CRUSTAL MOVEMENTS AND EARTHQUAKES DISTRIBUTION IN DOBRUDJA AND BLACK SEA.

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Abstract. The paper shows the results of the integrated interpretation of the geological, geophysical, geodesical and seismological information, undertaken in order to specify the crustal block that is part of the Dobrudja region and neighbouring zones and of the present-day kinematics of these ones. The purpose of the geophysical researches was to determine the major discontinuity's position (Moho, Conrad and the bottom of the sedimentary crust). The areal and spatial distribution of the seismic events, the deduction of the seismically compression and extension directions derived from studying the mechanisms of focus, the correlation of these ones with the known tectonics, allows us to establish the fault-like character of some tectonic events regarded as a consequence of the present-day kinematics of lithospherical blocks.

Key words: Earthquakes, crust, crustal movements, geodynamic.

INTRODUCTION

This paper is based on the systematic results of the former studies concerning the structure of terrestrial crust using deep seismic soundings, as a results of high precision leveling measurements and as well as the present day geodynamics processes emphasized by crustal earthquakes study.

The paper shows the results of the integrated interpretation of the geological, geophysical, geodesical and seismological information, all for specified crustal blocks that are parts of the Dobrudja region and the neighboring zones and of the present day kinematics of these ones.

The image of the deep structure is done for each major unit that are parts of the Dobrudja region and the Western part of the Black Sea.

Structural interpretation of geological and seismic data from Dobrudja and the Romanian Black Sea revealed, from south to north, three important structural units: the Moesian Platform, The North Dobrudjan Orogen and the Scythian Platform.

GEOLOGICAL SETTING

According to Săndulescu (1984), the Moesian Platform represents a Precambrian block involved in the Epihercynian European platforms. According to Visarion et al. (1988), this platform is composed by three different segments, bounded by the Peceneaga-Camena and Trotus crustal faults, Intramoesion Fault and Calimanesti-Tg. Jiu Fault, i.e. the "Dobrudjan", "Valachian", and "Danubian" domains respectively.

The Dobrudjan area of the Moesian Platform is situated between the Peceneaga-Camena crustal fault northwards and Intramoesian crustal fault southwards and comprises two second-order units, defined after their basement types.

The Central Dobrudja unit, an uplifted block is situated between Peceneaga - Camena Fault, along which this unit was not only uplifted (e.g. Visarion et al., 1988), but seems to display large dextral displacements (e.g. Rădulescu et al 1976; Visarion et al., 1988) and Capidava-Ovidiu Fault to the south-west. It is characterized by weakly metamorphosed Upper Vendian-Early Cambrian flyschoid deposits (Green Schists) unconformable overlying a middle Proterozoic metamorphic succession (e.g. Săndulescu 1984). West of the Danube river, the basement of Central Dobrudja type is deepening and extends towards the NW beneath the flysch and molasse units of the Eastern Carpathians (Figs.1, 2).

In the South Dobrudja unit, a second unit of the "Dobrudjan" part of the Moesian Platform, the mesometamorphic series of Proterozoic age , is covered, discordant by basic vulcano-sedimentary rocks. This unit extends from its contact with Central Dobrudja along the Capidava-Ovidiu to the Intramoesian Fault. The relationship between the two parts of Moesian Platform are not very clear, but according Visarion et al. (1988), the Central Dobrudja units is uplifted in respect to the South Dobrudja along Capidava-Ovidiu Fault, which seems to display also a right-lateral displacement.

In the Moesian Platform, deep refraction seismic profiles show depth Moho values around 35-40 km (Rădulescu, 1988).

The Intramoesian Fault is a deep crustal fracture (Săndulescu, 1984; Visarion et al 1988) its trace being underline by seismic epicenters (Rădulescu et al.,1976; Cornea and Polonic, 1979).

According to Visarion et al. (1990), the North Dobrudjan Orogen is the westernmost part of an

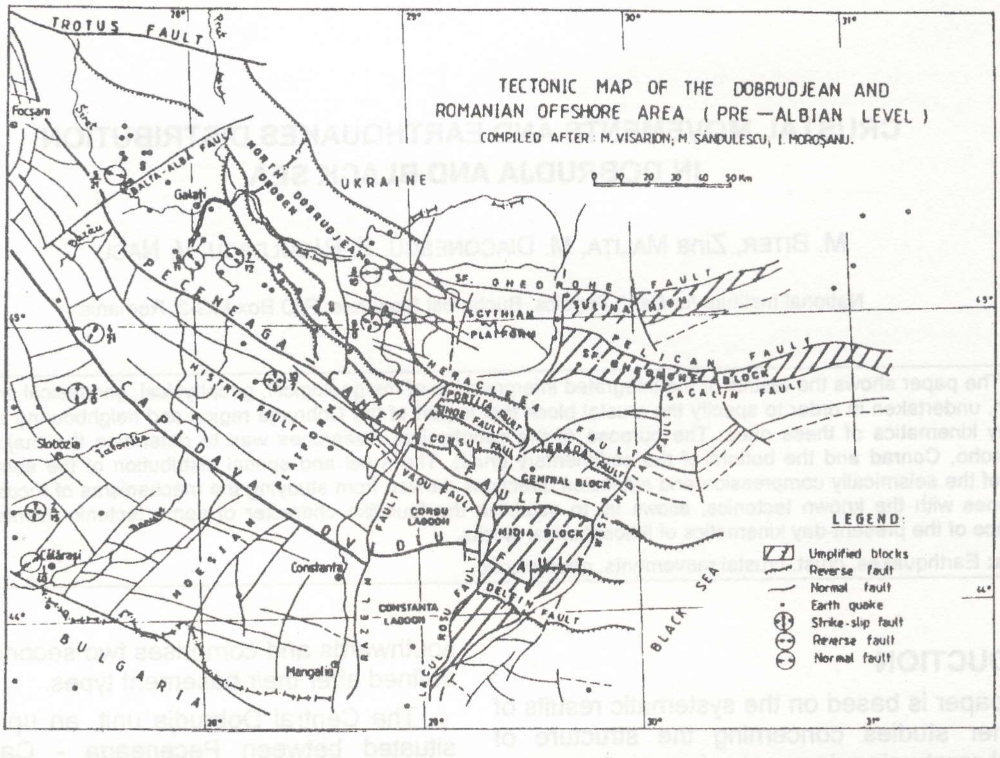

Fig. 1 Tectonic map of the Dobrudja and Romanian offshore area (pre-Albian level) (compiled after Visarion et al., 1990 and Morosanu, 1996). 1- umplified blocks; 2- reverse fault; 3- normal fault; 4- eartquake epicenters; 5- strike-slip fault; 6- reverse fault; 7- normal fault.

Early Alpine or Cimmerian Folded Belt. Several napes (Macin, Consul, Niculitel, Tulcea) of Jurassic or Neocomian age have been there recognized: they have a north or north-east vergency, toward the Scythian Platform.

The North Dobrudjan Orogen and the Moesian Platform are separated by the Peceneaga-Camena transcrustal fracture, which shows actually dextral strike-slip movements (Săndulescu and Visarion, 1988).

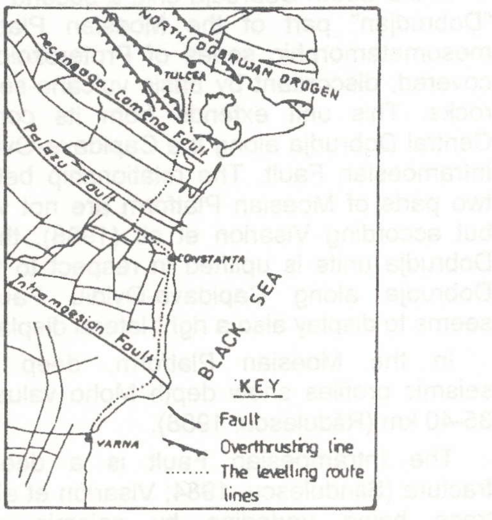

Fig. 2 Simplified geological sketch map of the Dobrudja area

The northern limit of the North Dobrudjan Orogen is represented by the Heraclea Fault, which forms the contact between the North Dobrudjan Orogen and Scythian Platform. The nature of this contact is an overthrusting contact (Morosanu, 1996). Eastward, the North Dobrudjan structures extend throughout the Western Black Sea basins.

According to Rădulescu et al. (1976), the Peceneaga-Camena Fault separates two regions with striking differences in crustal thickness. While the North Dobrudjan Orogen has a crustal thickness of 45-50 km, the Moesian Platform in the Central Dobrudja subunit display a decrease of crustal thickness of at least 10 km.

Northwards of the Heraclea Fault is situated Scythian Platform with a folded Caledono-Hercynian basement, covered by the Neocomian, Triassic, Jurassic, Permo-Carboniferens rocks, partly corresponding to the Predobrudjan Depression.

Deep reflection profiles show an overall thickness of 10 km for the sedimentary cover, with Conrad and Moho discontinuities being located at 20 and 40 km respectively (Răileanu et al., 1994) while seismological data show an average of 43 km crustal thickness (Enescu et al., 1988, 1992).

Data from seismic prospecting and drilling have helped deciphered the structure of the Romanian

Black Sea offshore area. The offshore consist of the main onshore tectonic units (Moesian Platform,

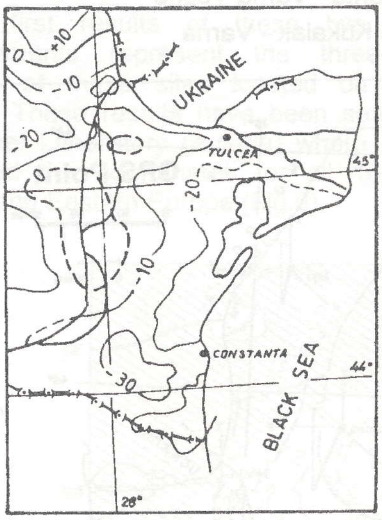

Fig. 3 Map of recent crustal movements in the Dobrudja area (mm/y) (after Popescu and Dragoescu, 1986)

North Dobrudjan Orogen and Scythian Platform).

Two fault systems are seen, one system in an E-W direction with an overthrusting to the north and the second system with N-S orientation which affects the first one. The last one system, is mainly represented by normal faults downthrown to the East. The first system was a result of compression tectonic forces. These fault systems are a results of distensional tectonic forces (Morosanu, 1996).

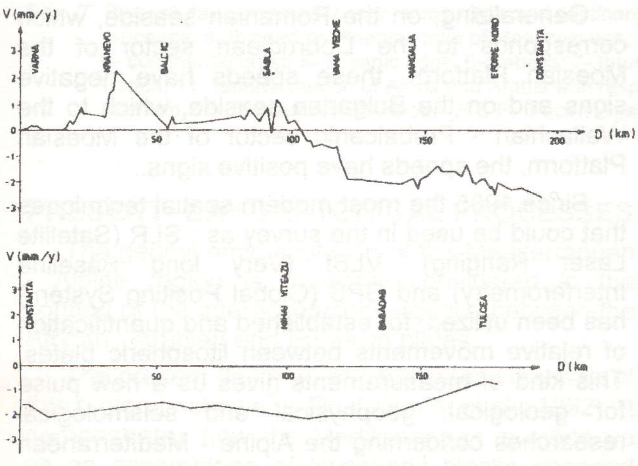

Fig. 4 The leveling route lines to study the actul vertical movements of the crust in the western Black Sea coast.

GEOPHYSICAL SETTING

The seismic studies with a large scale character supplied the first information about the regional structure of the terrestrial crust in Dobrudja.

The purpose of the researches was the determination of the major discontinuities positions (the base of the sedimentary crust, Conrad and Moho).

Since 1986 seismic studies with a deep target used query blasts as source of the seismic energy. Seismic recorder has been done on a longitudinal profile, with shot point at one end. Recorder equipment has been display along seismic profile among 1 to 3 km distance between them, in function of terrain morphology. Recorded data obtained, especially on lines: Turcoaia - Mahmudia - Techirgol and Turcoia - Mahmudia, permits the droning of the maps with izobathes at Moho level.

A synthesis of the former studies is presented by Rădulescu et al. (1988), and Pompilian et al. (1995). Their papers presents the image of the map with izobathes at the base of the crust in Dobrudja, emphasized by refraction seismic data (Fig.6).

In the North Dobrudjean sector the existence of the crustal block with large thins of 40-48 km has been pointed; the modification of the crustal structure has been done along Peceneaga-Camena Fault. In the central and Southern Dobrudja, terrestrial crust has a thinning from 38 km in the northern part to 30 km in the southern part. Concerning the Capidava-Ovidiu Fault the only seismic evidence has been obtained on Sitorman - Negru Voda profile.

CRUSTAL MOVEMENTS

The study of the crustal movements started in Romania in 1964, being based on repeated measurements of the level with a high precision and using the marks from national geodesical network of the first and second order. This method emphasize the vertical crustal movements in the present day. For Dobrudja, the measurements of the level were made with a high precision and repeated on the following routes:

- Tulcea - Constanta 1961-1974-1981,
- Constanta - Mangalia - Vama Veche 1964-1974-1981
- Constanta - Varna 1965, 1975, 1981, 1983 (Figs.3-5).

A map with recent vertical crustal movements has been elaborated on the base of nivelment measurements. This map indicates that in the Romanian seashore of the Black Sea exists a movement of sinking for terrestrial crust with a velocity of - 2.5mm/y, nearby Constanta. Towards Mangalia velocities of sinking are around - 1.0mm/y (Popescu and Dragoescu, 1986).

In the framework of cooperation with scientists from Bulgaria concerning the determination of the reciprocal altitude and for a unique system of locations for tide gauge, this system was connected through high precision level. These measurements have been used for the computation of vertical movements on the Black Sea coast (Dragoescu et al., 1989).

Considering the tide gauge registrations and the level registrations, the absolute speeds of the vertical movement of the tide gauge stations were calculated on the following lines of level:

- Constanta - Vama Veche
- Duran Kukalak - Varna

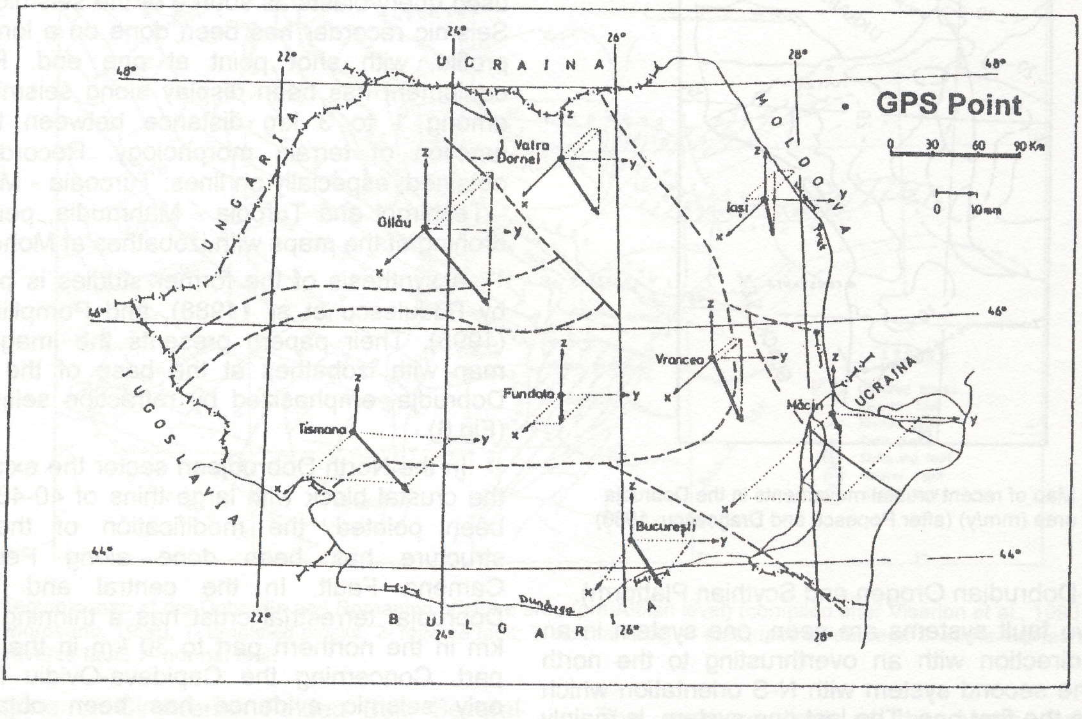

Fig. 5 Map with GPS network and results of GPS measurements. 1- point of measurements from CEGRN network

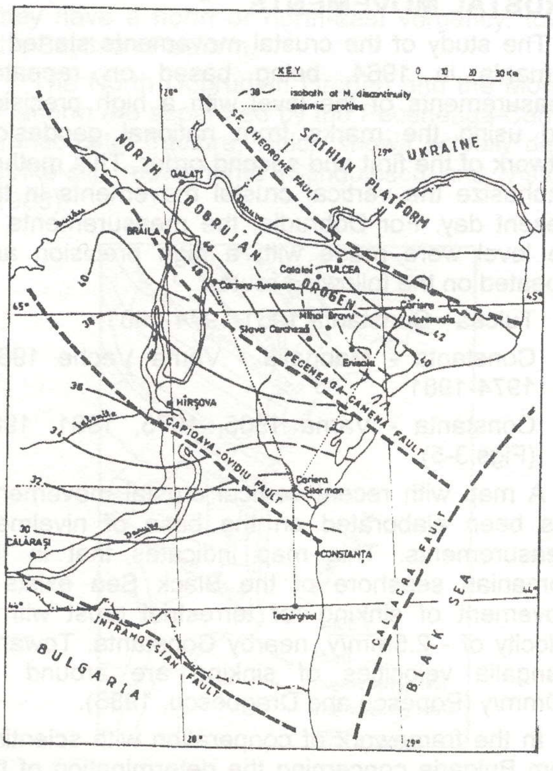

Fig. 6 Dobrudja. Map with isobaths at Moho discontininuity

- Varna - Burgas
- Burgas - Miciurin (making the relation between Vama Veche and Duran Kulak).

Generalizing, on the Romanian seaside, which corresponds to the Dobrudjean sector of the Moesian Platform, these speeds have negative signs and on the Bulgarian seaside, which to the Wallachian - Prebalcanic sector of the Moesian Platform, the speeds have positive signs.

Since 1985 the most modern spatial techniques that could be used in the survey as : SLR (Satellite Laser Ranging), VLBI (Very long Baseline Interferometry) and GPS (Global Positing System) has been utilized, for established and quantification of relative movements between litospheric plates. This kind of measurements gives us a new pulse for geological, geophysical and seismological researches concerning the Alpine - Mediterranean area.

Two international cooperation, with the Institute for Angewandte Geodesia – Frankfurt am Mein, Germany, as a part of the COPERNICUS program, concerning the realization of the project named "The tridimensional cinematics of the plates in Romania", permitted the achievement of the first period of GPS measurements placed in the Carpathian Arc Bend and its foreland, which first interpretations are presented in the paper.

The first results of these two series of measurements represent the three-dimension variation of these sites located on Romanian territory. These results have been send us from Lustruehel Laboratory (Austria) where have been calculated the coordinates for all 100 GPS in Central and Eastern Europe (Fig.6).

existence of some changes in the South-East to North-West directions for the lithospheric blocks which are parts of the Eastern Carpathians foreland. Consequence of the collision between African and Arabian plate, those movements are favorable by the existence of a ruptural tectonic which groups more transcrustal faults (the Trotus Fault, the Peceneaga-Camena Fault, Capidava-Ovidiu Fault, Intramoesian Fault) with a long evolution, having a general direction from

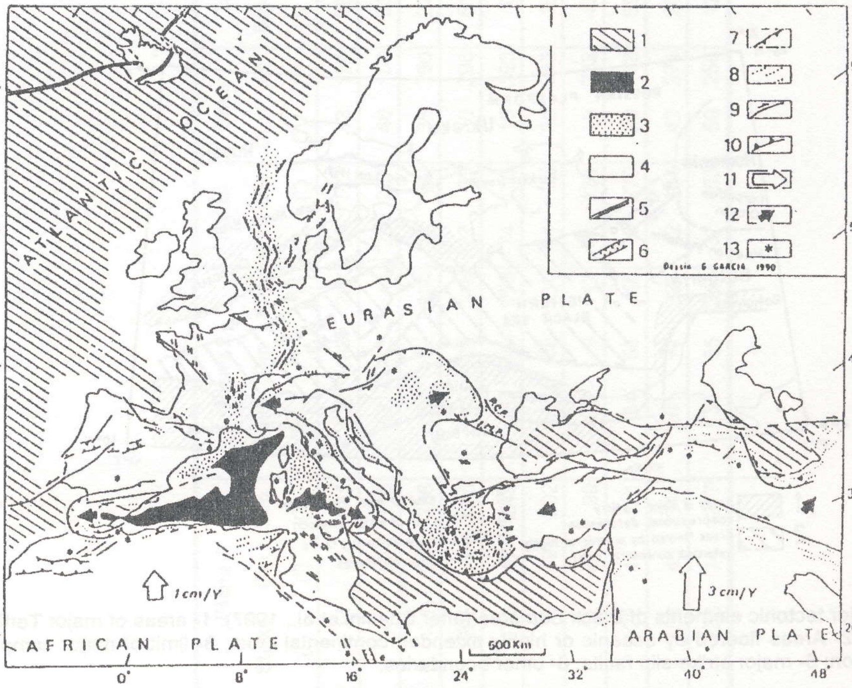

Fig. 7 Present day geodynamic map; subduction and continental collision zones in the Mediterranean and surrounding area. 1-oceanic or thinned continental crust of Mesozoic age; 2- oceanic crust of Cenozoic age; 3- thinned continental crust; 4- continental crust; 5- oceanic ridge; 6-grabens; 7- thrust and reverse fault; 8- fold; 9- strike slip fault; 10- subduction trench; 11- relative motion of Africa and Arabia with respect to Eurasia; 12- block movements with respect to Euroasian platform; 13- Quaternary volcanoes. P.C.F. -Peceneaga-Camena Fault; I.M.F.-Intramoesian Fault.

PRESENT- DAY TECTONICAL PROCESSES

The geodynamic evolution of the Mediterranean - Alpine region is generally considered in the context of the interaction/convergence between the African - Arabian and Eurasian plates.

The present day map of geodynamic features of this region is shown in Fig.7 (Rebai et al., 1992). It demonstrates how the Mediterranean is made up as an assemblage of litospheric blocks engaged into a variety of kinematics processes including subduction, back-arc spreading, rifting, thrusting and reverse faulting, strike-slip faulting and lateral expulsion of lithosperic blocks (e.g. Alboran Sea, Anatolian, Carpathians blocks).

In their quasitotally, the evolution geotectonic models (which concern the present dynamics of the great structural units) create a postulate for the

southeast to northwest.

Recently, several dynamic modeling studies have been emphasized the role of the rifting processes in the Black Sea region (i.e. N. Gorur, 1977; A. G. Robinson,1996) .

According to G. Spadini et al. (1997), the Black Sea is generally considered to be results of the back-arc extension associated with the northward subduction of the Tethysian plates. However, deep-reflection seismic studies have shown that are two extensional basins in the Black Sea which have coalesced in their postrift phases (Fig.8).

The western Black Sea opened with the separation of a fragment including the western and Central Pontides (north Turkey) from Moesian Platform (Romania and Bulgaria). Rifting began in the middle Barremian, with the major postrift subsidence and probable an oceanic crust emplacement in the Cenomanian. The Western Black Sea, rifted with the dissection of an Upper Jurassic to the Lower Cretaceous carbonate platform, had been established on the southern margin (Moesian Platform) of the northern supercontinent Laurasia (Finetti et al., 1988; Gorur, 1997).

The rifting in the Eastern Black Sea probably began in the Late Paleocene with the rotation of the Mid - Black Sea High from Shotsky Ridge - geological mentioned units, the distribution of hypocentres and the mechanism of earthquakes have been an important source of data. In the study area occurred 110 earthquakes with hypocentres at depth 0-40 km and magnitudes of 30-7.20 Mw (magnitude scale based on seismic moment – Kanamori, 1977). There are included the event from 1892-1997 (Fig.1). There have been selected a number of 10 seismical events (Table 1), the fault plane solutions were calculated with Wickens and Hodgson program (1967) and

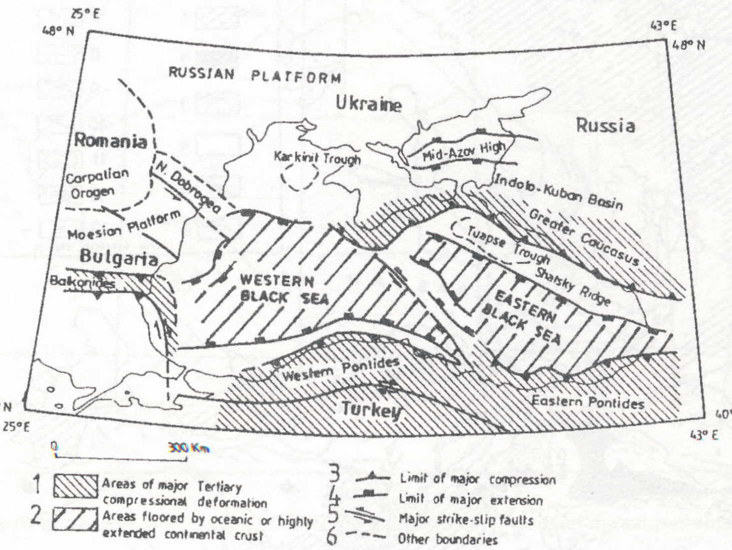

Fig. 8 Map with major tectonic elements of Black Sea area (after Spadini et al., 1997). 1- areas of major Tertiary compressional deformation; 2- Areas floored by oceanic or highly extended continental crust; 3- limit of major compression; 4- limit of major extension; 5- major strike-slip faults; 6- other boundaries.

Caucasus (Russia) (Spadini et al., 1997).

In the geodynamic context mentioned above, the Dobrudja region, as part of the Carphatic foreland and edge of the Western part of the Black Sea Basin, present interest from structural point of view as long as the actual cinematic of structural units constitutive is under the influence of the geodynamic proceses of the Alpino - Carpathian - Pannonic system and Vrancea area (as part of Carphatic Foreland)on one side and on other side by the movements of the crust from Black Sea (post-rift phase).

The areal and spatial distribution of the seismic events, the deduction of the seismic compression and extension directions deduced from the study of mechanism of focus, the correlation of these ones with the known tectonics, permits us to established the active character of the fault of some tectonic accidents regarded as a consequence of the present day cinematics of the lithosphere blocks.

For touching the proposed purpose, this being the emphasis of the present-day cinematics of the lithospheric blocks which constitute the great modified by Oncescu (1980) being on the first arrivals in P wave, registered at the Romanian seismical stations (telemetred and conventional).

The parameters which had been taken in consideration, had been taken over from the tables of the mechanical, focal solutions for the earthquakes from Romania which appeared in the INCDFP annual reports (a great party from them being calculated again).

For the correlation of the seismical events with the known tectonics, had been used the studies elaborated by Visarion and Săndulescu (1988, 1990), Morosanu (1996), which by synthesizing the geological and geophysical data, had made specifications concerning the constitution of the socle of the deep structure and of the disjunctive tectonics which characterize the platform units (the Moesian Platform) and North Dobrdjean Orogen (Fig.1).

The epicenters have been represented by full circles. The earthquakes which have fault plane solutions have been numbered from 1 to 10, under

Table 1 Location of the earthquakes

No	Date	Origin	Epicenter		Depth	Magnit		Plane 1			Plane 2			Paxis		Baxis		Taxis		Fault type
		time	Lat.	Long.		M_S	M_L	Strike	Dip	Slip	Strike	Dip	Slip	Az	Dip	Dip	Az	Dip	Az	
	Y/M/D	h:m:s	(°N)	(°E)	(km)			(°)	(°)	(°)	(°)	(°)	(°)	(°)	(°)	(°)	(°)	(°)	(°)	
1	5/30/94	13:07:49	44.15	27.27	40	2.5		14	15	331	132	83	257	51	27	13	134	36	234	normal
2	12/8/80	19:51:17	44.36	27.24	15	3.8		60	46	178	331	85	44	28	277	46	153	31	25	strike-slip
3	7/15/94	12:57:19	44.78	27.46	0	2.3		121	75	306	230	39	204	47	69	35	290	22	184	normal
4	9/16/94	14:03:18	44.98	27.53	21	2.1		295	73	80	145	20	118	27	33	10	298	61	190	strike-slip
5	7/19/87	2:18	45.57	27.76	21		4.7	178	47	248	29	48	298	74	13	16	193	0	103	normal
6	2/4/85	23:37	45.29	28.12	11	3.3	4	76	69	302	197	38	216	54	26	30	243	18	143	normal
7	9/11/80	23:24:24	45.30	28.20	12	4.7		52	87	99	338	9	17	41	134	9	232	47	331	revers
8	11/1/81	9:07:13	45.19	28.95	10	5.2		22	41	121	34	56	66	8	270	20	178	69	21	revers
9	8/19/94	14:33:32	44.99	28.95	0	2.4		158	45	341	261	77	226	42	131	42	274	20	23	strike-slip
10	6/3/92	20:21	44.80	28.35	7	3.2		238	74	217	136	55	340	37	103	50	258	12	3	strike-slip

fraction line being written the estimated depth of the focus (Fig.1)

The solutions of the plan of the fault allow the finding out the axial directions of the compression or of the extension on a source. In the trying of detailing the distribution of the seismical events, as well as of distribution of the hypocenters (Fig.9) results a strong concentration of the appearance in North Dobrudjan Orogen and in the southern part of underthrusted of Scythian Platform, the all area could be considered active from seismo-tectonic point of view.

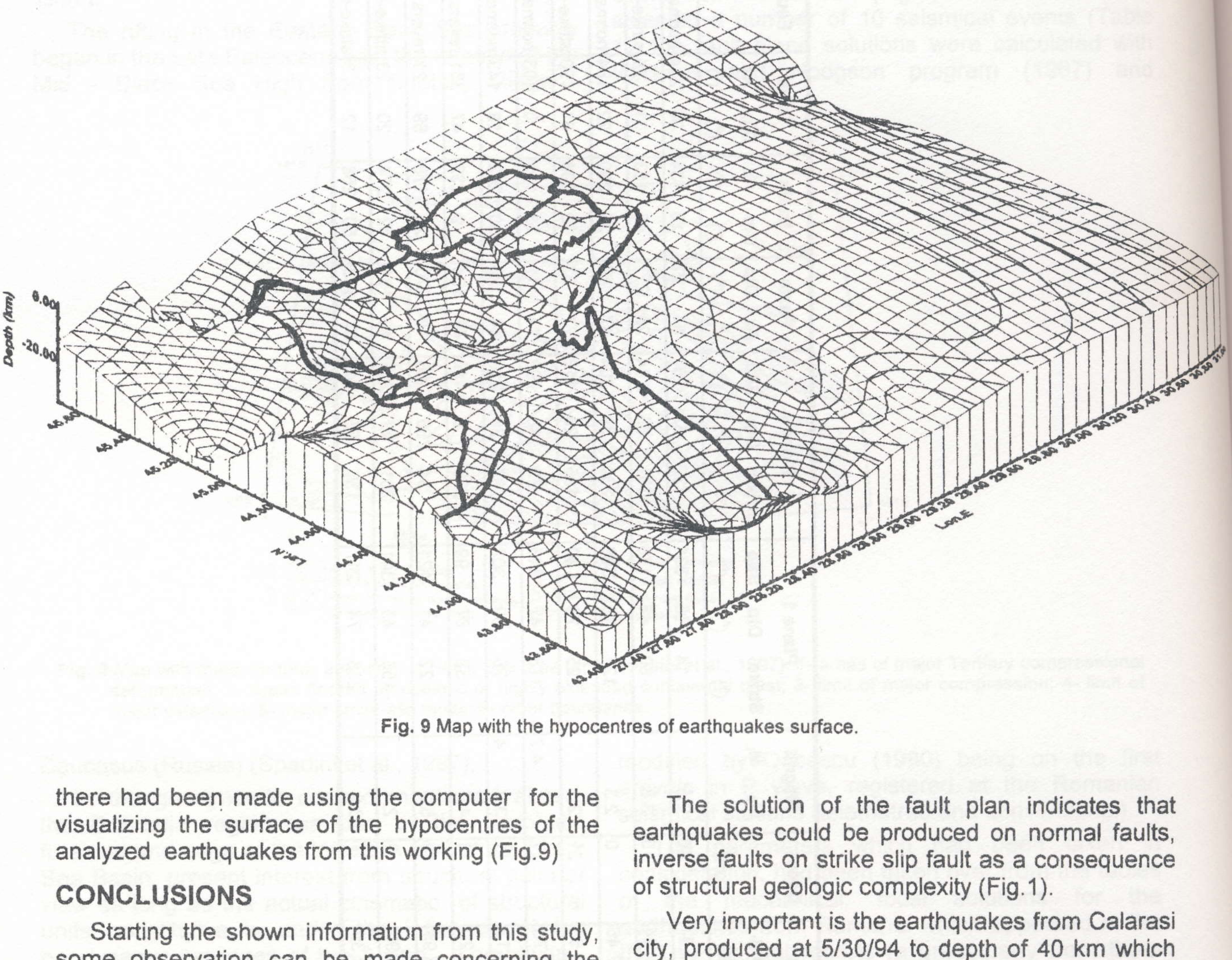

Fig. 9 Map with the hypocentres of earthquakes surface.

there had been made using the computer for the visualizing the surface of the hypocentres of the analyzed earthquakes from this working (Fig.9)

CONCLUSIONS

Starting the shown information from this study, some observation can be made concerning the present day cinematic of the lithospheric blocks, which are part constituents of the Dobrudjan area.

The first GPS measurements done on the Romanian territory in the framework of CEGORN-CEGRN project, confirm the differential movement of the lithospheric blocks from the studied area on the NW - SE direction (one of this measurementpoint has been emplaced at Macin in the North Dobrudjan Orogen, Fig.5).

At a very carefully examination of the areal distribution of the earthquakes epicenters (Fig.1) The solution of the fault plan indicates that earthquakes could be produced on normal faults, inverse faults on strike slip fault as a consequence of structural geologic complexity (Fig.1).

Very important is the earthquakes from Calarasi city, produced at 5/30/94 to depth of 40 km which put in evidence the transcrustal and active character of Intramoesian Fault. Moho discontinuity is situated at 30 km in this area (Fig.1).

The high frequency of earthquakes situated west of Danube (Moesian Platform) and relative alignment on the N-S direction mark a thinning step of structures of the platform towards Carphatian Foredeep.

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