

PORTUGAL

**SECÇÃO PORTUGUESA DAS UNIÕES INTERNACIONAIS
ASTRONÓMICA E GEODÉSICA E GEOFÍSICA
(SPUIAGG)**

**INTERNATIONAL ASSOCIATION OF SEISMOLOGY
AND PHYSICS OF THE EARTH'S INTERIOR
IASPEI**

NATIONAL REPORT

1999 – 2002

**PRESENTED TO THE XXIII GENERAL ASSEMBLY
OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS**

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Coordinated by

**Prof. Dr. Luis Alberto Mendes-Victor,
National Correspondent of IASPEI**



FOREWORD

I am very pleased to present the IASPEI Portuguese National Report, which was prepared under the guidelines of the Portuguese Committee Board of Directors.

This 1999-2002 report was produced by the national correspondent after consultation of the institutions and research centers involved in the related fields.

The scientific progress achieved in this last four years reflects the national policy in improving the structures to frame the scientific and technological research and developing a new approach and procedures to evaluate the Portuguese system. It is worthwhile to mention that some scientific domains the additional funding supplied by the EU have permitted the expression of good visibility of the Portuguese capability and expertise in the fields of the Association.

The Portuguese National Correspondent,

Luís Alberto Mendes Victor

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INTERNATIONAL ASSOCIATION OF SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR IASPEI

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**CENTRO DE GEOFÍSICA DA UNIVERSIDADE DE
LISBOA/INSTITUTO GEOFÍSICO DO INFANTE D. LUÍS**

DESCRIPTION

The Geophysical Centre of the University of Lisbon (CGUL)/Geophysical Institute D. Luís (IGIDL) is a research group established in 1976. The Unit is composed of researchers with a background mainly in Physics and Geophysics. It covers the fields of Solid Earth Physics, Meteorology and Natural Hazards. Most of the researchers have academic responsibilities and actively collaborate in undergraduate and graduate teaching.

CGUL/IGIDL deploys most of its effort on scientific research and development, promoting the knowledge of the physical processes related to natural Earth phenomena. In this sense, conducts research on several areas of Earth Sciences combining theoretical approaches, numerical (and physical) modeling, and a range of applications from the global scale earth processes to the local scale environmental problems.

CGUL/IGIDL integrates knowledge from several physics based disciplines to the study of Earth processes. This combination of research skills shapes the centre and allows the development of interdisciplinary approaches in a diversity of fundamental areas: Natural Hazards, Global Change, Earth Observation and Earth Dynamics.

CGUL/IGIDL is involved in monitoring, playing a role in some of the geophysical global networks (e.g. FDSN, Federation of Digital Broad-Band Seismograph Networks, ORFEUS, Observatories and Research Facilities for EUROpean Seismology and TREMORS, Tsunami Risk Evaluation through seismic MOMent from a Real-time System). A particular emphasis is made on new deep sea monitoring efforts due to its relevance to the global earth studies.

CGUL/IGIDL promotes the strengthening of the links between the research community and the major state laboratories, through open data share and cooperative research. Particularly, CGUL/IGIDL maintains cooperative research efforts in collaboration with the Institute of Meteorology (IM), the Institute of Geology and Mining (IGM), the National Laboratory of Civil Engineering (LNEC), the Institute of Nuclear Technology (ITN) and the Industrial Technology Institute (INETI).

CGUL/IGIDL actively promotes the collaboration with other research groups, in the national and the European space, developing close links with the main international geophysical and meteorological organizations, and actively participating in a significant number of European or International initiatives. CGUL/IGIDL also promotes the connection with IUGG (International Union of Geodesy and Geophysics) through the Portuguese Committee (SPUIAGG).

ORGANIZATION

The internal structure of CGUL is based on a Scientific Council (SC, that incorporates all the PhD members) and an Executive Committee headed by the coordinator (L Mendes Victor between 1999 and 2000; J M Miranda after January 2001). The Executive Committee includes also a vice-coordinator (P M Miranda between 1999 and 2000 and Paula Teves-Costa from 2001).

The CGUL research has been organised along three major integrated themes: Natural Hazards, Atmospheric Modeling and Marine Geophysics. Each of these research themes is coordinated by a senior researcher (L. Mendes Victor, P. Miranda and J. M. Miranda).

Regular meetings involving the coordination or the whole Centre SC are used to keep track on the development of research and infrastructures and to define and evaluate work progress.

Research is mainly project-oriented but basic pluriannual funding is used to keep a stable scientific effort in the areas where the competitiveness of CGUL is higher or that are considered critical for future developments. In solid earth geophysics, CGUL maintains a significant commitment in laboratory infrastructure and observation networks, linked to the global earth observation systems.

Facilities and equipment are managed by CGUL as means available to the whole scientific community. In this sense, data acquired on a continuous basis are freely disseminated and researchers from other research centres have free access to available laboratory means.

CGUL maintains close links with LATTEX, particularly in the areas of Tectonophysics, Neotectonics and Geodesy. A significant fraction of the work presented here with emphasis on any of these topics was done cooperatively. The same principle applies in what concerns Deep Sea Research and Magnetic Mineralogy, that have been developed in close relation with CREMINER group, and in the geological aspects of Tsunami Research, that have been developed with our colleagues from CeGUL research centre.

Most CGUL researchers teach at the University of Lisbon, which hosts the centre. This link allows a direct relationship between research and graduate training in the framework of Master and PhD degrees offered by the University of Lisbon. A part of CGUL operation is still developed in the Escola Politécnica Campus, within the IGIDL (Instituto Geofísico do Infante D. Luís) particularly in what concerns short period seismic observation and Ocean Bottom Seismograph technology.

CGUL integrates ICTE, a non-profit network that groups most of the research groups and state laboratories related with Earth Sciences.

The CGUL maintains a close cooperation with the civil protection authorities (at national and municipal levels). During the last years, CGUL was involved in the seismic

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risk study of the Lisbon Metropolitan Area, and since 2001 it is also involved in the study of the seismic risk of the Algarve region.

Within the cooperative work between CGUL and IM (Meteorological Institute) two large research programs were designed during 2001 to structure the re-organisation of the Portuguese Meteorology (WECMAP PROGRAM) and Geophysics (SUMMO PROGRAM). These proposals received an excellent scientific evaluation by an international referee board and have been approved very recently.

INTERNATIONAL LINKS

IRIS: In the second half of 2001, a very broadband station, equipped with a STS-2 seismometer and with a TITAN 3NT 24-bit acquisition system, was installed in Cedros (Faial Island) in the framework of ULISSEIS. Data from this station have been already sent to the IRIS consortium (Incorporated Research Institutions for Seismology) in SEED format. IRIS is a consortium of United States Universities that have research programs in seismology, its purpose is to develop and operate the infrastructure needed for the acquisition and distribution of high quality seismic data globally. Data from an existing broadband station in Evora (EVO) have been converted to SEED format and the necessary procedures to make it openly available to the scientific community are now underway.

ORFEUS (Observatories and Research Facilities for European Seismology) was founded by a group of institutions from 12 European countries and has now more than 50 participants. CGUL is a participant of this facility. ORFEUS activities are distributed between the ORFEUS Data Centre (ODC) and four working groups and steered by an executive Committee and Board of Directors. The ODC acts as a regional data center in the global system of seismological data centres and is hosted by the seismological section of the Royal Netherlands Meteorological Institute in The Netherlands. The working groups on station sitting, technical support, mobile stations and Seismological Software Library (SSL) are coordinated by ORFEUS, but rely heavily on the data users. Regarding the Working Group on Sitting and Station Standards, one representative for each country with independently operated broadband stations and one for each multinational broadband network in Europe was selected. A CGUL member has been nominated as the representative for Portugal.

FDSN: The Federation of Digital Broad-Band Seismograph Networks (FDSN) is a global organization. Its membership is comprised of groups responsible for the installation and maintenance of broad-band seismographs either within their geographic borders or globally. This cooperation helps scientists all over the world to further the advancement of earth science and particularly the study of global seismic activity. In the following of the establishment of the ULISSEIS network, the CGUL was invited to become a FDSN member.

CGUL is linked through SPUIAGG (Secção Portuguesa da União Internacional de Astronomia, Geofísica e Geodesia) to IUGG (International Union of Geophysics and

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Geodesy) and its divisions (mainly IASPEI, IAGA and IAMAP). CGUL also contributes to global monitoring networks and actively participates in most international geophysical programmes (e.g. InterRidge, MARGINS, EUROPROBE).

During 2000 the COSEA (COordinated Seismic Experiment in the Azores) Memorandum of Understanding was established between CGUL, SIVISA (Azores University), IM, ETH, Carnegie DTM and IPGP for the deployment, operation and maintenance of a temporary broadband seismic experiment in the Azores Islands and for the collection, distribution and scientific exploitation of data. Most of the effort is directed towards the study of the EU/AF plate boundary and the tomography of the mantle.

The study on anisotropic tomography of the Atlantic (Silveira et al., 1998, Silveira and Stutzmann, 2002) gave a broad picture of the seismic velocity and anisotropy of the upper mantle, but the obtained tomographic model is limited to a lateral resolution of about 500 km.

The Internal Advisory Committee (presently: Alan Thorpe, António Ribeiro, Filipe Duarte Santos, Jean Bonnin, Senos Matias) follows the planning and the activity of CGUL initiatives and produces annual reports that are used to support the short term and long term developments of the Centre. CGUL promotes regular meetings with all the geosciences research groups within the University of Lisbon (CeGUL, LATTEX and CREMINER) and a proposal for a new Associated Laboratory was submitted Ministry of Sciences FCT, grouping UL Earth and Planetary sciences research groups (the above plus CAAUL, Centre of Astrophysics and Astronomy, University of Lisbon).

FACILITIES AND EQUIPMENT

OBS Laboratory

CGUL/IGIDL owns 5 OBS instruments, equipped with 3 component SP seismometers, designed by T. Carrack at Bullard Labs. The electronics and power supply are inside 17" glass spheres, and the releases are from Marine Acoustics. The geophone package uses industry standard 4.5 Hz sensor elements with a depth rating of 6000 m. Complementary instruments (Deck Units, Master Clock) are available.

ESL Laboratory

CGUL/IGIDL Short Period Seismic Network is composed by 10 portable digital recorders equipped with 3 component sensors (CDJ-S2, 2Hz, 5700 Ohms, HATHOR 3 Seismic Station). Dynamic range is: 20b/20Hz, 18b/100Hz, 15b/250Hz; Sampling frequency 1-300 Hz. This portable network is being used since 2001. The ESL includes also a seismic refraction and reflection equipment to perform profiles up to 130 m long. After 2001 CGUL owns equipment devoted to microtremor measurements.

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ULISSEIS

ULISSEIS (University of LISbon SEISmic network) is a network of broadband stations, with the standard configuration defined by FDSN (Federation of Digital Seismographs Networks). The permanent code LX has assigned to the ULISEIS network by FDSN, and CGUL became a member of the Federation since 2002.

Data from an existing broadband station in Évora (EVO) have been converted to SEED format and were made available to the whole scientific community through GEOSCOPE.

Data from Cedros (Faial Island) station have been sent to the IRIS consortium in SEED format on a regularly basis.

CGUL also established a work program with LDG to make all data from TREMORS BB stations available through ULISSEIS.

SHORT PERIOD DIGITAL SEISMIC OBSERVATIONS

IGIDL has maintained permanent digital seismic stations located in Lisbon, Almeirim and Marmeleite. Data are integrated into the national seismological network managed by the Institute of Meteorology.

RESEARCHERS

António Rodrigues Tomé - *Meteorology and Climate Research*

António Roque de Andrade Afonso - *Environmental Geophysics*

Carlos Alberto Leitão Pires - *Meteorology and Climate Research*

Carlos da Camara - *Meteorology and Remote Sensing*

Fernando Acácio Monteiro Santos – *Geo-electromagnetism*

Fernando Ornelas Marques - *Tectonophysics*

Isabel Trigo - *Meteorology and Remote Sensing*

Jorge Miguel Miranda – *CGUL Coordinator*

José Zeferino Rodrigues Simões - *Seismology*

Luis Alberto Mendes Victor - *Seismicity and Natural Hazards*

Luis Henriques Marques Matias - *Marine Geophysics*

Maria Ana Carvalho Viana Baptista - *Seismicity and Tsunami Research*

Maria Antónia Olaio Valente - *Meteorology and Climate Research*

Maria Graça Medeiros Silveira – *Seismic Tomography*

Maria Paula Teves Costa - *Seismicity and Natural Hazards*

Maria Rita Sampaio Nolasco - *Marine Geophysics*

Maria Solange Mendonça Leite - *Meteorology and Climate Research*

Miguel Cortez Teixeira - *Meteorology and Climate Research*

Pedro Alberto Miranda - *Meteorology and Climate Research*

Raimundo Oliveira Vicente – *Geodesy - Retired Professor*

Ricardo Trigo - *Meteorology and Climate Research*

COLLABORATORS

António Soares - *Geophysical Instrumentation*
João Paulo Teixeira - *Meteorology, NRC, USA.*
António Pedro Viterbo - *Meteorology, EMCWF, Reading.*
Pedro Silva - *Rock Magnetic Laboratory*
Mário Almeida - *Meteorology, Institute of Meteorology*
Luisa Senos - *Seismology, Institute of Meteorology*
Carlos Corela - *OBS technology, IGIDL*
Fátima Espírito Santo - *Climatology, Institute of Meteorology*
Fernando Carrilho - *Seismology, Institute of Meteorology*

SCIENTIFIC PRODUCTIVITY

Publications in refereed international scientific magazines

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POST-GRADUATION

Master Thesis

António de Carvalho Jerónimo, "Estudos de Interpretação de perfis sísmicos da região do Baixo Congo", Mestrado em Ciências Geofísicas, especialidade de Geofísica Interna, FCUL, 2002, supervisor L. Matias.

Hugo Matias. Interpretação tectono-estratigráfica da área do Marquês de Pombal, a Oeste do Cabo de S. Vicente. Supervisor: L. Matias.

Pedro M. Silva, "Propriedades Magéticas de Rochas em Ambientes Geodinâmicos Extremos". Mestrado em Ciências Geofísicas. Supervisor: J M Miranda.

Alexandra Carvalho "Estudo do regime de equilíbrio mecânico na margem oeste ibérica por métodos gravimétricos", (finished 2000). Supervisor: J M Miranda.

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Carlos Corela. Placa de aquisição de dados da estação sísmica Mini DOBS (finished December 2001). Supervisors: J. Sousa lopes e L. Mendes Victor.

Célia Marreiros. Site effects estimation using microtremor records (Determinação de efeitos de sítio por análise de microssismos). Supervisor Paula T. Costa.

Emília Gomes. Modelação sísmica não linear unidimensional de formações geológicas superficiais na Área Metropolitana de Lisboa. Supervisor: P. Teves Costa.

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GENERAL ACTIVITY

Sources and identification of structures

Portugal is an area of moderate seismicity characterized by a small number of very large events (Mendes-Victor et al., 1999). If we consider a probabilistic approach to hazard estimation, we can get, for exceeding probability (5%) and period of time (50 years), peak ground accelerations that reach 0,4 g (Teves Costa et al., 2001). Seismic risk assessment based on urban statistical information pointed out that Lisbon and Algarve areas have high seismic risk potentials.

A new line of research was initiated in 2002 (L. Matias, P. Teves-Costa, G. Viegas) in order to better characterize the seismic action in the near field. The evaluation of strong ground motion in the near source range is made through the computation of synthetic acceleration records at a grid of stations surrounding a fault. The wave modeling is based on a discrete wave number representation of the wave field described by Bouchon (1981). The effects of source and propagation complexity are included in the model, due to a Kinematical description of the source that controls the nucleation, the propagation of the rupture and the space-time history of slip during the rupture process. Synthetic accelerograms are computed for several fault and rupture models in order to investigate the effect of the rupture process and source geometry on near source strong motion records. The methodology was applied to the Faial 1998 earthquake in order to evaluate if directivity effects can explain the earthquake effects observed.

The identification of the source of major earthquakes that affected the Portuguese territory can strongly affect all risk calculations. The combination of tsunami with seismicity studies (Baptista et al., 1998; Mendes Victor et al., 1999) proved to be a valid approach to address this major question. This kind of studies that combine

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hydrodynamic modeling with source studies have been developed for the 1755 with success and must be continued for the 1722 event (fundamental to establish seismo-tsunami hazard in Algarve area), 1761 (a poorly understood earthquake close to the Portuguese coast that generated a tsunami observed along the Caribbean Islands) and 1531 (also poorly known event that ravaged the Lisbon estuary).

The analysis of geophysical data acquired along the SW Portuguese margin in recent years is still progressing. Preliminary results concerning a detailed geological description of the 1755 earthquake source have been presented yet (Zitelinni et al., 2001) but there is no strong identification on any candidate source able to justify both the earthquake and tsunami, even if the Marques de Pombal thrust appears to be a part of such a source (Baptista et al., 2000, Terrinha et al., 2001). This question, that deals with the understanding of the present day behaviour of the Eurasian/African plate boundary along SW Iberia, will continue to be faced, through active OBS operation.

Portugal mainland faces two distinct margins, the western and southern margins with quite different Mesozoic and Cenozoic tectonic settings. The western margin started its formation during Triassic rifting and has been considered a passive margin from Cretaceous times (after oceanic break up between Newfoundland and Iberia) until present; however, Ribeiro and co-workers (1996) proposed that the western Portuguese margin should be considered in a state of incipient subduction. In what concerns the southern Portuguese margin, work based on palinspastic restoration of plate movements of the North Atlantic Azores-Gibraltar region indicate consumption of approximately 150 km of crust between Portugal and Morocco from Late Cretaceous times to Present however, the subduction zone responsible for this process has not been found yet nor any other type of plate boundary between Africa and Iberia.

One of the main geophysical characteristics of the Portuguese margins is its moderate instrumental seismicity (Mendes Victor et al., 2000). The occurrence of highly destructive historical earthquakes and tsunamis which source was never located in a convincing way, and the existence of large active thrusts (over 1000 m throw, Zitellini *et al.*, 1999) points to the fact that a large amount of unknowns do persist, in spite of the recent efforts on systematic multi-channel seismics surveys conducted by IAM (Iberian Atlantic Margin, 1995), and Zitellini et al. (1999).

The main scientific goals defined internationally in what concerns the Iberian Western Margin include in particular: (i) the investigation of the still unfound Africa-Iberia plate boundary, its location, geometry and articulation with the low angle faults identified in the western Portuguese margin; (ii) the investigation of the deep structure, initial kinematics and the mechanisms of the Iberian Margin formation and their homologues; (iii) the investigation of the nature of the transitional crust and the location of the ocean-continent boundary; (iv) the study of margin segmentation and its crustal and mantle control.

Significant improvements have been obtained by the coupled analysis of low frequency MCS and OBS data (Gonzalez et al., 1998). Moreover, the occurrence of salt or volcanic layers is a screen to the propagation of seismic waves, when using a conventional seismic acquisition system. By allowing to record long offset rays, sampling the deep structure beneath the screen, combined analysis of low frequency

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MCS and OBS data a seismic image beneath salt layers occurring in the studied areas have been provided.

Under the MATESPRO project, the SW Iberia Seismogenic Zone was surveyed in 2002 by the VOLTAIRE cruise (http://doc.igm.bo.cnr.it/V2002_REP/index.html), co-funded by the Italian Research Institutes and co-organized with the IGM- Bologna.

The main goal of the project VOLTAIRE was the study of the active tectonic processes occurring at continental margins of SW Iberia which determine a high concentration of natural hazards linked to seismicity, tsunami generation and large submarine mass wasting. The mitigation of these hazards requires a deep knowledge of the dynamics along margins and surrounding basins, and implies multidisciplinary and high-resolution marine geophysical investigations. The research work is focused on the Southwestern Margin of the Iberian Peninsula, from the eastern border of the Tagus Abyssal Plain to the Guadalquivir Bank. The project represents a further step on a long standing cooperative effort among European institutions for the study of this area.

The main objective of the project was the detailed investigation, based on multi-channel seismic reflection profiles, of the most active tectonic structure of SW Iberia, i.e. the southern termination of the Marquês the Pombal, the Horseshoe Fault (HSF) and the Guadalquivir Bank (GB), where these structures accommodate and partition the strain across a wide and diffuse plate boundary zone. In addition, one of the purposes was to enlighten the main pre- and syn-compressional episodes observed at the sedimentary basins and to correlate with the outcropping of morphological structures

The VOLTAIRE cruise allowed the acquisition of 1111.1 km of multichannel seismic data, 1469 km of magnetic profiles and 1260 km of CHIRP SBP acquisition profiles plus 2 sites cored.

In the aim of SESAME project (EU), CGUL is involved on the study of the use of the H/V technique, using microtremor measurements, to estimate site effects. These studies concern since the acquisition method (including also the performance of the digitizer systems and sensor types), to the data processing and data interpretation. During 2002 CGUL finished the experimental field tests, and performed several tests concerning the main processing parameters and different processing techniques. The CGUL designed and develop a graphical interface, that will be included in a software package for microtremors (H/V) processing, that will be openly distributed for end-users at the project end. CGUL also used the H/V technique, looking for site effects, in several towns of the Algarve region (Lagos, Portimão and Faro). These results will included a revision of seismic hazard estimation for this region.

THE AZORES SEISMOGENIC ZONE

The study of the seismic sequence initiated by the 9th July 1998 Mw=6.2 earthquake continued in 2002 under MASHA and STAMINA projects. On one side the waveform database was completed and has been under revision, with over 12000 events only for

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the year 1998. On the other side the study of Shear-wave polarization analysis of the earthquake sequence, in order to estimate the crustal seismic anisotropy and its relation with the tectonics of the area, was invited.

The initial work was performed on a set of 112 selected events, for which the focal parameters were better constrained (in terms of location, depth, focal mechanism, etc). In recent years, CGUL has applied standard geophysical techniques to the study of three main targets: (i) the Azores Triple Junction, (ii) the SW Iberian margin and (iii) the Iberian hercynian massif. These approaches involved mainly passive or active seismic surveys (e.g. Gonzales et al., 2001; Klingelhofer et al., 2000; Miranda et al., 1998), gravity (e.g. Luis et al., 1998), magnetic (e.g. Luis et al., 1994; Silva et al., 2000) and electromagnetic (e.g. Monteiro Santos et al., 1999, 2000) studies and a combination of modeling and inversion techniques. More recently, there is a growing effort concerning the bridge between geophysical regional scale parameters and laboratory measurements of rock properties, particularly AMS and magnetic mineralogy (e.g. Silva et al., 2001), to better constrain the geological interpretation of geophysical data.

In the period 2000-2002 multidisciplinary studies involving geophysical, tectonophysical and mineral physics techniques have been developed. A particular emphasis was made on experimental tectonics that has been developed with success in recent years by Marques and co-workers (e.g. Marques and Cobbold, in press, Rosas et al., 2002).

Most of the target problems correspond to marine systems, either in the margin or in the Mid-Atlantic Ridge. The availability of national means and a close relationship with some of the most relevant international research groups (with high level marine equipments) allow CGUL to reinforce the existing laboratory and field facilities (including OBS, LEMUR and MT stations). This strategy allow CGUL to be a partner in most of the international research initiatives, particular those related with the North Atlantic.

SEISMIC HAZARD ASSESSMENT

CGUL continues to be involved in seismic hazard studies for several regions in Portugal. The improvement on the attenuation laws estimation allowed a new seismic hazard assessment for the Lower Tagus valley. Seismic hazard assessment was also performed, in a general approach, for the Algarve region. During 2002, detailed seismic hazard studies have been conducted for the Algarve region, involving multidisciplinary approaches, under contract to the National Civil Protection Authority.

INTERACTION WITH THE CONSTRUCTION

Recent disasters (e.g. Taiwan 1999.09.20 or Istambul 1999.08.17) pointed out the importance of understanding the dynamic behaviour of buildings and soil foundations under severe seismic load conditions. The development of analytical tools and

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numerical models suffered a great improvement but the real behaviour of any structure is still a difficult step, due to the great number of parameters needed to describe it and its sensitivity to the construction techniques. The discrepancy between predicted and observed behaviour of structures is particularly evident in what concerns historic monuments and ancient buildings due to their structural elements and degradation of materials. We will focus our work in the experimental determination of the dynamic behaviour of real structures, using portable accelerometers networks and environmental or active sources. This study will be developed in Lagos, after a large scale test that is being conducted on a building at Parque das Nações (Baptista et al., 2001).

PASSIVE MARGIN STUDIES

Crust and upper mantle velocities can be converted to density. Sediments thickness will be obtained from MCS data. By combining those two pieces of information with the free-air gravity satellite data, a 3-D gravity model of the margins will be build. This model will enable us to try and extend the conclusions obtained along 2D seismic transects to the whole studied area. To characterize the ocean-continent transition zone, magnetics are still one of the best geophysical research tools, even in areas of weak anomalies. Here the best approach is the use of deep-tow instruments. The coverage of the deep abyssal plains around Iberia is very poor and we will improve it in the near future.

The importance of topography and gravitational potential as primary controls on stress distribution within the lithosphere has long been recognized (e.g., Artyushkov, 1973). Marshak et al. (1992) called attention to three persisting questions: (i) Why do arcuate thrust belts form? (ii) What factors control their shapes? (iii) Do they initiate in curved form, or do they acquire their curvature by oroclinal bending? However, to the present, no modeling work (theoretical or experimental) has been published on the effects of topography by itself. Previous experimental work has typically used rigid indenters or obstacles (e.g., Macedo and Marshak, 1999). We intend to conduct experimental modeling with the aim to analyse whether the evolution of thrust belts is strongly dependent on topography, considered as a second order indenter.

Elastic cores develop at the boundaries between brittle and ductile domains whenever its stress level is below the brittle yield limit and its viscosity is too high to relax stresses at its strain rates. There is a tendency to ignore thin elastic layers in large-scale modeling of mantle lithosphere interaction, which is usually done by approximate treatment of brittle-elastic layers as high viscous and/or high power-law materials. However, such a treatment eliminates very important modes of instabilities and ‘memory’ of lithospheric deformation.

Land Recordings

In 2002 under a bi-lateral cooperation agreement between ICCTI and IFREMER it was possible to continue the processing and interpretation of SISMAR data with French colleagues. This cooperation resulted in the elaboration of models for all profiles in the SISMAR survey (leg 1) that are being presented at International meetings and have

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been the subject already of a paper in a refereed journal (Gutscher et al., 2002). The most important result is that, in the NW Moroccan margin, there is no evidence of serpentinized upper mantle as has been found elsewhere (Bay of Biscay, Tagus and Iberian Abyssal plains, Congo and Zaire Bassins). The deep salt basin is underlain by thinned continental crust. The crustal thinning from 35 km to 10 km is observed in a 150 km wide zone. The shortening is not homogeneous and it seems that the continental lower crust is missing in the deep basin. Magnetic anomaly S1 outlines the limits of the salt basin thus introducing an important constrain for pre-breakup kinematic reconstructions. A master thesis is being prepared with the work already performed on SISMAR dataset.

DAKHLA cruise

Following the success of SISMAR cruise, the IFREMER group organized in 2002 the DAKHLA mission in order to study the deep structure of the Moroccan margin offshore DAKHLA. This cruise (co-funded by TFE) had the participation of the CGUL OBS's with the successful deployment and recovery of 6 instruments (100%). This activity strengthened the cooperation between CGUL and IFREMER (DRO/GM) regarding the Deep Geology investigations.

COMBINING SPACE, EARTH AND DEEP-SEA MONITORING PLATFORMS

Forthcoming years will most probably see the installation of new satellite based facilities to continuously monitor the Earth. Most of existing techniques to measure surface displacements (and infer deformation and deformation rates) are based on GPS or InSAR. Weather prediction models and global climate models also increasingly integrate information from observation satellites, and GPS (or InSAR) processing asks for high quality atmospheric data, which can be used to deduce atmospheric parameters. In the next three years CGUL will focus on meteorological and geophysical applications of remote sensing, developing further the interdisciplinary areas that concern meteorologists and tectonophysicists.

Recent advances on real time geodetic measurements allow the possibility to directly measure ground deformation with 1 mm accuracy. Time periods of the order of 1 to 10 years can clearly monitor absolute displacements related with plate tectonics, either in the Azores triple junction or in the Eurasia-African plate boundary). In the case of the co-seismic deformation generated by earthquakes which epicentres are close to land (as is the case of most of Azorean earthquakes) the order of magnitude of the displacement field can be one order of magnitude above the method accuracy.

The first well-studied case is the 1998 July Faial earthquake which co-seismic displacement reached 6.0 cm in SW direction for the horizontal component and 6.0 cm downwards for the vertical component (Fernandes et al., 2002). The integration of dense geodetic measures with sparse long time series generated by TANGO initiative (Bastos *et al.*, 1997) with detailed networks (e.g. STAMINA) will give a new light on the geodynamics of the triple junction, defining in a quantitative way the geometry and

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kinematics of the plate motion, that complement the indirect determinations made from aeromagnetic data (Luis et al., 1994) and OBS (Miranda et al., 1998).

Radar interferometry was first demonstrated in the mid-80's with Seasat images obtained in 1978 and. During the last few years, the radar images collected by the satellites ERS1, ERS2, JERS and RADARSAT have been used with success to create interferograms. This technique proved to be useful to "regionalize" the displacement field, mainly because GPS observations are always made on a discrete number of points. First studies on Faial and Pico islands (Catita et al., 2002) showed that InSAR data reflects co-seismic deformation field associated with the 1998 July Faial earthquake.

AZORES HOT SPOT AREA

Ridge Related Research

After the end of a large cooperative effort devoted to the identification of active HT systems along the Mid-Atlantic Ridge (MARFLUX, AMORES at the EU level and AMAR at the national level) a large amount of geophysical data and samples was organized in CGUL and several research initiatives were developed to explore this very valuable information. These data (and samples) were fundamental for the launch of scientific initiatives directed to the Monitoring of the Mid-Atlantic Ridge (MOMAR) in connection with the InterRidge program, integrated studies concerning the Azores domain and Hot-Spot Ridge interactions (STAMINA) and the vertical structure of the MAR (ISO-3D and SEHAMA).

The tectonics of the Azores domain and, in particular, the conditions that lead to the development of the islands' volcanoes, and their present behaviour are not yet well understood. The recent geophysical studies made in the area [Miranda et al, 1999; Luis *et al.*, 1999, Lourenço *et al.*, 1999] established a general framework based on passive OBS experiments, gravity and bathymetric compilations. However, most of the local scale features are largely unknown.

During 2002 CGUL conducted several studies coupling geophysical and geodetic techniques (Fernandes et al., 2002) mainly GPS. Important results have been obtained concerning the co-seismic deformation associated with the 1998 Faial earthquake and a large effort is being made concerning the evaluation of the historic geodetic data and corresponding volcanic and seismic activity.

Saldanha Massif Environment

The *Saldanha* Massif was discovered in July 1998 during the Portuguese-French AMAR cruise. It has been explored only superficially and its existence was suspected prior to this cruise, because the water column in the area is characterized by very large methane anomalies. Fluids were collected and are currently being analysed, but the temperature of hydrothermal fluids has not been measured. These fluids do not exit through chimneys, but in a diffuse fashion directly out of the seafloor, at a depth of 2200 m.

Work conducted during 1999 focused on the study of the magnetic properties of samples from Saldanha Site, the analysis of the relationship between the magnetic

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mineralogy and the petrogenesis and, finally, the identification of correlations between tectonics (deduced from sonar and swath data) and geology.

ISO 3D

During 2000 data collation of Madrigals Cruise took place in Southampton, but its results are not yet fully processed. However, the technology developed under this MASTIII project was used in the framework of a contract with a major oil company and tested in the margin of Africa. CGUL participated in all operations (laboratory work and sea). The CGUL group is deeply involved on the CAM-1 cable deep soundings and on the study of the fine scale magnetic structure of Lucky Strike.

The monitoring of the retired submarine cable CAM-1 started in 2000, after some months in test now almost with two years of continuous observations, the first results have been published (Monteiro Santos et al., 2002).

DEEP GEOPHYSICAL SOUNDINGS AND EARTH TOMOGRAPHY

During 2000 the group finished a survey of 11 LMT (Long period) sites in the SW Iberia in co-operation with the University of Frankfurt. The interpretation of these soundings was the subject of monograph. Some of the results were included in a 2D interpretation of the electromagnetic investigation of the upper mantle electrical conductivity distribution, performed with the CAM-1 cable (Monteiro Santos, 2002 (GJI in revision)).

Several AMT soundings will be carried out in Azores (Terceira Island) in the scope of the projects STAMINA and VAMEM. The preliminary results were presented in the 9th EEGS Meeting in Prague.

Several magnetotelluric soundings have been carried out in the SW Iberia in cooperation with Barcelona University.

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our Educational Seismological Project, EDUSEIS, is a confrontation of school students with the current practice of scientific data acquisition and management. Recent networking evolutions make available in the classroom data and tools which were only used in research laboratories. The rapid growth of digital electronics is just as quickly revolutionizing scientific practice, though, even among scientists, there are few who really appreciate how fundamental this revolution is. Technology is being driven more by an economic impetus than by the need to solve important problems - be they scientific or social - and scientists often have had to become reactive rather than proactive to technology. This, of course, is even truer for the educational environment. While industry debates the launching of communication systems comprising hundreds of satellites, and the Internet is soon likely to become to the average household what the telephone is now, teachers have obvious difficulty to adapt. This is, in particular, true for secondary education. Many schools now offer basic courses in the use of computers, word processing packages, or even simple programming languages. But does this give the students a sense of how chemistry, physics, biology are affected by the digital revolution? Does it give the students an idea of the power of information technology? Since the latter can be used and misused, the health of our democratic societies may ultimately depend on how well can children cope with information technology. A second fundamental change is the rapid growth of multidisciplinary studies of the environment. Increased population density has made natural hazards such as earthquakes, volcanic eruptions and hurricanes more costly both in terms of human life and in terms of economic damage. How the education system should react to such changes is not very clear. Some aspects have hardly even been debated. Meanwhile, the gap between what is taught in schools and what is done in the real world is growing rather than diminishing. This is a dangerous situation. An under-educated population is at the mercy of those who control the information technology.

Experimental projects will make students active participants rather than passive consumers and the selected vehicle for such training is seismological observation, which offers a number of clear advantages: earthquakes are spectacular and 'in the news', hence likely to attract the attention of the students; the digital observation of seismic waves involves large quantities of data but not so large that it cannot be handled by personal computers of the type now acquired by many schools; the development of cheaper instrumentation now allows schools to participate actively in data acquisition, using the Internet to share data; the analysis of seismograms involves many sciences, and may be illustrative in classes of physics, mathematics, geography, geology, and social science. PEPP in United States of America and EduSeis in Europe are based on recent development of new technologies which allow the use of high quality and low-cost seismic instrumentation in schools."

In 2002 under the "Live Science" project ROSEA (coordination by L. Matias), more seismic stations were installed in two high-schools in the Terceira Island, extending the whole project to 8 schools in 4 of the Azores Islands. In Portugal Mainland the CGUL also participated in the "Live Science" project EMES in order to maintain the operation of the seismic stations installed and to extend their activities to other experimental projects in the earth sciences.

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MEETING ORGANIZATIONS

2^a Assembleia Hispano-Portuguesa de Geodesia y Geofisica : Lagos, Portugal, February 2000. L. Mendes Victor, chairman. (Scientific Committee includes J M Miranda, P M Miranda, P Teves Costa, L M Matias, F. Santos).

3^a Assembleia Hispano-Portuguesa de Geodesia y Geofisica, Valência, Espanha, Fevereiro de 2002. (Scientific Committee includes L M Victor, J M Miranda, P M Miranda, P Teves Costa, L M Matias, F. Santos).

4^o Encontro Nacional sobre Sismologia e Engenharia Sísmica – 2.ème Rencontre en Génie Parasismique des Pays Méditerranéens, Faro 28-30 October 1999. P. T. Costa, member of the organizing committee.

Training course on “Earthquakes: Vulnerability, preparedness and scenarios”, CERU, Lisbon 6-11 November 1999, L. Mendes-Victor, course director.

Rencontre de Montpellier, Council of Europe’s EUR-OPA Major Hazard Agreement. Montpellier, 12-14 December 2001. L. Mendes-Victor, member of the organizing committee.

Coastal and Tsunami Early Warning Systems, Council of Europe’s EOR-OPA Major Hazard Agreement. Lagos, 1-3 November 2001. L. Mendes-Victor, president of the organizing committee.

The *XXVII General Assembly of the European Seismological Commission (ESC)* was organized in September 2000 (10 to 15), at the University of Lisbon. It had the participation of 405 scientists from all over Europe. L. Mendes Victor chaired the meeting and the Regional Organization Committee included J. Cristina and P. Teves-Costa. The Scientific Committee included F. Santos, J.M. Miranda, L.M. Matias, P.M. Miranda and P. Teves-Costa. The new ESC Board was elected, including Prof. Luis Mendes-Victor (CGUL), Prof. Claudio Eva (Univ. Genoa, Italy), Prof. Domenico Giardini (ETH, Switzerland), Prof. Suhadolc (Univ. Trieste, Italy), Dr Alice Walker (BGS, UK).

DIVISION OF SEISMOLOGY OF THE INSTITUTO DE METEOROLOGIA REPORT

1. Introduction

The work developed by the Division of Seismology of the Instituto de Meteorologia is compiled in the following paragraphs.

2. Seismic catalogue

The seismic catalogue task is being carried out. The bibliographic research for historical data is presently done. Currently, a database structure is being discussed in order to store all this historical information.

On 2002, it was performed a major revision of the Mainland Portugal catalogue for the period 1970 to 2000. This process included the integration of all phase arrivals reported on regional and global bulletins, revision of the available waveforms and relocation of all hypocenters using a same software program (HYPOCENTER).

3. Seismic network

3.1 Mainland Portugal and Madeira archipelago

The deployment of stations of the Mainland Portugal and Madeira telemetric digital network began in mid 1993 and was finished in the beginning of 1998, with the installation of the 14th station. There are two stations of this type at Madeira archipelago, and twelve at Mainland Portugal. The stations are equipped with enhanced three component short-period sensors (flat velocity response from 5 sec to 40 Hz) and digitizers with 120 dB of dynamic (96 dB of resolution). All stations are remotely accessed through public telephone lines.

The network is equipped with automatic acquisition and data retrieval software, running on a Solaris platform, which retrieves the data to a waveform database from where it is manually analysed.

Starting 1999, the processing system was largely improved with the adoption of the SEISAN software packaged as a base for standard routine processing, together with some internal software development.

On 2000, the analogue telemetric network acquisition was also improved with the installation of a new digitizer at the central facilities of IM, with capability to store 3 days of continuous data in a ring-buffer system, and also with automatic event detection capability.

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On 2001, the communication system was partially improved with the installation of digital telephone lines (ISDN) to access some of the stations.

On late 1995, and within the framework of the European RAPID TRANSFRONTIER SEISMIC DATA EXCHANGE NETWORK project, a regional Algarve seismic short period network was installed. The project ended on the beginning of 1997, but the network has been running until late 2000. Due to technical, financial and legal reasons, it has not been possible to restart its operation.

All the phase data for local, regional and distant earthquakes, together with the computed hypocenters, are published in monthly preliminary bulletins.

3.2 Azores

The installation of a digital telemetric seismic network was started on 1998 and was concluded by the end of 2002. Twelve three-component stations constitute the network: 9 of them equipped with enhanced short-period seismometers (flat velocity response from 5 sec to 40 Hz) and 3 with short-period sensors (flat velocity response from 1 Hz to 80 Hz) and digitizers identical to the ones in Mainland Portugal. The stations transmit segmented data through UHF radio links and conventional telephone lines. Most of the data from the Central group is concentrated at a central recording facility located at Horta (Faial Island). From Horta it is sent to the main installation of IM in Ponta Delgada, São Miguel Island, where the remaining data (one station from Central Group, four from Eastern Group and two from the Western one) is received.

On 2000, the analogue telemetric network acquisition was also improved with the installation of a new digitizer at the central facilities of IM at Horta City. The digitizer specifications are similar to the one described in the previous section.

All the phase data for local, regional and distant earthquakes, together with the computed hypocenters, are published in monthly bulletins within the framework of the SIVISA (Azorean Seismic Surveillance Network) protocol.

3.3 Global

Two very broadband stations, belonging to other institutions, are being operated and maintained by the Division of Seismology: CMLA station, installed at São Miguel on 1996, which belongs to the IRIS/IDA network; MTE station, installed on 1998 as an upgrade of the existing analogue one, and belonging to the GEOFON network.

4. Geomagnetic campaigns

For aeronautical purposes were done declination observations at:

- Airports of Mainland Portugal in 2001
- Airports of Açores and Madeira Islands in 1999, 2000, 2001, 2002

For the previous works the comparison of field instruments of the IM was done with the standards of Toledo Magnetic Observatory (Spain). The Magnetic Observatory of Coimbra due to its location (urban area) can't, any more, be used.

Also a few works of geomagnetic prospecting for private entities were done.

5. Participation in projects

CTBTO – Comprehensive Test Ban Treaty Organisation – On 1999, IM has been chosen by the PTS to be the local partner for the operation and maintenance of two IMS stations: one T-Phase hydroacoustic station and one Infrasound array, both in Açores Islands. The Division of Seismology has performed the site survey for the installation of the T-Phase hydroacoustic station.

IRIS/IDA – Since 1996, IM is the local responsible for the operation and maintenance of the CMLA station, which belongs to the San Diego University. On late 2002, some improvements have started to be introduced, namely on the data transfer process, which is now done through the Internet.

GEOFON – Since 1997, the Division of Seismology has been co-operating with the Potsdam GFZ in the installation and operation of a very broadband station at Manteigas, Portugal, and belonging to the GEOFON network. On 2002, significant improvements in the data transfer system have been introduced.

Participation in several national projects, mainly funded by the Science and Technology Foundation (FCT): DISPLAZOR - Tectonic, volcanic and landslide displacement monitoring at Faial, Pico and S. Jorge (Açores) using GPS; SHELT – Seismic hazard evaluation of the lower Tagus Valley; GEOALGAR – Geodynamic control and seismic characterization of the Algarve Region; ECARISCOPO – Elements for the characterization of seismic risk in the southern region of Mainland Portugal; MASHA – Multi-scale approach for seismovolcanic hazard investigation in the Azores; RIOSA – Reinforcement of the Azores Observatory Infrastructures; ROSEA – Network for Seismic Observation in the Azorean Schools.

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ÉVORA UNIVERSITY

Évora Geophysics Centre (CGE)

Director of the unit: Prof. Rui Namorado Rosa

Web page: <http://www.cge.uevora.pt>

Team of Seismology and Physics of the earth's interior

1. INTRODUCTION

The Geophysics Centre of Évora, with almost 10 years of existence, has methodically and persistently acquired increasing expertise in the fields of Seismology, Applied Geophysics, Geology, Atmospheric Physics and Satellite Remote Sensing, Climate Dynamics, Scenarios and Impacts of Climate Change through a firm strategy of capacity building in highly qualified scientific human resources. The research team of the Centre currently has 48 members, of which 40 are based at the University of Évora where half of these have a PhD

1.1 Overview

The Centre for Geophysics of Évora was created in 1991 under the Science Programme (Programa Ciência) and research activities began in 1993, developing its scientific research in the areas of Sciences of the Earth, climate, environment and space and covered the following activities:

- . R&D projects;
- . Advanced training;
- . Organization of Conferences/Workshops and Advanced Courses;
- . Cooperation with other institutions, promotion of scientific awareness and providing technical advice.

In the following areas:

- . Atmospheric Physics /Climate / Meteorology;
- . Internal Geophysics / Seismology;
- . Tectonics / Geodynamics;
- . Systems Dynamics.

The aim of the research is to contribute to a better understanding of:

- . Physical properties of the terrestrial crust and the main geotectonic units
- . Seismic source and earthquake focal mechanism;
- . Geologic and seismic risks;
- . The optical, chemical and electrical properties of the constituent atmospheric gases, aerosols and clouds;
- . Remote sensing of the atmosphere and of the physical and chemical properties of the terrestrial and atmospheric constituents;
- . Climate variability, climate forcing, regional scenarios and impacts of climate

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change;

- . Mesoscale meteorological phenomena;
- . Transfer processes and transport in cavities and porous media;
- . Dynamical phenomena: studies of turbulence, climate behaviour and biological phenomena;

and spans theoretical, experimental, observational and modelling activities.

Advanced training activities include academic training of researchers, collaboration with researchers with post-doctoral grants and with invited scientists .

The co-operation with other institutes includes:

- . Collaborative protocols with SNPC, EDP, IM, IGM
- . Dissemination of scientific knowledge in Secondary Schools: educational seismic network, geology in the summer.
- . Development of prototypes: earthquake machine, vertical seismometer and UV-Vis spectrometers.
- . Participation in several bilateral programmes: CRUP/DAAD, CRUP/CNIG, ICCTI/CNR, ICCTI/CNRST, etc

1.2 Scientific Team

- . Prof. Mourad Bezzeghoud (Coordinator of the team)
- . Prof. Augusto Fitas
- . Prof. Antonio Correia
- . Prof^a. Rosa Duque
- . Dr. José F. Borges
- . Dr Bento Caldeira

1.3 Technical team

- . Eng. Mouhaydine Tlemçani (Ph.D)
- . Eng. José Pombinho
- . Eng. Paulo Canhoto
- . Samuel Bárias
- . Sérgio Aranha

2.0 - MAIN ACTIVITIES OF THE SEISMOLOGY AND INTERNAL GEOPHYSICS GROUP

2.1 Principal Fields of Research in the period 1999-2002

- .
- Seismic sources and earthquake focal mechanisms
- Seismotectonics and seismic hazard models in Portugal.
- Heat flow studies
- Studies of the geomagnetic field

2.2 Principal Results

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- Heat flow in Portugal.
- Temperature change in southern Portugal using geothermal information.
- Focal mechanisms in the Ibero-Magrebian region.
- Seismic source, moment tensor and seismic strain rate in the Azores-Iberia-African plate boundary.
- Development of a earthquake machine
- implementation of a school seismic network in Évora region
- DIRDOP: Development of a programme for determine the seismic rupture directivity from broad band data using Doppler effect (in progress).

2.3 Organization of Scientific Conferences

- Internacional meeting on “**Geothermics at the turn of the century**”, 2000, Évora, Portugal.
- International meeting on **Dams: Impacts and Hazard**, 14-15 November 2002, Universidade de Évora, Portugal.
- Física 2002, 13^a **Conferência Nacional de Física (National Conference of Physique) e 12^o Encontro Ibérico para o Ensino da Física**, 6 - 10 de September 2002, Évora, Portugal.

2.4 Training

- Post Graduate Positions: 2 Ph.D. Students
- Participation in the “*Ciência Viva*” programs
- Presentations at public exhibitions and museums (1999-2002) :
 - Simple seismic instruments were developed for schools, with which a local earthquake was located.
 - Earthquake machine in “*Terra, um planeta dinâmico*” (organised by the tectonic group, CGE) was exhibited very successfully in the Pavilion of Knowledge in Lisbon and will continue as a permanent exhibition at “*Centro Ciência Viva*” de Estremoz (Portugal).

2.5 Projects R&D, Patents and Prototypes

Finished

- **Earthquake source parameters and fault kinematics in the Azores region** Bilateral, **Participant Institutions:** Universidade de Évora (UE), Universidad Complutense de Madrid (UCM) and Universidad de Extremadura.
- **School Seismic Network of the Évora region (MOSIRE)** - nº PIII-433/Ciência e Viva III/1998-2000, **Geophysical Center of Évora. Participant Institutions:** Universidade de Évora (UE), Esc. B23 de Arraiolos, Esc. Sec. de Évora, Esc.Sec. de Monsaraz

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- **School Seismic Network of the Azores region (ROSEA)**. n° PIII-433/Ciência e Viva III/1998-2000, **Geophysical Center of Lisboa/U. Lisboa**. **Participant Institutions:** CGE/Universidade de Évora (UE).
- **Chaotic behavior of the experimental spring-block model B-K"** – CGE. **Participating institutions:** CGE/UE
- **Study of the climatic change in Portugal using borehole temperature data** – Bilateral. **Participating institutions:** Universidade de Évora, Geophysical Institute of the Academy of Sciences of the Czech Republic
- **Study of the magnetic secular variation using archaeomagnetic data** – Bilateral. **Participating institutions:** Universidade de Évora, University of Alberta (Canadá)
- **Borehole and Climate** (1998-2002 UNESCO/IGCP428 programme)
- **The geoelectrical structure of southern Portugal** – Bilateral. **Participating institutions:** Universidade de Évora, University of Alberta (Canadá)
- **Earthquake Machine and chaotic behaviour of the experimental spring-block model B-K**. FCT, Centro de Ciência Viva de Estremoz, (2001-2002), **Geophysical Center of Évora**.
- **Seismic source in Argélia**. (with Universidade Complutense de Madrid and CRAAG, Argel)
- . **Current**
 - **Climate change detected in borehole temperature profiles and its coupling to airtemperatures**, ICCTI/ CZECH Republic, (2001-2002), **Participants** Geophysical Center of Evora / Geothermal Laboratory of the Czech Academy of Sciences
 - **Protection of thermal groundwater resources in seismic areas**, EU/Programme,IC15-CT98-0132(1999-2002), **Participants:** GeoTecBuro (Germany), Institute of Geophysics of the Georgian Academy of Sciences, CGE.
 - **LUCKYFLUX (Lucky strike heat flow project)** (with the Institut de Physique du Globe, France) – (CNRS)
- . **Submitted**
 - **Earthquake Source and Seismic Strain Rate Mapping: Portugal in the context of the Western part of the Eurasia - Africa Plate Boundary**. SAPIENS, FCT, (2001-2004), **Geophysical Center of Evora**. **Participants:** CGE, IM.

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- Seismic Vulnerability of Water Supply Systems - SeisWater. **SAPIENS, FCT (2002-2005)**. Participants : **CGE, IST, Water Company from Algarve**.

- **Protection of thermal groundwater resources in seismic areas**. Submitted to INCO/Copernicus- (PL 971198, IC 15.CT98- 0132) European Union (Programme (2001-2002). **Participating institutions**: Geophysikalisch-Technisches Buro (Germany), Institute of Geophysics of the Georgian Academy of Sciences, Centro de Geofísica de Évora, Seismological Institute of the Academy of Sciences of Turkmenistan, Institute of Physics of the Earth of the Academy of Sciences of Russia.

2.6 Publications

. *Books (chapters)*

Correia A. et al. (2002): "Portugal" in "Atlas of the Geothermal Resources in Europe". Publication No. EUR 17811 of the European Commission.

. *Proceedings (Editor)*

1999-2002

Correia A. 2000. Internacional meeting on *Geothermics at the turn of the century*, Évora, Portugal.

Silva, A.M., Araújo A.A, M. Bezzeghoud, R. N. Rosa and R. Salgado, 2002. International meeting on *Dams: Impacts and Hazard*, 14-15 November 2002, Universidade de Évora, Portugal, 95 p.

Crawford P., Jesus A., Stadler A., Correia A., Providencia C., Borges J. F., Marques J. P., Ferreira L., Carvalho L., Valente M., Bezzeghoud M., 2002. Física 2002, *Conferência Nacional de Física*, 6-10 de Setembro de 2002, Évora, Portugal. 616 p.

. *Articles (International journals with Referee)*

2002

Bezzeghoud M. e J.F Borges. Mecanismos focais dos sismos em Portugal continental e margem adjacente. Física de la Tierra, Sismicidade de la Península Ibérica, Eds: E. Buforn y A. Udias, vol. 15, in press

Yelles-Chaouch A.K., H. Djellit, H. Beldjoudi, M. Bezzeghoud and E. Buforn. The Ain Temouchent earthquake of December 22th, 1999. *Pageoph*, 161, 3, in press

Buforn E., M. Bezzeghoud, A. Udias and C. Pro. Seismic source in the Iberian-African plate boundary. *Pageoph*, 161, 3, in press

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Yasukuni O., J. Matsushima and A. Correia, 2002. Magnetic spectral analysis in Portugal and its adjacent seas (*accepted for publication in Tectonophysics*).

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Okubo, Y., Matsushima, J. and Correia, A., 2002, Curie point depth analysis in Portugal and its adjacent seas (*accepted for publication in Tectonophysics*).

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Correia, A. and Safanda, J., 2001, Ground surface temperature history at a single site in southern Portugal reconstructed from borehole temperatures. *Global and Planetary Change*, 29, nos 3-4, 155-165.

Borges, J.F., Fitas, A.J., Bezzeghoud, M., and Costa, P.T., 2001, Seismotectonics of Portugal and its adjacent Atlantic Area, *Tectonophysics* 337, 373-387.

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Correia, A. and Safanda, J., 1999, Preliminary ground surface temperature history in mainland Portugal reconstructed from borehole temperature logs. *Tectonophysics*, 306, 269-275.

Correia, A. and Ramalho, E.C., 1999, Thermal models of southern Portugal based on seismic velocity patterns and radiogenic heat production. *Tectonophysics*, 306, 261-268.

Jones, F.W. and Correia, A., 1999, Comparison of 2-D and 3-D EM models of a magnetotelluric survey in southern Portugal. In *Three-Dimensional Electromagnetics* (Michael Oristaglio and Brian Spies, Eds.), *Geophysical Developments* no. 7, Society of Exploration Geophysicists, 375-386.

Ramalho, E.C., Lourenço, M.C. and Correia, A., 1999, Geothermal resources of mainland Portugal. *International Geothermal Association News*, 37, 7-9.

Bezzeghoud M. and E. Buforn, 1999. Source parameters of 1992 Melilla (Spain, Mw=4.8), 1994 Alhoceima (Morocco, Mw=5.8) and 1994 Mascara (Algeria, Mw=5.7) earthquakes and seismotectonic implications. *Bul. Seis. Soc. Am.*, 89, 2, 359-372

Teves Costa P., J.F. Borges, I. Rio, R. Ribeiro, C. Marreiros, 1999. Source parameters of old earthquakes: semi-automatic digitization of analog records

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and seismic moment assessment, *Natural Hazards*, 19, 205-220.

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2002

Caldeira B., M. Bezzeghoud, J. F. Borges e A. Fitas, 2002. Comportamento caótico do modelo experimental B-K bloco-mola. *2.º Simpósio de Meteorologia e Geofísica da APMG*, 12-15 Fevereiro, Évora, Ed: Instituto de Meteorologia, Lisboa, 22-27. ISBN:972-8157-35-5.

Borges J. F., M Bezzeghoud, C. Pro, E. Buforn e A. Fitas, 2002. Processo de ruptura nos sismos dos Açores de 1997 a 1998. *2.º Simpósio de Meteorologia e Geofísica da APMG*, 12-15 Fevereiro, Évora, Ed: Instituto de Meteorologia, Lisboa, 48-53. ISBN:972-8157-35-5.

Borges J. F., M. Bezzeghoud, B. Caldeira e A. Fitas, 2002. Monitorização sísmica da região de Évora e o sismo de Montemor de 20 de Março de 2002. *13.ª Conferência Nacional de Física*, 6-10 de Setembro de 2002, Évora, Portugal, pp. 328-329.

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Caldeira B. A., M. Bezzeghoud, J. Borges e A. Fitas, 2000. "Protótipo de um modelo mecânico da formação de sismos". 12 a Conferência Nacional de Física, 27-30 de Setembro de 2000, Figueira da Foz, Portugal , pp. 229-230.

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Ayadi A., C. Dorbath, A. Lesquer and M. Bezzeghoud, 1999. P-wave teleseismic velocity tomography of the Hoggar Swell (Central Sahara, Algeria). *IUGG99*, Birmingham, July 26th-30th, p. B.150.

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Michael E. Evans e António Correia, 2000. " Resultados preliminares de um estudo arqueomagnético em Portugal".. *Proceedings da 2ª Assembleia Luso-Espanhola de Geodesia e Geofísica*, Lagos, Portugal.

Safanda J. e A. Correia . 2000, "Evolução da temperatura no solo e acoplamento entre a temperatura do solo e do ar - estudo para um furo termométrico em Évora". *Proceedings da 2ª Assembleia Luso-Espanhola de Geodesia e Geofísica*, Lagos, Portugal.

Correia A. e Jan Safanda, 2000. "Regime térmico litosférico na região sul de Portugal Continental baseado em modelos geotérmicos bidimensionais". *Proceedings da 2ª Assembleia Luso-Espanhola de Geodesia e Geofísica*, Lagos, Portugal.

Correia A. e Frederick W. Jones, 2000. "Estudo magneto-telúrico na região sul de Portugal: uma nova estratégia de interpretação". *Conferência Internacional "Geothermics at the turn of the century"*, Évora, Portugal.

Correia A., 2000. "Heat flow and heat production in southern Portugal"*Conferência Internacional "Geothermics at the turn of the century"*, Évora, Portugal.

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