Geochemical monitoring integrated in a real-time hydrological network (*)

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Summary. — Hydrological data relative to springs and water wells collected by the Hydrografic National Service in Naples indicate that some anomalies can be correlated with the seismic activity in Southern Apennines. In this paper we report some hydrological anomalies for the November 23, 1980 earthquake and suggest that an improvement of the hydrometeorological network of the Hydrographic National Service can reveal geochemical and hydrological anomalies before the earthquakes.

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1. – Introduction

Researches of earthquake forerunners are directed chiefly to determine if short-term prediction is possible by analysing the variations of some indicators. The study of the geochemical and hydrodinamic characteristics of acquifers is considered a valid contribution for the knowledge of the natural processes that precede earthquakes and, consequently, for their forecasting; important changes in the water-rock interaction are, in fact, caused by the preseismic stresses in the area where the tectonic deformation gives origin to the seismic event. Many clear anomalies in the behavior of acquifers have been noticed before a seismic event: a sudden increase of spring flows and/or of the piezometric levels of water wells and the increase of the emanation of deep gases.

In Italy the monitoring of geochemical parameters for the surveillance of seismic and volcanic areas has been disregarded, mainly because of a limited availability of means and experienced personnel.

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For an effective monitoring a surveillance network with automatic stations is compulsory. The choice of sites suitable for the installation of multiparametric stations for the monitoring of seismic precursors is based on:

– the location of hydrogeological structures where short-term pre- and co-seismic hydrologic anomalies are singled out;

– the eventual recurrence of hystorical earthquakes;

– finding some distinctive geochemical and hydrodinamic parameters of fluids and deciding which variations are "critical" in order to assume them as precursory phenomena.

2. – Hydrogeochemical monitoring

Our research group has analysed some geochemical and hydrological anomalies that cannot be ascribed to environmental or antropic causes, comparing them with the seismic activity in Southern Apennines and pointing out that significant variations of radon gas (Arca *et al.*, 1984; Pece and Tranfaglia, 1992; Sabbarese *et al.*, 1994), of piezometric levels and of spring flow (Onorati *et al.*, 1994) and of river flow rate

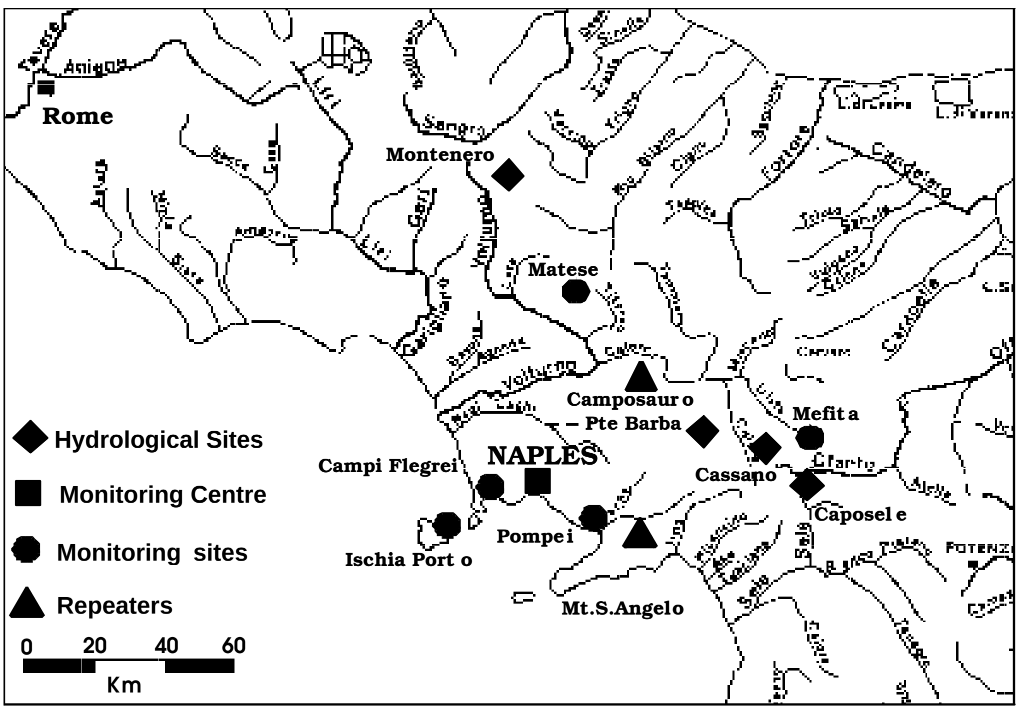

Fig. 1. – Sketch map of uppermost Southern Italy with the positions of the sites with hydrological anomalies correlated to the Irpinia earthquake of November 1980 and the new monitoring sites with automatic stations to be connected to the hydrometeorological network of the Hydrographic National Service.

(Onorati and Tranfaglia, 1994) occurred in some sites concurrently with nearby seismic events. This occurrence has been clearly evidenced in volcanic areas (Capaldi *et al.*, 1992; Del Pezzo *et al.*, 1981).

Recently we have analysed the sequences of data relative to some springs and to the piezometric levels of more than 100 wells from 1926 to 1990 measured by the Naples Bureau of the Hydrographic National Service; our aim is to pick out anomalies not imputable to environmental or antropic causes and to localize zones (wells, springs) where geochemical parameters could be monitored. Figure 1 shows the drainage patterns in Southern Italy where the drainage divide in Apennines is outlined together with the directions of surface runoffs toward the main watersheds on the Adriatic and Tyrrhenian sides. The sites where we plan to install some multiparametric automatic stations for hydrochemical monitoring are also indicated.

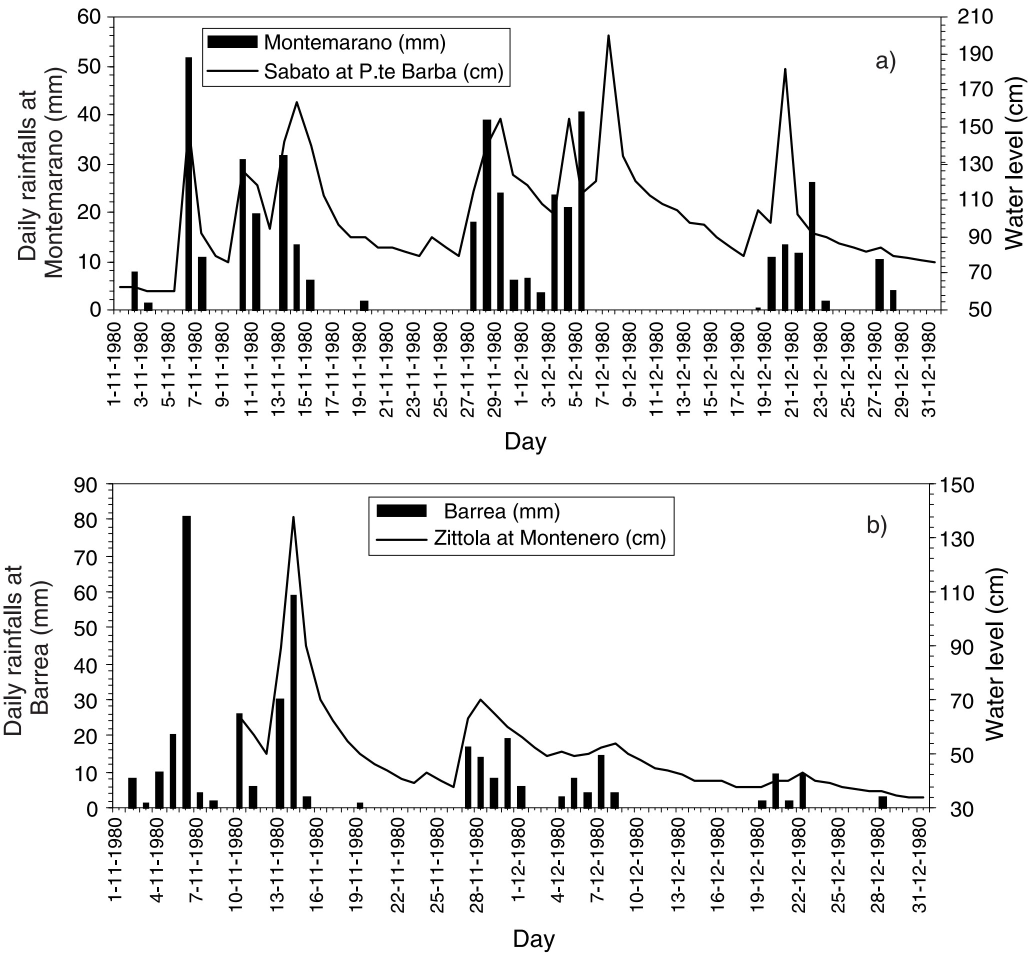

Fig. 2. – Hydrological anomalies correlated to the Irpinia earthquake of November 23, 1980; a) hydrometric level of the Sabato river at the P.te Barba; b) hydrometric level of the Zittola river at Montenero. Daily rainfalls are also shown.

The pre- and co-seismic stresses and the tectonic deformations have been studied (Onorati *et al.*, 1994) in order to find a possible model of interaction between stress state and hydrological variations in underground waters, springs and rivers of Campanian-Lucanian Apennines.

At present we are performing a more detailed analysis of hydrological anomalies in springs, rivers and wells concomitant with the earthquake of 1980 in Irpinia. Figures 2a) and b) show hydrological anomalies correlated with the earthquake of 23 november 1980 detected at hydrometric sections in the Sabato and Zittola rivers. These figures

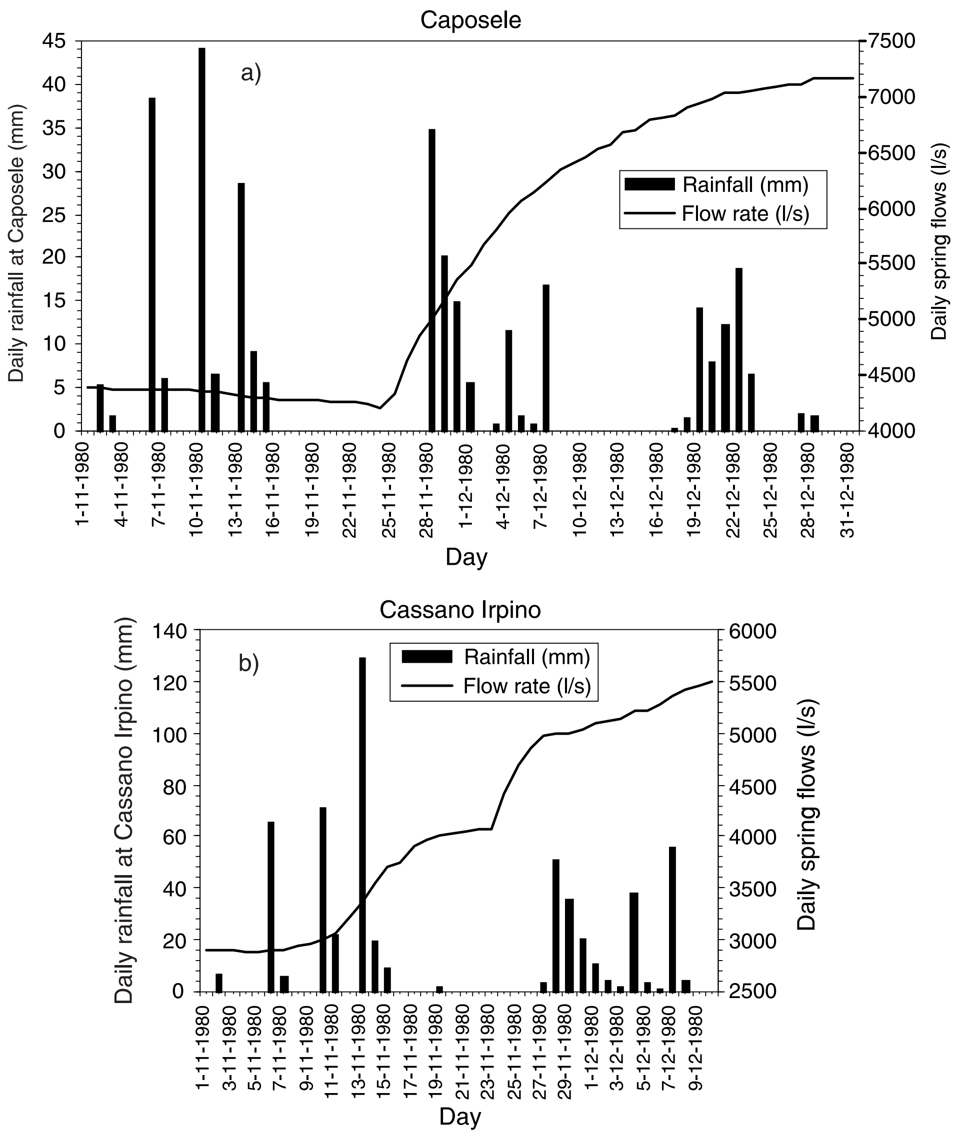

Fig. 3. – Hydrological anomalies correlated to the Irpinia earthquake of November 23, 1980: a) flow rate at the Caposele spring; b) flow rate at the Cassano Irpino spring.

show an increase of hydrometric levels which started on November 24. Anomalous variations, not imputable to the rainfalls, have been noticed also in the flow rate of Caposele and Cassano Irpino Springs (figs. 3a), b)).

In the first phase of the monitoring program for the study of precursors, the installation of automatic stations in 3 volcanic areas (Mt. Vesuvius, Island of Ischia and Campi Flegrei) and in two seismogenetic area of Southern Apennines (Matese and Irpinia zone) is considered (fig. 1). The parameters that can be monitored are: piezometric level, temperature, electrical conducibility, salinity, total dissolved solids, oxygen, *p*H, turbidity. Data will be collected through the automatic monitoring network of the Hydrographic National Service. In its final configuration the geochemical surveillance network must be composed by 10-12 stations, half installed in Campanian volcanic areas and the remaining localized near great springs in seismogenetic areas of the Southern Apennines.

The preliminary purposes of the proposed network for geochemical surveillance can be summarized in the following points:

1) To know the geochemistry of fluids in seismic and volcanic areas in order to estimate which variations of some parameters are significant and to ascertain if they are critical and can be assumed as precursory phenomena of earthquakes or eruptions.

2) To localize the areas in volcanic zones around Naples or in seismic zones of central and southern Apennines where to monitor continuously hydrogeochemical parameters. This monitoring will help to clarify the changes in the behavior of underground waters before and after an earthquake and the relationships with the tectonic deformations.

3) To find a definitive relationship between pre-seismic stresses and position of active fractures and geochemical and hydrological variations in wells and springs so that the latter can be assumed as sure precursors in the studied areas.

3. – Real-time hydrogeochemical monitoring network

In 1993 the Naples Bureau of the Hydrographic National Service started the continuous monitoring of hydrologic parameters by a network of automatic stations and teletransmission. This network (Tranfaglia, 1994) is constituted by 31 stations, 3 repeaters and the acquisition Centre in Naples, controlling a total of 55 sensors (25 ultrasonic hydrometers placed on bridges, 16 pluviometers, 13 thermometers and 1 hygrometer). The repeater systems agree with the EEC regulations; the network frequencies are in the range 437–447 MHz and the transmitting antennas are interference-free; their power supply is ensured by generators because of adverse weather conditions for long periods of the year.

The Monitoring Centre is composed by 3 functional blocks: front-end Data Acquisition System (DAS) and its peripherals; Mars elaborator (with special sofware for real-time hydrometerological applications) and its peripherals; Communications channels.

The DAS acquires and performs a preliminary analysis of the data from the peripheral stations: it calls the stations periodically (at present each 30 minutes), records all the data on magnetic media and ascertains if some alarm threshold, linked to absolute levels or to some tendency in the data, is exceeded. Through the DAS we perform also real-time visualization and printing of data and reports, selective calls, reconfiguration of the network and all the other operations to manage it.

The peripheral stations have multitasking processors, EPROM and RAM buffered memories. Presently they can control up to 16 sensors. The data are transferred to the Centre by radio transmission, but also transmission by modem-phone line is possible. The power supply is given by batteries charged by solar panels. A fully charged battery supplies power for about 30 days performing the measurements and transmitting the results.

Apart some minor problem, all the stations worked regularly; only routine annual maintenance has been made, during which sensors were checked and memory buffers were changed.

Rarely electromagnetic noise generated spikes on the transmitted signals, mainly in the line from the repeaters to the Centre. The sofware of the DAS can easily detect these spikes as anomalies in the signals and then eliminates them.

4. – Conclusions

In Southern Apennines we found that some earthquakes produced clear forerunner signals in various areas where geochemical and hydrological parameters were controlled.

If the results are indicative of the geochemical phenomena associated to the changes of the stress field we envisage to implement the real-time network and amplify the already installed monitoring stations with other sensors for a better geochemical characterization of water-tables.

Today there are no valid earthquake precursors, but many effects are invocated as good forerunners: geophysical changes (v_p/v_s, telluric currents, electromagnetic effects), geochemical changes (chemical composition, pH, water temperature, gases like Rn, CO_2) and hydrological changes (piezometric levels, spring and stream flow).
Probably the simultaneous observation of all these effects can constitute a sure forecasting. Many efforts and money are necessary for this purpose.

Taking into account that earthquakes not always are preceded by all the above-mentioned precursory phenomena, and that in today's technology can provide probes for many geochemical and geophysical parameters at affordable cost, we maintain that a regional monitoring network can be installed in order to continuously control as many parameters as possible.

The presence of an already installed hydrological network of the Hydrographic National Service in Campania can furnish a valid occasion to increase the number of parameters to monitor water-tables and springs.

We envisage that the proposed improvement of this network can reveal many and contemporaneous anomalies in the trends of the monitored parameters; the examination of trends and anomalies is fundamental in order to produce a valid model of the interaction between stress fields and hydrological behaviour in the monitored areas; this model can be considered reliable and confident in order to verify the occurrence of pre-seismic anomalies.

REFERENCES

ARCA S., BONASIA V., IANNACCONE G., LODDO M., PECE R., PINGUE F. and SCARPA R., *Studio di un'area sismogenetica campione* (*Sannio-Matese*), *Atti 3º Convegno Nazionale Gruppo Nazionale Geofisica Terra Solida* (Esagrafica Ed.) 1984, pp. 735-748.

CAPALDI G., PECE R. and VELTRI C., *Radon variation in groundwaters in the Campi Flegrei Caldera (Southern Italy) during and after the 1982-1984 bradyseismic crisis, Pageoph*, **138** (1992), 77-93.

DEL PEZZO E., GASPARINI P., MANTOVANI M. S. M., MARTINI M., CAPALDI G., GOMES Y. T. and PECE R., *A case of correlation between Rn anomalies and seismic activity on a volcano* (*Vulcano Island, Southern Tyrrhenian Sea*), *Geoph. Res. Lett.*, 8 (1981) 962-965.

ONORATI G. and TRANFAGLIA G., *L'anomalia idrologica che ha preceduto i terremoti del maggio 1984 nel Parco Nazionale d'Abruzzo. Accademia Nazionale dei Lincei, Convegno su "Terremoti in Italia: previsione e prevenzione dei danni"* (Compomat, Rieti) 1994.

ONORATI G., PECE R., TRANFAGLIA G. and ZOLLO A., *Sismicità e regime delle falde acquifere nell'Appennino meridionale, Atti 13º Conv. GNGTS, Roma, 28-30 novembre 1994* (Esagrafica Ed.) 1994, pp. 12.

PECE R. and TRANFAGLIA G., *Correlazioni tra emissioni di radon ed attività sismica nell'Appennino Meridionale, Atti 11º Convegno Nazionale Gruppo Nazionale Geofisica Terra Solida, Roma, 9-11 dicembre 1992* (Esagrafica Ed.) 1992, pp. 155-158.

SABBARESE C., DEL PEZZO E., DE MARTINO S., GASPARINI P. and PECE R., *Il Radon nell'area epicentrale del terremoto dell'Irpinia* (*1980*), *Atti "Territorio ed Ambiente", IV Conf. Scient. sulle ricerche del gruppo geomineralogico, 21-23 aprile 1994* (Defrede, Napoli) 1994, pp. 149-150.

TRANFAGLIA G., *Realizzazione di una rete idrometeorologica in teletrasmissione nei Bacini del Liri-Garigliano e del Volturno - Atti del Convegno "Atmospheric Physics and Dynamics in the Analysis and Prognosis of Precipitation Fields", Roma 15-16 novembre 1994* (Enea Tecnografico) 1994.