On a Precursor of a Strong Tectonic Earthquake

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Abstract

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V. I. Ulomov, B. Z. Mavashev

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The study of the causes of earthquakes is directly connected with the most important problem of earthquake prediction. At present, few would doubt that the occurrence of an earthquake is associated with a sharp shear displacement of masses of rock in the depths of the earth' s crust or in deeper horizons of the Earth. The abrupt displacement, in turn, is due to elastic stresses accumulated to a limiting degree, which ultimately cause the destruction of the solid medium. We shall not touch here on the nature of the origin of elastic stresses; the study of the character of the accumulation of elastic forces and of the dynamic features of the medium being deformed is one of the possible ways of predicting earthquakes.

Studies begun in Tashkent long before the Tashkent earthquake of 26 IV 1966 (magnitude 8) and continuing up to the present show that the most promising method for monitoring the growth of elastic stresses and the character of deformation of buried rock masses is systematic observation of the gas and chemical compositions of thermomineral waters of deep origin, in particular of their radon content.

The thermomineral waters of the Tashkent basin occur in Tashkent at a depth of 1300–2400 m in the aquifer of the Cenomanian deposits. In general, the water basin is fed by atmospheric precipitation in the foothill parts of the Tashkent region and partly by migration of waters of deeper origin. The intensity of inflow of the latter, or changes in the content of their gaseous component, determine variations in the amount of radon in the Tashkent thermomineral water basin. The presence of a system of tectonic disturbances in the crystalline basement of the region under study, the relatively high temperature of the water (about 60°), and the weak radioactivity (less than 10 Mache units) make it possible to consider the radon waters as confined to zones of tectonic faults ([1]). Radon is an inert gas, and its entry into water is caused by diffusion from the "capillaries" of the rock by emanation. As has been established, emanation is determined mainly by the structure of the rock, by the presence in it of channels through which radon, released from radium, enters the surrounding medium. It is obvious that the destruction of the crystalline lattices of minerals and the development in the rock of a network of capillaries facilitate the intensive release of radon. V. I. Vernadskii repeatedly pointed out the possibility of capillary enrichment of the chemical and gaseous compositions of mineral waters. It is

Fig. 1. Change in radon content in thermomineral water of the Tashkent water basin in the epicentral area of the earthquake of 26 April 1966.

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also known that at certain stages of geological development a change in the composition of thermomineral waters proceeds very slowly, while during periods of intensive geological processes it may be very significant.

Figure 1 presents the curve of radon content in the thermomineral water of the Tashkent basin for the period 1956–1967. The studies were carried out with an SG-1M instrument at the N. A. Semashko Scientific-Research Institute of Balneology and Physiotherapy in collaboration

with the Central Seismic Station "Tashkent" of the Institute of Seismology of the Academy of Sciences of the Uzbek SSR. Water samples were taken at the mouth of a deep borehole that happened to be located in the immediate vicinity of the Pleistoseist area of the Tashkent earthquake of 26 April 1966. The latter occupies an area of about 10 km^2 in the central part of the city. "Floating up" along the fault began at an 8-kilometer depth and spread to depths of the order of 3–4 km. Seismological and geodetic studies made it possible to represent the mechanism of the numerous aftershocks as the result of elastic-plastic relaxation of elastic energy that arose as a result of shear dislocation of rocks in the suprafocal zone.

Fig. 1. Change in radon content in thermomineral water of the Tashkent water basin in the epicentral area of the earthquake of 26 April 1966.
1 –measurements of radon content (the last measurement of the maximum radon content, $M = 3.98$, was made on 20 IV 1966),
2 –moments of the earthquake of 26 IV 1966 and of strong aftershocks,
3 –stages of deformation

Analyzing the results obtained and following the principles of the mechanics of deformable media, while at the same time bearing in mind the possible limitation of these principles under the real conditions of heterogeneous continuous media, the course of deformation of a certain volume of rocks in the hypocentral region can, with a sufficient degree of reliability, be represented in the form of four stages (see Fig. 1).

Stage I. Prolonged, slowly increasing elastic-plastic deformation, accompanied by compaction of a large volume (closure of pores, small cracks, deformation of less solid inclusions, etc.).

Stage II. Relatively rapid elastic deformation, also accompanied by a decrease in the volume of the rock masses and by disturbance of the crystal lattices of individual minerals.

Stage III. Plastic deformation, practically not accompanied by a decrease in the volume of the rocks. Under conditions of enormous all-round compression, this stage ends with a sharp shear displacement of rock masses—an earthquake.

Stage IV. Relaxation of elastic stresses that arose as a result of the displacement of masses. This process is accompanied by a series of elastic-plastic rupture disturbances in the supra-focal zone (aftershocks) and is completed by the maximum release of elastic stresses in the focal zone. In the case of shallow occurrence of the focus, as was observed in Tashkent, slow deformation of the Earth' s surface occurs in the epicentral region. The change (increase) in the volume of the rock masses in this case proceeds—

is not monotonic, but is determined by the character of the displacements during the period of repeated shocks. The duration of this stage is close to that of the preceding one.

Thus, the slow elastic-plastic deformation of the enclosing "capillary" waters of rocks promoted, over the course of several years, their "squeezing out" (and possibly also the enhancement of radon dissolution in them) and their transport into the interior of the water basin (stage I). In mid-1965 the process of mechanical compaction of the rock masses reaches its limit and their elastic deformation begins, which over the course of 3–4 months intensively "squeezes out" water, enriching it with radon through the disruption of the crystal lattices of minerals, and causing it to move toward the Earth' s surface (stage II). Then the influx of radon stabilizes for a time. This is due to the onset of plastic deformation (stage III). Both processes are interrupted by a disruption of the integrity of the rocks in the focal zone and, consequently, by a significant release of the accumulated elastic stresses—an earthquake. After this, the overlying mass, compressed during the displacement of the block of rocks in the earthquake focus, is intensely deformed. The "dissipation" of elastic stresses, as already noted, begins immediately after the earthquake in the form of repeated shocks that gradually decrease in strength and number. Thus the focal region is unloaded and the former regime of influx of deep waters, and consequently of radon as well, is restored.

Thus, the immediate precursor of a possible disruption of the integrity of rocks may be the stabilization of the radon concentration in thermomineral water of deep origin that begins after a rapid increase. Fully aware of the singular nature of observations of this kind, we consider it extremely necessary to include the hydrogeochemical method in the program of comprehensive geological-geophysical investigations aimed at searching for earthquake precursors.

Note added in proof. After the present article had already been sent to the editors, a report was received from Tashkent that from 14 to 15 March 1967 the radon content in the thermomineral water of the Tashkent basin rose sharply from 1.7 to 3.2 Mache units and remained at this level for a week; on 23 March a magnitude-7 earthquake occurred in Tashkent. After this, the radon concentration varied sharply within the range 1.2–5.0 Mache units, and after a week had practically settled at its usual level. This is the first case in which it has been possible to trace variations in radon content during a strong aftershock.

Institute of Seismology
Academy of Sciences of the Uzbek SSR

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CITED LITERATURE

1. *Fundamentals of Balneology*, 1, Moscow, 1956.

Note: Figure translations are in progress. See original paper for figures.