Research on relationships between escaping radon and stress-strain of the crust (*)

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Summary. — A contrast study on escaping radon and dissolved radon in groundwater has been introduced. The correlation between radon variation and earth solid tide—the mechanical foundation for using radon change to predict earthquakes—has been analyzed in this paper.

PACS 91.30.Px – Phenomena related to earthquake prediction.
PACS 91.25.Ey – Interaction between exterior sources and interior properties.
PACS 92.40.Kf – Groundwater.
PACS 01.30.Cc – Conference proceedings.

1. – Introduction

In China, research on using the randon content variation in groundwater to predict earthquakes was started in 1966, the beginning of a high seismic activity period in this century in China.

In the past 30 years, a radon observation network for earthquake monitoring has been established in China with 330 observation stations and 366 sites (table I, fig. 1). Studies on using radon concentration in groundwater in earthquake prediction have been carried out. Meanwhile, the mechanisms of using radon as earthquake precursor have also been studied [1-3].

Through this network, we have obtained numerous radon observational data on radon content variation in groundwater before more than 80 earthquakes ($M_S \geqslant 5.0$) in the area covered by the radon observational stations in China. Among them, we have systematically studied 72 cases and confirmed the existence of radom precursory anomalies before many of them, especially before five strong earthquakes of $M_S \geqslant 7.0$.

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TABLE I. – *Statistics of observational stations and sites in different parts of China.*

Region	National network		Regional network		Local netvork		Total number	
	stations	sites	stations	sites	stations	sites	stations	sites
Northern China	14	17	15	21	20	20	49	58
Northwestern China	16	26	11	11	55	57	82	94
Southwest China	11	14	25	25	5	5	41	44
Southern China	8	10	16	16	15	15	39	41
Eastern China	12	12	33	35	19	19	64	66
Northeastern China	7	11	10	10	38	42	55	63
Total	68	90	110	118	152	158	330	366

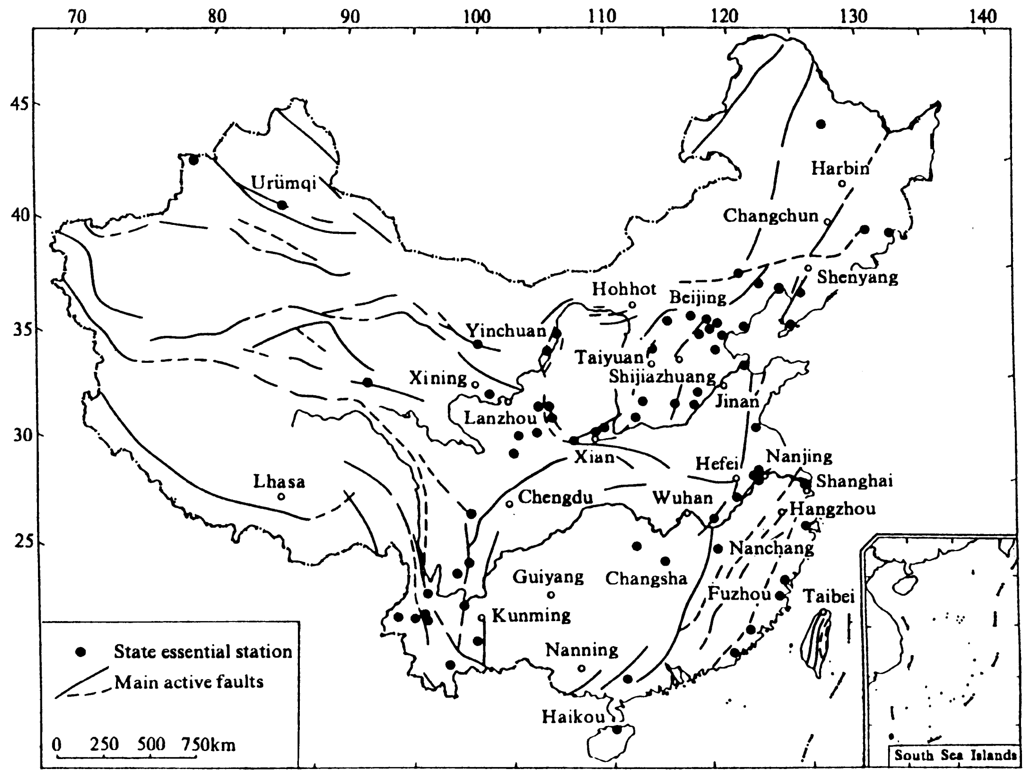

Fig. 1. – Distribution of the national seismo-hydrogeochemical observational network in China.

In this paper, we put the stress on the research on the mechanisms of radon earthquake precursors. For several years we have carried out investigations on the various aspects of this problem [1]. A series of experimental studies have been carried out under laboratory conditions and under field conditions. Different understandings have been obtained in these fields. It is well known that the development and accumulation of crust stress in the rock stratum before an earthquake, and our field and laboratory observation and experiment indicate that, in the broad area of earthquake formation, the change of pressure and temperature status in the rock causes a change in the groundwater-rock medium system. This change, in fact, sets up a new balance in the groundwater-rock dynamic state which then causes a chemical and physical variation in groundwater. We all agree, that in the formation of earthquakes, the main change is the stress change in the rock stratum. Therefore, the research on the relation between chemical components in groundwater and rock stress variation is very important to successfully solve the problem of the mechanisms of radon precursors.

2. – Dissolved radon and escaping radon

Radon exists in groundwater in two forms, dissolved radon and isolated gas. The latter become gas radon when it escapes from the water. This part of radon is called escaping radon, which is very easy to lose. Therefore we have prepared a two-channel automatic radon content measurement instrument (model SD-1) to measure both dissolved radon and escaping radon. This instrument is capable of taking continuous measurements 24 h/day.

We have carried out a contrast study on escaping radon and dissolved radon of groundwater. Through comparative observation, we found that the concentration of escaping radon far exceeds that of dissolved radon in groundwater. Irrespective of hot water well or cool water well, it is a common characteristic that the content of escaping radon is several times up to 66 times as large as that of dissolved radon in groundwater (table II). The migratory rate of escaping radon is quite different from that of dissolved radon because the state of the two kinds of radon in groundwater is different. The precursory anomalous shape of escaping radon in groundwater is more obvious than that of dissolved radon. The anomalous amplitude is also greater and easier to distinguish and identify [4, 5].

Through the above-mentioned researches, it is further verified that the escaping radon in groundwater is more sensitive to the stress-strain variation of the crustal rock and contains much more information related to earthquakes than the dissolved radon. Therefore we can expect good results in using escaping radon to study the relationship between radon and stress-strain of the crustal rock.

3. – Relationship between radon variation and earth solid tide

So far, the earth solid tide is a deformation phenomenon which we can not only calculate in advance but also observe and record every day. If the radon change in

TABLE II. – *Comparison of dissolved radon and escaping radon in groundwater at different stations.*

Item	Station					
	Dongsanqi	Yongqing	Xiongxian	Huailai	Haikou	Shantou
Water temperature (°C)	25	75	67	88	48	102
Dissolved radon (Bq/l)	14.7	11.1	7.8	4.4	14.3	28.6
Escaping radon (Bq/l)	58.7	55.5	55.4	55.5	152	1900
Ratio of escaping radon to dissolved radon (time)	4.0	5.0	7.1	12.6	10.6	66.4

groundwater is caused by the rock stress change, the earth solid tide should also cause the radon change in groundwater. Therefore, we decided to study whether or not the variation of radon concentration in groundwater has the characteristics of earth solid tide [6]. That will be a strong proof for the cause-effect relationship between rock stress and radon content.

In order to demonstrate the correlation between variations of radon content and stress-strain of the crust, we selected the Dongsanqi well in Beijing to carry out studies on the relationships between radon and earth solid tide in 1988. While a set of Sacks-Evertson borehole strainmeters is placed on the bottom of the well, we installed the automatic radon content measurement instrument of model SD-1 on the top of the well for comparative observation and research (fig. 2).

The relationships between radon time series and the sun and moon tide force is showed in the compound figure of the radon time series spectrum and volumetric stress spectrum. Figures 3a, b, c show the time series spectrum of escaping radon, theoretical volumetric stress spectrum and observed volumetric stress spectrum, respectively. The spectral distributions of these sets of data are the same.

The waves with bigger amplitudes in all the three figures are the diurnal waves. Their period is 28.4 hours and 25.6 hours in the diurnal wave group. The other group of waves with second bigger amplitudes are the semi-diurnal waves. Their period is about 12.8 hours.

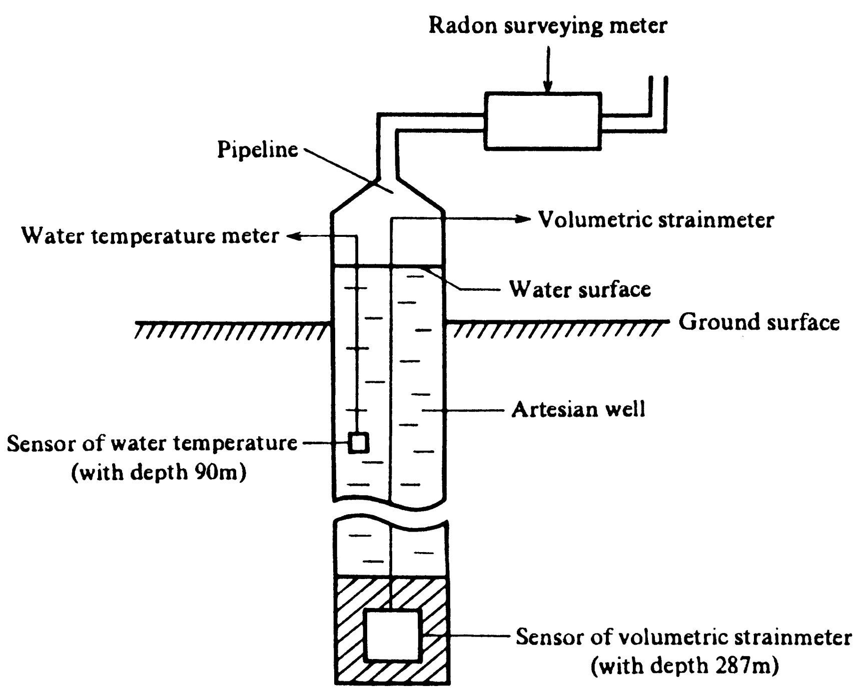

Fig. 2. – The sketch of the equipment installed in the observatory well at the Dongsanqi station of Beijing.

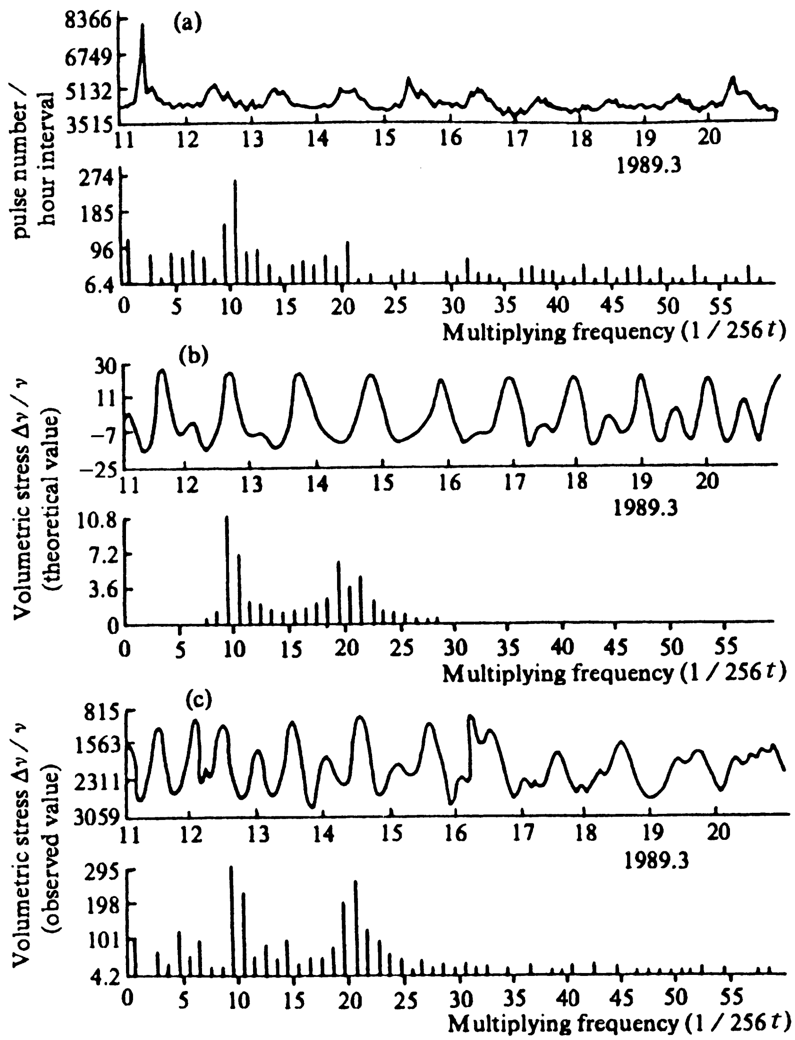

Fig. 3. – Comparison of spectral analysis results (t-unit in hours). a) The time series spectrum of escaping radon; b) the theoretical volumetric stress spectrum; c) the observed volumetric spectrum.

Besides what mentioned above, we have also analyzed the tide factor of the radon series and removed the noise components from the observational data by the analysis of mathematical filtering. It is found that the change of radon content in groundwater is unanimous with the change of measured volumetric stress.

The fact that the radon time series has the same kind of spectral distribution as the crust stress spectrum strongly supports that radon variation is a kind of tide change caused by the change of sun and moon tide forces. It also means that in general conditions, the sun and moon forces are the main reason for radon variation in groundwater.

4. – Conclusion

From the discussion above, it is clear that the variation of radon content in groundwater is related to the change of the earth solid tide, and the radon variation in groundwater indicates the change of stress in rock. The mechanical foundation for using radon variation to predict earthquakes is therefore credible.

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