Геология планет

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ГЕОХИ РАН
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The course content

1. Solar system, Earth

2. The Moon and Mercury

3. Venus

4. Mars

5. Small bodies: Asteroids, comets, meteorites

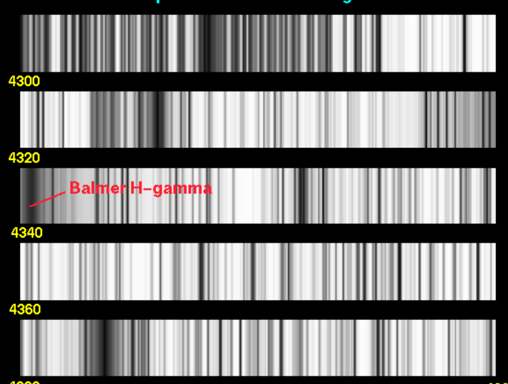
6. Outer planets and their satellites

7. Geological processes in the Solar system (summary)

Solar system

Our Sun is a star of spectral class G2V

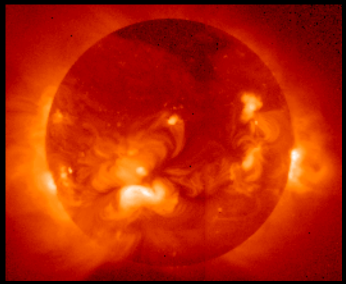
Distance from Earth	149 million km = 1 AU
Diameter of the Sun	1.4 million km
Mass of the Sun	333,000 mass of Earth
Mean density	1.4 g/cm^3
Density in the center	160 g/cm^3
Temperature of photosphere	6,000 K
at the center	15,000,000
Period of rotation, equator	25.6 days
poles	36 dfays



Composition (mass. %)

H	73.46	Fe	0.16	M	0.05
He	24.85	Ne	0.12	S	0.04
O	0.77	N	0.09		
C	0.29	Si	0.07 other 0.1		

Sun in UV



Sun in X-ray

- Solar wind
- 11-year cycle of magnetic activity

Interplanetary matter and magnitospheres

- Finely disseminated matter between planets and other bodies of the Solar system системы.

- Includes dust, cosmic rays and hot plasma of solar wind. Temperature of interplanetary matter ~ 100,000 K, while its density in the vicinity of Earth ~ 5 particles / cm^3; it decreases with increase of distance from the Sun as R^{-2}.

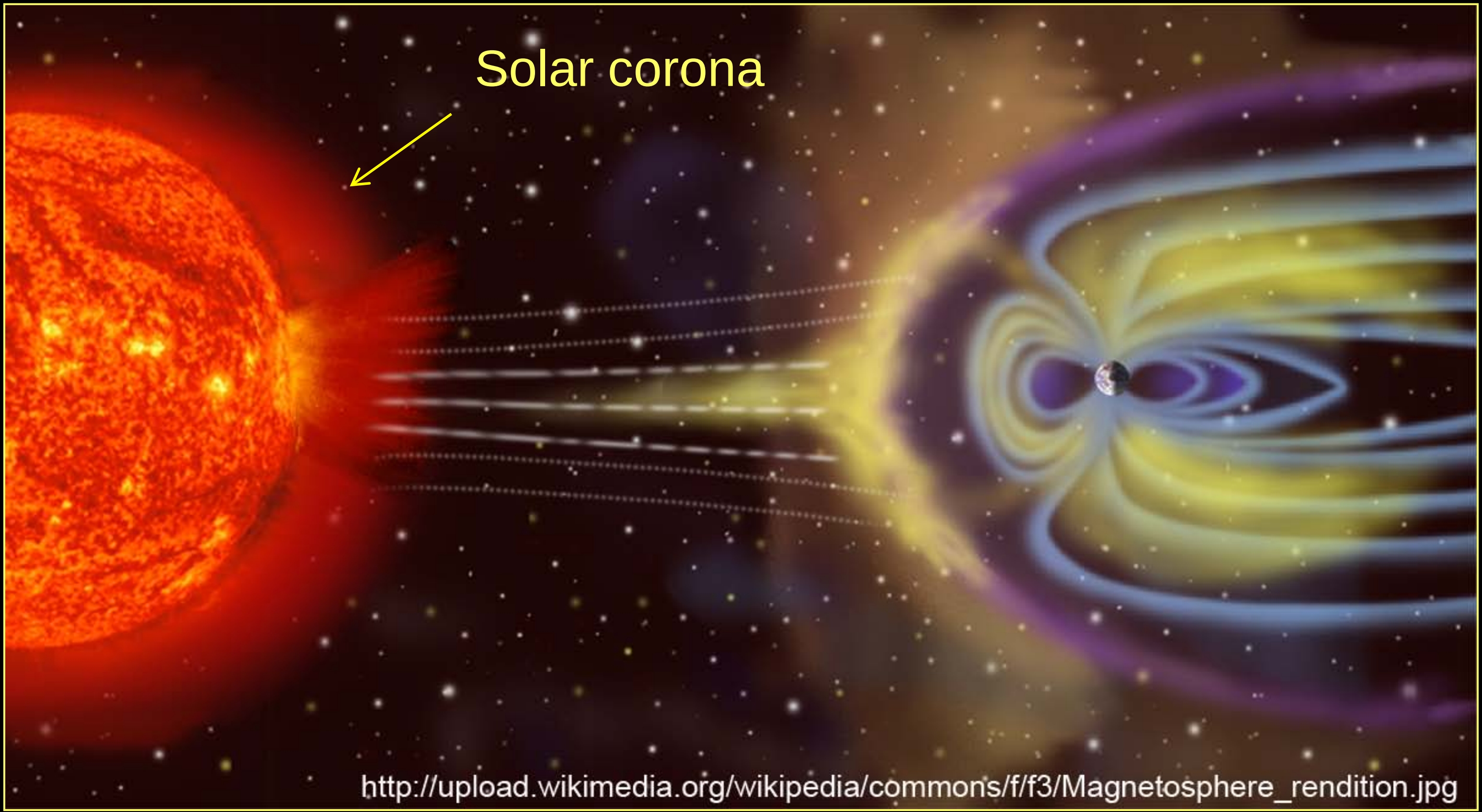
- Plasma caries magnetic field of the Sun.

- Outer edge of the Solar system is a boundary between flux of solar wind and interstar matter – so called heliopause (~100 AU from the Sun).

Launched in 1977 Voyager 1 is now in "Interstellar space“ (134 AU) and Voyager 2 is currently (111 AU) in the outermost layer of the heliosphere where the solar wind is slowed by the pressure of interstellar gas.

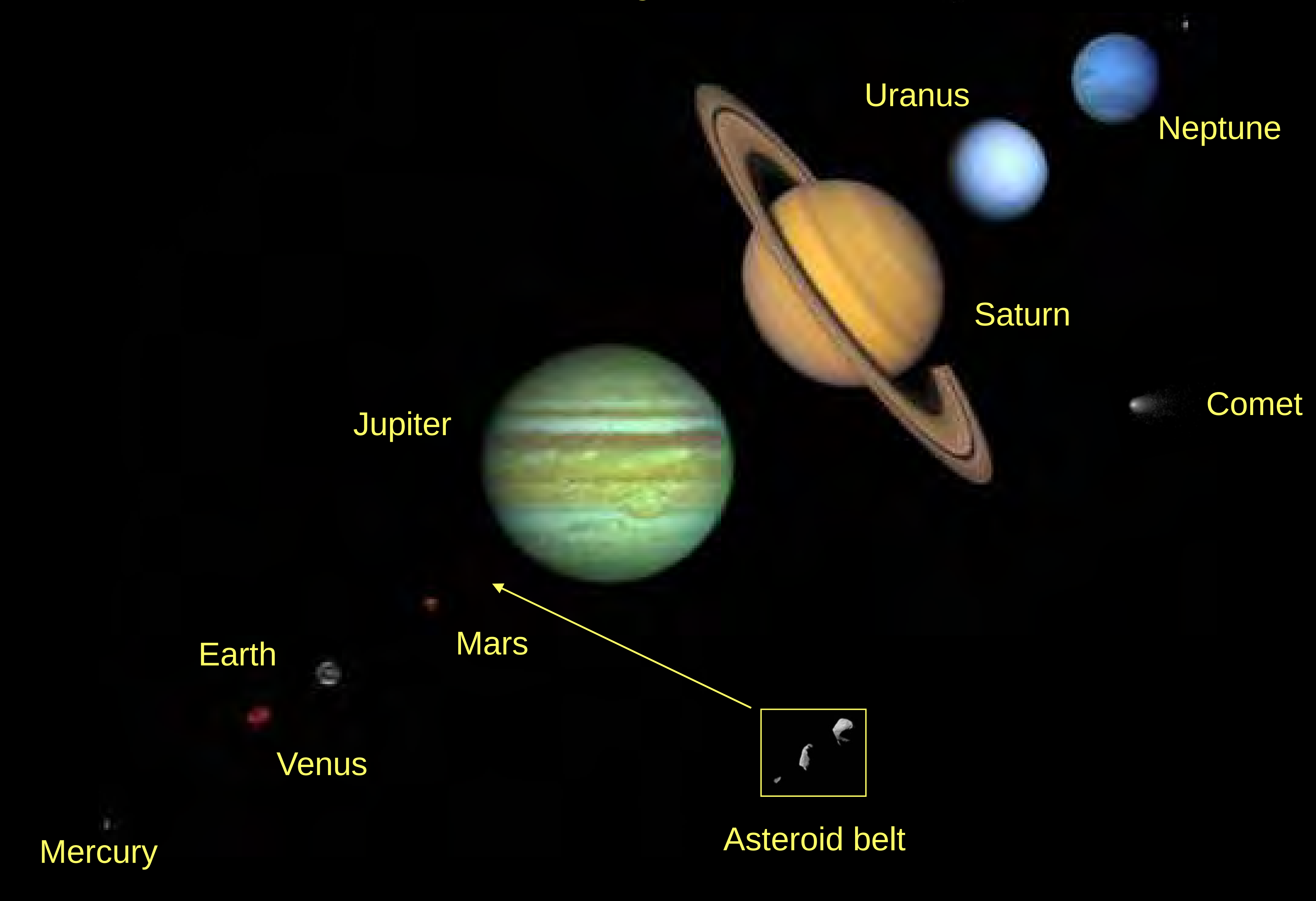
Solar wind - particles, mostly, electrons and protons, leaving solar corona. Very rarified: in the vicinity of Earth – a few particles per cm^3.

In the air we breath - $\sim 2.7 \times 10^{19}$ particles in cm^3.

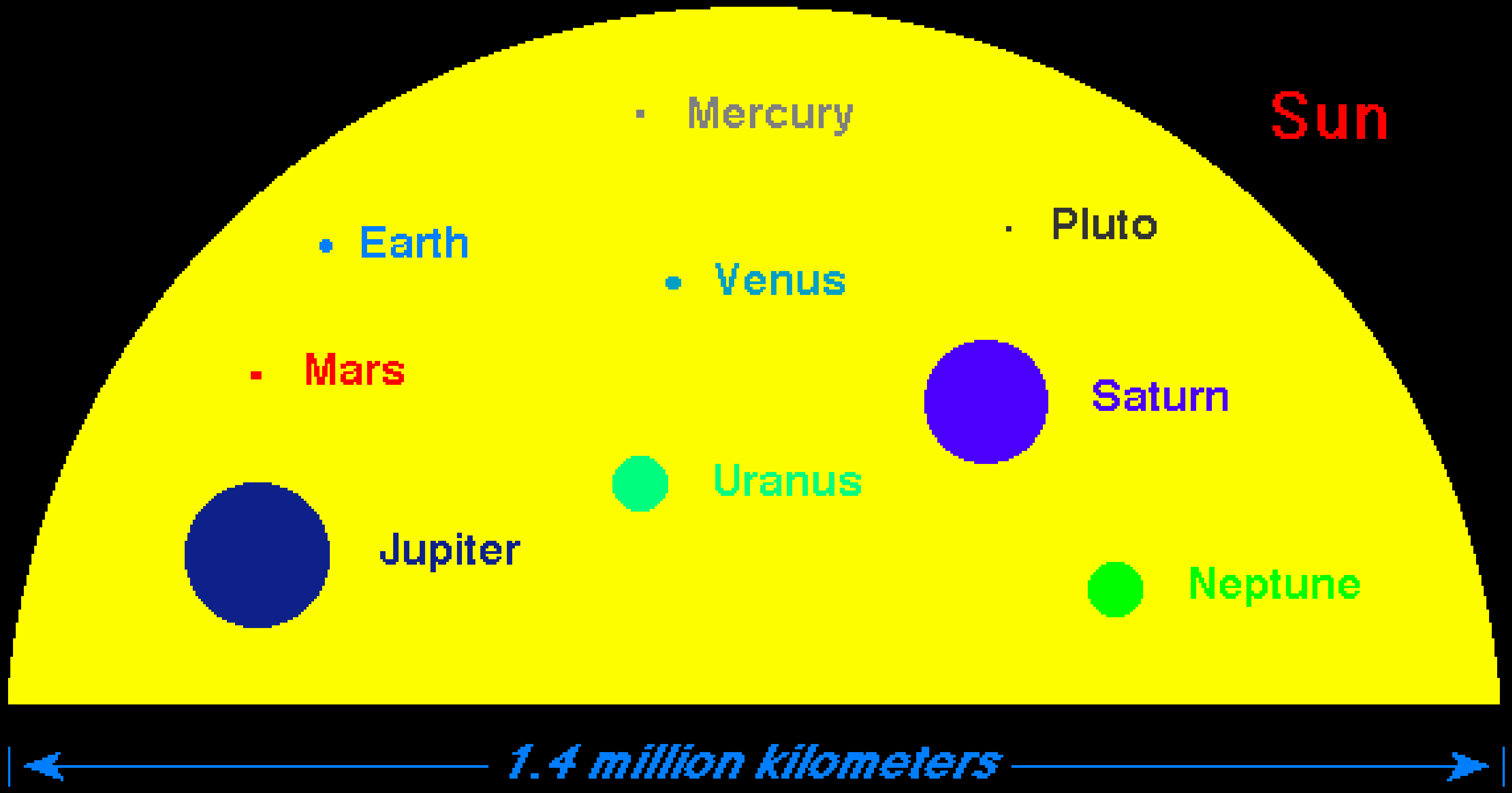


Magnetosphere: Part of space, in which magnetic field of planet predominates over magnetic field of solar wind.

Planets of the Solar system



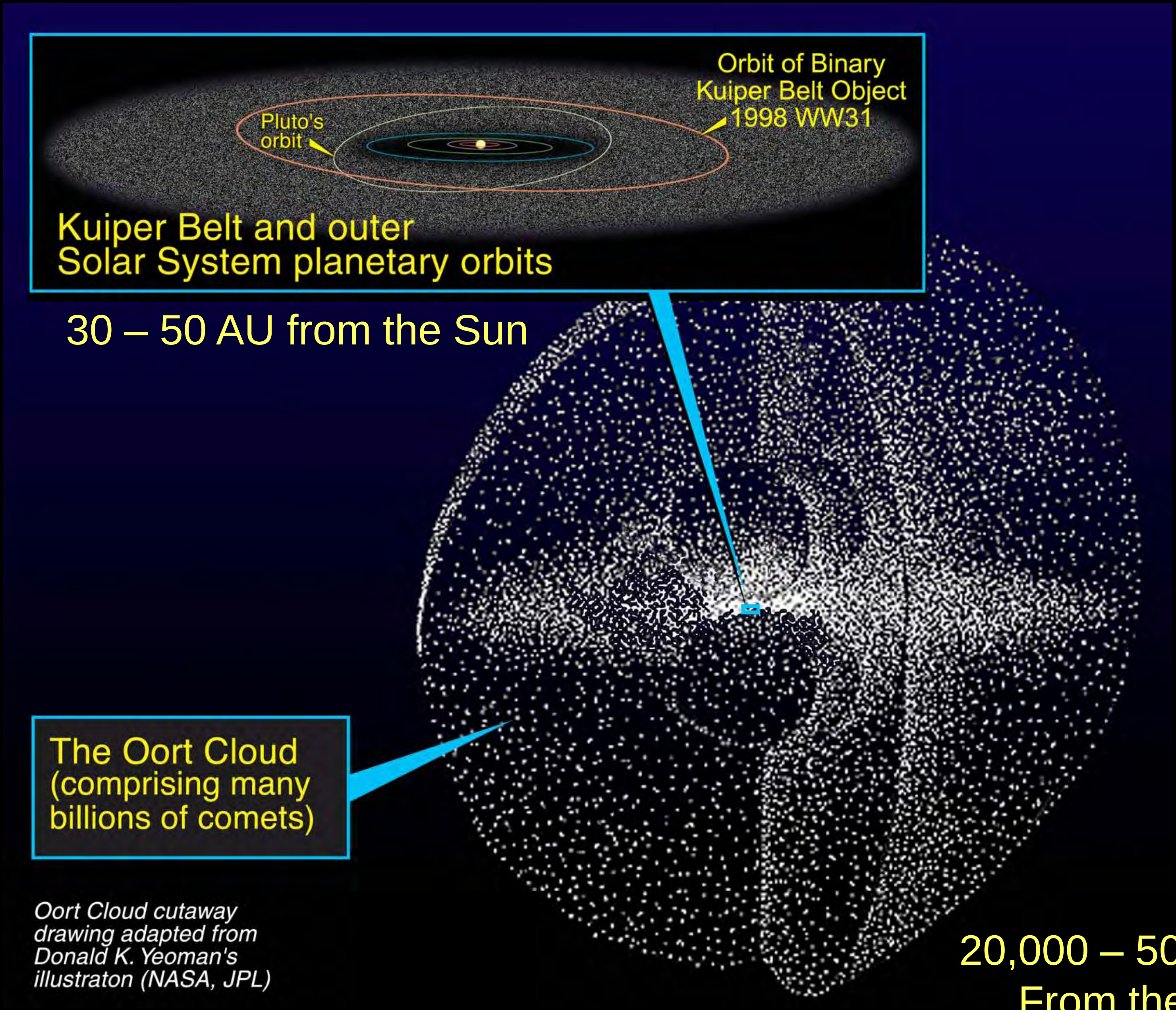
Relative sizes of the Sun and planets



Planets of the Solar system

	Mercury 1	Venus 2	Earth 3	Mars 4	Jupiter 5	Saturn 6	Uranus 7	Neptune 8	Pluto 9
Distance from the Sun, au	0.4	0.7	1.0	1.5	5.2	9.5	19.2	30	39
Radius, km	**2,400**	**6,050**	**6,378**	**3,390**	**71,400**	**60,300**	**26,200**	**25,200**	**1,200**
Mass, M_{Earth}	0.06	0.82	1	0.11	317	95	14.5	17	0.003
Density. g/см^3	5.4	5.2	5.5	3.9	1.3	0.69	1.3	1.6	2.0
Albedo	0.06	0.76	0.36	0.16	0.43	0.61	0.35	0.35	0.38
Number of known satelites	0	0	1	2	16 / ~60	17 / ~30	15 / ~20	8	1 / 3

Kuiper belt and Oort cloud



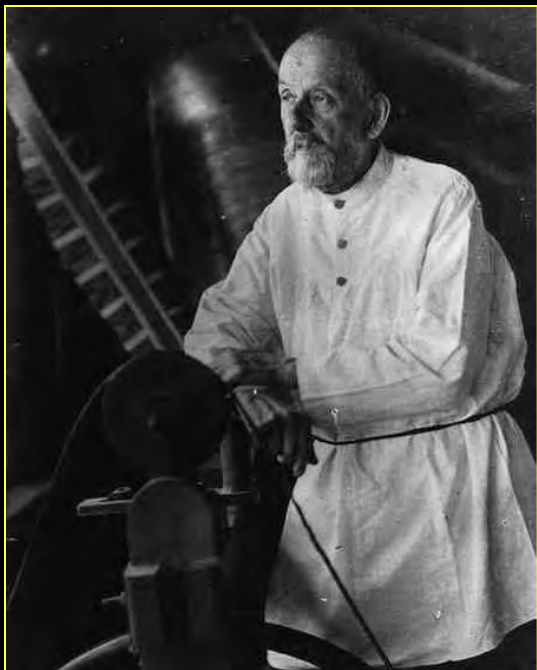
20,000 – 50,000 AU
From the Sun

Solar system studies
became effective
with development of rockets

Rockets have been invented in ancient China

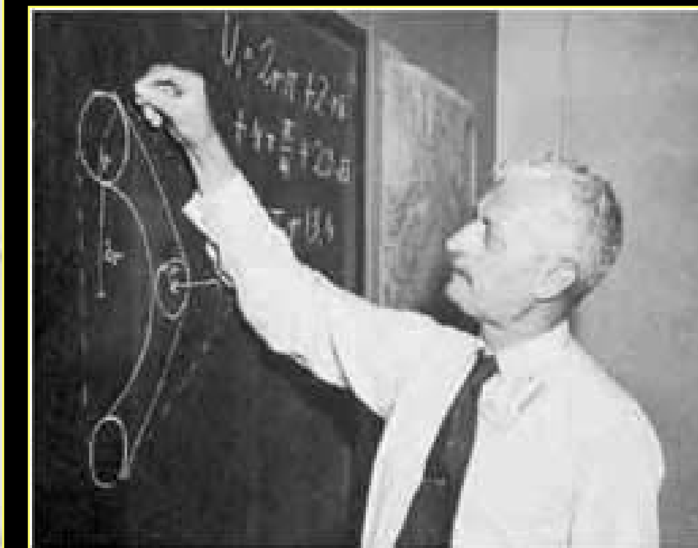
They were used for military purposes and for fireworks

Fathers of space flights



Konstantin Tsiolkovsky
Russian,
Theoretician
of rocketry
1857-1935

Robert
Goddard
American,
Rocket engineer
1882-1945

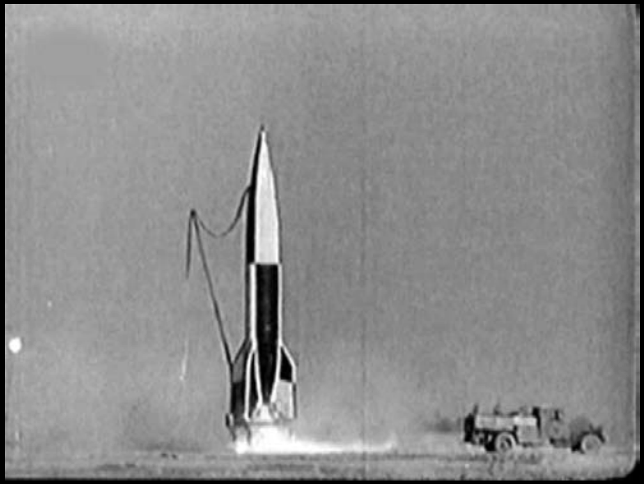


Hermann
Oberth
German
Rocket engineer
1894-1989

Space flights to the Moon and further

Role of V2 in modern rocket industry

In Germany
1944



In the Soviet Union
End of 40s

In USA
End of 40s

Wernher von Braun from V2 to Saturn 5

The plant, which produced V2, in Peenemunde, Germany

The plant

V2

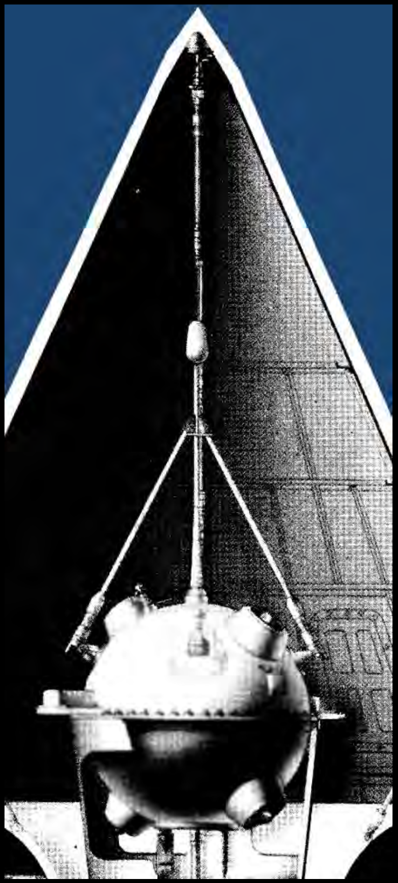
V1

Russian rocket

Beginning of space era:
Sputnik and first flights to the Moon

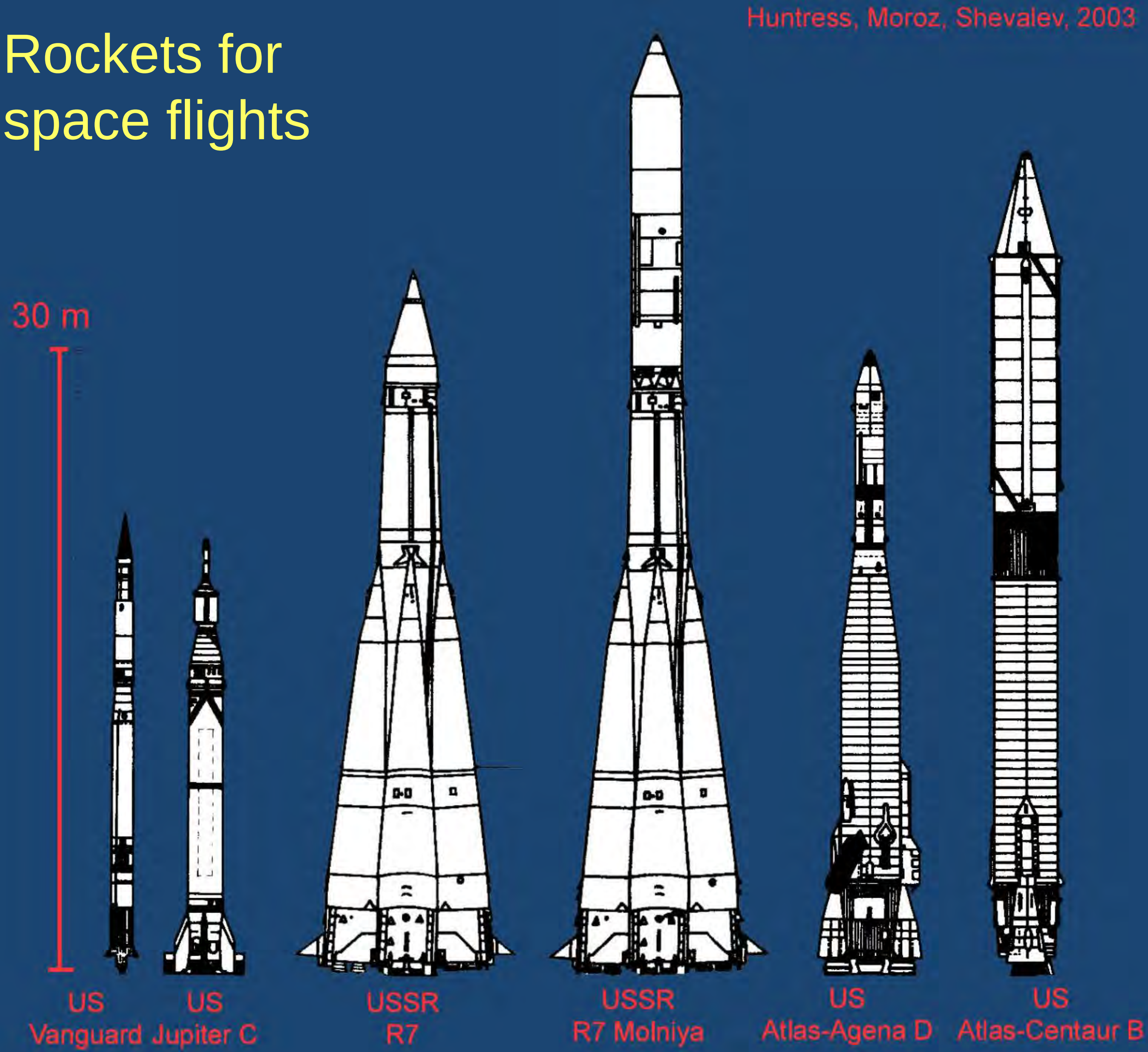
Sputnik
October 4, 1957

Sergey Korolev
Soviet
rocket engineer
1906-1966



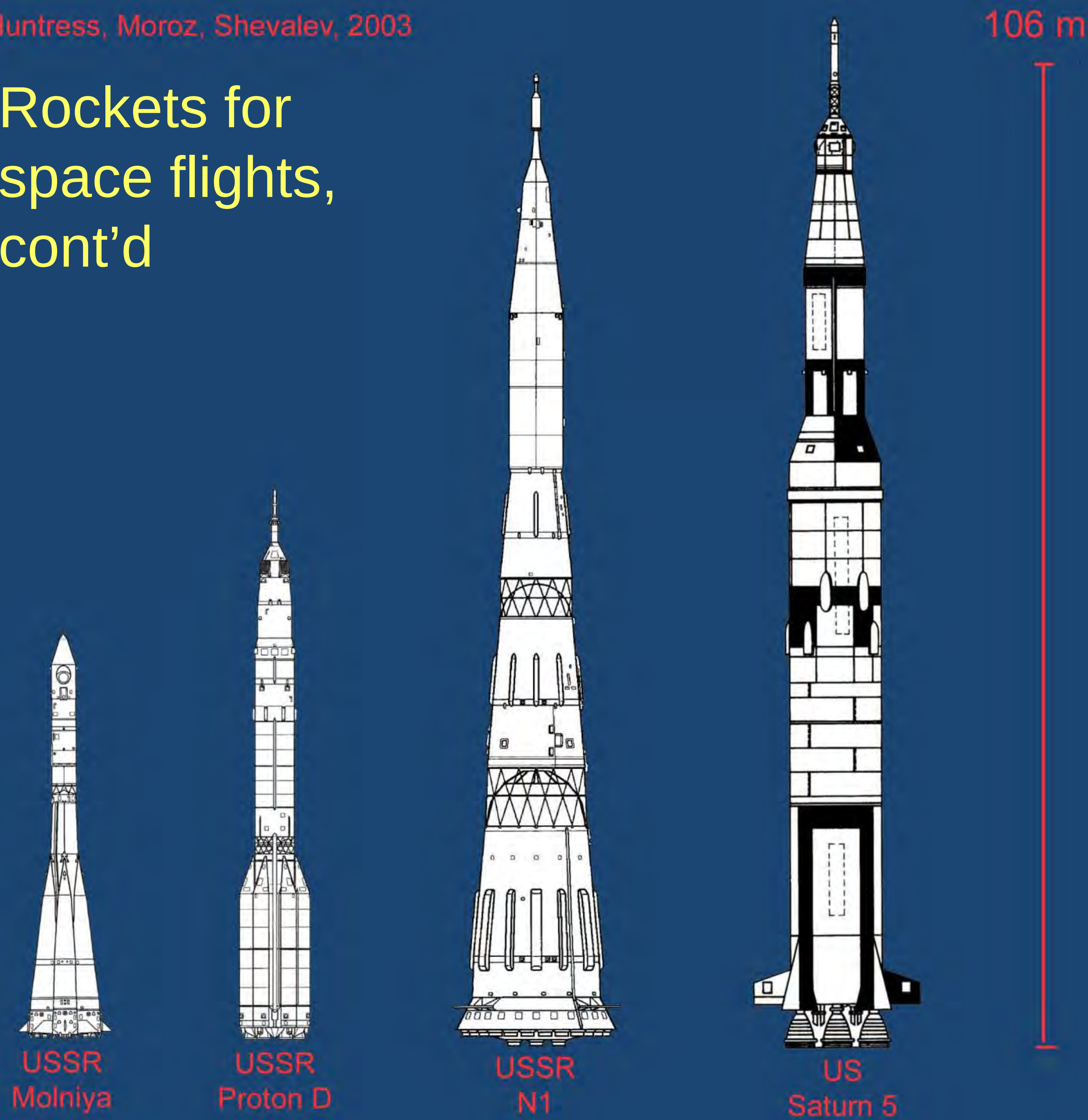
Luna 1
January 2, 1959

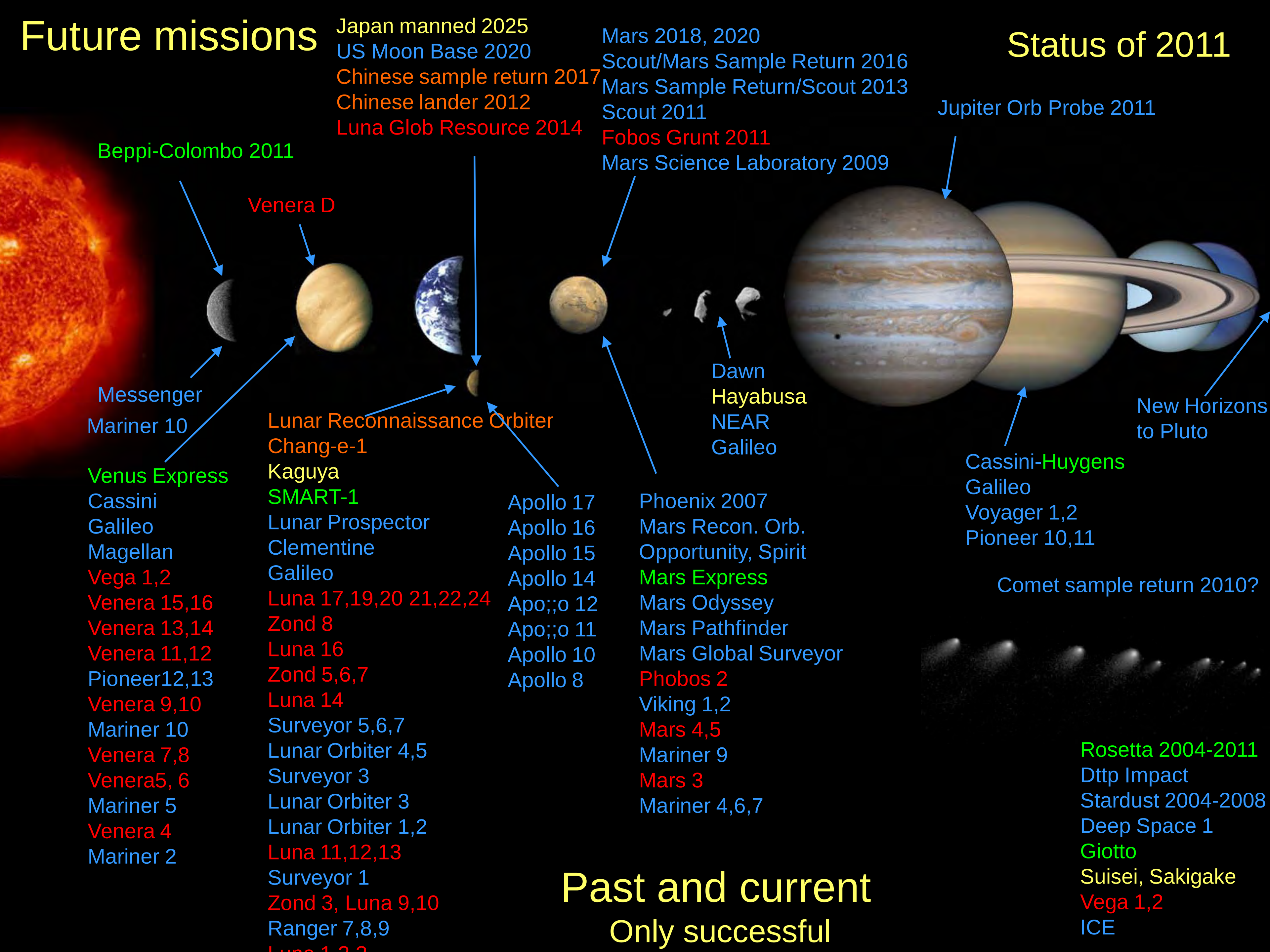
Rockets for space flights



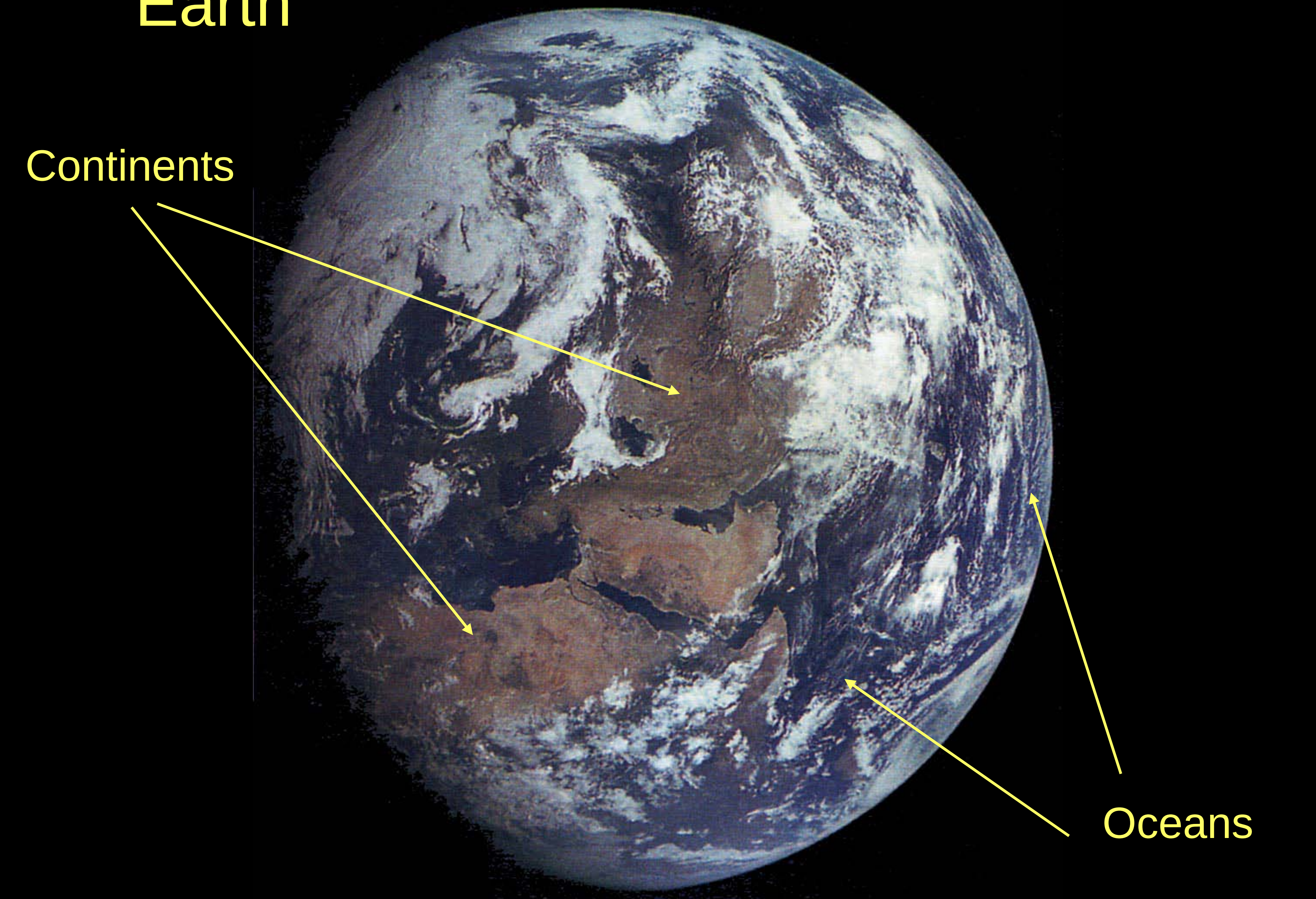
Huntress, Moroz, Shevalev, 2003

Rockets for space flights, cont'd




Future missions
Japan manned 2025
US Moon Base 2020
Chinese sample return 2017
Chinese lander 2012
Luna Glob Resource 2014
Mars 2018, 2020
Scout/Mars Sample Return 2016
Mars Sample Return/Scout 2013
Scout 2011
Fobos Grunt 2011
Mars Science Laboratory 2009
Status of 2011
Jupiter Orb Probe 2011
Beppi-Colombo 2011
Venera D
Messenger
Mariner 10
Venus Express
Cassini
Galileo
Magellan
Vega 1,2
Venera 15,16
Venera 13,14
Venera 11,12
Pioneer12,13
Venera 9,10
Mariner 10
Venera 7,8
Venera5, 6
Mariner 5
Venera 4
Mariner 2
Lunar Reconnaissance Orbiter
Chang-e-1
Kaguya
SMART-1
Lunar Prospector
Clementine
Galileo
Luna 17,19,20 21,22,24
Zond 8
Luna 16
Zond 5,6,7
Luna 14
Surveyor 5,6,7
Lunar Orbiter 4,5
Surveyor 3
Lunar Orbiter 3
Lunar Orbiter 1,2
Luna 11,12,13
Surveyor 1
Zond 3, Luna 9,10
Ranger 7,8,9
Apollo 17
Apollo 16
Apollo 15
Apollo 14
Apo;;o 12
Apo;;o 11
Apollo 10
Apollo 8
Phoenix 2007
Mars Recon. Orb.
Opportunity, Spirit
Mars Express
Mars Odyssey
Mars Pathfinder
Mars Global Surveyor
Phobos 2
Viking 1,2
Mars 4,5
Mariner 9
Mars 3
Mariner 4,6,7
Dawn
Hayabusa
NEAR
Galileo
Cassini-Huygens
Galileo
Voyager 1,2
Pioneer 10,11
New Horizons
to Pluto
Comet sample return 2010?
Rosetta 2004-2011
Dttp Impact
Stardust 2004-2008
Deep Space 1
Giotto
Suisei, Sakigake
Vega 1,2
ICE
Past and current
Only successful

Earth



Zond 7 image of Earth

Third planet from the Sun
Distance from the Sun = 149 million km = 1 AU
One satellite – the Moon

Orbital period = 1 year = 365 days
Rotation around axis 24 hours

Equatorial diameter 12 756 km
Polar diameter 12 712 км

Mass of Earth 5.97 x 10 ^{24} kg
Mean density 5.5 g/cm^3
Gravity acceleration 978 cm/s^2

Hydrosphere 1.35 x 10^{21} kg
Atmosphere 5 x 10^{18} kg

N_2 78%, O_2 21%,
Ar ~1%, CO_2 0.04%

Apollo 17 image of Earth

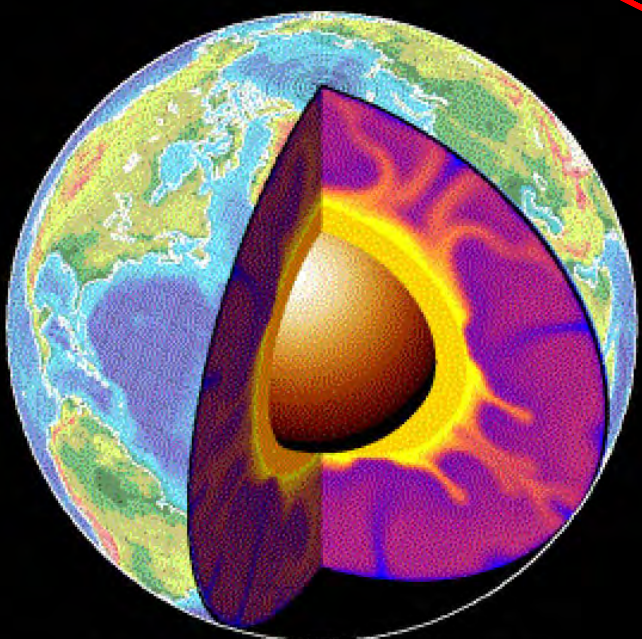
Courtesy of NASA

Earth interiors

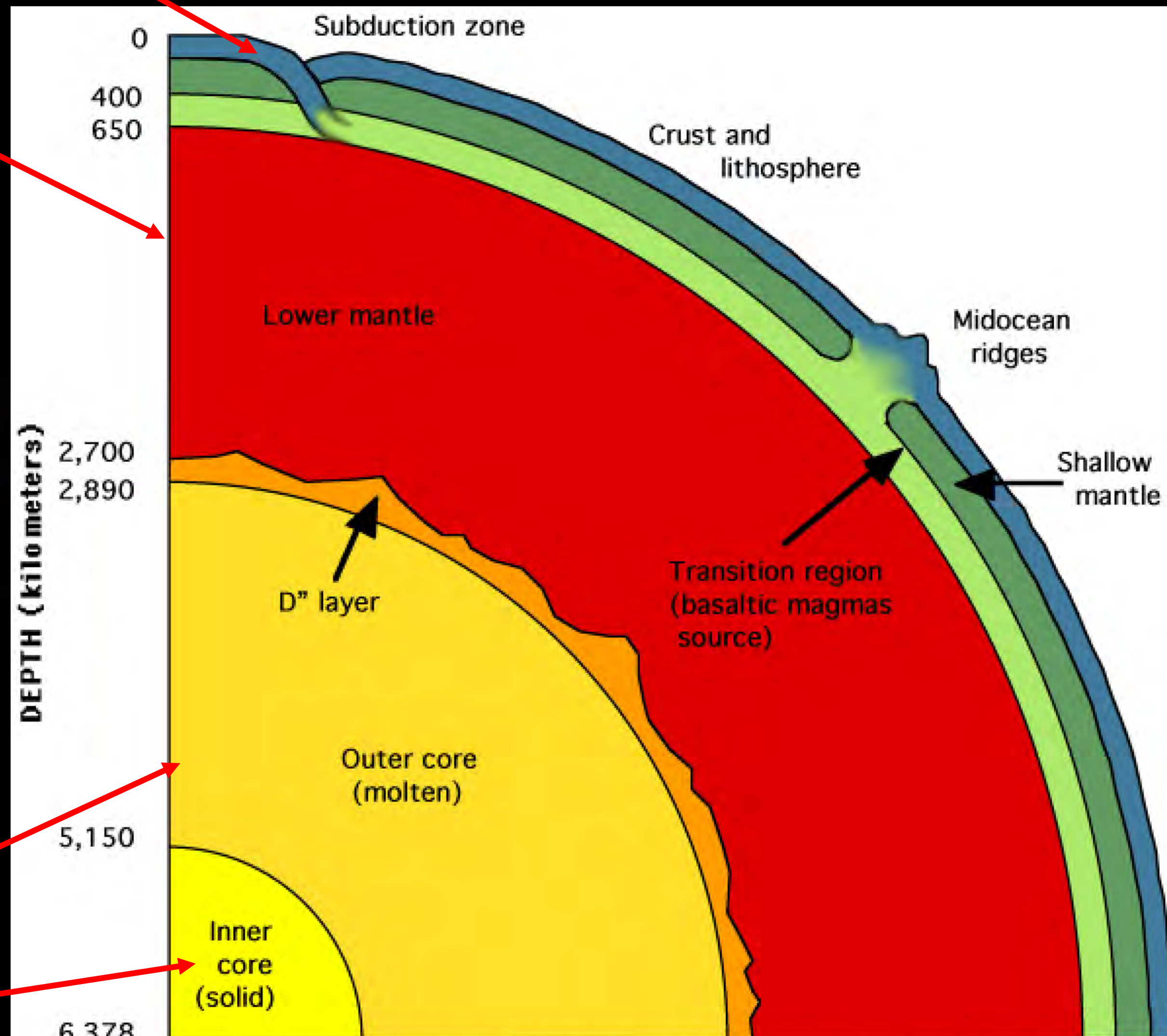
Crust – granites, basalts, sedimentary rocks

Lithosphere = crust + rigid upper part of the mantle

Mantle– peridotites, dunites



http://www.washington.edu/burkemuseum/geo_history_wa/



http://www.math.montana.edu/~nmp/materials/ess/geosphere/expert/activities/planet_earth/

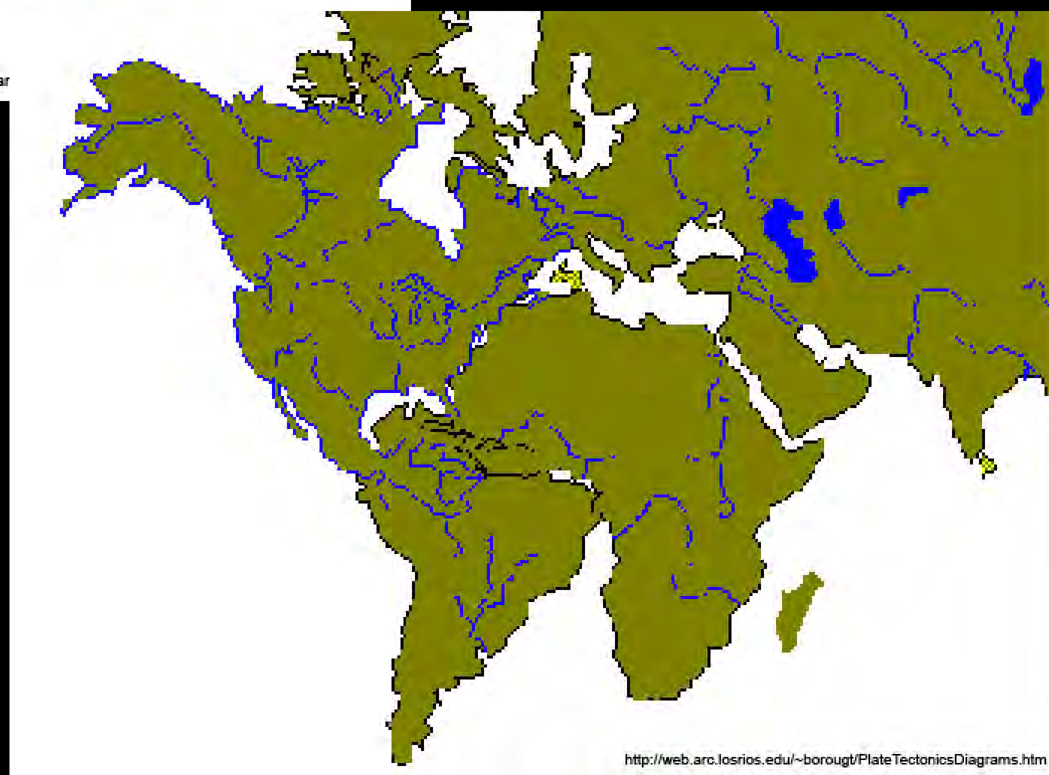
Outer core – melted iron

Inner core – solid iron

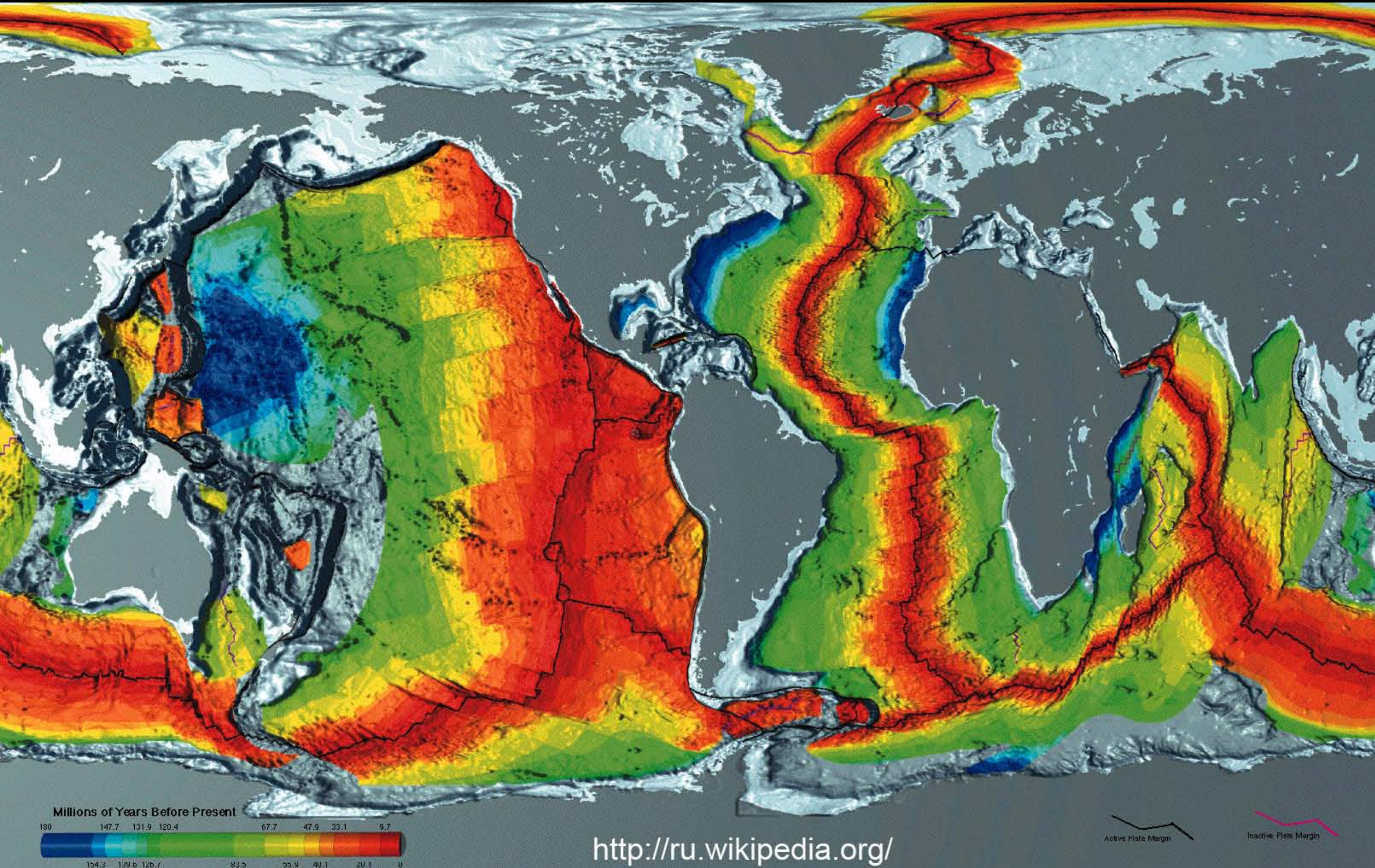
Plate tectonics -
- working heat engine of Earth

Alfred Wegener
1880-1930

In 1912 г. German geophysicist Alfred Wegener payd attention that outlines of Earth continents can be arranged in the way that supercontinent Pangea formed. So in publications of 1920-1929 he suggested a hypothesis of continental drift. It was rejected that time by majority of geophysicists.

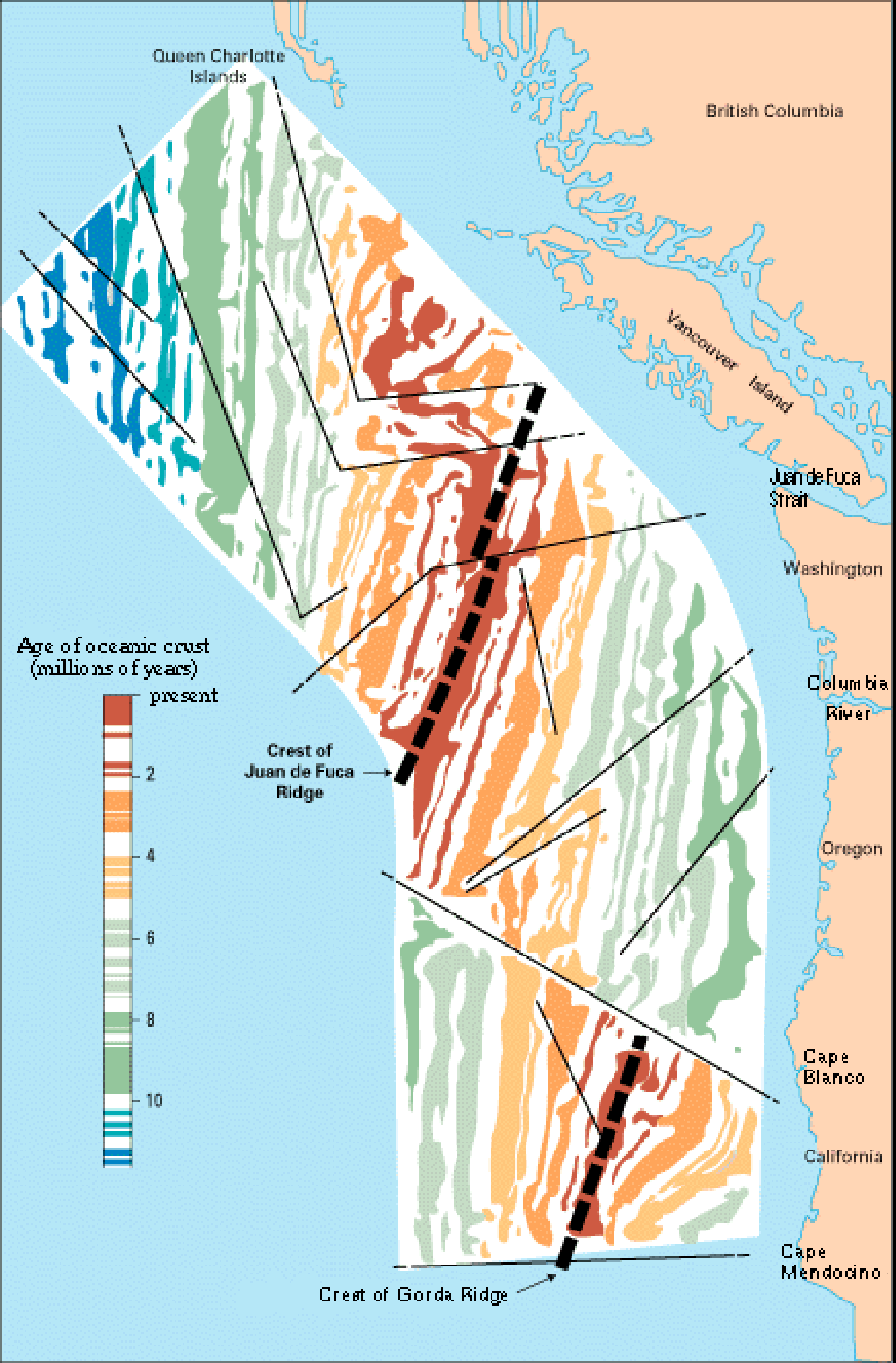


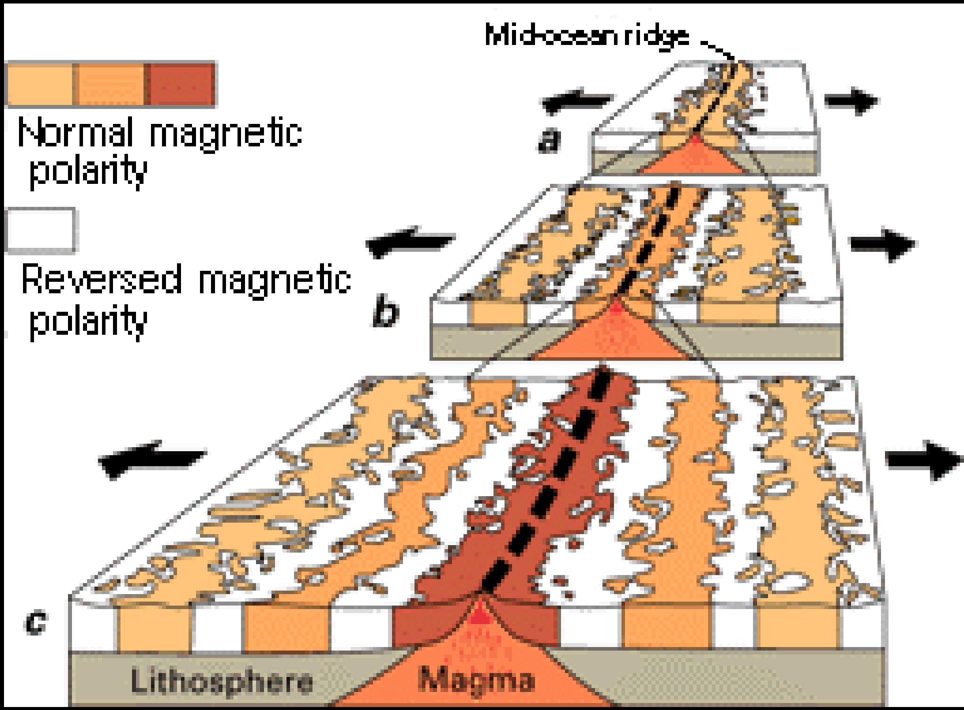
Wegener's hypothesis resurrected in 1960's in the form of plate tectonics, mostly, as a result of study of the ocean floor.



Age of the ocean floor basalts

Stripe magnetic anomalies as evidence of oceanic floor spreading

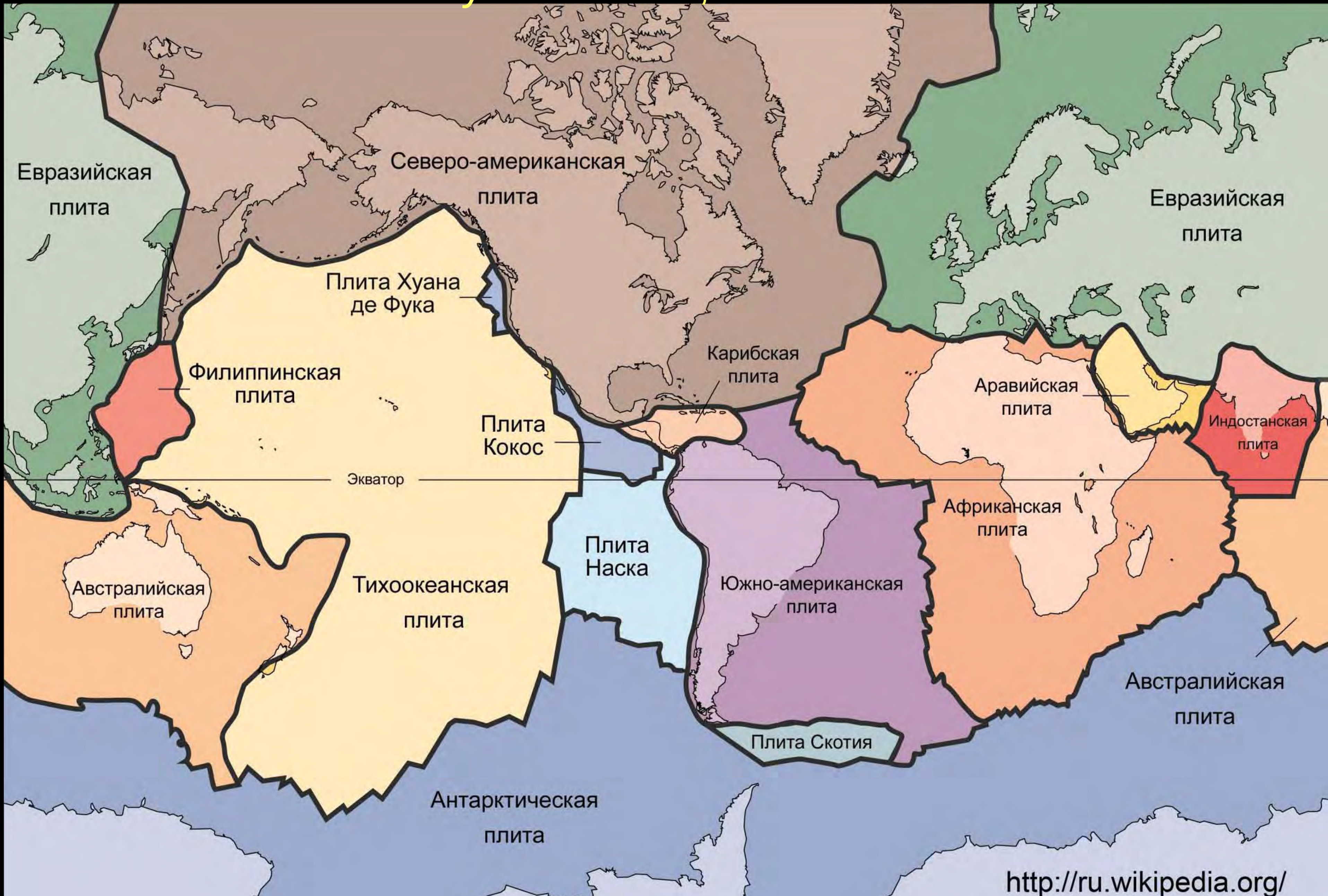




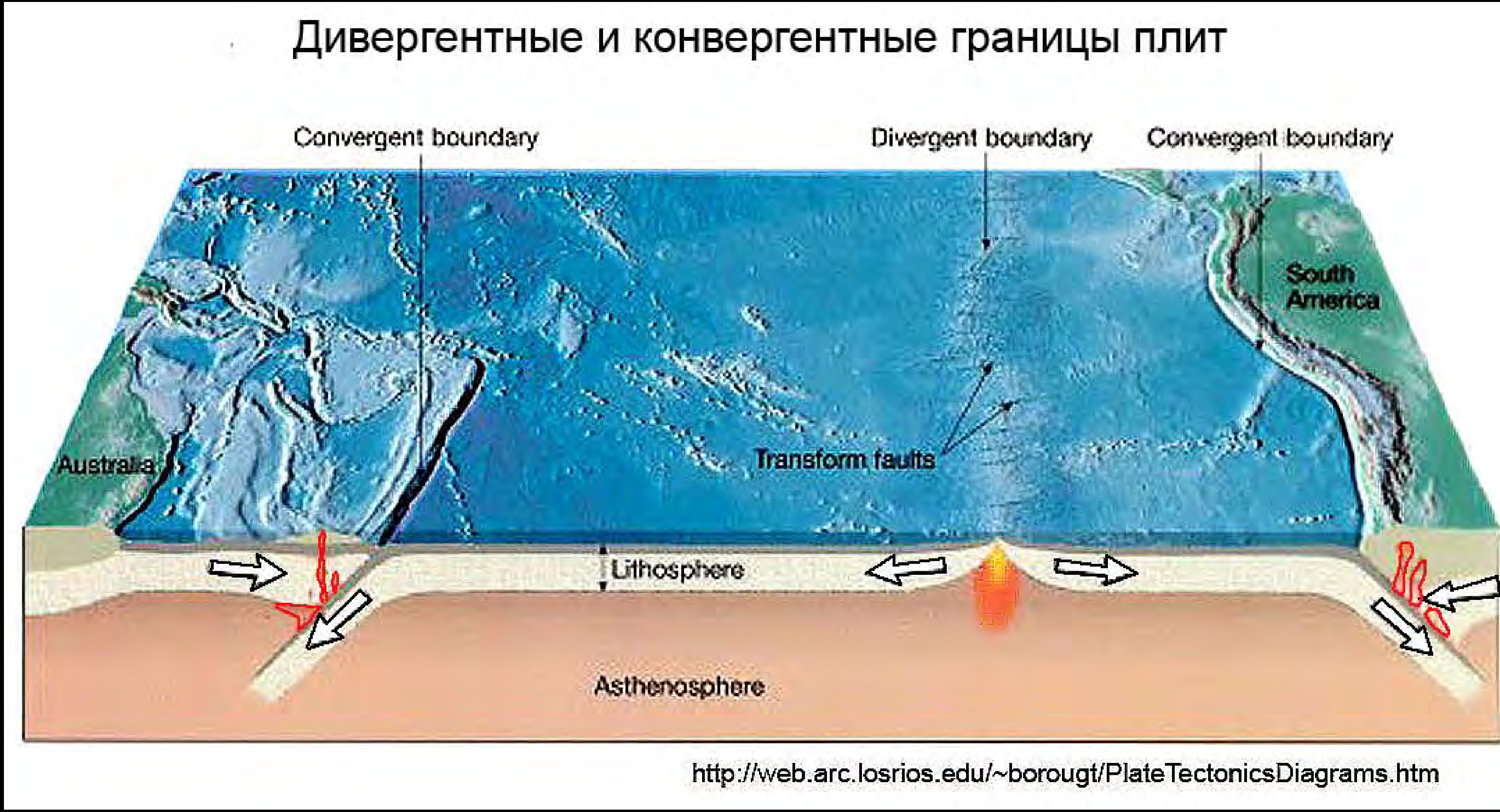
http://web.arc.losrios.edu

Lithospheric pl;ates of Earth.

Include not only continents, but oceanic floor too



Two types of boundaries of lithospheric plates: Divergent and convergent



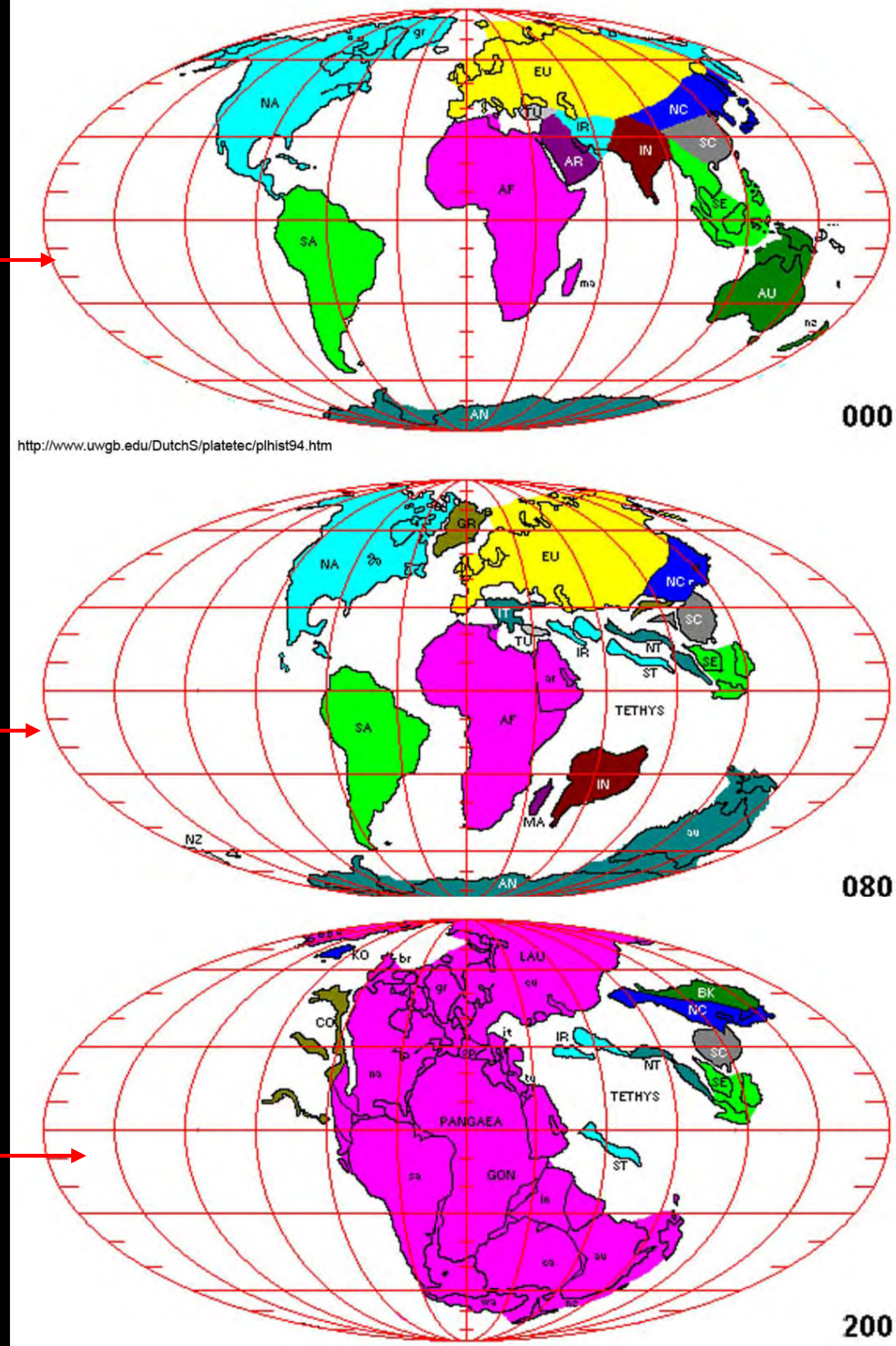
Continents of Earth now and in the recent past –
– reconstruction based on geological and geophysical data.

In the history of Earth there were 3-4 super-continents:
2.7, 1.9, 1.2 и
0.6-0.4 billion years ago –
supercontinental cycle

Now

80 my ago

200 my ago

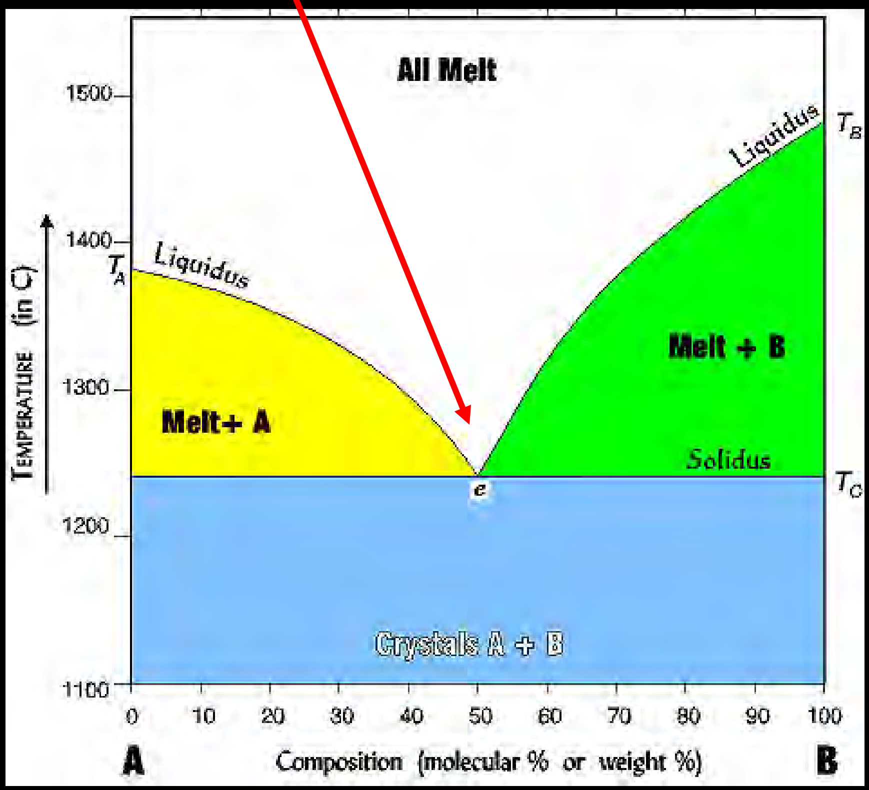


Endogenic processes:
Volcanism

Volcanism

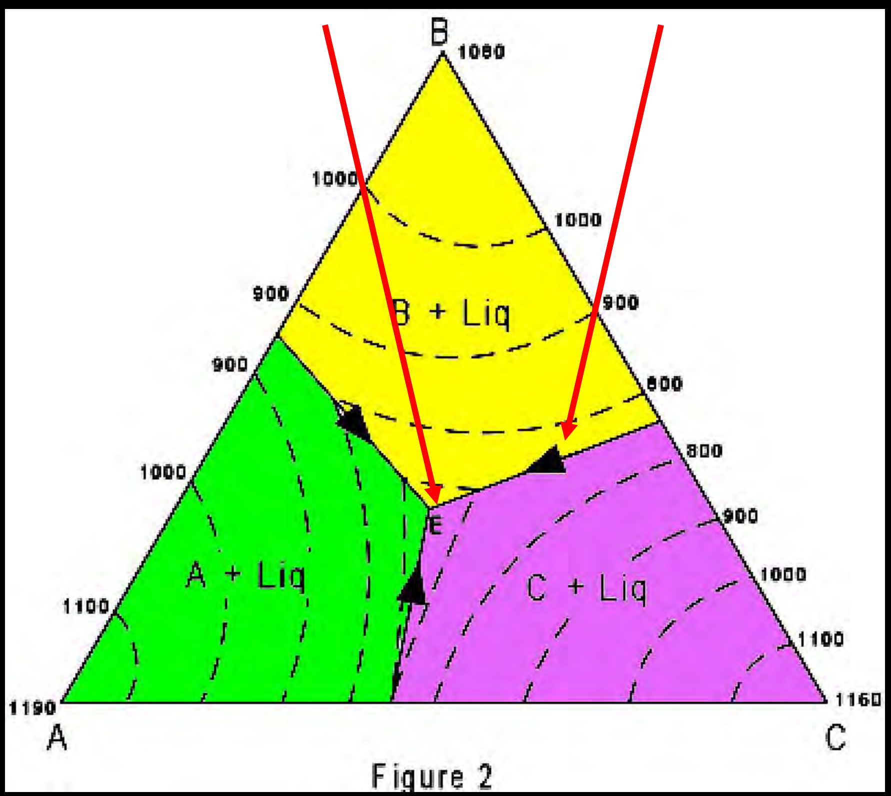
Magmas (melts) appear as ***the result of partial melting in planet interior***, as a rule, due to decrease of pressure in the process of rise of mantle material (convection, hot diapir)

Binary eutectic



Ternary eutectic

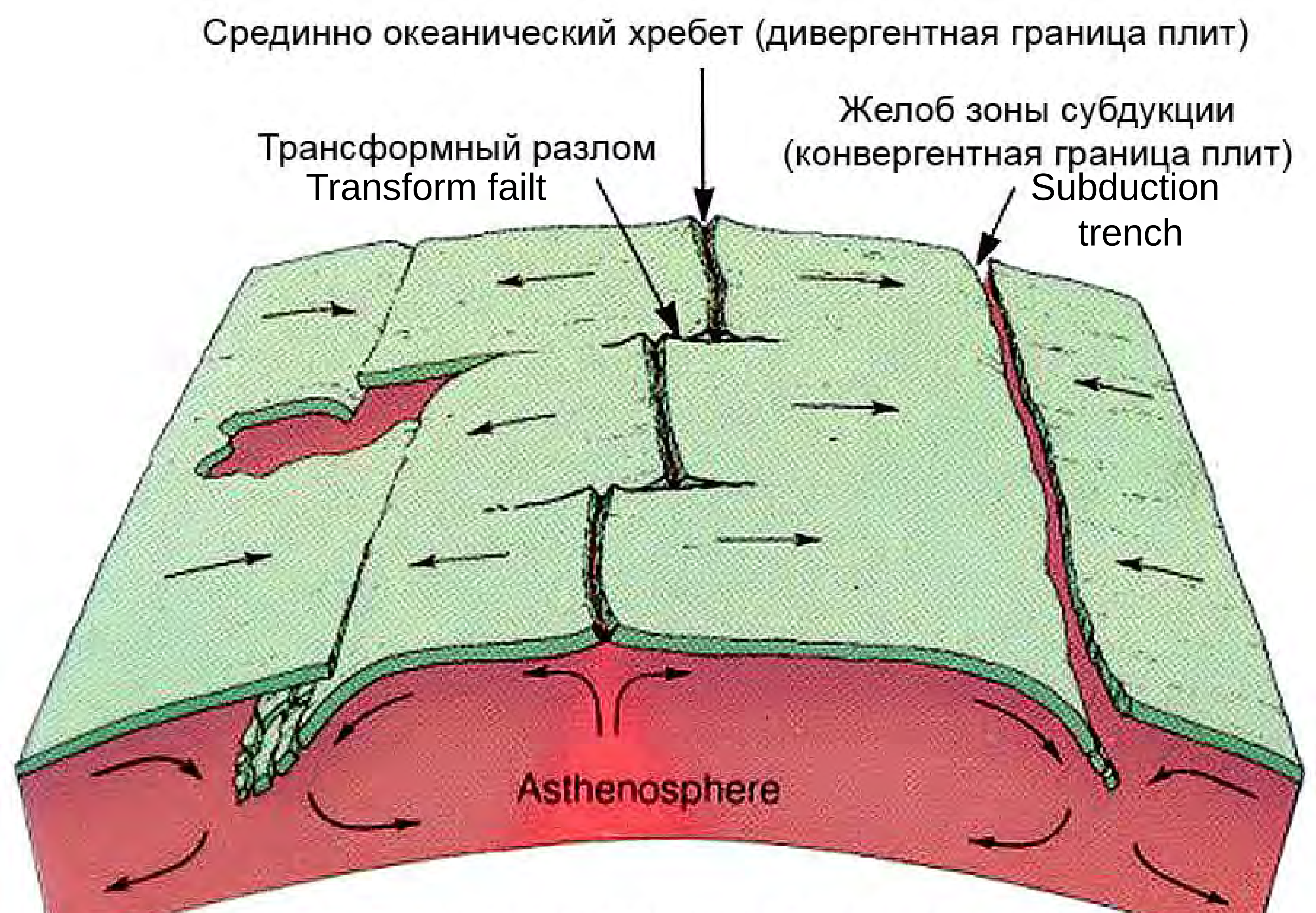
Cotectic



In the process of dry partial melting of the mantle material basaltic magmas formed. In the process of partial melting with participation of H_2O more differentiated magmas (andesites, granites) formed.

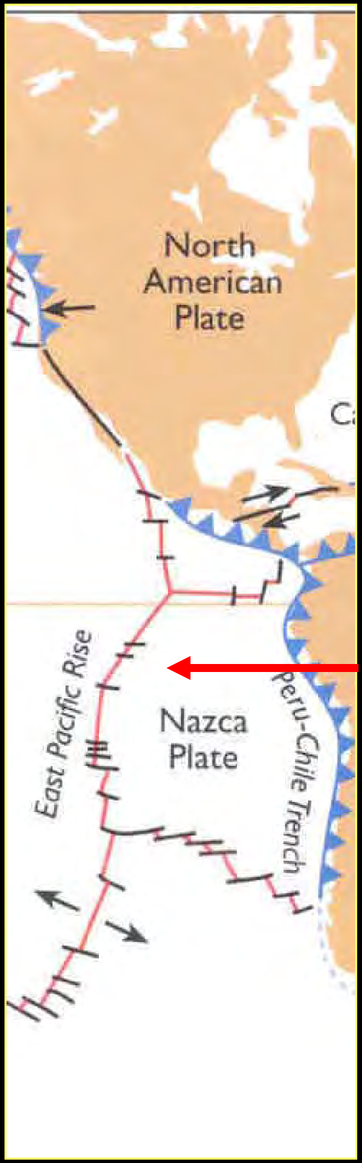
Volcanism of divergent zones

Midoceanic ridge (divergent plate boundary)



http://web.arc.losrios.edu/~borougt/PlateTectonicsDiagrams.htm

Eruption of basaltic pillow lavas in spreading zone

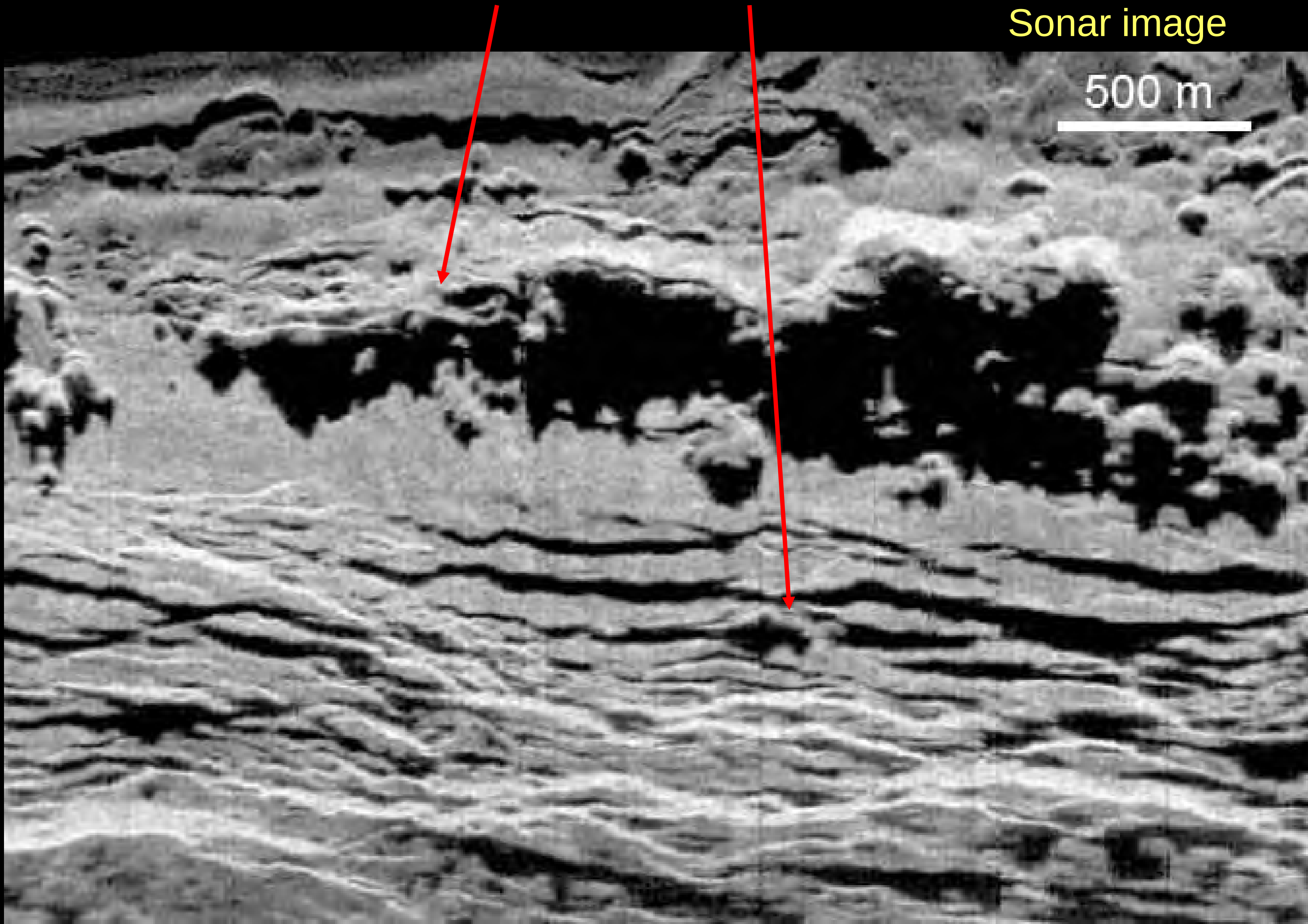


A few meters

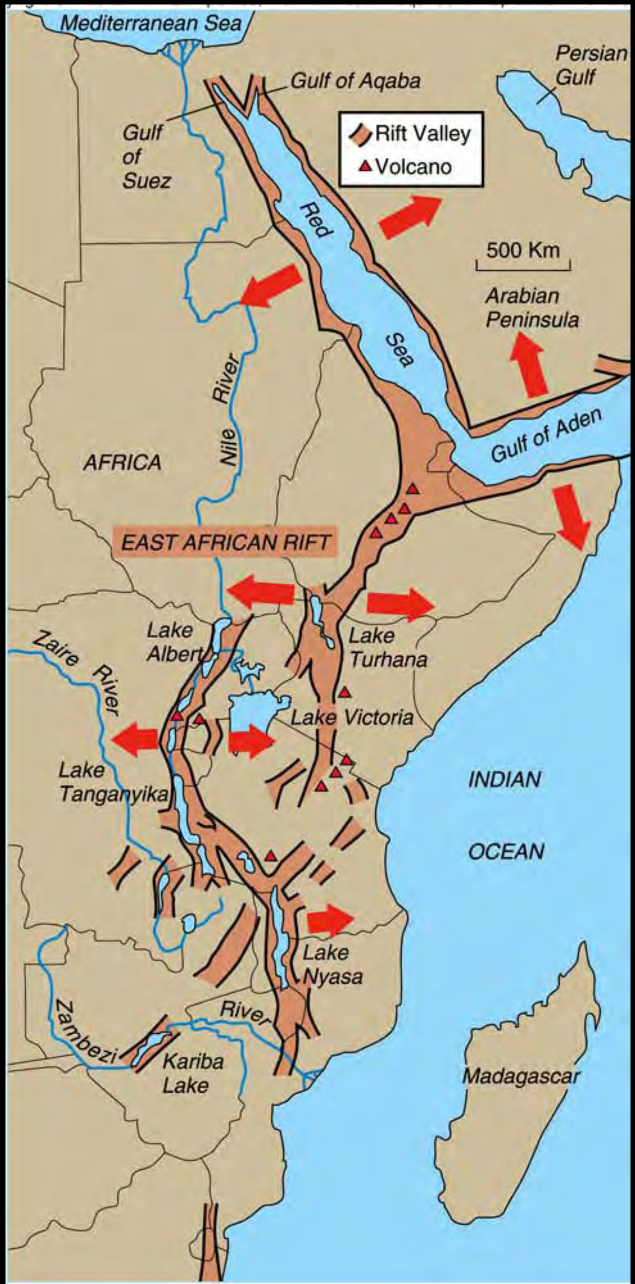
Mid oceanic ridge

Small volcanic ridges and faults in spreading zone

Sonar image

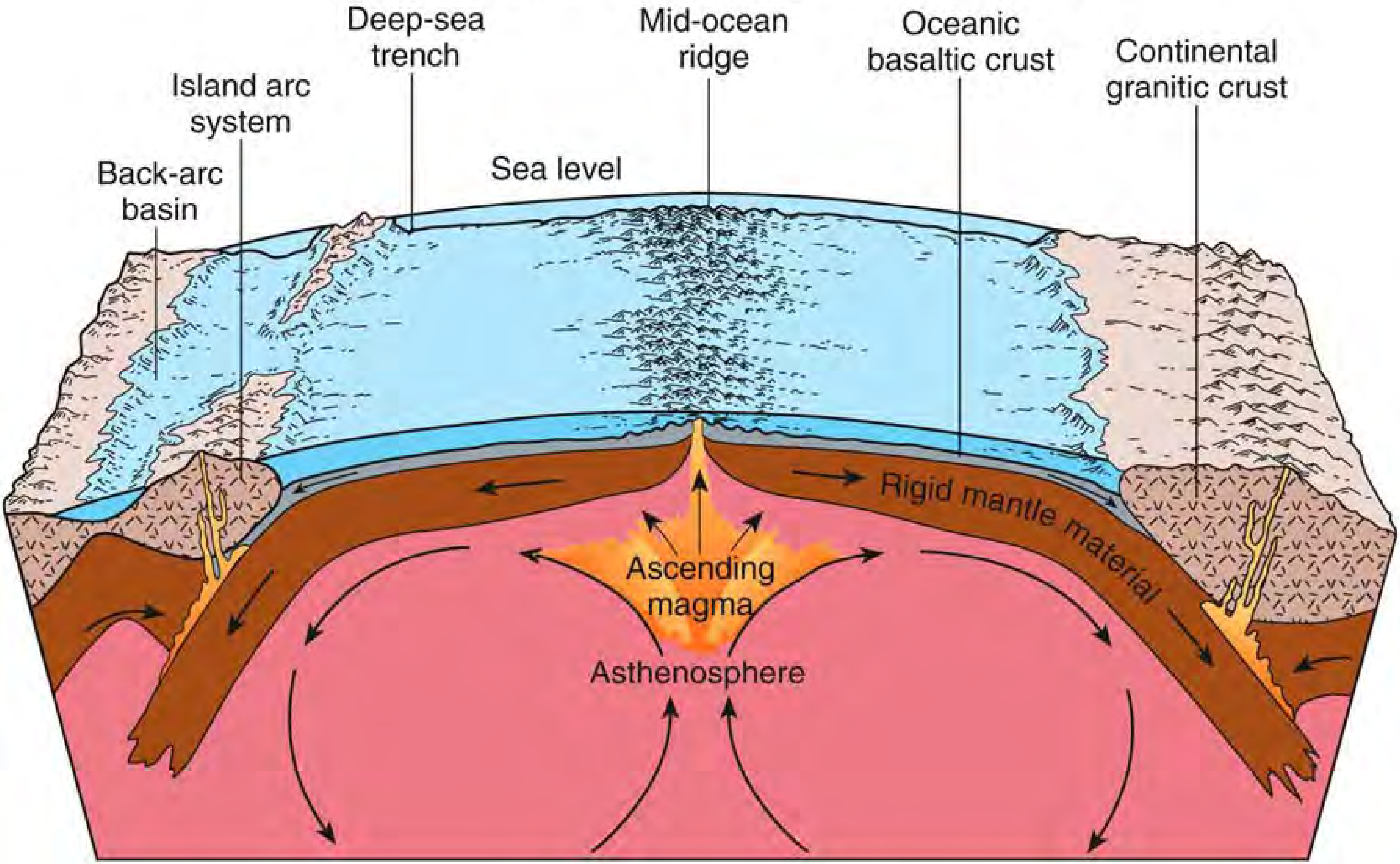


Rift zones of East Africa

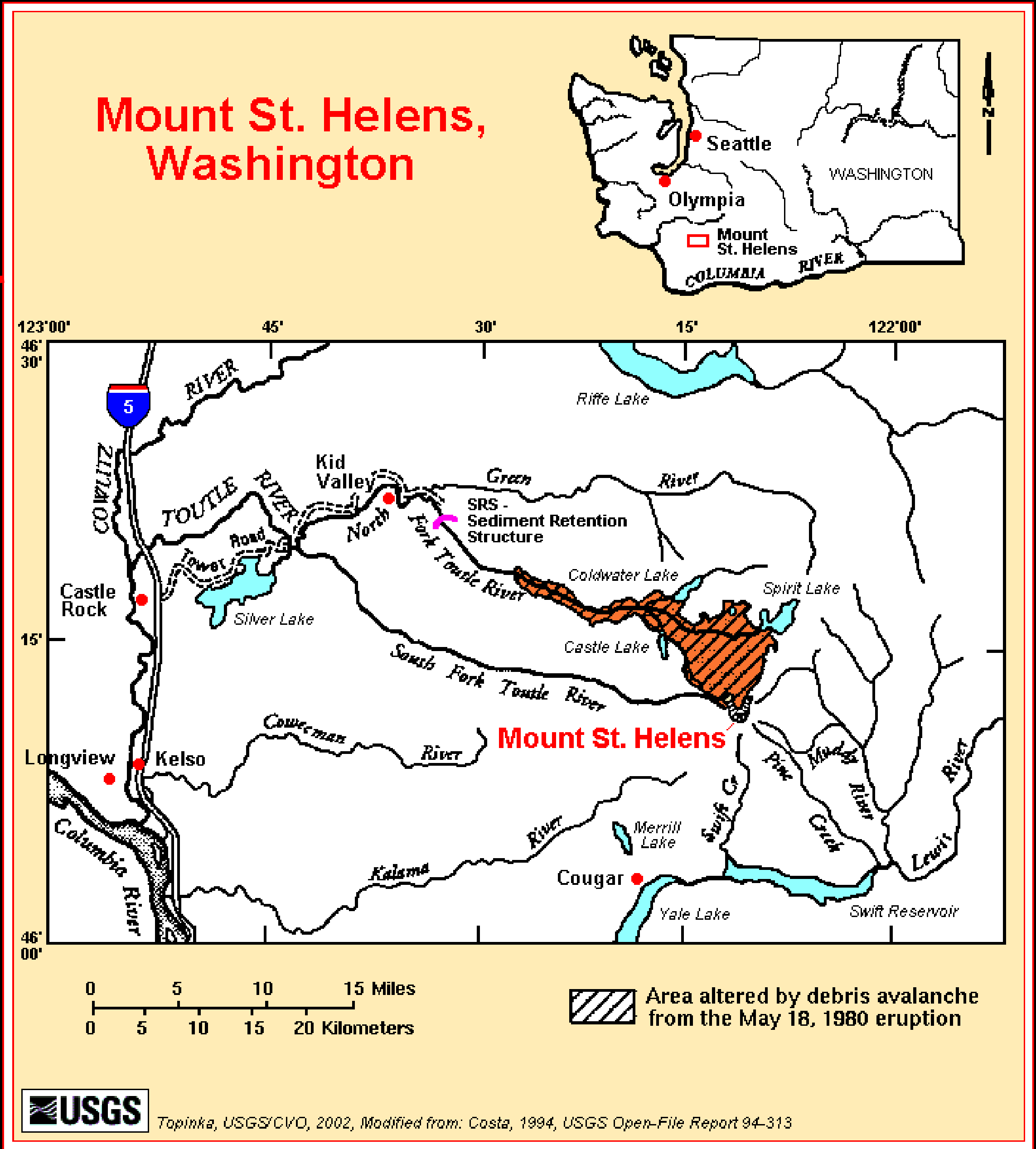


Nyiragongo volcano in rift zone of East Africa

Divergent and convergent plate boundaries: Convergence case

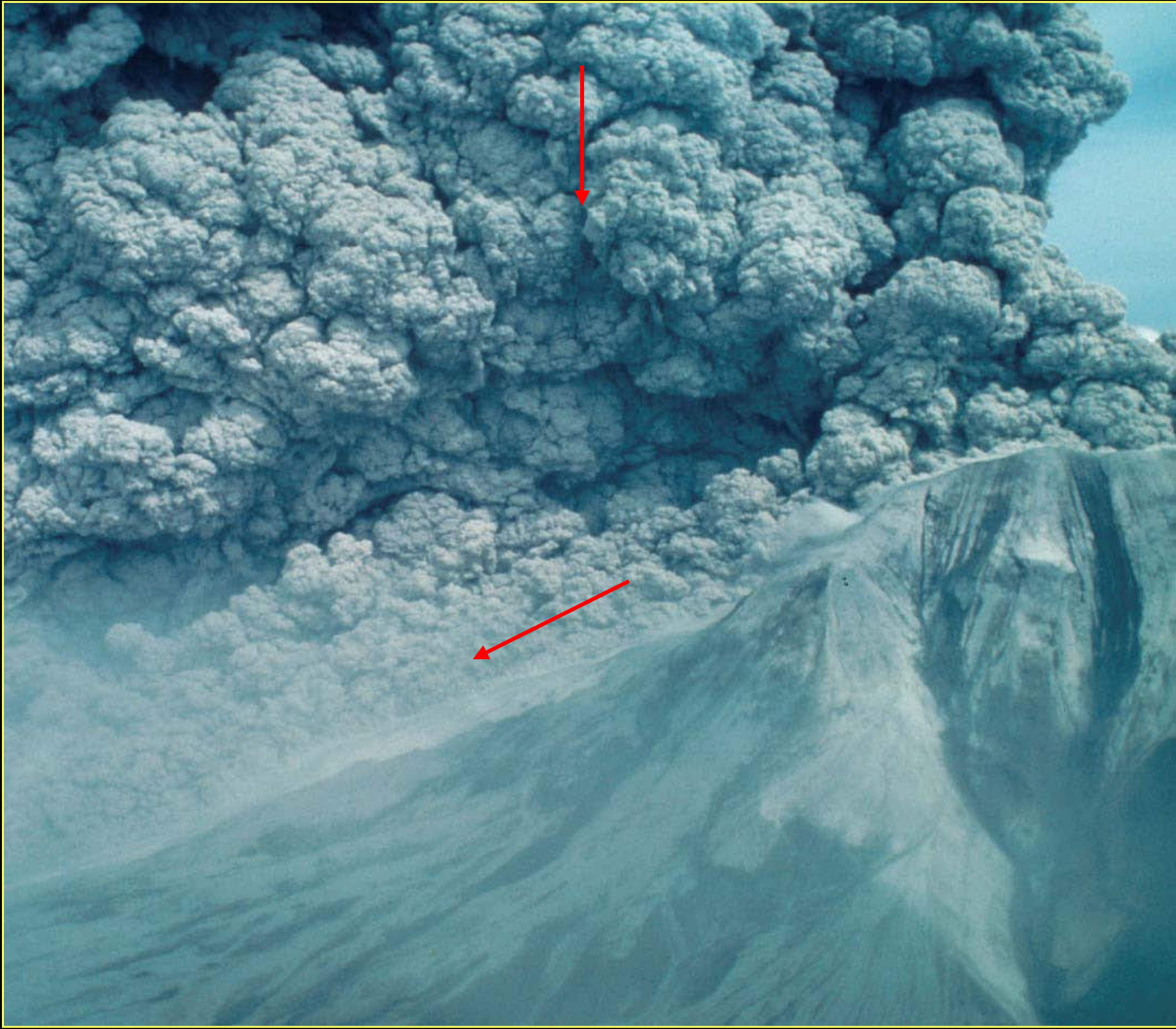


St. Helens volcano location



St. Helens volcano: pre eruption

St. Helens blast and nuee ardente
May 18, 1980



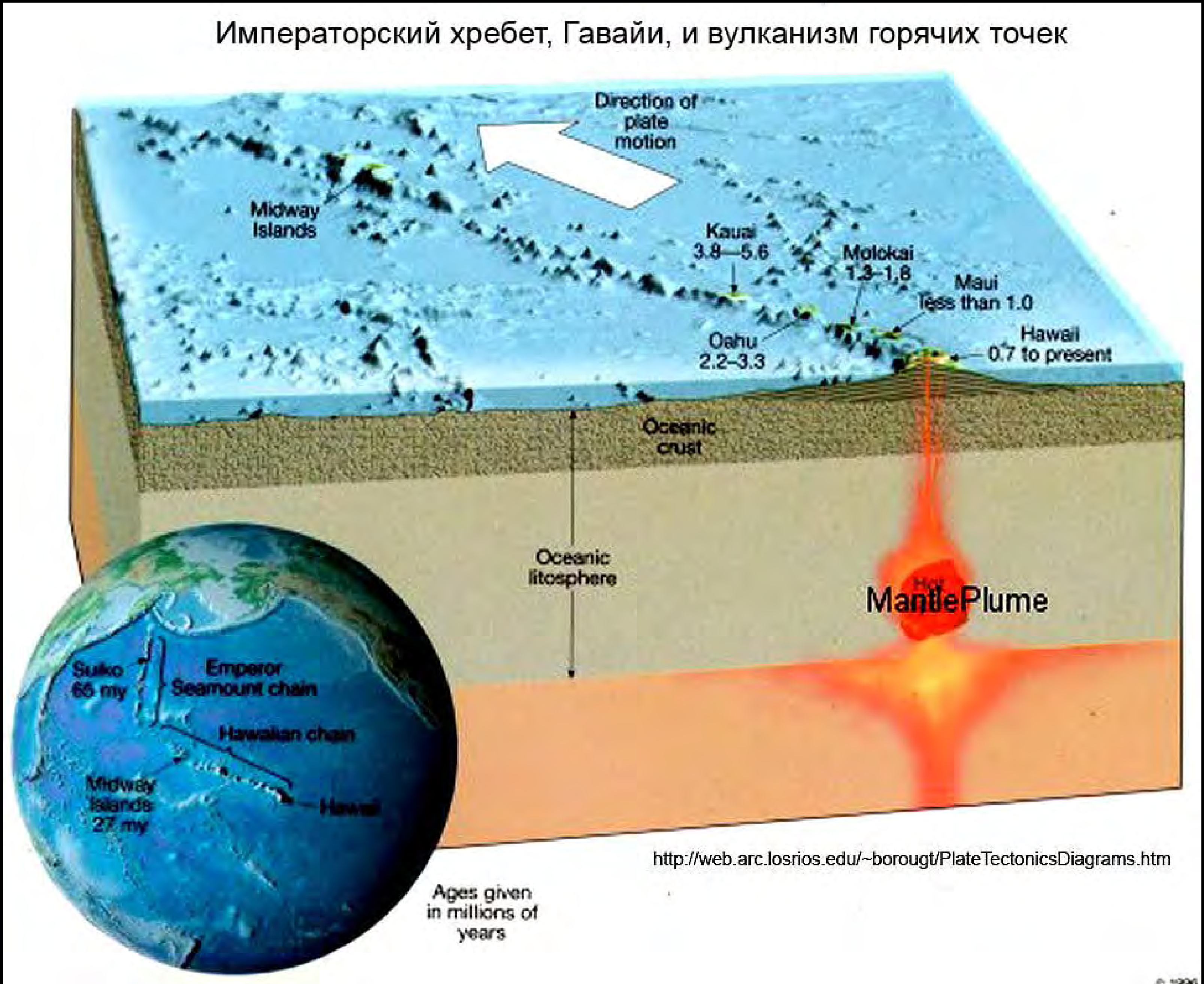
Blast

Nuee ardente

St. Helens pyroclastic deposit

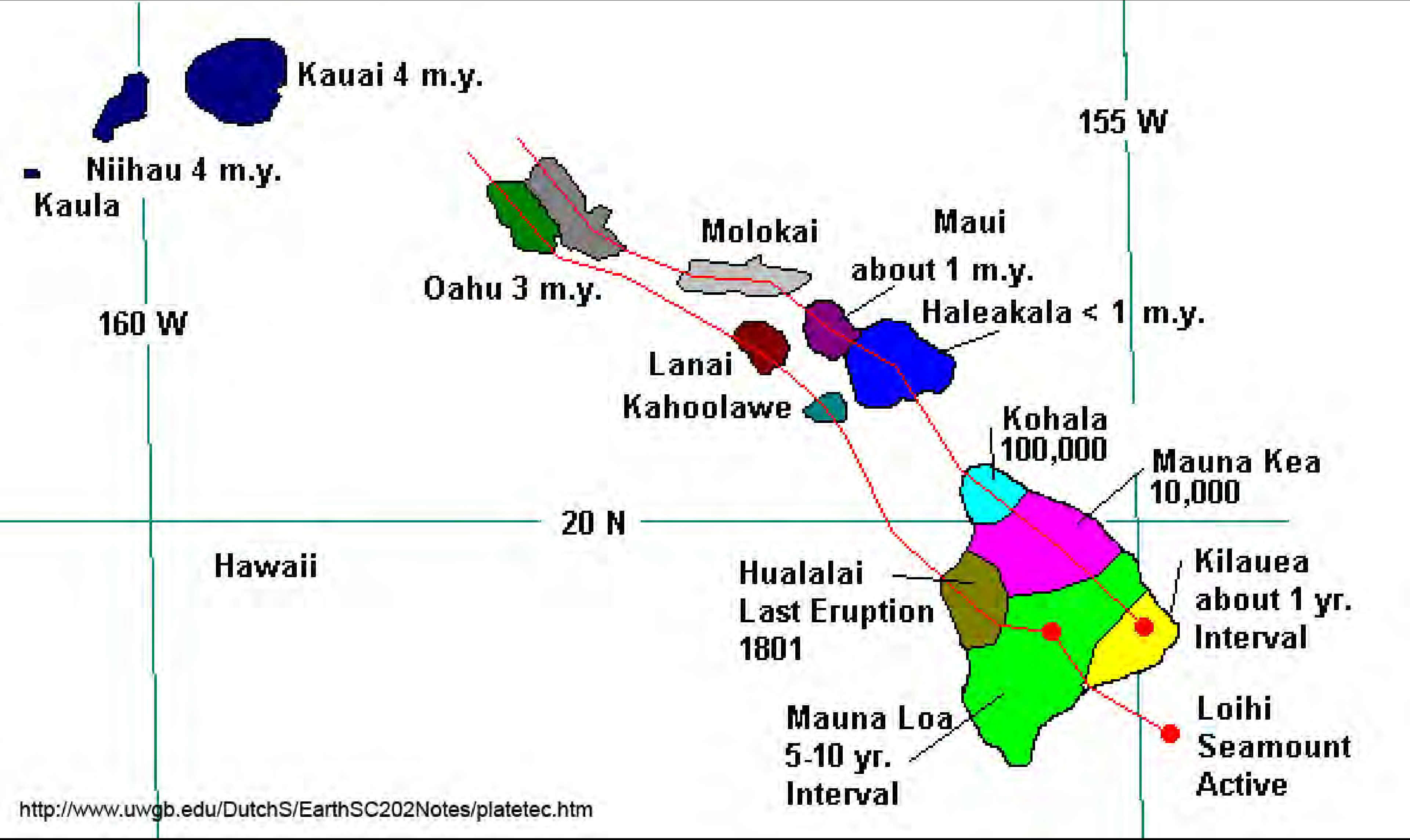
St. Helens pyroclastic tongue

Hot spot volcanism



Hot spot volcanism

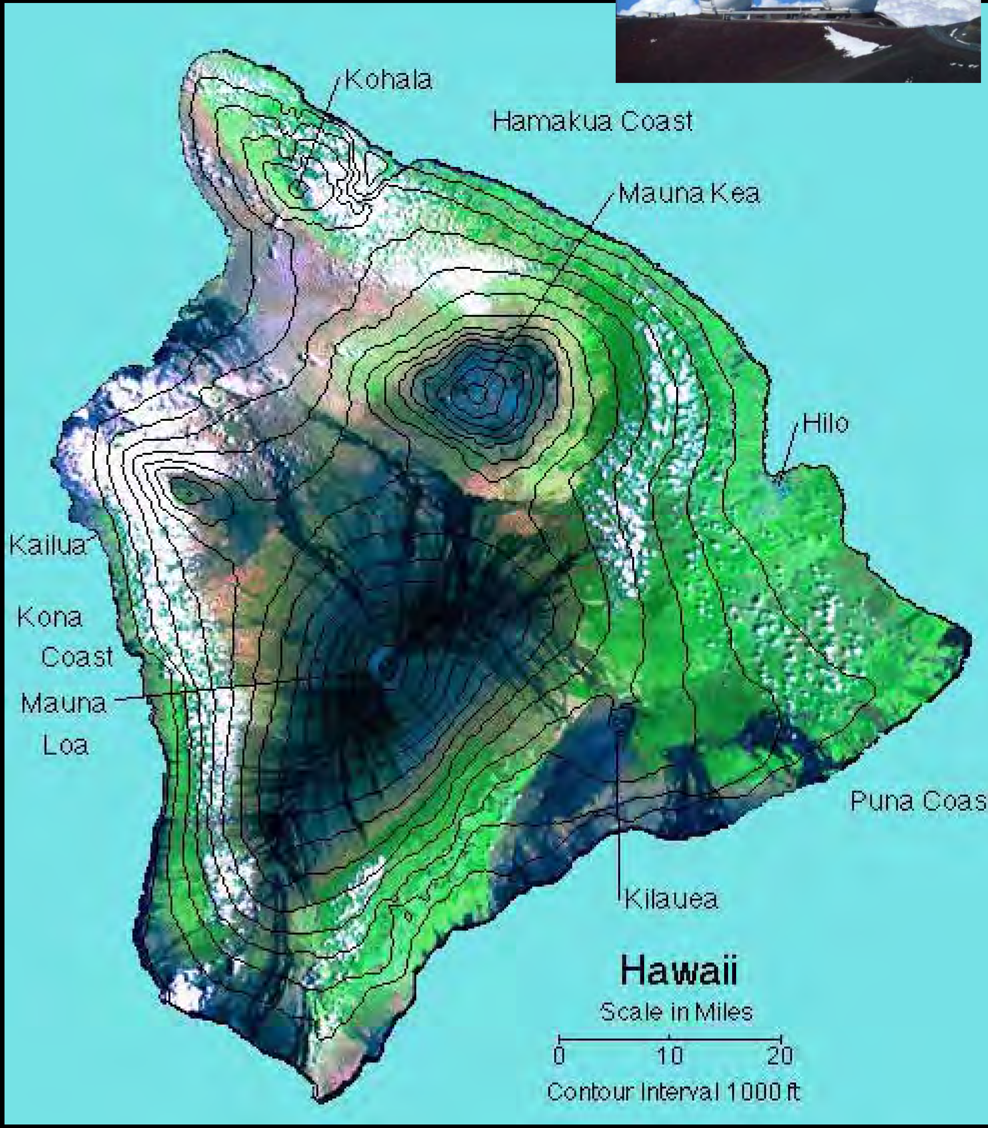
Age of volcanism on the islands increases towards north-east



http://www.uwgb.edu/DutchS/EarthSC202Notes/platetec.htm

Big island Hawaii: Hot spot volcanism

Landsat image



The map

Hawaii, Summit of Mauna Loa volcano

Photo of USGS

Eruption in Kilawea caldera

Eruption of Mauna Kea volcano

Photos of USGS

Hawaii, solidified lavas aa and pahoehoe

Fountaining of lava forms cinder cones, Hawaii

USGS photo

Cinder cone and Mauna Kea volcano behind

Endogenic processes:

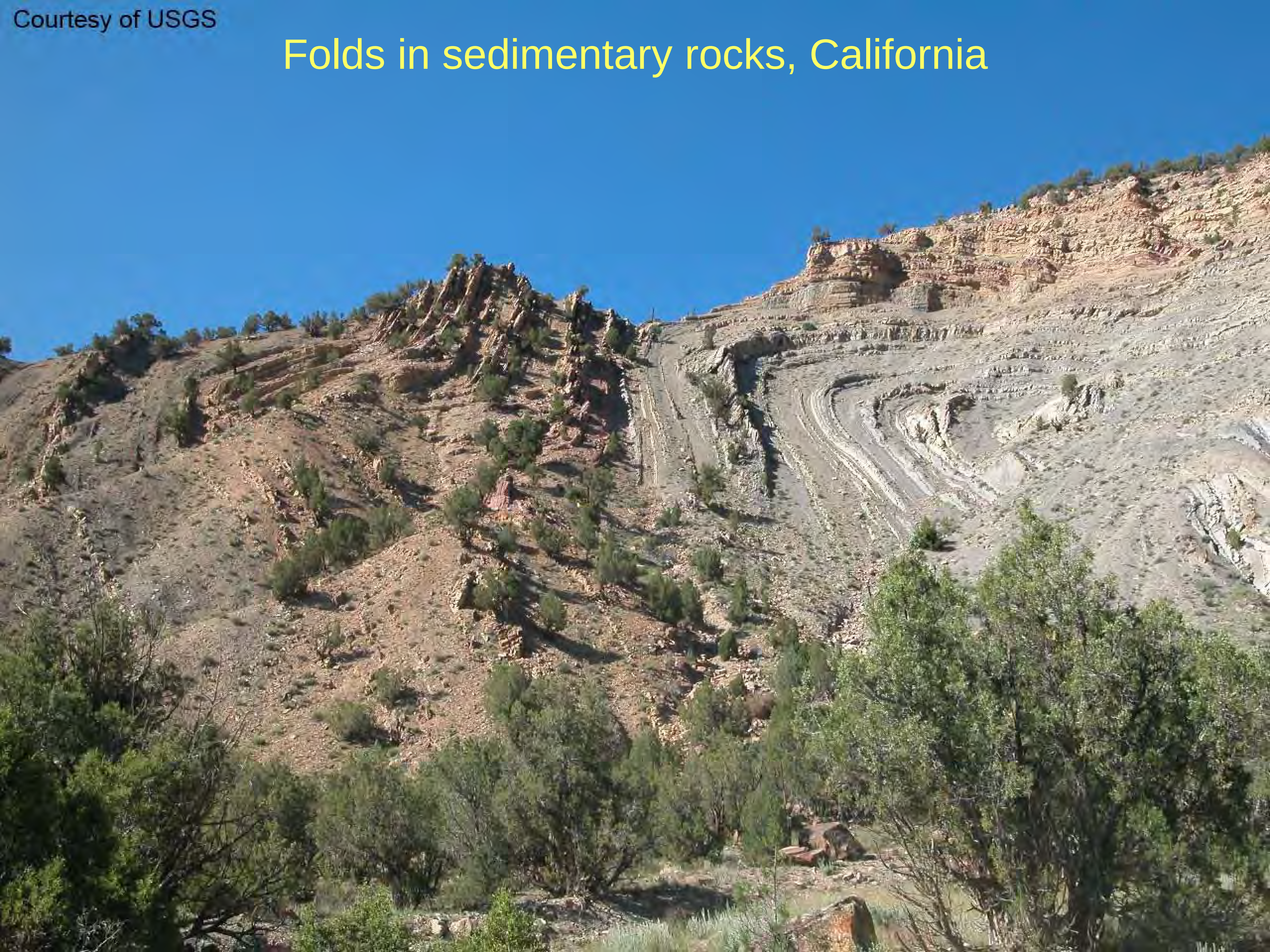
Tectonics –

- Deformation of rocks of the Earth crust

Spreading: Rifts of the Red Sea and Akaba Bay

Courtesy of USGS

Folds in sedimentary rocks, California



Folds to the north from Normuz strait: Convergence zone in the past

Tectonic ridges Meckering, Australia. Formed as a result of earthquake

Photo of Geological Survey of Australia

Ttectonic breccia Red Point, California

Exogenic processes:
Work of water

Grand Canyon, Colorado, USA

Badlands, California, USA

Meanders of Pecatonica river, Wyoming, USA

USGS photo

Alluvial deposits, Southern Ontario, Canada: Sand , gravel, pebbles

Lacustrine deposits, Southern Ontario, Canada: Silt (very fine sand), clay

Death Valley, California, USA

Salt deposits in Death Valley, California, USA

Rocky shore Point Reies, California, USA

Pebble shore of eastern Sussex, England

Layers of limestone ($CaCO_3$), Arizona, USA

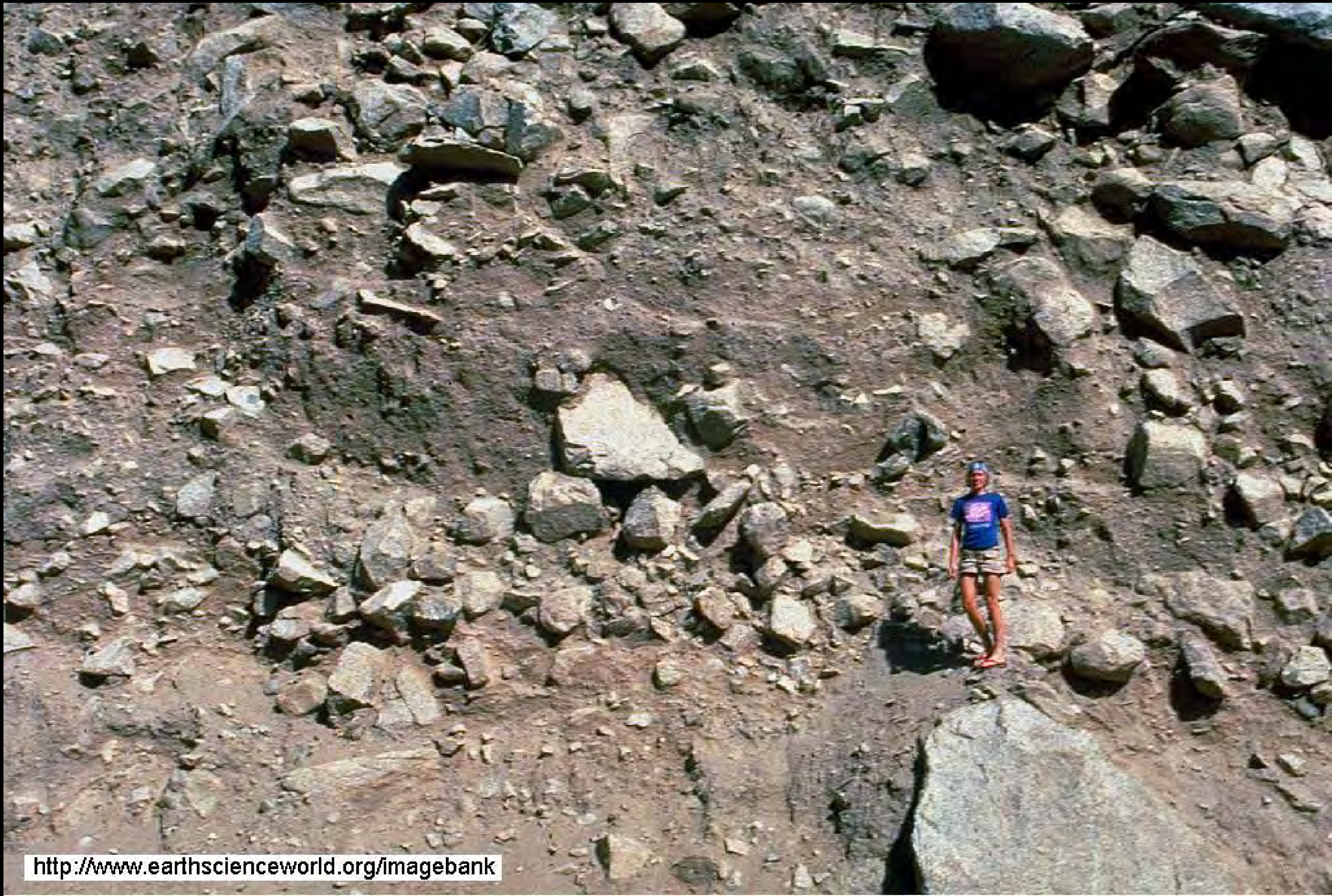
In most cases, limestones are remnants of organisms (shells, etc.)

Exogenic processes:
Work of ice
and permafrost phenomena

Atabaska glacier, Alaska, USA

Rock glacier Morenny, Tien-Shan, Middle Asia

Moraine deposits, Sierra Nevada, USA



Permafrost polygons in North America

Photo of Geologic Survey of Canada

Photo of Geologic Survey of USA

Exogenic processes:
Work of wind

Atlantic coast of Namibia, Africa:
Dust brought by wind into the ocean

Sand dunes of Namibia

Yardangs – parallel ridges, cut by wind

Exogenic processes:
Work of gravity
(Downslope movement)

Landslide, Los Angeles, USA

Down-slided material, Los Angeles, USA

Formed in one short in time event. This was provoked by earthquake

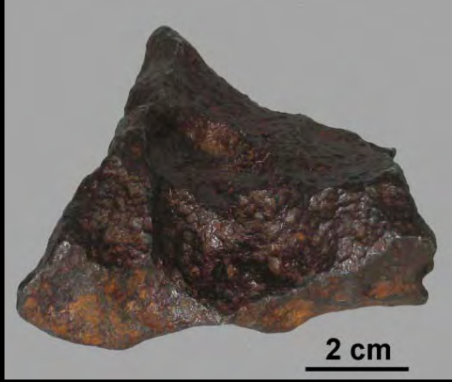
Talus at the foot of a slope, California, USA

Accumulated gradually – piece by piece

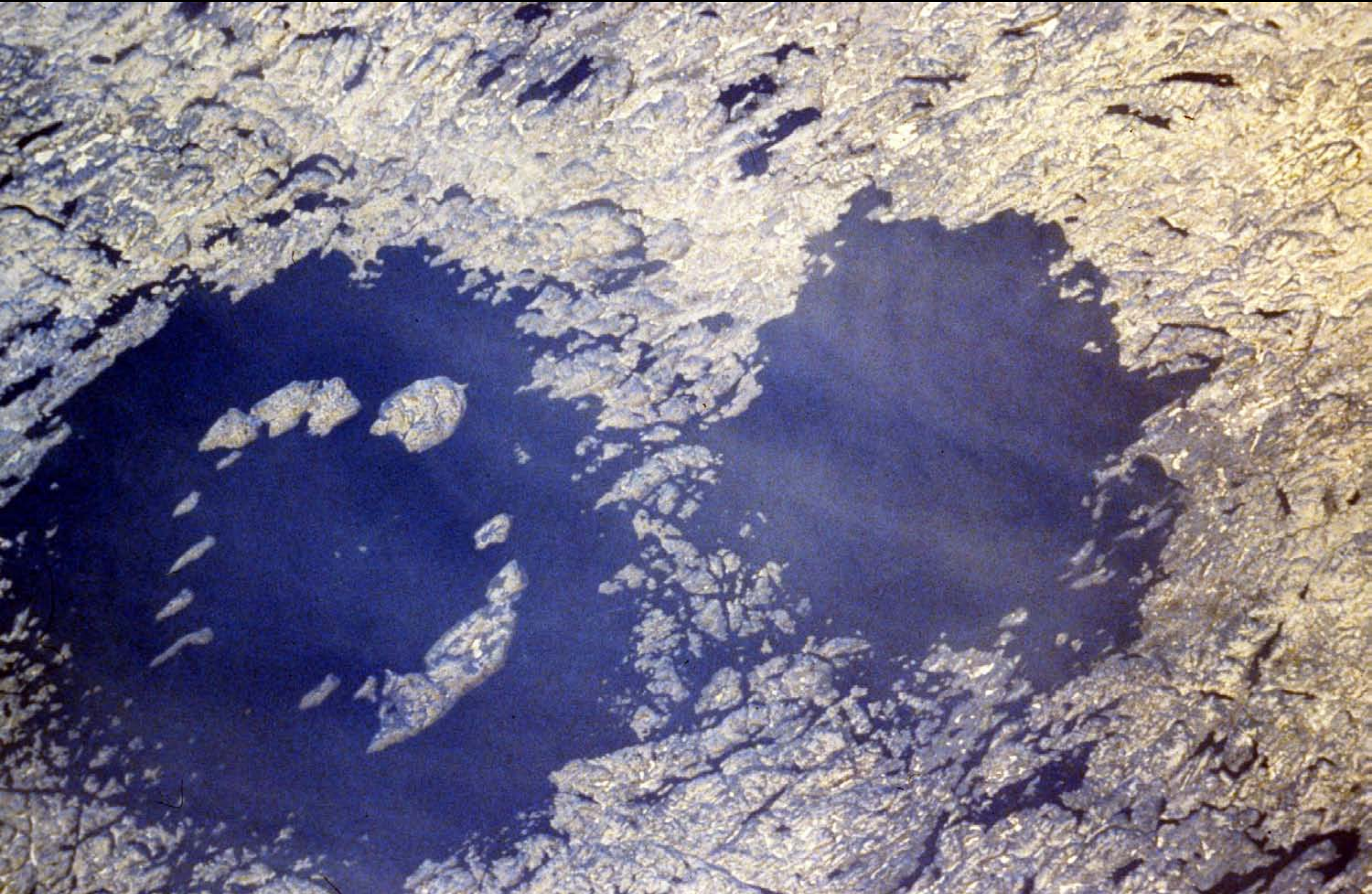
Impacts of asteroids, comets and meteorites

Meteoritic crater Sterlitamak
Russia, 1990

Impact crater Meteor,
Arizona, USA
D = 1.2 km
Formed ~50,000 years ago



Craters Clear Water West (36 km) & East (26 km) Quebek, Canada



Life
and its influence on the planet Earth

Underwater life

Coral reef. Part of limestones – are lithified corals

Life on the Earth surface

People

Anthropogenic landscape, Madagascar

Anthropogenic landscape, New York city, USA

Image from Google Earth

Photo of A.T. Basilevsky

Drying of the Aral Sea, Middle Asia – Kazakhstan // Uzbekistan

1988

2015

Earth, view from the near-lunar orbit

Снимок Apollo 8