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PRELIMINARY DATA ABOUT THE ASTHENOSPHERE STRUCTURE IN BULGARIA

Dimcho Josifov, Boyko Ranguelov, Emil Oynakov (BG)

ABSTRACT

A deep asthenosphere structure is investigated by the methods of passive seismic method. As a probe signal, the microseismic noise is used. The microseismic background is composed from different surface waves of Raleigh, generated by different sources. The noise has a wide spectrum, thus providing the different depth's penetration. The broadband seismic records of the sparsely distributed seismic stations on the Balkans provide the reliable information for the Method of Microseisms Sounding (MMS). The application of the method reviles the velocity inhomogeneities responsible for the low and high velocity layers under crust, interpreted as asthenosphere (low velocity bodies) and possible non transparent diffuse areas (high velocity bodies), isolating the crust from the asthenosphere more mobile strata. The maps of the asthenospehre depths and thicknesses are presented.

INTRODUCTION

During the last years the research interest to the vertical and lateral inhomogeneities in the deeper earth's interior increased dramatically. Most of the geodynamic features are related to the under crust located low seismic velocity layers called with the general word "asthenosphere". As an origin of deep fluids, movable substrate and fast changing surface this medium varied in the depths of 60-100 km to the 500-600 km, mostly developed in the interval of 100 to 300 km. The main reason this depth interval to be constructed of partially melted strata is the P-T relationship. The possible high temperature for some deep formed rocks higher then the melting point for them even at this higher pressure is the main reason to the existence of the .asthenosphere. High temperatures, high conductivity, low velocity of the S-waves and the large variations of the upper boundary of this layer (under continents and oceans) are the main geophysical characteristics of the asthenosphere.
Using the methods of so called "passive seismics" - such method of the microseismic noise sounding (called MSS) apply the microseismic noise as a probing signal. This method was performed and well explored to study deep structure of some seismogenic zones. The high effectiveness of the method (related mainly with the exploitation of the existing digital broadband seismic stations) and relatively good resolution in vertical and horizontal domain permit to use the method for the research and investigation of the low velocity layers and bodies at the depths of Bulgaria. The low velocity layers and bodies are interpreting as representative for the asthenosphere. The lower boundary of these inhomogeneities is not always possible for stable outlining due to the relatively low efficiency of the method at higher depths of 300 km, but the obtained results are enough correct to give the representative picture of the tendencies and trends of asthenosphere behavior. .

THEORETICAL FUNDAMENTAL

The method of Micro Seismic Sounding (MSS) is based on the inversion of the amplitude-frequency domain of the microseismic noise to depths. [А.Горбатиков. 2006]. The main assumption is that the vertical component of the low frequency part of the noise amplitudes is determined by the fundamental modes of the Raleigh waves representing the main part of the seismic noise. The method is based on the suggestion that the inhomogeneities in the earth crust and upper mantle change the spectrum of the low frequency seismic noise as follows:
The spectral amplitudes of a fixed frequency f decrease over high seismic waves velocity zones and vice versa – they increased over low seismic velocity zones. Thus the low velocity layers and bodies can be determined in the 3D space domain.
The technology of measuring and processing provide [8]:
1. Consistent measurements of statistical sustainable microseismic spectra at all points of the network or profile. Reaching statistical sustainability micro seismic signal accumulated over the experimentally determined time-interval of stationary signal is equal to 1-2 hours.
2. Building on the map or profile of distribution of the amplitudes of each frequency in the spectrum.
3. Calculation of the received maps or accounts to the appropriate depth, proceeding from the relationship:

$$H(f) = k_G \lambda_R(f) = k_G \frac{c_R(f)}{f} \quad (1)$$

where *H(f)* - the depth of the layer of which is being built image, λ_R- wavelength of the fundamental Raleigh mode, f - frequency in the spectrum of the micro-seismic signal for which calculations is made, c_R - phase velocity of the fundamental mode wave of Raleigh respective frequency *f*, k_G - coefficient of the depth attached to the attenuation experimentaly estimated in the range 0.4-0.5.
The processing and construction of the image consists of the following procedure. For each frequency f in the obtained spectrum a spatial curve (or map) is plotted. The distribution of the variation of the intensity of the micro-seismic signal is indicative for the inhomogenities modified the amplitude-frequency spectrum. The obtained curves (in 2D) and/or map (in 3D) are attached to depth. Based on the obtained profile curves plotted to the horizontal axis of the coordinates and the vertical axis – the depths corresponding to the profile or map. [А.Горбатиков. 2008.]
The horizontal resolution of the method is about 4% of the wave length and about 8% determination of the depth – respective /vertical resolution of the investigated anomalous inhomogeneous body. The vertical resolution thus can reach 15-16%. All established resolution are due to the previous experimental works and can change according the conditions of the strata. [E. Oynakov. 2016.], [E. Ойнаков, Б.Рангелов 2015], etc.
The frequency f is related to the depth of the inhomogeneous body *H* and the velocity of the fundamental mode of the Raleigh wave $V_r(f)$ by the relationship [А.Горбатиков. 2008].

$$H = 0.5\ V_r(f)/f. \quad (2)$$

As a result of the application of this method the velocity contrast of the seismic waves is the main parameter obtained in 2D and 3D views of the deep Earth's interior structures. For easier visualization the attenuation in the amplitude-frequency domain is presented in dB.

ORIGIN OF THE ASTHENOSPHERE

The asthenosphere is the most dynamic part of the upper mantle providing forces and material of the geodynamic machine of the Earth. The seismologists obtain data about a low velocity layer

investigation the travel times of the seismic waves (in particular the S-waves). Later the geologists and geophysicists obtain the reason for such behavior and since these times the interest to the depth and time development of the asthenosphere has an increasing interest. The main reason of the existence of the asthenosphere is the P-T relationships for some deep originated rocks which have melting point above pressure crystallization – Fig.1.

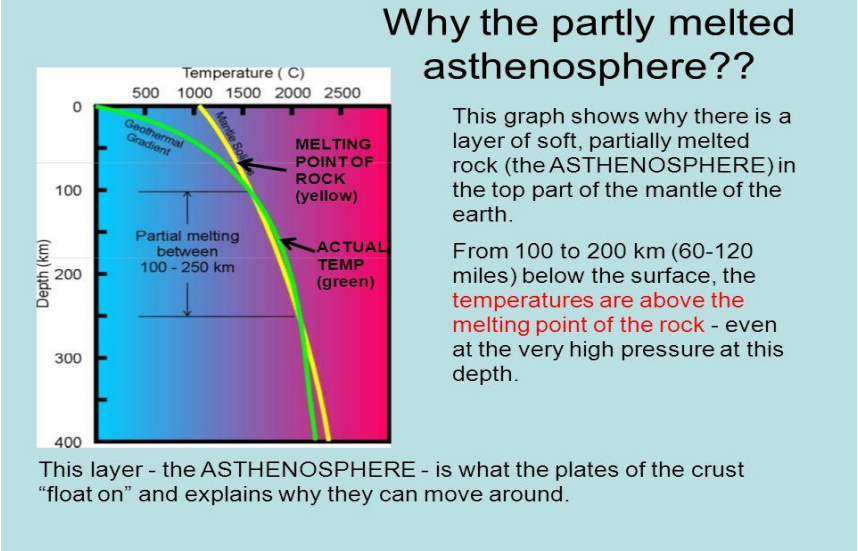

Fig.1. The explanation of the asthenosphere origin.

It is important to mention that under the ocean bottom the asthenosphere has low depth of the upper boundary and is thicker then under the continents, where the low velocity layer is located deeper and has lower thickness [Ringwood A., 1970]. This is easy explainable having in mind the Erath crust has larger thickness in the continents and thinner in the oceans. The fluids (partially melting rocks) saturated asthenosphere appeared as a good stratum for the continental movements, easy explains the subduction process, volcanism and deep magmatism.

EQUIPMENT NETWORK

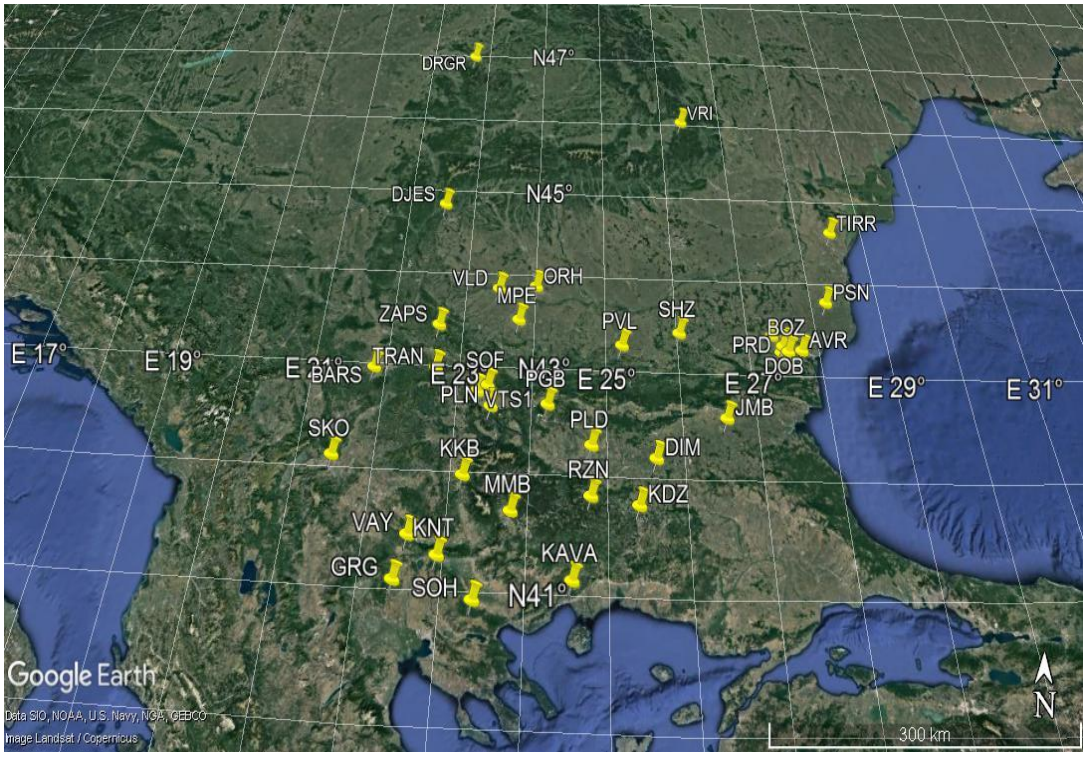

Fig.2. Map of the seismic stations locations used in this study

An important factor providing high resolution of the MMS is the density of the broadband seismic stations registering the microseismic noise. The higher density provides best resolution both – at shallow and deeper horizons. The presented map compromises the density with the availability – Fig.2. The intermediate information is inferred by interpolation and extrapolation of the results obtained after the attenuation is calculated. The average distance of less then 50 km is considered satisfactory. [Емил Ойнаков, Бойко Рангелов, 2016] The time interval for the records is selected to be 1 hour during the night (low artificial noise) The basic station is PSN (Preselenci).

HIGH AND LOW VELOCITY LAYERS IN BULGARIA

As a result of the performed methodology and used equipment the deep structure interpreted as preliminary data about the asthenosphere position obtained by the MMS is presented at different levels of signal frequency-amplitude attenuation in dB (respective depths) in 3D diagrams used for better visualization (Figures: 3; 4; 5).

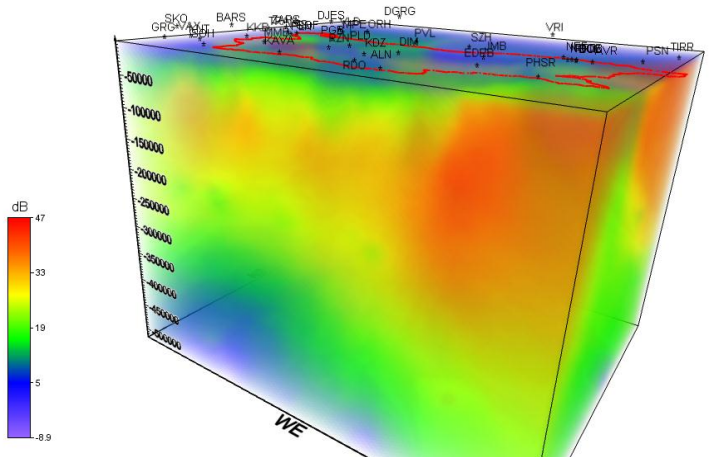

Fig.3 Deep 3D view of the low velocity (warm colors) and high velocity (colder colors) structures according the depth. (view from SE)

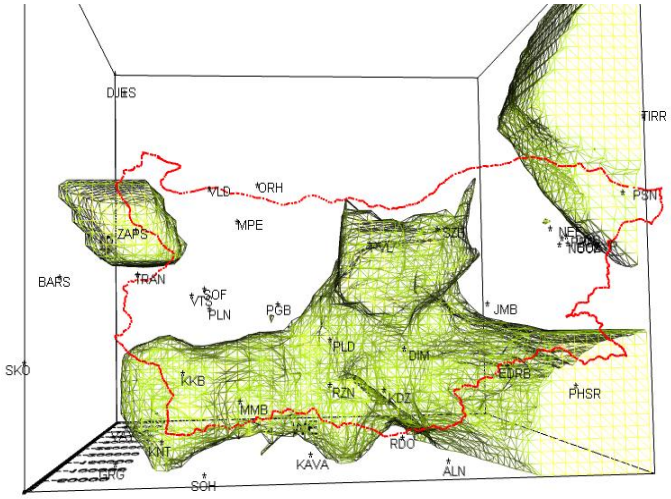

Fig.4 Projection on the earth surface of the low velocity layers

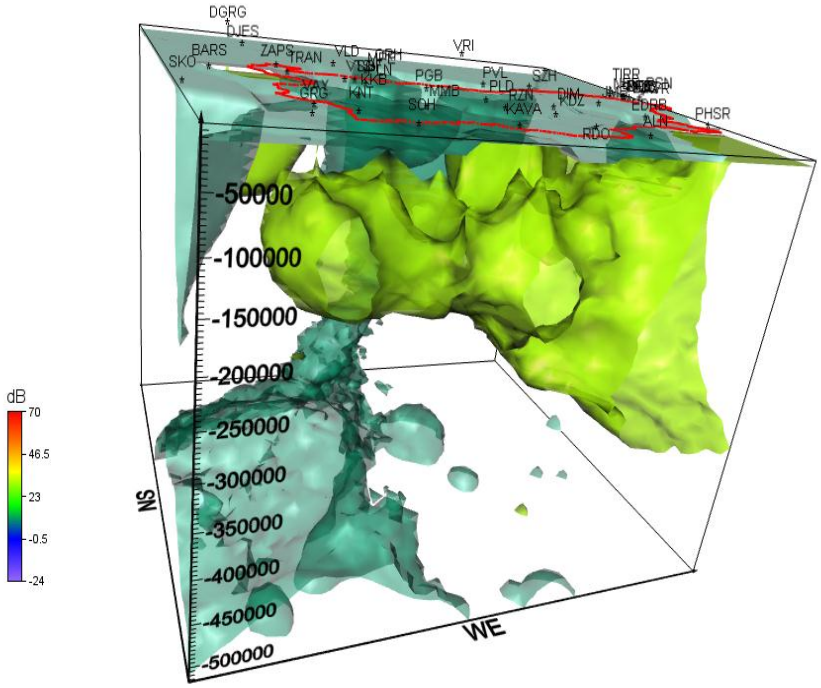

Fig.5 3D stereogram of the low velocity layers (light green) and high velocity layers (dark green). The intermediate velocity layers are not colored.

The detailed study of the low velocity and high velocity layers (bodies) reveal the complex character of the asthenosphere (if accepted as interpretation of the low velocity layers). The block regionalization could be extracted. The main criteria for such a regionalization could be the behavior of the average depth of asthenosphere as well as the thickness of the layers (Fig.6).
The high velocity layers are interpreted as solid bodies which are stable, with low permeability and thus can serve as isolators between the low velocity layers and the earth crust (Fig.7).

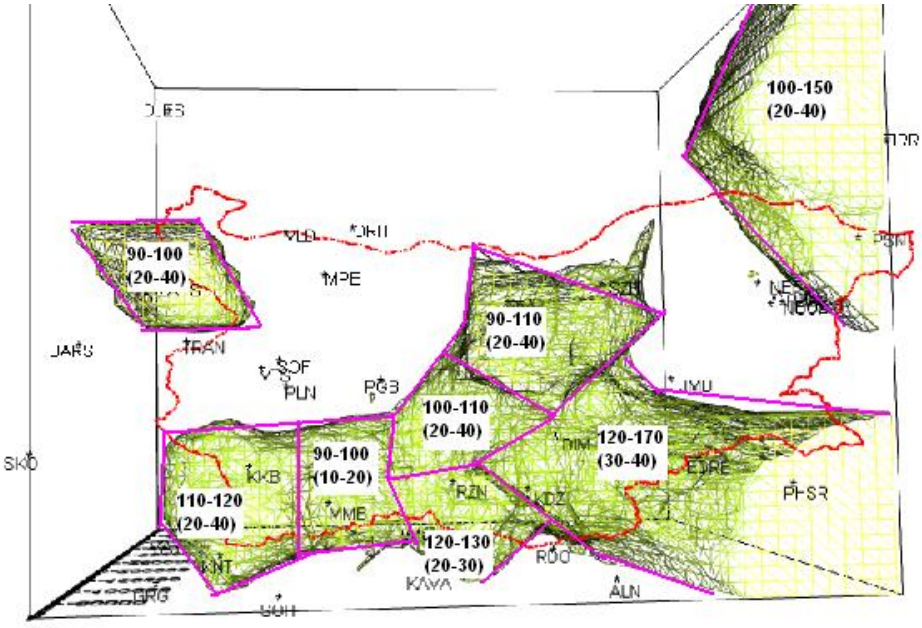

Fig.6 Block regionalization of the low velocity layers (projection to the surface). Numbers are average depths.

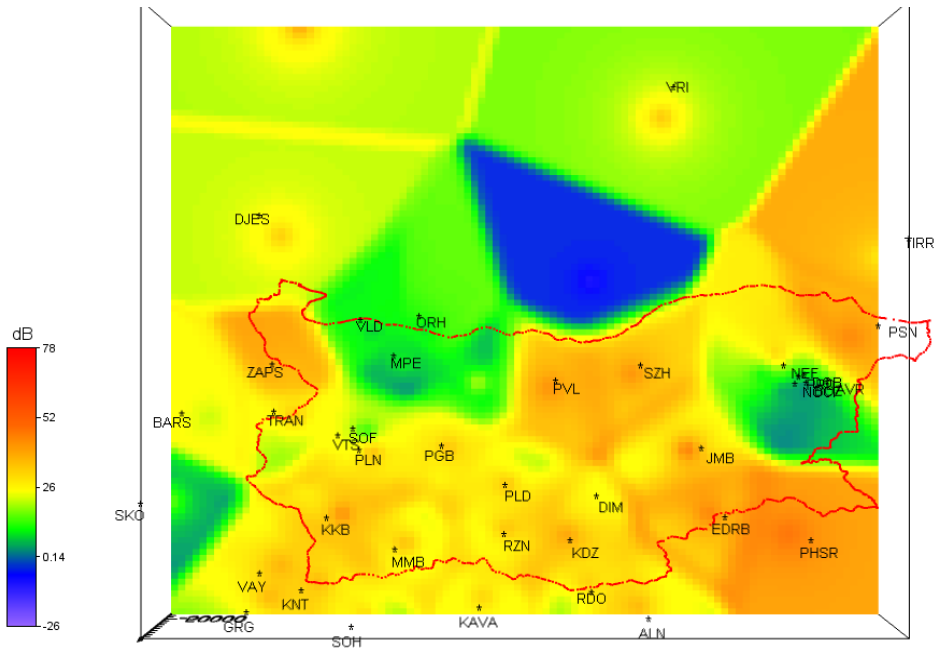

Fig.7 High velocity bodies (blue and green) at 60 km depth. They are interpreted as stable, not permeable block, which isolate the earth crust from the asthenosphere.

CONCLUSIONS

The deep structure of the low and high velocity layers (bodies) under the territory of Bulgaria is presented. The results are obtained due to the performance of the Method of the Micro Seismic Sounding (MSS) and give 3D diagrams at different depths. They are interpreted as asthenosphere and give the preliminary image of the asthenosphere's structure of the deep interior of Bulgaria.

The horizontal and vertical resolution tends to be enough with the presented density of the digital broadband seismic stations. The stationary of the microseismic noise is provided by the same one hour records in the calm time intervals during the night time and stability of the selected basic station.

The block regionalization is performed for different block structures, as a fundamental issue for further research.

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AUTHORS:

Prof. Dimcho Josifovs, PhD
Sofia, NTS-MDGM, 1000 Bulgaria
Prof. Boyko Ranguelov, Ph.D,
Sofia, MGU, 1700, Bulgaria
E-mail: *branguelov@gmail.com*

Assist. Prof. Emil Oynakov,
Sofia, NIGGG-BAS,
Sofia 1113, Bulgaria
E-mail: emil.ilievmg@gmail.com