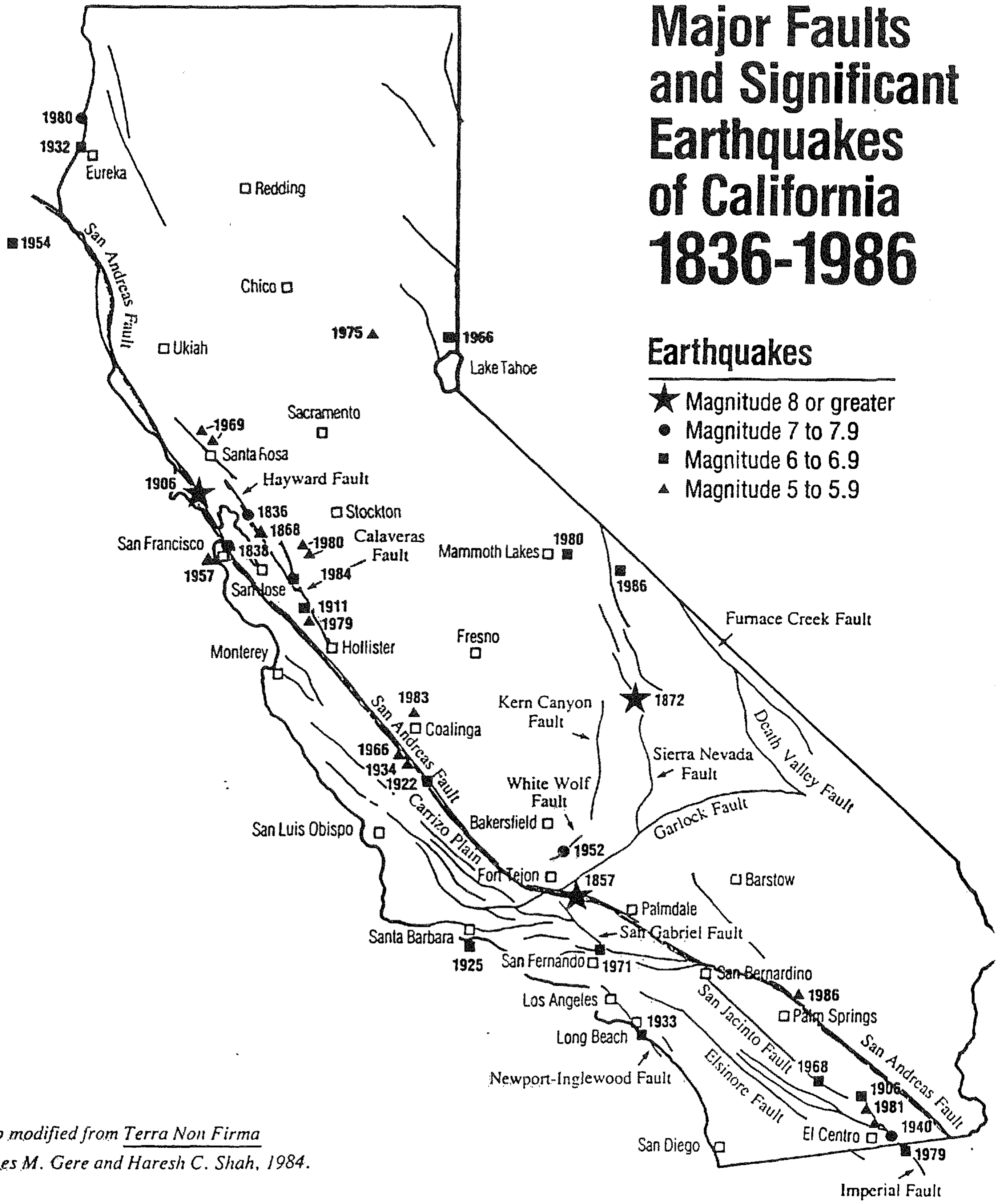
Seismic Study of Gas Transmission Lines

Project Review Meeting
Phase 1 Results

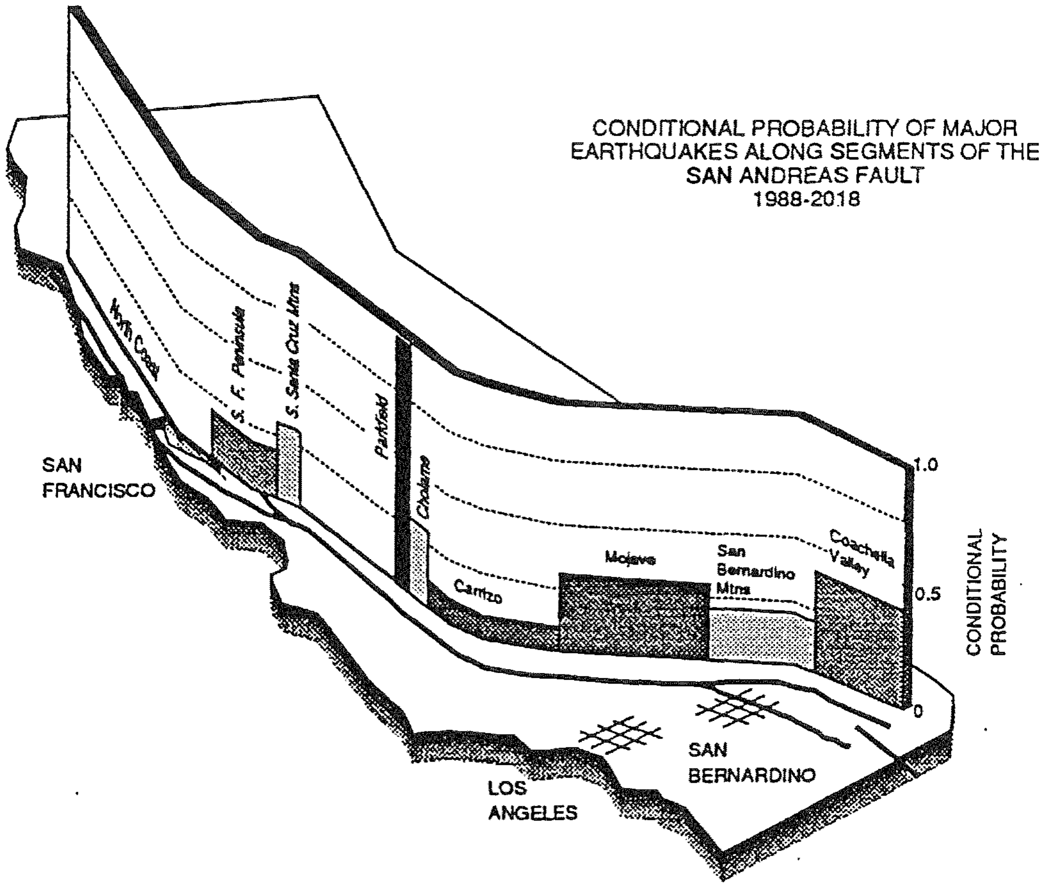
Bridge Room, Fourth Floor
Golden Gate Region Headquarters
303 Second Street
San Francisco

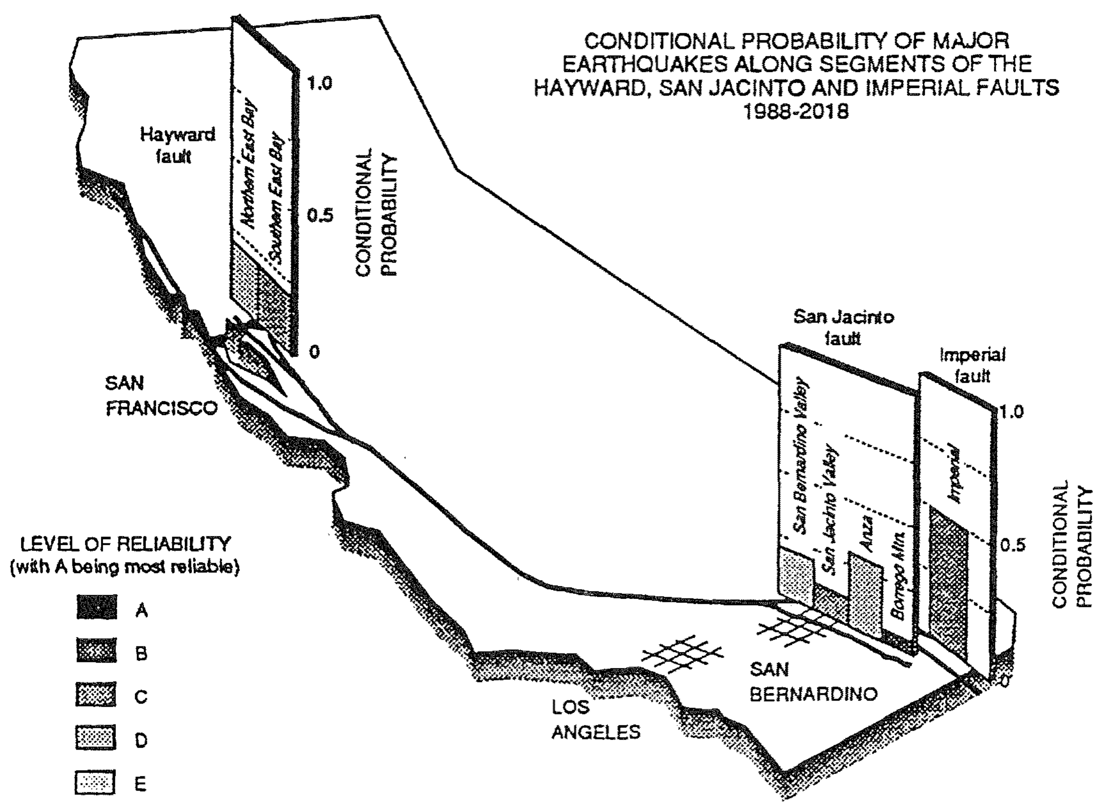
October 13, 1989, 1 to 4 PM

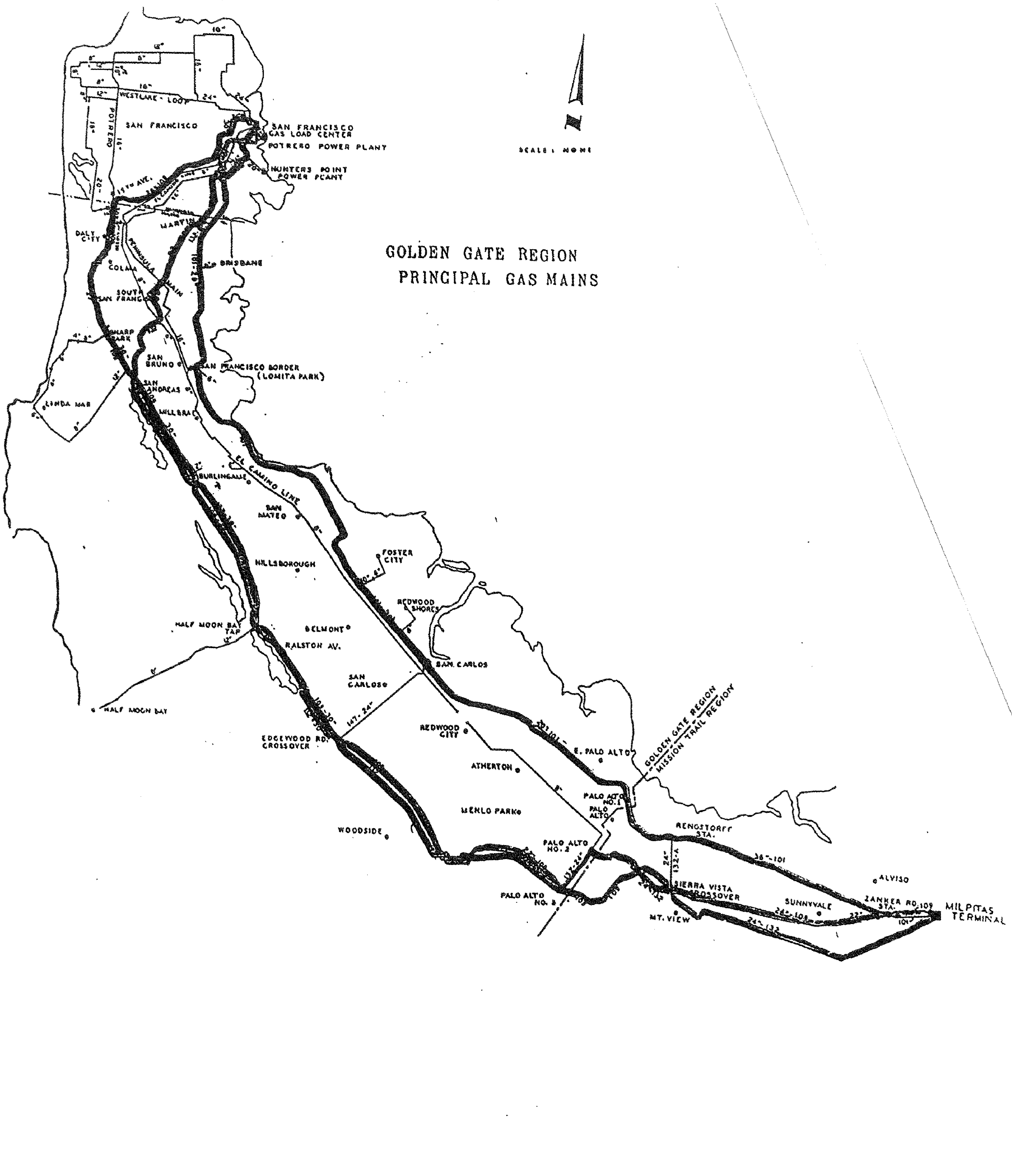
Major Faults and Significant Earthquakes of California 1836-1986



Map modified from Terra Non Firma
James M. Gere and Haresh C. Shah, 1984.


CONDITIONAL PROBABILITY OF MAJOR EARTHQUAKES ALONG SEGMENTS OF THE SAN ANDREAS FAULT 1988-2018
North Coast
S. F. Peninsula
S. Santa Cruz Mtns
Parkfield
Cholame
Carrizo
Mojave
San Bernardino Mtns
Coachella Valley
1.0
0.5
0
CONDITIONAL PROBABILITY
SAN FRANCISCO
LOS ANGELES
SAN BERNARDINO


CONDITIONAL PROBABILITY OF MAJOR EARTHQUAKES ALONG SEGMENTS OF THE HAYWARD, SAN JACINTO AND IMPERIAL FAULTS 1988-2018
Hayward fault
Northern East Bay
Southern East Bay
1.0
0.5
0
CONDITIONAL PROBABILITY
SAN FRANCISCO
San Jacinto fault
San Bernardino Valley
San Jacinto Valley
Anza
Borrego Mtn.
Imperial fault
Imperial
1.0
0.5
0
CONDITIONAL PROBABILITY
LOS ANGELES
SAN BERNARDINO
LEVEL OF RELIABILITY
(with A being most reliable)
A
B
C
D
E


GOLDEN GATE REGION
PRINCIPAL GAS MAINS
SAN FRANCISCO
SAN FRANCISCO GAS LOAD CENTER
POTRERO POWER PLANT
HUNTERS POINT POWER PLANT
WESTLAKE LOOP
DALY CITY
COLMA
SOUTH SAN FRANCISCO
BRISBANE
SAN BRUNO
SAN ANDREAS
MILLBRAE
SAN FRANCISCO BORDER (LOMITA PARK)
BURLINGAME
EL CAMINO LINE
SAN MATEO
HILLSBOROUGH
FOSTER CITY
REDWOOD SHORES
HALF MOON BAY TAP
HALF MOON BAY
BELMONT
RALSTON AV.
SAN CARLOS
EDGEWOOD RD. CROSSOVER
REDWOOD CITY
ATHERTON
MENLO PARK
WOODSIDE
E. PALO ALTO
GOLDEN GATE REGION
MISSION TRAIL REGION
PALO ALTO NO. 1
PALO ALTO NO. 2
PALO ALTO NO. 3
RENGSTORFF STA.
SIERRA VISTA CROSSOVER
MT. VIEW
SUNNYVALE
ALVISO
ZANKER RD. STA.
MILPITAS TERMINAL
36"-101
24"-109
24"-132
147-24"
101-30"

Seismic Study of Gas Transmission Lines for Golden Gate Region Gas Department

Scope of Work

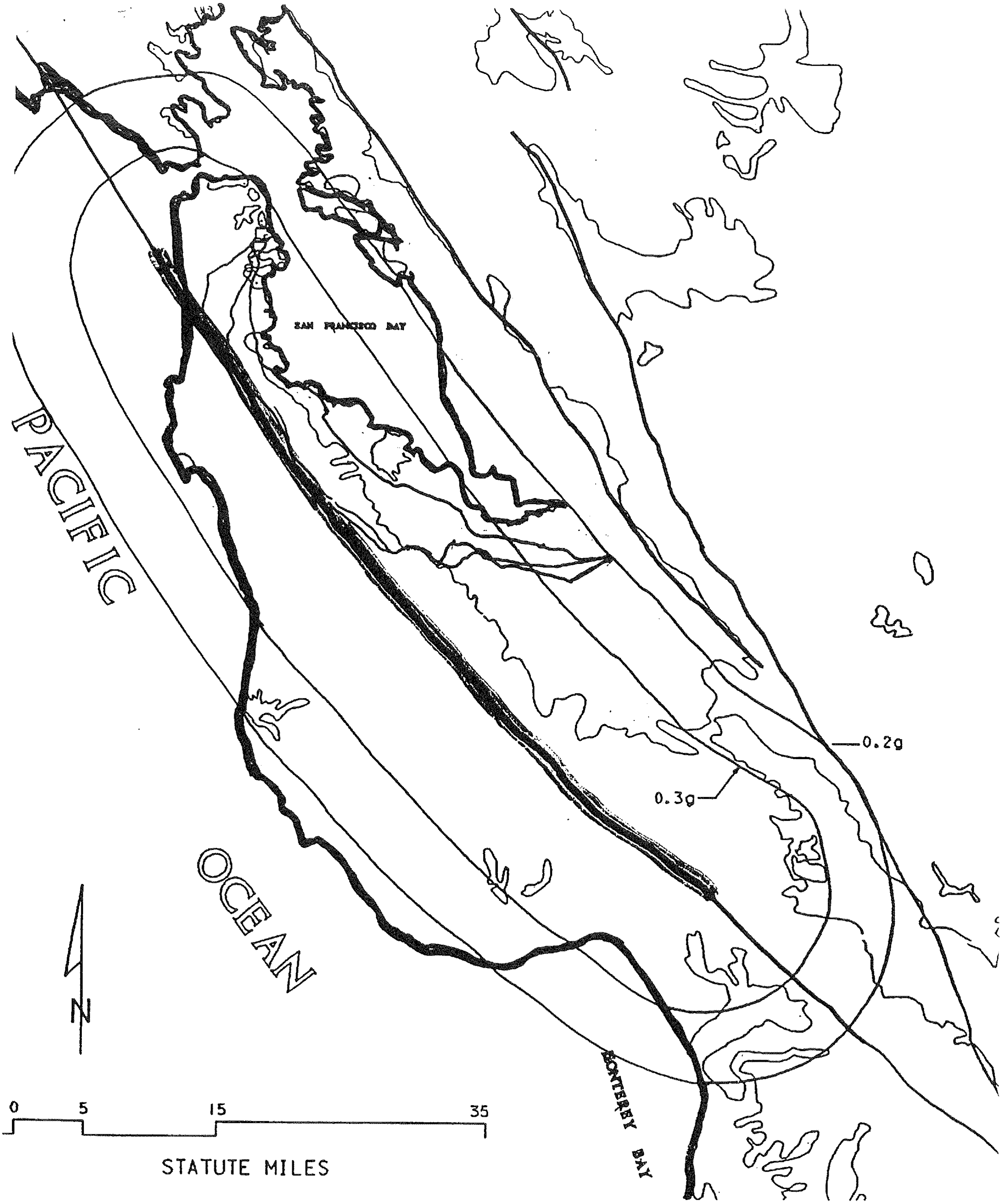
Phase 1

Task 1: Collect data at a map scale of 1/24,000 or larger

Data sets:
- faults and associated deformation
- bedrock geology
- Quaternary geology
- seismicity
- topography
- landslides and landslide potential
- liquefaction potential
- differential settlement and lurching
- geotechnical borings
- groundwater

Task 2: Summarize earthquake effects for the 1906 San Francisco earthquake relevant to gas line corridors Compile available case histories of performance of welded steel pipelines in earthquakes.

Task 3: Meet on October 13, 1989 to review results of the study and plan the scope of additional activities.


SAN FRANCISCO BAY
PACIFIC
OCEAN
0.2g
0.3g
MONTEREY BAY
N
0
5
15
35
STATUTE MILES

POTENTIAL GEOLOGIC HAZARDS FOR GAS PIPELINES

ALONG THE SAN FRANCISCO PENINSULA CORRIDORS

Process	Potential Consequences
• Ground rupture due to faulting	Lateral slip up to 10-15 feet across San Andreas fault. Geometry of fault/pipe crossing determines type of stress on pipe.
• Landsliding and other slope failures	Horizontal and vertical movement of up to tens or hundreds of feet; collapse of trench walls during construction.
• Seismically-induced ground failures	Liquefaction, sliding, lurching and lateral spreading with up to tens or possibly hundreds of feet of lateral movement; differential settlement of up to several feet.

PROCEDURES FOR PHASE I INVESTIGATIONS

Task 1:

- Gather geological, geotechnical, and historical data
  - U.S. Geological Survey
  - California Division of Mines and Geology
  - Libraries at U.C. Berkeley, Stanford U., San Jose S.U.
  - Seismic Safety Elements of counties, cities, and towns
  - Earthquake Engineering Research Institute
  - PG&E and Geomatrix project files
  - Unpublished research materials
- Compile data and pipeline locations on U.S.G.S. 1:24,000 (1 inch = 2000 feet) topographic quadrangle base maps. Organize data into three topical overlays.
- Assess geologic conditions along each pipeline corridor; prepare interpretive maps and tables.
- Prepare reference bibliography

Task 2:

- Compile 1906 earthquake effects into an overlay and associated tabulation
- Gather welded pipe performance data into an annotated bibliography and file copies of publications

FOCUS OF GEOLOGIC STUDIES FOR GAS PIPELINE CORRIDORS

Process	Geologic Studies Focused On:
• Ground rupture due to faulting	Active faults (slip within last 11,000 years), e.g., San Andreas, Hayward faults
• Landsliding and other slope failures	Construction phase: - Unconsolidated or poorly consolidated materials - Saturated materials Long-term pipeline performance: - Historic landslides - Landslide scarps, deposits - Geologic conditions that promote susceptibility to landsliding * steep slopes * fractured, sheared, and/or poorly consolidated materials * high groundwater, springs and seeps * clay-rich materials * formations characterized by numerous slope failures * structural orientation of geologic units * artificial modification of slope and drainage conditions

FOCUS OF GEOLOGIC STUDIES (continued)

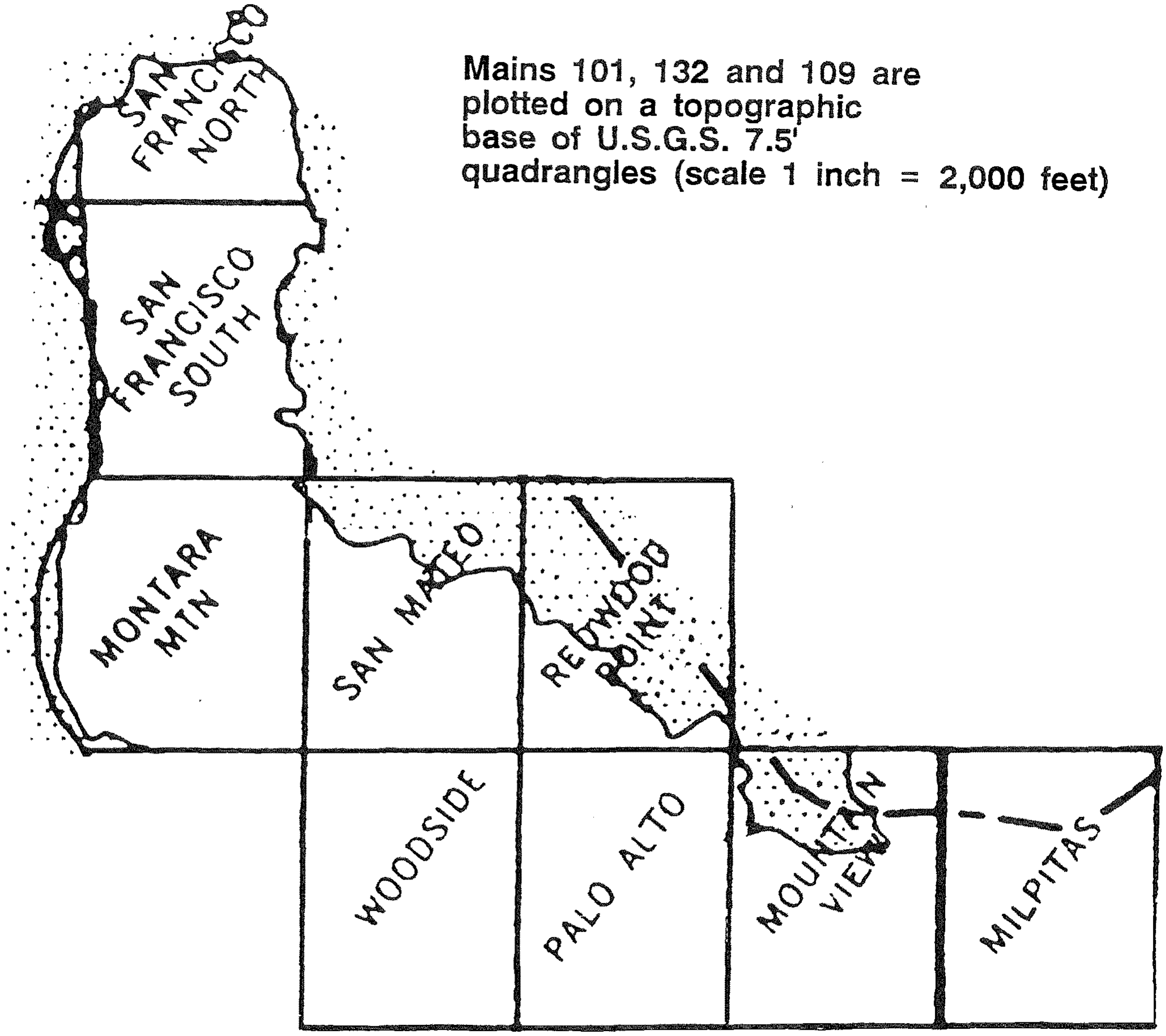
Process	Geologic Studies Focused On:
• Seismically-induced ground failures	- Historic ground failures
- Liquefaction and related effects (lurching, lateral spreading, differential settlement)	- Geologic units with a high susceptibility to liquefaction, especially those containing saturated, unconsolidated, poorly graded silts and sands. Susceptible geologic units include: * Artificial fill on Bay Mud * Sloughs and channels within Bay Mud * Young alluvium * Beach and dune sands
- Landsliding	- See above; landsliding may be seismically triggered
- Ground cracking	- Free faces adjacent to landslide- and liquefaction-prone units; areas underlain by liquefaction-prone units

MAP PRODUCTS OF PHASE I INVESTIGATION

- Base Map with Pipeline Corridors
    - Faults and key geologic units overlay
    - Historic landslides and seismically-induced ground failures overlay
    - Ground failure susceptibility map overlay
- Evaluated Geologic Conditions along Pipeline Corridors

BASE MAP

Mains 101, 132 and 109 are plotted on a topographic base of U.S.G.S. 7.5' quadrangles (scale 1 inch = 2,000 feet)



Base Map consists of 4 sheets:

1. San Francisco North, San Francisco South quads.

2. Montara Mountain, San Mateo and Redwood Points quads.

3. Woodside and Palo Alto quads.

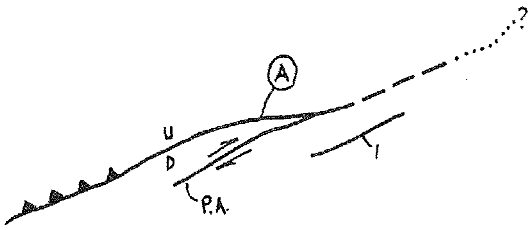
4. Mountain View and Milpitas quads.

FAULTS AND KEY GEOLOGIC UNITS

Types of Geologic Features Shown

- Faults
- Key geologic units for assessing ground stability
  - large-dimension landslide deposits
  - dune and beach sand
  - artificial fill
  - bay mud
  - younger alluvium
  - older alluvium
  - bedrock (Tertiary and older formations)
- Contacts between units

FAULTS



Historically active fault, dashed where approximately located (± 100 ft), dotted where covered or concealed, queried where existence uncertain. Paired arrows show sense of strike slip displacement; U = up, D = down; saw teeth of upper plate on thrust fault.

///// area of most probable location of covered fault

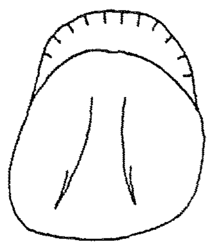
PA - potentially active fault

I - inactive fault

-Ⓐ Location of significant historic fault rupture information (see Table A)

KEY GEOLOGIC UNITS

———————— - - - Geologic contact, dashed where approximately located.



Landslide deposit; hachures indicate headscarp, where present. Arrows indicate direction of downslope movement. Areas subject to soil creep and underlain by colluvial materials* $\leq$10 ft in thickness not shown.

* colluvium - Unconsolidated, poorly stratified deposits of soil, slope wash, talus, etc., that move downhill primarily in response to gravity.

KEY GEOLOGIC UNITS

Unit	Age	Characteristics	Potential Hazards
Dune/Beach sand	Late Quaternary ($\leq 0.1 \times 10^6$ yr)	Homogenous, poorly graded sand. Poorly consolidated.	• Unstable on steep slopes. • Susceptible to liquefaction if saturated.
Younger Alluvium	Late Quaternary	Mixtures of silt, sand and gravel. Poorly consolidated.	• Susceptible to liquefaction if poorly graded and saturated. • Prone to moderate ground shaking.
Older Alluvium	Quaternary ($\leq 2 \times 10^6$ yr)	Like young alluvium but moderately to highly consolidated.	• Prone to sliding on steep slopes.

KEY GEOLOGIC UNITS

Unit	Age	Characteristics	Potential Hazards
Bay Mud	Late Quaternary ($\leq 0.1 \times 10^6$ yr)	Clays and silty clays with lenses of silty sand	• Prone to settlement, lurching and lateral spreading. • Poorly graded sand and silt lenses within Bay Mud susceptible to liquefaction. • Prone to strong ground shaking.
Artificial fill	Historic	Highly variable	• Poorly engineered fills prone to differential settlement and slope failures, and to liquefaction, especially if located on Bay Mud.

KEY GEOLOGIC UNITS

Unit	Age	Characteristics	Potential Hazards
Landslide deposits	Quaternary ($\leq 2 \times 10^6$ yr)	Heterogeneous, variable consolidation	Easy to destabilize if: - oversteepened slopes - saturated - strong ground shaking
Bedrock	Tertiary and older ($\geq 2 \times 10^6$ yr)	Highly variable; typically highly consolidated.	Slope failures possible if: - highly fractured/ sheared - clay-rich - saturated - steep slopes - adverse structural orientations - natural slope and drainage conditions modified

HISTORIC LANDSLIDES AND SEISMICALLY-INDUCED GROUND FAILURES

Historic landslide data from U.S.G.S. maps and records, PG&E records, and Seismic Safety Elements of local counties, cities and towns. Landslides shown by:

○ 1939 — location and date (if known) of landslide

Seismically-induced ground failures from U.S.G.S. reports (primarily Youd and Hoose, 1978). Units shown are:

▲ lq — Liquefaction related effects

- lurching
- lateral spreading
- differential settlement
- sand volcanoes

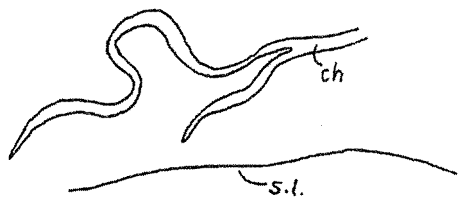
● ls — seismically-induced landsliding

■ gc — ground cracking of unknown origin

Historic ground failures are summarized in Table B.

GROUND FAILURE SUSCEPTIBILITY MAP

- Shows the location of mid 1800's shoreline of San Francisco Bay (after Nichols and Wright, 1970); with major channels and sloughs



ch - channel

s.l. - shoreline

- Areas susceptible to slope failure during an earthquake (after Wieczorek et al., 1985)

  - high susceptibility: 15 to 25% of slope is likely to fail in a major earthquake

  - moderate susceptibility: approximately 15% of slope likely to fail during earthquake

Factors upon which landslide susceptibility is based:

- steepness of slope
- geologic materials present
- strength of weakest geologic unit
- pore water pressures within slope
- maximum expected ground acceleration from future earthquakes

PHASE 1 RESULTS

Based upon review and compilation of available data, the three pipeline corridors are segmented according to known and inferred geologic conditions:

- Identified adverse geologic conditions
- Uncertain geologic conditions
- No identified adverse geologic conditions

IDENTIFIED ADVERSE GEOLOGIC CONDITIONS

Red segments or localities: identified by presence of known adverse geologic conditions to pipelines:

- Crossing the trace of an active fault
- Crossing an active deep (> 10') landslide
- Crossing areas with known high susceptibility to liquefaction
  - localities that liquefied during previous earthquakes
  - poorly graded, unconsolidated saturated silts and sands: channels within/beneath artificial fill and Bay Mud
  - nonengineered fills on Bay Mud (if near historic liquefaction failures)

UNCERTAIN GEOLOGIC CONDITIONS

Yellow segments or localities: identified by the presence of general geologic conditions that might, under adverse local circumstances, pose a hazard to pipelines:

- areas with a high susceptibility to landslide movement
- areas underlain by ≥ 10' of Bay Mud
- areas of artificial fill (if no record of historic liquefaction failure)
- crossing the trace of a potentially active fault or the projected trace of an active buried ("blind") fault, or potential (unmapped) splays of the San Andreas fault
- areas of potentially large differential settlement, e.g., contacts between Bay Mud and artificial fill or younger alluvium

The yellow designation means there is insufficient site-specific information to assign an area/locality to either red or green classifications.

NO IDENTIFIED ADVERSE GEOLOGIC CONDITIONS

Green segments identified by an absence of reported geologic conditions that pose potential hazards to pipelines.

- No active fault crossings
- No active landslide crossings
- No deposits with known high susceptibility to liquefaction

EXAMPLE OF SITE-SPECIFIC INVESTIGATIONS

- Active fault crossing
  - detailed mapping including analysis of pre-development photographs
  - trenching to determing precise location and width of active fault trace(s)
  - evaluatation of expected fault slip parameters: net slip, slip distribution including zone width plus horizontal and vertical components, recurrence frequency
  - evaluate alternative possible mitigations of fault crossing conditions
    * orientation of pipeline with respect to fault
    * depth of burial; properties of pipe trench backfill

EXAMPLE OF SITE-SPECIFIC INVESTIGATIONS

- Areas with high susceptibility to landsliding

  - review available site-specific geologic and engineering data

  - conduct detailed mapping including analysis of pre-development slope conditions

  - perform geotechnical investigations to determine slide dimensions (especially depth of failure surface), groundwater conditions, and engineering characteristics of earth materials

  - evaluate potential ground motions and site-specific slope failure potential

  - evaluate alternative possible mitigations of landslide susceptibility

EXAMPLE OF SITE-SPECIFIC INVESTIGATIONS

- Areas with high susceptibility to liquefaction

  - review available bore hole and site-specific geologic data (e.g., CalTrans)

  - perform geotechnical investigations to determine groundwater conditions and engineering characteristics of earth materials

  - evaluate potential ground motions and site-specific liquefaction potential

  - evaluate alternative possible mitigations of liquefaction susceptibility