Engineering Geology:

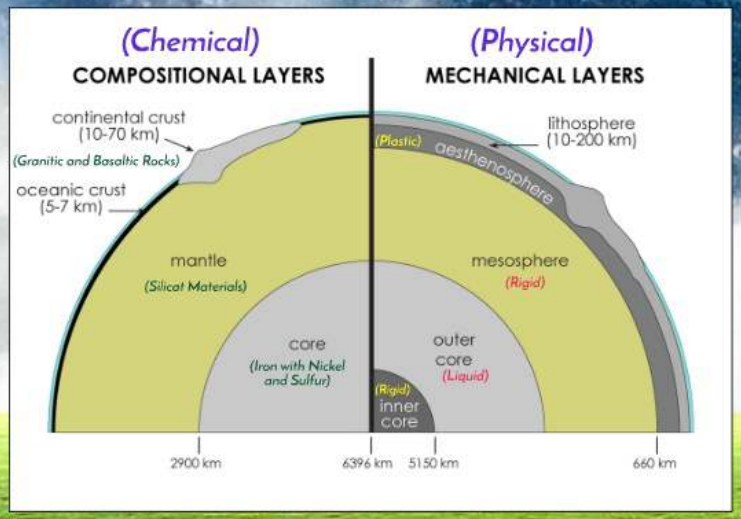
Understanding the Earth

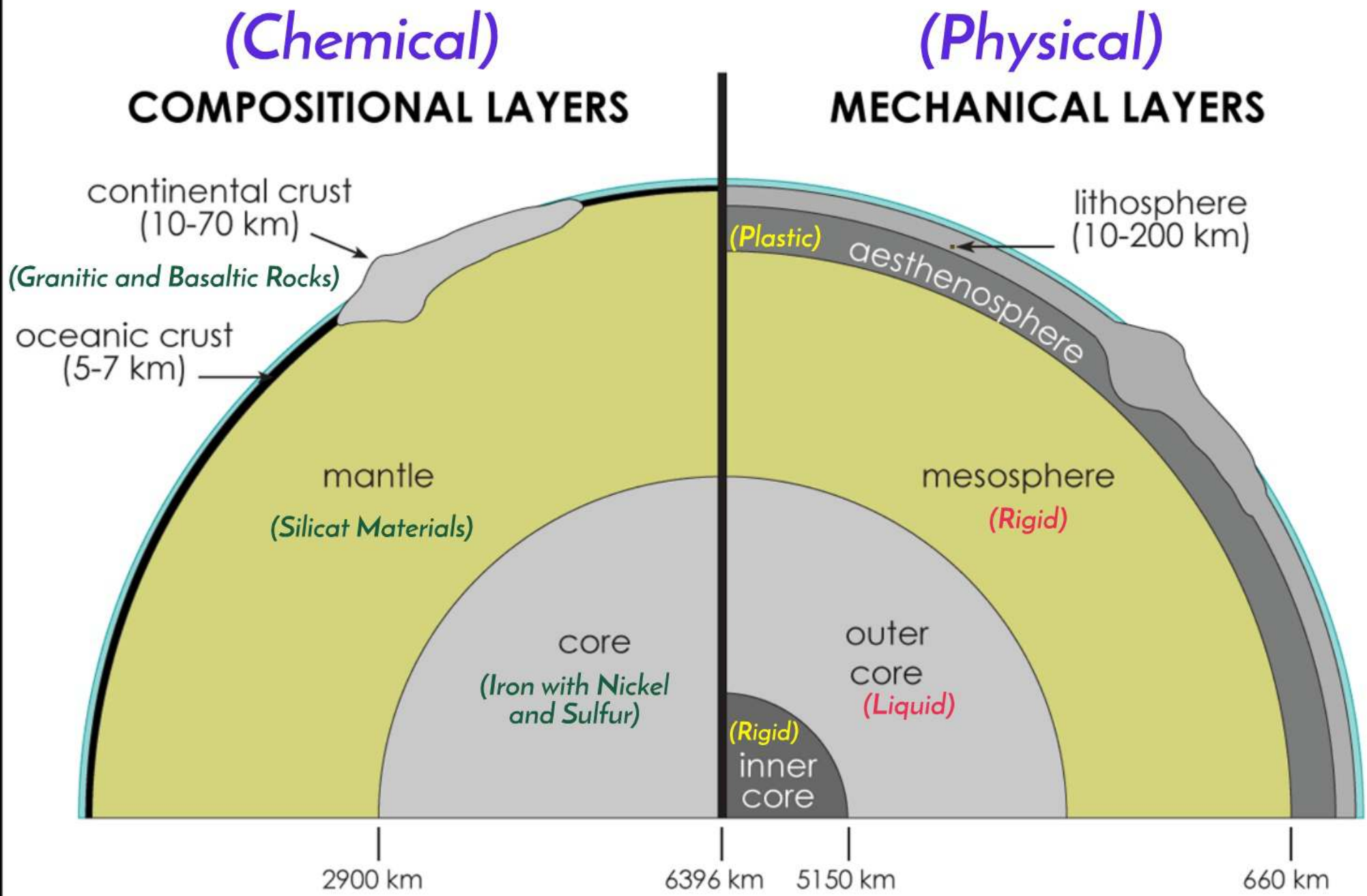
زمین شناسی مهندسی:

شناخت زمین

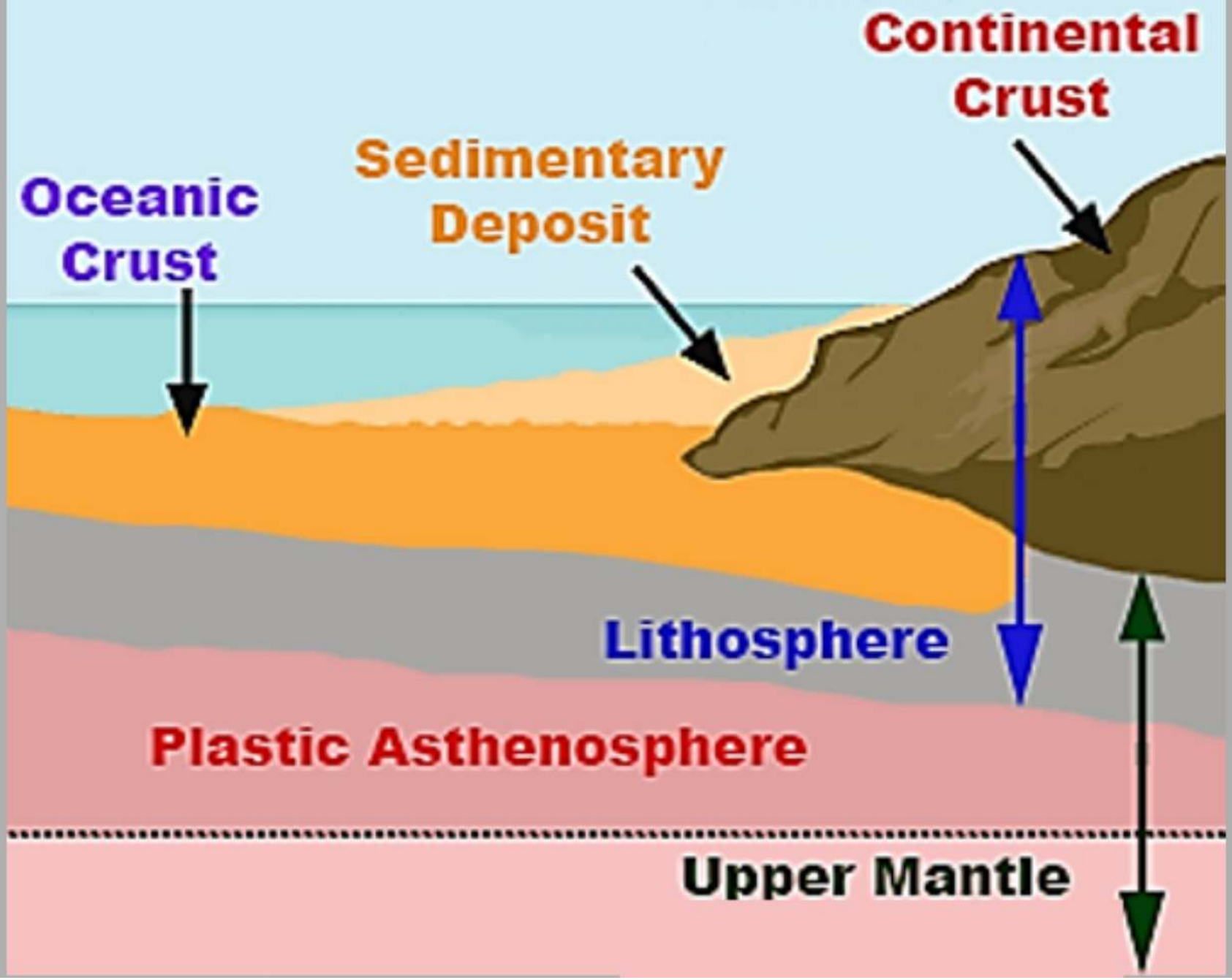
Earth's Layers

Chemical Mechanical Division




(Chemical)
COMPOSITIONAL LAYERS
(Physical)
MECHANICAL LAYERS
continental crust
(10-70 km)
(Granitic and Basaltic Rocks)
oceanic crust
(5-7 km)
mantle
(Silicat Materials)
core
(Iron with Nickel and Sulfur)
(Plastic)
aesthenosphere
lithosphere
(10-200 km)
mesosphere
(Rigid)
outer core
(Liquid)
(Rigid)
inner core
2900 km
6396 km
5150 km
660 km

لیتوسفر= پوسته + بخش جامد گوشتهٔ بالایی



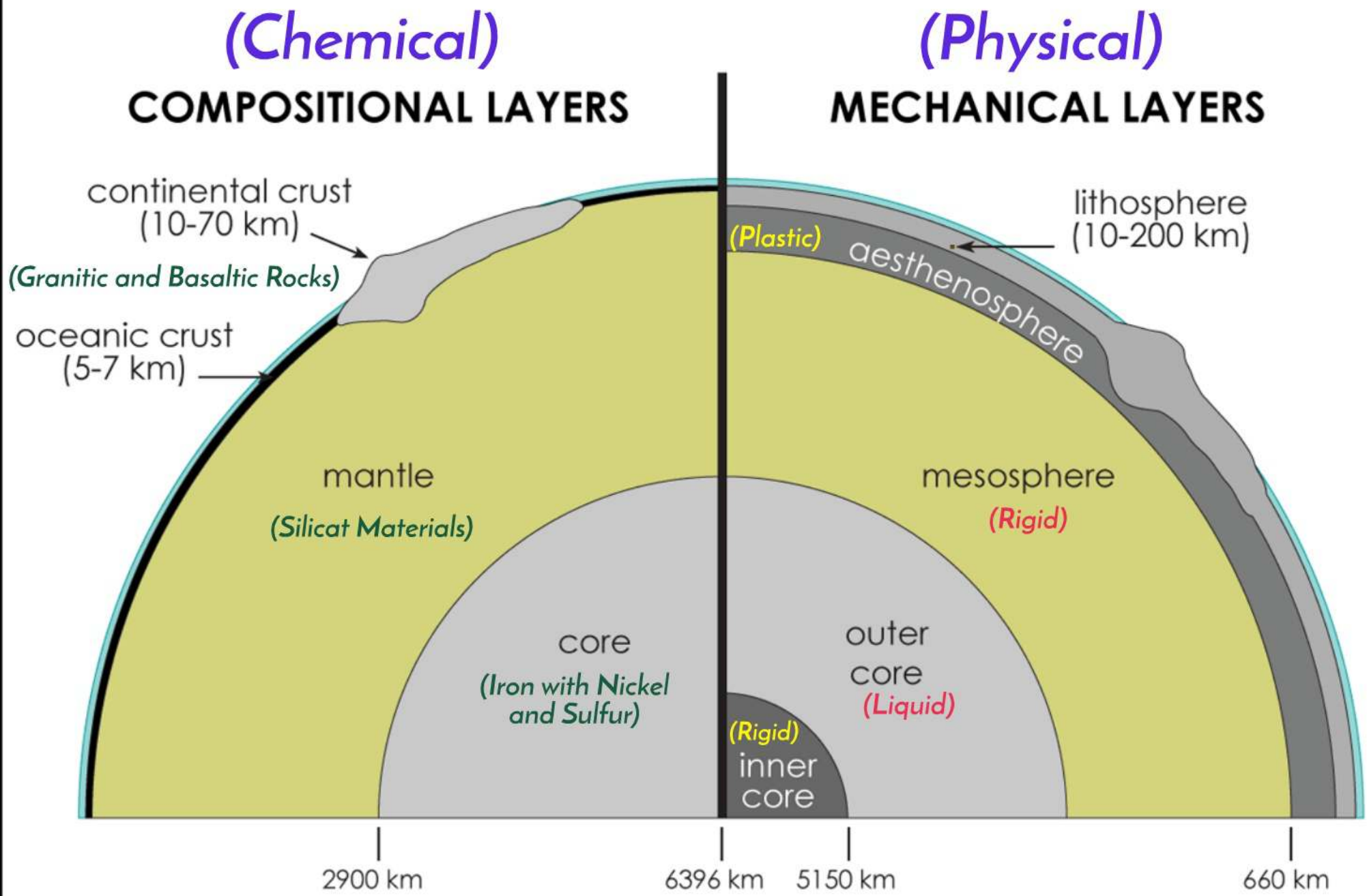

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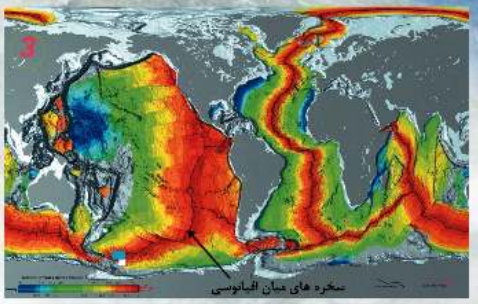
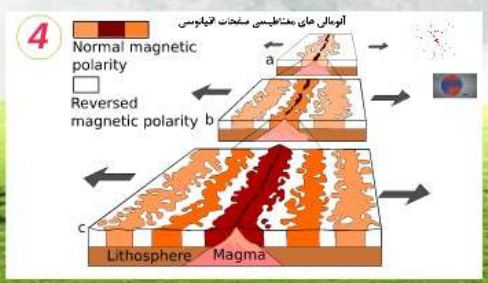
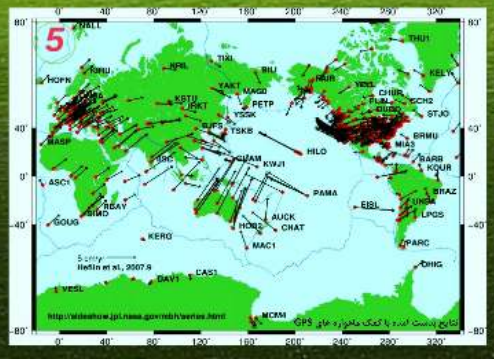
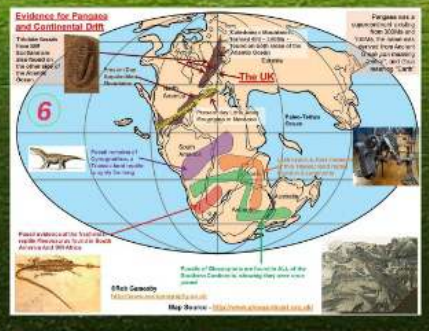
Plate Tectonic

Clues of Tectonic Plate movements



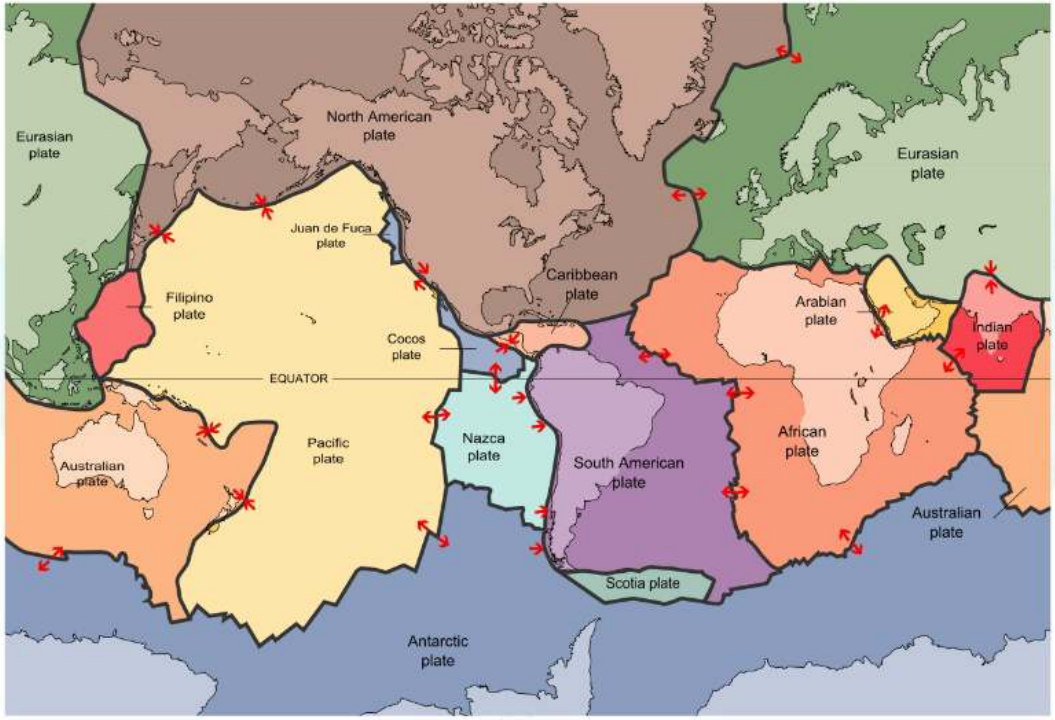






زمین ساخت صفحه ای

شواهد حرکت صفحات تکتونیکی زمین



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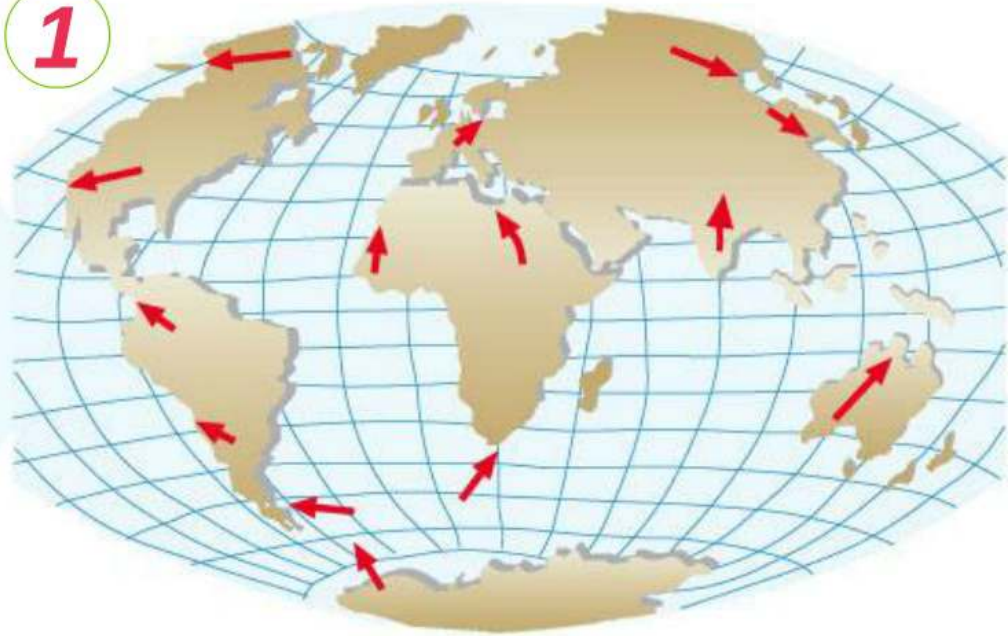

(b)

در حال حاضر پوستهٔ زمین از ۱۳ صفحهٔ متمایز تشکیل شده است.

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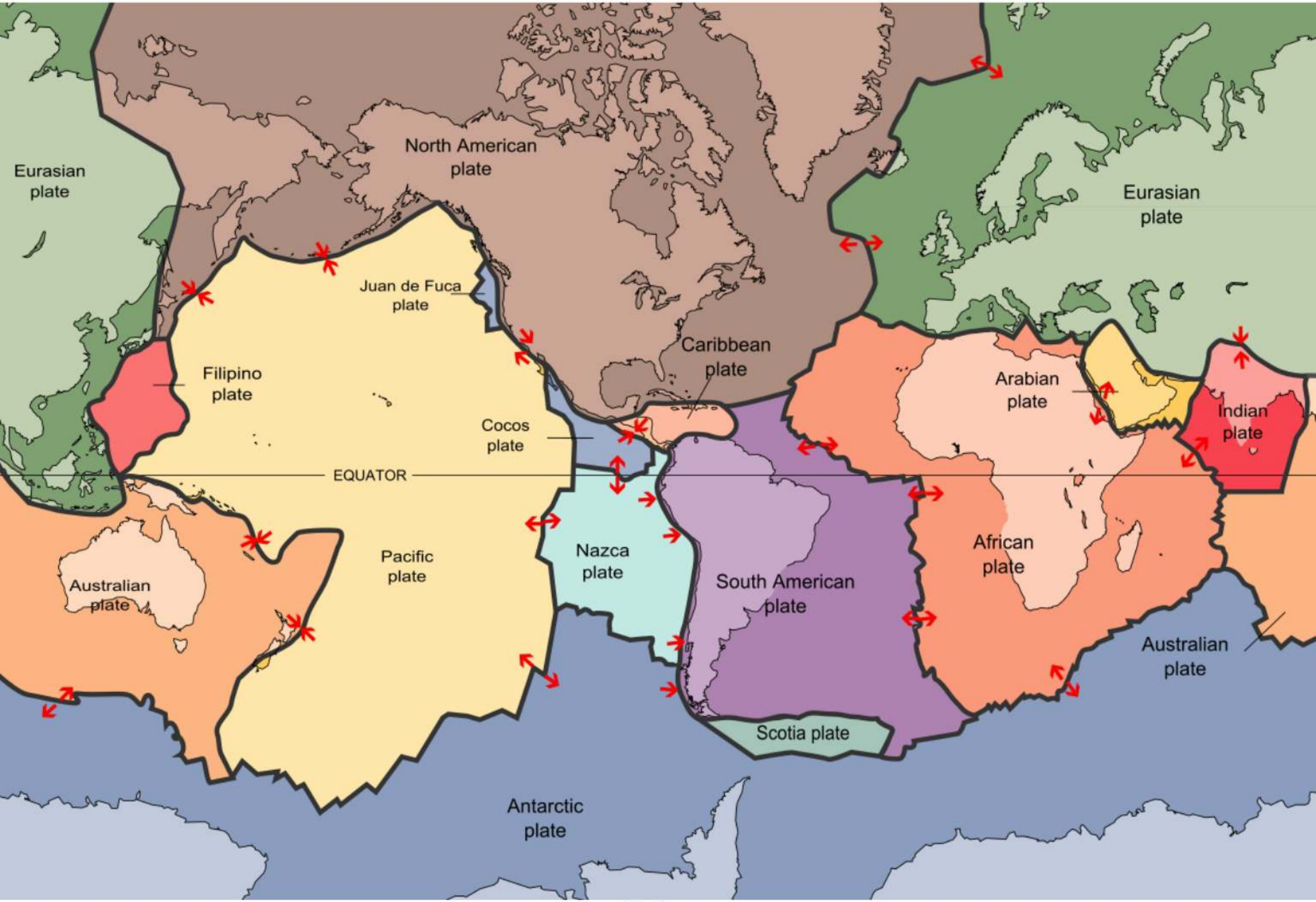
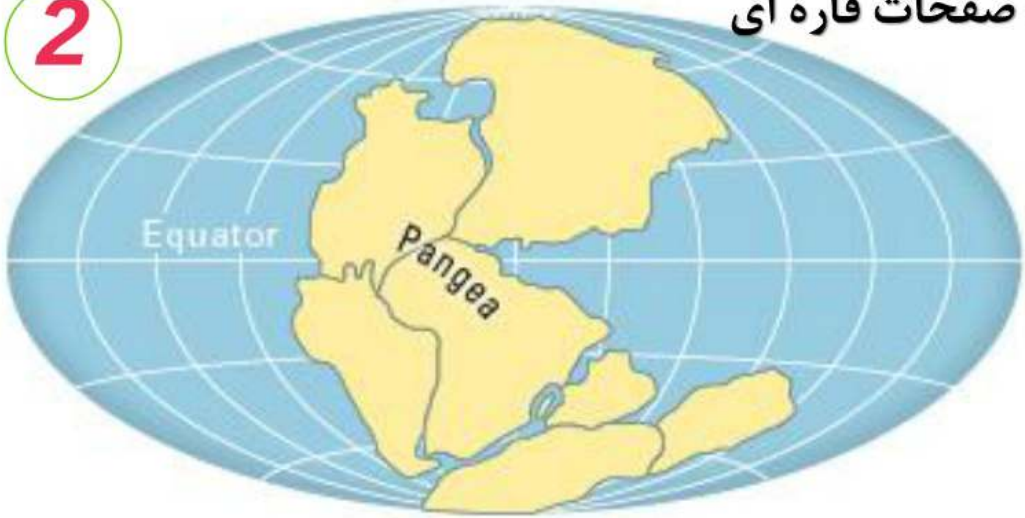
2

انطباق پازل مانند صفحات قاره ای


Eurasian plate
North American plate
Eurasian plate
Juan de Fuca plate
Caribbean plate
Filipino plate
Arabian plate
Indian plate
Cocos plate
EQUATOR
Pacific plate
Nazca plate
African plate
Australian plate
South American plate
Australian plate
Scotia plate
Antarctic plate

2

انطباق پازل مانند صفحات قاره ای



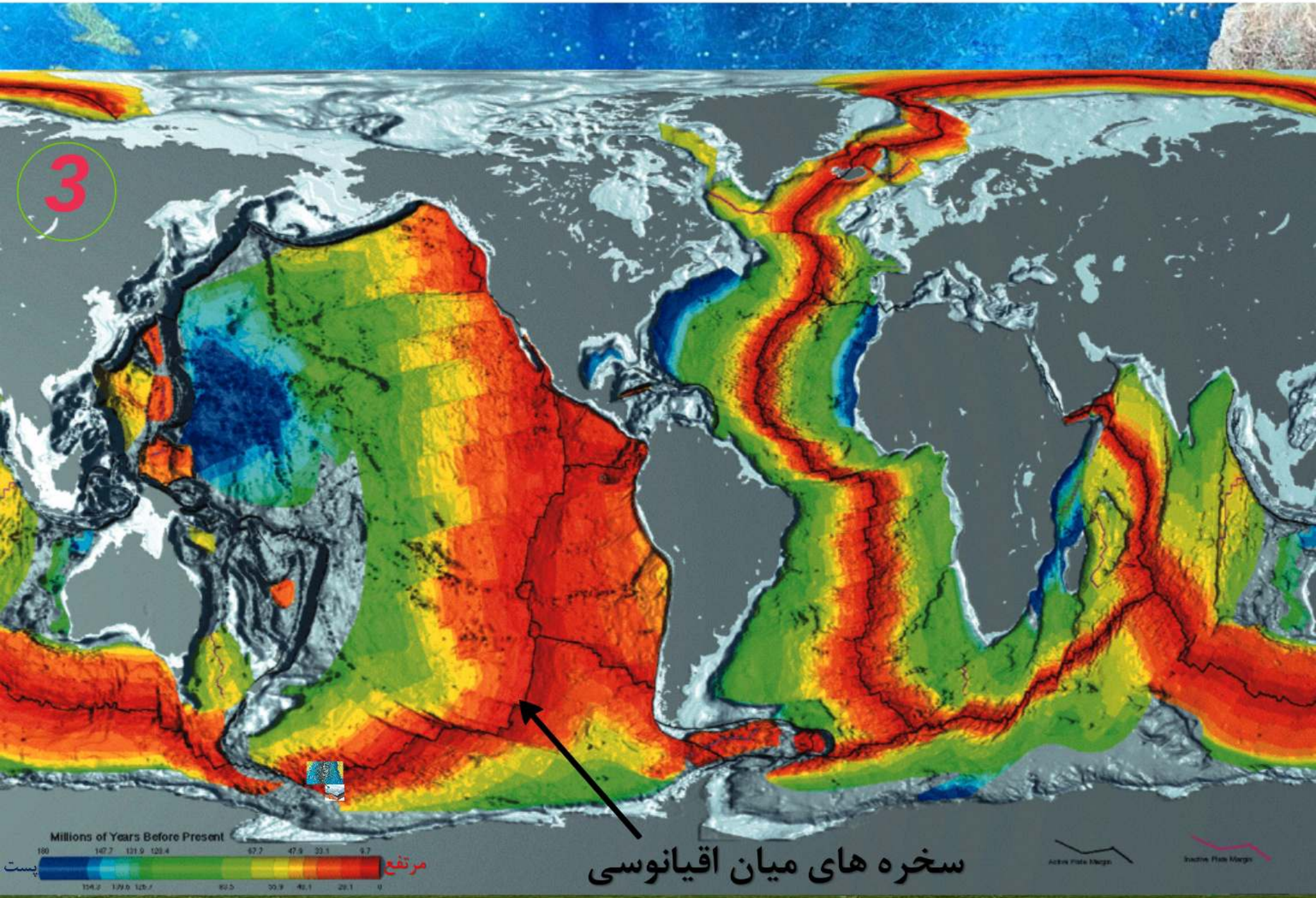
225 million years ago

150 million years ago

100 million years ago

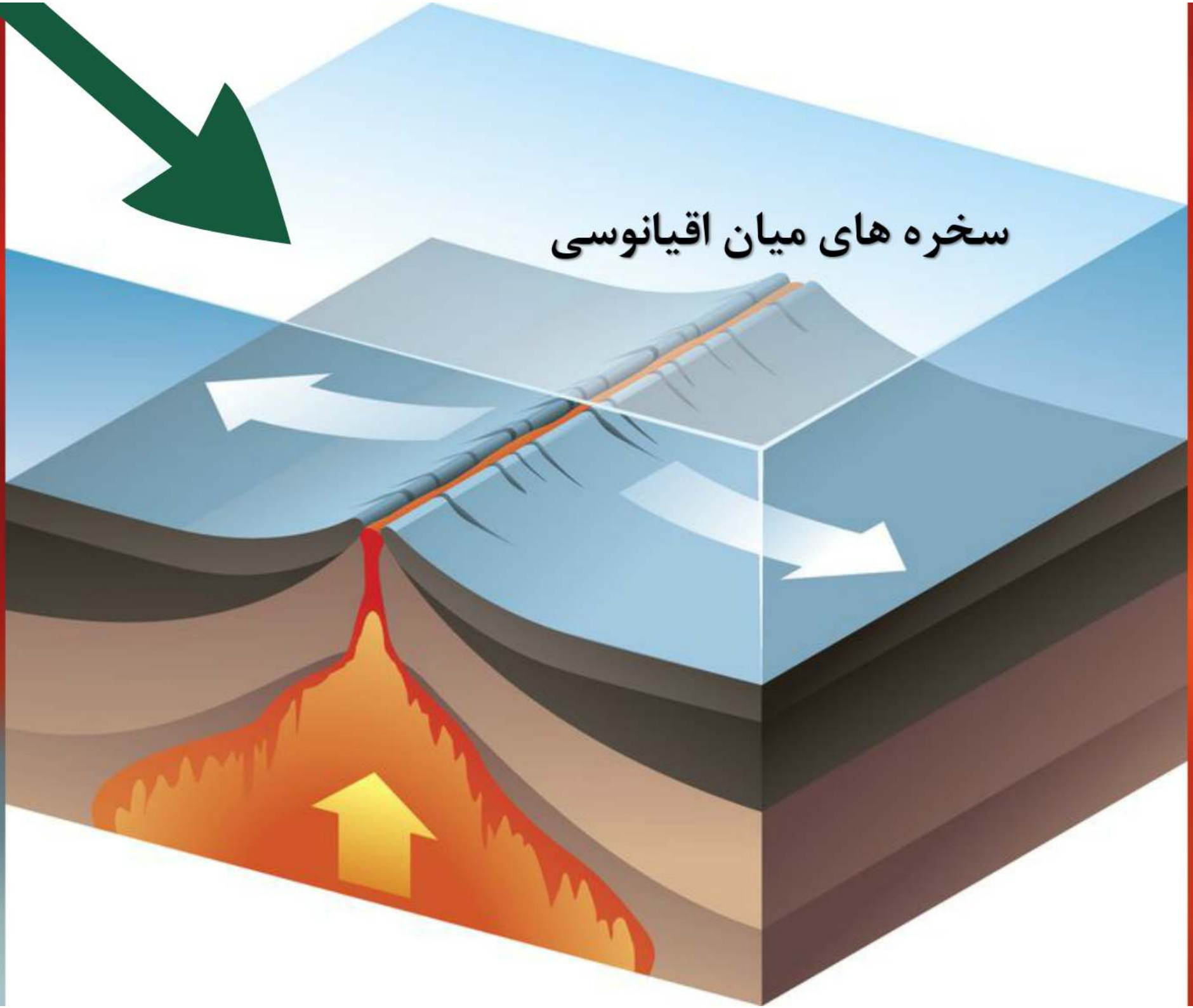
Earth today

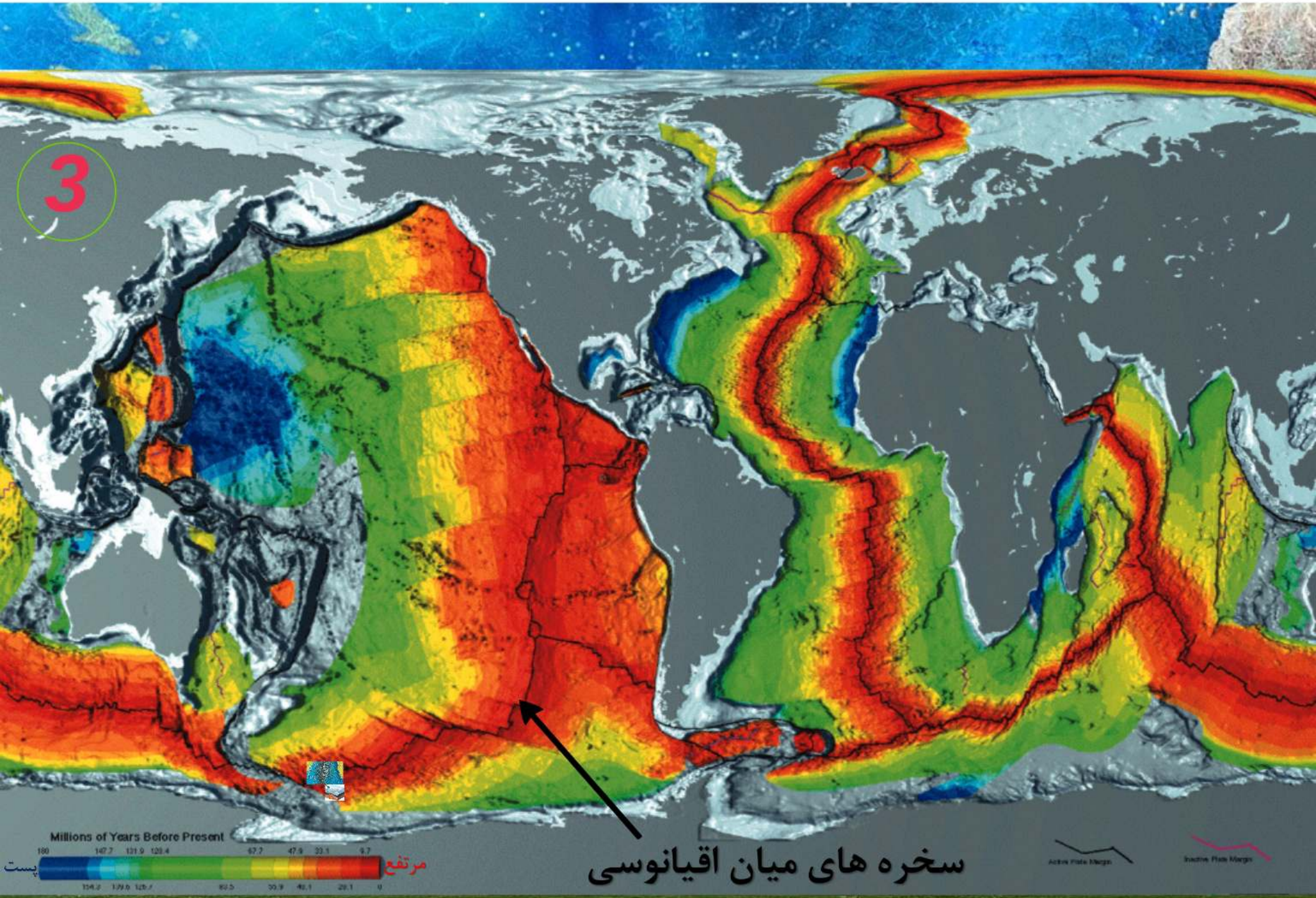
© 2007 EB Inc.



سخره های میان اقیانوسی

گسل های تغییر شکل دهندهٔ
امتداد لغز

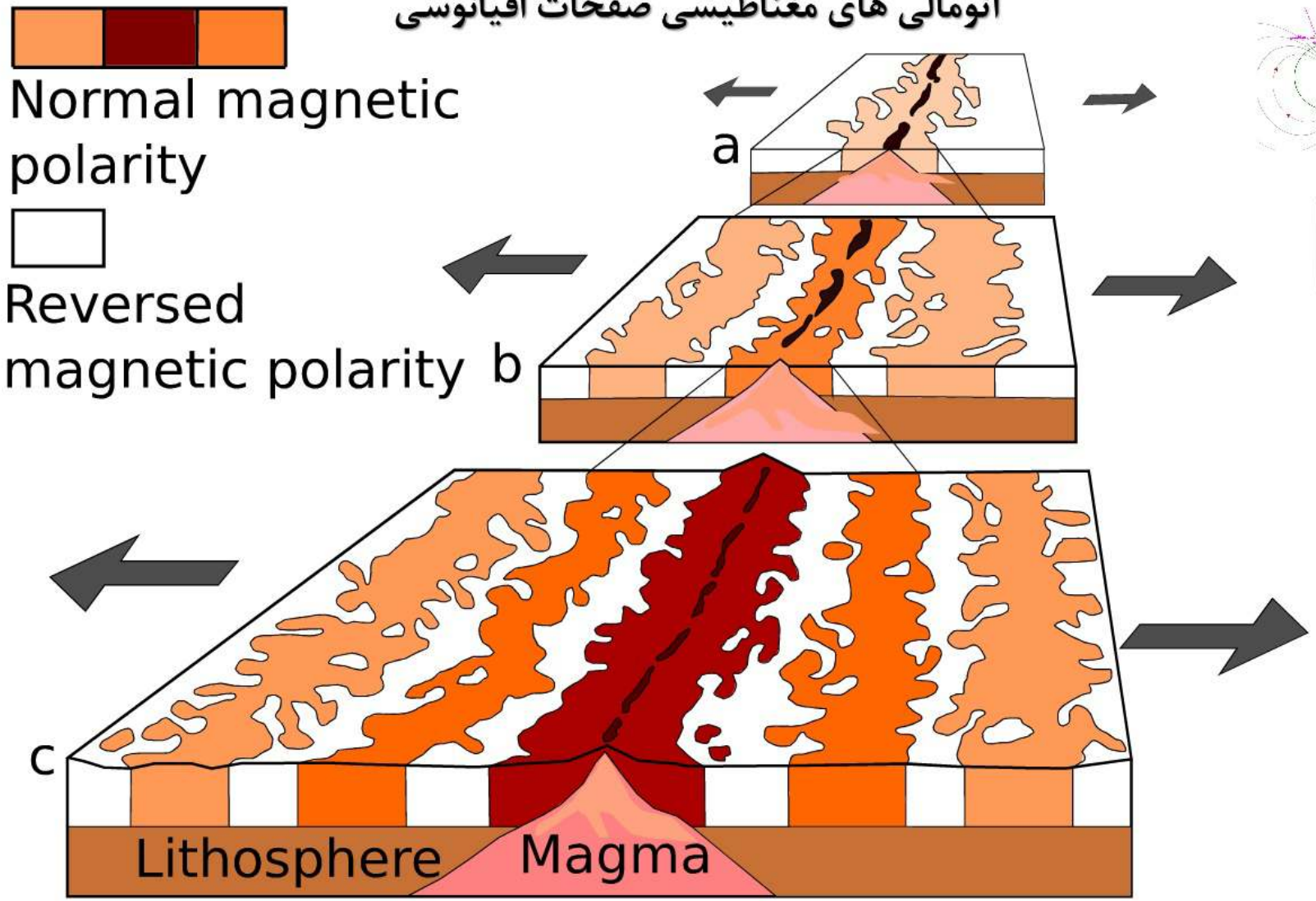

سخره های میان اقیانوسی

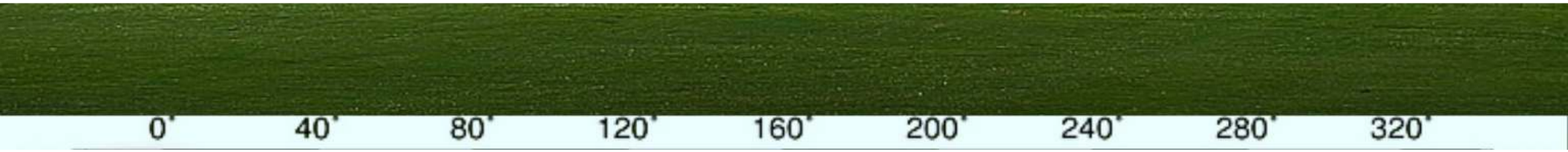


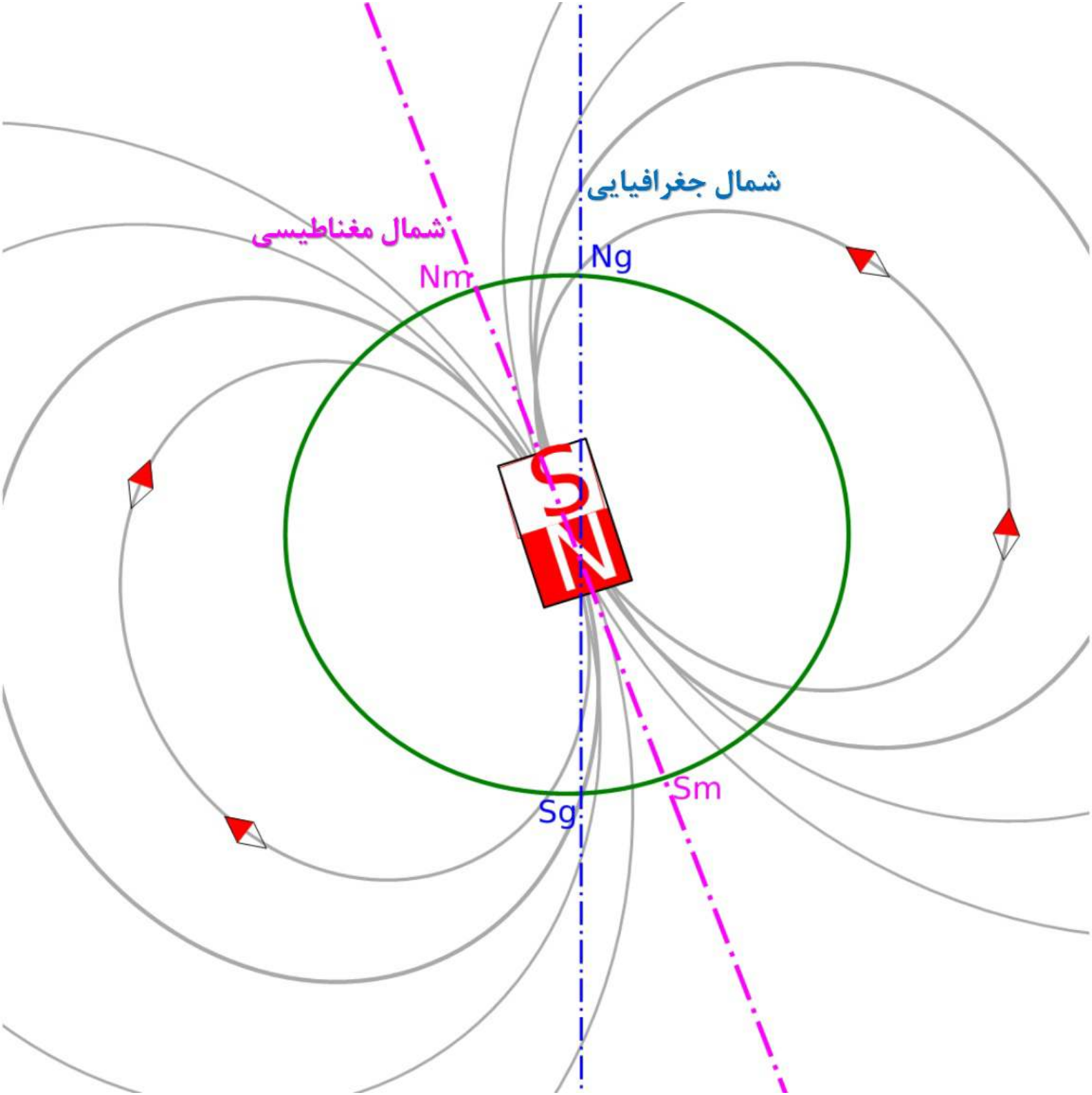
سخره های میان اقیانوسی

4

آنومالی های مغناطیسی صفحات اقیانوسی

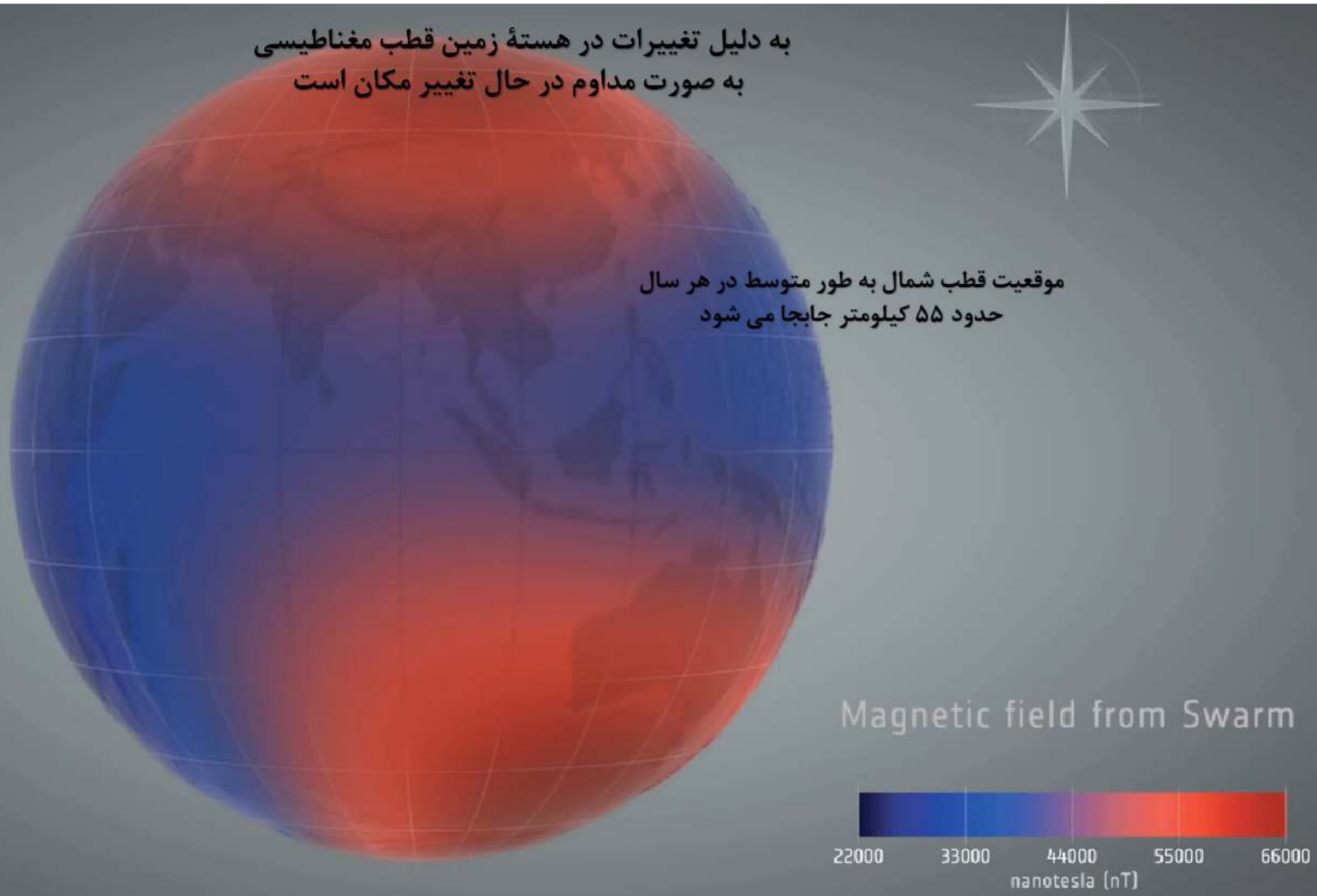





شمال جغرافیایی
شمال مغناطیسی
Ng
Nm
S
N
Sg
Sm

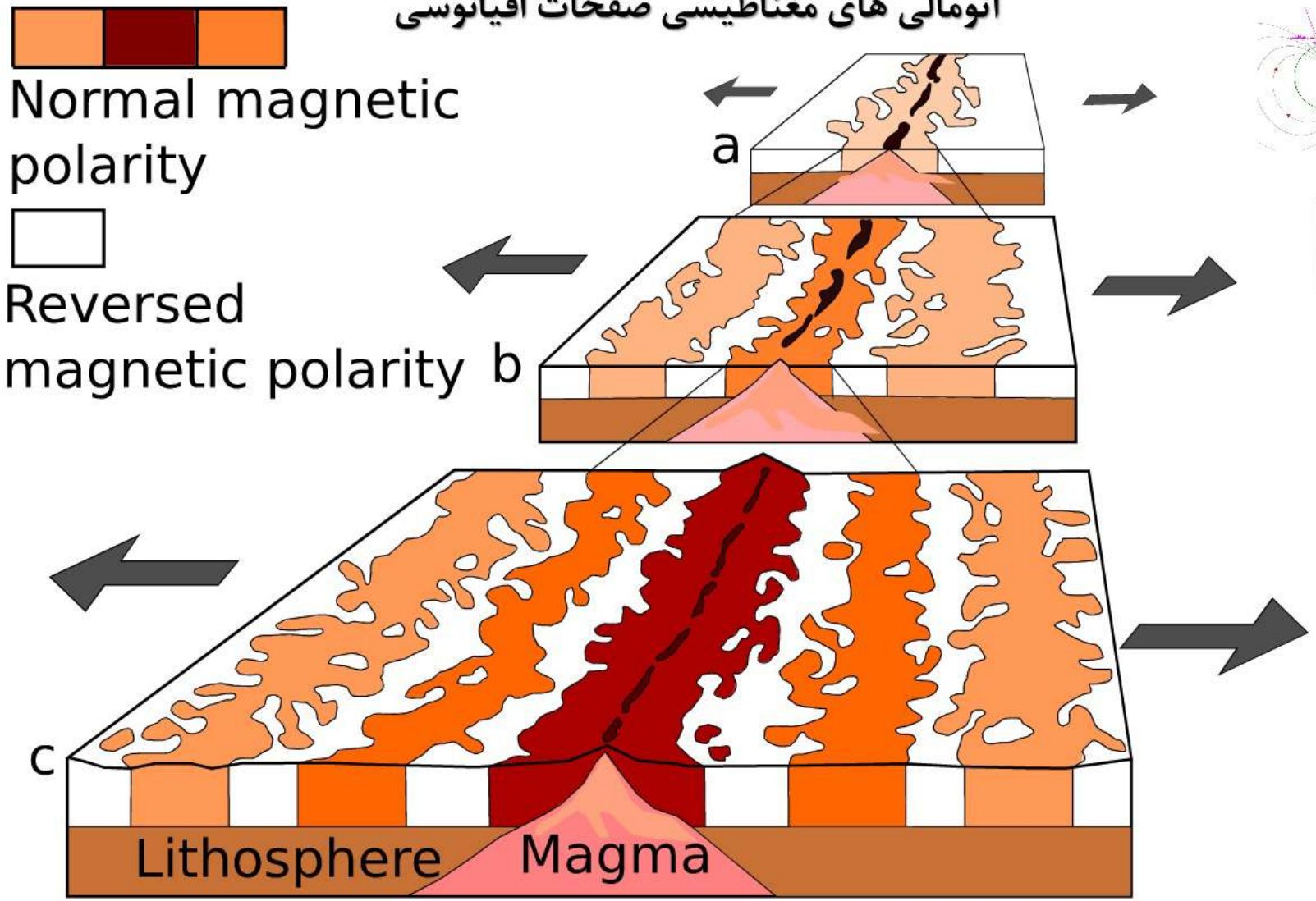
به دلیل تغییرات در هستهٔ زمین قطب مغناطیسی
به صورت مداوم در حال تغییر مکان است

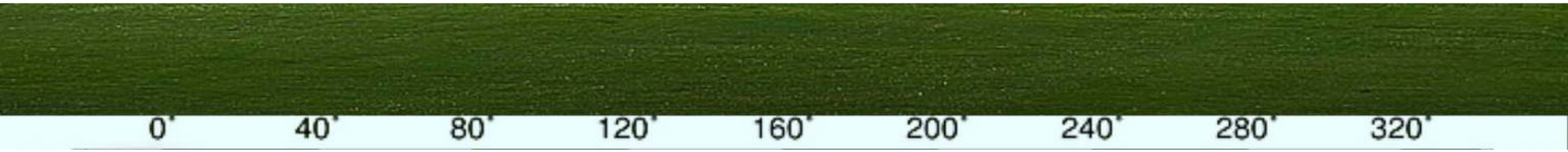
موقعیت قطب شمال به طور متوسط در هر سال
حدود ۵۵ کیلومتر جابجا می شود

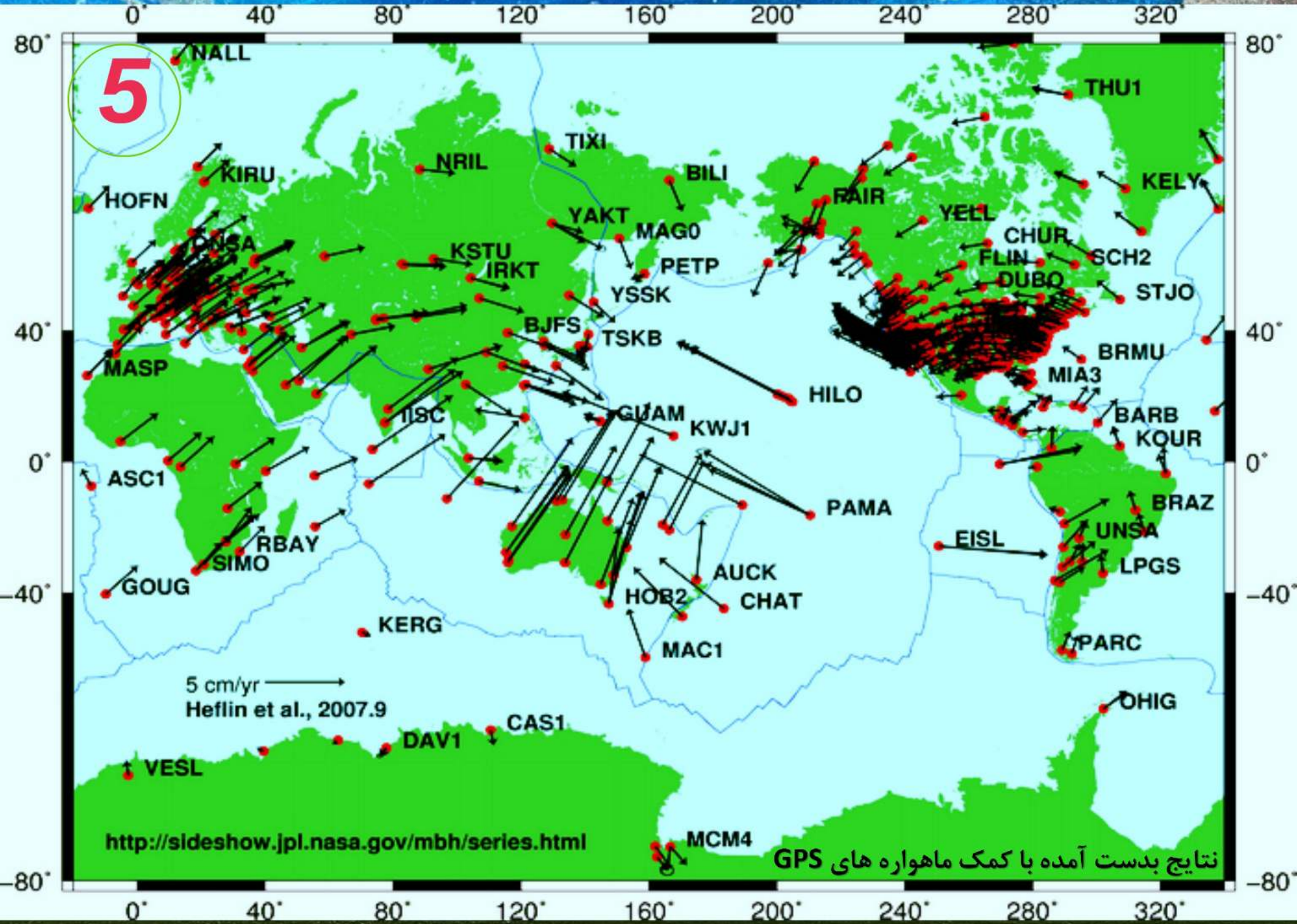


4

آنومالی های مغناطیسی صفحات اقیانوسی






5
NALL
THU1
TIXI
NRIL
KIRU
BILI
KELY
HOFN
RAIR
YELL
YAKT
MAG0
CHUR
KSTU
FLIN
SCH2
IRKT
PETP
DUBO
YSSK
STJO
BJFS
TSKB
BRMU
MASP
MIA3
HILO
IISC
GUAM
BARB
KWJ1
KOUR
ASC1
PAMA
BRAZ
UNSA
EISL
RBAY
SIMO
LPGS
AUCK
GOUG
HOB2
CHAT
KERG
MAC1
PARC
5 cm/yr
Heflin et al., 2007.9
OHIG
CAS1
DAV1
VESL
http://sideshow.jpl.nasa.gov/mbh/series.html
MCM4
نتایج بدست آمده با کمک ماهواره های GPS
0°
40°
80°
120°
160°
200°
240°
280°
320°
80°
40°
0°
−40°
−80°

Evidence for Pangaea and Continental Drift

Pangaea was a supercontinent existing from 300Ma and 100Ma, the name was derived from Ancient Greek *pan* meaning "entire", and *Gaia* meaning "Earth"

Trilobite fossils from SW Scotland are also found on the other side of the Atlantic Ocean

6

Caledonian Mountains, formed 490 – 390Ma - found on both sides of the Atlantic Ocean

Eurasia

The UK

Present Day Appalachian Mountains

North America

Central Pangean Mountains

Present day Little Atlas Mountains in Morocco

Africa

Paleo-Tethys Ocean

Fossil remains of Cynognathus, a Triassic land reptile roughly 3m long

South America

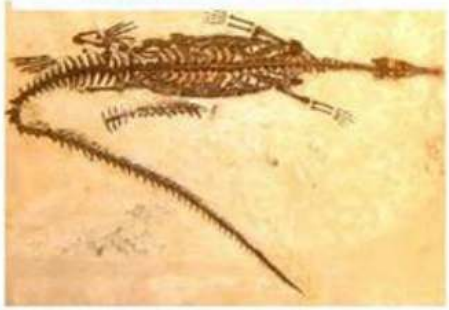
Lystrosaurus, fossil remains of this Triassic land reptile found in 3 continents

India

Australia

Antarctica

Fossil evidence of the freshwater reptile Mesosaurus found in South America And SW Africa



Fossils of Glossopteris are found in ALL of the Southern Continents, showing they were once joined

©Rob Gamesby
http://www.coolgeography.co.uk

Map Source - http://www.glosgeotrust.org.uk/

7

نقشه زمین‌ساخت و لرزه‌خیزی جهانی

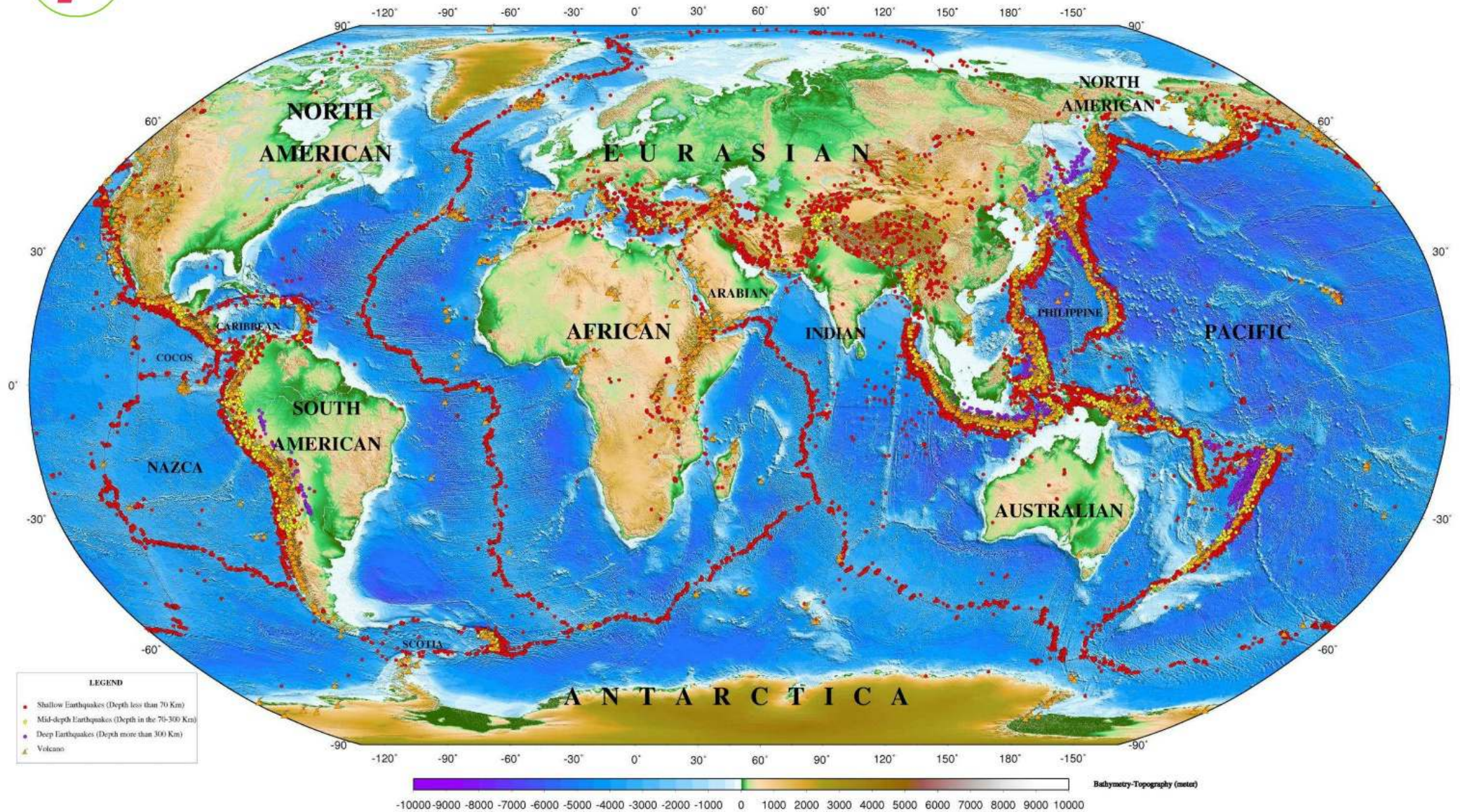
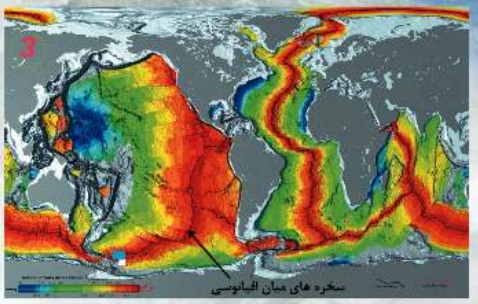
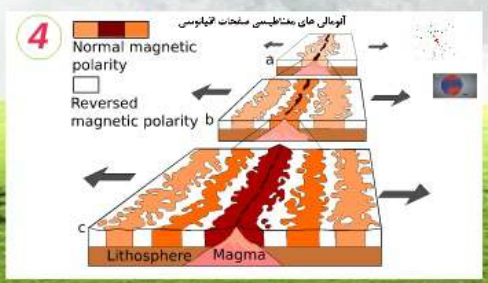
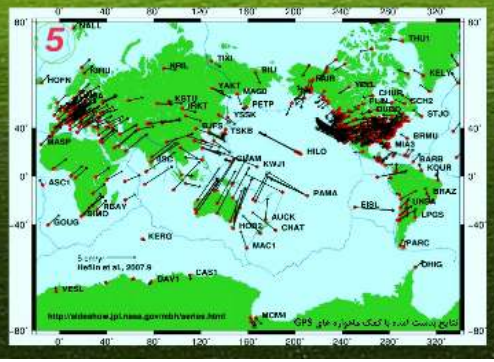


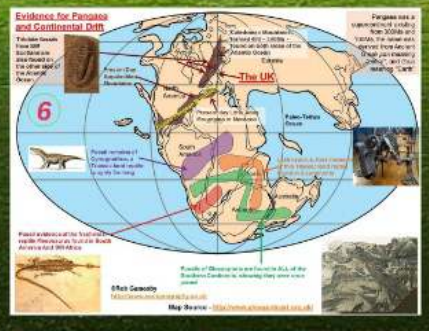
Plate Tectonic

Clues of Tectonic Plate movements







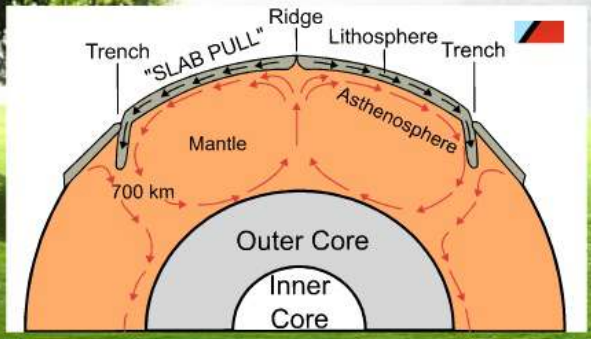


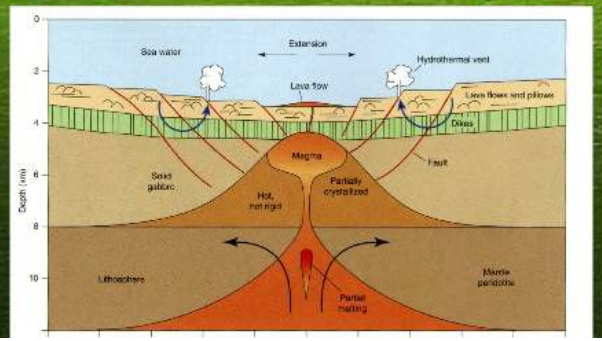
زمین ساخت صفحه ای

شواهد حرکت صفحات تکتونیکی زمین

Why Plates Move?

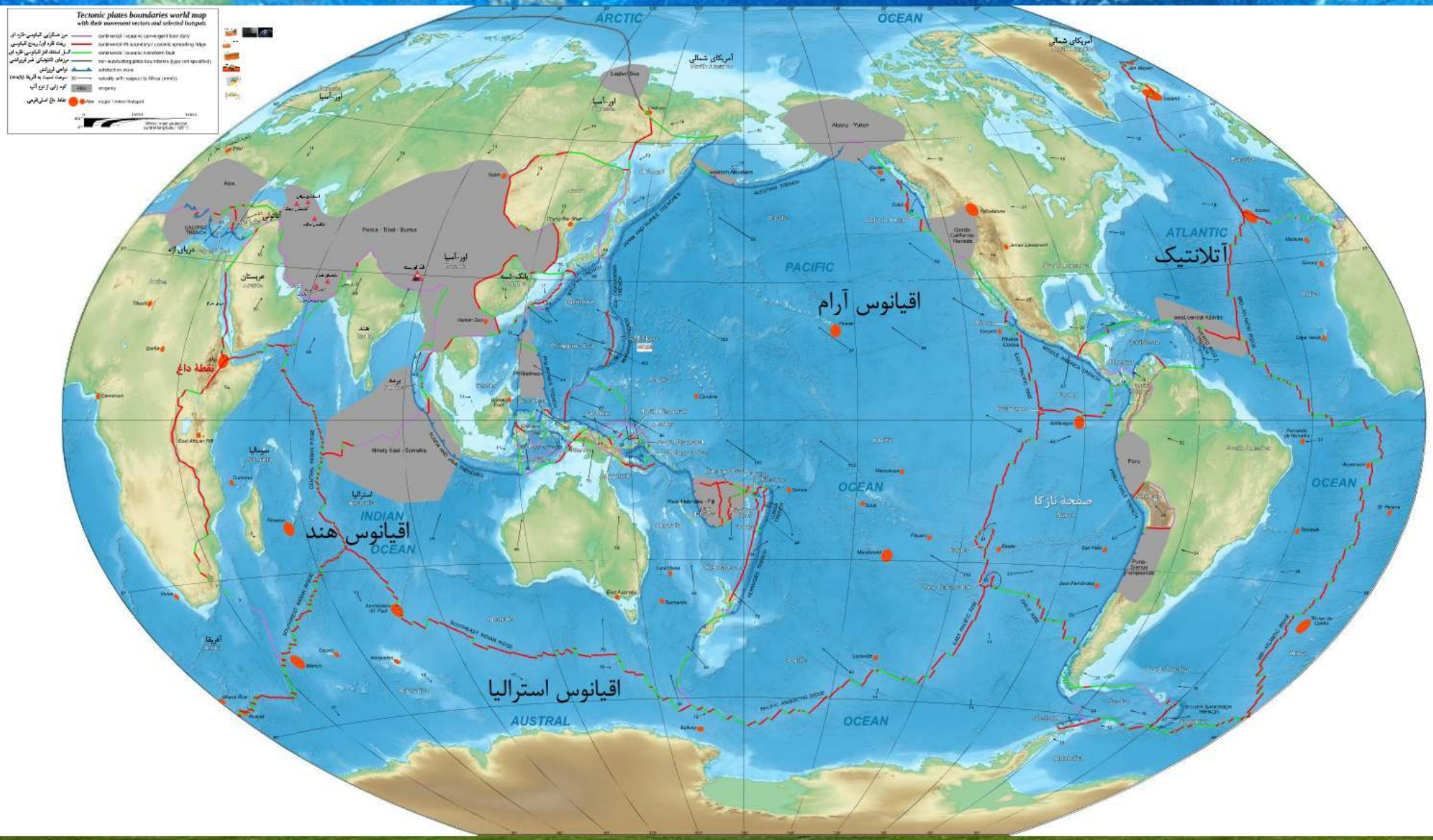
Divergent and Convergent Boundaries



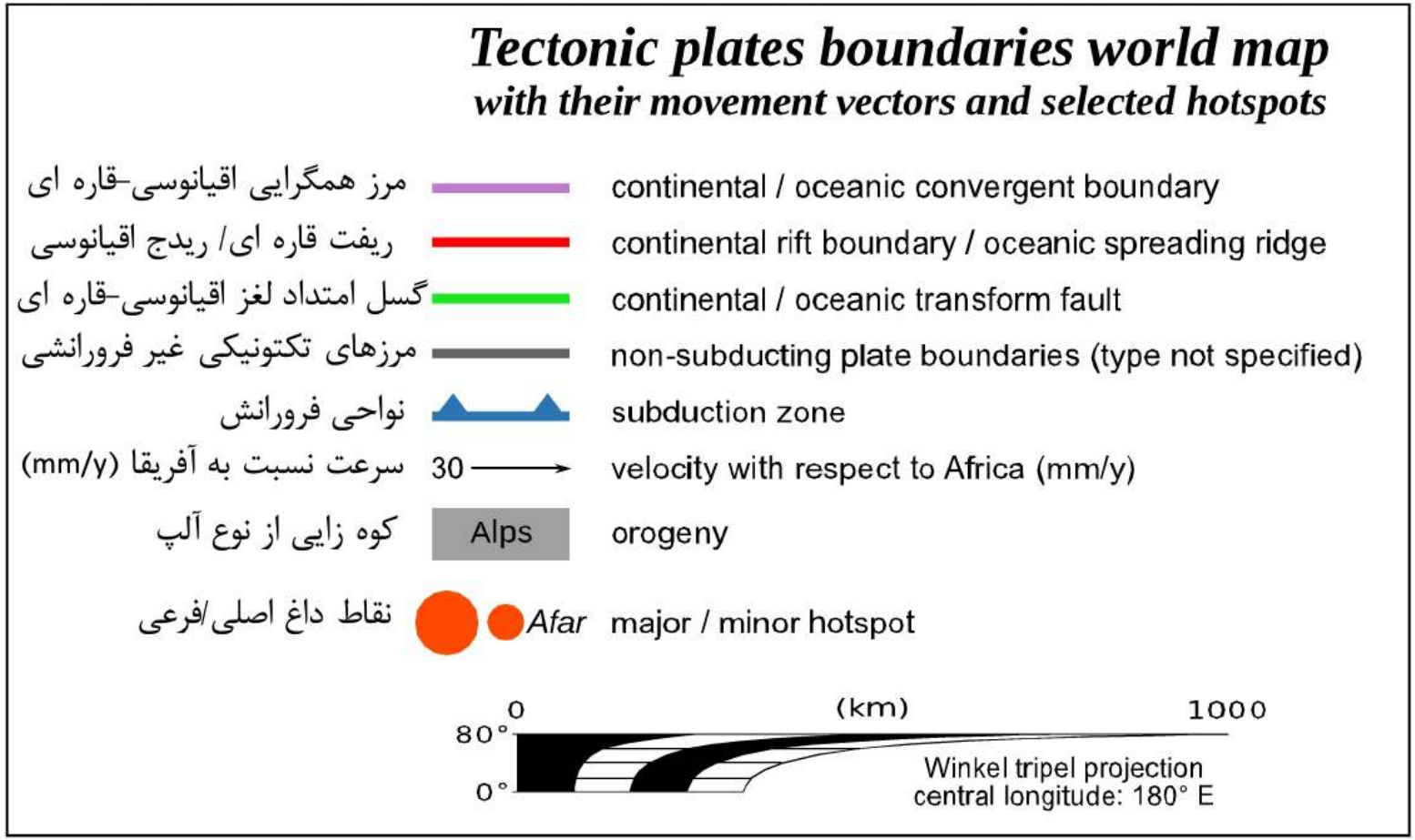


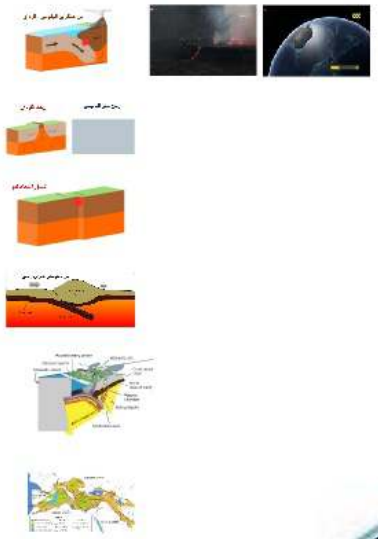
چرا صفحات لیتوسفری حرکت می کنند؟

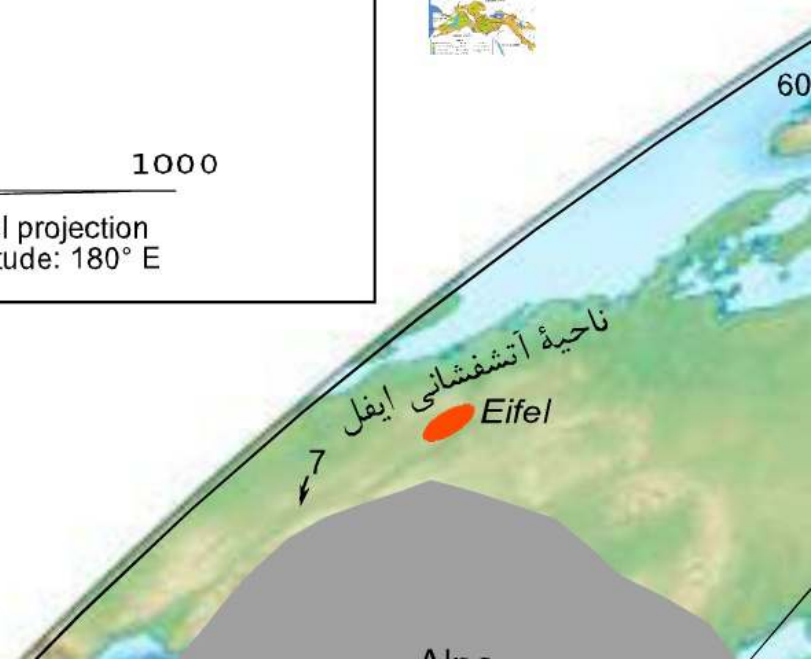
مرزهای واگرا و همگرا


Tectonic plates boundaries world map
with their movement vectors and selected hotspots
ARCTIC
OCEAN
آمریکای شمالی
اورآسیا
PACIFIC
اقیانوس آرام
ATLANTIC
آتلانتیک
OCEAN
INDIAN
OCEAN
اقیانوس هند
نقطهٔ داغ
صفحهٔ نازکا
اقیانوس استرالیا
AUSTRAL
OCEAN
OCEAN

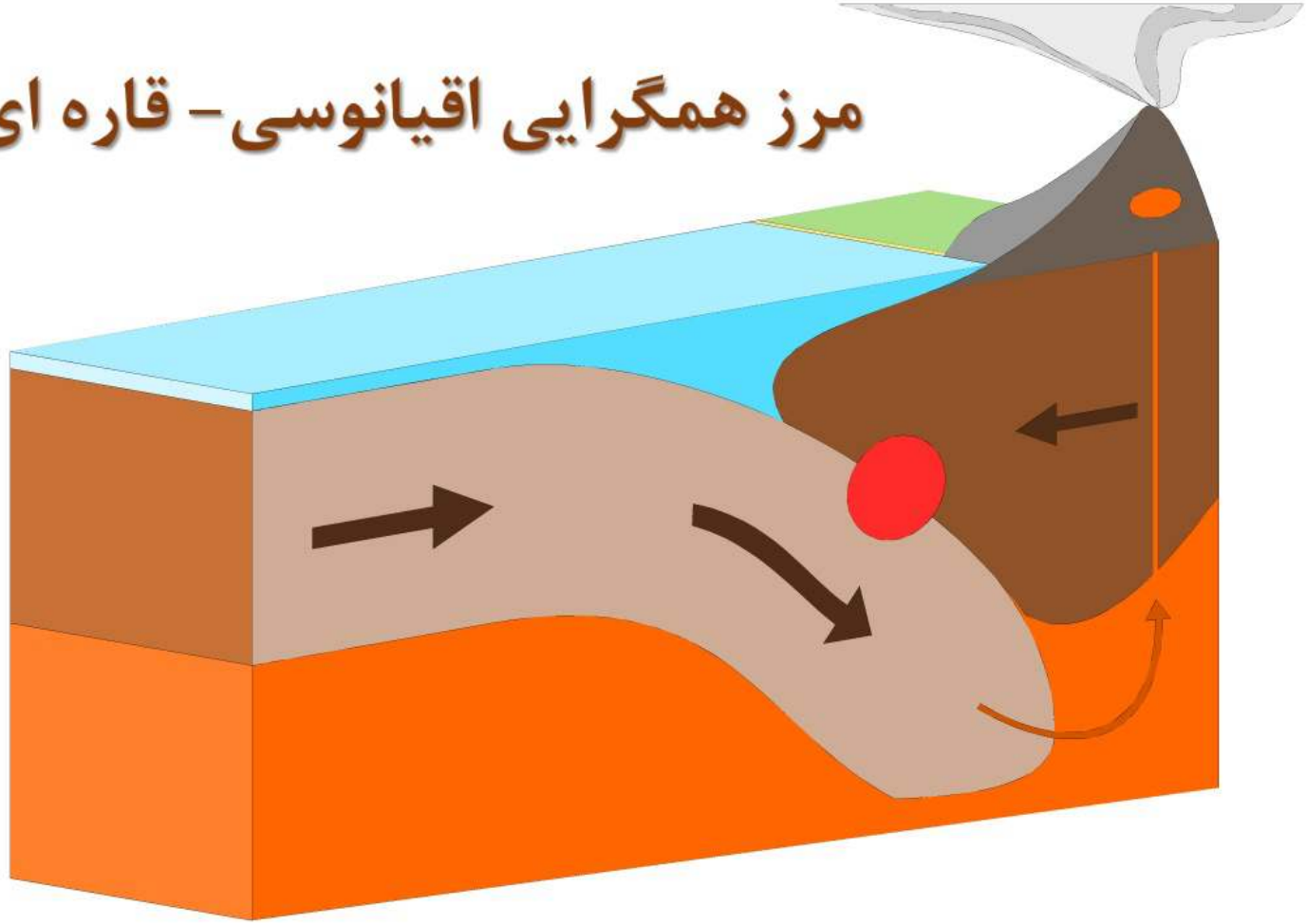
Ridge

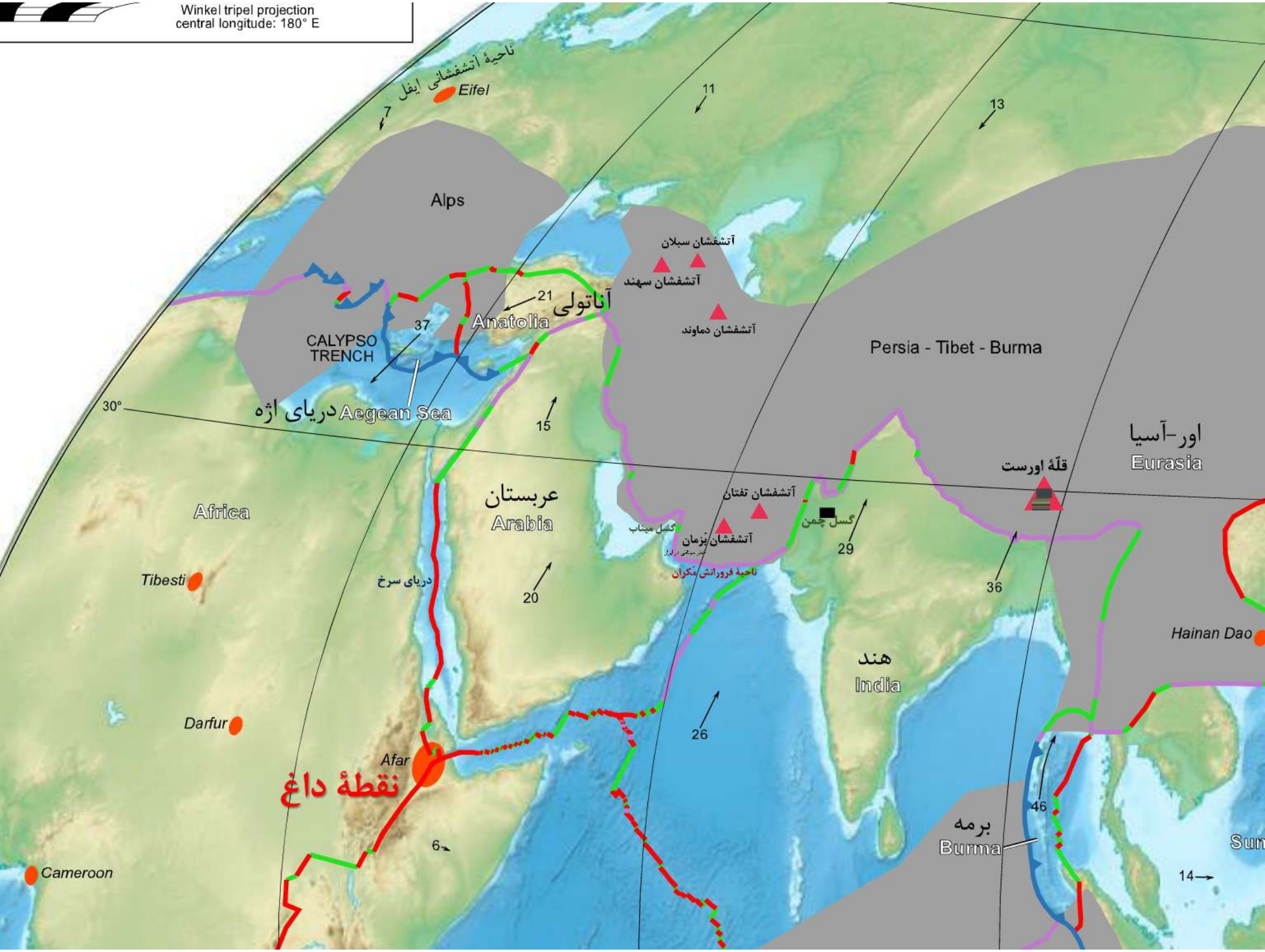

Tectonic plates boundaries world map
with their movement vectors and selected hotspots
مرز همگرایی اقیانوسی-قاره ای
continental / oceanic convergent boundary
ریفت قاره ای/ ریدج اقیانوسی
continental rift boundary / oceanic spreading ridge
گسل امتداد لغز اقیانوسی-قاره ای
continental / oceanic transform fault
مرزهای تکتونیکی غیر فرورانشی
non-subducting plate boundaries (type not specified)
نواحی فرورانش
subduction zone
سرعت نسبت به آفریقا (mm/y)
30
velocity with respect to Africa (mm/y)
کوه زایی از نوع آلپ
Alps
orogeny
نقاط داغ اصلی/فرعی
Afar
major / minor hotspot
0
(km)
1000
80°
0°
Winkel tripel projection
central longitude: 180° E

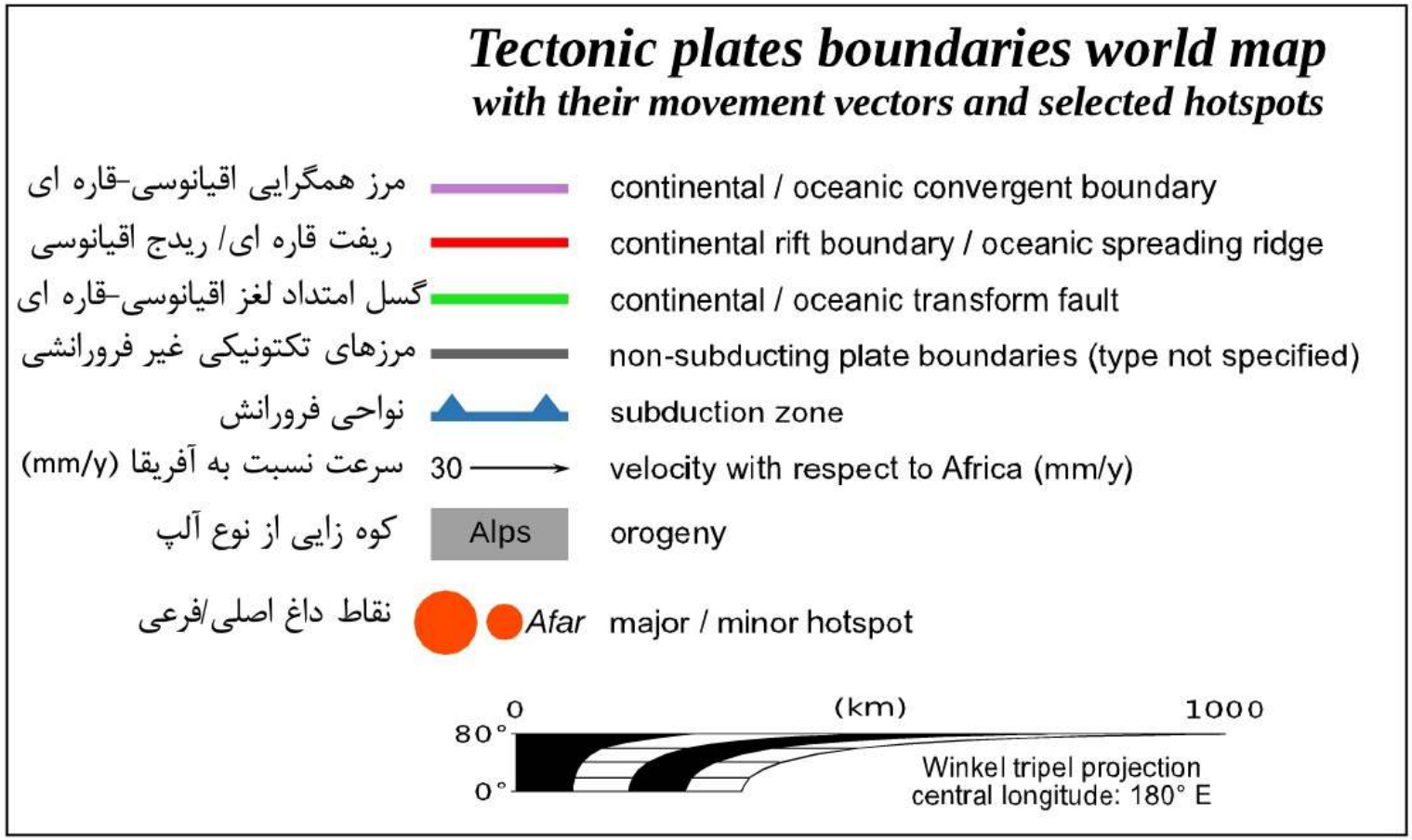



60
ناحیهٔ آتشفشانی ایفل
Eifel

مرز همگرایی اقیانوسی- قاره ای




Winkel tripel projection
central longitude: 180° E
ناحیهٔ آتشفشانی ایفل
Eifel
7
11
13
Alps
آتشفشان سبلان
آتشفشان سهند
آتشفشان دماوند
21
آناتولی
Anatolia
37
CALYPSO
TRENCH
Persia - Tibet - Burma
30°
دریای اژه
Aegean Sea
15
اور-آسیا
Eurasia
قلّهٔ اورست
آتشفشان تفتان
عربستان
Arabia
Africa
گسل چمن
گسل میناب
آتشفشان تزمان
29
ناحیهٔ فرورانش مکران
36
Tibesti
دریای سرخ
20
Hainan Dao
هند
India
Darfur
26
Afar
نقطهٔ داغ
46
برمه
Burma
6
Cameroon
14


Tectonic plates boundaries world map
with their movement vectors and selected hotspots
مرز همگرایی اقیانوسی-قاره ای
continental / oceanic convergent boundary
ریفت قاره ای/ ریدج اقیانوسی
continental rift boundary / oceanic spreading ridge
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continental / oceanic transform fault
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30
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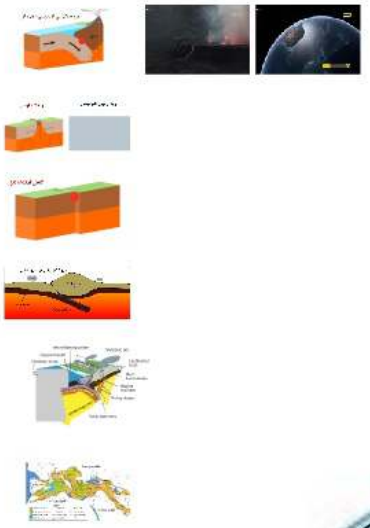
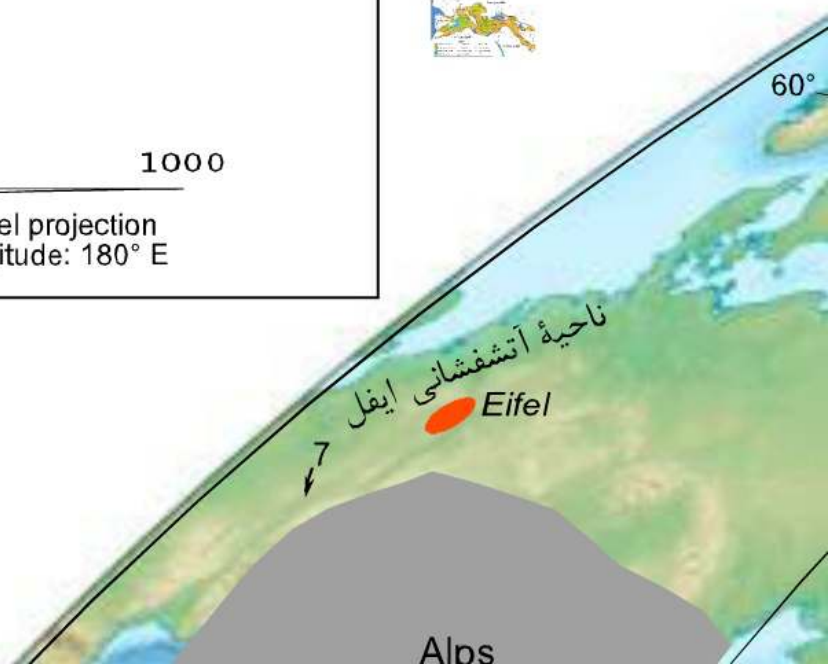
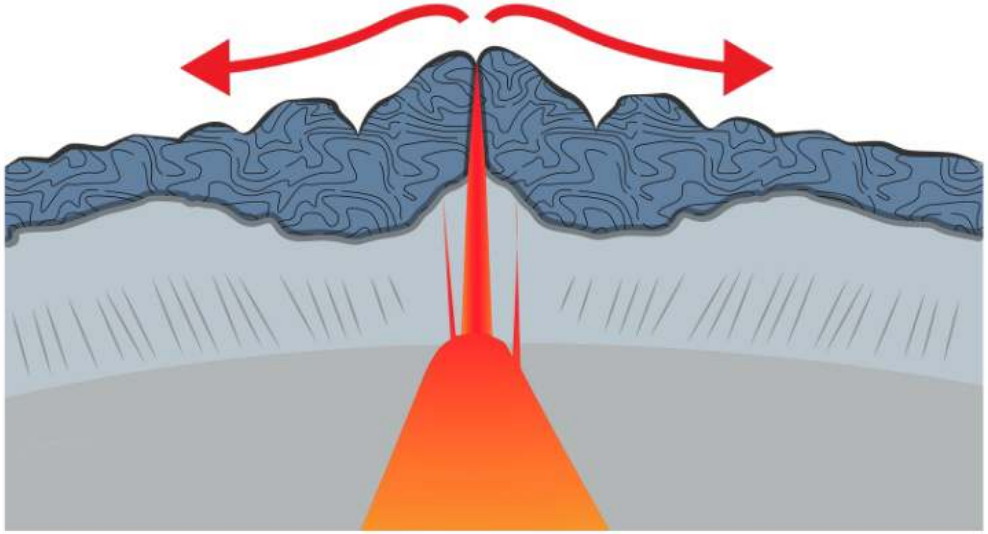
کوه زایی از نوع آلپ
Alps
orogeny
نقاط داغ اصلی/فرعی
Afar
major / minor hotspot
0
(km)
1000
80°
0°
Winkel tripel projection
central longitude: 180° E

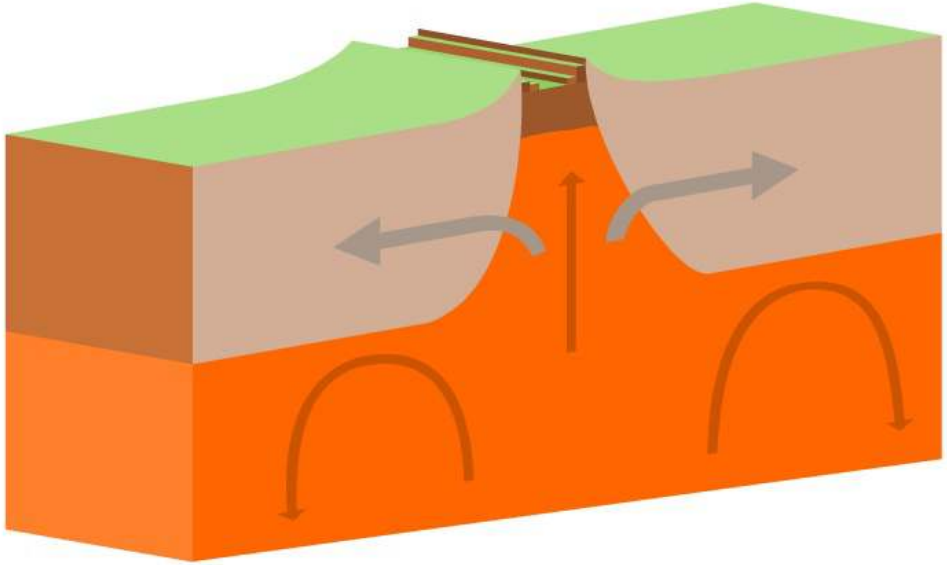


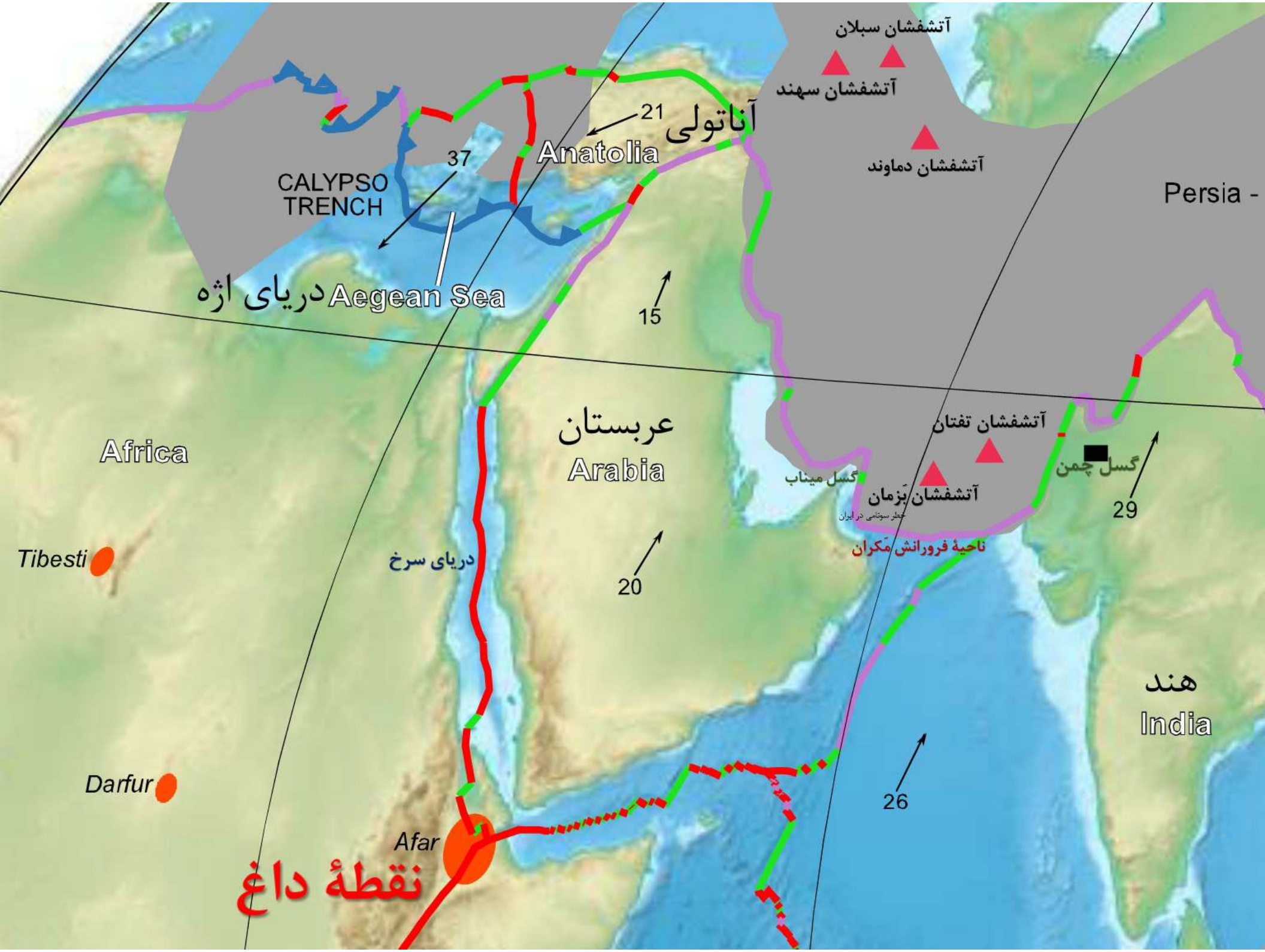

60°
ناحیهٔ آتشفشانی ایفل
Eifel
Alps

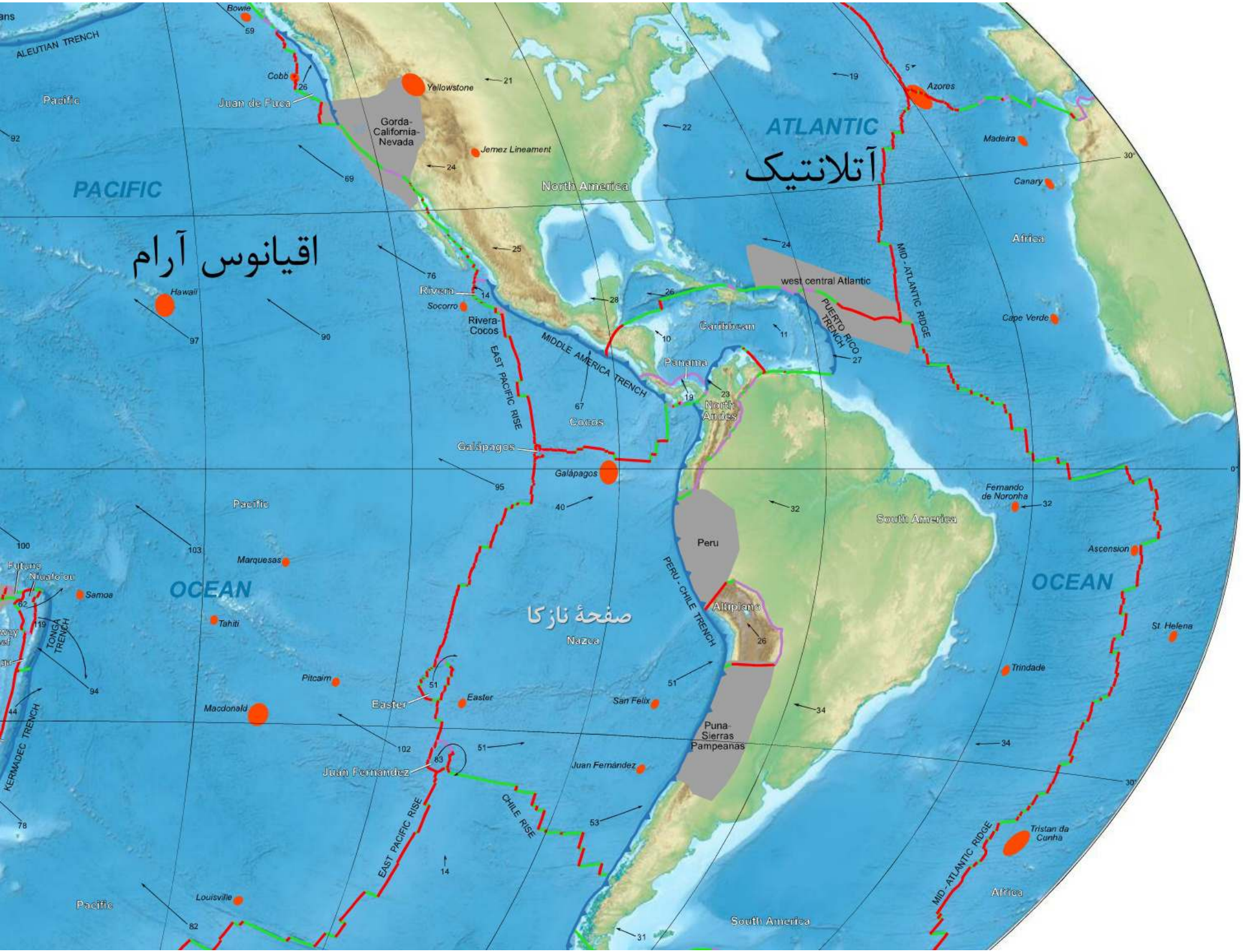
ریدج میان اقیانوسی

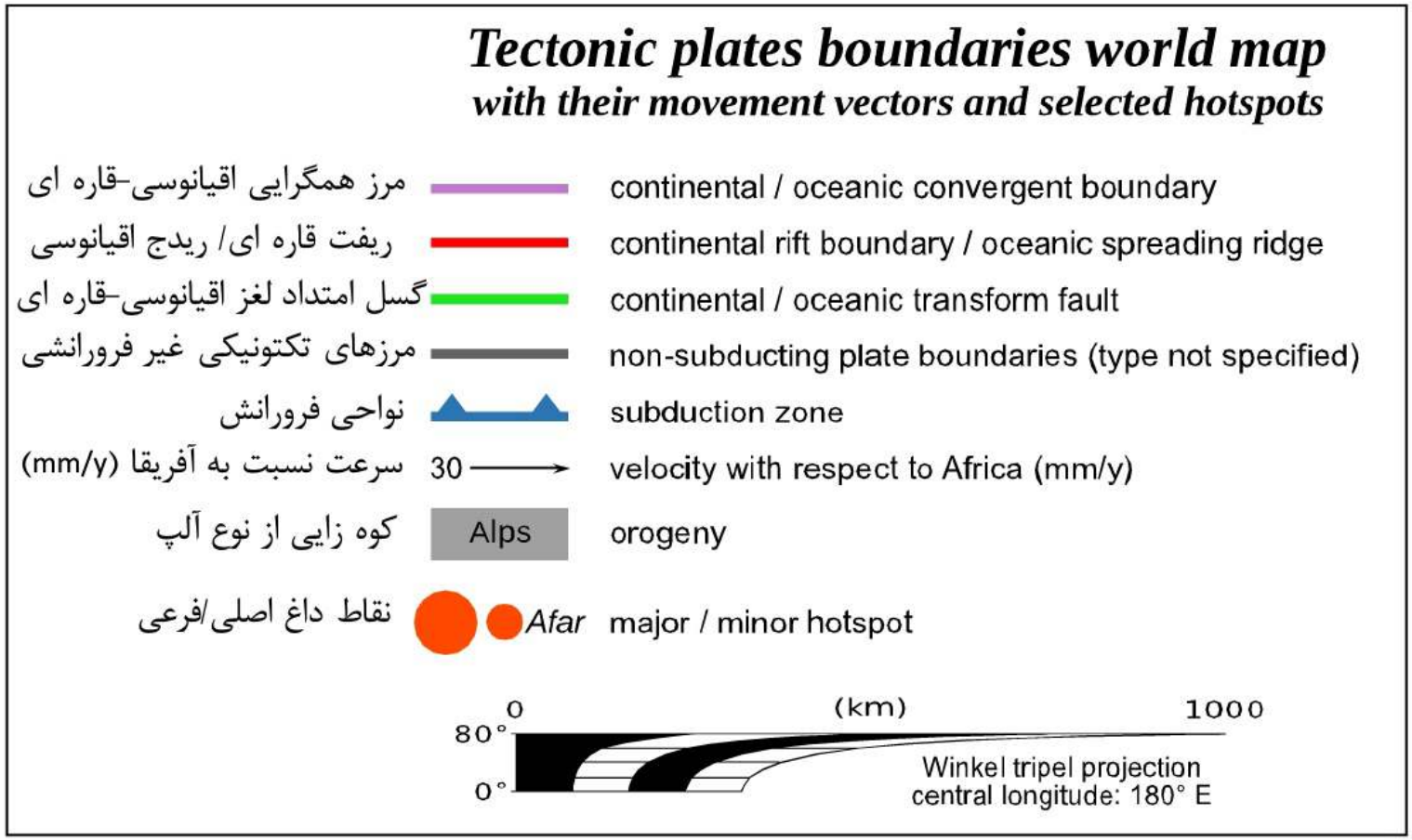


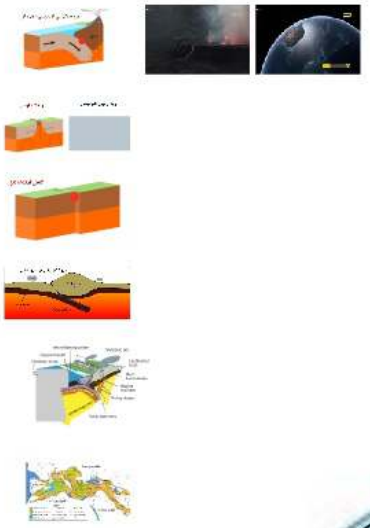
ریفت قاره ای

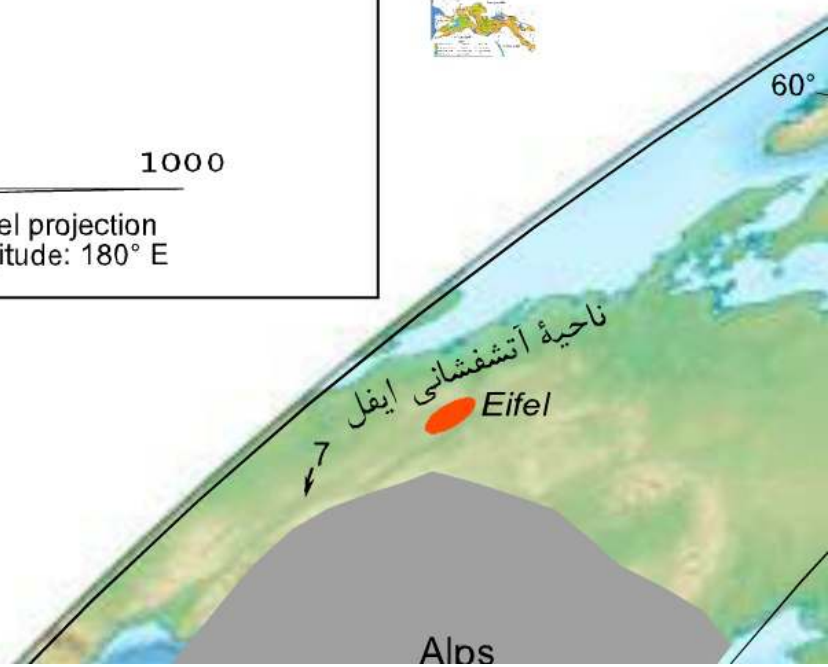



آتشفشان سبلان
آتشفشان سهند
آتشفشان دماوند
آناتولی
Anatolia
21
37
CALYPSO
TRENCH
Persia -
دریای اژه
Aegean Sea
15
عربستان
Arabia
Africa
آتشفشان تفتان
گسل چمن
گسل میناب
آتشفشان بَزمان
خطر سونامی در ایران
29
ناحیهٔ فرورانش مَکران
Tibesti
دریای سرخ
20
هند
India
Darfur
26
Afar
نقطهٔ داغ

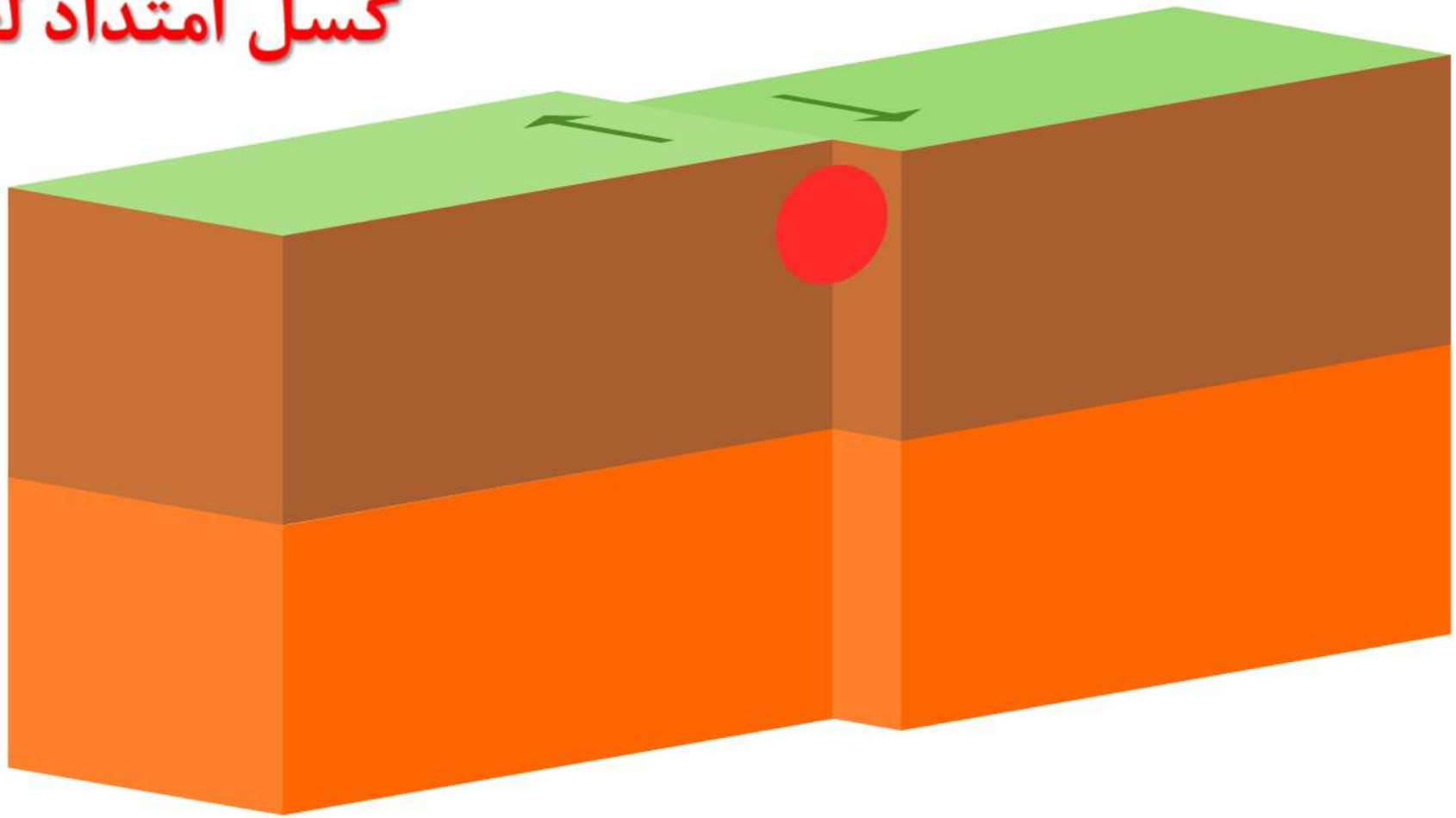

ALEUTIAN TRENCH
Pacific
PACIFIC
اقیانوس آرام
Bowie
Cobb
Juan de Fuca
Yellowstone
Gorda-California-Nevada
Jemez Lineament
North America
ATLANTIC
آتلانتیک
Azores
Madeira
Canary
Africa
Cape Verde
MID-ATLANTIC RIDGE
west central Atlantic
PUERTO RICO TRENCH
Caribbean
Panama
North Andes
Hawaii
Rivera
Socorro
Rivera-Cocos
EAST PACIFIC RISE
MIDDLE AMERICA TRENCH
Cocos
Galápagos
Pacific
Marquesas
OCEAN
Samoa
Tahiti
TONGA TRENCH
KERMADEC TRENCH
Pitcairn
Macdonald
Easter
صفحهٔ نازکا
Nazca
PERU - CHILE TRENCH
Peru
Altiplano
San Felix
Puna-Sierras Pampeanas
Juan Fernández
CHILE RISE
Louisville
South America
Fernando de Noronha
Ascension
St. Helena
Trindade
Tristan da Cunha

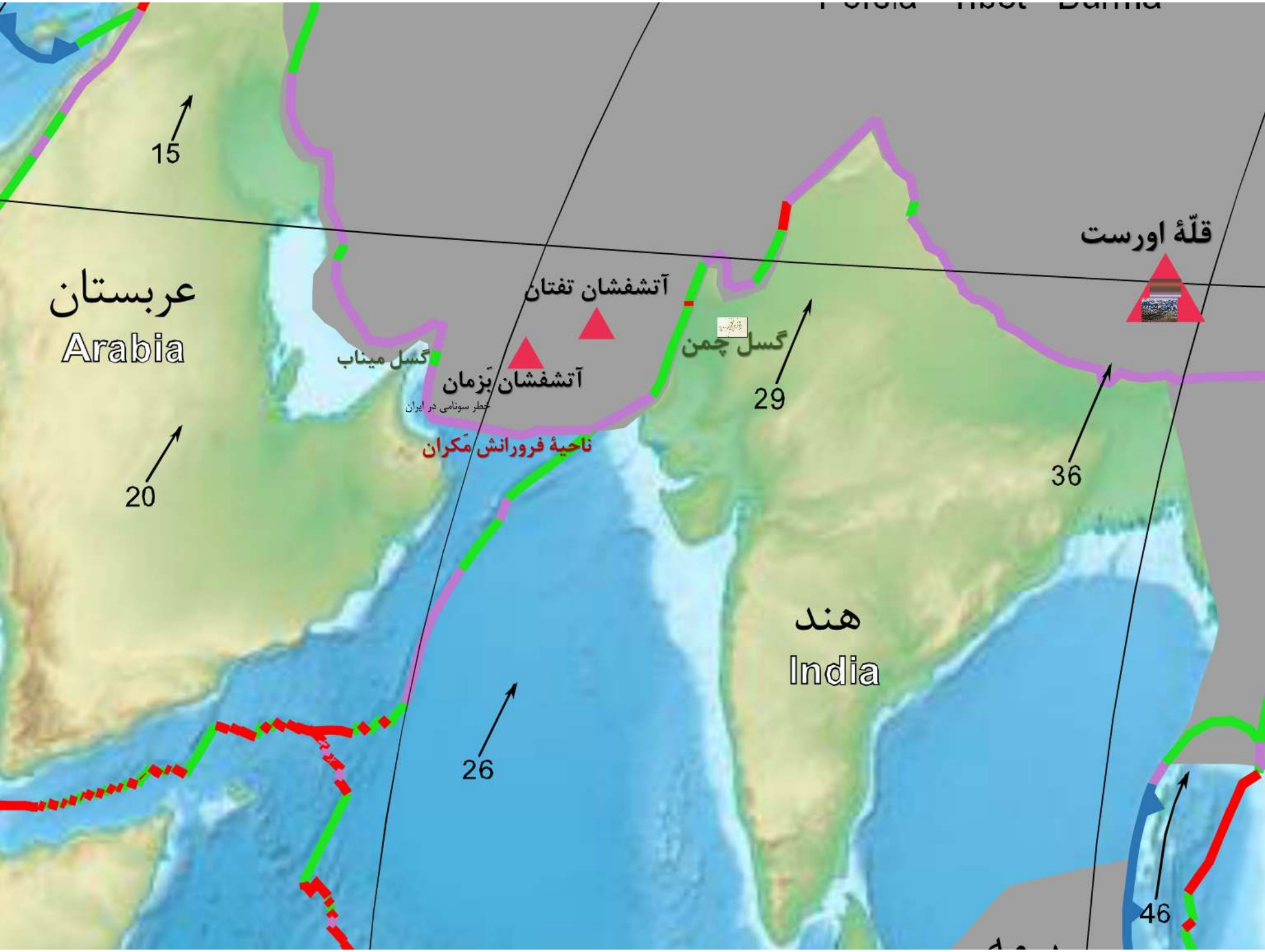

Tectonic plates boundaries world map
with their movement vectors and selected hotspots
مرز همگرایی اقیانوسی-قاره ای
continental / oceanic convergent boundary
ریفت قاره ای/ ریدج اقیانوسی
continental rift boundary / oceanic spreading ridge
گسل امتداد لغز اقیانوسی-قاره ای
continental / oceanic transform fault
مرزهای تکتونیکی غیر فرورانشی
non-subducting plate boundaries (type not specified)
نواحی فرورانش
subduction zone
سرعت نسبت به آفریقا (mm/y)
30
velocity with respect to Africa (mm/y)
کوه زایی از نوع آلپ
Alps
orogeny
نقاط داغ اصلی/فرعی
Afar
major / minor hotspot
0
(km)
1000
80°
0°
Winkel tripel projection
central longitude: 180° E



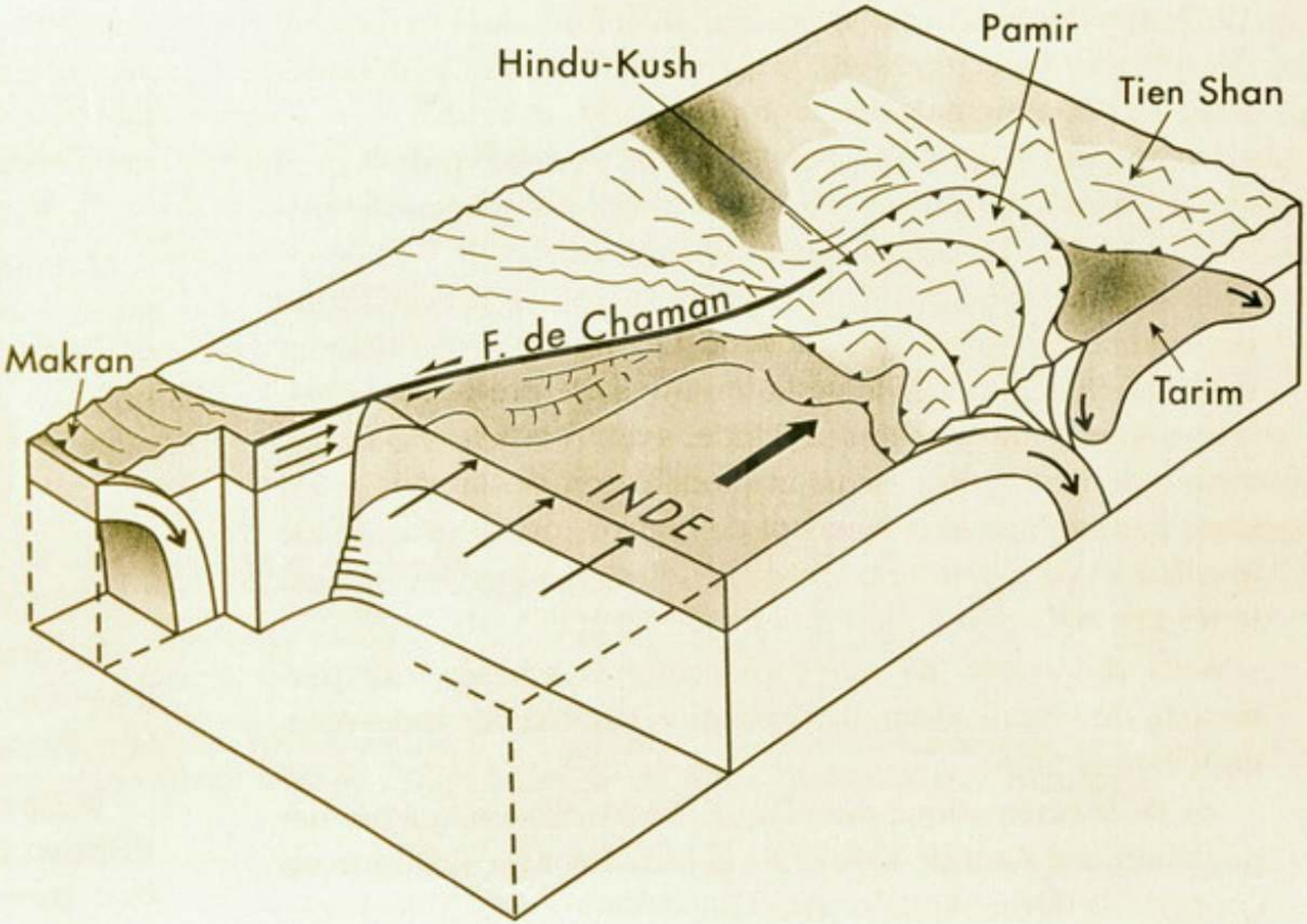

60°
ناحیهٔ آتشفشانی ایفل
Eifel
Alps

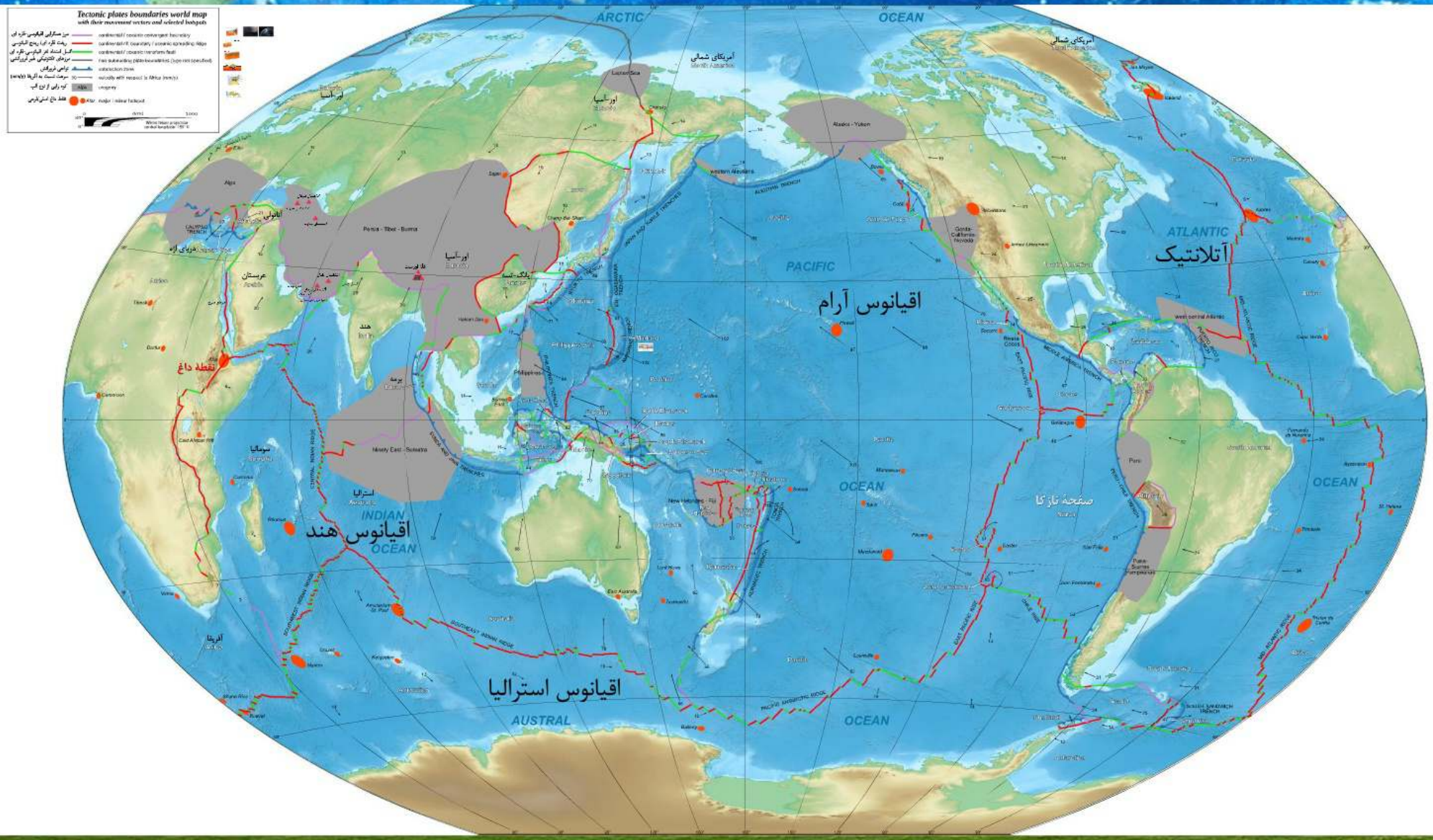
گسل امتداد لغز



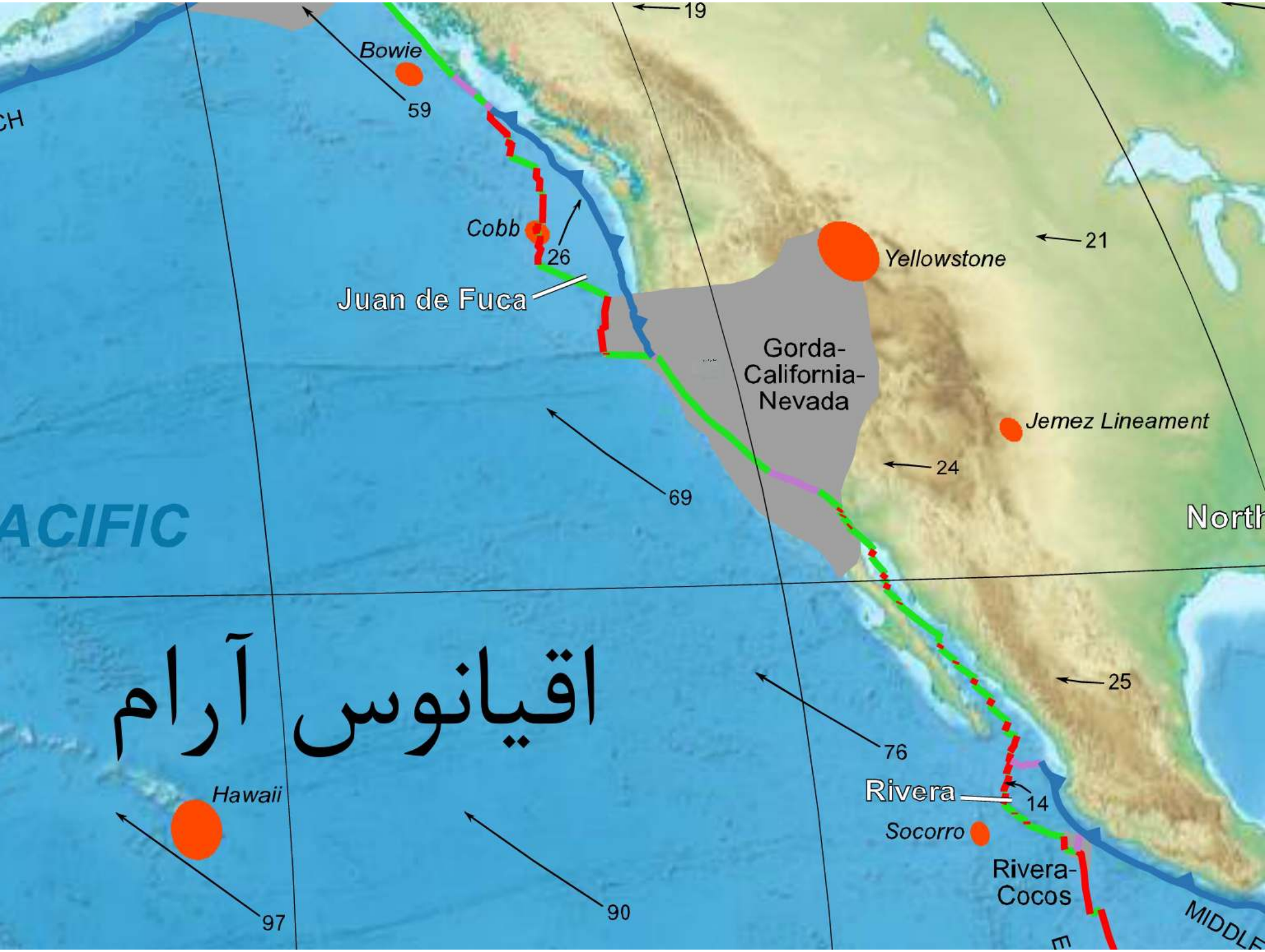

15
عربستان
Arabia
20
آتشفشان تفتان
گسل میناب
آتشفشان بَزمان
خطر سونامی در ایران
ناحیهٔ فرورانش مَکران
گسل چمن
29
قلّهٔ اورست
36
هند
India
26
46

A 3D model of the India–Asia collision at plate scale




Tectonic plates boundaries world map
with their movement vectors and selected hotspots
ARCTIC
OCEAN
آمریکای شمالی
اوراسیا
PACIFIC
اقیانوس آرام
ATLANTIC
آتلانتیک
نقطه داغ
INDIAN
OCEAN
اقیانوس هند
صفحهٔ نازکا
اقیانوس استرالیا
AUSTRAL
OCEAN

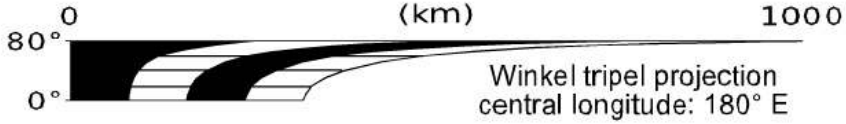
Ridge

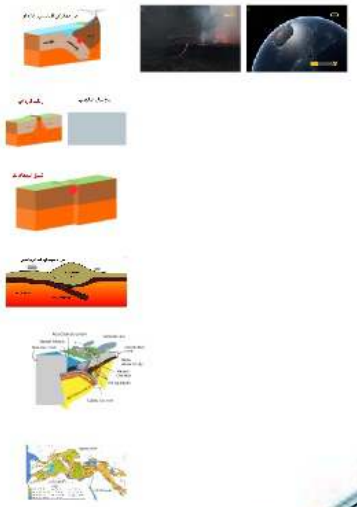

19
Bowie
59
CH
Cobb
26
Juan de Fuca
Yellowstone
21
Gorda-
California-
Nevada
Jemez Lineament
24
69
ACIFIC
North
اقیانوس آرام
25
76
Rivera
14
Hawaii
Socorro
Rivera-
Cocos
97
90
MIDDLE

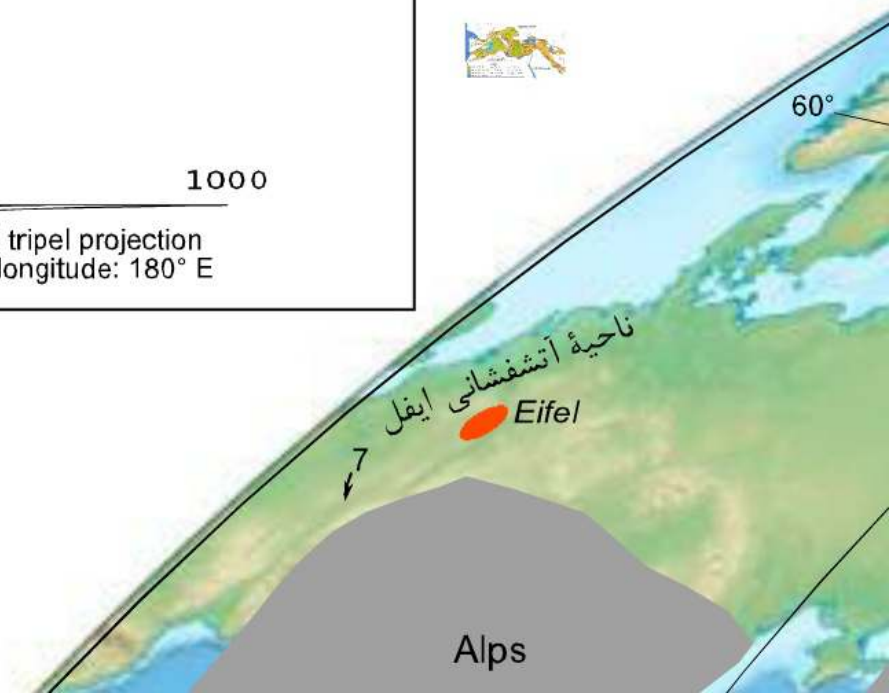
گسل سن آندریاس

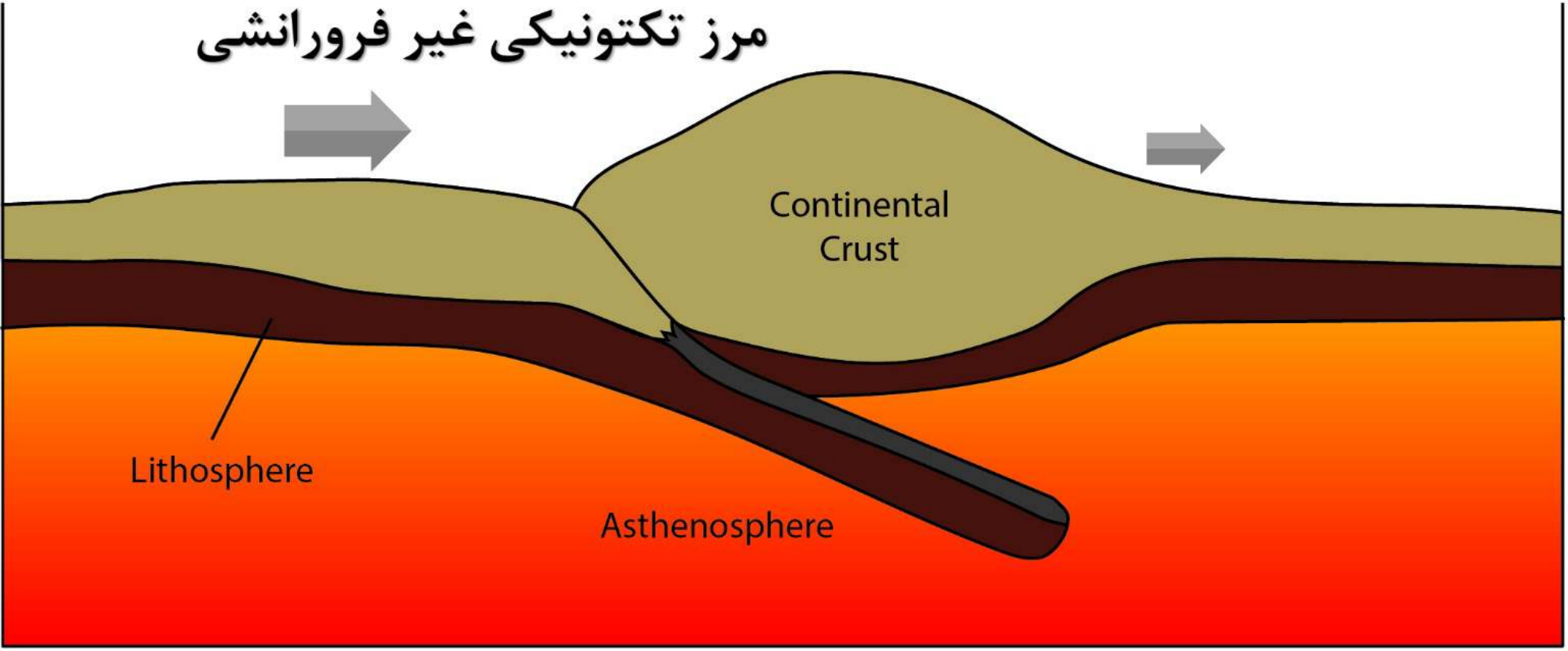
Tectonic plates boundaries world map
with their movement vectors and selected hotspots

مرز همگرایی اقیانوسی-قاره ای		continental / oceanic convergent boundary
ریفت قاره ای/ ریدج اقیانوسی		continental rift boundary / oceanic spreading ridge
گسل امتداد لغز اقیانوسی-قاره ای		continental / oceanic transform fault
مرزهای تکتونیکی غیر فرورانشی		non-subducting plate boundaries (type not specified)
نواحی فرورانش		subduction zone
سرعت نسبت به آفریقا (mm/y)	30 →	velocity with respect to Africa (mm/y)
کوه زایی از نوع آلپ	Alps	orogeny
نقاط داغ اصلی/فرعی	*Afar*	major / minor hotspot

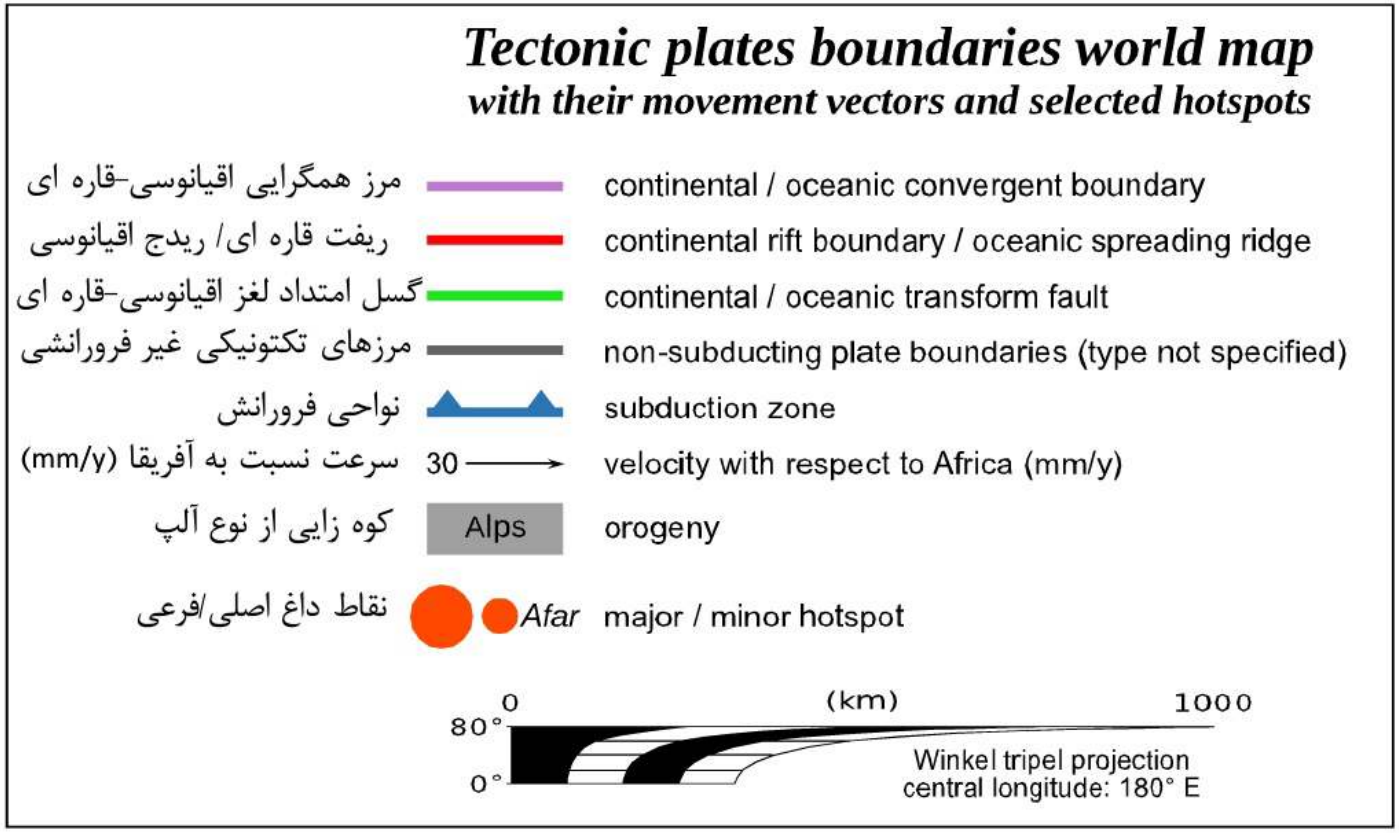


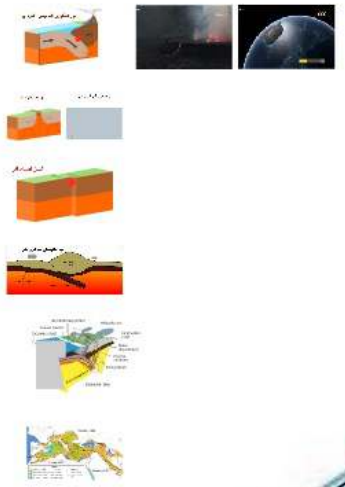


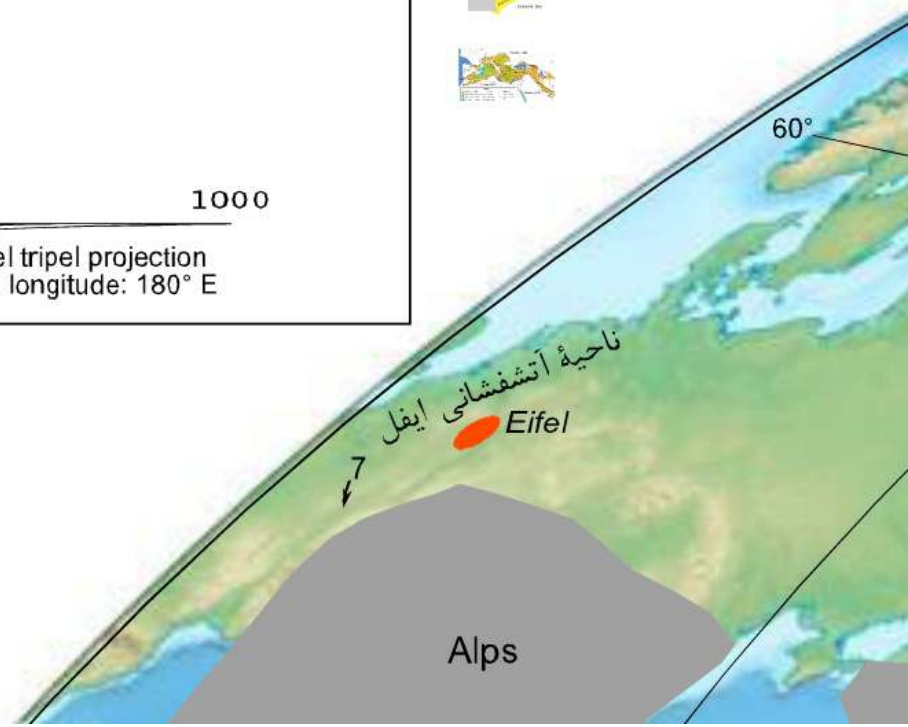


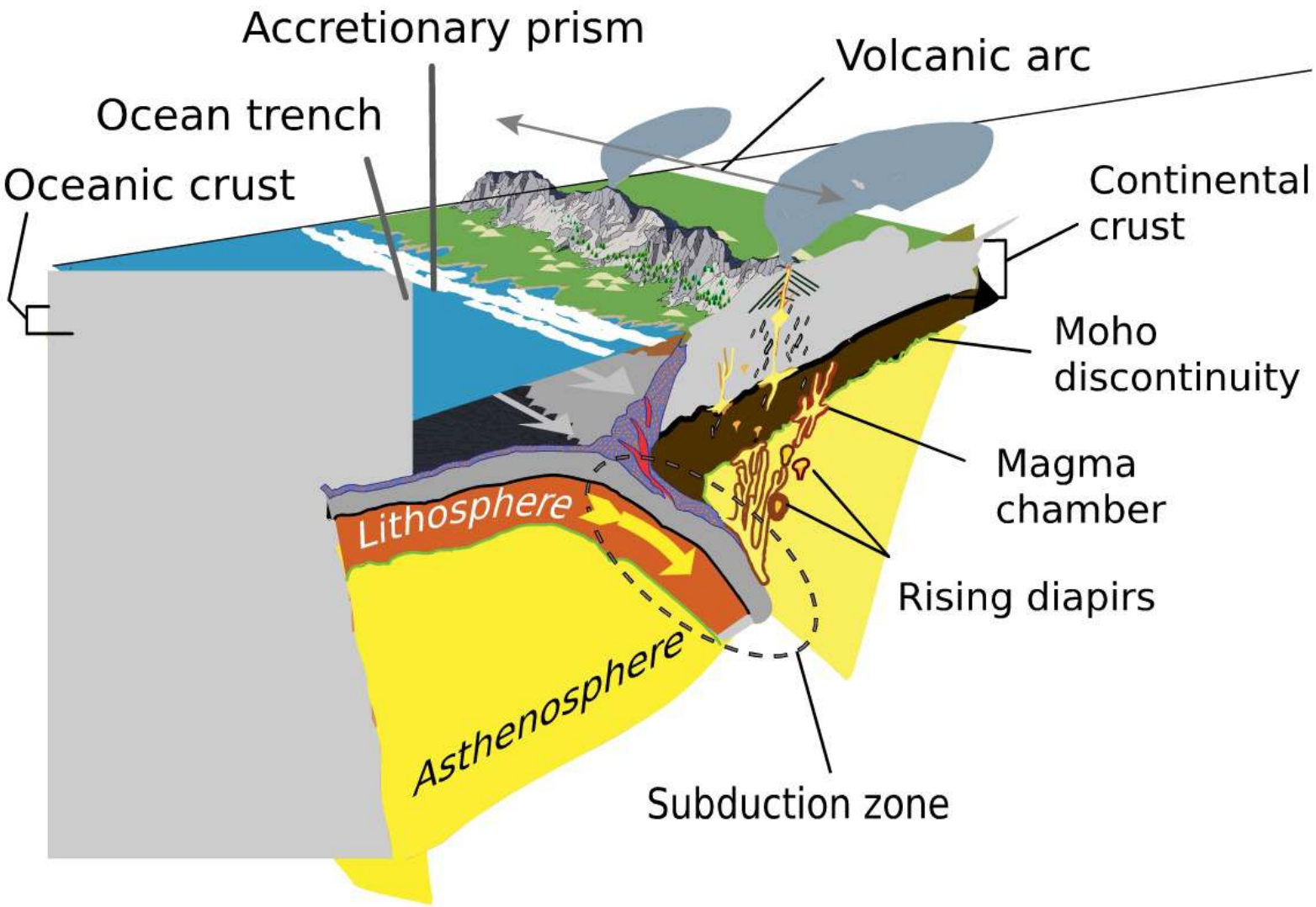

مرز تکتونیکی غیر فرورانشی
Continental
Crust
Lithosphere
Asthenosphere

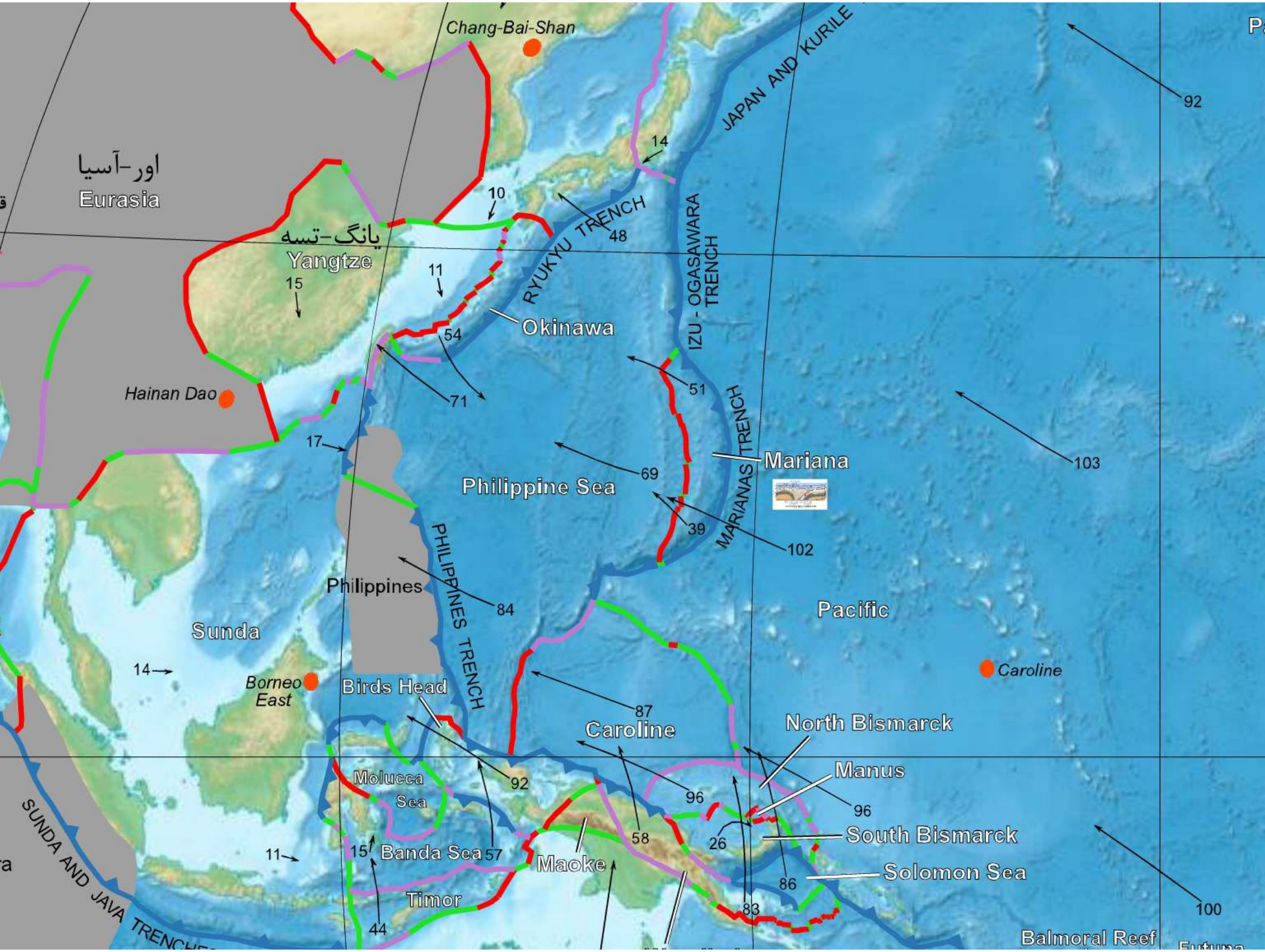
ARCTIC
30°
60°
90°
120°
150°
180°
آمریکای شمالی
North America
Laptev Sea
اور-آسیا
Eurasia
Chersky
14
16
13
18
10
Sajan
Okhotsk
western Aleutians
Amur
ALEUTIAN TRENC
JAPAN AND KURILE TRENCHES
Chang-Bai-Shan
Pacific
Persia - Tibet - Burma
92
قلّهٔ اورست
یانگ-تسه
Yangtze
11
48

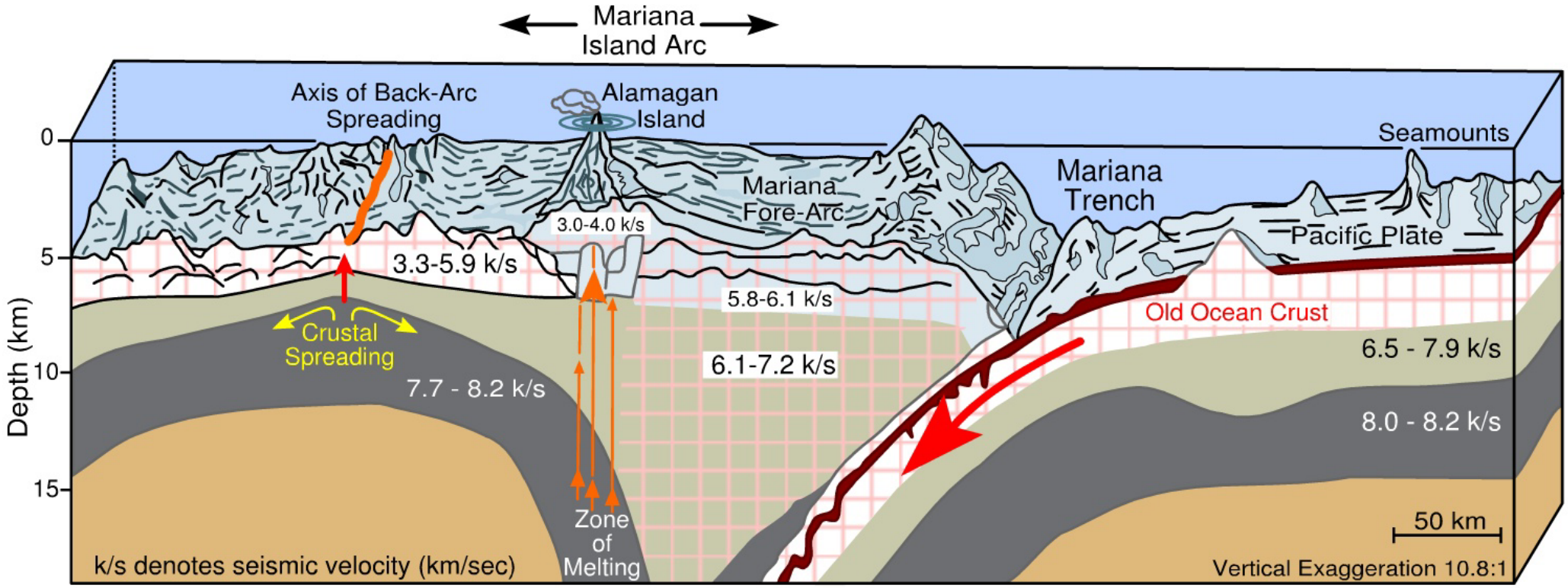

Tectonic plates boundaries world map
with their movement vectors and selected hotspots
مرز همگرایی اقیانوسی-قاره ای
continental / oceanic convergent boundary
ریفت قاره ای/ ریدج اقیانوسی
continental rift boundary / oceanic spreading ridge
گسل امتداد لغز اقیانوسی-قاره ای
continental / oceanic transform fault
مرزهای تکتونیکی غیر فرورانشی
non-subducting plate boundaries (type not specified)
نواحی فرورانش
subduction zone
سرعت نسبت به آفریقا (mm/y)
30
velocity with respect to Africa (mm/y)
کوه زایی از نوع آلپ
Alps
orogeny
نقاط داغ اصلی/فرعی
Afar
major / minor hotspot
0
(km)
1000
80°
0°
Winkel tripel projection
central longitude: 180° E




60°
ناحیهٔ آتشفشانی ایفل
Eifel
Alps


Accretionary prism
Volcanic arc
Ocean trench
Oceanic crust
Continental crust
Moho discontinuity
Magma chamber
Lithosphere
Rising diapirs
Asthenosphere
Subduction zone


Chang-Bai-Shan
JAPAN AND KURILE
92
14
اور-آسیا
Eurasia
10
48
RYUKYU TRENCH
IZU - OGASAWARA TRENCH
یانگ-تسه
Yangtze
15
11
Okinawa
54
71
51
Hainan Dao
17
69
Philippine Sea
Mariana
103
39
102
MARIANAS TRENCH
PHILIPPINES TRENCH
Philippines
84
Pacific
Sunda
14
Borneo East
Birds Head
Caroline
87
Caroline
North Bismarck
Manus
Molucca Sea
92
96
96
58
26
South Bismarck
11
15
Banda Sea
57
Maoke
86
Solomon Sea
Timor
83
100
44
SUNDA AND JAVA TRENCHES
Balmoral Reef



Island arc crust, including rocks from contemporary volcanism and from older, rifted, volcanic arcs.

Basalic crust, including old crust on the Pacific Plate and young crust formed in the back-arc.

گودال یا درهٔ ماریانا با طول و عرض ۲۵۵۰ در ۶۹ کیلومتر، دارای عمق شناخته شدهٔ ۱۱۰۰۰ کیلومتر زیر سطح دریا بوده و عمیق ترین نقطهٔ پوستهٔ زمین است.

Cross-Section Sketch of Mariana Arc

(After Hussong and Fryer, 1981)

Tectonic plates boundaries world map

with their movement vectors and selected hotspots

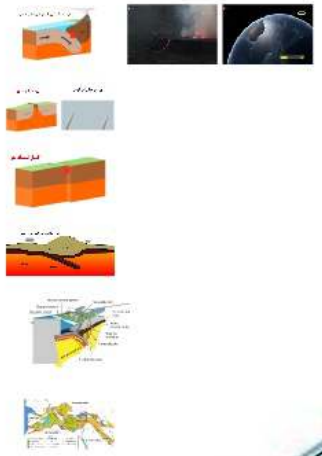
مرز همگرایی اقیانوسی-قاره ای		continental / oceanic convergent boundary
ریفت قاره ای/ ریدج اقیانوسی		continental rift boundary / oceanic spreading ridge
گسل امتداد لغز اقیانوسی-قاره ای		continental / oceanic transform fault
مرزهای تکتونیکی غیر فرورانشی		non-subducting plate boundaries (type not specified)
نواحی فرورانش		subduction zone
سرعت نسبت به آفریقا (mm/y)	30 ⟶	velocity with respect to Africa (mm/y)
کوه زایی از نوع آلپ	Alps	orogeny
نقاط داغ اصلی/فرعی	*Afar*	major / minor hotspot

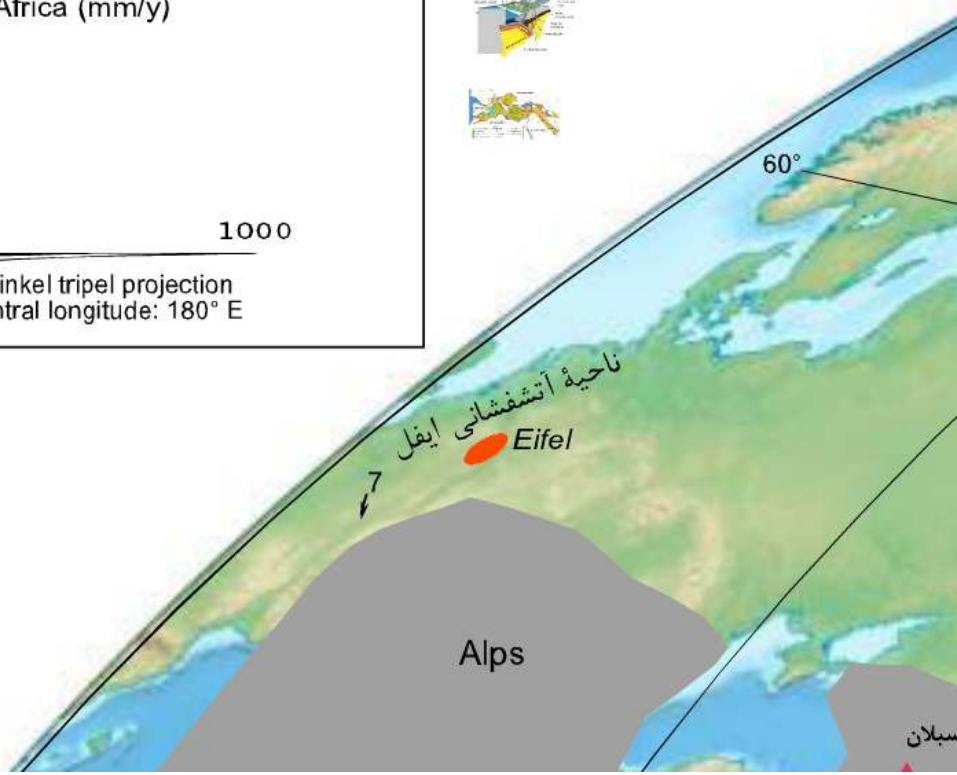
0 (km) 1000

80°

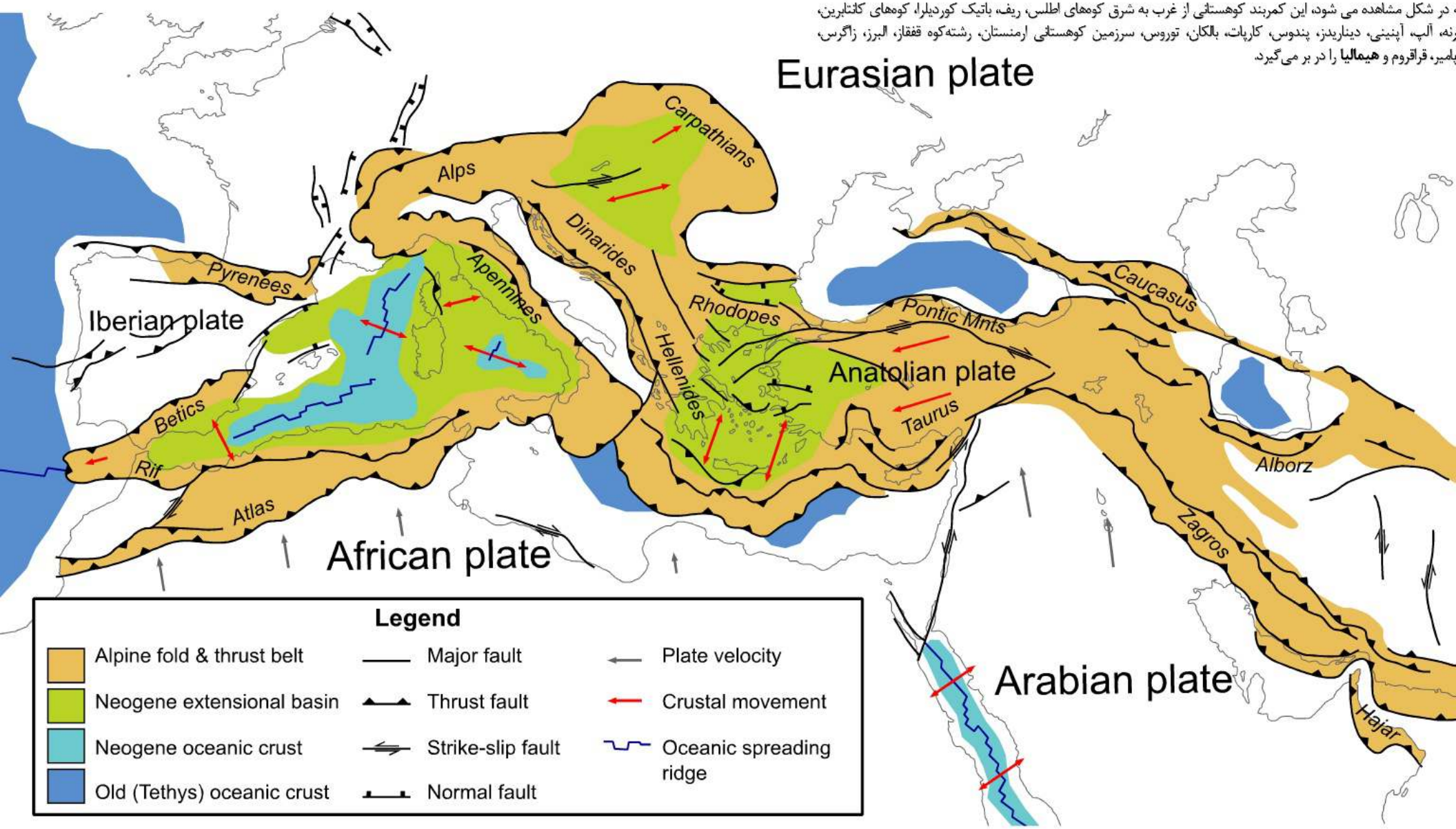
0°

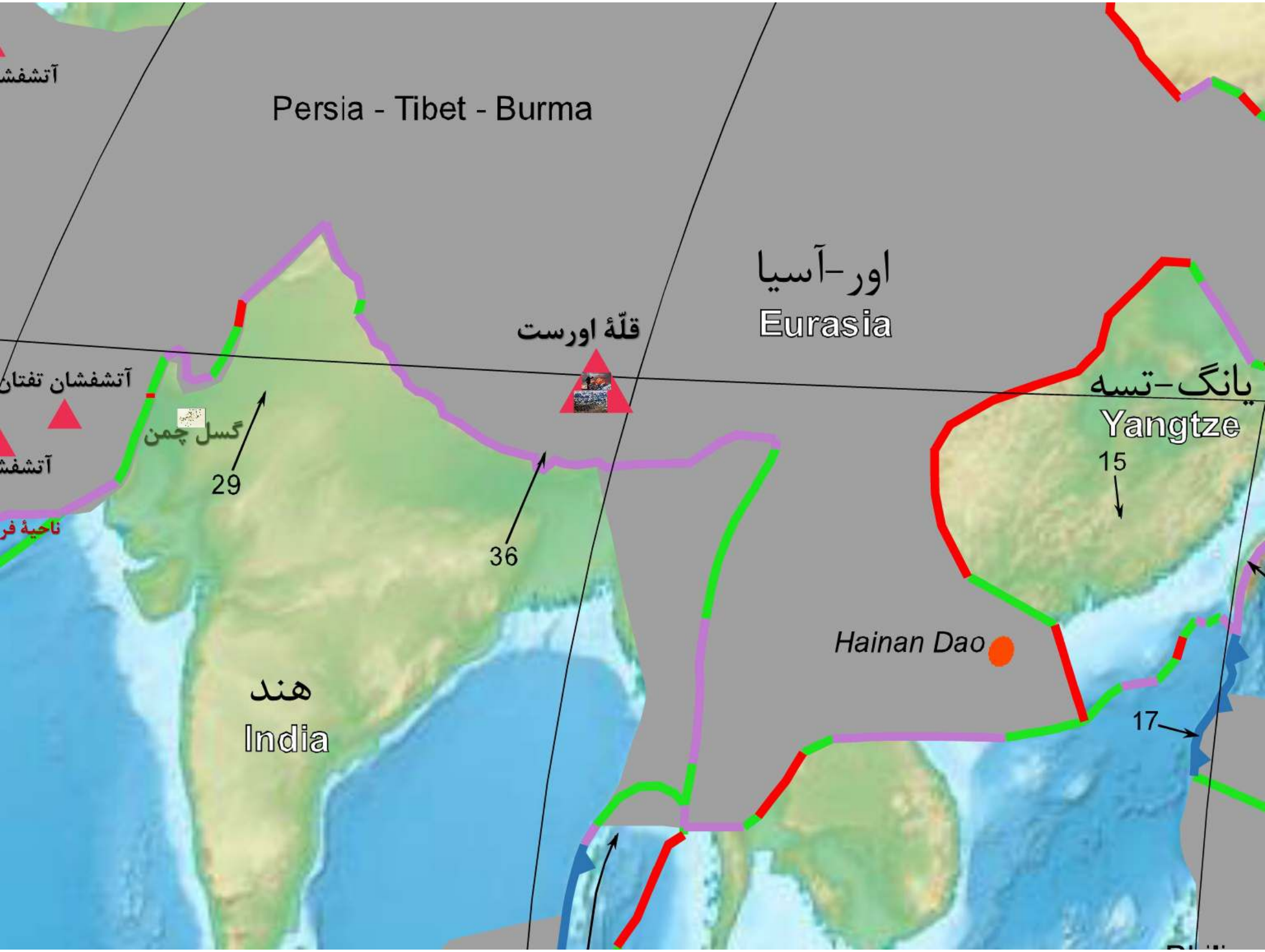
Winkel tripel projection
central longitude: 180° E





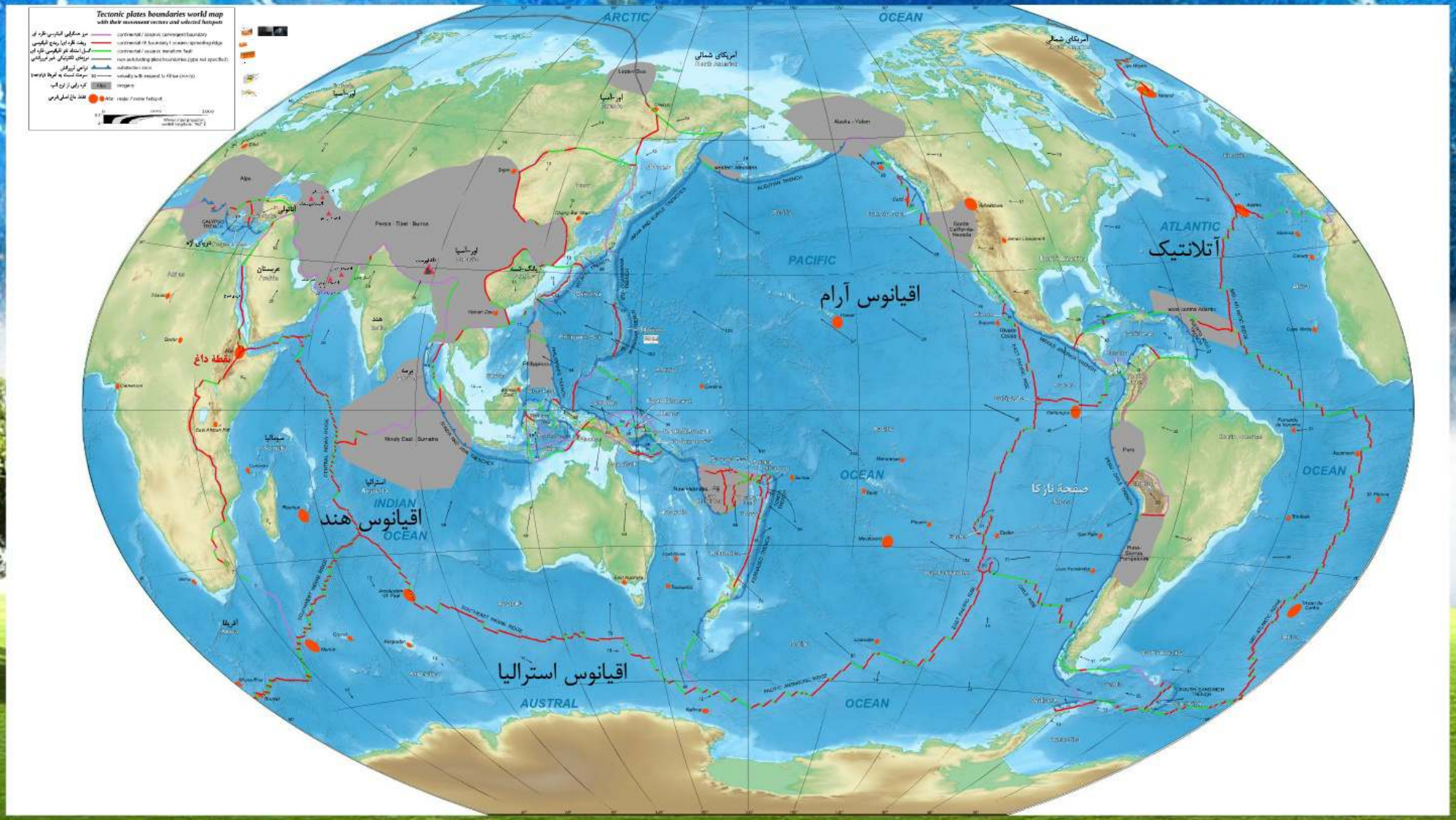
در شکل مشاهده می شود، این کمربند کوهستانی از غرب به شرق کوههای اطلس، ریف، باتیک کوردیلرا، کوههای کانتابرین، رنه، آلپ، آپنینی، دیناریدز، پندوس، کارپات، بالکان، توروس، سرزمین کوهستانی ارمنستان، رشته‌کوه قفقاز، البرز، زاگرس، پامیر، قراقروم و **هیمالیا** را در بر می‌گیرد.




آتشفش
Persia - Tibet - Burma
اور-آسیا
Eurasia
قلّهٔ اورست
آتشفشان تفتان
گسل چمن
29
36
آتشفش
ناحیهٔ فر
یانگ-تسه
Yangtze
15
Hainan Dao
هند
India
17

Chomo Lonzo
(7818 m)
Makalu (8462 m)
Mount Everest (8850 m)
Lhotse (8516 m)
Nuptse (7861 m)
Changtse
(7553 m)
North Face
Gyachung Kang
(7952 m)
Cho Oyu
(8201 m)
East Rongbuk
Glacier
South Col Route
North Col-North Ridge Route
Rongbuk Glacier
Rong River
Tibetan Plateau

زلزلهٔ ۷/۸ ریشتر ۲۰۱۵ در نپال ۹۰۰۰ کشته و ۲۲۰۰۰ زخمی برجا گذاشت.
علت وقوع آن، فرورانش صفحهٔ هند به زیر صفحهٔ اورآسیا و تشکیل کوههای هیمالیا است.
دانشمندان معتقدند شهر کاتماندو پس از این زلزله ۳ متر به سمت جنوب جابجا شده است.
همچنین ایشان مدعی هستند قلّهٔ اورست در اثر این زلزله یک متر پایین رفته است که
البته اندازه گیری دقیق و اثبات آن ۸۰۰ هزار دلار هزینه دارد.



Ridge

Lithosphere

Tectonic plates boundaries world map
with their movement vectors and selected hotspots

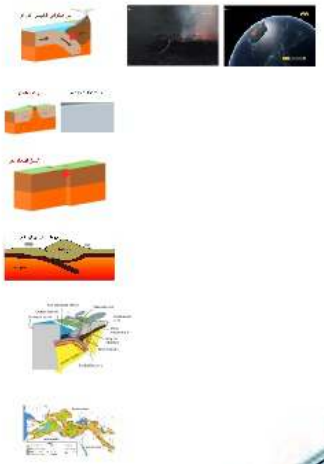
مرز همگرایی اقیانوسی-قاره ای		continental / oceanic convergent boundary
ریفت قاره ای/ ریدج اقیانوسی		continental rift boundary / oceanic spreading ridge
گسل امتداد لغز اقیانوسی-قاره ای		continental / oceanic transform fault
مرزهای تکتونیکی غیر فرورانشی		non-subducting plate boundaries (type not specified)
نواحی فرورانش		subduction zone
سرعت نسبت به آفریقا (mm/y)	30 →	velocity with respect to Africa (mm/y)
کوه زایی از نوع آلپ	Alps	orogeny
نقاط داغ اصلی/فرعی	*Afar*	major / minor hotspot

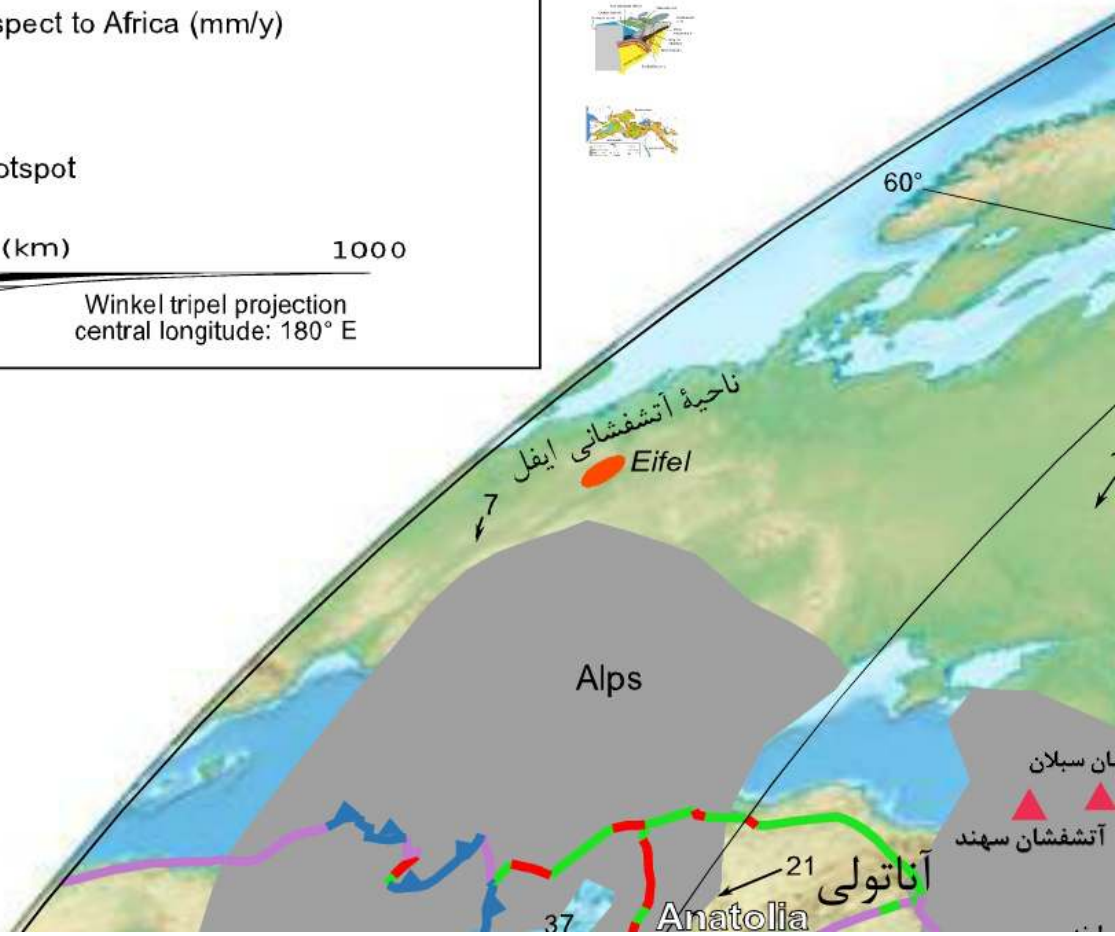
0 (km) 1000

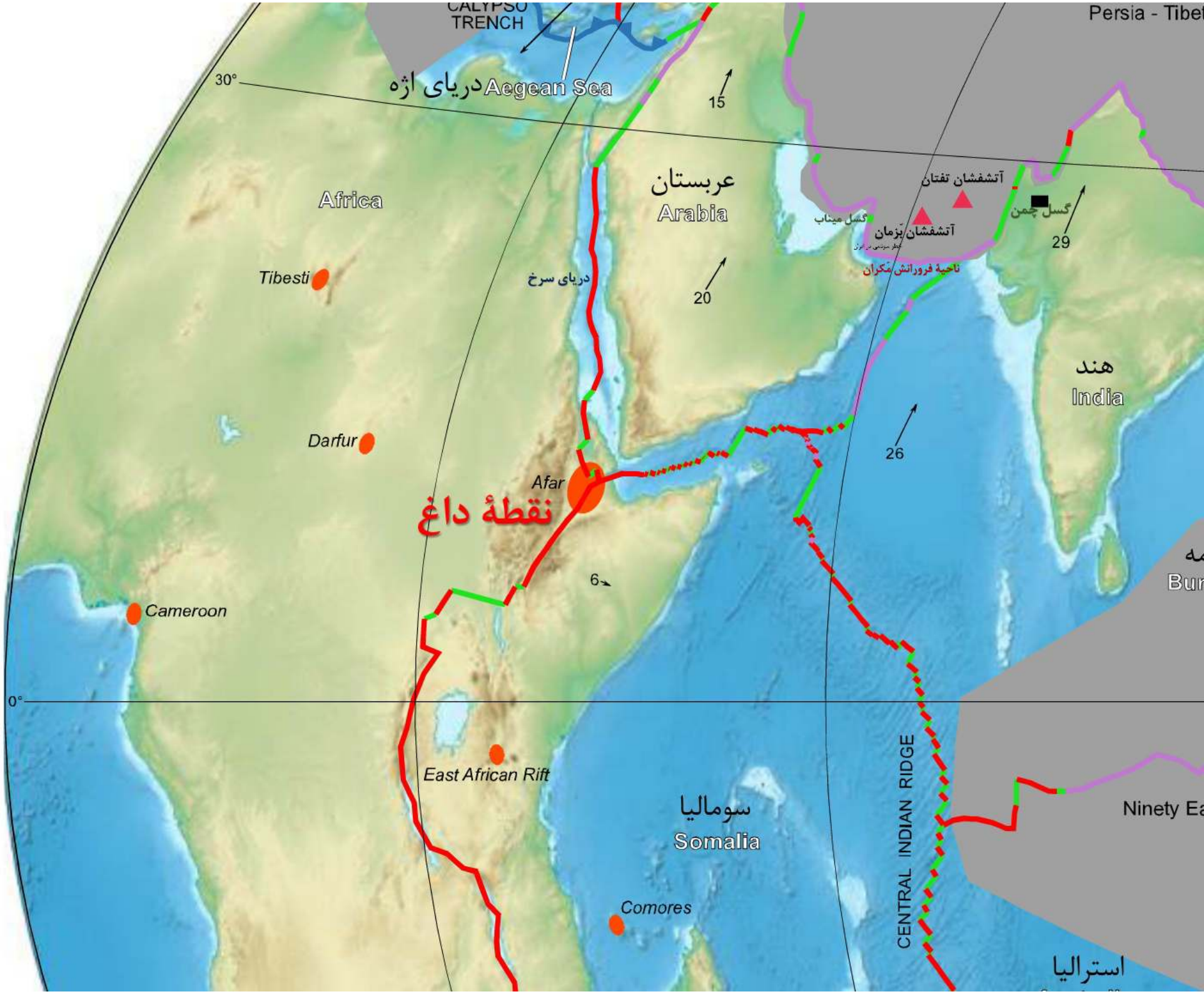
80°

0°

Winkel tripel projection
central longitude: 180° E

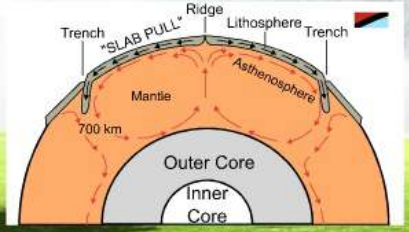


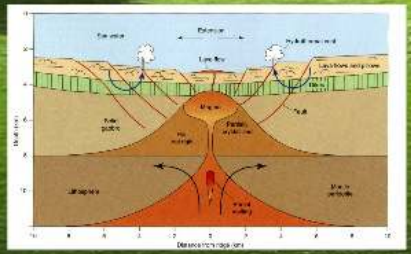



CALYPSO TRENCH
Persia - Tibet
30°
دریای اژه
Aegean Sea
15
Africa
عربستان
Arabia
آتشفشان تفتان
گسل چمن
گسل میناب
آتشفشان بزمان
29
ناحیهٔ فرورانش مکران
Tibesti
دریای سرخ
20
هند
India
Darfur
26
Afar
نقطهٔ داغ
6
Cameroon
0°
East African Rift
سومالیا
Somalia
CENTRAL INDIAN RIDGE
Ninety Ea
Comores
استرالیا

Why Plates Move?

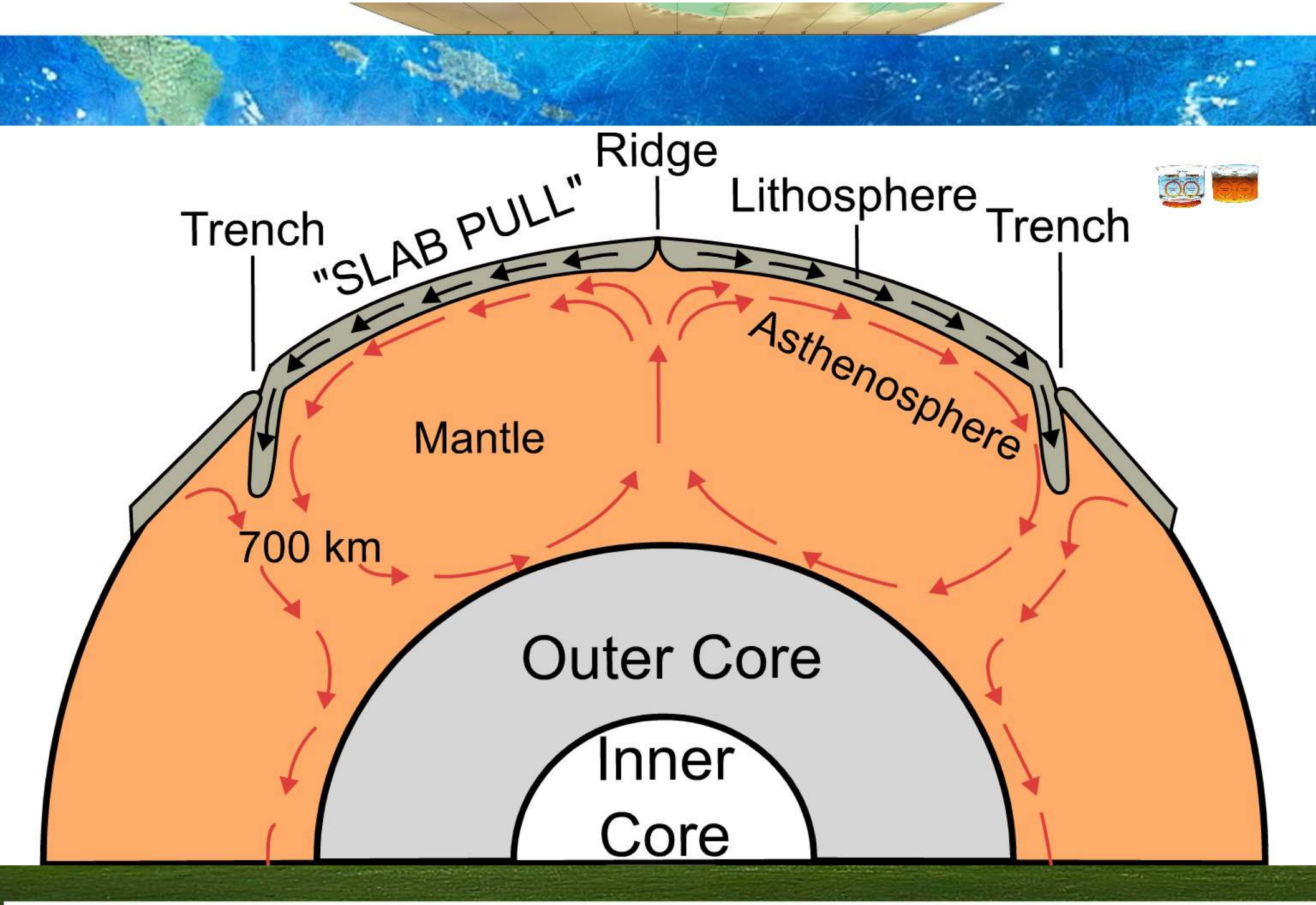
Divergent and Convergent Boundaries

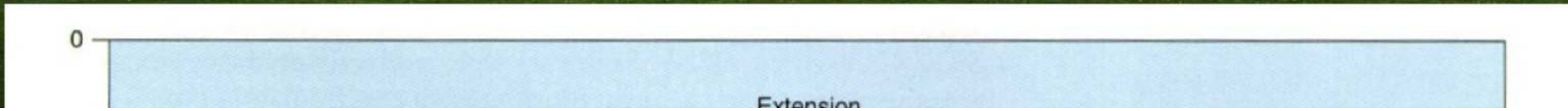


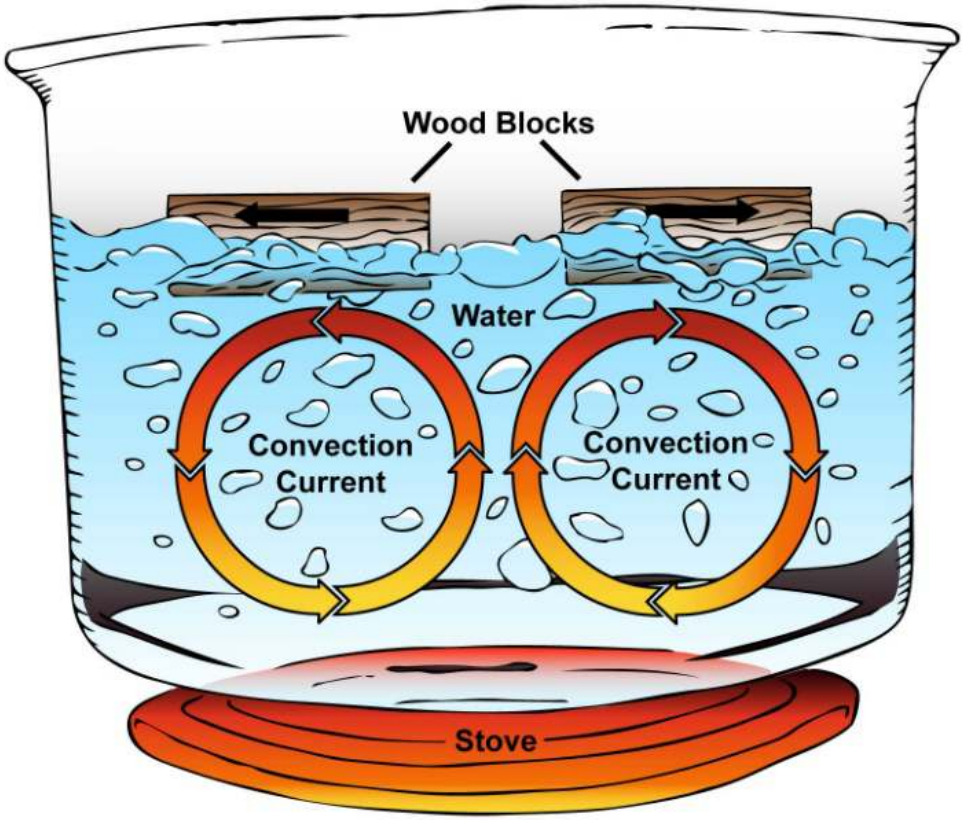


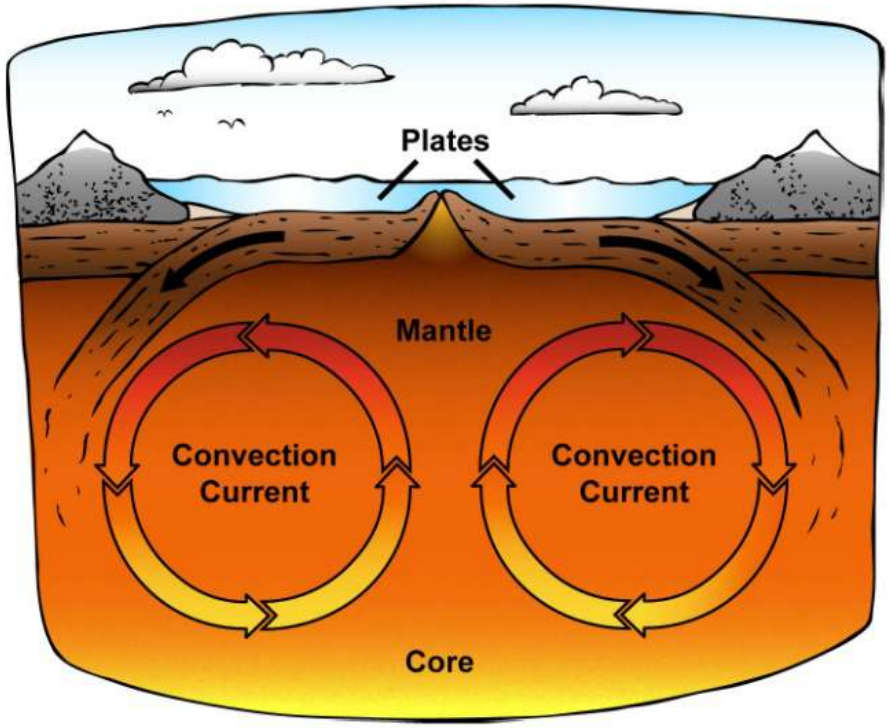
چرا صفحات لیتوسفری حرکت می کنند؟

مرزهای واگرا و همگرا


Ridge
Lithosphere
Trench
"SLAB PULL"
Trench
Asthenosphere
Mantle
700 km
Outer Core
Inner
Core

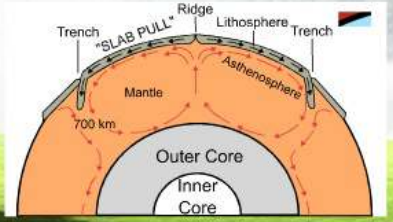

0
Extension

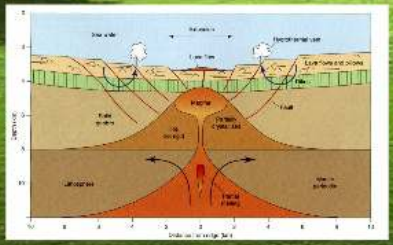

Wood Blocks
Water
Convection Current
Convection Current
Stove


Plates
Mantle
Convection Current
Convection Current
Core

Why Plates Move?

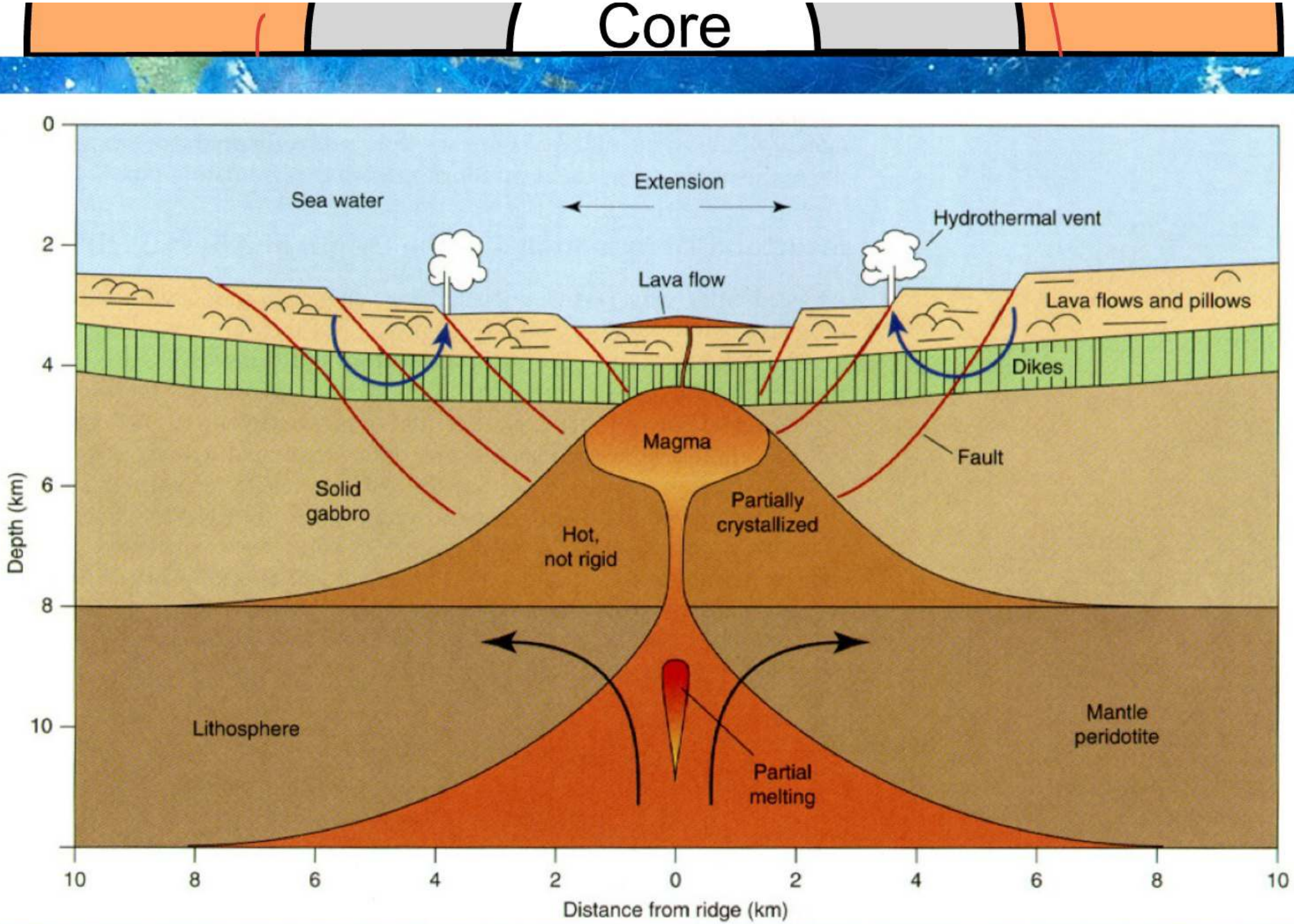
Divergent and Convergent Boundaries

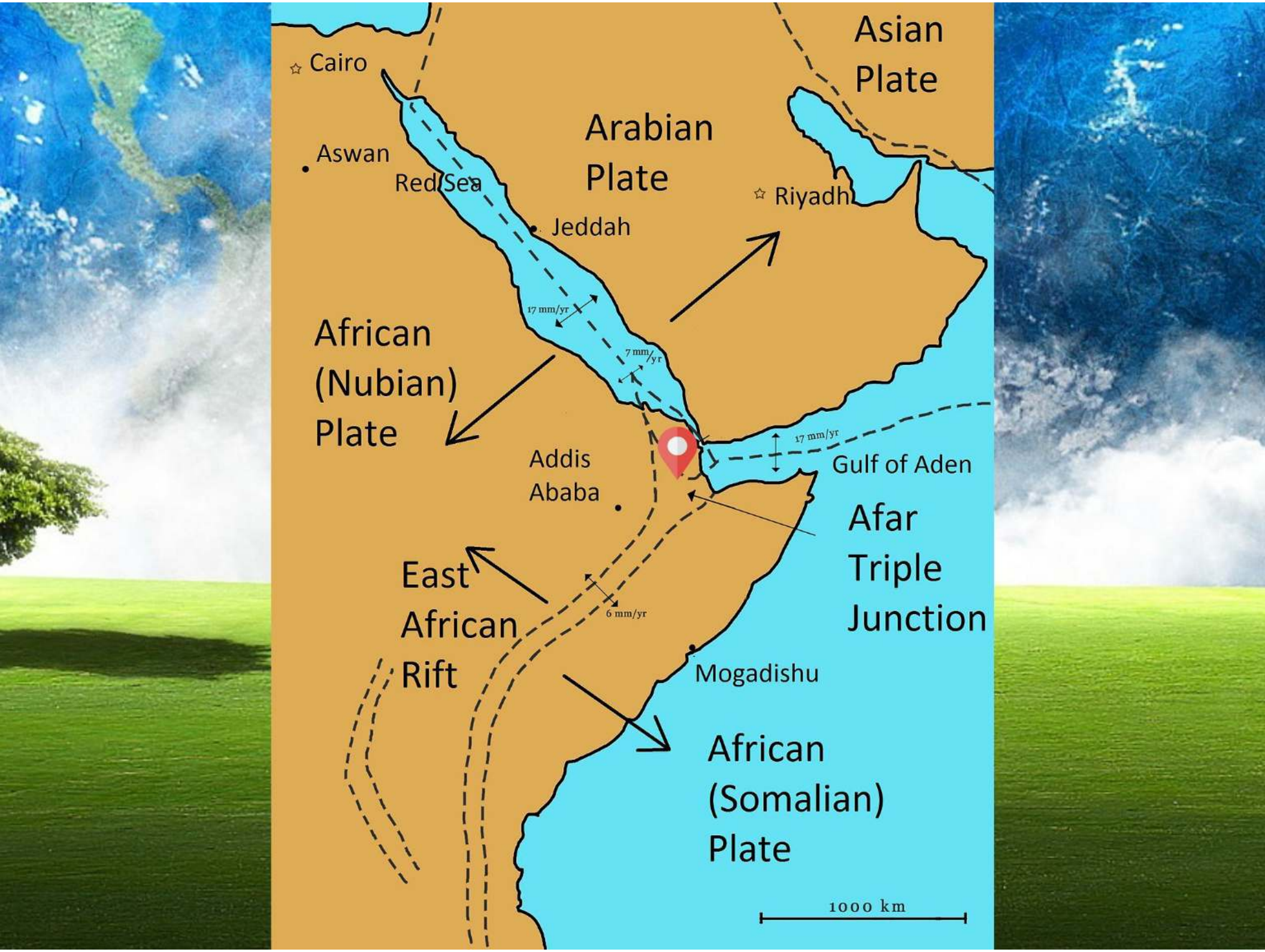


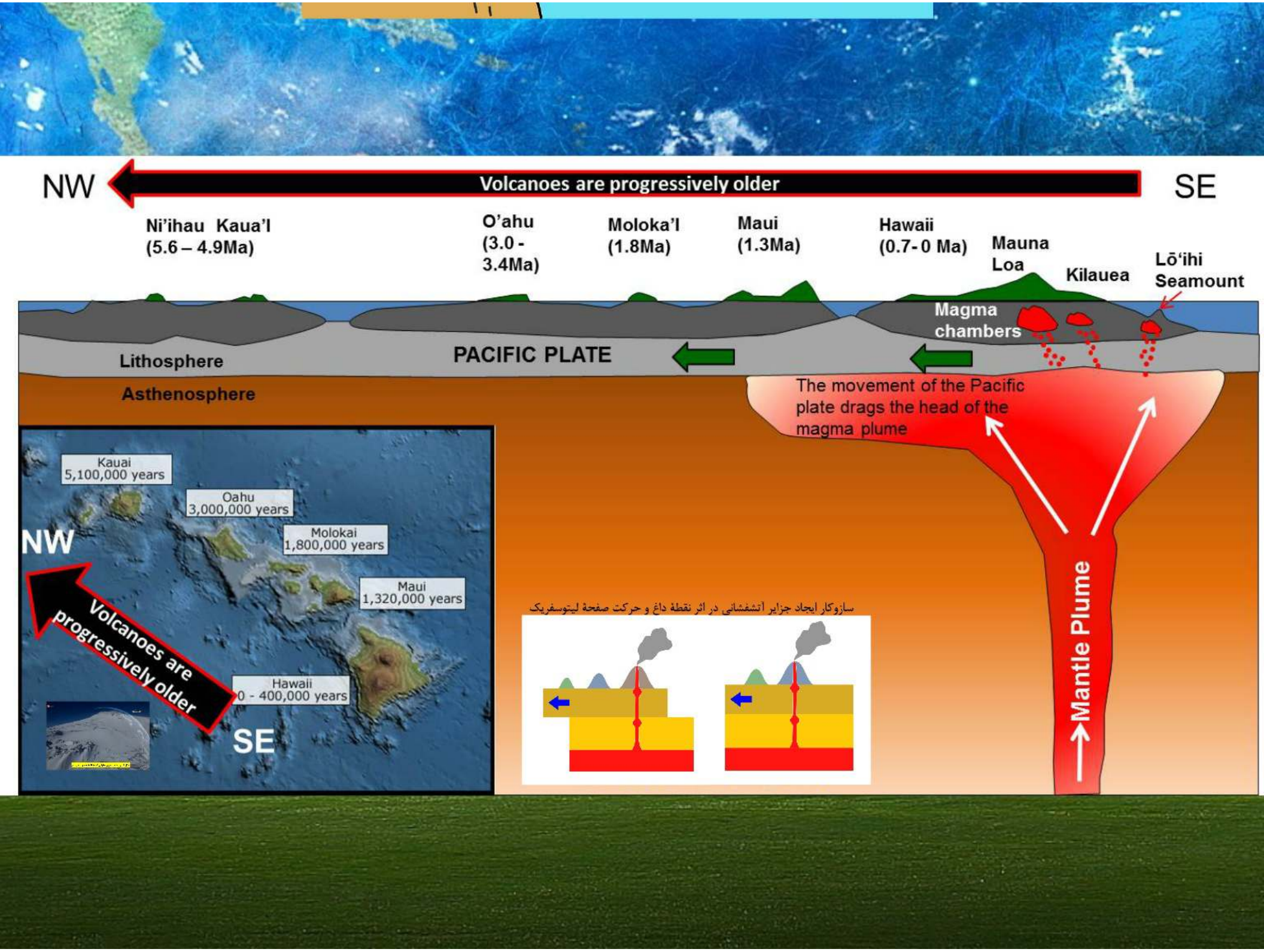


چرا صفحات لیتوسفری حرکت می کنند؟

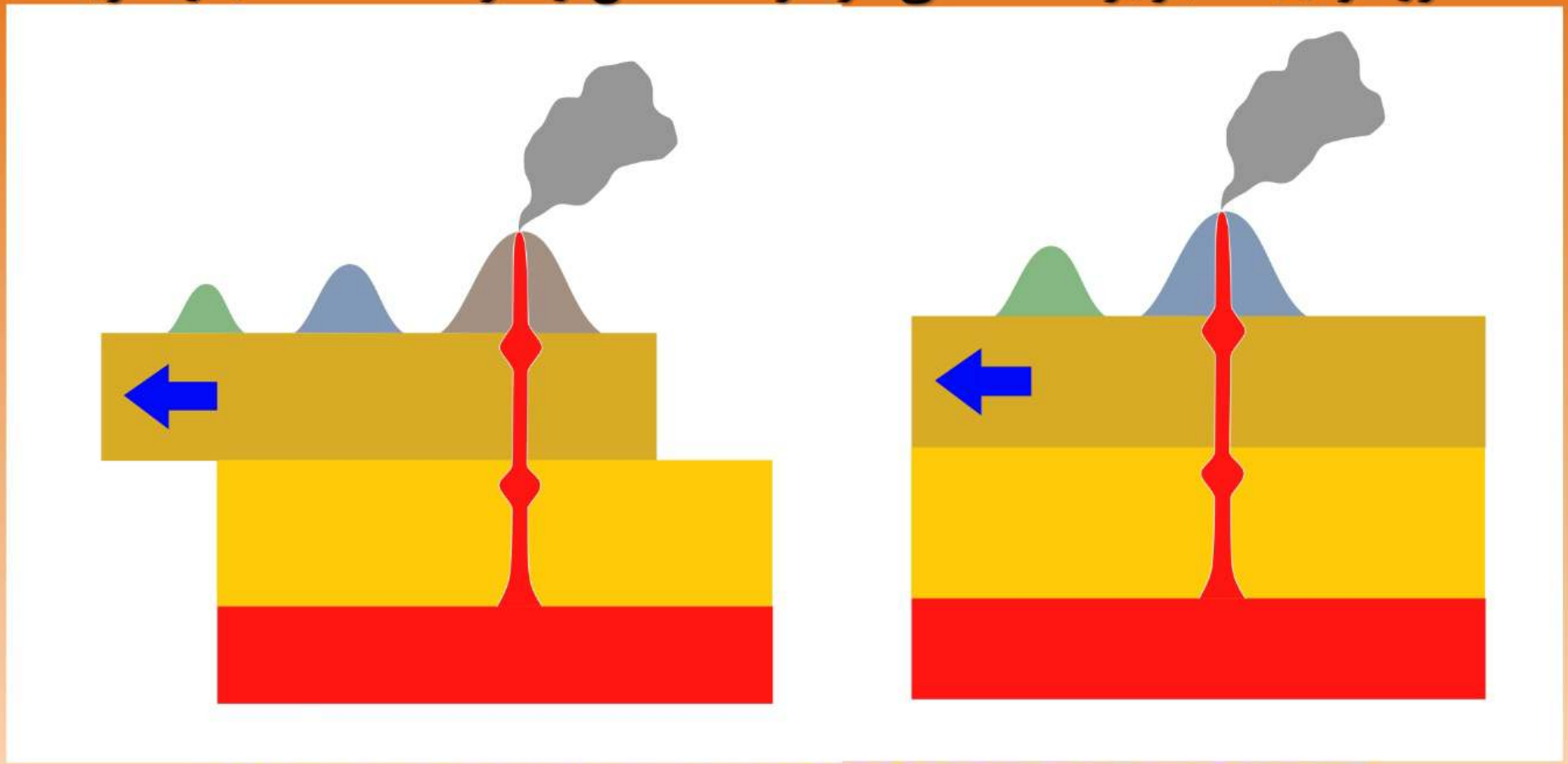
مرزهای واگرا و همگرا

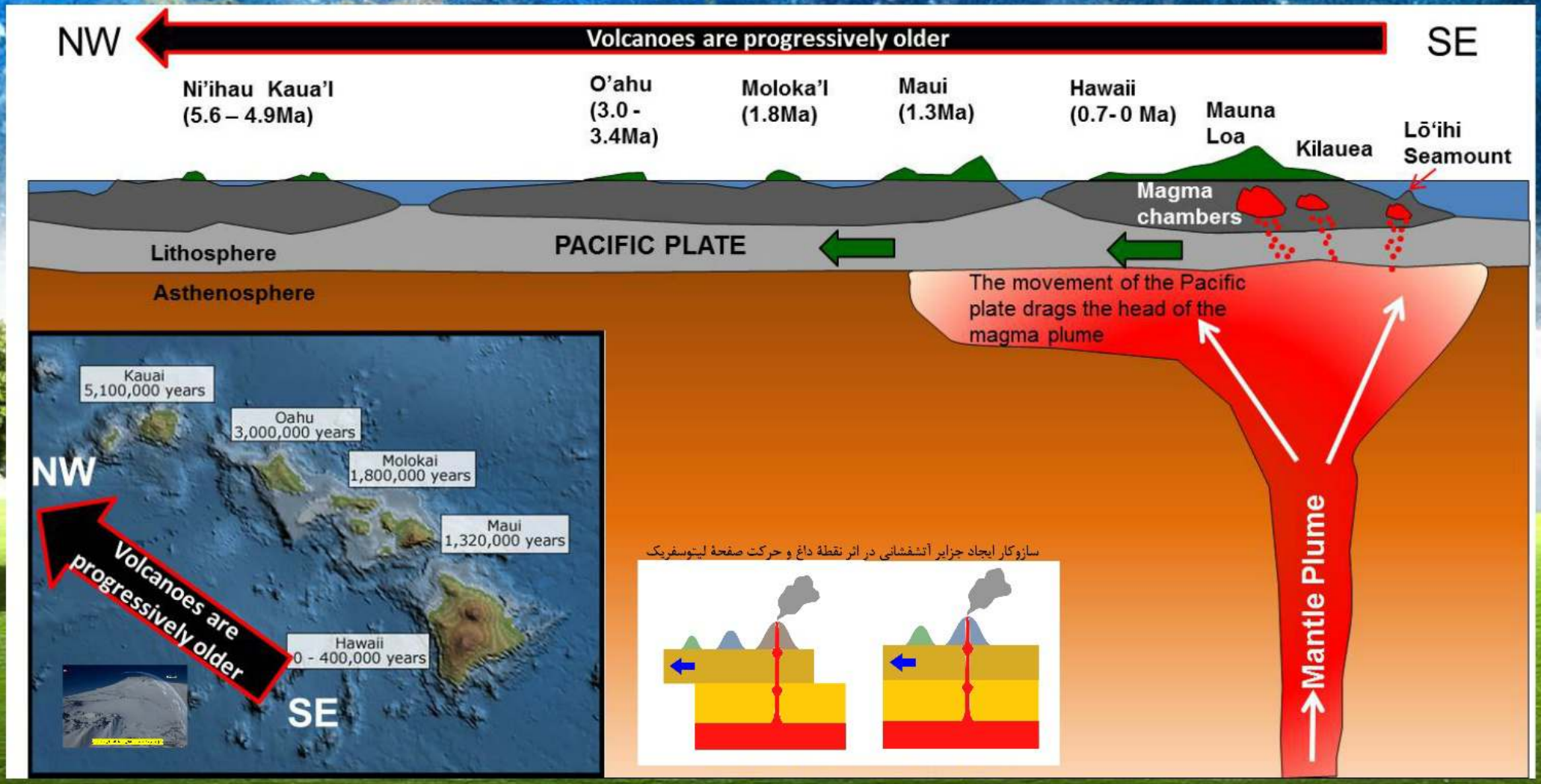

Core
Sea water
Extension
Hydrothermal vent
Lava flow
Lava flows and pillows
Dikes
Magma
Fault
Solid gabbro
Partially crystallized
Hot, not rigid
Lithosphere
Mantle peridotite
Partial melting
Depth (km)
0
2
4
6
8
10
10
8
6
4
2
0
2
4
6
8
10
Distance from ridge (km)


Asian Plate
Cairo
Arabian Plate
Aswan
Red Sea
Riyadh
Jeddah
17 mm/yr
7 mm/yr
African (Nubian) Plate
17 mm/yr
Gulf of Aden
Addis Ababa
Afar Triple Junction
East African Rift
6 mm/yr
Mogadishu
African (Somalian) Plate
1000 km


NW
Volcanoes are progressively older
SE
Ni'ihau Kaua'I
(5.6 – 4.9Ma)
O'ahu
(3.0 -
3.4Ma)
Moloka'I
(1.8Ma)
Maui
(1.3Ma)
Hawaii
(0.7- 0 Ma)
Mauna
Loa
Kilauea
Lō'ihi
Seamount
Magma
chambers
Lithosphere
PACIFIC PLATE
Asthenosphere
The movement of the Pacific
plate drags the head of the
magma plume
Mantle Plume
Kauai
5,100,000 years
Oahu
3,000,000 years
Molokai
1,800,000 years
Maui
1,320,000 years
Hawaii
0 - 400,000 years
NW
SE
Volcanoes are
progressively older
سازوکار ایجاد جزایر آتشفشانی در اثر نقطهٔ داغ و حرکت صفحهٔ لیتوسفریک

سازوکار ایجاد جزایر آتشفشانی در اثر نقطهٔ داغ و حرکت صفحهٔ لیتوسفریک

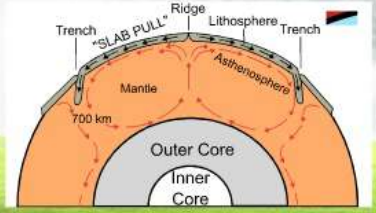


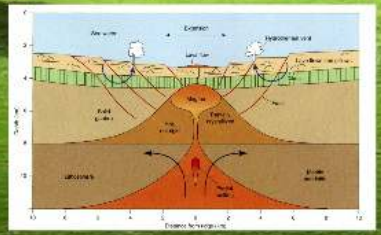

NW
Volcanoes are progressively older
SE
Ni'ihau Kaua'I
(5.6 – 4.9Ma)
O'ahu
(3.0 -
3.4Ma)
Moloka'I
(1.8Ma)
Maui
(1.3Ma)
Hawaii
(0.7- 0 Ma)
Mauna
Loa
Kilauea
Lō'ihi
Seamount
Magma
chambers
Lithosphere
PACIFIC PLATE
Asthenosphere
The movement of the Pacific
plate drags the head of the
magma plume
Mantle Plume
Kauai
5,100,000 years
Oahu
3,000,000 years
Molokai
1,800,000 years
Maui
1,320,000 years
Hawaii
0 - 400,000 years
NW
SE
Volcanoes are
progressively older
سازوکار ایجاد جزایر آتشفشانی در اثر نقطهٔ داغ و حرکت صفحهٔ لیتوسفریک

شکل گیری سلسله جزایر هاوائی توسط نقاط داغ زیر اقیانوس

Why Plates Move?

Divergent and Convergent Boundaries



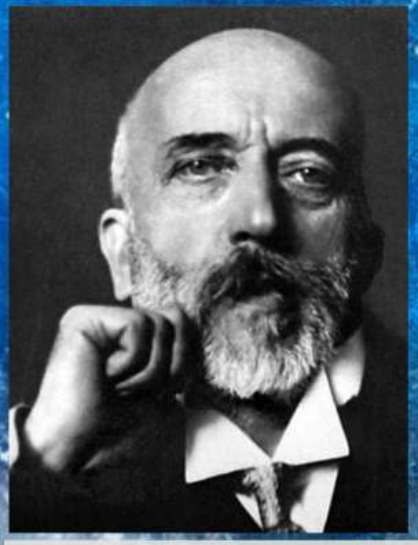


چرا صفحات لیتوسفری حرکت می کنند؟

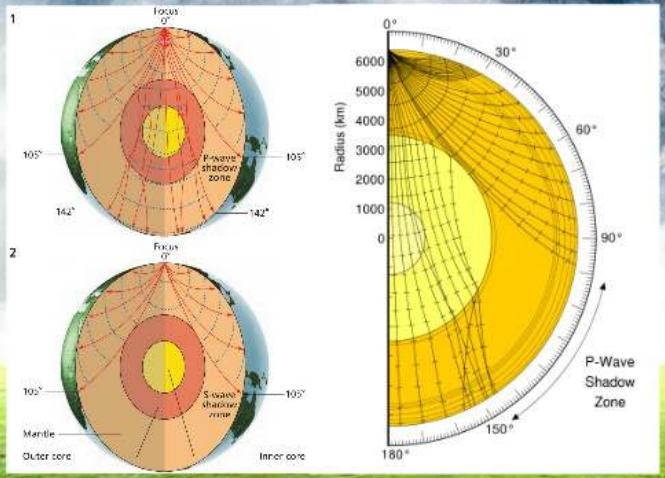
مرزهای واگرا و همگرا

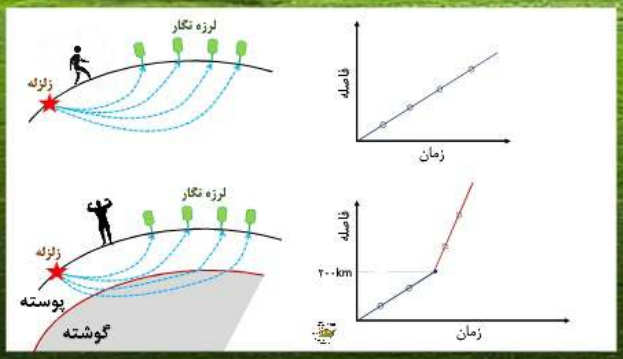
Earth and Seismic Waves

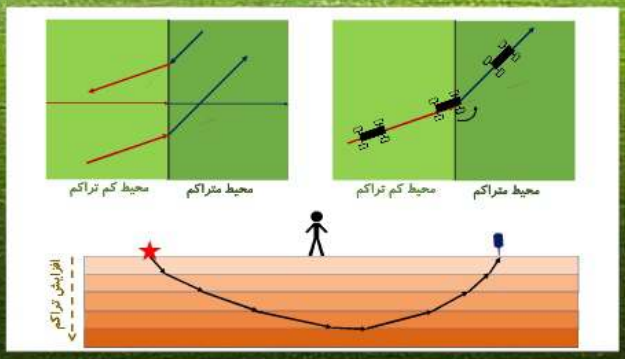
How we Know about the Earth's Core



Andria Mohorovicic



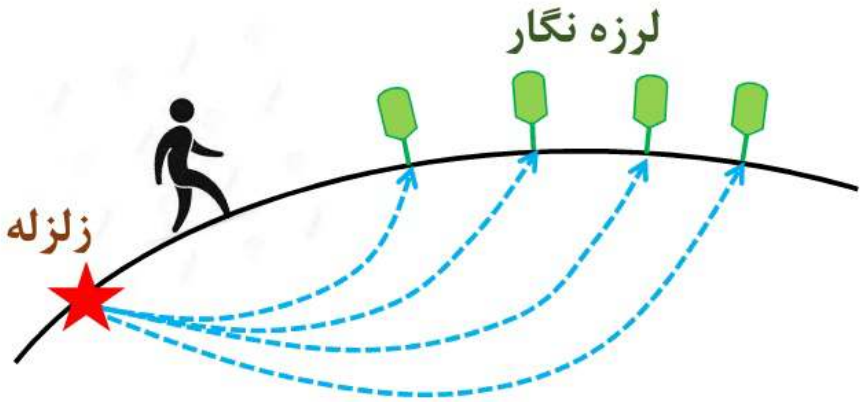


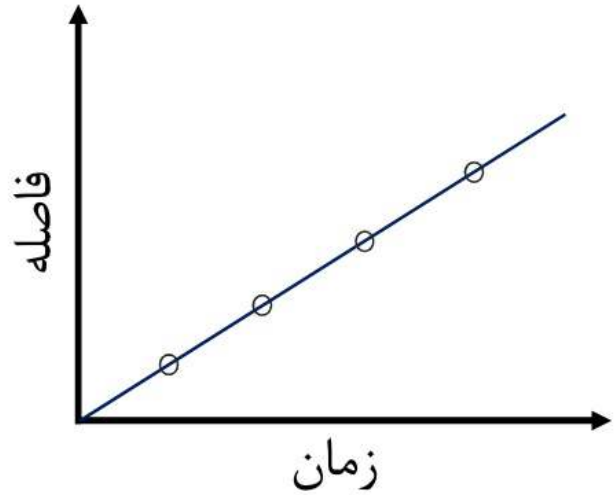


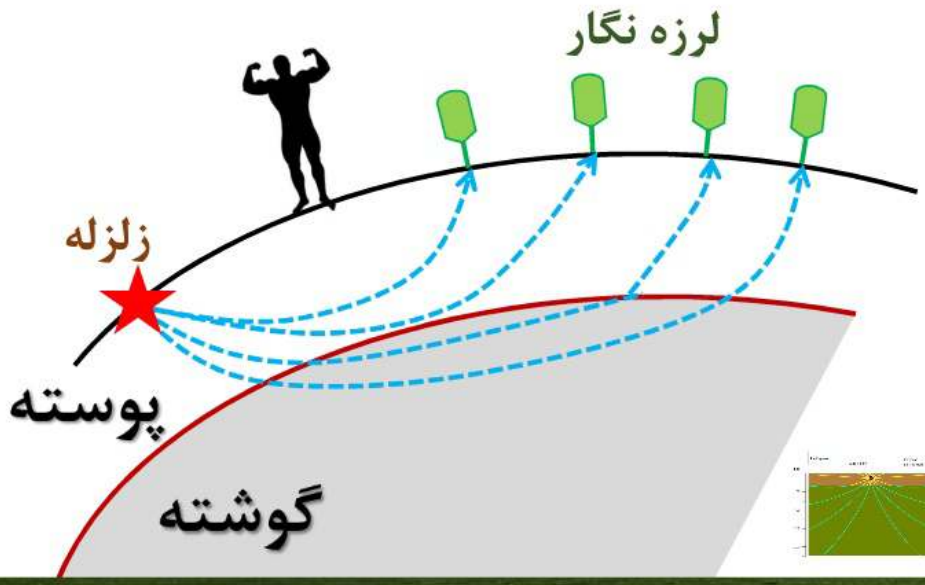
[redacted]

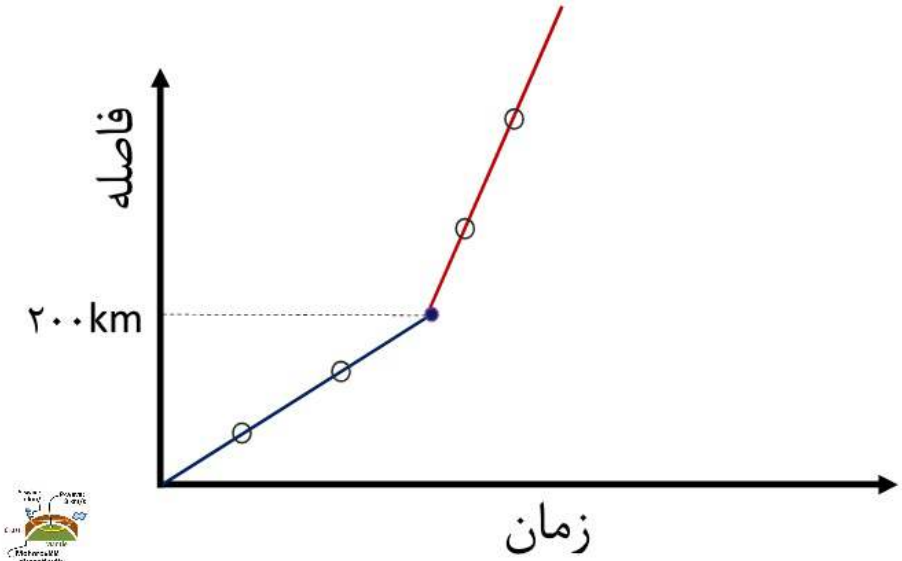
[redacted]

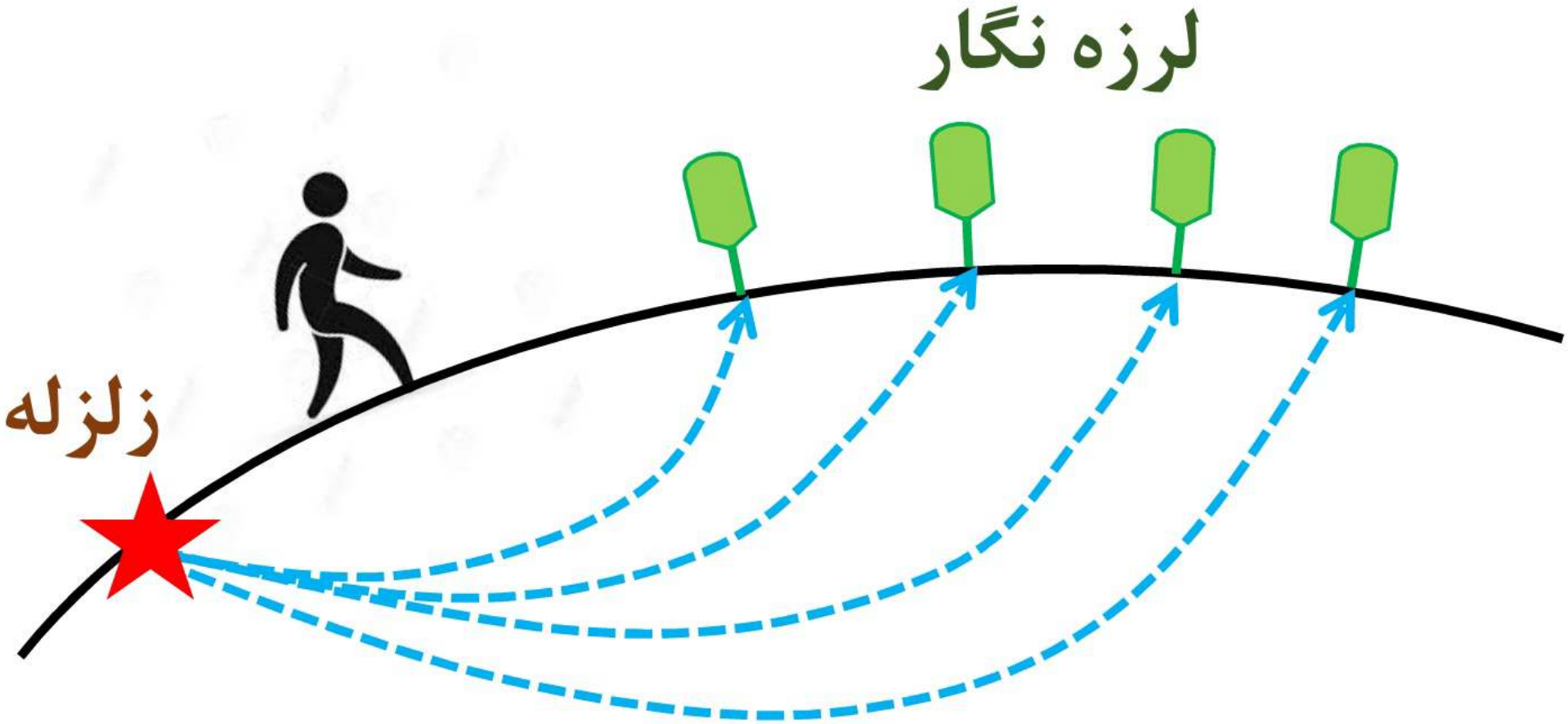
موهورویچ در ابتدا یک هواشناس بود که بعد با عنوان زلزله شناس شهرت گرفت. زمانی که در سال ۱۹۰۹ در جنوب شرقی شهر زاگرب زلزله ای رخ داده بود، تعدادی لرزه نگار در نقاط مختلف کشور کرواسی نصب شده بود. موهورویچ با مشاهدهٔ نتایج بدست آمده از لرزه نگارها توانست مرز بین پوسته و گوشته (مرز موهو) را کشف کند.

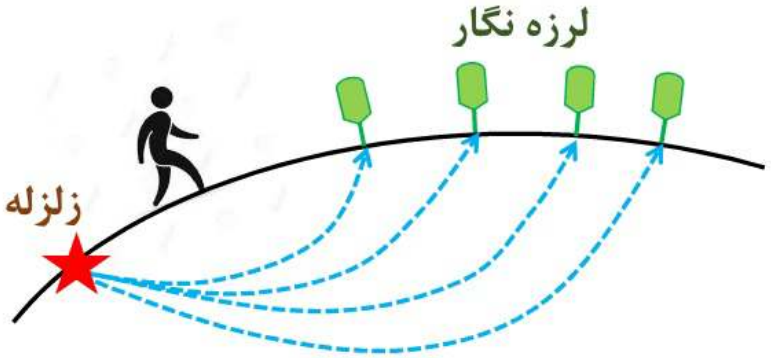

لرزه نگار
زلزله

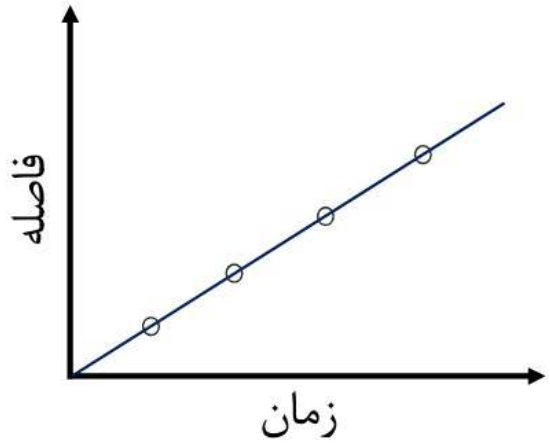

فاصله
زمان

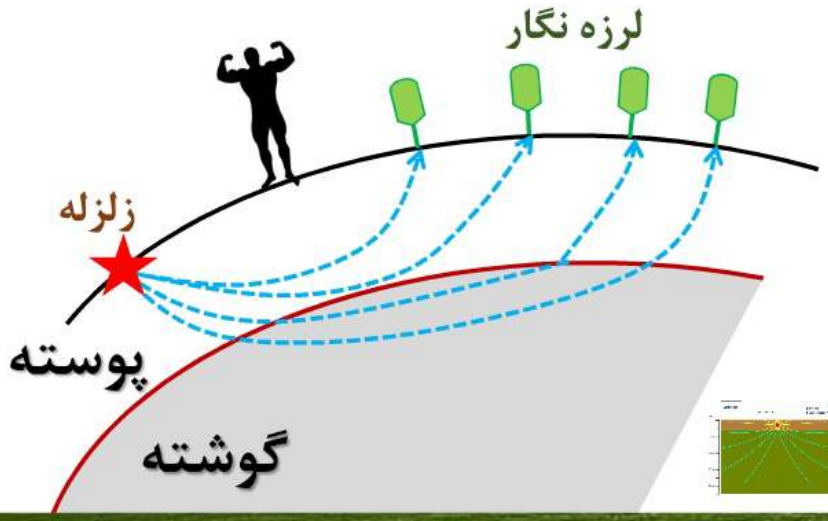

لرزه نگار
زلزله
پوسته
گوشته

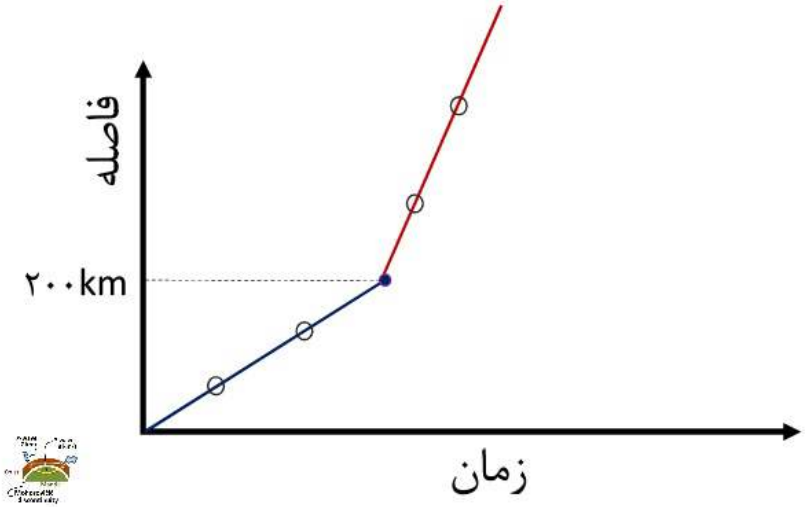

فاصله
۲۰۰km
زمان

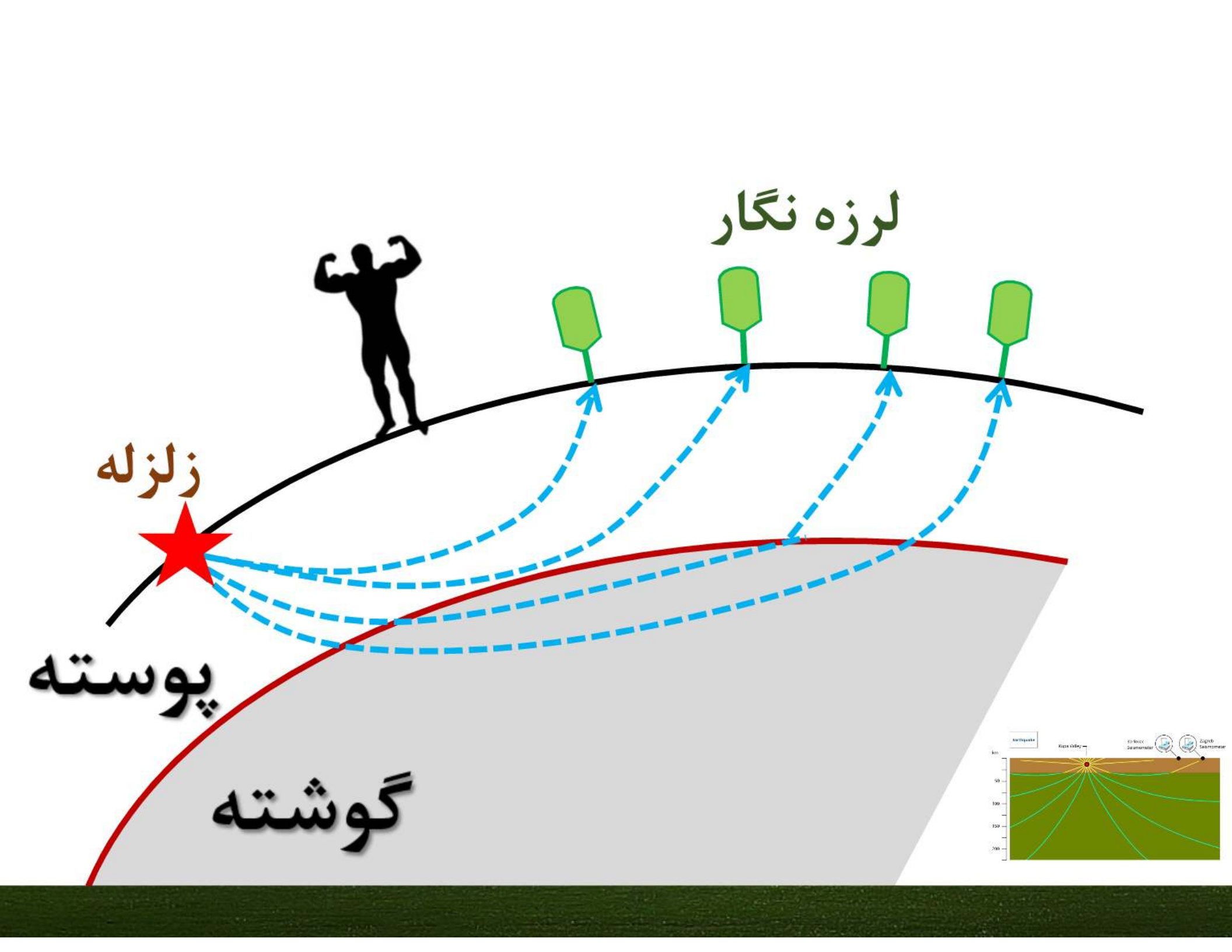

لرزه نگار
زلزله

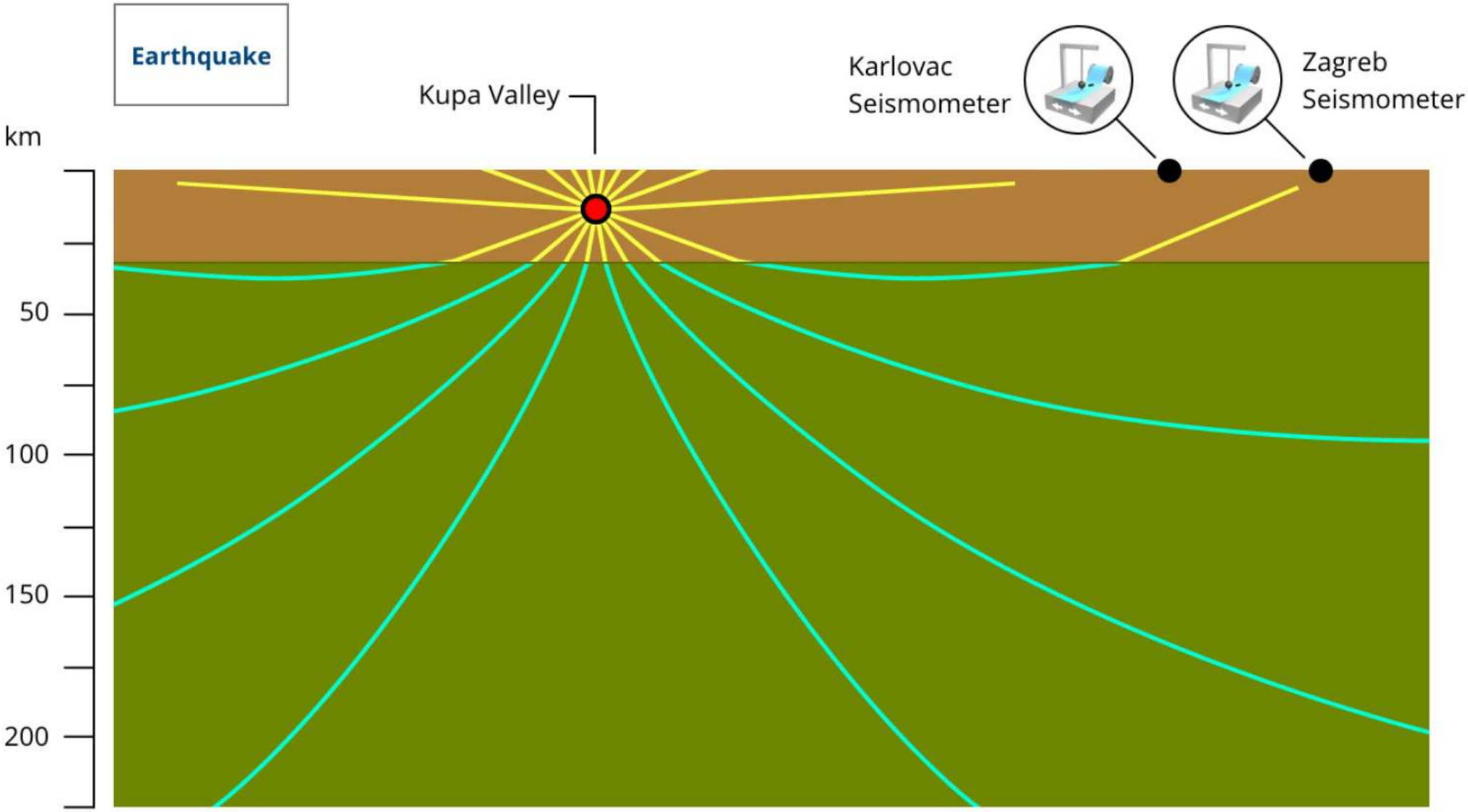

لرزه نگار
زلزله

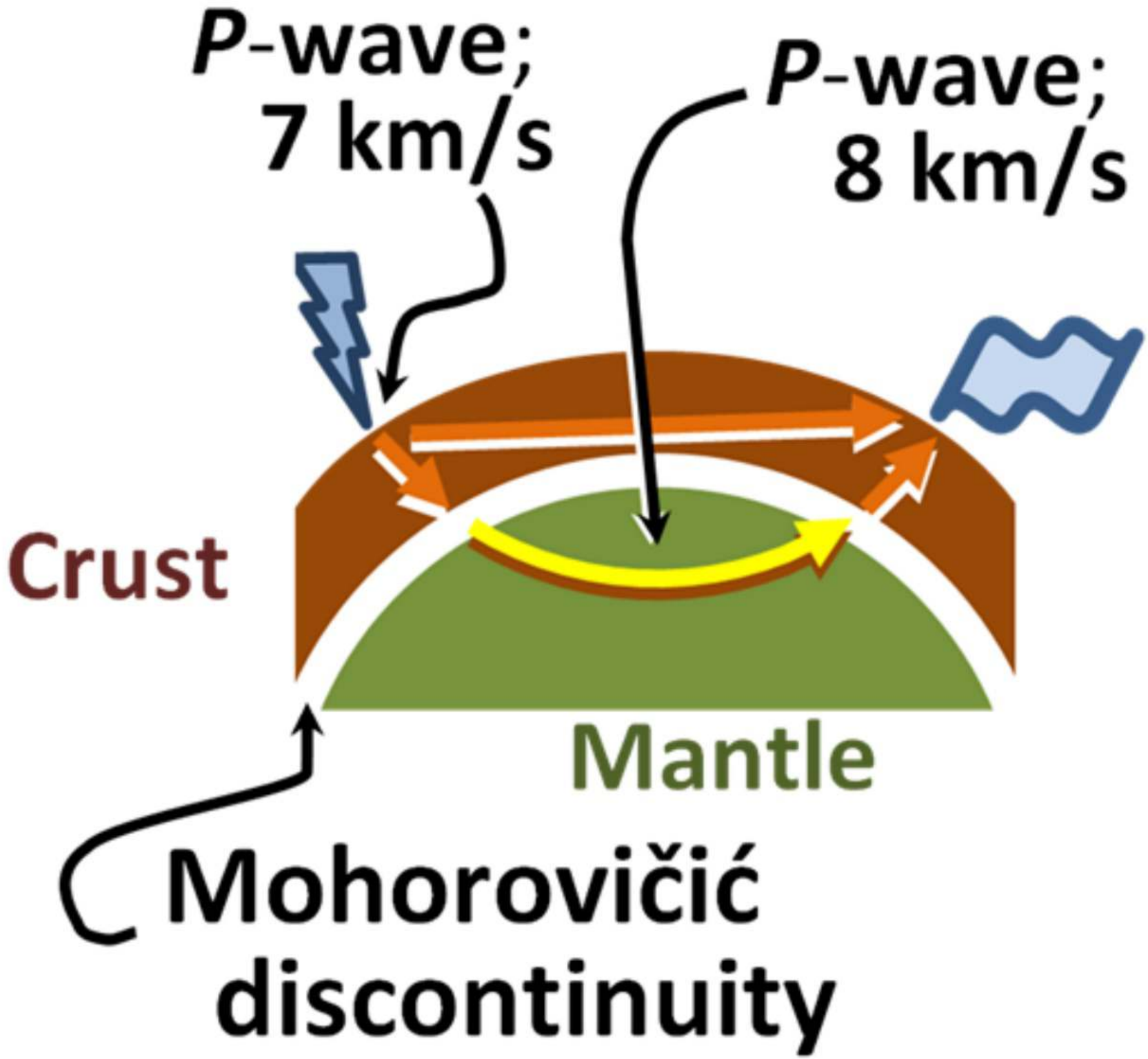

فاصله
زمان


لرزه نگار
زلزله
پوسته
گوشته

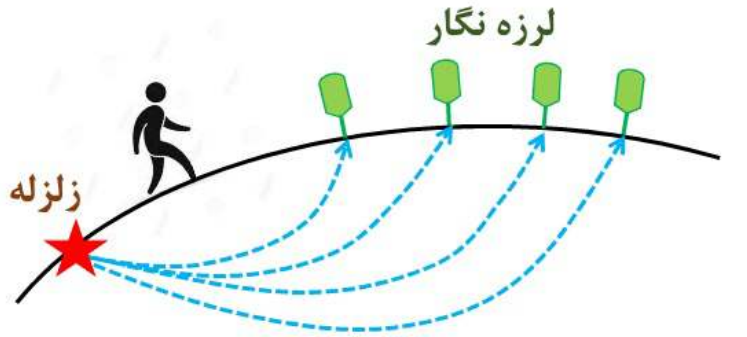

فاصله
۲۰۰km
زمان

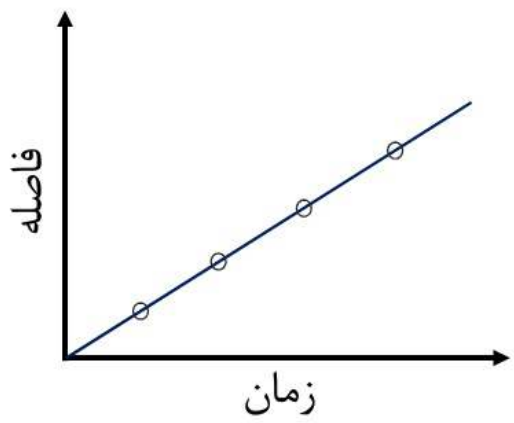

لرزه نگار
زلزله
پوسته
گوشته

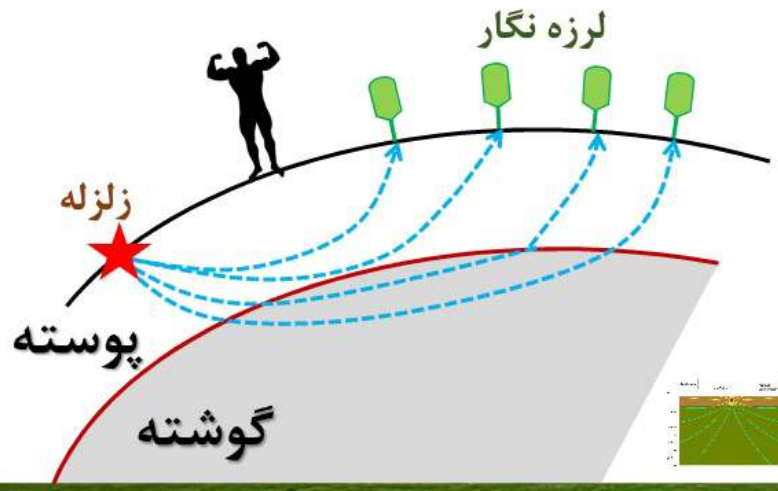

Earthquake
Kupa Valley
Karlovac
Seismometer
Zagreb
Seismometer
km
50
100
150
200

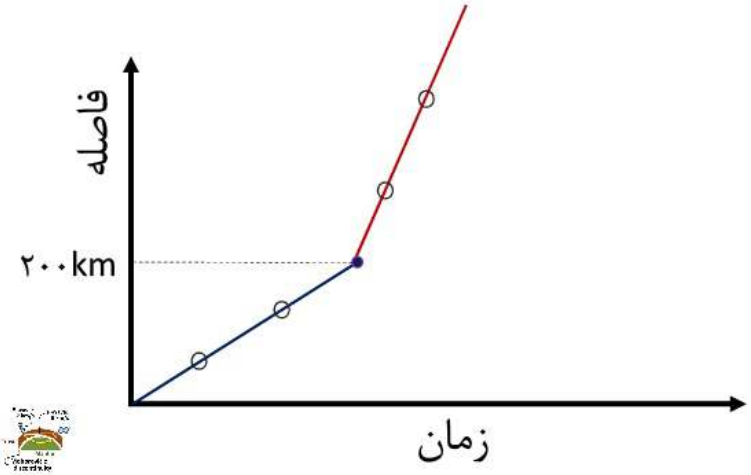

P-wave;
7 km/s
P-wave;
8 km/s
Crust
Mantle
Mohorovičić
discontinuity

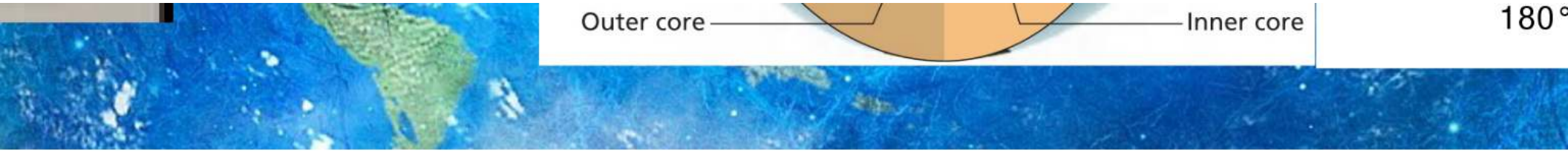
موهورویچ
بعد با عن
زمانی ک
شرقی ش
تعدادی ل
کرواسی
مشاهدهٔ
توانست
(مرز موه

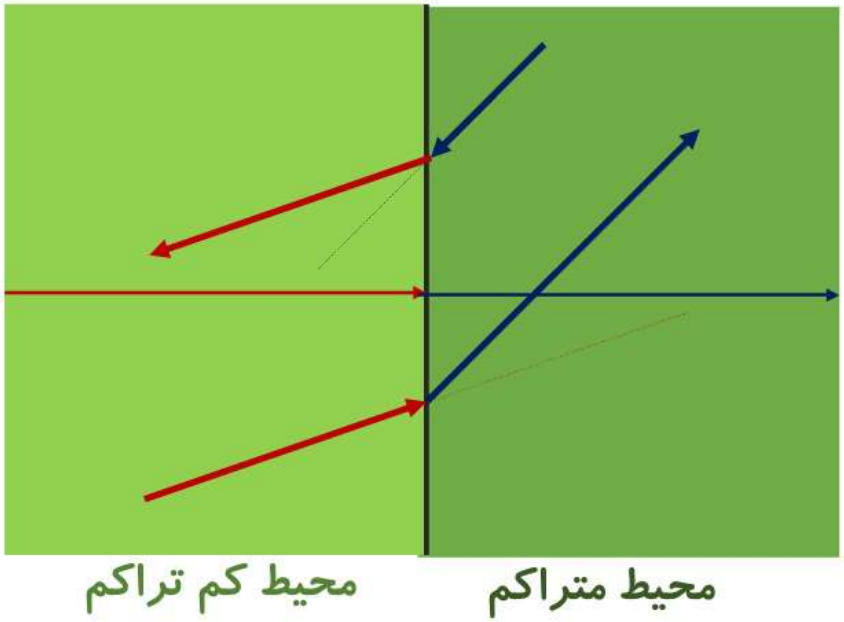


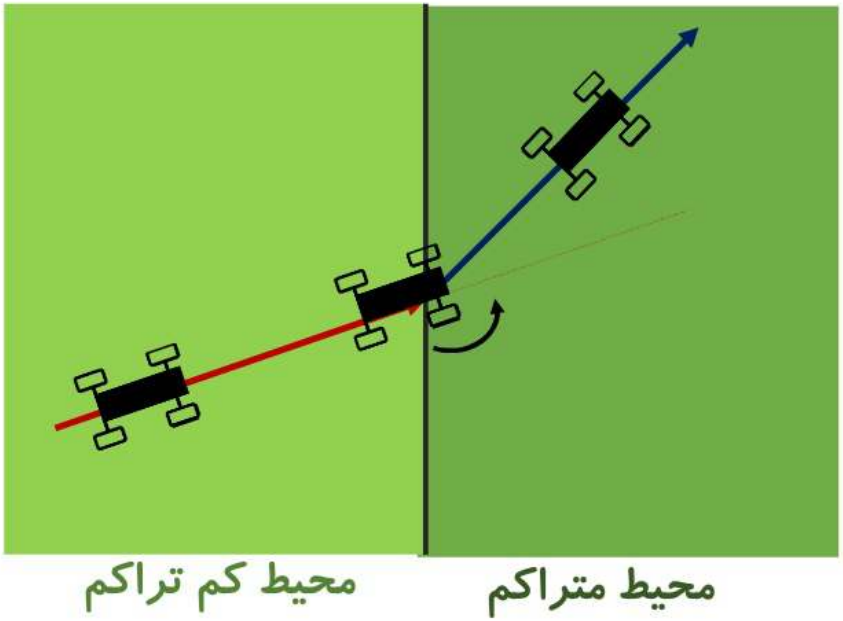







Outer core
Inner core
180°


محیط کم تراکم
محیط متراکم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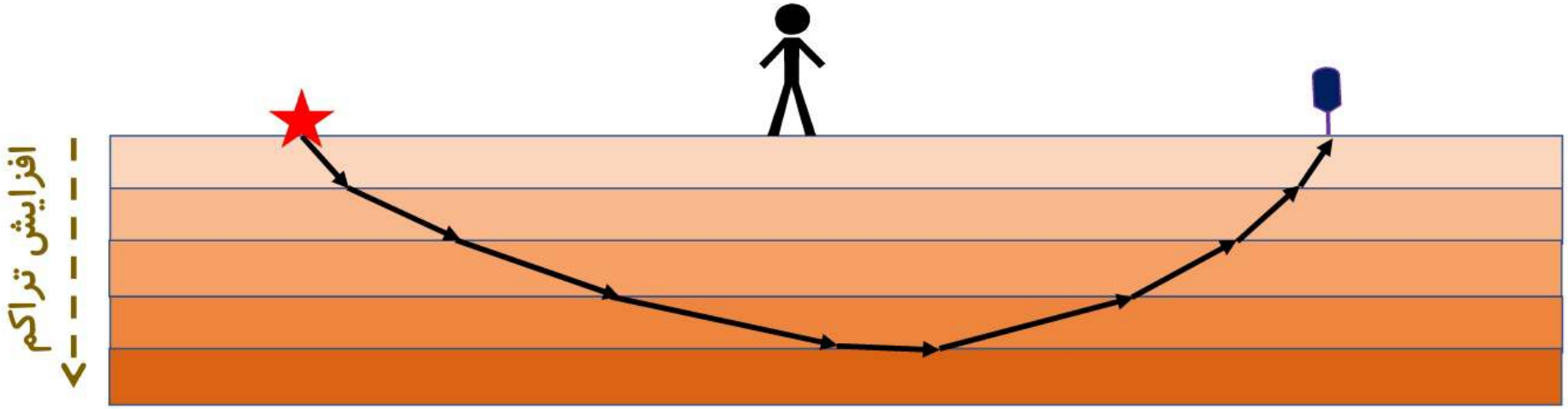
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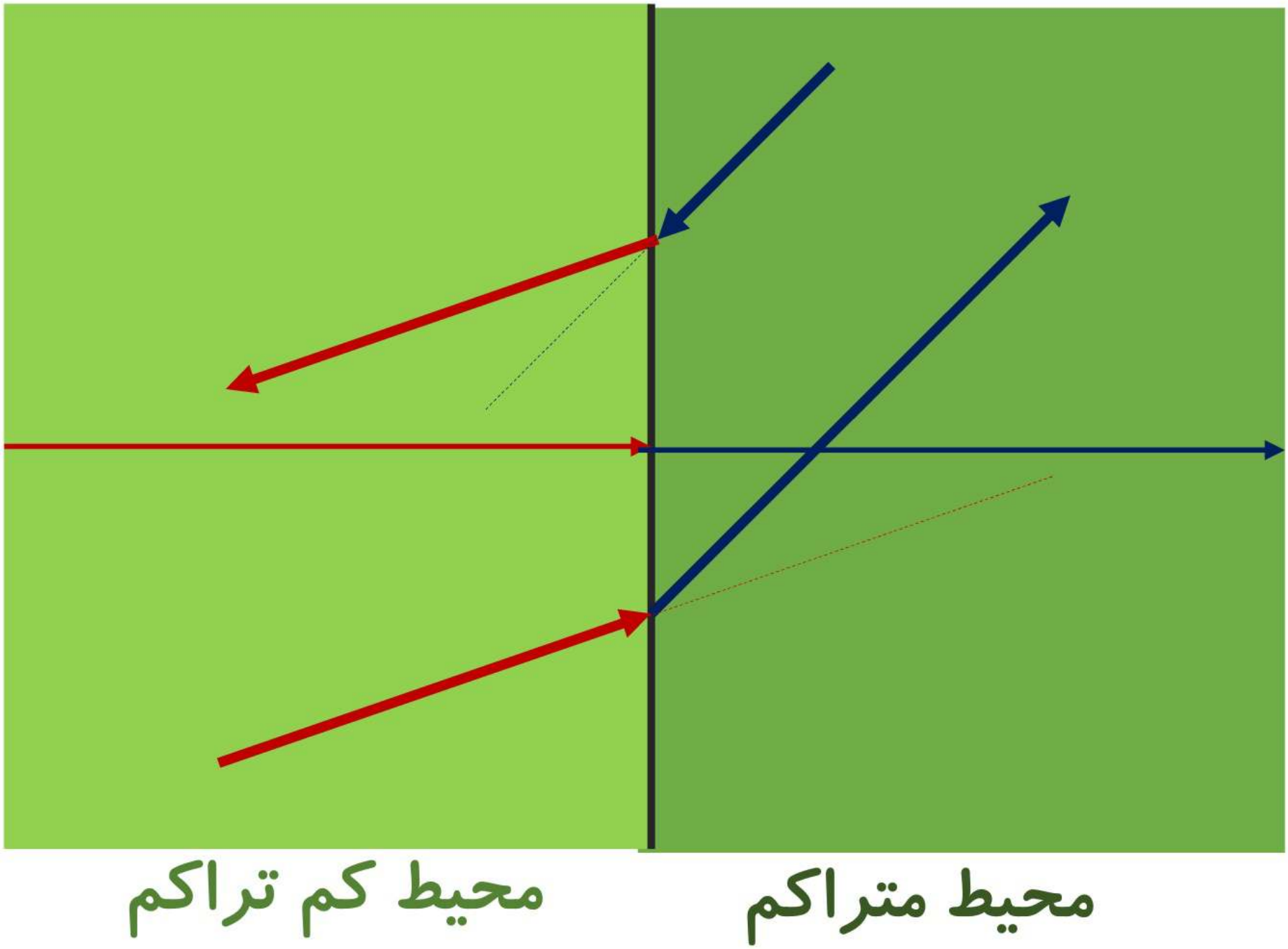
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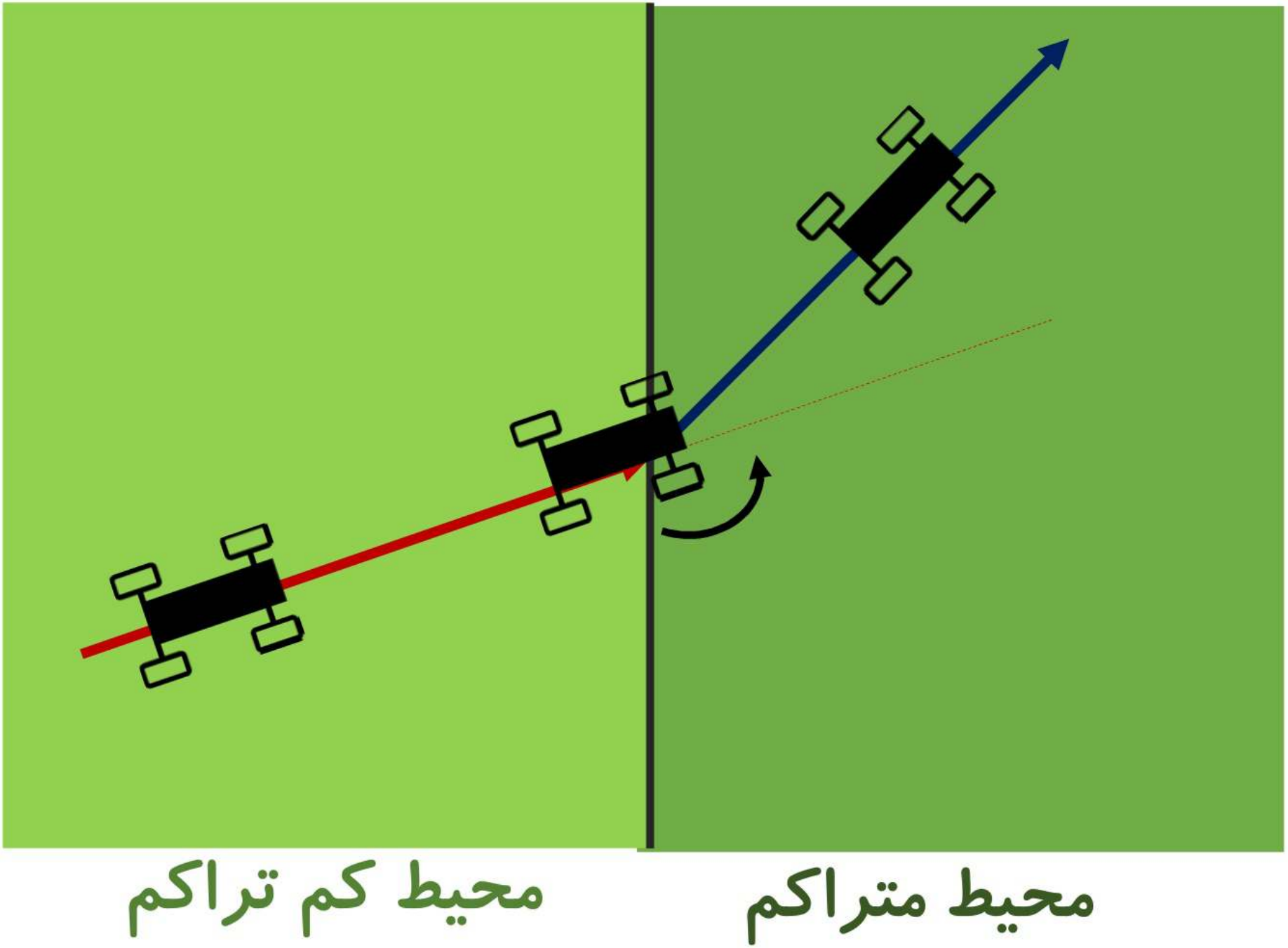
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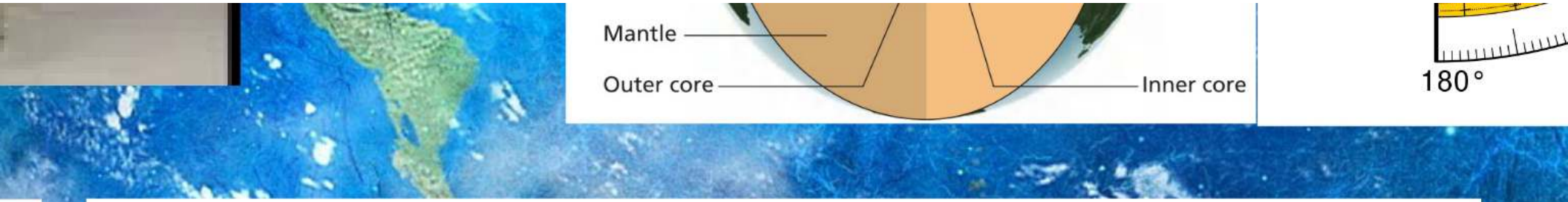
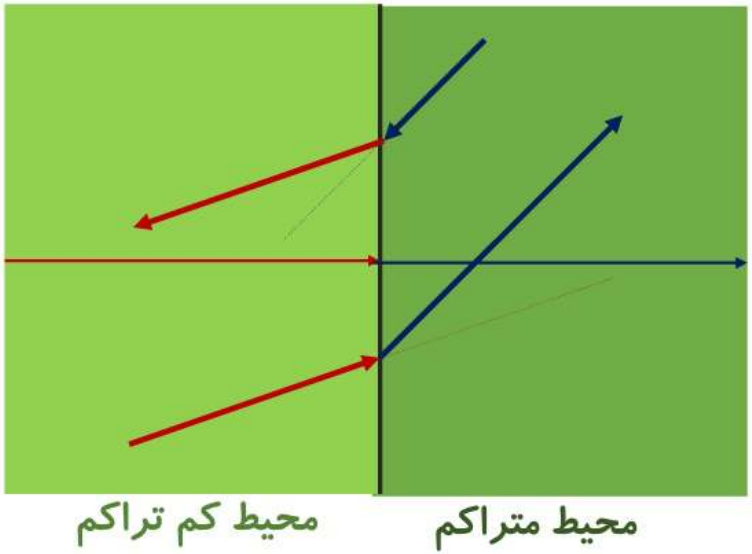

Mantle
Outer core
Inner core
180°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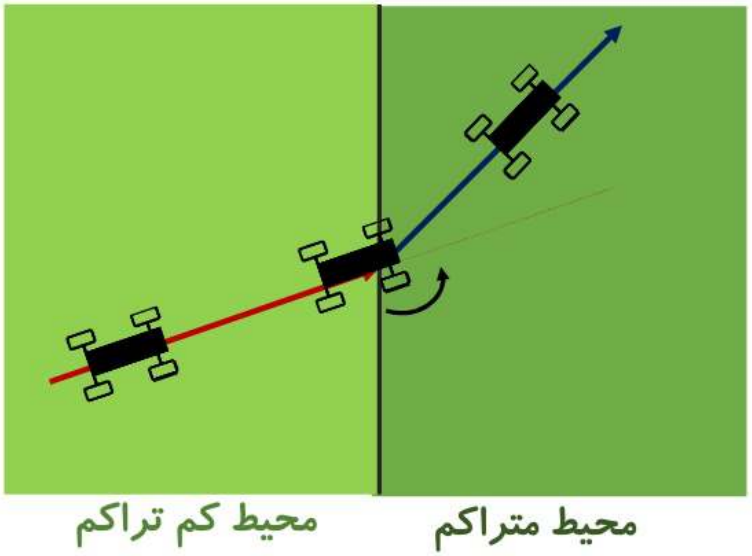
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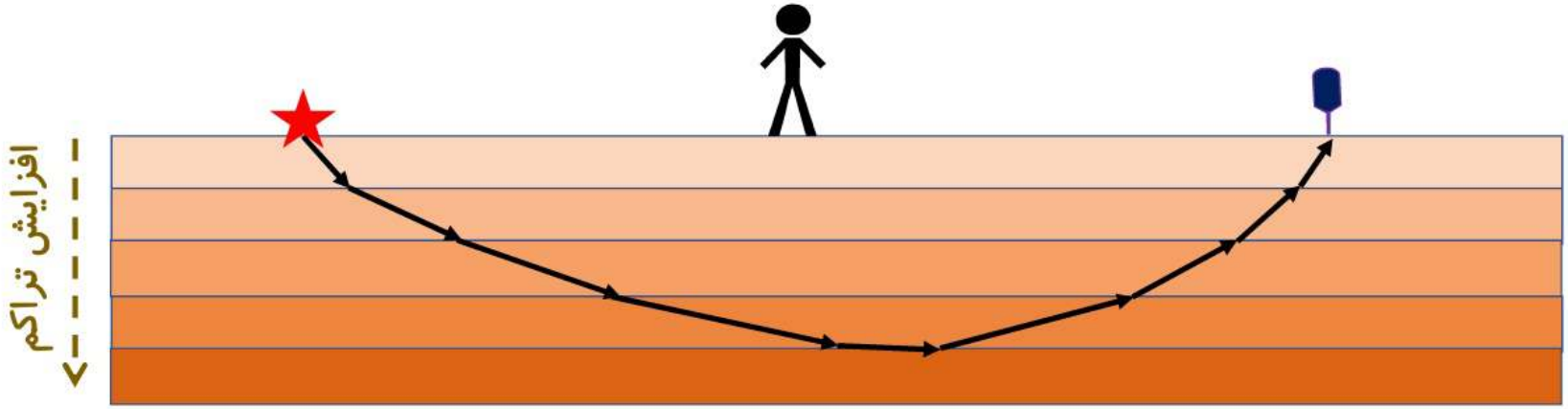
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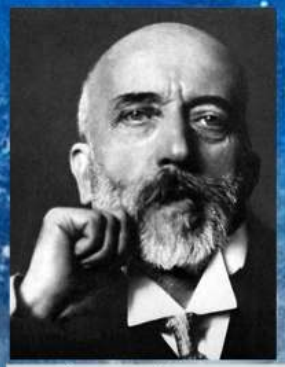
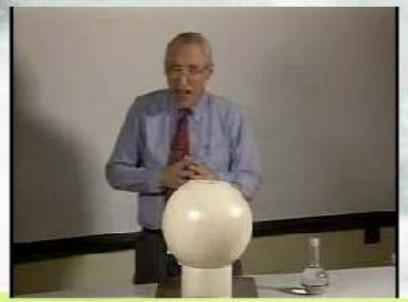
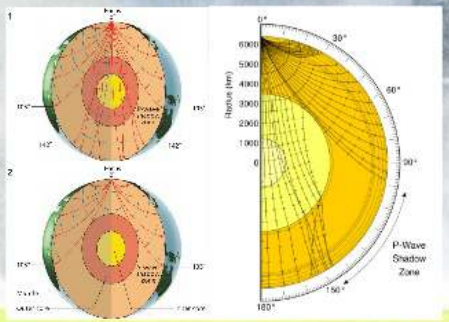
Earth and Seismic Waves

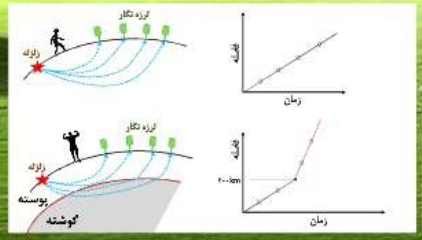
How we Know about the Earth's Core

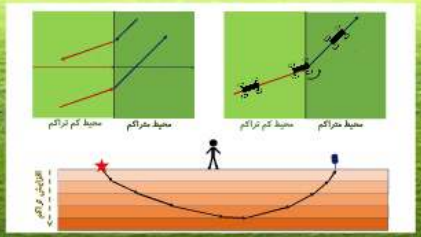


Andria Mohorovicic









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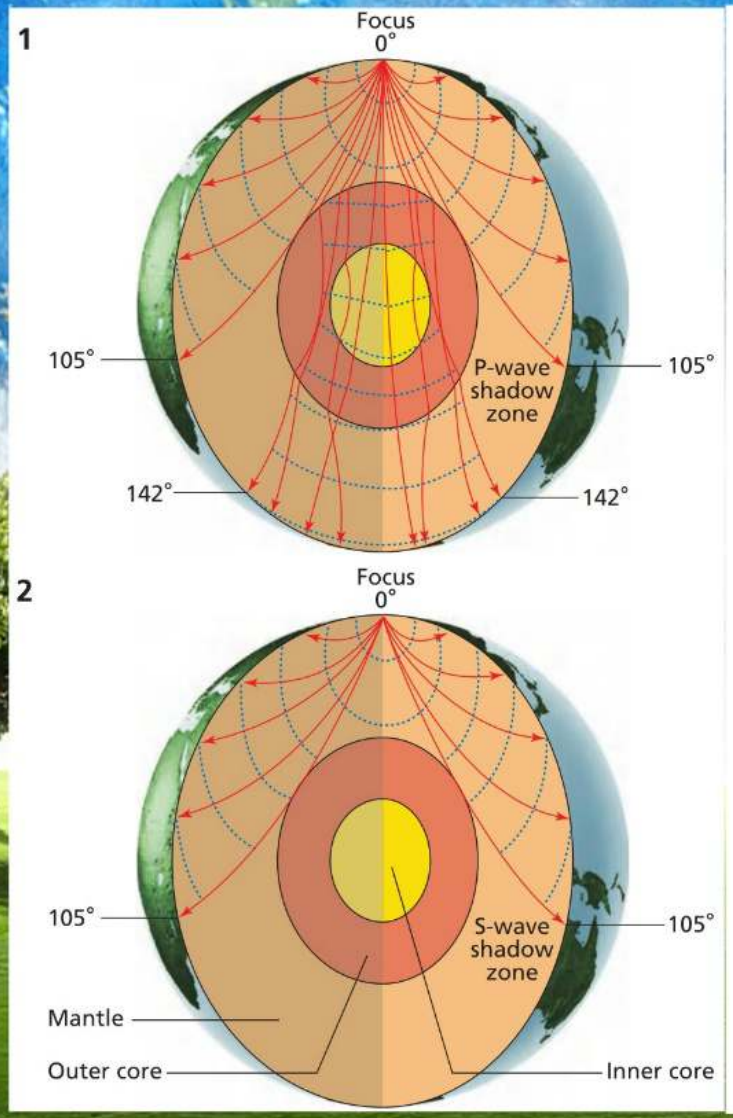
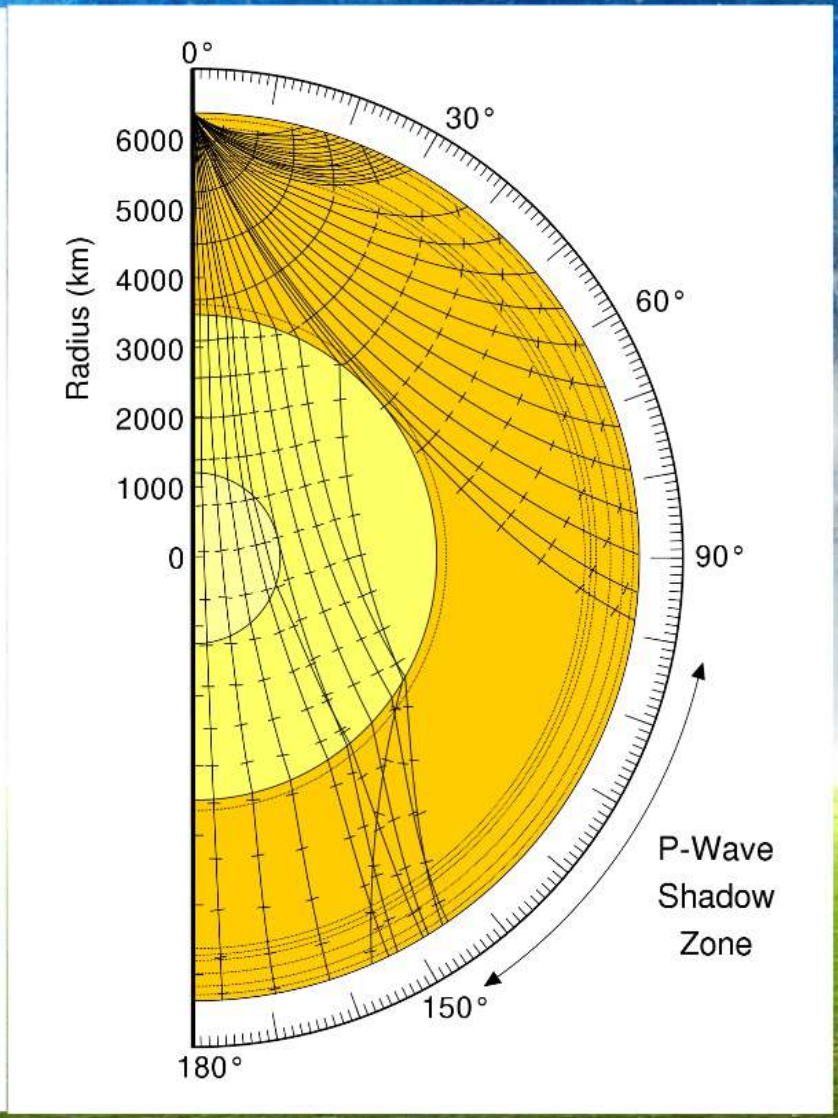
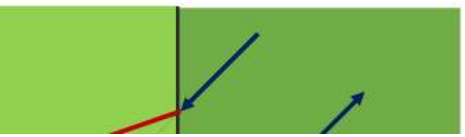
Andria Mohorovicic







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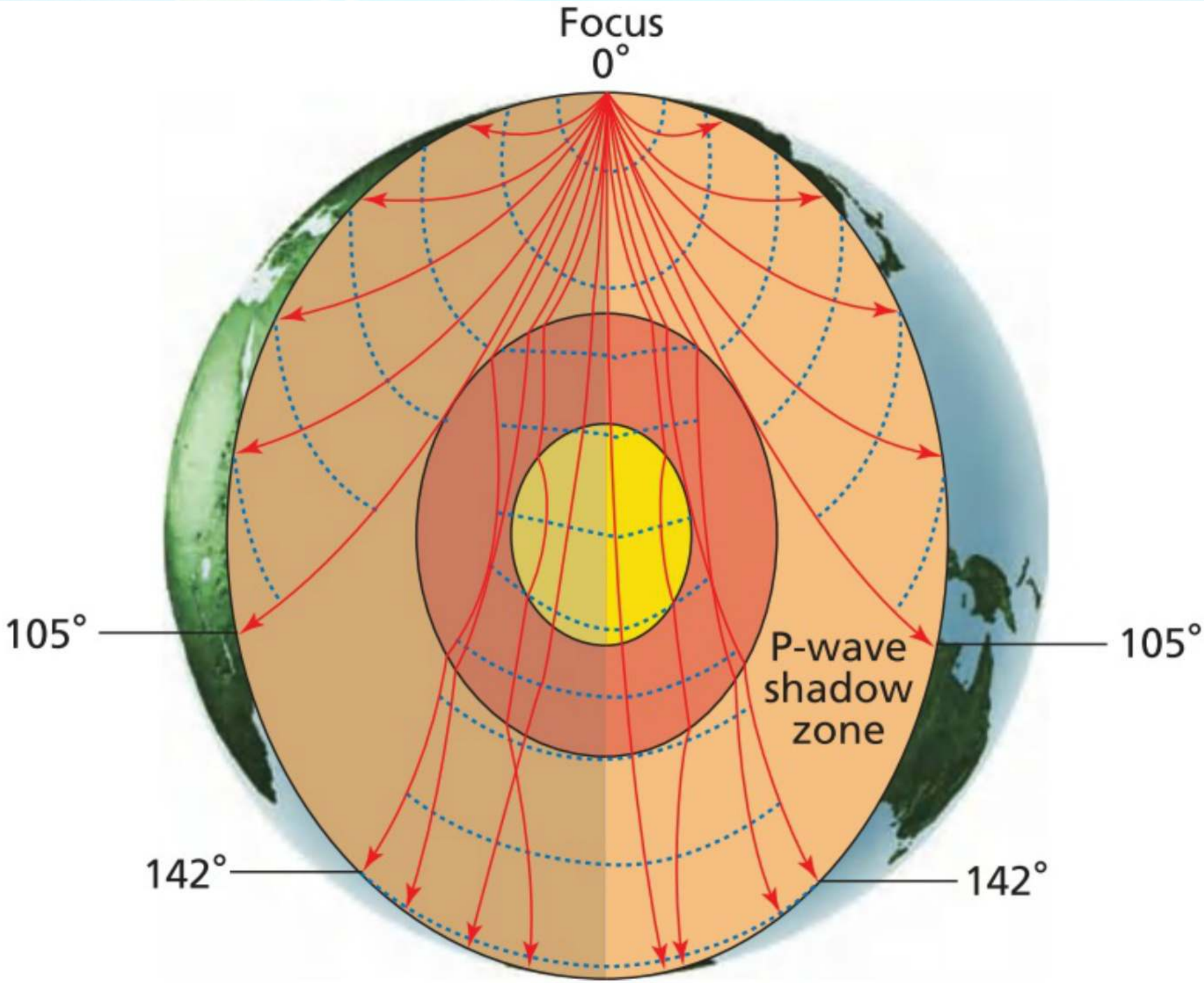

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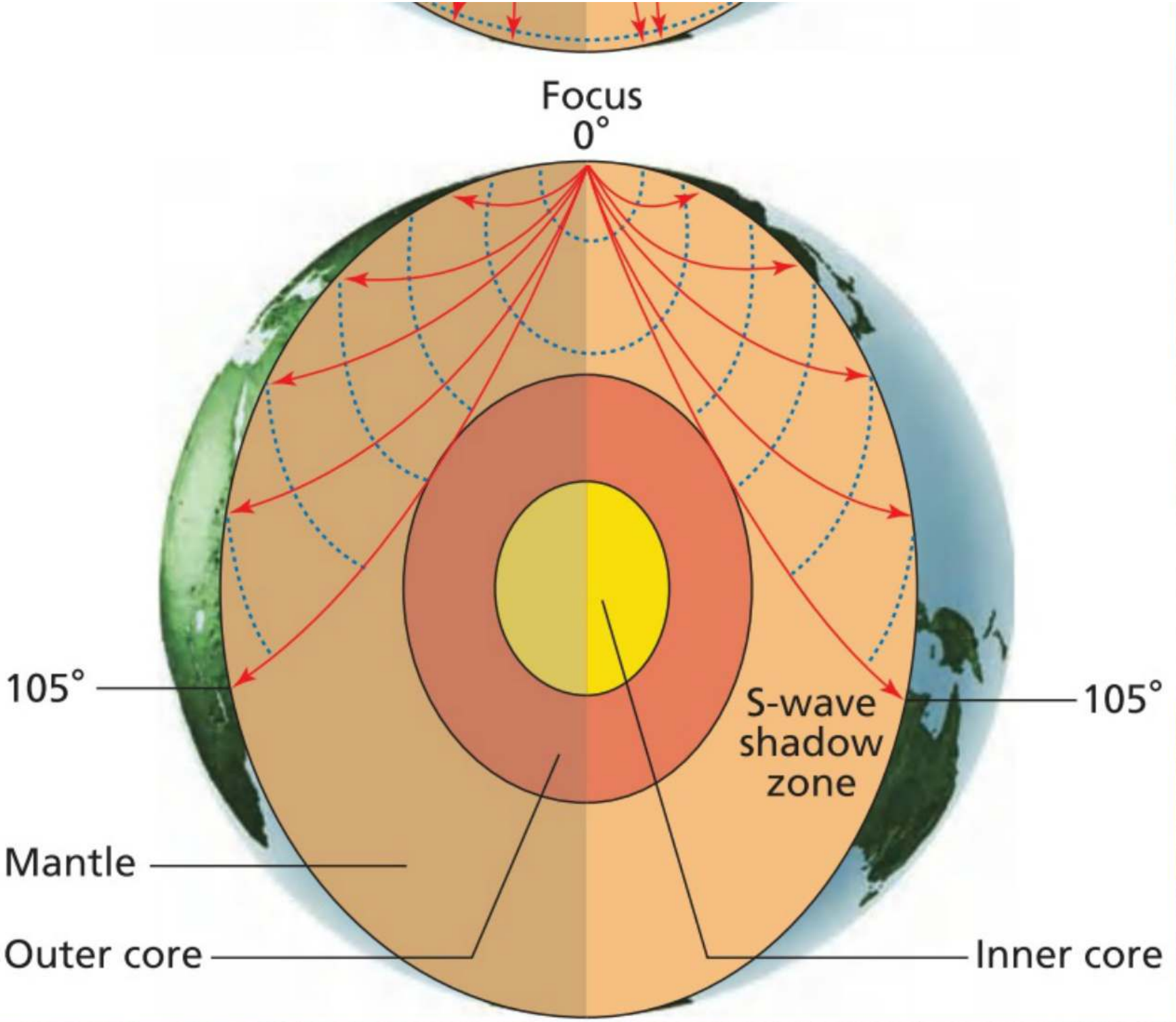
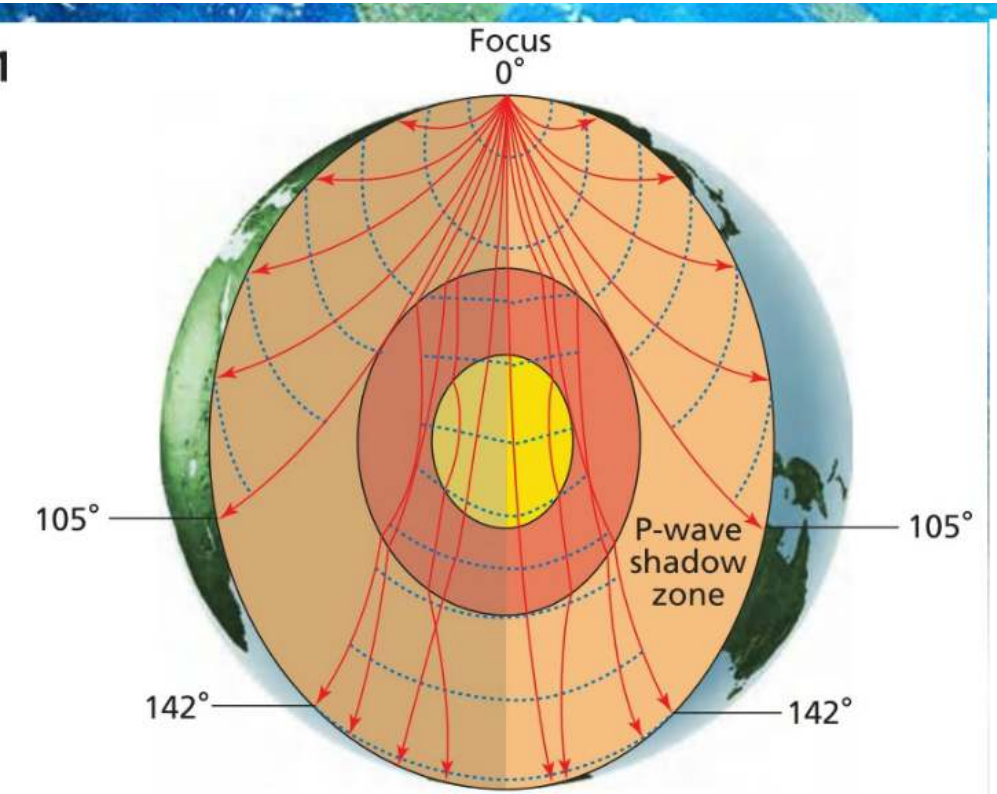
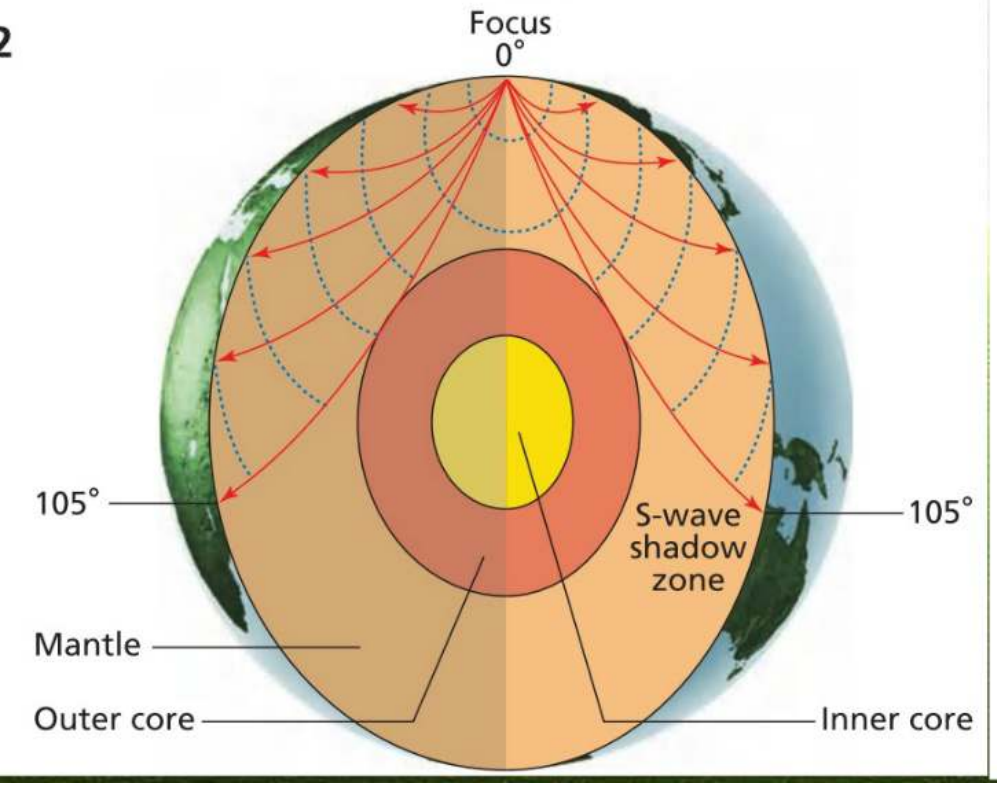
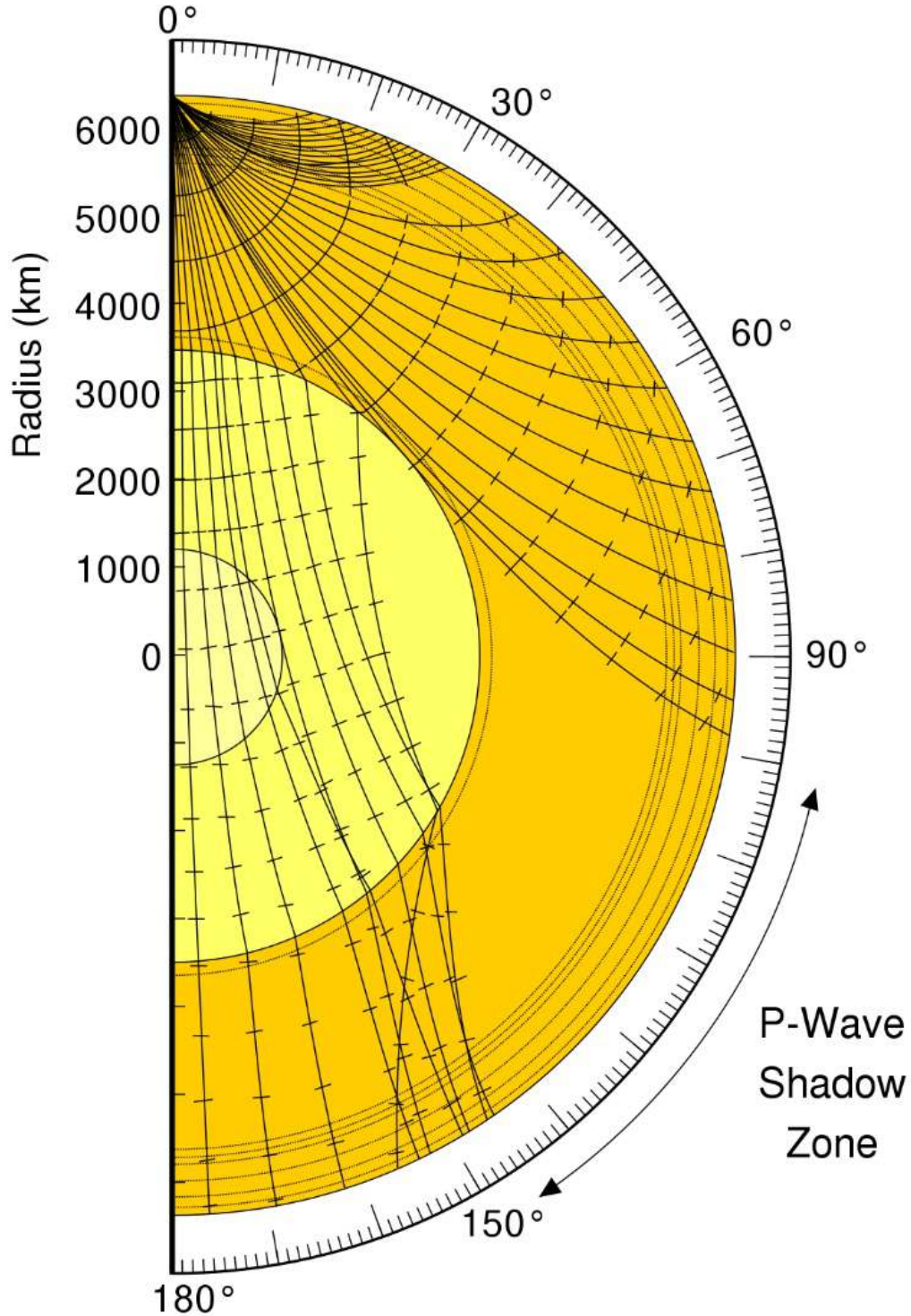

Focus
0°
105°
105°
S-wave
shadow
zone
Mantle
Outer core
Inner core


1
Focus
0°
105°
105°
P-wave
shadow
zone
142°
142°


2
Focus
0°
105°
105°
S-wave
shadow
zone
Mantle
Outer core
Inner core


0°
30°
60°
90°
150°
180°
Radius (km)
6000
5000
4000
3000
2000
1000
0
P-Wave
Shadow
Zone