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CHANGES IN RADON CONCENTRATION AT BLUE MOUNTAIN LAKE, NY

A. Mogro-Campero
R. L. Fleischer
R. S. Likes (all at: General Electric Research and Development Center, Schenectady, NY 12301)

Radon concentration has been measured since November of 1976 at various sites on the western shore of Blue Mountain Lake, NY. This region is one of the most persistent earthquake centers in the Northeastern United States. Most of the temporal record consists of weekly readings at the bottom of 60 cm deep holes using the nuclear track technique to count alpha particle decays.

We have identified a small area (with scale length of a few meters) where the radon concentrations with respect to surrounding sites is repeatedly elevated by factors of ~10 to 100. The hole with elevated radon concentration contains water whose radon content is measured. Recently an electronic detector was installed in this hole and hourly readings were recorded together with the outputs of a weather station operating nearby. This apparatus will be used to determine the short-term temporal behavior of the radon and assess the influence of various meteorological parameters. The day our radon monitoring began a magnitude 4 earthquake occurred about 14 Km from our site. Since the first several months the long term radon concentration has decreased by a factor of ~50, during a time in which there were no earthquakes above magnitude 2.

T 122

SEASONALLY CORRECTED RADON ANOMALIES

G. F. Birchard
W. F. Libby (both at: Institute of Geophysics and Planetary Physics, Univ. of California, Los Angeles, Los Angeles, CA, 90024)

Radon concentrations measured in shallow soil holes along the San Jacinto Fault zone using Track Etch* detectors display an annual cycle which correlates inversely with soil temperature and directly with soil moisture content. High radon concentrations existed at least two weeks before and after the largest earthquakes measured between March, 1975 and August, 1978 (the M4.7, 2 August 1975, M4.3,11 August 1976, and the M4.4, 5 June 1978 earthquakes). An inverse relationship between the increase in radon concentration and the distance of the detector from the epicenter was evident for the 11 August 1976 earthquake which was located within 4 km. of the nearest site. A strong trend towards higher radon concentration from September, 1976 through August, 1978 dominates all patterns. This trend, which is probably either the result of meteorological differences between 1977 and 1978 or the precursor of an earthquake, will be discussed.

T 123

DATA FROM THE CALTECH AUTOMATED RADON-THORON MONITORS*

M. H. Shapiro†
J. D. Melvin
T. A. Tombrello (all at: W. K. Kellogg Radiation Lab., Caltech, Pasadena, CA 91125)
J. H. Whitcomb (Seismological Laboratory, Caltech, Pasadena, CA 91125)

The Caltech automated Radon-Thoron monitors are microprocessor controlled instruments designed for field measurements of radon levels in subsurface fluids and gases for earthquake prediction research. The first prototype instrument has been in operation over a water-filled static borehole in Pasadena for more than 16 months. The instrument samples the radon level from the borehole three times per day. Weekly averages of the data over the period of operation exhibit a yearly cycle that appears due to thermoelastic stresses on the environs of the borehole. Response of the instrument to nearby seismic events, and to the heavy rainfall of the 1977-1978 winter will be discussed. A second prototype instrument has been in operation for a shorter period of time in a closed tunnel at Big Dalton Canyon near Glendora. Data from this instrument show much larger short term variations than the Pasadena instrument. These variations appear to be related to local meteorological conditions, and may indicate that the site is not sufficiently decoupled from the atmosphere.

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†Also: Physics Department, California State University, Fullerton, CA 92634.

T 124

ANOMALOUS CHANGES IN RADON EMANATION AND GROUND WATER QUALITY

Chi-Yu King (U. S. Geological Survey, Menlo Park, CA 94025)

Five earthquakes of magnitudes between 4.0 and 4.3 have occurred within a network of radon-emanation monitoring stations in central California since the beginning of monitoring in May, 1975. This gradually expanded network now consists of more than 60 stations deployed along several major strike-slip faults between Santa Rosa and Cholame. These earthquakes generally occurred during time periods when the local radon emanation was anomalously high. The spatial and temporal distribution of the radon anomalies will be described.

Water level (or flow rate) and quality (temperature, conductivity and pH value) have been repeatedly measured at several water wells and springs. Anomalous changes have been observed at the time of a few larger local earthquakes.

T 125

RADON PRECURSOR STUDIES IN ICELAND

Egill Hauksson
John G. Goddard (both at: Lamont-Doherty Geological Observatory of Columbia University, Palisades, N.Y. 10964)
Sigurdur E. Pálsson (Science Institute, University of Iceland, Reykjavik, Iceland)

Current results indicate that radon anomalies which could prove useful for earthquake prediction occur prior to some earthquakes in Iceland. Sampling techniques for radon have been developed for low temperature geothermal wells (<100°C) which emit two different phases, a water phase and a nitrogen gas phase. The gas phase is usually <2% of the total volume but it has 5 to 10 times higher radon activity. The short term behavior of radon in a seismically inactive area has been investigated by twice weekly sampling of two wells in the city of Reykjavik for a period of three months. In a more active area the geographical variation of radon in wells and springs has been mapped in the Southern Iceland Seismic Zone (SISZ) and the Tjornes Fracture Zone (TFZ), both active transform faults crossing populated areas in Iceland. Seven geothermal wells within the SISZ and two wells within the TFZ were chosen to study radon variations with time and to correlate observed variations with local earthquake activity. Weekly sampling has been in progress since January 1978. The largest earthquakes which have occurred during 1978 within the SISZ were 31 March, M=3.3; 3 July, M=2.7; 28 August, M=3.5. The event of 31 March occurred 5 km away from the closest sampling station but only minor changes in radon can be related to the event. The 3 July event was preceded by an anomaly showing a fourfold increase in radon activity and a duration of 20 days at sampling station Fludir (321 m deep) 12 km away. Other sampling stations with much shallower wells located 6 km and 12 km from the epicenter of this event show only minor changes. A similar anomaly occurred at Fludir prior to the 28 August event.

T 126

GEOCHEMICAL RESEARCH RELATED TO EARTHQUAKE PREDICTION AT LAKE JOCASSEE, SOUTH CAROLINA

Pradeep Talwani
W.S. Moore
Jin Chiang (all at: Geology Dept., University of South Carolina, Columbia, S.C. 29208)

Continous low level seismic activity was found to occur at Lake Jocassee after the impoundment of the reservoir in 1975. In addition to monitoring seismic activity, we began (in Jan. 1976) a series of geochemical measurements in an effort to search for precursors to $M_L \sim 2$-2.5 events.

Discrete water samples were collected from wells and a spring and their radon content was determined by scintillation counting. These data were comparable to those obtained from a continuous Rn monitor in the spring using an ionization chamber. Soil Rn measurements in track-etch cups were started in 1977. Other geochemical measurements included chlorinity, conductivity, and alkalinity of the water samples.

The results of the data collected so far indicate: (a) There are seasonal fluctuations in the radon concentrations in the spring, with a period of ~46-47 weeks, the radon content being 25 to 40% lower in summer. (b) Anomalous changes in the radon concentrations occur both before and after earthquakes. The timing of the anomaly was found to be dependent on the distance of the epicenter to the radon sample site. (c) Both high and low anomalous radon values were obtained. (d) The soil radon method was found to be useful in determining areas of high and low Rn concentrations, but not for a study of short term temporal changes. (e) Other geochemical measurements may provide clues to the depth to the source of the Rn anomalies.

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GEOCHEMICAL MEASUREMENTS PERTINENT TO EARTHQUAKE PREDICTION

Ta-liang Teng (Department of Geological Sciences, University of Southern California, Los Angeles, California 90007)

Field groundwater sampling work started at U.S.C. in October, 1974, over an area along a "locked" segment of the San Andreas fault from Gorman to San Bernardino. To date, an extensive sampling network has been established over the extended Palmdale bulge area with primarily regular weekly sampling from sites that include cold springs, hot springs, deep irrigation wells, and artesian wells. A year ago, we began monitoring radon content of groundwater issuing from the Sierra Nevada batholith deep inside the Pine Creek tungsten mine at the north end of the Owens Valley. Data from these monitoring efforts will be discussed. We are actively pursuing the development of a continuous groundwater radon monitoring system. Currently, through collaboration with Dr. Wakita (Japan) and Dr. King (USGS), a Japanese continuous radon counting system has been operating in one of our instrumented wells since February, 1978. The author recently returned from a trip to the People's Republic of China where he had a chance to examine a newly constructed continuous radon monitoring system. A report will be given discussing the various characteristics of these different systems.

T 128

INVESTIGATION OF RADON AND HELIUM AS POSSIBLE FLUID-PHASE PRECURSORS TO EARTHQUAKES

R. Poreda
Y. Chung
J. E. Lupton
R. Horowitz
H. Craig (all at: Scripps Institution of Oceanography, UCSD, La Jolla, CA 92093)

Radon, helium, and other dissolved gases (Ar, N_2, CH_4) in 25 thermal springs and wells along S. California fault zones have been monitored since 1974 as part of the USGS Earthquake Hazards Reduction program. In these thermal springs helium, argon, and nitrogen variations in individual sites plot in linear arrays representing two component mixtures. A "deep" component with excess He, Rn, CH_4, and sometimes N_2 mixes with surface water of the spring containing essentially no He, Rn, or CH_4, but equilibrium concentrations of Ar and N_2 corresponding to atmospheric solubilities at the spring temperature.