

# Measurement of radon in ground waters of the Western Caucasus for seismological application



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## ABSTRACT

Results of radon ( $^{222}\text{Rn}$ ) concentration measurement in ground waters in the Western Caucasus are described. In 2010–2011 each day at 12:00 Moscow winter time (9:00 GMT) sampling in volume of 0.5 l of waters was carried out in two wells at depth of 30 m and 180 m. In 2012 three times per day (7:00, 12:00, 17:00) this sampling was already carried out. Radon from water was extracting by degassing method with use of bubbler. Measurements of alpha activity of gas in scintillation (ZnS) chambers were done. The water radon data with seismic, meteorological and the Sun-Lunar data were compared. The mathematical method of definition of “splashes” in radon data before regional earthquakes is considered. The greatest probability in 72% of the forecast of regional earthquakes for the data from a well of 30 m depth was received. Correlation between meteorological and radon data is absent. Correlation of lunar phases and solar activity with radon data is discussed. In July–December, 2012 sampling of water from 15 wells and measurements of radon were carried out. The distance between wells was near 50 km. Changes of radon maps in territory of South Russia during earthquakes are shown.

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## 1. Introduction

For many years, the measurement of soil radon ( $^{222}\text{Rn}$ ) for seismological application has been conducted in galleries and caves (Tsvetkova et al., 2005) and on the Earth surface in faults, landslips and mud volcanoes (Tsvetkova et al., 2012) of the Northern Caucasus. Regularities of changes in the soil radon concentration during regional earthquakes were discovered, and some methodological questions were also considered (Nevinsky and Tsvetkova, 2005; Nevinsky et al., 2012). These regularities corresponded to regularities of change of concentration of soil radon during the earthquakes, described by other authors (e.g., Birchard and Libby, 1980; Mogro-Campero et al., 1980; Sugisaki, 1981; Fleischer and Mogro-Campero, 1985; Nagamine and Sugisaki, 1991; Steinitz et al., 2003; Planicic et al., 2004; Chyi et al., 2005; Zmazek et al., 2005; Vizzini and Brai, 2012; Tarakçi et al., 2014; Mirhabibi et al., 2014; Cigolini et al., 2015). The gamma background was continuously measured simultaneously with soil radon in the galleries of the Northern Caucasus. Changes in the gamma background during earthquakes were also observed (e.g., Tsvetkova et al., 2003).

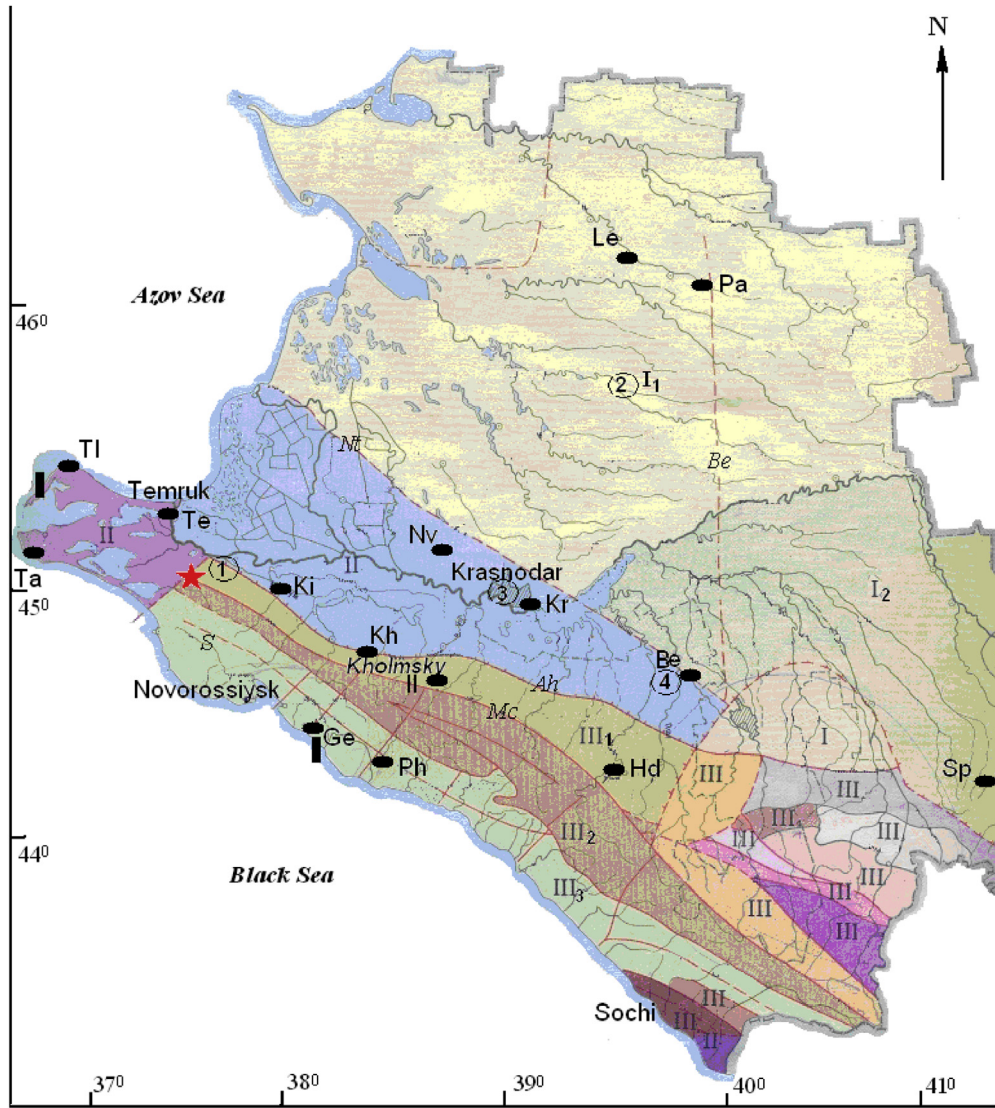
Since 2010, we have added continuous measurements of the radon concentration in ground waters to the measurements of the environmental radioactivity for seismological application in the Western Caucasus.

Seismological application of radon measurements in ground waters is repeatedly described in international publications (e.g., Ulomov and Mavashev, 1971; Asimov et al., 1979; Hauksson and Goddard, 1981; Sugisaki and Sugiura, 1986; Friedmann, 1991; Monnin and Seidel, 1992; Isotopic., 1993; King, 1993; Igarashi et al., 1995; Ghose et al., 1998; Biagi et al., 2000; Heinicke and Koch, 2000; Hartmann and Levy, 2005; Das et al., 2005; Kuo et al., 2006b; Chaudhuri et al., 2007; Choubey et al., 2009; Ghosh et al., 2009; Wang and Manga, 2010; Chaudhuri et al., 2011; Ren et al., 2012; Tsunomori and Tanaka, 2014; Kuo, 2014).

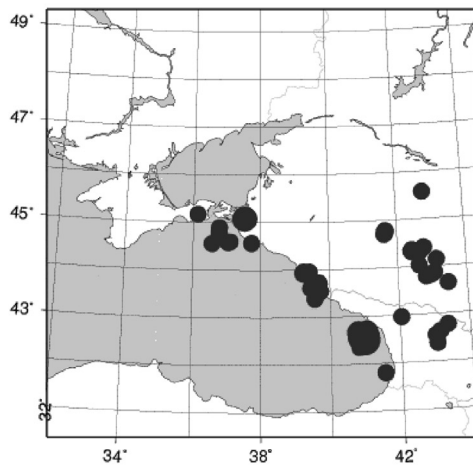
Different forms of changes in the radon data before, during and after earthquakes were observed (e.g., Hauksson, 1981; Dubinchuk, 1993; Renet et al., 2012). Different models (Perfect Mixing Model, Volatilization Model, Dilatancy Diffusion Model, etc.) of changes in the radon concentration in ground waters before earthquakes were offered by different authors (e.g., Dubinchuk, 1993; Pinault and Baubron, 1996; Scholz et al., 1973; Tsunomori and Tanaka, 2014; Kuo et al., 2006a; King, 1993; Varhegyi et al., 1992). In the last century, in the Soviet Republics of Central Asia, a large volume of research on the variations in the water radon concentration during

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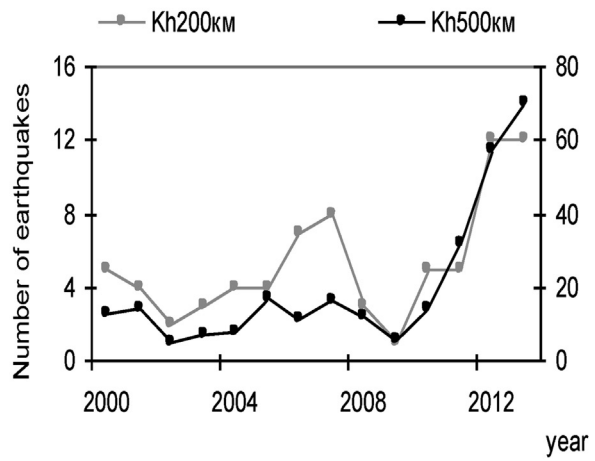
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a)



b)



c)

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