

Universidad Complutense
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SEMINARIO DE ASTRONOMIA Y GEODESIA
(Coordinado con el Consejo Superior de Investigaciones Científicas,
Departamento de Mecánica y Astronomía)

Publicación núm. 114

COMUNICACIONES PRESENTADAS EN
EL IX SYMPOSIUM INTERNACIONAL DE
MAREAS TERRESTRES. NUEVA YORK 1981

por

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PRESENTADO EN EL IX INTERNATIONAL SYMPOSIUM
ON EARTH TIDES, NEW YORK

M A D R I D
1981

INDICE

	<u>Página</u>
VIEIRA, R., and TORROJA, J. M.: «A possible Contribution of the Gravimetric Tides to the Study of the Discontinuities of the Earth Crust»	3
VIEIRA, R., TORO, C., and SUKHWANI, P.: «Ocean Effects on Gravity Tides in the Iberian Peninsula» ...	7
OREJANA, M., and VIEIRA, R.: «Transforming an Askania GS-15 Gravimeter into a Zero Gravimeter»	13
OREJANA, M., VIEIRA, R., and TORO, C.: «Development of an Electronic Pendulum for Microinclination Recordings»	17
LAMBAS, F., VIEIRA, R., and GIMENEZ, E.: «Automatic Control Module of Tilts, Calibrations and Data Acquisition for LaCoste-Romberg Gravimeters, Models G and D»	21

A Possible Contribution of the Gravimetric Tides to the Study of the Discontinuities of the Earth Crust

R. VIEIRA and J. M. TORROJA, Madrid

with 2 figures and 1 table

Vieira, R. & Torroja, J. M., 1983: A possible contribution of the Gravimetric Tides to the Study of Discontinuities of the Earth Crust. Proceedings of the Ninth International Symposium on Earth Tides, pp. 669-672.

Abstract: We are developing a profile of the vertical component stations in the Iberian Peninsula, with NS direction along the meridian of Madrid, which crosses the separation of two zones called "Meseta Norte" and "Meseta Sur." These comprise a deep fault that begins in Alentejo, Portugal, and continues in the "Dique de Plasencia" till the Easter Foot-hills of the Central System. The differences in the physical structure of both zones have not yet been studied by the most convenient geophysical technique, but a deep seismic profile perpendicular to the direction of contact is a project pending for next year.

There is clearly a discrepancy between the results obtained for the gravimetric tides and in the north and south part of that anomaly that has led us to establish a small network for a detailed study of the zone. The network comprises five stations, three to the north and two to the south, with a maximum distance between them of 100 km. The results show a sensible difference in the phase of the M_2 and in the amplitude and phase of the residuals of the same component between the north and south stations. We expect better knowledge of the structures of the zone from the seismic profile which will indicate to us whether a more detailed study of the zone is needed.

Keywords: gravity profile, fault, discontinuities.

The network of stations we have established extends from the northern to the southern tips of the Iberian Peninsula, crossing the range of hills of the "Central System", that separate the "Meseta Norte" from the "Meseta Sur". These two plateaus are separated by an old and inactive fault. The fault extends from Alentejo in Portugal to the eastern most mountains of the Central System.

The results of the first stations set up at the northern and southern area of this fault showed a discontinuity with the normal configuration to give a coherent relation.

Therefore, we decided to extend the number of stations to the north and to the south along this possible discontinuity, with a small network of five stations. The locations are chosen so

that the distances between the individual stations was relatively small, not more than 60 km.

Table 1 shows the results. Although the results are not conclusive, the possibility of detecting those discontinuities convinced us to continue the investigation.

Figures 1 and 2 show the general configuration of the isophases and the isoamplitudes of the residues with respect to the Molodensky model 1 for the M_2 tide in the Iberian Peninsula. There is the same discontinuity in the center in both figures. We can not tell, at present, whether the instrumental and observation errors are the reason for the discontinuity. We plan to continue this investigation with better instrumentation including tilt and seismic profiles.

This work has been developed in the Department of Mechanics and Astronomy of the C.S.I.C. and the Department of Astronomy and Geodesy of Complutense University, with financial support from both Centers and with the subvention given by the Assesory Commission of Scientific and Technical Investigation of the Presidency of the Government.

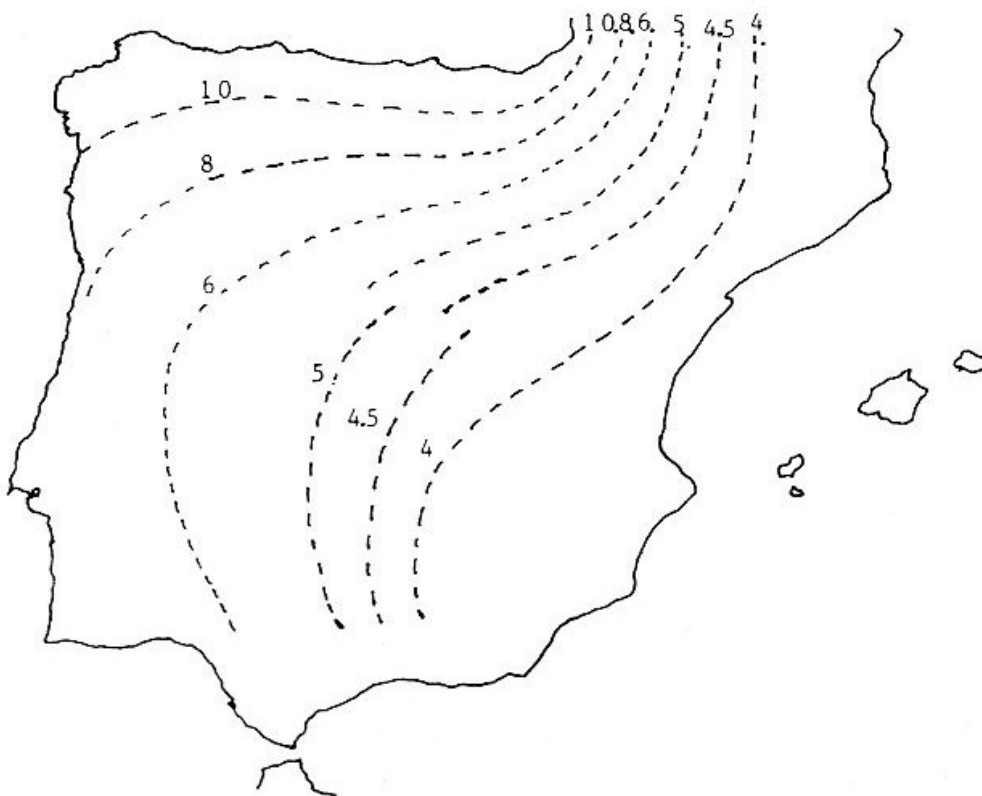


Fig. 1. M_2 Observed Phase

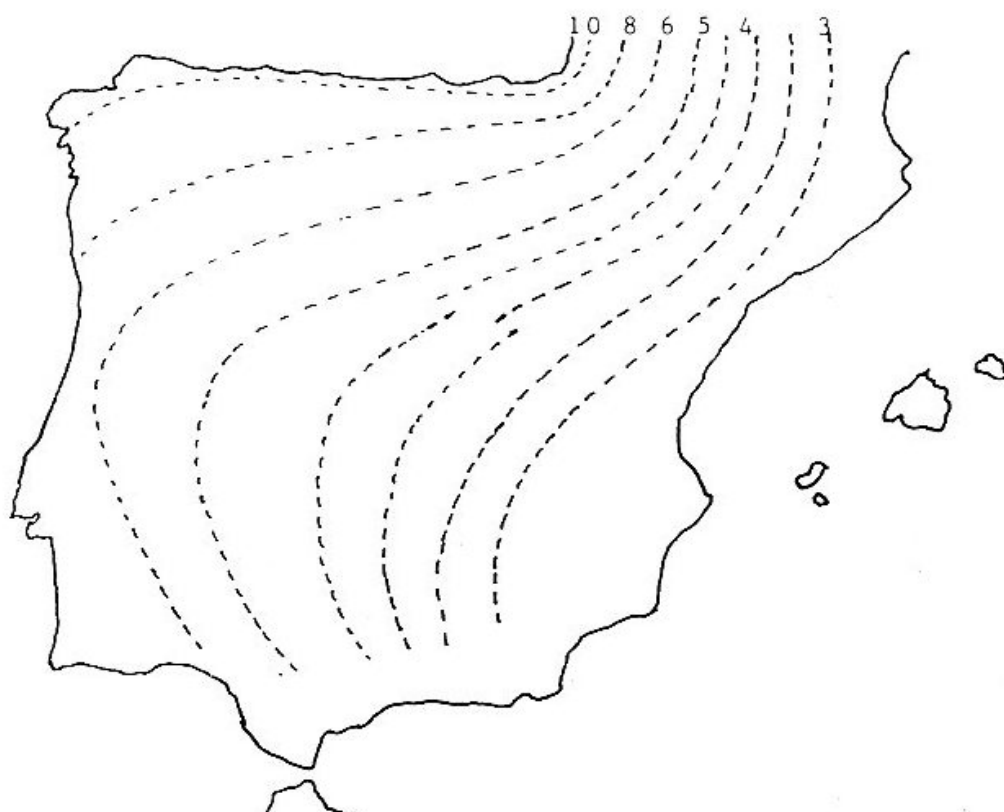


Fig. 2. Residues with respect to Molodensky 1.

Table 1. Net of the "Sistema Central" Vertical Component.

	λ	γ	h	$\delta(M_2)$	$\alpha(M_2)$	B	β
North Station 0407 Sepulveda	3 44	41 18	1.040	1.1725	4.10	3.58	84
0414 S. Ildefonso	4 00	40 54	1.191	1.1500	4.70	4.08	98
0412 Carbonero	4 16	41 07	920	1.1554	5.07	4.35	95
South Station 0401 Valle	4 05	40 23	1.280	1.1509	5.10	4.44	97
0402 Madrid	4 16	40 16	630	1.1530	4.50	4.00	99

$(\vec{B}, \beta)$: Observed residues with respect Molodensky 1

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DISCUSSION

- Q: Have you checked the influence of the Mediterranean Sea tides in southern Spain? (Schwiderski)
- A: Yes, we have digitized a M_2 map for the Mediterranean Sea to the 8'E meridian. The influences on Spanish gravity stations is considerable, more than 0.6 μ gal for the stations placed less than 250 km of the south lateral of Spain. (Vieira)
- Q: Is there a geological feature such as a fault at the discontinuity in earth tidal contours? (Bostrom)
- A: Yes, there is a very old and not active fault between the north and south stations. (Vieira)

Ocean Effects on Gravity Tides in the Iberian Peninsula

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with 1 figure and 4 tables

Vieira, T., Toro, C., & Sukhwani, P.K., 1983: Ocean effects on Gravity Tides in the Iberian Peninsula. Proceedings of the Ninth International Symposium on Earth Tides, pp. 431-436.

Abstract: As a continuation of our research presented at the 8th International Symposium on Earth Tides in Bonn, we have completed a total of 14 stations of the vertical component in Spain.

The strong ocean influence in these data makes them a good test for the different maps of oceanic tides. Starting from the maps of Schwiderski, Hendershott, Parke and Zahel, the effects of the ocean tides have been computed for our gravimetric stations.

We have prepared maps for the neighborhood of the Iberian peninsula, including the Alboran and Balearic seas, using results from hydrography and pelagic observations. The new maps, digitized with a grid of $0^{\circ}.5 \times 0^{\circ}.5$, have been computed for the Spanish stations, and they have been completed simultaneously for the mentioned maps.

Keywords: gravity tides, ocean maps, Spain.

1. Gravity tide observations

Observations have been made in 14 stations of earth tides in Spain (see Figure 1). With the exception of Madrid and Valle de los Caídos, the time series are four to six months long. The characteristics of these stations are shown in Table 1, and Table 2 shows the results for the main components, diurnal and semidiurnal.

2. Ocean effects

Because of the strong semidiurnal character of the ocean data in the latitude, where the stations are located, we have studied the ocean effect mainly of the wave M_2 .

Table 3 shows the values of the observed and calculated loading and attraction effects for Schwiderski, Hendershott, Parke, Zahel and the Iberian maps. We can observe that the best fit is undoubtedly given by Schwiderski's map. Except for the stations very near the sea, the differences between observed values and those computed for Schwiderski's map are smaller than $\log$.

The strong influence of the Gulf of Biscay causes, as we foresaw,

a decreasing phase difference in the profile towards the center of the peninsula. The same effect is observed in the amplitudes and phases of the residuals. Because of this strong influence, we have prepared a map for the Iberian M_2 wave which includes the zone between the parallels 32°N and 47°N and meridians 8°E and 15°W , digitized with a grid of $0^\circ.5 \times 0^\circ.5$. We plan to improve it with a better study of the results and errors of the hydrographic observations.

Table 1. Stations of the Iberian Tidal Gravity Profiles

Nº	NAME	λ (W)		ϕ		h	d	N	INST.
0401	VALLE	4	05	40	23	1280	350	1200	*
0402	MADRID	4	16	40	16	630	310	500	**
0403	GRANADA	3	22	37	07	774	50	140	L301
0404	SANTANDER	3	49	43	27	25	0	132	L434
0405	BURGOS	3	43	42	21	850	120	166	A212
0406	S.FERNANDO	6	15	36	28	25	0	90	L434
0407	SEPULVEDA	3	44	41	18	1040	240	160	A212
0408	ARCAS	2	08	40	00	990	170	180	L434
0409	CUBILLOS	5	44	41	34	667	220	120	L301
0410	TOLEDO	4	02	39	52	512	320	130	L301
0411	SANTIAGO	8	33	42	52	250	40	170	L301
0412	CARBONERO	4	16	41	07	920	315	90	L434
0413	C.REAL	3	56	38	59	600	250	160	L301
0414	S.ILDEFONSO	4	00	40	54	1191	280	80	L301
0480	PORTO ***	8	40	41	05	50	0	---	L258

* A212,L434,L301,ET15

** A212,L434

*** GROTEN 1978

d : approximate distance to the nearest see.

N : nº of days of recording.

Table 2 DIURNAL AND SEMIURNAL WAVES .

	N	$\delta(O_1)$	$\delta(P_{11}K_1)$	$\alpha(O_1)$	$\alpha(P_{11}K_1)$	INSTR.
S.FERNANDO	1676	1.1510	1.1518	-0.11	0.43	L.434
GRANADA	2880	1.1630	1.1584	-0.41	0.18	L.301
C.REAL	3600	1.1446	1.1509	-0.45	0.64	L.301
TOLEDO	2592	1.1635	1.1650	-0.35	0.97	L.301
ARCAS	2976	1.1503	1.1272	-0.48	4.81	L.434
MADRID	7200	1.1540	1.1520	-0.40	0.30	*
VALLE	12000	1.1520	1.1420	-0.20	0.44	**
CARBONERO	2016	1.1526	1.1383	-0.45	0.47	L.434
SEPULVEDA	2976	1.1563	1.1124	-0.61	0.30	A.212
CUBILLOS	2640	1.1452	1.1438	-0.38	0.49	L.301
BURGOS	3696	1.1543	1.1676	-0.70	1.12	A.212
SANTIAGO	3456	1.1733	1.1656	-1.01	0.61	L.301
SANTANDER	2784	1.1610	1.1661	-0.45	1.14	L.434

* A212,L434.

** A212,L301,L434,ET15.

	$\delta(N_2)$	$\delta(M_2)$	$\delta(S_2K_2)$	$\alpha(N_2)$	$\alpha(M_2)$	$\alpha(S_2K_2)$	INSTR.
S.FERNANDO	1.0612	1.1058	1.1692	3.67	6.26	5.48	L.434
GRANADA	1.1015	1.1588	1.2044	3.13	3.58	2.64	L.301
C.REAL	1.1146	1.1499	1.1880	2.95	3.19	2.42	L.301
TOLEDO	1.1281	1.1593	1.2106	1.77	3.75	2.02	L.301
ARCAS	1.1184	1.1563	1.1944	4.06	3.91	4.52	L.434
MADRID	1.1160	1.1530	1.1820	5.55	4.50	2.85	*
VALLE	1.1190	1.1509	1.1870	5.40	5.10	3.50	**
CARBONERO	1.0906	1.1554	1.1922	6.28	5.07	2.46	L.434
SEPULVEDA	1.1270	1.1725	1.2117	2.23	4.10	1.50	A.212
CUBILLOS	1.1084	1.1461	1.2018	7.20	6.50	4.72	L.301
BURGOS	1.1379	1.1840	1.3035	6.55	6.38	3.52	A.212
SANTIAGO	1.0701	1.1435	1.2414	11.93	11.31	7.64	L.301
SANTANDER	1.1102	1.2048	1.2841	15.25	12.17	6.13	L.434

* A212,L434

** A212,L301,L434,ET15

Table 3. Observed and calculated loading and attraction effects residues with respect to Molodensky I.

TIDAL WAVE M_2	Observed load		SCHWIDERSKY		HENDERSCHOTT		PARKE		ZAHLE (4X4)		IBERIAN M_2	
	B	β	L	λ	L	λ	L	λ	L	λ	L	λ
S.FERNANDO	6.5	117	6.4	121	8.2	117	11.2	119	4.9	138	4.5	129
GRANADA	3.4	93	3.4	108	6.2	106	8.8	109	3.7	120	2.8	117
C.REAL	3.0	101	3.7	105	8.4	106	11.3	108	3.9	119	2.7	108
TOLEDO	3.4	93	3.9	103	7.9	102	10.8	105	4.1	118	2.8	110
ARCAS	3.5	95	3.4	97	5.1	109	7.4	98	3.6	110	2.4	105
MADRID	4.0	99	4.0	100	7.1	98	9.7	102	4.1	116	2.8	107
VALLE	4.5	97	4.3	101	7.8	99	10.6	102	4.2	118	3.0	108
CARBONERO	4.3	95	4.6	100	8.1	97	10.9	101	4.3	117	3.2	106
SEPULVEDA	3.6	84	4.3	98	7.5	94	10.2	99	4.3	115	3.2	104
CUBILLOS	5.5	99	5.4	103	11.0	99	14.3	102	5.0	123	3.8	108
BURGOS	5.4	83	5.5	95	8.8	91	11.6	95	4.5	113	4.0	100
SANTIAGO	9.2	100	9.1	108	11.3	101	14.5	104	7.7	133	6.6	113
SANTANDER	10.1	86	8.7	94	9.8	89	12.7	93	4.9	112	6.9	95

Table 4. Trans Iberian tidal gravity profile observed and calculated loading and attraction effects residues with respect to Molodenski model I.

	B	β	L_s	λ_s	x_s	x_s	L_I	λ_I	x_I	x_I	$L_s - L_I$	$\lambda_s - \lambda_I$
S.FERNANDO	6.56	117	6.40	121	0.48	48	4.49	129	2.38	92	2.06	80
GRANADA	3.45	93	3.40	108	0.90	13	2.77	117	1.48	42	0.80	75
C.REAL	2.95	101	3.73	105	0.81	-60	2.66	108	0.45	54	1.08	97
TOLEDO	3.35	93	3.96	103	0.88	-35	2.76	110	1.07	44	1.27	87
ARCAS	3.49	95	3.45	97	0.13	24	2.44	105	1.17	73	1.09	71
MADRID	4.00	99	4.05	100	0.09	-25	2.82	107	1.28	80	1.30	85
VALLE	4.44	97	4.31	101	0.33	32	2.99	108	1.60	76	1.39	86
S.ILDEFONSO	4.08	98	4.35	100	0.25	-39	3.10	106	1.10	75	1.31	86
CARBONERO	4.35	95	4.57	100	0.45	-31	3.19	106	1.36	68	1.44	87
SEPULVEDA	3.58	84	4.52	98	1.36	-42	3.17	104	1.25	23	1.41	84
CUBILLOS	5.53	99	5.39	103	0.41	31	3.80	108	2.04	69	1.64	91
BURGOS	5.44	83	5.51	96	1.24	-3	4.02	100	1.98	47	1.52	85
SANTIAGO	9.18	100	9.10	108	1.28	17	6.61	113	3.09	72	2.58	95
SANTANDER	10.07	86	8.70	94	1.89	46	6.92	95	3.45	66	1.78	90
PORTO*	5.10	110	7.57	114	2.51	-57	5.00	118	0.71	32	2.60	106

(B, β) OBSERVED

(L_s, λ_s) CALCULATED SCHWIDERSKI MAP M_2

(L_I, λ_I) CALCULATED IBERIAN MAP

$$(x_s, x_s) = (B, \beta) - (L_s, \lambda_s)$$

$$(x_I, x_I) = (B, \beta) - (L_I, \lambda_I)$$

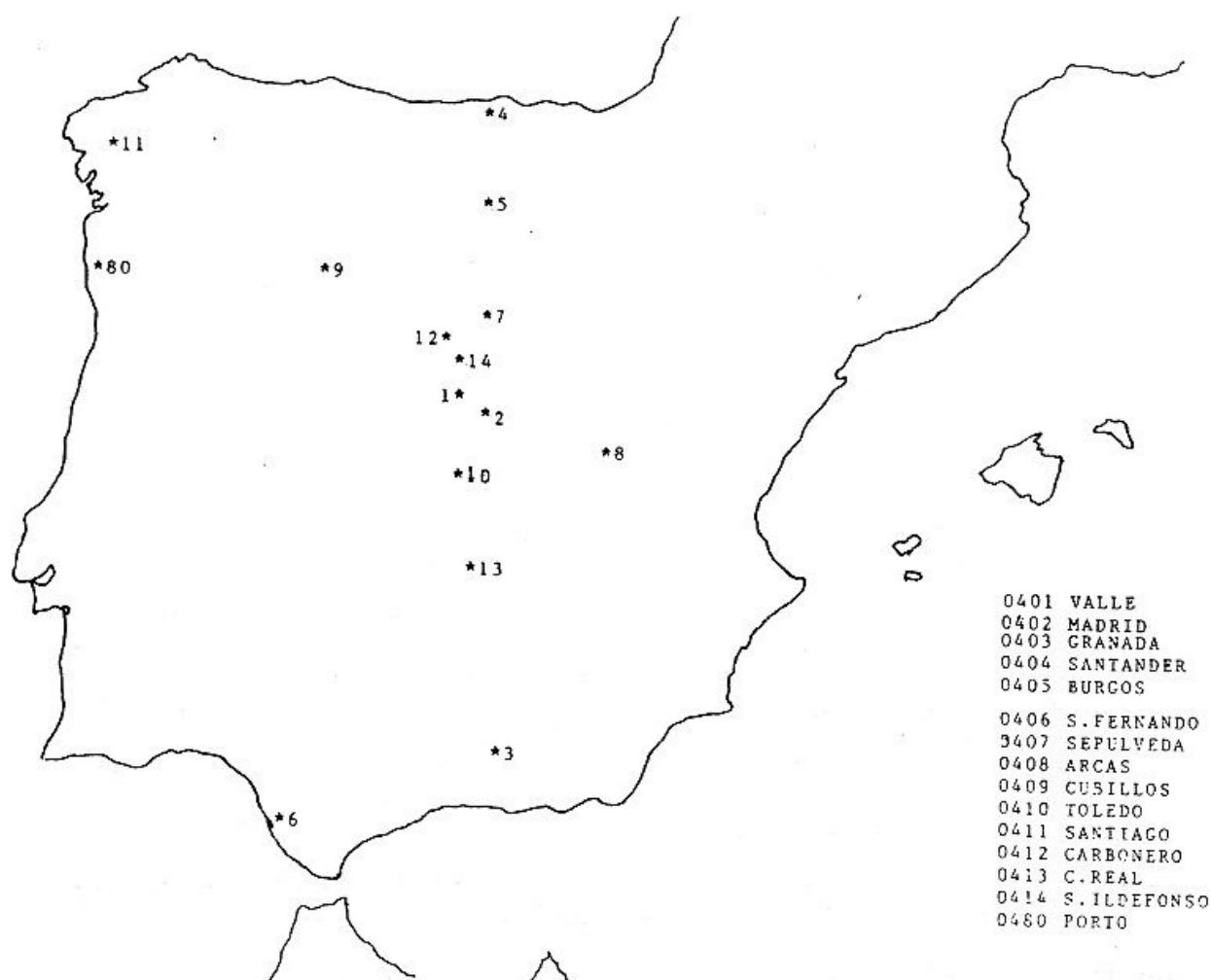


Figure 1. Stations

ACKNOWLEDGEMENTS

We want to express our gratitude to the International Centre for Earth Tides for its collaboration. Calculation programs given by the ICET have been used.

This research is being conducted at the Department of Mechanics and Astronomy of the C.S.I.C. and the Department of Astronomy and Geodesy of Complutense University, with support of both Centers and with subvention given for this purpose by the Assesory Commission of Scientific and Technical Investigation of the Presidency of the Government.

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Transforming an Askania GS-15 Gravimeter into a Zero Gravimeter

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with 1 table

Orejana, M. & Vieira, R., 1983: Transforming an Askania GS-15 Gravimeter into a Zero Gravimeter. Proceedings of the Ninth International Symposium on Earth Tides, pp. 311-313.

Abstract: One problem in recording the vertical component of earth tides with conventional gravimeters is that conventional gravimeters are a nulled instrument and built for relative gravity measurements. When recording variations of g , systematic perturbations occur in the mechanical parts of the instrument. Consequently, problems of hysteresis appear in the spring which originate variations in the sensitivity of the instrument.

We present a modification of an Askania GS-15 gravimeter, into a zero instrument, without any interference in the fundamental parts of the gravimeter. The modified gravimeter has been working for more than a year, and obtaining good results.

Keywords: instrumentation, gravimeter, Askania.

1. Principles of the transformation

The system uses the calibration coil of the gravimeter to offset the modifications in the geometry of the instrument due to the relative variations of g . An invariable system from a mechanical point of view is obtained.

The electronics consist of a proportional servo-mechanism with a second order filter, to minimize the spurious energy in the coil causing free oscillations. The servo works positively or negatively to reduce the energy to a fourth of that supplied with the servo.

1.1 Results with modifications

The detector remains fixed with the servo reference as a null point, independent of possible variations in the gain. The springs remain in the same position. The relative positions between coil and mass are also stationary, so that the force from the coil on the mass is proportional to the intensity of the circulating current.

Given that the temperature in the interior is constant, the resistance of the coil will also be constant, and then the compensating force applied to equilibrate the system depends only on

the potential difference applied to the coil.

We have thus achieved mechanically and electrically stable system, which permits a continuous calibration based on the constants given by the manufacturer of the instrument, and which takes into account that the electronic output is the same as that of the signal applied to the calibration coil to compensate for the variation of g . The function, which relates the variation of g with the electronic output, must be constant.

Possible failures of this modification can be the mechanical perturbation due to the thermal variations in the system. Studies presently being done indicate that if the variations in the intensity are always smaller than $\pm 300 \mu A$ the absorption of energy by the mechanical system does not affect the results.

2. Results

Table 1 gives results for the same gravimeter in the same station in a series with the original Askania instrument and in one with the modified Askania (zero gravimeter).

The sensitivity of the gravimeter has only varied at a rate of $\pm 0.5\%$ since January 1980 when it was modified. As the results show the diurnal component $P_1 S_1 K_1$ and semidiurnal component $S_2 K_2$ have anomalous values in amplitude and phase, it is probably not due to the transformation, as the same problem is present in the results before the modification. In September 1982, the gravimeter will be placed inside a hermetic container, probably in another station with better controlled thermal conditions.

Table 1. Station 0401 Valle, vertical component

	(O_1)	(O_1)	$(P_1 S_1 K_1)$	$(P_1 S_1 K_1)$	(N_2)	(N_2)	(M_2)	(M_2)	$(S_2 K_2)$	$(S_2 K_2)$
ASK. GS 15	1.1551	0.83	1.0982	0.36	1.1164	6.27	1.1574	5.17	1.1895	4.22
76-8-8/76-11-17	0.0099	0.49	0.0074	0.39	0.0161	0.82	0.0031	0.15	0.0058	0.28
ASK. GS 15	1.1625	-0.85	1.1311	3.26	1.1315	5.86	1.1557	5.11	1.1717	2.48
78-10-7/79-4-13	0.0116	0.57	0.0073	0.37	0.0128	0.64	0.0023	0.11	0.0046	0.23
ASK. GS 15*	1.1519	-0.23	1.1178	1.17	1.1254	5.11	1.1528	5.01	1.1569	3.38
80-5-1/81-4-26	0.0049	0.24	0.0031	0.16	0.0082	0.41	0.0016	0.08	0.0033	0.16

* Askania transformed

ACKNOWLEDGEMENTS

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Development of an Electronic Pendulum for Microinclination Recordings

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with 2 figures and 1 table.

Orejana, M., Vieira, R., & Toro, C., 1983: Development of an Electronic Pendulum for Microinclination Recordings, Proceedings of the Ninth International Symposium on Earth Tides, pp. 315-318.

Abstract: Technical problems in recording small variations in the vertical direction caused by earth tides make necessary a revision of the methods used up to now. Fundamental modifications in the horizontal pendulums with Zöllner suspension have made possible the construction of a new electronic clinometer that has been in operation since 1978 at our "Valle de los Caídos" stations. A description of the system is presented as well as an evaluation of the results. The capacitive system introduced in this new pendulum can be the base for new experiences in vertical pendulums and extensometers for studies of earth tides and of geodynamics.

Keywords: instrumentation, capacitive transducer, tilt.

1. Description

The main features of the new clinometer are a Zöllner suspension with quartz wires like the classic VM pendulums except that the shape of the tetrahedron support has been changed slightly to allow more free space for the electronic installation (see Figure 1). The mass of the pendulum has been replaced by a plane of the same weight as the VM.

Figure 1 shows the arrangement of the capacitive system so that the forces introduced by the mechanical system are central ones. This allows the use of long periods without the disadvantage of the beam adhering to any ends.

The amplifier-detector system has been designed so that there are no variations of the output of the transducer when there are variations of voltage. Its stability depends only on the power voltage which is highly stable. The power supplies to the detector system are square and not sinusoidal, to allow the use of CMOS technology for the digital part of FET amplifiers for the analog part. Therefore, low power consumption and high stability have been obtained (see Figure 2).

A mechanical system has been developed that is operated by a servo-mechanism with remote control that allows the blocking, un-

Fig. 1.
Modified configuration

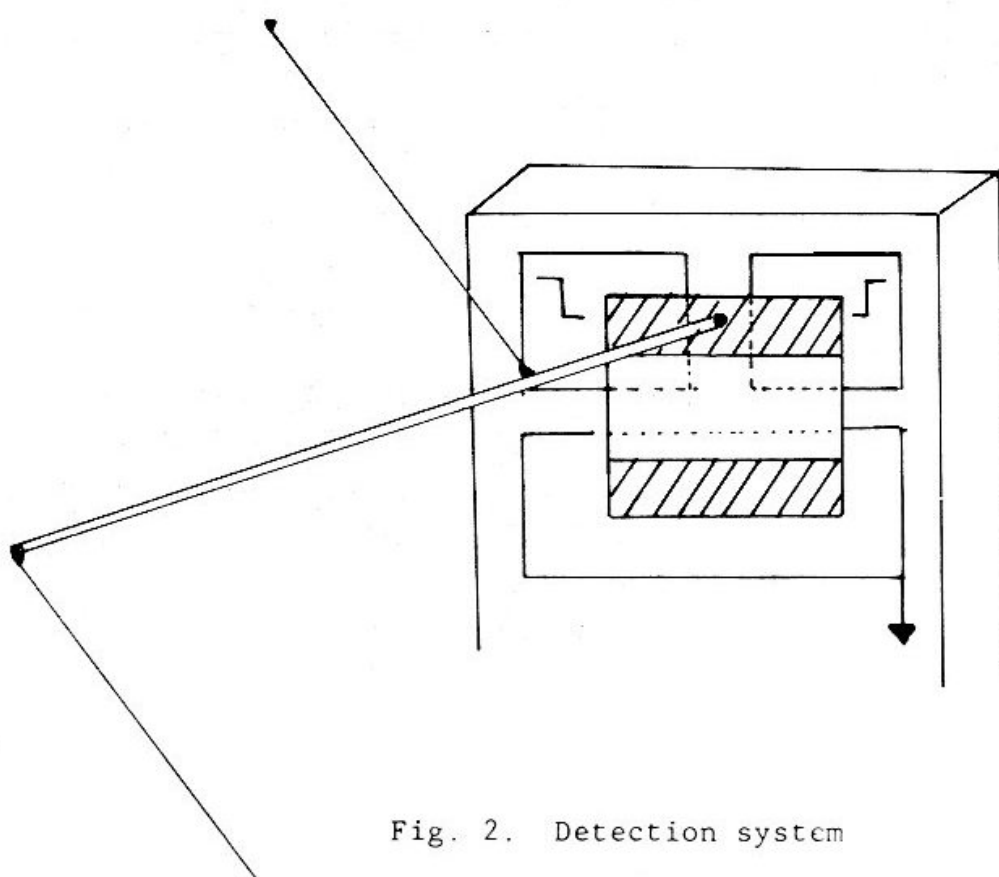
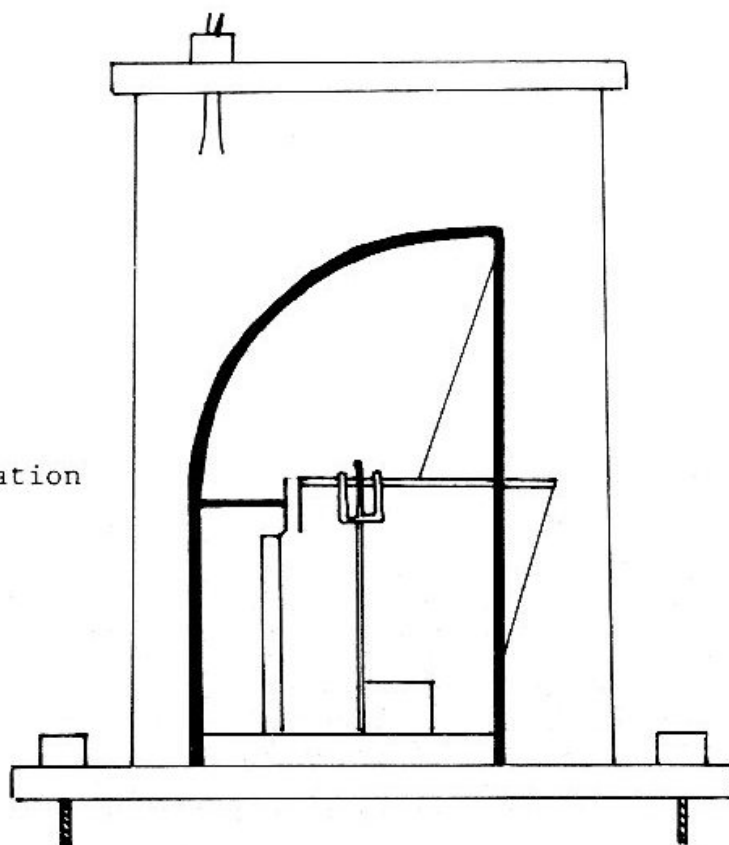


Fig. 2. Detection system

blocking and leveling of the pendulum without any manual operation.

The entire assembly is mounted inside a stainless steel cylinder. The cylinder can be scaled and is fixed to the leveling platform so that it can rotate on the footing. Figure 1 shows that any change in the azimuth can easily be detected.

The calibration system being used is the expandable crapaudine VM.

- 1) The new electrical pendulum has a good signal-to-noise ratio and the possibility of treating the data automatically;
- 2) its detector does not introduce lateral forces, allowing mechanical amplifications that enhance the signal-to-noise ratio;
- 3) The electronics have low consumption and stability;
- 4) A blocking and automatic leveling system have allowed us to install the clinometer in small or difficult access places;
- 5) a pressure screw allows us to seal the system;
- 6) the orientation can be varied rotating the cylinder platform.

2. Results

Our prototype pendulum was installed at "Valle de los Caídos" station in July 1978. Since then, different series of data were obtained concerning the stability of the system as well as possible modifications of the instrument.

Table 1 shows that results of the analyses correspond to different stages of the experiments. Results in 1976 and 1977 from the same station using a VM pendulum with photographic record are also included. The instruments were calibrated by using the same crapaudine.

In 1980 two new electronic pendulums were set up on the Geodynamic Laboratory in Walferdange, Luxemburg, but due to technical problems they did not work correctly until July, 1981.

ACKNOWLEDGEMENTS

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Table 1

STATIONS: 0401 VALLE

COMPONENT: E-W

PENDULUM VM 121	Nº 975	22 - 7 - 74	22 - 3 - 77
	$\delta(O_1)$	$\alpha(O_1)$	$\delta(M_2)$ $\alpha(M_2)$
	0.6942	1.18	1.1196 10.11
	0.0203	1.67	0.0039 0.20
ELECTRONIC PENDULUM U.M.1	Nº 180	27 - 3 - 79	29 - 9 - 79
	$\delta(O_1)$	$\alpha(O_1)$	$\delta(M_2)$ $\alpha(M_2)$
	0.6811	-0.29	1.1079 10.07
	0.0400	2.02	0.0054 0.28
ELECTRONIC PENDULUM U.M.1	Nº160	21 - 1 - 80	28 - 7 - 80
	$\delta(O_1)$	$\alpha(O_1)$	$\delta(M_2)$ $\alpha(M_2)$
	0.6901	0.65	1.1120 10.07
	0.0135	1.02	0.0023 0.19

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Automatic Control Module of Tilts, Calibrations and Data Acquisition for LaCoste-Romberg Gravimeters, Models G and D.

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with 2 figures

Lambas, F., Vieira, R. & Gimenez, E., 1983: Automatic Control Module of Tilts, Calibration and Data Acquisition for LaCoste-Romberg Gravimeters, Models G and D. Proceedings of the Ninth International Symposium on Earth Tides, pp. 293-297.

Abstract: Among the set of instruments presently used for the continuous recording of the variations of g , the most frequently employed are LaCoste-Romberg models G and D. The characteristics of these models are well known. They are easy to handle, inexpensive, and give good results.

It is important that improvements in the design of these instruments keep pace with mathematical theory. This paper describes the apparent limitations of these gravimeters, focusing on improvements in the design of the module for automatic control, recordings of the inclinations, and calibrations that are being adapted for the G and D models of the LaCoste-Romberg gravimeter.

Keywords: instrumentation, LaCoste-Romberg, electronic level, calibration, automatic control.

1. Improvements in LaCoste-Romberg models G and D

The characteristics and limitations of these instruments are well known. This paper describes the limitations and suggests some solutions for improvement.

The major problems that we have found in using these instruments for recording the variations of g are: 1) These astatic gravimeters, used for the relative measurement of g , are built small and lightweight for easy operation, and consequently there is a certain instability in the positioning of the instruments which causes variations in sensitivity and in phases. Any change in leveling produces a change of gravity. It is necessary to operate the instrument at the minimum point of sensitivity to tilt. Improved results have been obtained by mounting the instrument on a heavier base (MELCHIOR, 1978). A continuous control of tilts is advised. 2) Methods of calibration generally used for these gravimeters are based on (a) calibration tables supplied by the manufacturer; (b) comparison at fundamental stations where a system of constants has been determined; (c) periodic control of sensitivity that is achieved by direct use of the micrometric screw and a comparison

of the micrometric measurement to the displacement of the pen on the recorder. This procedure must be automated to avoid errors introduced by the operator touching the instrument. 3) Results from stations which have not always been reliable indicated the necessity of selecting new stations. For this reason, we have carefully considered the effects of pressure and temperature variation when analyzing the different components and residuals.

2. Solutions adopted

An automatic control module has been developed to be used with LaCoste-Romberg gravimeter No. 434. This module consists of (a) a microprocessor to control the whole station recording; (b) two electronic levels with a continuous record to control the tilt of the instrument; (c) a programmable automatic system for calibration; (d) continuous control and record of pressure and temperatures; (e) cassette recording of all the parameters--time, gravity, tilt, pressure and temperature--and the parameters are recorded analogly; (f) the possibility of all types of autocorrections in the position of the gravimeter; (g) stable power supply of the whole system.

3. Methods used for improvement

3.1 Tilt and drift control

A capacity system with a spirit level has been used to control the inclination (see Figure 1). With a level of 10 sec per 2 mm, an accuracy of 0.1 sec has been obtained with an excellent repeatability. Variations of temperature up to 3°C do not affect the measurements.

Two levels placed on the base of the gravimeter were previously calibrated in a comparator where the micrometric screw was replaced by an interferometrically calibrated Verbaandert-Melchior crapaudine. The linearity has been verified by changing the inclination 1 sec along the whole level.

Automatic correction of the drift produced by changes in the tilt can be introduced by means of two motors acting on the leveling screws of the instrument.

3.2 Automatic positioning of the system

The module has been constructed in such a way that once the instrument has been set up, it automatically takes the position of

least sensitivity to the tilt. This operation takes place in the microprocessor but will be realized only after the gravimeter has been installed at a new station.

3.3 Automatic calibration

A system for automatic calibration has been established that is similar to the one adopted for drift. The calibration can be programmed in time and space, for either a specific and continuous number of days or for better positioning of the mass. The demultiplication corresponds to a full revolution of the micrometric screw for 2000 steps of the motor.

3.4 Complements of the system

Two sensors, one for recording pressure and the other for recording temperature, have been introduced. The observed values are automatically recorded using the previously-fixed periodicity. Parameters are also recorded.

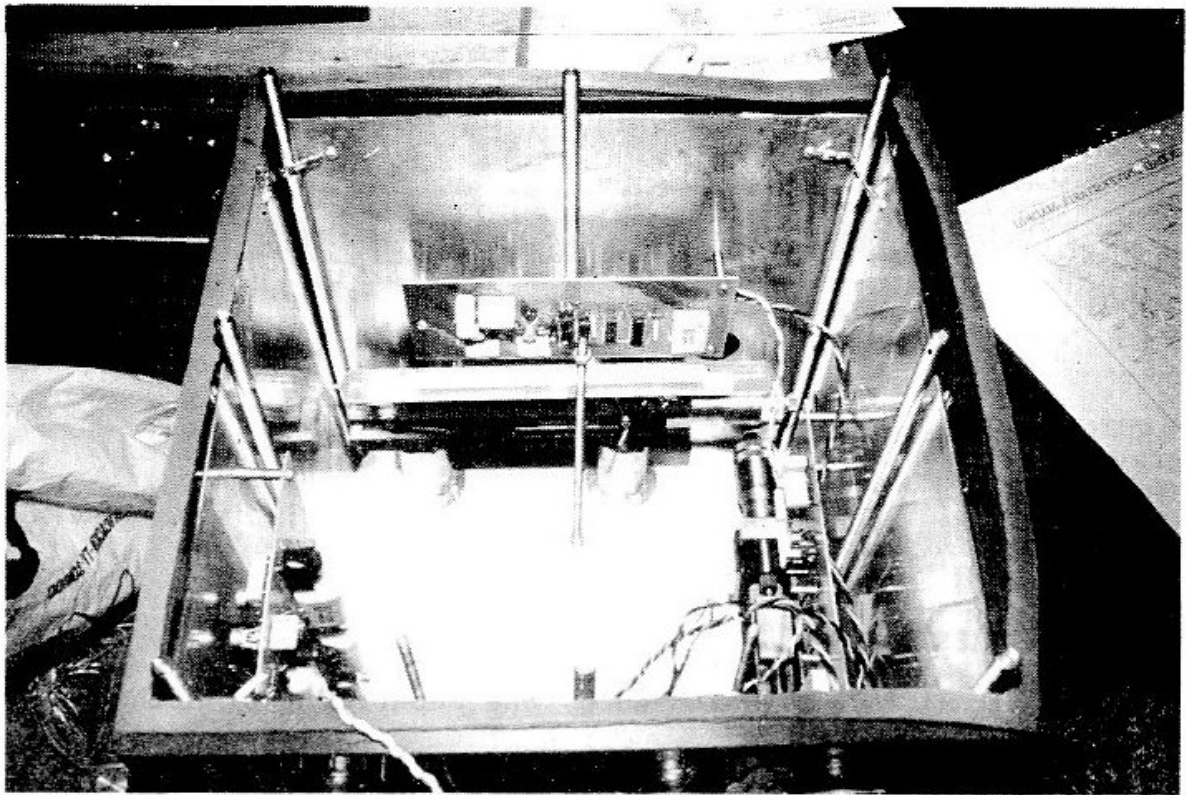


Figure 1. The capacitive system with a spirit level for controlling the inclination.

The microprocessor has two keyboards. One keyboard permits the system programs and the second keyboard introduces fixed programs. Figure 2 shows the displays for the time and output of the gravimeter.

We are now working on the selection of adequate numerical filters for the output of the gravimeter as well as considering the possibility of converting this instrument to a zero gravimeter.

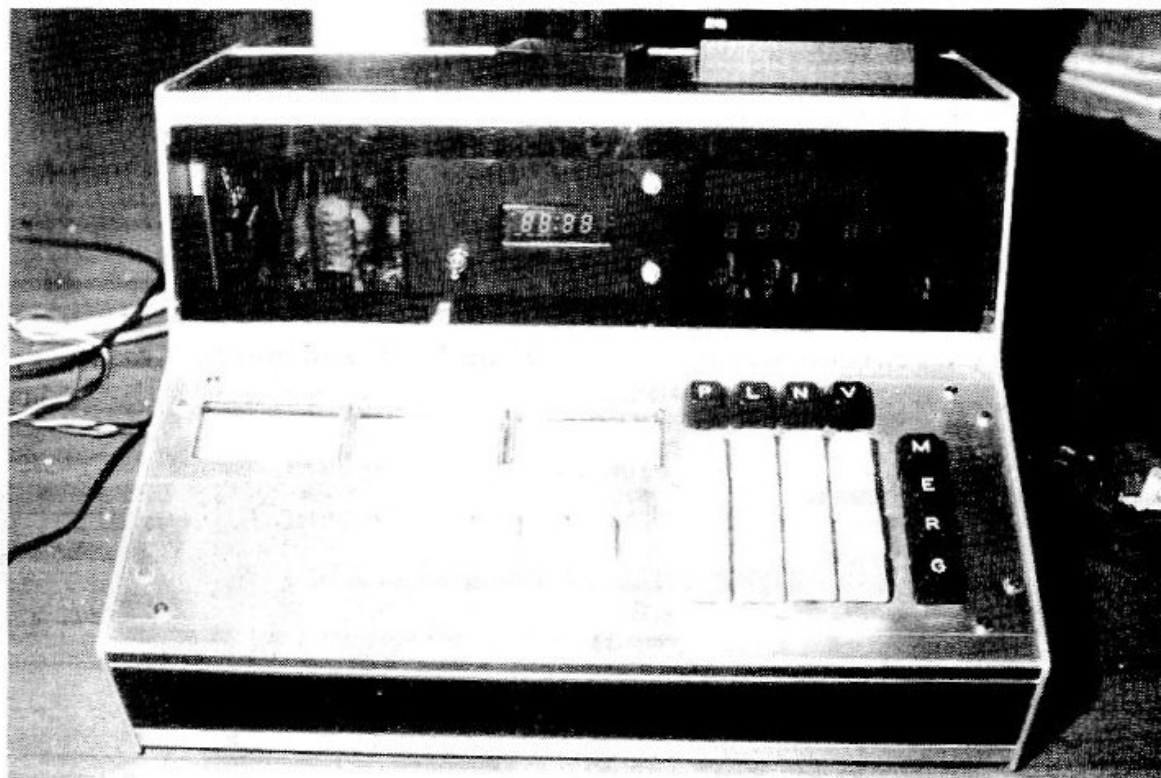


Figure 2. The displays for the time and output of LaCoste-Romberg gravimeters.

ACKNOWLEDGEMENTS

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DISCUSSION

Q: Did you check the effect of temperature variations on the automatic leveling system? (Ducarme)

A: Yes, we have studied the effect of temperature variations and they are not important for smaller variations of 3°C. (Vieira)

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