



# **BRAZIL**

**International Union of Geodesy and Geophysics (IUGG)**

**NATIONAL COMMITTEE REPORT 2011-2015**

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**Edited by Luiz Paulo Souto Fortes**

**Brazilian Institute of Geography and Statistics (IBGE)**

**June 2015**

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## 1. Introduction

*Luiz Paulo Souto Fortes, Director of IUGG National Committee*

This report covers the scientific activities undertaken in Brazil in the areas of Geodesy, Geomagnetism, Aeronomy, Physical Sciences of the Ocean, Seismology and Physics of the Earth's Interior during the time period of 2011-2015. It also includes a historical retrospective in Brazil regarding the Physical Sciences of the Ocean's activities.

### 1.1 Composition of the National Committee of Brazil

#### **BRAZIL**

##### **ADHERING ORGANIZATION**

Diretoria de Geociências  
Instituto Brasileiro de Geografia e Estatística  
Avenida Brasil 15671, Parada de Lucas  
Rio de Janeiro, RJ, 21241-051

<http://www.ibge.gov.br>

##### **NATIONAL COMMITTEE**

**Director:** L. P. S. FORTES

**Executive-Secretary:** M. C. B. LOBIANCO

##### **National Correspondents of the Associations**

**IACS:** J. C. SIMÕES

**IAGA:** S. L. FONTES

**IAMAS:** T. AMBRIZZI

**IASPEI:** M. S. de ASSUMPÇÃO

**IAG:** D. BLITZKOW

**IAHS:** C. A. G. SANTOS

**IAPSO:** A. R. de MESQUITA

**IAVCEI:** R. V. CONCEIÇÃO

**Luiz Paulo Souto FORTES**

*Director, National Committee  
IUGG Liaison to the Cartographic Office of  
the United Nations*  
Diretoria de Geociências  
Instituto Brasileiro de Geografia e Estatística  
Av. Brasil 15671, Parada de Lucas  
Rio de Janeiro, RJ  
BRAZIL - 21241-051  
E-mail: [luiz.fortes@ibge.gov.br](mailto:luiz.fortes@ibge.gov.br)

**Jefferson Cardia SIMÕES**

*IACS National Correspondent*  
Centro Polar e Climático, Instituto de  
Geociências  
Universidade Federal do Rio Grande do Sul  
Av. Bento Gonçalves 9500  
Porto Alegre, RS  
Brazil - 91501-970  
E-mail: [jefferson.simoed@ufrgs.br](mailto:jefferson.simoed@ufrgs.br)

**Sergio Luiz FONTES**

*IAGA National Correspondent*  
Observatório Nacional  
Rua General José Cristino 77, São Cristóvão  
Rio de Janeiro, RJ  
Brazil - 20921-400  
E-mail: [sergio@on.br](mailto:sergio@on.br)

**Tercio AMBRIZZI**

*IAMAS National Correspondent*  
Instituto de Astronomia, Geofísica e Ciências  
Atmosféricas  
Universidade de São Paulo  
Rua do Matão 1226  
São Paulo, SP  
E-mail: [ambrizzi@model.iag.usp.br](mailto:ambrizzi@model.iag.usp.br)

**Maria Cristina Barboza LOBIANCO**

*Executive Secretary, National Committee*  
Coordenação de Geodesia  
Diretoria de Geociências  
Instituto Brasileiro de Geografia e Estatística  
Av. Brasil 15671, Parada de Lucas  
Rio de Janeiro, RJ  
BRAZIL - 21241-051  
E-mail: [maria.lobianco@ibge.gov.br](mailto:maria.lobianco@ibge.gov.br)

**Denizar BLITZKOW**

*IAG National Correspondent*  
Departamento de Engenharia de Transportes,  
Escola Politécnica  
Universidade de São Paulo  
Caixa Postal 61548  
São Paulo, SP  
Brazil - 05413-001  
Fax: +55-11-3091 5716  
E-mail: [dblitzko@usp.br](mailto:dblitzko@usp.br)

**Celso Augusto Guimarães SANTOS**

*IAHS National Correspondent*  
Departamento de Engenharia Civil e Ambiental  
Universidade Federal da Paraíba  
João Pessoa, PB  
Brazil - 58051-900  
E-mail: [celso@ct.ufpb.br](mailto:celso@ct.ufpb.br)

**Afranio Rubens de MESQUITA**

*IAPSO National Correspondent*  
Instituto Oceanográfico  
Universidade de São Paulo  
Praça do Oceanográfico 191  
São Paulo, SP  
Brazil - 05508-900  
E-mail: [ardmesqu@usp.br](mailto:ardmesqu@usp.br)

**Marcelo Sousa de ASSUMPÇÃO**  
*IASPEI National Correspondent*  
*Member, IASPEI Executive Committee*  
*Secretary General, IASPEI Latin American*  
*and Caribbean Seismological Commission*  
*(LACSC)*  
Instituto de Astronomia, Geofísica e Ciências  
Atmosféricas  
Universidade de São Paulo  
Rua do Matão 1226  
São Paulo, SP  
Brazil - 05508-090  
E-mail: [marcelo@iag.usp.br](mailto:marcelo@iag.usp.br)

**Rommulo Vieira CONCEIÇÃO**  
*IAVCEI National Correspondent*  
Instituto de Geociências  
Universidade Federal do Rio Grande do Sul  
Caixa Postal: 15.001  
91501-970 Porto Alegre, RS  
BRAZIL  
[rommulo.conceicao@ufrgs.br](mailto:rommulo.conceicao@ufrgs.br)

## **2. International Association of Geodesy (IAG)**

*Denizar Blitzkow, IAG National Correspondent*

### **2.1 Activities related to the Brazilian Geodetic Reference Frames**

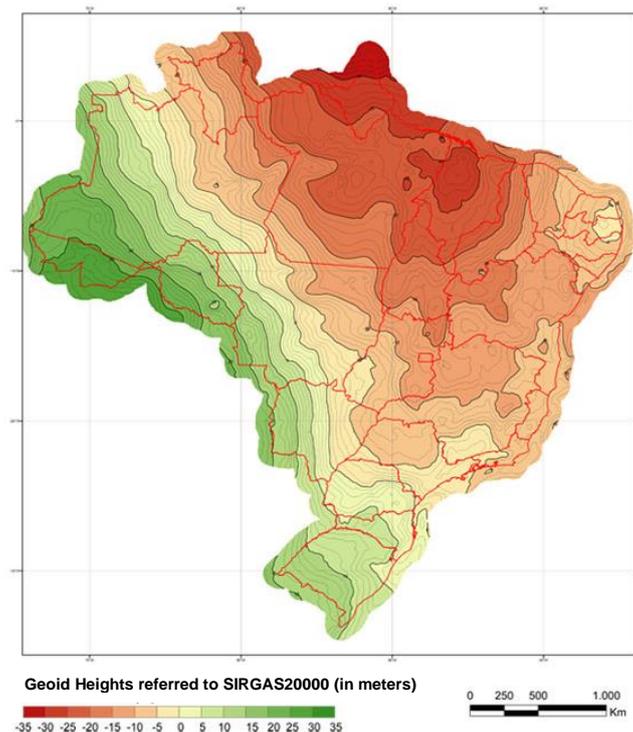
In 2011 a considerable effort was carried out by the Brazilian Institute of Geography and Statistics (IBGE) on the re-adjustment of the leveling network. Much attention was dedicated to issues like identification of bench marks (BM), materialization and connection of BM with gravity and GPS. A revision of the BM descriptions with comparison to Google Earth was also addressed. Temporal analysis of leveling sections from 1945 to 2010, in a total of 74,169 BM, was undertaken. Files were reformatted for processing with GHOST (Geodetic adjustment using Helmert blocking Of Space and Terrestrial data), a software package developed by the Canadian Geodetic Survey. New leveling campaigns supported by GPS for checking inconsistencies were realized. The final results have been the update of 69,590 BM information in the data base.

Leveling network densification: there have been efforts in the densification of the levelling network in the last three years in different parts of Brazil, like States of Ceará, São Paulo, Minas Gerais, Pernambuco and Amapá. During this time period, a total of 1,006 BM have been established and measured using electronic levels.

A special attention has been addressed to the Brazilian Network of Tide Gauges for Geodesy. A total of five stations along the coast (Imbituba, Macaé, Salvador, Fortaleza and Santana) continuously observe the sea level, with the first four of them also part of the GLOSS (The Global Sea Level Observing System) network.

IBGE is paying special attention to gravity surveys for the improvement on the geoid model in Brazil. In 2011 a total of 34,000 gravity points were reprocessed taking into account the height values derived from the new adjustment of the leveling network. A big effort has been addressed to gravimetric surveys in São Paulo, Minas Gerais, Santa Catarina, Rio Grande do Norte, Ceará, Mato Grosso do Sul, Goiás, Paraíba and Sergipe states in the last few years with a total of 5,017 new gravity stations.

An improved geoid model is in preparation at the moment, to be concluded by the end of this year, in substitution to MAPGEO2010 – the current model adopted in Brazil (Fig. 2.1). It will include airborne gravity data in Amazonas and in Paraíba basins, along with additional data from recent gravity surveys.



**Fig. 2.1 MAPGEO2010 Geoid Model**

The SIRGAS2000 geocentric reference frame, at Epoch 2000.4, was adopted in Brazil in February 2015 as the only official geodetic frame in the country, after the conclusion of a 10-year transition period. To make this possible, IBGE has made several data, information and services available to producers and users during the past years in order to allow them to smoothly adopt this new frame. For instance, coordinates of all geodetic stations referred to SIRGAS2000 are easily accessible through an user-friendly interface on the Internet; the establishment of a PPP (Precise Point Positioning) service at IBGE website, which generates results referred to the new frame, in cooperation with Natural Resources Canada; a new geoid model referred to SIRGAS2000; the transformation program ProGrid to convert coordinates referred to the old systems (Córrego Alegre and SAD 69) to the new one; the modernization and evolution of the Brazilian Network for Continuous Monitoring of GNSS (RBMC), the active geodetic network of Brazil (Fig. 2.2), currently composed by 117 stations, with 92 out of them working in real-time; etc..

In the international scenario, it should be mentioned the role played by IBGE Coordination of Geodesy as a SIRGAS Processing Centre as well as a Combination Centre, weekly processing the SIRGAS continental network.

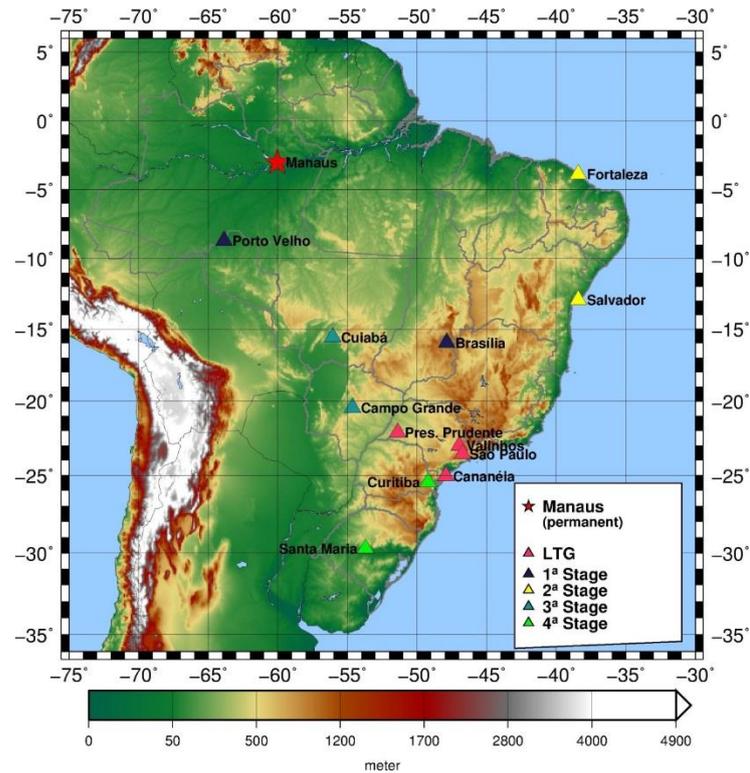
## REDE BRASILEIRA DE MONITORAMENTO CONTÍNUO DOS SISTEMAS GNSS



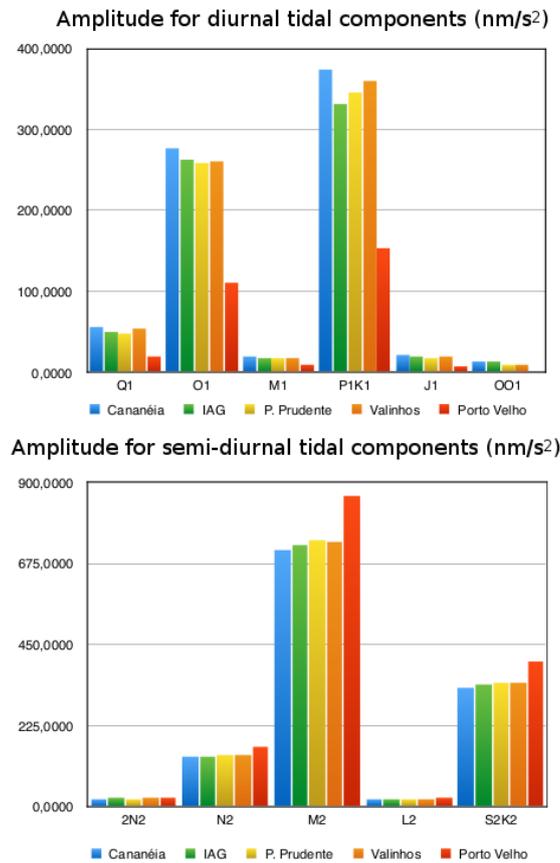
**Fig. 2.2 The Brazilian Network for Continuous Monitoring of GNSS (RBMC)**

### 2.2 Earth Tide Program

University of São Paulo and GEORADAR, supported by a few organizations, are involved in a project for Earth Tide model for Brazil. The idea is to occupy a sequence of 13 stations around the country for one year in each station. The cities planned for occupation are: Cananea, Valinhos, São Paulo, Presidente Prudente, already observed; Porto Velho, Manaus, under observations at the moment; Brasília, Fortaleza, Salvador, Cuiabá, Campo Grande, Curitiba and Santa Maria, to be observed in the future. For this purpose two gPhone gravimeters are available. Fig. 2.3 shows the distribution of the stations. Fig. 2.4 shows the amplitude of the diurnal and semi-diurnal components for five stations already observed.



**Fig 2.3 Distribution of sites to be observed for Earth tides**



**Fig 2.4 Results for 5 stations already observed**

### 2.3 Absolute gravity network

The Institute of Geography and Cartography of the State of São Paulo owns a gravity meter A-10 with its operation under the responsibility of the University of São Paulo (Fig. 2.5). The gravity meter is involved in various activities in Brazil, Argentina, and Venezuela, with the possibility of undertaking measurements in Ecuador, Peru, and other countries. Fig. 2.6 shows the establishment since 2013 of the new (green point) and reoccupied (red points) absolute stations in São Paulo State. The idea is to establish an absolute gravity network in South America.



Fig. 2.5 Absolute gravity meter A10-32

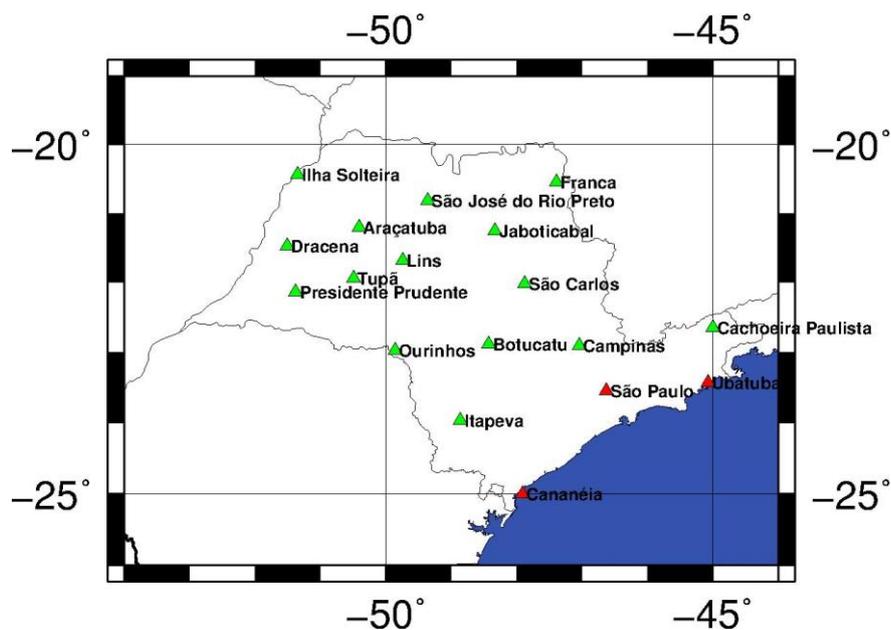


Fig. 2.6 Absolute gravimetric stations in São Paulo State

### **3. International Association of Geomagnetism and Aeronomy (IAGA)**

*Sergio Luiz Fontes, IAGA National Correspondent*

#### **3.1 Introduction**

This report presents a brief summary of the research activities of the main Brazilian institutions with activities related to the International Association of Geomagnetism and Aeronomy (IAGA) during the 2011-2014 period. It is not a comprehensive document and additions are welcome.

The main Brazilian institutions actively involved in IAGA-related activities during the last four years included: INPE – National Institute for Space Research in the State of São Paulo and the ON – National Observatory in the State of Rio de Janeiro, both subordinated to the Ministry of Science, Technology and Innovation. Other institutions with relevant activities in Geomagnetism and Aeronomy are the Center for Astrophysics and Radioastronomy – CRAAM from Mackenzie University ([www.craam.mackenzie.br](http://www.craam.mackenzie.br)) and ‘INPE’s associated groups’ in departments from UNIVAP (State of São Paulo), UFRN (State of Rio Grande do Norte), UFSM (State of Rio Grande do Sul), UFCG and UFPB (both in State of Paraíba). The reader is referred to the websites of each of these cited institutions.

#### **3.2 ON – National Observatory**

Founded in 1822, the National Observatory – ON ([www.on.br](http://www.on.br)) in State of Rio de Janeiro pioneered the geomagnetic measurements in Brazil and in the past four years has promoted the following research activities and services:

- **Expansion of the Brazilian Network of Geomagnetic Observatories**

The new Pantanal Magnetic Observatory was installed in 2012 in Central Brazil in cooperation with GFZ – The German Research Centre for Geoscience in Potsdam. The other two observatories in regular operation are the Vassouras magnetic observatory (1915) in State of Rio de Janeiro, under the Intermagnet Network and recently modernized, and the Tatuoca Magnetic Observatory (1957) in North Brazil, all running modern digital systems.

- **Program of magnetic repeat stations**

The Brazilian Network of Magnetic Repeat Stations, composed by just over 100 magnetic stations distributed along the country, was maintained fairly irregularly due to financial restrictions and lack of human resources.

- **Studies related to magnetic field time variations**

These studies encompassed predominantly magnetic field time variations (jerks, magnetic dipole variations, equatorial electrojet – EEJ, etc.) related to the internal structure of the Earth.

- **Electromagnetic (EM) Induction Studies**

In the past four years, regional EM studies (predominantly magnetotellurics) to probe the Earth's electrical conductivity structure from tens of meters to tens of kilometers depth were carried out in crystalline terrains of South East Brazil, at the Borborema Province, and in several sedimentary basins including Santos basin, Parnaíba basin, Parecis and Paraná basins.

- **Magnetic Instrumentation and calibrations**

ON has developed magnetometers for the Brazilian Navy and provided services related to magnetic calibrations of aircrafts.

- **The Brazilian Pool of Geophysical Equipment ([www.pegbr.on.br](http://www.pegbr.on.br))**

The Brazilian Pool of Geophysical Equipment, funded by Petrobrás and hosted at ON, initiated its activity in 2009 and provided several magnetometers and magnetotelluric systems for various scientific projects conducted by INPE, ON and USP (University of São Paulo) scientists.

Please visit ON website for complementary information.

### **3.3 INPE – National Institute for Space Research**

The National Institute for Space Research of Brazil ([www.inpe.br](http://www.inpe.br)) is a premier research institute in the country which reached 60 years of existence and pursues both research and service activities concerned with Geomagnetism and Aeronomy. Some of the research areas include:

- **Airglow studies**

Main research activities are related to probing the ionosphere and thermosphere and ionized atmosphere based on computational simulation and experimental observations.

- **Spatial Plasma Physics**

Ionospheric studies based on rocket and satellite experiments.

- **Geomagnetic Variations and EM studies**

Comprehensive broad scale Geomagnetic Depth Soundings – GDS and Magnetotelluric – MT surveys have been conducted by INPE in the past years in several regions of Brazil, mainly in the Borborema Province, in North East Brazil, Central and South East Brazil, including cratonic terrains and the Parana sedimentary basin.

- **Space Weather studies**

EMBRACE (<http://www2.inpe.br/climaespacial/portal/>) is the INPE's Portal devoted to the study and monitoring of Space Weather in Brazilian territory. It undertakes continuous real time data acquisition of multi-physics parameters with a pleiade of instruments, including:

- The Brazilian Solar Spectroscope (BSS), the only instrument in south Equator for real time daily monitoring of solar activity obtained from radio waves spanning from 1,000 to 2,500 MHz;
- The Brazilian Decimetric Array (BDA), a radio-interferometer system with several antennas operating in the frequency spam of 1.2-1.7, 2.8 and 5.6 GHz;
- The Embrace Magnetometer Network – flux-gate systems operating in the frequency range 0.1 to DC and running real time in about 10 stations in Brazil;
- The Embrace GNSS system, based on Global Navigation Satellite Systems (GNSS) receivers in cooperation specially with the Brazilian Institute of Geography and Statistics (IBGE);
- Ionosondes using radar techniques to detect time variations of the ionospheric plasma electron density with electromagnetic energy pulses scanning frequency between 1 and 30 MHz.

Please visit INPE website for all available products and a more detailed view of ongoing research in Geomagnetism and Aeronomy.

### **3.4 Main Scientific Events**

The main scientific events held in Brazil between 2011 and 2014 related to Geomagnetism and Aeronomy were:

- I MAGNET BRAZIL – held in Buzios town, State of Rio de Janeiro, from 5 to 10 June 2011, aimed at contributing to innovation in magnetic observatories, geomagnetic data from satellite and the planning for the SWARM mission, challenges on global magnetic field modeling, core dynamics, paleomagnetism and archaeomagnetism;
- IV Brazilian Symposium of Spatial Geophysics and Aeronomy, held in São Carlos town, State of São Paulo, from 10 to 14 September 2012, reporting research progresses in space weather and its forecast, Sun-Earth relationship, interaction between atmospheric layers, GPS application in atmospheric research, atmospheric electricity, among others;
- V Brazilian Symposium of Spatial Geophysics and Aeronomy, held in Natal city, State of Rio Grande do Norte, from 29 September to 4 October 2014, covering space weather and its forecast, Sun-Earth relationship, interaction between atmospheric layers, GPS applications in atmospheric research, atmospheric electricity, atmospheric physics, geomagnetism, ionosphere, etc.

Two successive editions of the International Congress of the Brazilian Geophysical Society, held in Rio de Janeiro city, State of Rio de Janeiro, in 2011 and 2013, had special sections dedicated to Spatial Geophysics.

#### 4. International Association for the Physical Sciences of the Ocean (IAPSO)

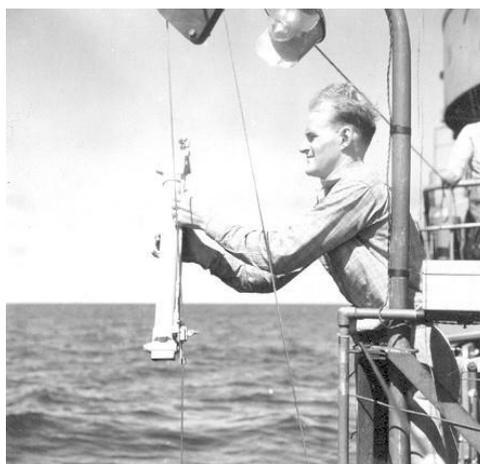
*Afranio Rubens de Mesquita*, IAPSO National Correspondent

##### 4.1 Introduction

First participation of Brazil in international research programs on Physical Oceanography occurred during the Geophysical Year from 1957 to 1958 of the past century. At that time, research in Physical Oceanography was mostly performed by the Brazilian Navy and many oceanographic cruises were pioneered by Admiral Paulo Moreira da Silva (Fig. 4.1), to the Equatorial Atlantic and also to the Brazilian Southeastern coast. With the advent of the Institute of Oceanography of the University of São Paulo in 1946, other scientists, as Dr Ingvar Emilsson (Fig. 4.2), organized cruises (1956), yet with the help of the Brazilian Navy, which provided the necessary ship time for the field work. First cruises were also directed to the Southern part of the coast and later, in the sixties, to the Western Equatorial Atlantic, in cruises organized by the International research program of Equalant.



**Fig. 4.1 Admiral Paulo  
Moreira da Silva**



**Fig. 4.2 Dr Ingvar Emilsson**

Since then, many Educational Institutions were created in cities along the Brazilian coast and the number of graduated students in Physical Oceanography has increased significantly. Several government owned institutions as UFRJ (Universidade Federal do Rio de Janeiro), State of Rio de Janeiro, other already existing military organizations, as DHN (Directory of Hydrography and Navigation) of the Brazilian Navy, and also recent private Institutions as FURG (Fundação Universidade Federal do Rio Grande), State of Rio Grande do Sul, and UNIVALI (Universidade do Vale do Itajaí), State of Santa Catarina, among many others, have produced then the oceanographic knowledge up to the present. In this revised report, only the oldest academic oceanographic Institution of the country is covered, in retrospect.

## 4.2 Academic Research

The Institute of Oceanography of the University of São Paulo (IOUSP) was created in the Department of Animal Production of the Secretary of Agriculture of the State of São Paulo, Brazil, on December 31<sup>st</sup>, 1946, as per State Decree number 16685. The “Instituto Paulista de Oceanografia” was a section of the Division of Fishes and Animals of the Forests of the Department of Animal Production. Three months later, on March 13<sup>th</sup>, 1947, its subordination was transferred to the Directorate of Animal Production of the Secretary, as per Decree number 16919. The first attribution of the Institute of Oceanography was: “to study the physical, chemical and biological factors that influence the productivity of the sea aiming, mainly, at its economical aspect”.

Four years later, on December 4<sup>th</sup>, 1951, the “Instituto Paulista de Oceanografia” was incorporated to the University of São Paulo, as per Law number 1310, as a Research Unity of the University, under the new name of “Instituto Oceanográfico”, a position that gave it greater research autonomy.

As a Research Unit of the University, as per State Law number 5470, the Institute acquired the possibility of offering Courses of Oceanography leading to postgraduate education of Oceanographers and training of Technical staff. In 1975 the Institute was raised to the status of a Teaching Unit of the University of São Paulo and started to have ample teaching and research autonomy. In 2001, a general 5 year-undergraduate course in Oceanography started with disciplines in all (Physical, Chemical, Geological and Biological) branches of the Ocean Science.

The research work in Oceanography is carried out by means of Oceanographic Research Vessels, when sea material is collected for laboratory analysis and also *in situ* measurements of all oceanic physical, biological, chemical and geological processes. The first oceanic cruise with the participation of scientists of the “Instituto Paulista de Oceanografia” was organized to the Island of Trindade in the South Atlantic. In the early days, there were intense participation of the University people in Vessels of the Brazilian Navy such as the Solimões and Baependi. The first research vessel of the Institute of Oceanography was the NOC Ungava, a sailing vessel adapted to the research work at sea.

The teaching activities began in 1963 and in 1968 with the postgraduate courses in Oceanography to Biologists, Physicists, Chemists and Geologists leading to Master’s and Doctor’s degrees, respectively.

The current infrastructure of the Institute includes the Department of Biological Oceanography, the Department of Physical, Chemical and Geological Oceanography, a Library, the Oceanographic Museum, the Research Stations of Cananéia and Ubatuba, two boats for coastal work and the NOC Prof W Besnard for the open sea.

The NOC Prof W Besnard (Fig. 4.3) was projected in the Department of Naval Engineering of the Polytechnic School of the University of São Paulo. She was built in Norway in 1968 weighing 700 tons, with a length of 49.35m. She can carry 16 scientists, 23 crew members and has autonomy of 20 days. The smaller fishing boats, the Velliger and the Albacora, both 14m long, are used for coastal research work based on the Research Stations of Cananéia and Ubatuba, in the Coast of the State of São Paulo.



**Fig. 4.3 The NOc Prof W Besnard - photo by Francisco Vicentini**

In order to better carry out its purposes, the Institute developed the capacity to measure *in situ* the oceanic (physical, chemical, geological and biological) processes by using research ships. A laboratory for instrumentation with the capability of calibrating thermometers, salinity and pressure sensors was established. There was the development of oceanographic/meteorological buoys for measuring surface meteorology parameters, ocean properties, T, S, currents, etc., together with the development of bottom pressure devices with acoustic recovery and several other modern devices.

A library holding 11,000 books and about 800 current scientific journals gives support to the work. The publication of results of the scientific staff is made through the Brazilian Journal of Oceanography, that is the substitute of the originally named “Boletim do Instituto Oceanográfico”, and Technical Reports, that substituted the previous publications under the titles: “Climatológico Boletim”(Climatological Bulletin), “Relatório Interno” (Internal Report) and “Relatórios de Cruzeiros” (Cruise Reports).

### **4.3 The Geophysical Year**

The research activities of the Geophysical Year were an incentive for developing climatological measurements that started in the Research Stations of Cananéia, in the Southern part of the State of São Paulo, and Ubatuba, in the Northern part of the State . In response to this incentive the first oceanographic-meteorological field work in the “Mar Virado”, in the Bay of Ubatuba, occurred in the years of 1958 and 1960.

As a follow-up, in the year 1963, there was an intense participation of scientists in International programs of research such as the Equalant I. This participation was entirely possible with the help of the Vessels of the Brazilian Navy.

Soon after the incorporation of the NOc Prof W Besnard to the University of São Paulo in 1967, Physical Oceanography there was her first cruise from Norway to Brazil, the VICKINDIO (Vickings and Indians) expedition and later she played a key role in multi-disciplinary research programs, such as the GEDIP (Executive Group for the Development of Fish Industry of the State of Rio Grande do Sul) that occurred in the Southern Part of the Brazilian coast.

The Program for Marine Geology and Geophysics (PGGM) for the continental margins started in 1969, which produced the first geological charts of the Brazilian coast. With similar objectives the Global Reckoning of the Continental Brazilian Margins (REMAC) program was established with the important participation of the NOc Prof W Besnard, in collaboration with Petrobras (Brazilian Oil Company), DNPM (National Department of Mineral Production) – CPRM (Geological Survey of Brazil), and of CNPq (National Council for Scientific and Technological Development).

#### **4.4 GATE and FGGE International Programs**

In the years 1974 and 1979 global International programs for measuring the meteorological and oceanographic processes of the air-sea interface were organized by WMO (World Meteorological Organization) and ICSU (International Council for Science), which involved several research oceanographic ships, land and sea meteorological stations for upper soundings, and then the newly developed satellite technology for globally measuring several physical variables of the atmosphere and the oceans.

The participation of scientists of the Institute of Oceanography of the University of São Paulo came through the NOc Almt Saldanha and the NHi Sirius, from DHN (Directorate of Hydrography and Navigation), in the Southern winter months of 1974, during GATE (GARP [Global Atmospheric Research Program] Atlantic Tropical Experiment). In the year 1979, their participation was on board in the NOc Prof W Besnard, during the FGGE (First Global GARP Experiment) simultaneously measuring, for the first time on a global scale, the oceans and the atmosphere.

#### **4.5 Other International Programs**

Other major programs engaged by physical oceanographers of IOUSP were: TOGA (Tropical Ocean Global Experiment); WOCE (World Ocean Circulation Experiment); the Brazilian Antarctic Program during the period of 1986 to 1990 financed by CIRM (Interministerial Commission for Sea Resources); the Mussel Watch Program covering the Brazilian Coast from 1992 to 1994; the ECOLAB program for mangroves of Suriname and the Northern States of Brazil; SARP (Sardine-Anchovy Recruitment Project); and IGBP (International Geosphere-Biosphere Programme), the multidisciplinary international program of research for Global Changes resulting from the current economic activities of humanity.

#### **4.6 First Local Research Programs**

Other participation of the NOc Prof W Besnard in 1975 was for the launching of a submarine cable for communications connecting the Virgin Islands in the Caribbean (USA) and Recife

(Brazil). During the period from 1976 to 1983, supported by FINEP (Brazilian Innovation Agency) of the Presidency of the Republic, she was engaged in measurements for the Integrated Project for the Rational Exploration of the Marine Environment, covering the coastal area between Cabo Frio, State of Rio de Janeiro (RJ), and Cabo de Santa Marta, State of Santa Catarina (SC). Measurements in Physical Oceanography of currents, sea level, TS and surface meteorology were systematically taken following similar previous pioneering measurements taken in the 60s on board the Navy ship NOc Almt Saldanha with much simpler equipment, as for example, the Ekman current meters.

The program on Sea Level and Tides with the acronym PAVASAS (Anphidromic Points and Seasonal Variations of the Equatorial and South Atlantic), financed by FAPESP (São Paulo Research Foundation) and CNPq, extended to the platform non-permanent pelagic measurements of sea level bottom pressure.

Other programs involving Physical Oceanography participation in multidisciplinary studies were financed by CIRM to study the sardines in the Southeastern coast. From 1985 to 1990, OPIS (Oceanography of the Internal Platform of São Sebastião, State of São Paulo) was funded by FAPESP. COROAS (1992) (Oceanic Circulation in the Western Region of the South Atlantic) was financed by FAPESP and CNPq aiming at studies of the Brazil current.

REVIZEE (1994) (Living Resources in the Exclusive Economic Zone) program aimed at cataloguing the live resources of the Brazilian shelf along the Exclusive Economic Zone in response to the United Nation's Convention of the Law of the Sea (UNCLOS). DEPROAS (2000) (Dynamics of the Shelf Ecosystem of South Atlantic Western Region), aimed at detailing the penetration of the South Atlantic Central Water (SACW) in the Southeastern continental platform.

#### **4.7 Other Research Programs**

Another recent program is the PIRATA (Pilot Research Moored Array in the Tropical Atlantic), an operational program with objectives of studying the ocean-atmosphere interactions in the tropical Atlantic and its impacts in the climate variability. The multinational effort involves measuring the sea surface meteorology and the oceanic currents of the tropical Atlantic with moored buoys. The multinational program SACC, a consortium for the study of climate changes involving scientists of various countries of the Americas for modeling the South Atlantic convergence zone, is also in operation.

GLOSS (Global Sea Level Observing System) of IOC/UNESCO (1993), involving permanent sea level measuring systems in many countries of the globe, has 9 (nine) stations along the Brazilian coast. The GLOSS sea level station of Cananéia, holding the GLOSS number 194, has produced, since its installation in 1946, about 50 years of continuous measurement of the sea level in the tropical Atlantic.

SIRGAS (Geocentric Reference System for the Americas), contributing to the measurement of vertical and horizontal displacements of the crust using GNSS (Global Navigation Satellite Systems), and relative and absolute Gravity in the Research Stations of Cananéia and Ubatuba, are activities which started in 2005 at those stations.

Absolute Gravity (2007) measurements at the Research Stations of Cananéia and Ubatuba and at the Institute of Astronomy, Geophysics and Atmospheric Sciences (IAG) facilities in the University campus are registered in the Fundamental Brazilian Gravimetric Network (Observatório Nacional/Ministério da Ciência e Tecnologia) and in the International Network of Absolute Gravity Stations.

#### **4.8 First Local Impacts**

Among the various contributions to physical oceanographic knowledge of local relevance was the discovery of the upwelling phenomena in the Southeastern Brazilian coast, which has its maximum of occurrence during the summer months, being more intense near the area of Cabo Frio, State of Rio de Janeiro. The phenomenon is of great importance as it brings the bottom waters, which are fertile in nutrients, to the surface, fertilizing the area. It is governed by the seasonal winds, the planetary vorticity and the water masses in the area. The seasonal behaviour of these water masses allowed the “seasonal thermal inversion” identification by showing that surface waters have a typical seasonal variation of the Southern Hemisphere, while the bottom water has a typical seasonal variation of the Northern Hemisphere.

The phenomenon is under study and various detailed local and general theories are being proposed for its understanding by means of computer solutions of the hydrodynamic nonlinear equations. Numerical models are also of importance to predict the tidal heights induced by the winds and currents in the Southeastern area and particularly in the channel of São Sebastião, where an important harbor for Petrobras is located.

Sea level studies lead to significative contributions in the field of analysis and predictions of the sea level. Sea level predictions are currently made for the ports of Cananéia, in the Southern coast of the State of São Paulo, and Ubatuba, in the Northern coast of the State , where the Institute maintains permanent stations for measuring the sea level and surface meteorology.

The border of the platform upwelling in the Western oceanic side was detected, that is the object of theoretical studies bearing in mind its scientific and practical nature, as well as its relationship with the Brazil Current, which flows close and along the border. Brazil current, its meanders and vortices, are the focuses of fertile studies, which are presently underway. The Malvinas Current and its influence, with waters of the River Plata in the Southeastern coast, was detected and is another major physical phenomena currently under studies.

Contributions of global scope related to the sea level called the attention of the public sector with regard to the increase of the rate of variation of the sea level and the grey perspectives that it shades to the coastal regions of the country, which may include the Amazon area via its major river and tributaries.

Coastal and estuarine studies of sea level and currents relative to the internal areas of the cities of Cananéia, Santos, Ubatuba and São Sebastião, State of São Paulo, and Angra dos Reis, State of Rio de Janeiro, describe in details the surface and bottom circulation patterns and are basic environmental elements to the rational use of these areas that have significant socio-economic relevance.

Contributions to the Northeastern (“Nordeste”) Brazilian area identified, for the first time, periodicities of the rainfall regime of meteorologically almost aleatory nature that showed unexpected interannual, decadal and longer periodicities. These periodicities in rainfall are of fundamental socio-economic value to the prediction of the draughts which are intense in the area. Further work showed that they are related and caused by the El Niño phenomenon that occurs in the Equatorial Pacific.

Equatorial research has led to discoveries of large scale permanent vortices in the Western Atlantic near the Amazon River mouth; the seasonal variability of the equatorial system of current towards Africa and countercurrent towards Brazil; the Undercurrent that submerged at 100m depth, in the West, flows from the Brazilian coast to the East Africa continent; the Equatorial system of all sort of currents are trapped by the rotation of the Earth, forming great meanders around and along the Equatorial line, and are reflected in the African coast.

Dissipation of energy via the phenomenon of internal waves, as internal tides, was determined as tidal components of higher order - open ocean nonlinear components - generated by the tides in the vast area of the abyssal Atlantic. The spectral characteristics of the Equatorial Atlantic measurements down to 500m, from hours to tenths of days, were heuristically estimated for the first time in the Western oceanic side of the Atlantic.

There was a great deal of pressure on research projects towards the development of instrumentation for data collecting and several measuring artifacts to be used on board and at sea, such as met-oceanographic buoys, and others as current meters, CTDs, pressure gauges, that were built by local companies and soon were encompassed by larger international manufacturers.

An effort led to the development and construction of the first Brazilian Batiscaf, aimed at recovering lost equipment at São Pedro and São Paulo rocks during the FGGE program. The development of the BATIUSP was the starter of the Brazilian industry of encapsulated divers for deep sea exploration that has successfully been developed from that time on, under the support of the Navy and Petrobras.

Physical Oceanography during the Antarctic expeditions of the NOc Prof W Besnard was planned to support biological activities, so that to help the first national expedition effort to that continental area. The national impact of her first presence in the icy continent was great and a very significant event in the history of the University of Sao Paulo.

#### **4.9 Further Studies**

In the last quarter of the 20<sup>th</sup> century there was a great deal of development coming from technology based on space research and the field of computation producing huge global cultural and economic interchange among nations. The launching of several satellites to measure the sea surface physical variables gave new boost to synoptic, as well as to time series of Physical Oceanography measurements, on a global scale.

Several solutions of the hydrodynamic nonlinear equations by new and fast computers involving the physical variables of the oceans were developed global wise. Following these lines, the first numerical model of the equatorial waters was developed at the Institute based

on satellite altimetry data, actually measured currents and actual sea level heights in order to study the Equatorial Atlantic system of trapped currents.

There were fruitful studies on the mesoscale dynamics associated to currents of western boundary, as the Brazil Current, with emphasis in the dynamic instability and vortices generation. The air-sea interaction was intensively analyzed via several solutions of the hydrodynamic air-sea coupled equations. Sea satellites measurements as by scatterometers and altimeters were applied to the studies of Rossby waves and the phenomenon of Ekman pumping over the South Atlantic ocean.

Estuaries, Bays, Tidal Channels and Coastal areas were fully scrutinized by highly instrumented mooring programs, aided with very fine computing grids for interdisciplinary studies covering biology, (coastal farming) chemistry, (pollution control) and geology, (sediment transport), funded by several local agencies as FAPESP, CNPq and Petrobras.

The sea level that has been measured since 1956 at the research station of Cananéia produced the first reliable estimate (40cm/cty) of the sea level increase at the Brazilian coast. Measurements are studied in conjunction with the Gravity and GNSS measurements at stations of Cananéia, Ubatuba and the University Campus.

#### **4.10 Courses on Oceanography**

Courses of the Institute of Oceanography at the University of São Paulo are offered to the community as a Citizen's Right, not as a Service to the Citizens, and so they are all free of charge. The University welcomes all interested students of the International community to make their application to the courses.

- The five-year undergraduate course of Oceanography covers the scientific areas of Biology, Geology, Chemistry and Physics, leading to the Bachelor Degree in Oceanography. The Physical Oceanography part of the Course is lectured by lecturers with vast research experience from American, European and Asian Universities, in theory and in measuring the oceanic motions of all physical causes, in the oceans basins, continental platforms and in estuaries;
- The Institute also offers Courses of Extension such as the one-year course on: Measurement, Analysis, Prediction and Numerical Modeling of the Sea Level, aimed at graduates in Oceanography, Meteorology, Engineering, Physics, Statistics and others;
- An Open Course of Basic Concepts on Oceanography is also offered, on Sunday's mornings, to the community of São Paulo and of the cities of Cananéia and Ubatuba on the Coast of the State of São Paulo.

#### **4.11 Divulged and Published Articles**

- **BJO (Brazilian Journal of Oceanography)**

The research staff of the Institute publishes regularly in the Brazilian Journal of Oceanography (former "Boletim do Instituto Oceanografico"), as well as in the Technical

Reports (former “Cruise Reports” – “Relatório de Cruzeiro”) and Internal Reports (“Relatório Interno”) of the Institution, as well as in other international journals of the community. Their full curriculum can be accessed in the address: <http://cnpq.lattes.br> from where the references below were selected.

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## **5. International Association of Seismology and Physics of the Earth's Interior (IASPEI)**

*Marcelo Sousa de Assumpção, IASPEI National Correspondent*

### **5.1 Introduction**

Seismology research in Brazil has been carried out mainly by five different research groups in federal or state universities: UnB (University of Brasilia), USP (University of São Paulo), UFRN (Federal University of Rio Grande do Norte, Natal), ON (National Observatory, Rio de Janeiro), and UNESP (São Paulo State University, Rio Claro). In addition, IPT (São Paulo Institute of Technology) also runs several stations to monitor dam-induced seismicity. A new group has just been established at UFMS (Federal University of Mato Grosso do Sul, Campo Grande).

In the last four years, the major seismological activities were: 1) the establishment of the new permanent Brazilian Seismographic Network (RSBR), 2) the shooting of two 700 to 800 km long seismic refraction profiles, in Northeastern (NE) Brazil and the other in Southeastern (SE) Brazil, and 3) the use of the Brazilian Geophysical Pool for several temporary deployments by different institutions.

### **5.2 RSBR - Brazilian Seismographic Network (“Rede Sismográfica do BRasil”)**

Funded mainly by Petrobras, within its Geotectonic Program, a new permanent 80-station seismographic network was implemented during the last few years through a joint effort of USP, UnB, ON and UFRN. Each of these institutions installed and maintains about 20 stations each. The network spans the whole country, although higher station density was deployed along the SE coast and in the NE region because of higher seismic activity in the offshore SE continental margin and in NE Brazil, respectively. Data from 30 stations are transmitted by satellite link (especially in the Amazon) and 50 stations are connected via cell-phone link (2G/3G technology) or local wi-fi providers.

Significant improvement was achieved both in monitoring Brazilian events, as well as small Andean earthquakes where magnitudes down to 3.5 mb are routinely located in the subduction zone of Bolivia, Chile and Argentina.

Besides the four institutions responsible for their sub-networks, other groups also contribute to the RSBR net through some of their stations (such as IPT and UNESP) or by help with field support (UFMS). On-line data from some stations are also used by other national networks in South America, such as in Bolivia, Argentina, and Chile. RSBR data is open through the portal <http://rsbr.gov.br>.

### **5.3 Deep Seismic Refraction Lines**

An 800 km long N-S deep seismic refraction profile was shot in March 2011 crossing various geological units of the Borborema Province and the northern part of the São Francisco craton, NE Brazil. Stations were deployed at every 2.2 km and shots were fired at every 50 km with

charges of 1.5 ton. Mainly vertical-component stations were used with L4A sensors and Texan dataloggers. At every 10th stations a three component system (L4A-3C + DAS130) was installed in order to complement the refraction data with teleseismic information, as well as improve S-wave identification. The equipment was provided by the PEG-BR (Brazilian Pool of Geophysical Equipment), hosted at the National Observatory, Rio de Janeiro. Preliminary results show a crustal thickness about 30 km beneath the Potiguar marginal basin, increasing to about 40 km beneath the northern part of the São Francisco craton.

Another deep seismic refraction line was shot in October 2013 in SE Brazil across the intercratonic Paraná Basin and the Brasília and Ribeira foldbelts, called PABBRISE (PARaná Basin Brasília-Ribeira Seismic Experiment), which is part of the Petrobras (CENPES) project "Continental to oceanic crustal transition in southeast Brazil: deep seismic refraction, magnetotelluric and geological studies in the Paraná Basin and Ribeira Belt domains". The NW-SE profile crossed the state of São Paulo from Santa Clara do Oeste (near the Paraná River at the NW extreme) to Caraguatatuba (on the coast at the SE extreme), passing through the northeastern Paraná Basin, the southern Brasília belt and the Ribeira belt.

The seismic line was ~700 km long with stations every 2 km and shots of 1.5 ton every 50 km along the profile. Two shots had larger charges of 4.5 ton. The same instrumentation was used, borrowed from PEG-BR, as in the previous experiment. Preliminary results show a crust about 41 km thick (including up to 5 km of basin deposits) close to the Paraná River, limited by a reworked and transitional Moho, thinning southeastwards to 31 km in the coastal region.

The two refraction experiments were carried out by the LabLitos at UnB with field work collaboration from USP. They were both funded by the project "National Institute of Tectonic Studies" (INCT-ET), a research program of the "Ministry of Sciences and Technology" (MCT).

#### **5.4 Projects supported by PEG-BR (Brazilian Pool of Geophysical Equipment)**

A national pool of geophysical equipment was set up in 2009 at the National Observatory, Rio de Janeiro, with support from Petrobras, to be used by any Brazilian research group in temporary field deployments. The Pool consists of 40 broadband seismic stations for passive source seismology, 350 short-period stations (L4C-Texan) for active source experiments, 60 short-period 3-component stations (L4A-3C + DAS130) for both active source experiments as well as aftershock deployments. In addition, the Pool also has equipment for Magneto-Telluric studies surveys, Geodesy, etc. During 2011-2014 15 experiments were supported with the following distribution:

- UnB (University of Brasilia): six experiments using broadband and short-period stations for passive seismological studies (crust and upper mantle structure) mainly in Northeastern and Central Brazil. Most experiments borrowed only a few stations and lasted from a couple of months to two years. One of the main results from these experiments was the finding of a thin lithosphere (low P-wave velocity at lithospheric depths) between the Amazon and the São Francisco cratons;

UFRN (Federal University of Rio Grande do Norte): three deployments were carried out with up to 32 stations for periods between one and two years each. The instruments were deployed in NE Brazil both for passive source experiments as well as aftershock studies. Besides mapping crustal and upper mantle structure, these deployments allowed several new focal mechanism studies and a better mapping of the regional stress field in NE Brazil.

ON (National Observatory): One experiment, lasting 1.5 years in SE Brazil deploying 20 broadband stations to study crust and upper mantle structure.

UNESP (State University of São Paulo): a 15-station short-period set (Texans) was loaned for shallow seismic refraction experiments and interferometric studies in São Paulo state.

UFBa (Federal University of Bahia): a two-year long deployment with 20 broadband stations is under way in NE Brazil for crustal and upper mantle studies in cooperation with UnB.

## **5.5 Conclusion**

Several seismology groups in Brazil are actively conducting temporary deployments and a wealth of data has been acquired in recent years improving our knowledge of deep crustal and upper mantle structure as well as allowing a better understanding of crustal stresses and seismo-tectonic characteristics.