Groundwater helium content related to the Spitak (Armenia) and Karymski (Russia) earthquakes (*)(**)

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Summary. — The Spitak and Karymsky earthquakes occurred with $M = 6.9$ in Armenia and in Kamchatka (Russia), respectively. As regards the Spitak earthquake, we analysed the groundwater helium content data collected by three Georgian and one Armenian measurement sites; as regards the Karymsky earthquake, we analysed the groundwater helium content data collected by two measurement sites in Kamchatka. The first analysis has pointed out that precursory anomalies appeared in the northern area with respect to the Spitak epicentre; on the contrary, only co-post seismic anomalies were revealed in the southern area. As regards the Karymsky earthquake, no pre-co-post seismic variation in the groundwater helium content was revealed at both the measurement sites. The analysis of other hydrogeochemical parameters, collected in these sites, revealed that one site does not show any anomaly; on the contrary, at the other measurement site clear preseimic anomalies appeared in some hydrogeochemical parameters. A possible explanation of the quoted results is presented.

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PACS 92.40.Kf – Groundwater.
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1. – Introduction

Groundwater helium content is a very common parameter in studying earthquake precursors [1-6]. Here, we present and discuss the behaviour of this parameter on the occasion of two strong earthquakes that occurred in the former Soviet Union.

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2. – Earthquakes and hydrogeochemical stations

The Spitak earthquake occurred in Armenia (fig. 1) on December 7, 1988 with a magnitude $M = 6.9$. The hypocentre was estimated at a depth of about 4 km [1]. A good set of groudwater helium content data was collected at three Georgian (LIS, VAR, QUA) and one Armenian (KAJ) measurement sites. The location and some

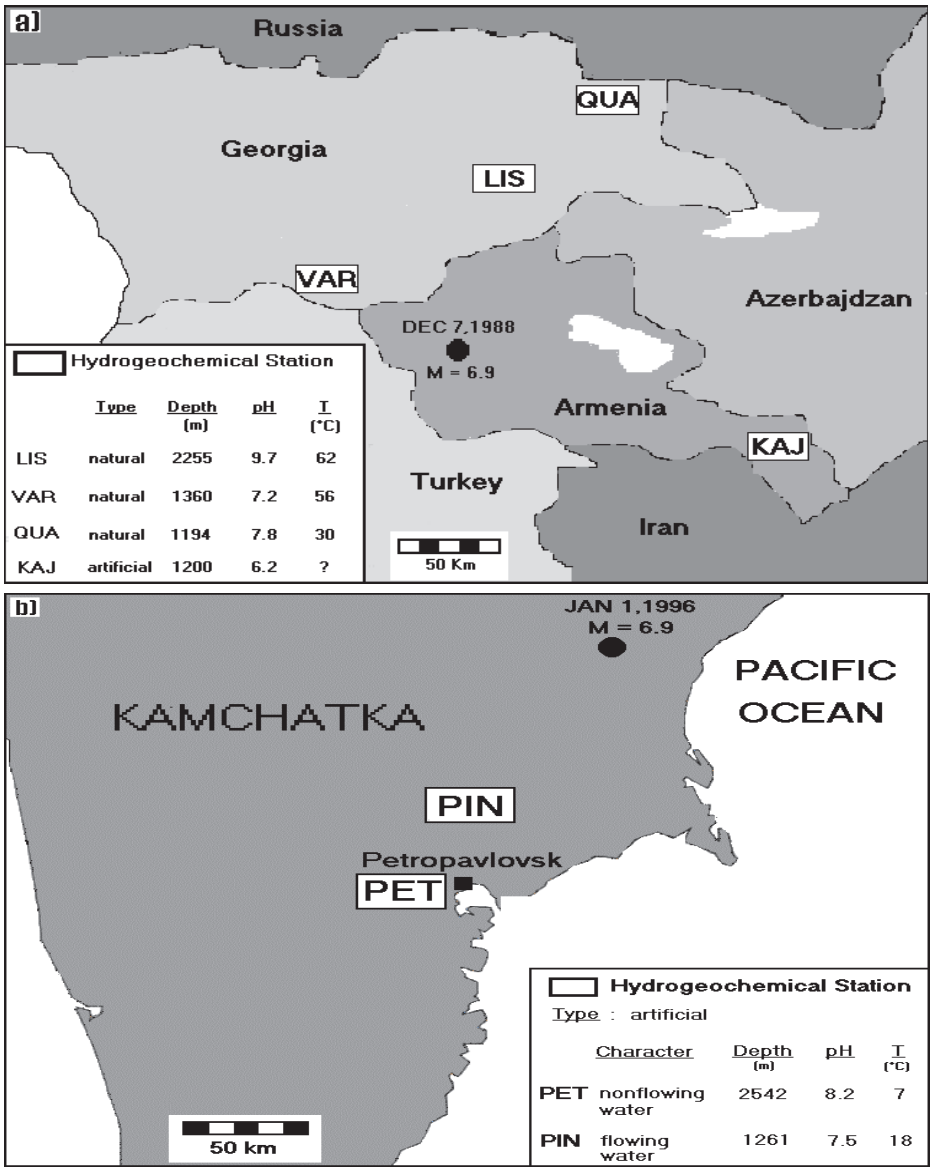

Fig. 1. – a) Map showing the Caucasus area with the location of the Spitak earthquake and the hydrogeochemical stations. b) Map showing the Kamchatka Peninsula with the location of the Karymsky earthquake and the hydrogeochemical stations.

characteristics of these sites are indicated in fig. 1. The helium content in water was measured once a day using a 1 litre sample, by means of an INGEM-1 instrument [7, 8]. The sensor is a miniature magnetic discharge pump, that is supplied with a diffusive quartz membrane which has a high selectivity for helium.

The Karymsky earthquake occurred in Russia, in the Kamchatka Peninsula (fig. 1) on January 1, 1996. The magnitude was 6.9 and the focal depth was estimated as 10 km or little less. A good set of groundwater helium content data was collected at two Russian (PET and PIN) measurement sites, the location and some characteristics of which are indicated in fig. 1. The groundwater helium content is measured by chromatograph "Gasochrom" [9, 10] after thermovacuum degassing.

3. – Results

The helium content in groundwater at LIS, VAR and QUA sites from January 1987 to April 1991 is shown in the plots of fig. 2a. The 3σ level (dotted horizontal lines) is indicated on each plot and the occurrence of the Spitak earthquake is also shown.

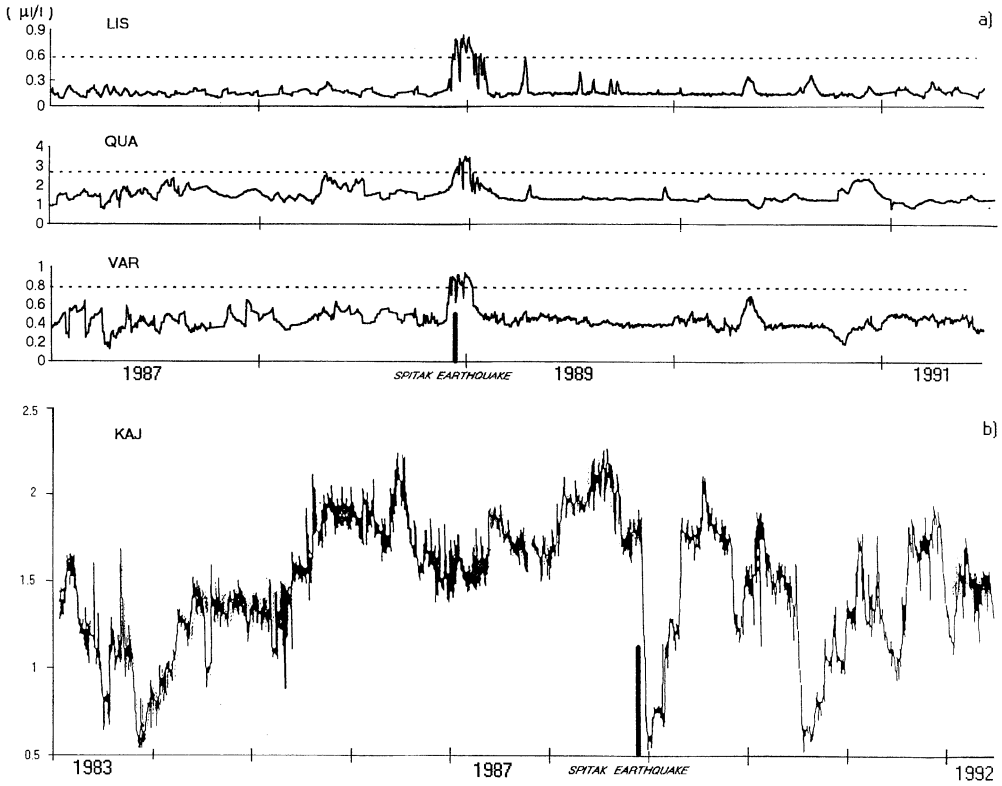

Fig. 2. – a) Helium content time-series at the LIS, VAR, and QUA springs from January 1987 to April 1991. The horizontal dotted lines represent the 3σ level. b) Helium content time-series at the KAJ well from January 1983 to October 1992. On both figures the occurrence of the Spitak earthquake is indicated by a bold vertical line.

The helium content data was obtained in the framework of a scientific cooperation between Italian and Georgian researchers, that began in 1985.

The helium content in groundwater at the KAJ site from January 1983 to October 1992 is shown in fig. 2b and the occurrence of the Spitak earthquake is also indicated. The plot is drawn by Balassanian *et al.* [11].

As shown in fig. 2a, there are significant increases in the helium content of water at the three Georgian sites, on the occasion of the Spitak earthquake. The anomalous increases in the helium content of water rises above the 3σ level starting from 2-9 days before the earthquake [1, 3]. On the contrary, no preseismic variation appears in the groundwater helium content at the Armenian station. (fig. 2b). In fact, the significant decrease in the helium content that is shown in fig. 2b appears on the occasion of the Spitak main shock [11]. After the earthquake, more than 100 days seem to be necessary for the helium content to return to "normal" values [11]. Some other similar decreases are shown in fig. 2b that seem to be related to other earthquakes [11] and they cannot be considered in this paper.

The helium content in groundwater at PIN and PET sites in Kamchatka from January 1992 to September 1997 is shown in fig. 3 and 4, respectively. In the same figures the content of some other gases and some ions in groundwaters in also shown. The occurrence of the Karymsky earthquake is indicated. The hydrogeochemical data we reported are obtained in the framework of a scientific cooperation between

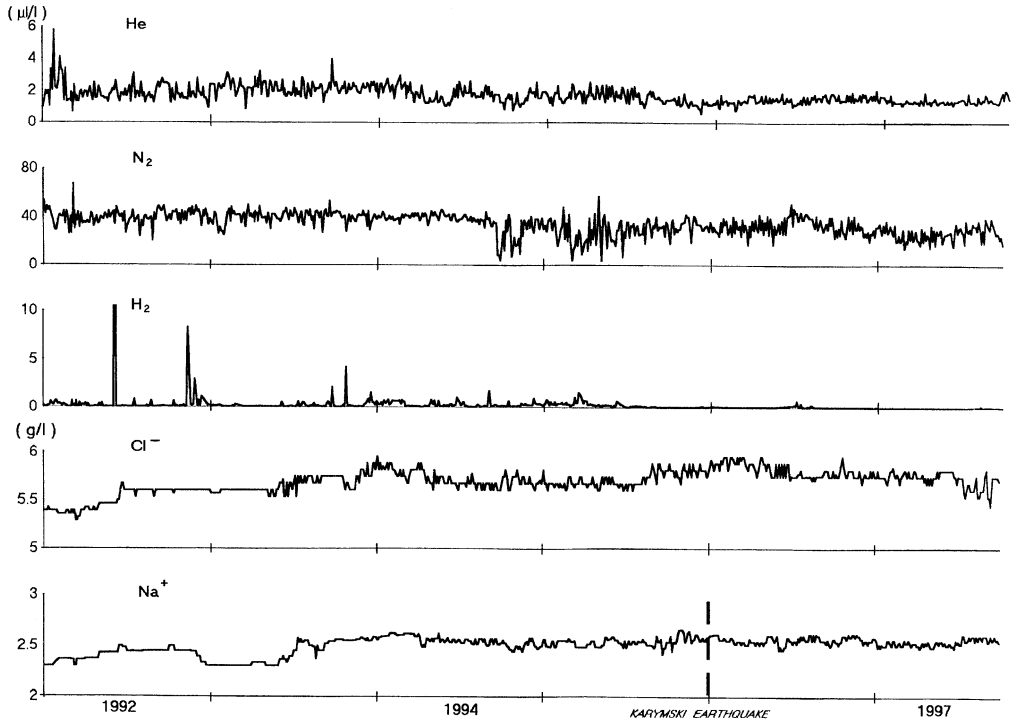

Fig. 3. – Time-series of the He, N_2, H_2, Cl^-, and Na^+ contents at the PIN hydrogeochemical station from January 1992 to September 1997. The vertical bold line indicates the occurrence of the Karymsky earthquake.

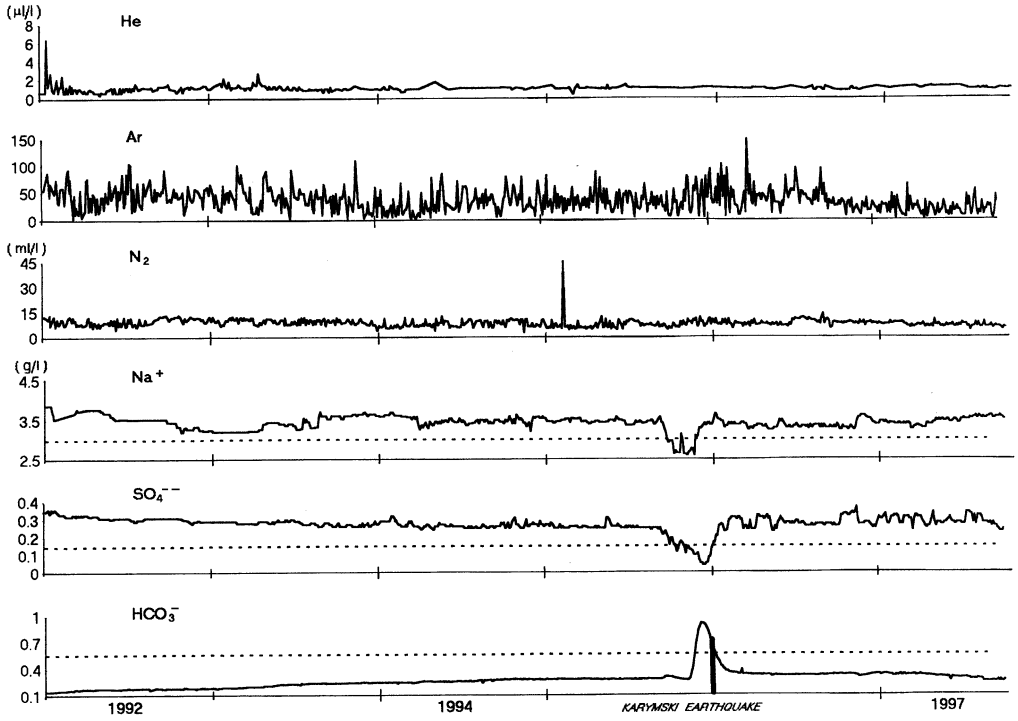

Fig. 4. – Time-series of some gas (He, Ar and N_2) and ion (Na^+, SO_4^{--}, and HCO_3^-) contents at the PET hydrogeochemical station. The 3σ level is indicated by a dotted horizontal line on each ion trend. A bold vertical line represents the occurrence of the Karymsky earthquake.

researchers from Italy and Kamchatka that began in 1992. As shown in fig. 3, no pre-co-post seismic variation in the helium content at the PIN site seems to appear on the occasion of the earthquake. This absence exists also in the content of other gases and ions. As regards the PET site (fig. 4), the content of helium and other gases in the water does not show any significant variation on the occasion of the Karymsky earthquake. On the contrary, as shown in fig. 4, significant variations in the ions content appear. These variations rise over the 3σ level, that is represented by the dotted horizontal lines in fig. 4, at a different time varying from 45 to 85 days before the earthquake.

4. – Discussion

At first, let us consider the Spitak earthquake. The behaviour of the helium content of water we presented is in agreement with those of other geochemical and geophysical parameters. In fact, as reported in the literature [1, 11], it appears that in the northern area, with respect to the Spitak earthquake, precursory anomalies were revealed; on the contrary, in the southern area only co-post seismic variations occurred. This means that the propagation of the preseismic stress readjustment from the Spitak epicentre was anisotropic, that is mainly in the northern area, and this is in agreement with the main tectonics of Caucasus. So, the increase of the helium content of waters that was

revealed in the Georgian site is related as first to an intensification of the microfracturing processes and/or changes in the existing cracks accompanying the stress readjustment processes that affected the northern area during the preseismic phase and, then, to the aftershocks activity [1, 3]. On the contrary, the co-post seismic decrease of the helium content in water at the Armenian site is related to the great changes, particularly in the groundwater circulation [11], that were produced by the Spitak main shock in the east-southern area with respect to the epicentre.

Now, let us consider the Karymsky earthquake. As concerns the PIN site, the absence of anomalies in the content of both gases and ions seems to indicate that the stress readjustment processes relating to the Karymsky earthquake have not reached the water-bearing stratum that is connected with the water in the PIN well. Hydrogeochemical measurements at this site started in 1977. During these last 20 years some strong earthquakes ($M > 6.5$) occurred in the most active seismogenetic area of Kamchatka [12], that is the one located offshore, along the south-eastern coast of the Peninsula (fig. 1). Also on these occasions no anomalies were observed in gas and ions contents of water at the PIN site. So, up to now, the water-bearing stratum of this site seems quite isolated, that is not connected with the water that crosses those zones where generally pre-co-post seismic stress readjustment happens. As concerns the PET site, the presence of clear preseismic anomalies in ions content of water testifies that the stress readjustment processes related to the Karymsky earthquake reached the water-bearing stratum that is connected with the water in that well. So, why anomalies are absent in helium and other gases content? A possible explanation of the behaviour above could be as follows: the focal depth of the Karymsky earthquake was large enough (more than twice as that of the Spitak earthquake). So, the induced preseismic stress readjustment involved the lowest part of the water-bearing stratum, that is the zone where the temperature is higher, and in such circumstances the solubility of ions in groundwater was better than that for gases.

In this paper we proposed a similar model as concerns another measurement site in Kamchatka and other earthquakes [12].

5. – Conclusions

We presented data concerning groundwater helium content on the occasion of the Spitak and Karymsky earthquakes. We showed both anomalies that are related to the earthquakes and the absence of anomalies. On the basis of data concerning other geophysical and geochemical parameters a possible justification for both the presence and the absence was proposed. Probably some other models can be proposed.

We think that the attempt to look always for anomalies does not help the research on earthquake precursors.

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