MINISTERIO
DE EDUCACION
Y CIENCIA

CSIC

Instituto de
Astronomía y Geodesia

The Geodynamic Laboratory of Lanzarote

Ricardo Vieira - Emilio Vélez

Instituto de Astronomía y Geodesia (CSIC-UCM)

Facultad de Ciencias Matemáticas. Plaza de Ciencias, 3. 28040 – MADRID

ricardo_vieira@mat.ucm.es; emilio_velez@mat.ucm.es

Summer School on Micro-Gravimetric Methods: static and dynamic aspects

Lanzarote, Canary Islands, October 23-28, 2005

Summary

1. IAG activities in the field of gravity
2. Investigations of IAG in Canary Islands
3. The Geodynamic Laboratory of Lanzarote (LGL)
   - Presentation
   - Structure
   - Instrumentation
   - Analysis of Observations
4. Acknowledgements

IAG activities in Gravity

- IAG is the main Institute in Spain in relation with the studies of the gravity field.

- It has two permanent laboratories: Madrid-Facultad and Valle de los Caidos.

- Our investigations are focused to:
  - Earth Tides
  - Geoid determination
  - Gravity survey
  - Inversion methods
  - Geodynamical applications
  - Software development
  - Instrumentation
  - …

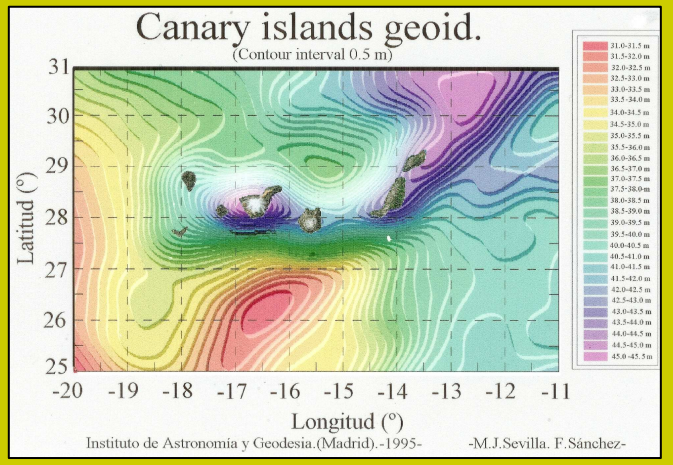
Laboratory of Gravity in Madrid

Absolute Station of Valle de los Caídos

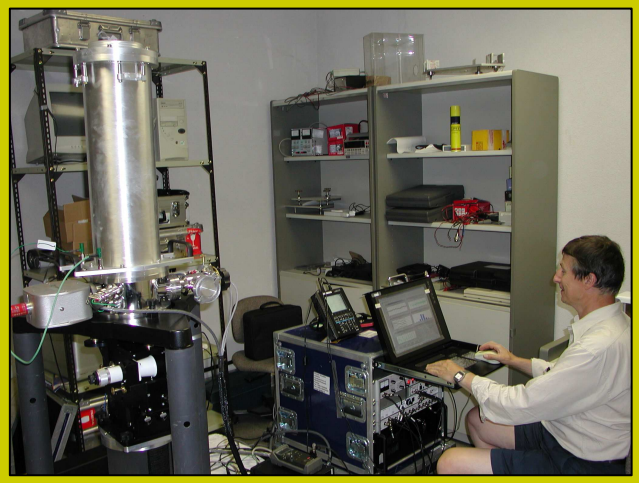
IAG activities in Gravity

- **MAIN RESULTS**

  - ✓ Iberian Earth Tides Network
  - ✓ Iberian Geoid IBERGEO
  - ✓ Canary and Açores Geoid AZORCAN
  - ✓ Absolute Gravity measurements
  - ✓ Calibration Line Madrid-Valle
  - ✓ Inversion methods for Earth Crust investigations
  - ✓ Analysis methods for Earth Tides
  - ✓ Applications of gravity survey to archaeological studies
  - ✓ Application of gravity to risk maps



Canary Islands Geoid



Collaboration with the Geodettinen Läitos (Finland) 1989-2005

Investigation Items of IAG in Canary Islands

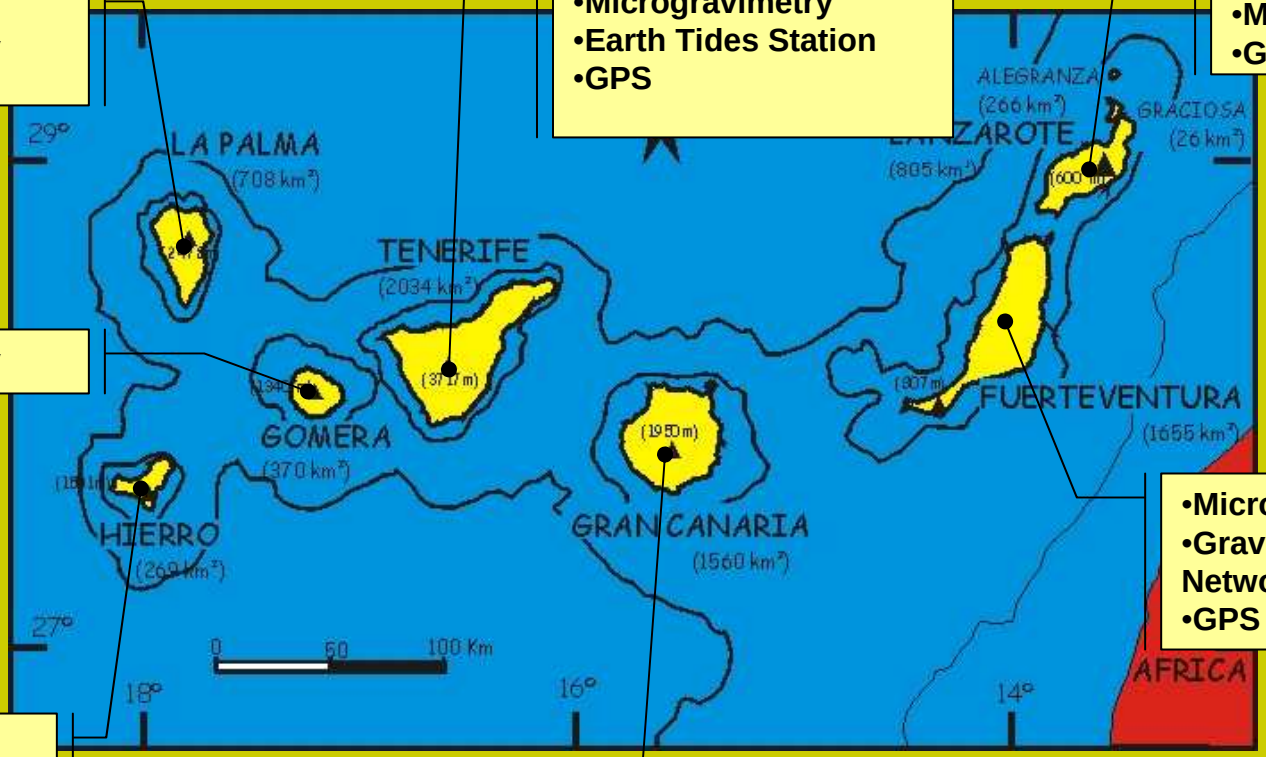
- ***Crust Deformation***
- ***Space Geodesy*: GPS**
- ***Determination of Geoid***
- ***Geodesic Networks***
- ***Gravimetry and Micro-gravimetry***
- ***Earth and Oceanic Tides***
- ***Gravity Inversion***
- ***Software development and modelization.***

Investigation Items of IAG in Lanzarote Island

- ***Instrumentation in Geodynamics***
- ***Software development for the analysis of multiparametric observations***
- ***Earth and Oceanic Tides***
- ***Gravimetry and Microgravimetry***
- ***Deformation***
- ***Sea level variations***
- ***Earth-Oceanic-Atmosphere interaction***

LABORATORIO DE GEODINÁMICA DE LANZAROTE

IAG activities in Canary Islands



- GPS
- Microgravimetry

- Geodesic Network for the control of the deformation in the Teide Volcano
- Microgravimetry
- Earth Tides Station
- GPS

- Laboratory of Geodynamic of Lanzarote
- Gravimetry/GPS Network
- Microgravimetry
- Microsismic
- GPS

- Microgravimetry

- Microgravimetry
- Gravimetry/GPS Network
- GPS

- Microgravimetry
- Deformation
- GPS
- Earth Tides Station

- GPS
- Microgravimetry

LABORATORIO DE GEODINÁMICA DE LANZAROTE

INSTITUTO DE ASTRONOMÍA Y GEODESIA

CSIC

CASA DE LOS VOLCANES
Área de Educación y Cultura

TIMANFAYA

Presentation

- The **Geodynamic Laboratory of Lanzarote (LGL)** depends of the **Institute of Astronomy and Geodesy (IAG)**, mixed center of the **Spanish Council for Scientific Research (CSIC)** and the **Complutense Madrid University (UCM)**.
- Starts its activity in 1986 as a consequence of the collaboration between the Cabildo de Lanzarote and IAG (*..."to make of Lanzarote Island a Natural Laboratory where we can develop all kind of experiences with the goal to study the geodynamic activity and help, with the Civil Protection Authorities, to the surveyor of the volcanic risk"*).
- The Laboratory is dedicated to apply geodesical and geophysical techniques in the study of a active zone of the Earth.

Scientific Goals

- ***Instrumentation*: Development and Experimentation.**
- ***Continue surveyor of the geodynamic activity of the zone*.**
- ***Study of the Earth-Oceanic-Atmospheric interaction*.**
- ***Mathematical development of methodology for the analysis and interpretation of results*.**
- ***International Collaboration*.**

LGL

- ⇨ **surface: ≅ 860 km²**
- ⇨ **nº of sensors: 76**
- ⇨ **volume of data: ≅ 300.000 samples/day**
- ⇨ **store capacity: ≅ 12 GB/year**
- ⇨ **investigation activity:**
  - **investigation projects: 16**
  - **investigators: > 30**
  - **papers: > 70**
  - **congress presentations: > 80**

National and International Collaborations

- **National Institutions:**
  - Cabildo de Lanzarote - Casa de los Volcanes
  - Parque Nacional de Timanfaya
  - Museo Nacional de Ciencias Naturales – Dpto. de Volcanología (CSIC)
  - Universidad de Cádiz
  - Instituto Geográfico Nacional

- **International Institutions:**
  - Institute of Seismology of Wuhan - Chinese Seismological Bureau (China)
  - Royal Observatory of Belgium (Bélgica)
  - Institute of Physics of the Earth - Rusian Academy of Science (Rusia)
  - Geophysical Institute - Bulgarian Academy of Sciences (Bulgaria)
  - European Center for Geodynamics an Seismology (Luxemburgo)
  - Nordic Volcanological Institute (Islandia)

- **Companies:**
  - ATEC Aplicaciones Tecnológicas S. L.
  - GEONICA S. A.

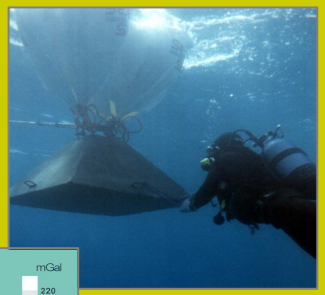
Structure of the LGL

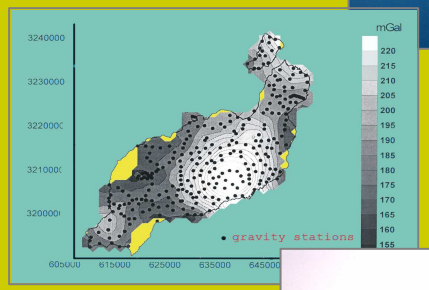
- **3 Permanent Observation Modules**
  - Cueva de los Verdes (CUE)
  - Parque Nacional de Timanfaya (TIM)
  - Jameos del Agua (JAM)

- **Temporally Stations**

- **Networks of Measurements**
  - Gravimetry
  - Levelling
  - GPS

- **Specific Studies**
  - Microsismic





Geodynamic Control Network

• The **Geodynamic Control Network of Lanzarote** was designed selecting 33 points covering all the island.

• In this stations, *gravimetry, GPS, vertical gravity gradiant and microsismic observations* have been done.

Situation

- Permanent Observation Modules
- Temporally Stations
- Control Networks

CUE

TIM

JAM

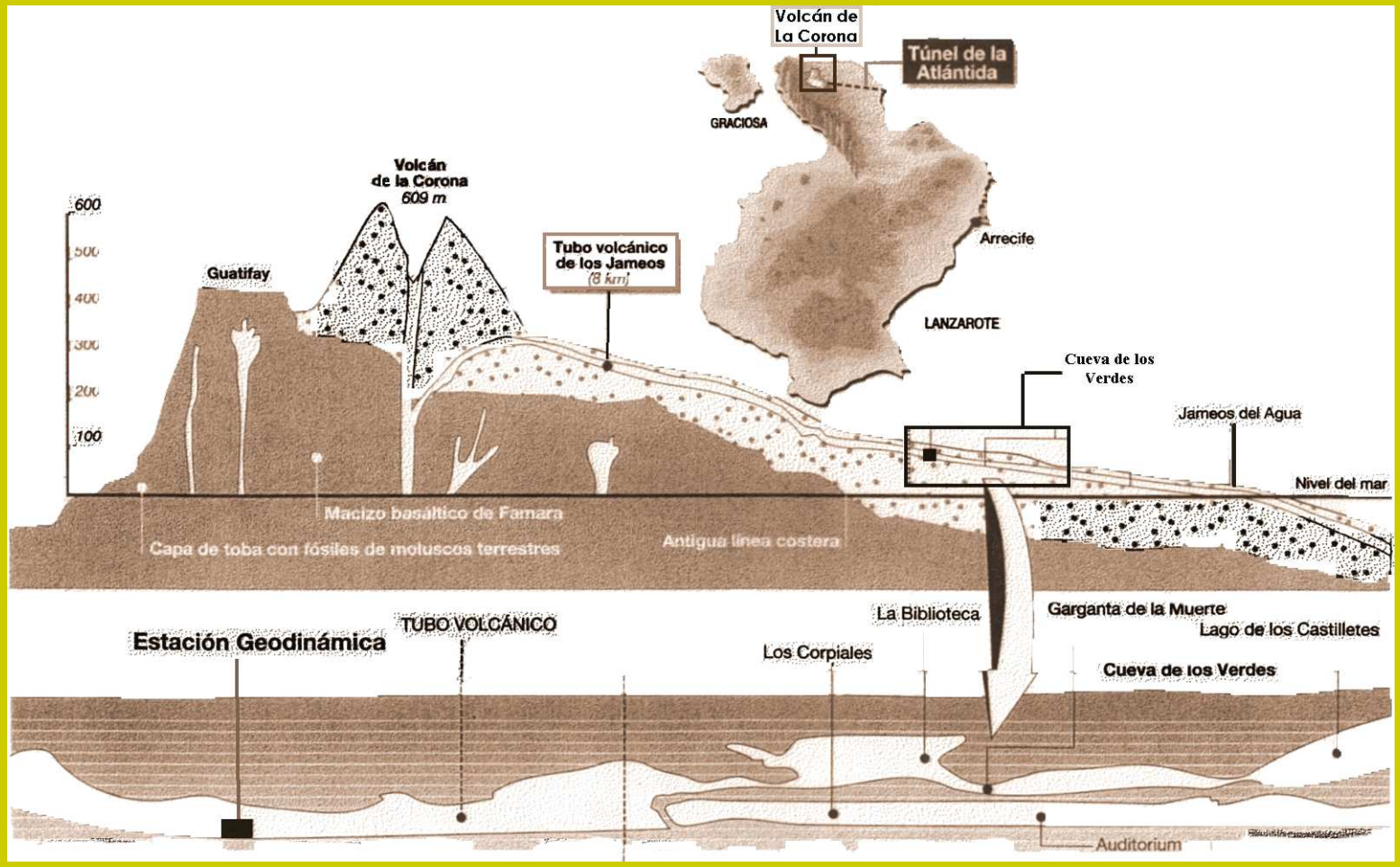
Cueva de los Verdes

- The Volcano of ***La Corona*** erupted few thousands years ago. Its lavas make up a lava flows field where enormous lava tubes have formed which, from the base of the volcano, reach to the sea.

- The volcanic tube of the Corona volcano is almost 7 km long, carries on under the sea at least 1.5 km as ***Túnel de la Atlántida***. Its course can be seen on surface by 16 Jameos, partial cave-ins of the roof.

- Through one of these Jameos visitors can enter to ***Cueva de los Verdes***. From there to coast line, the tunnel goes bellow the sea several places where small lakes can be found.

Volcanic Tube of “La Corona” Volcano



Observation Module
“Cueva de los Verdes”

- It’s inside the tunnel, to 1 km far from the line cost, 5 km from the volcano and 37 m over the sea level.
- We are doing continues observations of the acceleration of the gravity, vertical desviation and deformation.
- The instrumentation installed allow to us, with a high precision, register the three components of the earth tide, also every anomalous variation that could be in relation with the geodynamic activity of the island.
- Seismic and meteorological equipments complement the installations to study the interactions between the earth, the ocean and the atmosphere.

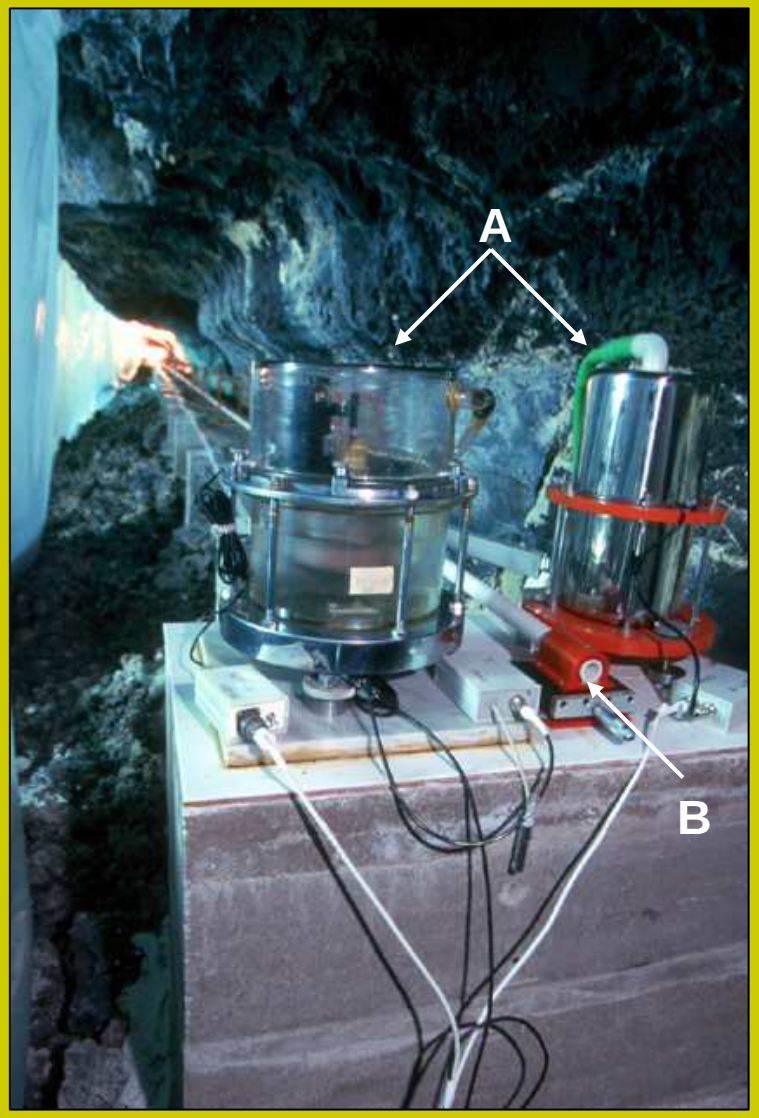
Instrumentation Installed

Observation Module “Cueva de los Verdes”

Instrumentation Installed

A. Relative Gravimeter
B. Tilt-meter type “Vertical Pendulum” and Vertical Extensometer
C. Broadband Seismic Station

Instrumentation Installed



A. Tilt-meter type “Water Tube”
B. Rigid Extensometer

Detail “Water Tube”

***Characteristics*:**

- Dimension of the pots: 231 mm
- Cristal tubes ensambled 1.5 m x 1 mm x 25 mm
- Destilled water + alcohol + oil
- Calibration system incorporated
- Magnetic sensor (fixed to the float)

***Calibration*:** Plunger device with a micrometer screw situated in the center of the base line.

$$i = \frac{\Delta H \times K}{L \times \Delta V} \qquad K = \frac{r_p^2}{r_1^2 + r_2^2} \times \frac{1}{sen1''}$$

ΔH = desplazamiento del émbolo

r_p , r_1 y r_2 = radios del émbolo y las cabezas

ΔV = desplazamiento medido en el sistema de salida

Detail “Rigid Extensometer”

***Characteristics*:**

- Ceramic tubes ensambled
- Dimension: 1.5 m
- Suspended system with double cooper thread (figura 1)
- Magnetic sensor in the free end (figura 2)

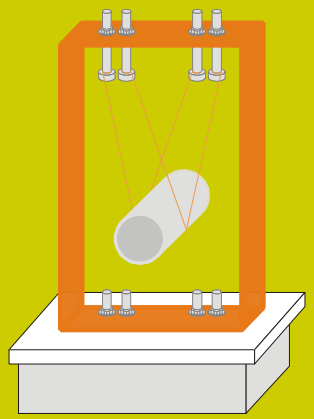


Figura 1

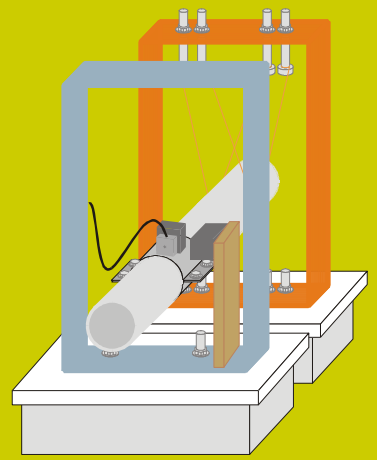


Figura 2

Instrumentation Installed

Horizontal Pendulums “VMR”

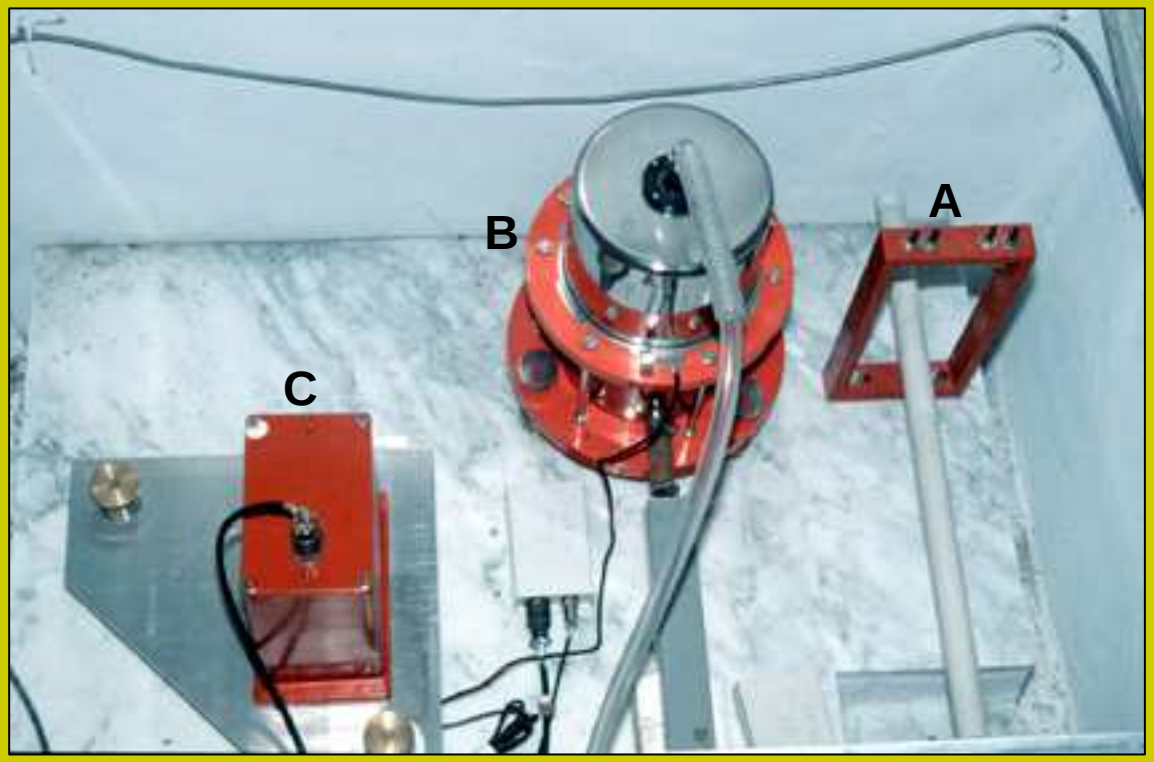
Parque Nacional de Timanfaya

- Between 1730 and 1736 a series of eruptions originated important groups of volcanic formations. The eruptions took place in the area of *Timanfaya* and represent a very important volcanic episode.
- The eruption was one of the biggest basaltic volcanic events. The shape of the island experienced great changes in the center-western sector. The lava covered 200 km^2, destroying 24 villages and devastating extensive fields.
- Multiples fractures were opened in Timanfaya, where appeared more than 100 cones. From the *Montaña Rajada* (Mountain Cracked) towards the north-east we can see an important alignment, the *Montañas del Fuego* (Mountains of Fire), and towards the west and extensive lava field reaches the sea.
- The last eruption on the island was in 1824 when three mouths opened up on a fracture inside the zone included in the park or pre-park.

Observation Module
"National Park of Timanfaya"

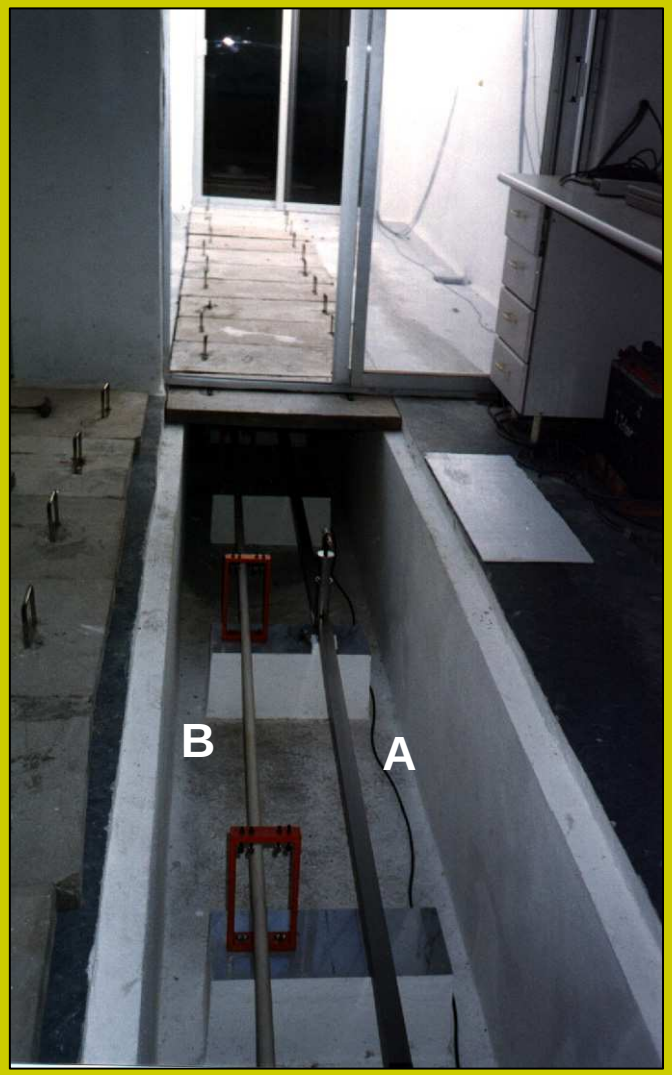
- The Laboratory of the National Park of Timanfaya is located in a zone of geothermal anomalies, caused by a residual magmatic chamber, where temperature can reaches from 100-200 ºC, at a few centimetres below the surface, to 600 ºC at 13 meters depth.
- The laboratory is divided in two parts. The first one, the laboratory of *Casa de los Camelleros*, is underground laboratory and it is located in the based of *Timanfaya Volcano*. The second one is outdoors laboratory, over a geothermal anomaly, 100 meters far to the Casa de los Camelleros.
- Tiltmeters, extensometers, thermometers,… are included in the equipment installed in the laboratory.
- The main goal is the study of possible deformations in relation with the anomalies presents and the general geodynamic activity.

Instrumentation Installed



A. Extensometer
B. Tiltmeter type “Water Tube”
C. Tiltmeter type “Vertical Pendulum”

Instrumentation Installed



A. Extensometer
B. Tiltmeter type “Water Tube”

Instrumentation Installed

High Temperature Thermometer at 10, 20 y 30 m deepth

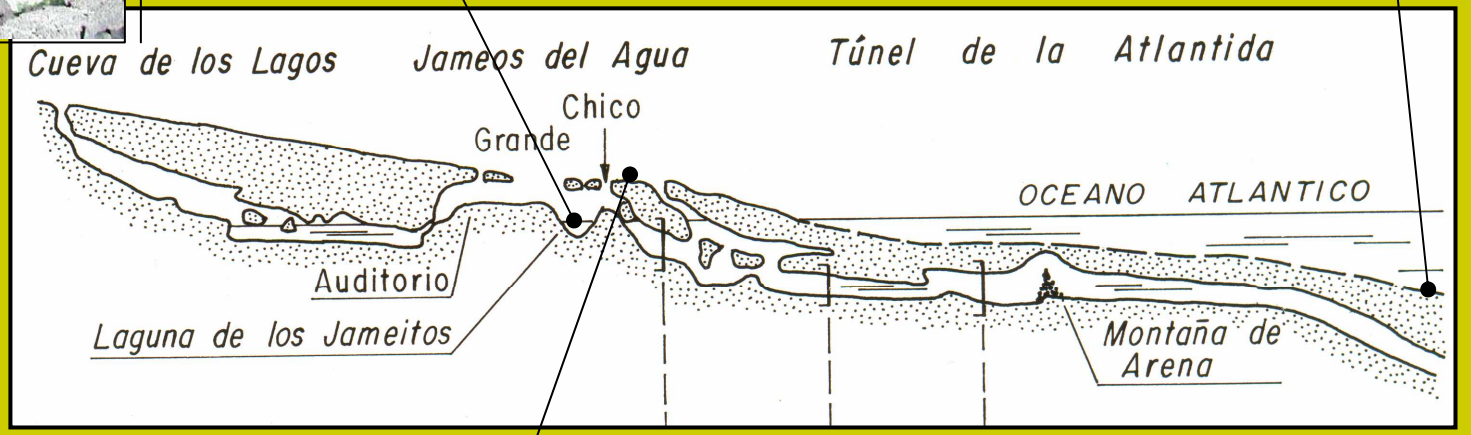
Observation Module
Jameos del Agua

- The lava flows of the La Corona eruption form a large malpais that arrive to the sea from the top of Famara, originating several volcanics tubes.
- The last part on the surface is calling ***Jameos del Agua***, in where the tube goes bellow the sea level several times forming small lakes.
- From there, the tunnel go into the sea at least 1.5 km more in the ***Tunnel of Atlantida***.

Observation Module
“Jameos del Agua”

- This is the best place to make studies in relation with the oceanic tides and sea level, being an important contribution to the investigations about the Climatic Change.
- To can study with precision the possible variation of the sea level is necessary to correlate this with the vertical movements of the crust. For that we have a permanent GPS station and a Geodesic Network around the GPS signal.
- It’s the perfect complement for the observations in Cueva de los Verdes and National Park of Timanfaya.
- We have doing temporally experiences with the installation of tide gauge in the *Cueva de los Lagos* and out of Jameos, at 8 m. depth in front of the coast.

Sea Level Laboratory



Casa de los Volcanes

- Volcanological Center of Scientific Cultural, Pedagogic and Touristy interest, that depends of the Art, Culture and Touristy Centers Network of the Excmo. Cabildo de Lanzarote. Its installations has 2.500 m^2, divided in two flors.
- It's situated in the ***Natural Park of Malpaís de la Corona***, over the part of the tunnel known as ***Jameos del Agua***.
- The objective is the understanding of the volcanology and its scientific promotion.
- In Casa de los Volcanes is the ***Data Reception Center of the LGL*** in Lanzarote. The information from the differents modules is received, stored and transmitted to the IAG ***Data Analysis Center*** in Madrid.

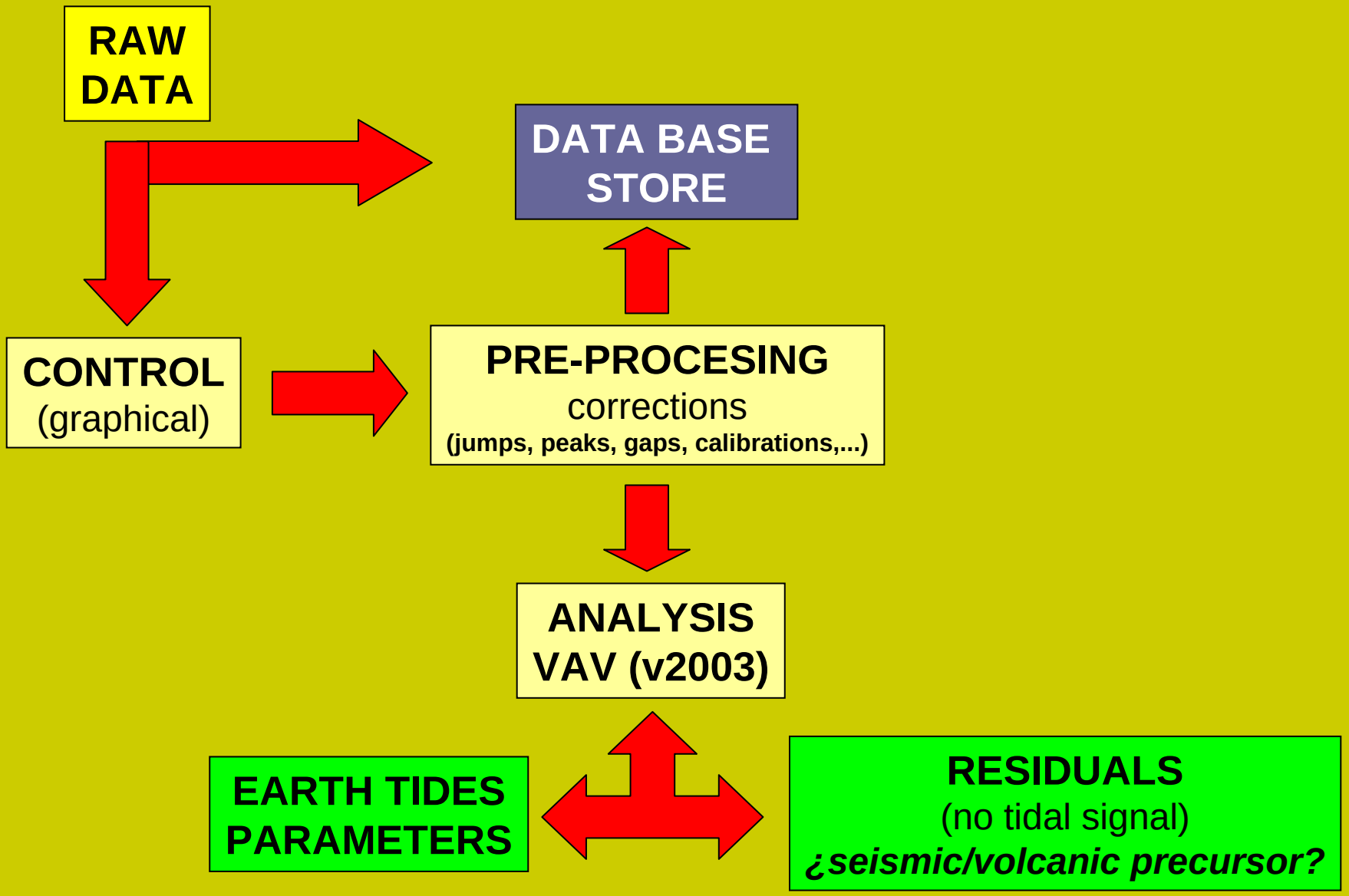
Observation techniques

- ***Deformation***
  - Clinometers
  - Extensometers
  - Geodesic networks (high precision levelling, distances, GPS)
- ***Earth Tides***
  - Gravimeters
  - Clinometers
  - Extensometers
- ***Oceanic Tides – Sea Level***
  - Tide gauges
- ***High Temperature***
- ***Meteorological Parameters***
  - Temperature
  - Atmospheric pressure
  - Humidity
- ***Structure of the Crust***
  - Gravimetric networks
  - Microsismicity

Instrumentation

	Cueva de los Verdes	Parque Nacional de Timanfaya	Jameos del Agua	Total
Barometer	3	2	-	5
Clinometer	11	8	1	20
Extensometer	3	2	-	5
GPS	-	1	1	2
Gravimeter	1	1	-	2
Hygrometer	1	-	-	1
Luxmeter	1	2	1	4
Tide gauge	-	-	5	5
Sismometer	3	-	-	3
Termometer	7	16	6	29
Aux. Sistems	11	16	5	32
Total	41	48	19	108

Analysis of Observations



VAV (v2003)

A. P. Venedikov, J. Arnoso, R. Vieira

- ***Program for the analysis of earth tides data, based in previous versions* MV66, NSV, VAV (v2002).**
- ***Calculation algorithm: aplication of the Method of the Least Squares over the data transformed in the time/frequency domain.***
- ***Concept: for a good detection of non-tidal signals is necessary a good tidal analysis.***

Relation between the well-known tidal signal and the observed signal

VAV (v2003)

- ***Model of the tidal signal*: *y(t) = s(t) + d(t) + ε(t)***
- ***Input*: ordinate of the observed signal *y(t)*, unequeally spaced, and the model of potential (Tamura 1200/2000 waves).**
- ***s(t) = Re*$\Sigma X_\omega H_\omega e^{i\phi\omega(t)}$, $X_\omega = \delta_\omega e^{i\kappa\omega}$**
- ***Output*: δ_ω (amplitude) y κ_ω (phase)**
- ***Aplications*:**
  - Location of anomalies in data.
  - Temporal variations of the tidal parameters.
  - Determination of the drift.
  - Determination of disturbances in the signal (p. e. Atmospheric pressure)
  - **Loock for non-tidal signals**.

- Reference: *"VAV (2003). A program for tidal data processing". Computer & Geosciences, 29,487-502.*

Acknowledgements

- **Projects REN2001-2271 and INTERREG IIIB MAC 2.3/A7 & 03/MAC/2.3/A4 have supported this research.**

- **We are grateful to the staff of Casa de los Volcanes for the help given.**

- **More information…**

  www.iag.csic.es/LGL/Index.html