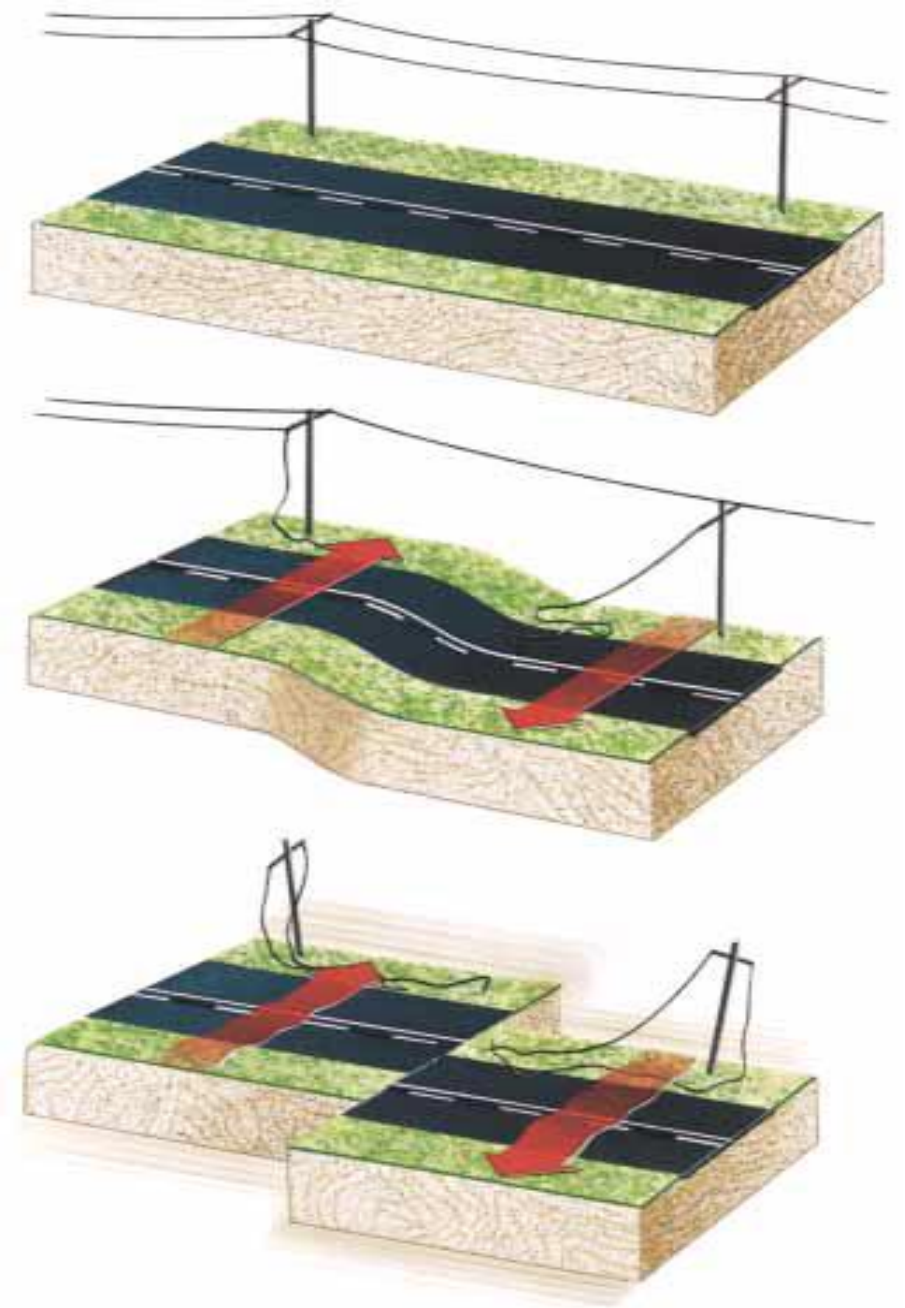
2. EARTHQUAKES

An **earthquake** is a sudden motion or trembling of the Earth caused by the abrupt release of energy that is stored in rocks. Knowledge concerning the earthquakes is crucial for engineering purposes since they deform the crust and cause damages.

Strong earthquakes of Turkey

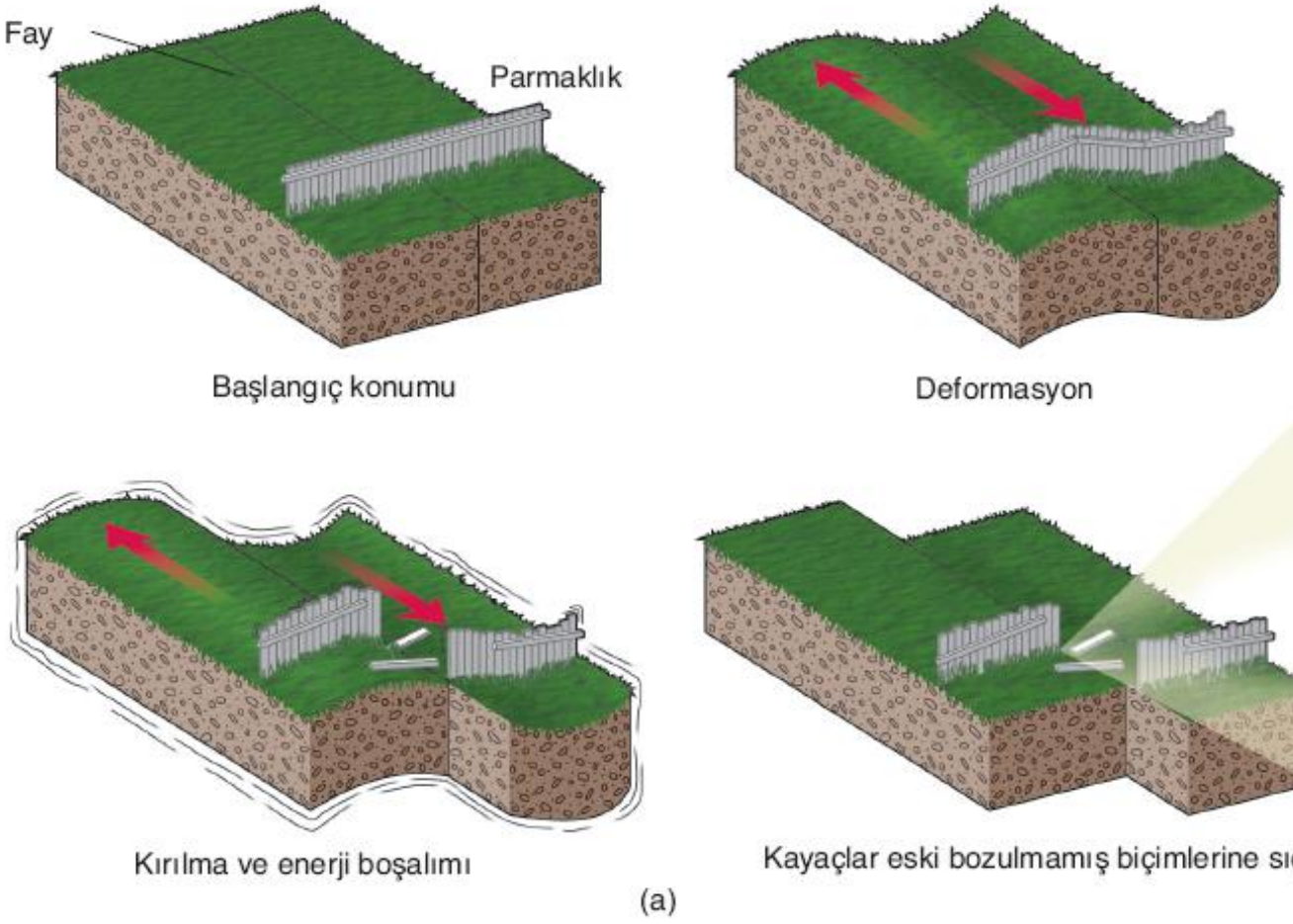
1268	Cilicia	~7
September 10, 1509	Istanbul	7,2 Mw
February 23, 1653	Izmir	7,5
August 17, 1668	Anatolia	8
July 10, 1688	Izmir	7 Ms
February 28, 1855	Bursa	6,7
June 2, 1859	Erzurum	6,1 Ms
April 3, 1881	Çeşme	7,3 Mw
April 29, 1903	Malazgirt	6,7 Ms
August 9, 1912	Mürefte	7,3 Ms
October 4, 1914	Burdur	6,9 Ms
September 13, 1924	Horasan	6,8 Ms
October 22, 1926	Kars	6 Ms
March 31, 1928	İzmir	6,5 Ms
May 18, 1929	Suşehri	6,1 Ms
May 7, 1930	Hakkâri	7.2-7.5 Ms
January 4, 1935	Erdek	6,4 Ms
April 19, 1938	Kırşehir	6,6 Ms
September 22, 1939	Dikili	6,6 Ms
December 26, 1939	Erzincan	7,8 Ms
November 15, 1942	Bigadiç	6,1 Ms
December 20, 1942	Erbaa	7
June 20, 1943	Hendek	6,6 Ms
November 26, 1943	Ladik	7,4
February 1, 1944	Gerede	7,5
October 6, 1944	Ayvalık	6,8 Ms
August 17, 1949	Karlıova	6,8

August 13, 1951	Kurşunlu	6,9
March 18, 1953	Yenice	7,2 Ms
July 16, 1955	Söke	6,8 Ms
April 25, 1957	Fethiye	7,1 Ms
May 26, 1957	Abant	7,1
October 6, 1964	Manyas	7 Ms
August 19, 1966	Varto	6,7
July 22, 1967	Mudurnu	7,2
September 3, 1968	Bartın	6,5 Ms
March 28, 1969	Alaşehir	6,5 Ms
March 28, 1970	Gediz	7,2 Ms
May 22, 1971	Bingol	6,9
September 6, 1975	Lice	6,6 Ms
November 24, 1976	Muradiye	7,5 Ms
October 30, 1983	Erzurum	6,9 Ms
March 13, 1992	Erzincan	6,8
October 1, 1995	Dinar	6,1 Ms
June 27, 1998	Ceyhan	6,2 Ms
August 17, 1999	Adapazarı	7,6
November 12, 1999	Düzce	7,2
February 3, 2002	Afyon	6,5 Mw
January 27, 2003	Pülümür	6,1 Mw
May 1, 2003	Bingöl	6,4 Mw
March 8, 2010	Elâzığ	6,1 Mw
April 19, 2011	Simav	5,8 Mw
October 23, 2011	Van	7,2 Mw



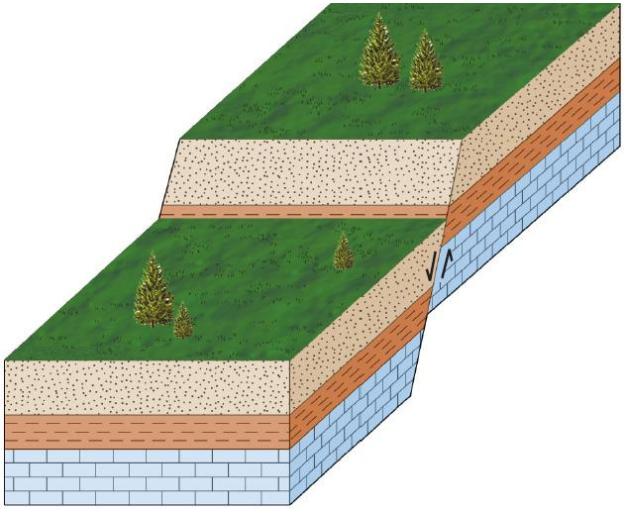
(a) A rock stores elastic energy when it is distorted by a tectonic force. When the rock fractures, it snaps back to its original shape, creating an earthquake. In the process, the rock moves along the fracture.

(b) (b) Moving rock and soil fractured and displaced this roadway during the Loma Prieta earthquake in 1989.

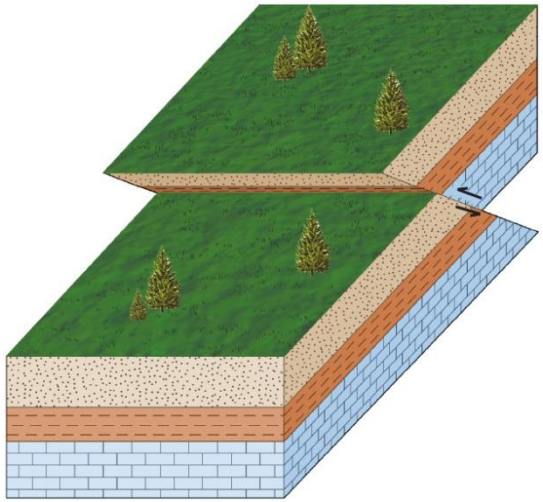


a) According to **Elastic rebound theory, (Esnek sıçrama kuramı)** when rocks are deformed, they **store energy** and **bend.** ***When the internal strength of the rocks is exceeded, they fracture, releasing the energy as they rebound to their former undeformed shape***. ***This sudden release of energy causes an earthquake.*** b) During the 1906 San Francisco earthquake, this fence in Marin County was displaced nearly 5 m.

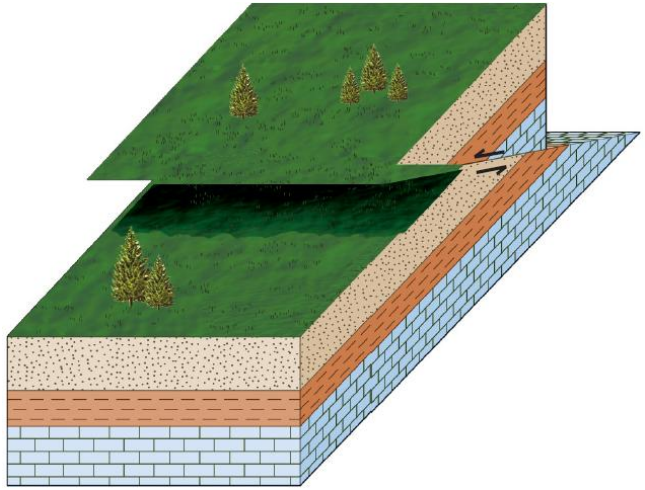
Types of deformations which can cause earthquake



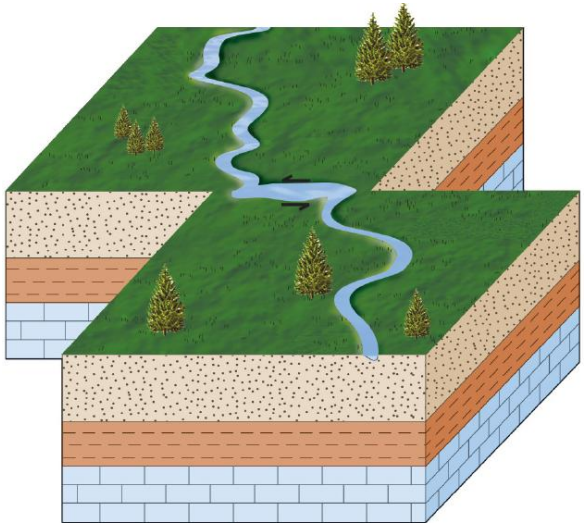
Normal Fault



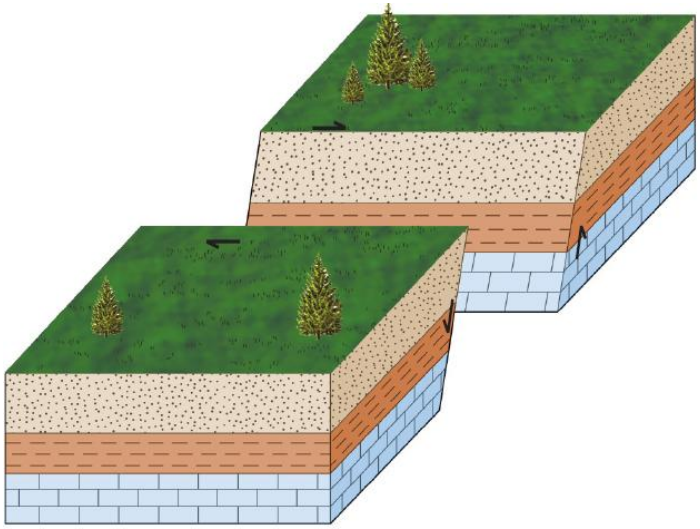
Reverse Fault



Thrust Fault



Strike-slip Fault



Oblique Fault

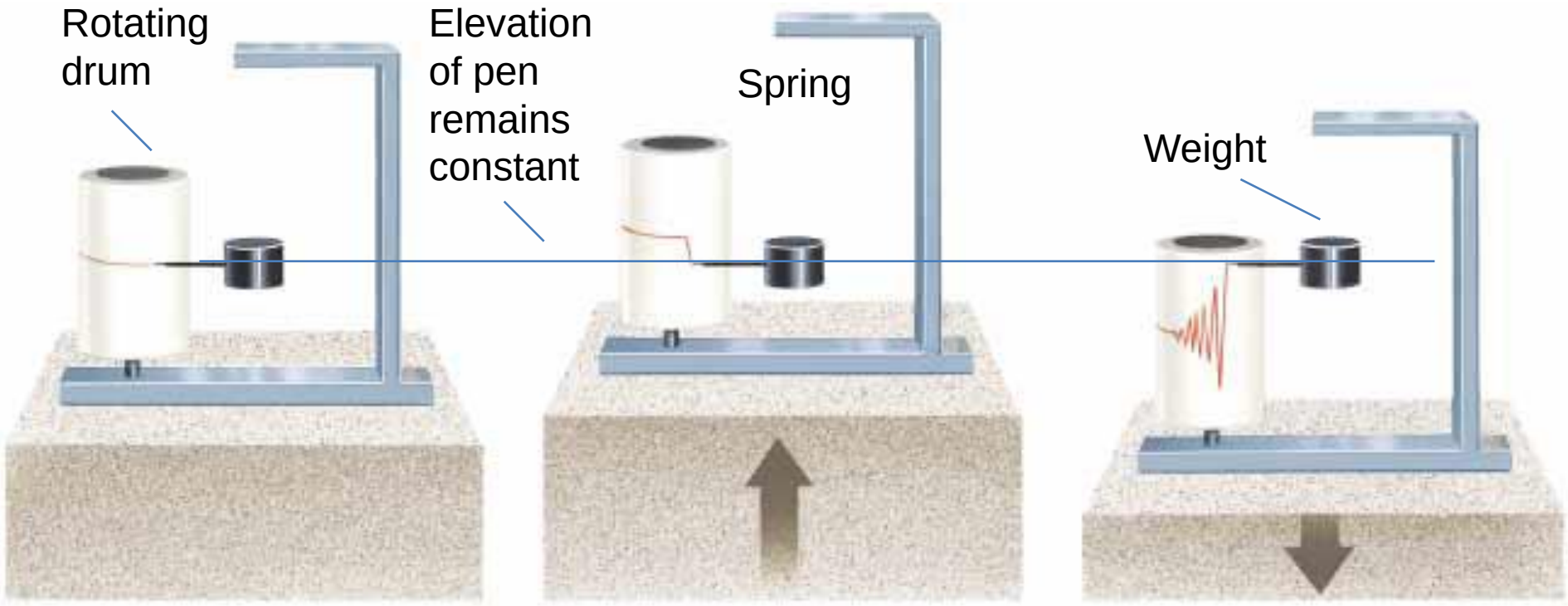
SEISMOLOGY AND MEASUREMENT OF SEISMIC WAVES

A **seismology,** is a study of earthquakes.

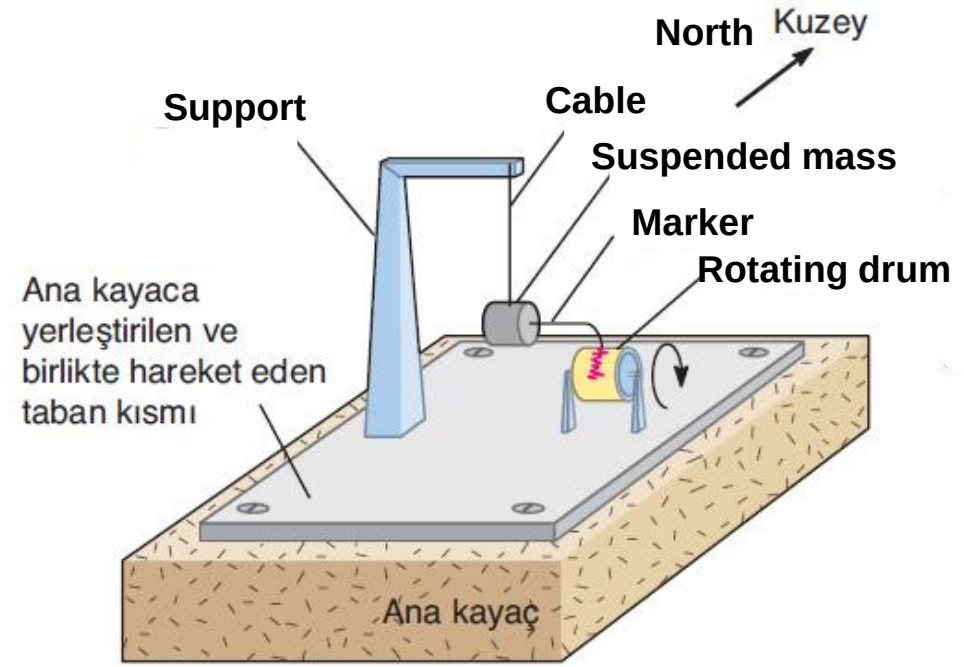
A **seismograph** ***is a device*** that records seismic waves. To understand how a seismograph works, consider the act of writing a letter while riding in an airplane. If the plane hits turbulence, inertia keeps your hand relatively stationary as the plane moves back and forth beneath it, and your handwriting becomes erratic.

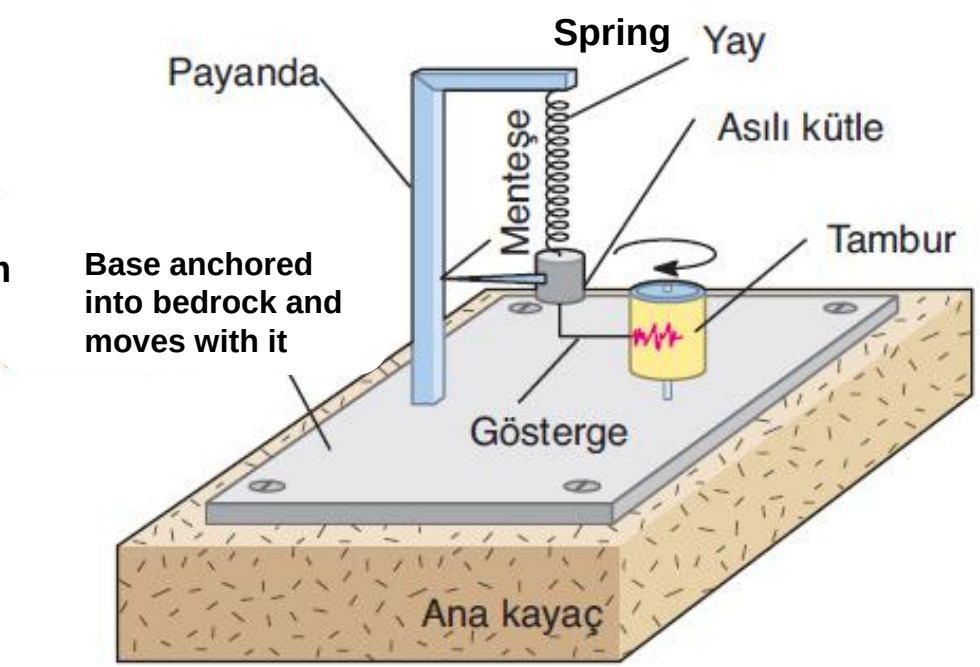
Early seismographs worked on the same principle. A weight was suspended from a spring. A pen attached to the weight was aimed at the zero mark on a piece of graph paper. The graph paper was mounted on a rotary drum that was attached firmly to bedrock. During an earthquake, the graph paper jiggled up and down, but inertia kept the pen stationary. As a result, the paper moved up and down beneath the pen. The rotating drum recorded earthquake motion over time.

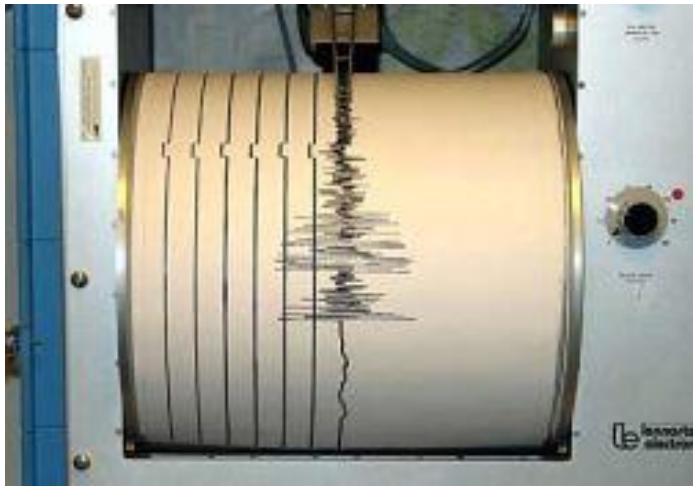
This ***record of Earth vibration is called a*** **seismogram.** Modern seismographs use electronic motion detectors which transmit the signal to a computer.



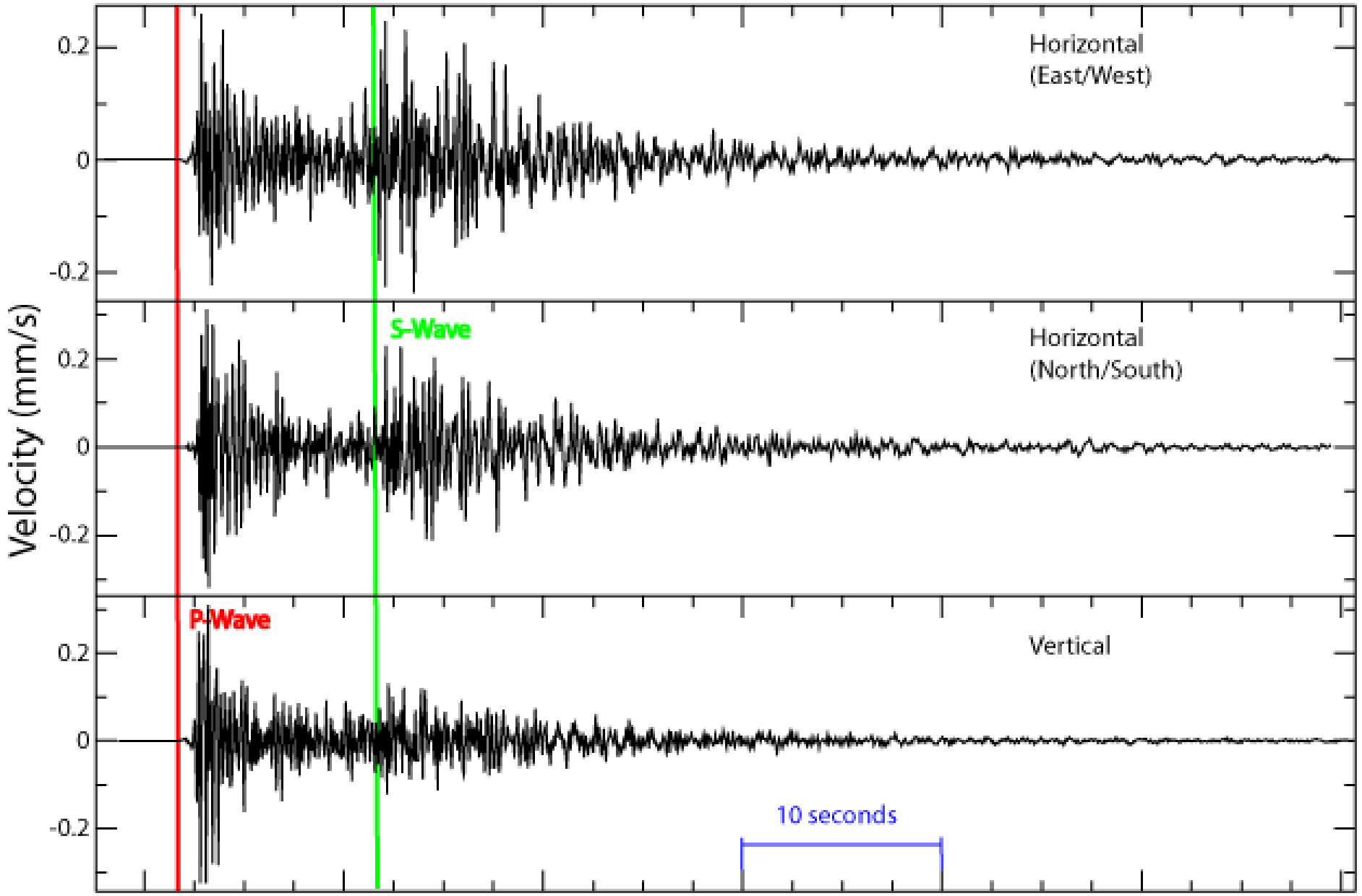
A seismograph records ground motion during an earthquake. When the ground is stationary, the pen draws a straight line across the rotating drum. When the ground rises abruptly during an earthquake, it carries the drum up with it. But the spring stretches, so the weight and pen hardly move. Therefore, the pen marks a line lower on the drum. Conversely, when the ground sinks, the pen marks a line higher on the drum. During an earthquake, the pen traces a jagged line as the drum rises and falls.





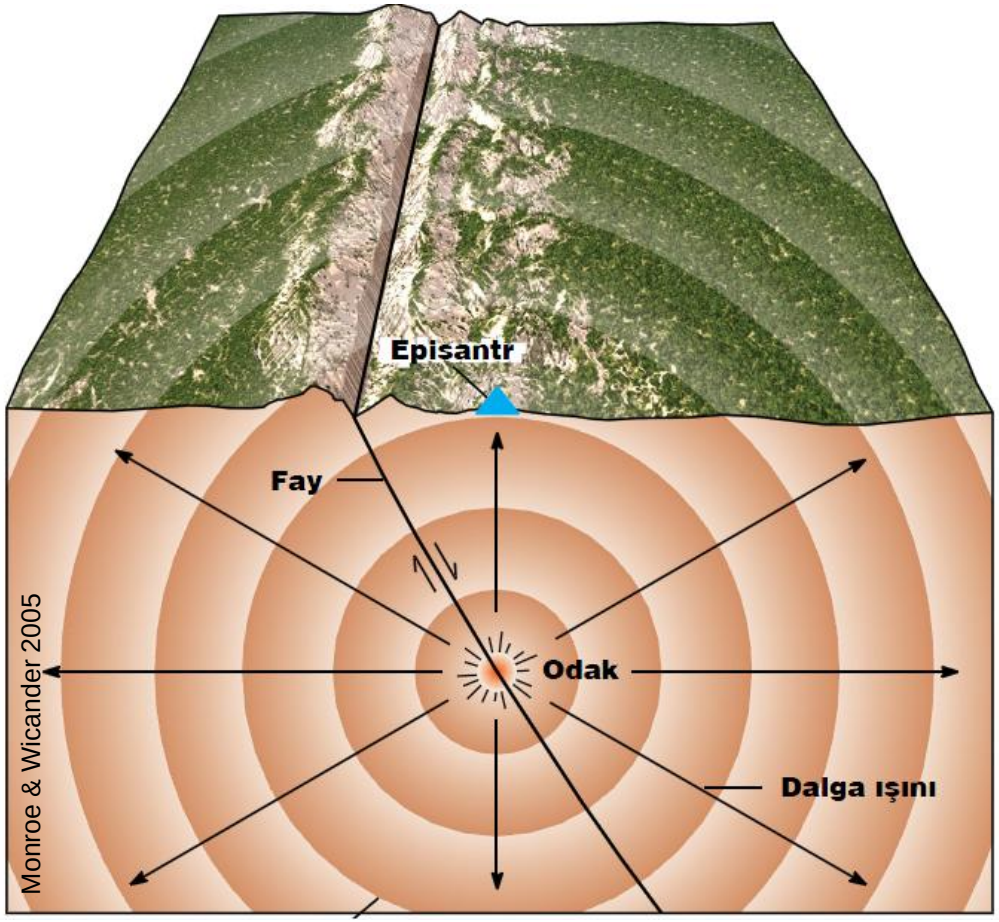


A horizontal-motion seismograph (upper left), a vertical- motion seismograph (upper right). Because of its inertia, the heavy mass that contains the marker remains stationary while the rest of structure moves along with the ground during an earthquake. Earthquakes recorded by seismograhs (lower photos) .



Seismograms showing the arrival order and pattern produced by an eartquake waves.

The Focus (Merkez-odak) and Epicenter (Merkez üstü) of an Eartquake



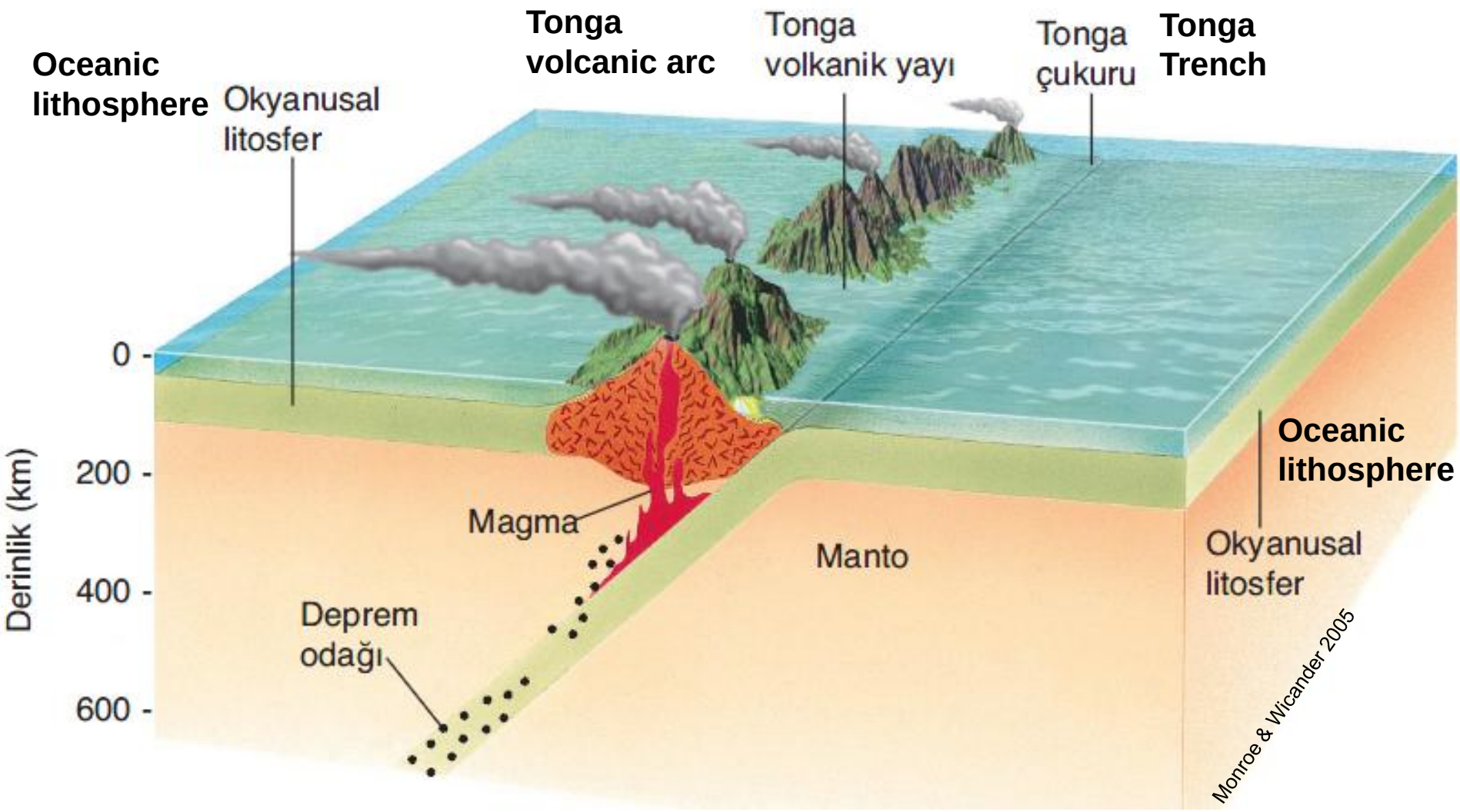
The **focus (iç merkez-odak)** of an earthquake is the location ***where rupture begins and energy is released***. The place on the surface vertically above the focus is **epicenter (dış merkez)**. Seismic wave fronts move out in all directions from their source, the focus of an earthquake.

Three categories of earhquakes based on focal-depth:

1. Shallow focus earthquakes. Focal depth less than 70 km.

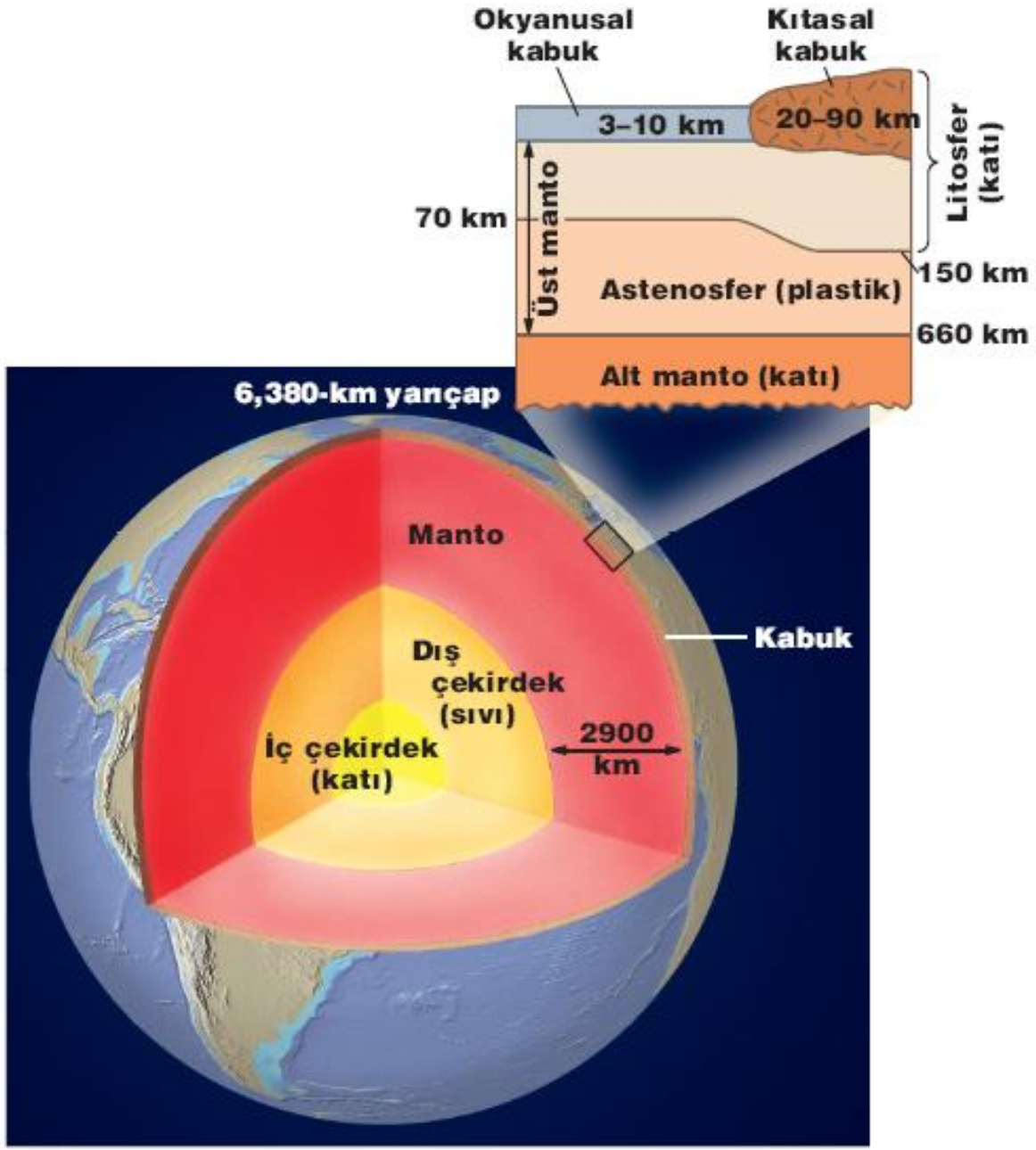
2. Intermediate focus earthquakes. Focal depth between 70-300 km.

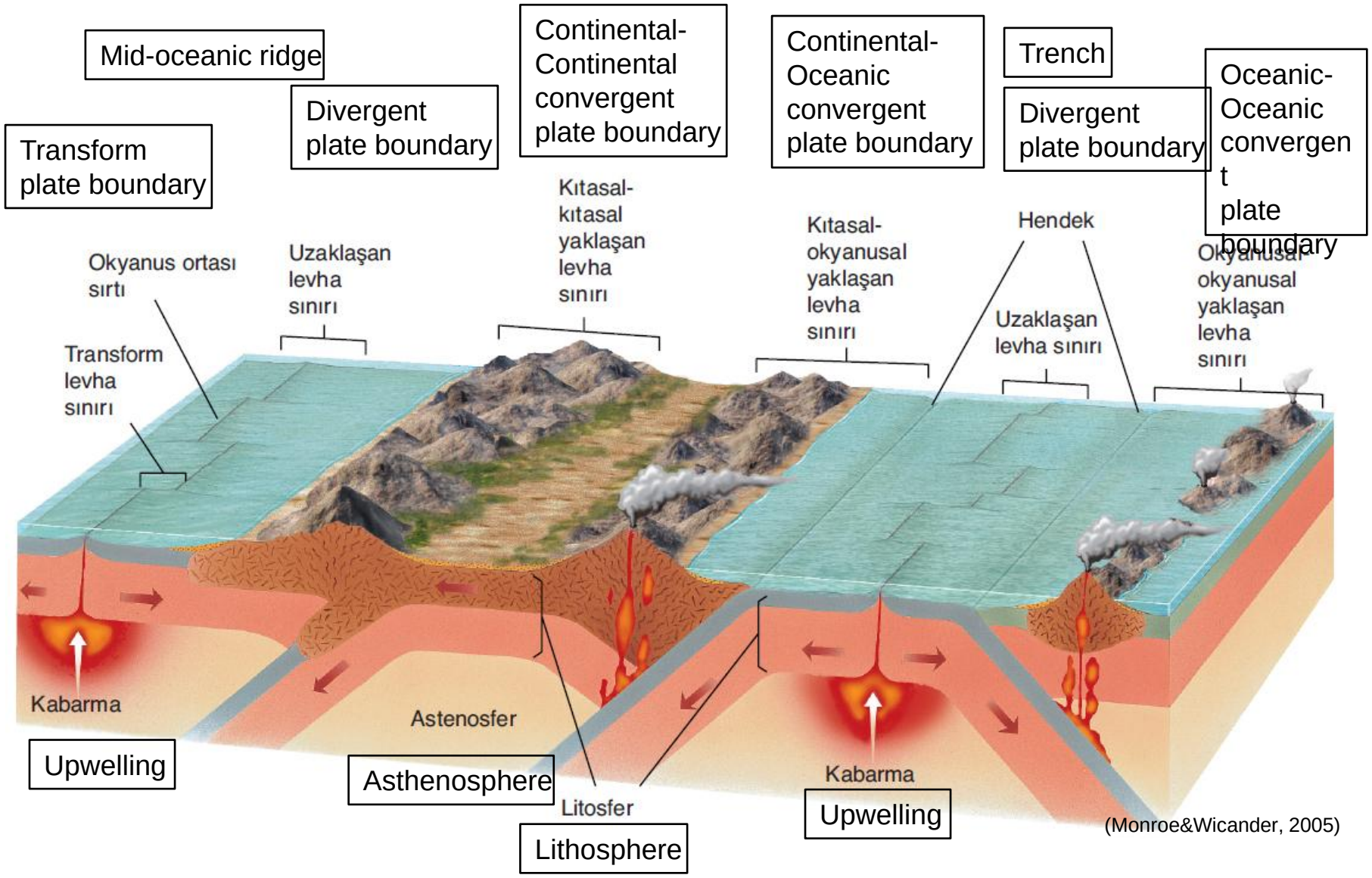
3. Deep focus earthqukes. Focal depth deeper than 300 km



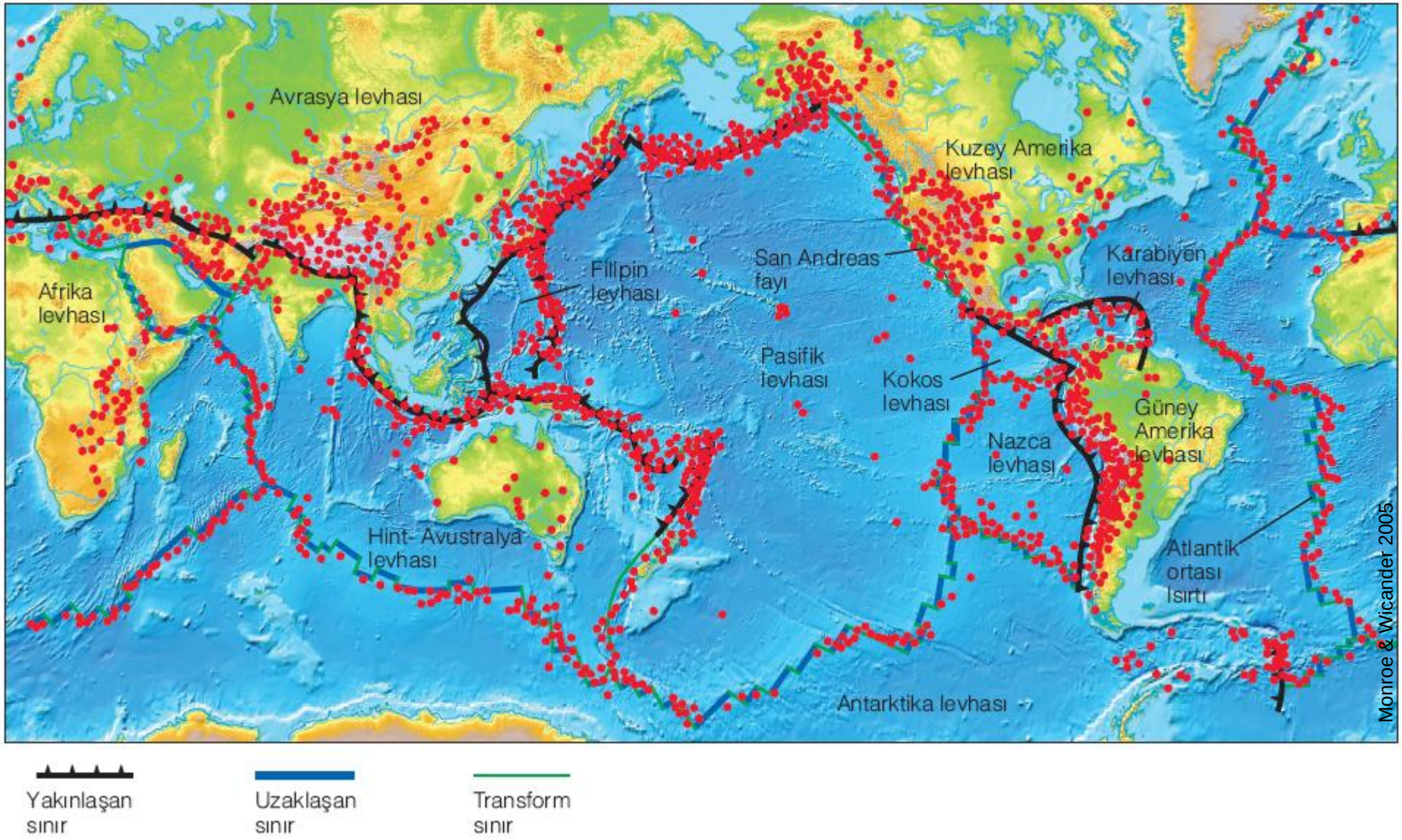
Focal depth increases in a well-defined zone that dips approximately 45 beneath the volcanic arc in the South Pacific. Dipping seismic zones are called **Benioff zones**.

WHERE DO EARTHQUAKES OCCUR, AND HOW OFTEN?





An idealized cross section illustrating the relationship between lithosphere and underlying asthenosphere and the three principal types of boundaries convergent (yaklaşan), divergent (uzaklaşan) and transform (transform).

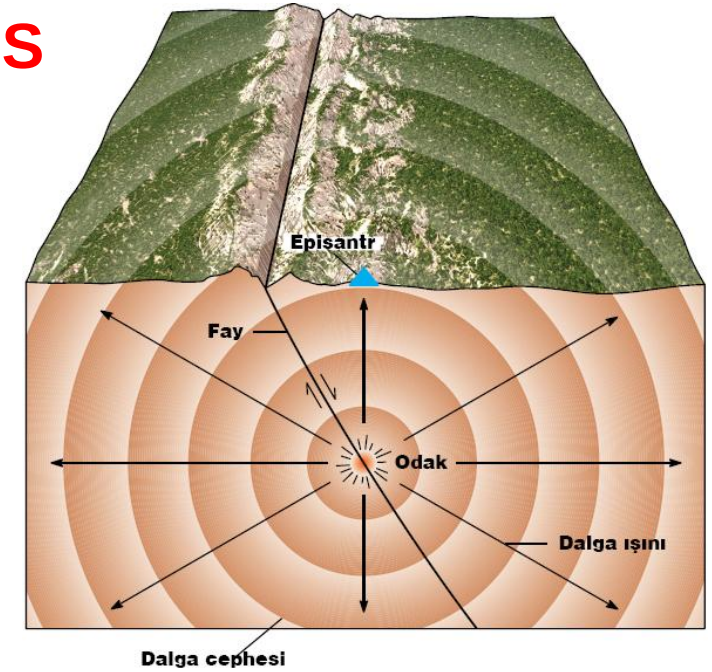


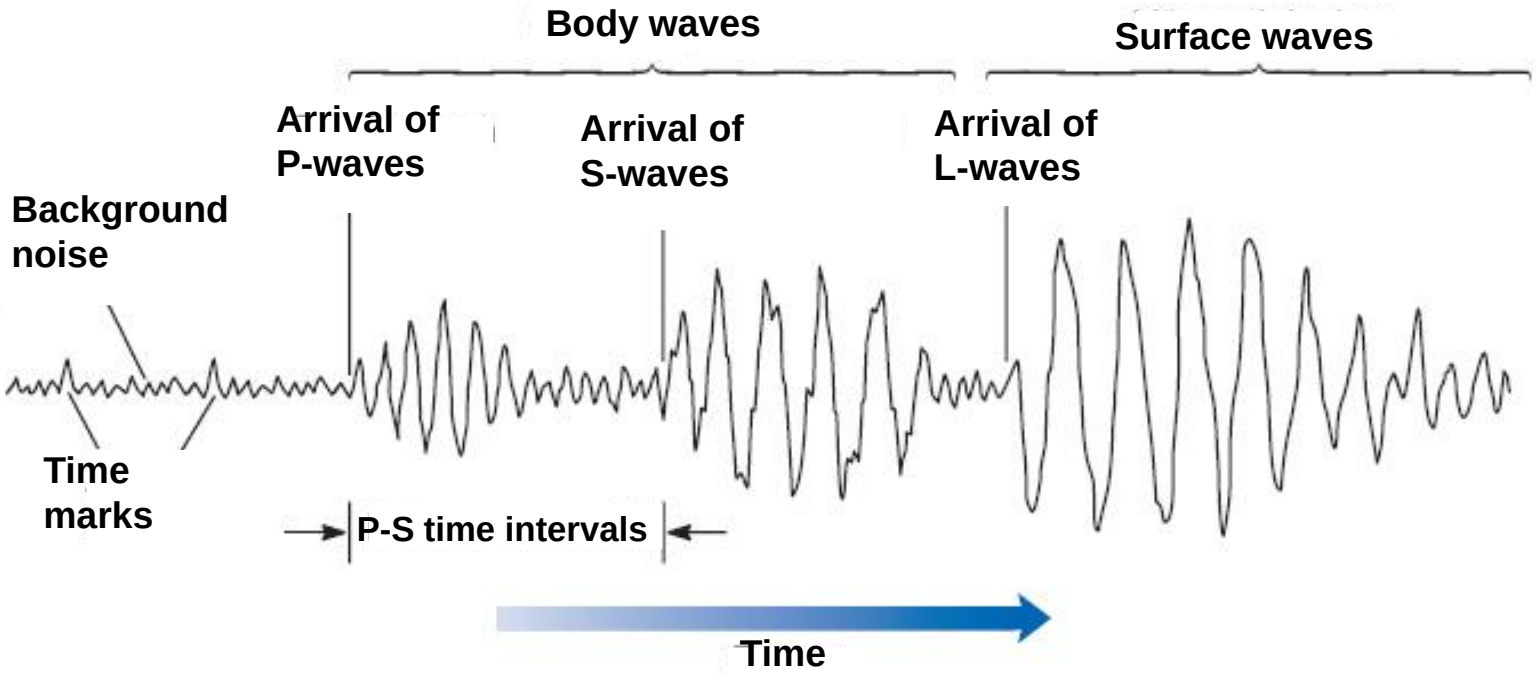
The relationship between plate boundaries and earthquake epicenters. %80 of earthquakes occurs around Pacific; %15 along Mediterranean-Asian belt; %5 either in intraplate or along mid-oceanic ridges. Red points show earthquake epicenters.

EARTHQUAKE (SEISMIC) WAVES

An earthquake generates two types wave:

1. Body waves (Cisim dalgaları)
2. Surface waves (Yüzey dalgaları)

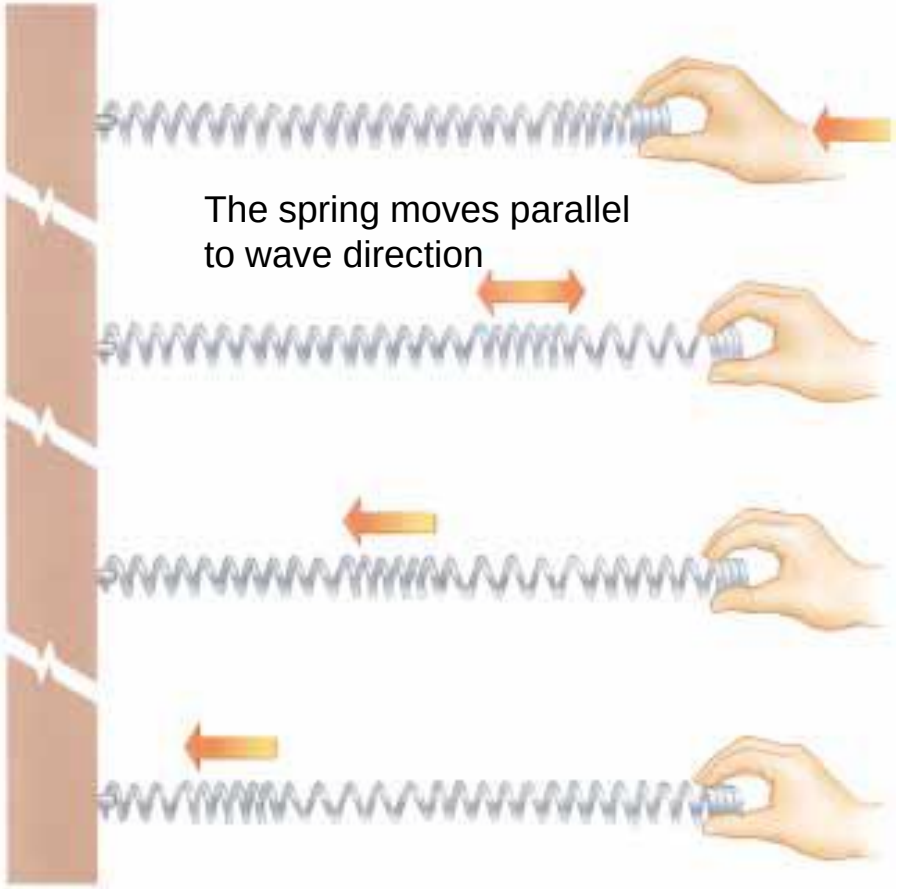


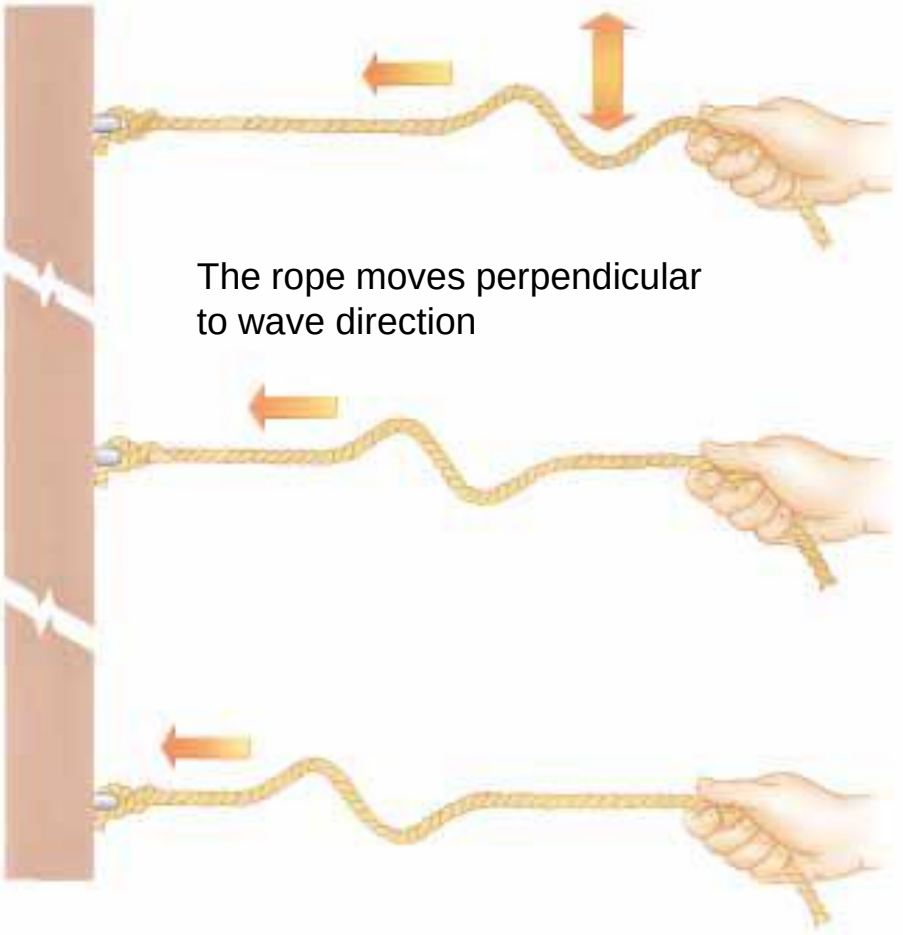


1. Body waves (Cisim dalgaları): An earthquake generates two types of body waves. **P-wave** or **primary waves** and **S-waves** or **secondary waves.**

P-waves are the **fastest** seismic waves and can **travel through solids, liquid and gases**. P-waves are compressional waves, or push-pull.

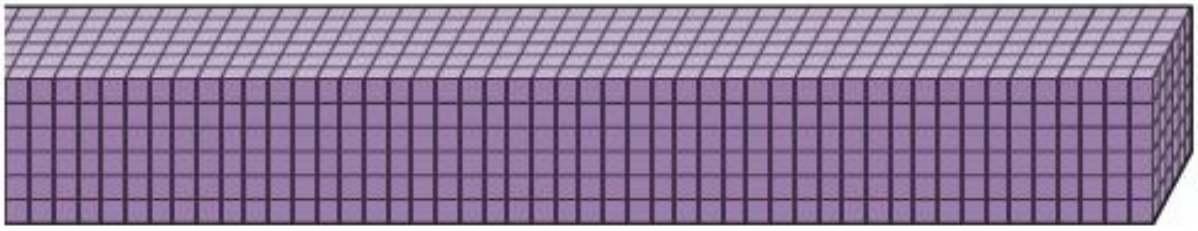
S-waves, are **slower** than P-waves and **can only travel through solids**. S-waves are shear waves because they move the material perpendicular to the direction of travel, thereby producing shear stresses in the material they move through.



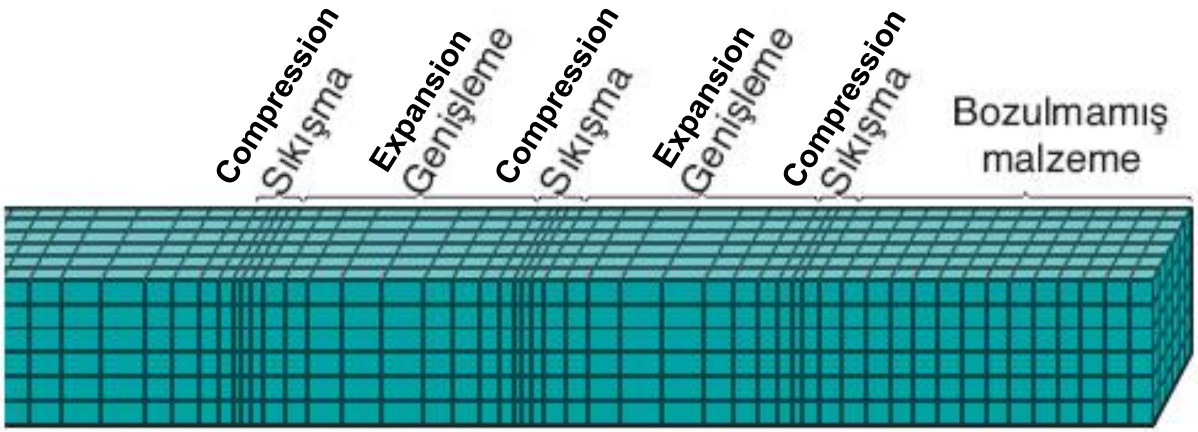


Model of a P wave; ***a compressional wave.*** The wave is propagated along the spring. The particles in the spring move parallel to the direction of wave propagation.

Model of an S wave; ***a shear wave***. The wave is propagated along the rope. The particles in the rope move perpendicular to the direction of wave propagation.

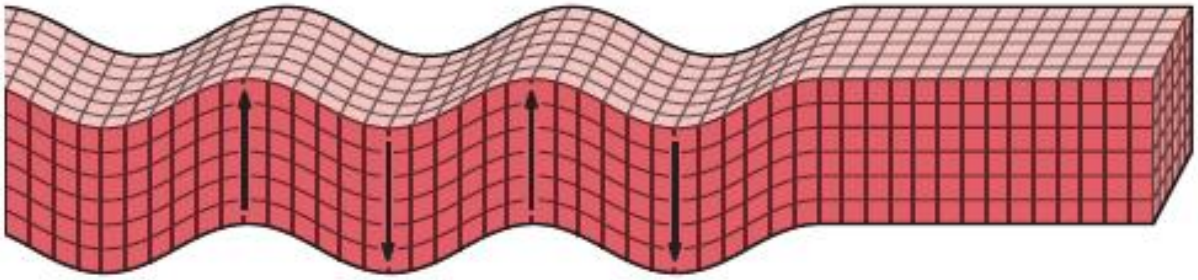


(a) Bozulmamış malzeme **Undisturbed material**



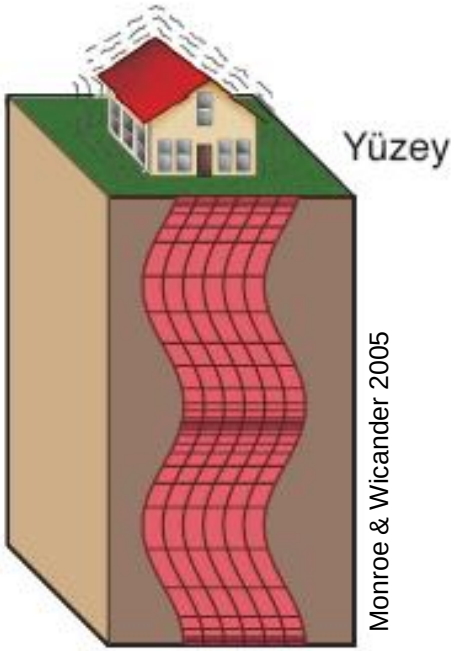
(b) Birincil dalga
Primary wave

Dalga hareketinin yönü
Direction of wave movement



Secondary wave **Wavelength**

(c) İkincil dalga

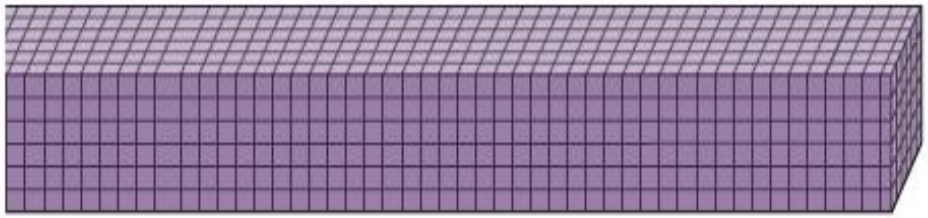


Focus
Odak

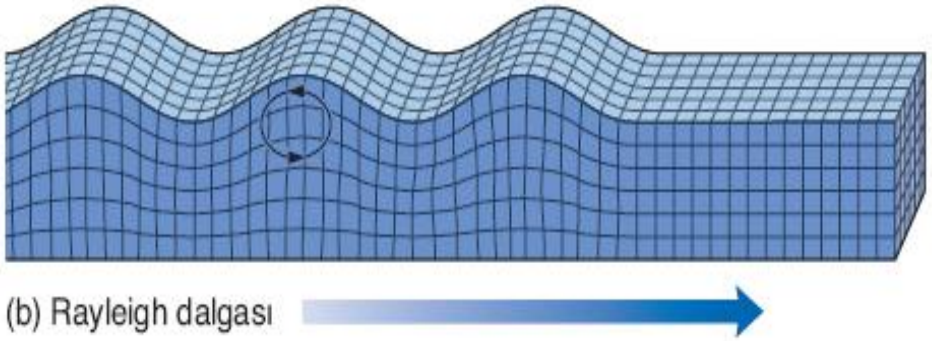
(d)

2. Surface waves: Surface waves travel along the surface of the ground, or just below it, and are slower than body waves. Surface waves generally produce a rolling or swaying motion, much like the experience of being in a boat.

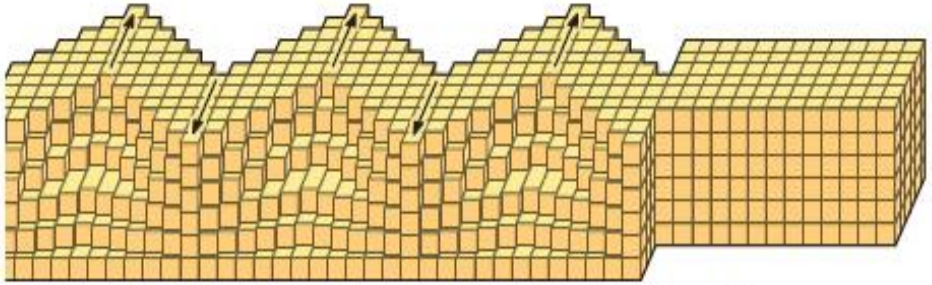
The two most important surface waves are **Rayleight waves (R-waves)** and **Love waves (L_waves).**



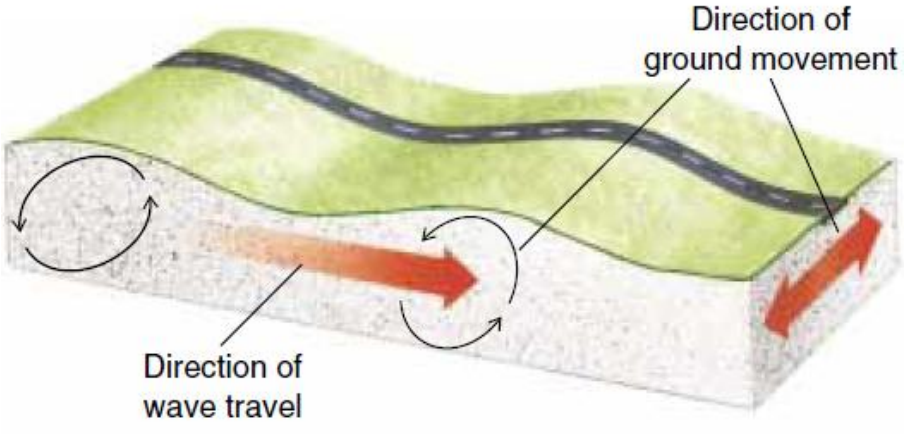
(a) Bozulmamış malzeme **Undisturbed material**



(b) Rayleigh dalgası



(c) Love dalgası



Rayleigh dalgası

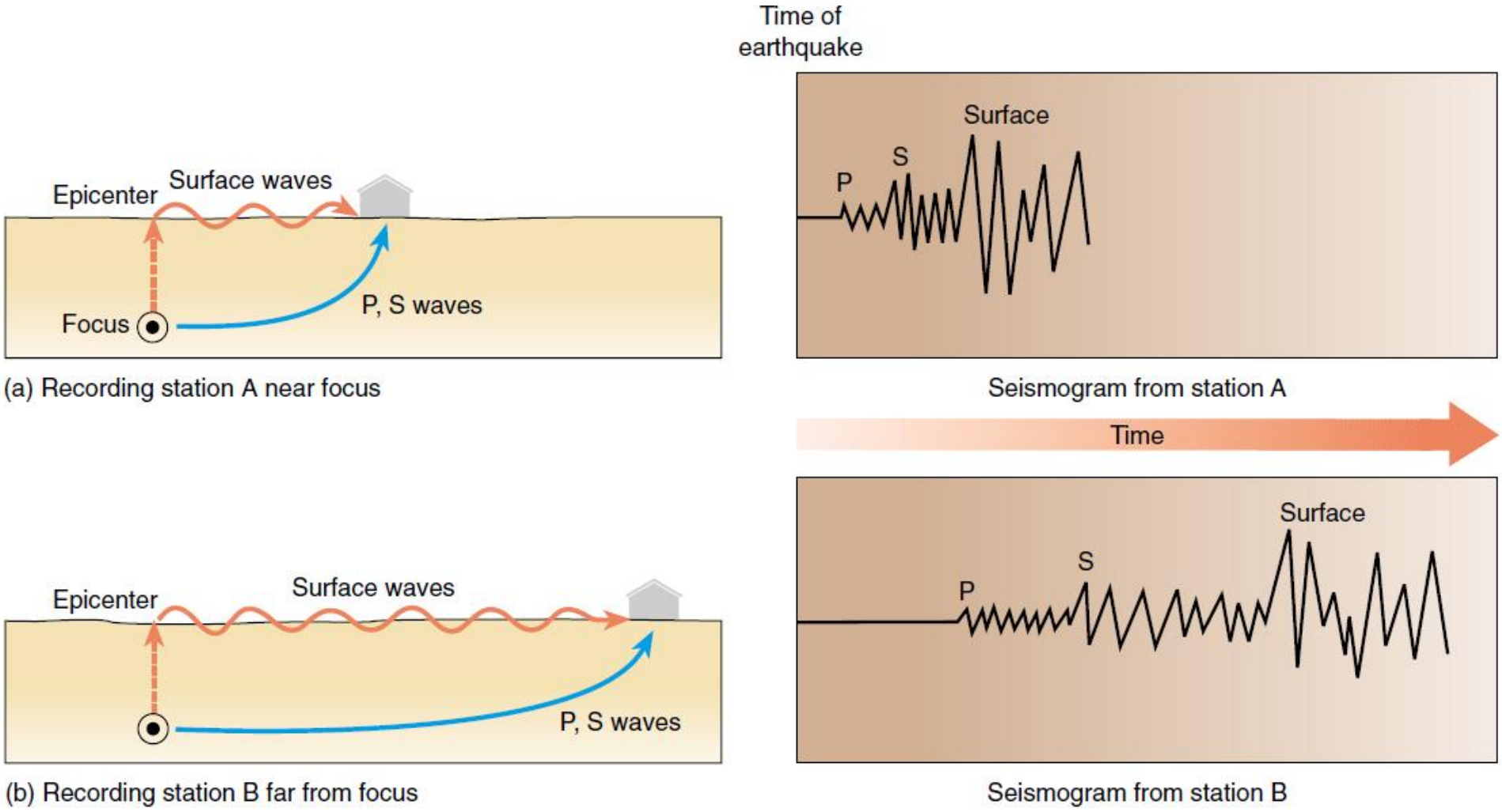
Love dalgası

(d)

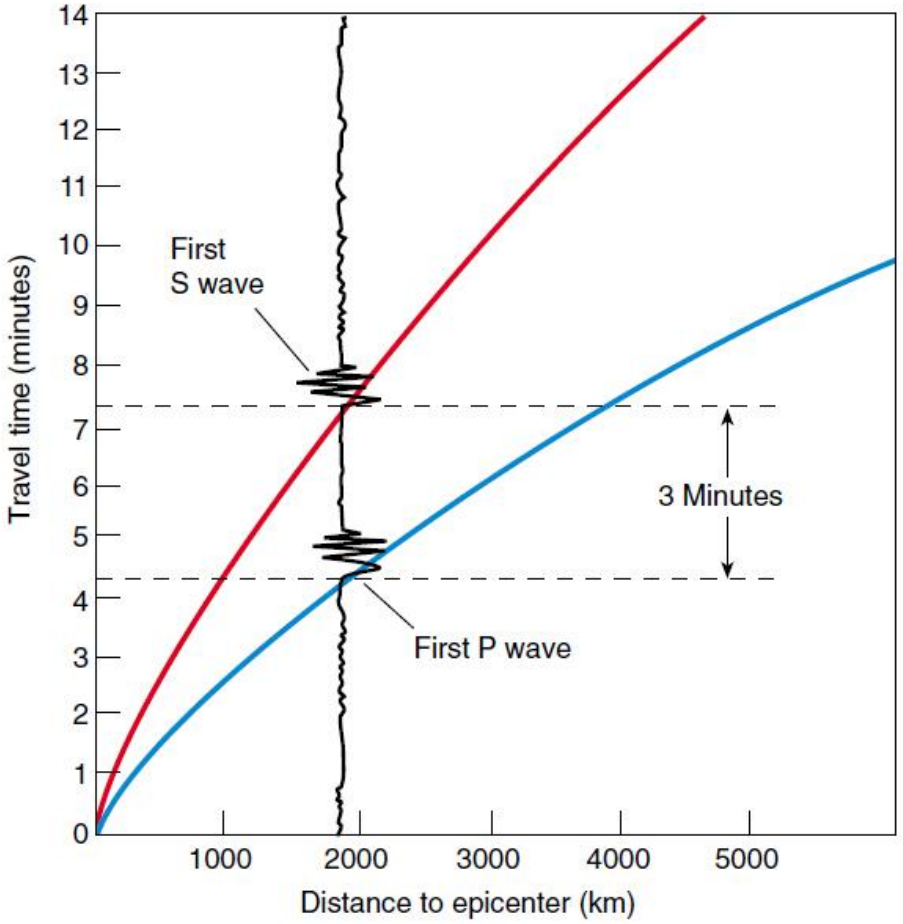
Monroe & Wicander 2005

(b) R-waves move material in an elliptical path in a plane oriented parallel to the direction of wave movement.
(c) L-waves move material back and forth in horizontal plane perpendicular to the direction of wave movement.
(d) The arrival of R- and L-waves cause the surface to undulate and shake from side to side..

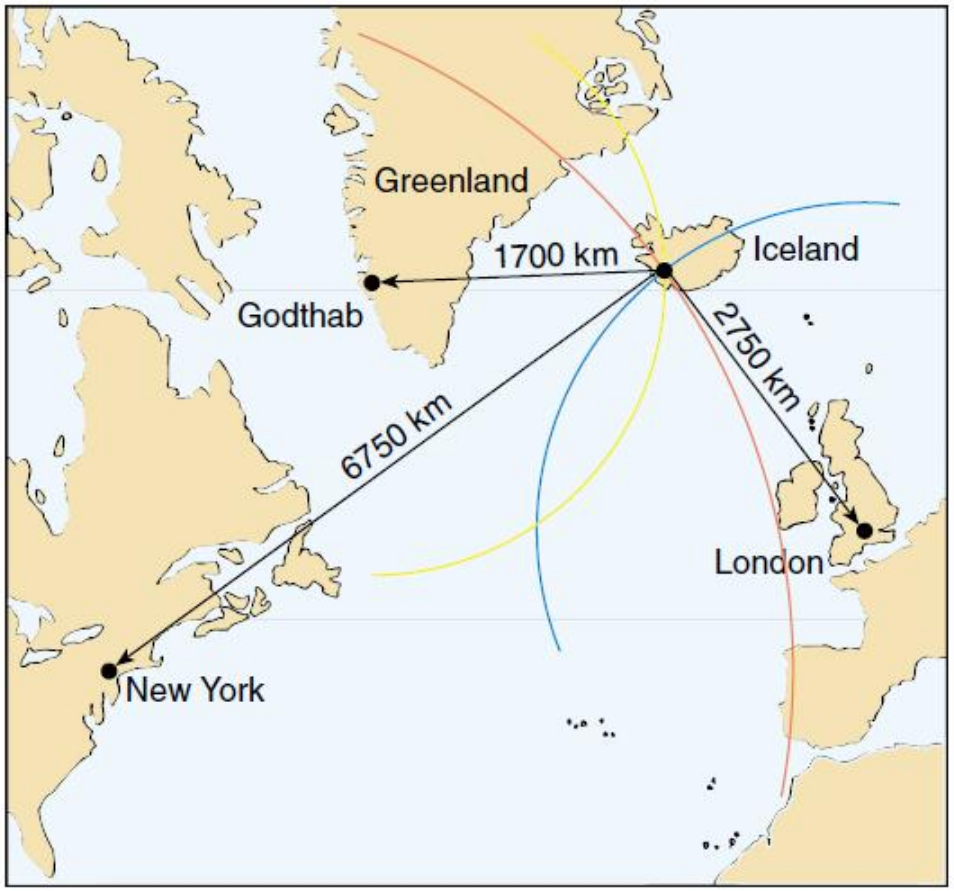
HOW IS AN EARTQUAKE'S EPICENTER LOCATED?



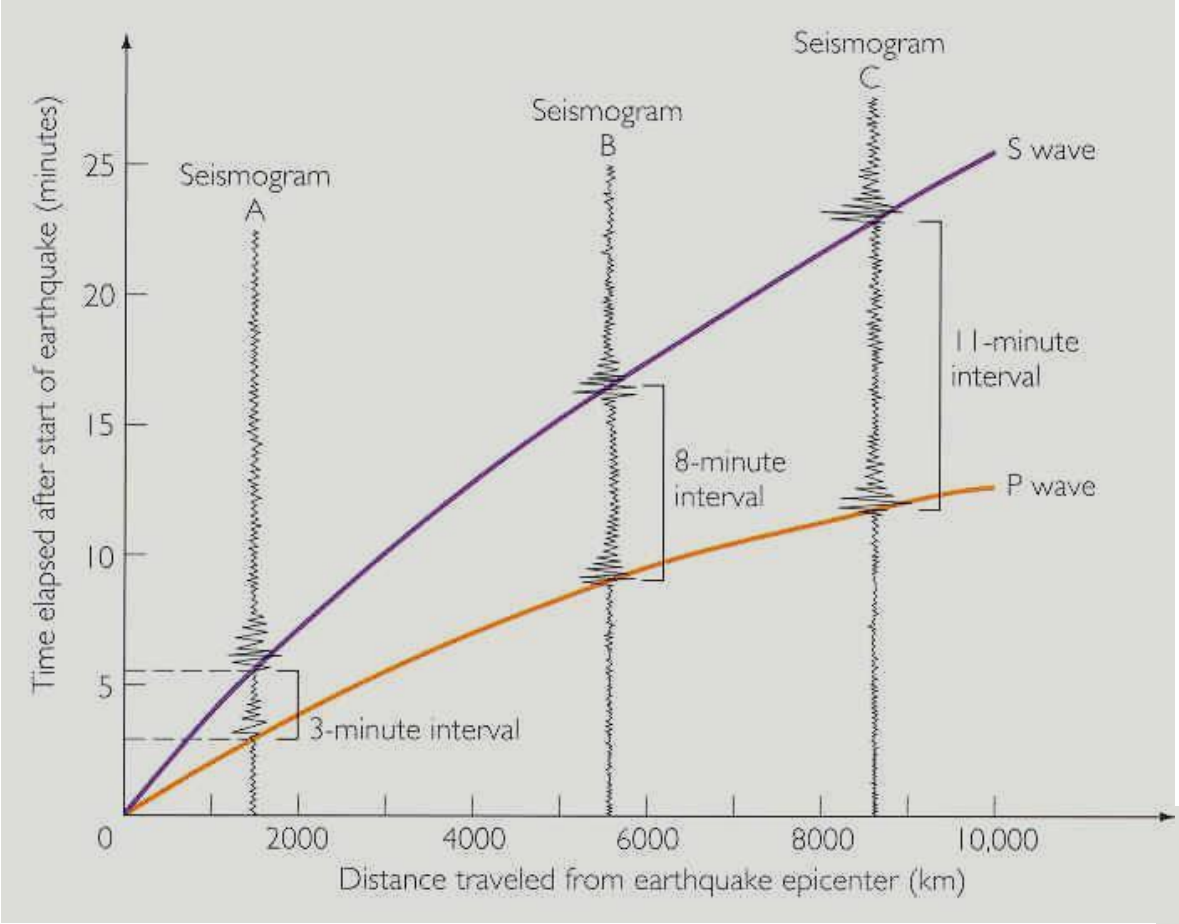
The time intervals between arrivals of P, S, and L waves at a recording station increase with distance from the focus of an earthquake.

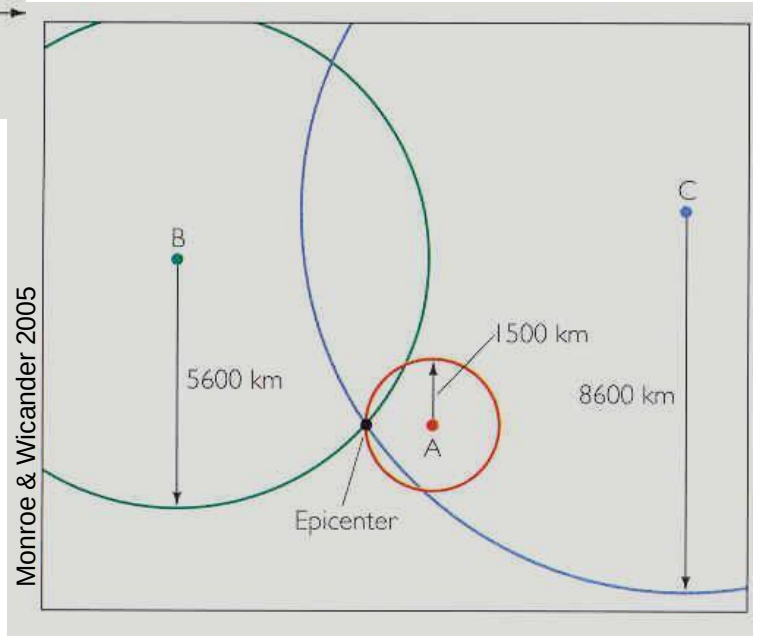


A time-travel curve. With this graph you can calculate the distance from a seismic station to the source of an earthquake. In the example shown, a 3-minute delay between the first arrivals of P waves and S waves corresponds to an earthquake with an epicenter 1900 kilometers from the
seismic station.



Locating an earthquake. The distance from each of three seismic stations to the earthquake is determined from time-travel curves. The three arcs are drawn. They intersect at only one point, which is the epicenter of the earthquake.


Seismogram C
Seismogram B
Seismogram A
S wave
P wave
11-minute interval
8-minute interval
3-minute interval
Time elapsed after start of earthquake (minutes)
0
5
10
15
20
25
2000
4000
6000
8000
10,000
Distance traveled from earthquake epicenter (km)


B
C
A
5600 km
1500 km
8600 km
Epicenter
Monroe & Wicander 2005

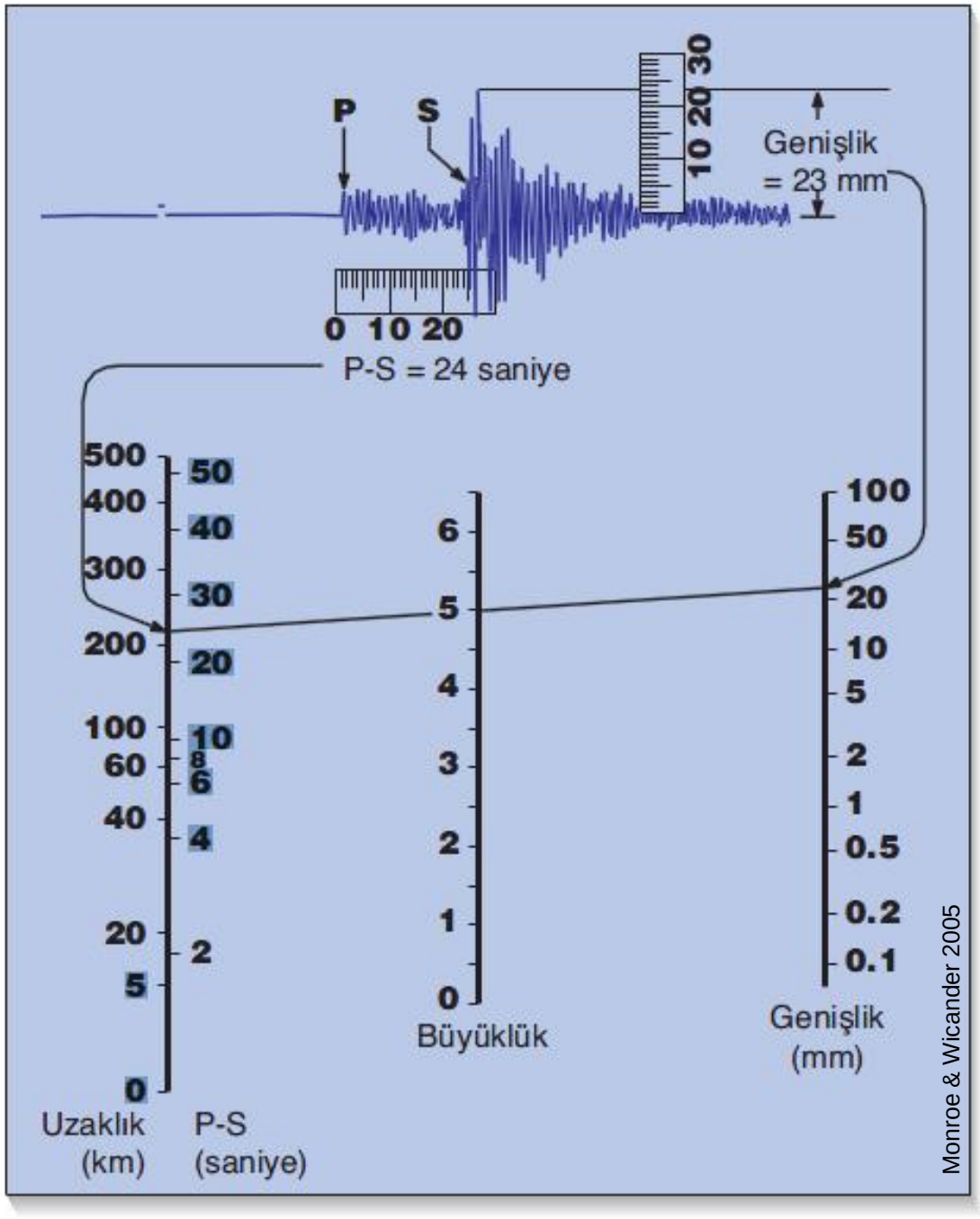
MEASUREMENT OF EARTHQUAKE MAGNITUDE (BÜYÜKLÜK) AND INTENSITY (ŞİDDET)

The **Richter magnitude scale** (**Richter scale**) assigns a magnitude number to quantify the size of an earthquake. The ***Richter scale***, developed in the 1930s, ***is a base-10 logarithmic scale, which defines magnitude as the logarithm of the ratio of the amplitude of the seismic waves to an arbitrary, minor amplitude, as recorded on a standardized seismograph at a standard distance.***

As measured with a seismometer, an earthquake that registers 5.0 on the Richter scale has a shaking amplitude 10 times greater than an earthquake that registered 4.0 at the same distance. As energy release is generally proportional to the shaking amplitude raised to the 3/2 power, an increase of 1 magnitude corresponds to a release of energy 31.6 times that released by the lesser earthquake. This means that, for instance, an earthquake of magnitude 5 releases 31.6 times as much energy as an earthquake of magnitude 4.

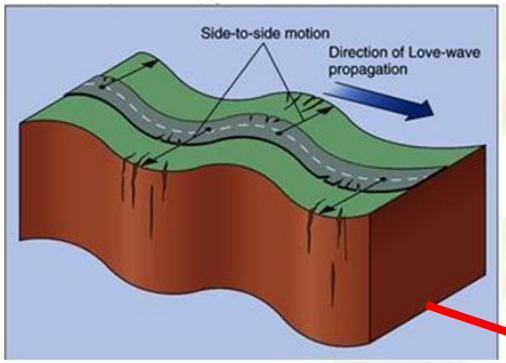
The intensity is a number (written as a Roman numeral) describing the severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures.

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest,especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.



The Richter Magnitude Scale measures the the total amount of energy released by an earthquake at its source. The magnitude (büyüklük) is determined by measuring the maximum amplitude (genişlik) of the largest seismic wave and marking it on the right-hand scale. The difference between the arrival times of the P- and S- waves (recorded in seconds) is marked on the left-hand scale. When a line is drawn between the two points, the magnitude of the earthquake is the point at which the line crosses the center scale.

The main natural hazards caused by an eartquake are mostly named as **“SEISMIC HAZARDS”**.



Seismic hazards that earthquakes may produce

Ground shaking

Surface fractures

Mass movements

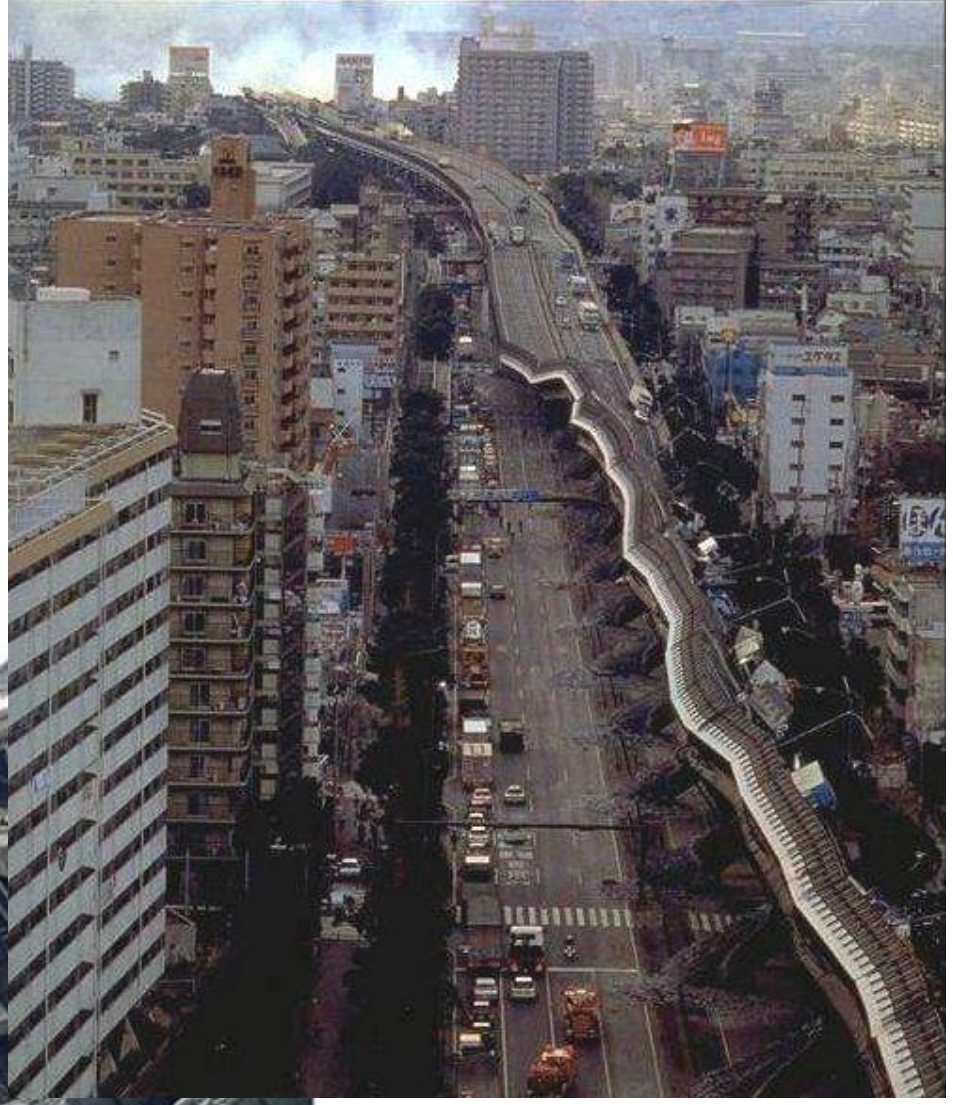
Liquefaction & lateral spreading

Tsunamies

GROUND SHAKING

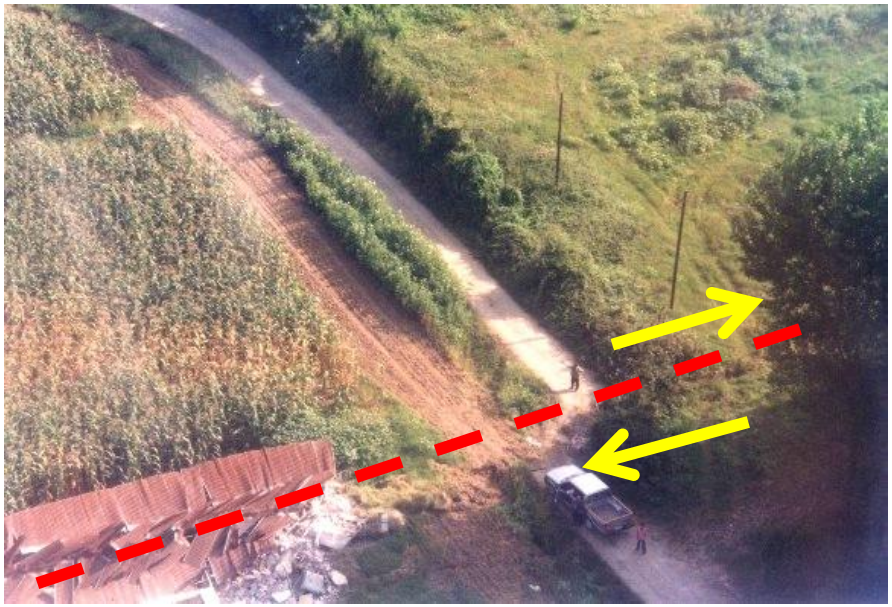
1995 Kobe, M: 7.2

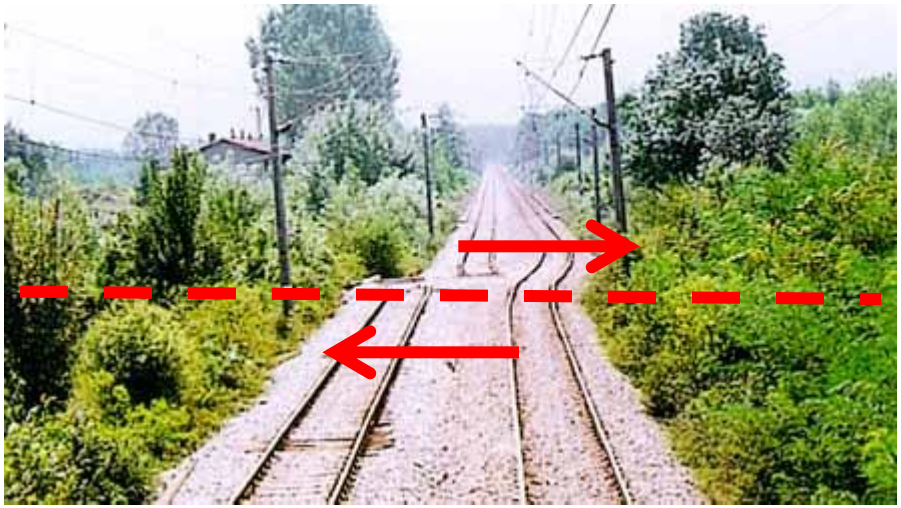
1995 kobe, M: 7.2



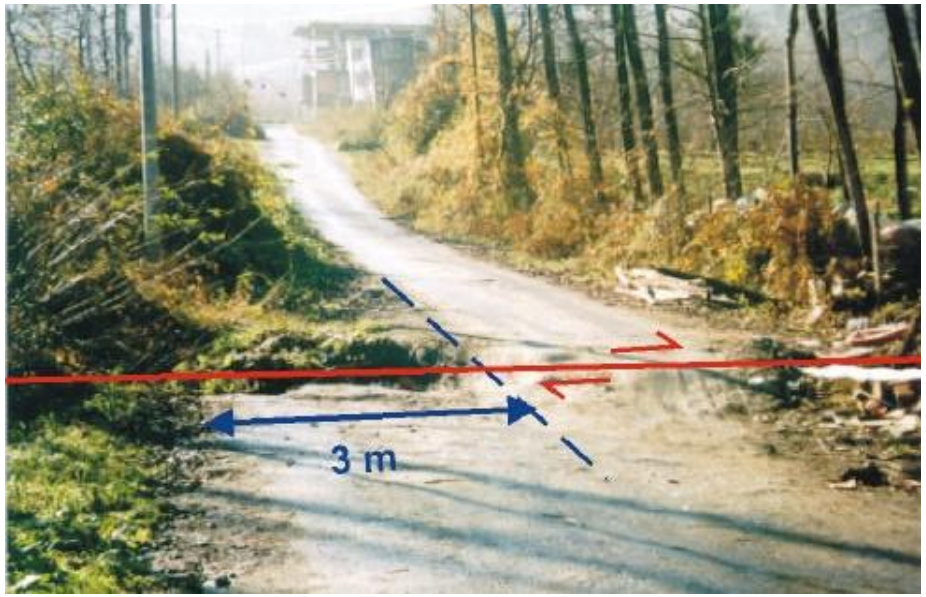
SURFACE FRACTURES

1999 Kocaeli Earthquake





2010 Darfield D. (Y. Zelanda)

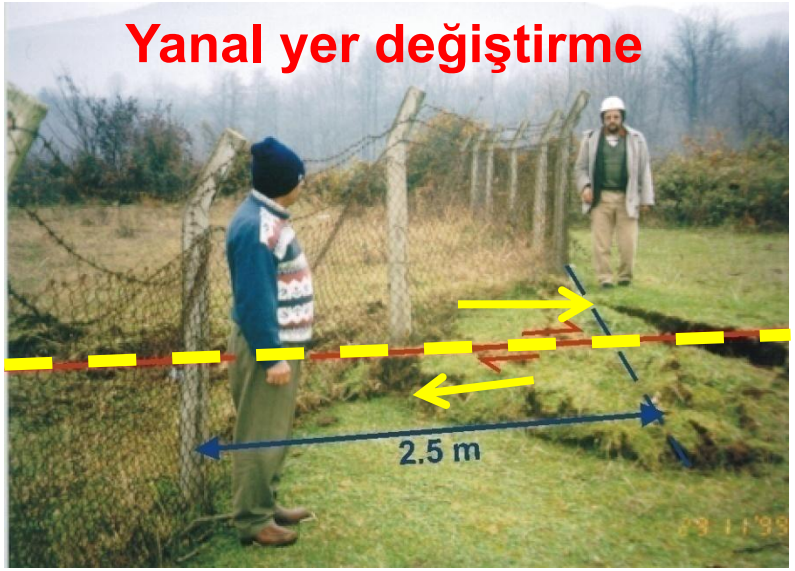


1999 Düzce Earthquke *(Aydan vd., 2000b)*

1999 Kocaeli Earthquake *(Aydan vd., 2000a)*

Düzce Depremi (12 Kasım 1999)

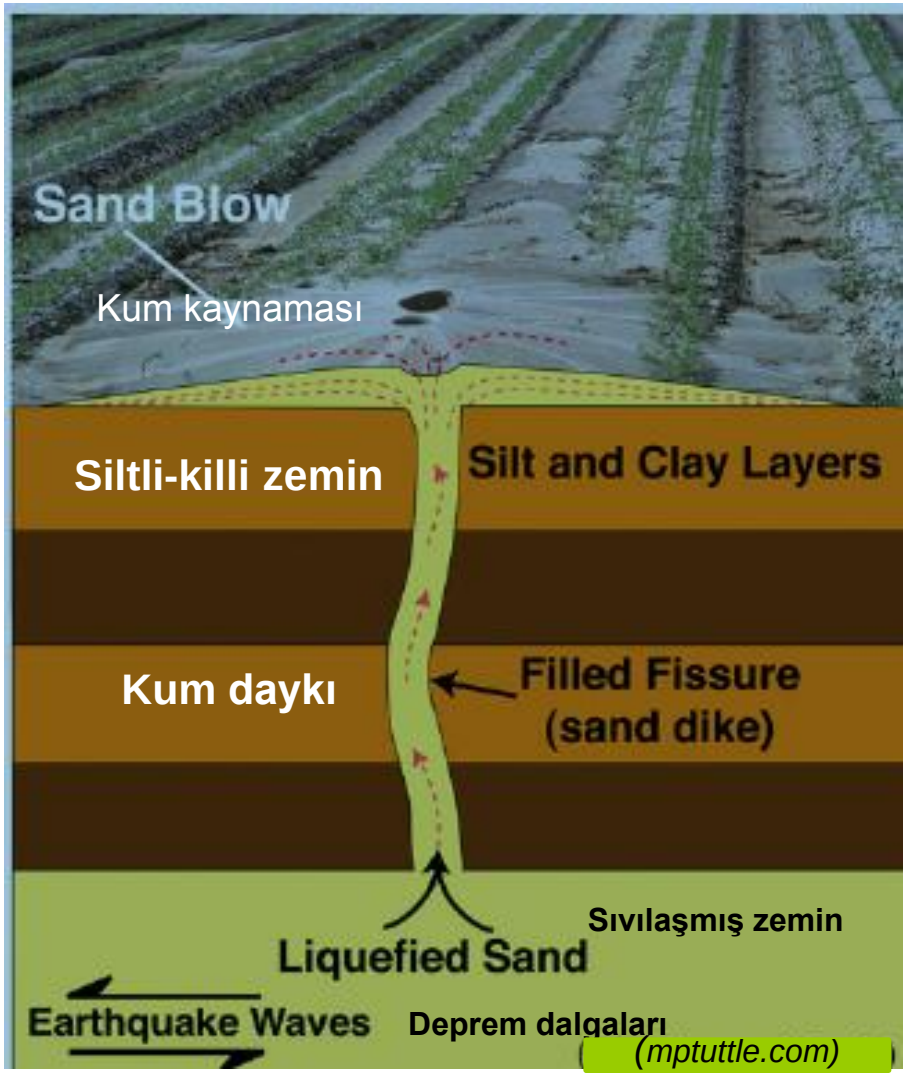
(Aydan vd., 2000b)

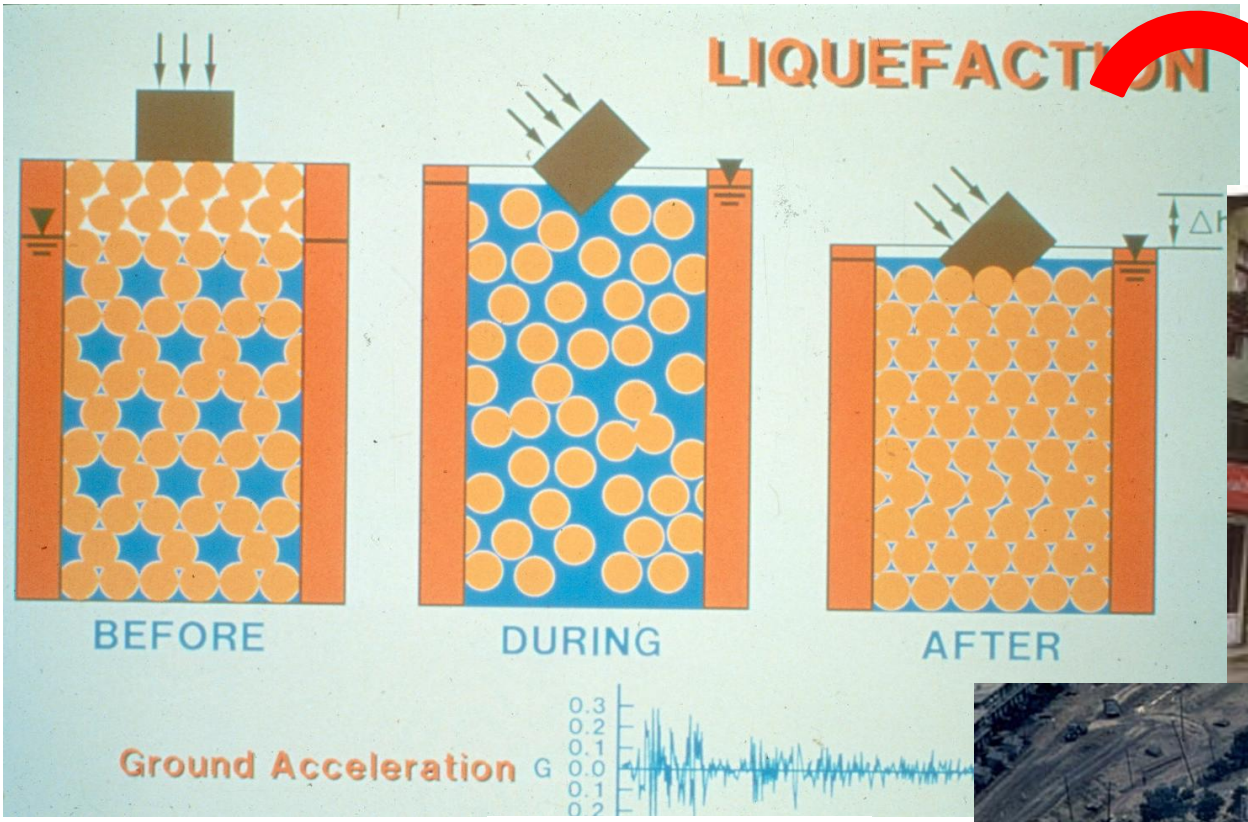


(Aydan vd., 2000b)

LIQUEFACTION (SIVILAŞMA)

Loose sand and silt that is saturated with water can behave like a liquid when shaken by an earthquake Earthquake waves cause water pressures to increase in the sediment and the sand grains to lose contact with each other, leading the sediment to lose strength and behave like a liquid. The soil can loose its ability to support structures, flow down even very gentle slopes, and erupt to the ground surface to form sand boils. Many of these phenomena are accompanied by settlement of the ground surface — usually in uneven patterns that damage buildings, roads and pipelines





(Mitchell, 2002)

1999 Kocaeli Depremi

(Aydan vd., 2000a)

Yer ivmesi

(Committee on Earthquake Engineering, 1985')

SAND BLOW

1964 Alaska Depremi, Mw: 9.2, Ms: 8.4

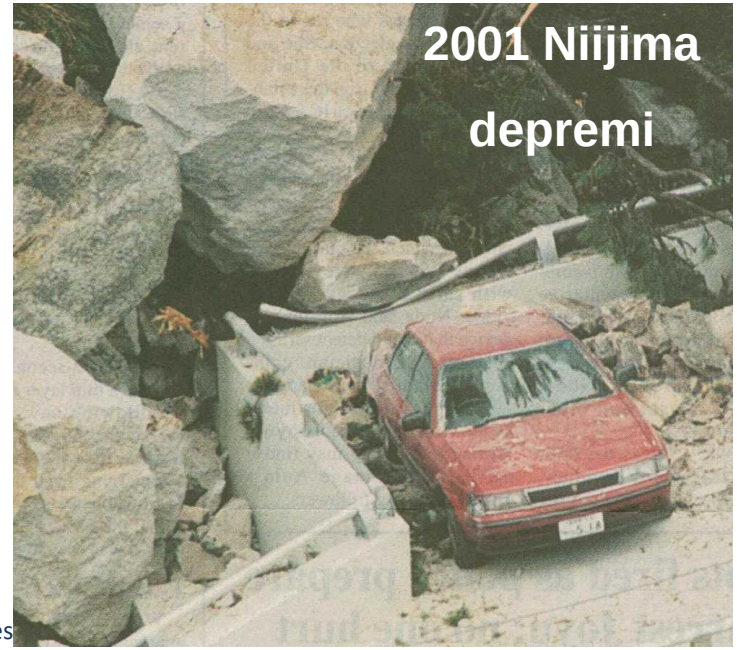
LANDSLIDES TRIGGERED BY EARTHQUAKES

2011 Christchurch (Yeni Zelanda)

Bakacak E-5 Karayolu Dolgusu Duraysızlığı (1999 Düzce Depremi)

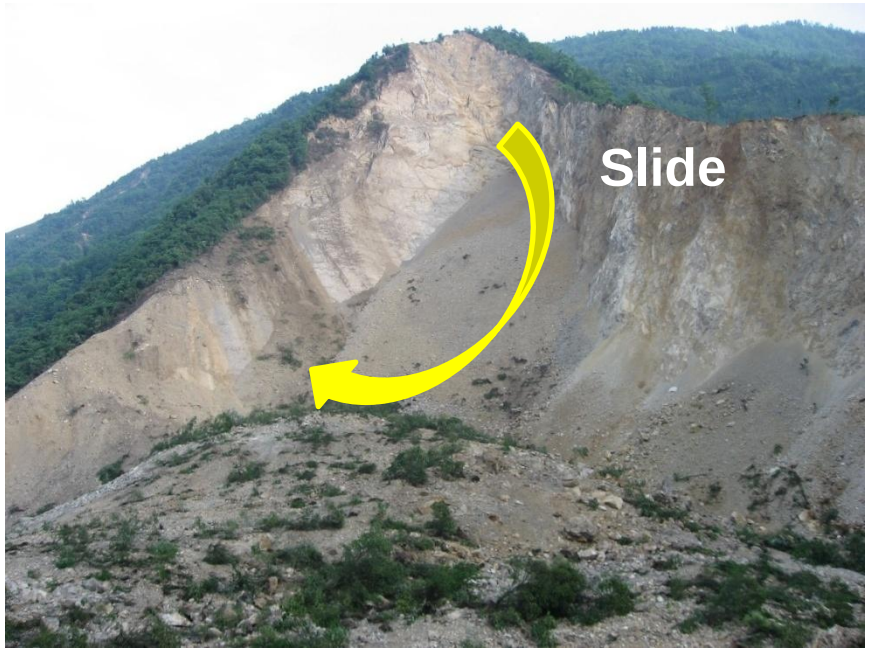
(Foto: Ö. Aydan)

Japonya



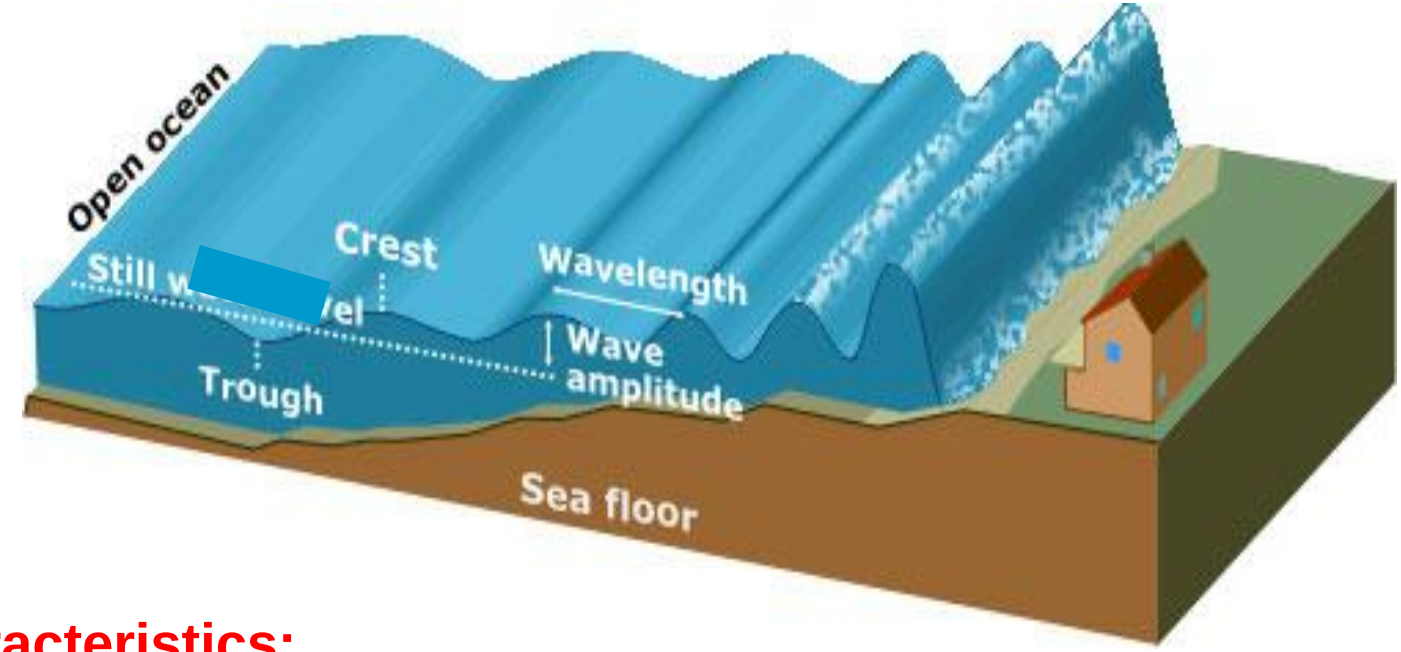
(Aydan, 2012)

2008 Wenchuan Depremi (Çin): 900'den fazla heyelan



(Aydan, 2012)

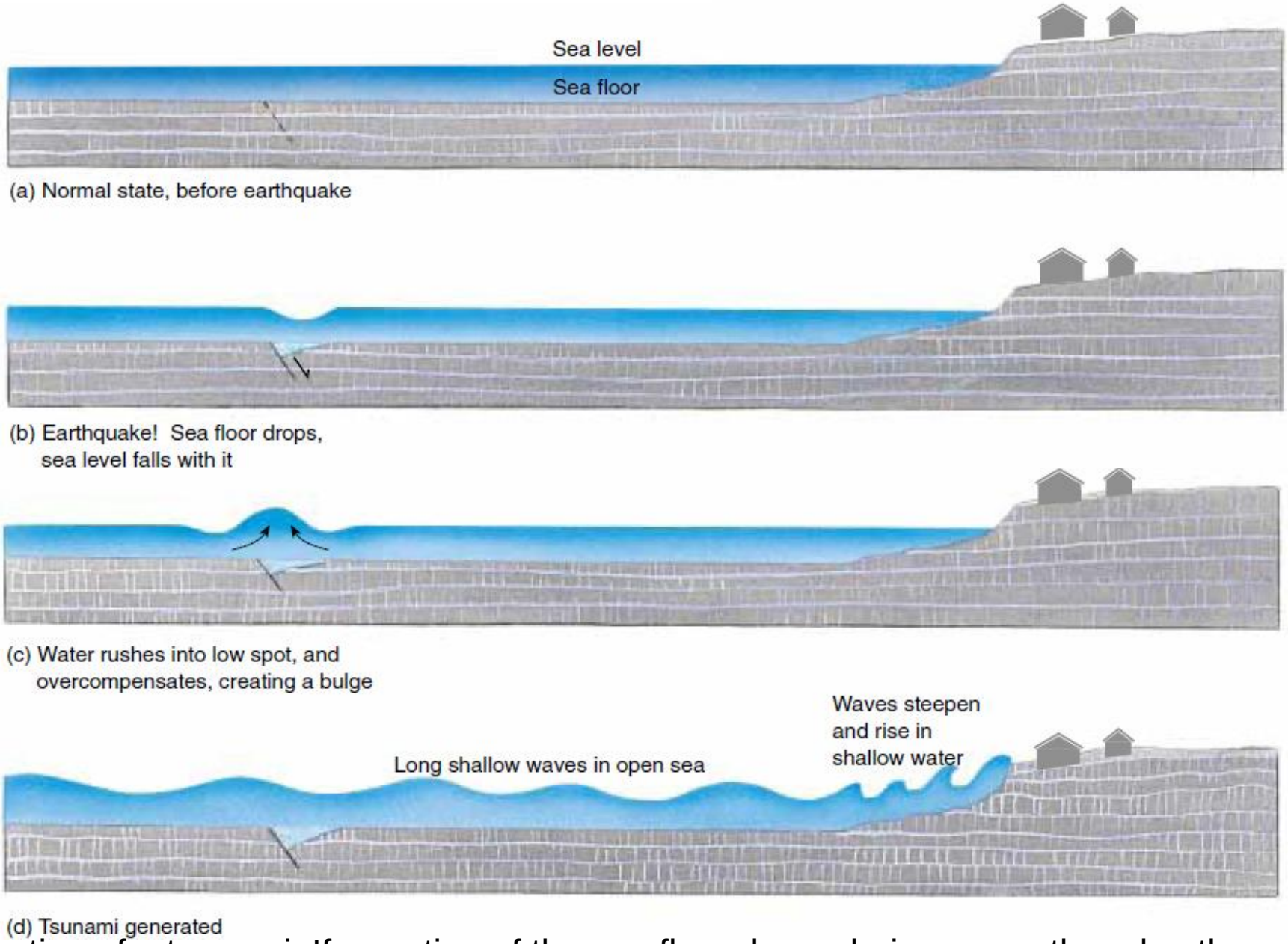
TSUNAMIES



(www.coursehero.com...619939-EPS131)

Characteristics:

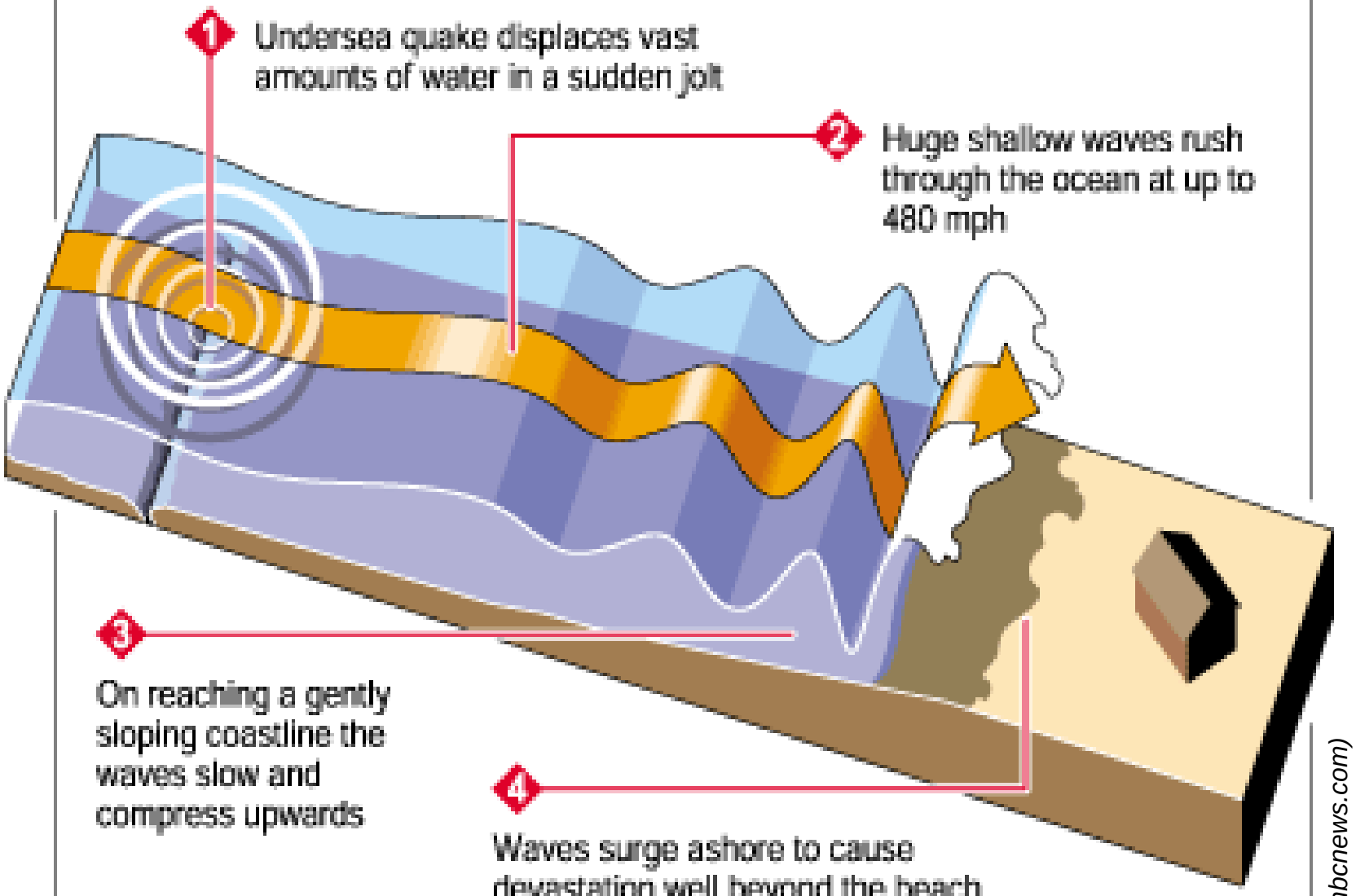
- Wave period: 2-200 min.
- Height: 10-100 m
- Speed: 200 m/s (440 mil/saat)



Formation of a tsunami. If a portion of the sea floor drops during an earthquake, the sea level falls with it.Water rushes into the low spot and overcompensates, creating a bulge. The long, shallow waves build up when they reach land.

HOW TSUNAMI FORM

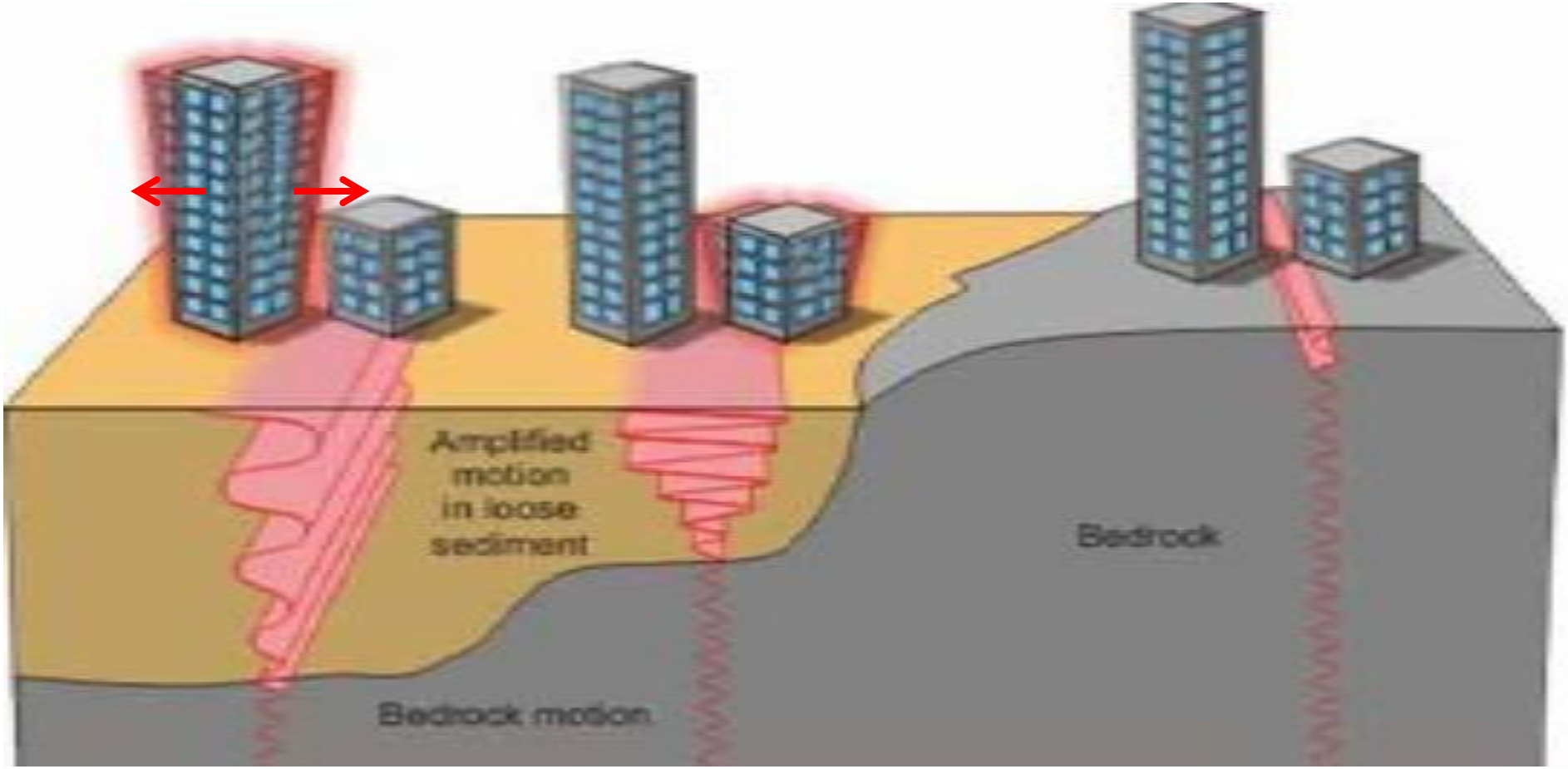
The world's biggest quake in 40 years unleashed walls of water that devastated coastlines around the Indian Ocean.

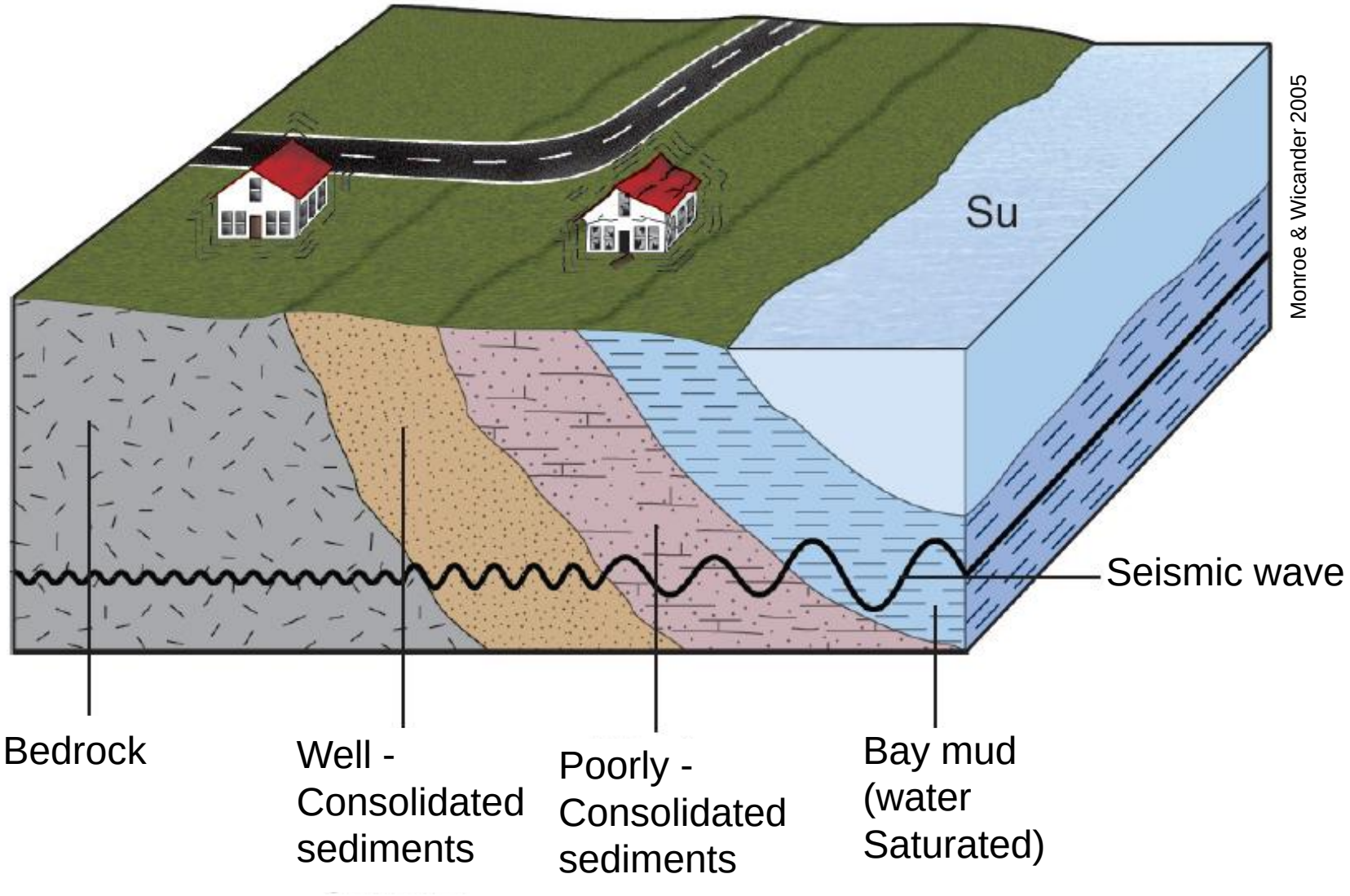


(minbcnews.com)

2004 Sumatra Depremi, Mw: 9.1

SITE AMPLIFICATION
(Zemin Büyütmesi)





The amplitude and duration of seismic waves generally increase as they pass from bedrock to poorly consolidated or water saturated materialThus structures built on weaker material typically suffer greater damage than similar structures built on bedrock.

FIRES

1906 San Francisco

(earthquake.usgs.gov)

(www.coursehero.com)

1906 San Fransisco

Yangınlar sarsıntının neden olduğu hasarın **on katı hasara** neden olmuştur.

(www.coursehero.com)

Fıres related with broken of gas pipes (1994 Northridge D., ABD)

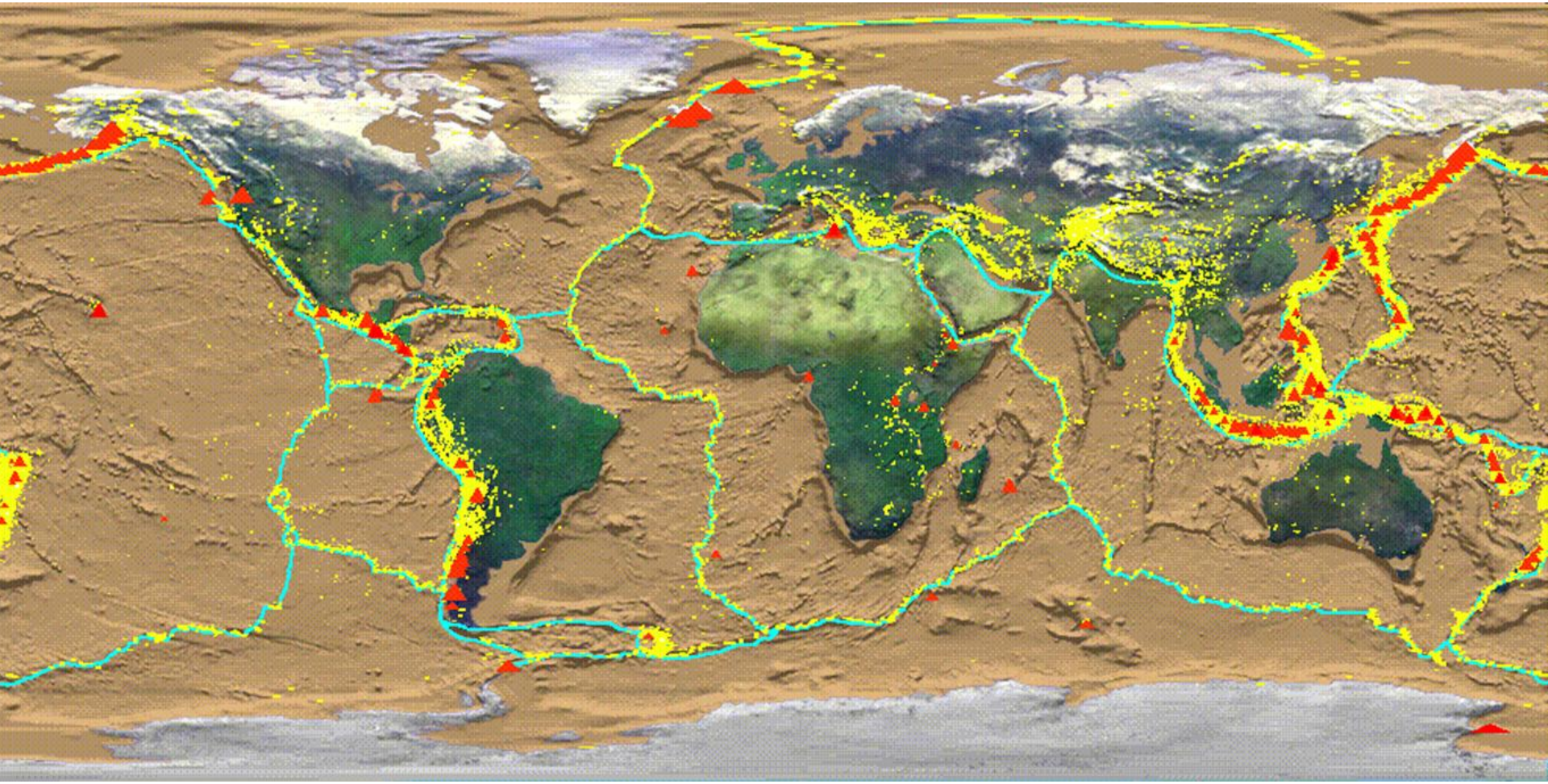
(Foto: M. Rymer)

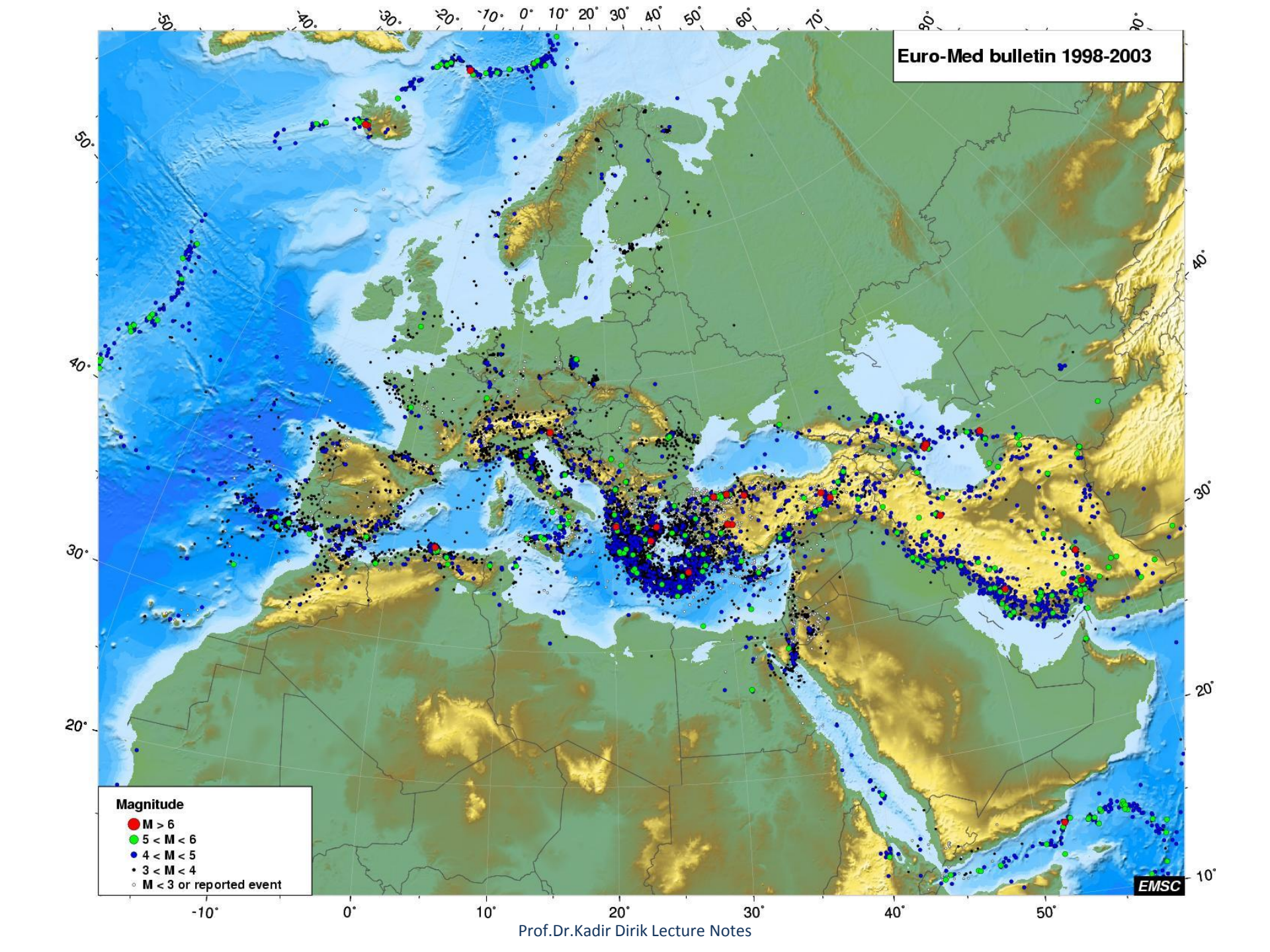
1999 Kocaeli

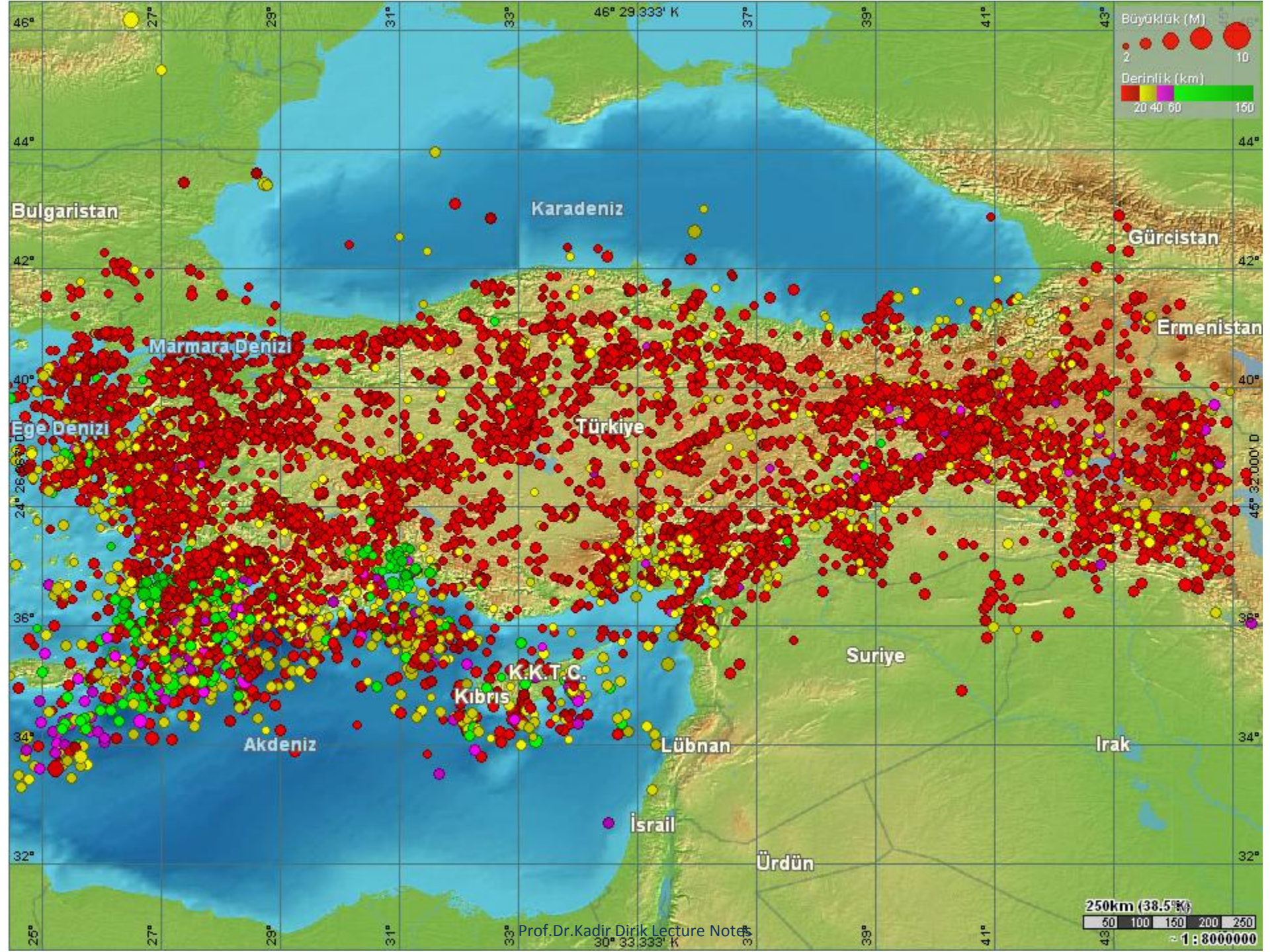
(Fotolar: Internet)

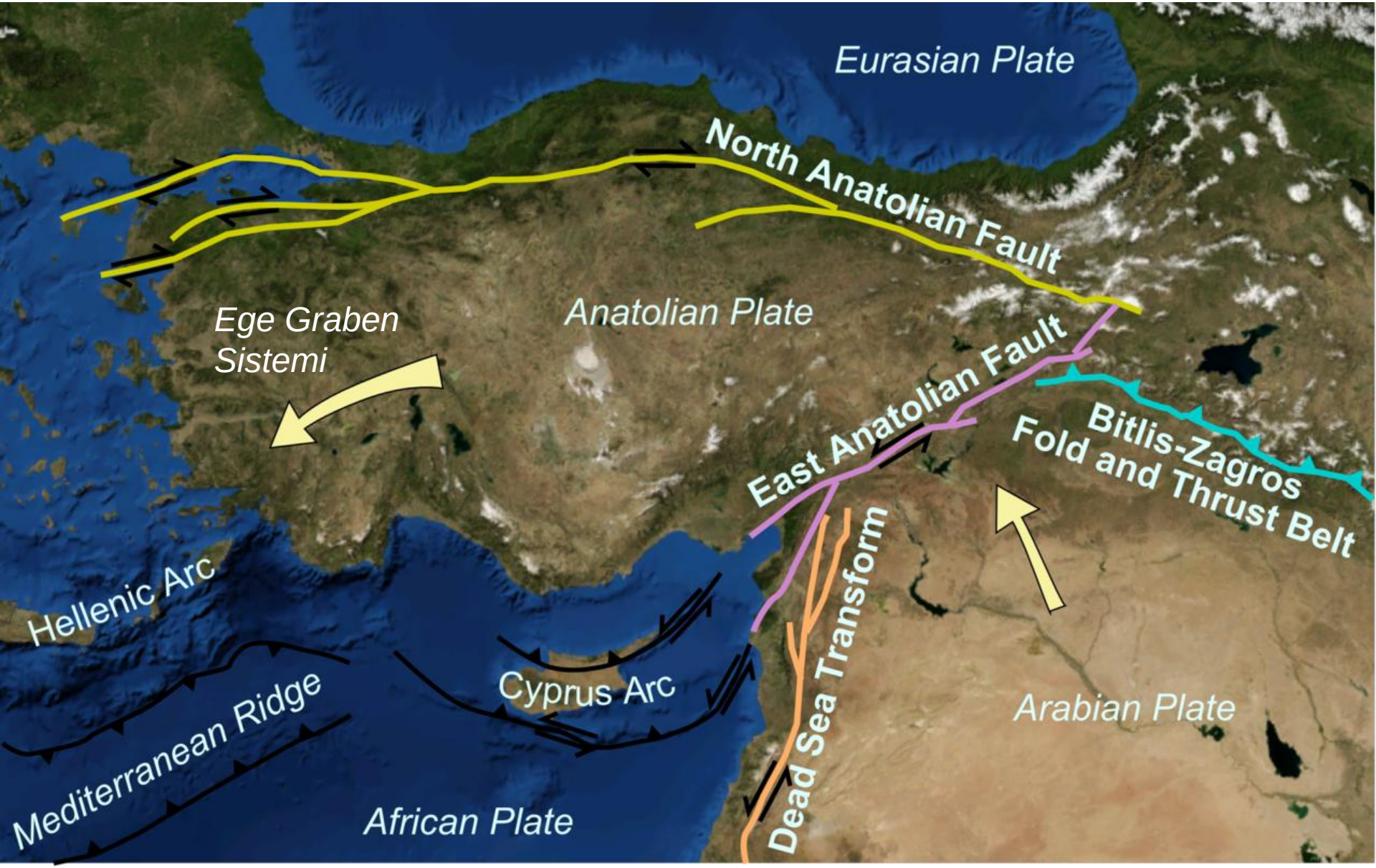
2011 Japonya Depremi, Mw: 9

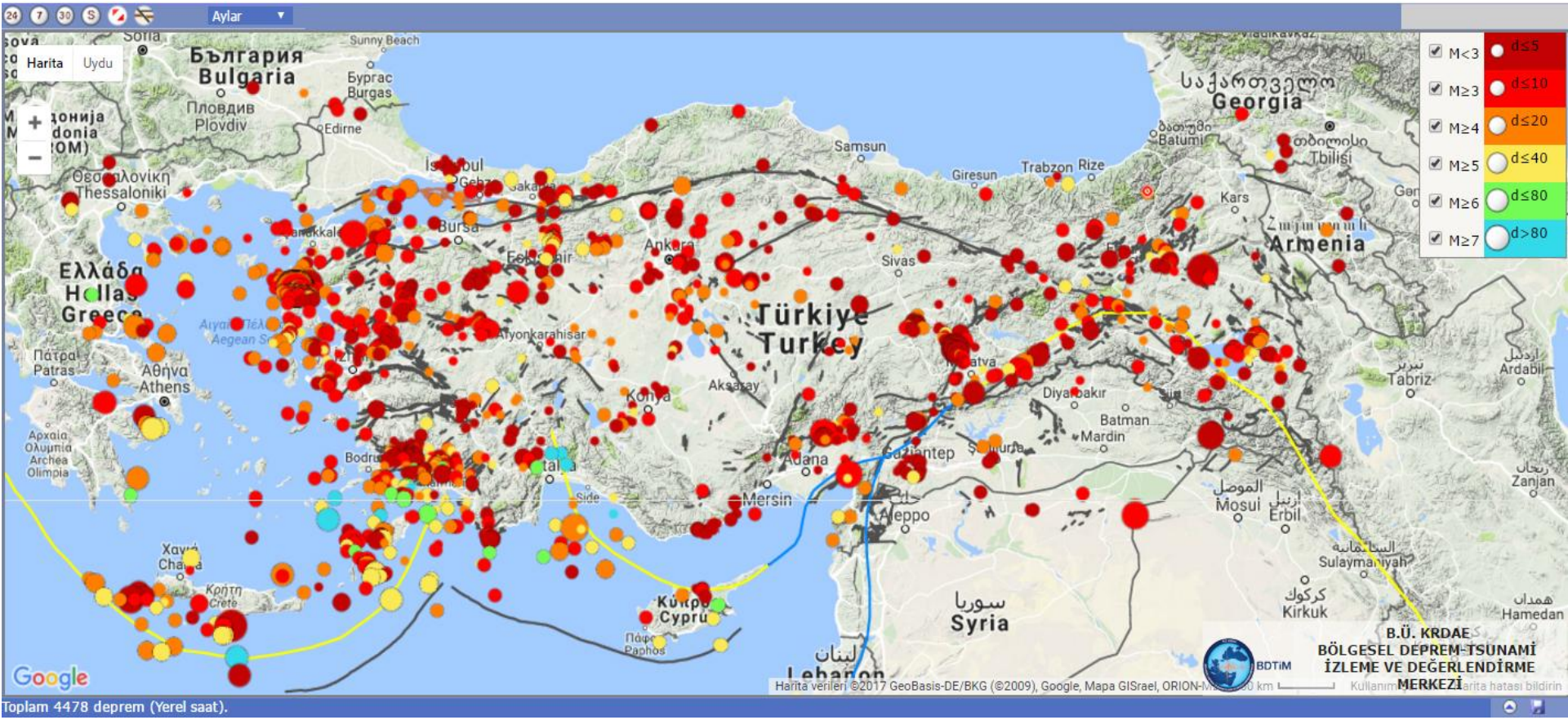
1995 kobe Depremi, M: 7.2




Euro-Med bulletin 1998-2003
Magnitude
M > 6
5 < M < 6
4 < M < 5
3 < M < 4
M < 3 or reported event
EMSC


Büyüklük (M)
2
10
Derinlik (km)
20 40 60
150
Bulgaristan
Karadeniz
Gürcistan
Ermenistan
Marmara Denizi
Ege Denizi
Türkiye
Suriye
K.K.T.C.
Kıbrıs
Akdeniz
Lübnan
Irak
İsrail
Ürdün
250km (38.5°)
50 100 150 200 250
≈ 1:8000000


Eurasian Plate
North Anatolian Fault
Ege Graben Sistemi
Anatolian Plate
East Anatolian Fault
Bitlis-Zagros Fold and Thrust Belt
Hellenic Arc
Cyprus Arc
Dead Sea Transform
Arabian Plate
Mediterranean Ridge
African Plate


Aylar
Harita
Uydu
M<3
M≥3
M≥4
M≥5
M≥6
M≥7
d≤5
d≤10
d≤20
d≤40
d≤80
d>80
Türkiye
Turkey
Ελλάδα
Hellas
Greece
Armenia
Georgia
Syria
Sofia
Thessaloniki
Athens
Patras
Bursa
Ankara
Samsun
Trabzon
Giresun
Rize
Sivas
Konya
Adana
Mersin
Gaziantep
Diyarbakır
Batman
Mardin
Tabriz
Mosul
Erbil
Kirkuk
Sulaymaniyah
Hamedan
Zanjan
Ardabil
Aleppo
Tbilisi
Batumi
Kars
Edirne
Plovdiv
Burgas
Sunny Beach
Crete
Cyprus
Paphos
Lebanon
Google
BDTİM
B.Ü. KRDAE
BÖLGESEL DEPREM-TSUNAMİ
İZLEME VE DEĞERLENDİRME
MERKEZİ
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Toplam 4478 deprem (Yerel saat).