Groundwater chemistry in some Italian seismic areas: space and time correlations with tectonic features and seismic activity

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Research program and methodology

Some results of the ING research program on geochemical earthquake forerunners, launched in 1990 (Dall'Aglio *et al.*, 1991), are discussed herewith. The research activity is performed along with two guide-lines dealing with:

1) Performing test-site studies in Italian seismic areas in order to identify and to select the sites for a geochemical monitoring network in the earthquake prediction research (Dall'Aglio *et al.*, 1992.). Geochemical and hydrogeological analyses are carried out on test-sites; deep-fluids pathfinders elements, such as ^{222}Rn, NH_3, H_2S, CO_2 ^4He, SiO_2, Sr, Li, Rb, Cs, B, Fe, Mn, As, Hg, are analysed too, in the ENEA laboratory (Brondi *et al.*, 1986).

Herewith are stressed the links between fluid geochemistry and seismotectonic features also in relation with 1990–1992 seismic and volcanic activity. Some test-site are discussed: Albani Hills, eastern Sicily, Mt. Etna, northern Calabria.

2) Designing and managing geochemical monitoring prototypes and networks with the purpose to analyse continuously physicochemical and environmental parameters for the seismic surveillance. The Albani Hills test-site is discussed.

The shape of the observed anomalies makes them to be considered like short term

precursors (i.e. from a few hours/days to several months). In order properly to carry out these geochemical researches, strategy of continuous monitoring instead of discrete one is preferred, especially for the ^{222}Rn (Igarashi *et al.*, 1993).

The Albani Hills test site

The Albani Hills volcanic structure is considered as a waning geothermal system, in regard to the circulating fluids. The main Albani Hills aquifer chemistry is tightly controlled by the CO_2-H_2S deep-input. The stress-field variations should affect the pore pressure at depth and the opening of new fracture zones along the NW-SE Albani Hills seismogenetic belt, allowing the interaction between gases and groundwaters under monitoring. In the Albani Hills test-site, a geochemical station prototype is yet on-line from September 1990, implemented by CISE - IDRONAUT (Milano, Italy), in accordance with our design.

In a second stage, we installed in October 1992 a continuous ^{222}Rn monitoring system (1 record/hour), together with the geochemical station. Our system is cheap, easily-handled and simple to use. We discuss an anomaly that occurred in November–December 1992 with a possible correlation with seismic activity. Anomalies of ^{222}Rn could be hidden in case of discrete monitoring, because of t' e particular shape and duration of them.

We discuss also an anomaly in the physicochemical conditions, with a possible correlation to a Vulsini District seismic swarm, during February 1992 (1700 low magnitude events with M_{max} = 3.8). The geochemical monitoring together with the seismic data represent one of the few tools that actually could confirm some geodynamical processes, such as seismicity triggered by deep-fluids, with a clear impact on the earthquake prediction research.

Test-site studies in seismic areas

The Eastern Sicily: the 13/12/90 earthquake. Soon afterwards the December, 13, 1990, eastern Sicily (Augusta, Brucoli towns) earthquake (M = 5.4), the ING organized macroseismic, seismological and geochemical studies, aimed at defining the epicentral zone and the seismogenic structure, in a interdisciplinary task (Dall'Aglio *et al.*, 1993).

In particular, unexpected evidence was found of a steady decrease of the P_{CO_2} values in groundwaters (Brucoli Sulphureous Spring}), near the epicenter, after the earthquake. The observations enable us to reconstruct the geochemical processes triggered by the 1990 seismic sequence, i.e. a sudden and strong release of CO_2 of deep origin, due to a probable co-seismic (or pre-seismic ?) pore pressure uprising.

Spatial anomalies, closely related to the structural settings of the northern Iblean

Foreland, in regard to some of the parameters related to deep-gases uprising (CO_2, H_2S, NH_3, ^{222}Rn, Eh), are pointed out from contour line maps. The variation in space-time of geochemical flows accompanying the 1990 seismic activity, are all possible evidences of the activity of the NNW-SSE fault system along the Ibleo-Maltese Escarpment. This hypothesis should be considered when locating the seismogenic source of the December, 1990 earthquake.

Mount Etna: 1991 eruption and seismicity. Within the framework of the ING-GNV geochemical studies of Mount Etna, two hydrogeochemical surveys (~ 40 samples) were performed in November 1991 and June 1992, just before and after the paroxysmal phase of the 1991 eruption (Dall'Aglio *et al.*, 1993). The analytical results show that the CO_2 input in groundwaters is the most important leaching factor in the water–rock interaction and this evidence is confirmed by the study of the mineral equilibria (SOLMINEQ88 code). The geochemical anomalies in space and time stress the role played by gaseous input along fractures from where the magma issues (i.e. Val Calanna site shortly before it was buried by the eruption, exhibits an anomalous concentration of Ca, Sr and H_2S). It was possible to hypothesize the water–rock interaction processes was more intense before than after the eruptive paroxysmal phase. This result is supported by the changes of the chemical composition between the two surveys.

The northern Calabria test-site. During the month of May 1993, a geochemical survey in the northern Calabria seismic area, was carried out by ING; here, some of the most important seismotectonic features of southern Italy, such as Sangineto line and Crati Graben, are located.

The clustering of the studied groundwaters (hydrothermal and cold aquifers), also by Factor Analysis, and the links with the structural patterns, founded in the Crati Graben and the Sibari Plain, allow to point out the independence of hydrogeological circuits; moreover is possible to set the steady and background conditions of the geochemical patterns during aseismic period. ^{222}Rn (up to 5000 pCi/L in water), He, H_2S and CH_4 seem to be the most suitable parameters for seismic surveillance in this area.

Conclusions

The work developed, within the earthquake geochemical forerunners research program, carried out until now by the ING, stresses the needs and the guide-lines for the impending future:

1) Before the installation of any geochemical monitoring system, a multidisciplinary task-study is necessary about the seismic region chosen as a test-site for earthquake prediction experiments.

Only a few examples exist, also in the international literature, about earthquake prediction test-sites, also with geochemical task.

2) Geochemical surveying on a regional scale is prerequisite; a huge number of geochemical variables, such as physicochemical parameters, environmental characteristics and pathfinder elements, that give information on deep-fluids discharges, must be taken into consideration: often, considering the test-sites studies compared in literature, only a few variables such as ^{222}Rn and/or temperature, are taken in consideration, without a general geochemical overview.

3) Once the proper sites for the geochemical monitoring are selected, the single station should be designed with the highest versatility either in the sensors, hardware and software or in the remote devices; these criteria are the main in the critical stage of a prototype/network designing.

4) The geochemical earthquake prediction research couldn't be released from the technological and theoretical developments of the geophysical disciplines dealing with the seismology; for this reason the few researh units and projects, now operative in the geochemical national and international framework, should adopt a univocal and similar research guide-line, focalizing the work on common finalities to study the seismogenetic processes.

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