THE "PARADOX" EARTHQUAKES – POSSIBLE EXPLANATIONS

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Abstract: *We present the definitions of "paradox" earthquakes and seismic sources. We further investigate some recent scientific explanations of the strange seismic events and sources. The time interval considered covers from ancient to recent seismic events around the globe.*

ПАРАДОКСАЛНИТЕ ЗЕМЕТРЕСЕНИЯ – ВЪЗМОЖНИ ОБЯСНЕНИЯ

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Ключови думи: *парадоксални земетресения, възможни научни обяснения*

Резюме: *Дадена е дефиниция на „парадоксални" земетресения и парадоксални сеизмични огнища. Потърсени са научни обяснения за „странностите" на тези земетресения и сеизмични източници. Разгледани са редица световни, необичайни сеизмични явления от древността до днес.*

Introduction

There are many "paradox" earthquakes and seismic sources located on the Earth. To be clearer what we mean by "paradox", we classified them by the following DEFINITION:
Earthquakes with the following characteristics:

- Their observed effects can not be clearly modeled by recent seismological knowledge and practice

or

- Show peculiarities, which are not common for the dominant number of earthquakes

or

- Are located in not easily explainable locations

or

- Generate most extreme and some time curios effects, demonstrated and/or observed for the first time.

DEFINITION of "paradox seismic sources".
Sources which:

- Generate "paradox" earthquakes
- Have unusual peculiarities which are not common for the global seismic sources

Or in more general – strange earthquakes and seismic sources are those with unusual location, strange properties, which demonstrate effects observed for the first time and have curios characteristics.

The goal of this paper is to give a lot of examples of strange earthquakes and seismic sources in the Earth's interior and to try to offer possible scientific explanations of their uniqueness.

Historical events and descriptions

Lisbon, (Portugal) 1755. (M>8.0 occurred 1st November 1755, more then 30 000 victims from the quake and the following tsunami).

Unique peculiarities:
- unusual location
- unknown source
- huge tsunami generated (10-12 m)
- no model fits the observations

Illustrations:

Fig. 1. Lisbon earthquake 1755 – historical pictures

Possible explanations – not all details of the epicenter's location and the tsunami generation have yet been discovered. There are suggestions about underwater slides (turbidities) generated by the strong earthquake.

Mississippi (New Madrid) great earthquakes, US 1811-1812.

A sequence of extremely strong (M7.8-8.6) earthquakes changing the land elevation more then 20 meters in some places – fig.2. Tsunami generated in the Mississippi river. New Madrid and St.Louis were strongly affected. (Historic Earthquakes, 2011)

Unique peculiarities:
- unusual location
- tsunami generation in the river
- huge land elevation's
- no tectonic explanation

Illustrations:

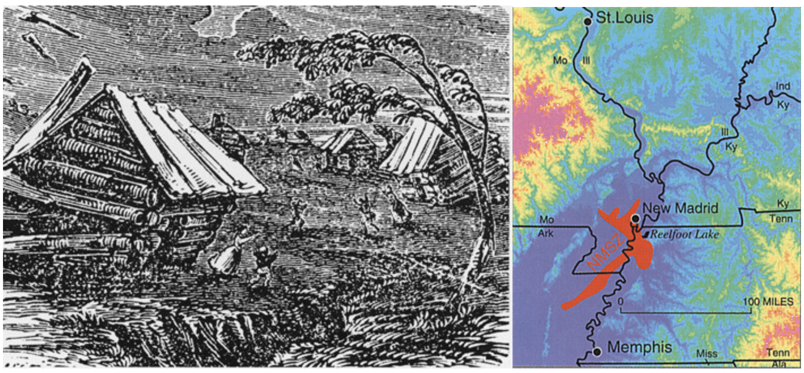
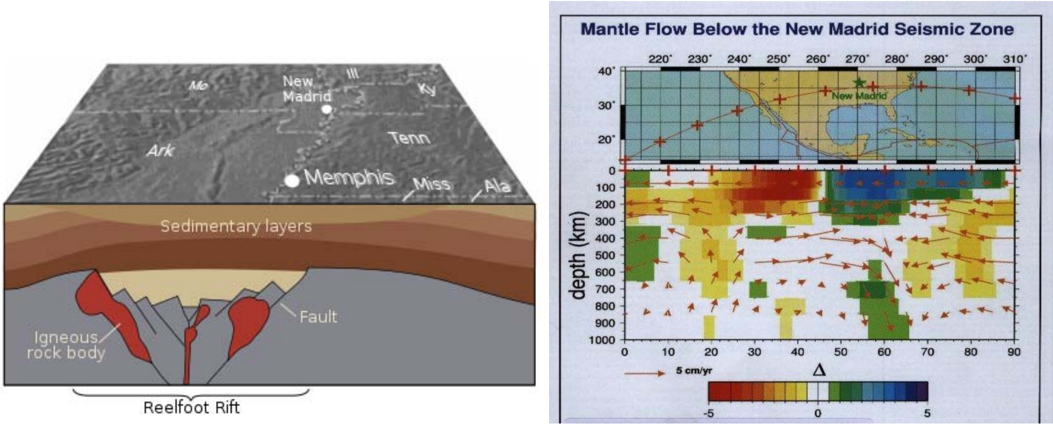


Fig. 2. Drawing of the Mississippi earthquake and land elevation on the Earth's surface (red spot)

Possible explanations – there are 2 hypotheses about the tectonic position of these huge seismic events:

- activation of very old seismic active faults (less probable)
- mantle flow under the New Madrid area (more probable)



a) b)

Fig. 3. New Madrid seismic zone and possible models: a) ancient faults; b) mantle flows (GRL, 2007)

Assam (India) 1897 - M8.3 **o**n June 12.

Unique peculiarities:

- maximum observed macroseisnmic intensity – up to XII (land elevation changes up to 200 meters)
- fault slip about 18 m
- relatively low mortality rate

Illustrations:

Fig. 4. Surface effects of Assam earthquake

Possible explanations about the high paleoseismal intensity and land elevation/subsidence changes – soft soil conditions and activated landslides

More recent paradox seismic events

Messina, (Italy) 1908 December 28, M7.5

Unique peculiarities:

- devastating tsunami generated
- very high mortality rate (about 25-30 000 deaths – the most deadly modern European earthquake with tsunami)
- high intensity concentration of macroseismals observed at the epicenter area

Illustrations:

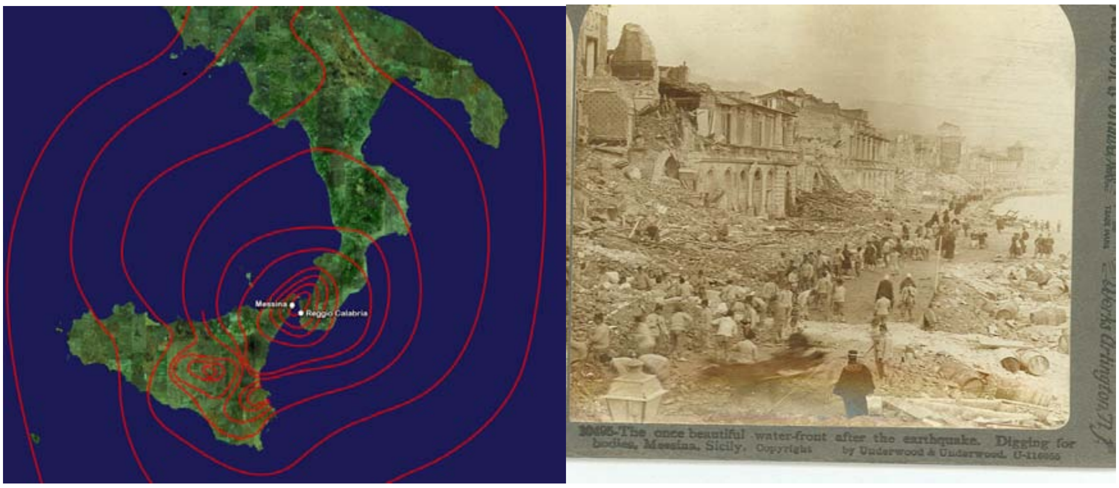


Fig. 5. Messina earthquake 1908 - macroseismic map and picture of destructions

Possible explanation:
No seismotectonic model fits the observations. New and detailed investigations are necessary.

Lituya Bay (Alaska), 1958 9th of July, 1958 M7.9

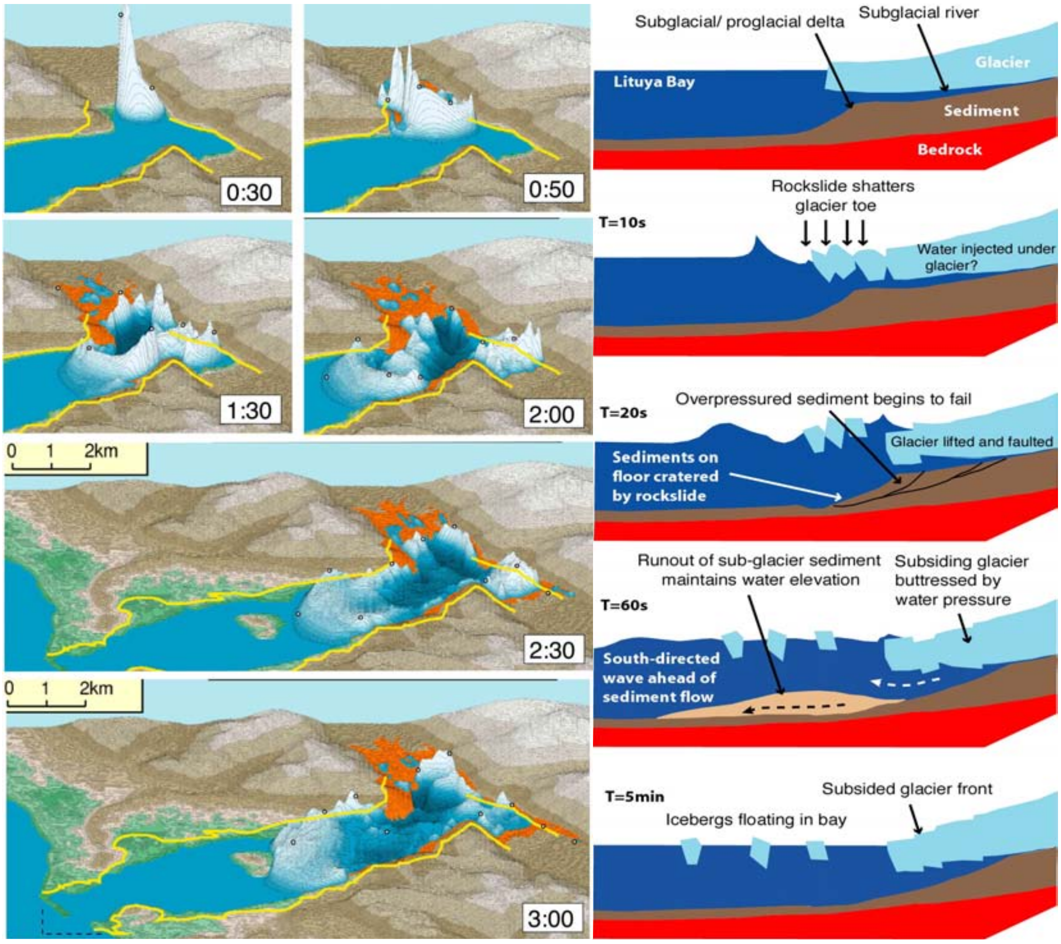
Unique peculiarities:

- the highest tsunami observed ever in the globe history – 525 meters
- difficulties for tsunami generation by such an earthquake
- splashed water by the landslide
- difficulties to explain so huge tsunami generation of relatively not extremely strong earthquake
- deficit of sediments by landslide to produce so huge tsunami

Illustrations:

Fig. 6. Lituya bay – aerial view – the cleaned hill slope by the tsunami is visible at the back side.

Possible explanation:
Considering the glacier sliding block together with the landslide – done by Ward S. & Day S. 2010.



a) b)

Fig. 7. Two models – a) on the left and b) on the right - modeling the generation of the highest tsunami wave in the global history (525 m.) – according (Ward S. & Day S. 2010)

Chile (1960, 22nd May M9.4-9.6**) and Alaska (1964,** 27th March M9.3**) earthquakes**

Unique peculiarities:
- the strongest ever recorded events

Possible explanations:
Generated in the areas of active subduction

Sakhalin (Neftegorsk) earthquake, 1995 M7.0
- shallow under the city of Neftgorsk seismic event
- unexpected place, not considered by the seismic zoning maps of Russia
- not special rescue works done
- The total collapse of the city.
- No rescue and recovery works considered effective.

Illustrations:

Possible explanation:
More critical review is needed.

Fig. 8. Heavy damages by the Neftegorsk earthquake

Sumatra, 2004. 26th December M9.1

Unique peculiarities:

- the unexpected, most powerful seismic event in the Indian ocean
- the hugest tsunami generated – more then 30 meters observed in some places
- the very long underwater rupture observed (more than 1200 km.
- extremely high mortality rate – 3 continents, 8 countries and more then 1 200 inhabitants affected
- more then 300 000 deaths reported – the deadliest disaster in the recent human history

Illustrations:

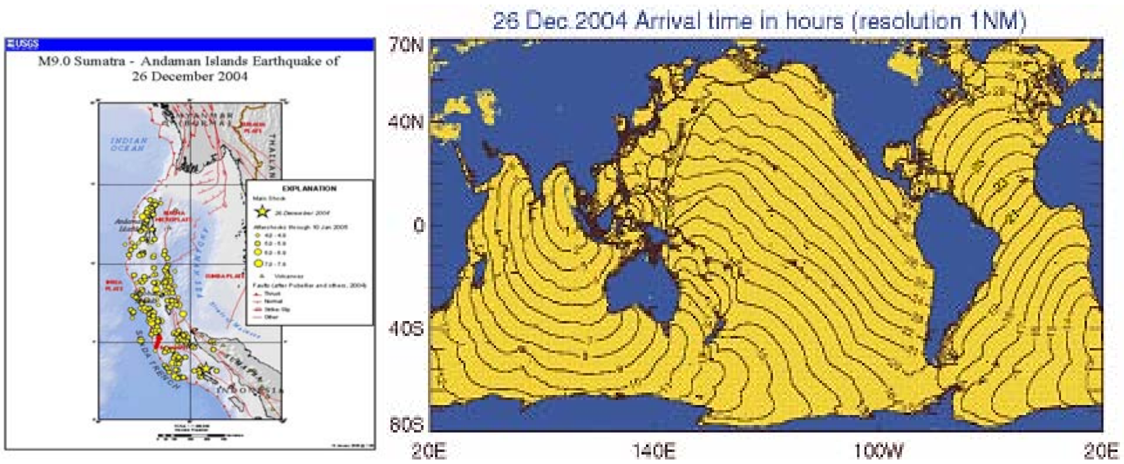


Fig. 9. The Sumatra 2004 earthquake source zone (left) and the tsunami travel times (right) all over the world

Possible explanations:

- subduction zone generation
- underwater slides reported
- first time huge GPS displacements reported

Indian Ocean strike-slip strong earthquakes, 2012 - 11th April M8.6 (8.38UTC) and M8.1 (10.43UTC)

Unique peculiarities:

- unexpected location

- short time interval between the main shocks
- strike-slip mechanisms
- specific space distribution of the aftershocks

Illustrations:

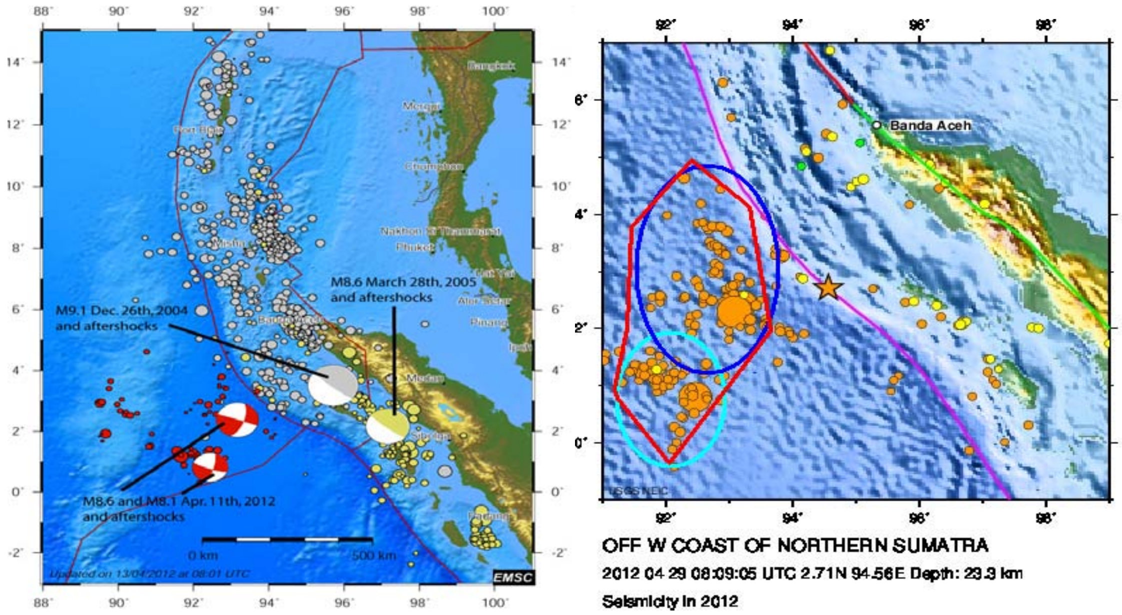


Fig. 10. The strike-slip earthquakes of 11th April, 2012 (red and white circles) and their aftershocks positions (blue and cyan ellipses). The unusual position (red polygon) suggests the new tectonic boundary formation.

Possible explanations:

- Formation of a new recent tectonic boundary, meaning new tectonic phase..
- Needs long time observations for confirmation.
- This hypothesis is presented for the fist time in the Earth's science history.

Chile, 2010, (M8.8) on 27th February 2010, M8.8

Unique peculiarities:

- for the fist time GPS displacements are observed over the whole continent (South part of the South America

Illustrations:

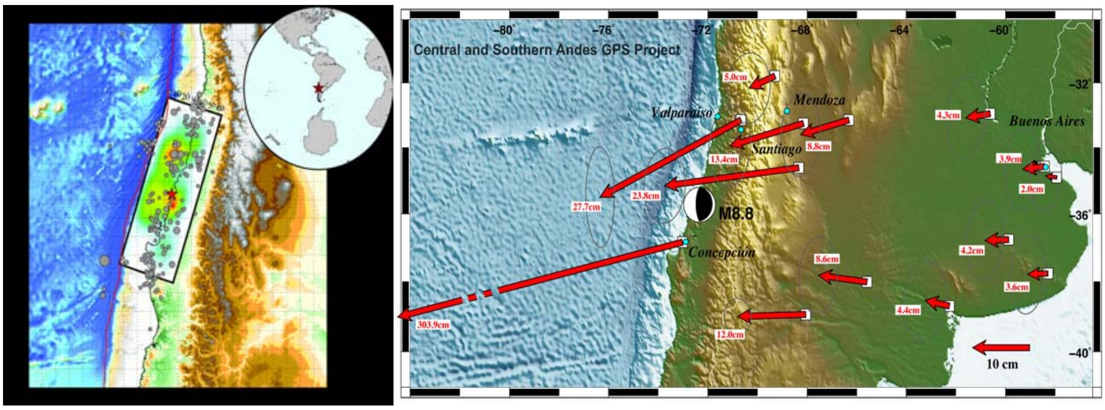


Fig. 11. The strong earthquake zourse zone (600x100x50 км.) and the displacements of the part of South America continent due to the Chile earthquake (27th Feb., 2010) and the GPS measured displacements (red arrows).

Possible explanations:

- GPS nonlinear displacements have been observed. This means that the rebound effect has been observed with a very large displacements over huge part of a continent
- If such events are registered now, there must be such effects observed in the past and the task of the contemporary geology is to discover these past effects.

Japan, 2011, 11th March, 2011, M9.0

Unique peculiarities:

- For first time the seismic zoning of Japan was shown to be wrong. In some places the observed seismic acceleration reached about 10 times higher value that is predicted by the seismic zoning map of Japan.
- For first time the seismic (SEWS) and tsunami (TEWS) early warning systems acted simultaneously, saving the lives of many, many people.
- For first time the world media disseminated information about tsunami inundation in real time
- For first time the movements (displacements) of big islands was documented in details by GPS measurements – fig. 12.
- For fist time the NPP catastrophe was triggered by earthquake and tsunami.
- For first time the tsunami heights reached about 22 meters in some places including the higher level overlapping the protective tsunami wall in front of Fukushima NPP
- For the first time the dense GPS network show the displacements of the whole country

Illustrations:

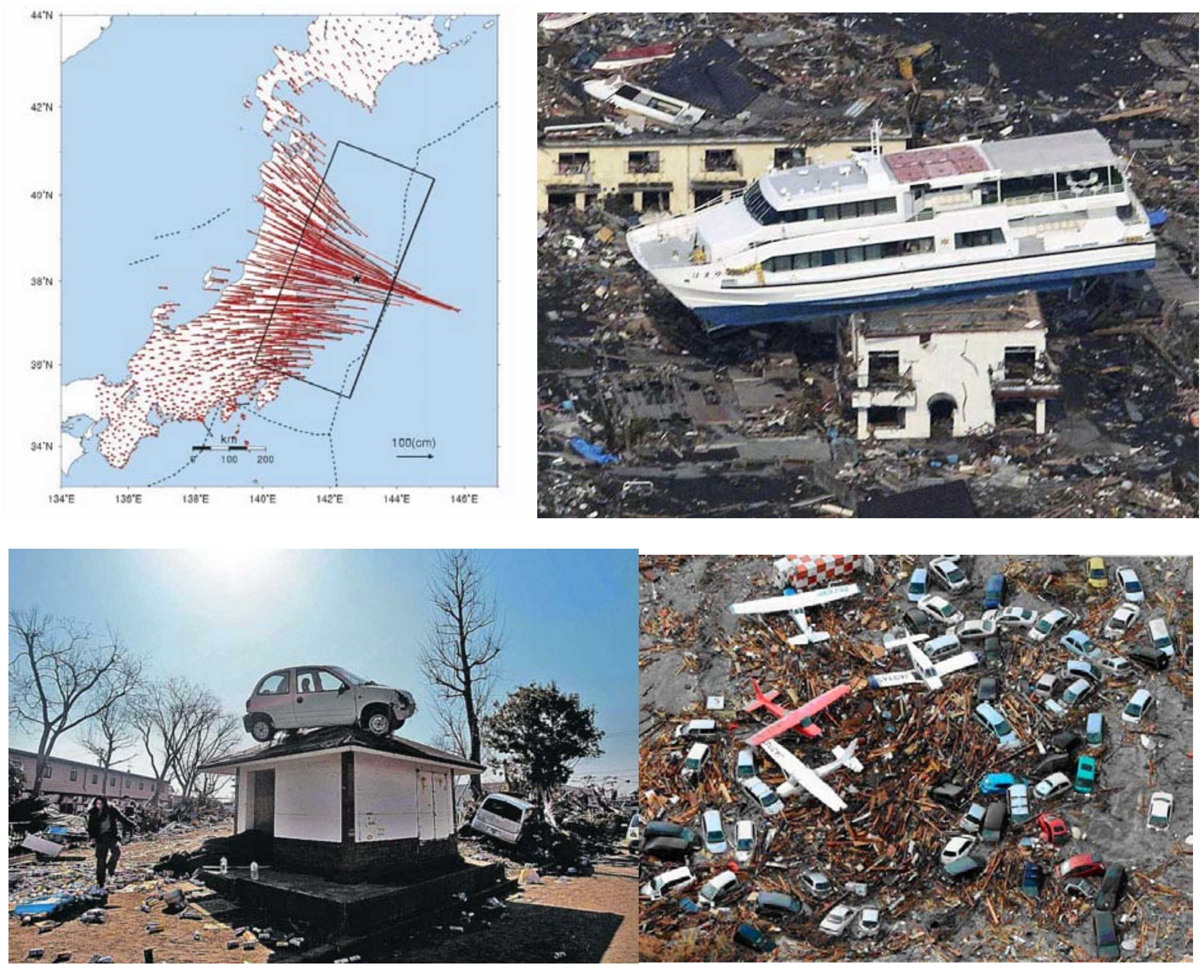


Fig. 12. Consequences by the Japan, 2011, M9 earthquake

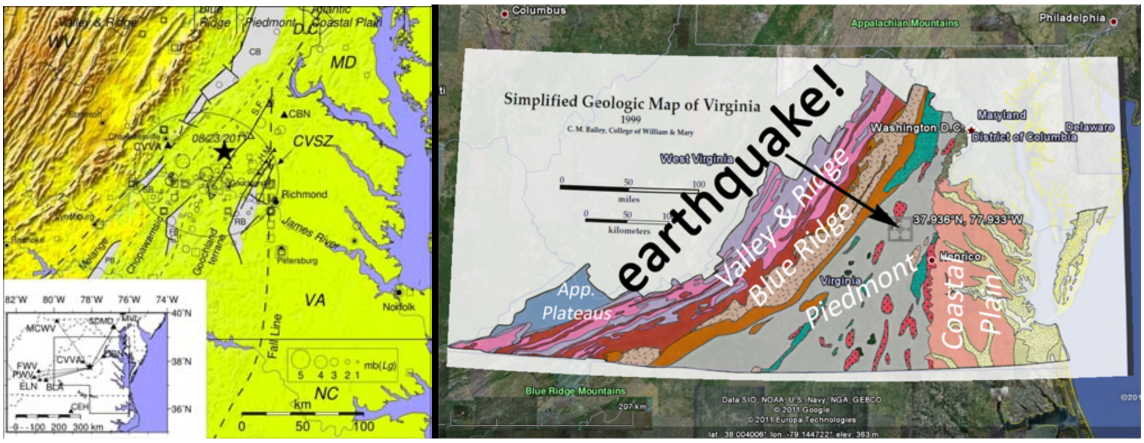
Possible explanations

- triple point junction of the three continental plates merging in that area.
- the scientists apologized to the people and specialists that they did not expect so huge event.

Virginia earthquake, US, 2011, 23rd August, M5.9

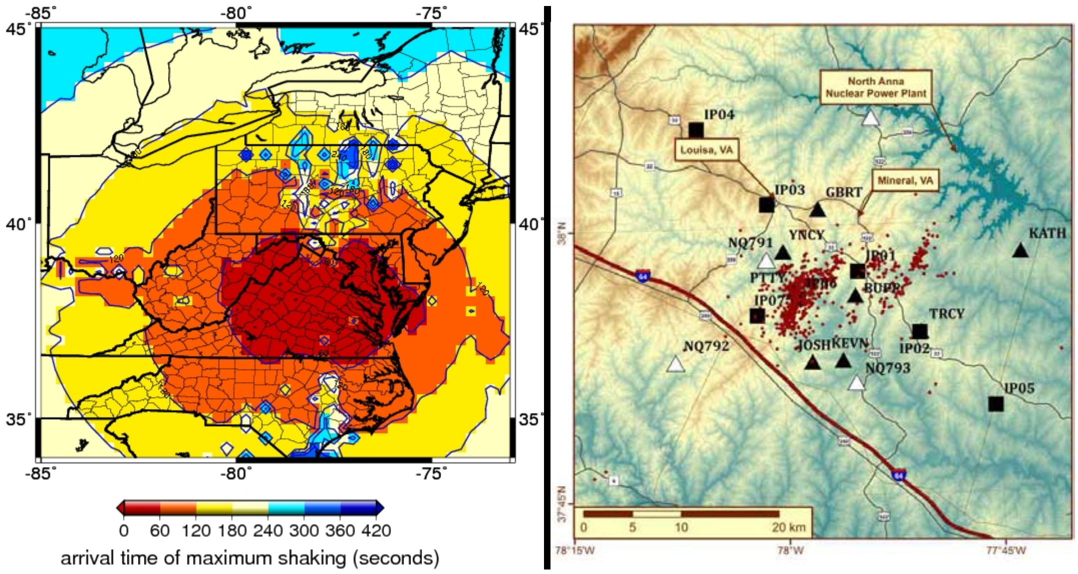
Unique peculiarities:

- The quake occurred in a fault system (fig.13 a) located in Proterozoic and Paleozoic rocks (fig. 13 b) – with age of more then 500 million years.
- The time distribution of the maximum shaking movements has strong peculiarities, related to the modification and delay in several seconds that the standard model predicts. The highest anomalies are located north and south of the epicenter – fig 14 a) and the aftershocks are positioned perpendicularly to the direction of the main fault system, which is unusual – fig.14 b).
- The fault movement generated by the quake was characterized as trust event. In such case, with the determined depth of the hypocenter, such magnitude has to create surface rupture. Such rupture was not detected.



a) b)

Fig. 13. The faults system of the M5.9 occurred – a) and the simplified geology map of the region – b)



a) b)

Fig. 14. The maximum shaking time distribution – a) and the aftershocks locations of the M5.9 Virginia earthquake – b)

Possible explanations:

There are 2 hypotheses about the Virginia earthquake|

- The first one is related to the heavy rain origin of the quake. According the seismologist Betim Muco's idea, the heavy rains put into the Earth's interior enough water to 5-6 km depth, which generated the sliding effect on the fault in 45^0 dipping. Another evidence of this hypothesis is

that the most distant landslide occurred due to the quake was detected at 250 km far from the epicenter. This is a world record for such size of events.
- The second hypothesis about the origin of the Virginia earthquake of 2011 is related to the idea of the detachment of some parts of the Earth's crust to higher depths in the mantle. Such effects are considered to occur at depths more than 50-60 km.
- In both hypotheses contradictory elements can be found.

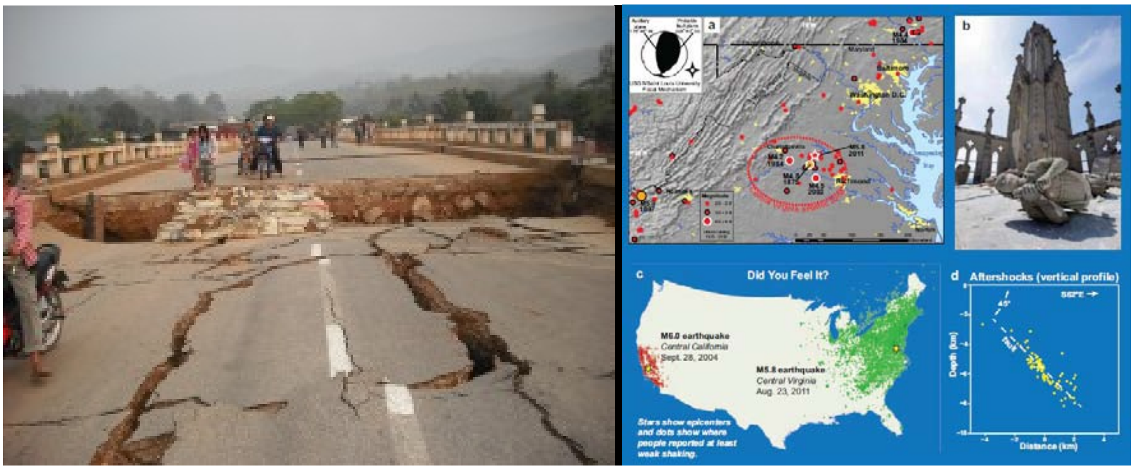
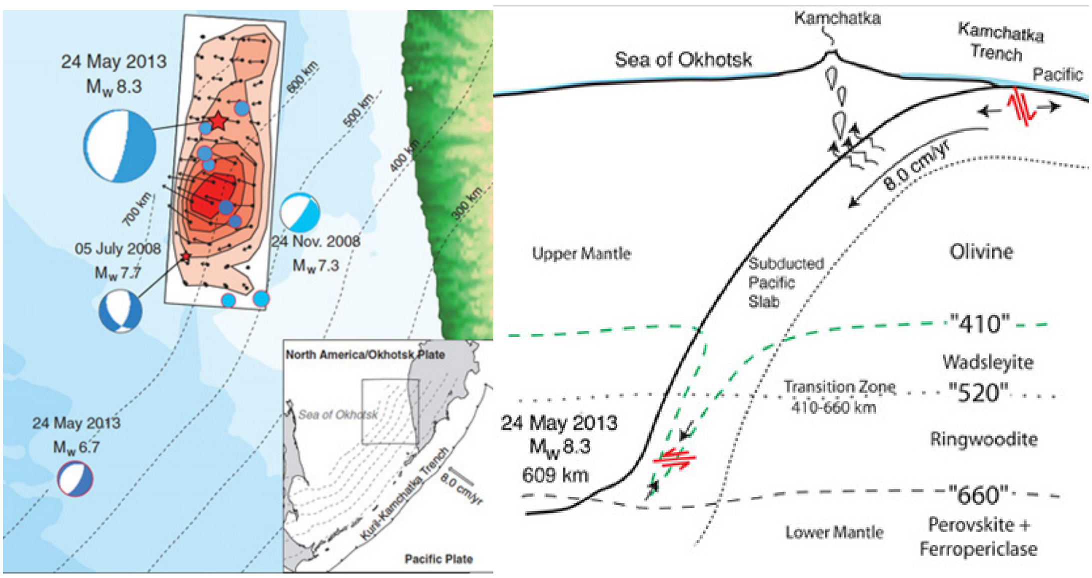


Fig. 15. Consequences of the M5.9 earthquake in Virginia

Sea of Okhotsk deepest and strongest earthquake, 2013, May 24, M8.3

Unique peculiarities:
- "It's a mystery how these earthquakes happen. How can rock slide against rock so fast, while squeezed by the pressure from 610 kilometers of overlying rock?" said prof. Thorne Lay, at the University of California. It is still unexplainable, how these deep earthquakes (more than 610 km) can happen."

Illustrations:



a) b)

Fig. 16. Sketch of the earthquakes mechanism - a); the deep profile of the subduction zone – b). (https://en.wikipedia.org/wiki/2013_Okhotsk_Sea_earthquake)

Possible explanation:
Some researchers explain with the destruction of the crust material at such depths. Others consider phase transitions of the elementary content of the deep Earth's interior

Nepal, 2015, 25th April, M7.8 and 12th May, M7.3

Unique peculiarities:

- both shocks occurred in the same geodynamic environment – the collision of the Indian subplate with the Asia main plate.
- the geodynamic environment is pure compression and this is proved by the mechanisms of the shocks
- the second shock (as the main aftershock) shows typical for the strike-slip events, macroseismic elongated field, which is very strange in the compression geodynamic regime

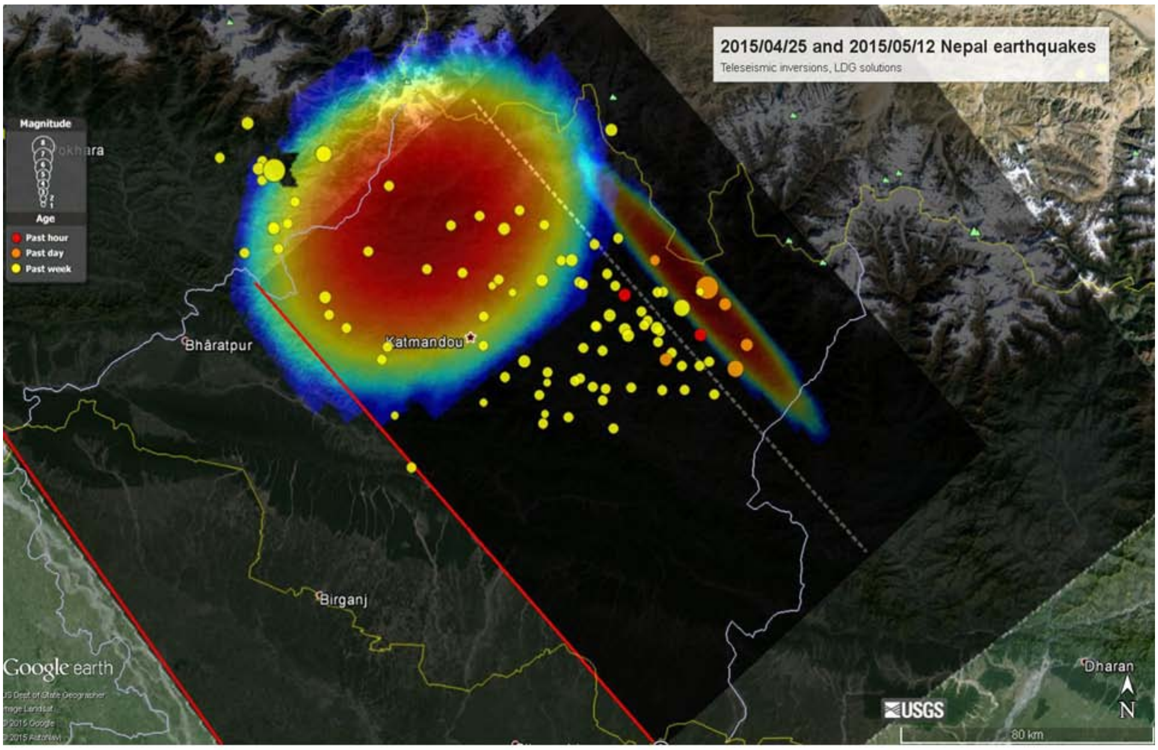


Fig. 17. Macroseismic fields of the strongest Nepal seismic events – 25th April (M7.8) and 12th May (M7.3), 2015. The comparison shows completely different seismic energy emission. The isometric one is for the first shock and elongated one – for the second event. This can explain easily the lower damages generated by the second shock. The all aftershocks location outline pretty well the seismic source area of the seismic activated region – in general elongated in NW-SE direction (http://earthquake.usgs.gov/earthquakes/.)

Possible explanation:
It is rather unusual to have so different macroseismic fields of both shocks. The first one demonstrated typical trust type event, but the second one is exceptional.

Paradox seismic sources:

Vrancea seismic zone

Unique peculiarities:

- Very sharp seismogenic layer at depths of 90 to 160 km.
- Very frequent strong earthquakes
- Unusual generating mechanism of the intermediate earthquakes
- Very specific energy emission confirmed by the macroseismic field
- there is not unified model which can explain all mentioned peculiarities.

Illustrations:

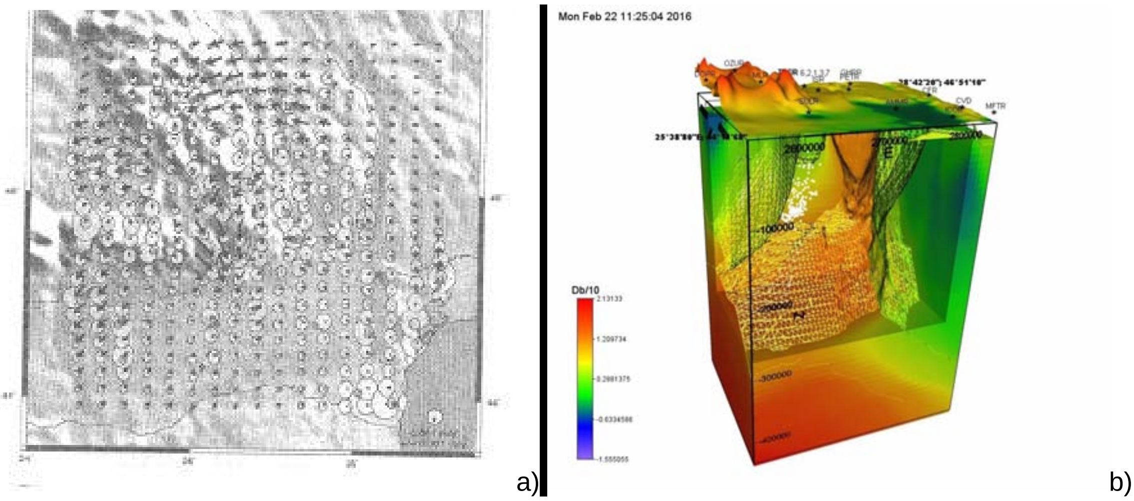


Fig. 18. Surface 2D projection of the GPS modeled the spiral structure of the Vrancea source – a) and 3D model of the velocity structure around the Vrancea earthquakes (white dots) – b). (Schmitt G., et al., 2007; Е. Ойнаков, Б. Рангелов., 2016).

Possible explanation:
Two main hypotheses (both have internal contradictions):
- this is a slab component remaining of an ancient subduction zone
- this is a part of the Earth's crust entering the interior of the globe not very far in the past geological times in a way of the turbulence theory application

Hindu Kush seismic zone

Unique peculiarities:

- relatively small area of concentration of large earthquakes
- Very frequent strong earthquakes
- far from any big continental collision and fault structures.
- Unusual generating mechanism of the earthquakes and the seismogenic layer is like pyramid turned down with its top
- The seismic source produces very strong earthquakes on the whole range of depths – starting from earth's surface, down to 300 km
- there is not unified model which can explain all mentioned peculiarities.

Illustrations

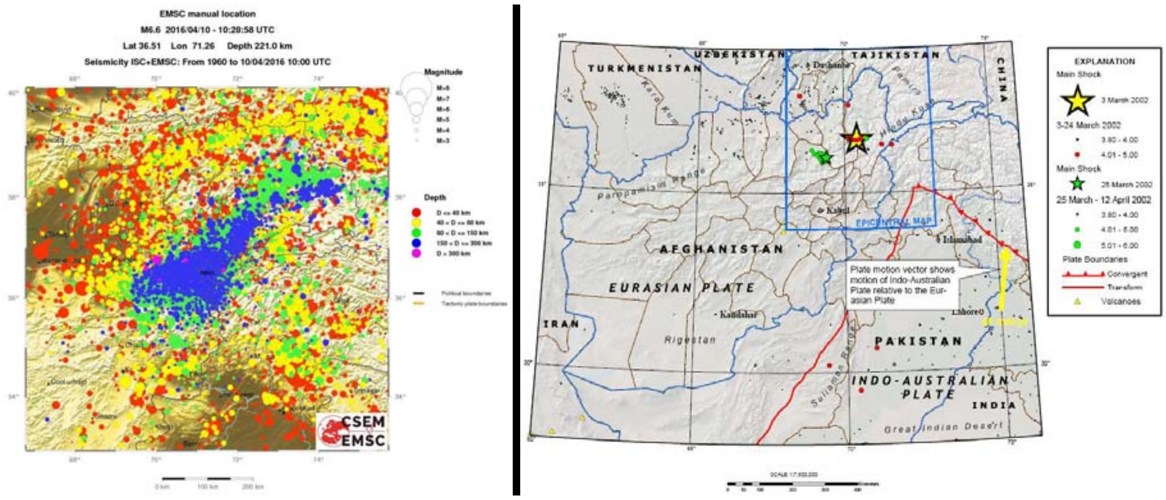


Fig. 19. The Hindukush seismic source – location and seismic events depths distribution (web: CSEM-EMSC)

Possible explanation:
Looks like triple junction of subduction areas, but without any other similarities.

Gibraltar seismic zone

Unique peculiarities:

- shallow and very deep earthquakes in a narrow zone

Illustrations:

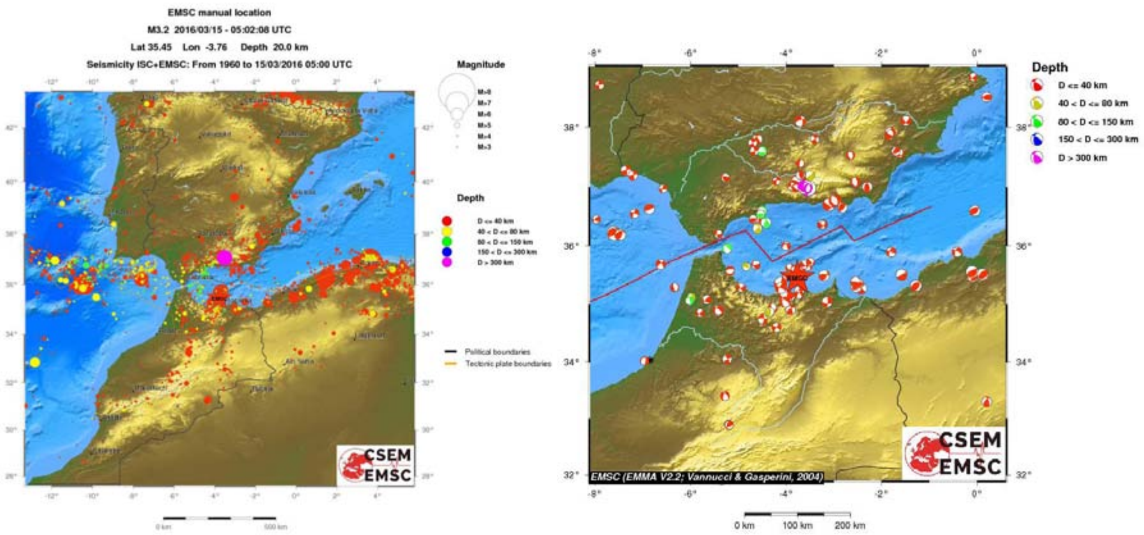


Fig. 20. “Gibraltar source” – deepest seismic events in Europe occurred at depths even more then 600 km (CSEM-EMSC).

Possible explanation:
Probably remains of an ancient subduction zone.

Conclusion

A collection of strange, unusual – called “paradox” earthquakes – has been presented. The aim of the work is to attract the attention of the specialists and non-specialists to the great variety of cases the mother Earth can generate.

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