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# A PROPOSAL FOR A GEOPHYSICAL DETECTION METHOD OF THE GROUNDWATER SURFACE VARIATIONS CAUSED BY SEA WATER INTRUSION: FIRST EXPERIMENTAL RESULTS

*SUMMARY*

*In this paper are shown the first experimental results about the comparison between sea tide and gravity acceleration variation. The sea tide recording was carried out by «Ente per lo Sviluppo dell'Irrigazione e la Trasformazione Fondiaria in Puglia e Lucania» in the port of Bari. The gravity variation was recorded for six days using a gravity meter La Coste & Romberg model D connected to a paper recorder, located in the Palazzo Ateneo basement about 700 m far from the sea. The paper recording was calibrated with many instrumental direct readings; they were corrected for diurnal variation to detect possible gravimetric effects of groundwater surface variations. The preliminary results encourage us to carry on these studies in different geological situations and at different distances from the sea. This research should allow a better understanding of the sea water intrusion influence on watertable; this is an important target in order to solve some hydrogeological engineering problems.*

## 1. INTRODUCTION

The purpose of this paper is to examine the gravimetric method possibilities to give some information about watertable fluctuations produced by sea water intrusion in Apulian Creataceous limestone. This kind of investigation

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could contribute to solve some hydrogeological problems regarding groundwater level oscillation. They were widely studied by several authors by means of observation wells, artificial tracers and so on [2, 5, 6, 9, 12, 14]; mathematical models were used to interpret the obtained data [6, 9].

We are trying to detect the gravimetric effect of the watertable fluctuations by measuring the time variation of gravity acceleration in a fixed recording station. This station was settled at Bari in the Palazzo Ateneo basement, about 700 m far from the sea; its coordinates are: Lat. 41° 07.20' N= Long. 16° 52.03' E; altitude 2.5 m m.s.l..

Some informations about geological and hydrogeological features of this area can be found in specific papers concerning the built-up area of Bari [3, 4, 7, 13, 16].

## 2. PRELIMINARY EVALUATIONS

The presence of a water-bearing stratum has been proved in the underground of Bari. Some studies [5, 6, 8, 9, 12] pointed out the existence of a relationship between sea level oscillation and watertable variation.

From a gravimetric viewpoint this fluctuation is the same as an oscillating variation of density in a layer located between the higher and the lower level of groundwater. If this layer is shallow and thin in comparison with its horizontal size, the gravimetric effect doesn't depend on the depth and approches the effect of an infinite plate, i.e.

$$g_z = 2\pi G \rho h \qquad (1)$$

where G is the gravitational constant, $\rho$ and h are respectively the density and thickness of the layer.

The density variation caused by water table fluctuations is equal to the effective porosity multiplied by water density. If we assume a value of 30 cm for h and a rock porosity of 20%, from (1) the amplitude of $g_z$ variation results to be about 3 μgal.

## 3. RECORDINGS AND DATA PROCESSING

The gravity meter La Coste & Romberg model D 40 has an high sensitivity (about 1 μgal). In field surveys the measure precision is rather inferior than 1 μgal, however the results of some studies [10, 15] suggest the possibility to approach such a precision in laboratory measures.

In order to achieve this target, the instrumental readings were carried out without clamping every half for 12-13 hours a day from the 14th to the 20th of April 1983; a digital millivolmeter connected to the electronic readout was used to zero the gravity meter index.

The instrument was also connected to a paper recorder whose advancing rate was regulated on 12 cm/h; it was calibrated by comparing the direct reading values with the ones interpolated on the paper record. The relationship resulted clearly linear with a square correlation coefficient of 99.8% (Fig. 1).

The paper recording was sampled with a 10 minutes step for two periods: the first one started at 2 o'clock p.m. April 14th and ended at 8 o'clock a.m. of April 17th; the second one started at 8 o'clock a.m. of April 18th and ended at 9 o'clock a.m. of April 20th.

The sampled values were converted in μgal and plotted in fig. 2a. The largest part of the gravity variations is due to the lunar and solar gravitational attraction called «diurnal variation»; a computing program was used to obtain a theoretical plotting of this variation; in Fig. 2 it was compared with experimental recordings and with differences δ between the two data series.

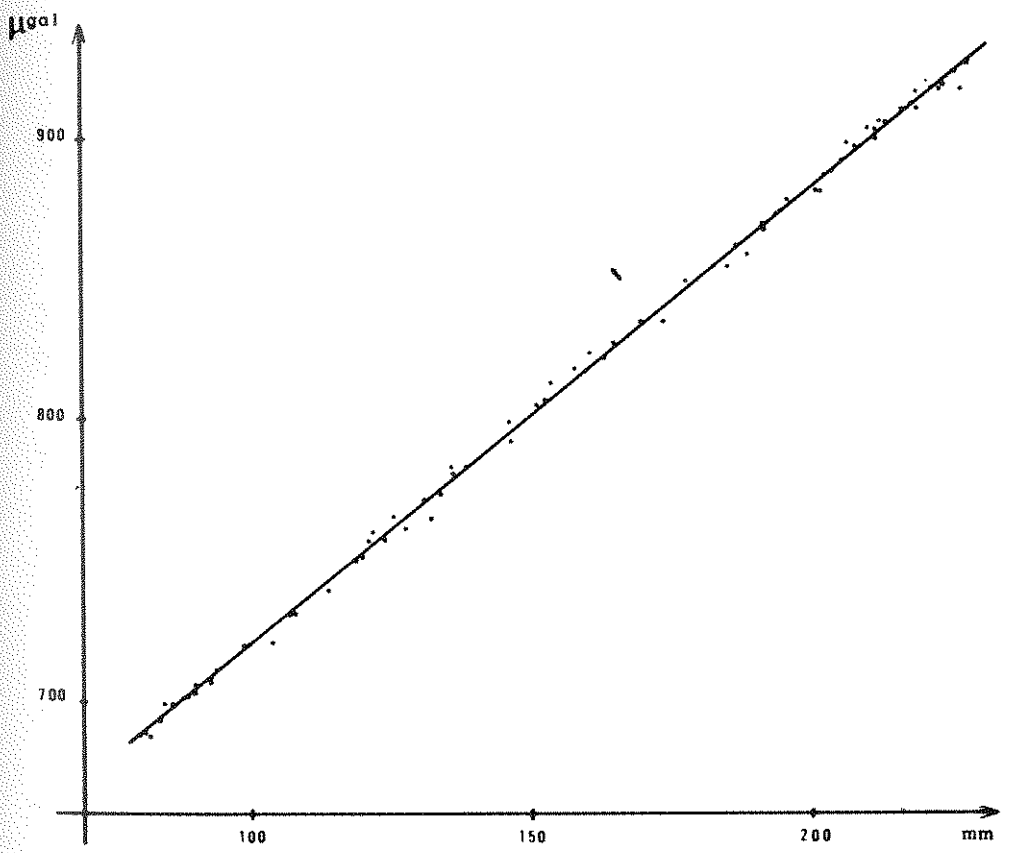


Fig. 1 – Relationship between paper records (in mm) and direct reading values (in μgal) of gravity variation measured by the LCR D 40.

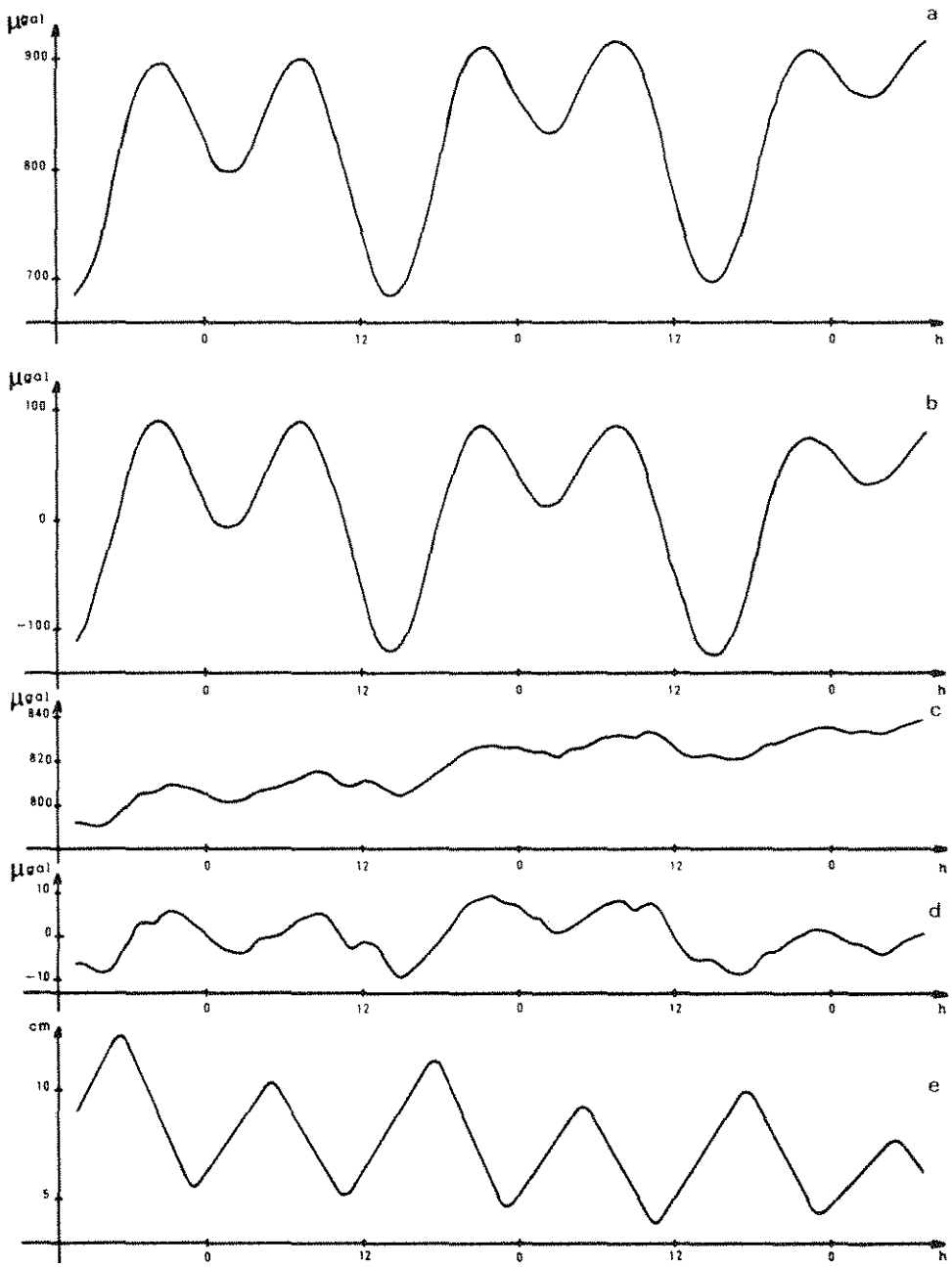


Fig. 2 – Comparison, concerning the first examined period (April 14th - 17th), among
a - recorded gravity variation;
b - theoretical gravity variation for the gravimetric tide;
c - δ values (differences between a- and b-);
d - δ values after the linear trend removal;
e - sea tide level measured in the port of Bari (in cm; arbitrary altimetric reference).

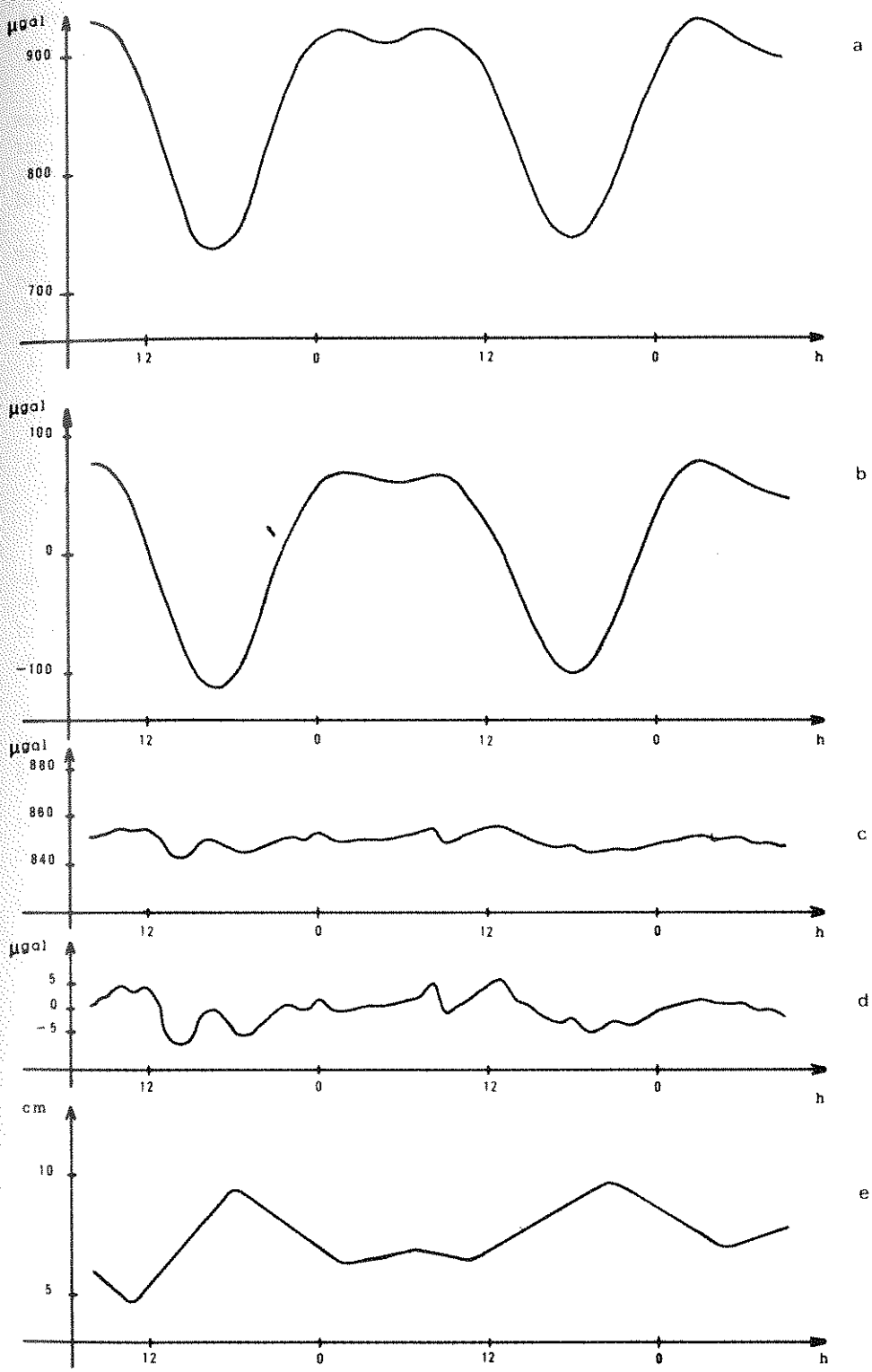


Fig. 3 – Comparison, concerning the second examined period (April 18th - 20th), among a-, b-, c-, d-, e-, as above.

For the first examined period it can be noticed a clear trend in δ values caused by instrumental drift. Preceding studies [1] pointed out the gravimeter LCR D 40 has a not linear trend over long time interval and this actually agrees with the change of the trend slope in the second examined period (Fig. 3). The result of trend removing is represented in Figs. 2d-3d.

It is interesting to compare gravity variations and sea tide recorded by the «Ente per lo Sviluppo dell'Irrigazione e la Trasformazione Fondiaria in Puglia e Lucania»: there is an evident phase-shift of about 3 hours and a half between a relative minimum of gravity and the following high tide; a similar delay is between the latter and a relative maximum of δ value.

## 4. PRELIMINARY INTERPRETATION AND FUTURE PERSPECTIVES

It can be noticed the amplitude of δ oscillation decreases with the amplitude of gravimetric and sea tide. However δ values are quite great in comparison with the expected groundwater effects, probably for superimposition of different gravimetric effects with different period such as pression influence, meteoric water intrusion and so on.

It should be possible to remove most of these effects with a spectral analysis (11) directed to determine in details the amplitude of periods around the main tide ones (about 12 and 24 hours): there should be a peak corresponding to the groundwater effect.

In order to confirm its indentification it should be useful to compare this analysis results with the ones concerning other recondings in different geological and hydrogeological situations and at different distances from the sea. The amplitude of tidal periods of δ values should change in a recognizable way if it was controlled by groundwater effects.

Notwithstanding some problems to be solved, the identification and evaluation of groundwater gravimetric effect is a quite attractive target; it should allow to calculate the product $\rho^h$ by means of equation (1) and to determine the rock gross porosity or the amplitude of tidal watertable fluctuation if one of these parameters is known.

## 5. CONCLUSION

We intend to carry on this attempt to detect the gravimentric effect of watertable oscillation caused by tidal sea water intrusion. This target is theoretically attainable and should allow to obtain some interesting hydrogeological informations.

The reliability of this method could be confirmed with forthcoming appolications in different geological situations and possibly even near observation wells.

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