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SEISMOGENETIC MODELS BASED ON KELVIN-MAXWELL VISCOSITIES

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SUMMARY

Large-scale geophysical-geodynamical models using deep rock visco-elasticities better represent evolutions of certain long-duration seismic crises than classical models do, when based only on rock elasticity. Actually, the introductions of time-constants dependent by suitable viscosities, enable one to suggest L-Transform specific models for certain deep Apennine geo-structures at sub-regional scales. These models theoretically describe stress asymptotical evolutions which show or monotonously increasing or one-minimum trend versus time, the latter also lasting for some months, at least in particular cases. Following to the discussion suggested by Flügge 1967, who considers a rigid cylinder filled up by a visco-elastic medium at hydrostatic pressure, a seismo-genetic model is now proposed, related to geodynamical situation described above. This specific Flügge's model adopted two typical materials, showing a) elastic-dilatation and Maxwell-distortion, or b) Kelvin-dilatation and Maxwell-distortion, respectively; this is a first visco-elastic approach, which could be extended to other model material. When the Elastic-Dilatation/Maxwell-Distortion Model is adopted, this visco-elastic model accounts for monotonous increasing of hydrostatic pressures versus time t, firstly showing a sudden pressure step lesser than p, followed by an exponential asymptotic increase of hydrostatic pressure tending to p value. As the theoretical cylinder is actually made by real rocks, it is conceivable that these rocks could locally collapse also at pressure values lesser than p°; as a consequence, energy can be released at a number of energy levels as far as the macroseismic phenomenon follows its own evolutions. When the Kelvin-Dilatation/Maxwell-Distortion Model is adopted, this visco-elastic model accounts for a characteristic theoretical trend of hydrostatic pressures versus time t, firstly showing a sudden pressure step as high as p, then p° values go down toward a minimum, experiencing an inflexion point, and then increase, finally following an asymptotic behaviour of hydrostatic pressure, tending to the same p value: this trend in not in contrast with selected groups of seismological evidences, also supporting possible deep geo-structural models. As the theoretical cylinder is actually made by real rocks, it is conceivable that these rocks could locally collapse also at pressure values lesser than p°; as a consequence, energy could be released at a number of energy levels as far as the macroseismic phenomenon follows its own evolutions. According to these hypotheses, long earthquakes in Umbria-Marche areas (Central Italy) are considered consequences of regional/sub-regional situations characterising Adriatic Foredeep, in the frame of a broader geophysical-geodynamical picture for the Central Mediterranean Sea

INTRODUCTION

A very simple, one-dimensional visco-elastic model was proposed, see also for the following Finzi-Contini 1977, to represent some essential features of the Apennine Range, in the frame of geodynamical evidences related to its shape. The aim of this research was to verify that also extremely small mechanical actions are able to induce consistent deformations in geo-structures when visco-elasticity is considered. Actually, geo-structures stressed in the elastic domain reach a certain equilibrium configuration and do not experience further evolution. An improved version (Finzi-Contini 1982a,b) of that one-dimensional model introduced three sub-vertical, viscous solids, suggested by gravimetrical interpretation and coherent with geothermal evidences (Corrado & Rapolla

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1977, Scandone 1979, Panichi et al 1982, Mantovani & Boschi 1982), able to account for three systems of oval gravimetrical highs, locally perturbing the long gravimetrical through caused by the Adriatic Foredeep, running along the Eastern slope of the Apennine Range. According to this model, those viscous solids, supposed horizontally squeezed by African Plate actions, basically induce vertical deformations within visco-elastic slabs placed at their tops, see e.g. Finzi-Contini 1986.

3 - THE SUGGESTED SEISMO-GENETIC MODEL

A model suggested by Flügge (1967) considers a rigid cylinder filled up by a visco-elastic medium at hydrostatic pressure p, see Figs. 1, 2 and 3: this Flügge's model adopts two different materials, showing a) elastic behaviour in dilatation and the Maxwell law in distortion, or b) Kelvin dilatation and Maxwell distortion; this is a classical visco-elastic approach, which could be extended to other model material, Caputo 1985; Körnig & Müller 1989. A seismo-genetic model has been proposed (Finzi-Contini 1997, 1998) see the following considerations, related to the described geodynamical situation: 1) A gravimetrical interpretation of the local highs perturbing the long negative gravimetrical through, basically parallel to the Apennine Ridge along its Eastern slope, admits thin Apennine-parallel sub-vertical parallelepipeds, as long as some 80 kms, which are laterally squeezed by African Plate actions, Finzi-Contini 1982b; 2) Consequently, viscous materials are vertically pushed up, deforming slabs resting upon those oval boxes, according to shapes which can be represented by oval boxes filled up by the aforesaid viscous materials from below at hydrostatic pressure p. These oval boxes play the role of the theoretical rigid cylinder proposed by Flügge's model, and are approximated by a cylinder for simplicity, Finzi-Contini 1997; 3) During the filling phenomenon, which is assumed to follow the Flügge's model equations as for p(t), it is reasonable that local collapses arise at different energy levels in the walls of geo-structures, represented by the oval boxes), which are actually made by real materials; owing to these collapses, seismic energy travels away from these locally collapsed walls in the

surrounding rocks around; 4) According to the actual nature of the quoted box walls, collapses might occur at different energy levels, in particular, lesser than the ones corresponding to the theoretical p(t) values suggested by the Flügge's model. These p(t) values can be considered as estremal values, and can be assumed able to give useful pieces of information on a certain seismic series evolution. In fact, they correspond to the top possible values suggested by the p(t) Flügge's model, while lower energy values can be considered able to increase seismic noise, useless to propose reliable model forecasts; 5) According to this hypotheses, tentative extrapolations of the seismic series might be suggested as far as the phenomenon continues, as in particular it will be shown below for some selected situations; in this way, families of extremal curves are obtained, which propose successive forecasts according to the choices of a geo-structure model and a visco-elastic material.

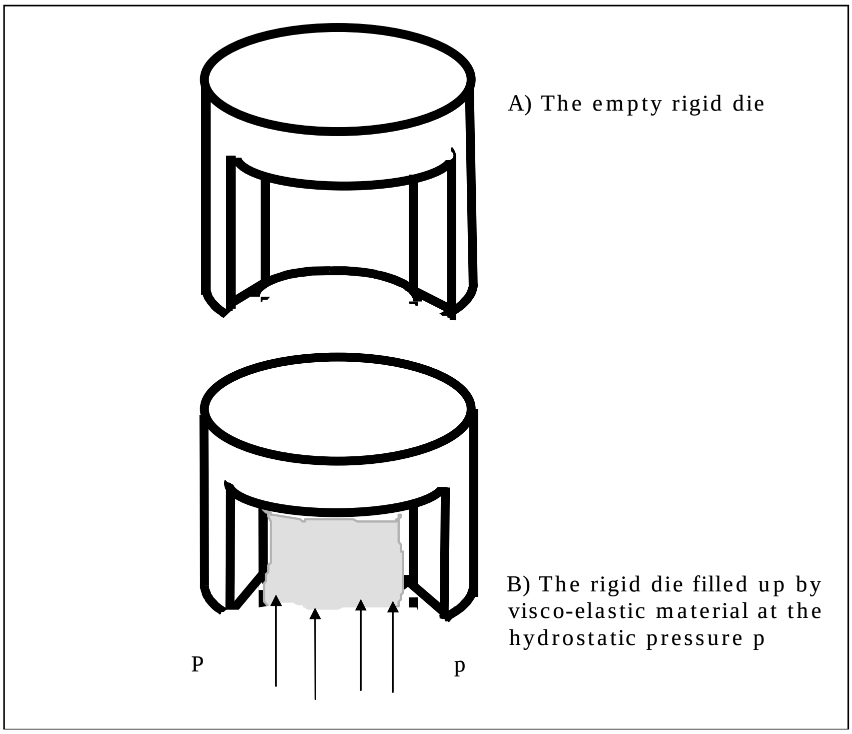
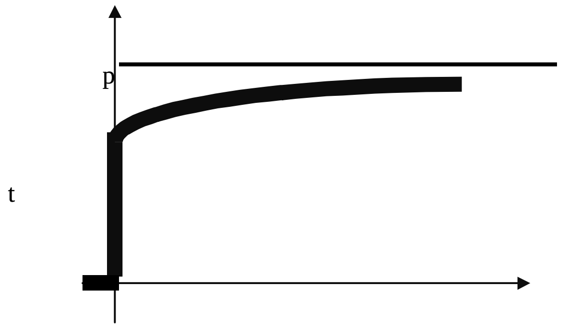


Figure 1 -The rigid die adopted by the Flügge' model



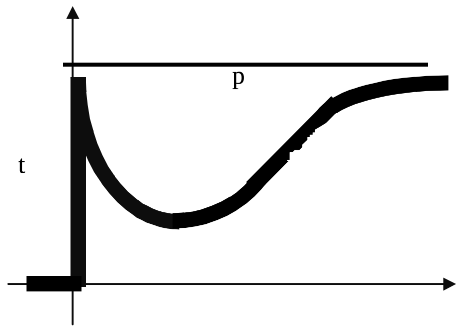


Fig. 2 - The Elastic-Dilatation and Maxwell-Distortion Model see eq.(b

Fig. 3 - The Kelvin-Dilatation and Maxwell-Distortion Model see eq.(b

3.1 - The Elastic-Dilatation/Maxwell-Distortion Model

Theoretically this visco-elastic rock model accounts for a monotonous increasing hydrostatic pressures versus time t, see Fig. 2, firstly showing a sudden pressure step lesser than p, followed by an exponential asymptotic increase of hydrostatic pressure tending to the p value. Some comments are needed to introduce an interpretation approach. As the theoretical cylinder is actually made by real rocks, it is conceivable that these rocks can locally collapse also at pressure values lesser than p°; as a consequence, energy can be released in a number of energy levels as far as the macroseismic phenomenon follows its own evolutions. On the other hand, a reliable interpretation curve should be concerned with the highest possible values of p° , in order to account for the p° values consistent with the theoretical model. To do so, again one might use extremal p° values to select the best-fitting curve: more exactly, such a curve should be controlled by the equation

$$\sigma_y = - p[1-3q'_1 \exp(-\lambda t)/(3Kp'_1 + 2q'_1)] \qquad (a).$$

3.2 - The Kelvin-Dilatation/Maxwell-Distortion Model

This visco-elastic rock model accounts for a characteristic theoretical trend of hydrostatic pressures versus time t, see Fig. 3, firstly showing a sudden pressure step as high as p, lower p° values down to a minimum, experiencing an inflexion point, finally followed by an asymptotic increase of hydrostatic pressure, again tending to the same p value. Some comments are needed to introduce an interpretation approach. As the theoretical cylinder is actually made by real rocks, it is conceivable that these rocks can locally collapse also at pressure values lesser than p°; as a consequence, energy can be released in a number of energy levels as far as the macroseismic phenomenon follows its own evolutions. On the other hand, a reliable interpretation curve should be concerned with the highest possible Maxwell-Distortion Model values of p°, in order to account for the p° values consistent with the theoretical model. To do so, again one might use extremal p° values to select the best-fitting curve of possible extremal values: more exactly, such a curve should be controlled by the equation

$$\sigma_y = - p[1-3q'_1 (\exp(-\lambda_2 t)-\exp(-\lambda_1 t))/p'_1 q''_1 (\lambda_1-\lambda_2)] \qquad (b).$$

and its actual trend will be determined by at least one of the possible extremal values given by pieces of seismic information. this trend in not in contrast with selected groups of seismological evidences, also supporting possible deep geo-structural models. As the theoretical cylinder is actually made by real rocks, it is conceivable that these rocks could locally collapse also at pressure values lesser than p°.

As a consequence, energy could be released at a number of energy levels as far as the macroseismic phenomenon follows its own evolutions. In addition to that, as this best-fitting procedure can be accomplished according to the phenomenon evolution, owing to the long actual time-constants, one is able to plot a family of best-fitting curves, by using the last meaningful seismic evidence as an extremal reliable value.

4 - FIELD EVIDENCES FROM ACTUAL EARTHQUAKES

On the basis of the previous considerations, a number of semi-quantitative comparisons between selected actual earthquakes have been made: one example is shown by Fig. 4 and Fig. 5.

An additional consideration, with reference to the earthquake of march 27th, having its hypocenter as deep as some 40÷50 kms, according to official press information - which is much higher than the other hypocentral depths during the previous six months of seismic activity in that area - suggests to use the same squeezing model at least for a first-approximation approach to a rough interpretation. Provided that the same rock parameters are assumed, the border conditions consider now a total layer thickness of some 30÷40 kms placed above the hypocentral volumes, which belong to a medium forced to collapse at that geophysical environment. In other words, the accumulation of the squeezing actions during such a long sequence brings to such a deformation amount at the hypocentral depth that seismic energy is released also there, even if for the shallow earthquakes (5÷15 kms) of the same time interval a certain bottom plane was assumed as a rigid border condition. Actually, according to recent field evidences, now that assumption has to be considered only a theoretical working hypothesis and the gravimetrical models for the thin viscous parallelepipeds have to be rearranged, at least for their bottom bases depths.

CONCLUSIONS

In this work it has been shown that the Rigid Die (cylinder) Flügge's Model gives possible interpretation trends also with regard to long and very-long seismological evidences, as occurred in Central Italy during 1997 and 1998. It should be emphasised that Kelvin-Dilatation/Maxwell-Distortion Model is controlled by such an equation, which considers a sudden increase of the stress ad the walls of that cylinder, followed by a decrease, a minimum stress point and then a trend characterised by an inflexion point, finally tending to the initial stress value. These features of the Flügge's Model are not in contrast with long earthquakes evidences recently experienced in Umbria-Marche, provided suitable time constant are deduced by using the relative equation, once one admits to represent local deep gravimetrical highs (sub-regional scale) by using rigid cylindrical models, where a visco-elastic material (Kelvin-Dilatation/Maxwell-Distortion Model), is forced to experience hydrostatic pressure.

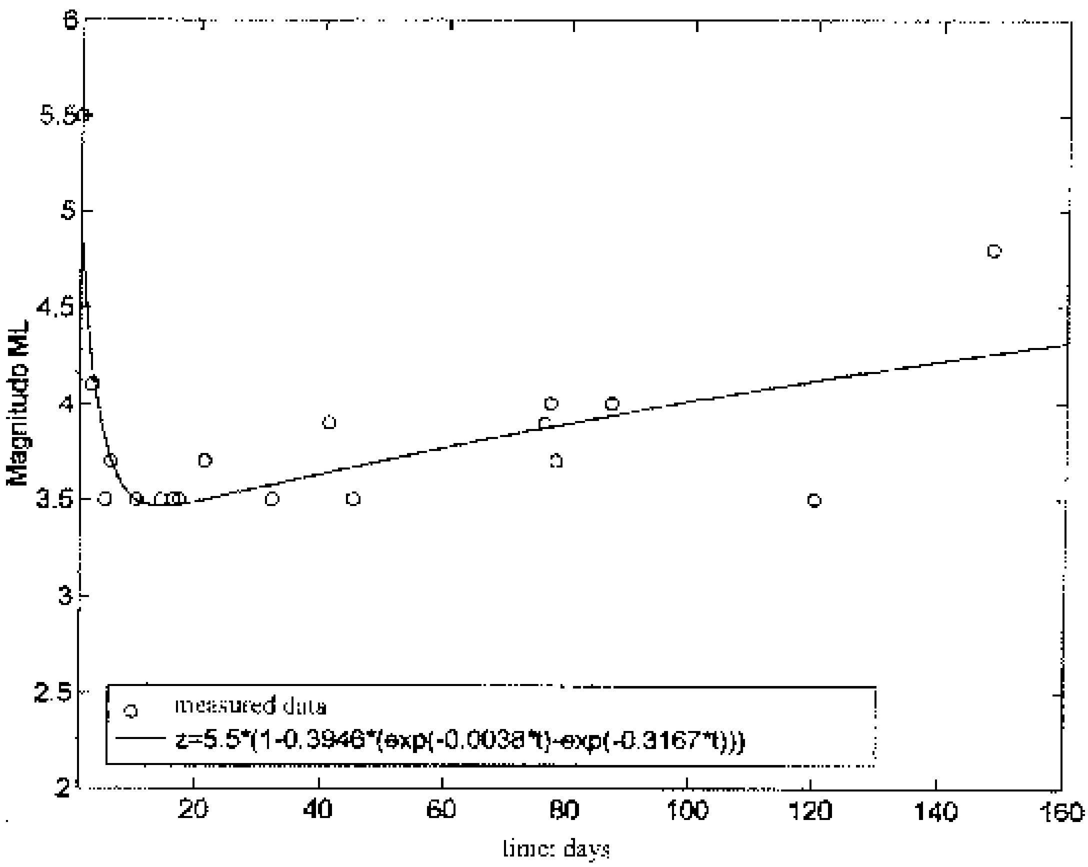


Fig. 4 – "19th sept. 1979 – 28th feb. 1980" – Seismic Sequence Valnerina's Epicentral Area

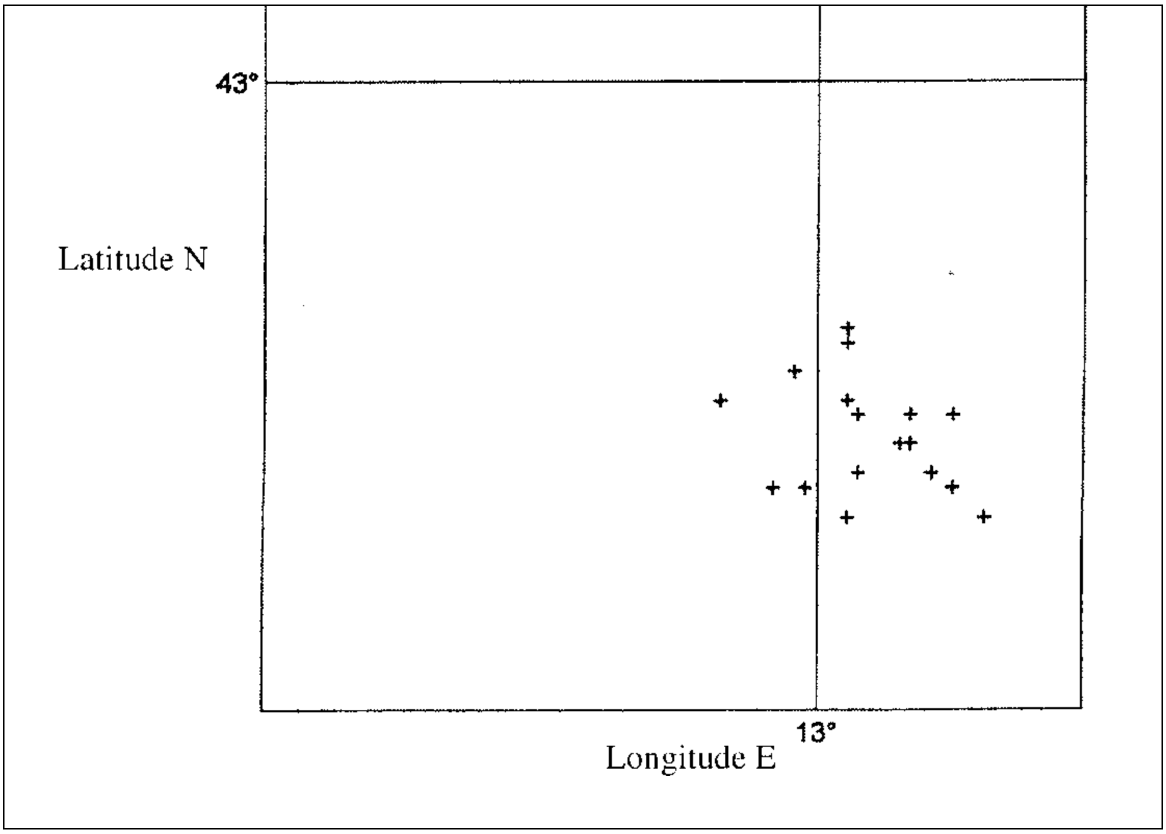


Fig. 5 – Epicenter spacial plot, see Fig. 4

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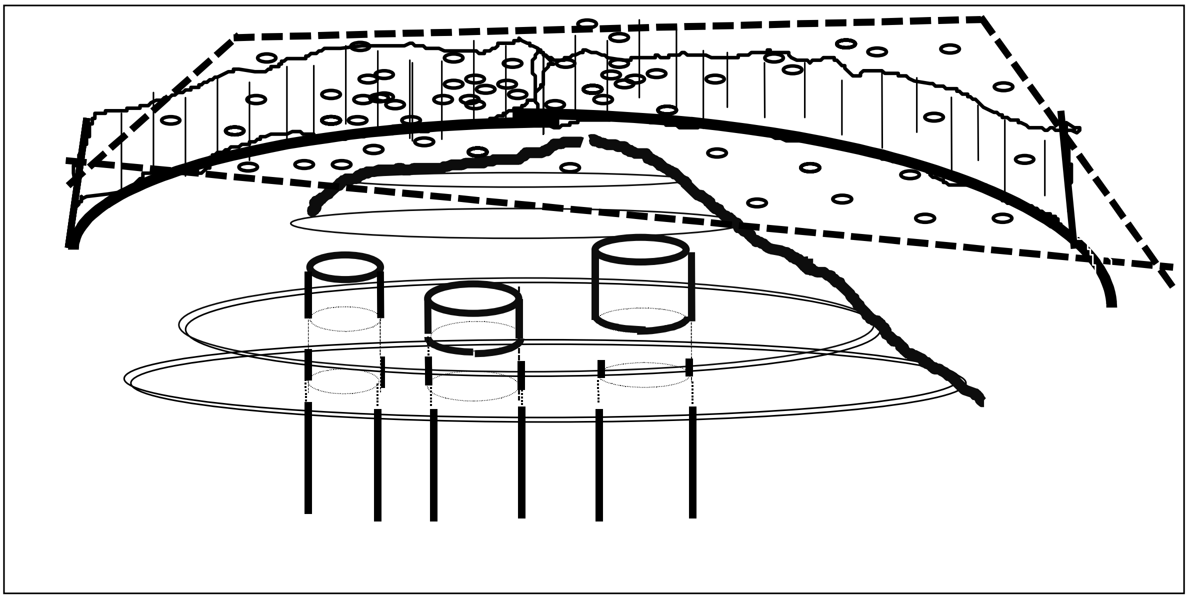

FIG. 6 - A very schematic representation of suggested seismo-genetic structures, from the bottom to the top:

a) three possible deep cylinders of visco-elastic materials according to Kelvin Dilatation/Maxwell Deformation; b) hill-shaped volume containing them inside rigid cavities, in order to account for the Flügge's Model; c) upper visco-elastic geo-structures, classically deformed by the actions from below; d) a portion of the topographic surface (contoured by the dotted quadrilateral); e) qualitative distributions of epicentres on that surface, denser above the tops of the bottom cylinders.