EARTH´S SURFACE MOVEMENTS - introduction

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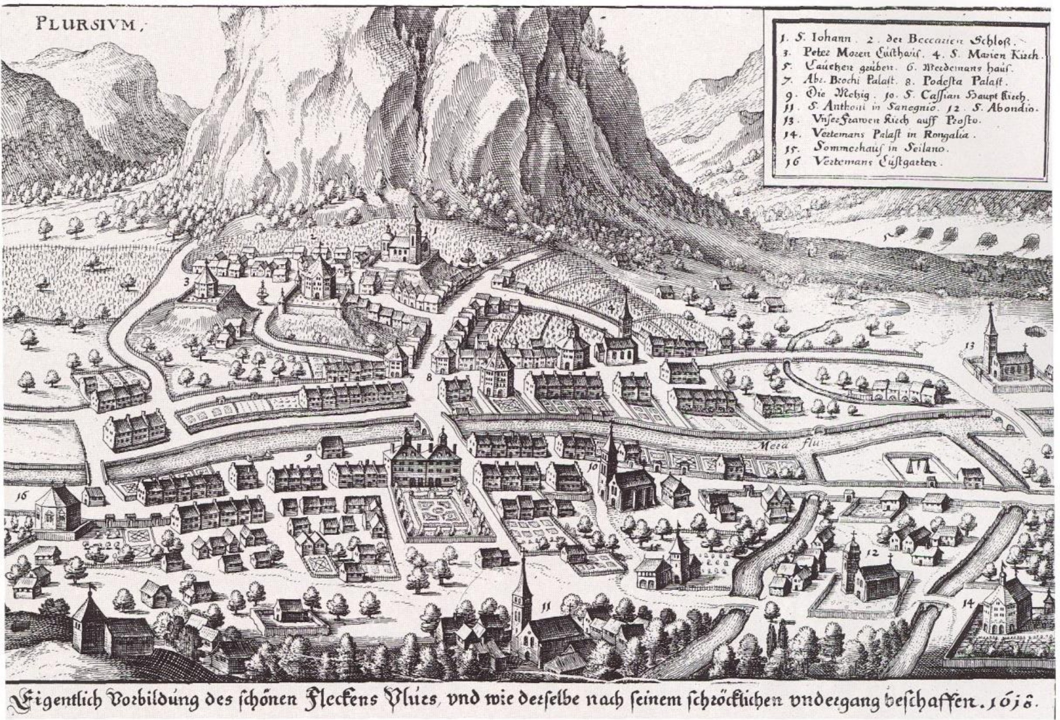
Why is necessary to study dynamic (engineering) geology?

There are known catastrophic events from the history…..

Historical consequences:

Villach (Austria), 25.1.1348
Destroyed by strong earthquake
I_0 = IX

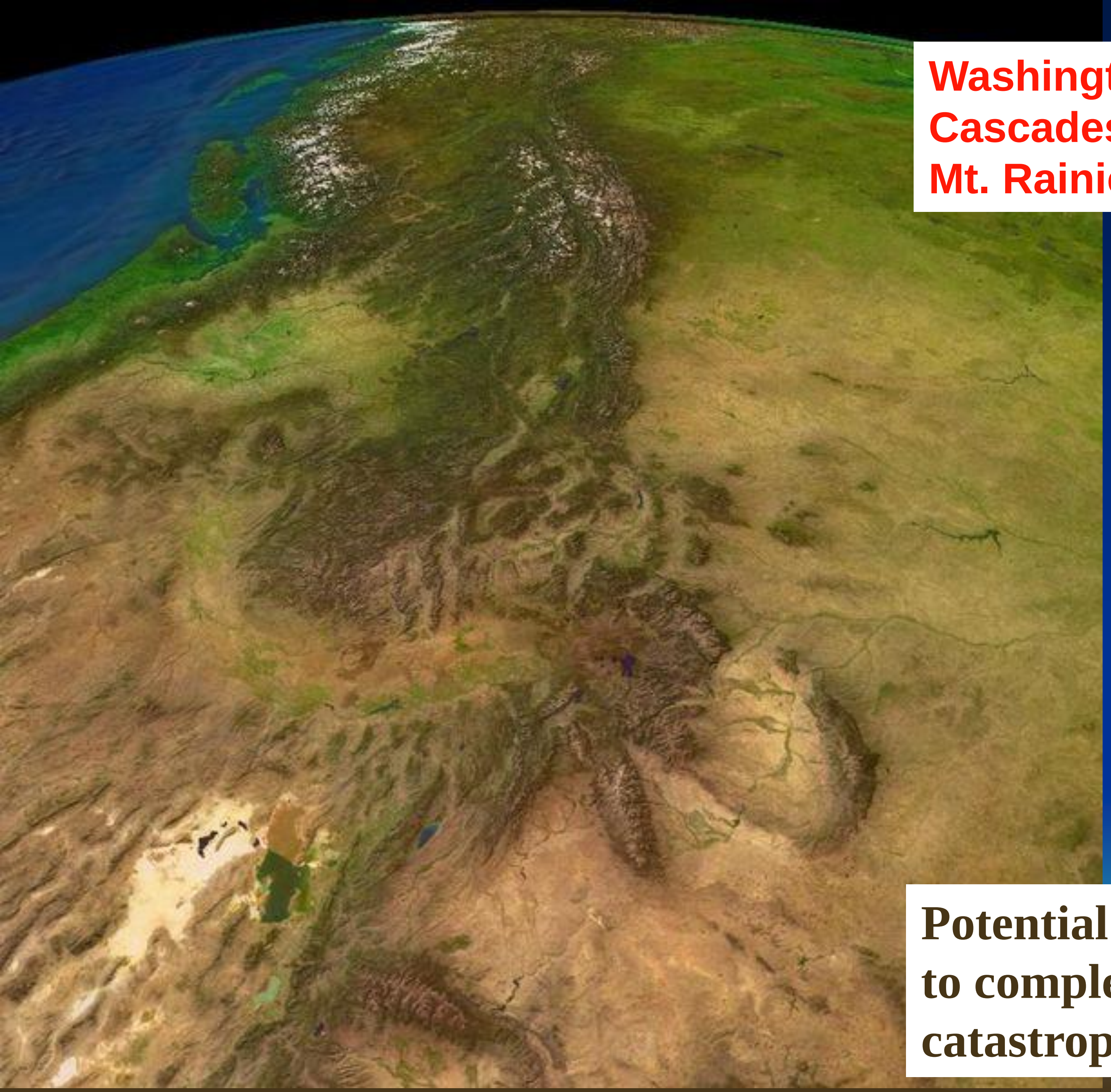
Basel (Switzerland) – destroyed by strong earthquake
18.10.1356 I_0 = IX-X



Piuro (Italy) 25.10. 1618

Destroyed by large rockslide

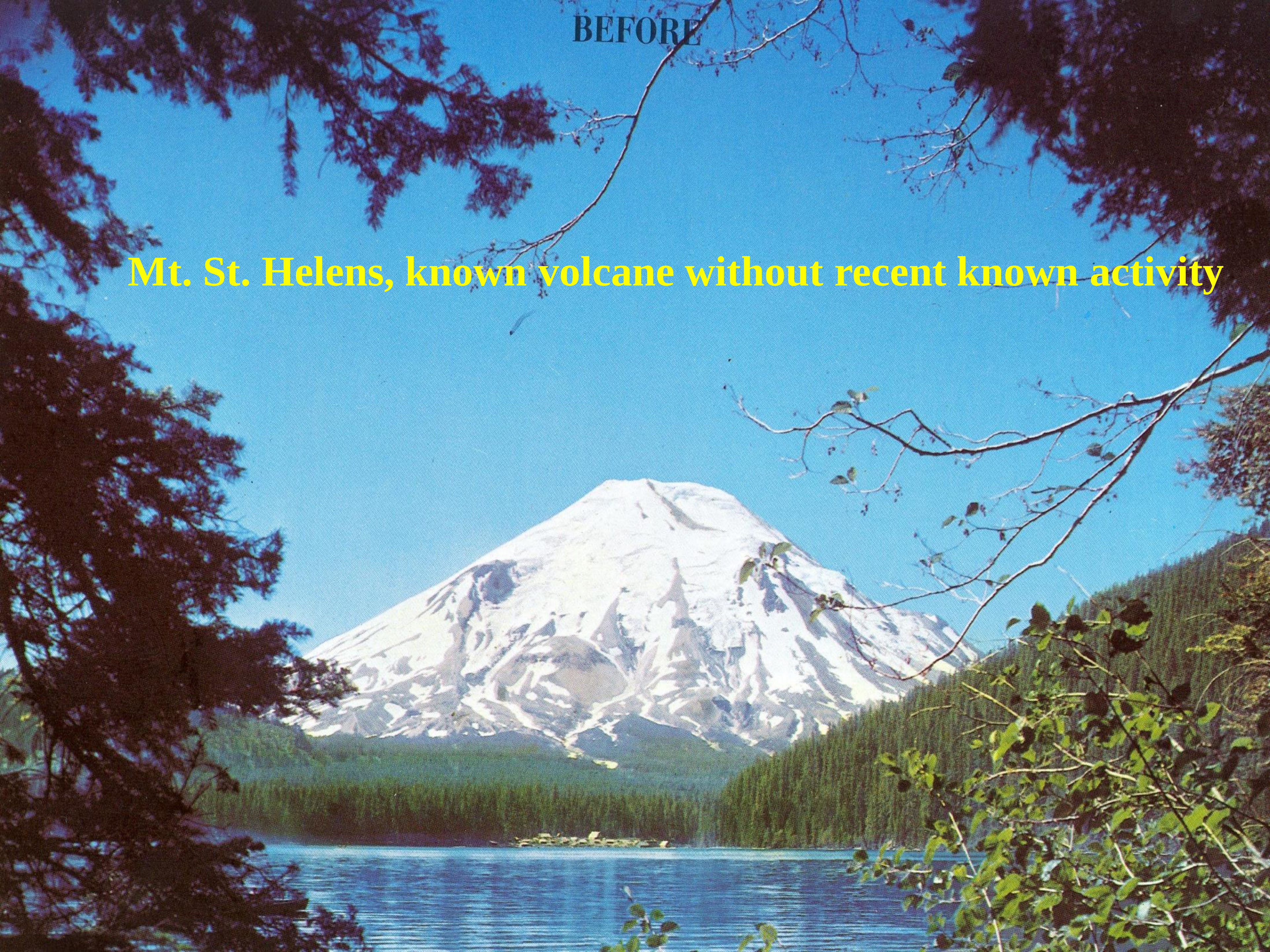
Komárno (Slovakia) 18.6.1763 large earthquake I_0 = VIII-IX

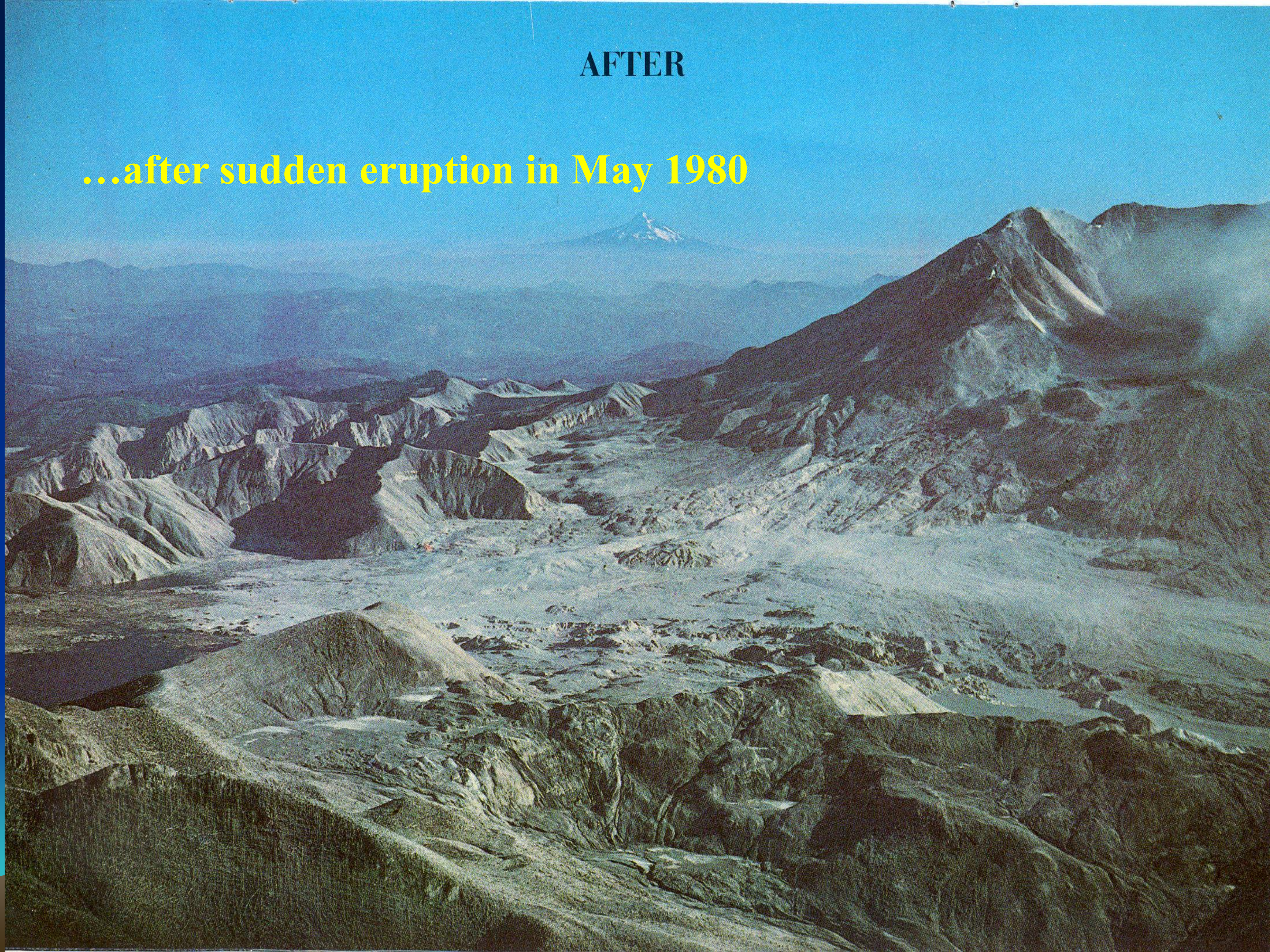


Washington, USA
Cascades Mountains
Mt. Rainier – 4.391 a.s.l.

Potential hazard resulted to complex regional catastrophy in 1980

Mt. St. Helens, known volcane without recent known activity




AFTER
…after sudden eruption in May 1980


Destruction is visible more than 30 years after eruption

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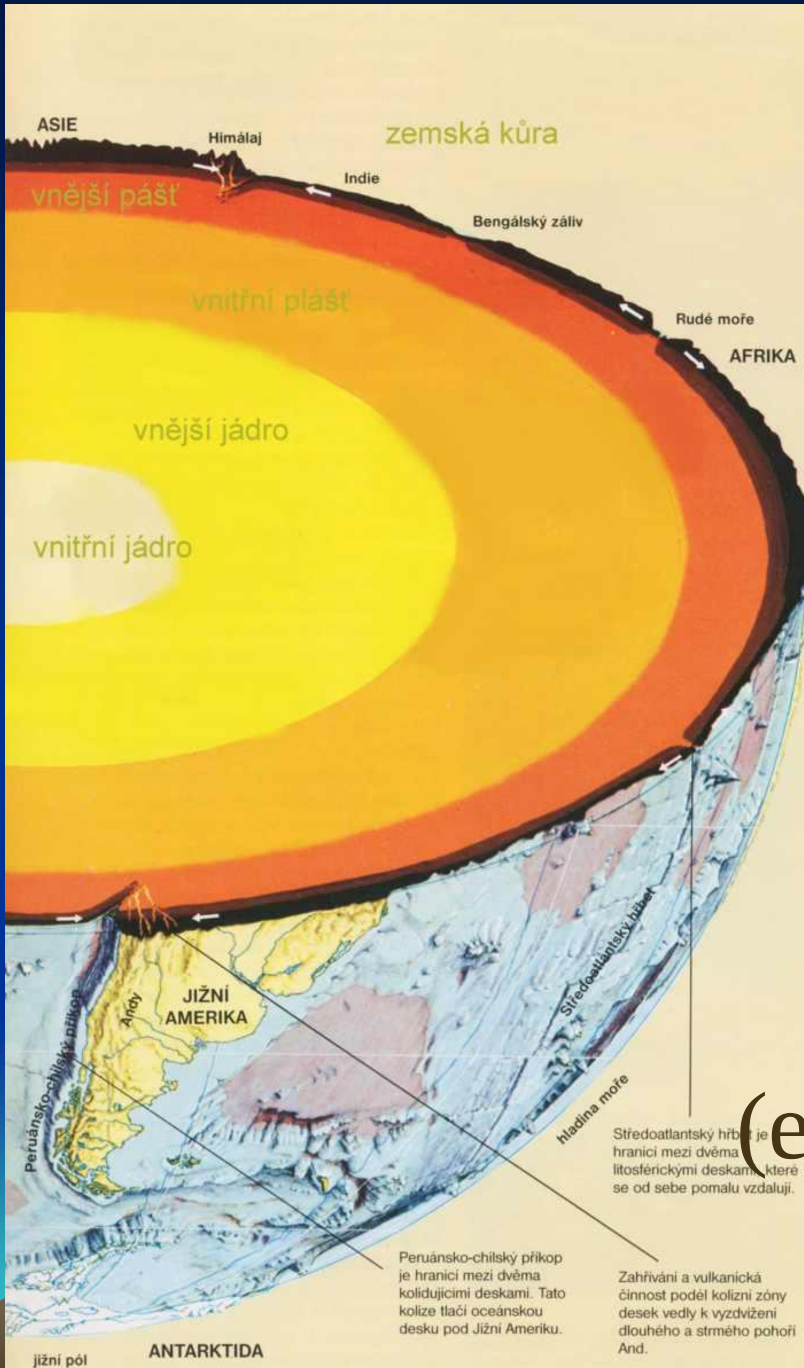
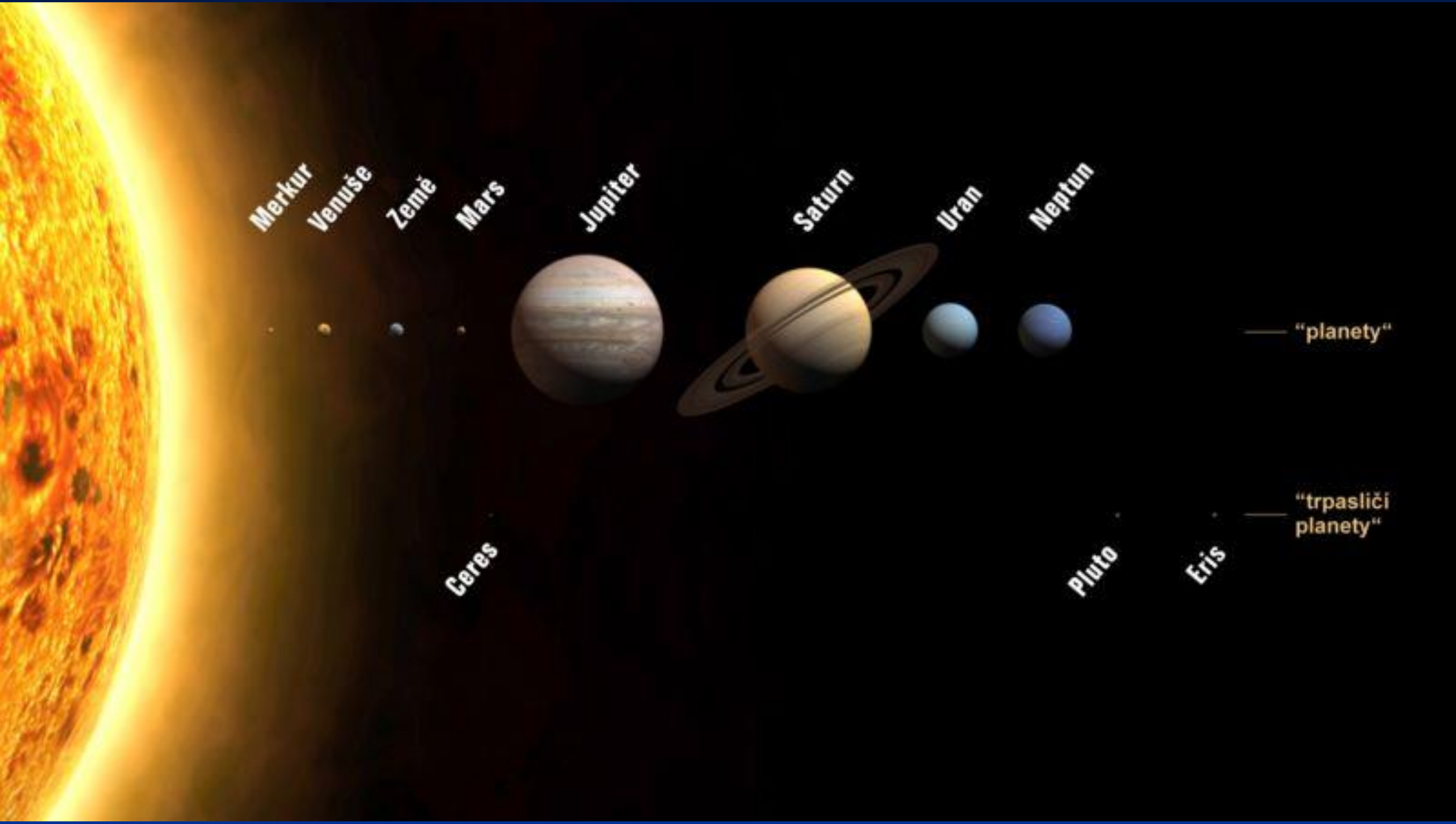


TECTONIC MOVEMENTS

- Mechanical movement of parts of the Earth´s crust and Upper manttle resulted to changes of geological structure as well as morphology of the Earth´surface

(endogenous and cosmogenic influences)

Cosmogenic influences


Merkur
Venuše
Země
Mars
Jupiter
Saturn
Uran
Neptun
“planety“
“trpasličí
planety“
Ceres
Pluto
Eris

Major tidal influences on Earth

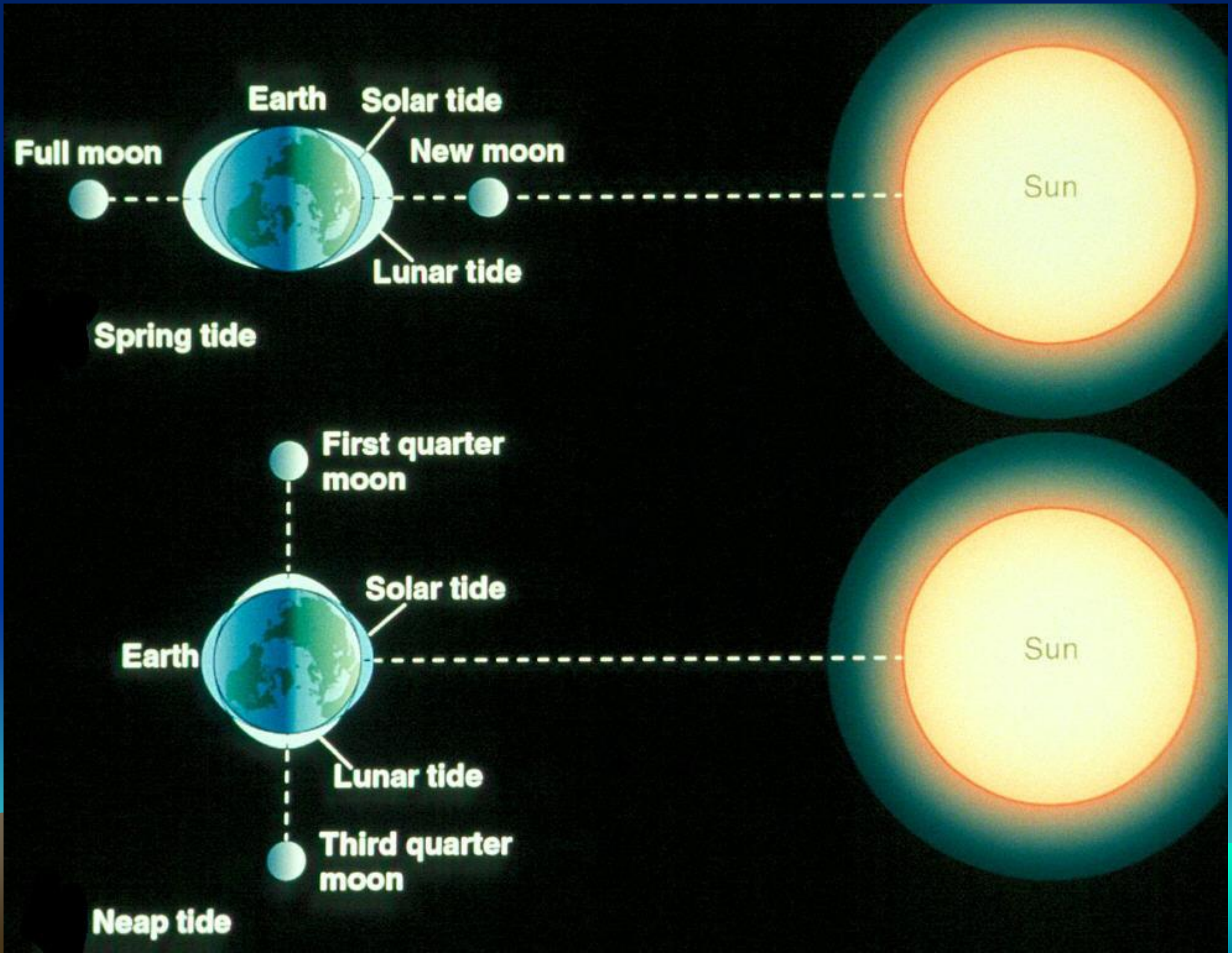
$$F \propto \frac{m_1 m_2}{r^3}$$

Though much more massive than the moon, the sun is so much farther away that its tidal influence is less than half.

	Sun	Moon
Mass	$2.0*10^{33}$ g	$7.3*10^{25}$ g
Distance	150,000,000 km	385,000 km
Tidal effect	0.46	1.00

Earth-sun-moon system: tide systematics

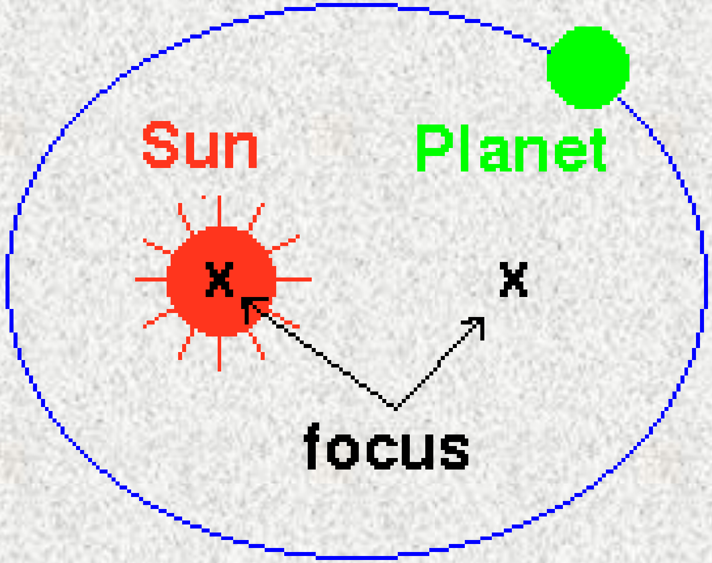
Recall that the tidal bulges are identical on the sides of the Earth facing or opposite the moon. The same is true of the tides raised by the sun, except the solar tides are only ~46% as large as those of the lunar tides.



Orbits

- Kepler's Laws of Planetary Motion

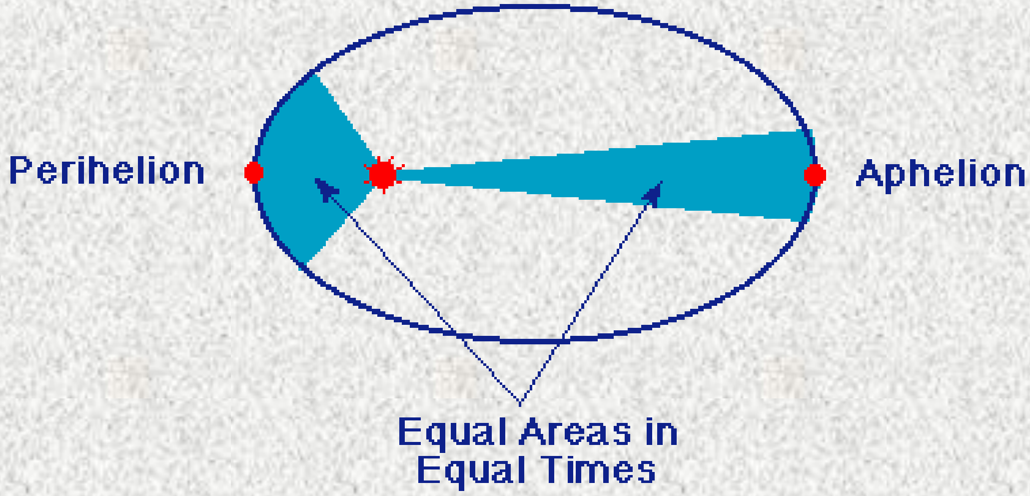
I. The orbits of the planets are ellipses, with the Sun at one focus of the ellipse.



Orbits

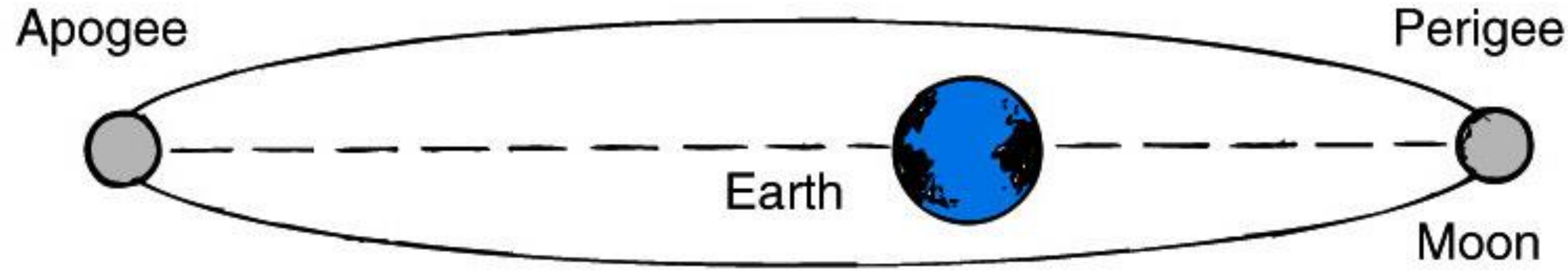
- Kepler's Laws of Planetary Motion

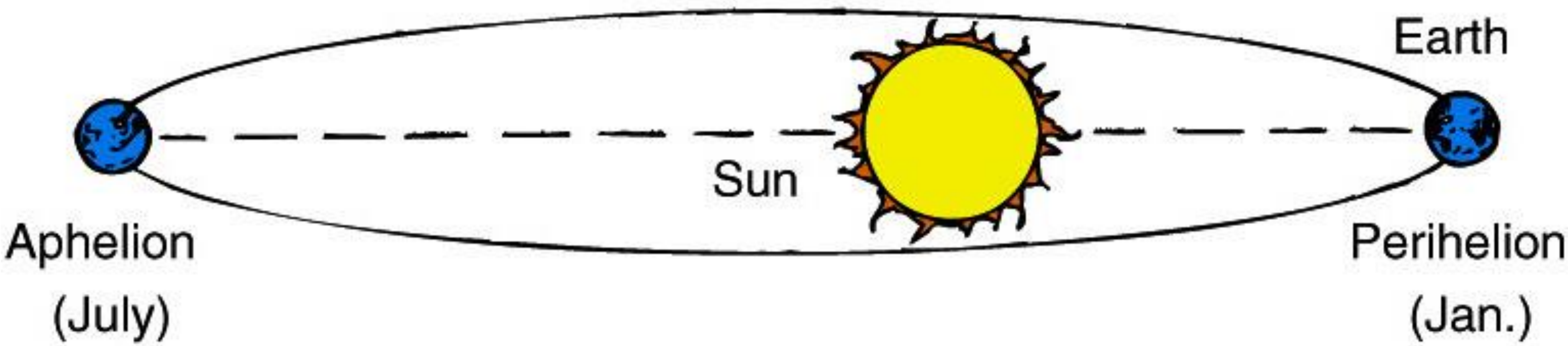
II. The line joining the planet to the Sun sweeps out equal areas in equal times as the planet travels around the ellipse.



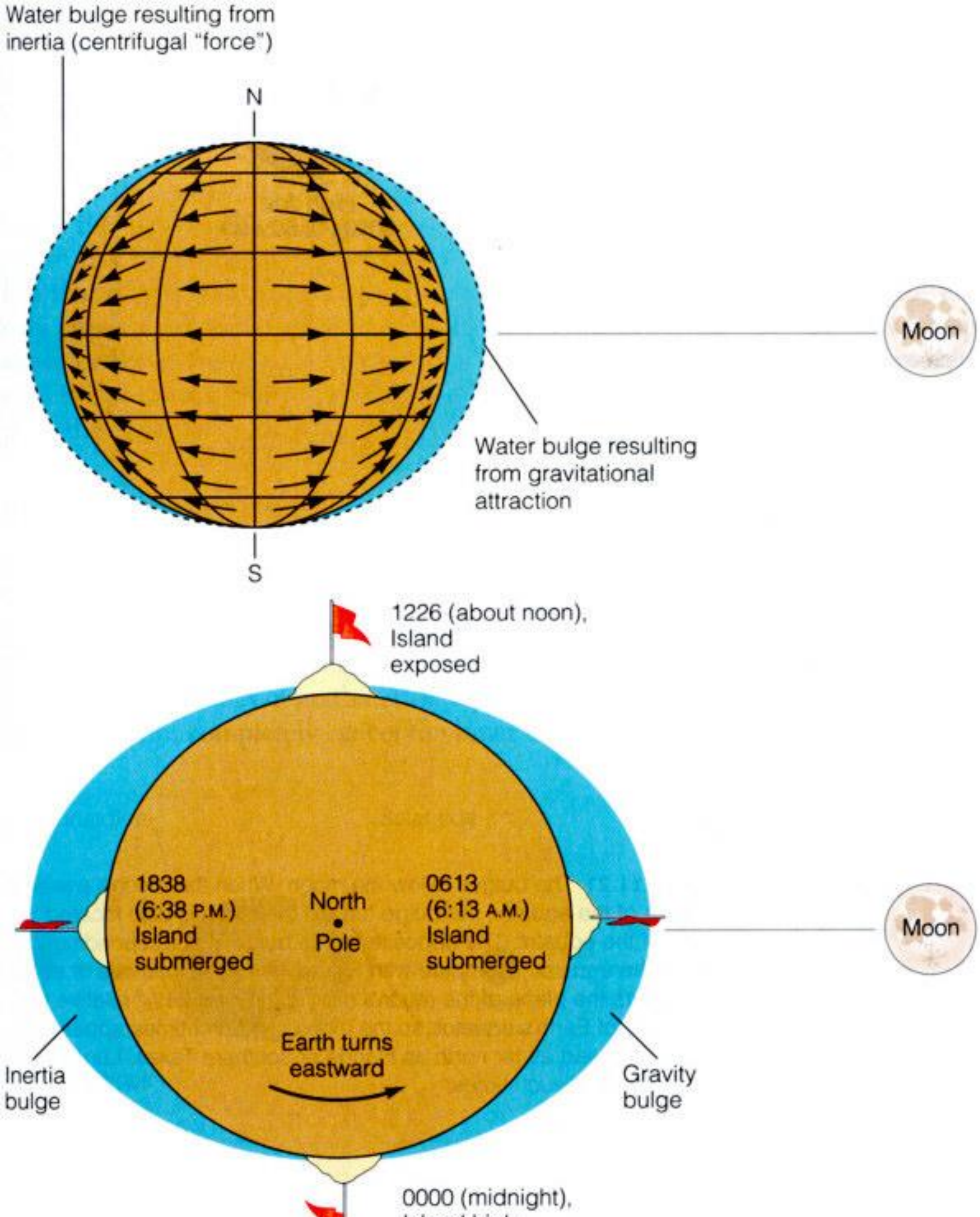
Ellipticity of Earth and moon orbits

The orbits of the *moon around Earth* and of the *Earth around the sun* are ellipses. The Earth-moon orbital distance varies from 375,200 to 405,800 km, so the lunar tidal effect varies by 11.8% over a lunar month (inverse cube law). The Earth-sun distance varies from 148,500,000 to 152,200,000 km, so the solar tidal effect varies by 3.7% over a year.





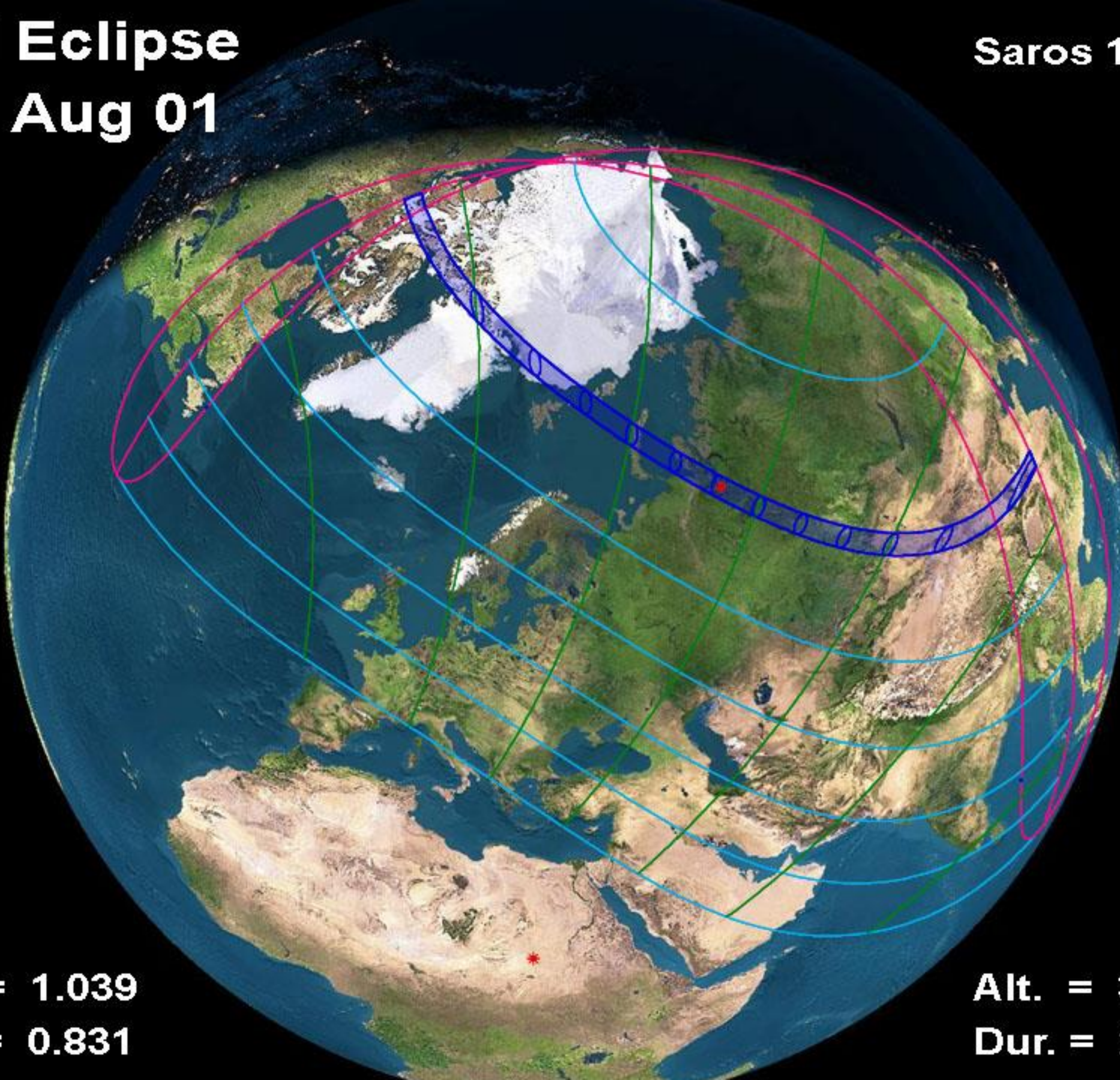
Earth-moon system: resultant forces on Earth's surface



The centrifugal and gravitational tidal vectors are shown resolved over the Earth's surface. The vectors show that water is drawn into the tidal bulges, reaching maximum bulge elevation at points nearest and farthest from the moon. The lower diagram shows how, in a simple-minded model, two low and two high tides are expected daily.

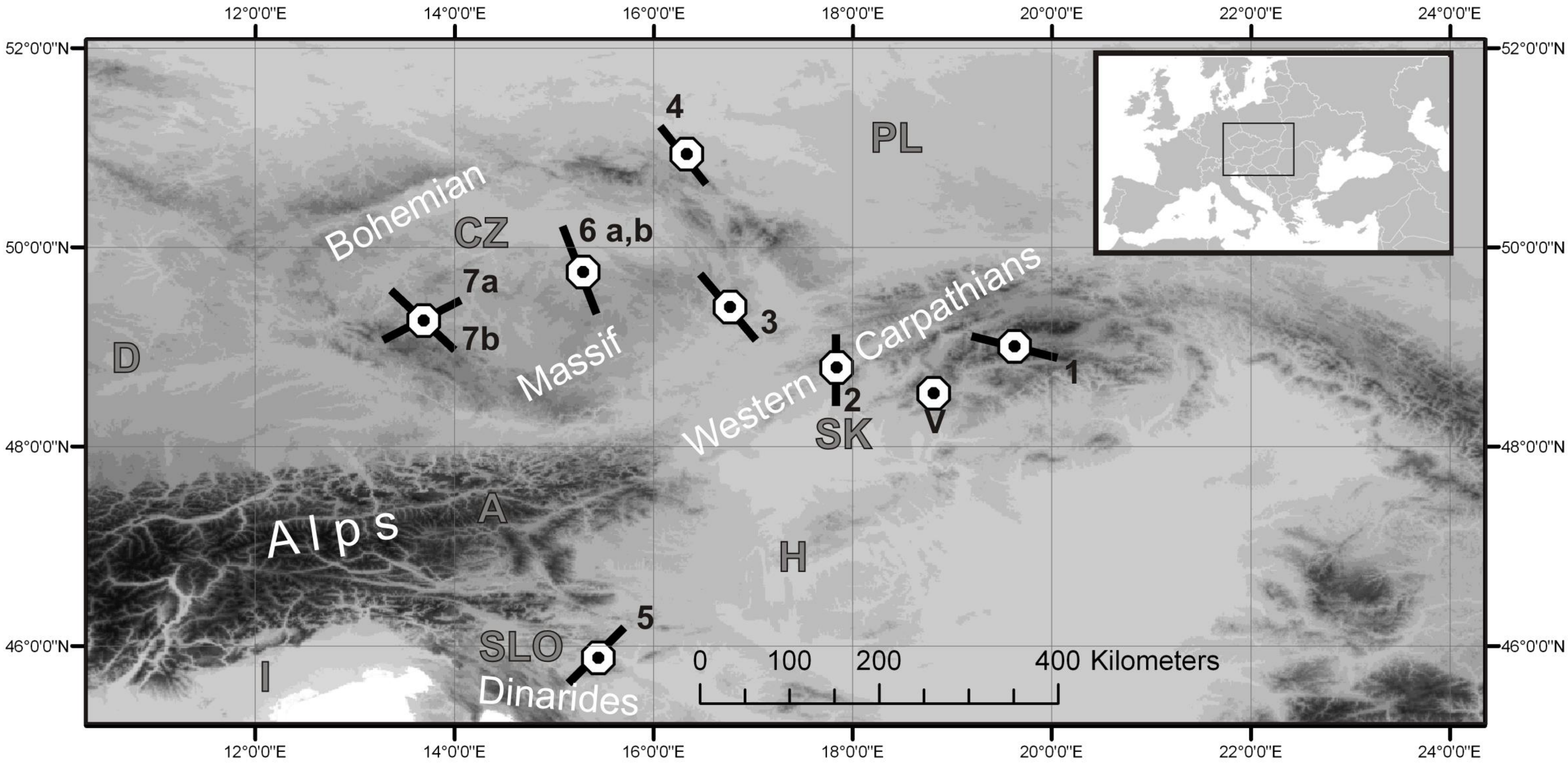
Total Eclipse
2008 Aug 01

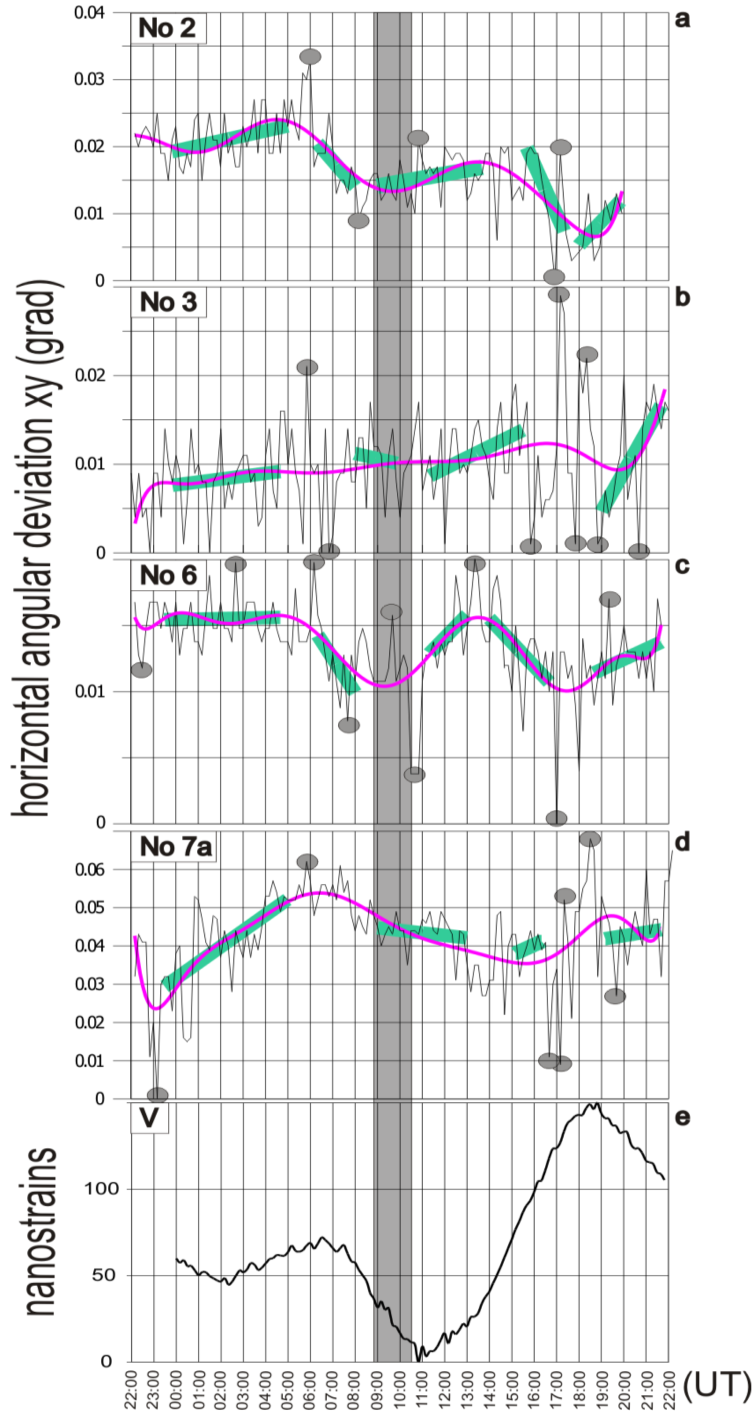
Saros 126



Mag. = 1.039
Gam. = 0.831

Alt. = 34°
Dur. = $2^m\ 27^s$


12°0'0"E
14°0'0"E
16°0'0"E
18°0'0"E
20°0'0"E
22°0'0"E
24°0'0"E
52°0'0"N
50°0'0"N
48°0'0"N
46°0'0"N
4
PL
Bohemian
CZ
6 a,b
7a
7b
3
D
Massif
Western Carpathians
2
1
V
SK
A
Alps
H
5
SLO
I
Dinarides
0 100 200 400 Kilometers



horizontal angular deviation xy (grad)
nanostrains
No 2
No 3
No 6
No 7a
V
a
b
c
d
e
0.04
0.03
0.02
0.01
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100
50
22:00
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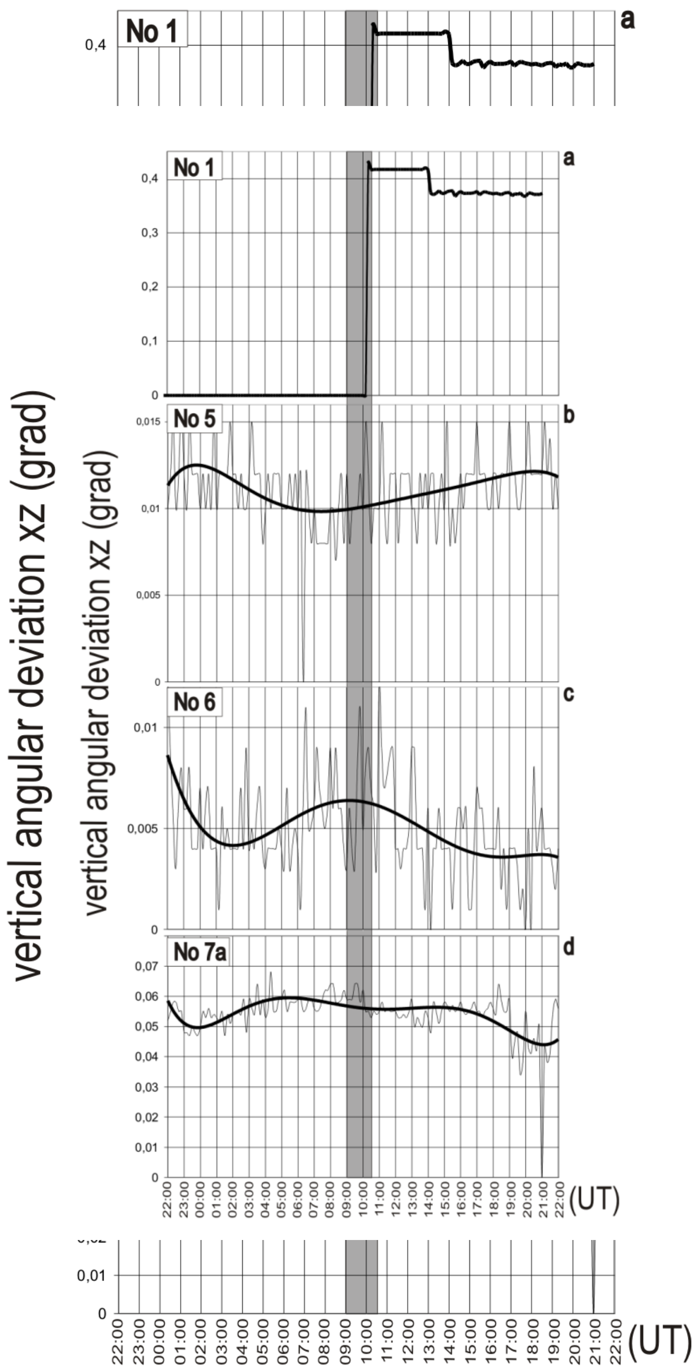
(UT)


No 1
a
0,4
No 1
a
0,4
0,3
0,2
0,1
0
No 5
b
0,015
0,01
0,005
0
No 6
c
0,01
0,005
0
No 7a
d
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0
vertical angular deviation xz (grad)
vertical angular deviation xz (grad)
22:00 23:00 00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00
(UT)
0,01
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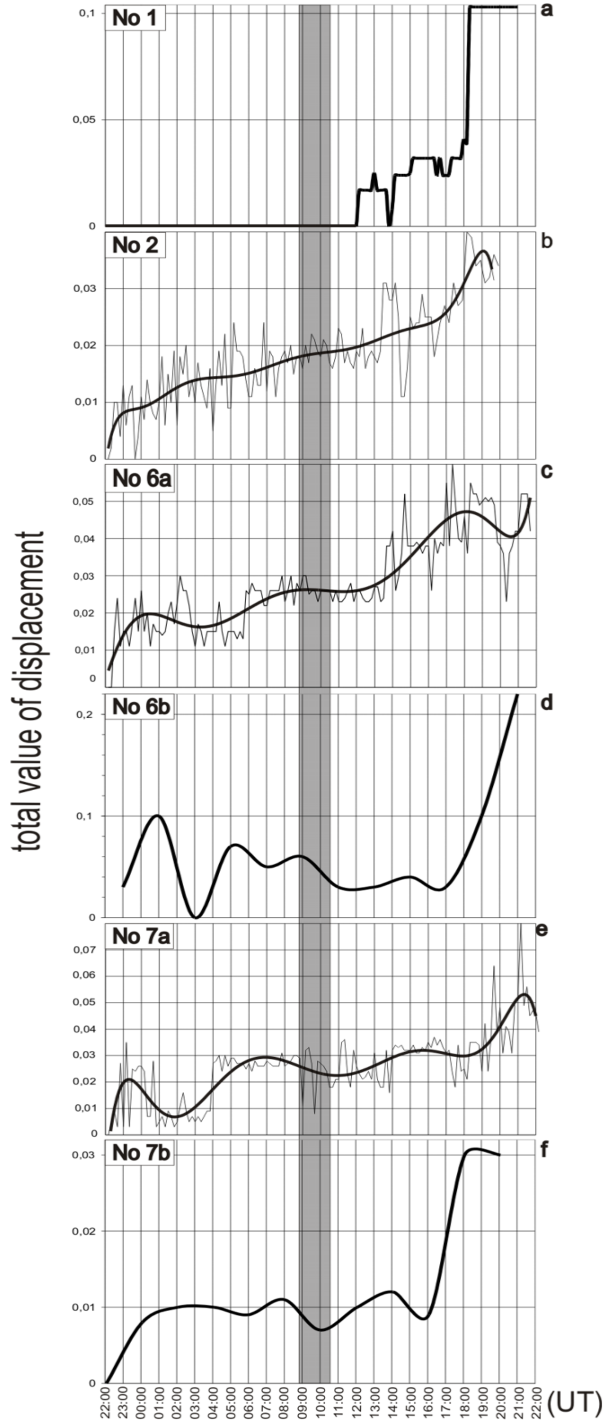
22:00 23:00 00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00
(UT)


total value of displacement
No 1
a
No 2
b
No 6a
c
No 6b
d
No 7a
e
No 7b
f
0,1
0,05
0,03
0,02
0,01
0,05
0,04
0,03
0,02
0,01
0,2
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(UT)

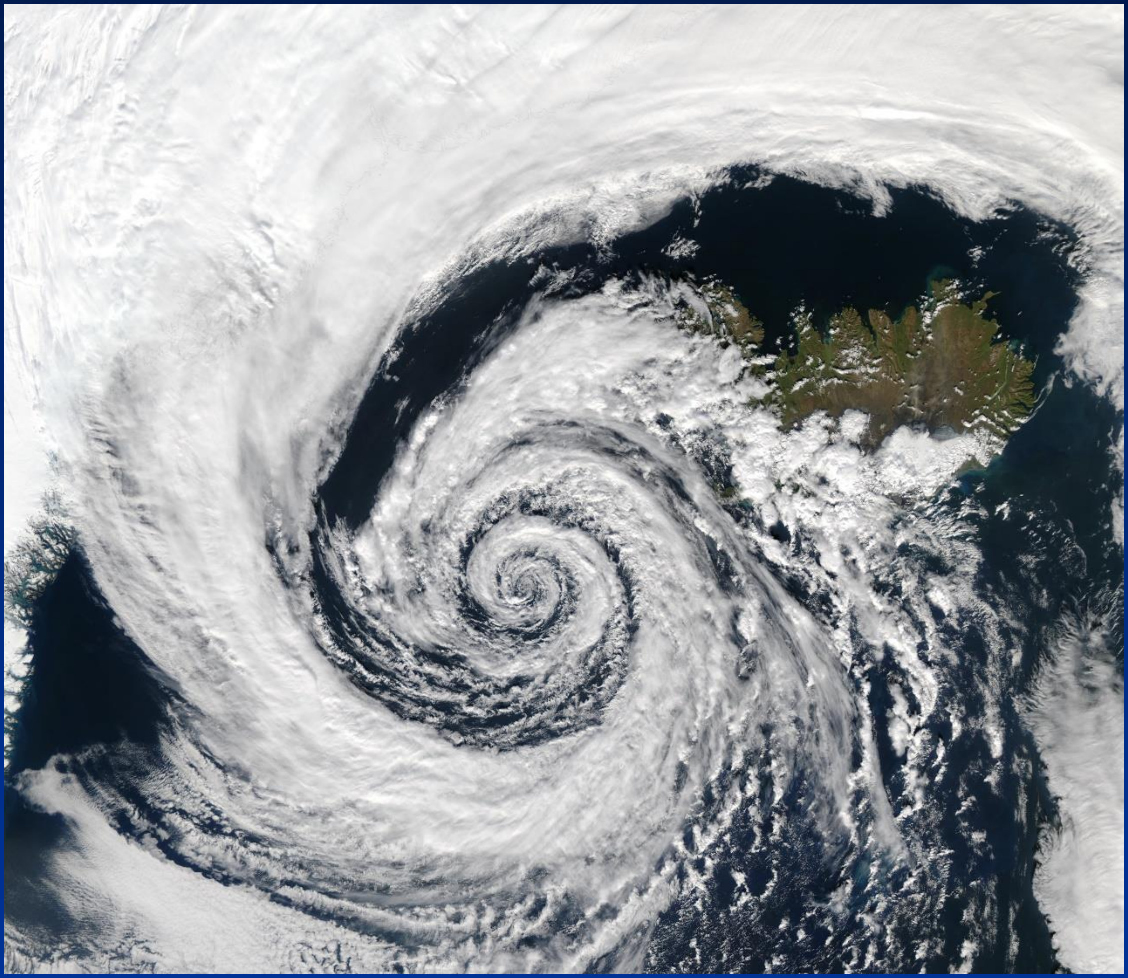
Earth rotation
- Coriolis efect

Note! It is not centrifugal effect!!

Each mass moving in direction of longitudes decline to the right in the northern hemisphere and to the left in the southern hemisphere due to Earth´s rotation

Example – river erosion
Northern hemisphere: south-northwards flowing rivers erode more a western flanks

Coriolis efect can demonstrated in meteorology. Above northern hemisphere low presure atmosphere rotated always to the left (anticlockwise) and high presure to the right (clockwise)



Atmospheric low presure rotates anticlockwise above Island due to equilibrium between Coriolis power and atmospheric presure distribution

Endogenous influences

TECTONIC MOVEMENTS

- **NEOTECTONICS**
  - SINCE TERTIARY WITH CONTINUATION TO QUARTERNARY
- **RECENT TECTONICS**
  - DURING HISTORICAL EPOCH UP TO NOWADAYS (about last 10 000 years – present)

(more precisely defined by International Nuclear Commission)

Selected hypotheses on tectonic movement and development

1. **Plutonic (elevated) hypothesis** (Alexander Humboldt): caused by uplift of magma

2. **Contraction hypothesis** (René Descartes): gradually cooling Earth

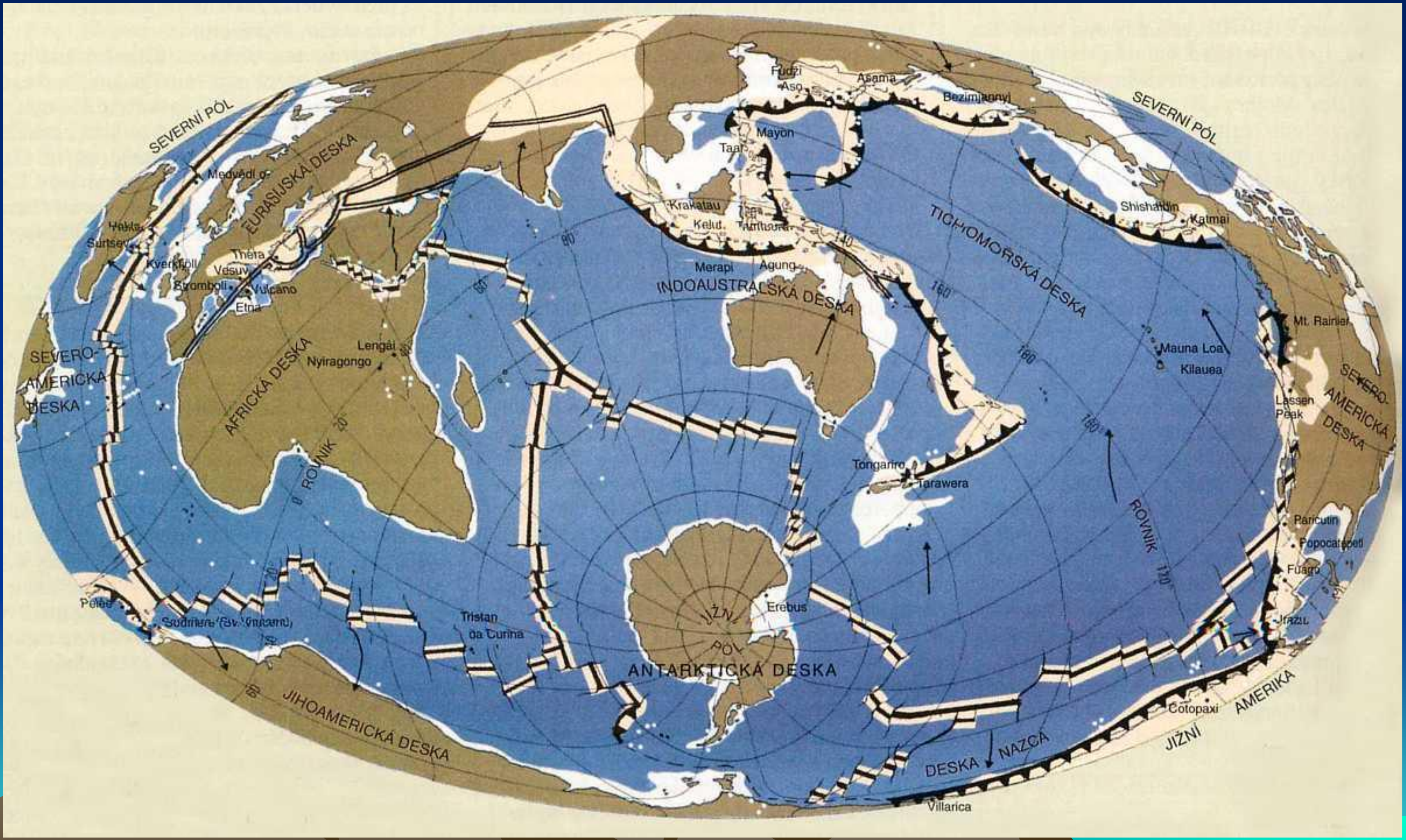
3. **Isostatic hypothesis**: litosphere equilibium is affected by denudation and sedimentation, melting of ice etc.

4. **Continent drift hypothesis**: in 1858 Antonio Snider noticed remarkable agreement of continental forms – especially Africa and Southern America; in 1912 Alfred Wegener formulated hypothesis on old continent Pangea devided to Laurasia and Gondwana

5. **Hypothesis of mantle convection** (1928 Artur Holmes) – cause of continental drift

6. **Global plate tectonics**

Global Plate Tectonics



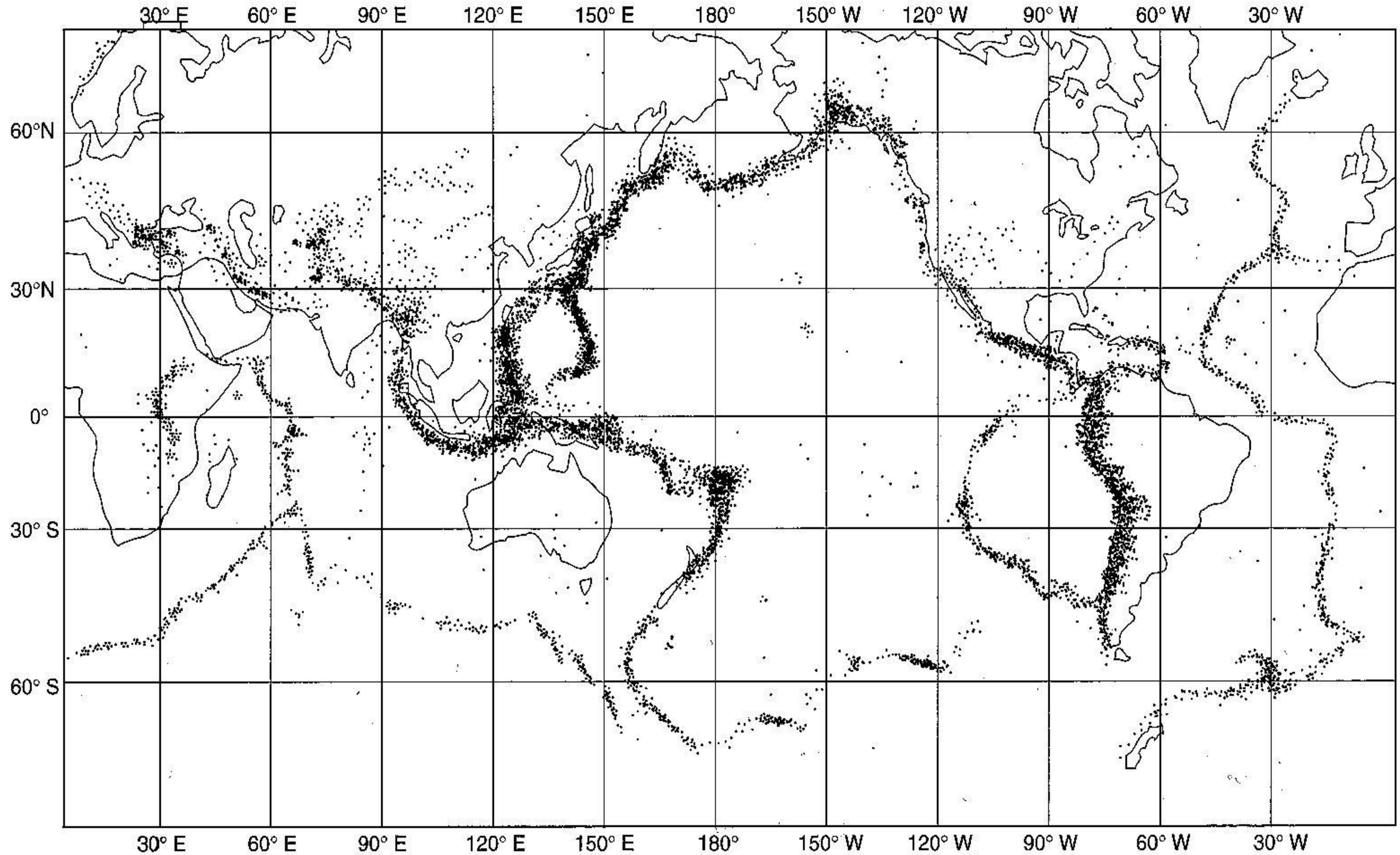


Figure 1.5 Map of global seismicity (1963–1988, Richter magnitude M ≥ 5), delineating belts of earthquake activity that define plate boundaries. Compare with Figure 1.2. (Courtesy of U. S. National Earthquake Information Center.)

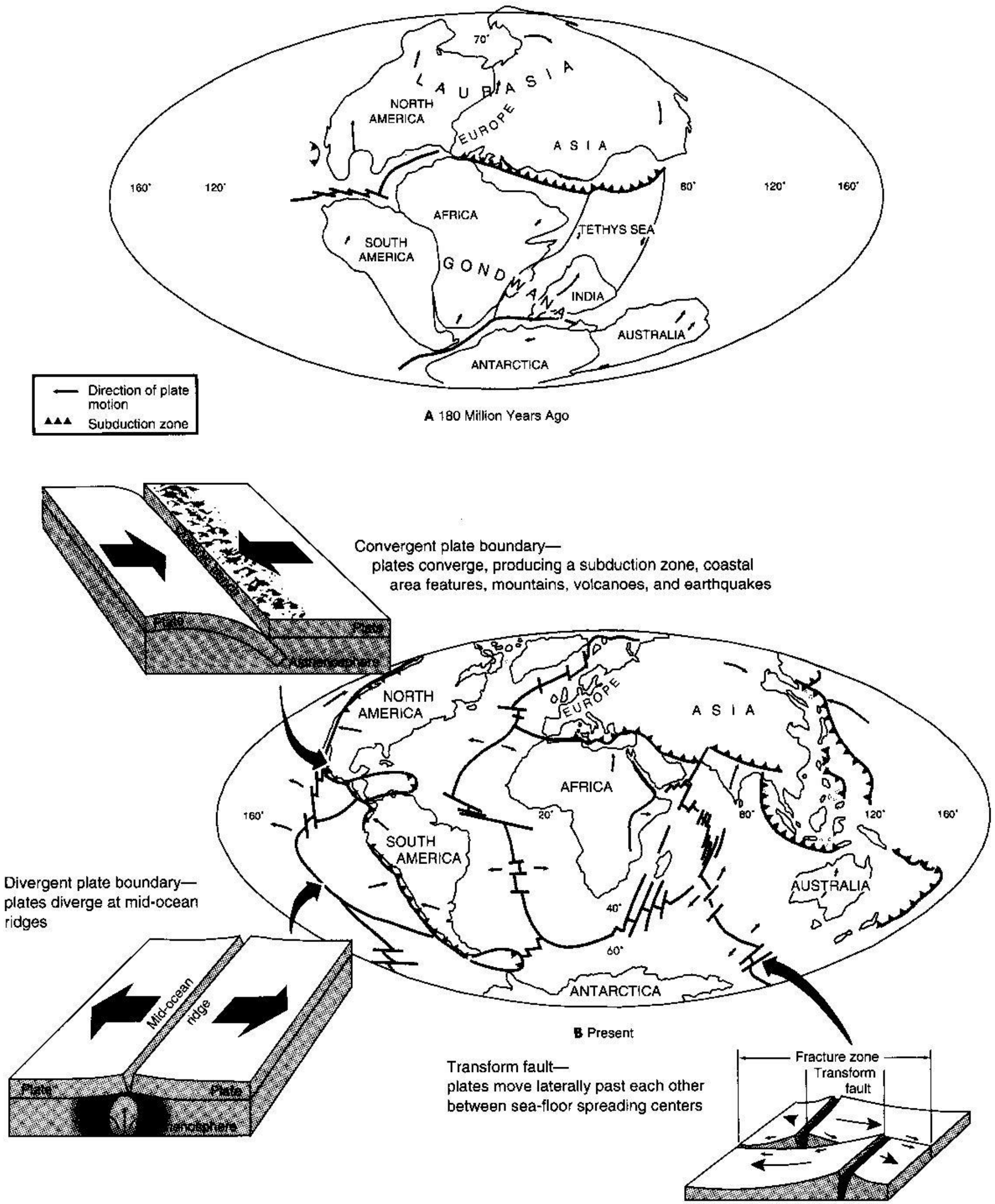
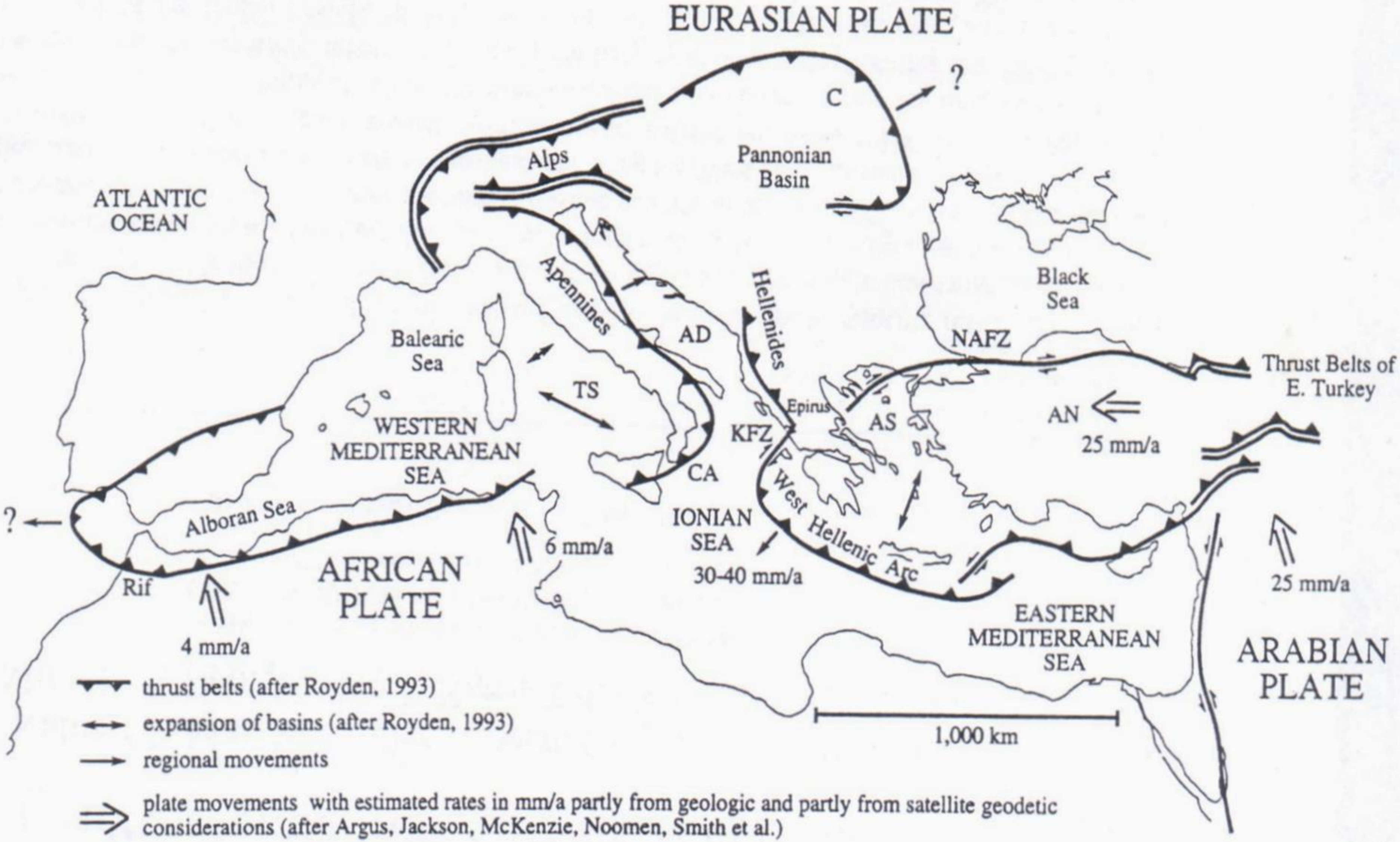


Figure 1.4 The supercontinent Pangaea (Laurasia and Gondwana) started to break up approximately 200 million years ago. Shown here are the inferred positions of the continents at 180 million years ago (a) and at present (b). Arrows show directions of plate motion. See text for further explanation of the closing of the Tethys Sea, the collision of India with Asia, and the formation of mountain ranges. (From Dietz and Holden, 1970. *Journal of Geophysical Research*, 75: 4939–4956. Copyright by the American Geophysical Union; Modifications and block diagrams from Christopherson, 1994. *Geosystems*, 2nd ed. New York: Macmillan.)



NAFZ = North Anatolian Fault Zone (with Northern Aegean Extension)
KFZ = Kephalonia Fault Zone
TS = Tyrrhenian Sea
AD = Adriatic Sea
AS = Aegean Sea
AN = Anatolian microplate
C = Carphathians
CA = Calabrian Arc

Mechanism of tectonic movements

- Conception 1
  - Sea floor spreading within rift zones and plate subduction
- Conception 2
  - Vertical uplift of the Earth´s crust and very slow flow of rock mass from uplift center due to gravity

Conception 1

Sea floor spreading

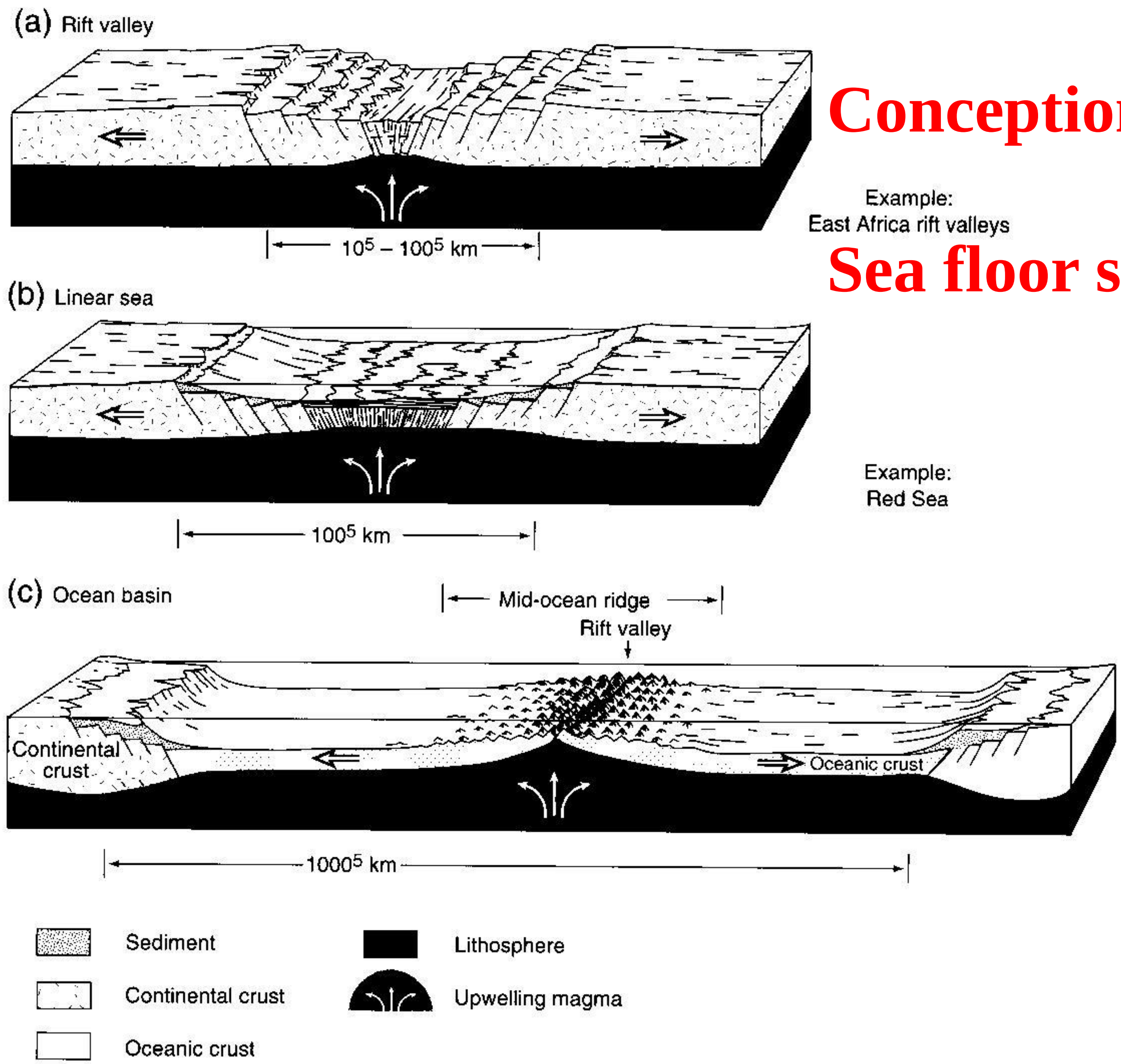


Figure 2.16 Landforms produced when the crust is pulled apart. Rifting and sea-floor spreading produce rift valleys, linear seas, and ocean basins. (After Lutgens and Tarbuck, 1992. *Essentials of Geology*. New York: Macmillan.)

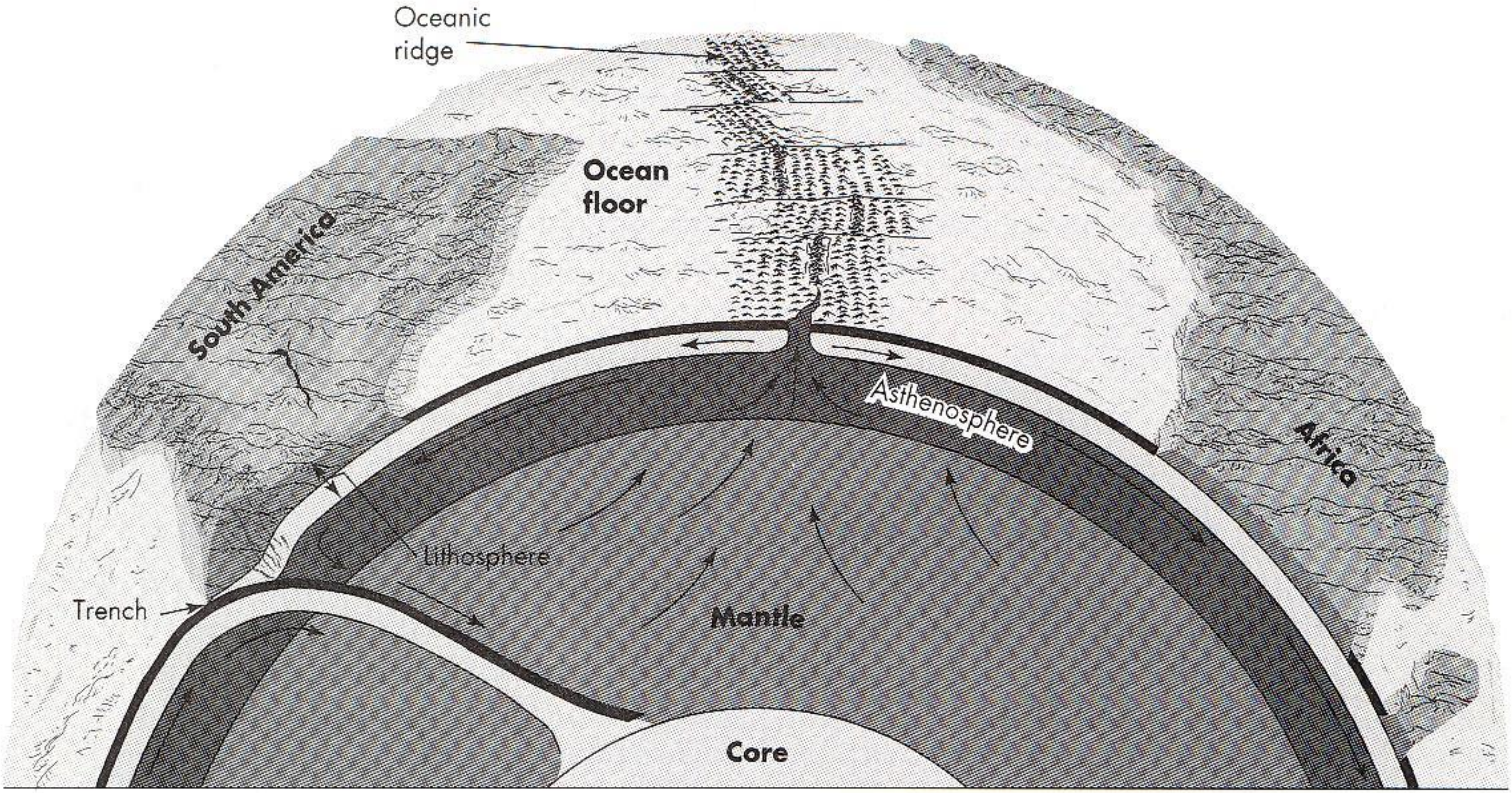
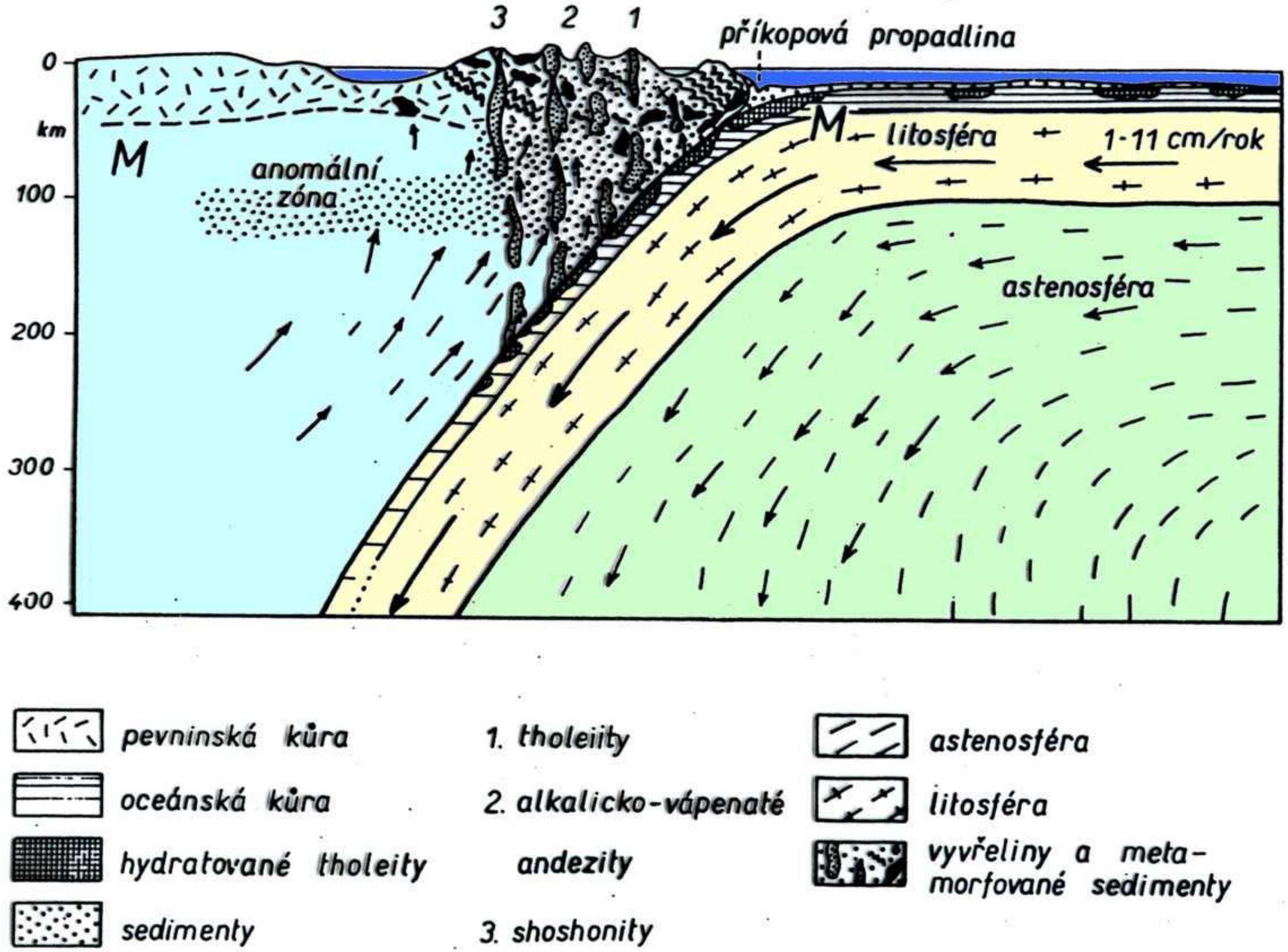


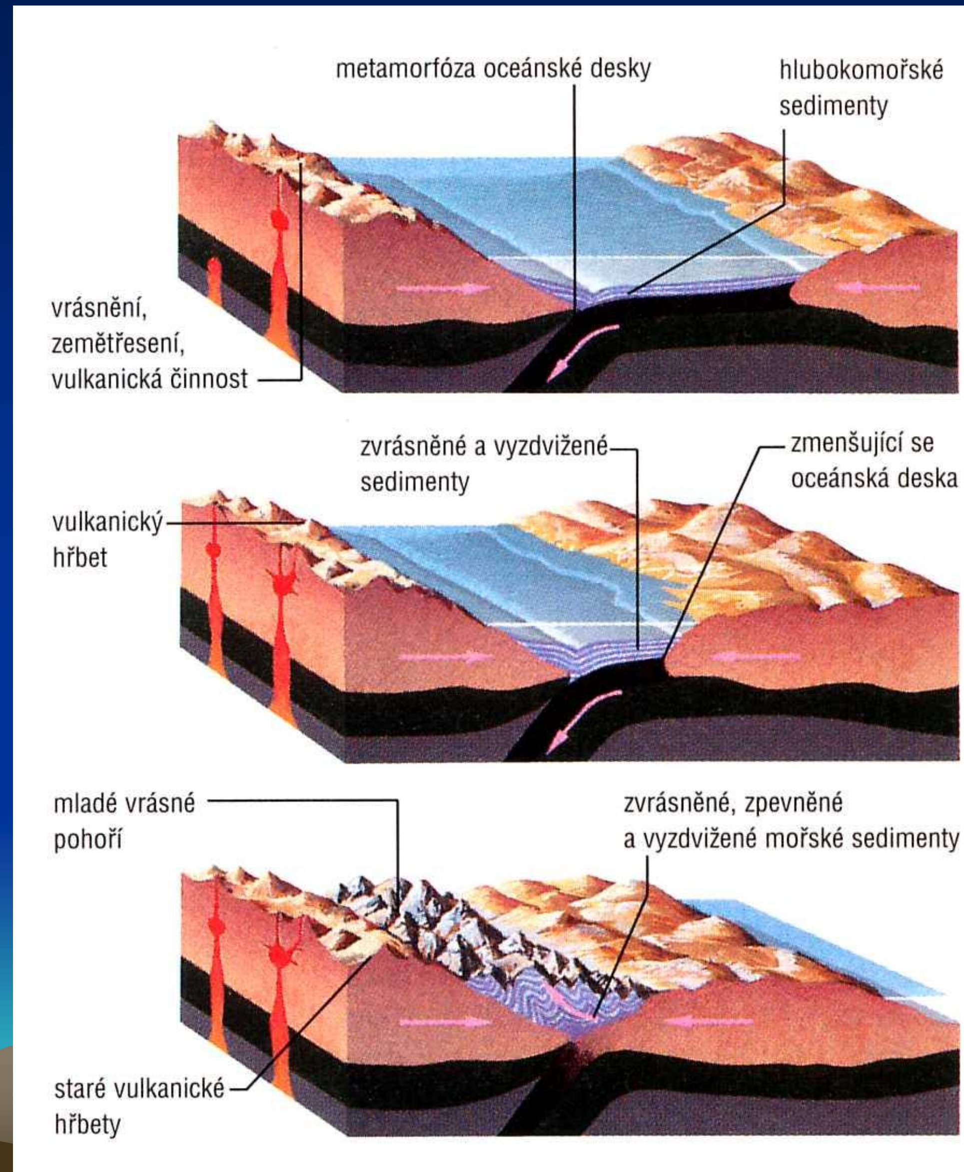
Figure 1.3 Model of plate movement, sea-floor spreading, and mantle convection (Modified after Grand, 1994, *Journal of Geophysical Research*, 99:11,591–11,621). The outer layer (lithosphere) is approximately 100 km thick and is stronger and more rigid than the deeper asthenosphere, which is a hot and slowly-flowing layer of relatively low-strength rock. The oceanic ridge is a spreading center where the plates pull apart, drawing hot, buoyant material into the gap. After these plates cool and become dense, they descend at oceanic trenches (subduction zones). This process of spreading produces ocean basins, and mountain ranges often form where plates converge at subduction zones. (Modified after Hamblin, 1992. *Earth's Dynamic Systems*, 6th ed. New York: Macmillan.)



Podsunování oceánské kůry pod pevninskou (subdukce) a její přetavování v plášti. Vulkanismus ostrovních oblouků je zonální, podle toho, jak hluboko zasahují přívodové kanály. (Podle P. Jakeše, 1970.)

- Subdukce desky NAZCA

- Subdukce Indoaustralské desky



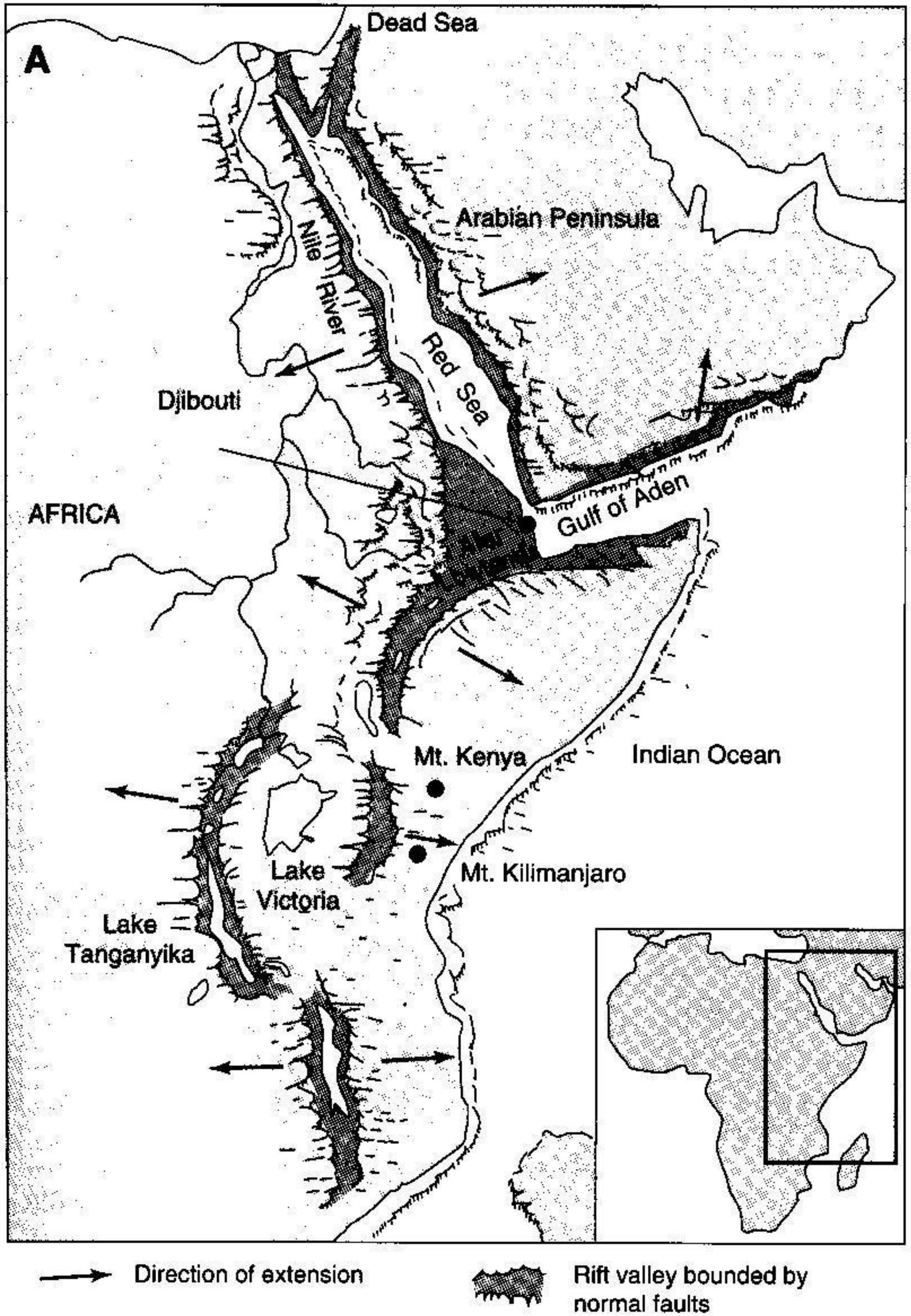


Figure 2.17 (a) East African Rift system. (From Lutgens and Tarbuck, 1992. *Essentials of Geology*. New York: Macmillan.)

Mechanisms of tectonic movements global scale

- **Orogenesis**
  - Collision of lithospheric plates – development of mountain ranges – horizontal pressure prevails

- **Tafrogenesis (rift development)**. Tafrogens are large tektonic grabens crossing young platfoms
  - **Rift hypothesis** – (mostly used) – rifts developed due to subsidence of rock blocks along elevation axis, so under horizontal extension regime
  - **Ramp hypothesis** – rifts developed in the regime of horizontal compression as a thrusts along so called ramp valleys. Graben like morphology developed by collapsandsubsidence of clocks along valley.

Basic mechanisms of tectonic movements
local scale

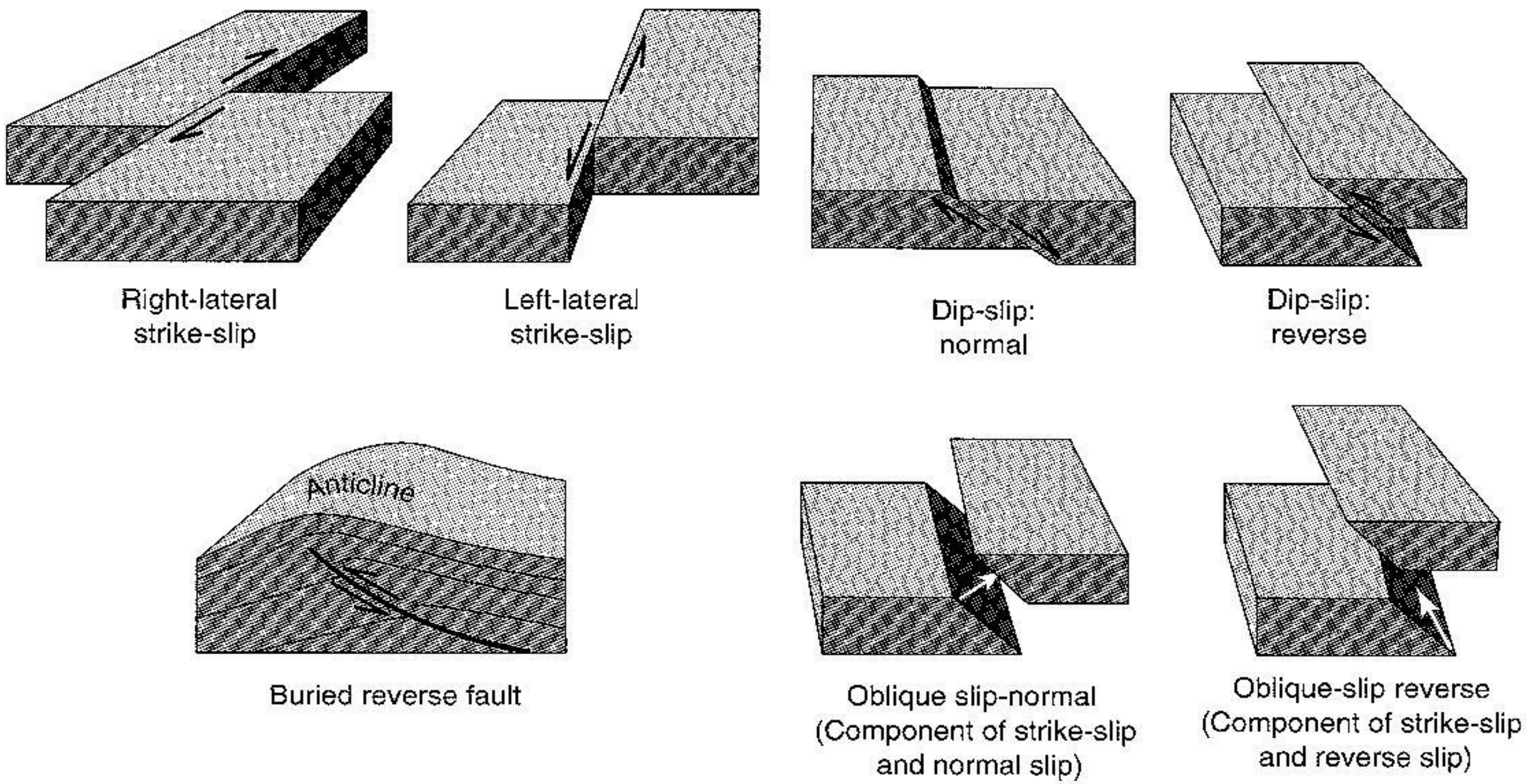
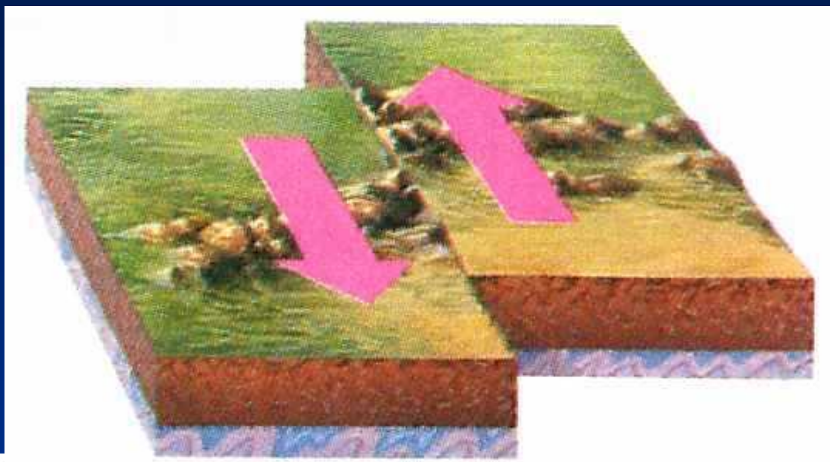
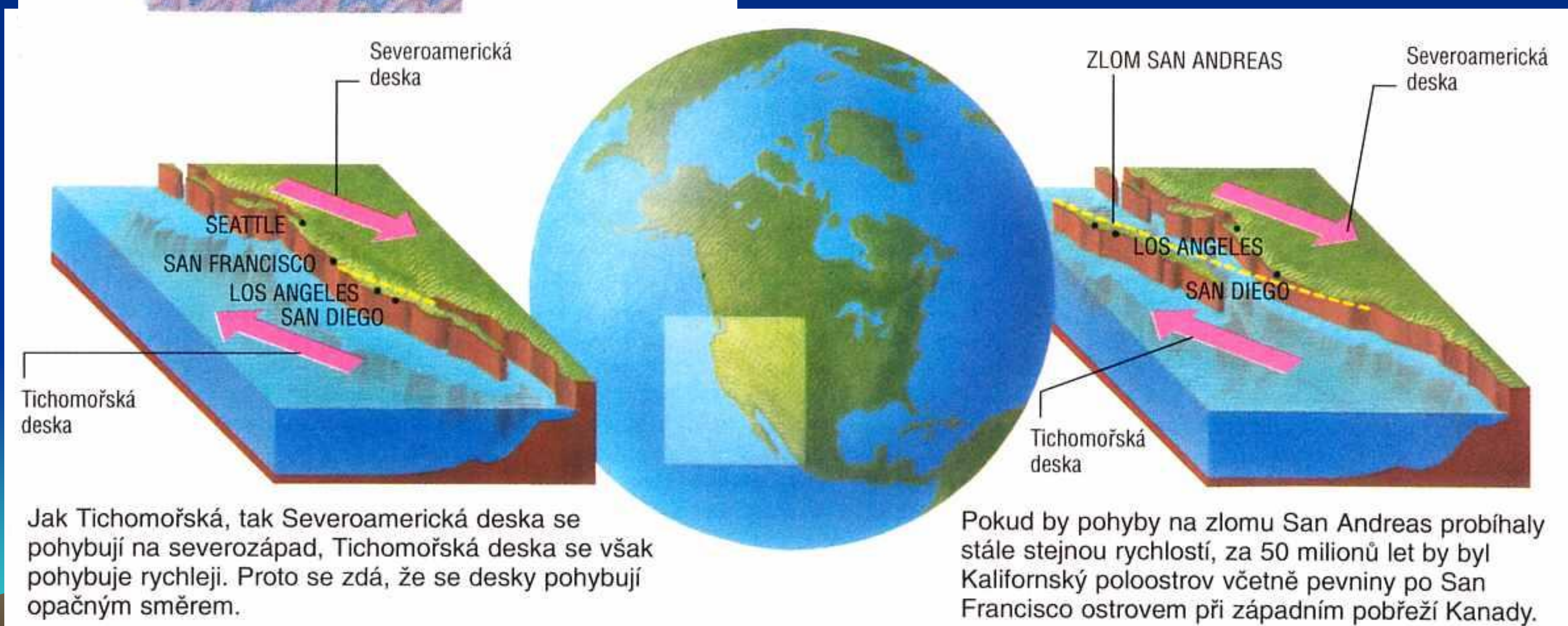


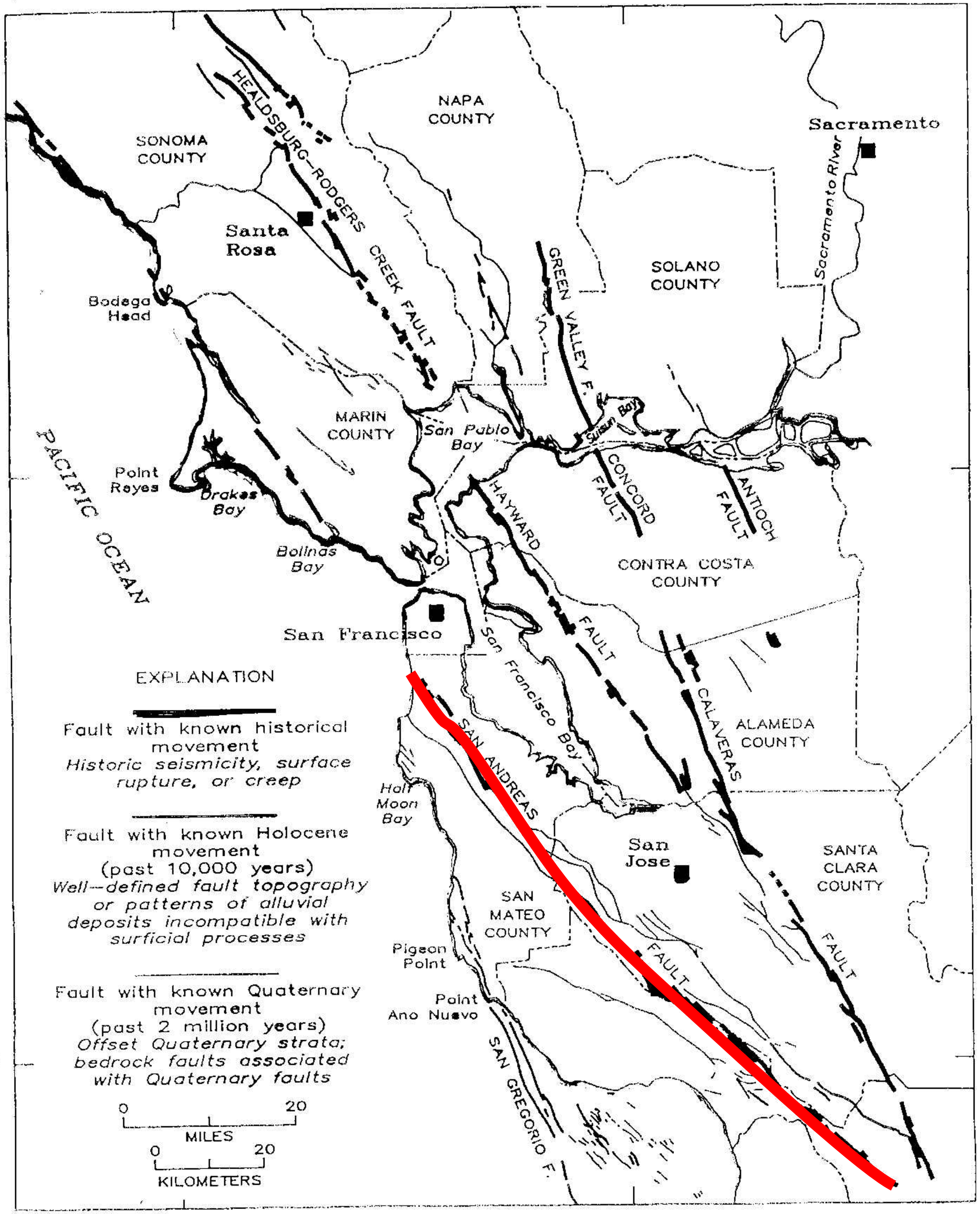
Figure 1.6 Types of fault movement based on the sense of fault motion. (Modified from Wesson et al., 1975. U. S. Geological Survey Professional Paper 941A.)

Large horizontal slips – regional scale



- San Andreas





- **San Andreas fault**

Regional vertical movements -Gravitional - tectonical deformations

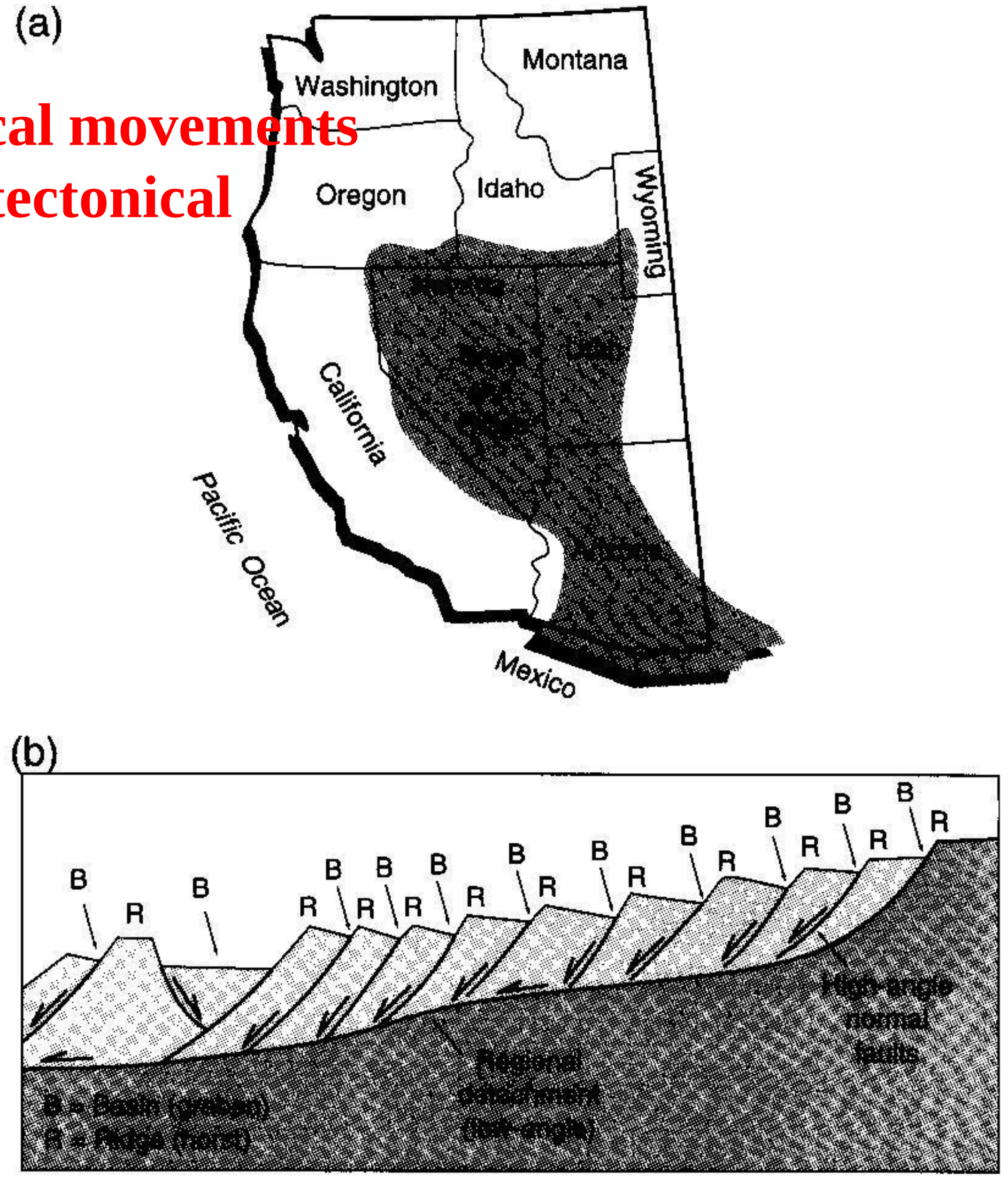


Figure 2.18 (a) Location of Basin and Range province, and (b) regional tectonic framework, including high-angle normal faults that produce the basins and ranges, and regional low-angle detachment faults.

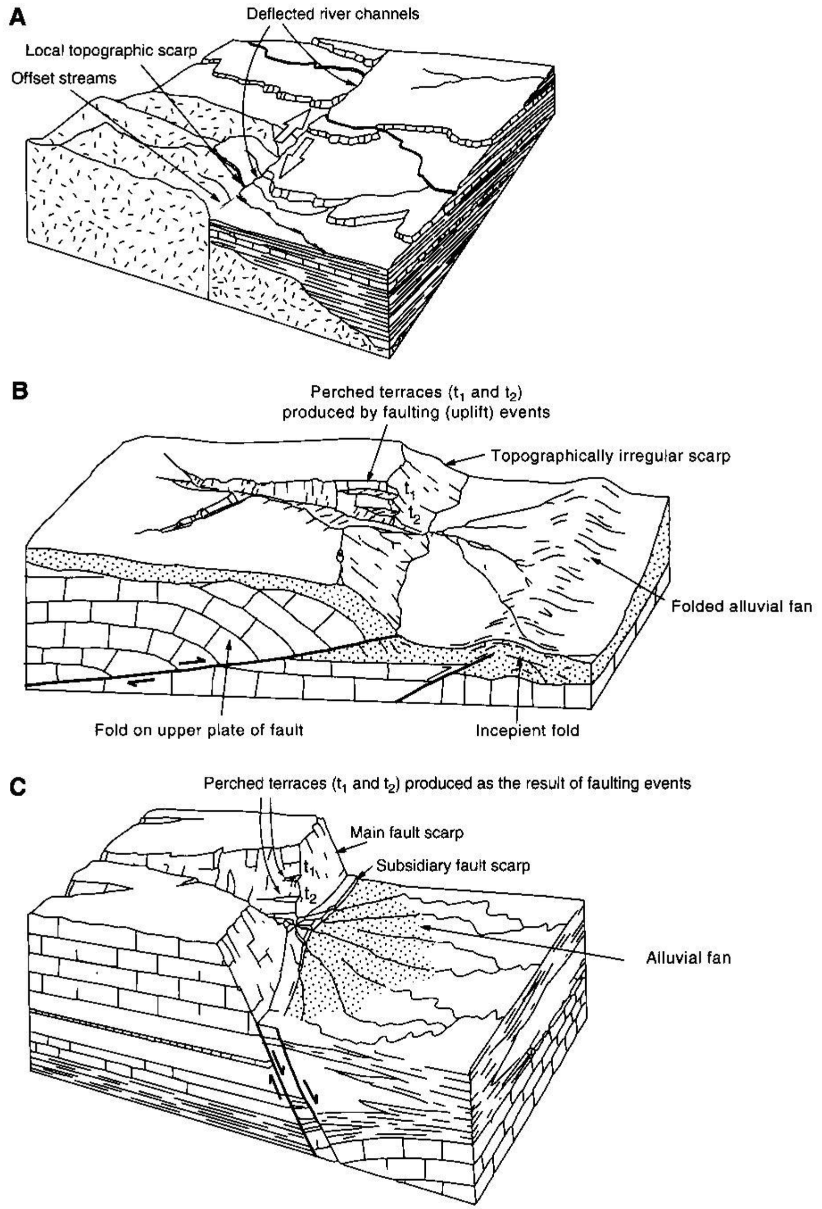


Figure 1.7 Idealized diagrams showing types of topographic expression possible with different types of faults. (a) A strike-slip fault showing a local topographic scarp, deflected river channels, and offset streams. (b) Thrust fault (low-angle reverse fault) with a fold above the fault tip. Topography shows an irregular scarp, perched terraces (t_1 and t_2) produced by faulting (uplift) events, and a folded alluvial fan. (c) Normal fault, with topography showing main and subsidiary fault scarps, perched terraces (t_1 and t_2) produced by faulting (uplift) events, and an alluvial fan. (After Ramsay and Huber, 1987. *Modern Structural Geology*, Vol. 2. New York: Academic Press.)

Break