

RADON MONITORING IN THE SOUTH ICELAND SEISMIC ZONE

Páll Einarsson, Páll Theodórsson, Ásta Rut Hjartardóttir, and Guðjón I Guðjónsson

Science Institute, University of Iceland, Sturlugata 7, 101 Reykjavík, Iceland

Abstract

Studies of radon concentration in water from geothermal wells were initiated in the South Iceland Seismic Zone in 1977 (Hauksson and Goddard, 1981) spurred by strong indications that radon changes occurred prior to earthquakes. After 18 years of monitoring radon using a labour intensive method (Lucas cell) on discrete samples, a greatly improved method, using a liquid scintillation (LS) detector, was developed in 1999, where 200 ml water samples were sent twice a week to our laboratory for radon measurement in a simple automatic sample changer (Guðjónsson and Theodórsson, 2000). In order to get a continuous radon record and reduce working time a new system was developed for continuous measurement of radon in geothermal pumping stations. These projects have provided evidence for a relationship between earthquakes and radon excursions (Einarsson *et al.*, 2007).

The 1977-1993 time series revealed many earthquake-related radon anomalies, both positive and negative (Jónsson and Einarsson, 1996). They occurred mostly prior to the seismic events. Significant earthquakes were selected according to the criteria $M \geq 2.4 \log D - 0.43$ and $M \geq 2$ where M is the magnitude and D is the distance to a radon monitoring station. Thus 98 independent seismic events were selected. They were in the magnitude range 2 - 5.8. The main results were:

1. Radon anomalies were observed before 30 of the significant events.
2. 35% of all observed anomalies were related to seismicity.
3. 80% of the anomalies observed before earthquakes were positive.
4. If a positive anomaly is detected at one station, the probability of a significant earthquake occurring afterwards is 38%.
5. Some sampling sites were found to be more sensitive than others. The sensitivity appears to depend on local geological conditions.
6. A few radon anomalies appeared to be related to eruptive activity of the neighbouring Hekla volcano.

A new radon program was initiated in 1999 using a new instrument based on a novel liquid scintillation technique. Sampling from geothermal wells in the South Iceland Seismic Zone began a year before the two destructive earthquakes of June 2000 (M_w 6.5) occurred. Water samples were taken about twice a week. The June 2000 earthquakes originated in the

middle of the sampling network. Large variations in radon were observed that were correlated over the whole seismically active zone and were apparently related to the seismic events (Einarsson *et al.*, 2008). The following features can be verified:

1. Pre-seismic decrease of radon. Anomalously low values were measured in the period 101-167 days before the earthquakes.
2. Pre-seismic increase. Spikes appear in the time series 40-144 days prior to the earthquakes.
3. Co-seismic step. The radon values decreased at the time of the first earthquake. This is most likely related to the co-seismic change in ground water pressure observed over the whole area.
4. Post-seismic return to pre-seismic levels about 3 months after the earthquakes, probably also linked with the pressure change in the geothermal systems.

References

- Einarsson, P., P. Theodórsson, Á. R. Hjartardóttir, G. Jónsson, and G. I. Guðjónsson, 2007, Radon monitoring programs in the South Iceland Seismic Zone 1977-2006. Proceedings of International Brainstorming Session on Geochemical Precursors for Earthquakes, September 11-13, 2006, Saha Institute of Nuclear Physics & Variable Energy Cyclotron Centre, Kolkata, India. Macmillan India Ltd, p. 3-11.
- Einarsson, P., P. Theodórsson, Á. R. Hjartardóttir, and G. I. Guðjónsson, 2008, Radon anomalies associated with the earthquakes sequence in June 2000 in the South Iceland Seismic Zone, *Pure appl. geophys.* 165, 63-74. PAGEOPH. Topical. "Terrestrial fluids, earthquakes and volcanoes: The Hiroshi Wakita Volume II", eds. Nemesio Perez, Sergio Gurrieri, Chi-Yu King and Yuri Taran, doi:10.1007/s00024-007-0292-6.
- Guðjónsson, G. I. and Theodórsson, P., 2000, A Compact Automatic Low-level Liquid Scintillation System for Radon in Water by Pulse Pair Counting, *Applied Radiation and Isotopes* 53, 377-380.
- Hauksson, E. and Goddard, J., 1981, Radon Earthquake Precursor Studies in Iceland, *J. Geophys. Res.*, 86, 7037-7054.
- Jónsson, S. and P. Einarsson, 1996, Radon anomalies and earthquakes in the South Iceland Seismic Zone 1977-1993. In: *Seismology in Europe* (Ed. B. Thorkelsson *et al.*), European Seismological Commission, Reykjavík, p. 247-252.