THE GEOTECTONIC FRAMEWORK OF A PECULIAR SEISMOGENETIC AREA – THE VRANCEA SEISMIC ZONE (ROMANIAN CARPATHIANS)

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The area concerned by this papper covers the Carpathian Foreland (East European Kraton, Scythian and Moesian platforms as well as the North Dobrogea – South Crimea Cimmerian Chain) and the East Carpathians Bend Area. Excepting the East European Kraton all the other Foreland units as well as the main transcrustal faults (Trotuş, Peceneaga-Camena, Capidava-Ovidiu and Intramoesian) prolongate within the Western Black Sea continental plateau. The analyse of the structure and the variability of the Continental Crust and the Lithospheric Mantle across the East Carpathians, the Foreland and the Western Black Sea Basin allowed to be proposed a structural-genetic model for the Intermediate Vrancea Earthquakes. They generated within the Vrancea Lithospheric Anomaly. This is an anomalous thickening of the Lithospheric Mantle generated by a compressive decoupling of the Lithospheric Mantle with respect to the Continental Crust.

Key words: Carpathian Foreland; Structural-genetic Model; Vrancea Lithospheric Anomaly.

INTRODUCTION

The Vrancea Seismic Zone is situated within the East Carpathians, salient, Bending Area, covering, the Outer Flysch nappes, the Subcarpathian Nappe and the Inner limb of the Focşani Depression (the deepest area of the Carpathians Molasse Foredeep). There are two types of earthquakes:

– *normal*, located within the continental crust and

– *intermediate*, between 70 and 170 km, located, at different levels, within the Lithospheric Mantle.

The geotectonic frameworck of this seismogenic area shows peculiar features in some aspects different in respect with the "classical" models. The analyse of the geotectonic model of the Vrancea Seismic Zone (VSZ) is tributary to the understanding of the geological structure and evolution of the East Carpathians and of the Western Black Sea.

STRUCTURE AND EVOLUTION OF THE WESTERN BLACK SEA AND ITS SURROUNDING AREAS

The geological structure of the Western Black Sea and the surroundings geotectonic units is dominated by the existence[1,2] of (Fig. 1):

– two Precambrian Platforms (the East European Kraton and the Moesian Platform),

– a Caledono-Hercynian Platform (Scythian Platform),

– the Cimmerian North Dobrogea – South-Crimea Chain and,

– the sygmoidal Carpatho-Balkano-Pontides chains.

The **East European Kraton** is represented, in front of the East Carpathians, by its south-western sector (the **Moldavian Platform**). It is built up by a Pre-Vendian, Archean-Proterozoic metamorphic basement intruded by plutonic bodies (granites, anorthosites and Rapakiwi granites). The sedimentary cover is of Vendian-Neogene age, showing several sedimentary cycles. The boundaries of the Moldavian Platform are deep lithospheric fractures:

– the southern segment of the **Tornquist-Teysseire Zone** on its western border and,

– the **Bistrița-Vaslui Fault System**, on its southern border, prolongating, toward est, within the continental plateau of the Odessa Bay and, further away, within the Azov Sea (Figs. 1 and 2).

The **Moesian Platform** shows a Precambrian metamorphic basement with Archean elements and, mostly, Middle and Upper Proterozoic formations. The sedimentary cover is of Cambrian –Neogene age with several sedimentary cycles. It is to stress out the "German" lithofacies of the Triassic. The Platform is bounded toward west, north-west and south by the Danubian and, respectively, by the Prebalkan units.The north-eastern boundary of the Moesian Platform is the **Peceneaga-Camena Fault**. This bounds it from the North-Dobrogea Orogene and, further away toward north-north-west, from the Sythian Platform. The Peceneaga-Camena Fault is the south-easternmost segment of the Tornquist-Teysseire Zone The Moesian Platform is divided in two panels by the **Intramoesian Fault**. North of the Intramoesian Fault develops the Dobrogean Sector and, south of it, the Walachian-Prebalkan Sector (Fig. 3). The basement of the Dobrogean Sector is well known from outcrops in the Central Dobrogea (mesometamorphic forma-tions of Middle-Upper Proterozoic and ankimetamorphic formations – the "Green Schists" – of Vendian age). In South Dobrogea the Platform basement is known from boreholes (Proterozoic mesometa-morphic formations and Archean gneisses). The basement of the Wallachian-Prebalkan Sector, certainly of Precambrian age, is lesser known, only from few boreholes north of the Danube (retromorphic formations and some plutonic bodies).

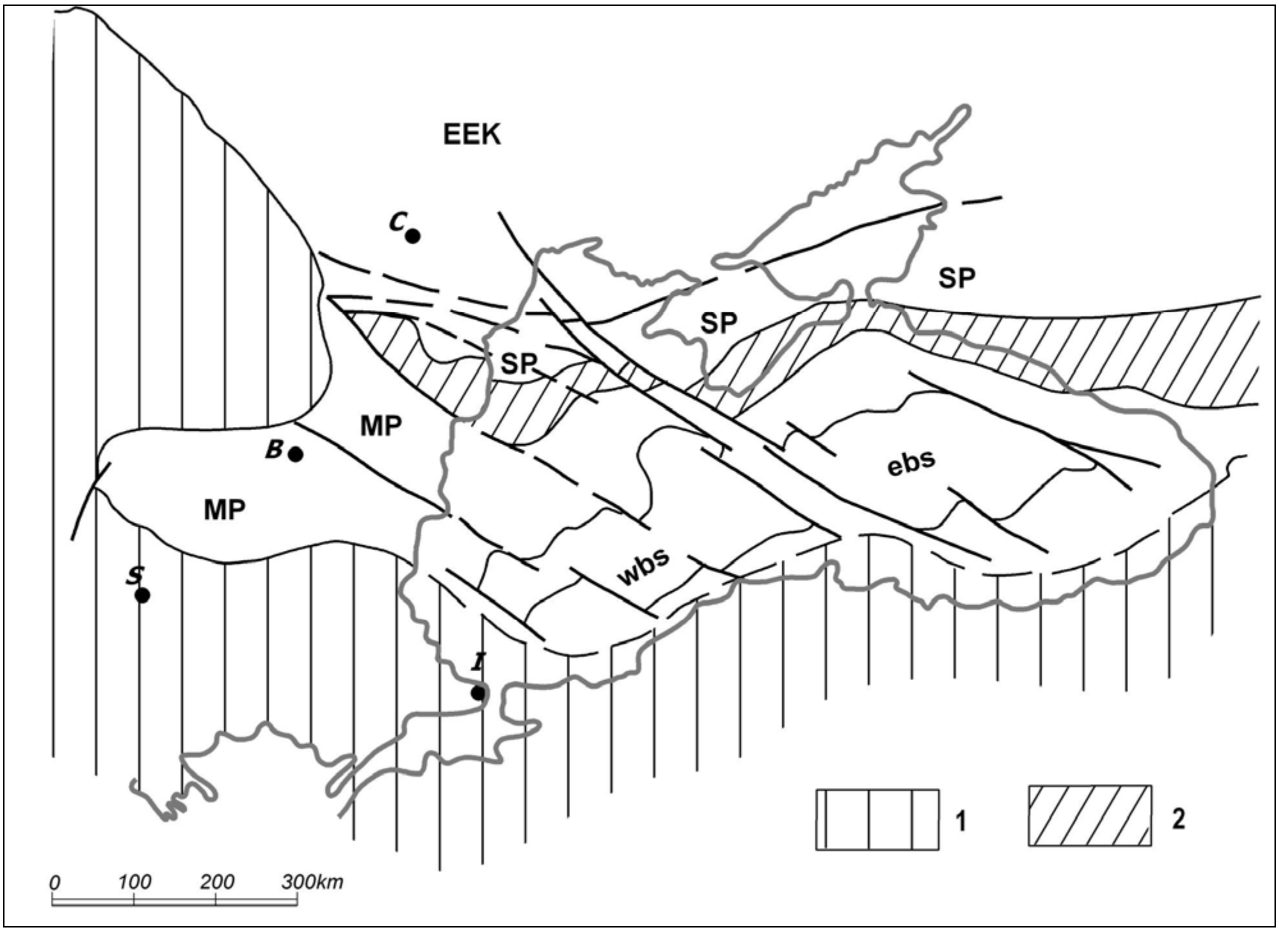

Fig. 1. General Geotectonic Sketch of the Black Sea and the surrounding areas:
1. Carpatho-Balkan-Pontides chains, 2. North Dobrogea – South Crimea – Caucasus chains, EEK – East European Kraton, SP – Scythian Platform, MP – Moesian Platform, wbs – Western Black Sea basin, ebs – Eastern Black Sea basin;
B – Bucharest, C – Chisinau, I – Istanbul, S – Sofia.

The **Scythian Platform** is developed westward and southward of the East European Kraton. The folded basement of this platform is of Caledono-Hercynian age. Pre-Vendian metamorphics and Vendian-Lower Carbo-niferous formations, partly ankimeta-morphosed, were tectonised together during, at least, two tectonogenetic cycles: the oldest of Caledonian age (Middle Devonian "phase") and the second of Hercynian age (Middle Carboniferous "phase"). The Platform Cover start with Upper Carboniferous formations and during several sedimentary cycles reach the Neogene. A peculiar feature is the "German" type of the Triassic. The southern limit of the Scythian Plate shows a peculiar shape: it is represented by the overthrusting surface of the North Dobrogea Orogene above the Scythian Platform [8,11] (Fig. 2).

The **North Dobrogean Orogene** is located between the Scythian Platform and the Moesian Platform. It prolongate within the Western Black Sea continental plateau and join, further eastward, the South Crimea Chain, named also the "Alpine Crimea" (Figs. 1 and 2). The North Dobrogea-South Crimea is a Cimmerian chain generated in two compressive tectognetic moments ("phases"): end-Triassic and end-Jurassic (or Neocomian). It proceed from an intra-continental complex rift, distensive since the Lowermost Triassic, but mostly in the Spathian-Carnian time-span when a within-plate ophiolitic complex generated. The North-Dobrogean Orogene is bounded north-west ward by the **Trotuş Fault** (Fig. 2). This is a crustal (or even lithospheric!) fault which:

– represent the transversal northern boundary of the North Dobrogean Rift and, consequently of the North Dobrogean Orogene, prolongating also within the Scythian Platform and

– have a left-lateral component, shifting elongated NNW-SSE parts of the Moesian Platform and of the Scythian Platform westward in an area actually situated below the Moldavidian nappes (Outern Flysch Zone) of the East Carpathians.

The **Western Black Sea** is an aquatorial area showing two kinds of crust: continental and oceanic-type (basaltic crust).

The continental crust develops within the continental plateau and represent the natural prolongation of the on-shore continental crust with all its structural units (Fig. 2). South of the Odessa Bay the North Dobrogea Orogene prolongate toward east and join the South Crimea Chain (see above). The Scythian Platform prolongate, across the Odessa Bay in Central and North Crimea, limited toward north by the East European Kraton. The Moesian Platform and its main transcrustal fractures – the Peceneaga-Camena, the Capidava-Ovidiu and the Intramoesian faults – prolongate also, southeastward – across the continental plateau. The oceanic-type crust is specific for the Western Black Sea central basin (Figs. 1 and 2). It is documented following geophysical data, mostly gravimetric and seismic ones. (Tectonic Map of Europe, second edition). This oceanic-type crust was generated by extensive tectonic processes. They occurred by the splitting of the continental crust of the Moesian Domain which (since the splitting) covered the whole space situated between the North Dobrogea-South Crimea and Carpatho-Balkan-Pontides chains. The splitting determinated the drifting of the actual Moesian Platform toward west and north-west, along the main transcrustal faults mentioned above (Fig. 2). The drifting determinated important underthrustings, mostly below the tectonic units of the South and East Carpathians. The drifting of the Wallachian-Prebalkan block generated also the important recers-type bending of the South Carpathians. The extensive "opening" of the Western Black Sea central basin and consequently the driftings mentioned above were generated by convection cells situated within the Astenosphere, with an anti-clockwise movement (Fig. 4).

The Western Black Sea central basin is trended in respect with the Eastern one by a more elevaded ridges (the Central Black Sea Ridge and Archangelsky Ridge[9]) which is dominated by north-west – south-east oriented stricke-slip faults (Figs. 1 and 2). It is not yet demonstrated but it is very possible that the Central Black Sea and the Archangelsky ridges shuld be continental crust ridges.

The **Carpatho-Balkan Chain** is a segment of the Alpine (Tethyan) Chains of the southern Europe. It prolongate, in the northern Minor Asia, by the **Pontides**. The major structures of the Carpatho-Balkan and Pontides chains, proceed from the tectonic deformation of the Tethys Ocean and its continental margins. The deformations occurred in several periods since the Middle Cretaceous until the Neogene. The youngest are of Lower Pleistocene age – the so called "Wallachian Phase" – and are located along the outernmost Bend Area of the East Carpathians (Fig. 2). These Lower Pleistocene deformations are limitated northward by the Trotuş and Peceneaga-Camena faults and south-westward by the Intramoesian Fault[2,7].

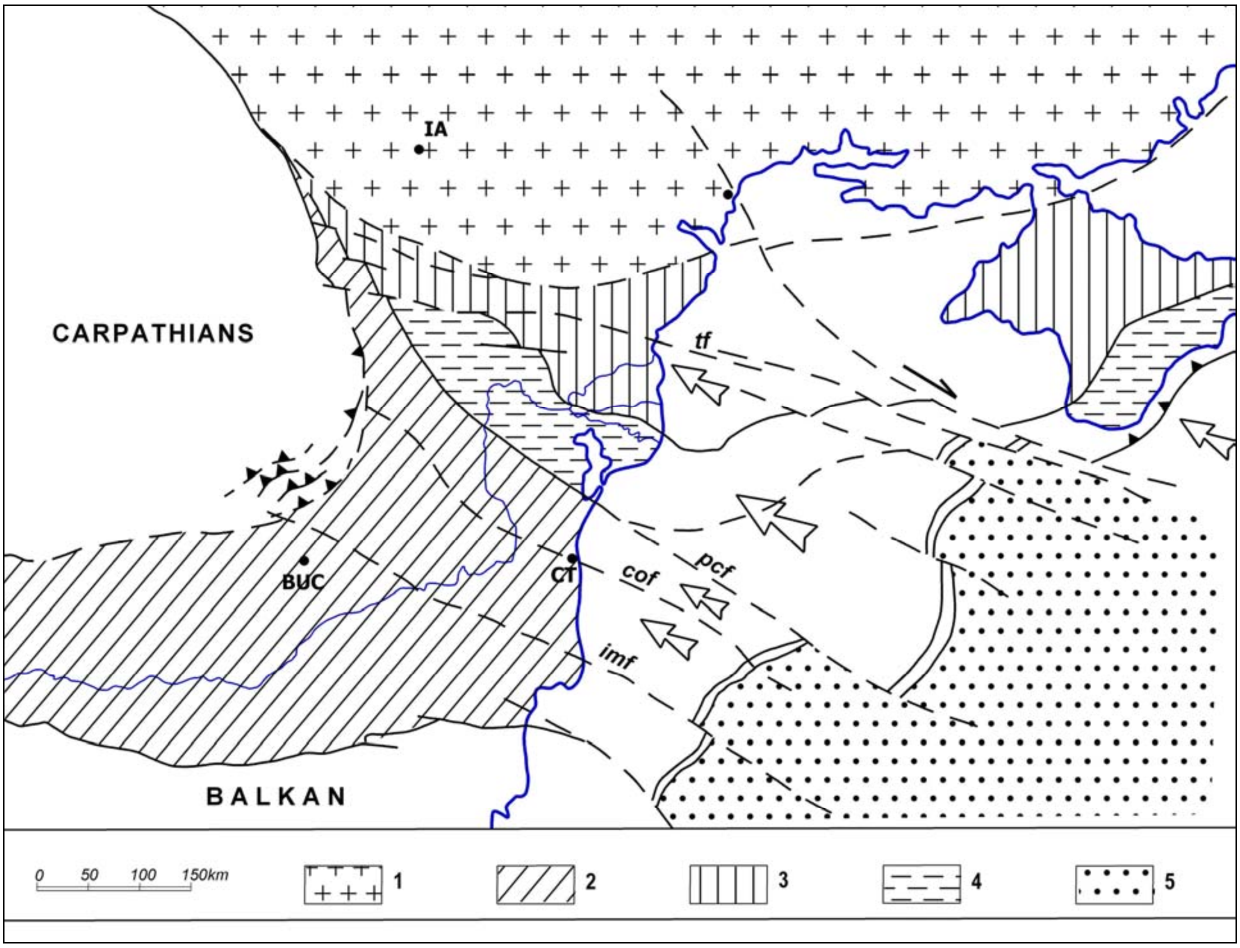

Fig. 2. Tectonic Sketch of the Western Black Sea and Carpathian Foreland:
1. East European Kraton, 2. Moesian Platform, 3. Skythian Platform, 4. North Dobrogea – South Crimea Cimmerian Chain,
5. Lower Pleistocene structures, pcf – Peceneaga-Camena Fault, imf – Intramoesian Fault, tf – Trotuş Fault,
cof – Capidava-Ovidiu Fault.

The geotectonic symmetry axis of the Alpine chains is represented by the Main Tethyan Suture Zone. It is built up by deformed and squeezed units constituted of mesozoic oceanic crust and associated sedimentary formations. Along it, subduction processes of different intensities occurred during the Upper Jurassic, the Cretaceous and the Lower Miocene. Outward of the Main Suture, within the Eastern and Southern Carpathians, continental crust bearing nappes develop bounded outside by a "satellite" subduction zone, where the oceanised and/or the thinned crust of the Flysch Zone nappes were consumpted. The Flysch and Subcarpathian nappes, which are cover nappes (built-up exclusively by sedimentary formations) are overthrusted above the, underthrusted, Foreland. In front and, partly, above the outernmost nappes of the East Carpathians is situated the Molassic Foredeep, known in the East Carpathians Bend Area as the Focşani Depression (Fig. 3).

THE STRUCTURE OF THE LITHOSPHERE ACROSS THE EAST CARPATHIANS BEND AREA AND THE RELATIOSHIPS WITH THE VRANCEA SEISMIC ZONE

With the purpose to have a more general view of the deep structure of the East Carpathians Bend Area we will annalyse a trans-lithospheric general cross-section running from the Apuseni Mts, across the Transylvanian Depression, the East Carpathians and the Focşani Depression, up to the Western Black Sea. It constitute a modern and more larger version of a similar but more restrained cross-section[5,6,7]. The most important recent published data concerning the thickness of the Lithosphere within the Carpathian realm[3] and the thicknesess of the upper and lower crust in Romania[4] allowed us to improve a new deep cross section (Fig. 3).

Several important general geotectonic features may be stressed out from the analyse of this deep cross-section:

– since the continental plateau of the Western Black Sea until the Apuseni Mts the crust is of continental-type, certainly with a complex structure as a result of its Mesozoic-Cenozoic evolution;

– the Western Black Sea central basin have a Cretaceous-Cenozoic oceanic-type crust ;

– the Lithospheric Mantle shows different thicknesses, the most important thickening being situated below the outern East Carpathians Bend Area.

The complex structure of the continental crust along the deep cross section is determinated, as mentioned before, by the complex Mesozoic and Cenozoic evolution of the Tethyan Ocean and its Continental Margins (mostly the European one).

It is possible to recognize[5] three panels of the continental crust separated by Mesozoic or Tertiary subduction zones:

– the Foreland Panel represented, on the cross-section, by the Moesian Platform, including its underthrusted segment below the Flysch Zone and Subcarpathian nappes;

– the Transylvanian Panel in the upper part of which were generated the Central East Carpathians nappes (Bucovinian, Subbuco-vinian and Infrabuco-vinian nappes);

– the Pannonian Panel including the Northern Apuseni.

Between the Pannonian and the Transylvanian panels is situated the Main Tethyan Suture which shows also bilateral obducted units. Between the Transylvanian and the Foreland panels a "satellite" subduction zone, where was consumpted the oceanized and the thinned crusts of the Flysch and Subcarpathians nappes.. The first one was active during the Upper Cretaceous, Paleocene and Neogene. The second one was active during two periods: Upper Cretaceous – Paleocene, in the South Carpathians and Neogene, in the Eastern Carpathians).

The Foreland continental crust shows different thicknesses. The most expressive one is situated below the Focşani Depression where a significant thining occur. It is determinated by the important and rapid subsidence of the Focşani Depression. In fact since the Upper Sarmatian (12 My) until the Lower Pleistocene (1,8 My) eight kilometers (8 km) of molassic sediments were acumulated (in the axial zone) (Fig. 3). This fact stress out a rapid and important subsidence which was allowed by the extensive thinning of the continental crust.

In the eastern margin of the Foreland Panel the transition between the continental crust of the continental plateau and the oceanic-type crust of the Western Black Sea central basin is, more or less sharp. Perhaps it is generated by a dense set of parallel normal (extensive) faults, parallel to the steep continental slope.

The Lithospheric Mantle shows a very large variability of its thicknesses. The most expressive feature is the important thickening of the Lithospheric Mantle below the westernmost segment of the Foreland Panel (see above). But it is important to stress out that this over-drawed thickening is limited arealy by two trans-lithospheric fractures (Fig. 4). The fractures correspond, at the crustal level, with the Trotuş Fault, towards north and the Intra-moesian Fault, toward south-west!! There is to remember that within the panel bounded by the two fractures are arealy restricted the Lower Pleistocene deformations known in the outernmost strip of the East Carpathians Bend Area!

Consequently an important remark concern the fact that the volume where are concentrated the intermediate earthquakes of the Vrancea Seismic Zone is "hosted" within this thickened Lithospheric Mantle (Fig. 3). Similar, but more generalized, conclusions were presumed also before[1,5,9].

If it is tacken into account the Neogene geodynamic evolution of the East Carpathians Bend Area it is possible to stress out some basic features.

1. Between the Burdigalian (aprox. 19 My) and the Middle Sarmatian (aprox. 8–9 My) the primary thinned and oceanic-type crust of the Flysch and Subcarpathians troughs were consumpted gene-rating the East Carpathians Neogene Volcanic Chain. The suture generated by these events is situated, actually, between the Foreland and Transyl-vanian panels of the Continental Crust (see Fig. 3).

2. The "Wallachian. Phase", Lower Pleistocene, deformations developed between the Trotuş Fault and the Intramoesian Fault (Fig. 2) documented a crustal compressive field within the area delimitated by the two trans-lithospheric faults. The trans-lithospheric nature of the two mentioned fractures is documented by the map of the lithospheric thicknecess[3].

3. Consequently it is necessary to be accepted the existence of an anticloackweise astenospheric convection cell (Fig. 3), developed between the Western Black Sea Basin and the panel where the Lithospheric Mantle shows an expressive thickening.

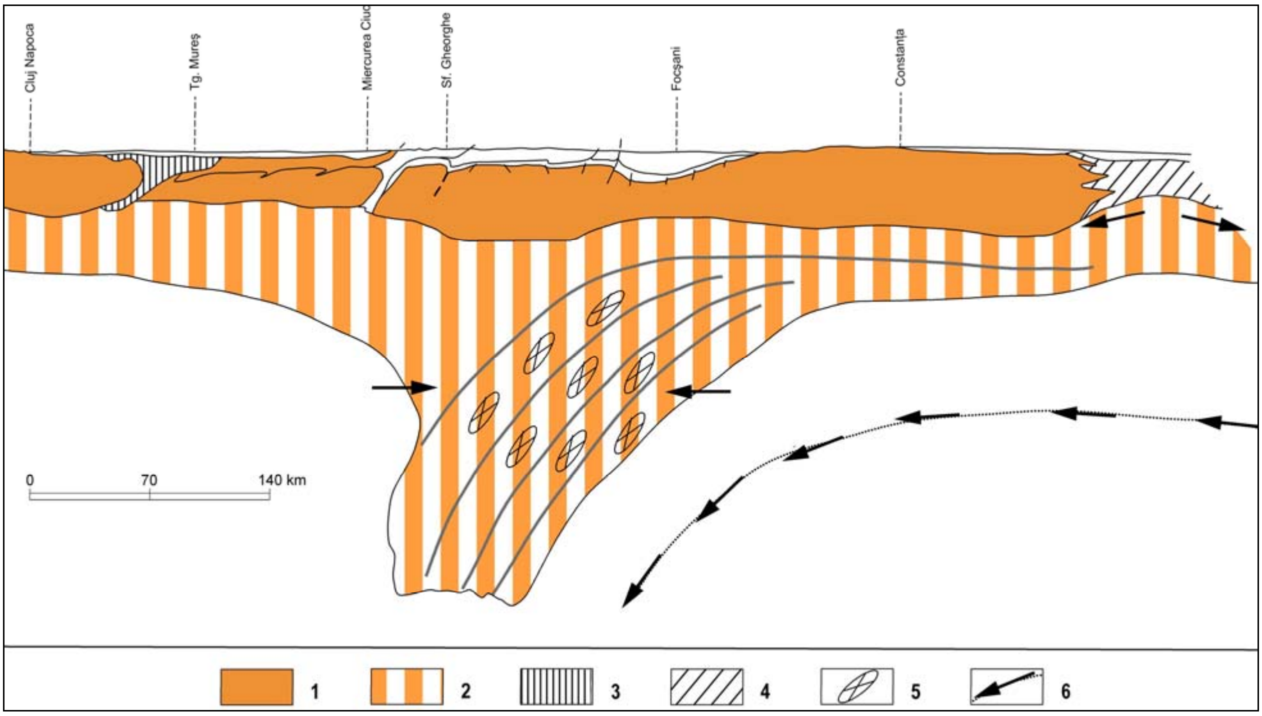

Fig. 3. Lithospheric Cross-Sections Apuseni Mts. - East Carpathians-Black Sea:
1. Continental Crust, 2. Lithospheric Mantle, 3. Main Tethyan Suture Zone, 4. Western Black Sea Basin,
5. Vrancea Intremediate Earthquakues Focuses, 6. Astenospheric Cell.

4. Within this thickened “anomaly” of the Lithospheric Mantle – which may be named the **Vrancea Lithospheric Anomaly** – develops a compressive stressed volume, within which oblique and parallel discontinuities surfaces (fractures) develops. Along these fractures occurred, between 70 and 170 km, the Intermediate Earthquackes of the Vrancea Seismic Zone (Fig. 3).

5. The growing of the thickness within the Vrancea Lithospheric Anomaly is determinated by the decoupling of the Lithospheric Mantle in respect with the Continental Crust. The decoupling occurred, above an Astenospheric convection cell, within the panel situated between the Trotuş and the Intramoesian faults. This decoupling induced, in the Continental Crust of this panel, compressive stress which generated the “Wallachian Phase” (Lower Pleistocene) deformations.

CRITICAL CONCLUSIONS

The analyse of the structure and evolution of the Western Black Sea Basin, as well as of the

East Carpathians Bend Area and its Foreland allowed us to develop the peculiar model of the Vrancea Seismic Zone.

Following this model the Vrancea intermediate earthquakes generated within an compressive anomalous thickening of the Lithospheric Mantle, named the Vrancea Lithospheric Anomaly. This is caused by a compressive decoupling of the Lithospheric Mantle in respect with the Continental Crust, determinated by an Astenospheric convection cell. The Cell rotation is anticlockwise and is connected to the extensive development of the Western Black Sea Basin; basin which is characterized by an “oceanic-type crust.”

The relatively restricted Vrancea Seismic Zone, concerning the intermediate earthquakes, is limitated by two translithospheric fractures: the Trotuş and the Peceneaga-Camena faults, north-eastward and the Intramoesian Fault, south-westward.

The Vrancea Lithospheric Anomaly and consequently the seismogenetic Vrancea volume is entirely situated within the Lithospheric Mantle corresponding to a panel of the Moesian Platform.

Consequently it is obviously that the Vrancea seismogenetic volume may be not situated at a “triple junction” of several plates because:

– the whole area situated north of the Egean subduction zone of the African Lithospheric Plate below the European Lithosphetic Plate, correspond to the same plate;

– the "plates" considered in the so called "triple junction" don't exist in their supposed boundary[11];

– "Moesia" is a Precambrian microplate, drifted from the Gondwana and incorporated within the European Plate at the end of the Paleozoic;

– "East European Kraton separated in

Respect with the Moesian Platform by the Scythian Platform[11], both incorporated within the European Plate.

Concerning a possible Quaternary subduction existing in the Vrancea seismogenic area it is to stress out that:

– since the Black Sea continental plateau until the Apuseni Mts. and further below the Pannonian Depression there are a continuously – even if not homogeneous – continental crust and a corresponding – even if not of the same thicknesess – lithospheric mantle;

– there are not known regional Quaternary calc-alkaline active volcanics connected to supposed Quatrenary subductions.

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