RELATION BETWEEN THE COMPOSITION, STRUCTURE, EVOLUTION OF EARTH CRUST AND SEISMIC ZONATION OF THE TERRITORY OF ARMENIA

A. V. Harutyunyan [1] and H. M. Petrosyan [2]

ABSTRACT

In the last decades a numerous publications on the Lesser Caucasus seismicity had been published, and the new long-term seismic hazard map of the territory of Armenia had been compiled, and the new geological and geophysical factual data on crust deep structure had been obtained as well as the detailed geological maps by the ophiolite belts of Armenia had been compiled. The elastic and density properties of the rocks on high termobaric parameters had been investigated, based on which the numerous geological and geophysical profiles had been interpreted. The petrographic section and crust evolution were introduced.
In the article, the innovative 3-dimensional block-scheme of the crust in the territory of Armenia was presented based on the comparison of the above-mentioned and other materials was presented , and defined that the most seismically active zones are coincided with ophiolite belts. Suggestion has been made that the seismic activity is stipulated by the protrusive permanent intrusion of serpentinized masses into the upper horizons as well as dehydration of the rocks at the different depths of the ophiolite belts.
The ultimate objective of the research is the correct and in-time evaluation of the seismic hazard in the territory of Armenia [15].

Introduction

The Lesser Caucasus is located in the northern-eastern part of Anatolia -Caucasus-Iran region. The peculiar feature of the territory of Armenia is the complicated tectonic composition: availability of deep faults and ophiolite structures, volcanity and seimicity etc. Many facts regarding the tectonic structure and composition , location of deep faults, mechanism of geological structure formation, volcanity had been obtained through complex geological and geophysical investigations provided in recent years.
However, some problems concerning the crust deep structure and composition, seismicity, fluid regime and evolution of the crust, in general, remain arguing yet. Results of the geophysical research obtained through different methods were often indefinitely interpreted. Aiming at raising of interpretation exactness the seismic properties and density of the rocks have been investigated at the laboratory of experimental tectonics of the SEUA in the conditions which were modeling the termodynamic media of the deep structure of the Earth. Such investigations for different areas of the world are carried out at the labs of high temperatures and pressures in the developed countries (USA, England, Japan, Russia, Switzerland France and Germany).

1. Main features of the long-term seismic hazard map of the territory of Armenia

In 1998 the Armenian National Survey for Seismic Protection (Armenian NSSP) under the leadership of Prof. S. Balassanian, had developed the probabilistic map of general seismic zonation (scale: 1:500.000) [7, 17].
The data-set included the maps as follows: density of earthquake epicenters in time and magnitudes, parameters of earthquake sources mechanisms, isoseists of strong earthquakes, seismic violations and active faults, zones of possible earthquake, modern vertical drifts, tectonic, geological and topographic maps as well as accelerograms of strong earthquakes, unified national seismic catalogue.

---

[1] Associate professor, State Engineering University of Armenia, Yerevan City, 0009, Armenia, avhk@seua.am
[2] PhD, Armenian National Survey for Seismic Protection, Yerevan City, 0054, Armenia, hrachikp@yahoo.com

The clearing house of the knowledge included analysis of seismic regime, creation of 3-dimensional physical and geological model of the crust, and creation of the dynamic physical and geological models of the crust based on the newest materials of the modern movements of the crust using seismic, geological and geo-structural data.
The research has resulted in the map with four seismic hazard zones: a=0.2g, 0.3g, 0.4g and 0.5g (Fig. 1) with 90% probability of the value non-exceeding. Two zones of the most seismic hazard (a=0.5g) are defined.

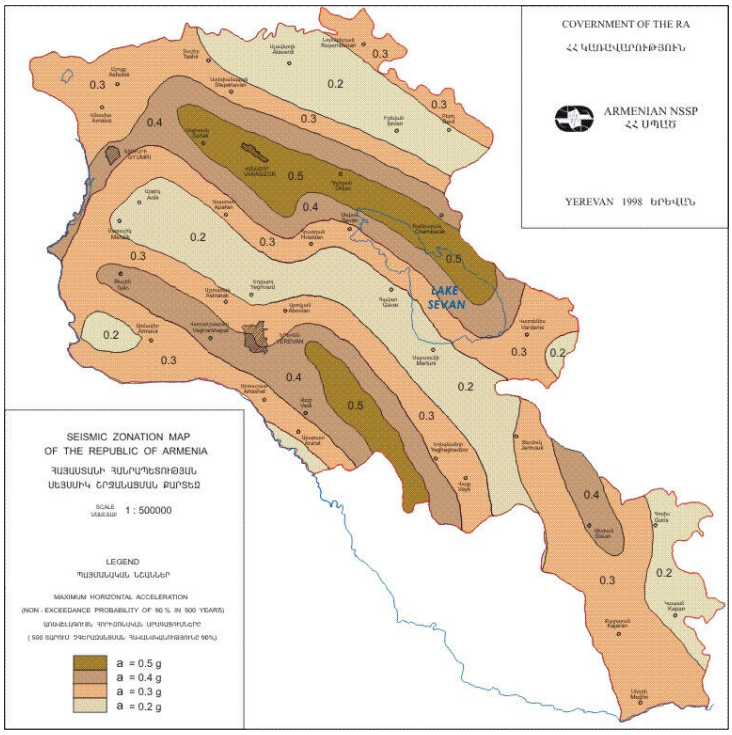

Figure 1. The long-term seismic hazard map of the territory of Armenia, compiled by the Armenian NSSP in 1998.

2. Analysis of the geological and geophysical data and research results on high temperature and pressure parameters

A vast amount of geological and geophysical research had been fulfilled in recent decades in Armenia. Most significant results of geological and geophysical research had been accounted and interpreted for developments of the authors [3-6].
The heterogeneity of the crust had been defined through seismic investigations [9, 13]: availability of high-speed (4-6km and 22-35km) and low-speed (5-13km and 35-50km) layers, lenticular low-speed and high-plastic structures had been defined rightly at the source zone of the Spitak earthquake.
The gravitation minimums at the toe of the crust had been defined in some regions of Armenia basing on gravimetric data, and the author guess that it was connected with media incompaction.
The geo-electrical section, as MTS revealed, had shown the availability of high-conductivity layer (5 Om.m) at the depths of 35-50km. It should be noted that in some zones the conductivity had decreased up to 50.000Om.m. The diapiric structure has emerged from the high-conductivity layer in the northern area of the Yerevan-city and raised from the toe of the crust up to the depths of 8-10km from the surface of the earth. High conductivity of the lower layers of the crust may be stipulated either by semi-melted condition of material or by availability of hydrated rocks.

Estimation of temperature had revealed that the geo-isothermal line of 400^0C within Hoktemberyan basin (Vedi ophiolite belt) is at the level of Moho border. The temperature of 530^0C is observed at the Moho border in Ijevan trough [11]. The temperature of 200^0C [12] is observed at the depth of 6km in the northern part of Yerevan where the diapiric structure is revealed at the depth of 8-10km. The thermal flow is absent here and so there is no semi-melted material available, and the high conductivity is stipulated by hydration of the rocks at the depths mentioned.

The availability of the lenticular low-speed and density, and high-plastic and high-conductivity structures at the toe of the crust, especially beneath the source zone of the Spitak earthquake at the depths of 35-50km is non-arguable fact.

The deep structure, composition and evolution of the crust in the territory of Armenia were provided basing on the research results of the rocks at high temperature and pressure and other geological and geophysical data [2-6] (Fig.2).

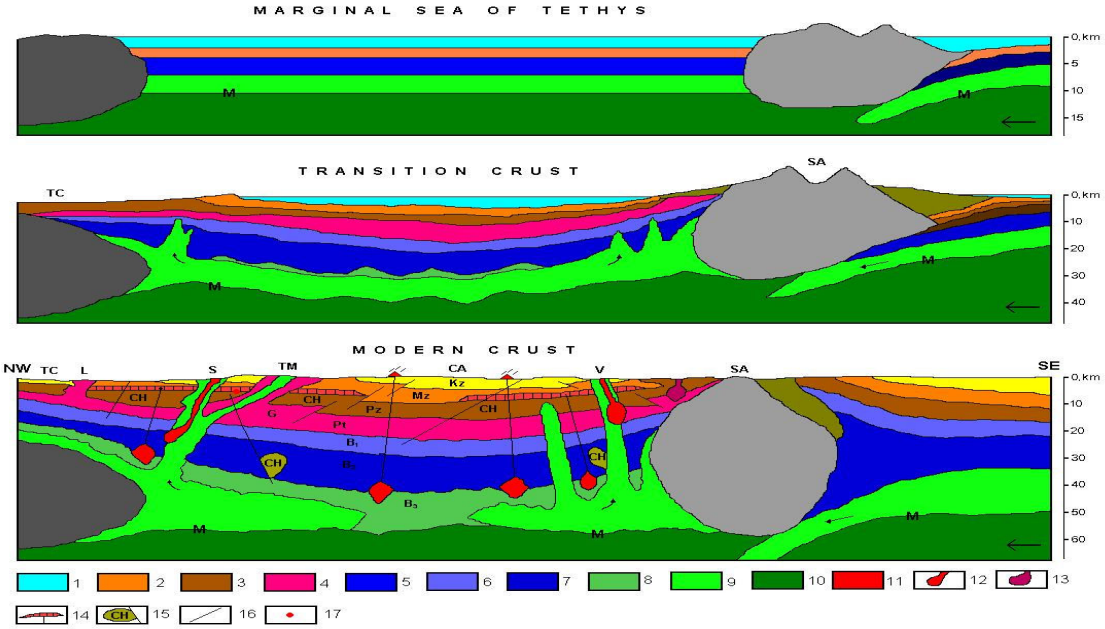

Figure 2. Structure, composition and evolution of the crust in the territory of Armenia [3]

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.

According to petrophysical section the above mentioned lenticular bodies in the toe of the crust are wholly matched the hydrated rocks such as serpentinites, serpentinized ultrabazites and amphibolites. Petrological research leaded to the conclusion that in the central Armenia andesite-bazalts are re-melted products of gabbro-amphibolites at the depths of 30-40km [8]. Up to seismic parameters the high speed gabbroide layer is appeared above the serpentinized and amphibolized layers. Relatively low speed rocks of gabbro-diorite composition are laid above gabbroide layer. Pre-Cambrian metamorphized complex is forming the granite layer above which the sidementary and volcanogenic deposits of Paleozoic, Mesozoic and Cenozoic are appeared.

3. On ophiolite structures formation mechanisms of the territory of Armenia

The principal structural elements of the crust within the territory of Armenia are appeared to be Sevan and Vedi ophiolite zones which had been studied in detail including interrelation of rocks comprising ophiolite triad, composition of melange, contact behavior of oceanic blocks of crust and containing rocks, and petrography and chemical composition, etc [1, 10, 16]. The geological maps of the ophiolite structures of different scales have been compiled (Fig.3).

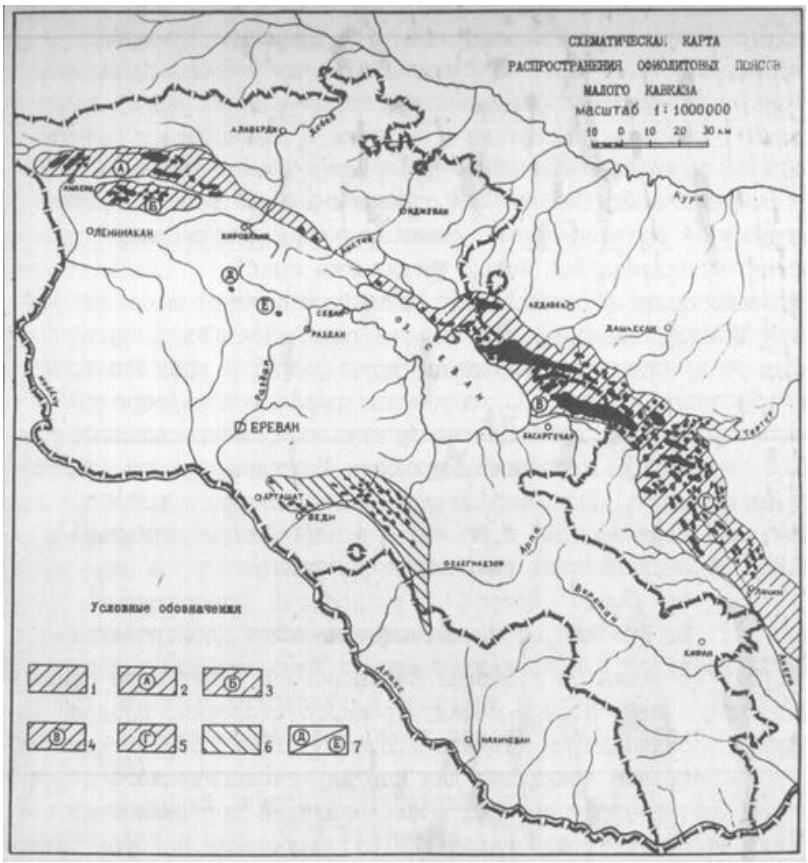

Figure 3. The schematic map of the ophiolite belts location of the territory of Armenia [1]

The problem of ophiolite zones' formation in the territory of Armenia is not yet solved in spite of extensive and long study [3, 4]. The results obtained highlighted yet some aspects of the problem. Those structures are controlled by deep faults and are appeared to be the protrusive intrusions. The petrophysical section and evolution of the crust in the territory of Armenia provided it is evident that the low density, high plastic serpentinized layer located at the toe of the crust is crucial for the formation of the ophiolite zones. Those rocks had been protrusively intruding into upper horizons of the crust along the deep ruptures involving the blocks of different sizes from the layers laid above. The volcanites are the secant bodies in the ophiolite belts presented by rocks of alkaline medium and rarely acid composition.

4. The results of comparative analysis of the materials

Comparing the maps of seismic zonation and location of the ophiolite belts, and petrography the innovative block diagram of the crust of the territory of Armenia has been created (Fig.4).

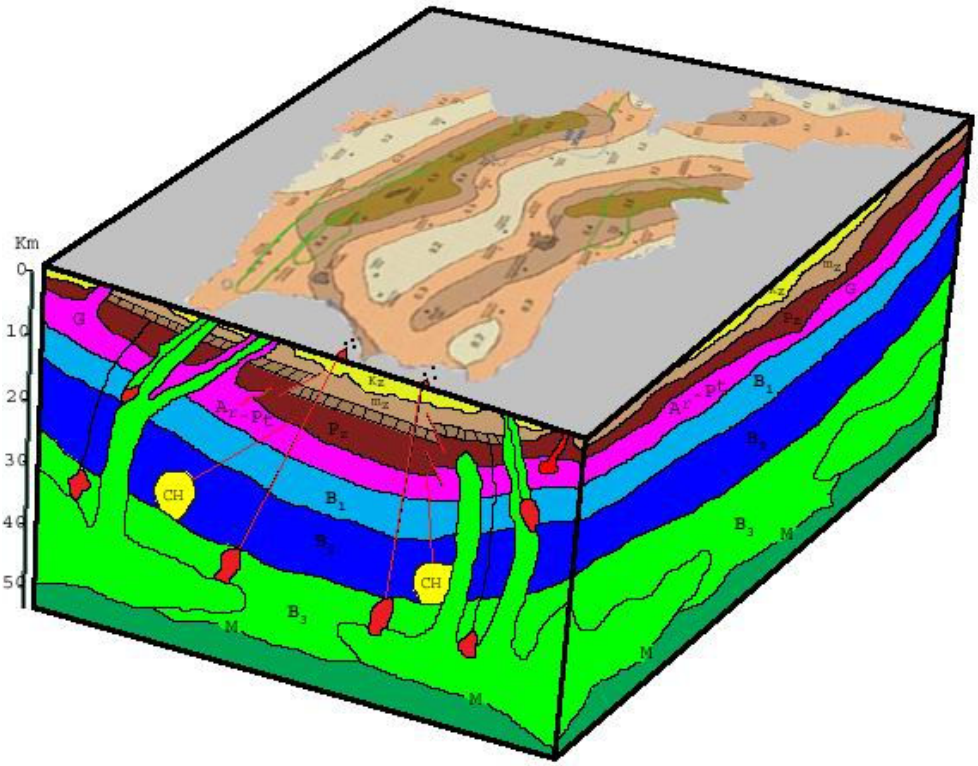

Figure 4. **Block diagram of the crust of the territory of Armenia**

The full coincidence of both most seismic hazardous zones and both ophiolite zones is noted. As to interrelation of the deep processes and seismicity the following should be mentioned:
1. The zones of the highest seismicity (a=0.4-0.5g) are coincided with the zones of ophiolite structures and deep faults whereas the comparatively low seismicity (a=0.2-0.3g) is noted in other regions including volcanogenic central trough of Armenia.
2. According to the model of crust evolution the ophiolite structures are formed due to permanent protrusive intrusion of serpentinized masses from the toe of the crust (35-50km) into upper horizons. It is natural to assume that the permanent intrusion of serpentinized massess through fault zones has drastically occurred accompanying with seismic shakings.
3. The process of protrusive intrusion of serpeninized masses encourage the development of deep faults and is accompanying with them.
4. Uneven distribution of the deep tectonic strengths within ophiolite structures may cause the dehydration of serpentinized masses and amphibolites and formation of magmatic and seismic sources. The dehydration is accompanying with the release of the energy and drastic change of the size of the rocks (up to 30%). Those processes may be accompanied with seismic shakings.

Conclusion

Comparing the results of research fulfilled in last decades in three directions: deep structure, ophiolites and seismic zonation one could admit that the main reason of seismic processes may be the protrusive intrusion of serpentinized masses into upper horizons of the crust. The process of dehydration of serpentinized masses may accompany the general process of seismigenic phenomena. It may be assumed that those processes permanently occur nowadays as well.

Acknowledgement

The authors are sincerely grateful to Ms Armenuhi Abrahamyan and Ms Lilit Sargsyan from the Armenian NSSP and Mr Sargis Grigoryan and Mr Enok Abazyan, post-graduates of SEUA for assistance in preparing the materials and compiling of the article.

References

1. Abovyan S.V., 1981, *Maphite and ultra maphite intrusive complexes of the ophiolite belts of Armenian SSR,* AS publishers, Yerevan (in Russian).
2. Harutyunyan A.V.,1975, Research on elastic properties and density of basites and ultra basites of the ophiolite belts of Armenia on high pressure (up to 20Kb), *dissertation for PhD,* USSR AS, Institute of Physics of the Earth, Moscow (in Russian).
3. Harutyunyan A.V., 1992, On petrography section of upper lithosphere of the territory of Armenia*, Annali of AS of Armenia*, 92, N4 (in Russian).
4. Harutyunyan A.V., 1998, On structure and composition of the crust of Lesser Caucasus and formation of deep ophiolite underthrusts, *Geology and Prospecting, Annali of HEI*, N2, Russian Federation, (in Russian).
5. Aslanyan A.T., Volarovich M. P., Harutyunyan A.V., Levikin A.I., 1975, On structure, composition and plastic characteristics of the crust and upper mantle in the territory of Armenia, *Annali of AS of Armenian SSR*, 61, N3 (in Russian).
6. Aslanyan A.T., Harutyunyan A.V., 1988, On the problem of deep structure of the ophiolite zones of the Lesser Caucasus, *Annali of HEI, Armenian SSR, Earth Sciences*, N5 (in Russian).
7. Balassanian S.Yu., Nazaretyan S.N., Amirbekyan V.S., 2004, *Seismic protection and its organization,* Eldorado Publishers, Gyumri (in Russian).
8. Genshaft Yu.S. et al,1982, Ksenolites and magacrystals in the lava of the Gegam upland (Armenia), *Physical and chemical investigations of deep magmatic products,* Nauka publishera, Moscow (in Russian)
9. Goritovskaya I.V., Study of deep structure of Armenia through nearby earthquakes recorded by the Zemlya stations, *Geological fields and seismicity*, Nauka publishers, Moscow (in Russian)
10. Knipper A.L., 1975, *Oceanic crust and the structure of Alpine folded region*, Nauka, Moscow (in Russian)
11. Mirijanyan R.T., 1979, Prognostic evaluation of the temperature in deep crust layers in the territory of the Armenian SSR, *Annali of AS of Armenian SSR, Series Earth Sciences* (in Russian)
12. Mirijanyan R.T., Vardanyan K.S. 1985, Rock temperature change in depth in the territory of the Armenian SSR, *Annali of AS of Armenian SSR, Series Earth Sciences* (in Russian)
13. Mikhaltsev A.V., et al. 1990, Deep geophysical research in seismically hazardous zones, *Earth interior prospecting and preservation* (in Russian)
14. Hovhanisyan Sh. S., 1977, Crust structure of the territory of Armenia, *Annali of AS of Armenian SSR, Series Earth Sciences* (in Russian)
15. Petrosyan H. 2004, *Testing and prediction of earthquakes*, 157pp
16. Satian M.A., 1984*, Ophiolite troughs of Mezotetis*, Armenian SSR AS publishers, Yerevan
17. Balassanian S., 1999, Seismic Hazard assessment for the Caucasus test area, *Annali di Geofisica*, 42, N6.