XITH INTERNATIONAL SYMPOSIUM ON EARTH TIDES

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STRUCTURAL AND OCEANIC EFFECTS IN THE GRAVIMETRIC TIDES OBSERVATIONS IN LANZAROTE (CANARY ISLANDS)

R. Vieira, J. Fernandez, C. Toro and A.G. Camacho.

Instituto de Astronomia y Geodesia
(C.S.I.C. - U.C.M.)
Facultad de Ciencias Matematicas
Ciudad Universitaria
28040-Madrid.

ABSTRACT:

Since 1987, and as part of the research project that the I.A.G. is carrying out in the Canary Islands, records are obtained of gravimetric and ocean tides, pressure, temperature, etc. on the island of Lanzarote. The structural and geodynamic features of the island make our observations especially interesting because they may help to further research of the possible correlations of responses to tidal forces and other parameters such as crust structure and thickness, geothermic anomalies, etc. In this paper, we present the results obtained until now and a preliminary appraisal is given of these results in view of various previous hypotheses.

1. INTRODUCTION

The Island of Lanzarote is the most northerly and easterly of the fundamental islands of the Canary Islands. The historic volcanism of the island last appeared in the 18th and 20th century, being of special importance the eruption which took place from 1730 to 1736 in the southern zone of the island and which gave rise to important morphological changes which affected one quarter of its physiognomy in the zone which today is the National Volcanic Park of Timanfaya. Whereas the geographic and geodynamic characteristics of Lanzarote, it was decided to install, at this island, a geodynamic station as a laboratory of experimentation techniques and in order to improve the sounding systems, to prevent the volcanic risk. The volcanic tunnel of the volcano "La Corona", originated thousands of years ago, northward of Lanzarote island, has been the place chosen for the station. Until now, equipment was installed for the permanent registration of gravity variation and rock temperatures, as well as air temperature sensors, barograph, tiltmeters, seismographs, sea-level gauges, etc.

Currently, there is a series of over two years of high-quality registers of gravity tides. These observations were analized and the results obtained were studied taking into account other results obtained from the analysis of other registers, such as the oceanic tide and the variations of atmospherical pressure. For the best calculation of the oceanic effect, we proceeded to prepare cotidal and corange local charts using empirical data and laying the same conditions that were established for the Iberia maps (R. Vieira el al., 1986).

2. GEODYNAMIC SETTING

Although there still exist many problems both in relation to the genesis and to the overall geodynamic setting of the Canary Islands, the numerous geological and geophysical research projects carried out here enable us to know certain important characteristics which, with regard to Lanzarote Island, we may summarize as follows:

1) According to Ara7a et al., 1978 (figure 1), and other authors, the Canary Islands must be considered as independent volcanic structures and as having different ages and histories.
2) According to Ara7a et al., 1976 (figure 2), Lanzarote consists of a large basaltic intrusion on an anomalous mantle. All the other islands are located on an ocean crust, penetrated by dykes, through which the volcanic eruptions take place.
3) The structural model of Lanzarote obtained by Banda et al., 1981 from deep seismic profiles, may be seen in Figure 3; the discontinuity of Mohorovic is located at a depth of approximately 11 kilometers although in the magnetotelluric studies carried out by Ortiz et al., this discontinuity may be at a depth of 13 kilometers.
4) The gravimetry of Lanzarote, Sevilla and Parra, 1975, and later Vieira et al, 1988, figure 4, enables us to distinguish three zones of maximums: a central zone where the highest gravity values are reached, and two lateral zones, one in the north, which affects the region situated to the north of the La Corona volcano and La Graciosa Island, very close to Lanzarote, and another in the south, of lesser importance. Among the three zones of maximums there are zones of minimums which coincide with the historic and subhistoric eruptions on the island (Fuster et al., 1968; figure 5); one which especially stands out is the zone of the National Volcanic Park of Timanfaya, where we find the minimum of the island. This distribution of anomalies favors the theory of raised and independent blocks with a system of intermediate deep dykes. With this theory, an explanation may be found for the differences seen between the structures of Lanzarote and Fuerteventura, despite their proximity, as may be seen in the structural diagram obtained from the deep seismic profiles which were corroborated by magnetotelluric studies.
5) Lanzarote has important geothermic anomalies in the southern zone of Timanfaya, in the Monta7a del Fuego, with thermic measurements of 6003 C at a depth of only 12m. Nevertheless, this anomaly may be local, as a result of a small residual magmatic chamber of the last important eruption of 1730 - 1736.

3. GEODYNAMIC STATION

In the geodynamic setting described above, and which for obvious reasons is of great scientific interest, in agreement with the local authorities and with the support of the C.S.I.C., it was decided to initiate the installation of various sensors which would allow for permanent auscultation of the dynamics of Lanzarote. While it is true that the last eruption on the island took place several decades ago (1924) and two and a half centuries have passed since the great eruption which resulted in the National Volcanic Park of Timanfaya, it is also certain that these periods of time are very short in what we could term the active life of a volcanic zone; consequently Lanzarote must be considered an island with active volcanism, although it is apparently in a lethargic state.

The volcanic tunnel of the La Corona volcano was selected for the base site of the installation (T. Bravo, 1964; figures 5 and 6). This tunnel was formed by the flow of subhistoric eruption lavas (some three thousand years ago) which affected the northern zone of the island and which gave rise to the extensive "malpais" of La Corona and in its inside to the largest volcanic tunnel known, which starts from the slope of said volcano and runs for approximately 7 km eastward, entering the sea where it goes on for at least another 2 km, according to speleological data of the expedition which in 1987 broke the underwater speleological record.

The station comprises three models:

A) Observation module A; located inside the volcanic tunnel at approximately 1,500m from the coast line.

In module A, the following have been installed:

1- Lacoste Romberg gravimeter, model G N°434, modified as a zero gravimeter by Dr. Van Ruymbeke.
2- Pressure, temperature and humidity sensors.
3- Short period seismograph of the National Museum of Natural Sciences.
4- High precision sensors for measuring rock temperatures. Collaboration with the O.R.B. and the I.C.S.G.
5- Two component vertical pendulum. Collaboration with the O.R.B. and the I.C.S.G.
6- 16 channel data acquisition system.

B) Module B is located at the intersection of the volcanic tunnel with the ocean, where a lake is formed which is the entrance to the underwater section of the tunnel. In this lake, a pressure sensor has been installed in order to measure sea level variations. The tunnel, although through apparently very small ducts, is in contact with the ocean, and tide variations are obtained, although with a phase lag of around twenty minutes with regard to external variations. Just one month ago, pressure and temperature sensors were installed in the same place.

C) The third module is located in the zone, very close to the mareograph, in which the "Casa de los Volcanes" has been formed. This site is both of scientific and tourist interest, and will be inaugurated next December, coinciding with the Meeting of the Working Group on Volcanism which is being organized by the European Science Foundation. In this third module are to be found recording systems and the central computer, which, as we will see in another paper, collects information from all the sensors that have been installed; some of these outputs are available for use by visitors to the "Casa de los Volcanes".

All the instruments installed, and those others that are expected to be installed in the near future, are connected to what we could term an auscultation of the volcanic activity in the Canary Islands, where an attempt is being made to monitor parameters which at a given moment may provide prior information in the face of possible risks of eruption.

4. RESULTS OBTAINED

The more than two years of records of gravimetric tides obtained to date have been analysed and the results are shown in Table 1. The excellent quality of the station is reflected both in the m.q.e. in the determination of the amplitude/phases of the harmonics, and in the standard deviation of the D, SD and TD bands.

The unique features of the station made us consider contrasting the theory put forward in Madrid by Yanshin et al.,1986, on the possible relationship between geothermic flow and tide factors. The problem of calculating the oceanic effect is, as with other stations close to the sea, of great transcendence. The obtention of these correction values directly from the Schwiderski Charts (Schwiderski, E.W.; 1980) are slightly different to those we had obtained from the analysis of close mareographs. For this reason, and maintaining the same conditions that we established for the Iberia Charts (Vieira et al.,1986), we have extended said charts to a zone including the Canary Islands and the Madeira islands (C.Toro; 1989). In the same way, a digitalization grid has been created, which is perfectly adapted to the form of the coastline of the Canary Islands. The value obtained for the oceanic effect in the Cueva de los Verdes station is therefore the result of the Schwyderski Chart, for what we may term the far effect, and within the limits, $25^\circ N \leq \varphi \leq 35^\circ N$, $-10^\circ W \leq \lambda \leq -19^\circ W$, the part which is obtained from the new charts of the Canary Islands. In this paper we only refer to the M2 chart, which is the only complete one to date.

We must point out that the amplitude and phases variations effects observed in barographic stations located on the continental shelf are greatly attenuated in Lanzarote, a small volcanic island located over 400 km from the African coast. This constitutes a further incentive for continuing research in the good laboratory formed by the island because pressure correction is easier to model.

The calculated oceanic effect is: total indirect oceanic effect, $L = 7.95$, $\lambda = 165.30$; the vector (B, β) observed with regard to the Molodenski model 1, is $B = 90.4$, $\beta = 162.5$; the residual vector (X, κ), difference between (B, β) and (L, λ), in this case is:

$$X = 1.17,$$
$$\kappa = 144.80.$$

The components $X \cos\kappa$, $X \sin\kappa$, will be :

$$X \cos\kappa = -0.9555,$$
$$X \sin\kappa = 0.6751.$$

The first conclusion of interest is that we observe that the cosine component of the residual vector gives a value of almost minus one, which apparently contradicts the hypothesis of Yanshinet al, 1986, which related the negative anomalies to stable zones and the positive ones to regions with stability problems, such as those of basaltic volcanism and tectonic tension of Iceland the Strait of Badel Manded. So this would seem to be our most coherent result with those encountered in the East of Africa in zones of rift and in which there is also basaltic volcanism.

However, we must stress that the Cueva de los Verdes station is located on the zone recovered from the sea after the eruption of La Corona volcano, some two to three thousand years ago, Despite the good quality of the results, it is a singular station in which elastic response may certainly differ from that of the model.

It would also be of interest to install another gravimeter, because, although the L.R. N° 434 was installed in Lanzarote after being contrasted with others in Madrid, its constants might well vary, and this might affect the values of the vector (B,β) found and as a result, the residual vector (X,κ).

The analysis of pressure observations in "La Cueva de los Verdes" and oceanic tides in "Jameos del Agua" are given in tables 2 and 3. It were developed, for these analysis, the corresponding programs beginning from another in existence, principally of the I.C.E.T. and Venedikov program SV2 (Venedikov, A.P.; 1986). Although we are studying possible correlations and corrections between different parameters, in figure 8 the cotidal and corange oceanic variations for semidiurnal frequency were given; and in figure 9 the results, for the main groups of waves, of the cotidal corresponding to analysis made every 28 days during nine months series; the striped zone in the time axis corresponds to a bad observation period due to instrumental problems.

ACKNOWLEDGEMENTS:

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REFERENCES

- Araña, V.; Carracedo, J.C.(1978): "Los volcanes de las Islas Canarias.I.Tenerife". Ed. Rueda. Madrid, 151 pp..

- Araña, V.; Ortiz, R.; Badiola, E.; Banda,E. y Pavia, J.(1976): "Modelo estructural de la isla de Lanzarote a partir de perfiles sismicos". II Asamblea Nacional de Geodesia y Geofisica. Publ. I.G.N.pp. 2249-2255; Madrid.

- Bravo, T. (1964): "El volcan y el Malpais de La Corona, la Cueva de los Verdes y los Jameos". Publ. Cabildo Insular de Lanzarote, Arrecife, 32 pp..

- Fuster, J.M.; Fernandez, S.; Sagredo, J. (1968): "Geologia de las islas Canarias. Lanzarote". C.S.I.C, Madrid, 177 pp..

- Schwiderski, E.W. (1980): "Ocean Tides, part I. Global Ocean Tidal Ecuations". Marine Geodesy, vol. 3, 161.

- Sevilla, M.J.; Parra, V. (1975): "Levantamiento gravimetrico de Lanzarote". Rev. R. Acd. de Ciencias Exactas, Fisicas y Naturales, n. 49, pp. 257-284, Madrid.

- Toro, C. (1989): "Determinacion y evaluacion de las variaciones periodicas de la gravedad y de las desviaciones de la vertical en la Peninsula Iberica producidas por las Mareas Oceanicas". Ph. Degree, Univesidad Complutense de Madrid, Madrid.

- Venedikov, A.P. (1986): "Application of a program for Earth Tide data processing". B.I.M. n. 96, pp. 6490-6538.

- Vieira, R.; Camacho, A.G.(1989):"Gravimetria de lanzarote". I.A.G. internal document.Madrid.

- Vieira, R.; Fernandez, J.; Toro, C. y Camacho, A.G. (1988):"Estacion geodinamica del complejo Jameos del Agua-Cueva de los Verdes (lanzarote). Objetivos cientificos y estado actual de las instalaciones". VI Asamblea Nacional de Geodesia y Geofisica, Madrid, 5 pp.. In press.

- Vieira, R.; Toro, C.; Megias, E. (1986): "Ocean tides in the nearby of the Iberian Peninsula. Part I: M2 Iberia map". Proc. of the X Int. Symp. on Earth Tides. Ed. R. Vieira, Consejo Superior de Investigaciones Cientificas, Madrid. pp. 679-696.

- Yanshin, A.L.; Melchior, P.; Keilis-Borok, V.I.; De Becker, M.; Ducarme, B. and Sadovsky, A.M. (1986): "Global distribution of tidal anomalies and an attempt of its geotectonic interpretation". Proc. of the X Int. Symp. on Earth Tides. Ed. R. Vieira, Consejo Superior de Investigaciones Cientificas, Madrid. pp. 731-756.

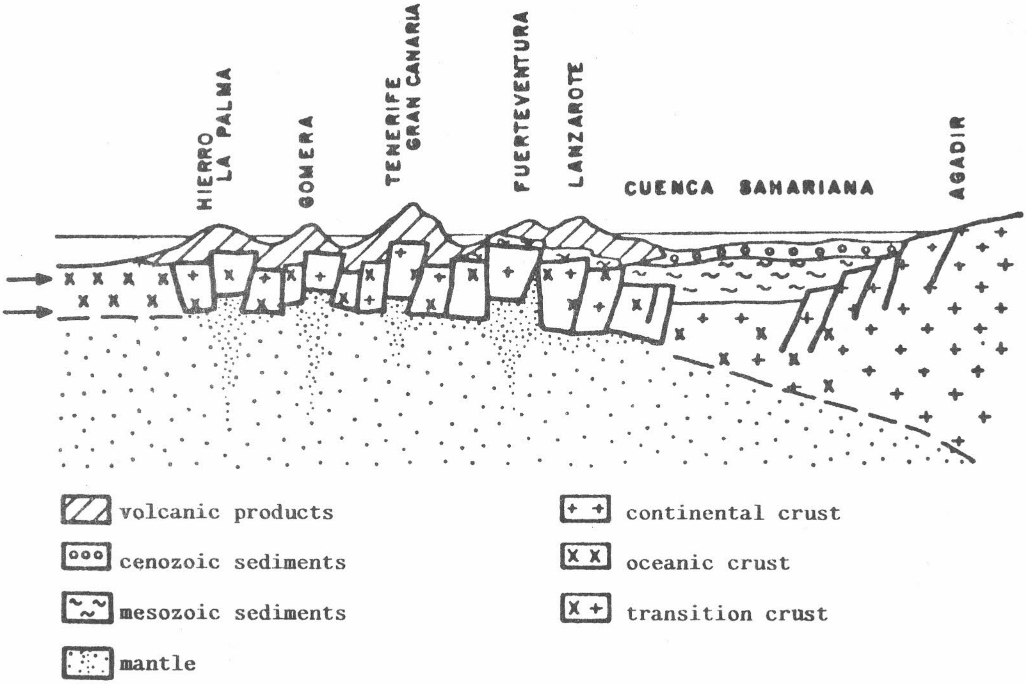


Fig. 1. Genetic model of the Canarian Islands. (Araña y Carracedo, 1978)

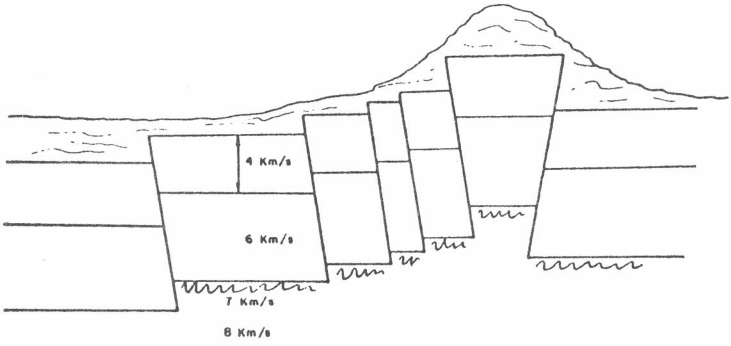


Fig. 2. Global structural model of Lanzarote (Araña et al. 1976)

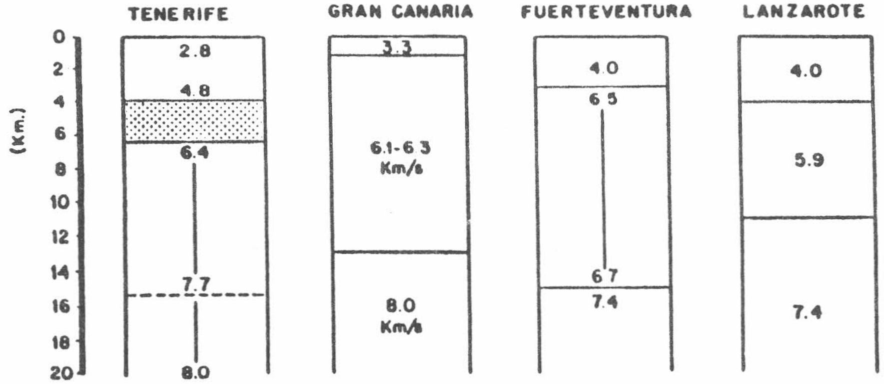


Figure 3. Structural model of Canary Islands (Banda et al. 1981)

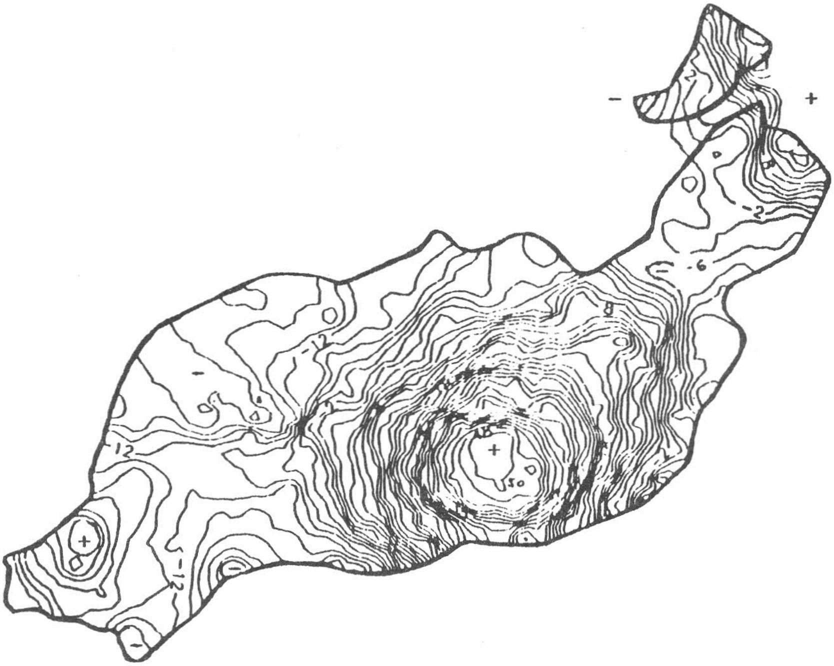


Figure 4.Residual gravity anomalies in Lanzarote (Vieira et al. 1988)

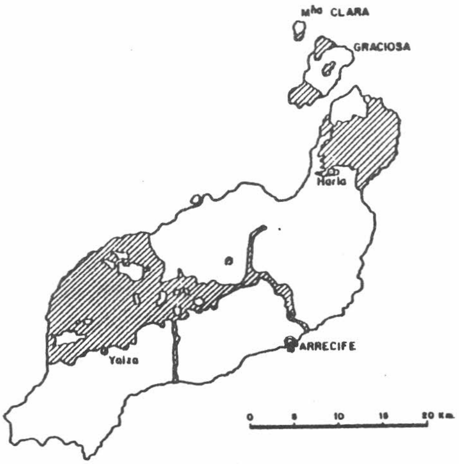


Figura 5. Recent volcanism in Lanzarote (Fuster et al. 1968)

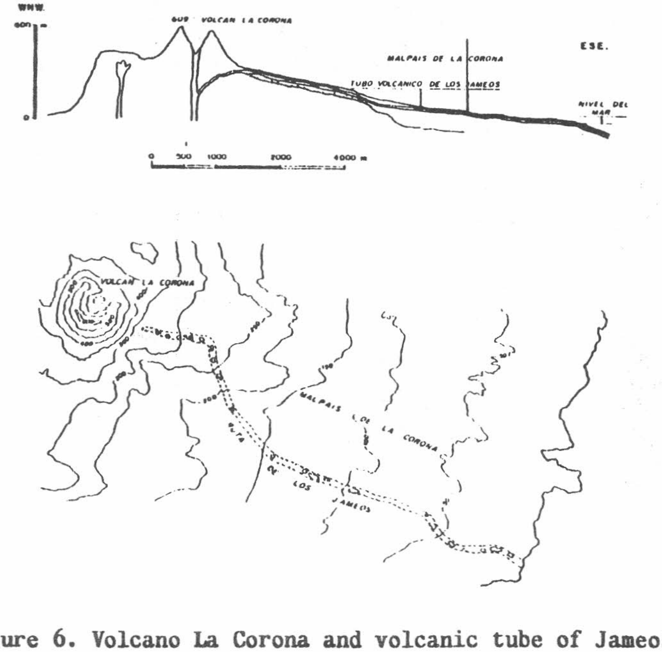


Figure 6. Volcano La Corona and volcanic tube of Jameos
(T. Bravo, 1964)

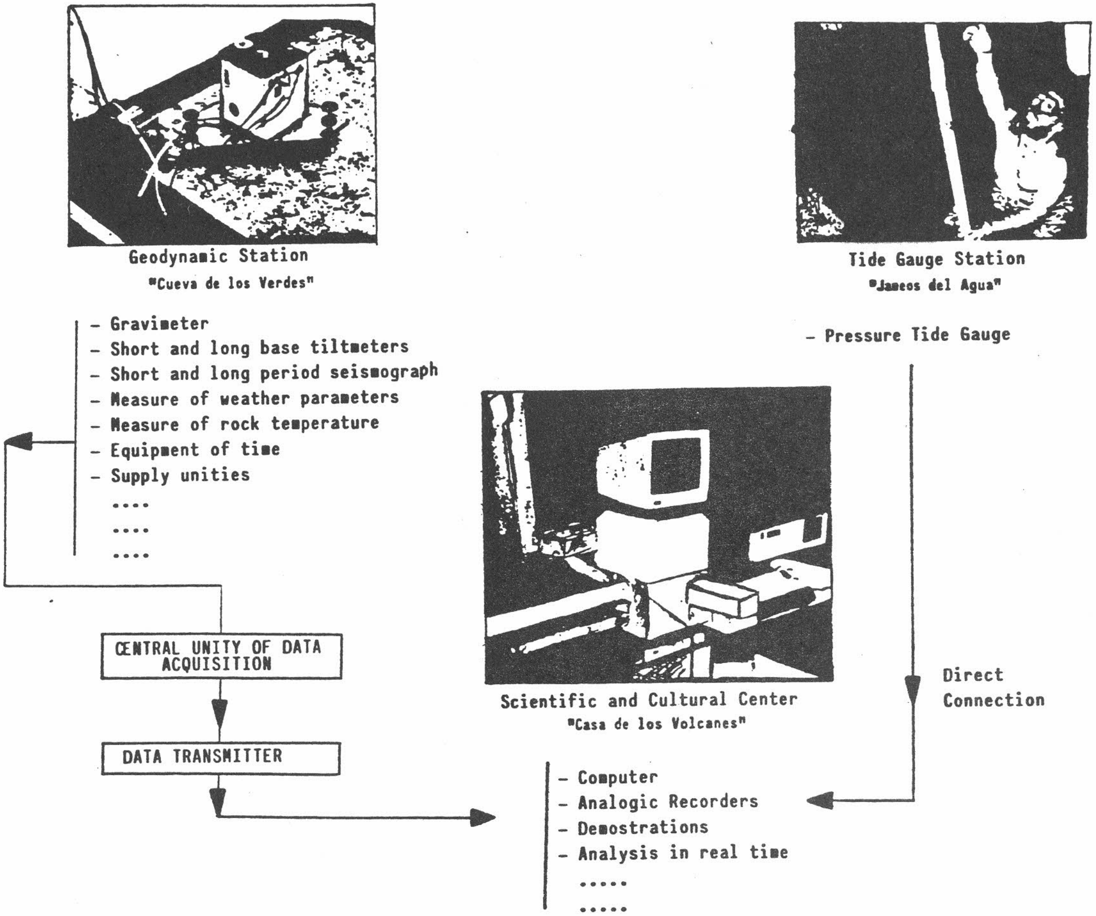
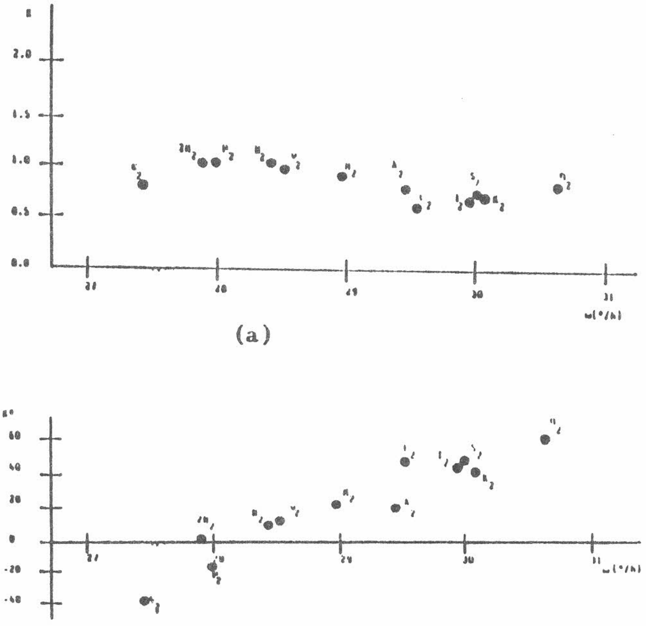

Geodynamic Station
"Cueva de los Verdes"
- Gravimeter
- Short and long base tiltmeters
- Short and long period seismograph
- Measure of weather parameters
- Measure of rock temperature
- Equipment of time
- Supply unities
....
....
....
CENTRAL UNITY OF DATA ACQUISITION
DATA TRANSMITTER
Tide Gauge Station
"Jameos del Agua"
- Pressure Tide Gauge
Direct Connection
Scientific and Cultural Center
"Casa de los Volcanes"
- Computer
- Analogic Recorders
- Demostrations
- Analysis in real time
.....
.....

Figure 7



(a)

(b)

Figure 8. (a) Amplitudes factor y (b) phases lag of the ocean semidiurnal tides in Jameos

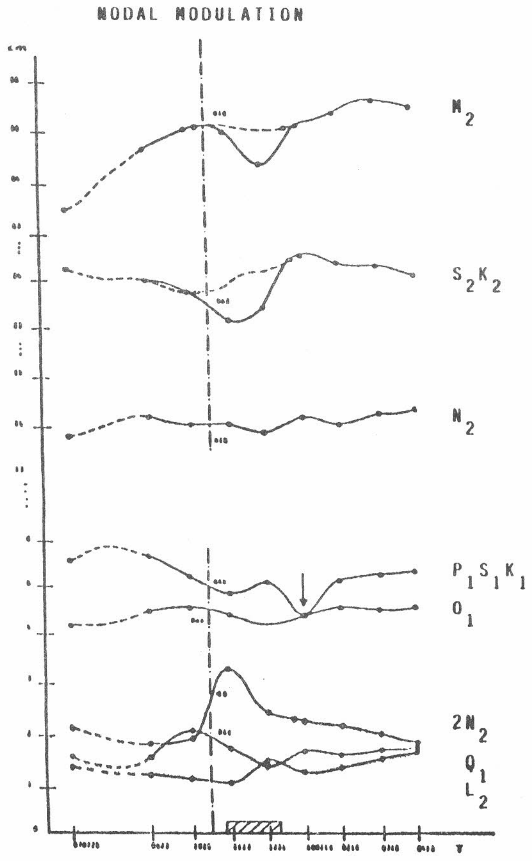


Figure 9.

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STATION          CUEVA DE LOS VERDES VERTICAL COMPONENT     SPAIN

29 09 N          13 26 W              H  060 M        P  40          D    1 KM


INSTITUTO DE ASTRONOMIA Y GEODESIA.
      C.S.I.C.-U.C.M.
FACULTAD DE CIENCIAS MATEMATICAS.
      28040 - MADRID

GRAVIMETRO  LACOSTE ROMBERG  MOD.G 434 METODO DE CERO (M.VAN RUYMBEKE)
REGISTRADOR MICROSCRIBE
CALIBRATION:   VALLE DE LOS CAIDOS  FUNDAMENTAL STATION
INSTALATION:   R.VIEIRA
MANTENANCE :   R.VIEIRA, J.FERNANDEZ

LEAST SQUARE ANALYSIS / VENEDIKOV FILTERS ON 48 HOURS / PROGRAMMING B. DUCARME
POTENTIAL CARTWRIGHT-TAYLER-EDDEN / COMPLET DEVELOPMENT
COMPUTING CENTER OF UNIVERSIDAD COMPLUTENSE DE MADRID
COMPUTER   IBM 360      PROCESSED ON   89/ 6/25

INERTIAL CORRECTION PROPORTIONAL TO THE SQUARE OF ANGULAR SPEEDS
NORMALISATION FACTOR   0.99203
PHASE LAG  O1  0.25   M2  0.50   O1/M2 0.50
INSTRUMENTAL LAG  173.10 MIN.
CORRECTION FOR DIFFERENTIAL ATTENUATION   M2/O1 1.00151   /MODEL 2/

434   87 515/87 525  87 528/87 6 3  87 711/871011  871111/871129  8712 3/871219
434   871223/88 215  88 219/88 3 4  88 310/88 314  88 317/88 430  88 5 4/88 6 7
434   88 619/88 723  88 727/88 9 9  88 929/8810 5  881013/881015  881022/881022
434   881027/881220  881226/881230  89 1 4/89 1 4  89 110/89 221  89 226/89 226
434   89 3 2/89 4 7  89 411/89 5 1  89 5 5/89 517  89 525/89 527  89 530/89 6 1
434   89 6 7/89 6 9  89 616/89 616

TIME INTERVAL   765.0 DAYS     14544 READINGS        27 BLOCKS

  WAVE GROUP    ESTIMATED AMPL.   AMPL.              PHASE              RESIDUALS
ARGUMENT    N WAVE       R.M.S.  FACTOR  R.M.S.   DIFF.  R.M.S.      AMPL.  PHASE

INVERTED READINGS
115.-11X. 11 SIGMQ1  0.24 0.02   1.2473 0.0886    -1.00   4.06       0.02  -14.0
124.-126. 10 2Q1     0.85 0.02   1.2721 0.0282    -0.78   1.27       0.08   -8.8
127.-129. 11 SIGMA1  0.99 0.02   1.2302 0.0231     1.38   1.07       0.06   22.8
133.-136. 20 Q1      5.95 0.02   1.1757 0.0036    -2.24   0.18       0.25  -71.6
137.-139. 10 RO1     1.15 0.02   1.2006 0.0190    -0.80   0.90       0.04  -22.3
143.-145. 16 O1     30.21 0.02   1.1435 0.0067    -1.37   0.03       0.84 -120.6
146.-149. 10 TAU1    0.30 0.03   0.8545 0.0735    -7.95   4.92       0.12 -159.3
152.-155. 15 NO1     2.37 0.01   1.1430 0.0071     0.07   0.35       0.03  175.3
156.-158.  7 KI1     0.44 0.02   1.1114 0.0435    -0.24   2.24       0.02 -174.3
161.-163. 10 P1     13.74 0.02   1.1177 0.0017     0.33   0.09       0.45  169.8
164.-164.  3 S1      0.20 0.03   0.6926 0.1035     6.33   8.72       0.14  170.6
165.-168. 20 K1     41.27 0.02   1.1106 0.0005     0.46   0.03       1.06  161.7
172.-174.  8 TETA1   0.45 0.02   1.1289 0.0441     4.50   2.24       0.04  112.2
175.-177. 14 J1      2.40 0.02   1.1529 0.0087     0.25   0.43       0.02  148.7
181.-183.  7 SO1     0.36 0.02   1.0300 0.0496    -0.13   2.75       0.05 -179.0
184.-186. 11 OO1     1.30 0.01   1.1396 0.0100     0.77   0.50       0.03  144.0
191.-195. 14 NU1     0.24 0.01   1.1039 0.0550     1.67   2.75       0.01  150.5

INVERTED READINGS
215.-22X. 19 EPS2    0.45 0.02   1.0699 0.0424    -7.55   2.27       0.07 -125.3
233.-236. 10 2N2     1.42 0.02   0.9773 0.0139    -2.80   0.81       0.28 -165.4
237.-23X. 10 MU2     1.72 0.02   0.9828 0.0109    -3.92   0.63       0.34 -159.5
243.-245. 13 N2     10.79 0.02   0.9844 0.0017     1.08   0.10       1.94  174.0
246.-248. 11 NU2     2.10 0.02   1.0088 0.0089     1.62   0.50       0.32  169.4
252.-258. 26 M2     57.83 0.02   1.0105 0.0003     2.69   0.02       9.04  162.5
262.-264.  5 LAMB2   0.46 0.02   1.0896 0.0423     1.23   2.22       0.03  161.7
265.-265.  9 L2      1.70 0.01   1.0514 0.0089     3.25   0.48       0.20  151.7
267.-272.  5 T2      1.62 0.02   1.0364 0.0108     4.60   0.60       0.24  146.8
273.-273.  4 S2     28.24 0.02   1.0605 0.0006     4.57   0.03       3.55  140.6
274.-277. 12 K2      7.64 0.01   1.0536 0.0018     4.38   0.10       0.99  143.7
282.-285. 15 ETA2    0.43 0.01   1.0639 0.0297     6.34   1.60       0.06  131.2
292.-295. 11 2K2     0.11 0.01   1.0570 0.0643     5.29   3.48       0.02  137.8

INVERTED READINGS
335.-375. 16 M3      1.06 0.01   1.0840 0.0097     2.08   0.51       0.10   23.8

STANDARD DEVIATION   D     1.57     SD     1.30     TD     0.68  MICROGAL
STUDENT FACTOR     T(S=95(,N> 589)=1.96

O1/K1  1.0296   1-O1/1-K1  1.2978   M2/O1  0.8837
CENTRAL EPOCH TJJ= 2447312.0
```

Table 1

```
                          MAREA ATMOSFERICA
                          -----------------

ESTACION                  CUEVA DE LOS VERDES (LANZAROTE)
SITUACION                 29 07 N  -  13 26 W
ORGANISMO RESPONSABLE     INSTITUTO DE ASTRONOMIA Y GEODESIA
                          ( C.S.I.C. - U.C.M. )

SENSOR DE PRESION         NUMERO  001
MODULO DE ADQUISICION
DE DATOS
INSTALACION               R.VIEIRA, J.FERNANDEZ
CALIBRACION               I.M.N.
MANTENIMIENTO             O.HERNANDEZ, R.VIEIRA, J.FERNANDEZ

ANALISIS                  MINIMOS CUADRADOS. FILTROS DE VENEDIKOV SOBRE
                          INTERVALOS DE 48 HORAS.
                          POTENCIAL CARTWRIGHT-TAYLER-EDDEN.
                          DESARROLLO COMPLETO
                          CENTRO DE PROCESO DE DATOS DE LA UNIVERSIDAD
                          COMPLUTENSE DE MADRID.   COMPUTADOR I.B.M. 4381
                          PROCESADO EL   89/ 6/25

INTERVALO DE OBSERVACION  871212/8810 7
                          302.0 DIAS       7248 LECTURAS

       GRUPO                 AMPLITUD            FASE
ARGUMENTO  N ONDA           H   E.Q.M.       DIF.  E.Q.M.

115.-11X. 11 SIGMQ1       0.008 0.0109      49.24   74.39
124.-129. 21 SIGMA1       0.014 0.0088      55.15   36.49
133.-139. 30 Q1           0.019 0.0116       7.56   35.04
143.-149. 26 O1           0.012 0.0120      80.66   56.28
152.-158. 22 M1           0.017 0.0095      88.42   32.39
161.-168. 33 P1S1K1       0.057 0.0121      53.24   12.18
172.-177. 22 J1           0.005 0.0112      -6.65  129.44
181.-186. 18 OO1          0.012 0.0075     -31.25   35.96
191.-195. 14 NU1          0.004 0.0075     -84.52   97.23

215.-22X. 19 EPS2         0.014 0.0134       5.35   55.50
233.-23X. 20 2N2          0.005 0.0109     -19.70  135.02
243.-248. 24 N2           0.004 0.0142      -6.69  223.05
252.-258. 26 M2           0.042 0.0142     -12.66   19.41
262.-265. 14 L2           0.023 0.0117      14.04   29.34
267.-277. 21 S2K2         0.527 0.0126     -59.92    1.37
282.-285. 15 ETA2         0.006 0.0093      -4.12   90.94
292.-295. 11 2K2          0.010 0.0052      85.44   31.17

335.-375. 16 M3           0.009 0.0076      74.83   48.85
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Table 2

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          RED DE MAREA OCEANICA  -  COMPONENTE VERTICAL
          --- -- ----- --------     ---------- --------

ESTACION                     JAMEOS DEL AGUA. CASA DE LOS VOLCANES. LANZAROTE.
SITUACION                    29 09 N   -   13 25 W
ORGANISMO RESPONSABLE        INSTITUTO DE ASTRONOMIA Y GEODESIA
                             ( C.S.I.C. - U.C.M. )

MAREOGRAFO                   001 (SENSOR DE PRESION)
REGISTRADOR                  MICROSCRIBE
INSTALACION                  R.VIEIRA
CALIBRACION                  R.VIEIRA
MANTENIMIENTO                R.VIEIRA, J.M. ESPINO , J. NAVERAN Y O. HERNANDEZ

ANALISIS                     MINIMOS CUADRADOS. FILTROS DE VENEDIKOV SOBRE
                             INTERVALOS DE 48 HORAS.
                             POTENCIAL CARTWRIGHT-TAYLER-EDDEN.
                             DESARROLLO COMPLETO
                             CENTRO DE PROCESO DE DATOS DE LA UNIVERSIDAD
                             COMPLUTENSE DE MADRID.   COMPUTADOR I.B.M. 4381
                             PROCESADO EL    89/ 1/13

INTERVALO DE OBSERVACION     87 712/87 829   87 9 9/8710 7   871012/88 425
                             290.0 DIAS      6432 LECTURAS       3 BLOQUES
EPOCA CENTRAL                FJ= 2447132.0

        GRUPO             AMPLITUD      FACTOR DE             FASE             RESIDUALES
ARGUMENTO  N ONDA        H  E.Q.M.   AMPL.    E.Q.M.     DIF.    E.Q.M.       AMPL.  FASE

115.-11X. 11 SIGMQ1    0.08 0.04    0.3439 0.1621     -12.16   27.00         0.20 -175.0
124.-126. 10 2Q1       0.43 0.04    0.5222 0.0524      17.84    5.76         0.56  166.4
127.-129. 11 SIGMA1    0.28 0.04    0.2762 0.0434      43.32    9.01         0.97  168.8
133.-136. 20 Q1        1.64 0.04    0.2630 0.0068      63.50    1.48         6.68  167.3
137.-139. 10 RO1       0.33 0.04    0.2746 0.0359      72.43    7.48         1.32  166.3
143.-145. 16 O1        4.51 0.04    0.1380 0.0013     -65.77    0.53        36.22 -173.5
146.-149. 10 TAU1      0.08 0.06    0.1839 0.1371     -69.12   42.72         0.47 -171.1
152.-155. 15 NO1       0.17 0.04    0.0667 0.0161      49.78   13.86         2.87  177.4
156.-158.  7 KI1       0.14 0.04    0.2752 0.0835     -17.13   17.38         0.44 -174.8
161.-163. 10 P1        1.45 0.05    0.0955 0.0033      34.80    2.01        18.35  177.1
164.-164.  3 S1        0.60 0.08    1.6795 0.2180      37.74    7.47         0.38   80.2
165.-168. 20 K1        5.27 0.05    0.1148 0.0010      38.65    0.60        48.21  176.1
172.-174.  8 TETA1     0.06 0.04    0.1128 0.0862      88.13   43.81         0.57  174.4
175.-177. 14 J1        0.08 0.04    0.0312 0.0158     -31.47   29.06         2.91 -179.2
181.-183.  7 SO1       0.06 0.04    0.1480 0.0930      87.60   36.03         0.50  172.7
184.-186. 11 OO1       0.12 0.03    0.0836 0.0202     -28.56   13.86         1.53 -177.9
191.-195. 14 NU1       0.03 0.03    0.1031 0.0996      34.68   55.35         0.29  176.9

215.-22X. 19 EPS2      0.43 0.06    0.8144 0.1168     -35.48    8.22         0.36 -136.4
233.-236. 10 2N2       1.85 0.07    1.0302 0.0404       2.57    2.25         0.25  160.5
237.-23X. 10 MU2       2.25 0.07    1.0374 0.0305     -15.98    1.68         0.71 -119.7
243.-245. 13 N2       14.08 0.07    1.0362 0.0050      11.24    0.28         3.37  125.4
246.-248. 11 NU2       2.52 0.06    0.9752 0.0250      13.90    1.47         0.82  132.3
252.-258. 26 M2       64.92 0.06    0.9151 0.0009      24.12    0.06        36.15  131.0
262.-264.  5 LAMB2     0.42 0.06    0.8051 0.1190      21.28    8.47         3.26  144.6
265.-265.  9 L2        1.30 0.05    0.6467 0.0226      47.25    2.00         1.73  146.6
267.-272.  5 T2        1.35 0.06    0.6979 0.0319      45.40    2.62         1.61  143.4
273.-273.  4 S2       24.01 0.06    0.7275 0.0019      47.17    0.15        28.16  141.3
274.-277. 12 K2        6.71 0.05    0.7470 0.0050      44.14    0.39         7.30  140.2
282.-285. 15 ETA2      0.41 0.04    0.8207 0.0840      63.09    5.86         0.54  137.1
292.-295. 11 2K2       0.06 0.02    0.4644 0.1822      89.10   22.48         0.16  158.1

DESVIACION TIPICA     D     0.25     SD     0.30     ( 0.1 MM )
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   WAVE GROUP         ESTIMATED          PHASE          RESIDUALS
ARGUMENT     N WAVE  AMPL.R.M.S.     DIFF.   R.M.S.   AMPL. PHASE
--------------------------------------------------------------------
327.-347.     6 345   0.085 0.028   -32.514  18.745    0.20-166.9
353.-355.     3 M3    0.285 0.028   201.618   5.690    1.24-175.2
363.-375.     8 365   0.031 0.007   159.349  12.735    0.09 172.5
382.-382.     1 S3    0.116 0.022   -25.053  11.660    0.11 -27.3
--------------------------------------------------------------------
STANDARD DEVIATIONS    TD   1.09
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--------------------------------------------------------------------
   WAVE GROUP         ESTIMATED          PHASE          RESIDUALS
ARGUMENT     N WAVE  AMPL.R.M.S.     DIFF.   R.M.S.   AMPL. PHASE
--------------------------------------------------------------------
455.-455.     1 M4    0.828 0.041    80.361    2.839   0.83  81.2
491.-491.     1 S4    0.118 0.040   -89.579   19.377   0.12 -95.2
--------------------------------------------------------------------
STANDARD DEVIATIONS    QD   2.09
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Table 3