FOURTH INTERNATIONAL SYMPOSIUM

ANALYSIS OF SEISMICITY AND SEISMIC RISK

PROCEEDINGS

I

Czechoslovak Academy of Sciences
Geophysical Institute

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ANALYSIS OF SEISMICITY AND SEISMIC RISK

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One believes that it is Poseidon
who shakes the earth and that chasms
caused by earthquake are attributable
to him ...

Herodotos VII, 129
(translation by A. de Selincourt)

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Proceedings of the 4^{th} International Symposium
on the Analysis of Seismicity and Seismic Risk
Bechyně Castle,Czechoslovakia, September 4-9, 1989

Crustal activities monitoring program in the Albani Hills volcanic group (Rome,Central Italy)

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Abstract

A geodetic and seismic research program is starting in the Albani Hills volcanic area (Central Italy).

The goal is to monitor crustal deformation in this seismogenetic area not far from Rome and important for the seismic risk of this town and for the villages built on this area. Seismic events up to VIII Mercalli Intensity (MCS) often occurred with a recurrent seismic activity generally located at shallow depth in the volcanic structure.

The aim of our program is to monitor ground tilt variation by pendulum and bubble tiltmeters and horizontal displacements by Global Positioning System (GPS) tecnique on defined networks. Furthermore precise relative gravity measurements will be made in the next future.

In this poster the geological features of the Albani Hills (Rome), instrumentation and networks are shown.

Geological outline

During the Upper Pliocene the Tyrrhenian area was characterized by extensional tectonics that build up horst and graben along the Apenninic chain and important faults along the Tyrrhenian coast. This situation made possible a magma upstart and the development of some volcanoes along the Tyrrhenian margin (Funiciello and Parotto,1978).

The Albani Hills volcanic group extends over an area larger than 60 Km in diameter South - East of Rome and belongs to the perityrrhenian volcanic province. Its story is characterized by an alkali-potassic magma (Fornaseri et al.,1963) started about 530.000 years ago till about 30.000 years ago. The volcanic activity was characterized from the beginning by magmatic explosions and lava flows that moved westwards to the side of the central edifice with a series of explosives episodes and the development of some craters. The eruptions and the phreatomagmatic explosions were caused by the deep water circulation, followed by a collapse of the whole southwestern side of the volcanic structure (Civitelli et al.,1975).

Seismicity of the Albani Hills area

The Albani Hills area is interested by a recurrent seismic activity with earthquakes of low magnitude and shallow hypocenters. The characteristics of the seismic sequences and the geological and structural features let us recognize this area as an isolated seismogenetic structure (De Simoni et al.,1984; Amato et al.,1984). The oldest news about the seismicity of the Albani Hills area came from 900 b.C., but only after 1700 we can get more information. The seimic catalogue shows a great number of earthquakes between 1900 and 1970 (Baratta,1901; Galli,1906; Molin,1981), and the larger intensity was more than once up to VIII Mercalli Intensity (1752, 1806, 1892, 1899, 1927). The last two important seismic sequences occurred in 1981 and 1987. The 1981 seismic swarm was characterized by a large number of earthquakes with low magnitudes (Md max = 3.4) and shallow depth hypocenters. The 1987 seismic sequence came out with a series of small instrumental earthquakes followed by two larger earthquakes of Md = 3.8 and 3.9 at a depth of about 20 Km. The highest intensity has been valued as a VI degree MCS and was felt even in Rome. The isoseismals show a weak exstension to N34W and N10E directions, according to the main tectonic structures of the area.

Networks

Because of the complexity of the deformation field that characterizes this seismic area and for the purpose of earthquake prediction, we need continuous measurements of crustal movements supplied by tiltmeters with high resolutions (microrad, nanorad), and by the repetition of geodetic surveys. However tiltmeters (strainmeters and extensometers as well), can't detect the tectonic movements in a wide area because of their short base and instability caused by instrumental drifts. Measurements of baselines of few kilometers lenght is much more effective to detect tectonic movements and strain accumulation and they can be measured with a precision of $10^{-6}\frac{\Delta l}{l}$ by GPS techniques. GPS method makes possible to observe a baseline network every day and in the next future every hour.

The national seismic network and the local seismic network (A.Amato et al.), supply the epicenter determination for a precise location of the earthquakes. This is very important for the definition of the seismogenetic structures and to understand the evolution of the seismic sequences and for a better interpretation of the tiltmeter signal.

GPS background

The Global Positioning System (GPS), uses radio sources of satellites of the Department of Defense of the United States of America that are recorded on the Earth surface by GPS receivers. It was developed to supply point positioning in all weather conditions and on all over the world for military purpose and now also for civil use. Over the last years the GPS was successfully employed in precision geodesy. The GPS geodetic survey can furnish the horizontal and vertical postion within a few centimeters even at large station separations (hundred kilometers), and for not intervisible stations. Position and lenght of the points are determined by a combined three dimensional equations. A GPS network can be used to outline the broad scale deformation patterns in seismically active regions. Besides GPS method is more feasible and less expensive than the conventional tecniques. In fact the points to be measured are chosen where they are required and do not need to be placed on mountain tops to ensure visual communication. Geodetic observations provide a direct measure of strain changes occurring at seismogenetic depths and can play an important role in determining the degree to wich large earthquakes are predictable.

The definitive satellite configuration will be of 18 active satellites at six different orbits at 60 degree intervals about the equator, each with three satellites. The orbital plane is at an angle of 55 degrees relative to the equator at a lenght of about 20.000 kilometers above the Earth with an orbit time of 11h 58min. The full constellation is expected to be developed by 1991. The satellites transit continuosly on two carrier frequencies: the L_1 (1575.42 Mhz, with a band of 19 cm), and the L_2 (1227.60 Mhz, with a band of 24 cm).

At the moment the our Wild-Magnavox WM-101 receivers operate only on the L_2 frequency, but during 1990 will be installed the L_2 frequency to improve their point positioning precision. The satellites transmit messages at a speed of 50 bits per second, containing all the parameters necessary for computing the satellites's position (Wild report n.24). In geodetic surveying the point positioning is made by the position of a point relative to other points. One receiver is fixed in a known reference point, the other(s) in a point whose position is to be determined. The sources of errors, such the inaccuracy of the satellite orbits, are eliminated and the accuracy improves.

Albani Hills GPS surveying

The GPS network consists of 11 points. In selection sites we've considered both scientific objectives and logistical problems applying some very important fondamental criteria for GPS observations:

- a clear sky view up to 20-25 degrees in all directions
- the existence of a permanent and stable monumentation
- the use of a reference marker screwed down in the concrete
- points easy to access by vehicle in all weather conditions
- absence of antennas wich might be a source of radio frequency interference

R.A. Snay (1986) developed a model of GPS campaign organization using more receivers. The main points are:

a) Each point of the network is measured the same numbers of times (2 or 3), always by a different receiver.

b) A baseline should not be observed more than one time.

Known the number of m times that one want to measure each station and the number of campaigns to make:

$$c = \frac{n \cdot m}{r}$$

For the Albani Hills GPS campaign we have considered r=4 m=3 n=12 where r = number of receivers; n = number of stations; m = number of times to measure each station. The longest baseline is about 33 Km long while the shortest is about 4 kilometers long to avoid bad refraction effects that could affect measurements of long baselines.

Instrumentation

The GPS instrumentation consists of four Wild-Magnavox WM-101 receivers. The WM-101 is a four channel L_1 frequency receiver at present capable of simultaneously receiving signals from up to six satellites. The data are stored in cassettes and are then output from a tape reading unit to the computer. The software PoPS supplied with the receivers, can adjust a network with up to ten stations.

Tiltmeters

horizontal pendulum tiltmeter

The horizontal pendulum tiltmeter is composed by a moving element, i.e. the horizontal pendulum with bifilar suspensions, a frame in which the wires are constrained and a bearing plate jointed it. The bearing plate has three screews that allow us to regulate the pendulum axis inclination and then to obtain the wished swing period. The period T may be written as

$$T = 2\pi\sqrt{\frac{\frac{4}{9}ml^2}{\frac{4}{9}mgl\ sin\ i + \frac{\pi\mu r^4}{I}}}$$

where

i = tilt angle, g = gravity acceleration, l = arm lenght, L = wires lenght

the pendulum sensitivity depends on the tilt angle i of his rotation axis with respect to the vertical, and then on T.

It can be shown that if ψ is the input signal and α is the instrumental response, in first approximation the sensitivity is given by

$$\sigma = \frac{d\alpha}{d\psi}$$

A pendulum tiltmeters station is composed by two tiltmeters placed with their arms perpendicular to each other along the geographic directions N-S and E-W. The Poggendorf's optical method provides to record the tiltmeters output. Each 24 hours a timer turns on an auxiliary lamp for a minute to mark the photographic paper.

Bubble tiltmeter

The sensor contains two orthogonally spaced bubbles that are sensitive to changes in resistance with a tilt angle variation through a balanced bridge network. If the tiltmeter is tilted around one axis, the bubble, which remains fixed with respect to the gravity, makes unbalanced the bridge and introduces an output voltage which is linear function of the tilt angle. The sensor electronics performs the functions of impedance matching, amplifying, demodulating and filtering both axes, furthemore it records instrumental temperature. The base is triangular with three screws to regulate the initial tilt angle.

Input power +/- 12V

operating temp. range -20 to +70 C

output range +/- 8V

dynamical range +/- 0.46 degrees (high magnification)

dynamical range +/- 4.60 degrees (low magnification)

output sensitivity 1.0 mV/μrad

output sensitivity 0.1 mV/μrad

output impedance 270 ohm

The portable control unit allows us to define the initial tilt angle and to check the tiltmeter. On its display tilt, temperature and internal voltage may be shown.

Recording system

The recording system consists of a micrologger Campbell 21X and a Sony tape recorder. The 21X is a small user friendly computer that is able to acquire and to compute analogic data up to 16 channels. Its big memory buffer allows us to access to its initial middle and final memory to check data in real time.

The recordings show time, X and Y tilt data, tiltmeter temperature, 21X temperature and the power voltage.

Conclusions

Monitoring the crustal deformation activity of the Albani Hills area with different instrumental networks is a powerful research method that allows us to know the tectonic behaviour of an important seismic area near Rome (Central Italy). The program will develop through the following main steps:

a)GPS monitoring

b)Tilt monitoring

c)Seismic monitoring

and in the future

d)Gravity monitoring

The networks will provide continuous measurements of tilt and seismic activities while GPS measurements will be made twice a year and gravity measurements once a year.

In the next future stable GPS stations with automatic data acquisition systems and data transmission by modem from the observation station to the Istituto Nazionale di Geofisica in Rome will be developed.

Bibliografia

- Amato A. et Al.: considerazioni sulla sismicità dei colli albani. Il periodo sismico del 1981. *Atti del II convegno GNGTS,Roma;1984.*

- Applied Geomechanics Incorporated. *Manuale clinometro AGI 702. AGI, Santa Cruz,* *California.1987*

- Applied Geomechanics Incorporated. *Manuale unità di lettura digitale. AGI, Santa Cruz, California.1987*

- Baratta M.: I terremoti in Italia, *1901.*

- Civitelli G. et Al.: caratteri deposizionali deli prodotti del vulcanismo freatico nei colli albani. *Geologica Romana,14,Roma,1975.*

- De Santis A., Magno L.: Caratteristiche e impiego del sistema 21X-FM100B come strumento automatico di acquisizione dati magnetici per campagna. *Nota Interna Istituto Nazionale di Geofisica, Roma,1986.*

- De Simoni B.,Di Loreto E.: Un approccio statistico sulla sismicità dei colli albani. *Atti del III convegno GNGTS,Roma,1984.*

- Fornaseri M.,Scherillo A.,Ventriglia U.: La regione vulcanica dei Colli Albani. *Eredi Dott. G. Bardi,XI,560 pp.,Roma 1963.*

- Funiciello R.,Parotto M.: Il substrato sedimentario nell'area dei colli albani. Considerazioni geodinamiche e paleogeografiche sul margine tirrenico dell'appennino centrale. *Geologica Romana, Vol.17,Roma,1978.*

- Galli: I terremoti del Lazio. *Ed. Pio Stracca,1901.*

- I terremoti dei Castelli romani dell'11 Aprile 1987. *Istituto Nazionale di Geofisica. Reparto Geodinamica. Rapporto macrosismico 3-87. Roma,1987.*

- Melchior P.: The tides of the planet Earth.*Pergamon, N.Y.,1978.*

- Molin D.: Sulla sismicità storica dei Colli Albani. *CNEN-RT/AMB (81) 11,1981.*

- Snay R.A.:Network design strategies applicable to GPS surveys using three or four receivers. *Bulletin Geodesique n.1,1986*

- Wild report n.24