ON RELATIONSHIP BETWEEN EARTHQUAKE SOURCE DEPTHS AND DEEP GEOLOGICAL COMPOSITION OF THE TERRITORY OF ARMENIA

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ABSTRACT

Armenia is situated at one of the most active segments of the Alpine-Hymalayen seismic belt, in the zone of collision of Arabian and Eurasian plates.
Basing on numerous geological and geophysical data the petrophysical section and mechanism of ophiolite structures formation are presented where the protrusive intrusion of serpentinized masses into upper horizons of crust is essential. Preliminary results on rock dehydration and polymorphous transformations in minerals which may trigger seismic shakings of crust.
Study of earthquake sources distribution in depth has shown that the maximum depth of earthquake hypo-centers is not exceeded 35 km and most earthquake sources in the Caucasus and Armenia are shallow ones which caused high intensity impact on the settlements. Data on petrophysical section as well as study of processes in minerals at high temperature and pressure are important for defining the physics of earthquake sources.
The relationship between the different depths of sources for strong regional (M>5.5) and local perceptible (3.5≤M≤5.5) earthquakes (source depths: 0-10km, 10-20km, 20-35km with controlling active faults as well as deep processes in the crust in the territory of Armenia is studied.
Preliminary results revealed the relationship in the system "earthquake source-active fault-protrusive intrusion of masses". The study is ultimately focused on right and in time evaluation of seismic hazard in the territory of Armenia [9, 10] and in prospect on solving the problem of earthquake prediction.

Introduction

There are different approaches to the problem of earthquake preparation and matter changes at the source area. The common view is that the earthquake reflects the rupture of media continuity either in the form of splitter on shift deformation (without significant change of volume), or directly on the account of volume change (increasing or decreasing). Such problem could be studied in detail using petrophisical sections and crust evolution models for concrete region. Such model for Lesser Caucasus was presented by the authors [1, 2, 5 and 6] on the basis of numerous geological and geophysical data and results of research at high temperature and pressure (Fig. 1). Geological and geophysical data revealed the crust capacity for Lesser Caucasus as 50±2km. The high plastic, low density, low speed and high conductivity layer consisted of serpentinites and in different scale serpentinized ultrabazites and amphibolites is located at the toe of crust (35-50km). The high speed layer of gabbro and gabbro-norites is located higher at the depth of 22-35km. The medium composition rocks namely gabbro-diorites are located above the gabbro layer. Further above is granite layer of metamorphized complex of Pre-Cambrian and Lower Paleozoic, and still further are sedimentary-volcanogenic formations of Mesozoic and Cenozoic.

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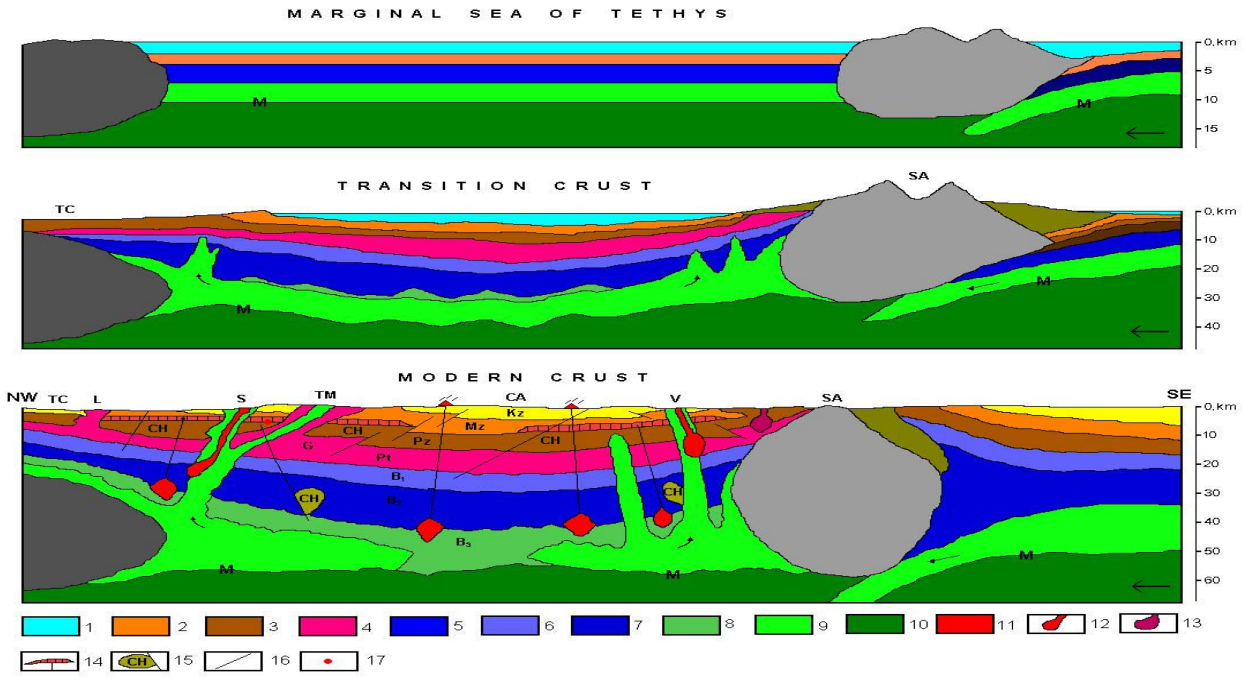

Figure 1. Structure, composition and evolution of the crust in the territory of Armenia [1]

1-water; 2-sedimentary layer; 3- weakly meta-morphized complex of the sedimentary layers; 4- meta-morphized complex of Pre-Cambrian and Lower Paleozoic (granite layer-G); 5- volcanogenic layer; 6-gabbro-diorite layer (B1); 7- gabbro layer (B2); 8- amphibolite and serpentine layer (B3); 9- serpentinized layer; 10- ultra-basites (upper mantle); 11- volcanic apparatus; 12- collision volcanites of ophiolites; 13-granite intrusion; 14- cover structures; 15- domain structures of hydrocarbons; 16- faults; 17- hypocenter of the Spitak 1988 Earthquake; TC- microplate of Southern Caucasus, L - Lock's massiv, S- Sevan ophiolite zone, TM-Tsaghkunyats massiv, CA- Central Armenian microplate, V- Vedi ophiolite zone, SA- South-Armenian microplate.

1. On rock dehydration and polymorphous transformations in minerals at high termobaric conditions

Geo-dynamic processes in the Earth's interior are connected, in particular with the processes occurred in different types of rocks in deep conditions. The experimental modeling of thermobaric conditions of deep zones of the Earth is provided to define the physics of those processes. The results of preliminary research for different rock types of Lesser Caucasus have been published [3, 4, 7].

As to the provided section of structure and composition of crust for Armenia (Fig. 1) the dehydration of serpentinized layer laid beneath the crust had permanently occurred during the geological era due to change of thermobaric conditions. The amphibolization of lower parts of gabbro occurred at high thermobaric conditions due to fusion of water vapor. The above results revealed that the processes in rocks are accompanied with dehydration of minerals and new mineral formation. The processes are accompanied with drastic change of seismic waves and volumes up to 30%.

Experiments have shown that some minerals undergone polymorphous transformations accompanied with phase change and drastic change of rock volume [7]. Attempt made explain the disdensification of carbonate rocks at the pressure up to 20kb. As to the authors the mineral calcite of carbonate rocks played the role of diffusive water in higher horizons of crust at great depths. Polymorphous transformation of the calcite is accompanied with phase change. The plastic calcite of metamorphous rocks at the depth of 10-20km poured into the cracks to expand and diversify them.

The process described cause some general effects similar to those of the process of dilatancy. In real conditions the effects obtained in laboratory would display more profoundly and in greater scale, and in specific conditions may be the reason triggering seismic shaking.
Therefore, the dehydration and polymorphous transformations may cause the geo-dynamic processes at different depths of crust, and so the seismic shakings of different magnitude may be caused by mentioned processes.

2. Earthquake source depth according seismological data

The preciseness of earthquake epicenter and hypo-center coordinates definition is equaled to ±3km. The geological model of the crust in the zone of seismic hazard in Armenia has the mosaic-blocked structure consisted of differently directed faults. The principal elements are the active blocks with bounding active faults. The most hazardous are the junctions of those faults.
According to seismological data [8] the earthquake sources in depth within Lesser Caucasus may be divided into three groups (Fig. 2).

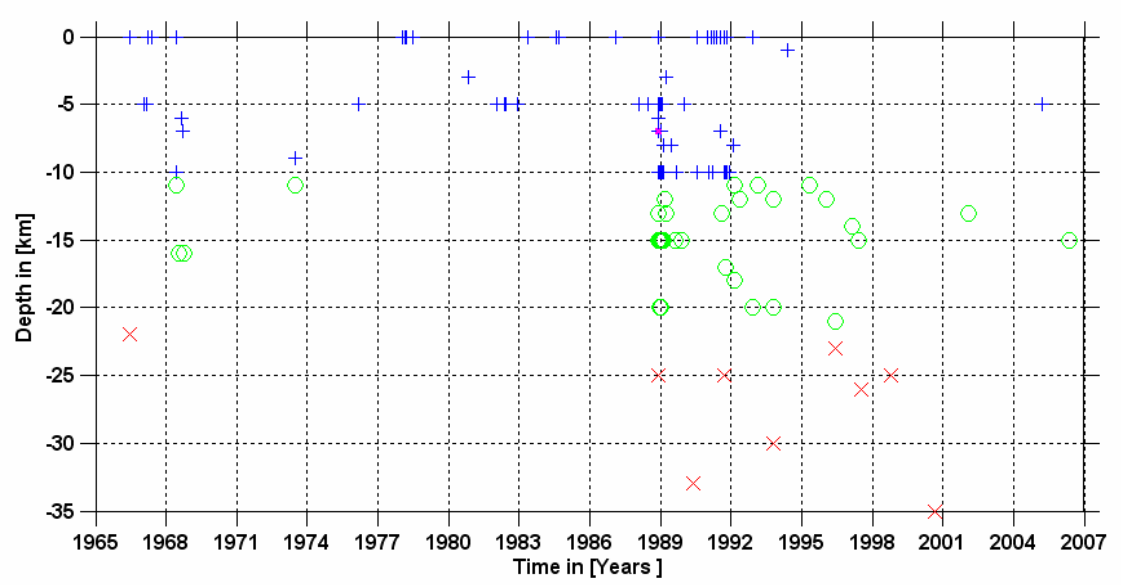

Figure 2. Earthquake sources in depth distribution in the crust for the territory of Armenia in 1965-2007 (M>3.5, 161 events)

According to the petrophysical section provided above the earthquake sources located at the depth of 0-10km are corresponding to volcano-sedimentary layer of Mesozoic and Cenozoic age (67 sources); 10-20km - metamorphous (granite) layer of Pre-Cambrian and Lower Paleozoic age (79 sources); 20-35km - relatively rigid gabbro and gabbro-diorite layer (only 15 sources). Lower than 35km the plastic, relatively low density serpentinites, and serpentinized ultra-basites and amphibolites are located and no earthquakes were recorded.

3. Results of comparative data analysis

The earthquakes of different magnitude adjourn to the different zones of seismic hazard.
Reviewing the earthquake epicenter map in the territory of Armenia it may be noted that the earthquakes (M≥3) with different depths of sources (0-35km) are observed only in the northern-west region of Armenia in the area of Sevan ophiolite belt at the junction of five well-known active faults in the territory of Armenia (Fig. 3).

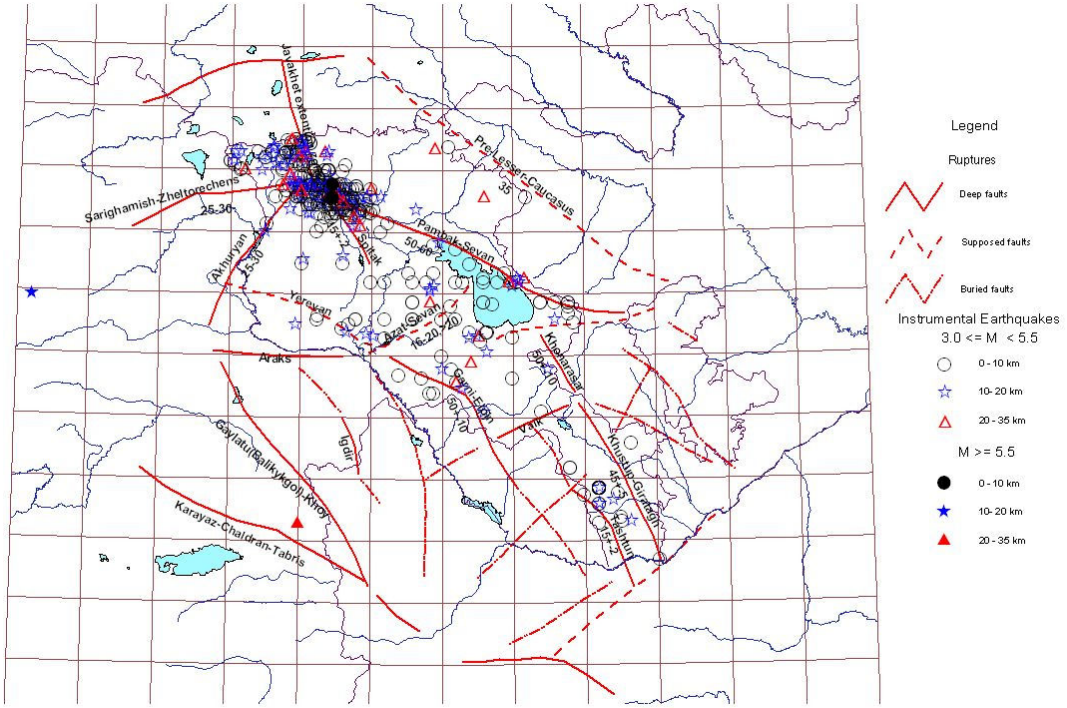

Figure 3. The earthquake epicenters in the territory of Armenia in 1965-2007

Source concentration at this junction may be caused by any reason including protrusive intrusion of high plastic, low density serpentinized masses as well as in depth dehydration of those rocks. Fault depth at this area reached to 50km. Lack of earthquake sources in the interval of 35-50km stipulated by the plastic condition of those rocks. The seismic activity was not observed at another Vedi ophiolite belt in 1965-2007 due to low tectonic activity.

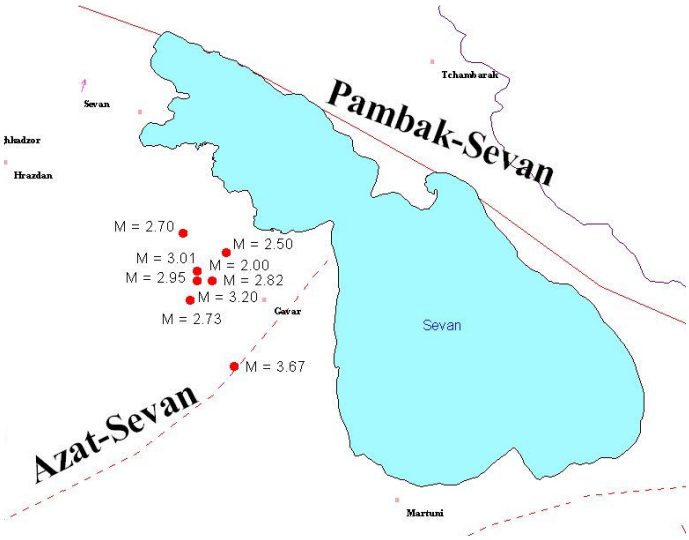

Figure 4. The epicenters of earthquakes occurred in the territory of Armenia on January 12-13, 2007

The earthquake sources ($3.0 \leq M \geq 5.5$) located at the depth up to 20km are observed in other regions of Armenia especially in the central trough. Some of those sources may be connected with polymorphous transformations in carbonate rocks of metamorphous (granite) layer and related rupture formation.
The formation of local earthquake sources and their expanding into the network of cracks in the result of mineral polymorphous transformation may be the reason of seismic shakings occurred on 12-13 January 2007 in Armenia to south-west of Lake Sevan (Fig. 4) (8 shakings, M=2.0-3.7, H=10-15km) at the zone of Azat-Sevan supposed active fault.

Conclusion

Comparing the results of research at high temperatures and pressures, and seismological data may somewhat highlight the formation of earthquake sources at deep horizons of the crust in the territory of Armenia. In ophiolite belts the earthquake sources up to depth of 35km (roof of serpentizied layer) may be caused by permanent protrusive intrusion of serpentized masses and their dehydration. In other regions of Armenia especially in the central trough the earthquake sources located at the depth of 10-20km may be triggered by polymorphous transformations in minerals. Therefore, there is the possibility of earthquake source physics definition which understanding may allow to bring nearer the solution of earthquake prediction problem.

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