The First ING Geochemical Monitoring Subsystem prototype designed by IDRONAUT S.p.A. (Milan, Italy): applications and possible development.

Calcara M., Quattrocchi F.

Istituto Nazionale di Geofisica

1. Introduction

At the end of the eighties, the ING launched a national research program, which concerned the geochemical premonitory events of earthquakes (Dall'Aglio et a1., 1988). Studies carried out in countries like USA, Russian Federation, China, Japan found that many geochemical parameters in the groundwaters could have changed in response to the stress-strain state variations of a crustal region with subsequent energy release, i.e. earthquake.

During the seventies, anomalies regarding some geochemical and hydrological parameters such as 222 Rn, water temperature, water flux, Re etc, were discovered a *posteriori*. Subsequently the occurrence of these anomalies was interpreted on the basis of a hypothesis called rock dilatation and water diffusion model (Scholz et a1., 1973) where the link between water-rock interaction processes and geodynamic features was emphasized. A detailed synthesis of the involved processes and models that could explain the occurrence of geochemical anomalies on physical basis may be found in Thomas (1988).

Dealing with the case histories of a great number of suspected earthquakes - related anomalies, it could be possible to consider them like short-term precursors (Wakita et al., 1988, Igarashi et al., 1993, Chung, 1985). A precursor phenomenon could be considered particularly valid if it occurs short1y (i.e. from months to days/hours) before an event, and the geochemical parameters seem to meet this requirement. So the most reliable and efficient method to seek and detect significant variation in geochemical parameters is the continuous monitoring in groundwaters.

On September 1990 ING installed the first prototype of Geochemical Monitoring Subsystem (GMS), designed in cooperation with the Department of Earth Sciences, University "La Sapienza" of Rome, CISE S.p.A. and IDRONAUT S.r.l. (Milan, Italy) (Dall'Aglio et al., 1990, 1991).

2. The prototype of the Geochemical Monitoring Subsystem.

After a preliminary study of the hydro geochemical and geological framework of the area (Quattrocchi & Venanzi, 1989), the GMS was installed in a volcanic and seismoge-netic structure, 25 Km South-eastward from Rome, where a CO_2 - rich well is drilled in the main vulcanite's aquifer of the Albani Rills. It is a region (Fig. 1) characterized by a "swarm" seismic activity, along a NW-SE seismogenetic belt (Amato et al., 1993).

The GMS is made up of two main parts (Fig. 2):

1) the Remote Station (RS);
2) the Central. Unit (CU), installed at ING, Rome.

2.1) The Remote Station is assembled with the following devices:

i) An IDRONAUT Ocean Seven Multiparametric Probe 301 that continuously receives- the water to be monitored from the “Barozze I” well. The flow outline is supplied by three filters that cut the particles >5 µm; a “logic flow” triggers an alarm routine when the water flow drops down an electro valve shuts off the flux in case of dangerous increase of water temperature. The monitored parameters are:

air temperature and atmospheric pressure,
water temperature,
electrical conductivity,
Eh,
pH,
pCO_2.

All the multiparametric probe sensors are placed in the flux cell, outside the moni-tored well. The flux cell is pressure regulated (0-5 atm) and its geometry does not allow the sensors to be dried.

ii) A MONITOR IDRONAUT 501 is the remote CPU, which manages the whole Remote Station either receiving data from the multiparametric probe, from external en-vironmental sensors, or controlling servomechanism and communicating with the CU via modem. The MONITOR is made up of a computer, with a buffer memory of 516 Kb, a digital keyboard, the analogical/ digital 1/ O interfaces, a serial port RS232, a serial port to Link the multiparametric probe (with FSK modulation).
Inside the MONITOR IDRONAUT 501 the CISEMONITOR software is installed; it can control up to thirteen devices, even if located outside the probe.
This Monitor configuration runs the following routine operations:

a) it continuously receives data from the probe and other devices storing up to 9700 full records (with date and time too);
b) it remains in standby for keyboard operation and I/O serial port requests;
c) it checks the alarms, comparing the analogical readings with the fixed minimum and maximum alarm range for each sensor, and when necessary starts with the alarm routine (i.e. sampling, disconnecting, rate of sampling, etc..);
d) it communicates with the CU via modem;
e) it also manages an automatic sampler.

The probe sensor readings are performed in a circular loop with a maximum recording frequency of one record every two seconds. The signal of every sensor is controlled in order to verify the signal persistence and to eliminate the electrical spikes with less than one second life. At present the time recording frequency is every three minutes.
The recorded data can be stored in the remote buffer and periodically (at present every four hours) unloaded through the serial port (to the CU -via modem or to a local PC).

2.2) The Central Unit is a 386 PC-IBM compatible,
where the CISELINK code is loaded, which controls the whole remote station. The Central Unit manages the bit communications with a MONITOR IDRONAUT 501. This system is able to control up to sixteen remote stations and performs the following routines:

a) monitors and recognizes the stations during the communications;
b) unloads the buffer data memory of the MONITOR IDRONAUT 501;
c) manages the automatic water sampler, which can operate at a regular time span or when an alarm is triggered;

d) stores a communication diary on every operation.

The CISELINK code shows a main menu with five principal choices:

RECORDS;
COMMUNICATION;
DATA TRANSFERT (ASCII format too);
CUSTOMIZATION;
UTILITIES

One COMMUNICATION subroutine is particularly useful: the on-line display - re-cording shows, in real time (one full record every two seconds) .all remote measured parameters, status, active alarms.

3. Examples of experimental data

Some examples of the stored data and earthquake - related anomalies obtained at “Barozze I” Well are shown (Fig. 3-4); detailed discussion is found in other publications (Quattrocchi et a1., 1992). In the present configuration the redox potential (Eh) and the CO_2 parameters are the most suitable and reliable for the earthquake prediction purposes. On the other hand the temperature and the electrical conductivity sensors are the most stable. In fact some problem remains with the reference electrode (for pH and Eh) because of a constant drift due to the consumption of the electrode; it requires a calibration every twenty days. In the impending future a new reference electrode will be installed by IDRONAUT, which requires the calibration routine every three months.

4. Future developments

This experience suggests some general considerations:

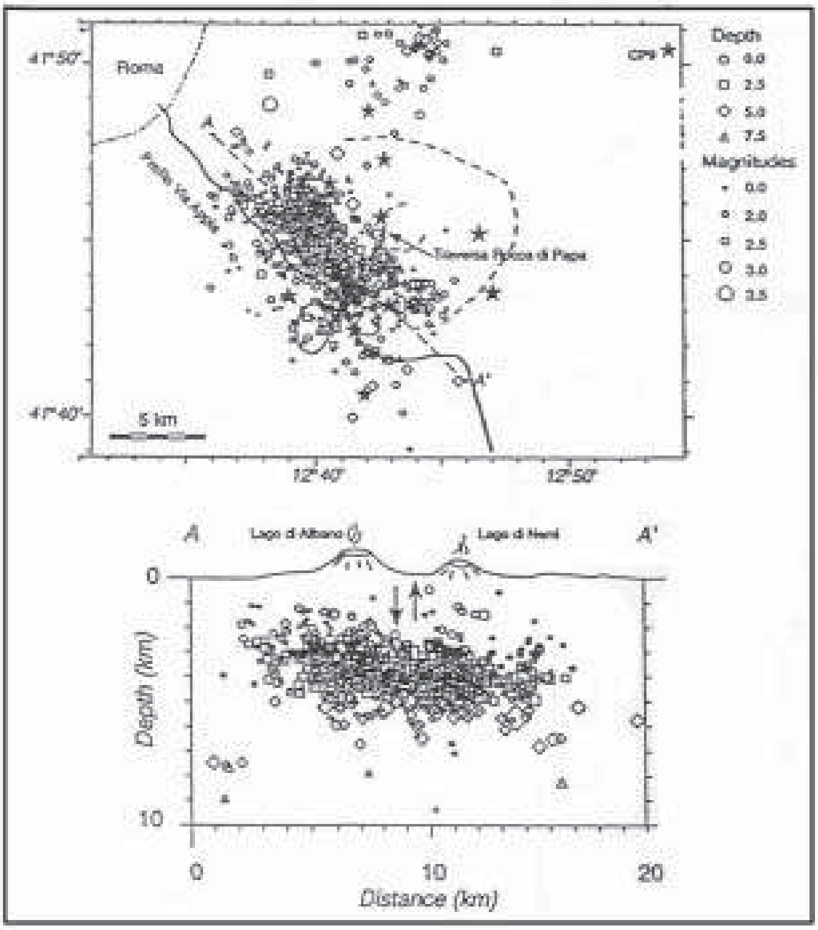
- the GMS was the first monitoring prototype for specific seismic surveillance on groundwaters, installed in Italy at that time (September 1990);
- the modularity of the system is the first prerequisite of this remote monitoring station: it can control up to twenty different sensors and a single central unit can manage sixteen remote stations;
- the GMS was designed for geochemical forerunner researches, but, due to its fe-atures, it could be applied for multiples purposes, for example the remote water quality control for civil purposes;
- considering the maintenance aspects, the main criteria of the Remote Station is install and forget; this will be the main difficulty to solve with the next prototype.

However the next step for the future monitoring station is a simplification in the remote system, with the aim of assigning more, if not almost the total control of the whole system to the Central Unit.

Acknowledgments: We wish to thank Prof. M. Dall’Aglio for launching the ING research project on geochemical earthquake forerunners, and Dott. Giovanni Venanzi for useful work during the assembling and managing of the first prototype. We are also thankful to the very helpful technician, Sig. I. Settembrini.

References

- *Amato A., Basili A., Boschi E., Cocco M., Di Bona M., Funiciello R*., (1991).
La sequenza sismica dei Colli Albani iniziata nell' Aprile 1989. Rapporto Interno ING.
- *Amato A., Chiarabba C., Cocco M., Di Bona M., Selvaggi G*., (1993).
The 1989-1990 seismic swarm in the Albani Hills volcanic area, Central Italy. Jour. Volc. Geotherm. Res., in press.
- *Chung Y.*, (1984/85).
Radon variations at Arrowhead and Murrieta springs: continuous and discrete measurements. PAGEOPH, 122, 294-308.
- *Dall'Aglio M., Funiciello R., Lombardi S., Gasparini C.*, (1988).
Research activities on earthquake premonitory events, present trend in Italy. U.N. Economie Commission for Europe Seminar on the Prediction of Earthquakes, Lisbon, Portogal, 14-18/ 11/1988, U.SEM.16/R.56.
- *Dall'Aglio M., Quattrocchi F., Venanzi G*., (1990).
La stazione automatica per lo studio dei precursori geochimici nei Colli Albani: il prototipo del sottosistema geochimico della rete sismica dell'ING. Atti IX Convegno Nazionale GNGTS, Roma, 95-100.
- *Dall'Aglio M., Gasparini C., Pagani F., Quattrocchi F., Venanzi G.*, (1991).
The italian geochemical monitoring subsystem for the study of earthquake forerunners: first results. Proceedings of the Int. Conf. "Earthquake prediction, State of Art". Strasbourg, Council of Europe, 15-18 Oct 1991.
- *Igarashi G., Tohjima Y., Wakita H.*, (1993).,
Time-variable response characteristics of groundwater radono Geoph.Res.Lett., 20, 17, 1807-1810.
- *Quattrocchi F., Venanzi G.*, (1989).
Sulla scelta di un sito per il monitoraggio di parametri idrogeochimici per lo studio dei premonitori sismici nell'area dei Colli Albani. Atti VIII Convegno Nazionale GNGTS, Roma, 259-265.
- *Quattrocchi F., Amato A., Calcara M., Chiarabba C., Funiciello R*., (1992).
Anomalie geochimiche correlabili alla sequenza sismica nell'area settentrionale dei Monti Vulsini (Castel Giorgio, Febbraio 1992). Atti XI Convegno Nazionale GNGTS 1992, Roma, 59-70.
- *Scholz C.H., Sykes L.R., Aggarwal Y.P.*, (1973).
Earthquake prediction: a physical basis. Science, 181,4102, 803-810.
- *Thomas D.*, (1988).
Geochemical precursors to seismic activity. PAGEOPH, 126, 241-266.
- *Wakita H., Nakamura Y., Sano Y.*, (1988).,
Short-term and intermediate–term geochemical precursors. PAGEOPH, 126, 267-278



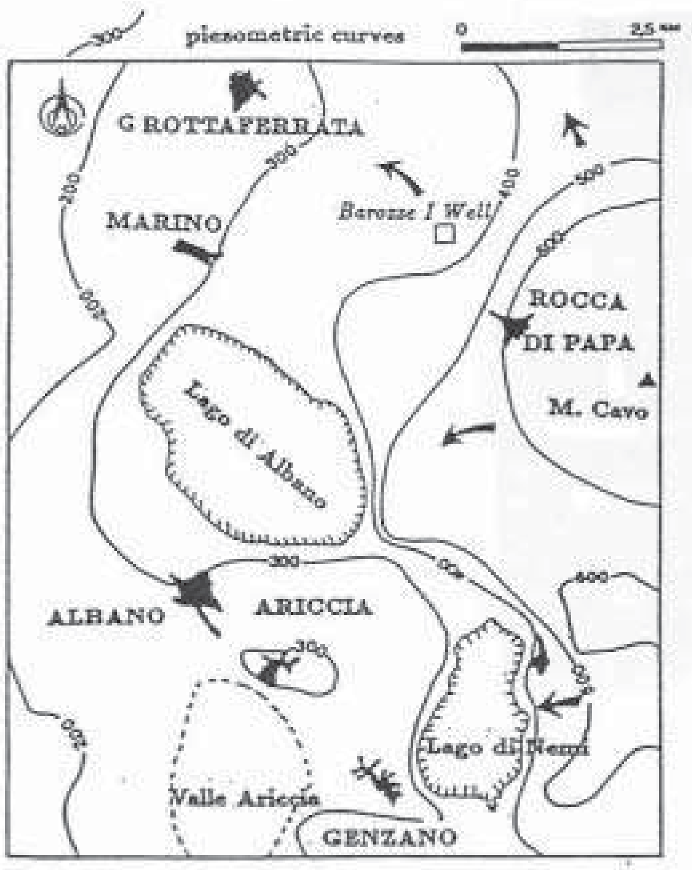


Fig 1. - Seismogenetic belt of the Albani Hills Volcanic district (Amato et al., 1991). The geochemical features of the Albani Hills main aquifer under monitoring at the *Barozze I well* are very steady (1990-1993 data set): the rare anomalies recorded until now are probably due to some variations in the acid and reducing gas input, because the geochemical parameters mostly involved are the redox potential (Eh) and the *pC02*. In default of other Remote Stations in the Albani Hills, the recorded anomalies explanation isn't univocal.

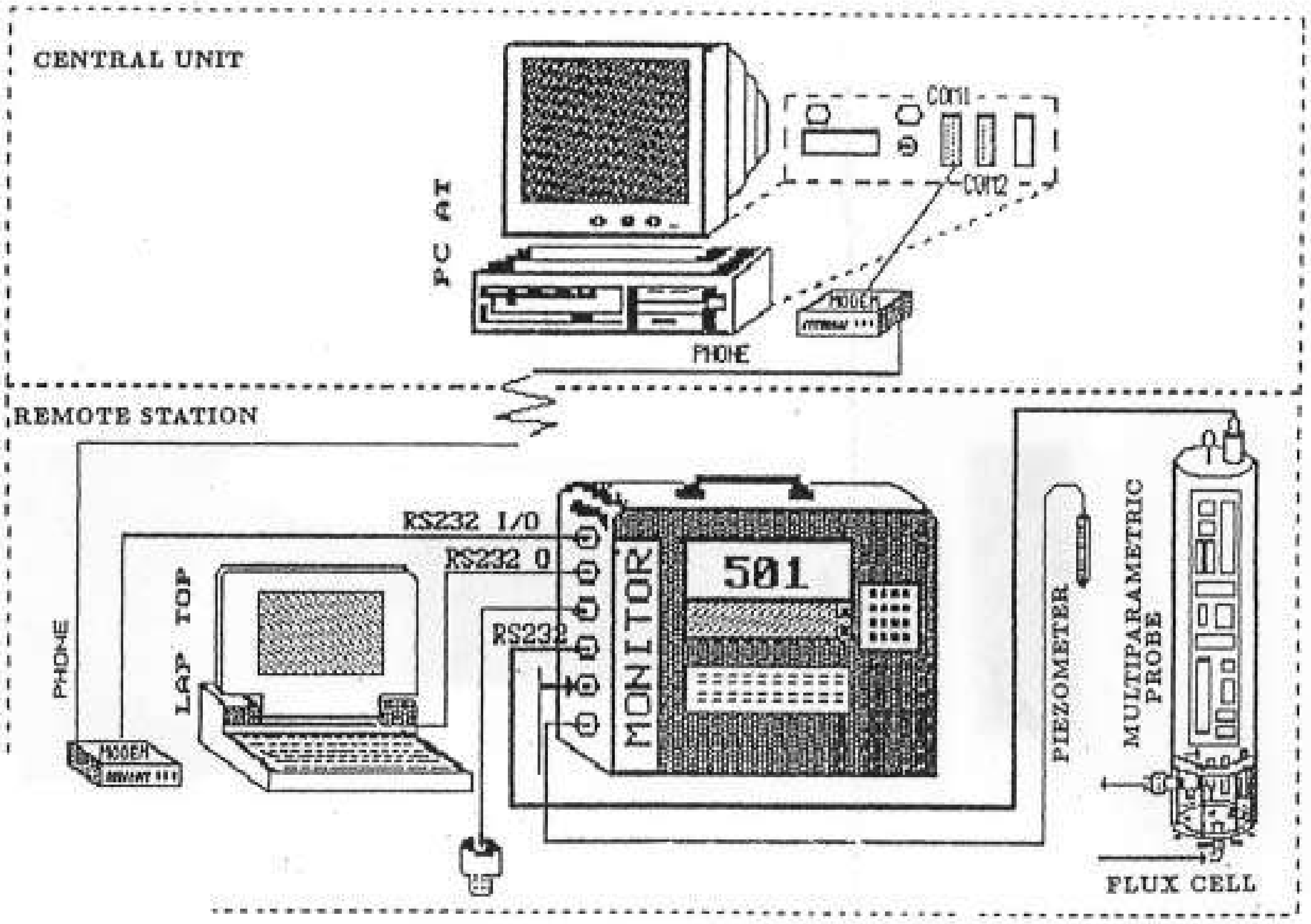


Fig. 2. Design of the first ING - GMS prototype (CISE - IDRONAUT, Milano, Italy) for the study of geochemical earthquake forerunners. A single PC – LAPTOP can manage the whole geochemical monitoring system (up to sixteen stations), also by every remote station in emergency time.

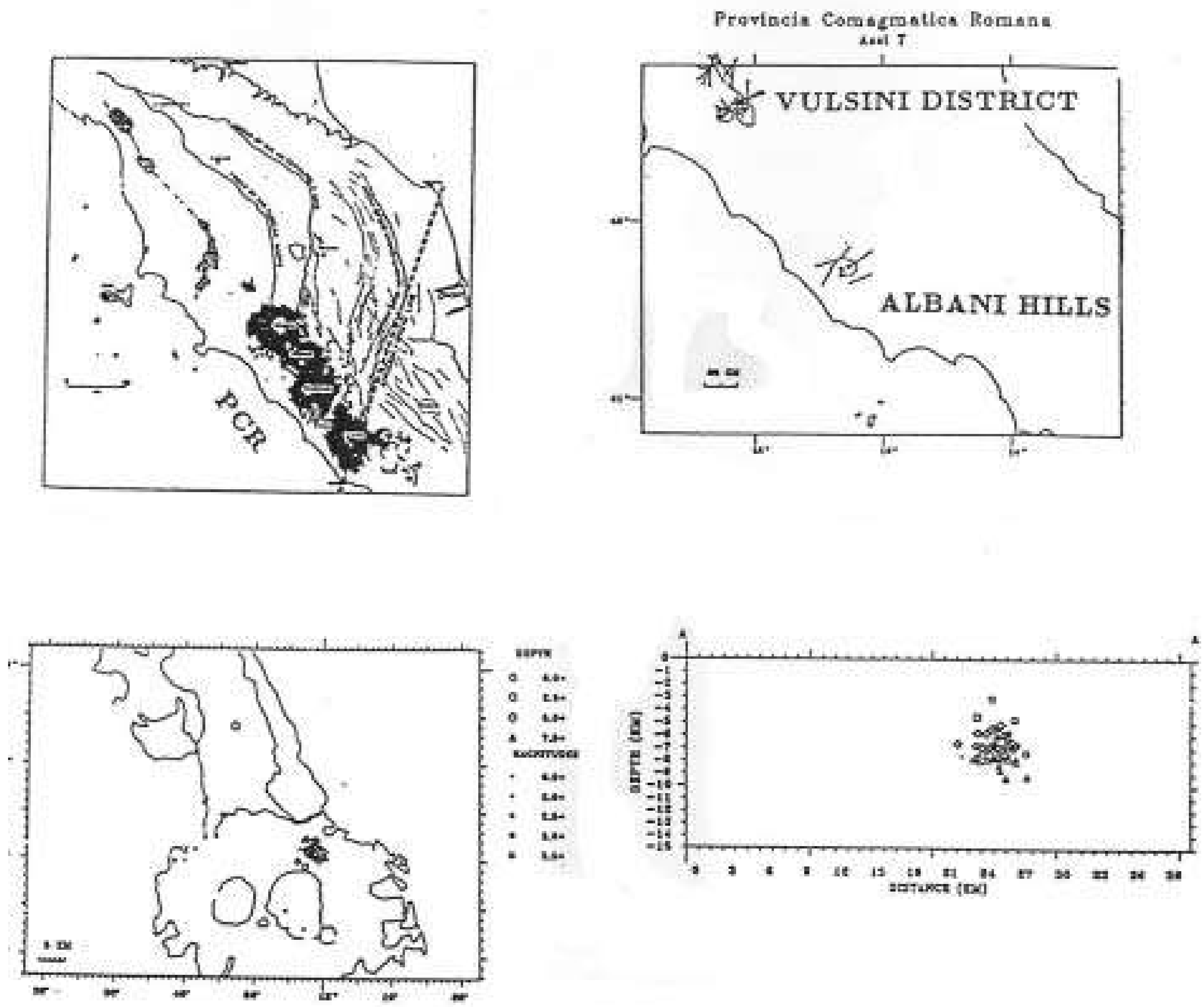


Fig. 3 During the February 1992, a seismic swarm occurred in the northern sector or the Vulsini District (c,d), with 1700 low: magnitude events *(Mmax=3.8);* at the same time, a geochemical anomaly was recorded: the redox potential (Eh) of the Albani Hills main aquifer dropped down (see fig. 4). We hypothesize that the two events are correlated in accordance with structural, seismological and geochemical remarks on the Roman Comagmatic Province (PCR), that is a NW-SE elonged volcanic district (a). A NE-SW T-axis was recognized in the PCR region from Vulsini to Albani Hills District (b). Recently the PCR was subjected to detailed seismological studies. The "Tosco Laziale" Perityrrenic Belt with its "swarm" seismicity, is of great importance in regard to the relation between the earthquakes generation and the geochemistry and dynamic or fluids. The ING geochemical station is the only one in the PCR that continuously records the physico chemical parameters, the *CO2* partial pressure, the atmospheric parameters and, recently, the 222 *Rn.*

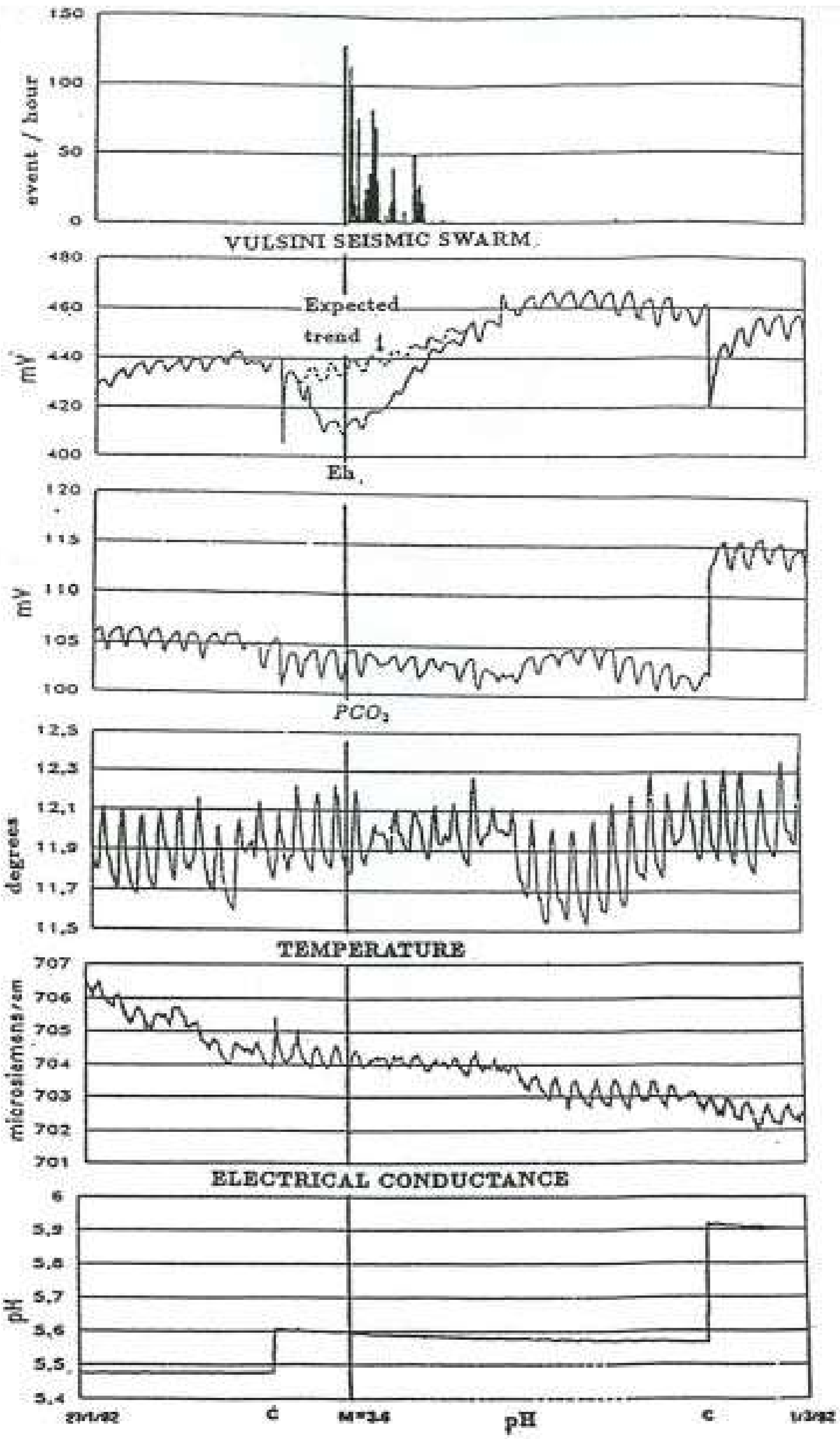


Fig. 4 Temporal trends or physico-chemical parameters and PCo2 values from the Barozze I Well monitoring station, installed in the Albani Bills seismic: region (Rome, 'Italy). The period considered is from 21/1/1992 to 1/3/1982, during which either the Eh geochemical anomaly (6-17/2/1992) or the Vulsini seismic swarm (-11/2/1992) occurred. The seismic activity begun with a M=3.8 event OD 7/2/1992 at 23:18 GMT   C= calibration routine.