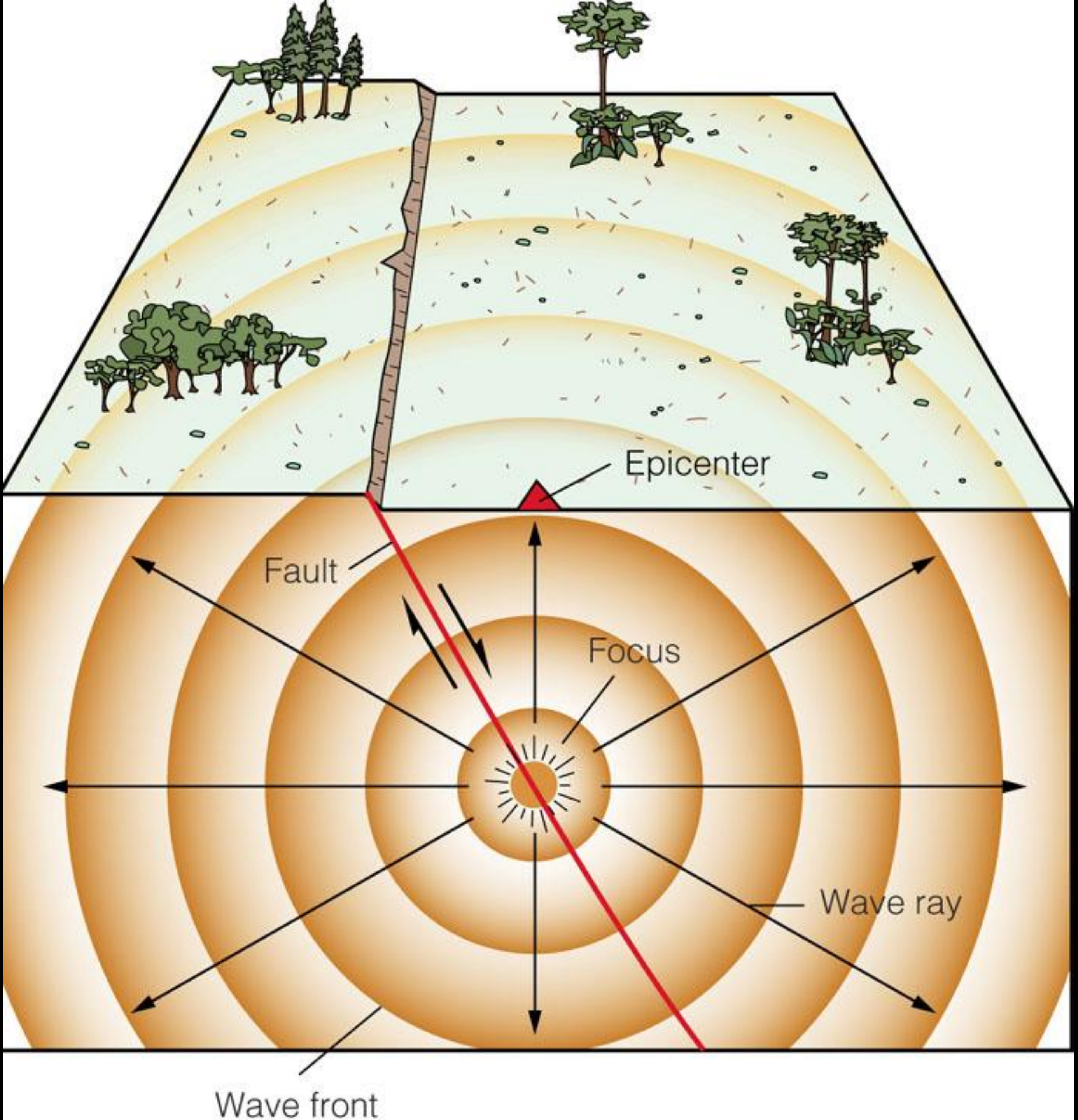
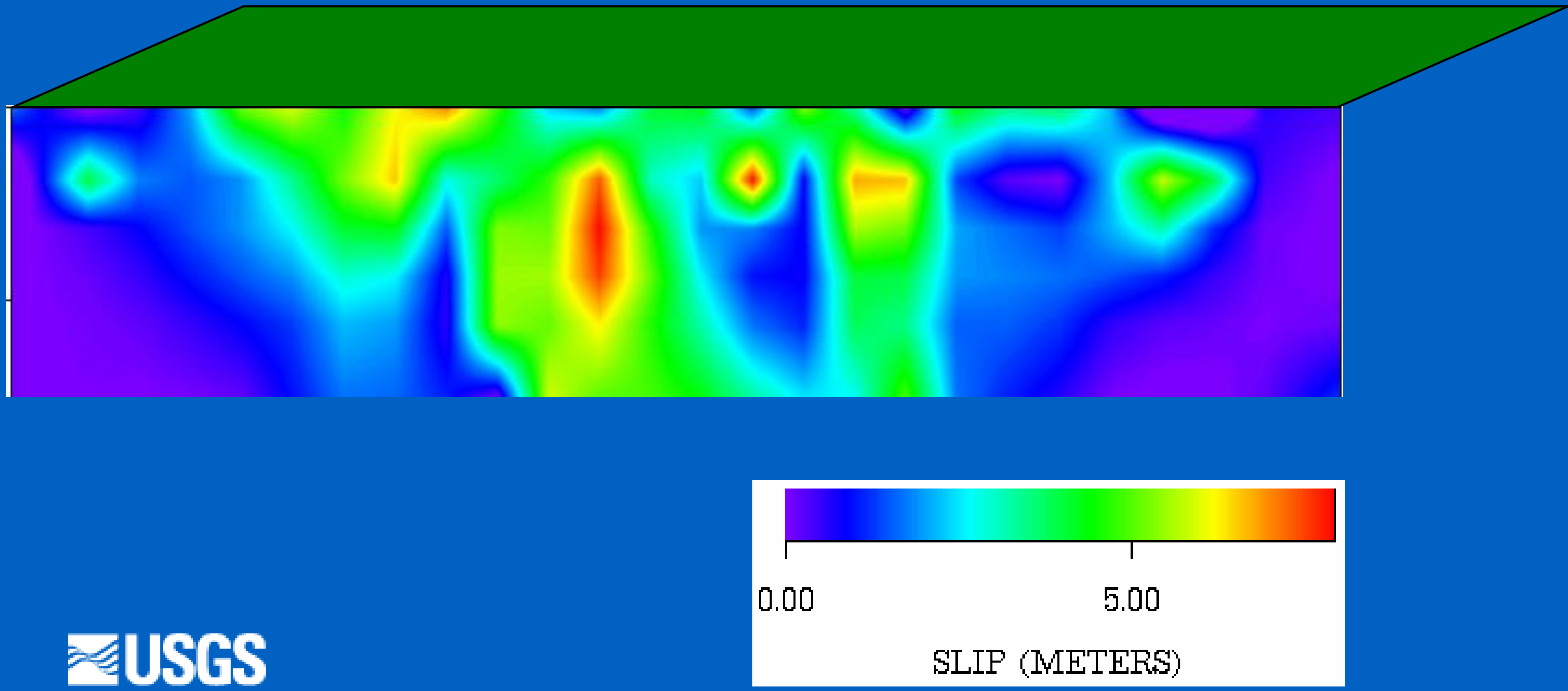
Earthquakes

focus and epicentre – fault rupture


Epicenter
Fault
Focus
Wave ray
Wave front

Rupture on a Fault

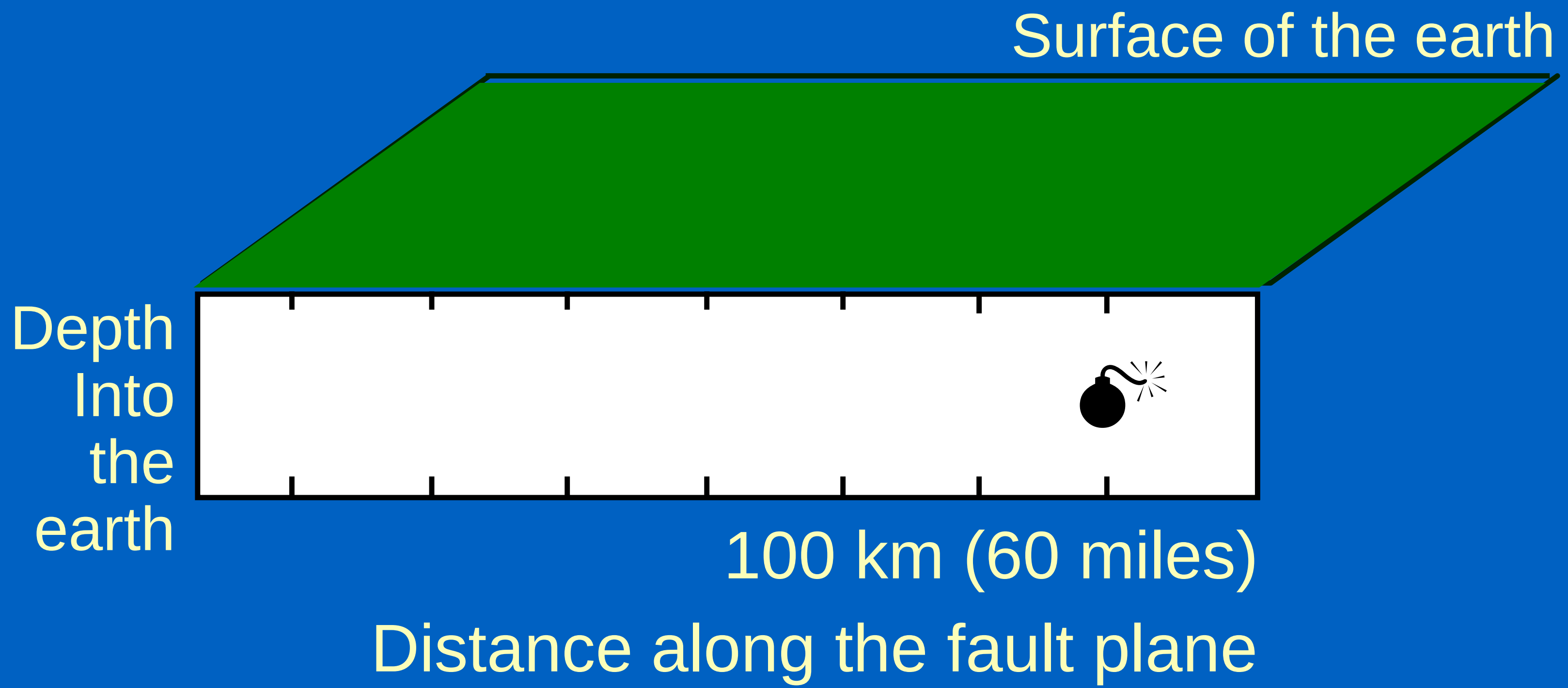
Total Slip in the M7.3 Landers Earthquake



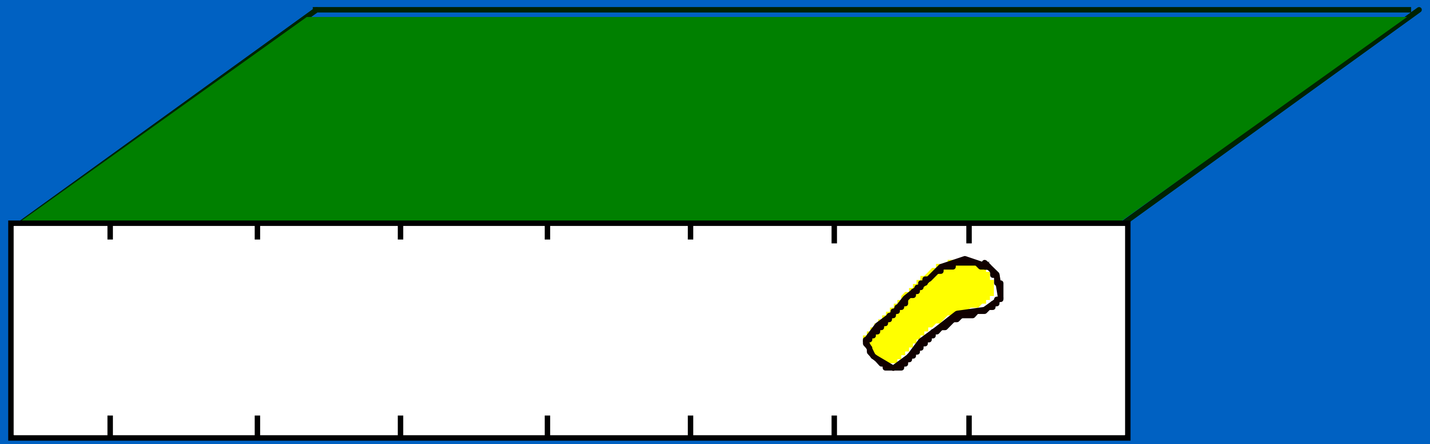
USGS

Slip on an earthquake fault

START

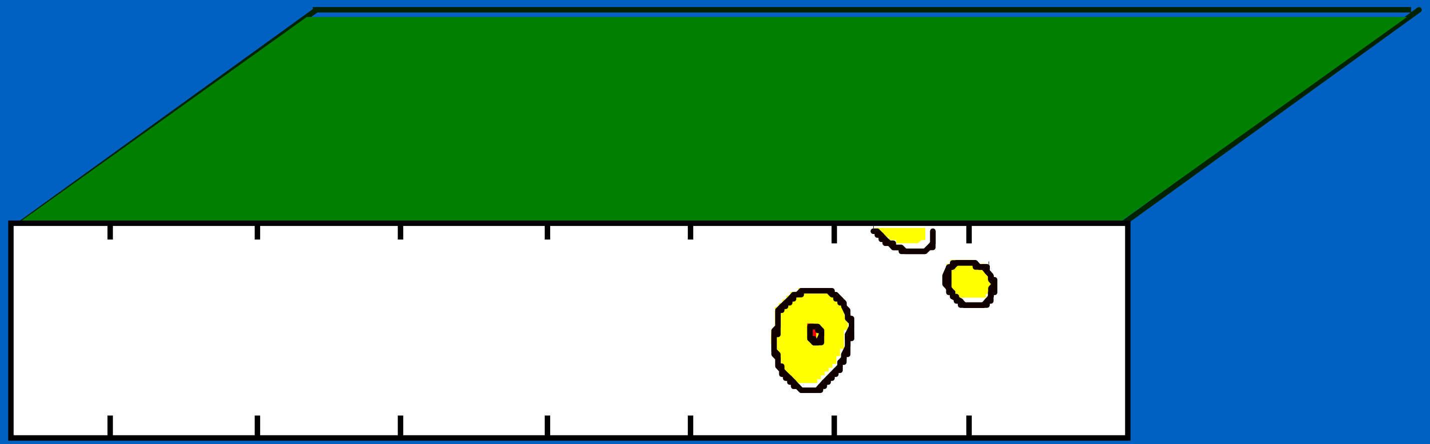


Slip on an earthquake fault
Second 2.0

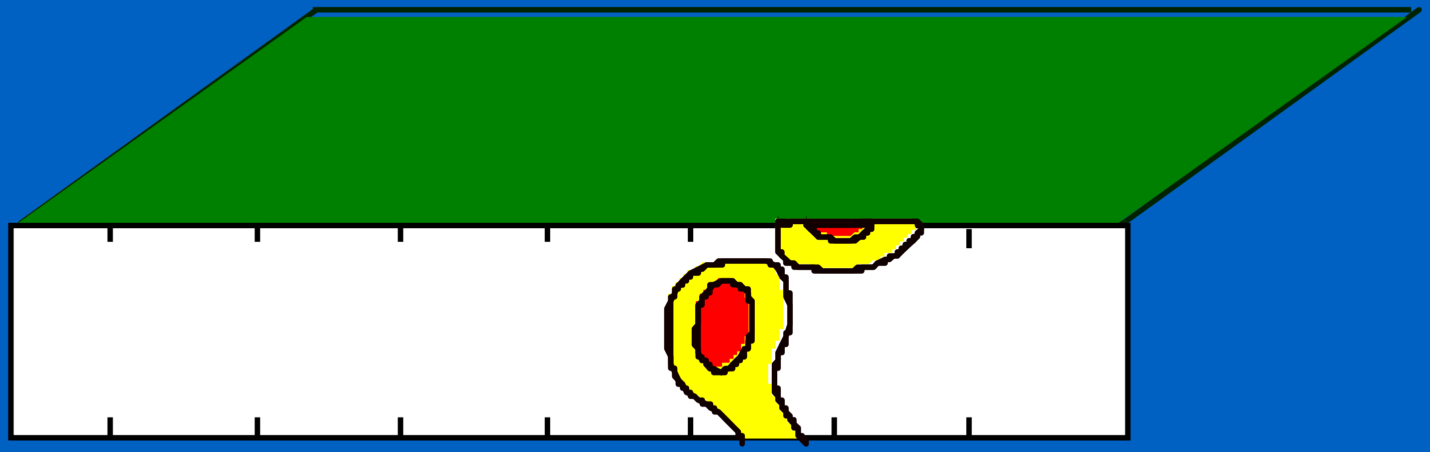


USGS

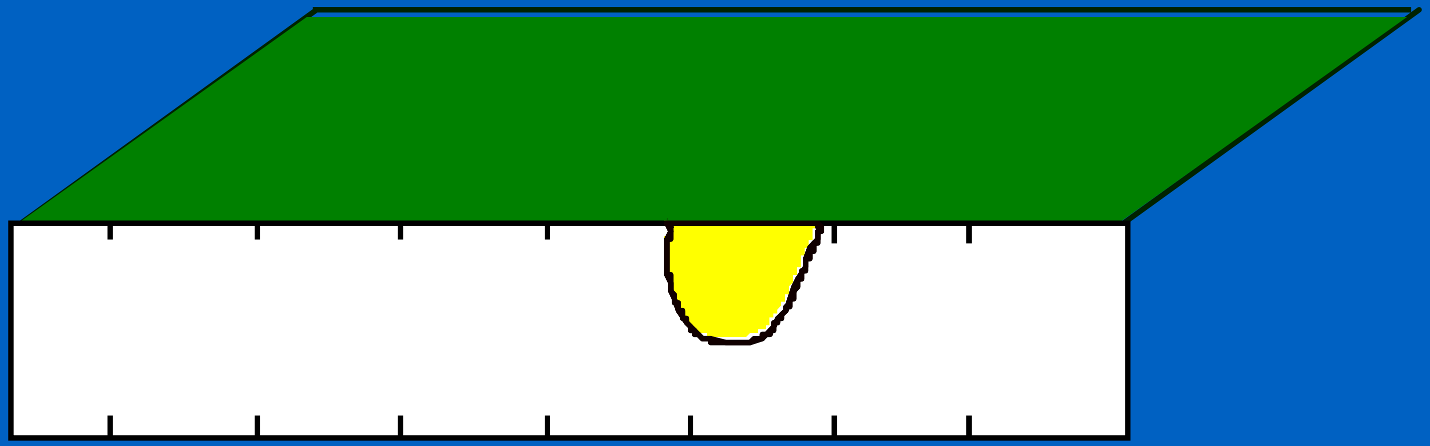
Slip on an earthquake fault
Second 4.0



Slip on an earthquake fault
Second 6.0

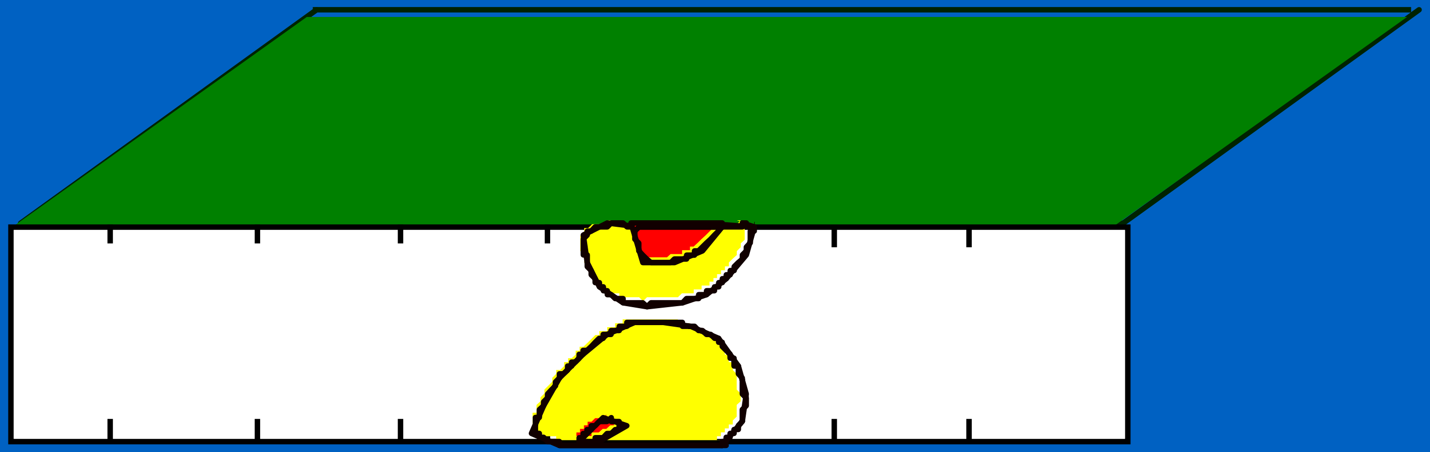


Slip on an earthquake fault
Second 8.0



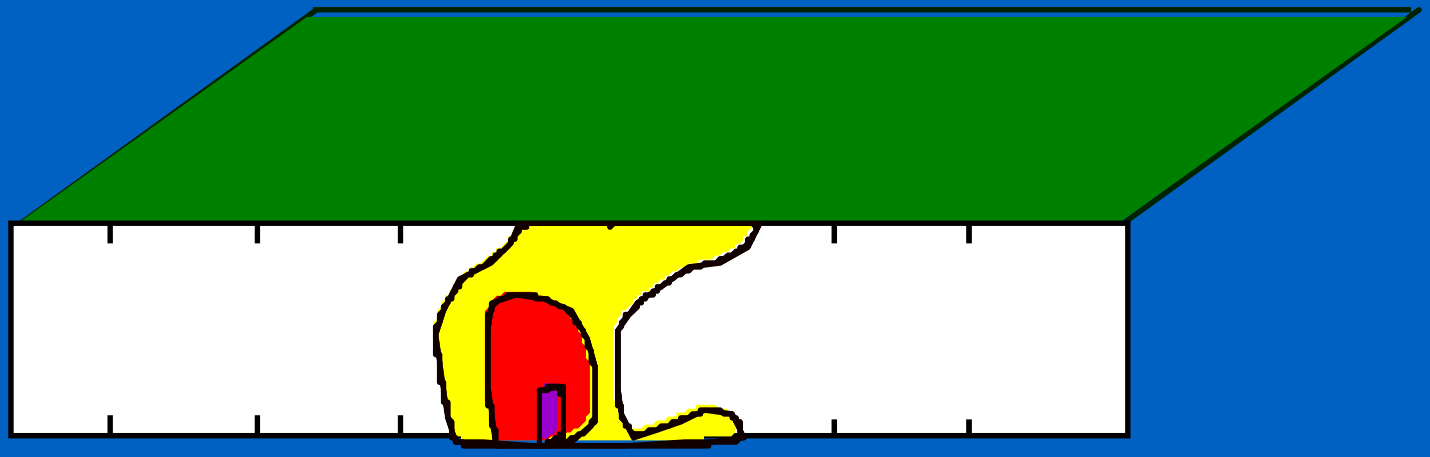
Slip on an earthquake fault

Second 10.0



USGS

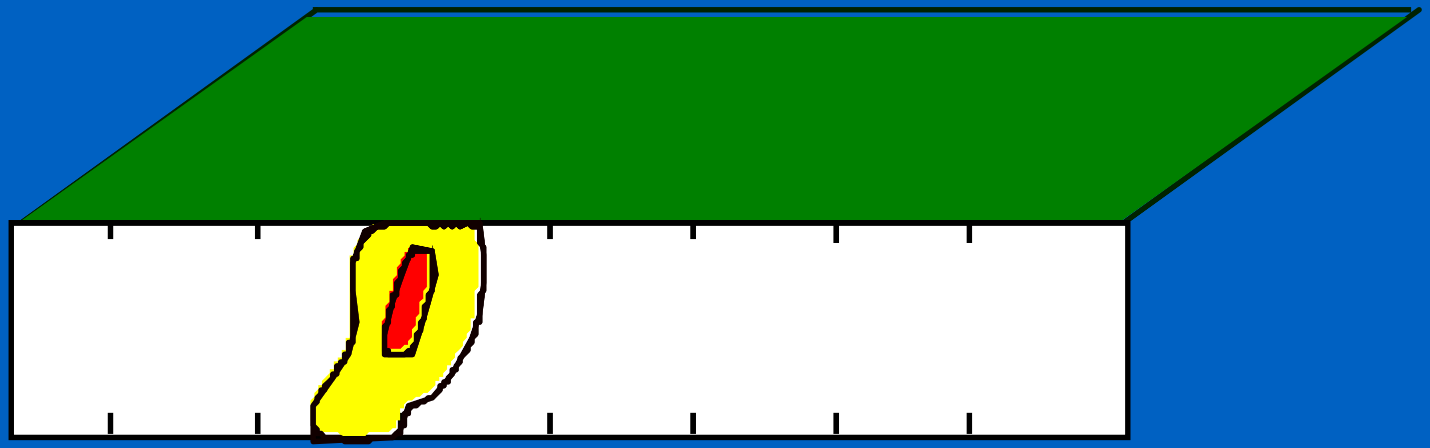
Slip on an earthquake fault
Second 12.0



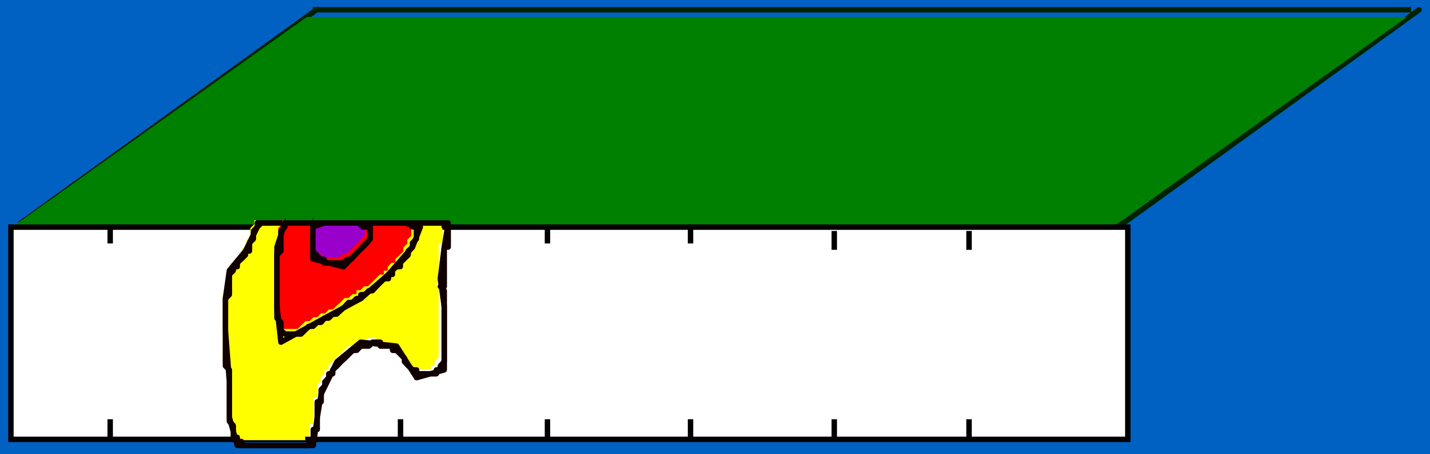
Slip on an earthquake fault
Second 14.0

USGS

Slip on an earthquake fault
Second 16.0

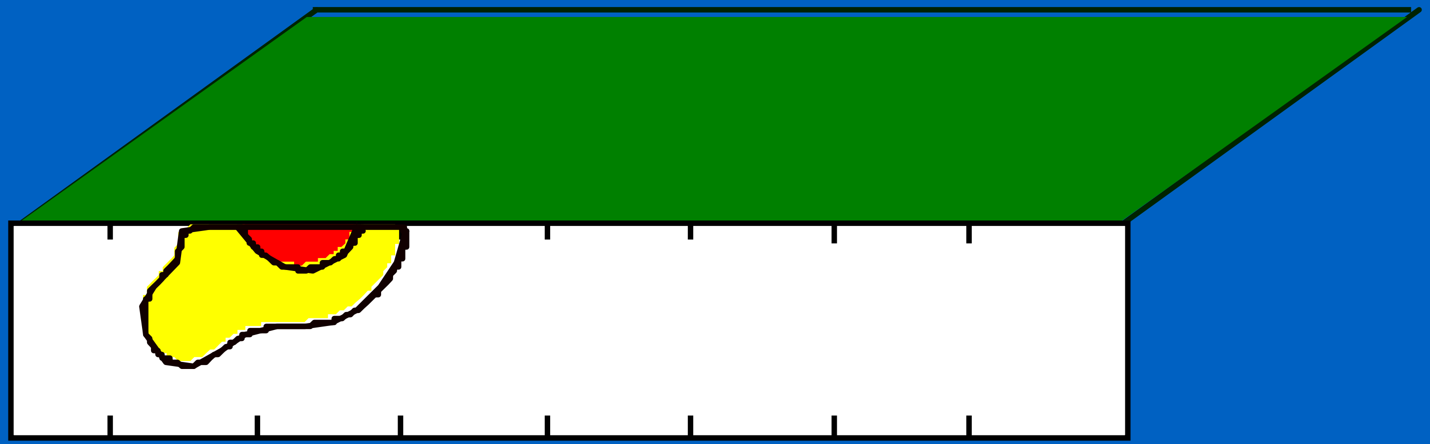


Slip on an earthquake fault
Second 18.0

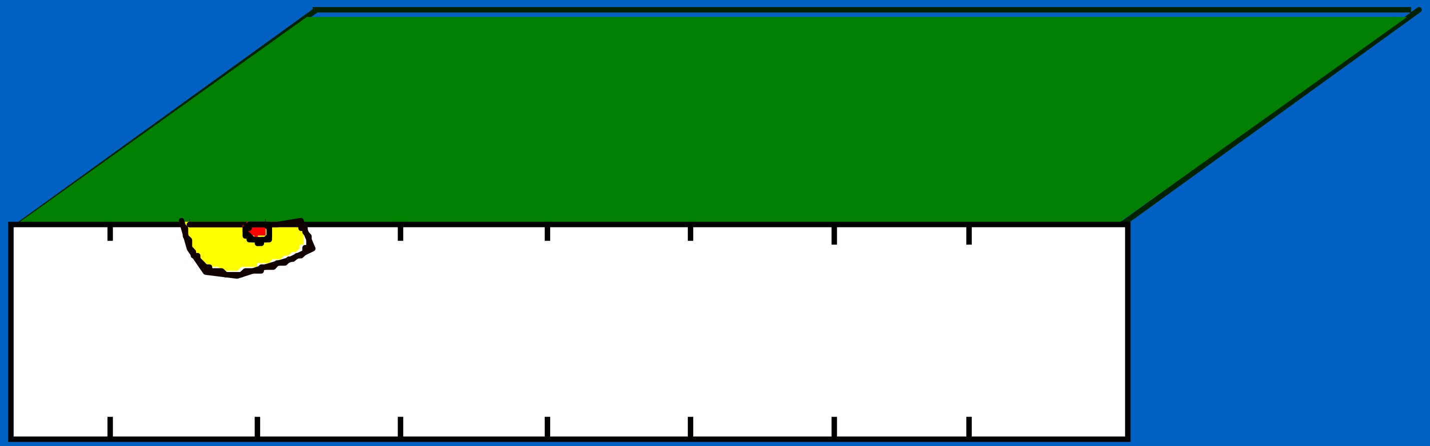


USGS

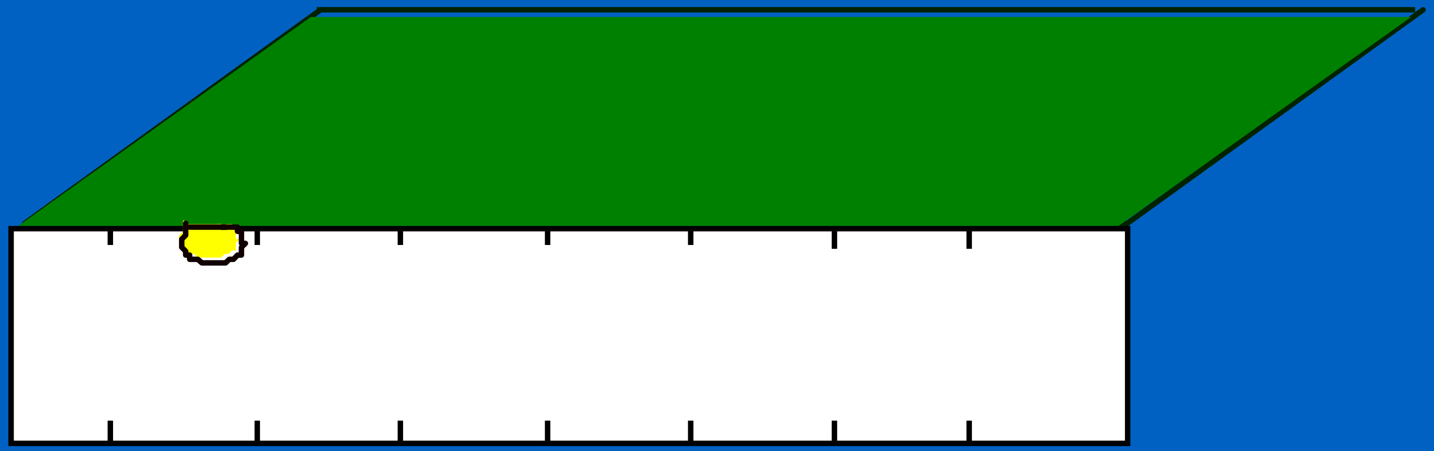
Slip on an earthquake fault
Second 20.0



Slip on an earthquake fault
Second 22.0



Slip on an earthquake fault
Second 24.0

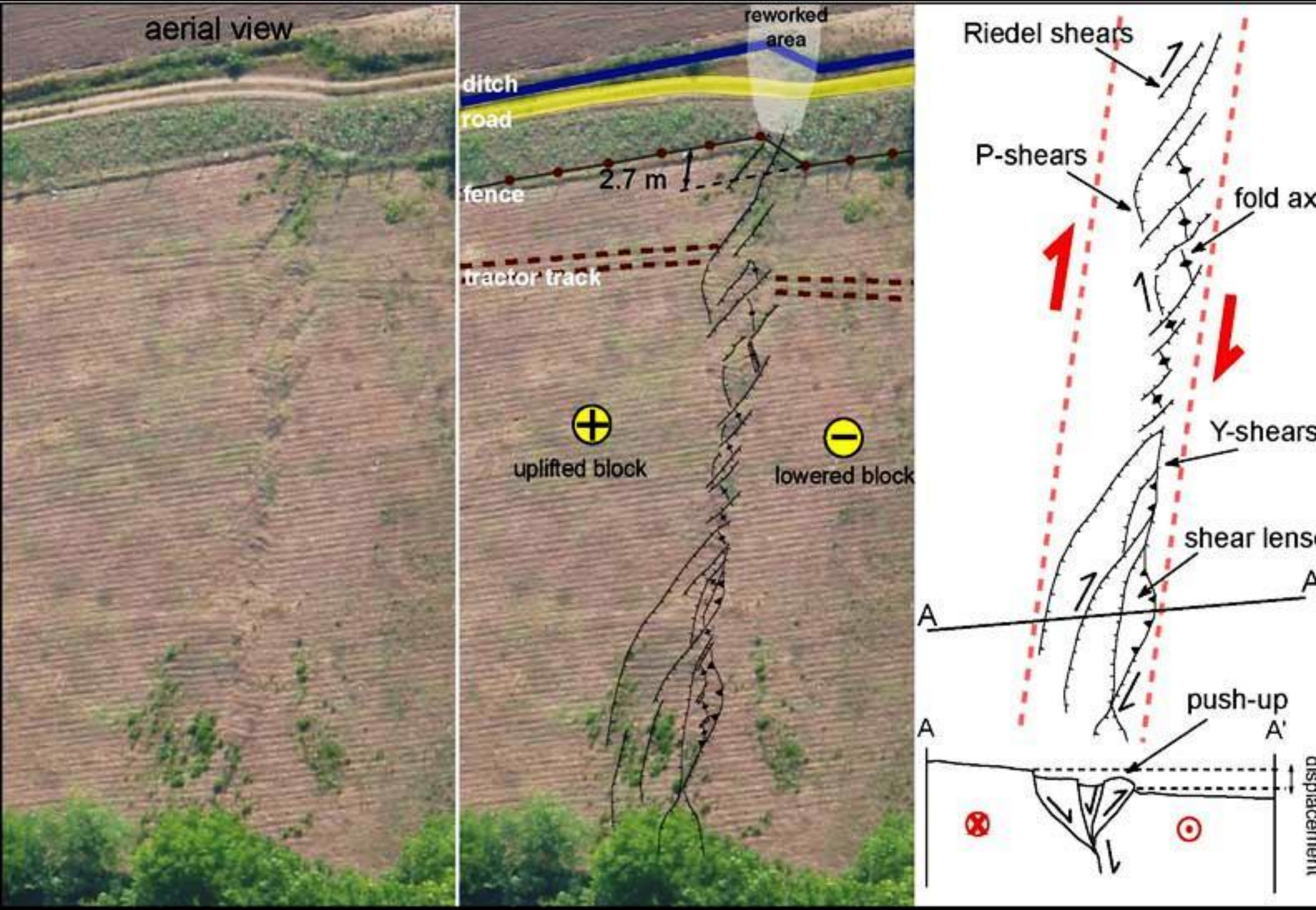


USGS

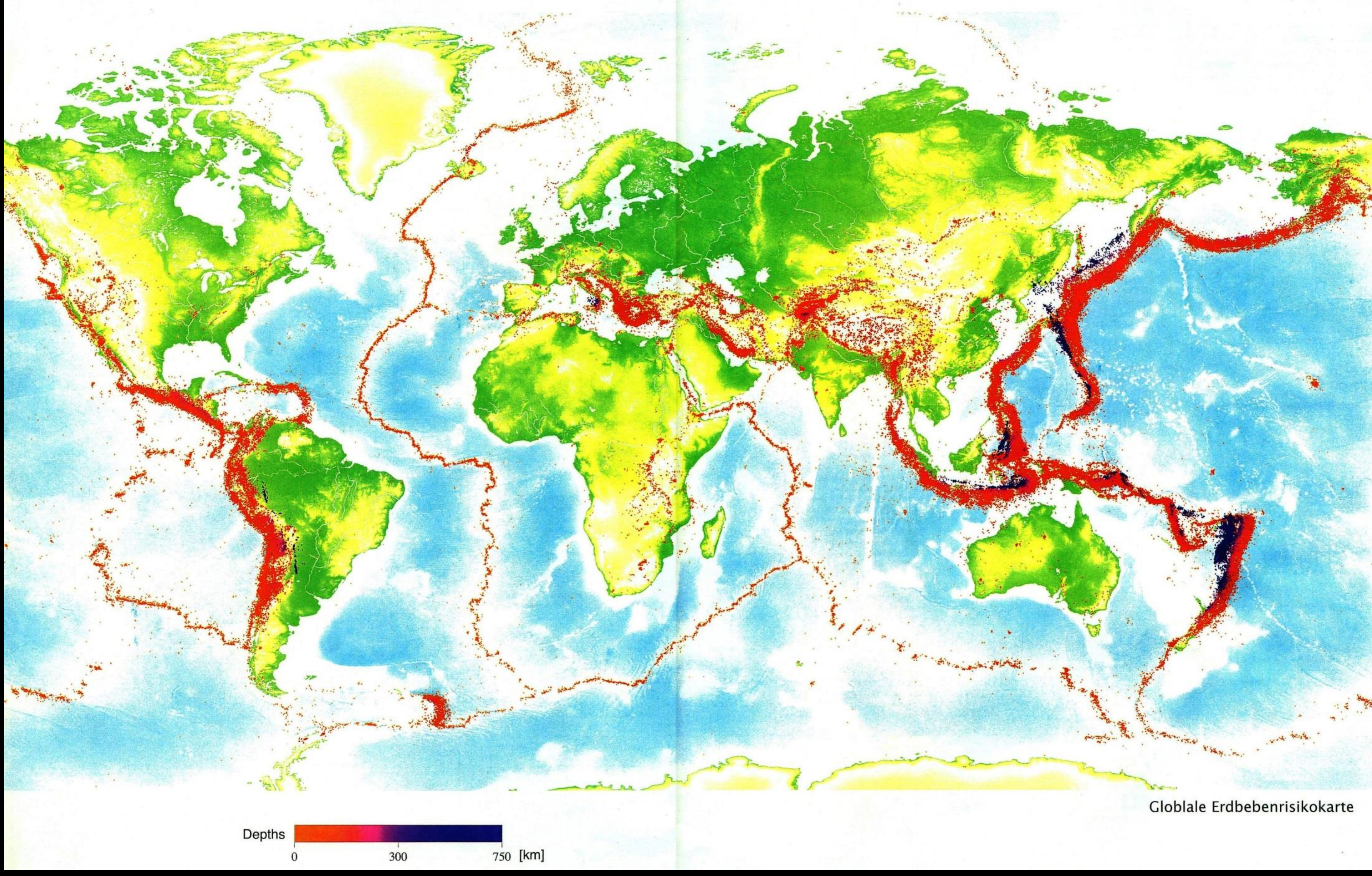
17 Ağustos 1999 Kocaeli depreminde fay atımı


Aytemiz
LPG
LOKANTA
TUVALETLER
MESCİT

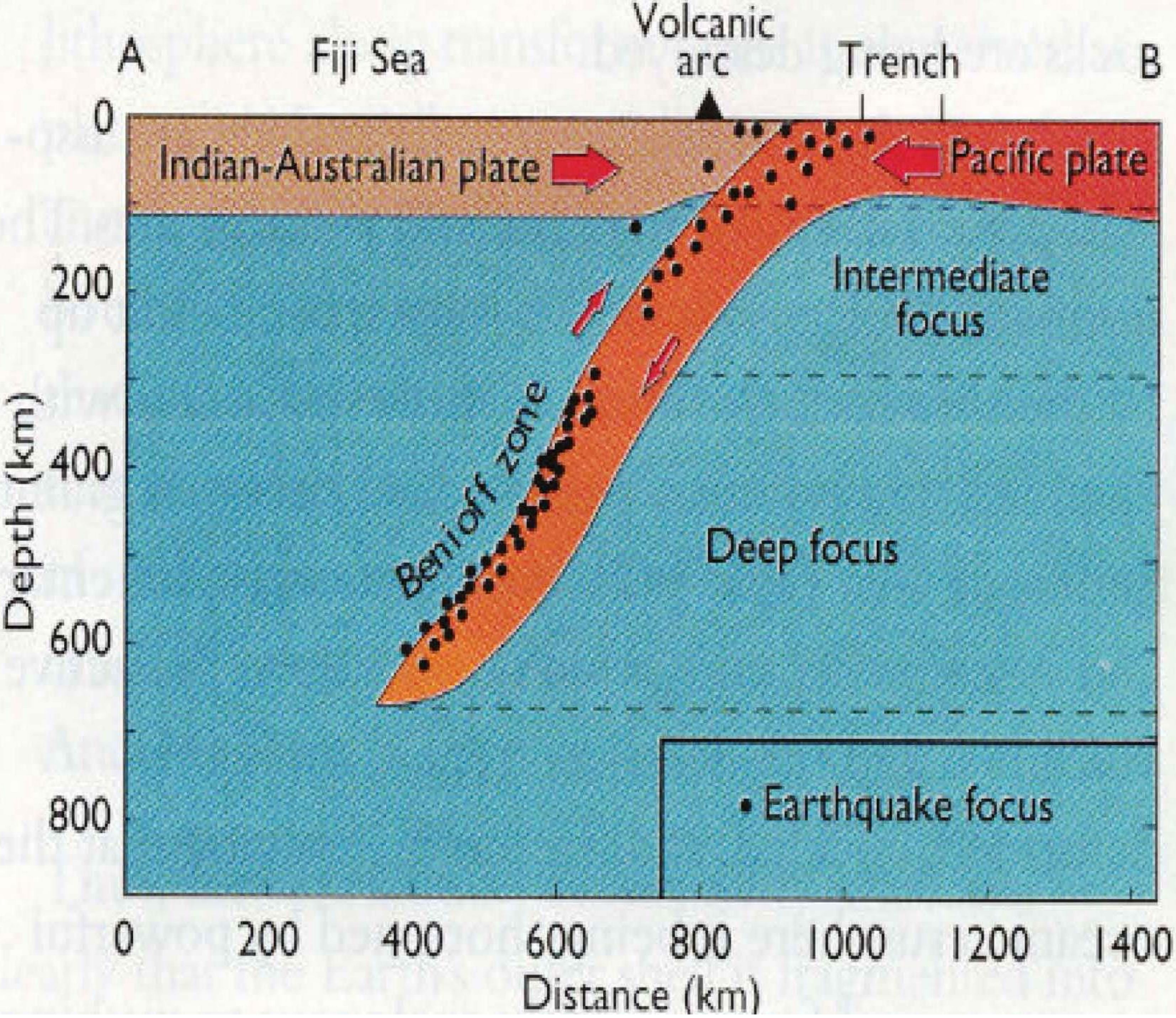

aerial view



aerial view
reworked area
ditch
road
fence
2.7 m
tractor track
uplifted block
lowered block
Riedel shears
P-shears
fold ax
Y-shears
shear lens
A
A'
push-up
displacement

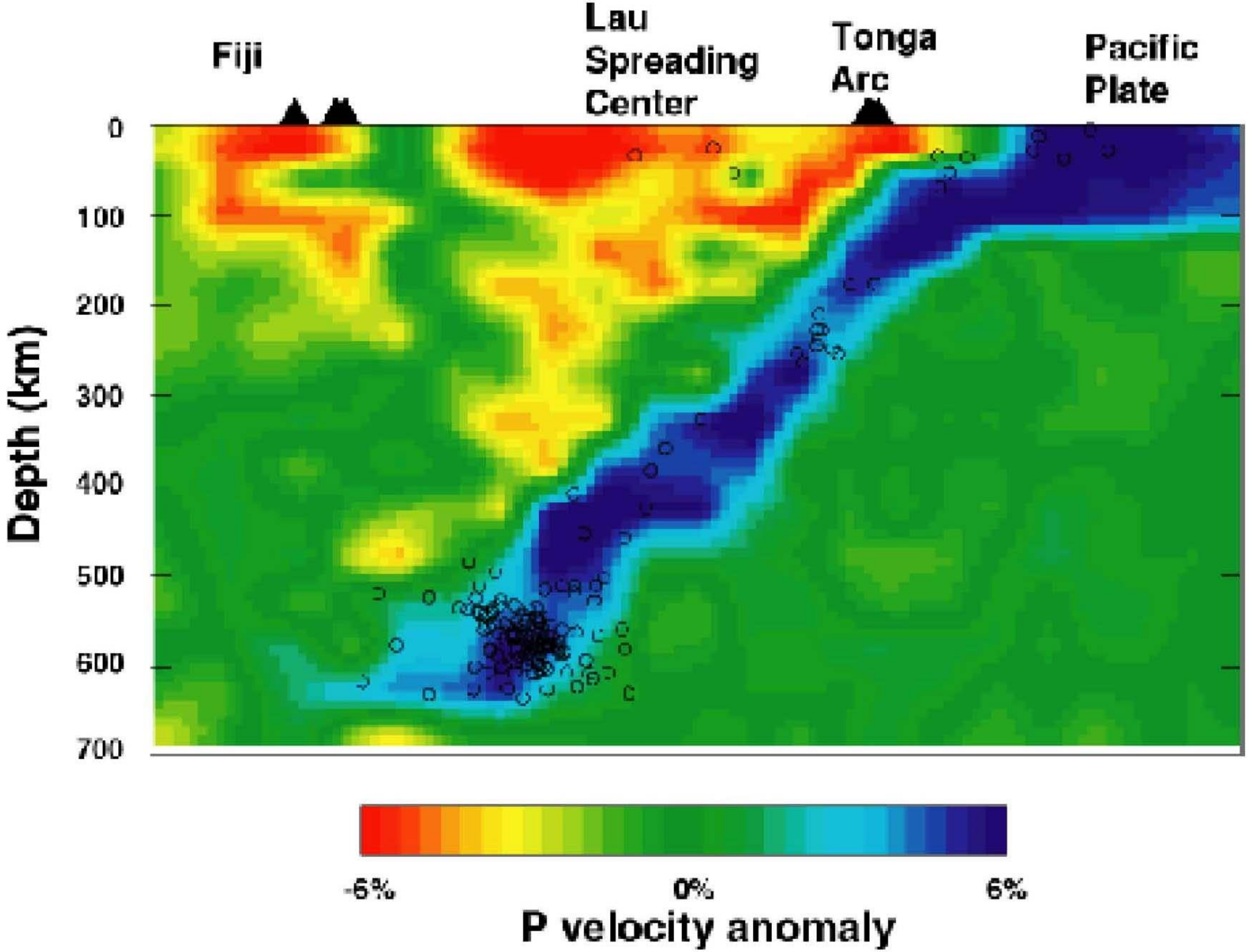


Globlale Erdbebenrisikokarte

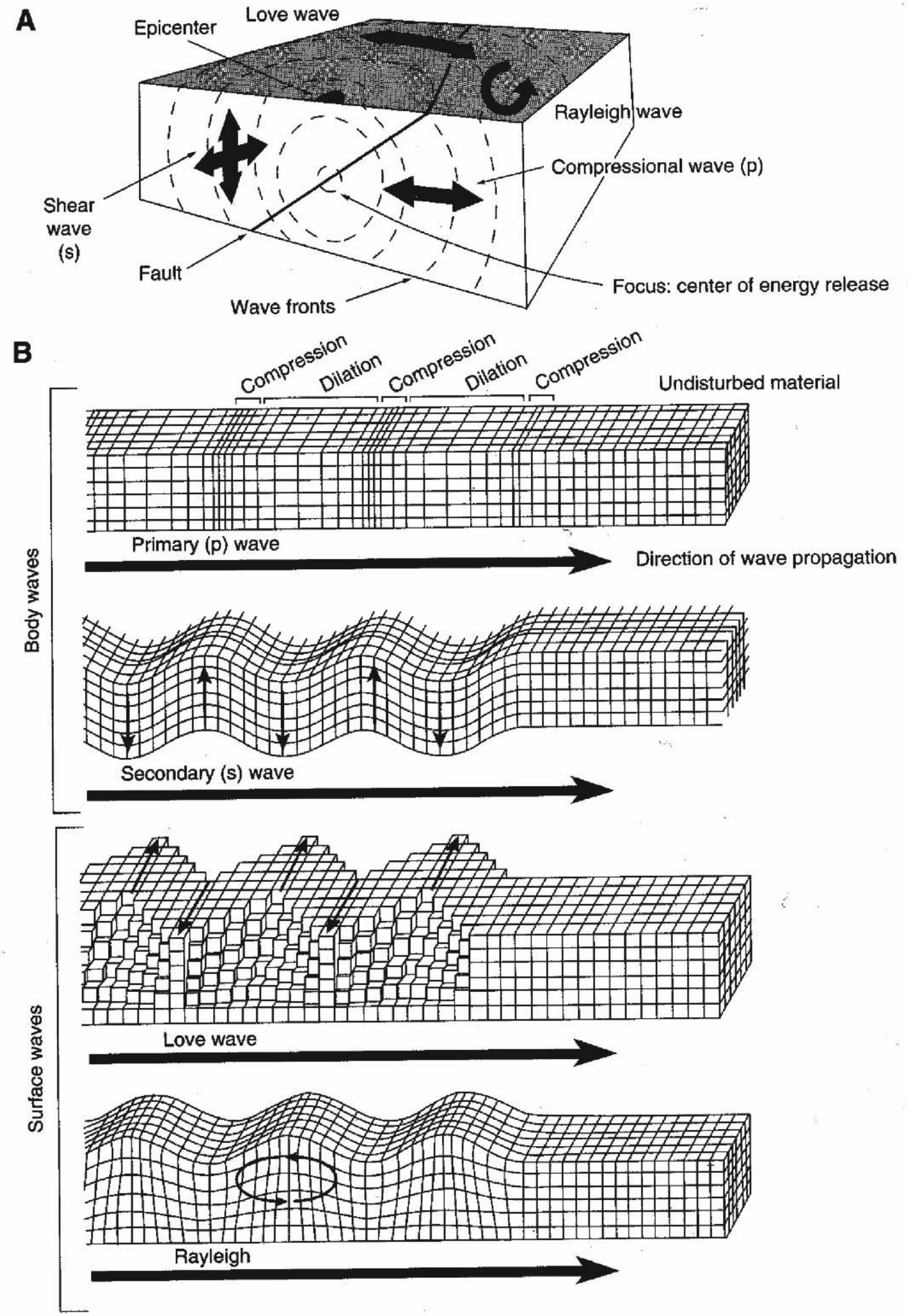


A
Fiji Sea
Volcanic arc
Trench
B
Indian-Australian plate
Pacific plate
Intermediate focus
Benioff zone
Deep focus
• Earthquake focus
Depth (km)
0
200
400
600
800
0
200
400
600
800
1000
1200
1400
Distance (km)

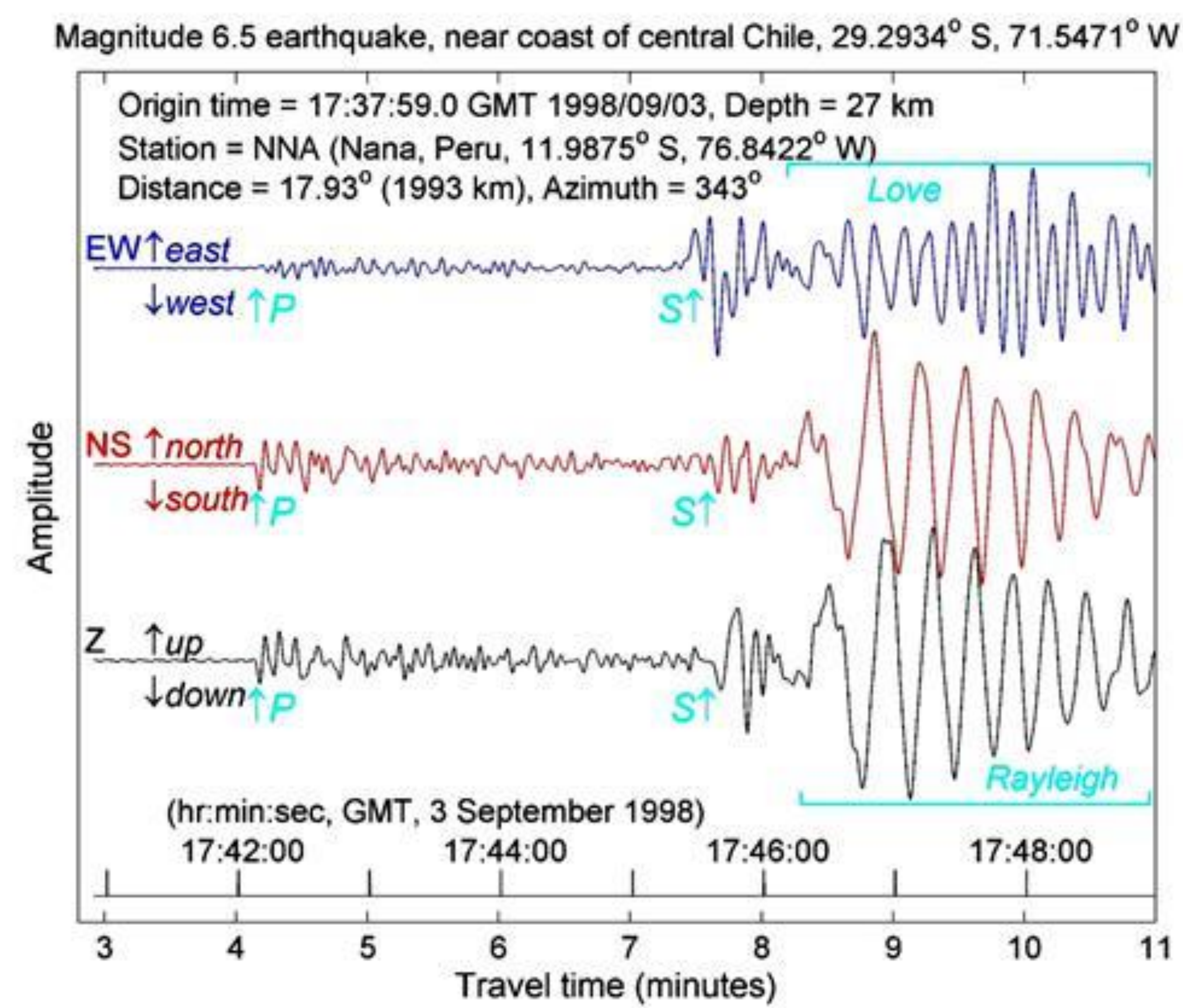
P-wave Tomography

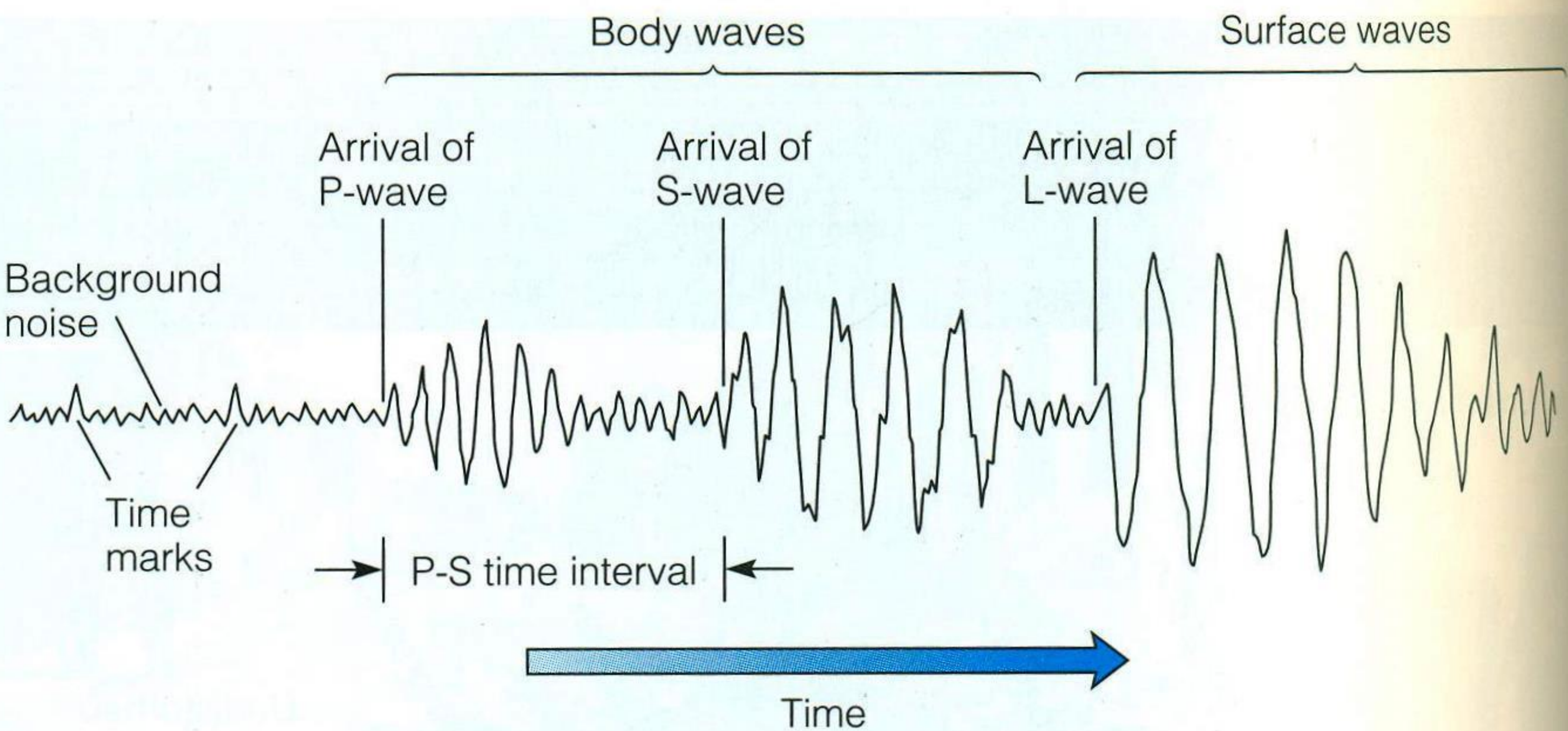


Seismic waves

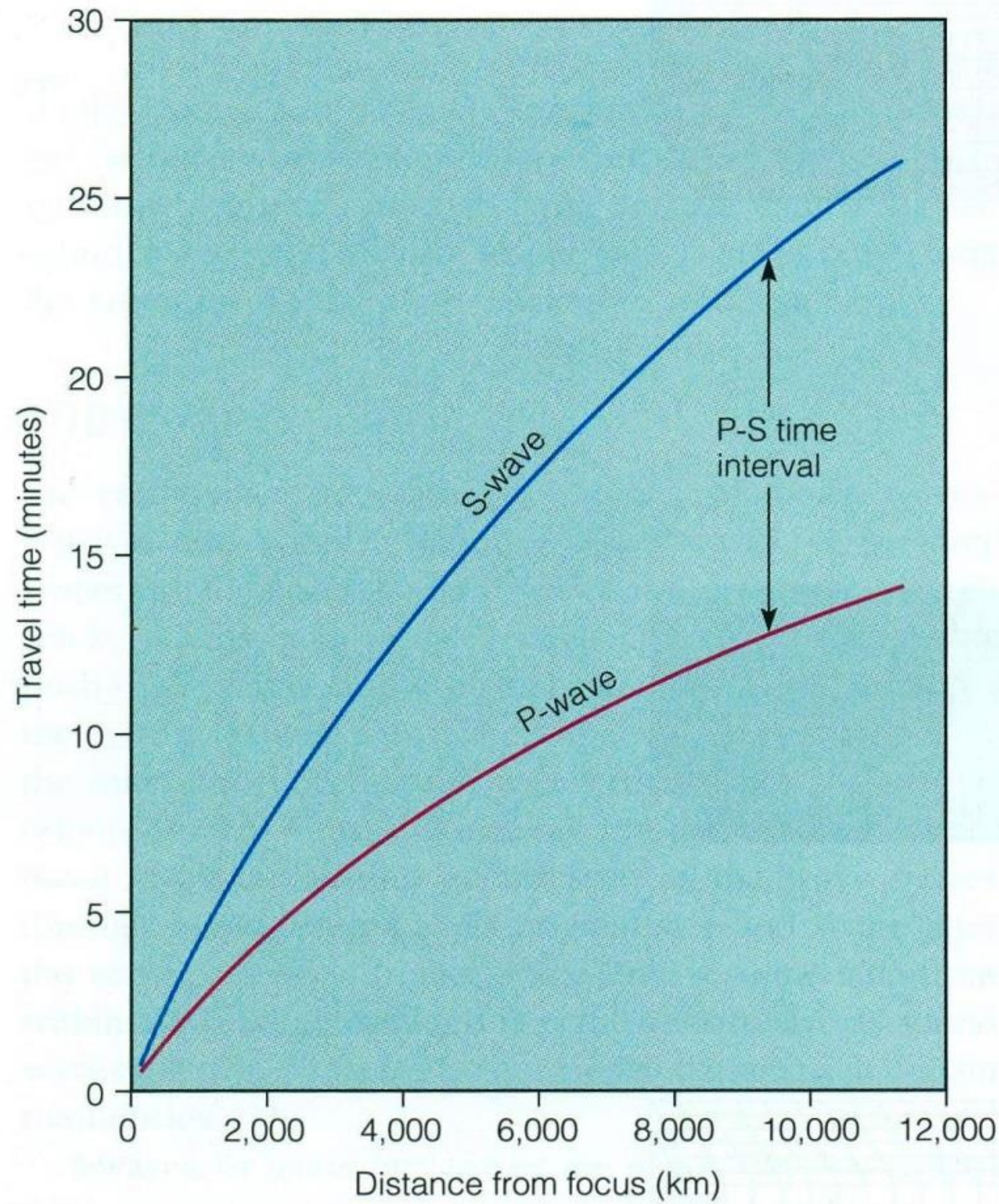


A. Directions of vibration of body and surface waves generated by an earthquake associated
with the illustrated fault. B. Propagation of body and surface waves (from Hays, 1981 and


Magnitude 6.5 earthquake, near coast of central Chile, 29.2934° S, 71.5471° W
Origin time = 17:37:59.0 GMT 1998/09/03, Depth = 27 km
Station = NNA (Nana, Peru, 11.9875° S, 76.8422° W)
Distance = 17.93° (1993 km), Azimuth = 343°
Love
EW ↑east
↓west
↑P
S↑
NS ↑north
↓south
↑P
S↑
Z ↑up
↓down
↑P
S↑
Rayleigh
Amplitude
(hr:min:sec, GMT, 3 September 1998)
17:42:00
17:44:00
17:46:00
17:48:00
3
4
5
6
7
8
9
10
11
Travel time (minutes)

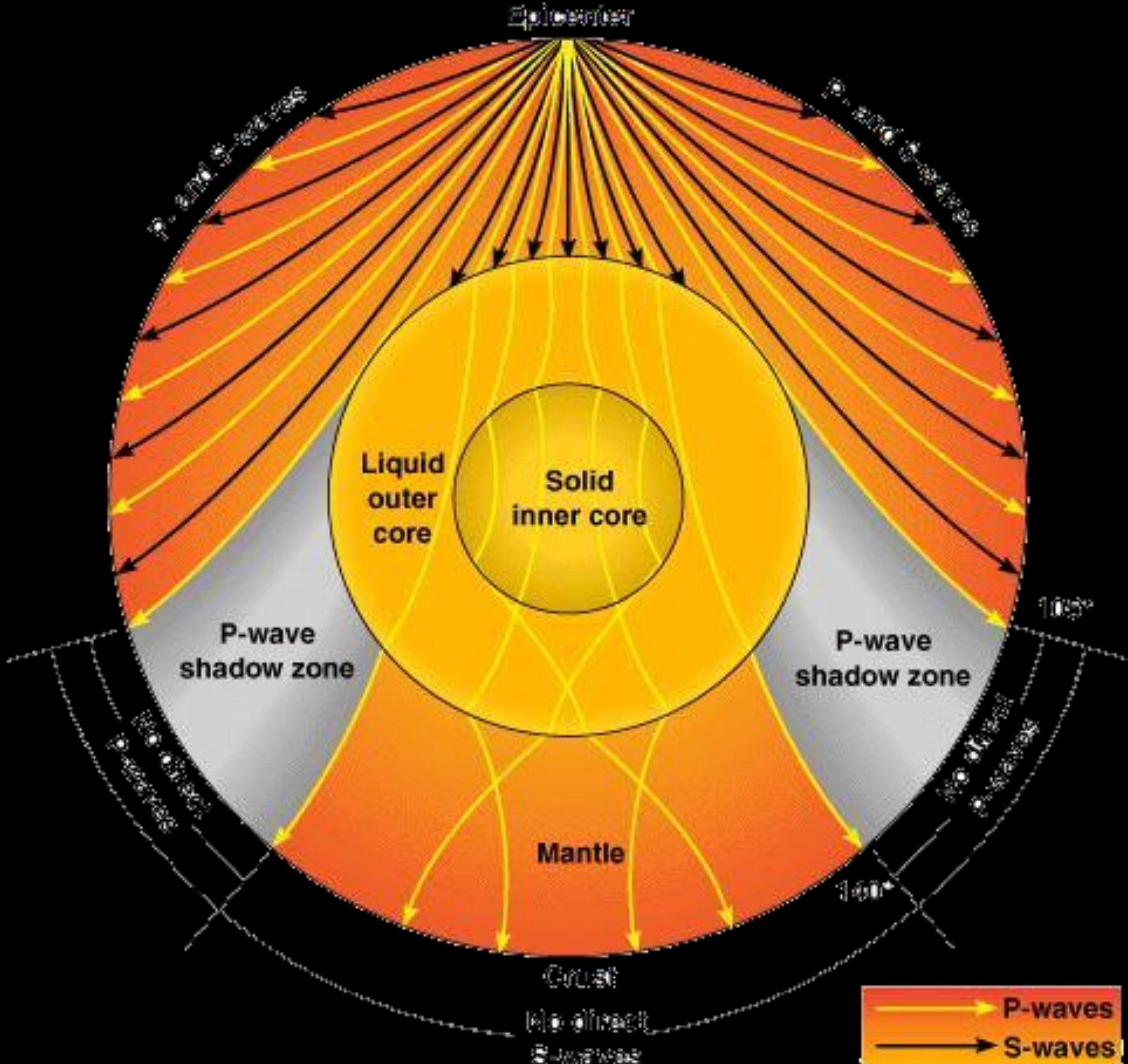


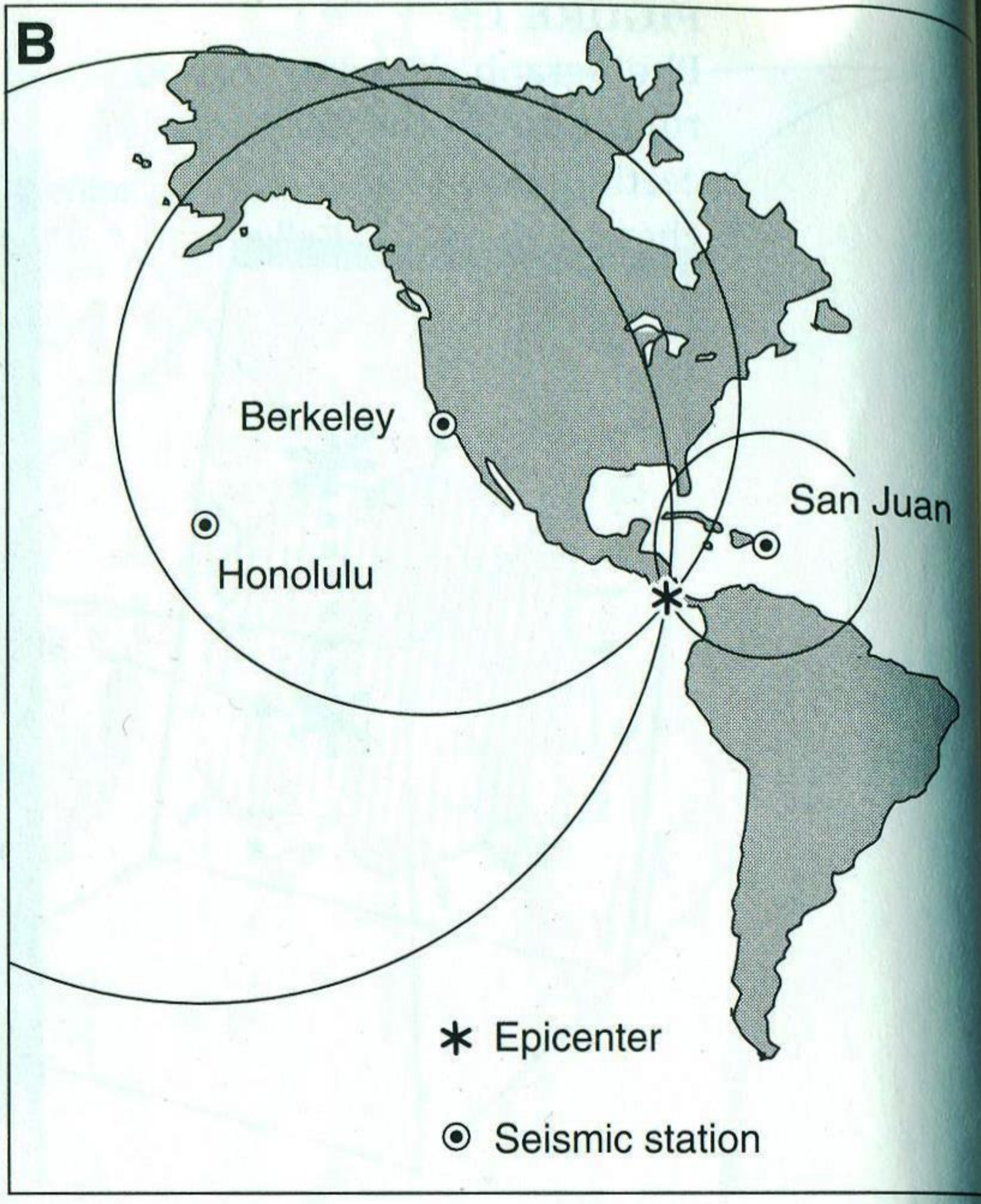
Body waves
Surface waves
Arrival of
P-wave
Arrival of
S-wave
Arrival of
L-wave
Background
noise
Time
marks
P-S time interval
Time



30
25
20
15
10
5
0
Travel time (minutes)
S-wave
P-wave
P-S time interval
0
2,000
4,000
6,000
8,000
10,000
12,000
Distance from focus (km)

Determination of earthquake epicenters


Epicenter
P- and S-waves
P- and S-waves
Liquid outer core
Solid inner core
P-wave shadow zone
P-wave shadow zone
105°
No direct P-waves
No direct P-waves
140°
Mantle
Crust
No direct S-waves
P-waves
S-waves


B
Berkeley
San Juan
Honolulu
Epicenter
Seismic station

Earthquake magnitude

Magnitude of an earthquake is based on the amplitude of the largest seismic wave corrected for distance and period of the wave

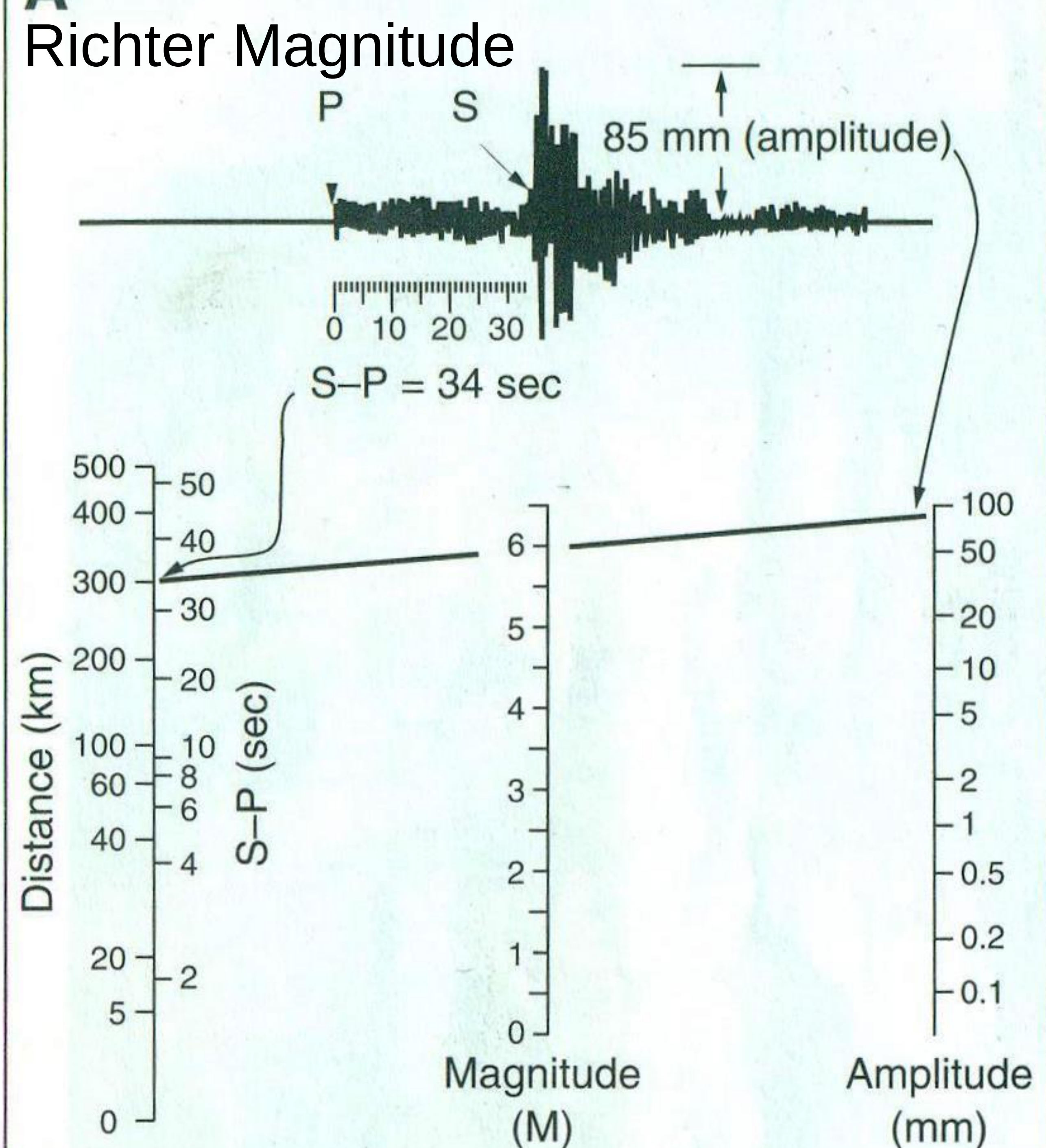
Magnitude scale are logarithmic

Richter magnitude M_L

Surface-wave magnitude M_S

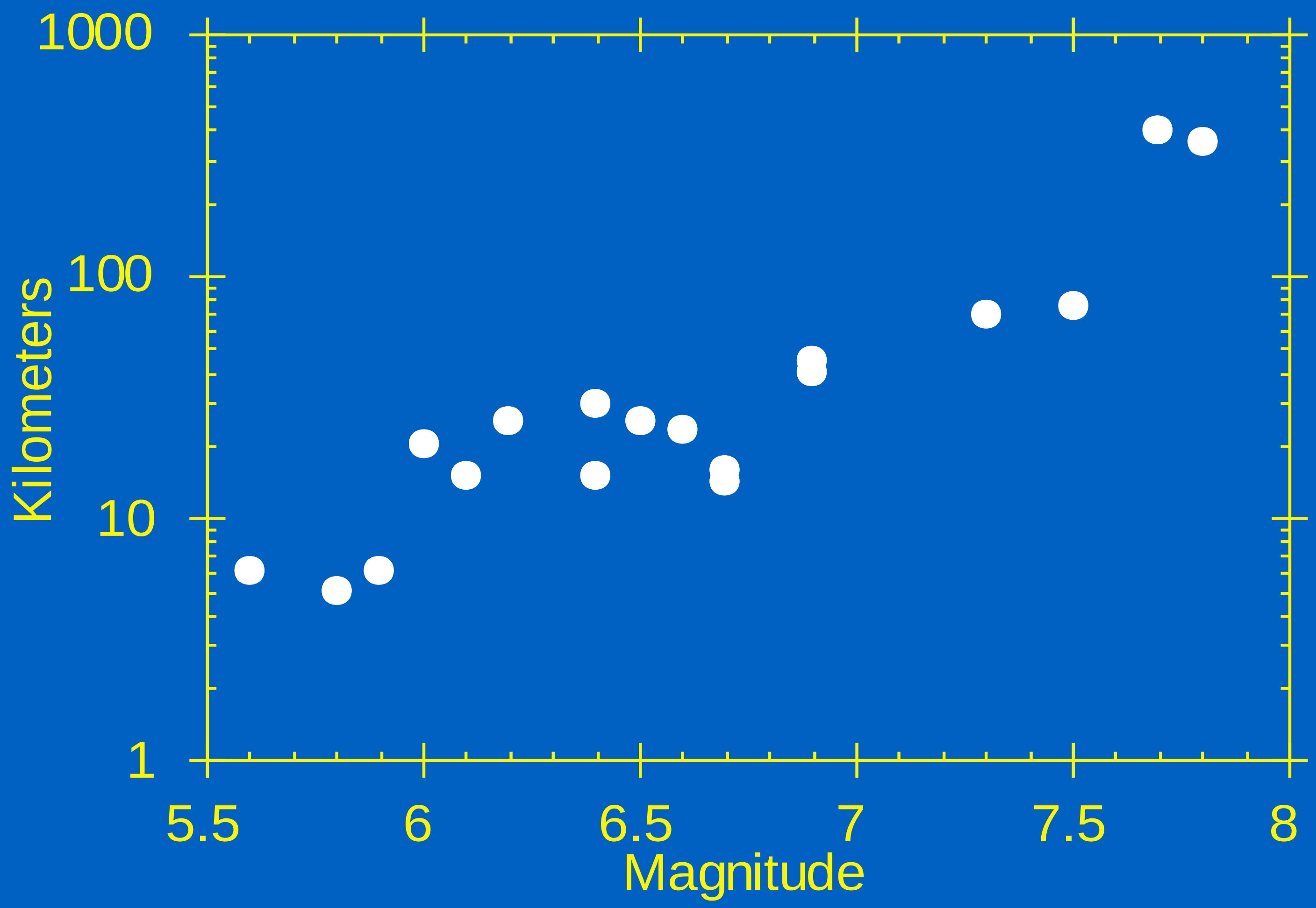
Body wave magnitude M_b

Richter Magnitude



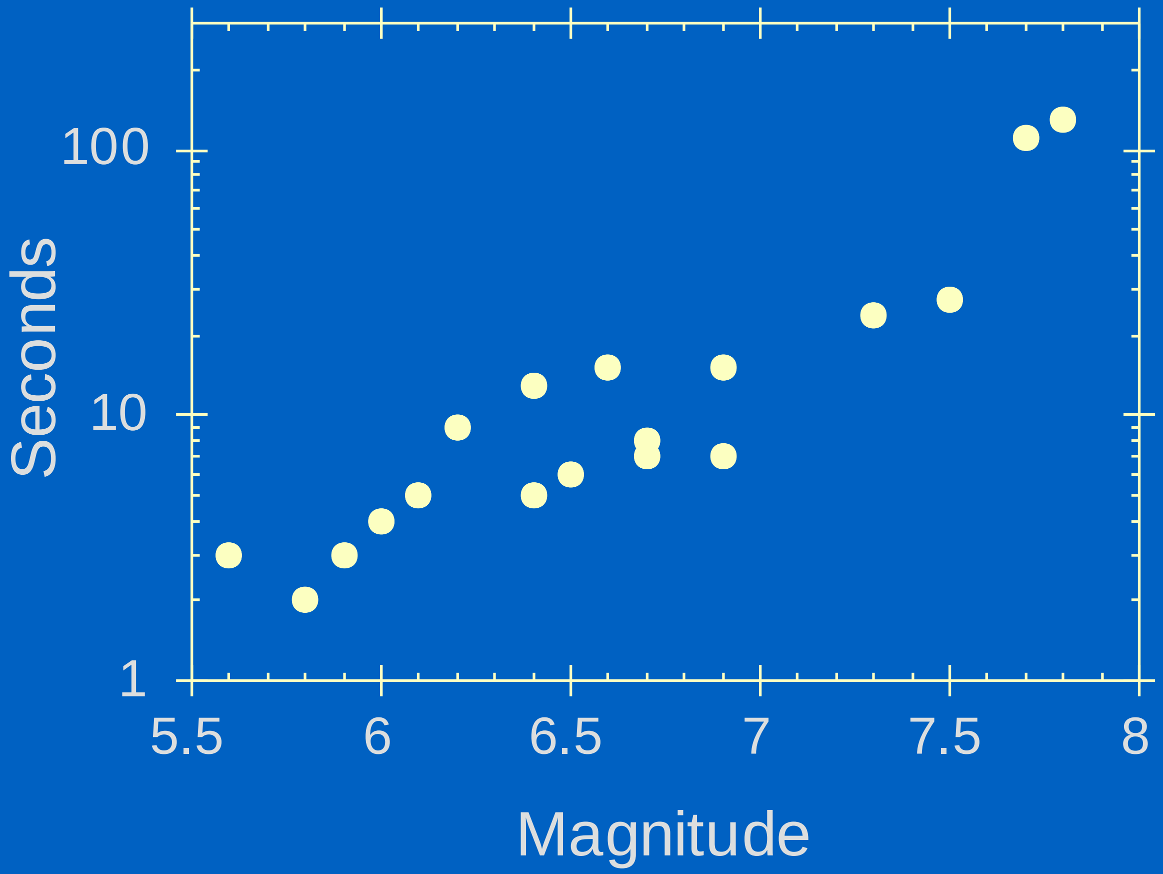
M	Approximate TNT	Joule	Example
0.0	15 g	63 kJ	
0.2	30 g	130 kJ	Large hand grenade
1.5	2.7 kg	11 MJ	Seismic impact of typical small construction blast
2.1	21 kg	89 MJ	West fertilizer plant explosion[
3.0	480 kg	2.0 GJ	Oklahoma City bombing, 1995
3.5	2.7 metric tons	11 GJ	PEPCON fuel plant explosion, Henderson, Nevada, 1988
3.87	9.5 metric tons	40 GJ	Explosion at Chernobyl nuclear power plant, 1986
3.91	11 metric tons	46 GJ	Massive Ordnance Air Blast bomb
6.0	15 kilotons	63 TJ	Approximate yield of the Little Boy atomic bomb dropped on Hiroshima (~16 kt)
7.9	10.7 megatons	45 PJ	Tunguska event
8.35	50 megatons	210 PJ	Tsar Bomba—Largest thermonuclear weapon ever tested. Most of the energy was dissipated in the atmosphere. The seismic shock was estimated at 5.0–5.2
9.15	800 megatons	3.3 EJ	Toba eruption 75,000 years ago; among the largest known volcanic events.
13.0	100 teratons	420 ZJ	Yucatán Peninsula impact (creating Chicxulub crater) 65 Ma ago (10^8 megatons; over 4×10^{29} ergs = 400 ZJ).

Bigger Faults Make Bigger Earthquakes



USGS

Bigger Earthquakes Last a Longer Time



Moment magnitude M_W based on seismic moment

Seismic moment $M_0 = \mu A u$

μ shear modulus $3.3x10^{11}$dynes/cm^2

A area of the fault

u average displacement on the fault plane

$$M_W = 2/3\log M_0 - 10.7$$

intensity

Intensity scales are subjective based on damage caused by an earthquake

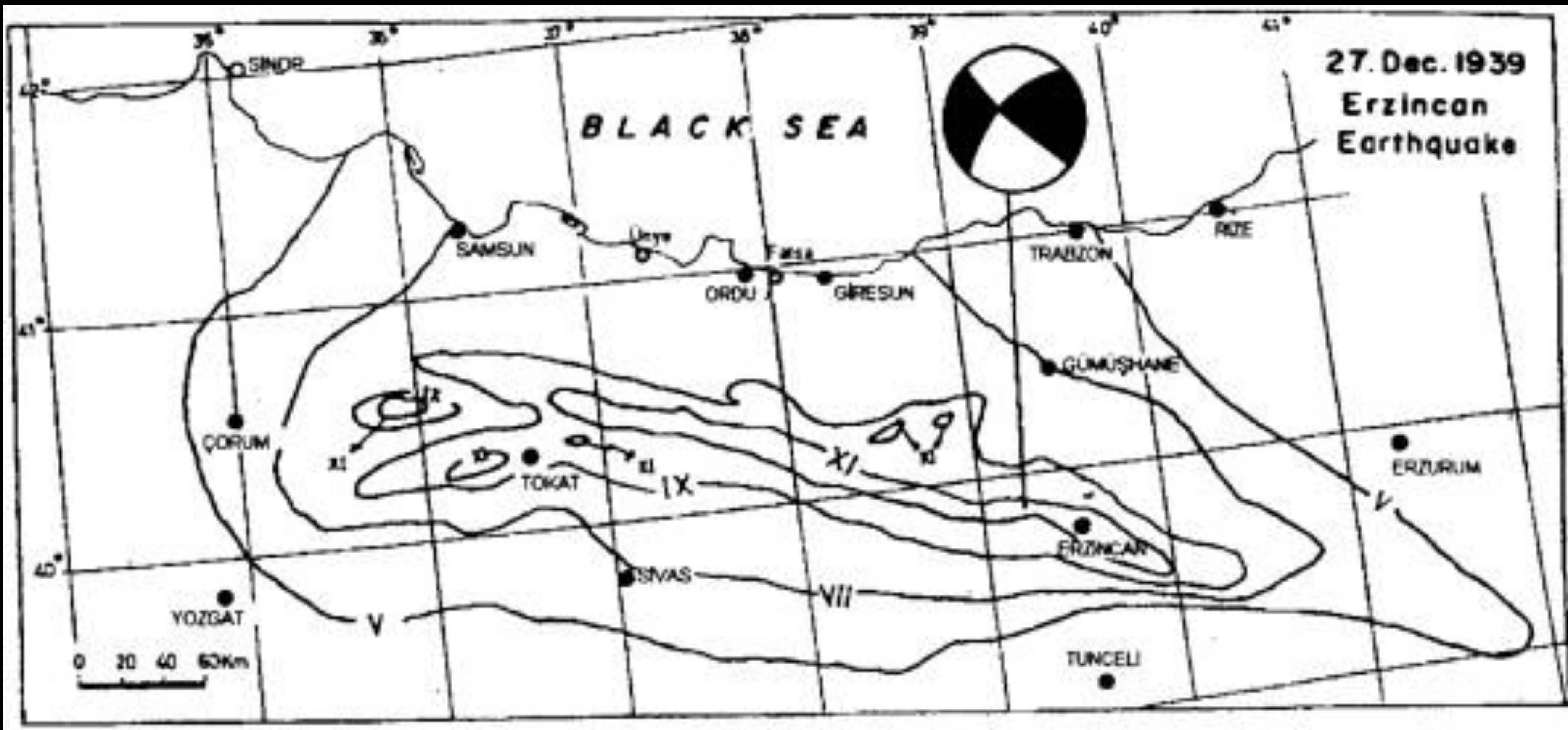
For a single earthquake there is a single magnitude value but several intensity values depending on the distance from the earthquake epicenter.

Modified Mercalli intensity scale (abridged).

Intensity	Effects
I	Not felt except by a very few under especially favorable circumstances.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an eanhquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.
IV	During the day felt indoors by many, outdoors by a few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building; standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.
VI	Felt by all; many frightened and run outdoors. Some heavy fumiture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy fumiture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars.
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
X	Some well-built wooden structures destroyed; most masonry and frame structures with foundations destroyed; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.
XI	Few, if any, masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely outof service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII	Damage total. Waves seen on ground surfaces. Lines of sight and level distoned. Objects thrown upward into the air.

[From Wood and Neuman, 1931. U.S. Geological Suivey, 1974. *Earthquake Infornialion Bulletin*, 6(5): 28]


Skopje
Скопје
Plovdiv
Пловдив
Edirne
Thessaloniki
Θεσσαλονίκη
Sakarya
Gebze
Bursa
Çanakkale
Ankara
Eskişehir
Greece



27. Dec. 1939
Erzincan
Earthquake
BLACK SEA
SINOP
SAMSUN
ORDU
GİRESUN
TRABZON
RİZE
GÜMÜŞHANE
ÇORUM
TOKAT
ERZURUM
ERZİNCAN
SİVAS
YOZGAT
TUNCELİ
IX
XI
VII
V
0 20 40 60Km

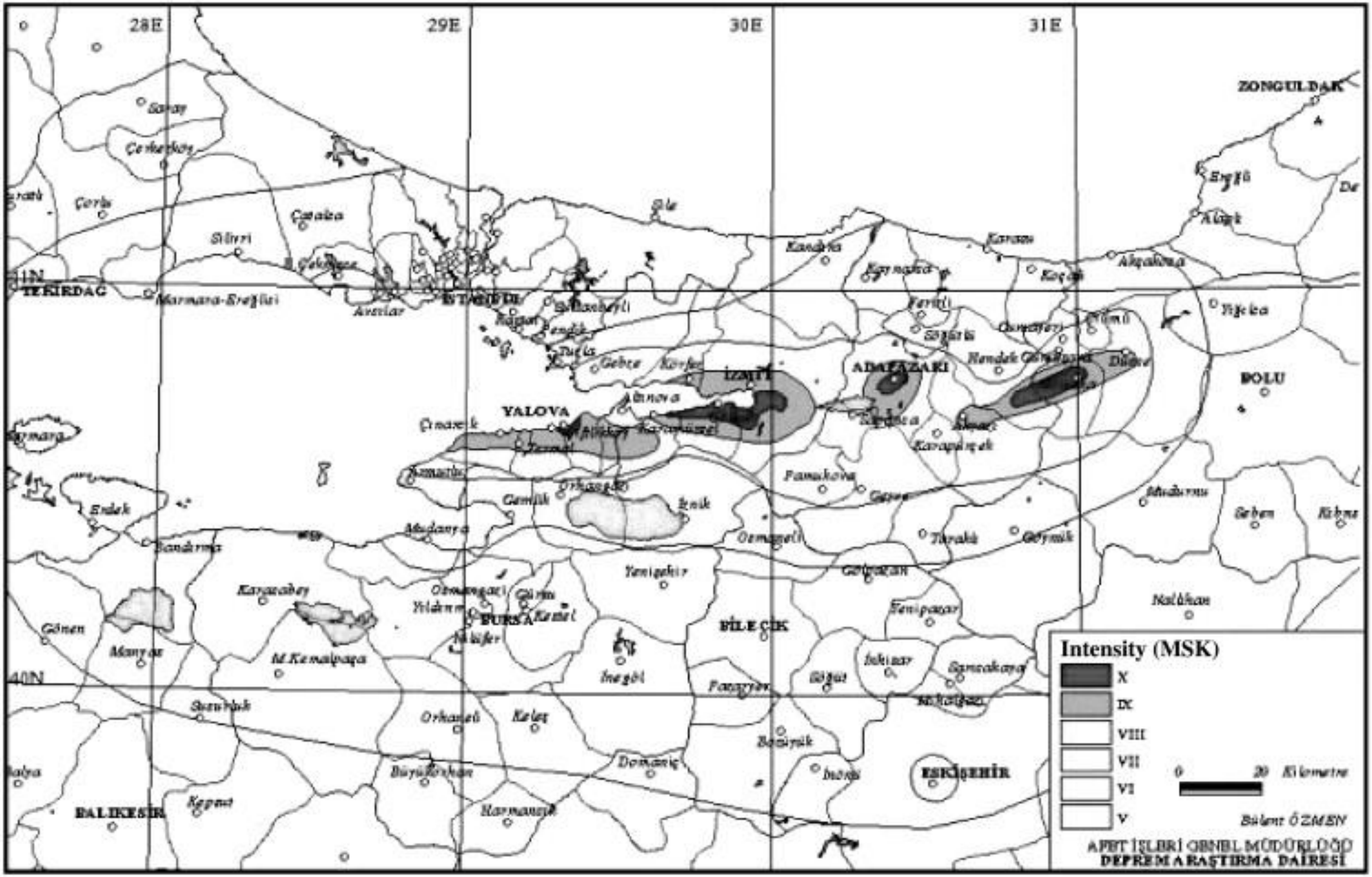

Dawson
Anchorage
II-IV
Whitehorse
V
VI
VII
XI
Juneau
Prince Rupert
km
Lituya Bay, Alaska
July 9, 1958 - Magnitude 7.9
Modified Mercalli Intensity
I
II
III
IV
V
VI
VII
VIII
IX
X+
Epicentre

site ampflication

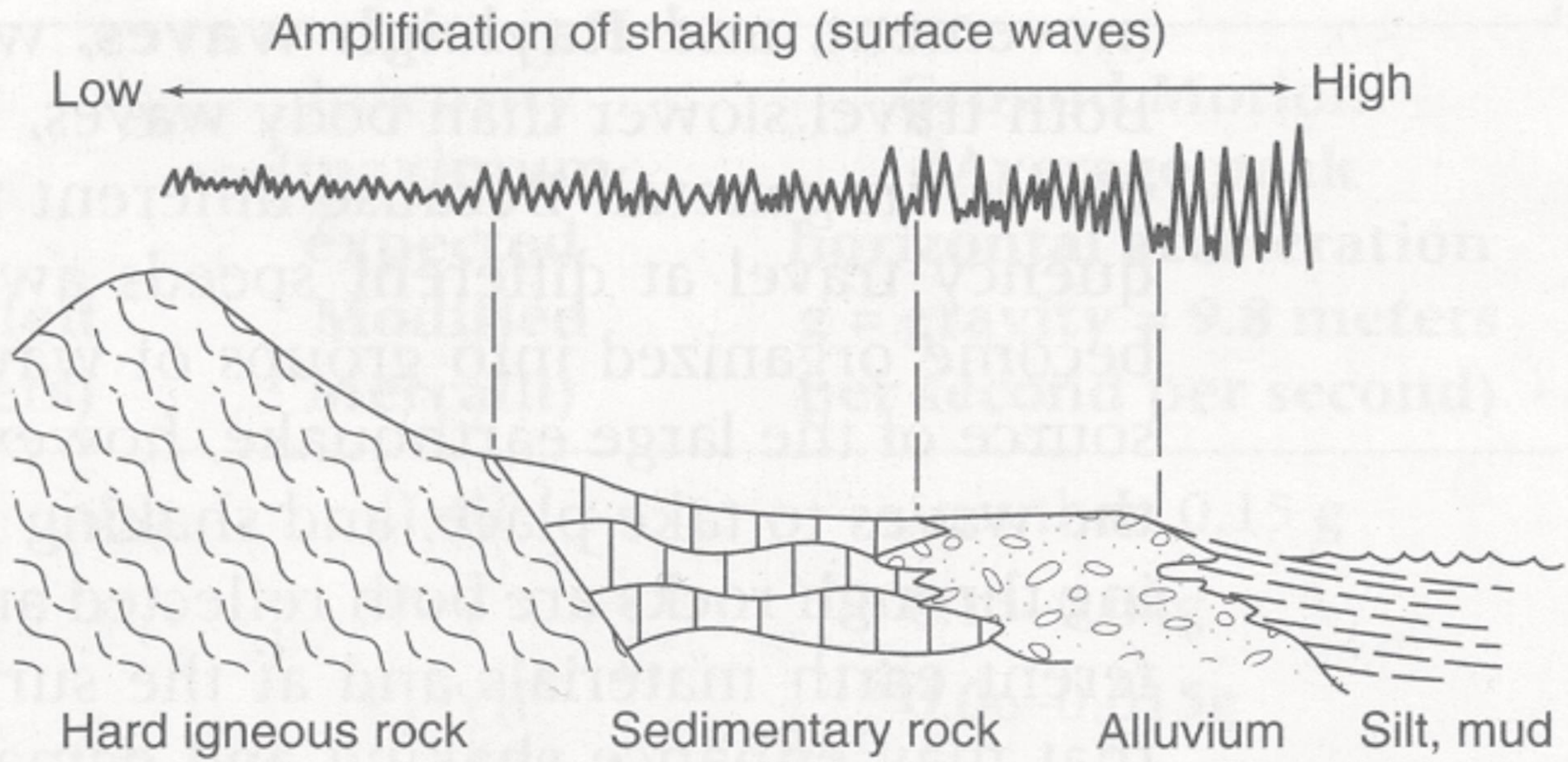
What Controls the Level of Shaking?

- **Magnitude**
  - More energy released
- **Distance**
  - Shaking decays with distance
- **Local soils**
  - amplify the shaking

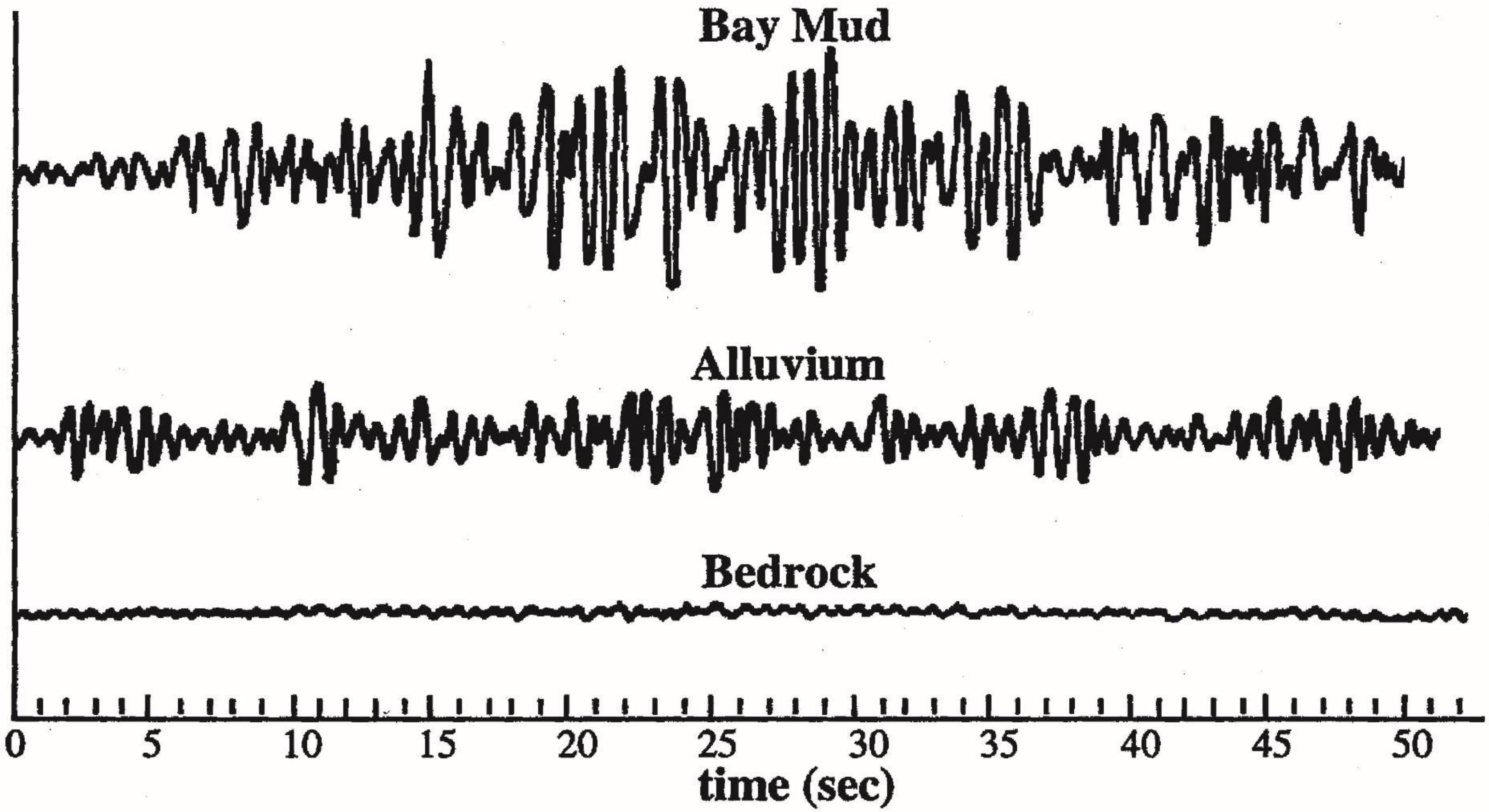
USGS



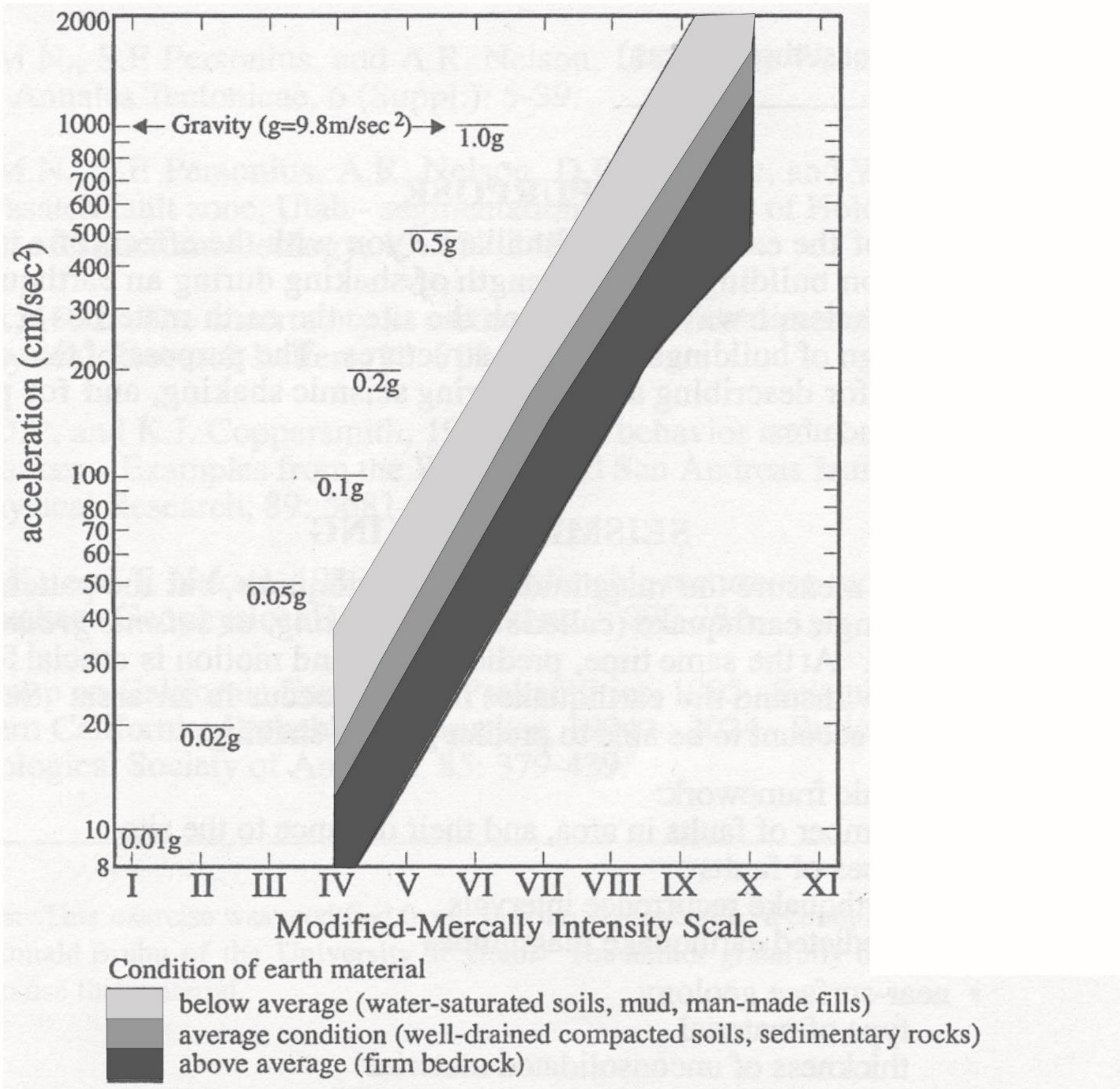
28E
29E
30E
31E
ZONGULDAK
TEKIRDAĞ
İSTANBUL
YALOVA
İZMİT
ADAPAZARI
BOLU
BURSA
BİLECİK
ESKİŞEHİR
BALIKESİR
Intensity (MSK)
X
IX
VIII
VII
VI
V
0
20 Kilometre
Bülent ÖZMEN
AFET İŞLERİ GENEL MÜDÜRLÜĞÜ
DEPREM ARAŞTIRMA DAİRESİ



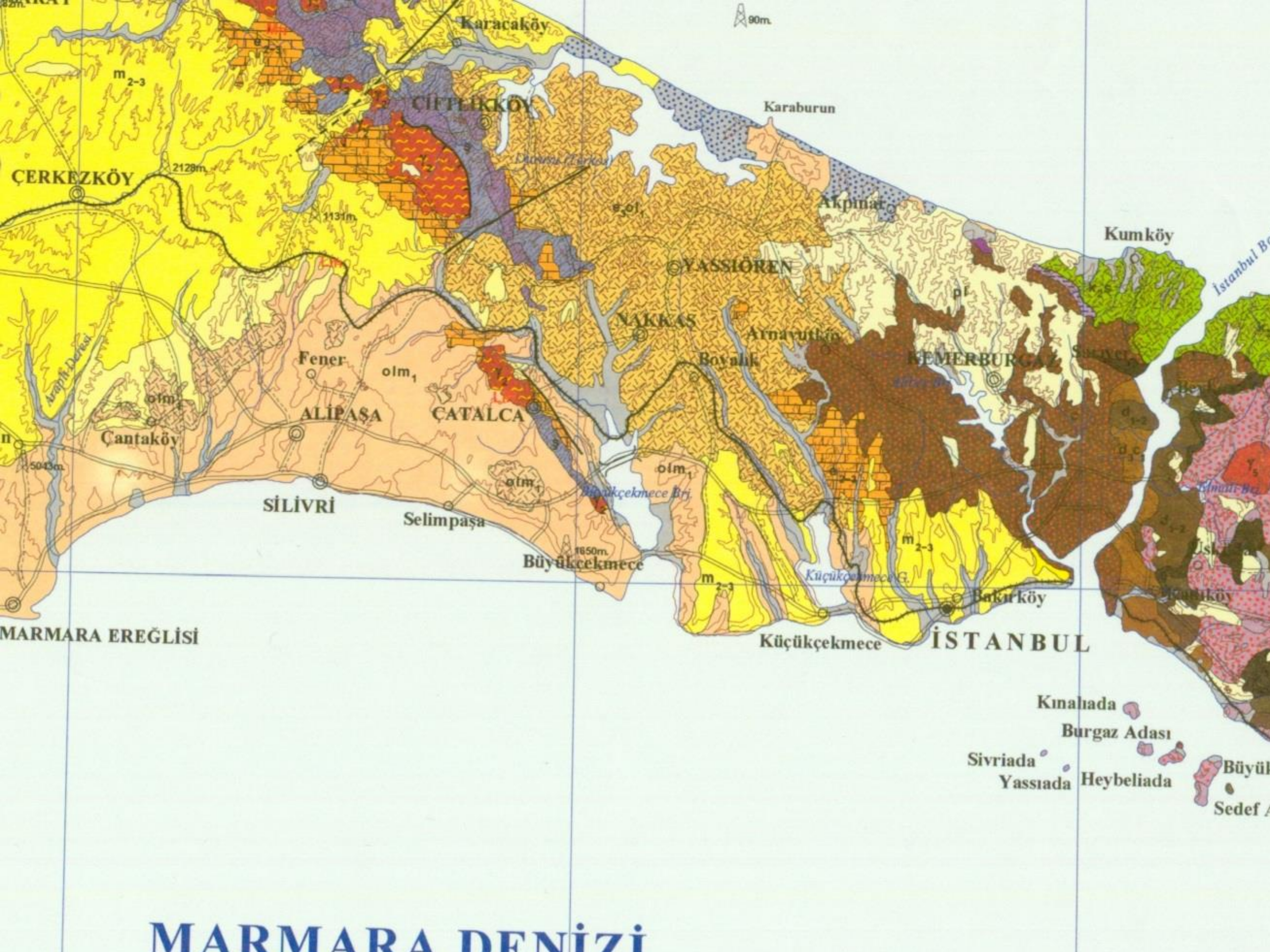
Relationship between near-surface earth material and amplification of shaking during an earthquake (Keller and Pinter, 1996).

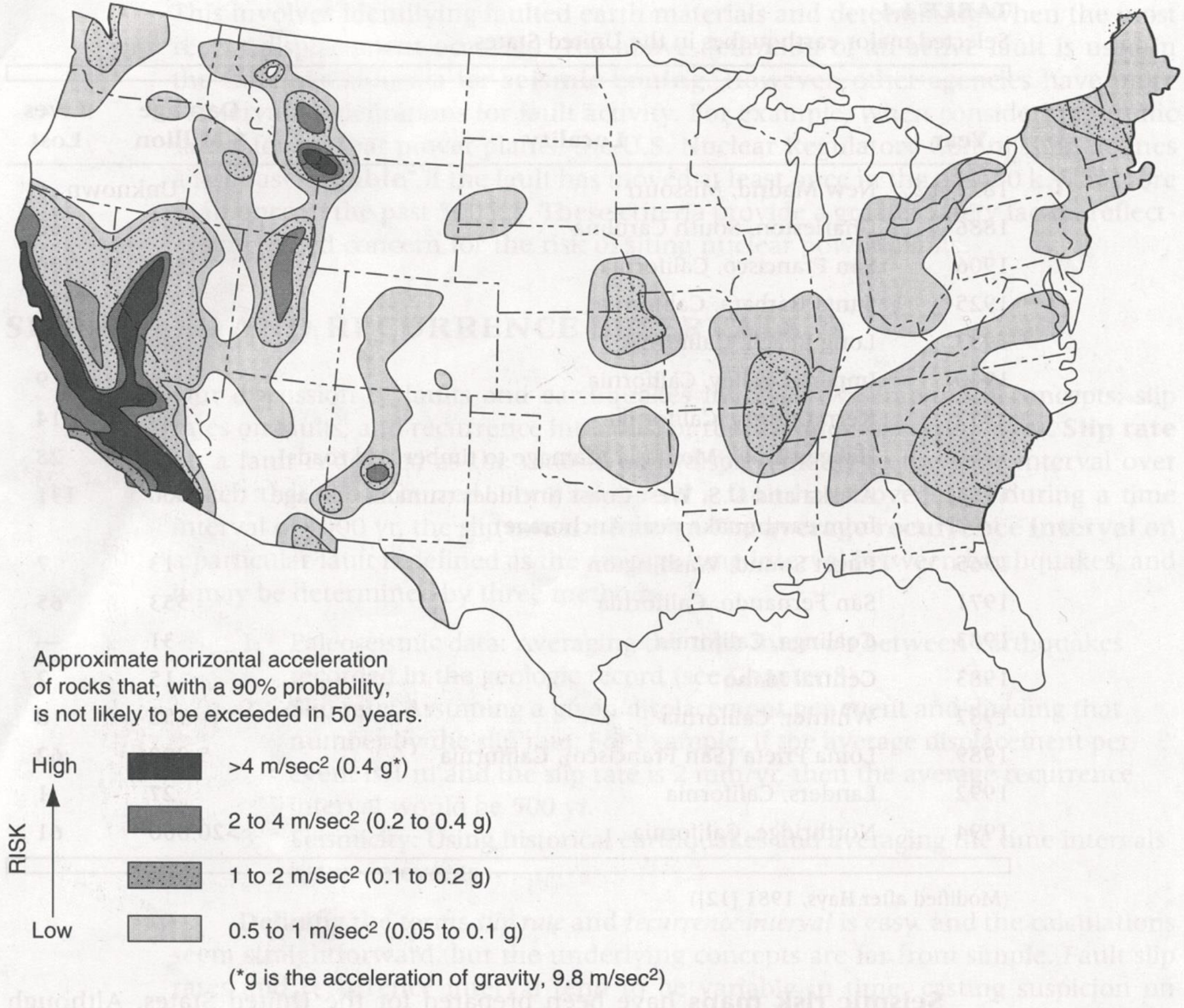


Horizontal ground motions of an underground nuclear explosion as recorded by accelographs in San Francisco. All materials were subjected to the same seismic waves (Borcherdt, 1975).

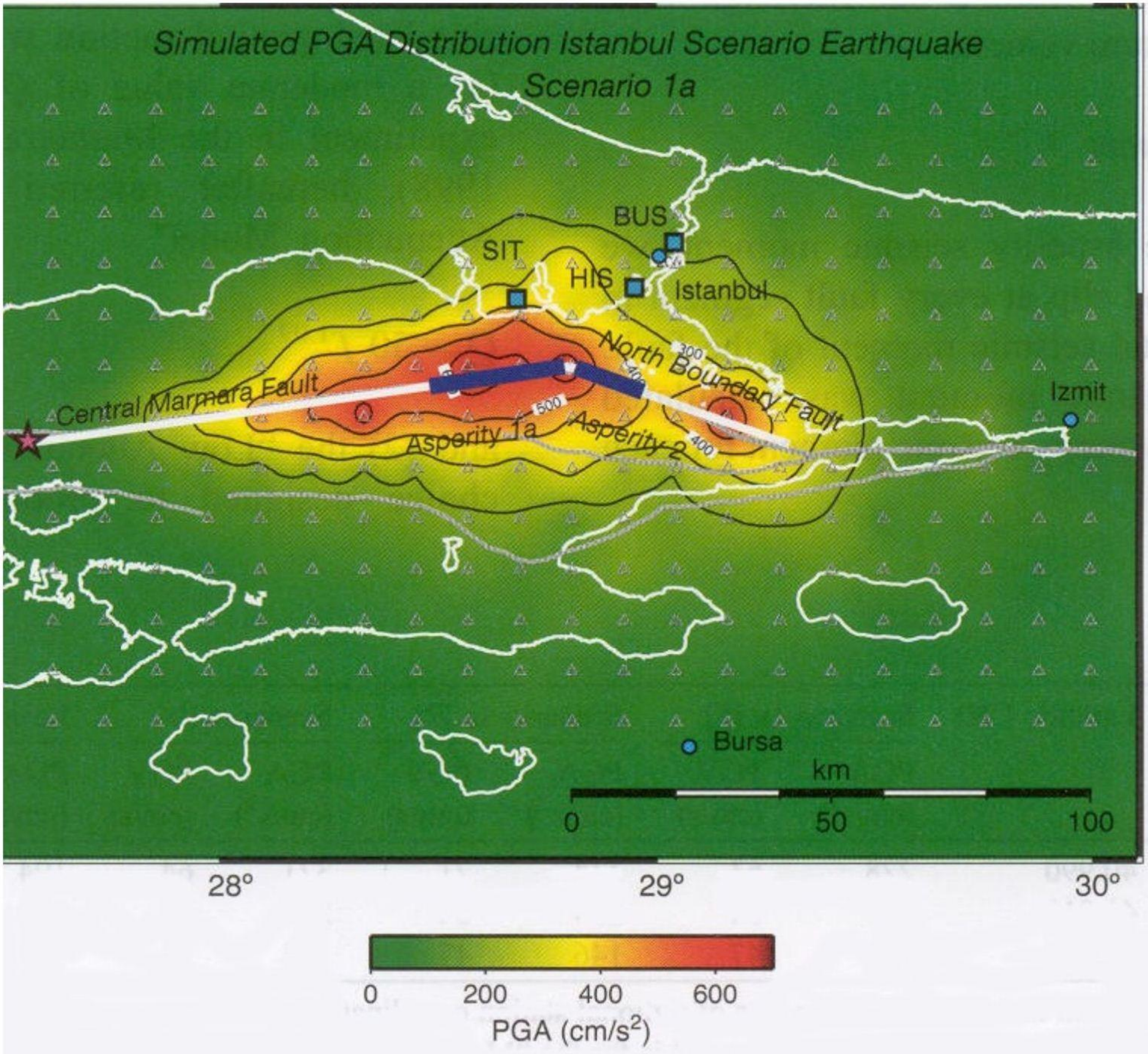


Seismic acceleration versus ground shaking intensity for different earth materials (Leed, 1973).


Karacaköy
ÇİFTLİKKÖY
Karaburun
ÇERKEZKÖY
2128m.
1131m.
Akpınar
Kumköy
YASSIÖREN
NAKKAŞ
Arnavutköy
Fener
olm1
Boyalık
KEMERBURGAZ
ALİPAŞA
ÇATALCA
Çantaköy
5043m.
SİLİVRİ
Selimpaşa
Büyükçekmece Brj.
1650m.
Büyükçekmece
Küçükçekmece G.
Bakırköy
MARMARA EREĞLİSİ
Küçükçekmece
İSTANBUL
Kınalıada
Burgaz Adası
Sivriada
Yassıada
Heybeliada
90m.
MARMARA DENİZİ

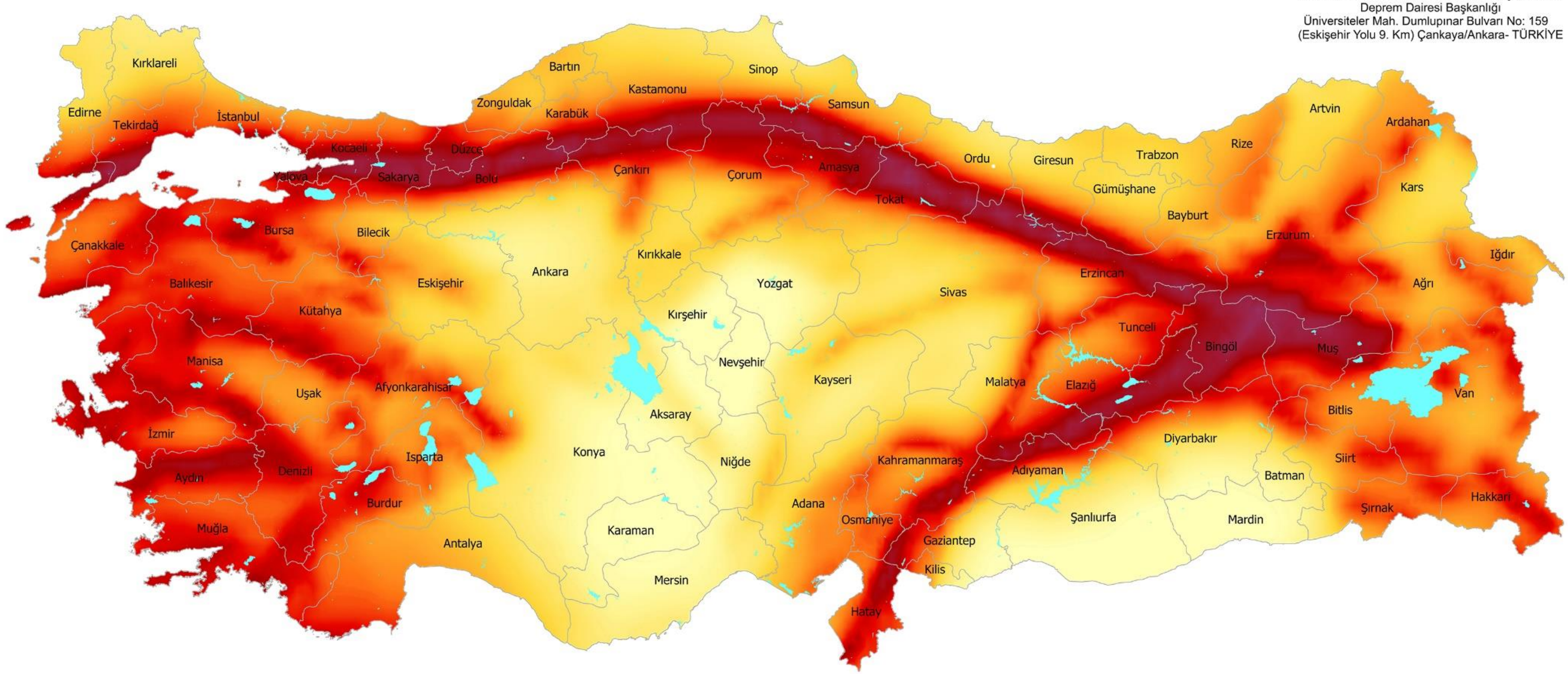


Seismic hazard map of the United States (Algermissen and Perkins, 1976)


Simulated PGA Distribution Istanbul Scenario Earthquake
Scenario 1a
BUS
SIT
HIS
Istanbul
North Boundary Fault
Central Marmara Fault
Asperity 1a
Asperity 2
300
400
500
400
Izmit
Bursa
km
0
50
100
28º
29º
30º
0
200
400
600
PGA (cm/s2)

TÜRKİYE DEPREM TEHLİKE HARİTASI

afadbaskanlik
AFET VE ACİL DURUM YÖNETİMİ BAŞKANLIĞI
Deprem Dairesi Başkanlığı
Üniversiteler Mah. Dumlupınar Bulvarı No: 159
(Eskişehir Yolu 9. Km) Çankaya/Ankara- TÜRKİYE



Bu harita, Afet ve Acil Durum Yönetimi Başkanlığı (AFAD) tarafından Ulusal Deprem Araştırma Programı (UDAP) kapsamında desteklenen UDAP-Ç-13-06 kod no'lu "Türkiye Sismik Tehlike Haritasının Güncellenmesi" başlıklı projenin sonuçları kullanılarak hazırlanmıştır.

Bu harita, zemin koşulu $(V_s)_{30}$ = 760 m/s esas alınarak hazırlanmıştır. Yerel zemin koşullarının neden olabileceği sıvılaşma, büyütme, farklı oturma gibi tehlikeleri içermemektedir.

Kaynak Gösterme; Bu haritanın kullanılmasında "AFAD, 2018. Türkiye Deprem Tehlike Haritası" şeklinde kaynak belirtilmesi gerekmektedir.

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AÇIKLAMALAR

EN BÜYÜK YER İVMESİ (g)

DÜŞÜK TEHLİKE — YÜKSEK TEHLİKE

0,0 0,1 0,2 0,3 0,4 0,5

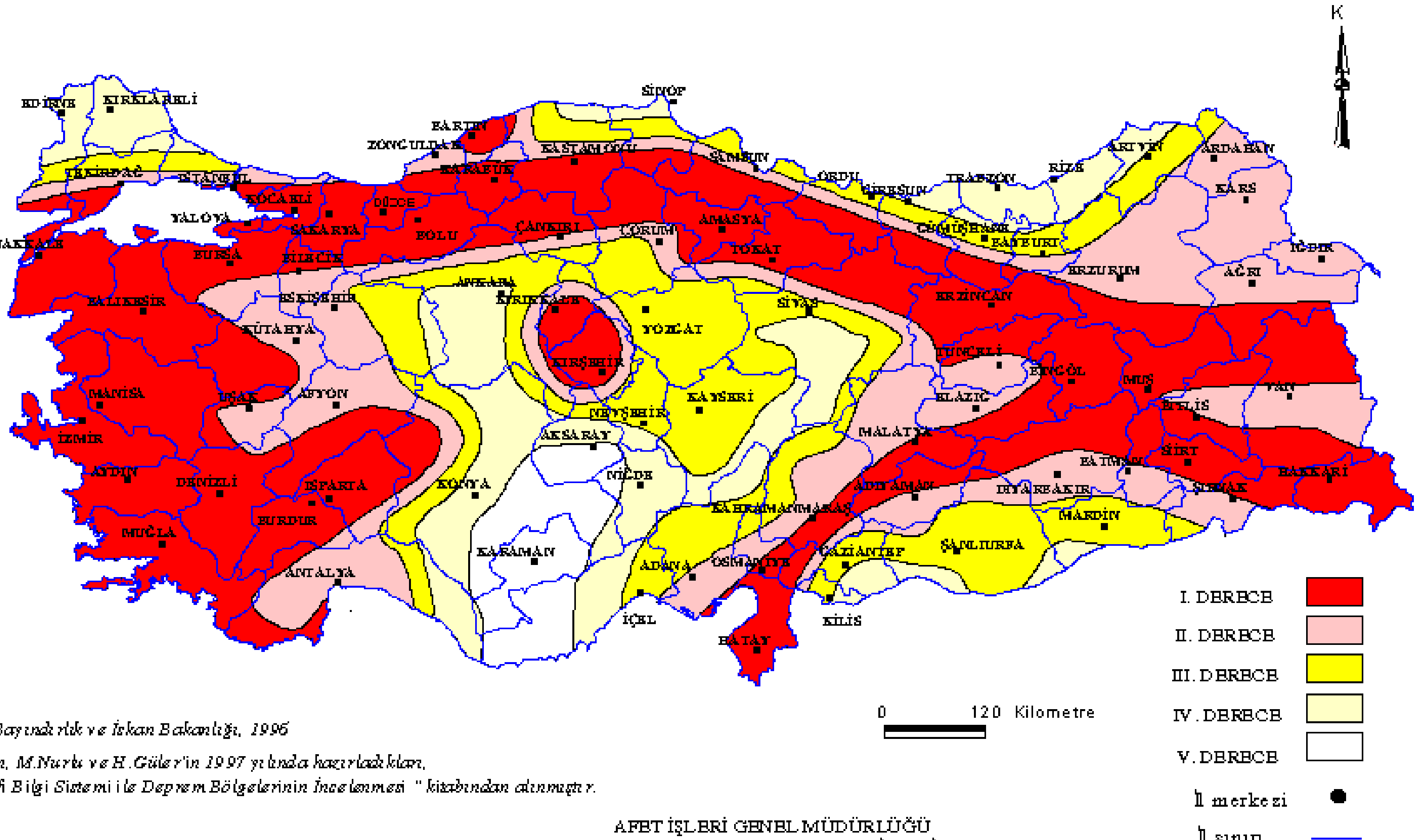
50 YILDA AŞILMA OLASILIĞI %10
(TEKRARLANMA PERİYODU 475 YIL)

K

Göl İl Sınırı

0 100 200 400 KM

DEPREM BÖLGELERİ HARİTASI*



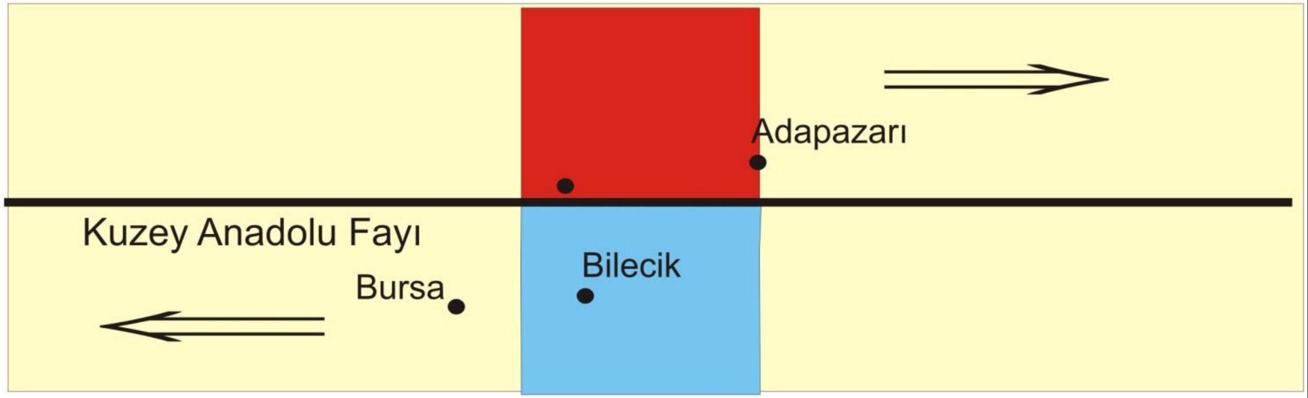
*T.C Bayındırlık ve İskan Bakanlığı, 1996

B.Özmen, M.Nurlu ve H.Güler'in 1997 yılında hazırladıkları,
"Coğrafi Bilgi Sistemi ile Deprem Bölgelerinin İncelenmesi" kitabından alınmıştır.

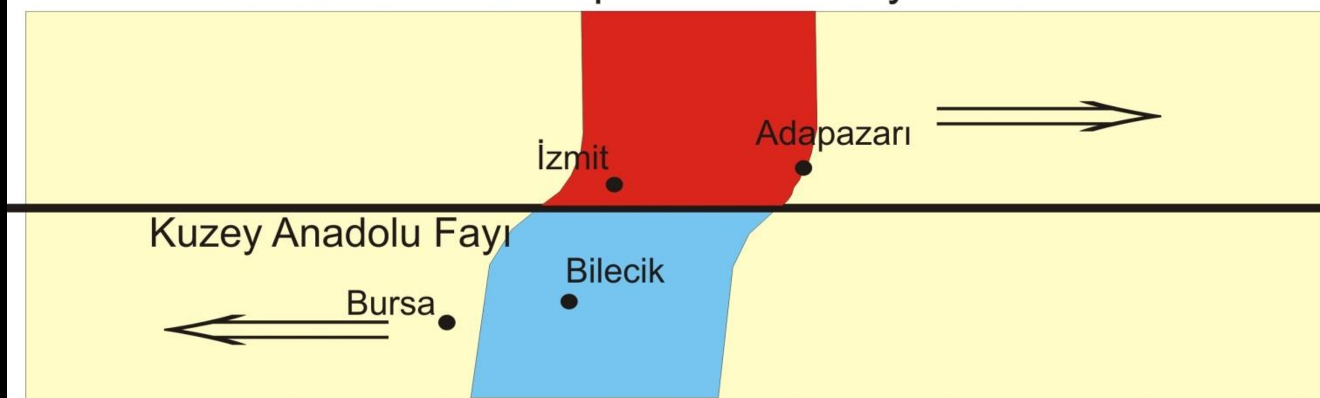
AFET İŞLERİ GENEL MÜDÜRLÜĞÜ
DEPREM ARAŞTIRMA DAİRESİ
ANKARA-TÜRKİYE

elastic rebound theory for the earthquakes

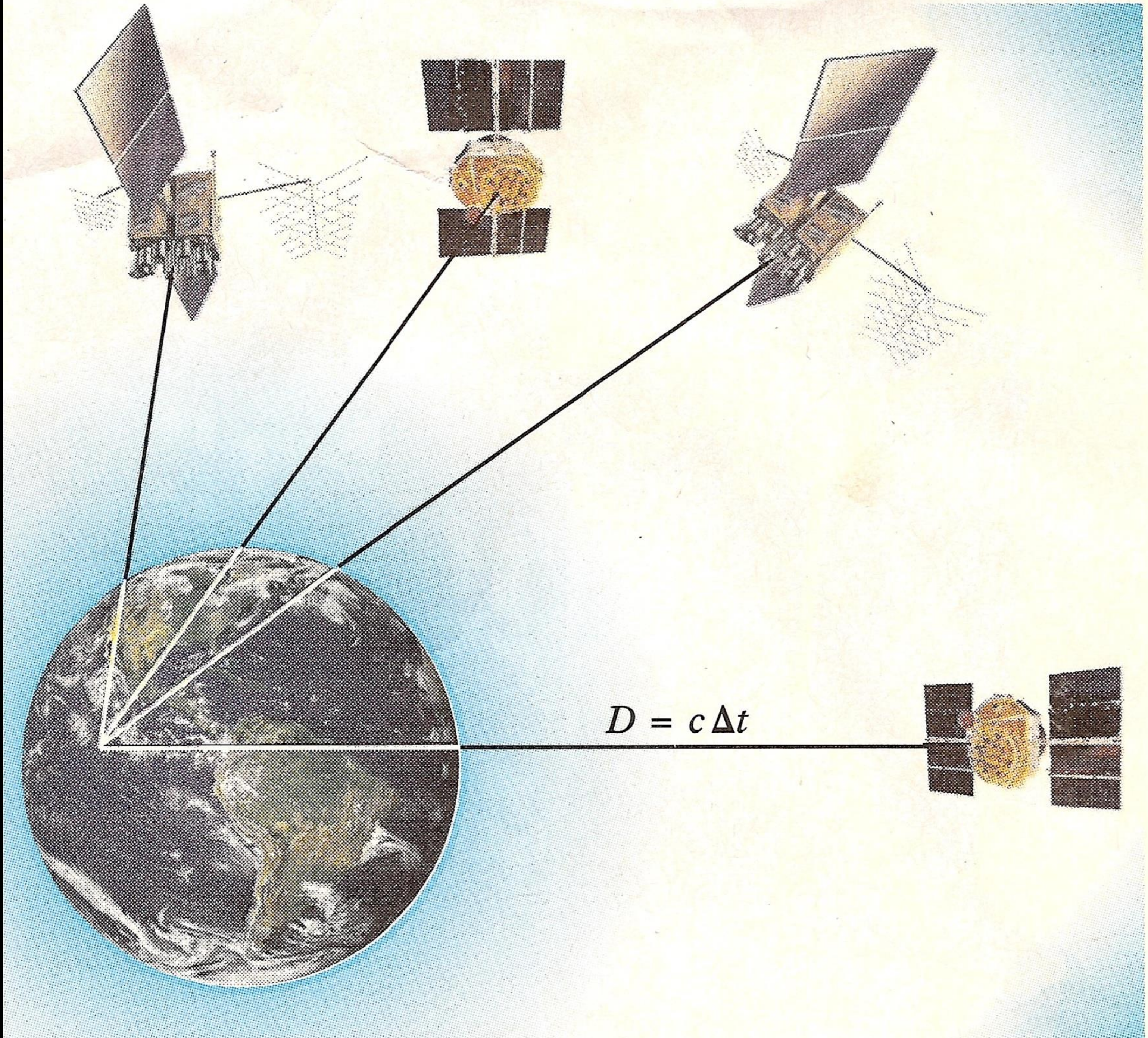
a. 18.8.1999 Kocaeli depreminden hemen sonra



b. 18.8.1999 Kocaeli depreminden 20 yıl sonra



c. Deprem oluyor ! (50-200 yıl sonra)



$D = c\,\Delta t$