

TECTONIC PLATES: STUDY OF MOVEMENT AND DEFORMATION - AREA VRANCIOAIA

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Abstract

In this paper we approach the study of tectonic plates, their classification according to their size and phenomena that occur due to movement of tectonic plates. In the content, there is also presented how they formed faults and the classification according to their geometry and genetic. We follow Vrancea's fault behavior through displacements and deformations that occur over time. This study is conducted by placing the parts in strategic objectives, monitoring benchmarks in time through leveling method of geometric means of order 0.

Keywords: plate tectonic, displacements, deformations, Vrancea area.

INTRODUCTION

The globe is divided into continental and oceanic regions, so we can say that the earth's crust has a different structure and development of geological importance.

Tectonic plates: The tectonic plate is a very large piece of crust, the total area of tectonic plates forming the Earth's surface. Earth's crust is divided by several tectonic plates and is divided into three subdivisions:

- Main (macroplates)
- Secondary (mezoplates)
- Tertiary (microplates)

Today it is known that there are seven macroplates:

- North American plate
- South American plate
- Antarctic plate
- Eurasia plate
- African plate
- Indian-Australian plate
- Pacific plate

Geological or tectonic structures are forms of reservoir rocks. Tectonic structures are formed after bending, cracks and other movements on deformations.

The movement is the changing of the spatial position of a point on the surface of land subjected to applications. (I. A. Kosîghin,

1962)

Deformation is the changing of the shape of an object by increasing or decreasing between characteristic points of the pursued object. Crust deformations present various sizes and shapes, they can be very small and very difficult to distinguish, but they also can reach spectacular dimensions. Deformations can be discontinuous, characterized by the fracture plans (disjunctive) and continuous deformation that make up the crease field. Between these two categories there is a continuous transition. (I. A. Kosîghin, 1962)

Tectonic movements. We distinguish four types of tectonic movements (V.V. Belousov – 1948):

Oscillatory movements - are the vertical movements of the earth's crust caused by its lifting and sinking because the crust rises in a place and immerse in another.

Crease movements - are the plastic deformation of the earth's crust, followed by the thinning strata in creases.

Breaking movements - is the formation of fractures or cracks in the earth's crust.

The movements of magma – represent the molten mass which is moving through the earth's crust.

The exogenous factors participate in an important way in the formation of the aspect of

the structure, the morphology and the construction material. Common and continuous interaction of the exogenous and endogenous factors lead to the formation of geological structure which is conditioned by the internal movements and by the internal development of earth, the endogenous factors occupying a leading role. (I. A. Kosîghin, 1962)

Factors influencing crust movements:

After the last ice age, there were changes in the amount of land that have been totally issued and suddenly by the pressure caused by the weight of ice, modifying the steady state of the earth's crust and mantle. Restoring equilibrium state is carried out slowly, with a speed that depends on the viscosity of the magma and hence vertical movements of the earth's crust. (Mircea Rebrisoreanu, 2003)

Plate Tectonics justify the crust's macromovements. The lithosphere consists of several moving plates that float on the asthenosphere. The direction and size of the tectonic plates are different resulting the following phenomena:

Formation of new crust portions it resulting from the divergent movement of the tectonic plates, thus the magma breaks through the asthenosphere to the surface.

The disappearance of portions of the earth's crust is due to mutual converging movements of the tectonic plates, so one of the plates gets into the other.

Shallow Earthquakes are caused by mutual sliding plates, by the shape of some frictions, and they generate the moving of continents and macromodifications in the structure of gravitational field and shape of the geoid.

The action of volcanoes generates displacements and deformations of local character.

Due to natural and anthropogenic factors changes in the upper crust appear and also generates displacements and deformations of local character.

Atmospheric factors are considered secondary factors that generate displacement and deformation of the crust.

Shifts and deformations in the crust along the coasts are due to tide seas.

The factor which is the root of an earth fissure is the earth tide, this it is characterized by raising and lowering the earth's crust under the

action of the Sun and Moon. (Mircea Rebrisoreanu, 2003)

Faults: The common rupture plan of two tectonic compartments after which occurs their displacement, placing them one against the other, constitutes a fault. Faults usually occur in portions under high tension and general layers. (Mircea Rebrisoreanu, 2003)

Geometry of a fault:

Fault plan (P) - is the surface on which the two compartments formed by rock fracture move (Fig. 1);

Direction of the fault (af) - is the line resulting from the intersection of the fault plan with a horizontal plan (Figure 1);

fault direction orientation (δ) - is the angle between the direction of the fault and the geographical meridian (Figure 1);

fault inclination (β) - is the dihedral angle formed between the fault plan and a horizontal plan (Figure 1);

Jump fault (step or leap) (ab) - is the movement of two points on the two compartments adjacent initially measured on the fault plan (Figure 2).

There are several types of jumps:

- Jump on tilt (ae; SI) - is total jump component is measured on tilt and represents the size of compartments displacement measured along the line of greatest slope of the fault plan;

- Vertical jump (ad; Sv) - is the vertical component of the total jump ;

- Horizontal jump (eb = ac) - is the horizontal component of the jumping on tilt, reflected in the amount of movement in the horizontal plan;

- Stratigraphic jump (Ss) - is the proper movement range of the lithological formations deposit (equal to the stratigraphic thickness of the deposits formed in the "tectonic gap"). (Mircea Rebrisoreanu, 2003).

Classification of the faults is done by geometric and genetic elements:

By the angle of the tilt of the fault plan to a horizontal plan:

- inclined faults (fault plan makes with the horizontal plan an angle different from 0° and 90°);

- vertical faults (fault plan makes with the horizontal plan an angle of 90°).

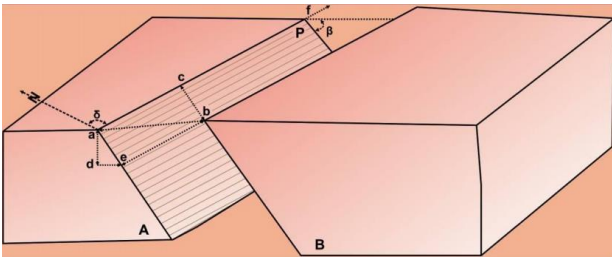


Figure 1. The movement of tectonic compartments in the plane of the fault (block diagram)

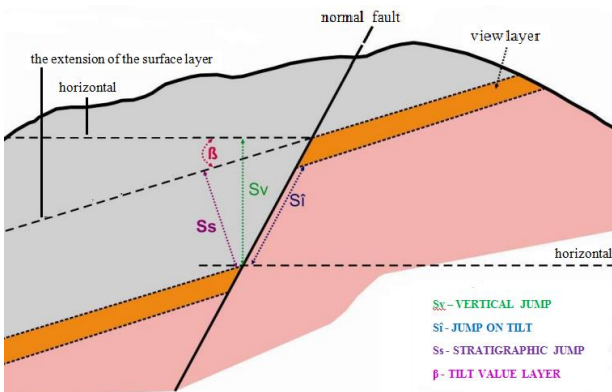


Figure 2. Jump fault (vertical section)

By direction of the movement of the compartment on fault plan:

In the case of inclined faults with vertical jump:
 - normal faults – the compartment above the fault plan moves downward, gravitational (arising under distension);

- reverse faults - compartments are displaced on fault plan "antigravity" (arising in compressional regime).

In the case of the detachment faults (with horizontal jump):

Transcurrent fault - compartments are moved only horizontally:

- dexter fault - tectonic compartment opposite the observer is shifted to the right;

- senestre fault - tectonic compartment opposite the observer is shifted to the left.

Transforming faults - are horizontally displaced fractures affecting oceanic rifts and usually have a path perpendicular to the rift. Transforming faults develop in the direction parallel to the Euler networks, as opposed to rifts having a parallel route with their meridians.

By the report of the fault plan tilt and rock layers:

- Comply fault - the fault plan inclined in the same direction as that of the layers without the inclination to have, necessarily, the same value;

- otherwise faults (irregular) - inclined fault plan backward the strata tilt.

After the report of the fault direction and the direction of layers: directional, horizontal and oblique.

After pairing mode of faults in the system of faults (= conjugate faults) - terms derived from cartographic allure: the relay faults, parallel faults, concentric faults, radial faults, etc.

In the case of the faults is observed the thickness increase in submerged compartments and its decrease in high compartments. These variations are of sudden character, in jumps and a more quiet on the wings; they represent an important clue, to be fastened to study faults accurately, because they enable to assess their training period and duration of their formation.

Displacements on faults. There is a close link between folds and faults resulting from the study of various kinds of anticline crease affected by faults. Subduction-related anticline folds develop on their flanks with large tilt exactly where layers were subjected to a high voltage. The amplitude of the faults related to folds in the lower horizons is higher, and in the upper is smaller, so it is established that faulting and folding are just different forms of unique tectonic movements.

The mechanical properties of the rock, depth of the deformation, the deformation speed, etc. presents an important role in the smaller or larger development of faults.

Creases and cover rocks can develop due to lateral movement in basis, and in this case, faulting preceded the folding. Faults on which plan's occurs displacement while increasing wrinkles are syngeneic to the process of folding.

Romania is on three continental tectonic plates whose meeting point is Vrancea area: East European plate, Intra-Alpine subplate and Moesian subplate (Fig. 3). Each of these continental tectonic plates are directly influenced by movements or pressures that confronts plate part.

Strong earthquakes in Romania occur at depths of 60-200 km, they occur at the junction of three tectonic continental plates, they are called subcrustal earthquakes, they have very high energy and are felt over large areas. Shear are produced, determined by the compression, this means that continental plates are pushed

together and one cedes at a certain depth. Breaking is determined by pressure from big land plate movements and by the influences which they have on micro-plates or subplates in Romania. In most cases, earthquakes are tectonic earthquakes, which are the result of sustained movement of lithospheric blocks along newly formed or existing faults in advance. (Liviu Constantinescu, Dumitru Enescu, 1985).

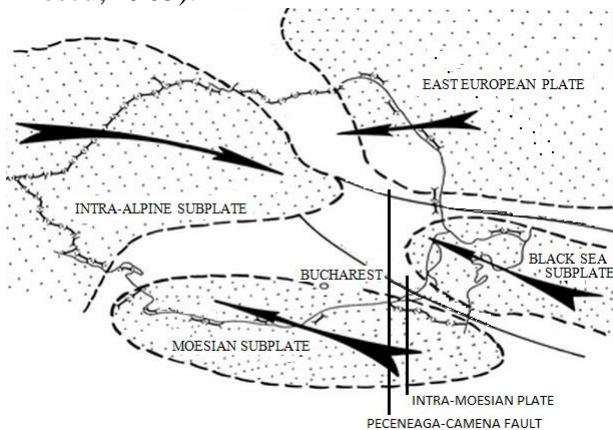


Figure 3. The meeting point of three continental plates (Vrancea)

Romania is tested also by earthquakes at a depth of 5-40 km, which are called between crustal earthquakes and they occur in areas of fault rupture (Mountains Fagaras, Timisoara area, system faults Carei - Oradea fault St. George on the edge of the North Dobrogea etc.). Research in this area has led so far to achieve fault plan solutions for about 100 earthquakes in Vrancea. Most Vrancea intermediate earthquakes are produced by sliding tilt, this being the reverse faulting, earthquakes ie compression. Only in a few cases it is normal faulting earthquakes or transcurent faulting. It was concluded that most of Vrancea earthquakes, especially in the strong ones, null vector direction is parallel to the direction of the Carpathian arc and direction of axis of crease- system. (Liviu Constantinescu, Dumitru Enescu, 1985)

MATERIALS AND METHODS

In the measurements it was used the reference system the Black Sea 1975. As a method it was present the geometric leveling method by means of order 0, with accuracy of $\pm 1 \text{ mm}\sqrt{L}$ measured in km and a maximum length of 30 m

portee, and as camera measurements, the NI 007 Zeiss, which belongs to the group of instruments compensating, with pendulum, high precision, together with the following accessories:

- a set of small groom with invar tape series: 50324, 50323;
- two sets of large groom with invar tape series: 26 707, 26 708 and 49 636, 54 686;
- Six leveling bolt weighing about 5 kg each.

Best verification of the equipment used was getting very close level differences between back and forth using the same section:

- the same level and the same set of surveyor's pole;
- same level and different sets of surveyor's pole;
- different levels and the same set of surveyor's pole;
- different levels and different sets of surveyor's pole.

Leveling repeatedly show that any point on the Earth's surface is moving or lifting or diving. Thus it is concluded that vertical tectonic movements on the surface have a general and continuous character. It follows that it is not possible an exact calculation of the influence of measurement errors on the elevation difference which is obtained by comparing the two leveling.

Geometric leveling is known as direct leveling (level difference is obtained from the difference in the readings on the surveyor's pole). It is widely used because of its very good accuracy. It is made with leveling tools called levels. Their axis of sight can be brought into a horizontal position. (Manea Raluca, 2010)

Geometric leveling middle. Leveling goal is to determine the difference in level between two points A and B. On each of the two points there is placed one surveyor's pole in perfect vertical position. Division 0 of the surveyor's pole is at the bottom. Halfway between points A and B are placed leveling tool. (Cornel Păunescu, Ileana Spiroiu, Marian Popescu, Vlad Păunescu).

We consider the meaning of A to B, surveyor's pole located at A is called back surveyor's pole and the surveyor's pole placed in point B the surveyor's pole located in or before. Based on this, we calculate the difference of level that can be positive or negative. The horizontal plan

of the telescope described vial when two surveyor's pole will intersect at a certain height. This horizontal plan is viewed by cross-hair of the level. On perform two readings with the horizontal cross-hair, one on the back surveyor's pole, one on the surveyor's pole located in or before. The reading on the back surveyor's pole is marked with a, and the reading on the surveyor's pole located in or before with b. Considering P_0 as zero datum plan, from point A goes a parallel to this plan. Also, the horizontal plan described by the telescope device is parallel to this plan. (Cornel Păunescu, Ileana Spiroiu, Marian Popescu, Vlad Păunescu).

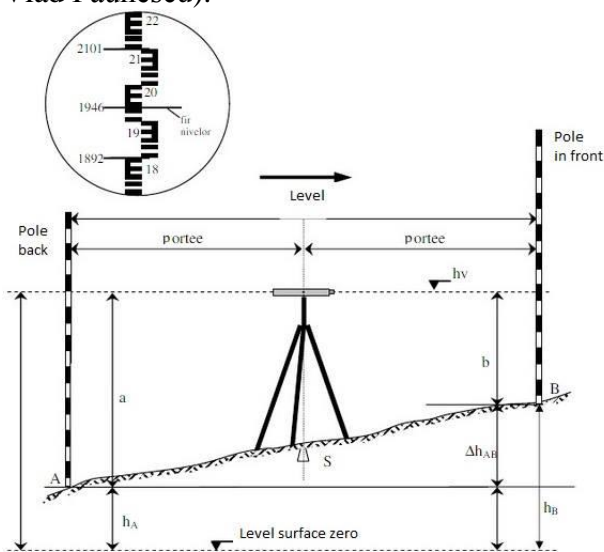


Figure 4. The principle of geometric leveling middle

From Figure 4 it can be seen:

$$\Delta h_{AB} = h_B - h_A \quad (1)$$

Where:

- Δh_{AB} level difference between points A and B;
- h_B altitude of the plane P_0 to point B;
- h_A altitude point A to P_0 plan.

Also in Fig. 4:

$$\Delta h_{AB} = a - b \quad (2)$$

A and b are direct readings so it can be calculated the level difference. Knowing the elevation of one of the points, for example, A point, it can determine the share of the other point B of equation (1):

$$h_B = h_A - \Delta h_{AB} \quad (3)$$

Knowing the elevation of point A and having read the surveyor's pole back, we can calculate the altitude of the plan of sight h_v or height i_v .

plan. The altitude of the plan of sight (described by the telescope horizontally level) is the vertical distance between the plan and the plan of sight P_0 .

$$i_v = h_A + a \quad (4)$$

Altitude point B resulting from altitude plan targeting:

$$h_B = i_v - b \quad (5)$$

The altitude plan of sight is used when it is desired to determine a large number of points around the level quoted. (Cornel Păunescu, Ileana Spiroiu, Marian Popescu, Vlad Păunescu).

RESULTS AND DISCUSSION

The section between km.40 + 200 to km.59 + 000 DN 2 D was measured return fully, moreover sections were measured between R 70 and R 72 rappers.

It was intended that tolerance $T = 1.5 \text{ mm}[\text{km}]$ round-trip between measurements is not exceeded. However, the steep sections due to readings taken at the ends groom to overcome this tolerance. The execution was carried out measurements in both directions so that the interval between the two measurements is minimized. Measurements return on the same section were not always performed by the same operator with the same set of surveyor's pole, or the same device. From this resulted the number of different stations back and forth between these sections. However, the respective sections, level differences between outbound and were within the tolerance. For the measurements was used the coincidence method pointing on the two graduated scales. It is obtained for each direction of measurement two level values difference level between the surveyor's poles placed behind and in front of the camera.

Benchmarks embodying moving points are called work parts and the stable ones - support parts. The total working parts and support parts with which it is followed the evolution of rock movement, is an observation station of displacement. The advantage is that they are stable in the long term and ensure continuously over time.

The landmarks are located both in the study area and they support changes horizontally and vertically but also in areas outside area

considered stable and representing the geodetic reference.

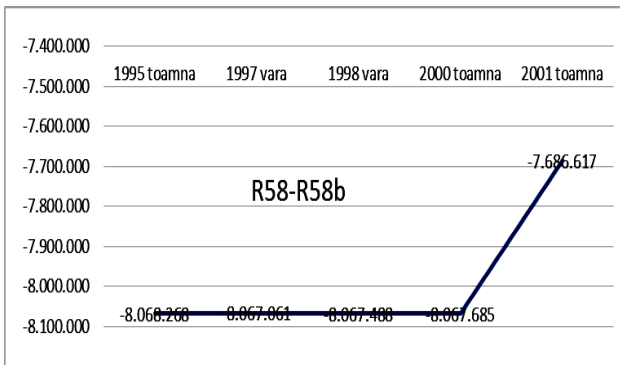


Figure 5. Landmarks behavior R58-R58b (1995 autumn – 2001 autumn)

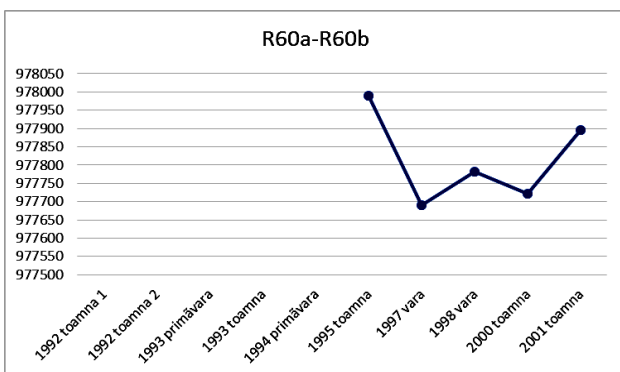


Figure 6. Landmarks behavior R60a-60b (1995 autumn – 2001 autumn)

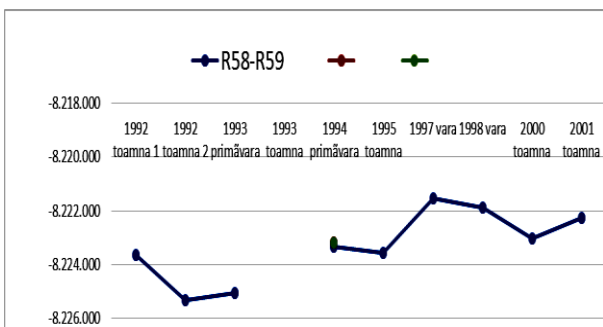


Figure 7. Landmarks behavior R58-R59 (1992 autumn - 2001 autumn)

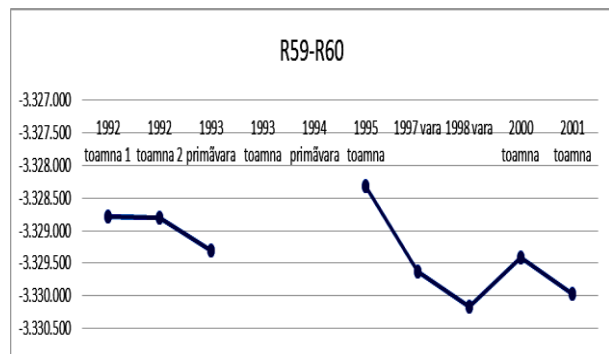


Figure 8. Landmarks behavior R59-R60 (1992 autumn – 2001 autumn)

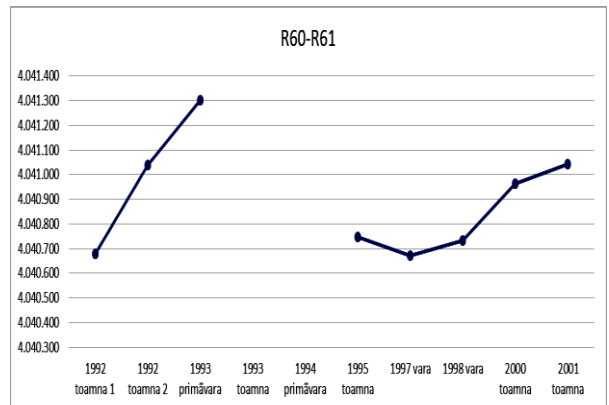


Figure 9. Landmarks behavior R60-R61 (1992 autumn – 2001 autumn)

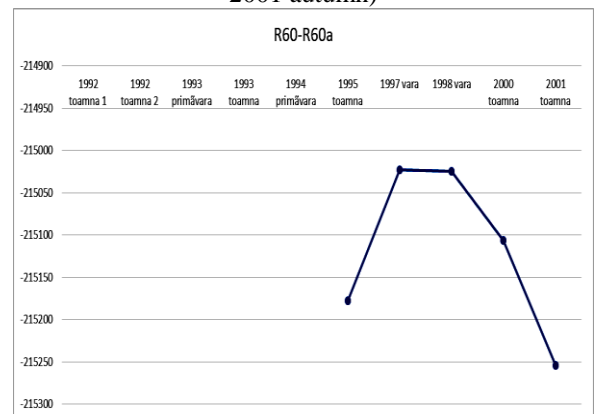


Figure 10 Landmarks behavior R60-R60a

Table 1. SUMMARY TABLE for leveling measurements performed in Vrancea

Landmarks	1992 autumn 1	1992 autumn 2	1993 spring	1993 autumn	1994 spring	1995 autumn	1997 summer	1998 summer	2000 autumn	2001 autumn
R58-R58b						-80.68	-80.67	-80.67	-80.68	-76.87
R58b-R58e						3.82	3.82	3.82	3.81	
R58e-R59						-5.37	-5.37	-5.37	-5.37	-5.36
R58-R59	-82.24	-82.25	-82.25		-82.23338 -82.23173 -82.23173	-82.24	-82.22	-82.22	-82.23	-82.22
R59-R59b						-36.21	-36.22	-36.23	-36.22	-36.22
R59b-R59a						3.43	3.43	3.43	2.93	2.93
R59a-R60						-0.5	-0.5	-0.5		
R59-R60	-33.29	-33.29	-33.29			-33.28	-33.3	-33.3	-33.29	-33.3
R60-R60a						-2.15	-2.15	-2.15	-2.15	-2.15
R60a-R60b						9.78	9.78	9.78	9.78	9.78
R60b-R61						32.78	32.78	32.78	32.78	32.78
R60-R61	X= 40.40678	X= 40.41040	X= 40.41303			X= 40.40746	40.41	40.41	40.41	40.41
R61-R62	0.42	0.42	0.42				0.42	0.42	0.42	0.42
R60-R62	40.82	40.83	40.83			40.83	40.82	40.83		
R62-R62a going							14.64			
R62a-R63 going							5.74			
R62-R63 going	X= 20.38495	X= 20.38491	X= 20.38245				20.38		20.39	20.39
R63-R63a						3.78	3.78			
R63a-R64						-11.86	X= -11.86311			
R63a-R63b							1.52			
R63b-R64							-13.38			
R63-R64	-8.08	-8.08	-8.08			-8.08	-8.08	-8.08		
R70-R70a										
R70a-R71							13.06	13.06		
R70-R71						18.15				
R151-R152a							-39.74	-39.74		
R152a-R152b						-1.23	-1.23	-1.23		
R152b-R152c						-0.09	-0.08	-0.08		
R152c-R153						8.6	8.6	8.6		
R151-R153				X= -32.45428	X= -32.45826 X= -32.46069 X= -32.46162		-32.45	-32.45		
R151-R152				-37.34	-37.34460 -37.34703 -37.34796					
R152-R153				4.89	4.89	4.89				
R153-R153a							23.88			
R153a-R154							17.78			
R153-R154				41.67	41.67		41.66	41.67		
R154-R154a							8.98	8.98		
R154a-R155							-22.86	-22.86		
R154-R155			-13.87	-13.88			-13.88	-13.88		
R155-R155a						-1.09	-1.08	-1.08		
R155a-R155b						4.72	4.72	4.72		
R155b-R156						4.84	4.84	4.84		
R155-R156				8.47	8.47	8.47	8.47	8.47		
R157-R157a							90.31	90.3	90.3	
R157a-R161							3.43	3.43	3.44	
R157-R161				X= 93.74329	X= 93.74348		93.74	93.73	93.74	
R161-R162				-65.09	-65.08		-65.09	-65.09	-65.1	-65.09
R162-R157b						11.94	11.95	11.95	15.1	7.79
R157b-R162a						-4.14	-4.13	3.15		
R162a-R162b						7.29	7.28			7.3
R162b-R162c						-22.28	-22.29	-44.73	-22.29	-22.29
R162c-R163						-22.44	-22.44			34.88
R163-R162d							-17.29	-17.29		
R162-R163				-29.63	-29.64	-29.63	-29.62	-29.62		
R163-R163a							45.78	45.78		
R163a-R163b							11.54	11.54		
R163b-R164							16.61	16.61		
R163-R164				73.94	73.94		73.93	73.93		
R165-R165a							2.99	2.99		
R165a-R165b							-45.55	-45.55		
R165b-R166							-97.66	-97.66		
R165-R166				-140.23	-140.24		-140.23	-140.23		

X = value obtained by calculation and not by direct measurement.

R61 = Landmark built into the wall Hall Barsesti;

R62 = Landmark buried in the schoolyard Barsesti;

R72 = Landmark built into the church wall Tulnici.

CONCLUSIONS

In this work we determined vertical movements in Vrancea fault zones, Vrancea County. We investigated the vertical displacements and changes before and after earthquakes 13/10/1992 and 23/10/1992 by: "Precision measuring line Focsani - Targu Secuiesc between R 47 and R 70 landmarks". We studied the behavior of Vrancea area over a period of nine years from 1992 to 2001.

In this study we found that this area is active and holds various displacements and deformations by differences in level results over time.

Looking at the real value of movements and deformations were still necessary to monitor the area in order to have a permanent control of

speed, direction and deformations in the study area.

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