International Association of Geodesy

I A G ACTIVITIES IN ROMANIA
1999 - 2003

Professional Organizations:

- Union of Romanian Geodesists
- Romanian Society of Geophysics

Institutions:

- *Technical University of Civil Engineering*
- *National Office of Cadastre, Geodesy and Cartography*
- *Romanian Space Agency*
- *Institute of Cadastre, Geodesy, Photogrammetry and Cartography*
- *Geological Institute of Romania*
- *Institute of Geodynamics "Sabba Stefanescu", Romanian Academy*

Universitary Education:

- *Technical University of Civil Engineering Bucharest, Faculty of Geodesy*
- *University of Bucharest, Faculty of Geology and Geophysics*

Publications:

- *Journal of Geodesy, Cartography and Cadastre*
- *Revue Roumaine de Geophysique, Romanian Academy (in English)*
- *Scientific Bull. Technical Univ. of Civil Engineering Bucharest*
- *Journal of the Institute of Cadastre, Geodesy, Photogrammetry and Cartography.*

PART I: POSITIONING

Horizontal Control Network

a) Working out the national GPS geodetic network

Within the framework of the Institute of Cadastre, Geodesy, Photogrammetry and Cartography (ICGFC) has been worked out "The Project of National GPS Network of Romania" (phase I). After implementing the project until the end of 2003, Romania will possess a new GPS network of 200 high precision points (± 2 cm) placed uniformly on the whole national territory. This network will be completed annually until it will come up with 4000 points in a compact network (in the year 2007).

The determination of the new points will depend on the recordings provided by GPS permanent stations, these being at ONCGC orders. From the funds of the pilot project concerning introduction of general cadastre and real estate publicity amounting to 35 million dollars, of which 25 million dollars financed by World Bank, it has succeeded in the acquisition in 2001 of 5 permanent stations. Five permanent stations make up the GPS network. These permanent stations placed at Suceava, Cluj-Napoca, Timişoara, Sibiu and Brăila, are equipped with Leica 530 receivers, Dorne-Margoline Choke-ring antennas (see appendix 2). The network becomes operative around 01.06.2003.

Within the framework of the Institute of Cadastre, Geodesy, Photogrammetry and Cartography will be organized a Processing and Control Centre which will stock the transmitted information and will coordinate the activity of thes 348 0 Td (r)Tj 3.6 0 Td 4004 0 Td ( )Tj -426.36 -

Main objectives in the field of geodesy

Objective 1. Rebuilding of national geodetic network in a modern conception for the connection to the international system.

Proposals:

1.1. Modernisation of national geodetic network by GPS technology by extending the number of points determined with this technology from approximately 200 points now to about 4000 – 4500 points, number considered to be the best for the Romanian territory, taking into account the dimension, form and relief of terrestrial space.
1.2. Assurance and maintaining the precision of GPS points in national network at the level required by international standards.

Objective 2. Extension of the network of permanent stations from 5 stations (Suceava, Brăila, Cluj-Napoca, Sibiu and Timişoara) to 10 – 15 permanent stations.

Objective 3. Setting up a coordination centre of GPS stations at the Institute of Cadastre, Geodesy, Photogrammetry and Cartography Bucharest and assurance a permanent connection between this centre and GPS stations placed in territory by Internet.

Objective 4. Endowment with GPS mobile receptors of the institutions subordinated to ONCGC in order to extend the GPS technology measurements and gradually reduce the classic techniques.

Objective 5. Providing the necessary equipment and software (necessary) for the transfer of GPS data from WGS (World Geodetic System) to the national reference system and vice versa.

Objective 6. Integration of the national geodetic networks in the international geodetic networks.

The Vertical Network

Integration of tide gauges in the national and international reference system

An important action was done in 2001 when by GPS determinations was integrated the five Romanian tide gauges installed at Mangalia, Sulina and Constanța in the national reference system and in the international geodetic system WGS-84 (see appendix 1).

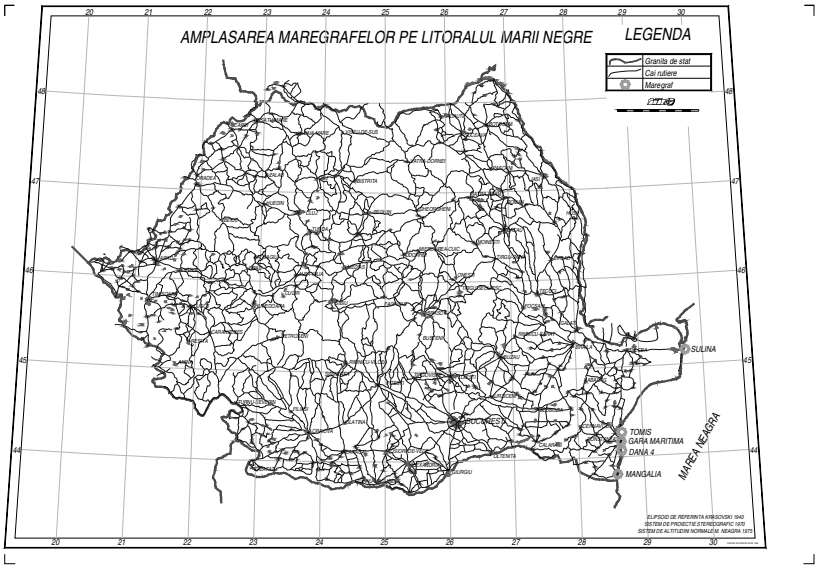
The achievements in this period, although relatively modest, constitute a solid base to extend the modern geodetic technologies on the Romanian territory in the next period, fact that will lead to compatibility with European standards and to the connection of the national geodetic networks with the international reference system.

Objective 1. Integration of the national vertical network in the international geodetic networks.

Proposals

1.1. Continuation of the cooperation within the framework of the European project EUVN;

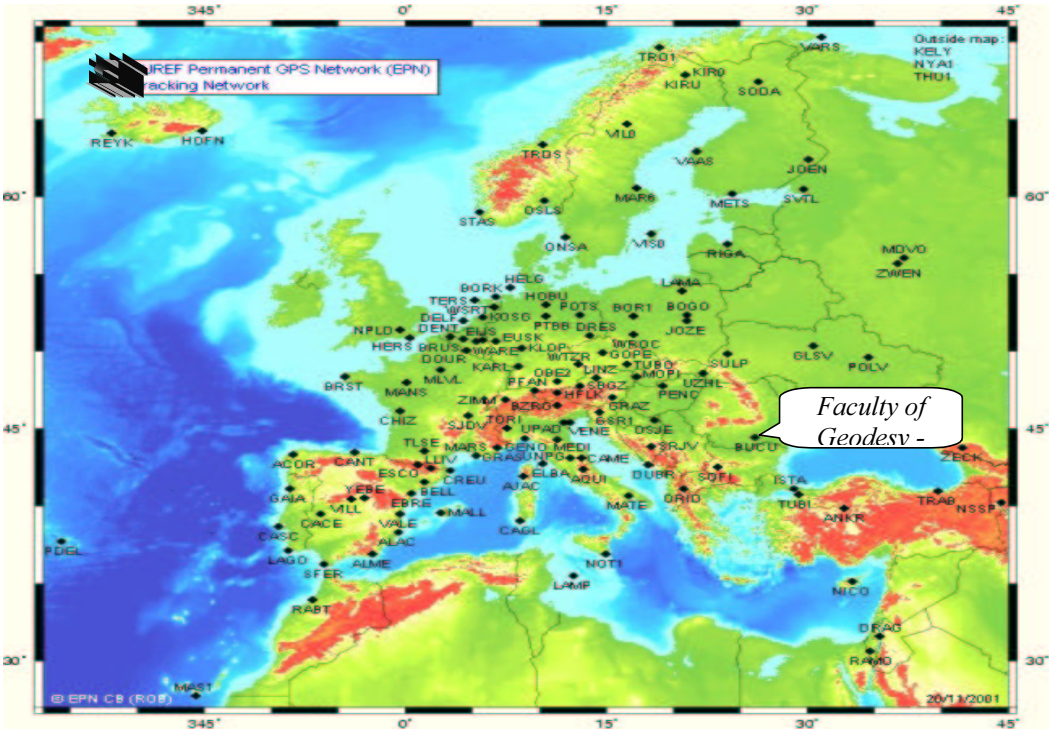
1.2. Cooperation with the National Institute of Researches and Sea Developments "Grigore Antipa" for the use of recorded data of the tide gauges net, installed and administrated by this institute on the Black Sea shore.



Tide gauges position on Black Sea shore.

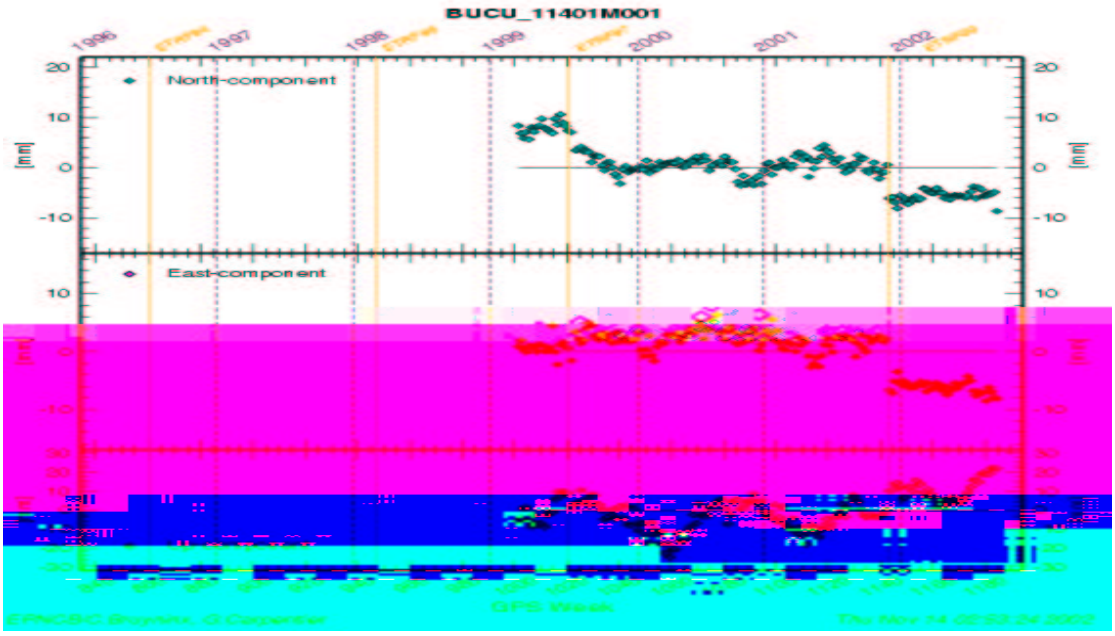
PART II: ADVANCED SPACE TECHNOLOGY

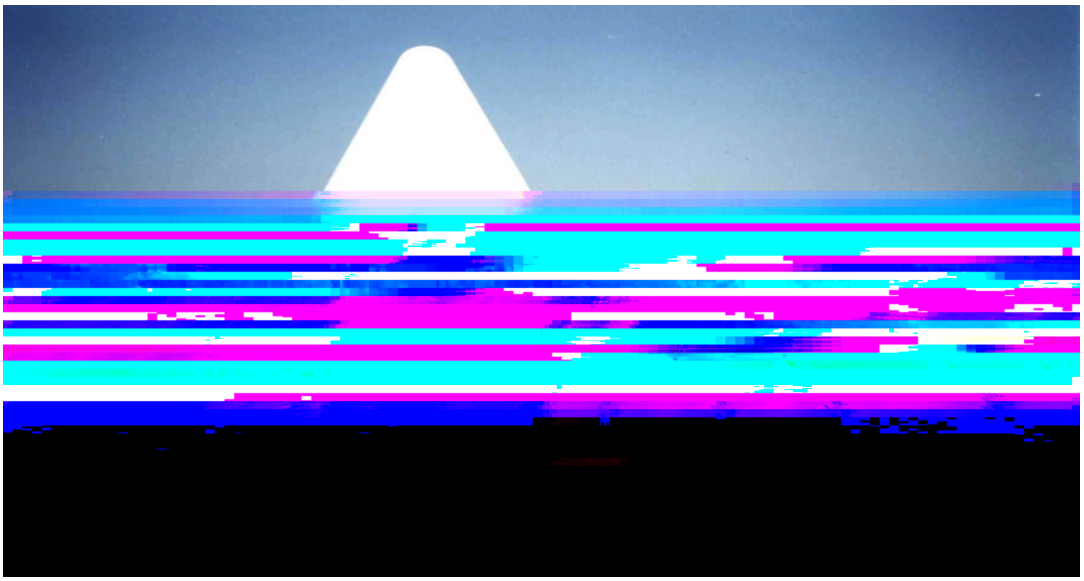
Activities on the BUCU GPS permanent station



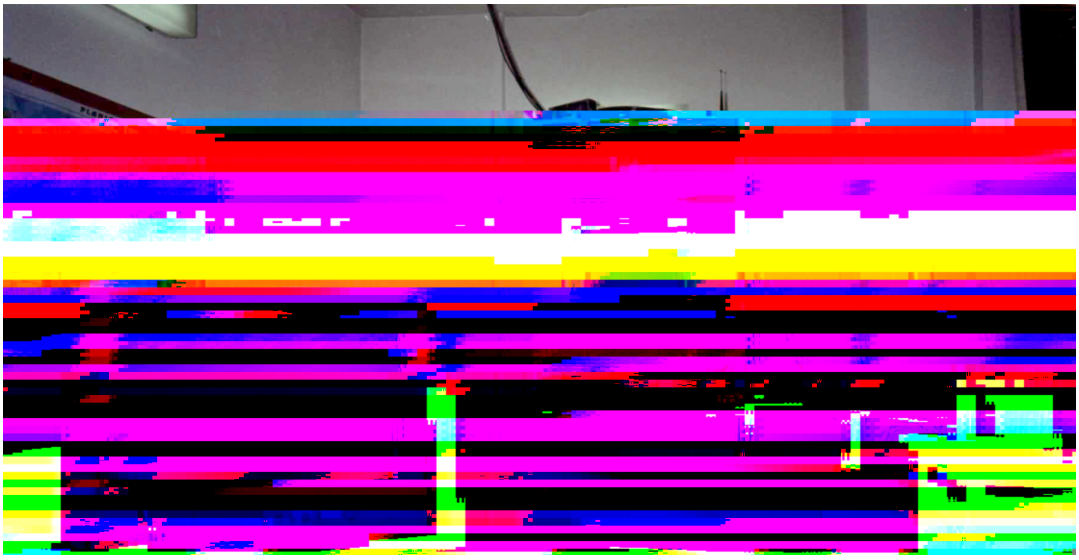
Kinematics in Romania" and Geodetic Institute Karlsruhe (GIK) network established in Romania for geodynamic purposes combined with earthquake research in Vrancea region. On this projects GPS data were delivered for 1999 (CERGOP), 2000 (GIK), 2001 (CERGOP) and 2002 (GIK) campaigns. A part of CERGOP"99 network was processed by a Romanian specialist at BKG Data Processing Center in Frankfurt a.M..

Inside Romania, BUCU station is part of Romanian GPS Permanent Stations Network including 6 stations: BUCURESTI, BRAILA, CLUJ, SIBIU, SUCEAVA, TIMISOARA. The other five stations are operated since 2001 by National Office for Cadastre, Geodesy and Cartography (ONCGC).

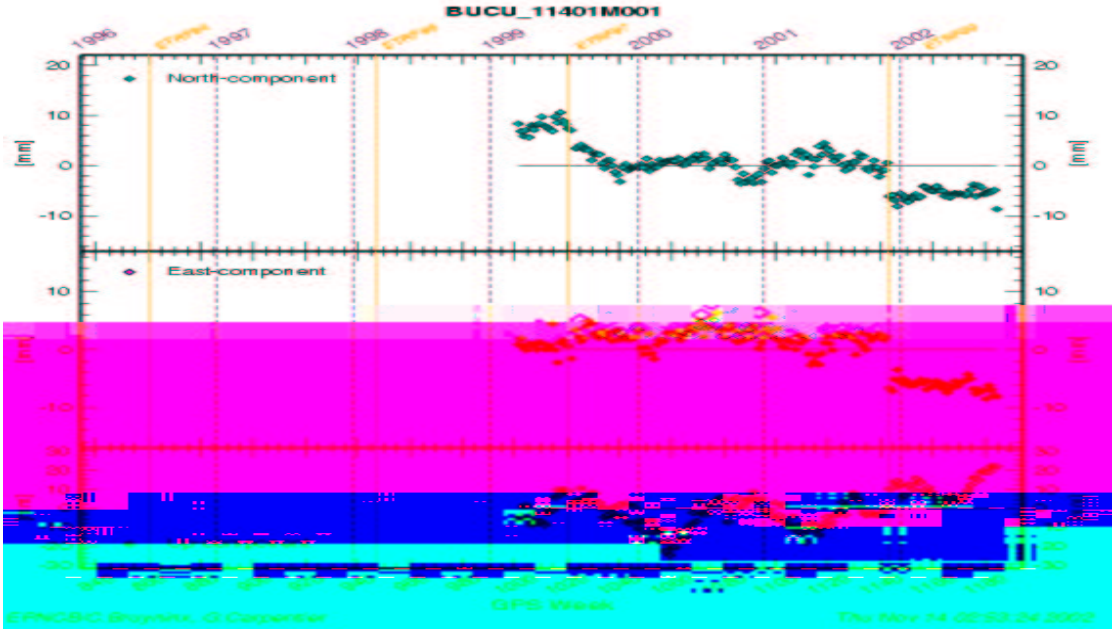




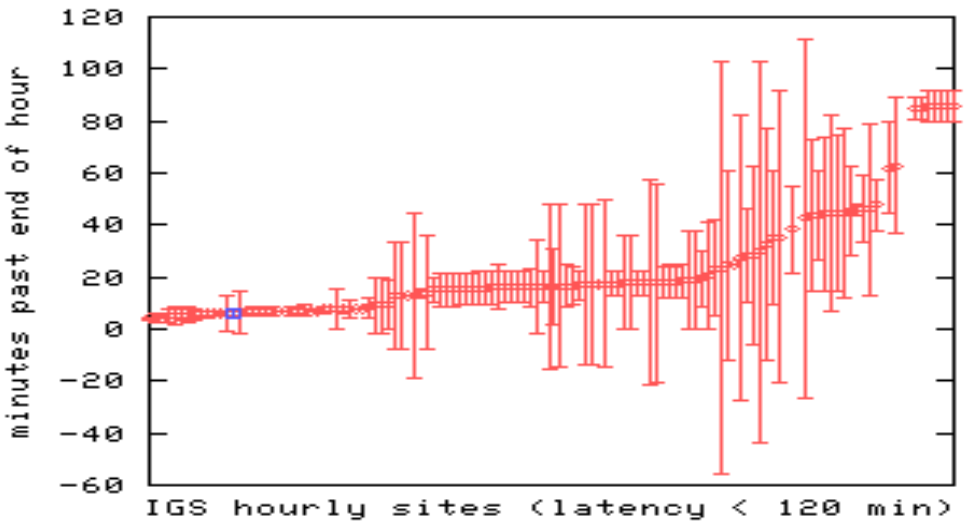
Ashtech Dorne-Margoline antenna at BUCU station



Equipment installed at BUCU GPS permanent station



Time Series Coordinates for BUCU (EUREF)



BUCU hourly latency (IGS)

Romanian array of GPS permanent stations

PART III: DETERMINATION OF THE GRAVITY FIELD

INTEGRATION OF THE ROMANIAN GRAVITY REFERENCE NETWORKS INTO THE GRAVITY SYSTEM OF CENTRAL EUROPE

Introduction

UNIGRACE project was started on 1998 under the umbrella of Central European Initiative and was EC funded. It was aimed to integrate gravity systems of the Central and Eastern Europe former socialist countries into the EC gravity standards. There was the Geological Institute of Romania who was responsible for the works carried out on the Romanian territory. First results have been already presented in the previous report of the IAG Romanian Committee in Birmingham. The extension of the international absolute gravity campaign during the year 2000 has allowed new field determinations on the Romanian territory. The second absolute gravity campaign was carried out by a Finnish team in Cluj-Napoca, Belis, and Constanta UNIGRACE sites, accompanied by special relative determinations. Final results were presented on the occasion of the 4th UNIGRACE Working Conference held in Trieste (Besutiu et al, 2000).

Main tasks

The activities developed within UNIGRACE project during the year 2000, on the Romanian territory, generally followed the scheduled tasks as described in the Annual Progress Report 1999 (Roşca and Beşuţiu, 2000), and recommendations of the 3rd UNIGRACE Working Conference (Sofia, 10-14 April, 2000). They mainly consisted of:

- the second absolute gravity campaign at the Romanian UNIGRACE sites;
- determination of a gravity vertical gradient function at every Romanian UNIGRACE station;
- gravity vertical gradient determinations at every station of the Romanian national gravity reference networks connected to the UNIGRACE station;
- relative gravity measurements on the UNIGRACE calibration line (Beliş – Cluj-Napoca) ;
- new gravity ties between the re-occupied UNIGRACE absolute gravity stations and stations of the first order reference network of Romania;

Absolute gravity determinations

A second absolute gravity campaign was performed by a Finnish team in co-operation with Romanian specialists in Cluj-Napoca, Belis, and Constanta UNIGRACE sites.
A ballistic gravity meter JILAG-5 was used on purpose following the same approach in data acquisition and processing as in the previous campaign made by the German team (thoroughly described in the previous report of the Romanian IAG Committee).

Gravity vertical gradient determinations

Gravity vertical gradient determinations focused both on the UNIGRACE sites and location of the gravity reference networks base stations which were used to transmit absolute gravity from the UNIGRACE network to the national gravity system. Vertical gradient

determinations were also performed at the ends of the Romanian UNIGRACE calibration line Cluj-Napoca – Beliş.
To achieve vertical gradient values, differential measurements were carried out at every site at different heights, according to the recommendations of the UNIGRACE Working Conference held in Sofia (0.30 m, 0.80 m and 1.30 m). The same gravity meter, LaCoste&Romberg D-214, was used on purpose, as in the year 1999.

Relative gravity determinations

Relative gravity ties have been performed between the UNIGRACE absolute gravity base stations and stations belonging to the Romanian national gravity reference networks. To secure the results of the UNIGRACE works, gravity ties between the main UNIGRACE stations and their safety points were also re-measured. Measurements were carried out with the same L&R D-214 gravity meter. The scale factor provided by the factory has been checked up along the calibration line Beliş – Cluj-Napoca, before and after the measuring campaigns.

Ground density assessment

On 1999 a research programme was started, aiming the development of a gamma ray technique for the direct assessment of ground density variation due to moisture changes (Roşca and Beşuțiu, 2000). This programme continued. As mentioned in the previous national report (Roşca, 1999), a gamma ray density logger owned by the University of Bucharest was used. This logging device was made by the Japan "Oyo Corporation" in 1980.
The logger has been provided with a 700 μCu Co^{60} source and a laboratory testing and calibration programme has been performed.
The field test for a ground density assessment technique was carried out in the hydrogeological borehole drilled for this purpose, close to the "Gilău" UNIGRACE station, in Cluj-Napoca. Simultaneously with the second absolute gravity campaigns made in Cluj-Napoca in October 2000, 6 density logs have been run in the "density observation" hydrogeological borehole.

Romanian gravity system evaluation

The main activities scheduled for the last year of the UNIGRACE project were dedicated to the evaluation and exploitation of the UNIGRACE results.
The evaluation of the Romanian gravity system mainly consisted in comparing absolute level and scale factor of the Romanian gravity reference network with the UNIGRACE standard (Besutiu et al, 2001). Gravity ties between UNIGRACE stations and base-stations of the national gravity reference networks were used on purpose. All the relative gravity determinations were made with the LaCoste & Romberg D-214 meter of the Geological Institute of Romania. Before and after the measuring campaign, the scale factor of the L&R D-214 meter was checked up on the Cluj-Belis UNIGRACE calibration line.
Gravity ties between UNIGRACE stations and the Romanian gravity reference networks (rgrn) base stations revealed small discrepancies only in the gravity datum (Besutiu et al, 2001).

Scale factor of the Romanian gravity system

The first attempt to construct a Romanian national gravity calibration line was represented by the calibration line Sinaia-Comarnic, settled in 1955 (Botezatu, 1961). The seven Nörgaard T.N.K. relative gravity meters owned by the Geological Committee of Romania were used on purpose. The mean value thus determined was 26.06 ± 0.03 mgal.
Several years later, with the technological improvements of the meters, another calibration line was settled, which is still in use. It is approximately central Romania located, in Brasov area. A gravity interval of about 78 mgal is obtained between Brasov and Poiana Brasov, for an altitude range of about 350 meters.
During the years, various values have been assigned to the gravity range along this calibration line, according to the instruments used. As a rule, whenever a new lot of gravity meters reached the country they were taken to measure on the calibration line. The average obtained by using the factory scale factor of each meter was considered as the calibrating standard. Every year, all relative gravity meters did perform several measurements on this calibration line and their scale factors were altered according to its value.
However, it is worth mentioning that:

(i) the line has been never checked up by using absolute gravity determinations;

(ii) the relatively small gravity interval along the Brasov-Poiana Brasov calibration line is not appropriate to compare scale factor for modern gravity meters (like LaCoste & Romberg instruments for instance).

Consequently, during the UNIGRACE absolute gravity campaigns in Romania, a new calibration line was settled between Cluj-Napoca and Beliş. It has two UNIGRACE base stations at its ends, where absolute gravity determinations were performed in 1998 and 2000 by a German, and, respectively, Finish team, using ballistic gravity meters. Relative gravity determinations along the UNIGRACE calibration line were also carried out with L&R D-214 meter (table 1).

Year	Gravity interval on the calibration line as provided by UNIGRACE absolute measurements - mgal -	Gravity interval on the calibration line as provided by LaCoste&Romberg D-214 - mgal-	Deviation -mgal-
1999	172.125	172.108	0.017
2000	172.118	172.098	0.020

Table 1 Gravity measurements on the BELIŞ-CLUJ calibration line

The scale factor of the Romanian gravity reference network scale was checked up by comparing a large gravity interval across the national territory (between Constanta and Cluj-Napoca – see table no. 2)

				Deviation

Gravity interval subject to analysis	Gravity meter	Δg according to rgrn (mgal)	Δg according to UNIGRACE (mgal)	Deviation	
				Absolute (mgal)	Relative (%)
Cluj-Napoca Constanta	L&R D-214	119.92	119.83	0.09	0.08

Table no. 2 Gravity interval between Constanta and Cluj-Napoca as provided by rgrn and UNIGRACE network

Comparing UNIGRACE and US-NIMA standards

Taking the advantage of the close neighborhood between the two absolute gravity base stations carried out by the US-NIMA and UNIGRACE teams in Constanta, several relative gravity ties were carried out to compare the US and EU provided gravity datum. Results are summarized in table no. 3.

Specification	Absolute value (mgal)		Evaluations (mgal)	
Station year	USNIMA 1995	UNIGRACE 2000	Gravity interval by L&R D-214	Deviation
Gravity (mgal)	980569.929	980570.175	0.262	0.014

Table no. 3 Comparison between gravity data provided by UNIGRACE and USNIMA stations in Constanta area

Conclusions

Following the analysis made on both national reference network datum and scale factor, it should be noticed that the gravity system of Romania is approaching well the European gravity standard. Several statements might conclude the brief analysis hereby made:

- gravity transferred from the first and second order rgrn to the UNIGRACE absolute gravity sites exhibited almost the same level;
- appropriate scale factor of the actual rgrn was evidenced;
- small difference between the absolute gravity provided by the American team and UNIGRACE teams (about ten microgals) was revealed;
- it is expected that the re-adjustment of the rgrn, as constrained on the UNIGRACE project results, would provide minor alterations only.

THE NATIONAL GRAVITY MAP OF ROMANIA

During the 1999-2003 the Geological Institute of Romania has continued to prepare various sheets of the National Gravity Map of Romania, at the scale 1: 200.000.
Raw data belonging to gravity surveys conducted over 30 years time span are brought at the same gravity datum to compile the maps. Accordingly, the following steps should be performed:

- unification of the local control networks and links to the national gravity reference networks in order to provide absolute gravity datum: following the operation, a maximum accuracy of 0.25-0.30 mgal is expected;
- integration of the leveling systems to the datum provided by Baltic Sea by links to various national reference networks (from I-st to IV-th order): the assumed accuracy obtained is estimated to 0.30 m;
- compilation of the topographical base according to the Gauss-Kruger projection system;
- unification of the geophysical corrections: the topography influence up to 30 km was considered and the Silva-Cassinis 1930 formula was used for the normal field evaluation;
- automat contouring has been performed to 1 mgal interval, for an estimated total inaccuracy of the map of about 0.5 mgal.

Each gravity map sheet is based on its own computer data file that contains: sheet code, year and author of survey, geographical co-ordinates of data points, relative gravity observed and local base station, absolute gravity, topography correction for 2000 kg/m^3 reference density, normal field and Bouguer anomalies.
Legend associated to every map exhibits information concerning: gravity system (IGSN 1971), normal field, location of the various survey used in the compilation and their authors
A program for the compilation of the national gravity map at the scale 1: 50.000 has been also started within the Geological Institute of Romania.
Besides, isostasy (using both Pratt and Airy-Heiskannen models), and gravimetric geoid studies for the whole Romanian territory have been continued (see http://www.igr.ro/dgl/).

CONSTRUCTION AND INTEGRATION OF THE GRAVITY REFERENCE NETWORK OF MOLDOVA INTO THE GRAVITY SYSTEM OF EUROPE

One of the first benefits of the UNIGRACE project was the integration of the gravity system of Republic of Moldova into the EU gravity system through its connection to the gravity system of Romania.
Reconstruction of the national gravity reference network of the Republic of Moldova (project A4) was possible within the framework of the scientific co-operation between the Geological Institute of Romania and the Institute of Geophysics and Geology NAS of Moldova (Besutiu et al, 2001). Research was supported through the Romanian Academy grant 6176GR/2000. Actually, the research is part of a larger project, GRANAT, a joint venture between Geological Institute of Romania, Institute of Geophysics NAS of Ukraine, and Institute of Geophysics and Geology NAS of Moldova, aimed to the merging of the gravity networks of Romania, Moldova and Ukraine.
The national gravity reference network of Moldova consists in seven first order base stations mainly located on the pillars of seismological stations of Moldova. They are connected within a triangle network by ten gravity ties. Each tie was at least twice measured during independent cycles carried out in different days by the L & R D-214 gravity meter of the Geological Institute of Romania.
Network gravity datum was provided through several cross-border gravity ties that enabled connection to the Romanian National Gravity Reference Network.

PART III: THEORY AND METHODOLOGY

In the frame of **National Plan for Research-Development and Innovation of Educational and Research Ministry, ROSA – Romanian Space Agency** coordinates the program **Technologies in aeronautic and space – aerospace field.**
The program contains the next subprograms:

- Strategy and infrastructure in the fields of space and aerospace.
- Space explorations
- Space applications
- Space and aerospace technologies and systems
- Products and applications of space and aeronautic technologies
- Centres of excellence

The subprograms have a marked interdisciplinary character and in their frame Geodesy has his incontestable role. In present the geodetic activity in Romania is integrated especially in the subprogram "**Space applications"** that follows objectives:

- New methods and techniques for space telecommunications, unconventional systems of communication, concepts for development the space systems for global informational infrastructure.
- Development of applications and integration of global position and navigation systems with communication and remote sensing systems in geographical information systems, cartographic systems, global systems;
- Applications of space techniques in monitoring systems of natural and anthropic disasters, especially for floods, droughts, sliding fields, earthquakes, pollutions, fires;
- New methods for acquisition, processing, classification, transmission, archiving of satellite remote sensing data came from optical sensors, IR, UV, radar, magnetic and gravitational sensors;
- Platforms without pilot for territory observations;
- Applications of satellite remote sensing for monitoring the specific national zones, especially the Basin of Danube, the Danube Delta, Black Sea, seismogenic Vrancea zone, forest zones;
- Applications of systems and space data for environmental and global changes studies, especially at national and regional level, applications for integration of satellite data in meteorology and hydrology;
- Usage of space techniques for telemedicine, especially for medical assistance in disadvantaged zones, for achievement of international networks, data bases, on-line surgery;
- Advanced techniques for raising the productivity in agriculture, based on usage of space data and on concepts of precise agriculture.

Since October 2002, under ROSA umbrella, a consortium formed by 4 institutes and firms: **IAROM, INTERGIS GROUP, UTCB and AEROSTAR** works together to the priority Program **STUDIES AND SYSTEMS FOR PARTICIPATION OF ROMANIA TO THE PROGRAM GNSS – ESA (EUROPEAN COMMITTEE).** The project proposes to achieve the objectives stipulated at the level of **aerospace** program, especially those of

Space Applications subprogram. The priority program is achieved by competent partners, but are expected other representatives of interested authorities in collaboration and direct application of the results, as well as other representatives which can enlarge the area of social-economic efficiency of the program. The estimated results of the project will permit to touch the following objectives:

- Identification of the fields in which applications and services based on GNSS could develop, the industrial, social and economic impact and the achievement of systems and applications for direct users;
- Implementation of navigation systems based on space technologies on Romanian territory, especially for monitoring and optimisation the transports using space technologies, based on data offered by GNSS;
- New applications of space, aerospace and aeronautic technologies;
- Infrastructure systems necessary for development of specialised multidisciplinary centres and for a park of advanced space and aero space technologies;
- Achievement of a space data base at regional level;
- Integration of Romania in European Space Agency and in space, aerospace and aeronautic international organisms.

The first activities in the frame of the program were orientated to the definition of the fundamental strategic directions for participation of Romania to the GNSS Program of ESA, achievement of a study concerning establishment of the technique and economic conditions for Romania to adhere to program GNSS and creation of a WEB page which should permit on one side information of those who are interested in the stage of GNSS systems implementation at European level comparative with the stage in Romania. On the other side, the WEB page should be able to spread information and interest data to the users of this technology.

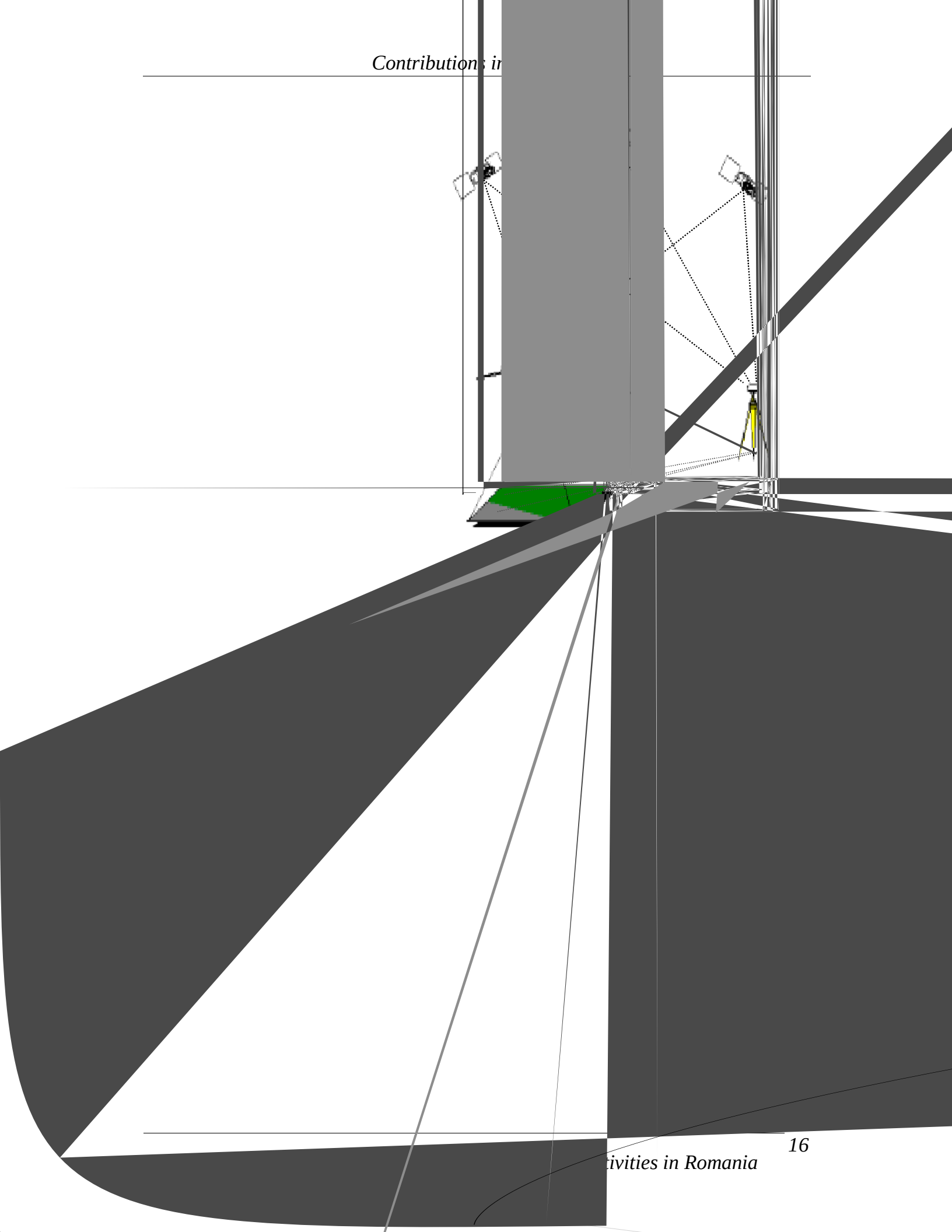
An achievement that can be taken into account is the establishment in the frame of ROSA of a **Pilot Centre of Application – GNSS (ANSAT)**, in present being defined the organization structure and the field of work for this Centre, which should sustain the adhere strategy by promoting the GNSS technology in all economic sectors, not only by emphasize the applications but also by economic policy forces.

The research project started in 2002 up to 2005 includes BUCU as GNSS (Global Navigation Satellite System) realization in Romania.

A number of state and private companies are presently using GPS data from BUCU permanent station for a lot number of applications: aerotriangulation projects inside Romania, geodetic and cadastral networks, GIS projects in Bucharest et al. In the same time, scientific investigations are performed by young scientists in the GPS field with the help of BUCU data: deformation studies, heterogeneous data adjustment, geoid investigations, kinematic applications, data quality monitoring, GPS/GIS studies.

BUCU permanent station located in the TUCEB campus serve also as a practical support for Satellite Geodesy lectures and training.

We can mention the good cooperation between BKG – Frankfurt a.M. and local authorities (University Senate and Faculty of Geodesy staff) in maintaining of the best performances for BUCU hardware, software and facilities (clima station, power supply, internet and GSM connection).



The Collaborative Research Centre CRC 461 carried out in August 2000 a new campaign in collaboration with the Geodetic Institute Karlsruhe. The stations are situated in the Vrancea region where the majority of the earthquake epicentres in Romania are located. The extension of the network in the north-south direction measures about 380 km and in the east-west direction about 250 km. The existing CEGRN of 6 stations in the area was densified with 25 new stations. The monumentation is done analogue to the CEGRN marking concept. The network densification will improve the results by a better coverage of significant tectonic units. The insertion of at least one permanent GPS station would improve the results considerably.

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COMPLEX STUDIES IN GEODYNAMICALLY ACTIVE AREAS, WITH A SPECIAL VIEW TO THE VRANCEA SEISMOGENIC AREA

The bending zone of the Eastern Carpathians has been for long under the attention of researchers due to the persistent intermediate-depth seismicity of Vrancea seismogenic area. Its specific geodynamic features and its geographical and tectonic environment make the Vrancea area a real "Natural Laboratory for Geodynamics", unique in the world. The location is shown in Fig.1. Among the peculiarities of this natural laboratory, we mention:

- the small, strictly confined area of the epicentral zone, corresponding to an ellipse-shaped area having its large axis, of about 70 km long, striking northeastward, and the small axis of about 35 km (Fig. 2);
- the almost vertical distribution of hypocenters to depths that exceptionally exceed 180 km, with a practically aseismic zone located between 40 and 60 km (Fig. 3);
- the high frequency of earthquake occurrence corresponding to the same epicentral area (small magnitude earthquakes occur, practically, daily);
- the fact that, several times in a century, earthquakes with magnitude significantly higher than 7.0 on the Richter scale are triggered;
- the extended area, situated in Romania, the Republic of Moldova, Bulgaria, Hungary, Yugoslavia, and even in Ukraine and Russia, affected by strong Vrancea events. This area is densely populated (the city of Bucharest has about 3 million inhabitants) and has numerous socio-economic objectives of highest importance, including nuclear power plants (Fig. 4);
- the presence of an ensemble of geodynamics observatories and observation points, grouped in polygons of Geodynamics, which benefit both from historical observations extending over more than a millennium, and from instrumental observations initiated about a century ago and improved continuously by addition of new instrumentation;
- its accessibility: the Polygon of Geodynamics Căldăruşani – Tulnici (Fig.5) encompasses the international airport Bucharest-Otopeni and the city of Bucharest – the capital of Romania – and is crisscrossed by a dense network of roads and railways.

The Institute of Geodynamics "Sabba S. Stefanescu" of the Romanian Academy (IG"SSS"AR) has at present a network of observatories and observation points, structured in profiles and geodynamics polygons, all having as a main purpose a better knowledge of phenomena leading to stress cumulating/ triggering in geodynamically active areas, with a special concern for the geodynamically active area of the Romanian Carpathians bend - the Vrancea seismogenic area. The network is concentrated in three geodynamics polygons: the Căldăruşani-Tulnici Geodynamics Polygon, the Crăciuneşti-Deva, Sarmizegetusa Regia, Padeş-Gorj Geodynamics Polygon and the Danube Delta - Mangalia Geodynamics Polygon (Fig. 5).

Among these polygons, a special place is occupied by the Căldăruşani-Tulnici Geodynamics Polygon (Fig. 6) which includes: (1) the Caldarusani Geodynamics Observatory; (2) the laboratories for equipment gauging and aging, arranged in the framework of the Căldăruşani Geodynamics Observatory, in the basement of the group of buildings that constitute the headquarters of the IG"SSS"AR and in the basement of the headquarters of the Romanian Academy; (3) several micro-polygons consisting of over 270 observation points, that allow performing repeated measurements, usually at 6 months up to 5 years intervals; and (4) underground laboratories, which allow data acquisition - within the limits of the possible, without interruption - corresponding to variations in the crust tilt and in the gravity, the magnetic and the electric fields.

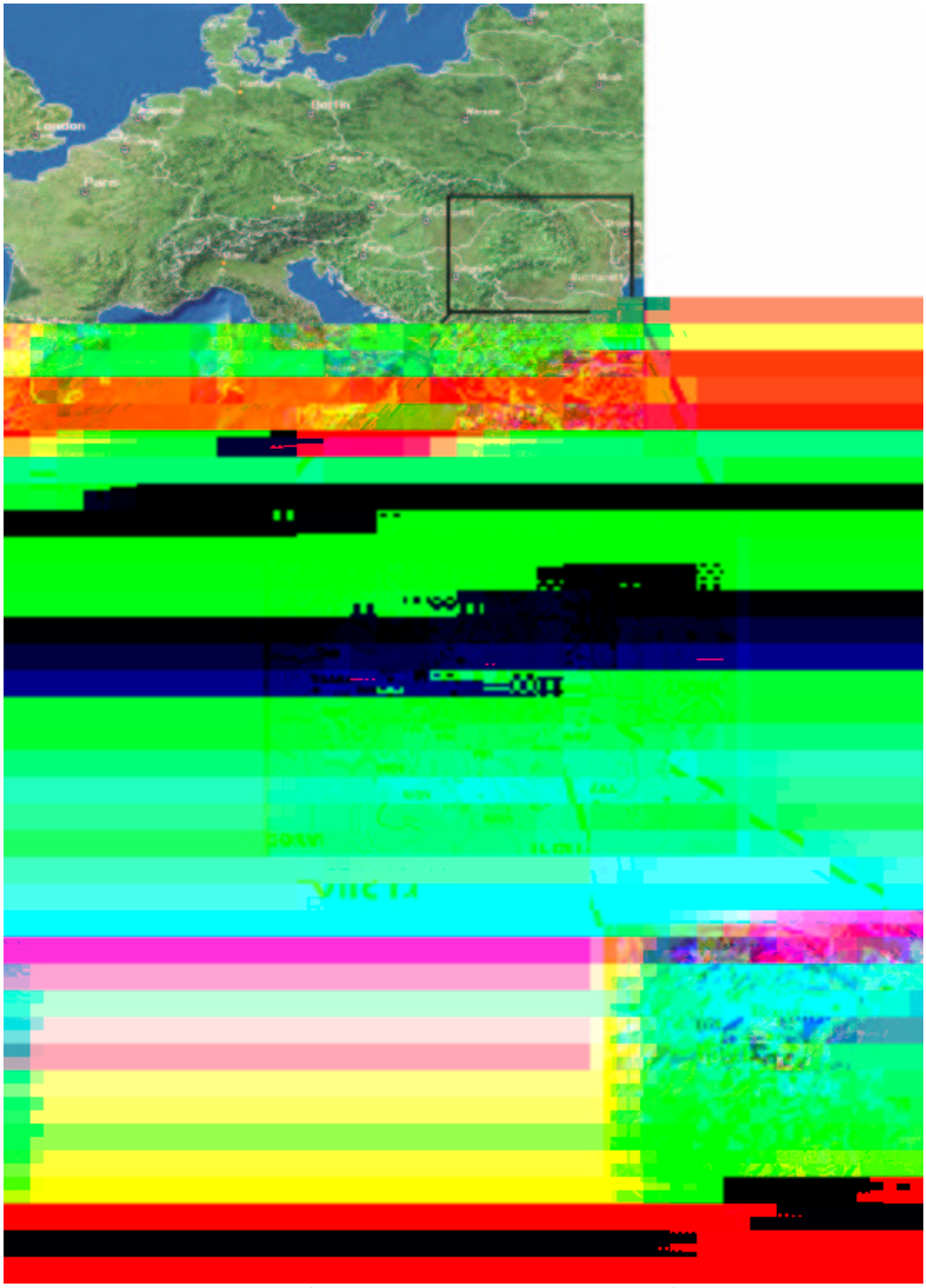

Fig. 1. The location of the Vrancea Natural Laboratory for Geodynamics

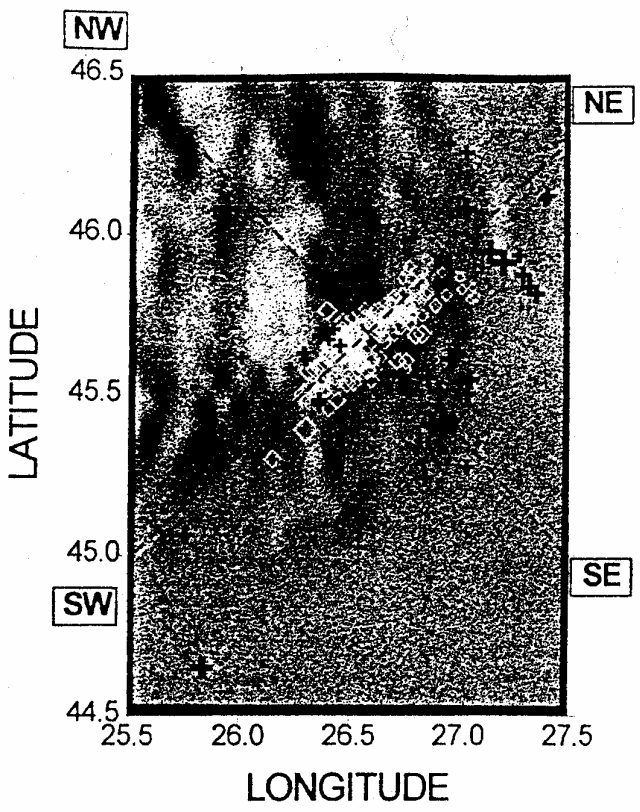

Fig.2. The epicentral area of the intermediate-depth earthquakes*

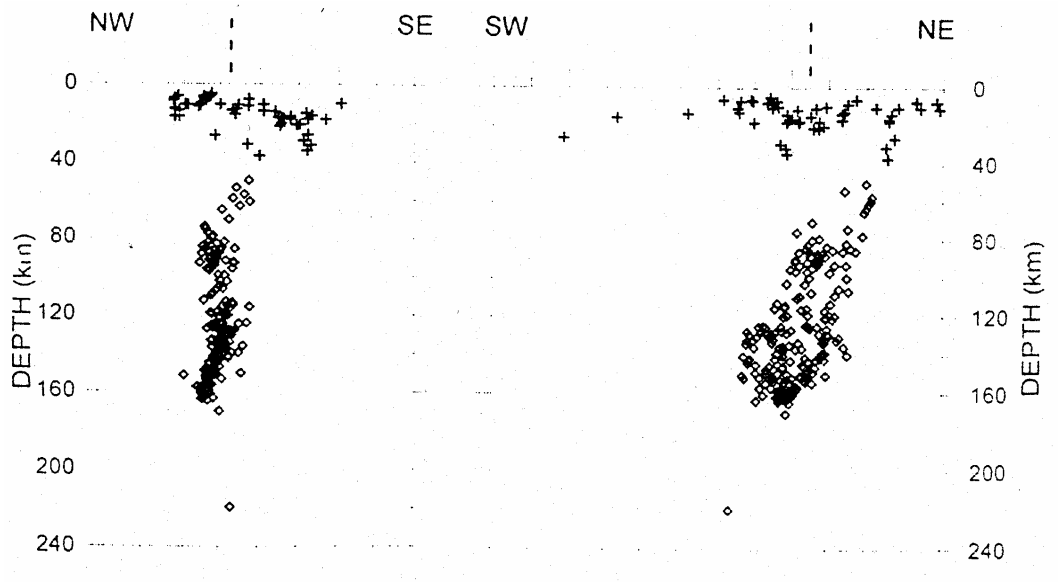

Fig.3. Hypocenters distribution on the NW-SE and NE-SW sections in the Vrancea area*

* **Oncescu, M.C. and Bonjer, K.P. (1997)** A note on the depth recurrence and strain release of large Vrancea earthquakes, *Tectonophysics, 272, 291-302*.

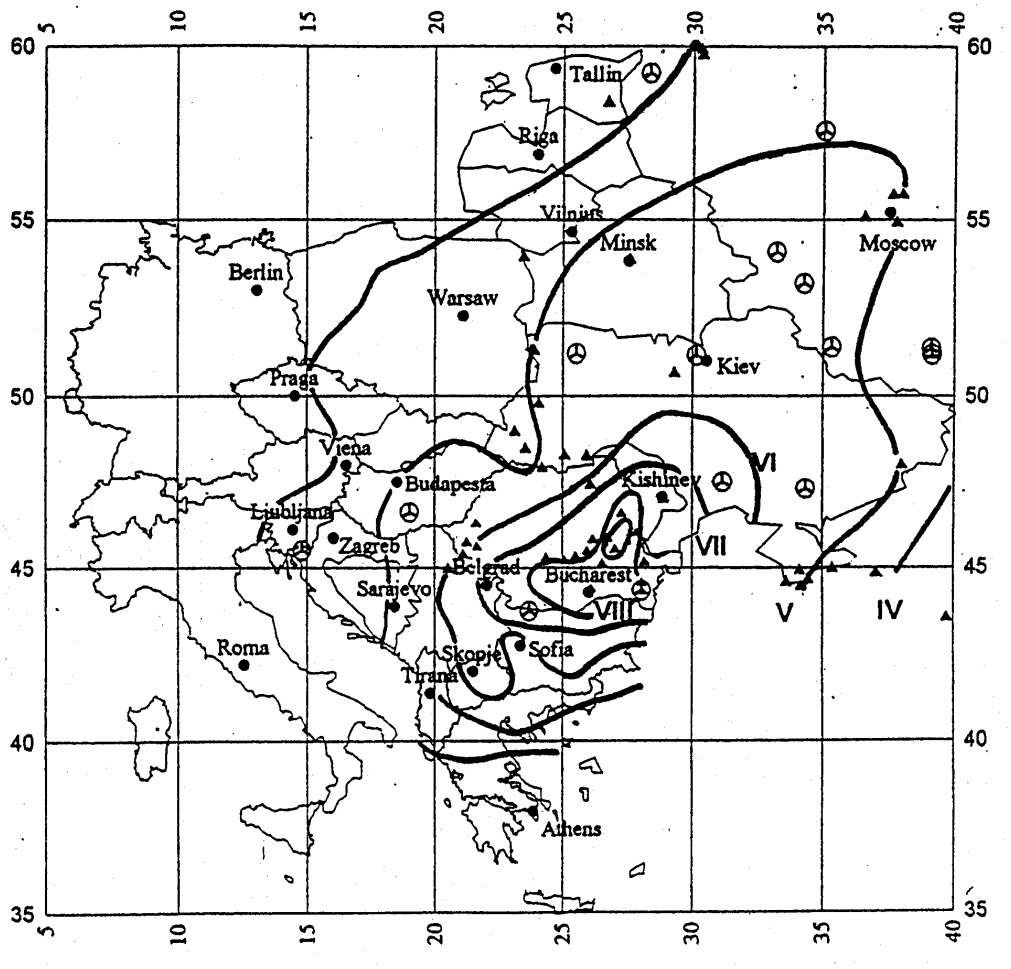

Fig.4. The isoseists map, for the march 4, 1977 Vrancea earthquake.

Fig. 5. The location of the geodynamics polygons of the *"Sabba S. Ştefănescu"* Institute of Geodynamics on the Romanian territory.

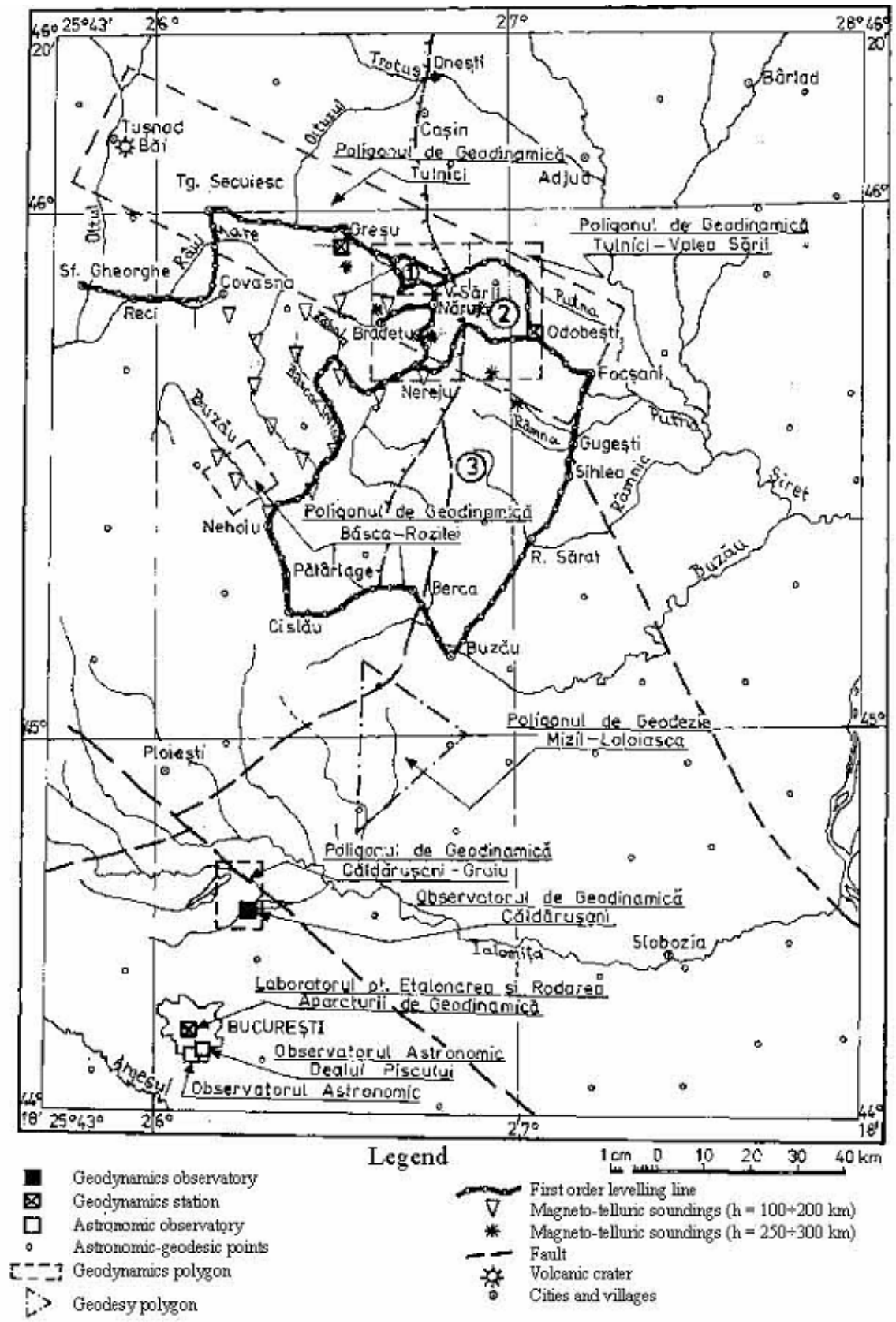

Fig. 6. Căldărușani-Tulnici Geodynamics Polygon

In 2001 the anniversary of four decades of existence of the Caldarusani Geodynamics Observatory took place, underlining the importance of the first, and up to now the only, co-operation established between one of the orthodox Christian church – the Romanian Orthodox Church – and science – the Romanian Academy, which started in 1961 with the inauguration (installing) of the Observatory in a building of the Caldarusani monastic complex (Fig.7). The observation points in the micro-polygons consists of benchmarks of a special design, buried at 2.0-2.5 m in the live rock, beneath the altered superficial zone and recent sediments; they are included in the first order national networks (the national geodetic network and the magnetic and gravimetric fields observation networks).

Fig. 7. The signatories of the collaboration between the Căldăruşani Monastery and t

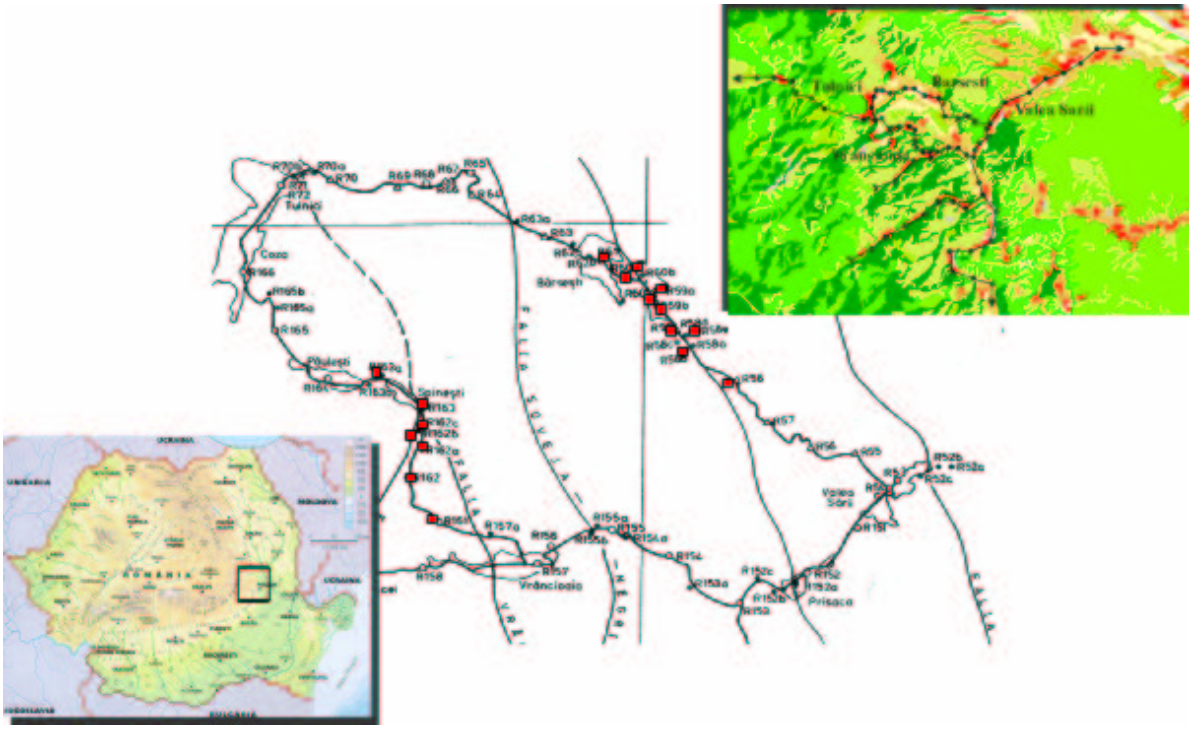

Fig. 8. The Mycropolygon I – Tulnici

The Crăciuneşti-Deva, Sarmizegetusa-Regia, Padeş-Gorj Geodynamic Polygon is constituted, in its northern part, of a set of underground observatories including laboratories at depths exceeding sometimes 500 m below the soil surface, where the sensors are located far from any influences of anthropic activities and at a distance of about 300 km of the Vrancea geodynamically active area; these laboratories, which allow recordings that are subject only to low perturbation by parasite noises, have the role to provide a valuable reference information. The Danube Delta - Constanța Polygon is dedicated to the monitoring of present-day phenomena of sedimentation / erosion dynamics, specific to the river water / marine water / crust contact.

To maintain the high standards of the research, specialists from other Romanian research units (The National Institute of Earth Physics, The National Institute for Building Research, the Geological Institute of Romania, the Geophysics Department of the Faculty of Geology and Geophysics, the Prospectiuni S.A. Enterprise, MINEXFOR Deva, etc.) are rallied to these activities, as well as specialists working in European research units with a similar profile (Institute de Physique du Globe - Paris, the Royal Observatory of Belgium, the Odendorf GeoObservatory of the Institute of Theoretical Geodesy of Bonn University, the Institute of Geophysics of the University of Karlsruhe, the Laboratory of Geophysics of Aarhus University, the United Institute of Earth Physics - Moscow, the Institute of Geophysics and Geology - Kishinew, the Institute of Geophysics - Bratislava, the Institute of Geodesy and Geophysics - Sopron, the Institute of Nuclear Research - Debrecen, a.s.o.), respectively from Japan (the Institute of Seismology and Volcanology of Hokkaido University) and the United States (the United States Geological Survey).

To strengthen the relations with the European centers of Geodynamics, respectively to make a direct contact to the achievements of these centers and to carry out, with equipment of own construction, connecting recordings, the Institute organized:

– in June-July 2000, a European Mission of Geodynamics in the framework of which a

group of 12 Romanian researchers visited the Schiltach Observatory of the Institute of Geophysics - Karlsruhe, the European Institute of Geodynamics - Luxembourg, the Royal Observatory of Belgium, the Odendorf GeoObservatory of the Institute of Theoretical Geodesy of the Bonn University, Institut de Physique du Globe - Paris, institutions in the framework of which the partners, Romanian and foreign - at the international co-operation concerning the Vrancea area - presented the achieved results, and

– in June 2001, the "Căldăruşani 2001" International Symposium, which allowed some of the European collaborators of the Institute to make a direct contact to the works that are carried out in the framework of IG"SSS"AR and particularly at the Căldăruşani Geodynamics Observatory and the Căldăruşani-Tulnici Geodynamics Polygon, respectively.

Also during 2001, the Institute of Geodynamics "Sabba S. Ştefănescu" of the Romanian Academy founded in cooperation with the United Institute of Earth Physics "O.Yu.Schmidt" of the Russian Academy of Sciences, the ***International Virtual Laboratory of Geodynamics***, an international laboratory open to the participation of researchers with preoccupations in this domain, from Romania and Russia, as well as from other countries. The International Virtual Laboratory of Geodynamics, supported by UNESCO - Paris, is currently becoming an international network of specialists activating in institutes interested in geodynamics. Up to this day, specialists from many other institutions have expressed their wish to join the Virtual International Laboratory of Geodynamics, from Romania (the Geodynamics Group in the Section for Oil, Mines and Geonomy of the Academy of Technical Sciences of Romania, The National Institute of Earth Physics, the Institute for Fine Mechanics, the National Institute for Building Research), from Germany (the Institute of Geophysics of the University of Karlsruhe), from the Republic of Moldova (the Institute of Geophysics and Geology of the Academy of Sciences in Chisinau), from France (Institut de Physique du Globe - Paris, le Département de Géophysique Appliquée de l'Université Pierre et Marie Curie, Académie de Paris), from Italy (International Centre for Theoretical Physics, Israel (Geophysical Institute of Israel), Bulgaria (Bulgarian Geophysical Socieety), Spain (Madrid University), Ukraine (Institute of Geophysics of Ukrainian Academy of Sciences).

A mobile Geodynamics laboratory is being modernized, which has been used for complex geophysical measurements in geodynamically active areas also outside the country (electromagnetic soundings, electrometric measurements, soil vibration measurements, measurements of the electric, magnetic, and gravity fields), providing information about the vertical distribution of some of the physical parameters which characterize the various compartments of the Earth interior, from Earth surface to depths that, for some of the parameters, may significantly exceed the thickness of the lithosphere.

During the report interval, the IG"SSS"AR has continued to focus its interest on fundamental research imposed by the tasks implied by the Priority Program of the Romanian Academy, *"Complex geophysical research in geodynamically active areas concerning especially the Vrancea seismogenic area"*, regarding particularly:

– the study of space-time variations of some parameters causally linked to the cumulating of stresses responsible for earthquakes occurrence;

– crustal deformations monitoring (relative displacement of tectonic blocks);

– tectonic hazard studies;

– the monitoring of space-time variations of the gravitational, geomagnetic, geoelectric fields and of Earth crust tilts;

– the creation and permanent maintaining at an international level of a mobile specialized equipment for complex studies in geodinamically active areas (seismoactive areas, landslides, underground cavities collapses, areas that became geodynamically active because of anthropic activity);

– modeling of the thermo-mechanical evolution of the lithosphere;

– non-linear analysis of geodynamic systems.

The complexity and interdisciplinarity of this research is illustrated by some review monographs [1-8]. The main results of the activity can be grouped as follows:

Geodetic and geophysical surveys in the Vrancea geodynamic poligons

Repeated high accuracy geometric leveling was performed on the benchmarks of the Micro-polygon no.1, especially within areas of some active faults. An original methodology for the adjustment of leveling data acquired at various epochs was worked out [9,10].

Several benchmarks of the high accuracy leveling polygon have been also GPS surveyed for horizontal displacement in three measuring campaigns: 2000, 2001, and 2002.

Gravity determinations on 20 high accuracy leveling benchmarks were also performed in 1999 and 2000, using a SCINTREX CG2 gravity meter .

Geoid undulations have been determined within the northern part of the Tulnici polygon (the micro-polygon no. 2: Valea Sării-Topeşti-Tulnici-Vrâncioaia-Valea Sării) by using astronomical determinations at the first order stations of the National Geodetic Network that encompass the seismogenic area. The obtained model has a contour interval of 0.5 m. The missfit to the quasi-geoid prepared by the Army Topography Service (DTM) proved to be below 0.5 – 1.2 mm [11].

Past and Recent dynamics

The Neotectonic study of the main crustal compartments on the Romanian territory, which takes into account the Neogene and Quaternary deformations, the faults and the flexures [12,13]. A new image of the recent vertical crustal movements on the Romanian territory, expressed in a map created by the interpretation of the repeated levelling data according to the structure and geodynamics of the area – a new method worked out in the Institute of Geodynamics, has been achieved [14-19].

The space-time evolution of tectonic units from the Vrancea orogene and its foreland has been studied [20,21]. Information on seismic longitudinal waves velocity from borehole loggings [22-24] and on generation, migration and trapping of the hydrocarbons [25] has been used to infer characteristics of the dynamism of the area. Correlation with the dynamic phenomena in a larger framework – the NW Pontic Domain – has been done [26].

Lithosphere structure

Based on seismic refraction and reflection data and on borehole data, the morphology and structure of the crystalline basement in the bending area of the Eastern Carpathians were presented and a map at the crystalline basement level has been [27,28]. Specialists from the Institute of Geodynamics contributed to interpreting the main discontinuities in the crust along a refraction profile crossing Vrancea area from NE to SW (Project VRANCEA ’99 – *see the IASPEI/Structure of the Lithosphere section of this report*) [29,30].

The structure of the crust and upper mantle in the Tethyan Suture and Trans-European Suture Zone on one hand, and the seismic active Vrancea zone, on the other hand, have been emphasized by means of magneto-telluric tomographies, 2D and 3D modeling [31-46]. According to these studies, the structure and the geodynamic evolution of the seismo-active Vrancea zone might be characterized by the presence of a descending relic continental slab connected with the European Platform and by the progressive change of the strike of the slab at depth, beginning with a NE-SW orientation at its upper part (at about 60 km) and getting to a N-S orientation at depths greater than 150 km, which suggests the slab has been twisted; this

geodynamic process is associated with the appearance of deformation and fracture of the relic slab (*see also the IAGA/Electromagnetic Induction section of this report*).

Stress field

The present-day stress field pattern on the Romanian territory, with special regard on the Vrancea region, has been studied in order to determine the direction and relative magnitude of the various forces controlling the plates motion. The direct, in-situ, measurements of the borehole breakouts and the derivations of the stress data by inversion from solutions of the crustal earthquake focal mechanisms has been used [43-49]. The pattern shows NW-SE compression, with specific variations for different crustal blocks.

Monitoring electromagnetic parameters

Monitoring the electromagnetic field simultaneously compared with seismic activity in the Vrancea zone, having as a final purpose to emphasize precursory phenomena, has been done in order to elaborate a methodology able to find out a new EM parameter, stable in time for a given geological structure, under non-seismic circumstances, the so called normalized function Bzn = Bzn/B*. The anomalous behavior of this parameter may be detected some days before a seismic event occurs [50-57] (*see also the IAGA/Electromagnetic Induction section of this report*).

Geochemical studies

Geochemical studies on water samples from selected springs in the Vrancea area (Caldarusani-Tulnici Geodynamics Polygon) have been initiated. Possible relations with the seismic activity have been evidenced, based on Na-K-Mg geothermometers [58,59]. The role of water in lithosphere has become a matter of study in the report [60-61]; a hypothesis on the role of juvenile water as a wave guide for acoustic and electromagnetic emissions by microcraking of stressed blocks has been advanced.

Physical properties of rocks

Borehole measurements within the limits of the Caldarusani-Tulnici Geodynamic Polygon were interpreted in terms of elastic parameters of rocks (Poisson ratio, rock compressibility, rigidity modules, Young's modulus), pressure (overburden pressure at a specific depth, pressure of the fluid filling the rock pore space) and temperature, in order to obtain the characteristics of the upper brittle crust and information on the maximum seismic risk area [62-68].

Modeling tectonic processes related to intermediate-depth Vrancea earthquakes

Thermal and rheological conditions in which the lithosphere evolved in the past have been analyzed by quantitative thermo-mechanical modeling for the Eastern Carpathians [69-72] (*see the IASPEI/Heat Flow Studies section of this report*). It was shown that the depth distribution of intermediate-depth seismic activity in the Vrancea area can be interpreted in terms of lithospheric strength only when the thermal structure in the continental collision area is affected by a pre-Miocene oceanic subduction and that the seismic gap observed between 40 and 60 km depth can be explained by including in the model the process of convergence of the continental lithosphere following the oceanic subduction; a model of lithospheric

thickening of a part of the Moesian Platform in the Eastern Carpathians bend, developed as an alternative to the subduction model for the intermediate-depth earthquakes of Vrancea area, requires a recent (~0.3 Ma) thickening of lithosphere by a factor of 3, with a very slight surface deformation, which makes it a less suitable a model for the intermediate-depth seismicity in Vrancea [71].

A new hypothesis on the Vrancea intermediate-depth seismicity has been proposed as an alternative to the subduction-related models. Based on the complex interpretation of geophysical data, the presence of an unstable transform-transform-compression triple junction has been postulated in the area [73-76]. Plate boundaries of the three lithosphere compartments joining the area (East European Plate, Moesian and Intra-Alpine micro-plates) are revealed, and their nature and dynamics are analyzed. The suggested model successfully explain some peculiar geological aspects in the area, such as the absence of the subduction-related volcanism and the missing crystalline-mesozoic zone in the bending area of East Carpathians, specific features of the South Harghita volcanism (typical for the plate wedge zones), the unusual symmetry of the Focsani foreland depression, etc, which could not be explained within subduction environment.

Non linear analysis and modeling

The research on this topic has followed several fruitfully interacting directions (*see also the IASPEI / Non linear analysis and modeling section of this report*):

a) Quantitative analysis of complex geosystem structures. These studies included structures from small to large scale: they focused on scaling properties and their heterogeneity, with a special concern for anisotropy. Due to the particular role they play for geodynamic processes, fragmentation phenomena and fractured rock structures have been carefully considered. The outcomes of these investigations provided useful information for the analysis and the modeling of geosystems dynamics. The most significant results consist of: i) a new approach to the quantitative characterization of complex anisotropic structures, which includes tortuosity maps reflecting scaling-anisotropy relations, and an orientation-sensitive multifractal algorithm [78, 85, 86, 88, 89]; ii) theoretical developments and practical applications in the field of the evaluation of irregular structures [90]; iii) a new way to evaluate complex structures, based on isocorrelation maps, meant to detect possible overprinting processes and applied to the study of geological microstructures (tracing successive processes having shaped the structure of a geosystem [77]).

b) Multiparametric analysis of geosystem dynamics. Earthquake generating processes were analysed at different scales – from fault dynamics [90,96] to regional seismogenic patterns in the Vrancea region [79]. These studies led to a new approach to complex geodynamic systems, with practical applications in the study of the space-time-magnitude variability of seismicity [91, 92].

c) Dynamic systems modeling. Based on conclusions drawn from the analysis of the structure and the dynamics of complex geosystems, as well as on recent effective modeling methods, these studies concerned large scale geosystems as well as complex systems involved in human-environment relations, providing insights with respect to key interactions [81, 84].

d) Information acquisiton and interpretation. Effectively interacting with the studies on the structure and the dynamics of geosystems, these investigations concerned mainly the scientific methods of dealing with information when confronted with complexity [82, 95, 97]. On the other hand, they also considered the impact of geodynamic phenomena and of the related information on public perception, highlighting their implications for decision making and hazard communication related to geodynamic hazards [80, 83, 94, 95].

Hazard and risk implied by the Vrancea seismogenic zone

Development of a quantification system for the seismic intensity, based both on macroseismic and instrumental data has been a concern of the Institute of Geodynamics in the report interval. The quantification in spectral terms of the seismic vulnerability and a data base for intensity spectra are being currently worked out. Several papers on these matters have been published [98-103].

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