



European Council  
of  
Civil Engineers



REPUBLIC OF BULGARIA  
Minister of Regional Development and Public Works



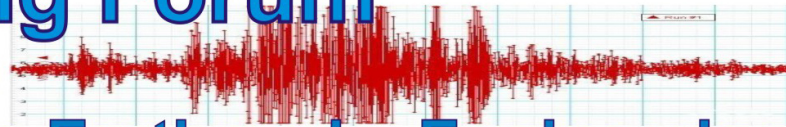
European Council  
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**BEF**  
**2021**

# Building Engineering Forum

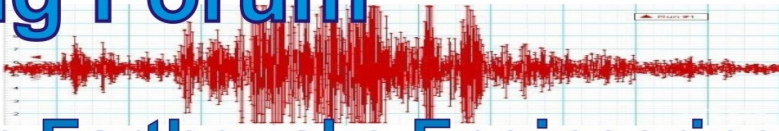
20-21 October 2021, Sofia, Bulgaria

International Conference on Earthquake Engineering

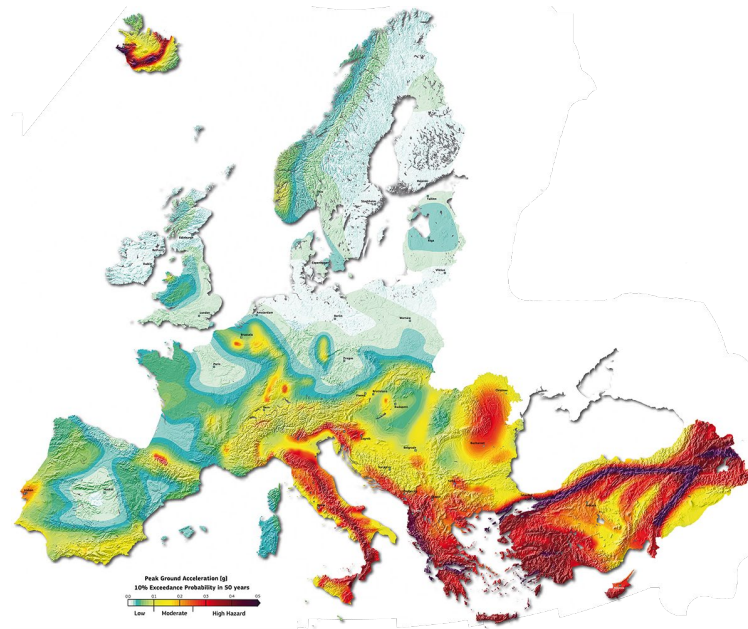


# Influence of earthquakes in geotechnics

Impact and examples



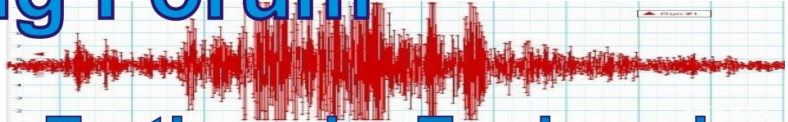
# Earthquake zones in Europe



Earthquake zones are concentrated in South and Southeast Europe, Iceland

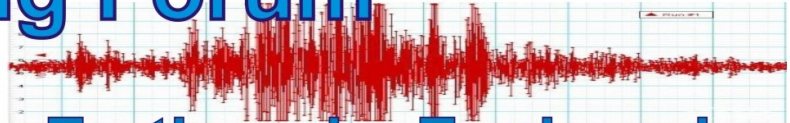
- Geological background

- **Iceland:** The reason is that Iceland is located on top of the Atlantic ridge: As the Eurasian and North American plates drift in opposite directions, Iceland is literally being torn apart, causing constant seismic activity.(North American plate)
- **South and Southeast Europe:** Earthquakes in Europe are essentially a result of stress in the earth's crust. For naturally occurring earthquakes, the source of this stress is plate tectonics. The Eurasian plate encompasses much of Europe's and Asia's mainland and moves with respect to the main neighboring plates in the South (African plate), Southeast (Anatolian microplate), and West (North-America plate).



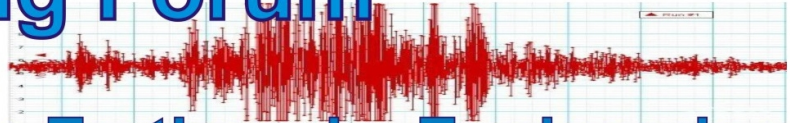
## Greece – African plate

This major plate with the most important effect on today's earthquake picture collided with Europe about 65 million years ago. As mentioned above, several smaller plates and ocean basins between the two plates have caused a very complex pattern of seismicity all around the Mediterranean. Today Europe and Africa are in direct contact in Southern Greece, where Africa goes below Europe (subduction). To the north of this active subduction zone is the Corinth Rift which is opening in a North-South direction. Greece is the country in Europe with the highest seismic hazard



# Turkey – Anatolian microplate

East of the Africa-Europe subduction zone is the Anatolian microplate, broadly occupying the area of Turkey. Its northern edge along Europe is known as the North-Anatolian Fault, along which several large earthquakes have happened throughout the 20th century (Magnitude larger than 7). A particularity is that these earthquakes in the past have happened progressively from East to West, approaching Istanbul.



# Iceland – North American plate

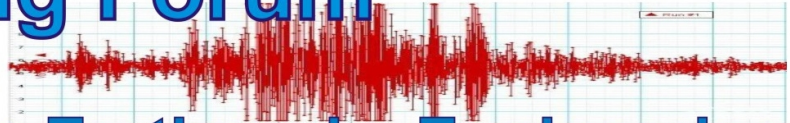
Europe's western neighbor is the North-American plate, regularly causing moderate size earthquakes at the bottom of the sea. The situation is more interesting in Iceland, where a hot spot on the plate boundary is creating an island and a complex zone of both tectonic and volcanic events. Iceland is not the only place where volcanic activity is present in Europe: Mount Etna and Mount Vesuvius are prime examples of this phenomenon.



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### Italy, Switzerland, Austria, Slovenia, Germany, France – Adriatic microplate

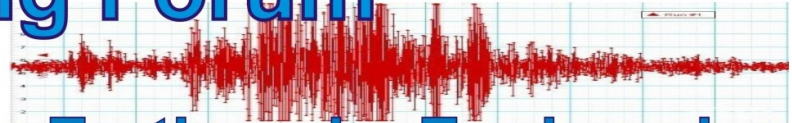
West of the Africa-Europe subduction zone is the Adria microplate, broadly occupying the area of Italy. This plate was previously a piece of Africa, and it has been pushed by Africa into Europe, causing the rise of the entire Alps. A well-known piece of Adria is the summit of Matterhorn. The Alps are a short but very complex mountain range, with a broadly distributed earthquake activity in Italy, France, Switzerland, Germany, Austria and Slovenia. The largest known Alpine event is a historical earthquake in 1348 with a Magnitude of 7, located on the border between Italy and Austria, near Villach. The well-known Basel earthquake of 1356 (Magnitude 6.6) is particular because it is located at the junction of the Alpine realm and the Rhine Graben. The country related to the Adria plate with the highest hazard is Italy, not because of the Alps but because of the Apennines spanning all along the peninsula.



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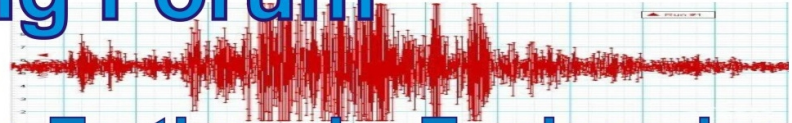
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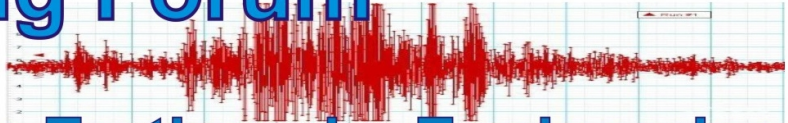
## Hungary, Slovakia, Ukraine, most of Balkan peninsula – Pannonian Basin and surrounding mountains

East of the Alps is a region with several small microplates and mountain ranges: The Pannonian Basin, the Carpathians to its North and East (Slovakia, Ukraine, Romania) and the Dinarides to its South (most of the Balkan Peninsula, all countries from Slovenia to Greece and Turkey). The movement of these plates has slowed down and the mountain ranges are moderately active today, except for the Southeastern corner of the Carpathians. This is known as the Vrancea zone, in Romania, where the last piece of lithosphere, which has not had place on the surface, is sinking to depth. In the 20th century there were four large earthquakes (Magnitude larger than 7) there, the latest in 1977. These put the city of Bucharest at risk and may cause tsunami on the Black Sea.



## Spain and Portugal – Iberian microplate

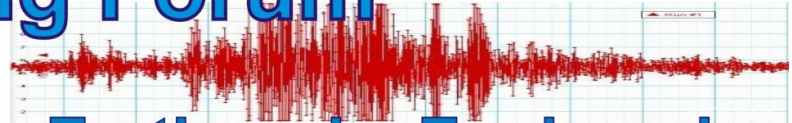
At the western end of the Mediterranean Sea the Iberia microplate is broadly occupying the area of Spain and Portugal. This plate has also collided with Europe, causing the rise of the Pyrenees. Current earthquake activity is in the Pyrenees and in the southern edge of the Iberia microplate, near Africa. The well-known tsunami, which hit Lisbon in 1755, was likely an earthquake offshore Europe in the Atlantic Ocean.



## General aspects

Earthquakes in Europe also occur in regions that are far from today's tectonic boundaries, such as in Germany, the Czech Republic and United Kingdom. These events are primarily caused by remnant stresses from the geologic history. Some of them can be associated to moving fluids in the Earth's crust, either naturally or artificially – man made e.g. fracking.

Seismic hazard maps based on computations on the probability of earthquakes happening in different areas of Europe maps must be regularly updated based on new methods that reflect the latest earthquake catalogues and recorded data. The current map highlights how seismic hazard should be an important consideration in the everyday life of many Europeans.



## Impacts of earthquakes on:

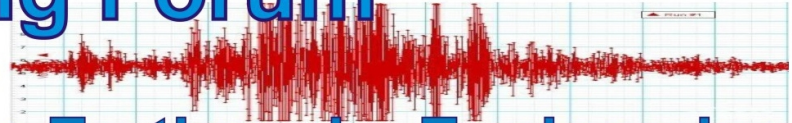
- Building environment - housing
- Infrastructure – bridges, railways, roads
- **Geotechnics**
- Other natural hazards

- **Geotechnics**

- Liquefaction
- Compaction
- Collapse of soil structures
- Slope slides
- Collapse of rock structures
- Rockfall

- **Natural hazards**

- Tsunamis
- Avalanches
- Icefall

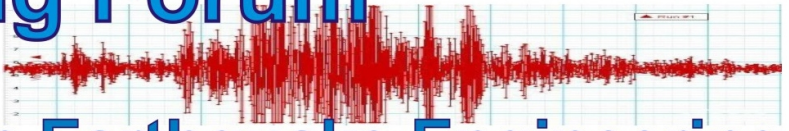


## liquefaction

Liquefaction is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking or other rapid loading. ...

Liquefaction occurs in saturated soils, that is, soils in which the space between individual particles is completely filled with water – this can be sand, sandy gravel, gravels





## compaction

soil compaction is the process in which stress applied to a soil causes densification as air is displaced from the pores ...

- Causing decrease of permeability

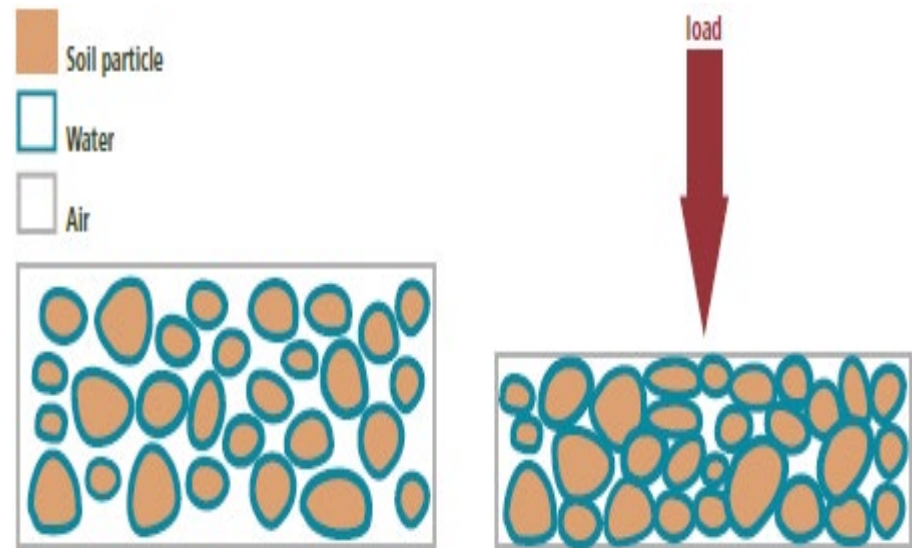
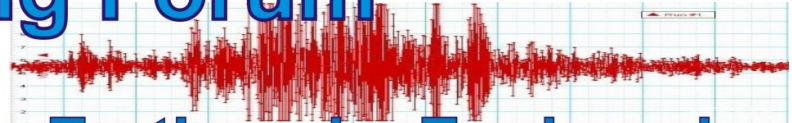


Figure 1. Soil compaction as the result of an applied force.



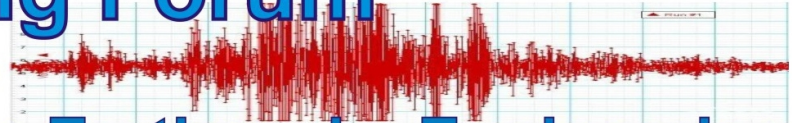
## Slope slides

As a result of earthquakes slope slides occur frequently induced by

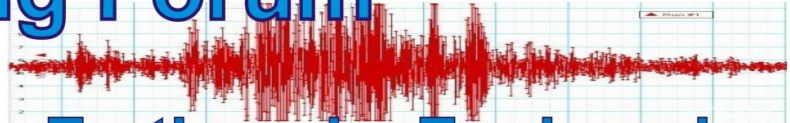
- permeability changes of subsoil
- Collapse of soil structure
- Collapse of retaining structures



Slope-slide in South-Kirgistan: 26.04.2004. slide devastated a village on the opposite river bank (picture by: GFZ/Sekt. 1.4)



A landslide caused by a strong earthquake covers a circuit course in Nihonmatsu city, Fukushima prefecture, northeastern Japan, Sunday, Feb. 14, 2021. The strong earthquake shook the quake-prone areas of Fukushima and Miyagi prefectures late Saturday, setting off landslides and causing power blackouts for thousands of people. (Hironori Asakawa/Kyodo News via AP)



- Questions:

Can all earthquakes trigger ground movements?

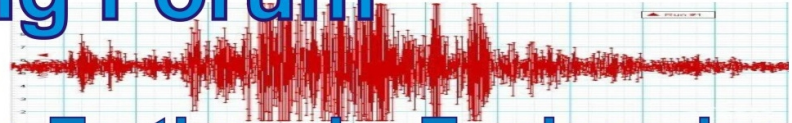
*Kefer* identified and analyzed all the ground movements triggered by earthquakes around the world between 1811 and 1980. He was thus able to define correlations between the characteristics of earthquakes that generate ground movements and those of induced ground movements:



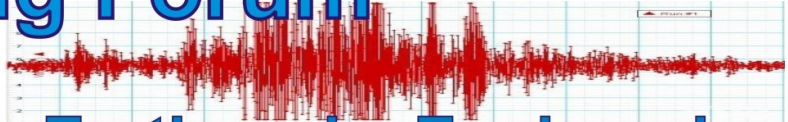
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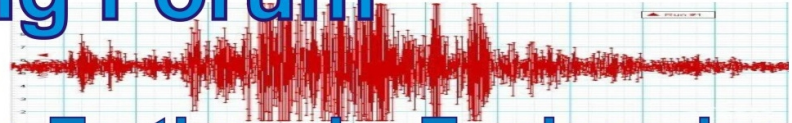


- 1st observation: **Most instabilities are triggered by earthquakes of moderate to high magnitude , typically greater than 5.** However, this notion of “minimum magnitude” or magnitude threshold should be considered with caution because it does not take into account the state of stability of the slope before the earthquake. This state, often poorly known, is the result of the entire history of “loading” (earthquakes, heavy rainfall).
- 2nd observation: **most of these ground movements do not occur beyond a certain distance from the source of the earthquake, which depends on the magnitude of the earthquake in question.** The higher the magnitude of an earthquake, the more likely it is to trigger ground movements at a long distance from the epicentre .



## Result:

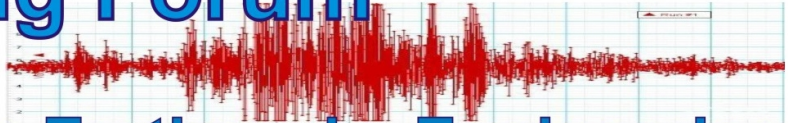
Earthquakes generally trigger superficial ground movements. However, the volume of instability can sometimes reach several million m<sup>3</sup>, as was the case during the earthquake of 31 May 1970 in Peru: the rock avalanche of Nevado Huascarán, with an estimated volume of 50 million cubic meters of rock, ice and snow, covered an exceptional distance of more than 16.5 km, at an estimated speed of 210-280 km/h. This rocky avalanche killed 20,000 people in the villages of Ranrahirca and Yungay in the valley.



The “intensity” of earthquake-initiated ground movements can be characterized by:

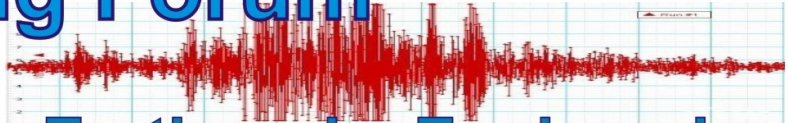
- The volume of materials moved by the movement;
- the mobility of these materials during movement;
- the area covered by the materials after the movement has stopped.

Keefer’s (1984) work has shown that this “intensity” depends on the magnitude of the earthquake under consideration: the higher the magnitude of the earthquake, the greater the “intensity” of the ground movements it may trigger.



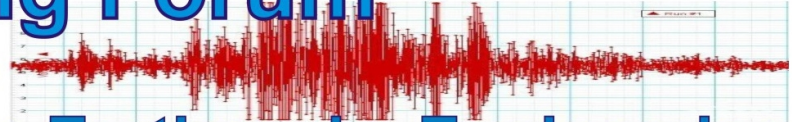
Some earthquakes can even reactivate old ground movements, as was the case during the earthquake of January 12, 2010 in Haiti: this earthquake triggered about 4500 ground movements up to a distance of 46 km from the epicenter. Of the 1273 landslides recorded as active before the 2010 earthquake, 572 were reactivated by the 2010 earthquake.

- Earthquake-initiated ground movements can have two types of effects:
- **direct effects:** deaths resulting from the burial of buildings or the crushing of vehicles by debris from ground movements, damage / destruction of buildings, communication networks, etc.
- **indirect effects:** the degradation or obstruction of roads by debris from ground movements can hinder the delivery of aid to victims or their evacuation to health centres.
- Sometimes debris from ground movements blocks the bed of rivers and **forms natural dams.**

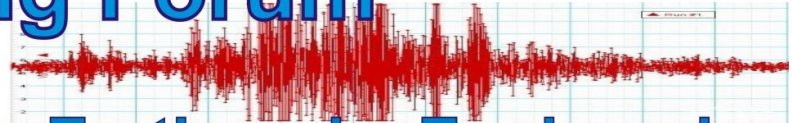


## Impact on rock

- Collapse of rock structures in karst
- Rockfall due to release of binding structure
- Rockfall along infrastructure – rail and road due to failure of retaining structures or unsecured rockslopes



- Collapse in karst cause
  - settlements
  - Slumps
  - Collapse of infrastructure and retaining structures
- Release of bindings in rock structures cause:
  - Mass movements
  - Rock avalanches
  - Rock slides



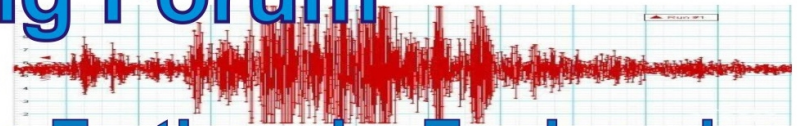
- In mountainous areas infrastructure is often built in a poor way – unsecured cuttings, etc.
- External stress or other influence leads to collapse and mass movements

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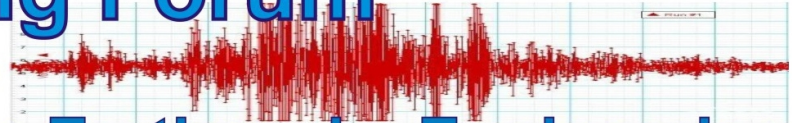
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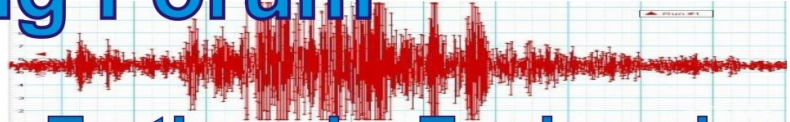
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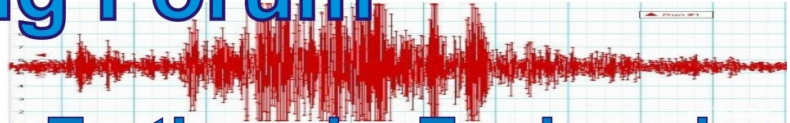
Rockfall after earthquake in NZ summit road, Port Hills February 2011



Rockfall Karakorum Highway – unsecured rockcuttings

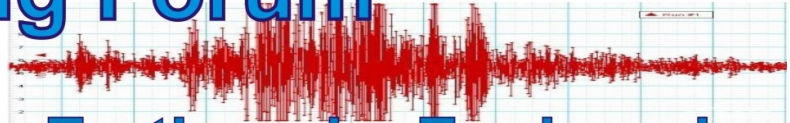


- Earthquakes have an impact on geotechnics:
  - Direct – deaths through burial by rockfall or crushing vehicles, destruction of infrastructure
  - Indirect – obstruction of infrastructure hinders delivery of aid or evacuation



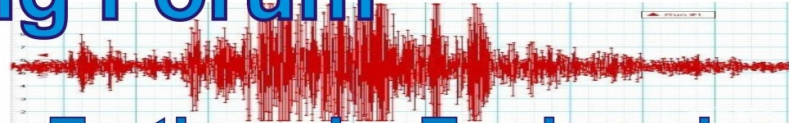
- Messages to remember - 1

Earthquakes with a magnitude greater than 5 are likely to trigger ground movements that can be responsible for a significant proportion of the victims and the damage associated with earthquakes.



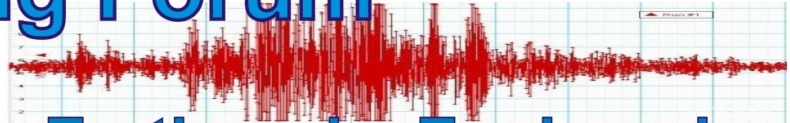
- Messages to remember - 2

Slopes have a low stability – mostly limit equilibrium -, which can be influenced by external influences and in particular by earthquakes causing huge mass movements.



- Messages to remember - 3

There is a wide variety of ground movements triggered by earthquakes and these phenomena are generally very complex.



- **Messages to remember - 4**

Reducing the risk posed by this type of hazard requires a better understanding of the mechanisms that trigger ground movements on the one hand and the mechanisms that control the speed and distance of material propagation on the other.



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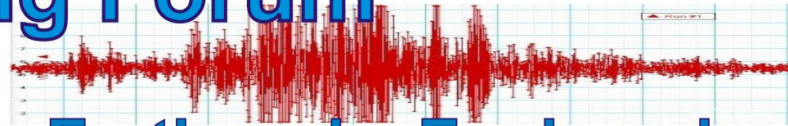
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# Thank you for listening!

Questions?