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Bibliography of radon in the outdoor environment and selected references on gas mobility in the ground

by
Allan B. Tanner

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Introduction

"Radon" denotes both the chemical element containing 86 protons in its nucleus, and the specific isotope of radon whose nucleus also contains 136 neutrons, giving the isotope a mass number of 222. A reference to "radon" or "Rn" is usually a reference to the isotope ^{222}Rn. Two other isotopes occur in nature, ^{220}Rn, conventionally called "thoron" or "Tn," and ^{219}Rn, conventionally called "actinon" or "An." All radon isotopes are noble gases, which implies that they occur as non-polar, monatomic molecules and are inert for practical purposes. They are also radioactive: half of a collection of radon atoms disintegrate in 3.825 days, their mean life is 5.52 days, and 90 percent disintegrate in 12.7 days. Thoron decays more rapidly: it has a half life of about 54.5 seconds, a mean life of about 78.6 seconds, and 90 percent disintegrate in about 181 seconds. Actinon decays most rapidly: it has a half life of about 3.92 seconds, a mean life of about 5.66 seconds, and 90 percent disintegrate in about 13 seconds.

Radon-222, ^{220}Rn, and ^{219}Rn are decay products of radium isotopes that are, in turn, members of radioactive series headed respectively by the radionuclides uranium-238, thorium-232, and uranium-235, which are so long lived that the present quantities of them are inferred to be the remainders of those nuclides that were present at the time of formation of the Earth. Over such a long period geologic processes have distributed both uranium and thorium widely in the crust. The uranium isotopes are particularly mobile in surface and ground waters, soils, and rocks wherever there is free oxygen. As a result, the radon isotopes are present practically everywhere, although in exceedingly minute concentrations by weight: maximum concentrations of radon in nature probably do not exceed 1 part in 10^{13} and concentrations of thoron and actinon are likely to be smaller by factors of 10^4 and 10^5, respectively. Typical concentrations are 10^2-10^4 lower in soil gases, and 10^6 lower in outdoor air, than these estimated maximum concentrations.

Despite such small concentrations, the radon isotopes have been measurable with fairly simple apparatus since the early days of radioactivity investigations. Radon-222 especially has been a subject of investigation in such diverse fields as medicine, petroleum exploration, atmospheric circulation, internal surface area of solids, uranium exploration, tracing near-surface faults, and public health. An extensive literature has developed in more than a dozen languages and in a wide spectrum of professional journals, theses, popular articles, and the "gray literature" of laboratory reports of limited availability.

Although quite tedious to operate by present standards, the electroscopes and electrometers of the pre-World War I era were reasonably accurate, and measurements made with them should not be dismissed out of hand because of their having been made long ago. Furthermore, experiments were often performed with much stronger sources, and consequently better statistical quality, than is typical of recent investigations. Therefore, the entire radon literature is worthy of consideration, although the modern interpretations of early results may differ markedly from those of their authors.

Scope

This bibliography is a collection of references that have come to my attention and have been transcribed to disk during various studies of radon and its precursors during the period 1951 to 1990. During the earlier part of that period, relatively few radon references were found and it was practical to include all of them. Since the latter 1960's the radon literature has increased greatly, and it has become necessary to restrict the scope of the bibliography primarily to the sources, occurrence, and behavior of radon isotopes in the outdoor environment, especially in soil. Relevant theoretical and laboratory experimental works and instrumentation are included. Some additional entries have been made for studies of processes not involving radon, but applicable to radon behavior; for example, diffusion and permeability information. Recent papers dealing exclusively with indoor radon and radon progeny behavior, indoor radon measurements and mitigation, epidemiological studies not related to geological characteristics, radiation biology of radon, and some oceanic and atmospheric papers have been mostly excluded. Despite the nearly 2000 entries, there are many other appropriate entries within the defined scope. Many other recent references are known but had not been transcribed to disk as of September 1990.

Format

This bibliography was originally compiled with a line editor and was subsequently reformatted in several successive word processor formats, the final version being WordPerfect® level 5.0. Translation to another word processor, or use with systems unable to display or print Greek letters, superscripts, subscripts, italic fonts, and the many diacritical marks may result in confusion. Although most transcription errors and format inconsistencies have been corrected by repeated editing, some remain.

Entries consist of the author name(s), year of publication, title of article, translation of title if not in English, title of collection, book, or symposium (if appropriate), title of journal or publisher, volume (and/or number in parentheses), and pagination. An effort has been made to give fuller references than is customary. For many entries I have included an abstract journal citation, an abstract, or annotations. Except for minor editorial changes and revision of many quantities to modern or Système International units, I have indicated my abstracts, annotations, and comments by square brackets, [ ]. Names and titles in the Cyrillic alphabet have been transliterated by the U.S. Board of Geographic Names' system, which appeared in *Geophysical Abstracts 148*, U.S. Geological Survey Bulletin 991-A, January-March 1952.

Abstracts or citations of abstracts appear from several sources: *Chemical Abstracts* (Chem. Abs.); *Geophysical Abstracts* (Geophys. Abs.), published from 1929 to 1971 by the U.S. Bureau of Mines and the U.S. Geological Survey; *Nuclear Science Abstracts* (Nucl. Sci. Abs.), published from 1948 to 1976 by the U.S. Atomic Energy Commission, Oak Ridge, Tenn.; *Science Abstracts* (Science Abs.), published from 1898 to 1924 by E.& F. Spon, Ltd., London; and *GeoScience Abstracts* (GeoSci. Abs.), published from 1959 to 1966 by the American Geological Institute, Washington. Unfortunately, many abstracts had to be removed from the listing because of copyright restrictions.

The bibliography is given in alphabetical order by the first author's surname and year of publication. No key words or indexing aids are given. In my experience, it is possible to accomplish a literature compilation in an hour by scanning the entire bibliography by means of the word processor and deleting entries not relevant to the search.

Système International (SI) Units and Prefixes

The conventional unit of radioactivity, the curie, equal to 3.7×10^{10} disintegrations per second, is being replaced gradually by the SI unit, the becquerel, equal to 1 disintegration per second. One picocurie per liter (pCi/L) is equal to 37 becquerels per cubic meter (Bq/m^3).

Under the SI, units can be modified by prefixes: multipliers that differ by factors of 10^3. These prefixes, their symbols, and the factors they represent are exa (E, 10^{18}), peta (P, 10^{15}), tera (T, 10^{12}), giga (G, 10^9), mega (M, 10^6), kilo (k, 10^3), milli (m, 10^{-3}), micro (μ, 10^{-6}), nano (n, 10^{-9}), pico (p, 10^{-12}), femto (f, 10^{-15}), and atto (a, 10^{-18}). These prefixes are commonly used with conventional units also; thus, one attocurie (1 aCi) equals 1×10^{-18} curie. The prefixes hecto (h, 10^2), deka (da, 10^1), deci (10^{-1}), and centi (10^{-2}) are also recognized, but their use is not encouraged.

Acknowledgments

I greatly appreciate the efforts of Mrs. Dorothy Baber, of the U.S. Bureau of Mines, who transcribed to disk about 900 entries from my collection of cards as of 1980 and then went about the task of editing them. I thank also two colleagues, F.E. Senftle and H.B. Evans, who furnished me with many references from *Chemical*

Abstracts, and the staff of *Geophysical Abstracts*, particularly Dorothy B. Vitaliano, Virginia S. Neuschel, Anatole J. Shneiderov and S.T. Vesselowsky, for their excellent abstracts of foreign-language papers. Many of the early references were found while I was working on a project supported by the Division of Research of the U.S. Atomic Energy Commission. Some recent references have been discovered incident to projects supported in part by the U.S. Environmental Protection Agency under Interagency Agreement DW14931927-01-0 and by the U.S. Department of Energy, Office of Health and Environmental Research, under Interagency Agreement DE-AI05-87ER60578. Lastly, I am indebted to many authors who have supplied me with copies of their works.

Abbatt, John D., J.R.A. Lakey, and D.J. Mathias, 1960
Natural radioactivity in West Devon water-supplies:
Lancet, 2: 1272-1274.
Nucl. Sci. Abs. 15:17142

Abe, S., K. Fujimoto, and K. Fujitaka, 1984
Relationship between indoor and outdoor gamma ray exposure in wooden houses:
Radiation Protection Dosimetry, 7(1-4): 267-269
Chem. Abs. 101:99856x

Abe, Siro, Kazunobu Fujitaka, and Kenzo Fujimoto, 1980
Natural radiation in Japan, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1034-1048

Abdulgafarov, K.K., and V.V. Cherdyntsev, 1957
O vydelenii geliya i radioaktivnykh emanatsiy iz mineralov [On the liberation of helium and radioactive emanations from minerals]:
Ucheb. Zap. Kazakh. Inst., 30: 21-24

Abdulgafarov, K.K., and V.V. Cherdyntsev, 1958
Issledovaniye vydeleniya radioaktivnykh emanatsiy i geliya iz prirodnykh mineralov v zavisimosti ot temperatury [Investigations of the liberation of radioactive emanations and helium from natural minerals in relation to temperature]:
Vyssh. Ucheb. Zavedeniy Izv., Geologiya i Razvedka, (9): 107-117.
Geophys. Abs. 180-327:
...Experiments on emission of helium and radon from monazite at different temperatures showed minimums on the curve at 900°C and at 1,100°C. A minimum for radon emission from uraninite occurs at 900°C. The curves for emission of thoron (Rn-220) and actinon (Rn-219) from monazite and uraninite have a maximum at 200°C. These emanations are probably liberated along microfractures and not by diffusion through the crystal lattice.

Abraham, P., 1966
A graphical method for the estimation of radon and thoron in atmospheric air:
Indian Jour. Pure Appl. Physics, 4: 27-29.
Nucl. Sci. Abs. 20:16679:
A graphical method for the estimation of radon and thoron in air by the alpha (or beta) activity measurements of filter paper air samples is described, assuming that radioactive equilibrium exists between the parent gas and the immediate daughter products. Graphs are presented showing radon and thoron concentrations for ratios of alpha (and beta) activities of the sample at different times after collection, for various periods. The application of the method is illustrated by a calculated example.

Abrashkin, Shmuel, 1976
Implantation of radioactive atoms by alpha recoil [in Hebrew].
Israel A.E.C., IA [Rep.] 1976, IA-1324: 116 p.
Chem. Abs. 87:92388e:

Abu-Jarad, F., and J.H. Fremlin, 1982
The activity of radon daughters in high-rise buildings and the influence of soil emanation:
Environment Internat., 8(1-6): 37-43

Ackers, J.G., 1984
Direct measurement of radon exhalation from surfaces:
Radiation Protection Dosimetry, 7(1-4): 199-201
Chem. Abs. 101:99843r

Ackers, J.G., 1985
A comparison of calculated indoor radon exposure with the results of measurements:
The Science of the Total Environment, 45: 245-250
[Table 2:

Material	Emanating power,%	Eff. diffusion length,cm
Concrete	25	15
Sand-limestone	15	15
Gypsum	10	15
Clay bricks	2	15]

Ackers, J.G., J.F. Den Boer, P. De Jong, and R.A. Wolschrijn, 1985
Radioactivity and radon exhalation rates of building materials in the Netherlands:
The Science of the Total Environment, 45: 151-156

Ackers, J.G., B.F.M. Bosnjakovic, and L. Strackee, 1984
Limitation of radioactivity concentrations in building materials based on a practical calculation model:
Radiation Protection Dosimetry, 7(1-4): 413-416
Chem. Abs. 101:99876d

Adamczewski, Ignacy, 1958
O zanieczyszczeniach promieniotwórczych naturalnych i sztucznych powietrza i wody [On natural and artificial radioactive contamination of the air and water]:
Acta Geophys. Polonica, 6(3): 243-259.
Geophys. Abs. 176-297:
The effect on human beings of radioactive contamination of air and water from nuclear tests is compared with that of natural radioactivity. The mean natural contamination from the earth's crust, water, and gases is tabulated. The necessity for systematic registration of intensity of artificial radioactivity is stressed, and a simple method proposed by Kowal for measuring the radioactivity of dust in the air and in atmospheric precipitations is described.

Adams, John A.S., Paulo M.C. Barretto, and Ronald B. Clark, 1972
Radon-222 loss from zircons and sphenes; stochastic considerations of discordant lead isotopic ages [abs.]:
Geol. Soc. America Abstracts, 4(7): 430.

Adams, J.A.S., Paulo M. Barretto, Ronald B. Clark, and Joe S. Duval, Jun., 1971
Radon-222 emanation and the high apparent lead isotope ages in lunar dust:
Nature [London], 231(5299); 174-175
[Emanating power of $<60\ \mu m$ fraction of Apollo 12 sample 12070 was 0.48± 50%; laboratory conditions inferred.]

Adams, J.A.S., and others, 1972
Development of remote methods for obtaining soil information and location of construction materials using gamma ray signatures for Project THEMIS (Pt. I. Radon emanation characteristics of rocks, soils and minerals, 1-60. Pt. II. Radon-222 loss effect on the U-Pb system discordance, 61-117)
Houston, Rice Univ. Dept. Geology, 166 p.
Ann. Rept. to U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Box 631, Vicksburg, MS 39180, Contract No. DACA 39-69-C-0048 (Negotiated)

Adams, J.A.S., P.M.C. Barretto, and R.B. Clark, 1973
Radon-222 emanation characteristics of lunar fines [abs.], in Lunar Science IV, Abstracts, 4-5: Houston, Lunar Sci. Inst.
[See Adams, Barretto, Clark, and Fryer, 1973, for full paper.]

Adams, J.A.S., P.M.C. Barretto, R.B. Clark, and G.E. Fryer, 1973
Radon-222 emanation characteristics of lunar fines, *in* Proceedings of the Fourth Lunar Science Conference, Houston, Texas, March 5-8, 1973:
Geochim. Cosmochim. Acta Suppl. 4, 2; 2097-2104
Chem. Abs.:66787r:

Adams, John A.S., and Paolo Gasparini, 1970
Gamma-ray Spectrometry of Rocks [Methods in Geochemistry and Geophysics, v. 10]:
Amsterdam, Elsevier Pub.Co., 295 p.
[P. 206-207: discusses delineation of faults where radon ascends along them.]

Adamski, Tadeusz, and Różá Przytycka, 1961
Contribution à l'étude de la coprécipitation du radium. [Contribution to the study of coprecipitation of radium]:
Polish Acad. Sci., Inst. Nucl. Research Rept. 266/IV, 2 p.
Chem. Abs. 57:132f; Nucl. Sci. Abs. 16: 18852:
The coprecipitation of radium chromate with barium chromate was studied using the Adamski method, even to the obtention of microcrystals in which the radium is concentrated along the axis of the crystal. The radon released forms two distinct gas bubbles in the interior which finally break the crystal.

Adamski, Tadeusz, Różá Przytyoka, Loch Trojanowski, and Bogdan Zukowski, 1963
New results obtained in the investigation of coprecipitation [in Polish]:
Second Yugoslavian Polish Symposium on Uranium Technology and Metallurgy, Zakopane, Poland, U.S. A.E.C. Pub. CONF-207-1, 39 p.
Nucl. Sci. Abs. 17: 39210:
"...even traces of radium can be removed from uranium solutions by coprecipitation with barium chromate. The logarithmic distribution coefficient and its dependence on the pH of the parent solution was also determined. The coefficient increases with decreasing pH."

Adkisson, C.W. and G.M. Reimer, 1976
Helium and radon-emanation bibliography--selected references of geologic interest to uranium exploration:
U.S. Geol. Survey Open-file Rept. 76-860: 44 p.

Aeckerlein, G., 1937
Die Erforschung des Erdinnern durch Emanationsmessung [Exploration of the interior of the earth by measuring emanation]:
Physikal. Zeitschrift 38(10): 362-370
The method of measuring the emanation absorbed by water in boreholes proved to be more efficient for determining depth profiles than the old method of measuring this emanation in the soil air on the surface of the ground. Tables showing radioactivity of water and of rock at various depths down to 120 m are given. Radioactive profiles drawn from the measurements in boreholes and a diagram showing the dependence of the content of Ra in rocks on the depth are presented.

Afonin, V.I., I.A. Koposov, Yu.A. Romanov, and V.G. Chernyayeva, 1957
Opyt primeneniya nazemnoy radiometricheskoy s"yemki v Nizhnem Povolzh'ye i Predkavkaz'ye [Experience in the use of ground radiometric survey in the Lower Volga area and the Ciscaucasus]:
Geologiya Nefti, (6): 48-52

Geophys. Abs. 178-341

Aithal, V. Seetharam, 1956
The measurement of alpha activities of Indian rocks and minerals using proportional counter:
Jour. Sci. Indus. Research (India), Sec. B, 15(4): 204-205
The results of radioactivity measurements on 50 rocks and minerals from various parts of India are tabulated, giving alpha activity (as number of alphas per mg per hr) and equivalent uranium (in parts per million). Some specimens of magnetite, magnetite apatite, pegmatite, and hornblende contain the equivalent of more than 0.001 percent of uranium. The highest, equivalent uranium 1,733 ppm in a magnetite from Bihar, is attributed to the presence of a higher percentage of thorium. Alpha activities of traprocks from different localities are nearly of the same order.

Åkerblom, Gustav, 1986
Investigation and mapping of radon risk areas:
Luleå, Sweden: Swedish Geological Co., Rept. IRAP 86036, 15 p. [To be pub. in Geol. Survey Norway Special Papers]
It is estimated that in Sweden 400-800 lung cases of lung cancer per year are caused from the inhalation of radon and radon daughters. Extensive regional surveys of radon daughters in dwellings, together with investigations of geology and building construction have revealed that radon in soil air is the primary source of indoor radon pollution. Documentation of the natural radiation environment in a geological context is invaluable for tracing areas of high radon risk, for understanding the local causes of indoor radon problems, and for choosing suitable remedial measures, both for existing dwellings and for future building construction. Classification of areas into high, normal, or low radon risk must take into account not only the distribution of uranium and radium in the bedrock and soils, but also such parameters as soil permeability, water content, and thickness of individual soil layers. Radon in soil air in gravel in glacial eskers, for example, has proved in Sweden to give rise to a serious radon problem. On the other hand, clays, with approximately the same radium content, do not generally give rise to a radon problem in dwellings owing to their very low permeability to movement of soil air.

Åkerblom, G., P. Andersson, and B. Clavensjö, 1984
Soil gas radon--a source for indoor radon daughters:
Radiation Protection Dosimetry, 7(1-4): 49-54
Chem. Abs. 101:99821g:

Akin, G.W. and J.V. Lagerwerff, 1965
Calcium carbonate equilibria in aqueous solutions open to the air. I. The solubility of calcite in relation to ionic strength:
Geochim. Cosmochim. Acta, 29: 343-352

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Geochim. Cosmochim. Acta, 29: 353-360

Alerico, J.S. and J.H. Harley, 1952
Evaluation of alpha-particle absorption by filter paper:
Nucleonics, 10(11): 87

Alekseyev, F.A., 1959
Radiometricheskiy metod poiskov nefti i gaz (o prirode radiometricheskikh i radiogeokhimicheskikh anomaliy v rayone neftyanykh i gazovykh mestorozhdeniy) [Radiometric method of oil and gas exploration (on the

nature of radiometric and radiogeochemical anomalies in the region of oil and gas fields)], in Yadernaya Geofizika [Nuclear Geophysics]:
Moscow, Gostoptekhizdat, p. 3-26
Geophys. Abs. 183-525

Alekseyev, F.A. and R.P. Gottikh, 1965
K voprosu o mekhanizme obrazovaniya radiometricheskikh anomaliy nad neftyanymi mestorozhdeniyami [Mechanism of origin of radiometric anomalies over oil deposits]:
Internat. Geology Review, 8(10): 1157-1171 (1966)

Alekseyev, F.A., V.I. Yermakov, and V.A. Filonov, 1958
K voprosu o soderzhanii radioelementov v vodakh neftyanykh mestorozhdeniy [On the problem of the content of radioactive elements in the wates of oil fields]:
Geokhimiya, (7): 642-649
Geophys. Abs. 183-516

Alekseyev, V.V., A.I. Nikonov, and Yu.P. Tafeyev, eds., 1957
Radiometricheskiye metody poiskov i razvedki uranovykh rud:
Moscow, Minsterstvo Geologii i Okhrany Nedr SSSR, Gosgeoltekhizdat., 610 p.; translated into English as, Radiometric Methods of Prospecting for and Investigating Uranium Ores, U.S. Atomic Energy Commiss., 1959, AEC-tr-3738 (Book 1), p. 1-337, and AEC-tr-3738 (Book 2), p. 339-640
Geophys. Abs. 175-346 and 178-331

Aliverti, Giuseppina, 1933
Quantitative Bestimmungen des Luftgehaltes an Radium-Thoriumemanation mittels einer neuen elektrischen Ausstromungsmethode [Quantitative determination of radium and thorium emanation content of air by means of a streaming method]:
Zeitschrift Geophysik, 9: 16-22

Aliverti, G[iuseppina], 1936
Su la carica e su la captabilita del RaA in aria atmosferica arricchita di Radon [On the charge and the detectability of ^{218}Po in atmospheric air enriched by radon]:
Gerlands Beiträge zur Geophysik, 48: 121-130

Aliverti, G[iuseppina], 1948
Nuovo metodo per la misura del contenuto radioattivo dell'aria tellurica [A new method of measuring the radon content of ground air]:
Annali Geofis., 1(2): 372-375

Aliverti, Giuseppina, and G. Lovera, 1949
Sulla esalazione del radon dal suolo [On the emission of radon from the soil]:
Annali Geofis., 2(1): 137-141
The amount of radioactive gas emitted by the soil depends on the radioactive content of the soil, meteorological conditions, and on the state of the soil. Theoretical and experimental determinations of the rate of escape of radon are reviewed and results tabulated. Calculations based on recent experiments in a small vertical hole at Pavia (see Geophys. Abs. 137, no. 10879) indicate diffusion of about nine atoms of radon per second per square centimeter of surface, much larger than other experimental determinations. Since radon diffusion in earth must be much smaller than in air, calculations are made using the average of three recent experimental determinations, and it is concluded that if this substitution is valid for Pavia, the diffusion of radon in earth at Pavia is about eight times smaller than in air.

Aliverti, Giuseppina, and G. Lovera, 1949
Su la influenza di alcuni elementi meteorologici du la diffusione del radon nell, aria tellurica [Influence of certain meteorological factors on the diffusion of radon from soil air]:
Annali Geofis., 2(1): 92-102
Geophys. Abs. 138-11316:
Differential equations are derived for the diffusion of radon from the ground into the air under constant and under varying pressure and temperature. From the solutions of these equations a set of values was computed for selected meteorological conditions. These values, presented in tables and in graphs were verified by measuring the radon content of the soil air at different depths in cylindrical holes drilled into the ground and provided with impermeable walls. These observations, made at different temperatures and under different atmospheric pressures, are in good agreement with the calculated values.

Aliverti, Giuseppina, and G. Lovera, 1949
Sul verificarsi o meno di una condizione presupposta nel nuovo metodo Aliverti per la misura della radioattivita' dell'aria tellurica [On the confirmation of minimum preconditions of the new Aliverti method of measuring radon in soil gas]:
Annali de Geofisica, 2(2): 258-266

Aliverti, Giuseppina, and G. Rosa, 1935
Zur Frage der Adsorption von RaEm an Kernen [On question of adsorption of radium emanation on nuclei]:
Gerlands Beitrage zur Geophysik, 44, 107-111
Chem. Abs. 29:5012:
[Adsorption of emanation on atmospheric nuclei was concluded to be very improbable.]

Allen, H.S., 1903-04
Radioactive gas from Bath mineral waters:
Nature [London], 68: 343 (1903); 69: 247 (1904)
[Gases in spring waters.]

Allen, S.J., 1907
Radioactivity in a smoke-laden atmosphere:
Phys. Review (December)

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The radioactive deposits from the atmosphere in an uncharged wire:
Phys. Review, 7(2): 113-138

Alter, H. Ward, 1980
Track Etch radon ratios to soil uranium and a new uranium abundance estimate, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 84-88, disc., p. 89

Alter, H. Ward, and Richard A. Oswald, 1983
Results of indoor radon measurements using the Track-Etch method:
Health Physics, 45(2): 425-428

Alter, H. Ward, and Richard A. Oswald, 1987
Nationwide distribution of indoor radon measurements: a preliminary data base:
Jour. Air Pollution Control Assoc., 37(3): 227-231

Alter, H.W., R.A. Oswald, and R.V. Wheeler, 1987

On the comparison of nuclear track and diffusion barrier charcoal adsorption methods for measurement of ^{222}Rn levels in indoor air:
Health Physics, 53(2): 198-199, with reply by B.L. Cohen, p. 199-200

Altschuler, Z.S., R.S. Clarke, Jr., and E.J. Young, 1957
The geochemistry of uranium in apatite and phosphorite:
U.S. Geol. Survey Rept. TEI-701, 131 p.

Alvarez, Manuel, 1949
Porosidad y permeabilidad en la relacion con la inyeccion de gas en un campo petrolero (Porosity and permeability in relation to gas injection in an oil field):
Petroleos Mexicanos, 72: 100-111
Geophys. Abs. 139-11604:
The flow of a mixture of liquids and gas through an underground formation is a more complicated phenomenon than that of a homogeneous fluid. Experiments and observations have shown that the permeability of a porous medium for gas is almost zero as long as the medium is saturated with liquid. When the liquid content is 90 percent of saturation the permeability for the gas begins to increase and reaches 30 percent of the permeability of the dry medium when the liquid content is 45 percent of the saturation. It reaches 90 percent when liquid content drops to 20 percent of saturation. Further decrease of the amount of liquid does not change the permeability for the gas. In accordance with these data the moment of gas injection into an oil deposit must be determined. This makes necessary the measurement of the pressure and of the ratio gas-liquid in the deposit. These observations refer primarily to sandstone, but are also applicable to limestone and dolomite.

Amano, Hikaru, Atsushi Kasai, and Takeshi Matsunaga, 1985
Simultaneous measurement of Rn and its progeny in cave air by liquid scintillation techniques and alpha-ray spectrometry:
Health Physics, 49(3): 509-511.

Amardeil, P., and R. Gonnard, 1962
Utilisation d'un compteur proportionnel à grande surface pour la mesure des faibles activités [Use of a large surface proportional counter for measuring low activities]:
France, Commissariat à l'Énergie Atomique, Centre d'Études Nucleaires, Grenoble, 15 p.
Nucl. Sci. Abs. 17:20343:
A proportional counter having a large surface (150 cm^2) is used at the Grenoble Nuclear Studies Center for the low-activity measurements made in controlling the site. This apparatus makes it possible to count directly high surface area filters (Dapaf filters for the study of the artificial radioactivity of air) and to monitor small river and rainwater samples.

Ambronn, Richard,
Vorrichtung zur Messung von Ra-Em, vorzugsweise des Em-Gehaltes der Bodenluft [Apparatus for the measurement of radium emanation, primarily of the emanation content of soil air]:
Deutsches Reichspatent 420,511

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in Jahrbuch des Halleschen Verbandes für die Erforschung der mitteldeutschen Bodenschatze, 3(2): 21, 44
[Rn in soil gas.]

Ambronn, Richard, 1922
Umschau, Frankfurt am Main, 26: 529-32, 766-9; 27: 55-9 (1923)

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Methoden der angewandten Geophysik [Methods of applied geophysics]:
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Chem. Abs. 86:76226z
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Australasia Coll. Radiologists Jour., 4: 104-105
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Royal Soc. [London] Proc., Ser. A 272(1348): 15-32
Nucl. Sci. Abs. 17:14275
The rate of escape of Rn-220 from solids containing radio-thorium depends upon both recoil and diffusion and is steady at any temperature if the distribution of radioactive material remains unchanged. At very high temperatures the emanating power of ThO_2 (and other oxides) increase with time at constant temperature; the emanating power-temperature characteristics eventually resemble those of a solid with a surface source of thoron. The enhancement of emanating power decays with time in such a way as to prove that Ra-224 is no longer uniformly distributed, although the distribution of the parent Th-228 is unchanged; the Ra-224 atoms, formed by recoil from Th-228, migrate during their lifetime to trapping sites, which, in this case, are on the surface. Similar effects are found with $BaThO_3$ and BaF_2, even though Ra-224 can replace Ba isomorphously; these compounds are anionic conductors and have only a low concentration of vacant cation sites at high temperatures. If (e.g., in BaO) vacant sites capable of accepting large cations are present in high concentration, the recoil atoms are trapped and retained in uniform distribution.

Anderson, R.Y., and E.B. Kurtz, Jr., 1956
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Econ. Geology, 51(1): 64-68

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Geophys. Abs. 79-2866
[Gives partial differential equation for diffusion of non-radioactive (hydrocarbon) gas through homogeneous overburden.]

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An attempt to forecast the moment of origin of recent tremors of the Tashkent earthquake through observations of the variation of radon [in Russian], *in* The Tashkent earthquake of 26 April 1966 [in Russian]:
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Geophys. Abs. 165-309:
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Nucl. Sci. Abs. 15:19631:
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Internat. Geol. Cong., 21st Copenhagen, Proc. pt. 15: 51-66.
A peat discovered during radioactivity prospecting in the Masugnsbyn area of northern Sweden shows a remarkably high uranium and radon content, related to the occurrence of radioactive springs in the vicinity. The source of the uranium is beneath the cover of postglacial sediments, the radioactive matter is transferred

to the peat, the humus of which serves as a collector of uranium. Preliminary laboratory experiments with leaching of uranium from radioactive iron ores from the area showed that waters containing HCO_3^- and having a pH of about 7.5 can leach an amount sufficient to account for the uranium content of the natural waters.

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Am. Geophys. Union Trans., 37(2): 216-220

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Oil and Gas Jour., 70(23): 88-91, 97

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Oil and Gas Jour., 70(24): 152-161

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Radioactivity of rivers and lakes in parts of Garland and Hot Spring Counties, Arkansas:
Econ. Geology, 48: 551-567
A wide range of radon content in surface waters was noted incidental to studies of radon in spring and well waters of Hot Springs and Potash Sulphur Springs, Garland County, Arkansas. Subsequently a reconnaissance survey of radioactivity of nearby streams and lakes showed the radon contents of streams range from 0.0084 to 1.07 nCi/L of water, and those of lakes range from less than 0.001 to 0.123 nCi/L. Streams flowing over Ordovician black shales contained an average of 0.275 nCi radon per liter of water. Those flowing over black Stanley shale of Mississippian age contained an average of 46 pCi/L of water. The radon content of Potash Sulphur Creek where it flows over the uranium-bearing rocks of the Potash Sulphur Springs syenite complex ranged from 0.09 to 3.16 nCi/L of water. Ground water in a drill hole in uranium-bearing rock contained an average of 58.75 nCi/L of water. Waters from small springs were shown to lose as much as 41.3 percent of total radon content in the first 4 feet of surface flow below the point of emergence. The methods of radon determination in the field are believed applicable to prospecting for low-grade uraniferous deposits, especially in black shale areas, in areas of heavy overburden, and in areas of saturation by ground water where ordinary detection devices may be somewhat limited.

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Nature [London], 180(4576): 85-96

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Sposob opredeleniya popravok za emanirovaniye radioaktivnykh rud v yestestvennom zaleganii pri radiometricheskom oprobovanii [A method of determining the corrections for emanation of radioactive ores in place in radiometric assaying]:
Ministerstvo Geologii i Okhrany Nedr SSSR, Voprosy Rudnoy Geofiziki, 3: 106-110
Quantitative estimation of emanation of radioactive ores in place is necessary in order to take that factor into account in radiometric surveying. The correction is calculated and the value of the emanation coefficient is estimated for several deposits. Comparison of independent sets of data confirms the validity of the method used. Quantitative estimation of ores in place shows that without introduction of the appropriate correction, estimates of reserves based on radiometric sampling may be much too low.

Asayama, Tetsuji, 1953
On the radioactivity of rocks in Japan and vicinity, I. Radium contents of volcanic rocks:
Kyoto Tech. Univ. Faculty Indus. Arts Mem. 2-B: 53-69
Geophys. Abs. 173-333:
A summary of the results of determinations of radium contents of volcanic rocks in Japan and vicinity by Japanese workers. The results of measurements on 20 rocks are tabulated; mean value for liparites and dacites is 1.19 pg of radium per gram of rock, of andesites 0.41 pg, and of basalts 0.33 pg. A general increase in radium in proportion to silica has been noted in rocks from central and western Japan but not in those from Hakone volcano or Ooshima Island. A tendency of radium to increase in proportion to potash is more distinct. In some cases a correlation was observed between radium content and order of eruption, suggesting concentration of radium in the residual magma during crystallization; but in other cases there was a decrease or no correlation at all. No definite conclusions can be drawn regarding the relation between texture or crystallinity and radium content; an earlier statement that glassy rocks are more radioactive is now qualified. The "pottery stones" (hydrothermally or pneumatolytically altered liparites of acid tuffs) show a higher radium content than lavas; radioactive elements may have been introduced with the altering solutions. Finally the geographic distribution of radium among and within volcanic zones is summarized.

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Die Radioaktivität der Deutschen Heilquellen und ihr Anteil an deren therapeutischer Wirkung [The radioactivity of German medicinal springs and their share of their therapeutic effect]:
München, 77 p.

Asher-Bolinder, Sigrid, D.E. Owen, and R.R. Schumann, 1989
Soil-characteristic and meteorologic controls on radon in soil gas in the semiarid western United States [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 497
The interaction between soil characteristics and meteorologic events affects soil structure and soil moisture. In turn, soil structure and moisture interact to influence both radon transport and emanation within the soil. Unirrigated smectitic clay-loam soil on a terrace deposit in Lakewood, Colorado, was monitored daily for soil-gas radon at depths of 50, 75, and 100 cm. Radon data were integrated with hourly weather data, and tensiometers measured soil moisture at study depths. Soil moisture during spring, summer, and fall ranged from 10 to 30 weight percent. Radon concentrations varied by an order of magnitude throughout the year; day-to-day variations of 100-200 percent were controlled mainly by barometric pressure changes. Transitory soil-moisture caps blocked soil-gas exchange with the atmosphere and also raised radon content. Larger seasonal radon variations were controlled primarily by interaction between soil cracks when present, and radon emanation, both of which were controlled mainly by soil moisture. Grain-to-grain permeability is limited in this smectitic soil. Insolation and evaporation due to wind both control soil-crack development. In summer to early fall soil cracks (as deep as 90 cm and as wide as 2 cm at the surface and 0.1-03 cm at depth) developed in the soil. Crack polygons 15-25 cm across persisted through summer and fall except when precipitation temporarily healed cracks at the surface. Radon concentrations at 100-cm depth in soil with surface cracks >2 mm wide were nearly half the concentrations noted when no cracks were present. Thus, atmospheric air diluted soil gas at depth in deeply cracked soil. Emanated radon from the six soil horizons varied by an order of magnitude, depending on water content. Soil horizons contained 2.0-2.8 pCi/g radium and emanated <100 to >1000 pCi/L-kg soil of radon in laboratory study. Radon emanation was maximized when water was 9-17 weight percent of the sample. Temperature effects were not discernible at 5, 20, 36°C, characteristic of much of the yearly weather range. Samples at -18°C, the low temperature extreme, showed lessened apparent emanation because ice within soil pores blocked transport from the soil.

Asher-Bolinder, Sigrid, Douglass E. Owen, and R. Randall Schumann, 1990
Pedologic and climatic controls on Rn-222 concentrations in soil gas, Denver, Colorado:
Geophys. Research Letters, 17(6): 825-828

Soil-gas radon concentrations are controlled seasonally by factors of climate and pedology [soil character]. In a swelling soil of the semiarid western United States, soil-gas radon concentrations at 100-cm depth increase in winter and spring due to increased emanation with higher soil moisture and the capping effect of surface water or ice. Increased soil moisture results from a combination of higher winter and spring precipitation and decreased insolation [solar heating] in fall and winter, lowering soil temperatures so that water infiltrates deeper and evaporates more slowly. Radon concentrations in soil drop markedly through the summer and fall. The increased insolation of spring and summer warms and dries the soil, limiting the amount of water that reaches 100 cm. As the soil dries, radon emanation decreases and deep soil cracks develop. These cracks aid convective transport of soil gas, increase radon's flux into the atmosphere, and lower its concentration in soil gas. Probable controls on the distribution of uranium within the soil column include its downward leaching, its precipitation or adsorption onto B-horizon clays, concretions, or cement, and the uranium content and mineralogy of the soil's granitic and gneissic precursors.

Ashman, G.C., 1908
A quantitative determination of the radium emanation in the atmosphere:
Am. Jour. Sci. Ser. 4, 26(152): 119-122
[Effect of weather on radon content of atmosphere; condensation of radon in copper tubing immersed in liquid air.]

Aswathanarayana, U., 1956
Transfer of radioactive matter through rocks by diffusion:
Bur. central séismol. internat. Pubs., sér. A, Travaux sci., (19): 137-149
Geophys. Abs. 173-328:
An attempt is made to apply the physical principles of diffusion in spherical shells to investigate the effect of a batholithic intrusion on the radioactivity distribution patterns in the intruded rocks. Starting with fundamental laws of diffusion, a mathematical analysis is developed to calculate the quantity of radioactive matter added to any unit area of cross-section in the spherical shell. Three cases are treated: first that of a batholith providing a continuous supply of radioactive elements to be diffused into the surrounding rocks, which have an initially uniform distribution of radioactive matter; the second case is similar but takes into account the diffusional history of radioactive ions; and the third assumes an initially variable distribution of radioactive matter in the country rock. The last corresponds best to conditions in nature but is an approximation at best, for several factors should be taken into account on which we have virtually no data. The existence of thermal gradients and decay of radioactive elements during diffusion should also be considered. Systematic work on this subject, therefore, requires more data on the consolidational history of a batholith, adduced from geological thermometry; on diffusion constants of radioactive elements through various rock types; on radioactive content of batholithic material; on the dimensional relationship between batholith and intruded rocks; and on temperature gradient in the country rock due to the batholith and its effect on the diffusion constants.

Atanasiu, G., 1962
Contribution to the radio-chronology of some natural deposits [in Romanian]:
Acad. Repub. Pop. Romine, Studii Cercetari Fiz., 13: 411-426
Nucl. Sci. Abs. 17:14483:
The results obtained for the dating of some natural deposits several thousand years old are reported. It was shown that some deposits of mineral waters contain only Ra and its descendants without any U which gives birth to the Ra. The U remains at some depth, fixed by physicochemical processes. By determining the Ra of recent deposits of a similar souce of mineral water and by determining the Ra of old deposits of the same source, the age of these deposits can be calculated. For example, for old deposits of chalky bedrock of the sources of Singeroz mineral water, an age of approximately 7900 years was found. Deeper beds of the same deposits have a greater age. Another method studied is based on the disintegration of C^{14}. It is shown how the radiocarbon of the atmosphere passes into stalactites and stalagmites of a cave where it produces a weak

beta activity of these concretions and, at the same time, an ionization of the air of the caves which contain chalky concretions during their formation. This method permits the dating of the cave concretions and an evaluation of the ionization of the air. It was found that the formation of a gram-mole of concretion produces in the air of the caves a quantity of $3x10^5$ ions/min approximately.

Atayev, S., T. Ashirov, Dzh. Ishankuliyev, and S.L. Tret'yakova, 1984
Radioaktivnyye emanatsii v podpochvennom vozdukhe v Ashkhabadskoy seysmoaktivnoy zone [Radioactive emanations in sub-soil air along the Ashkhabad active seismic zone]:
Akad. Nauk Turkmenskoy SSR, Izvestiya, Ser. Fiz.-Tekh., Khim., i Geol. Nauk, No. 5: 62-65.

Aurand, K., W. Jacobi, and A. Schraub, 1956
Untersuchungen über die Folgeprodukte des Radons im Gasteiner Thermalwasser [Investigations on the radon decay products in the Gastein thermal water]:
Österreich. Akad. Wiss. Sitzungsber., Abt. 2, Band 165, Heft 1-4: 133-148
Geophys. Abs. 169-123
Radioactivity of the thermal waters of Bad Gastein and Bad Hofgastein was measured at different points in their distribution system in order to determine whether the radon decay products were present in equilibrium quantities. In the large majority of samples, including those taken right at spring mouths, the short-lived decay products are present in less than 20 percent of the equilibrium amount. It is assumed that the same mechanism that causes precipitation and deposition of the decay products in the distribution system, between spring outlets and points of use, is also at work as the waters percolate underground, thus causing the deficiency at the outlet. The variation is so great among the various points measured that the mean value is without significance.

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A laboratory study of radon emanation from domestic uranium ores, *in* Radon in Uranium Mining, Proc. Panel, Washington, DC, 4-7 September 1973:
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Chem. Abs. 85:127415z:

Austin, S. Ralph, and Robert F. Droullard, 1978
Radon emanation from domestic uranium ores determined by modifications of the closed-can, gamma-only assay method.
U.S. Bur. Mines Rept. Inv. 8264: 74 p.
Chem. Abs. 88:160454w:

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Commonwealth X-ray and Radium Laboratory annual report for the year ended 30th June, 1961:
Australia Commonwealth X-Ray and Radium Lab., Melbourne, Rept. NP-10982, 30 p.
The service and investigational activities of the Commonwealth X-Ray and Radium Laboratory are reported. Radium, radon, x-ray, isotope, radiation, and advisory services are discussed. The work of the radiochemical and low-level measurement facility is described.

Avrorin, V.V., V.D. Nefedov, and M.A. Toropova, 1976
Concentration of radon and determination of small quantities of radon-222 [in Russian]:
Radiokhimiya, 18(4):518-519
Chem. Abs. 86:59997j

Aydarkin, B.S., and A.S. Pevzner, 1937
Opyt primeneniya emanatsionnogo metoda na zhil'nom mestorozhdenii toria [Experience in the application of the emanation method to vein deposits of thorium]:

Tsentral. Neft. i Gaz. Razved. Inst. Materialy, Geofizika, sbornik 4, p. 3-13.

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Control of radon and its daughters in mines by ventilation:
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[See Tsivoglou and Ayer, 1953.]

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Academic Press, New York; 177 p.

Baillieul, Thomas A., and J.J. Dexter, 1982
Evaluation of uranium anomalies in the Hylas Zone and the northern Richmond Basin, East-central Virginia, *in* Goodknight, Craig S., compiler, et al., Reports on Investigations of Uranium Anomalies:
Grand Junction, Colo., Bendix Field Eng. Corp., U.S. Dept. Energy Rept. GJBX-222(82), p. 1-16

Baker, J.H., W.A. Beetem, and J.S. Wahlberg, 1964
Adsorption equilibria between earth materials and radionuclides, Cape Thompson, Alaska:
USAEC TID-20638, U.S. Geol. Survey: 40 p.
Nucl. Sci. Abs. 18:25688:
The concept and derivation of a distribution coefficient were developed. Ion exchange and the nature of competition among cations are given. Distribution coefficients for carrier-free cesium, strontium, and iodine were determined on 17 samples of earth materials collected during July, 1961, in the vicinity of Cape Thompson, NW Alaska. High percentage uptake of these ions was measured under the test conditions. Cesium adsorption, at 1 day, was found to be represented by the mass-action equation. Distribution coefficients for cesium adsorption were so large that, in all but a few cases, very little of this nuclide would remain long in solution in natural waters of the area. Strontium adsorption was found to be a function of the calcium-plus-magnesium concentration and to be independent of the sodium concentration. In most samples, its equilibrium was reached in less than 1 day. Iodine sorption varied with percent organic matter for several days, a substantial part of it probably would be removed from solution in the natural waters.

Bakulin, V.N., 1969
Dependence of radon exhalation and its concentration in the soil on meteorological conditions [in Russian]:
Uch. Zap. Kirov. Gos. Pedagog. Inst., 30: 70-79
Chem. Abs.74(8):33637u:

Balek, Vladimir, 1981
Inert gases yield data on changes in solid material:
Industrial Research and Development, July: 114-119
First paragraph: Emanation thermal analysis (ETA) is a method for obtaining information about a material in the solid state and about changes taking place within the solid. The method is based on measurement of inert gases [Rn and Tn] released from the solid at various temperatures.

Balek, V., and K.B. Zaborenko, 1968
Use of inert radioactive gases for the study of solids [in Russian]:
Radiokhimiya, (10): 450-468
[Bibliographic survey, 92 references.]

Banerji, Partha and S.D. Chatterjee, 1964
Radon content of rainwater:
Nature [London], 204(4964): 1185-1186
Geophys. Abs. 219-318:
The radon content of about 40 samples of rainwater collected during the past rainy season in Calcutta was measured. The specific activity varied from 5×10^{-12} to 3×10^{-10} Ci/L. Maximum values could be associated with scant and isolated rainfalls, the specific activity diminishing rapidly as the amount of rainfall increased. For equivalent rainfalls, the specific gravity of nocturnal rains was usually less than that of diurnal rains, confirming the diurnal variation of radon content of the atmosphere.

Baranov, V.I., 1925
K teorii aspiratsionnogo pribora dlya izmereniya radioaktivnosti mineral'nykh kollektsiy [On the theory of an aspiration device for the measurement of the radioactivity of mineral collections (aggregates?)]:
Vestnik Geologicheskikh Komitet, vyp. 4.

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Opredeleniye absolyutnogo kolichestva aktiniya emanatsionnym metodom [Determination of the absolute quantity of actinium by the emanation method], *in* Meeting in Honor of the 50th Year of Scientific and Academic Service of Academician V.I. Vernadskiy, Proc., vol. 1.

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Radioaktivnyye metody i ikh primeneniye k issledovaniyu pochv [Radioactive methods and their application to soils research]:
Metody Issledovaniya Pochv, v. 4, vyp. 2

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Radiometriya [Radiometry]:
Moscow, Akad. Nauk Izdatel'stvo, 343 p.

Baranov, V.I., ed., 1957
Spravochnik po radiometrii dlya geofizikov i geologov [Handbook of radiometry for geophysicists and geologists]:
Moscow, Gosgeoltekhizdatel'stvo, 199 p.
Geophys. Abs. 174-309

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Opredeleniye emaniruyushchikh radioaktivnykh elementov po alfa-lucham [Determination of the radioactivity of emanating elements by alpha rays]:
Zhur. Analit. Khimii, 1(2): 129

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K teorii emanatsionnoy razvedki [On the theory of emanation prospecting]:
Gosudarstvennyy Radiyevyy Inst. Trudy, (2): 61-67
Geophys. Abs. 70-2302

Baranov, V.I., and Ye.G. Gracheva, 1937
K metodike izucheniya pronitsayemosti gornykh porod dlya radioaktivnykh emanatsiy [On a method to study of the permeability of rocks to radioactive emanations]:
Gosudarstvennyy Radievyy Inst. Trudy, (3): 117-122

Baranov, V.I., and Ye.G. Gracheva, 1938

O radioaktivnom gazoobmenye mezhdu pochvoy i atmosferoy [On radioactive gas exchange between soil and the atmosphere]:
Akad. Nauk SSSR Izv., ser. geogr., no. 1

Baranov, V.I., N.G. Marozova, and I.A. Mukbraneli, 1968
Emanation of genetically different soils [in Russian]:
Pochvovedeniye, (12): 52-59

Baranov, V.I., and A.P. Novitskaya, 1949
Diffuziya radona v prirodnykh gryazyakh [Diffusion of radon in natural muds]:
Akad. Nauk SSSR Biogeokhim. Lab. Trudy, (9): 161-171

Baranov, V.I., and A.P. Novitskaya, 1960
Humidity effects on emanation [in Russian]:
Radiokhimiya, (2): 485-490
Nucl. Sci. Abs. 15:2895:
An increase of emanation in humid air as compared with dry air was observed with uraninite, samarksite, and xenotime specimens. The same effect was noticed during thorium and radium evaporation from glass or pumice surfaces. It is postulated that the observed phenomenon is caused by a liquid film formed on the surface of the emanating material.

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Correlation of natural radioactive emanations in the air in relation to geologic conditions in the example of areas of certain crystalline and sedimentary rocks [in Russian]:
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Am. Geophysical Union Trans. 38(3): 386

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Am. Soc. Testing Materials Spec. Tech. Pub. No. 276: 278-288
Nucl. Sci. Abs. 15-5260:

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Uranium and radium in the ground water of the Llano Estacado, Texas and New Mexico:
Am. Geophys. Union Trans., 39(3): 459-466
Geophys. Abs. 173-334:
As the Ogallala formation in the Llano Estacado section of the High Plains of Texas and New Mexico is hydrologically and geologically isolated, the uranium and radium concentrations measured in water samples collected from 47 wells and springs in this formation are considered as inherent characteristics of the formation in this area. The uranium concentrations ranged from 0.9 to 12 parts per billion with a mean of 6.2 parts per billion, the radium concentrations from <0.1 to 0.8 pCi/L with a median of 0.1 pCi/L. The uranium concentrations tend to correlate with gross chemical characters of the waters in accordance with the expected chemical behavior of uranium. The deficiency in radium in all samples might be explained by ion exchanges.

Barker, F.B. and L.L. Thatcher, 1957
Modified determination of radium in water:
Anal. Chemistry, 29: 1573-1575

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Concentration of atmospheric radon and wind direction:
Nature [London], 190: 1092-1093
Nucl. Sci. Abs. 15:22547

Barreira, F. and J.M. Machado, 1959
Results of the determination of natural atmospheric radioactivity:
Rev. Fac. Cien, Univ. Lisboa, 2a Ser. B, 7: 57-75
Nucl. Sci. Abs. 17:3183:
Atmospheric Rn concentrations were determined almost daily in Lisbon from May 1956 to March 1958. The possible effects of wind direction, precipitation, relative humidity, and dust concentration on the Rn concentrations were studied. Continental winds were seen to be higher in Rn content than oceanic winds. Winds which traversed regions where U ores were located showed the highest Rn content.

Barrer, R.M. and D.M. Grove, 1951
Flow of gases and vapours in a porous medium and its bearing on adsorption problems. Part I. The steady state of flow:
Faraday Soc. Trans. 47, 826-837
A study was made of the steady state of flow of He, Ne, Ar, Kr, H_2, O_2, N_2, NH_3, CCl_4, and SO_2 through a bed of small nearly spherical analcite crystals. Flow rates, permeabilities, Knudsen and Poiseuille contributions to permeability, and permeability constants have been determined and used to test the applicability of several equations of flow. Significant deviations from the behavior suggested by these equations were observed, especially for vapors. Pore properties and total surfaces were determined using procedures based on steady-state flow data.

Barrer, R.M., and D.M. Grove, 1951
Flow of gases and vapours in a porous medium and its bearing on adsorption problems. Part II-Transient flow:
Faraday Soc. Trans. 47; 837-844
By measuring the time-lag L in setting up the steady state of flow, one may measure the diffusion coefficients of gases in a porous medium and obtain a mean pore radius and an interval surface of the porous medium independently of all steady state methods. In beds of analcite crystals the inert gases, permanent gases and CCl_4 behave as though they were not adsorbed appreciably at low pressures while ammonia and sulphur dioxide show strong adsorption effects. In very dilute adsorbed films of NH_3 and SO_2 surface diffusion, while not necessarily absent, is limited in extent. The lifetimes τ of molecules in the adsorbed states are then given by the equations: NH_3: $\tau = 3.1x10^{-11}$ exp(4300/RT) sec.; SO_2: $\tau = 6.6x10^{-11}$ exp(3010/RT) sec.

Barretto, Paulo M.C., 1971
Radon-222 emanation from rock and soils [abs.]:
Geol. Soc. America, Abstracts, 3(7): 499

Barretto, Paulo M.C., 1971
Radon-222 emanation from rock, soils, and lunar dust:
U.S. A.E.C. Rept. GJO-935-1(Pt. 2), p. 170-288
Nucl. Sci. Abs. 26(13):31027:
The ^{222}Rn emanation rate and the escape-to-production rate ratio were measured by alpha counting. The material was analyzed for different grain sizes, moisture, contents, and temps. Rn escape-to-production rate ratios 1 to 25 percent were found for rocks crushed to identical grain size classes and distinctly higher values, 20 to 70 percent were obsd. in soils. Natural materials at the earth's surface are divided into 3 categories: strong emanators, soils at 40 percent Rn escape-to-production rate; moderate emanators, igneous rocks at 10 to 15 percent; and poor emanators, sediments and some metamorphic rocks at 5 percent. The factors controlling the emanation rate are: grain size; nature matrix or groundmass; U distribution within the cryst.

structure; crystal damage resulting from radiation; and/or weathering. The general effect of moisture is a slight increase in the emanation rate. An escape-to-production rate ratio of 45± 20 percent was obsd. for 0.4 g of an Apollo 12 dust. The Rn isotope diffusion through the surface rubble and lunar atm. and the consequent fallout of Pb isotopes over the moon surface could provide a mechanism for Pb enrichment and depletion which might be related to the U-Pb discordant ages for fines compared to assocd. rocks.

Barretto, Paulo M.C., 1973
Emanation characteristics of rocks, soils and Rn-222 loss effect on the U-Pb system discordance [Ph.D. thesis]:
Houston, Rice Univ.: 166 p.

Barretto, P[aulo] M.C., 1975
Radon-222 emanation characteristics of rocks and minerals, *in* Radon in Uranium Mining:
Vienna, Internat. Atomic Energy Agency STI/PUB/391, p. 129-150
Chem. Abs. 85:127414y:

Barton, Charles J., R.E. Moore, and P.S. Rohwer, 1973
Contribution of radon in natural gas to the natural radioactivity dose in homes:
Oak Ridge, Tenn., Oak Ridge Natl. Lab. Rept. ORNL-TM-4154, 29 p.
Nucl. Sci. Abs. 28(2):2973:
The Rn concn. in natural gas supplied to several metropolitan areas in the U.S. was detd. and the av. value of 20 pCi/L was selected to est. the contribution of this source of natural radioactivity to doses from Rn daughters received by individuals in homes. Rn daughter concs. in the home atm. were calcd. by use of computer programs for an 8000-ft^3 house in which 27 ft^3 of gas per day is used for cooking in an unvented kitchen range. The total estd. dose to the bronchial epithelium included contributions from Rn daughters in the ventilation air, each of which was assumed to be present at a concn. of 0.13 pCi/L and from Rn plus daughters in the natural gas. The latter contribution averaged approx. 30% of the total dose. There was a 3.5% decrease in the estd. total dose when the air change rate increased from 0.25 to 2.0 per hr. Rn and Rn daughters entering the home with natural gas produce a negligible fraction of the total home dose to the respiratory system of home occupants from airborne Rn daughters.

Barton, C.J., R.E. Moore, and P.S. Rohwer, 1975
Contribution of radon in natural gas to the dose from airborne radon-daughters in homes, *in* Noble Gases [Symp.], Las Vegas, Nev., 1973:
U.S. Energy Research Development Administration Rept. CONF-739715: 134-143

Barzic, J.Y., 1976
Study of uranium mine aerosols [in French]:
Rept. 1976, CEA R 4743, 97 p.
INIS Atomindex 7(17), Abs. 260408:
With a view to radiation protection of uranium miners a study was made of the behavior of radioactive and nonradioactive aerosols in the atm. of an exptl. mine where temp., pressure, relative humidity, and ventilation are kept const. and in the air of a working area where the nature of the aerosol is dependent on the stage of work. Measurements of radon and daughter products carried out in various points of working areas showed that the gas was quickly diluted, equil. between radon and its daughter products (RaA, RaB, RaC) was never reached, and the radon aerosol contact was of short duration (a few minutes). By using a 7-stage Andersen impactor particle size distribution of the mine aerosol (particle dia. >0.3 μm) was studied. The characteristic diams. were detd. for each stage of the Anderson impactor, and statistical anal. verified that aerosol distributions in the lower stages of the impactor were log-normal in most cases. Finally, detn. of size distribution of alpha radioactivity showed it was retained on fine particles. The percentage of free alpha activity was evaluated by using a diffusion battery.

Bastin-Scoffier, Genevieve, 1961
Expose de methodes en spectrographie α. Application aux corps de la Famille du radium naturel (These) [Outline of methods in alpha spectrography. Application to compounds of family of natural radium (thesis)]:
Univ. Paris, NP-11090: 113 p.
Nucl. Sci. Abs. 16:4322:
Methods for magnetic spectrography of alpha particles are reviewed and a particular experimental arrangement is described that is designed for studies of the highly excited states of alpha emitting nuclei. This apparatus is used to measure the spectra from several nuclei in the Ra family: Po-210, Po-214, Po-218, Rn-222, Rn-226, Bi-210, Bi-214, and At-218.

Bateman, J.D., 1949
Prospecting with the Geiger counter:
Canadian Inst. Mining Metallurgy Trans., 71: 111-116
Geophys. Abs. 142-12279:
The Geiger-Müller counter and its use in prospecting for radioactive ores is described. Field experience has shown that 1 to 2 feet of solid rock, 3 to 5 feet of unweathered compact overburden, or a somewhat greater depth of loose soil may effectively shield even important pitchblende occurrences from detection with the counter. As the intensity of the emanations varies inversely as the square of the distance from the source, deposits may remain undetected by the portable counter at distances of 30 to 40 feet. Counter tubes for which the normal cosmic ray background count is of the order 40 to 40 impulses per minute are most satisfactory for counting by earphone.

Bates, Robert C., 1977
Rock sealant restricts falling barometer effect:
Mining Engineering, 29(12): p. 38-39
These analyses demonstrate that radon contamination resulting from a change in barometric pressure is reduced by a rock [sealant] coating. This, however, is not the major fact to be kept in mind. More important is that, despite the imperfection in the coatings, the radon concentration in the mine atmosphere was reduced through the use of coatings by more than 70% from an average of 480 to 140 [pCi/L].

Bates, Robert C., 1980
Time dependent radon loss from small samples:
Health Physics, 39: 799-801
In connection with a study of the effect of moisture on the radon emanation coefficient in small uranium ore samples, the question arose about the time needed to reach a steady-state flux of radon from a sample after opening of its sealed storage and counting can. It was felt intuitively that the time required to reach equilibrium would depend on the pore-filling fluid and the diffusion coefficient. No evaluation of this effect was found in the literature. A previously developed analytical code was used with a cylindrical model 9.2 cm long and 3.843 cm in radius, 0.2 porosity, 1E-7 cm^2 permeability, 300 K, and pore-fluid viscosity of 1.8E-4 g/cm-s. The periods required to reach a steady-state flux were computed to be 0.25, 1.25, 10.0, 70.0, and >100.0 hours, respectively, for diffusion coefficients of 1E-2, 1E-3, 1E-4, 1E-5, and 1E-6 cm^2/s.

Bates, Robert C., and John C. Edwards, 1978
Radon emanation relative to changing barometric pressure and physical constraints, *in* Conference on Uranium Mining Technology, 2d, Reno, Nev., November 13-17, 1978:
Background is given on the various equations used to describe diffusion and convective flow of radon in porous media. Equations developed by the Bureau of Mines for modeling diffusion and Darcy flow through multilayered porous media are described briefly and examples of their use are given. Cases evaluated include overpressurization, underpressurization, and cyclic pressurization of different-sized ore bodies. Another part of the analysis deals with the effect of pinholes on the effectiveness of a radon barrier coating.

Bates, Robert C., and John C. Edwards, 1981
The effectiveness of overpressure ventilation: a mathematical study, *in* Gomez, Manuel, ed., Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, International Conference, Golden, Colo., October 4-9, 1981:
Golden, Colo., Colorado School of Mines, Chap. 24, p. 149-154
Results are given of a mathematical study of overpressurization ventilation effects in underground uranium mines. The mathematics and computer codes make it possible to analyze many facets of transient and steady-state radon diffusion with Darcy flow. Rapid changes in radon flux occur after imposing a pressure differential across the model. Flux into the model mine drops to near zero and then increases to the steady state level, while the sink flux increases rapidly and then drops slightly to the steady-state level. Magnitudes of mine flux decreases and sink flux increases are dependent upon the distance from the mine to sink, permeability, and the amount of overpressure.

Bates, Robert C., and John C. Franklin, 1977
U.S. Bureau of Mines radiation control research, *in* Conference on Uranium Mining Technology, Reno, Nev., April 25-29, 1977, Proceedings:
Efforts by the Bureau of Mines to measure and reduce harmful concentrations of radioactive gas in uranium mines are discussed. Equipment has been developed for simultaneous monitoring of radon and radon daughters, temperature, relative humidity, absolute pressure, and air velocity. The effects of changes in weather conditions, ventilation, and mining methods on the mine atmosphere can therefore be evaluated. Addition of water to the rock substantially increases the radon emanation from rock walls. Control methods being evaluated include overpressurization, cyclic ventilation, bulkheading, backfilling with tailings, and application of sealants to the mine rock.

Bates, R.C. and R.L. Rock, 1962
Estimating daily exposure of underground uranium miners to airbone radon daughter products:
U.S. Bureau of Mines Rept. of Investigations 6106: 22 p.
Nucl. Sci. Abs. 17:20276:
The daily exposure of uranium mine workers to radon daughters was estimated by 2 methods of sampling, detailed and spot check. The breathing zones of 8 workmen in 3 underground uranium mines were sampled for an entire shift; 20 to 36 radon daughter samples were collected per manshift. Analysis indicated that a suitably accurate estimate for the full-shift exposure could be made by time weighting a lesser number of representative radon daughter samples. Additional detailed studies were made in 7 mines to learn more about the full-shift radon daughter exposures and to test the spot check method. The method is recommended for use by the mining companies, government agencies, and others who wish to evaluate the radon daughter exposure of uranium mine workers. The spot check method is simple, fast, and gives a reasonably accurate estimate of the full-shift exposure.

Bates, Thomas F. and Erwin O. Strahl, 1957
Mineralogy, petrography, and radioactivity of representative samples of Chattanooga Shale:
Geol. Soc. America Bull., 68(10): 1305-1314
Geophys. Abs. 171-309:
Alpha-tracks obtained from emulsion-covered thin sections of Chattanooga shale are not sufficiently concentrated at any spot to indicate the presence of a uranium mineral. Approximately 70 percent of the uranium atoms are randomly distributed throughout the fine-grained matrix; another 25 percent is concentrated in organic-pyrite-clay complexes such as nodules and discrete organic bodies. In unweathered samples there is no relation between uranium distribution and textural features such as bedding. The uranium was precipitated from sea water under reducing conditions and has not been redistributed following compaction of the sediment, except along joint planes and weathered surfaces.

Battaglia, A., E. Bazzano, and T. Carioni, 1984

Indoor dose in Milan:
Radiation Protection Dosimetry, 7(1-4): 283-285
Chem. Abs. 101:99860u

Bauer, W.J.C., and W.F.G. Swan, 1917
Results of atmospheric measurements made aboard the GALILEE, 1907-08, and the CARNEGIE, 1909-1916:
Carnegie Inst. Washington, Dept. Terrestrial Magnetism Pub. 3: 422 p.

van Bavel, C.M.H., 1952
Gaseous diffusion and porosity in porous media:
Soil Sci., 73: 73-80

Bear, Jacob, and Yehuda Bachmat, 1986
Macroscopic modelling of transport phenomena in porous media. 2: Applications to mass, momentum and energy transport:
Transport in Porous Media, 1(3): 241-269

Bechmat, Yehuda, and Jacob Bear, 1986
Macroscopic modelling of transport phenomena in porous media. 1: The continuum approach:
Transport in Porous Media, 1(3): 213-240

Beck, Harold L., 1974
Gamma radiation from radon daughters in the atmosphere:
Jour. Geophys. Research, 79(15); 2215-2221
Chem. Abs. 66820w:

Becker, A., 1906
Radioactivity of the ash and lava from the April eruption of Vesuvius [in German]:
Annalen der Physik, 20(3): 634-638
Sci. Abs. 1391 (1908)

Becker, A., and K.H. Stehberger, 1929
Über die Adsorption der Radiumemanation [On the adsorption of radon]:
Annalen der Physik, 1:529-555

Becker, F., 1934
Messungen des Emanationsgehaltes der Luft in Frankfurt a.M. und am Taunus-Observatorium [Measurements of the emanation content of air in Frankfurt am Main and at Taunus Observatory]:
Gerlands Beitr. Geophys., 42: 365-384
It is shown through measurements with Israel's emanometer in Frankfurt am Main and at Taunus Observatory that the emanation content of free atmospheric air is predominantly dependent on vertical convection. Investigations at the boundary layer of two air masses at about 820 m height show a concentration of radon at the underside of the inversion whereas above the radon content becomes vanishimgly small at greater heights from the sunken air.

Becker, K.H., A. Reineking, H.G. Scheibel, and J. Porstendoerfer, 1984
Radon daughter activity size distributions:
Radiation Protection Dosimetry, 7(1-4): 147-150
Chem. Abs. 101:99838t

Beckerley, J.G., 1960

Nuclear methods for subsurface prospecting:
Ann. Rev. Nuclear Sci., 10: 425-460

Been, J.M., G.M. Reimer, and S.L. Szarzi, 1989
Soil-gas radon distribution in Frederick County, Maryland:
Eos, Am. Geophys. Union Trans., 70(5): 500
Soil-gas radon concentrations in Frederick County, Maryland correlate with lithology and geologic structure. Highest concentrations are found in phyllites and schists; lower concentrations are found in the carbonates of Frederick Valley; lowest concentrations correlate with quartzite ridges and mountains. Ground spectral gamma-ray measurements correlate well with the radon in the extremes but the correlation becomes unclear in the middle range of radon concentrations between 500 and 2000 pCi/L. In some areas of the county, several populations of radon data are evident within a single geological formation. Such is the case for the rhyolites of the Catoctin Mountain region suggesting inhomogeneities within the volcanics. ¶The study was conducted in two phases in 1988. Seasonal variations influence soil-gas radon so that concentrations were 30 percent higher in a dry period in late July than during an extended wet period in May. Despite seasonal differences, the average concentrations in some areas exceed 2000 pCi/L and are great enough to indicate that there is a strong potential for indoor radon concentrations to exceed the 4-pCi/L action level recommended by the U.S. Environmental Protection Agency. A radon potential map of rocks and soils could be derived from this data base that would be useful for land planning and establishing construction practices to minimize the problem.

Been, Josh M., S.L. Szarzi, and G.M. Reimer, 1989
Radon as a geologic mapping tool [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(6): A143
Although the current interest in radon is a public health issue, most previous geologic studies that involved radon have been to evaluate its use for predicting volcanic eruptions, forecasting earthquakes, or locating uranium deposits. The wide range of soil- gas concentrations found in areal surveys, often several orders of magnitude, suggests that radon might be useful in mapping differences in rock type or geologic structure. A soil-gas reconnaissance survey of Frederick County, Maryland, has shown that the radon concentrations exhibit characteristic distributions for soils derived from various lithologies. The survey also indicates a contrast in radon concentration across major structural contacts or facies changes. While these concentration differences are not always unique, some are very distinctive. For example, quartzites, which form the core of ridges and mountains of the southern and western part of the county, have a mean radon concentration of <500 pCi/L, whereas phyllites, which occur in the Piedmont of the eastern part of the county, have a mean radon concentration of >1500 pCi/L. The Catoctin rhyolites exhibit three populations of radon concentrations, with means of about 700, 1300, and 2300 pCi/L, suggesting subtle chemical variations within the parent material. Radon concentration differences from 500 to over 4000 pCi/L occur within a few meters across the Martic Line, a contact separating the Cambro-Ordovician limestones of the Frederick Valley from the pelitic schists to the east. Traverses across the Triassic border fault, which roughly defines the western side of the Frederick Valley, exhibit similar strong contrasts in soil-gas radon concentrations. Although rock type and structural contacts are well defined in the areas of Frederick County included in this study, it may be possible to use radon soil-gas concentrations for mapping hidden lithologies and structural contacts.

Běhounek, Franz, 1925
New method of determining the content of radium emanation in the atmosphere:
Jour. Physique et Radium, 6: 397-400
See Chem. Abs. (1925) 1756-2
[Absorption of radon from 130-L glass chamber of air into CS_2 at -80°C. Solubility coefficients studied.]

Běhounek, F., 1926
Origin of penetrating radiation in the atmosphere [in German]:

Physikal. Zeitschrift, 27: 8-10
See Chem. Abs. (1926) 1175

Běhounek, Franz, 1927
Über die Verhältnisse der Radioaktivität in Uranpecherzbergbaurevier von St. Joachimsthal in Böhmen. (Radioaktivität der Quellen, Boden- und Grubenluft und der Atmosphäre) [On the proportions of radioactivity in the uranium mining district of St. Joachimsthal in Bohemia. (Radioactivity of springs, ground and mine air, and the atmosphere]:
Physikal. Zeitschrift, 28(9): 333-342

Běhounek, F., 1927
Researches on the electricity and the radioactivity of the atmosphere at Sitzberg:
Jour. Physique et Radium, 8: 161-181
See Chem. Abs. (1927) 3308

Běhounek, F., and M. Majerová, 1956
Radon content of the air:
Nature [London], 178(4548): 1457
Geophys. Abs. 168-266:
Experimental determination of the radon content of air by direct ionization measurements and by the filter-paper method indicate that even in a closed room there is no constant ratio between the active deposit collected on the filter paper and the radon content of the air.

Belin, R.E., 1958
A gamma radioactivity survey of some of the geothermal areas of the North Island of New Zealand:
New Zealand Jour. Geology and Geophysics, 1(1): 156-165
Geophys. Abs. 173-339:
A preliminary survey of gamma radioactivity of some geothermal areas in the North Island of New Zealand (the results of which are tabulated) showed a wide variation in the radioactivity of soils, pools, and sinters between separate thermal areas, particularly between sulfate and chloride areas. In the Waiora area the average radioactivity of stagnant hot pools was greater than that for hot springs. In some hot pools the variation in gamma radioactivity with depth showed the presence of comparatively active ledges. Sinter deposits around these pools were more radioactive than nearby soils. It is concluded that the radioactivity observed in the pools is controlled by physical and chemical characteristics of the pools and not by the water entering from depth. Radon measurements probably would yield more valuable information about the thermal areas than gamma-activity measurements because the inert gas would be affected only slightly by the characteristics of a given pool.

Belin, R. E., 1959
Radon in the New Zealand geothermal regions:
Geochim. Cosmochim. Acta, 16(1/3): 181-191
Geophys. Abs. 177-322:
Measurements have been made on radon and thoron associated with gas and condensate samples from fumaroles and pools along the Rotorua-Taupo graben New Zealand. Methods of collection and measurements are described briefly. The values of radon to gas (R_g) range from 0.8 to 320 nCi/L for pools and 0.32 to 340 nCi/L for fumaroles; values of radon to condensate (R_c) for fumaroles range from 7 to 340 nCi/L. Radioactive discharge is found to be greater from acid igneous regions than from intermediate igneous regions. The ratio of the average R_c values for fumaroles in the acid igneous regions to the average for those in intermediate regions is equal, within experimental error, to the ratio of gamma-ray counting rates of the surface rocks in the two regions. It is, therefore, suggested that steam or water brings the radioactive gases to the surface.

Bell, K.G., 1957
Uranium in petroleum and rock asphalt:
U.S. Geol. Survey Rept. TEI-697: 85 p.

Bell, Kenneth G., Clark Goodman, and Walter L. Whitehead, 1940
Radioactivity of sedimentary rocks and associated petroleum:
Am. Assoc. Petroleum Geologists Bull. 24(9): 1529-1547.
Determinations of the radioactivity of 21 sedimentary rocks and 7 associated crude oils have been made by the precision method developed by R.D. Evans. The specimens consisted of cuttings and cores from wells in the Bartlesville, Cromwell, Frio, Woodbine, and Viola-Simpson formations. Considerable variability in radioactivity was found in the sandstones (1.4 to 0.19 pg Ra/g) and limestones (1.3 to 0.18 pg Ra/g). The radium content of limestones decreases with increasing purity. The shales were uniform (1.2 to 1.0 pg Ra/g). Apparently, discrete mineral particles in sandstone and impurities in limestone account for their occasional high radioactivity. The radon content of the crude oils (0.47 to 0.05 pCi/g of oil) was in one sample 38 times, and averaged 10 times, the amount in equilibrium with the radium present. The results corroborate the inferences of former investigators that radon tends to concentrate in crude oil. Maximum radon content and maximum ratio of radon to radium were found in petroleum produced from a permeable, Oligocene (Frio) sandstone of high radioactivity. Cracking of hydrocarbons with generation of hydrogen has been proved by S.C. Lind [1928, 1938] to result from bombardment with alpha rays. The amounts of radioactivity found in these crude oils are quantitatively sufficient to cause appreciable cracking by alpha radiation during geologic time. These reactions, together with subsequent hydrogenation, may account for important changes in petroleum. This hypothesis would also explain the presence of hydrogen in some natural gases. The hydrogen content of soil gases is suggested as a possible method of geochemical prospecting for oil fields. [45 items in bibliography]

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New isotopes of emanation and francium: ^{223}Em, ^{224}Em, and ^{224}Fr:
Jour. Inorg. Nuclear Chem, 19:197-203
An examination of the products of the interaction of thorium with 230 MeV protons revealed evidence for the existence of the neutron-excess isotopes: Em^{223}, Em^{224}, and Fr^{224}. The existence of these three new isotopes was confirmed by identification of their decay products: Ra^{223} and Ra^{224}.

Belluigi, Arnaldo, 1942
Determinazione della potenza della coperture e profondita di alimentatori geologici metaniferi con misure gasometriche [Determination of the depth and stratum thickness of geological accumulations of methane by means of gasometric measurements]:
Metano, 4(11): 13 p
Geophys. Abs. 119-7714

Belyakova, L.D., V.V. Gromov, A.V. Kiselev, and V.I. Spitsyn, 1962
Adsorption of various substances on radioactive barium sulfate [in Russian]:
Radiokhimiya, (4): 410-421
Nucl. Sci. Abs. 17-14277

Bender, H., 1934
Über den Gehalt der Bodenluft an Radiumemanation [On the content of radium emanation in ground air]:
Gerlands Beitr. Geophysik, 41: 401-415
The radon content of the air within the soil was investigated by taking samples from different depths (25 cm to 150 cm) beneath the surface of a lawn-covered ground at Innsbruck (Tyrol). From the end of November, 1932, to the end of May 1933 the average content of radon was at a depth of 25 to 50 cm. 80 pCi/L, in 100 cm. 540 pCi/L, in 150 cm. 350 pCi/L. These figures are in good agreement with the results of the observers.

The emanation content is varying within very wide limits, the variations being greater in smaller depths. All processes which are apt to clog the soil-capillaries tend to increase the emanation content of soil-air, for instance freezing of the soil, large water content of the soil (after rain), and snow. The maximum amount of radon within the soil occurs in winter (February and the first part of March) and does not coincide with the time of the temperature minimum. The variations of the emanation content do not take place simultaneously in different depths. The regular (seasonal) changes of emanation content are occasionally disturbed by periods of rainy weather (May 1933). Rising barometric pressure increases the emanation content of the air in the soil while decreasing pressure causes the opposite effect. The smallest emanation content was found when the soil was very dry. The amount of thorium products (ThB, ThC, etc.) in the samples did not exceed a few percent of the total activity measured in each case. [See also Geophys. Abs. 66-2140.]

Benninger, Larry K., Dale M. Lewis, and Karl K. Turekian, 1975
Use of natural lead-210 as a heavy metal tracer in the river estuarine system:
Am. Chem. Soc., Symp. ser., 18 (Marine Chem. Coastal Environment): 202-210

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Primeneniye radiometricheskikh metodov dlya resheniya nekotorykh geologicheskikh zadach [Use of radiometric methods for solution of some geologic problems]:
Geofiz. Razvedka, (9): 80-90
Geophys. Abs. 198-288

Bernhardt, D.E., F.B. Johns, and R.F. Kaufmann, 1975
Radon Exhalation from Uranium Mill Tailings Piles. Description and Verification of the Measurement Method:
Las Vegas, Nev., U.S. Environmental Protection Agency, Office of Radiation Programs Tech. Note ORP/LV-75-7(A), 39 p.
....Using the accumulation technique, field measurements of the radon flux from uranium mill tailings were made at three mills and at one experimental plot. The sample collection technique, method of calculating results, and reproducibility of the technique are described. The exhalation data (fCi/cm^2-s) reveal that reproducibility is within about 10 percent and that the variation is less than the uncertainty associated with the linear regression analysis of the accumulated radon concentration versus time. Long term measurements (greater than about 8 hours) result in accumulated concentrations that approach the radon concentration in the surface soil gas, and invalidate the assumptions inherent in the accumulation technique.

Bhandari, N., and Rama, 1963
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The radioactive contents of samples of water from Lavey-les-Bains springs (Canton de Vaud, Switzerland) were determined using the method devised by Professor Lepape. A detailed description of apparatus and procedure is given. Corrections to be applied to these results are discussed, the most important among them being the reduction to the exact time when the sample was taken because of the rapid disintegration of some radioactive substances. Final precision of the determinations is estimated equal to 3 per mille. The average content was found to be 6.1 nCi/L. Only one other spring in Switzerland is more radioactive than that investigated here.

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Beagle dogs were exposed to an atmosphere containing radon and its radioactive daughters. Excretion of the resulting radiolead was determined over a long period of time by analysis of urine and feces for Pb-210 and analysis of tissues at the end of the experiment. Initial urinary Pb-210 excretion did not correlate with either the amount of Pb-210 deposited in the lungs or the amount in the whole body. However, the amount of Pb-210 stored in the skeleton was proportional to Pb-210 deposited in the lungs. Application of the findings in determining the radiation exposure of man from inhaled radon by analysis of urine for Pb-210 are discussed.

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Nucl. Sci. Abs. 17:30681:

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The role of radiation of radon and products of its decay on the therapeutic effect in functional and inflammatory diseases of the stomach:
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Otchet k rabote Kavgolovskoy opytno-metodicheskoy partii v 1931 g. [Report of the work of the Kavgolovo experimental-methodical party in the year 1931]:
Vses. Geol.-Razved. Ob"yedineniye Izv., 51(48): 1283-1293
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The experimental-methodological works executed in 1931 had for their object the study of the distribution of emanation in a homogeneous medium (alluvium) under natural conditions, this having been found necessary

in order to determine the depths at which the emanation method still gives favorable results. The observations performed showed that 30 kg of radioactive ore, being equivalent in concentration to 0.2% U_3O_8in a state of equilibrium with decomposition products, and 90 kg of ore equivalent as to its concentration to 0.01% U_3O_8, buried in sand at a depth of 5 m below the surface could be detected at a depth of 1 m from the surface. Moreover, observations showed that the distribution of emanation at depth is ruled by the course of barometric pressure. Approximate calculations of the speed with which emanation is moving in a sand medium along the vertical towards the surface give values of the order of 60 cm per day.

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L'étude du rayonnement pénétrant provenant de l'écorce terrestre [Study of penetrating radiation rising through the terrestrial surface]:
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Gosudarstvennyy Geol. Komitet SSSR, (4): 34-38
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Am. Jour. Science, Ser. 4, 21(126): 409-414

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On the radio-activity of uranium minerals:
Am. Jour. Science, Ser. 4, 25(148): 269-298
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Nucl. Sci. Abs. 16: 31967

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Radon concentrations in an underground structure as a function of pressure differentials between soil gas and indoor atmosphere [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 500
A research facility has been constructed [at Colorado State University, Fort Collins, Colo.] which contains two identical underground structures. Each structure is surrounded by an array of temperature, pressure, and moisture sensors. These devices are monitored continuously with a computer-controlled data acquisition system. A meteorological station also provides data on wind, barometric pressure, and outdoor temperature. Radon concentration inside the structures as a function of pressure differentials between the soil gas and basements will be presented. Comparisons with temperature changes and barometric pressure will be analyzed.

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of the presence of a fault, and vice versa; and finally it is found that there is great local variation of radon content of soil gases.

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The absorption of radioactive emanations by charcoal:
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The volatilization of radium emanation at low temperatures:
Philos. Mag., 20: 955

Boyle, R.W., 1911
The solubility of radium emanation; Application of Henry's Law at low partial pressures:
Philos. Mag., 22: 840-854
Chem. Abs. 6(4): 454 (1912):
The differences in the results obtained by previous observers are pointed out and are attributed to their methods. Much larger quantities of emanation were used and the amounts in the gas and liquid phases have been measured by the γ-ray activity. Henry's Law is shown to hold for emanation between partial pressures of 8×10^{-4} and 8×10^{-8} mm Hg. The following results were obtained for the coefficient of solubility of emanation in water: 0°, 0.506; 4.3°, 0.424; 5.7°, 0.398; 10.0°, 0.340; 14.0°, 0.303; 17.6°, 0.280; 20.0°,0.245; 26.8°, 0.206; 31.6°,

0.193; 34.8°, 0.176; 35.2°, 0.170; 39.1°, 0.160. Thus at 10°C a quantity of emanation will distribute itself between equal volumes of water and a gas so that about 1/3 will go to the water and 2/3 to the gas. The variation in temperature does not agree with Hofmann's results (Physikal. Zeitschrift, 6: 337, 1905). At 14°C the emanation is slightly more soluble than NO. Hg does not absorb the emanation. Sea water of specific gravity 1.022 at 14°C absorbs about 0.84 times as strongly as water. At this temperature pure ethyl alcohol absorbs 24.2 times as strongly as water, amyl alcohol 30.7 times, and toluene 45.2 times (cf. Ramstedt, Chem. Abs. 5: 3757).

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Ob izmenenii soderzhaniya radiya v vodakh skvazhin v zavisimosti ot ikh geneticheskogo tipa [Changes in concentration of radium in borehole waters according to their genetic type], *in* Nuclear Geophysicists Conference, Cracow, Poland, Sept. 24-30, 1962:
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Radioactive equilibrium in ancient marine sediments:
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Radioactive equilibrium within 11% was observed (± 12%) in 8 composite samples of marine sediments of Miocene or greater age. Direct U, Ra, and Th measurements and alpha counts were made. Radon losses ranged from 15 to 35%.

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The air content of small and large radioactive ions [in French]:
Acad. Sci. [Paris] Comptes Rendus, 252: 2119-2121
Transl. by Thomas E. Knatt, UCRL-Trans-738
Nucl. Sci. Abs. 15:19644

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The content of small and large radioactive ions in the air [in French]:
Geofis. pura e appl., 50: 235-242
Nucl. Sci. Abs. 16:33600:
The proportion and free life time of RaA atoms arising from the radioactivity of atmospheric radon, and caught by dust particles, large ions, and condensation nuclei, is evaluated, with the assumption that these atoms are identical to the ordinary small ions. Experimental verification of the calculation are made by catching small and large ions with Zeleny tubes, the axial electrode being negatively charged. Other particles being caught with electrical precipitation and filter paper, activities of different samples are measured by alpha counting. 1.5×10^{-4} per cm^3 small ions RaA concentration was found. Knowing the air radon value concentration, and with the assumption of radioactive equilibrium only between radon and RaA in free air, it is possible to evaluate the concentration of RaA caught by other particles.

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Methodology for the measurement of radon with passive instruments:
Radiation Protection Dosimetry, 7(1-4): 219-221
Chem. Abs. 101:99846u:

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Radon-222 in the lunar atmosphere:
Nature [London], Phys. Sci., 238(85): 107-109

Brodzinski, R.L., P.O. Jackson, and J.C. Langford, 1977
Measurements of radon concentrations in the lunar atmosphere:

NASA Contract Rept. NASA-CR-151327: 17 p.
NTIS Sci. Tech. Aerosp. Rep. 15(12), Abs. N77-22035
The Rn concentrations in the lunar atm. were detd. by measuring the ^{210}Po progeny activity in artifacts returned from the moon. Experiments performed on a section of the polished Al strut from Surveyor 3 and data obtained from the Apollo 16 Cosmic Ray Detector Experiment Teflon thermal shield are compared with other values of the lunar Rn concentration obtained at different times and different locations and by various techniques. Possible sources and release mechanisms compatible with all of the data are discussed. An experimental procedure to determine the relative retention coefficients of various types of material for Rn progency in a simulated lunar environment is described. The results of several experiments are given, and their effect on lunar Rn progeny measurements is discussed. A procedure is given for the analysis of a Teflon matrix for trace constituents.

Broecker, Wallace S., 1965
An application of natural radon to problems in ocean circulation, *in* Ichiye, Takashi, ed., Symposium on diffusion in oceans and fresh waters:
Palisades, New York, Columbia Univ. Lamont Geol. Observatory: 116-145 [Proc. of symposium at Lamont Hall, August 31-September 2, 1964]

Broecker, Wallace S., and Aaron Kaufmann, 1970
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Jour. Geophys. Research, 75(36): 7679-7681

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Radium-226 and radon-222--Concentrations in Atlantic and Pacific Oceans:
Science, 158(3806): 1307-1311

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Indoor and soil Rn measurements in the Albuquerque, New Mexico, area:
Health Physics, 51(4): 529-533

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Soil radon and uranium: Correlation with high indoor radon in the Albuquerque, New Mexico area [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(6): A145
High indoor radon in approximately 30% of private dwellings in the Albuquerque, New Mexico area has been reported previously by Brookins [see above]. The present study attempts to explain the areas of high indoor radon as a function of different soil and/o bedrock in the area. Soils have been sampled during summer and winter periods using alpha-track radon detectors. The values range from 40 to 890 pCi/L air at a depth of 38 cm. The gross mean average is 360 pCi/L for the area for summer readings and 200 pCi/L for winter readings. Both values are well over the USA average soil radon values of approximately 100 pCi/L. [It is not given where such a low concentration of radon in soil gas was obtained.–ABT] Analyses of soil uranium show a range in values from 1 to 6 ppm, with a mean of 3.1 ppm. Thorium values range from 3.3 to 28.8 ppm, and Th/U ratios range from 2.9 to 4.6. These values for U, Th, and TH/U suggest that soil U and Th are close to the values reported for the Sandia Granite, source of most of the pediment on which Albuquerque is built. Soil infiltration rates range from $\approx 6x10^{-4}$ to $4.5x10^{-3}$ cm/s for the samples, and soil moisture content ranges from 1.4 to 7.2%. A fair correlation of summer soil radon with moisture content and/or with percent silt, silt+clay, clay size fraction material is not established by this study. Soil radon values do correlate with regions in the Albuquerque area where high indoor radon is common. A better correlation of high indoor radon values with soils developed immediately over bedrock is observed. Further, all values of average soil and indoor radon increase significantly with proximity of the stations to the Sandia Mountains. Soil uranium also shows this trend. The data argue that regions of potentially high radon can thus be identified.

Brooks, J.R., 1989
Maryland geology and indoor radon [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 500
The first suggestion that Maryland could have a potential radon problem came from a report by Moschandreas and Rector [*q.v.*] during 1982. This study of 60 homes in and around Mount Airy indicated 30% of the homes surveyed contained radon in excess of 4 pCi/L. Aeroradioactivity maps of the State indicated that geology might be an important factor in determining where radon might be a problem. These maps together with the National Uranium Resource Evaluation Program data show a broad area of elevated radioactivity extending northeast from the Virginia [State boundary] line through Mount Airy and Westminster to the Pennsylvania border. This corresponds to a belt of phyllitic rocks which include the Ijamsville, Marburg, and Urbana formations. Other anomalies can be attributed to granitic rocks, faults, and Triassic sediments. Early in 1988 the Maryland Survey obtained several hundred indoor radon readings from the Maryland Department of Health and Mental Hygiene to see if elevated readings could be attributed to any particular geologic formation. These readings were then plotted on County Geologic Maps at a scale of 1:62500 and the geologic information along with the values and coordinates were entered into a computer database. The database showed that certain rock units or groups of rock units have recognizable indoor radon signatures. These signatures are influenced by rock and soil permeability as well as uranium content.

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Modeling indoor exposure to natural radiation:
Radiation Protection Dosimetry, 7(1-4): 91-94

Brown, L., B.M.R. Green, J.C.H. Miles, and A.D. Wrixon, 1984
Radon exposure of the U.K. population, *in* International Conference on Indoor Air Quality and Climate, 3d, Stockholm, August 20-24, 1984; Vol. 2: Radon, Passive Smoking, Particulates and Housing Epidemiology, Birgitta Berglund, Thomas Lindvall, and Jan Sundell, eds.:
Stockholm, Swedish Council for Building Research, Vol. 2, p. 61-65

Brownscombe, E.R., R.L. Slobod, and B.H. Caudle, 1950
Laboratory determinations of relative permeability: Pt. 1:
Oil and Gas Jour., 48(40): 68-69, 81-82; Pt. 2, 48(41): 98-102, 123
Geophys. Abs. 12663:
The spatial distribution of the phases within the porous system are said to largely determine the ability of a particular phase to flow. The authors suggest that the method used to introduce a second phase into a core specimen may have an appreciable effect on the observed relative permeability of the resulting system at a given saturation. Discussion of the capillary-pressure method of displacing one fluid by another, the dynamic displacement, and the solution-gas displacement are given in detail. The second part describes the equipment used in determining relative permeability by the capillary pressure method, its operation, and the reproducibility of the results. Such results obtained on natural and synthetic cores and on unconsolidated sands are presented and discussed.

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[Field measurements at Socorro, New Mexico showed that passing fronts exert pressure gradients sufficient to cause significant changes in ^{222}Rn flux across the soil-air interface. Pressure changes of 1-2% of atmospheric pressure can change the flux by from 20% to 60%, depending on the rate and duration of change. The field results fit a one-dimensional model of diffusion + soil-gas transport of radon in soil of 10^{-8} cm^2 permeability for pressure changes of 1 to 2 kPa for 1 to 2 days to yield Darcy velocities (*i.e.*, averaged over a unit geometrical area) *ca.* 10 μm/sec near the interface.]

Cliff, K.D., 1980
Measurements of radon-222 concentrations in dwellings in Great Britain, in Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1260-1270, disc., p. 1270-1271

Cliff, K.D., B.M.R. Green, and J.C.H. Miles, 1985
The levels of radioactive materials in some common UK building materials:
The Science of the Total Environment, 45: 181-186

Cohen, Bernard L., 1979
The role of radon on comparisons of effects of radioactivity releases from nuclear power, coal burning, and phosphate mining, *in* Internat. Conf. Health Eff. Energy Prod., 1st:
Atom. Energy Canada, Ltd., Rept. AECL-6958; 237-243
Chem. Abs. 94:52074n:

Cohen, Bernard L., and Ernest S. Cohen, 1983
Theory and practice of radon monitoring with charcoal adsorption:
Health Physics, 45(2): 501-508

Cohen, Bernard L., and Patrick Pondy, 1987
Comparison of purchased measurements with measurements in randomly selected houses as a source of information on ^{222}Rn levels in houses:
Health Physics, 53(4): 409-415

Collé, R., and J.M.R. Hutchinson, 1985
Development of a radon flux density standard, *in* Health Physics Soc. Ann. Mtg., 30th, Chicago, Ill., May 26-31, 1985:
Health Physics, Abstracts of Papers, no. TPM-D1

Collé, R., and Preston E. McNall, Jr., eds., 1980
Radon in Buildings:
U.S. National Bur. Standards Special Pub. 581, 84 p. [Washington, GPO]
[Proceedings of a roundtable discussion held at NBS, June 15, 1979.]

Collé, R., R.J. Rubin, L.I. Knab, and J.M.R. Hutchinson, 1981
Radon Transport Through and Exhalation from Building Materials; A Review and Assessment:
U.S. National Bur. Standards Tech. Note 1139, 101 p. [Washington, GPO]
The report 1) considers the routes of entry of radon into buildings, describes the basic models for radon transport through building materials, critically reviews the small number of existing values for the necessary transport coefficients, and summarizes the solutions of both steady-state and time-dependent transport cases; 2) reviews and considers how the microstructural properties and internal characteristics of building materials may affect the transport and exhalation of radon; 3) considers the exhalation process from a more macroscopic, phenomenological viewpoint, and summarizes selected experimental data on radium concentrations in building materials, radon flux and exhalation from soils and building materials, and the effects of meteorological variables on radon exhalation; and 4) reviews and assesses various measurement methodologies that are used for laboratory and in situ studies of radon transport and exhalation. Needs for further research in each area are also recommended.

Collie, J. Norman, and Sir William Ramsay, 1904
The spectrum of the radium emanation:
Royal Soc. [London] Proc., 73: 470-
[First observations of spectrum (11 lines) of Ra-emanation. (Rutherford & Royds, 1908)]

Collins, William B., 1963
Gamma radiation survey of the Gilbertown area, Alabama:
Alabama Geol. Survey Inf. Ser. 31: 11 p.
Geophys. Abs. 214-275:
A surface gamma radiation survey was made of Gilbertown and vicinity, Choctaw County, Ala., using car-mounted Geiger-Müller apparatus. The gamma intensity along five N-S traverses is slightly low in most parts of an area that includes the E-W-trending Gilbertown oil field, which produces from a depth of about 2,500 feet. The data are not adequate to confirm the hypothesis of Lundberg (see Geophys. Abs. 149-13742, 166-322) that gamma radiation surveys may be used to prospect for petroleum.

Collinson, A.J.L., and A.K.M.M. Haque, 1963
A scintillation counter for the measurement of radon concentration in air:
Jour. Sci. Instruments, 40: 521-523

Commission of the European Communities, *et al.*, 1988
Natural Radioactivity, Proceedings of the Fourth International Symposium on the Natural Radiation Environment, Lisbon, Portugal, December 7-11, 1987:
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Jour. Inst. Petr. 28: 141
[Use of gamma measurement to detect oil:]

Connor, R.D., 1963
Concentration of natural and airborne activities near ground level at Winnipeg:
Canadian Jour. Physics, 41(7): 1118-1134
Geophys. Abs. 203-305:

Concentrations of radon, thoron, and particulate fallout at Winnipeg have been evaluated on a day-to-day basis from December 1958 to May 1962; results are given in detail for the period linking the International Geophysical Year to the Canadian government's radiation protection program.

Cook, John C., 1959
Some unorthodox petroleum exploration methods:
Geophysics, 24: 142-154
[References to halo patterns and radioactivity on pp. 149-151.]

Cook, L.G., 1939
Untersuchungen über Chrom- und Eisenhydroxyde und ihre Bedeutung für Emaniermethode [Investigation of chromium and iron hydroxide and their importance in the emanation method]:
Zeitschrift physikal. Chemie, B42: 221-239.

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The uranium district of the Texas Gulf Coastal Plain, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1602-1622

Coppens, René, 1962
Radioactivité et tectonique [Radioactivity and structure]:
86^e Congres National des Societes Savantes, Montpellier, 1961, Section des Sciences Comptes Rendus, 425-428
The radioactivity has been measured on 95 rock samples collected from the Mortagne granite massif on the south and the Brioverien metamorphics (Eocambrian) on the north of an area of about 2 sq km immediately east of the Escarpier uranium deposits, south of the La Moine River and north of Mortiere. The highly variable radioactivity ranges from 0.3 to 10.7E-3 α/cm^2-s and corresponds to a uranium content of 0.04 to 0.05 percent. The zone of weakest activity averaging 0.97E-3 α/cm^2-s corresponds to the Brioverien metamorphics, whereas measurements on samples from the granite massif show an average of 2.74E-3 α/cm^2-s. Within the Brioverien a sharp difference exists between radioactivity in the east and west parts, and in the granite area the higher radioactivity seems to be definitely aligned. Geophysical studies in that area show a number of faults that are more or less mineralized over a zone of 25 to 50 meters showing higher radioactivity. The sharp separation in activity in the Brioverien is along a fault. In general, it is probable that the radioactivity varies with depth, and it is possible that a part elevated by faulting has been eroded thus bringing radioactivity that corresponds to rocks at depth to the surface.

Corry, Andrew V., 1929
Radioactive atmospherical method of measurement for geophysical prospecting:
Am. Inst. Mining and Metall. Engineers Tech. Pub. 200: 4 p
Geophys. Abs. 5: 18-19

Costanzo, G., and C. Negro, 1906
[Radioactivity of snow]:
Physikal. Zeitschrift, 7: 350-353
Sci. Abs. 1390 (1906)
[1) Freshly fallen snow, when collected at once, is strongly radioactive. 2) The activity is found to almost completely disappear after 2 hours. 3) Snow which has fallen on the ground appears to retain its activity somewhat longer than when it has fallen on a roof.]

Costanzo, G. and C. Negro, *ca.* 1908
[Ionization produced by the leaves of plants]:
Physikal. Zeitschrift, 8: 491

Chem. Abs. 2:372
Freshly plucked cedar needles were found to render the air very slightly conducting, the decay being similar to that of radioactivity.

Cothern, C. Richard, and William L. Lappenbusch, 1981
Thoughts about revising the radiation regulations in drinking water concerned with radioactivity, *in* Trace Substances in Environmental Health, no. 15, Columbia, Mo., June 1-4, 1981, Proc., p. 64-68:
Washington, U.S. E.P.A. Office of Drinking Water

Cothern, C. Richard, William L. Lappenbusch, and Jacqueline Michel, 1986
Drinking-water contribution to natural background radiation:
Health Physics, 50(1): 33-47

Cothern, C. Richard, and Paul A. Rebers, eds., 1990
Radon, Radium and Uranium in Drinking Water:
Chelsea, Mich., Lewis Publishers, Inc., 286 p.
[This book reviews the principal natural radionuclides in drinking water by means of the following sections: (1) Scientific background for the development of regulations for radionuclides in drinking water (Paul Milvy and C.R. Cothern); (2) Analysis of the health risk from ingested radon (D.J. Crawford-Brown); (3) Risk assessment and control management of radon in drinking water (W.A. Mills); (4) Treatment technology for removing radon from small community water supplies (N.E. Kinner *et al.*); (5) Radon transferred from drinking water into house air (C.T. Hess *et al.*); (6) An experimental test of the linear no-threshold theory of radiation carcinogenesis (B.L. Cohen); (7) Relationship of radium and radon with geological formations (Jacqueline Michel); (8) Occurrence of radionuclides in drinking water, a national study (Jon Longtin); (9) Raid on sanity: Policy and economic analysis of radionuclide removal from drinking water (D.W. Schnare); (10) Gastrointestinal absorption of soluble uranium from drinking water by humans (M.E. Wrenn *et al.*); (11) Determination of uranium in an analytical chemistry laboratory (C.-K. Liu *et al.*); (12) Removal of uranium from drinking water by conventional treatment methods (T.J Sorg); (13) Setting up a laboratory for radon in water measurements (C.T. Hess and S.M. Beasley); (14) Analytical methodology for radium in food and water (E.J. Baratta); (15) The price of confidence: The rationality of radium removal from drinking water (D.J. Crawford-Brown); (16) Removal of radium from drinking water (D.A. Clifford); (17) Disposal of radium from drinking water treatment (Norman Hahn); and a six-page glossary.]

Cothern, C. Richard, and James E. Smith, eds., 1987
Environmental Radon:
New York, Plenum Publishing Corp., 378 p.
[This compendium includes chapters by several authors on properties (Cothern), history and uses (Cothern), measurement (Crawford-Brown and Michel), sources (Michel), human exposure (Eichholz), dosimetry (Crawford-Brown), health effects (Cross), mitigation (Cook and Egan), and risk assessment and policy (Mills and Egan).]

Cotter, J., and D.M. Thomas, 1989
Ground gas radon response to meteorological perturbations [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 497
Soil gas radon activities have been monitored at depths ranging from one-half to two meters for a period of several months using recently developed passive electronic alpha particle counters. The devices continuously integrate alpha particle decays and record the decay rates at fifteen minute intervals for later retrieval. The results of this monitoring effort have shown that semi-diurnal barometric pressure changes as small as four millibars [≈400 Pa] produce a detectable variation in radon activity at depths of at least two meters and that larger synoptic pressure changes can increase or decrease radon concentrations by as much as 20%. Soil moisture has been found to have a substantial impact on the average radon activity at relatively low soil

moisture levels but, after soil water content exceeds 50% saturation, the variations are much smaller even when intense rainfalls bring soil moisture to saturation levels. Characterization of seasonal rainfall effects on radon transport to the surface are currently underway. We have also found that subtle differences in deployment protocol can have substantial impacts on the radon response to barometric and rainfall perturbations. These differences have suggested that even small discontinuities in soil permeability (eg. cracks or root cavities) may have a substantial effect on near- surface radon degassing. The results of our ongoing radon monitoring investigation will be presented along with our initial efforts at modelling radon mobility in response to meteorological effects.

Cotton, E.S., 1955
Diurnal variations in natural atmospheric radioactivity:
Jour. Atmos. Terrest. Physics, 7(1/2): 90-98
Geophys. Abs. 163:165:
The equation of the diffusion of radium emanation in the atmosphere has been solved by using several simplifying assumptions to determine the order of magnitude of variations as a result of changes in atmospheric exchange conditions, such as noctural inversions. Night-to-day ratios were calculated for various daytime concentrations and found to be variable, even for constant exhalation, and the value of the daytime content was found to determine the ratio even under the same exchange conditions. Observations near Bedford, Mass. in 1952 and 1953 are in reasonable agreement with the calculations. These individual diurnal variations may be explained on the basis of meteorological conditions, such as wind speed and temperature.

Courtier, G.B., 1959
Determination of radon and thoron in air:
Nature [London], 180: 382

Cowart, J.B., 1980
Variation of uranium isotopes in some carbonate aquifers, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 711-723

Cowart, J.B. and W.C. Burnett, 1989
Elevated radon generated in terra rossa in south Florida [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(6): A144
An elevated radon anomaly located just south of Miami, Florida, was discovered by a state-wide radon survey completed in 1987. The anomaly seems to coincide with an area known as "The Redlands", an area of *terra rossa* underlain by the Miami limestone, which was deposited about 120,000 years ago, as determined by U-series methods. *Terra rossa* is generally considered to be a residual soil although in the case of south Florida and the Caribbean islands, an airborne source for some constituents has been proposed by others. Be that as it may, the *terra rossa* samples from south Florida have developed unusual activity ratios for the uranium series nuclides. Using acid-leached samples, gamma spectroscopy indicates the Ra-226 is greatly in excess of U-234 with Pb-210 being intermediate in activity; by alpha spectroscopy Th-230 is greatly in excess of U-234. These results indicate that the processes operative in the formation of *terra rossa* retain Th-230 and Ra-226 while permitting loss of the parent uranium. The significant difference in activity between Ra-226 and Pb-210 suggests that such soils may be powerful radon-emitting sources.

Cowper, G., and S.D. Simpson, 1953
The determination of radon concentrations in air:
At. Energy Canada Rept. AECL-78, LE-36
Nucl. Sci. Abs. 9-6402:
Equipment for the determination of Rn concentration in air is described and illustrated. The air sample is admitted to a chamber in which is placed a thin foil held at negative potential, and behind this foil is a zinc

sulfide screen and an end-window photomultiplier. The Rn decay products, which by recoiling are left positively charged, are attracted to the foil, and subsequent alpha particles may be detected by the phosphor.

Cox, Malcolm E., 1980
Ground radon survey of a geothermal area in Hawaii:
Geophys. Research Letters, 7(4): 283-286.

Cox, M.E., K.E. Cuff, and D.M. Thomas, 1980
Variations of ground radon concentration with activity of Kilauea Volcano, Hawaii:
Nature [London] 288: 74-76

Crabb, D., R. Dudley, and A.W. Mann, 1984
Hinkler Well-Centipede uranium deposits, *in* Toens, P.D., leader, Surficial Uranium Deposits, Report of the Working Group on Uranium Geology, organized by the International Atomic Energy Agency:
Vienna, Internat. Atomic Energy Agency Rept. IAEA-TECDOC-322, pp. 133-136

Crews, William D., 1961
Radioactivity surveying:
Oil and Gas Jour. 59(19): 132-137
GeoSci. Abs. 3:3326
[Mentions relation between surface radioactivity and hydrocarbons at depth. [See also 1959, 57(32)]]

Crews, William D., 1962
Exploracion por radiactividad. [How radioactive surveys help find oil], Pt. 5:
Petroleo Interamericano, 20(12): 40-46 [in Spanish and English]
GeoSci. Abs. 6:1950
Four case histories of small areas in which radioactivity surveys were conducted demonstrate the accuracy with which hydrocarbon deposits may be located using this technique. The usefulness of the procedure can be greatly increased if done in conjunction with other exploration methods as shown by one example.

Croft, J.F., and K.E.G. Perry, 1962
An experimental study of the behaviour and detection of hazardous radon releases in air:
AEE W-R-149: 88 p.
Nucl. Sci. Abs. 17:23586:
[Maximum permissible Rn-222+ daughters under accident conditions should be reduced from 6E-5 to 6E-6 μCi-hr/cm^3.]

Crosthwait, L.B., 1955
A measurement of atmospheric radioactivity at Wellington:
New Zealand Jour. Sci. Technology, sec. B, 37(3): 382-384
Geophys. Abs. 165-300
A filter-paper method of collecting atmospheric radioactivity is described. Sixteen readings taken at Wellington, New Zealand in February 1955 show a mean radon concentration of 34 fCi/L. The method is considered reasonably good, particularly if only relative values are required, as for meteorological research.

Crozier, W.D., 1969
Direct measurement of radon-220 (thoron) exhalation from the ground:
Jour. Geophys. Research, 74(17): 4199-4205
[One m^2 open bottom ion chamber on ground surface; 5886 electrometer input tube; integrating ion current record; 10 sec RC flushed with filtered air 15 min of each hour. Exhalation rates (2.9 to 5.6) fCi/cm^2-s near Socorro, N. Mex.]

Crozier, W.D., and Norman Biles, 1966
Measurements of radon-220 (thoron) in the atmosphere below 50 centimeters:
Jour. Geophys. Research, 71(20): 4735-4741

Cüer, Pierre, 1946
Prospection de l'uranium par ses particules alpha [Prospecting for uranium by the use of its alpha particles]:
Annales Géophys. [Paris], 2(2): 147-159
We have attempted to perfect some of the simple methods of detecting and measuring alpha rays in order to utilize them in prospecting for uranium. By constructing sensitive and solid electrometers equipped with mobile disks, by adapting the technique of the photographic plate, and by experimenting with a new activating device, we succeeded in separating the uranium and thorium effects in the radioactivity measurements of deposits. The prospecting method thus developed was tested in the region of the Monts du Forez and Bois Noirs, where the number of known radioactive veins is relatively large. The results have revealed certain areas of strong radioactive concentration and brought to light the close relationship existing between physical measurements and geologic data.

Cullen, T. L., 1946
On the exhalation of radon from the earth:
Terrestrial Magnetism and Atmospheric Electricity, 51(1): 37-44
[Good historical review of rate of exhalation of radon from the earth.]

Cullen, T.L., 1957
Measurements of radon and thoron decay products in the air by the filter method:
Ann. Acad. Brasil Cienc., 19(4): 545-552

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Prediction of increased gamma fields after application of a radon barrier on concrete surfaces:
Health Physics, 30(6): 471-478
INIS Abs. 275615, 7(23): 5193
[Modeling - linear diffusion theory to multilayered porous media.]

Culot, Michel V.J., Keith J. Schiager, and Hilding G. Olson, 1978
Development of a radon barrier:
Health Physics, 35(2): 375-380

Culot, Michel V.J., Hilding G. Olson, and Keith J. Schiager, 1976
Effective diffusion coefficient of radon in concrete, theory and method for field measurements:
Health Physics, 30(3): 263-270

Curie, M., et al., 1931
International radium standard commission report:
Rev. Mod. Physics 3: 427

Curie, Pierre, and Danne, 1903
Diffusion of emanation out of reservoir vessel [in French]:
Acad. Sci. [Paris] Comptes Rendus, 136: 1314

Curtiss, Leon F., and Francis J. Davis, 1943
A counting method for the determination of small amounts of radium and of radon:
U.S. Natl. Bur. Standards Jour. Research, 31(181): RP 1557

Dadourian, H.M., 1906
The radioactivity of thorium:
Am. Jour. Sci., Ser. 4, 21(126): 427-432
[Thorium chemistry and decay scheme.]

Dadourian, H.M., 1908
On the constituents of atmospheric radioactivity:
Am. Jour. Sci., Ser. 4, 25(148): 335-342
[History of atmospheric radioactivity and mathematical treatment of decay of Rn and Tn daughters in air.]

Dadourian, H.M., 1908
Le Radium (April)
[Active deposit of Th in addition to that of Ra on charged wire.]

Dalu, G., 1968
Esame di un metodo per misure di radioattivita naturale [Investigation of a method of measurement of natural radioactivity (with English abs.)], *in* Assoc. Geofisica Italiana Convegno, 16th Ann., Naples, 1967, Atti:
Rome, Consiglio Nazionale Ricerche: 211-229

Damkjaer, A., and U. Korsbech, 1985
Measurement of the emanation of radon-222 from Danish soils:
The Science of the Total Environment, 45: 343-350

Damon, Paul E., and P.K. Kuroda, 1954
On the natural radioactivity of rainfall:
Am. Geophys. Union Trans., 35(2): 208-216

D'Amore, F., G.C. Ferrara, Si Nuti, and J.C. Sabroux, 1976
Variations in radon-222 content and its implications in a geothermal field:
Proc. Internat. Congr. Therm. Waters, Geotherm. Energy Vulcanism Mediterr. Area, 1: 184-200

Davies, B.L., and J. Forward, 1970
Measurement of atmospheric radon in and out of doors:
Health Physics, 19: 136

Davies, Joan M., and Hazel Inskip, 1985
Epidemiological studies related to enhanced natural radiation:
The Science of the Total Environment, 45: 509-518

Davis, Francis J., 1945
Report on analysis by radon measurement and alpha-particle counting:
Jour. Assoc. Official Agr. Chem., 28 682
[Radon measurement with ionization chambers]

Davis, Nancy M., Rudolph Hon, and Peter Dillon, 1987
Determination of bulk radon emanation rates by high resolution gamma-ray spectroscopy, *in* Graves, Barbara, ed., Radon, Radium, and Other Radioactivity in Ground Water. Hydrogeologic Impact and Application to Indoor Airborne Contamination. National Well Water Association Conference, Somerset, N.J., April 7-9, 1987, Proceedings:
Chelsea, Mich., Lewis Publishers, Inc., p. 111-129

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Implications of Apollo II results on lunar surface radioactivity [abs.]:
Am. Geophys. Union Trans., 50(11): 637

Dawson, J.A.T., 1946
Radon, its properties and preparation for industrial radiography:
Jour. Sci. Inst., 23: 138

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Background levels of naturally occurring radionuclides in the environment of a uranium mining area of northern Saskatchewan, Canada, *in* Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:
New York, John Wiley and Sons, p. 67-73

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Airborne radioactivity at Delhi:
Indian Jour. Pure and Applied Physics, 4: 30-32

Debierne, A., 1900
Sur un nouvel element radio-actif: l'actinium [On a new radioactive element: actinium]:
Acad. Sci. [Paris] Comptes Rendus, 130: 906-908

Debierne, A., 1904
Sur l'émanation de l'actinium [On the emanation of actinium]:
Acad. Sci. [Paris] Comptes Rendus, 138: 411-414
[Actinium emanation diminishes in several seconds. More than one daughter was found.]

Debierne, A., 1904
Sur le plomb radioactif, le radio-tellure et le polonium [On lead radioactivity, radio-tellurium and polonium]:
Acad. Sci. [Paris] Comptes Rendus, 139: 281-283
[Mme. Curie and M. Giesel contest radio-tellurium and consider it identical to polonium. Debierne separated radio-lead, isolated it three years, and then found polonium.]

Delaby, R., G. Charonnat, and M. Jamot, 1931
La radioactivité des eaux de quelques sommets des Vosges [Radioactivity from the peaks in the Vosges]:
Acad. Sci. [Paris] Comptes Rendus, 193: 1434-1436
[Radon activity of 8 spring waters from peaks in the Vosges ranged from 0.83 nCi/L to 63.5 nCi/L in rough correspondence to the radioactivity of the surface source rocks.]

Delaby, R., G. Charonnat, and M. Janot, 1932
La radioactivité des eaux du Ballon d'Alsace [The radioactivity of the waters from Ballon d'Alsace]:
Acad. Sci. [Paris] Comptes Rendus, 195: 1294-1297
[Higher emanation contents were found in spring waters from higher altitudes, but it is believed fortuitous. The emanation content of water was higher after passing through granitic rock, and is believed to depend on the radioactive (accessory) mineral content of the rock.]

Delaby, R.,G. Charonnat, and M. Janot, 1933
Nouvelles récherches sur la radioactivité des eaux du massif du Ballon d'Alsace [New research on the radioactivity of waters from the Ballon d'Alsace massif]:
Acad. Sci. [Paris] Comptes Rendus, 197: 1140-1142

[Variations of 10-25% were observed in the emanation content, approx. 0.1 μCi/L, of spring waters [la Savoureuse] with weather conditions (precipitation). Emanation was assumed to be lost to the air from surface waters.]

De la Cruz-Reyna, S., M. Mena, N. Segovia, J.F. Chalot, J.L. Seidel, and M. Monnin, 1985
Radon emanometry in soil gases and activity in ashes from El Chichon Volcano:
Pure and Applied Geophysics, 123(3): 407-421

Delibrias, G., 1954
Dosage du radon dans l'air [Determination of radon in the air]:
Jour. Physique et Radium, 15: 784-80A

Delwiche, C.C., 1958
Weathering of great world soil groups as related to general atmospheric radioactivity, *in* United Nations International Conference on the Peaceful Uses of Atomic Energy, 2d, Geneva:
Geneva, United Nations, paper UNP/404 USA
[Good review of fluctuation of interest in airborne radioactivity. Correlation of Rn and Tn concentration with smoke-laden atmospheres probably fortuitous, resulting from meteorologic factors favoring both. Radon generation by soils measured by evacuating 500 g soil, filling with air, and drawing into evacuated ion chbr-electroscope combination after 3-4 days. Values given for Rn in pCi/L of soil atmosphere at d=2.6 g/cm^3, 50% porosity. Emanating power not evaluated. Range approx. 50-1500 pCi/L. Radium in zircons found to be 1/100 of Rn observed; hence Rn generated by radium released by weathering and absorbed by the colloidal clays of the soil (tentative conclusion).]

Denny, E.H., K.L. Marshall, and A.C. Fieldner, 1928
Rock-strata gases in the Cripple Creek district and their effect on mining:
U.S. Bur. Mines, Rept. Inv.-2865
Chem Abs. (1928) 2344-8
[Earth breathing effect noted.]

Denschlag, J.O., 1961
Reactions of back-scattered atoms with gases [thesis]:
Mainz, Johannes Gutenberg Universität: 2 parts.
Nucl. Sci. Abs. 17:214
The work contains two parts. In the first part, back-scattering was applied as a model case for the fission recoils investigated in the second part. In the first section the charge of atoms back-scattered from thoron and actinon were investigated. It could be shown that the hypothesis formulated by Briggs is also valid for actinon and that the charge of the A and B bodies of the decay series at the end of their recoil paths is independent of the initial energies. In the second part a study was made to reproduce a formation of volatile lead Pb-212 compounds by back-scattering. For that reason thoron was permitted to decay in a methane atmosphere so that the hot lead atoms originating over Po have the possibility of reacting with the methane. A detection of volatile lead was not possible. A new electrolytic separation method for medium thick U lead was described. The formation of organic volatile iodine compound by reactions of hot fission recoil atoms with gaseous methane was detected with the help of such a U lead. Some quantitative assertions were indicated, but not proven definitely.

De Santis, L., 1961
Prime misure di radioattivita naturale dell'aria a Bari [First measurements of natural radioactivity of air at Bari]:
Geofisica Teor. ed Appl, 3(9): 3-18
Geophys. Abs. 184-492:

Background information is given on the normal concentration of radon and thoron in the atmosphere and on the techniques used in determination of the concentration of these elements in the air filtered by the International Geophysical Year station at Bari, Italy during the period from May 3 to August 4, 1960. The highest concentrations of Rn (894 pCi/m^3) and of Tn (53.1 pCi/m^3) were recorded on May 15, and the lowest concentrations of Rn (2.1 pCi/m^3) on June 18, and Tn (1.3 pCi/m^3) on May 6.

De Santis, L., 1963
Un metodo semplice per la misura della radioattivita naturale dell'aira [A simple method for measuring the natural radioactivity of the air [with English abs.]]:
Boll. Geofisica Teor. ed Appl., 5(18): 87-96
A simplified filtering method is proposed for the measurement of the natural radioactivity of the air. A procedure is described by which it is possible to determine the Rn concentration with only one measurement of the filter radioactivity at the end of a suction period provided that the value of the corrective factor is known. This factor is determined experimentally.

Dezsi, Z., 1962
An emanometer for determining the radon content of natural waters [in Hungarian]:
Magy. Tud. Akad. At. Kut. Int. [Debrecen] Kozlemen, 4: 51-55
Nucl. Sci. Abs. 17:134

Dezsi, Zoltan, 1962
Investigations of the uranium, radium, and radium emanation contents of natural waters of high uranium content [in Hungarian]:
Magy. Tud. Akad. Atommag Kut. Int. [Debrecen] Kozlemen, 4: 93-96
Nucl. Sci. Abs. 17, No. 5, 6293
Investigations are carried out on the uranium, radium, and radon contents of natural water samples taken from the "Taktakoz" region. The uranium content is determined by the fluorometric method, and the radium and radon contents are determined by radiometric methods. The water samples under test show radioactive decay inequilibrium between the quantities of U, Ra, and Rn in the water. The Rn content far exceeds the Ra content. On the other hand, the U content in waters obtained from near the surface exceeds the radioactive equilibrium value corresponding to the particular Ra content in the water, whereas it falls behind the corresponding Ra content in waters obtained from deeper wells.

Dienert, F., and E. Bouquet, 1907
Relation between the radioactivity of underground waters and their hydrology [in French?]:
Acad. Sci. [Paris] Comptes Rendus, 145: 894-896
Sci. Abs. 73 (1908); Chem. Abs. 2:1239:
The authors have previously found that the Paris water supply is slightly radioactive. One of the sources, the springs of Rueil [a tributary of the Aure], issues from a chalk bed. The electrical resistance and radioactivity of this spring water was determined almost daily for a year. At the same time the level of the underground water was noted by the depth of the water in a reservoir near the springs. These data are represented by three curves. A general parallelism of the curves is evident. The resistance of the water increases as the underground level of the water rises, and as fresh water is not radioactive, one would expect the water at high levels to be less radioactive; but the opposite was found, and so the authors conclude that the water readily dissolves the emanation in the soil, and that the surface soil is more radioactive than the underlying chalk beds. In confirmation of this view, water from the bottom of a boring into the chalk bed was found only ¼ as active as the spring water of the region. In another area the water from a boring extending down into the underlying chalk bed proved quite as radioactive as water that had come in contact with the surface soil, and both were more radioactive than the Reuil water. The chalk strata are therefore different in composition, although from a geological point of view they are the same.

Dike, P.H., 1906
The diurnal variation of the amount of radioactive emanation in the atmosphere:
Terr. Mag., 11(3): 125-129
[Definite, but irregular, diurnal variation in Rn daughter products in atmosphere 10 m above ground. Windy, rainy, cloudy days gave low measurements. Still, foggy, bright days gave high values. Maxima at 1 and 4 a.m.; minima at noon and 6 p.m. 12-fold variation.]

Dikun, A.V., V.M. Korobeynik, and I.N. Yanitskiy, 1975
O nekotorykh osobennostyakh razvitiyagelievoy s"emki [On some special developments of helium surveying]:
Akad. Nauk SSSR Izv., Ser. Geol.,1: 150-152
Chem. Abs. 83:82722n

Djuric, D., D. Panov, M. Kilibarda, L. Novak, and M. Vukotic, 1963
Polonium in the urine of miners as a measure of exposure due to radon:
Vienna, Internat. Atomic Energy Agency Preprint SM-41/60: 14 p.
Nucl. Sci. Abs. 17:41138:
By periodic measurements in the U mine in Yugoslavia, concentration of Rn in the air has been established in the range of 0.016 to 3.38 nCi/L.

Doerner, H.A., and Wm.M. Hoskins, 1925
Co-precipitation of radium and barium sulfates:
Am. Chem. Soc. Jour., 47(3): 662-675
[Found work of Germann (1921) inadequate to explain results when concentration of Ba^{+2} varied.]

Domanski, T., W. Chruscielewski, J. Liniecki, 1973
Determination of radon and its daughter products in the air using triacetate-cellulose (TAC) foils, *in* Health Physics Probl. Intern. Contam.
Proc. IRPA Eur. Congr. Radiat. Prot., 2nd: 521-527 [edited by Bujdoso, E., Akad. Kiado: Budapest, Hung.]

Domeij, B., I. Bergstroem, J.A. Davis, and J. Uhler, 1963
A method of determining heavy ion ranges by analysis of alpha-line shapes:
Arkiv Fysik, 24: 399-411
Nucl. Sci. Abs. 17:41581
A method of determining the depth distribution of Rn-222 atoms beneath the surface of a solid target by analysis of the line shape of the emitted alpha particles is described, and its application to the study of the range and range straggling of energetic atoms is presented. Mean range determinations in the energy interval 70 to 210 kev are given, and a comparison with ranges measured by the electrolytic peeling method shows satisfactory agreement. A discussion of the figures of merit of the method is given. It is shown that ranges of Rn-222 ions of energies above 20 keV can be readily measured.

Doshchechkin, V.P., and A.S. Serdyukova, 1969
Nekotoryye voprosy opredeleniya koeffitsiyenta diffuzii emanatsiy v gornykh porod [Some problems of the determination of the coefficient of diffusion of emanations in rocks]:
Vyssh. Ucheb. Zavadeniya Izv., Geologiya i Razvedka, 7: 73-76
The relationship is found between the coefficient of diffusion of emanations and the true diffusion coefficient in the pore material for a porous medium. Values of diffusion coefficients are found to depend not only on the makeup of the rock and pore structure, but also on moisture content. Therefore, the diffusion coefficient of rocks is not a constant physical parameter. In theoretical calculations of concentrations of emanation in rocks it is advisable to use the pore concentration.

Doyle, S.M., W.W. Nazaroff, and A.V. Nero, 1984

Time-averaged indoor Rn concentrations and infiltration rates sampled in four U.S. cities:
Health Physics, 47(4): 579-586

Droullard, R.F., T.H. Davis, E.E. Smith, and R.F. Holub, 1984
Radiation Hazard Test Facilities at the Denver Research Center:
U.S. Bur. Mines Inf. Circ. 8965, 22 p.
The Bureau of Mines has developed test facilities for use in a research program that deals with radiation hazards in mining. This report describes the radon test chamber located at the Denver Research Center and the Twilight experimental mine located near Uravan, Colo.

Droullard, R.F., and R.F. Holub, 1977
Continuous Working-Level Measurements Using Alpha or Beta Detectors:
U.S. Bur. Mines Rept. Investigations 8237, 14 p.
The Bureau of Mines has investigated techniques of using gross alpha or beta detectors to continuously measure working levels. Both methods measure radioactive particulates collected on a filter paper using a constant airflow. Inherent-error studies indicate a value of about ± 3 percent for the gross alpha method and about ± 8 percent for the beta method in typical mine atmospheres. However, the beta method avoids problems associated with alpha detectors and is therefore more useful. Applications of these continuous working-level detectors include work area monitoring of exposure levels in underground openings, such as mines and caves, and calibrating personal dosimeters exposed over extended time intervals.

Droullard, R.F., and R.F. Holub, 1985
Continuous Radiation Working-Level Detectors:
U.S. Bur. Mines Inf. Circ. 9029, 20 p.
The Bureau of Mines has used gross alpha and gross beta detectors to continuously measure radiation working levels for a number of years. During this time, improvements have been made in the design and performance of continuous working-level (CWL) detectors. This report discusses the improved designs and some of the operating principles and applications of CWL detectors in the measurement of radon daughter products in mines and dwellings.

Druilhet, A., D. Guedalia, J. Fontan, and J.L. Laurent, 1972
Radon-220 emanation deduced from measurement of vertical profile in the atmosphere:
Jour. Geophys. Research, 77(33): 6508-8514

Druilhet, Aimé, Daniel Guedalia, and Jacques Fontan, 1980
Use of natural radioactive tracers for the determination of vertical exchanges in the planetary boundary layer, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 226-241

DSMA Atcon, Ltd., 1983
Review of existing instrumentation and evaluation of possibilities for research and development of instrumentation to determine future levels of radon at a proposed building site:
Ottawa, Atomic Energy Control Board Research Rept. INFO-0096, 74 p.

Dua, S.K., P. Kotrappa, and D.P. Bhanti, 1978
Electrostatic charge on decay products of thoron:
Jour. Am. Indust. Hygiene Assoc., 39(4): 339-345
Chem. Abs. 89-50383k:

Duane, William, 1908
On the emission of electricity from the induced activity of radium:
Am. Jour. Sci. 4, 26(151): 1-13

[Measurement of electricity carried by alpha and beta particles themselves.]

Dueñas, M.C., 1983
Transporte de gas Radon en el suelo cerca de la superficie [Transport of radon gas in soil close to the surface], *in* Cuarta asamblea nacional de geodesia y geofisica, Vol. 2:
Madrid, Inst. Geogr. Nac., p. 909-916.

Dujardin, J., N. Bonningue, M. Fontan, and R. Cuvelier, 1962
New method for the measurement of radon by scintillation [in French]:
Atti Congr. Intern. Idrol. Climatol., Ischia, Italy, Oct. 4-8, 1958, 539-546
Nucl. Sci. Abs. 21967
Bubbling air in water containing radon carries the radon gas away with it. The mixed gases, air and radon, after concentration and dessication are introduced into a flask the inner surface of which has been coated with zinc sulfide powder activated with silver, and the bottom replaced by a highly transparent glass disk. The flasks are placed in front of a photomultiplying set that transforms light impulses into electric impulses. An electronic computer notes the results. The radioactivity of the thermal waters to be measured is compared to that of a standardized solution of radium. Thus, results are directly obtained. The dosage of radium salts is established in the same way, but only when radium-radon equilibrium has been obtained after 30 days. The results of some measurements are given.

Dupré la Tour, F., 1949
The radiactivity of some springs in Lebanon and Syria [in French]:
Acad. Sci. [Paris] Comptes Rendus, 229: 712-713
Chem. Abs. (1950) 44: 2379
Radiactivity measurements of 10 springs in Lebanon and Syria showed activities ranging from 0.007 to 6.15 nCi/L. [Ann. Rev. Nuclear Sci. 1: 471]

Durrance, E.M., 1978
Radon in the stream waters of East Devon, *in* Edwards, R.A, ed., Ussher Society Conf., 17th, Proceedings, 4(Pt.2); 220-228

du Toit, R.S.J., S.R. Rabson, and C.J. Verwey, 1963
Experience in the measurement of radon and radon daughter concentrations in the uranium mines of South Africa:
Vienna, Internat. Atomic Energy Agency Preprint Sm-41/10: 21 p.
Nucl. Sci. Abs. 17:41146

Duval, Joseph S., 1983
Composite color images of aerial gamma-ray spectrometric data:
Geophysics, 48(6): 722-735
Aerial gamma-ray data provide estimates of the apparent surface concentrations of potassium (K), equivalent uranium (eU), and equivalent thorium (eTh). These data can be expressed as nine radiometric parameters: K, eU, eTh, eU/eTh, eU/K, eTh/K, eTh/eU, K/eU, and K/eTh. The U.S. Geological Survey (USGS) has developed a technique which combines any three of these parameters to form a composite color image. The color image provides a partial synthesis of the radiometric data that can be used to aid geologic mapping and mineral exploration. The sample data set, from the Freer area in south Texas, illustrates the use of the color images.

Duval, J.S., 1989
Indoor radon prediction using gamma-ray spectrometric data [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 496

Because radium-226 is measured directly by gamma-ray techniques and because it is the progenitor of radon-222, spectral gamma-ray data can be used to estimate the amount of radon in soil gas, which then can be used to estimate relative indoor radon levels. The positive correlation between measurements of radon in soil gas and surface concentrations of radium confirms that the gamma-ray data can be used to estimate the radon in soil gas. Because such soil properties as emanation power and location of the radium affect the radon concentration at depth, the relationship between the surface radium and the radon in the soil gas varies from place to place. Comparisons of aerial gamma-ray data with average indoor radon levels in homes in New Jersey and in the Pacific Northwest show that the aerial gamma-ray data also can be used to estimate the relative indoor radon levels. However, the data from the Pacific Northwest indicate that soil permeability is a very important factor that significantly increases the average indoor radon for a given amount of radium in the soil. Although aerial and ground gamma-ray data provide useful tools for radon hazard assessment, geologic properties of the soils must be considered also; soil permeability is particularly important.

Duval, Joseph S., and William J. Jones, 1988
Regional aerial gamma-ray maps for Illinois and parts of Wisconsin, Iowa, Michigan, Indiana, Missouri, and Kentucky, *in* Marikos, Mark A., and Robert H. Hansman, eds., Geologic Causes of Natural Radionuclide Anomalies, Proceedings of the GEORAD Conference, St. Louis, Mo., April 21-22, 1987:
Rolla, Mo., Missouri Dept. Nat. Resources Spec. Pub. No. 4, p. 157-165.

Duval, J.S., W.J. Jones, and J.K. Otton, 1989
Radium distribution map and radon potential in northwestern United States, *in* Osborne, M.C., and Harrison, Jed, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 2, Symposium Poster Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9- 89/006b [Springfield, Va., NTIS Order No. PB89-167498], p. 3-41--3-49.

Duval, J.S., and J.K. Otton, 1990
Radium distribution and indoor radon in the Pacific Northwest:
Geophysical Research Letters, 17(6): 801-804

Duval, J.S., J.K. Otton, and W.J. Jones, 1988
Radium distribution and radon potential in the Bonneville Power service area:
U.S. Geological Survey Open-File Report 89-340, 126 p.

Duval, J.S., J.K. Otton, and W.J. Jones, 1989
Estimation of radon potential in the Pacific Northwest using geological data:
U.S. Department of Energy, Bonneville Power Administration report DOE/BP-1234, 146 p.

Duval, J.S., G.M. Reimer, R.R. Schumann, D.E. Owen, and J.K. Otton, 1990
Soil gas radon compared to aerial and ground gamma-ray measurements at study sites near Greeley and Fort Collins, Colorado: U.S. Geological Survey Open-File Report 90-648, 42 p.

Dyck, Willy, 1968
Radon-222 emanations from a uranium deposit:
Econ. Geology, 63(3): 288-289
Chem. Abs. 29246v:

Dyck, Willy, 1969
Development of uranium exploration methods using radon:
Canada Geol. Survey Paper 69-46,: 26 p.
Geophys. Abs. 279-378:

Results are given of tests carried out in surface waters and soils during the 1968 field season to determine applicability of the radon method for detailed prospecting for uranium. In Gatineau Hills, Quebec, results suggest that surface and underground water drainage is responsible for radon and radium in the lake systems, soil emanations outline radioactive pegmatites. A radon anomaly in surface waters of the eastern quarter of the Sudbury irruptive appears to be similar in origin to those in the Gatineau Hills. In the Elliot Lake area, four lakes were studied, two in contaminated channels and two in uncontaminated terrain overlying the uranium-bearing Matinenda Formation. Results from the contaminated lakes demonstrate some of the principles of radon prospecting very well. Radon levels in the uncontaminated lakes are a factor of ten lower than the contaminated. In general the studies have shown that the radon method can outline radioative sources on a reconnaissance scale as well as on a more detailed scale.

Dyck, Willy, 1969
Uranium exploration using radon in soils:
Canadian Mining Jour., 90(8): 45-49

Dyck, Willy, 1972
Radon methods of prospecting in Canada, *in* Bowie, S.H.U., Michael Davis, and Dennis Ostle, eds., Uranium prospecting handbook. Proceedings of a NATO-sponsored Advanced Study Institute on methods of prospecting for uranium minerals, London, Sept. 21 - Oct. 2, 1971:
London, Inst. Mining and Metallurgy, p. 212-241

Dyck, W., R.A. Campbell, and J.C. Polchat, 1978
Evaluation of He and Rn geochemical uranium exploration techniques in the Key Lake area, Saskatchewan: *in* Current Research, Pt. B:
Canada Geol. Survey Paper 78-1B, p. 39-44

Dyck, W[illy], A.S. Dass, C.C. Durham, J.D. Hobbs, J.C. Pelchat and J.H. Galbraith, 1971
Comparison of regional geochemical uranium exploration methods in the Beaverlodge area, Saskatchewan, *in* Boyle, R.W., ed., Geochemical Exploration, Proceedings, International Geochemical Exploration Symposium, 3d, Toronto, April 16-18, 1970:
Canadian Inst. Mining Metallurgy, Spec. Vol 11; 132-150

Dyck, Willy, and A.Y. Smith, 1968
Use of radon-222 in surface waters for uranium geochemical prospecting:
Canadian Mining Journal, 89(4): 100-103

Eaton, R.S., 1982
Radon and radon daughters in public, private and commercial buildings in communities associated with uranium mining and processing in Canada, *in* Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:
New York, John Wiley and Sons, p. 495-496

Eaton, R.S., and A.G. Scott, 1984
Understanding radon transport into houses:
Radiation Protection Dosimetry, 7(1-4):251-253
Chem. Abs. 101:99852t:

Ebersole, E.R., A. Harbertson, J.K. Flygare, and C.W. Sill, 1959
Determination of radium 226 in mill effluents:
Idaho Operations Office, Health and Safety Div., AEC: 26 p.
Nucl. Sci. Abs. 17:121:

Procedures are given for determination of Ra-226 in effluents from mills processing uranium ores. Alpha-energy spectra graphs are given for precipitates separated from the mill effluent by various methods. Samples for determination of Ra-226 were acidified with HNO_3 to make the sample 2 percent acid by volume. The radium is precipitated as sulfate with barium sulfate carrier and lead sulfate. These sulfates are dissolved in fuming perchloric acid, reprecipitated, and dissolved in EDTA-TEA solution. The pH of the solution is adjusted until barium and radium sulfates precipitate, leaving lead, radium daughters, and any thorium present in solution. The Ra-226 activity can be determined by alpha counting at 3 hr and one week after precipitation.

Ebert, H., and P. Ewers, 1902
Über die dem Erdboden entstammende radioaktive Emanation [On radioactive emanation originating from the soil]:
Physikal. Zeitschrift 4: 162-166

Economou, T., and A.R. Bowers, 1988
Effect of oxide precipitates on clay permeability [abs.]:
Geol Soc. America, Abstracts with Programs, 20(7): A338
Clay minerals such as montmorillonite are often used as sanitary landfill lining material because they posses many physical and chemical properties that are advantageous for sequestering wastes. Iron is naturally present in the soil environment in the form of Fe oxides, hydroxides, and oxyhydroxides, and is a major constituent of typical landfill leachates. This study examined how the association of Fe oxide precipitates with Na-montmorillonite affected clay permeability. Specific resistance to filtration was determined for Na-montmorillonite, Na-montmorillonite with an added concentration of 10^{-3} moles of Fe^{+3} per gram clay, and Na-montmorillonite with an added concentration of 10^{-3} moles of Fe^{+2} oxidized to Fe^{+3} per gram clay. Specific resistance, used primarily to evaluate sludge dewatering, is related to permeability by nature of the test parameters. Ferric oxide is reported to have a lower specific resistance to flow value than colloidal clay; likewise, it has a higher permeability than colloidal clay. The finding of this experimental study was that the specific resistance of Na-montmorillonite decreased one and two orders of magnitude with the addition of oxidized Fe^{+2} and Fe^{+3} ions, respectively, and approached the value of ferric oxide (without clay). This suggests that: (1) the integrity of sanitary landfill liners may be reduced if Fe oxides/hydroxides are present in the leachate; and (2) the Fe oxide was not present as discrete particles, but coated the clay, thereby masking its properties.

Edling, Christer, 1983
Lung Cancer and Radon Daughter Exposure in Mines and Dwellings:
Linköping, Sweden, Linköping Univ. Medical Dissertations, No. 157, 149 p.
For the elucidation of the interaction of radon daughters and smoking in causation of lung cancer, four case-referent [case-control] studies were undertaken, two regarding miners with occupational exposure to radon and radon daughters and two regarding rural populations with indoor radon daughter exposure. Also, correlation was studied between county-specific, directly age-standardized lung cancer mortality and background gamma radiation. The results and other facts indicate that radiation might be important for the initiation of lung cancer and that smoking is likely to act mainly as a promoter. In mines, exposure to radon and its daughters is associated with a substantial risk of lung cancer, but there seems to be a complex relationship between radon and radon daughter exposure and smoking, since smoking also causes bronchitis, hindering the exposure of the epithelium to the very short ranging alpha radiation, resulting in a more or less additive relation between radon daughter exposure and smoking. In dwellings a multiplicative interaction between the two factors is rather clearly pronounced. The studies in the rural populations as well as the correlation study strengthen the hypothesis that exposure to radon and radon daughters in dwellings is pertinent to the question of the etiology of lung cancer. Calculations of etiological fractions suggest that about 30% of the lung cancer mortality in the population might be due to avoidable indoor exposure to radon and radon daughters. Additional and quite comprehensive studies are necessary to achieve more definite conclusions about the effect of indoor radon daughter exposure, but the assessment of exposure will be a

formidable task, even prospectively. For practical and economic reasons, these future studies should preferably be of the case-referent approach, based on the guiding experiences obtained in the present investigation. [Abridgement of author's abstract]

Edvardson, Kay, 1962
Radioactivity measurements on food materials (preliminary report)[in Swedish]:
Sweden, Forsvarets Forskningsanstalt, Stockholm: 88 p.
Nucl. Sci. Abs. 18:23790:
A special group of experts was established by the Swedish Radiation Protection Board in order to prepare a program for coordinated measurements on radioactivity in foodstuff. The preliminary results of measurements made during the summer and autumn of 1962 are presented. The most important results are also given in English. The apparatus used in the measurement and the program set-up are described. The radioactivity of milk, meat, corn, fish, and vegetables with respect to ^{137}Cs, ^{40}K, ^{131}I, ^{89}Sr, ^{90}Sr, $^{96}Zr/^{95}Nb$ and ^{222}Rn were also measured.

Edwards, John C., and Robert C. Bates, 1980
Theoretical evaluation of radon emanation under a variety of conditions:
Health Physics, 39: 263-274

Efendiyev, G.Kh., and A.N. Nuriyev, 1963
Leaching of uranium and radium from clays [in Russian]:
Azerbaydzhan. Khim. Zhur., (4): 103-107

Eichholz, G.G., F.J. Clarke, and B. Kahn, 1980
Radiation exposure from building materials, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1331-1346

Ellett, William H., and Neal S. Nelson, 1985
Epidemiology and risk assessment: testing models for radon-induced lung cancer, Chap. 6, *in* Gammage, Richard B., and Stephen V. Kaye, eds., Indoor Air and Human Health:
Chelsea, Mich., Lewis Publishers, Inc., p. 79-107

El Nadi, Abdel Fattah, and M. Ammar, 1960
Thorium content in Nile Water:
Math. Phys. Soc. U.A.R. Proc., (24): 11-16
Nucl. Sci. Abs. 17(6):8414:
A study of thorium concentration in Nile water was carried out by the flow method using a cylindrical ionization chamber. The results indicate that the amount before and after flood has an average of 14.7± 0.6E-8 g/cm^3, while during flood it decreases to an average of 10.1± 0.7E-8 g/cm^3. This decrease may be attributed to the effect of the presence of suspended clays which may adsorb Tn gas on its surface and thus decrease the amount of Tn expelled during the process of deemanation.

El-Nadi, Abdel,and Hassan Omar, 1959
Radon content of atmospheric air at Giza:
Math. and Phys. Soc. U.A.R. Proc (23): 65-69
Nucl. Sci. Abs. 15:14565
[Mean in 1957 90 fCi/L (approx. 150 samples). Rainfall decreases Rn in air.]

El Nadi, Abdel Fattah, and Hassan M. Omar, 1960
Radon and thoron content in atmospheric air at Giza, Egypt:

Geofisica Pura e Appl., 45: 261-266
Geophys. Abs. 183-518:
The radon and thoron content of the air at Giza, Egypt, during the period January 1958 to July 1959 was determined by the emanometric technique. The concentration of radon and its decay products was (88± 4) fCi/L and that of thoron and its decay products was (51± 11) fCi/L.

El Nadi, Abdel Fattah and Hassan Omar, 1960
Radon and thoron content in soil air at Giza:
Math. Phys. Soc. U.A.R. Proc., (24): 49-56
Nucl. Sci. Abs. 17(7):8415:
The radon and thoron content in soil air at Giza was studied by using the emanation method. Four depths of 50, 100, 150, and 200 cm were investigated and it was found that the radon and thoron concentrations increase with depth. The mean value of the radon concentration in the depths 50, 100, 150, and 200 cm are 13.5, 43.9, 56.7, and 84.3 pCi/L respectively while the corresponding values of thoron equivalent concentrations are 15.4, 26.3, 64.5, and 72.7 pCi/L.

El Nadi, Abdel Fattah and H.M. Omar, 1961
Radium and thorium content in underground water of the Egyptian oil fields:
Math. Phys. Soc. U.A.R. Proc., (25): 1-5
Nucl. Sci. Abs. 18:25696:
The radium and thorium contents of underground waters in the oil fields were determined by the emanation method. For radium, values ranging from 0.19 to 4.32E-13 g/cm^3 were obtained. The relation between the chlorine and radium contents in the different wells considered was also studied. For thorium, values from 9.8 to 36.4E-8 g/cm^3 were obtained, approx. the same as for ordinary underground waters.

Elster, J. and H. Geitel, 1901
Über eine fernere Analogie in dem elektrischen Verhalten der natürlichen und der durch Becquerelstrahlen abnorm leitend gemachten Luft [On a further similarity in electrical content between natural air and that made abnormally conductive by Becquerel rays]:
Physikal. Zeitschrift, 2: 590-593
[Stated by Dadourian to have been original discovery of radioactivity in atmosphere.]

Elster, J. and H. Geitel, 1902
Über die Radioaktivität der im Erdboden enthalten Luft [On the radioactivity of air contained in soil]:
Physikal. Zeitschrift 3: 574-577

Elster, J. and H. Geitel, 1904
Über die Radioactivität der Erdsubstanz als eine der Ursachen des Ionengehaltes der Atmosphäre [On the radioactivity of Earth materials as one of the causes of the ion content of the atmosphere]:
Terrestrial Magnetism and Atmospheric Electricity [Baltimore], 9(2): 49-61

Emrich, Grover H., and Henry F. Lucas, Jr., 1963
Geologic occurrence of natural radium-226 in ground water in Illinois:
Internat. Assoc. Sci. Hydrology Bull., 8(3): 5-19
[See papers by R. Gilkeson and others for follow-up on subject.]

Engler, W., 1908
Influence of temperature on radioactivity:
Ann. Physik, 26(3): 483-520
Sci. Abs. 1431 (1908)
[Increase in radioactivity of substance during period of heating.]

Erbacher, Otto, and Boris Nikitin, 1932
Bestimmung der Löslichkeit von Radiumsulfat in Wasser bei 20° [Determination of the solubility of radium sulfate in water at 20°C.]:
Zeitschrift physikal. Chemie, 158: 216-230

Ergashev, S.E., and O. Aripova, 1967
Distribution of radium in subsurface waters of Cretaceous formations in a Central Asian artesian basin [in Russian]:
Akad. Nauk Uzbek. SSR Doklady, 24(8), 35-37
Chem. Abs. 5047j

Ericson, Sven-Olaf, and Hannes Schmied, 1985
The first long time comparison of techniques for passive integrated measurement of radon and radon daughter concentration performed in an occupied dwelling:
The Science of the Total Environment, 45: 405-415

Ericson, S-O., H. Schmied, and B. Clavensjö, 1984
Modified technology in new constructions, and cost effective remedial action in existing structures, to prevent infiltration of soil gas carrying radon:
Radiation Protection Dosimetry, 7(1-4): 223-226
Chem. Abs. 101:99847v

Eriksson, Erik, 1962
Radioactivity in hydrology, *in* H. Israël and A. Krebs, eds., Nuclear Radiation in Geophysics:
New York, Academic Press, p. 47-60

Espino Flores, A.L., 1953
Aguas radioactivas de la Republica Mexicana y determinacion de los elementos a que se debe su radioactividad [Radioactive waters of the Mexican Republic and determination of the elements to which they owe their radioactivity]:
Congreso Cientifico Mexicano Mem. Univ. Mexico, 2: 46-81
Geophys. Abs. 160-172
Data are given for 17 springs. Radioactivity ranges from 0.1 to 18.7 nCi/L. Helium (trace or 0.002 or 0.00042 percent by volume) is reported for 7 springs.

Evans, Robley D., 1935
Ionization currents produced by radon, RaA, and RaC' in cylindrical ionization chambers:
Phys. Review, 48(3): 177-186
Geophys. Abs. 79-2857

Evans, Robley D., 1936
Apparatus for the determination of minute quantities of radium, radon, and thoron in solids, liquids, and gases:
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The amount of Rn-220 and Rn-222 that emanates from thoriferous and uraniferous minerals is studied by alpha-spectrometry. It is found that it is not possible to ascertain any appreciable loss of Rn-220, but that a correlation exists between emanating power and the structural conditions of the solid in the case of Rn-222. The losses are especially favored by reticular disorder but are also noticeable in layered structures with zeolitic H_2O and a high base exchange capacity. It is concluded that in this type of solid the loss of Rn-222 is a result not only of the great development of specific free surface but also of the higher value of the diffusion coefficient throughout the solid.

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An investigation made in the Pyrenees during 1937 revealed that the radium emanation from subsoil rocks accumulates on the surface under the mountain snow. The air between the ground and the snow had a content of 1 nCi, whereas the average content of the free air in Paris was 0.10 pCi. Apparently the snow layer acts as an impermeable shield preventing the diffusion of emanations. A factor contributing to the concentration seemed to be the action of the wind, by means of which the emanation over the uncovered areas was swept in the direction of the snow-covered areas and forced under the layer of snow. A similar investigation in the less elevated and less steep Vosges Mountains in 1938 confirmed these findings. It showed that the accumulated emanation content varies proportionally to wind intensity and depends upon the nature of the relief and the subsoil. The maximum emanation-content here was less than in the Pyrenees. The daily readings are listed.

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On February 10, 1956, a circular hole about 10 cm in diameter was observed in the snow, which was 20 to 30 cm thick, near the summit of Puy-de-Dôme. The air temperature in this hole was about 3°C and the radioactivity 40 to 80 pCi/L (in contrast to the "normal" 30 pCi/L), indicating anomalies in the radon content underground.

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Radon distribution around the Hylas zone, VA: A product of lithology and ductile shearing [abs.]:
Geol. Soc. America, Northeastern Section, Abstracts with Programs, 21(2): 17
The distribution of radon in soil gas around the Hylas zone, Richmond, VA, is controlled by both lithology and ductile shearing. The Hylas zone lies in the Goochland terrane which contains the Grenville age State Farm granitic gneiss and Maidens Gneiss of multiple lithologies, the 330 Ma Petersburg Granite (Mpg), Triassic sediments in the Richmond Basin and small pegmatites of unknown age. The Hylas zone is a late Paleozoic dextral strike-slip ductile shear zone that cuts the Petersburg Granite and Maidens Gneiss and that was reactivated into a Triassic normal fault. Small pegmatites exhibit consistently high radiation with an average of 5.93 [ppm] equivalent uranium (eU) and 4527 pCi/L of radon (Rn) in overlying soils. The areally extensive Maidens Gneiss exhibits relatively low radiation regardless of lithology. Soil radon varied from 544 to 1300 and averaged 921 pCi/L and eU averaged 2.66 ppm. The Mpg is also areally extensive but exhibits relatively high radiation. Undeformed Mpg contains an average of 4.75 ppm eU and overlying soils average 1899 pCi/L. Several samples taken over a small shear zone within the Mpg yielded >7000 and up to 11318 pCi/L. The Hylas mylonites also exhibited elevated radiation but because they include several lithologies, eU and radon vary greatly. Radon in soil gas from over the mylonite averaged 3027 pCi/L but ranged from 1018 in the Maidens Gneiss to 12081 pCi/L in the Mpg. Similarly, eU averaged 3.88 ppm for the entire zone but was up to 7.07 ppm in the Mpg. The five highest concentrations of radon in water were also from the Hylas zone. Unfortunately, intense shearing commonly precludes distinguishing of protoliths.

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The concentration of radon (Rn-2?2) in soil gas over shear zones is controlled by the composition of the bedrock, amount of strain in the shear zone and the nature of the soil cover. In the Brookneal mylonite zone, southwestern Virginia Piedmont, uranium content of the bedrock varies as a function of shear strain. The zone lies within the homogeneous Melrose granite and therefore the effect of variable composition of the protolith is eliminated. Radon in overlying saprolite also varies as a function of strain and is 10 times higher over the most deformed part of the zone than the undeformed granite. The Hylas mylonite zone in the eastern Virginia Piedmont shears several rock units with highly variable compositions. The composition of each protolith is also a dominant factor in the radon concentration of the overlying saprolite. Soils above the intermediate to mafic gneisses contain up to 9 times less radon than those above pegmatites. Radon in soils above mylonites were up to 11 times higher than over undeformed counterparts. The Reservoir fault zone, New Jersey Highlands is a cataclastic shear zone and contains pegmatites with anomalous uranium concentrations. It also separates Grenville gneisses of the Reading Prong that exhibit elevated gamma radiation from Silurian/Devonian sediments with low gamma radiation. Unlike the other shear zones, soils above this area are glacial tills of a terminal moraine. Radon in these soils is highly variable and does not correlate with uranium concentration of the underlying bedrock. It appears to more closely reflect the composition of the glacial till.

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Geophys. Research Letters, 17(6): 813-816
[Uranium concentrations in bedrock and radon concentrations in soil gas in the overlying soils were studied in the unglaciated Hylas shear zone area of Virginia and in the glaciated Reservoir fault area of the New Jersey Highlands. Radon concentrations in soil gas and uranium concentrations in bedrock correlated directly where the overlying soils are not a product of glaciation.]

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A series of Ra solutions ranging from 1E-12 and 1E-7 curies was compared and standardized for the calibration of instruments used for measuring Rn. Three instruments for measuring Rn in breath, in laboratory air and

in boreholes used in U prospecting, were calibrated using a known quantity of Rn. For the Rn-in-breath apparatus the mean radon activity required to double background was 0.047 pCi/L (efficiency 42%) and the limit of detection was 0.01 pCi/L representing approximately 1 nCi or 0.01 maximum permissible burdens of Ra in the body. The exhaled Rn fraction determined for 5 subjects with known Ra burdens varied from 0.57 to 0.75. The Rn-in-air apparatus had a Rn sensitivity of 4 counts per second per 0.1 nCi/L and a limit of detection of 5 pCi/L. The Rn-in-borehole monitor gave 1.7 counts per minute from 10 pCi/L and had a limit of detection of 2 pCi/L.

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A highly sensitive system for the detection of small quantities of Rn-219 ($T_{1/2}$=3.92 sec) and Rn-220($T_{1/2}$=54.5 sec) has been developed. These isotopes are continually swept from a 5-ml acid solution containing their parents into a highly efficient 2-L scintillation counter. Through the use of a delayed coincidence technique involving the short-lived decay products of the emanation isotopes (Po-215, $T_{1/2}$=1.8 msec and Po-216, $T_{1/2}$=0.16 sec), the counter background is substantially reduced (0.03 cpm for actinon and 0.15 for thoron counting). The overall detection efficiencies are 45 and 46 percent, respectively. With this system as little as 4 pg Pa-231 per g (equivalent to 0.2 μg U-238 per g) and 20 ng Th-232 per g can be detected in 30-g samples of carbonate minerals.

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Geophys. Abs. 163-137:
The leakage of radon from a variety of primary and secondary uranium minerals has been measured. At room temperature, pitchblende shows a radon loss of 0.064 to 16.6 percent; uraninite, 0.58 to 0.80 percent; samarskite, about 0.03 percent; carnotite, 17 to 27 percent; zircon, 1.6 to 6.2 percent. Radon leakage increases with temperature so that at 150°C it is about twice that at room temperature. Between 200 and 300°C recrystallization ensues, reducing internal surface areas and radon leakage. Radon leakage measurements are necessary in order to estimate the correction to be applied to the 206/238 ages. If this is done as a function of temperature, if the average temperature at which the mineral has existed for its history can be approximated, and if no leaching has occurred, the 207/206 age agrees with the corrected 206/238 and 207/235 ages for a considerable variety of specimens. If leaching is absent, the 207/235 age seems to be most reliable; conversely if the three isotopic ages agree after correction for radon leakage, leaching of uranium and lead has probably not occurred.

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Urbana-Champaign, Ill., Univ. Illinois at Urbana-Champaign Water Resources Center Research Report 187 [UILU-WRC-84-0187], 50 p.
Stable and radioactive isotopes in groundwater were studied in an investigation of the natural geologic sources of high concentrations of Ra-226 and Ra-228 in confined aquifers in the Cambrian and Ordovician bedrock of northern Illinois. The covariation of δO-18 and δD determined that the groundwater has a meteoric isotopic composition. Groundwater in unconfined aquifers has δO-18 values (-6.6 to -7.9 per mille [per thousand]) that are similar to contemporary meteoric water. However, a source of recharge related to glaciation is required for groundwater in confined aquifers of the Cambrian and Ordovician that is significantly depleted in O-18 (δO-18 values range to -12.7 per mille and are less than -9 per mille over large regions). The covariation of δS-34 and δO-18 in dissolved sulfates determined a mixing line between two sources: oxidation of sulfide minerals and dissolution of marine evaporites. Dissolved sulfates from evaporite sources are present in large concentrations in confined aquifers but are of a different isotopic composition than evaporites of Cambrian or Ordovician age. Glaciation may be important with regard to recharge of the sulfates. The U-234/U-238 activity ratios in groundwater from the Cambrian and Ordovician are unexpectedly high; values range from 2.1 to 40.7. The lowest ratios occur in primary recharge zones. In unconfined aquifers values are greater than 20 over large regions. Alpha recoil damage is a mechanism that contributes to the disequilibrium. However, the regional variation in activity ratios and in U-234 concentrations supports the concept that glacial recharge has contributed to the high ratios. Radiological and geochemical mechanisms that partition U-238, U-234, and Th-230 on the sandstone matrix are important to the dissolved Ra-226 concentration.

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Nucl. Sci. Abs. 15:11290
The meter comprises a variable volume chamber with one wall formed by a detecting scintillator, a photomultiplier associated with the scintillator, and means for transforming the electron pulses into countable signals. The scintillator is a plate of methyl methacrylate covered by a layer of zinc sulfide and a film of corrosion-resistant plastic.

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Chem. Abs. 2:2501
The dependence of the amount of radium emanation in the ground air upon meteorological conditions was studied, and results similar to those of Brandes obtained. A low barometer, frozen ground, snow, and rainfall tended individually and collectively, to increase the amount of emanation, which varied between maximum and minimum limits of 4:1. Other observers have noted that the emanation content of atmospheric air is heightened by cold weather, a fact which the author finds difficult to reconcile with his own observations. c.f. Meteorologische Zeitschrift, Braunschweig 25: 410-412

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[This is a comprehensive conference, with emphasis on radon and radon decay products, including control, measurement, medical aspects, transport, and equilibria in air.]

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Preliminary estimation of high radon potential areas in EPA Regions 3 and 4 as indicated by geologic factors [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A337

Indoor radon concentrations result from a combination of geologic, environmental, and anthropogenic factors. To gain an understanding of the geologic component, maps of geologic factors related to radon have been prepared for the U.S. Environmental Protection Agency Regions 3 and 4 (generally, the southeastern and mid-Atlantic States) in support of EPA's Indoor Radon Program. Individual maps were prepared for the following factors: (1) uranium occurrences and rock formations elevated in uranium content, (2) rock formations and other areas that have equivalent uranium concentrations of approximately 3 ppm or greater from aerial radiometric survey data, (3) fault systems and Triassic-Jurassic dikes, and (4) carbonate rock formations. Indoor radon data and soil and house foundation characteristics were also examined. The principal source of uranium data for the first two factors listed above was the U.S. Department of Energy National Uranium Resource Evaluation Program. The areas most likely to contain high indoor radon concentrations were identified using a combination of the listed geologic factors. The principal high radon potential areas identified include most of the Inner Piedmont from southern Virginia to western Georgia, the Piedmont of southeastern Pennsylvania, the Inner Coastal Plain underlain by Cretaceous chalks, and the northern Kentucky Devonian and Ordovician black shales. Areas of low indoor radon potential include most of the Coastal Plain and the Cumberland Plateau.

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Spatial non-homogeneity and temporal variability in the emanation of radon from the lunar surface: interpretation [abs.], *in* Lunar Science IV, Abstracts, 307-308:
Houston, Lunar Science Inst.

Gorshkov, G.V., 1933
K voprosu o vliyanii narusheniy v nanose i ego sloistosti no skorost' rasprostraneniya v nem emanatsii radiya [On the effect of disturbances and stratification on the speed of radium emanation migration in alluvium]:
Zhur. Geofiziki, 3(3): 292-298
Geophys. Abs. 62-1962

Gott, Garland B., and James W. Hill, 1953
Radioactivity in some oil fields of southeastern Kansas:
U.S. Geol. Survey Bull. 988-E: 69-122
Geophys. Abs. 158-188:
Radium-bearing precipitates derived from oil-well fluids have been found in more than 60 oil and gas fields in southeastern Kansas. Most of the formations in the area have no higher concentration of radioactive constituents than is normally found in rocks of similar lithology, but in a few wells drill samples from beds just below the eroded top of the Arbuckle group and from some limestone in the Kansas City group have an abnormally high radium content. The radioactivity of the precipitates ranges from 0.000 to 10.85 percent equivalent uranium oxide and the uranium oxide content ranges from 0.000 to 0.006 percent. Most of the radioactivity is caused by radium. The highest radioactivity caused by radium in the rocks from this area that have been radiometrically analyzed is equivalent to that of 0.26 percent uranium oxide. This analysis indicates as much radium as would be found in equilibrium with about 0.5 percent uranium. It is suggested that significant quantities of uranium may be present in the subsurface rocks.

Goss, Dave, 1988
Radon and tunnels:
Berkeley, Calif., Univ. Calif., Lawrence Berkeley Laboratory Rept. SSC-N-480, 26 p.

Grabely, I., 1911
Variations in the quantity of radium emanation in the atmosphere:
Kurh. Z. Klin. Med. 71: 338-343
Chem. Abs. 3080 (1911)

Grace, John D., 1989
Radon anomalies in southern Michigan [abs.]:
Recent radon surveys in ten states by the U.S. Environmental Protection Agency have produced vast data on the geographic distribution and variability of indoor radon. Analysis of over 2000 screening measurements in Michigan indicates the presence of two major anomalies or "hot spots", one in the Northern Peninsula and the other in southeastern Michigan. The anomaly in the Northern Peninsula is reasonably well understood as it corresponds to uraniferous Precambrian bedrock. The anomaly in southeastern Michigan, where over 40% of the homes tested had readings above the 4 pCi/L recommended limit, is centered on Hillsdale, Lenawee, and Washtenaw Counties. The causes for this southern anomaly are not immediately apparent as there is no direct correlation of high radon readings with soil type, glacial deposit thickness, bedrock geology, structure, or aeroradiometric surveys. A detailed analysis of the E.P.A. data suggests, however, that the highest radon readings are associated with the Defiance, Fort Wayne, and Wabash moraines produced by the Lake Erie Lobe of the Wisconsin glacial stage. We have conducted a series of supplementary soil-gas radon measurements in the southern Michigan area which confirms the E.P.A. data. The results are interpreted with respect to the type, mineralogical character, and permeability of these deposits.

Gracheva, Ye.G., 1938

Vliyaniye struktury i poristosti porod na diffuziyu radioaktivnykh emanatsiy [The influence of structure and porosity of rocks on the diffusion of radioactive emanations]:
Gosudarstvennyy Radievyy Inst. Trudy, 4: 228-233

Grammakov, A.G., 1934
Emanatsionnyy (radonovyy) metod poiskov, issledovaniya i razvedki radioaktivnykh ob"yektov [Emanation (radon) method of search, investigation, and prospecting for radioactive objects]:
Tsentr. Nauchno-Issled. Geol.-Razved. Inst. Trudy, (7): 48
Geophys. Abs. 76-2647

Grammakov, A.G., 1936
O vliyanii nekotorykh faktorov na rasprostraneniye radioaktivnykh emanatsiy v prirodnykh usloviyakh [The influence of some factors on the spreading of radioactive emanations in natural conditions]:
Zhurnal Geofiziki, 6(2,3): 123-148
[Summary of Author's English summary: Experimental treatments are given for two questions: 1. Influence of moisture in a porous medium on coefficient of diffusion of emanation through it. 2. Influence of electrostatic field on diffusion coefficient. Theoretical consideration is given to movement of emanation by the combination of diffusion and transport mechanisms, for flow in one direction (in a cylinder) from a radioactive layer to a non-radioactive layer (eq. 5, 6, 12, 16, 20, 22, 26). The diffusion effect alone, obtained by setting the stream velocity = 0, is given. The influence of rock moisture was studied by determining K for thoron with varying moisture content. Thickness of a thorium-active layer and distance between the layer and ion-collecting detectors were additional experimental variables. It follows from the consideration of the above data and from the shape of the graphics (fig. 4-6) that with small moistures up to 6% approximately, the diffusion coefficient value varies very slowly, it oscillates in the range of (7-6)E-2 cm^{-2}/sec, but with further increase of moisture the diffusion coefficient decreases quickly, down to the value of 5E-3 cm^{-2}/sec with the moisture of about 17%.]

Grammakov, A.G., 1961
K teorii emanatsionnogo metoda dlya ob"yektov lokal'nogo tipa [On the theory of the emanation method for objects of a local kind], *in* Voprosy Rudnoy Geofiziki:
Moscow, Vses. Nauchno-Issled. Inst. Razved. Geofiziki, no. 2, p. 135-148
Geophys. Abs. 194-301

Grammakov, A.G., 1961
Nekotoryye voprosy teorii emanatsionnogo metoda [Some problems of the theory of the emanation method], *in* Voprosy Rudnoy Geofiziki:
Moscow, Vses. Nauchno-Issled. Inst. Razved. Geofiziki, no. 2, p. 86-93
Geophys. Abs. 194-295

Grammakov, A.G., N.V. Kvashnevskaya, A.I. Nikonov, M.M. Sokolov, N.N. Sochevanov, S.A. Suppe, and G.P. Tafeyev, 1958
Some theoretical and methodical problems of radiometric prospecting and survey, in United Nations Internat. Conf. on the Peaceful Uses of Atomic Energy, 2d, Geneva, 1958:
Geneva, United Nations, Proc., v. 2, p. 732-743
Geophys. Abs. 178-333

Grammakov, A.G., and N.M. Lyatkovskaya, 1935
O diffuzii radioaktivnykh emanatsiy v gornykh porodakh [On the diffusion of radioactive emanations in rocks]:
Zhur. Geofiziki, 5(3): 290-306
Geophys. Abs. 81-2974

Grammakov, A.G. and I.F. Popretinskiy, 1957
Raspredeleniye radona v rykhlykh otlozheniyakh pri nalichii oreolov rasseyaniya radiya [Distribution of radon in porous deposits in the presence of aureoles of dispersed radium]:
Akad. Nauk SSSR Izv., ser. geofiz. 6: 789-793

Grasty, R.L., 1989
The relationship of geology and gamma-ray spectrometry to radon in homes [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 496
Studies in Scandinavia, Britain, and North America have shown that there are regional variations in radon concentrations in homes that can be attributed to differences in the underlying rocks and soils. Homes built on granites invariably have elevated radon levels due to their increased uranium concentration compared with other rock types. The uranium concentration of the ground as measured by airborne gamma-ray spectrometry is shown to be a useful parameter for predicting potential radon problem areas. However, in Canada, the cities of Winnipeg, Manitoba and Regina, Saskatchewan have the highest radon levels and are situated on glacial lake clays. A cross-Canada airborne gamma-ray survey could not explain these elevated levels. Subsequent laboratory analyses of the Lake Agassiz clays underlying Winnipeg showed relatively high radium concentrations compared with most surficial materials. The differences between the airborne and laboratory analyses were attributed to radon loss from the surface of the ground and consequent reduction of the airborne signal. Because of their small size, clay particles are extremely efficient in emanating radon. Fracturing of the clays is common for the Interior Plains, and is believed to be a significant contributing factor to the high radon levels in Winnipeg and Regina. These fractures provide an efficient plumbing system for the radon to move through the ground. In addition, the Lake Agassiz clays are high in the mineral montmorillonite, which shrinks substantially on drying, not only enlarging the fractures but also making the clay itself more permeable to radon. The fracturing of the montmorillonite-rich clays, their radium content, and emanation efficiency are all factors which together with the dry conditions of the Interior Plains could contribute to the high radon levels found in Winnipeg and Regina and the adjacent states of North Dakota and Minnesota in the United States.

Grasty, R.L., J.M. Carson, B.W. Charbonneau, and P.B. Holman, 1984
Natural Background Radiation in Canada:
Geol. Survey Canada Bull. 360, 39 p.
...The highest levels of [gamma-ray] radioactivity [measured by airborne survey] were found in northern Canada and were generally related to granitic rocks; the lowest levels with the Athabasca sandstone....[However, these sandstones are hosts to the largest uranium deposits in the world, according to J.K Otton.]

Grauch, Richard I., and Katrin Zarinski, 1976
Generalized description of uranium-bearing veins, pegmatites, and disseminations in non-sedimentary rocks, eastern United States:
U.S. Geol. Survey Open-file Rept. 76-582, 114 p.
[This report succinctly describes various uranium occurrences, including some that are near the surface and may have severe indoor radon potential. For instance, the first entry for New Jersey remarks that a γ-ray anomaly associated with uranium mineralization in veins in a quarry extends to the knoll above. A housing development established subsequent to the exploration report proved to have some of the highest indoor radon concentrations ever discovered.]

Graude, Ch., and J. Rodier, 1955
Contribution à l'étude des eaux thermo-minerales de Moulay Yacomb (composition, vieillissement et radioactivité) [Contribution to the study of the hot mineral waters of Moulay Yacomb (composition, aging and radioactivity)]:
Soc. Sci. Nat. Phys. Maroc, Comptes Rendus, 4: 78-81
Geophys. Abs. 163-162:

The hot mineral spring of Moulay Yacomb, about 20 km NW of Fez in Morocco, discharges about 16 L/s of clear water accompanied by about 1 cm^3/s of gases. Radioactivity was measured by a goldleaf electroscope as 4.55 nCi of radon per liter (of gas) and 16.4 nCi/hr for the free gaseous emanations; 1.24 nCi of radon per liter (of water) and 71,000 nCi/hr for the dissolved gas, and practically no radioactivity for the water itself. The resistivity of the water was found to be 26.4 ohm-cm at 18°C, and remained constant during a 4-week period of observation.

Graue, G., 1931
Studien über die Oberflächenausbildung und Oberflächenänderung an Solen und Gelen des Thoriums und Eisens [Studies on the formation and change of surface area in brines and gels of thorium and iron]:
Kolloid-Bieh. 32: 403-462

Graustein, William C., and Karl K. Turekian, 1986
^{210}Pb and ^{137}Cs in air and soils measure the rate and vertical profile of aerosol scavenging:
Jour. Geophys. Research, 91(D13): 14,355-14,366

Graves, Barbara, ed., 1987
Radon, Radium, and Other Radioactivity in Ground Water. Hydrogeologic Impact and Application to Indoor Airborne Contamination. National Well Water Association Conference, Somerset, N.J., April 7-9, 1987, Proceedings:
Chelsea, Mich., Lewis Publishers, Inc.

Greeman, Daniel J., and Arthur W. Rose, 1988
Abundance and occurrence of U, Th and Ra in Pennsylvania and Georgia soils [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A337
The concentrations of uranium, thorium, and radium which are relevant in studies of radon and aerial radioactivity, have been measured in 5 soil profiles in Georgia and 5 in Pennsylvania by delayed-neutron activation, gamma spectroscopy, and radon bubbler methods. In 1- to 1.5-m deep profiles on shale, sandstone, limestone, granite, and schist in Georgia, uranium is mostly between 2 and 5 ppm with the A horizon depleted by 10 to 25% relative to the B [horizon]; thorium is similarly depleted up to 50%. Despite intense weathering, the uranium and thorium values suggest only slight mobilization from near-surface horizons. Radium is generally in approximate equilibrium with parent uranium. In three 1- to 2.5-m-deep soil profiles developed on carbonate in Pennsylvania, uranium (3-8 ppm) and thorium (3-10 ppm) are enriched 2- to 10-fold over the parent carbonate (average 0.6 ppm U, 1.7 ppm Th) and Th/U averages 1.6 *vs.* 3 in the parent. Both uranium and thorium increase with depth. In two profiles on sandstone, uranium and thorium contents are mostly 1.5-2.5 ppm and 3-5.5 ppm, respectively. Uranium increases only slightly with depth but thorium is depleted in near-surface horizons and doubles in concentration in illuviated zones [containing colloids, salts, and small particles from an overlying horizon]. Both the Pennsylvania and Georgia soils suggest greater net mobility of thorium than uranium, possibly because of recycling of uranium through vegetation, plus leaching of thorium from surface horizons. Radium at 4 sites in Pennsylvania is enriched to as much as 180% of equilibrium relative to uranium in A horizons and is slightly depleted in E horizons. Lower B and C horizons show approximate equilibrium. Selective extractions for a carbonate soil show that almost half the radium occurs in mobile or poorly crystalline forms (exchangeable cations, organic matter, Fe-Mn oxides). Radium generally correlates with Ca content and with high radon (up to 4500 pCi/L) in the soil air.

Green, B.M.R., L. Brown, K.D. Cliff, C.M.H. Driscoll, J.C.H. Miles, and A.D. Wrixon, 1985
Surveys of natural radiation exposure in UK dwellings with passive and active measurement techniques:
The Science of the Total Environment, 45: 459-466

Green, Linda L., Paul I. Jacobsen, Deborah S. McClellan, Thomas A. King, Patricia A. Gerry, Kenneth Novak, Chrystyna Rybicka, and Michael D. Rowe, 1986

Indoor Air Quality Environmental Information Handbook: Radon:
U.S. Dept. Energy Rept. DOE/PE/72013-2, 284 p. [Springfield, Va., Natl. Tech. Inf. Service]

Greenhalgh, D. and P.M. Jeffery, 1959
A contribution to the pre-Cambrian chronology of Australia:
Geochem. Cosmochim. Acta, 16(1/3): 39-57
Geophys. Abs. 177-10:
[Thirteen of 17 mineral specimens showed radon loss or lead loss, radon loss being more probable.]

Gregory, Alan F., 1956
Analysis of radioactive sources in aeroradiometric surveys over oil fields:
Am. Assoc. Petroleum Geologists Bull., 40(10): 2457-2474
Geophys. Abs. 167-248:
A re-evaluation of published airborne radioactivity surveys of the Redwater field, Alberta, and the Coalinga field, California, shows that the distinct gamma-ray patterns of these oilfields can be explained by sources of radioactivity at or near the surface of the ground that are unrelated to subsurface accumulations of oil. The surface distribution of radioactive elements can be correlated with areal geology, the distribution of soils, and surface and ground waters. A brief survey of the literature describing radioactivity anomalies over other oilfields supports these conclusions. Any correlation of these anomalies with deeply buried oil pools is believed to be fortuitous.

Gregory, J.N., and S. Moorbath, 1951
The diffusion of thoron in solids. Part I. Investigations on hydrated and anhydrous alumina at elevated temperatures by means of the Halın emanation technique:
Faraday Soc. Trans., 47: 84-859
This paper describes the measurement of the emanating power of hydrated and anhydrous alumina at elevated temperatures. Phase changes and recrystal-lization processes are clearly indicated in the initial heating of hydrated gamma-Al_2O_3. From an analysis of the results of reheating curves on gamma- and alpha-Al_2O_3, considerable information has been obtained regarding diffusion processes and physical changes such as sintering, grain growth, etc., which depend on diffusion. Variation of oxygen partial pressure above alpha-Al_2O_3 has shown how the diffusion of the inert gas is dependent on lattice defect equilibria.

Gregory, J.N., and S. Moorbath, 1951
The diffusion of thoron in solids. Part II. The emanating power of barium salts of the fatty acids:
Faraday Soc. Trans., 47: 1064-1072
The unusually high emanating power of the barium soaps has been investigated in a thoron flow apparatus by observing the effect of temperature variation on this property at low temperatures. A rapid fall in emanating power on cooling in every case showed that the unusual behavior of the soaps was due primarily to the very high rate of diffusion of thoron through the solid, and not due to a high specific surface. Analysis of the emanating power against temperature relationship showed clearly that it obeyed laws predicted by other workers, and it was possible to show from the results that the normal diffusion constant, against temperature relationship [$D=Do \exp(-Q/RT)$] held for the passage of thoron atoms through the solid soaps. Q and Do have been evaluated for each soap. The former is in all cases less than 10 kcal., and in conjunction with a relatively high Do (particularly with the higher molecular weight soaps) it explains the high room temperature emanating power and its marked dependence on temperature in the range 100 to 350 K. From these results some suggestions have been made regarding the possible mechanism of diffusion of thoron through the solid soap structure.

Greig, J.D., 1961
The determination of low radon and radium concentration in liquids and slurries:
Intern. Jour. Appl. Radiation and Isotopes, 11: 101-107

Nucl. Sci. Abs. 15:32114
A rapid simple procedure for the determination of low Rn and Ra concentrations in liquids and slurries is described. The method uses equipment available from air sampling. Activated carbon is used to concentrate the Rn without the necessity of extreme temperature conditions, and the method is applicable over the range 10^{-12} to 10^{-6} Ci Rn/L. It is believed that this technique may be useful in other applications involving the concentration of volatile radioactive material, either alone or in the presence of non-volatile active material. Applications to mining are discussed.

Greiner, N. Roy, 1985
Radon emanation from coals: effects of moisture and particle size:
Health Physics, 48(3): 283-288

Gribik, Ya.G., 1976
Ob ispol'zovanii radioaktivnosti podzemnykh vod Pripyatskogo progiba v neftepoiskovykh tselyakh [On the use of radioactivity of ground waters in the Pripet Basin for petroleum exploration purposes]:
Geol. Neft i Gaza, 2: 63-65

Griffin, C.E., W.S. Broecker, and A. Kaufman, 1962
Low-level actinon and thoron determination by delay coincidence counting [abs.]:
Jour. Geophys. Research, 67(4): p. 1638.

Grimbert, A., and J.M. Obellianne, 1962
Essais de prospection géochimique de l'uranium en pays aride [Experiments on geochemical prospecting for uranium in arid country]:
France, Commissariat à l'Énergie Atomique. Centre d'Études Nucleaires, Fontenay-aux-Roses), Rept. CEA-2219, 48 p.
Nucl. Sci. Abs. 17:20192:
The necessity for preliminary inquiries before applying routine geochemical prospecting techniques to the exploration of a new region is shown. Under conditions presumed to be unfavorable for geochemical prospecting as found in Nigeria along the banks of the Air, a preliminary examination showed that sampling of the stabilized superficial deposits at a depth of 15 cm made it possible to detect the presence of U-containing mineralizations hidden under about 20 m of sterile sandy deposits. To confirm this result, a boring located on a U-containing geochemical anomaly in a paleosol, encountered a mineralized formation at a depth of 28 m.

Grimbert, A., 1972
Use of geochemical techniques in uranium prospecting, *in* Bowie, S.H.U., Michael Davis, and Dennis Ostle, eds. Uranium Prospecting Handbook. Proceedings of a NATO-sponsored Advanced Study Institute on Methods of prospecting for uranium minerals, London, 21 Sept.-2 Oct. 1972:
Inst. Mining Metallurgy: 110-119, with disc., 119-120
[Minor mention of Rn and Ra methods. In disc., author stated that Ra in stream waters in an area stayed nearer the actual source of the anomalies than uranium].

Grjebine, T., G[erard] Lambert, and J.C. LeRoulley, 1972
Alpha spectrometery of a surface exposed lunar rock:
Earth Planet. Sci. Letters, 14(3): 322-324

Groer, Peter G., D.J. Keefe, W.P. McDowell, and R.G. Selman, 1976
Rapid determination of radon daughter concentrations and working level with the instant working level meter:
Occup. Saf. Health Ser. (Int. Labour Off.), 32: 115-131
Chem. Abs. 87:156389r:

Gross, S., and H.M. Sachs, 1982
Regional (location) and building factors as determinants of indoor radon concentrations in eastern Pennsylvania: Princeton, NJ, Princeton Univ. Center for Energy and Environmental Studies, PU/CEES Rept. 146, 117 p.

Grumbkov, A.P., 1959
Opyt razdel'noy registratsii avtomobil'nym radiometrom toriyevoy i radiyevoy sostavlyayushchikh gamma-izlucheniya pri poiskakh nefti [An experiment in separation of thorium and radium components of gamma radiation by an automobile spectrometer in prospecting for oil], *in* Yadernaya Geofizika:
Moscow, Gostoptekhizdat., p. 300-305
Geophys. Abs. 189-494

Grumbkov, A.P., and G.S. Semenov, 1963
Opyt spektrometricheskikh izmereniy yesestvennogo gamma-polya Zemli pri radiometricheskikh poiskakh nefti [Experience in the spectrometric measurement of the natural gamma field of the Earth in radiometric prospecting for oil], *in* Yadernaya Geofizika:
Moscow, Gostoptekhizdat, p. 207-221
Geophys. Abs. 208-288

Grune, Werner N., 1961
Natural radioactivity in ground water, Pt. I
Water and Sewage Works, 108: 409-411
Nucl. Sci. Abs. 16:17902:
A brief history of ionizing radiation and the creation by Congress of a new Division of Radiological Health within the Bureau of State Services is given. Studies made on the finding of radioactivity in a private well water supply in Maine in 1958 are discussed. The development and operation of a special type of combined scaler-scintillation detection system is described. (Public Health Eng. Abs., 42(4): April 1961)

Grune, Werner N., 1961
Natural radioactivity in ground water. Part II.
Water and Sewage Works, 108: 449-452
Nucl. Sci. Abs. 16:17903:
A study was made to develop a simple, reliable, and reproducible method for the analysis of certain naturally occurring radioisotopes in water. The procedure were to be applied to the analysis on ground water supplies during a field sampling program. Requirements differed from those of many analytical methods in that equipment had to be compact and portable. To achieve significant results during a comprehensive field survey, it was desirable that analytical procedures be as rapid as possible without loss of accuracy. Four analytical approaches were studied in the laboratory prior to the field survey: the precipitation of radon-222 daughters as sulfides with subsequent separation on a millipore filter for radon-222 analysis by alpha counting; the determination of radon and lead-210 by the solvent extraction method used for the separation of lead and bismuth from water; the deemanation of radon-222 from solution collecting the gases in an Erlenmeyer flask coated with a powdered, silver activated zinc sulfide screen followed by alpha scintillation counting; and analysis of ground water samples by means of gamma emitters. Results of each of the analytical procedures along with the sampling and analytical techniques used are discussed. (Public Health Eng. Abs., 42(4): April 1962)

Grune, Werner N., 1962
Natural radioactivity in ground water. Part III.
Water and Sewage Works, 109: 25-29
Nucl. Sci. Abs. 16:17904:

Aspects of instrumentation and the transistorized detection equipment are discussed. Improved methodology and results of the Maine and New Hampshire field survey are given. (Public Health Eng. Abs. 42(4): April 1962)

Grune, W.N., F.B. Higgins, and B.M. Smith, 1960
Natural radioactivity in ground water supplies in Maine and New Hampshire:
Georgia Inst. Technology, Dept. Sanitary Engineering, Project A-473, for Div. Radiological Health, Bur. State Services, U.S. Public Health Services, Contract SAph-73551: 185 p.
[High activities of radon and other radionuclides have been found in many wells in southern Maine and southeastern New Hampshire.]

Grune, Werner N., Frederick B. Higgins, Benjamin M. Smith, Joseph H. Mehaffey, Jr., 1960
Natural radioactivity in ground water supplies in Maine and New Hampshire: Final Report, October 26, 1959 to October 25, 1960:
Georgia Inst. Technology, Dept. Sanitary Engineering, Project A-473, for Div. Radiological Health, Bur. State Services, U.S. Public Health Services, Contract SAph-73551: 77 p.
Nucl. Sci. Abs. 16:22403:
Results are tabulated of a survey of natural radioactivity in ground water supplies in Maine and New Hampshire in 1959 and 1960. Sampling and analytical procedures are described that were developed to emphasize speed while preserving accuracy. A lightweight, compact, transistorized detection system for versatile uses was developed. Schematic diagrams and photographs are included.The system is designed to count two samples simultaneously and may be connected to a proportional counter converter for simultaneous counting of both alpha and beta particles. The system may also be operated as a manual gamma spectrometer after suitable calibration with radioactive sources.

Gübeli, O, and K. Stammbach, 1951
Zur Adsorption von Radon an Aktivkohle und Silicagel [On the adsorption of radon on active charcoal and silica gel]:
Helv. Chim Acta, 34: 1257-1263
The mixed adsorption of radium emanation (radon) with air as a carrier gas for the adsorbents silica gel and linden wood charcoal was investigated. At equal temperatures, the linden wood charcoal proves to be considerably more active than silica gel. The experimental data allow one to calculate the isosteric adsorption heats for both adsorption agents.

Gübeli, O., and M. Stoeri, 1954
Zur Mischadsorption von Radon an Aktivkohle mit verschiedenen Trägergasen [Concerning the mixed adsorption of radon on activated charcoal with various carrier gases]: Translated by Marcel I. Weinreich (Sandia Corp., Albuquerque) from Helv. Chim. Act. 37: 2224-2230 9 p.
Nucl. Sci. Abs. 18:23461:
Radon adsorption on wood charcoal was investigated with respect to its dependence on various carrier gases. The isosteric adsorption heats were ascertained mathematically from the experimentally determined adsorption data, as far as radon is concerned, which was accompanied by foreign gases such as air, nitrogen and carbon dioxide, including hydrogen.

Gübeli, O., and M. Stoeri, 1955
On the radon adsorption with activated charcoal in the open system of the free gas flow:
Translated by Marcel I. Weinreich (Sandia Corp., Albuquerque) from Helv. Chim. Acta, 38: 180-184, 8 p.
Nucl. Sci. Abs. 18:25031:
The adsorption of radon on activated charcoal was investigated by a dynamic method of free flow of gas through the system, utilizing distribution curves. Also the desorption of radium emanation in a nitrogen flux was examined for a maple wood charcoal of medium activity, using the quantitative approach.

Guedelia, Daniel, Jean-Louis Laurent, Jacques Fontan, Daniel Blanc, and Aimee Druilhet, 1970
A study of radon 220 emanation from soils:
Jour. Geophys. Research, 75(2):357-369
Geophys. Abs. 281-435:
A measurement method of Rn-220 soil emanation is presented. Some measurements are made by means of an experimental model in the laboratory in order to determine the influence of certain parameters on the emanation rate. The seasonal and daily variations of the Rn-220 flux are also studied. It is shown that the seasonal variations are due to the temperature difference between the air and the soil.

Guigue, Simone, 1952
Radioactivité des sources thermales de l'Algérie [Radioactivity of the hot springs of Algeria]:
Annales Inst. Hydrologie et Climatologie, 23(73): 93-113
Geophys. Abs. 164-264:
The radon content of specimens of water from 50 hot springs of Algeria has been measured, and in 7 of them found to be as much as 35 nCi/L of water. In general, Algerian hot springs were found to be more radioactive than those in France.

Guimond, Richard J., and Samuel T. Windham, 1980
Radiological evaluation of structures constructed on phosphate-related land, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1457-1474, disc., p. 1475

Gundersen, L.C.S., 1988
Radon production in shear zones of the eastern United States [abs.], *in* Radon in the Northeast: Perspectives and Geologic Research (conference), Troy and Albany, New York, May 31-June 2, 1988:
Northeastern Environmental Science, 7(1): 6
Many shear zones in the Appalachian Region of the eastern United States are characterized by high aeroradioactivity and/or have reported uranium occurrences. Shear zones have also been identified as the major cause of some of the highest indoor radon problems ever recorded in the United States. Uranium enrichment and increased permeability resulting from deformation are the two controlling factors in the severity of these problems. Shear zones formed in a variety of lithologies from Virginia, Maryland, Pennsylvania, and New Jersey are examined in this study and show anomalously high radioactivity. Uranium, indoor radon, and radon in soil gas that statistically sets the fault zones apart from their host rocks and indicates that processes directly controlled by deformation are causing the uranium enrichment. Radon measured in the soil overlying shear zones often exceeds radon production calculated from radium content of the soil because of the increased permeability in the shear zones. ¶In the Brookneal, Virginia shear zone, uranium and radon increase directly with increasing paleostrain measured in the Melrose Granite. The Boyertown, Pennsylvania shear zone is developed in metamorphosed Proterozoic sediments and is associated with some of the highest indoor radon in the United States. High temperature, oxidizing fluids present during ductile deformation of the Boyertown rocks, mobilized iron and uranium from crystals undergoing grain-size reduction. Iron and uranium were then coprecipitated in the C and S foliation bands that developed during deformation. In Montgomery County, Maryland, contacts between rocks of the Piedmont are commonly sheared and have high indoor radon and radon in soil gas associated with them. Equivalent uranium measured at the surface shows that radon production is also greatly infuenced by permeability. In Glen Gardner, New Jersey, a shear zone crossing a number of different lithologies in the Proterozoic rocks of the Reading Prong is associated with high indoor radon. During ductile deformation, volume loss in the rock causes a relative enrichment of uranium. It appears that there is little introduction of uranium into the zone from an outside source. However, where brittle textures are present, uranium may have been introduced locally into the shear zone. Available aeroradiometric, chemical, and indoor radon data show that many other shear zones in both the northern and southern Appalachians may have a high radon potential.

Gundersen, L.C.S., 1989
Anomalously high radon in shear zones, *in* Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 1, Symposium Oral Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006a [Springfield, Va., NTIS Order No. PB89-167480], p. 5-27—5-44.
Sheared fault zones throughout the Appalachian region of the eastern United States have the potential for creating anomalously high indoor radon. They are often characterized by high aeroradioactivity and/or have uranium occurrences. Shear zones are known to be the cause of severe indoor radon problems at Boyertown, PA, and Clinton, NJ, among the worst recorded in the United States. Factors controlling the radon concentrations at these locations are bedrock uranium enrichment, high permeability, and high radon emanation [emanating power or emanation coefficient]. These factors may be directly attributed to the deformation process of ductile shear, known as mylonitization of the rock. During mylonitization, the uranium concentration is increased by the addition of new uranium into the shear zone or by volume loss, leaving uranium relatively enriched as a residuum. The deformation texture imparted to the rock during shear increases its permeability. Oxidation of iron during deformation and subsequent weathering results in the distinctive iron "staining" characteristic of many shear zones. These iron oxides scavenge radium, increase the emanation of the rocks and soils, and make radon readily available to local ground waters. Case studies of shear zones in Pennsylvania, Virginia, New Jersey, and Maryland show anomalously high radioactivity, uranium, indoor radon, and radon in soil gas that statistically sets them apart from their undeformed host rocks. Shear zones can be local as well as regional areas of high radon, especially in mountain belts such as the Appalachians.

Gundersen, L.C.S., 1989
Geologic control on radon [abs.]:
Geol. Soc. America, Northeastern Section, Abstracts with Programs, 21(2): 19-20
Of the many factors affecting the amount of radon available to enter a home, geology and climate are the most important. These two parameters control the distribution of uranium and radium in rocks and soil, the rock and soil chemistry, the permeability and weathering profile of rocks and soil, and the emanation of radon. Rock types most likely to cause indoor radon problems include carbonaceous shales, glauconitic sandstones, phosphorites, chalk, some limestones, some glacial gravel deposits, uranium-bearing granites, and metamorphic rocks of granitic composition, and mylonite. Rock types least likely to cause radon problems include marine quartz sands, noncarbonaceous shales and siltstones, most clays and fluvial sediments, metamorphic and igneous rocks of mafic composition, and most volcanic rocks. Exceptions exist within these general lithologic groups because of the formation of localized uranium deposits such as hydrothermal vein deposits and sedimentary roll-front deposits. Geologic studies of radon conducted on metamorphic rocks of the northeastern United States during the past three years indicate that radon in soil gas, when used with geology, is an effective predictor of the severity of indoor radon problems in homes with basements. More than a thousand indoor radon and soil-gas radon measurements have been correlated with the underlying geology and indicate that on the average, the radon concentration measured in the home is one percent of the concentration measured in the soil. Thus, if the radon concentration of the soil is 2000 pCi/L, the indoor radon concentration will be 20 pC/L. For indoor radon concentrations in the 4 pCi/L or less range, the indoor radon-to-soil-gas radon concentration ratio is usually less than one percent and commonly 0.5 to 0.7 percent. For indoor radon greater than 20 pCi/L, the concentration ratio may be greater than one percent. In severe situations, such as Boyertown, Pennsylvania, the radon concentration measured in homes is 10 percent or more of the concentration measured in the soil. Permeability is the major control on the variation of the concentration ratio from the average of one percent. In other climatic and geologic terrains one percent may not be the average. For example, in the southeastern United States, where slab-on-grade is the favored construction practice, the amount of soil-gas radon that enters a home is expected to be much less. Hopefully, regional models based on geology, climate, and construction will be developed for other parts of the United States.

Gundersen, Linda C.S., 1989
Predicting the occurrence of indoor radon: A geologic approach to a national problem [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 280

Indoor radon has been cited as a significant contributor to as many as 20,000 lung cancer deaths per year. This statistic from the Environmental Protection Agency has been challenged and supported by a number of studies in recent years and is a controversial subject among health physicists, State, and federal governments, the real estate industry, and homeowners. Equally controversial are the methods of testing for radon in the home and for assessing and predicting the severity of the indoor radon problem in the United States. Of the many factors affecting the amount of radon available to enter a home, geology and climate are the most important. These two parameters control the emanation of radon, the rock and soil chemistry, uranium and radium distribution and the permeability and weathering profile of rocks and soil. As geologists we have the task of understanding the processes involved with the distribution and migration of radon. An understanding of the processes will lead to assessment and prediction of its occurrence. However, the amount of radon available to a home and the amount actually occurring in the home can be very different. Another set of complex factors including architecture, construction materials, and heating systems must be considered. Can all these parameters be regionally assessed? Studies conducted in the northeastern and mid-Atlantic regions of the United States indicate that radon in soil gas, when used with geology, is an effective predictor of the severity of indoor radon problems in homes with basements. More than a thousand indoor and soil-gas radon measurements have been correlated with the underlying geology and show that, on the average, the radon concentration measured in the home is one percent of the concentration measured in the soil. In other climatic and geologic terrains, one percent may not be the average. For example, in the southeastern United States, where slab-on-grade is the favored construction practice, the amount of soil-gas radon that enters a home is expected to be much less. Regional models based on geology, climate, and construction can be developed for other parts of the United States. Aerial radioactivity is an effective predictor of regional radon anomalies and correlates well with geology. Other geologic methods currently being examined use radon emanation, permeability, and radium concentration in the soil.

Gundersen, Linda C.S., 1990
Grain size and emanation as controlling factors in soil radon [abs.], *in* The 1990 International Symposium on Radon and Radon Reduction Technology, Atlanta, Ga., 19-23 February 1990:
Preprints, Vol. III, no. C-VI-4

Gundersen, L.C.S., and A.E. Gates, 1988
Redistribution and enrichment of uranium in mylonite zones as a function of deformational processes [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A179-A180

In the Appalachian Region of the eastern USA, shear zones are often characterized by high aeroradioactivity and/or have documented uranium occurrences. Shear zones have also been identified as the major cause of some of the highest concentrations of indoor radon (a daughter product of uranium). Detailed geologic, structural and geochemical studies of two ductile shear zones reveal that deformational processes control the redistribution and enrichment of uranium. The deformational texture increases permeability and radon emanation, compounding the probability of increased radon production. In the southern Virginia Piedmont, the Melrose Granite has been deformed by a single late Paleozoic event to form the Brookneal Mylonite zone. Uranium, radon, and surface gamma radiation can be directly correlated with shear strain determined using the angle between C and S bands. Uranium is hosted in titanite and zircon in the undeformed granite. During deformation and grain size reduction, uranium is redistributed (on a thin section scale) by oxidizing fluids into the foliation of the rock. It is then associated with epidote, sericite, and hematite. On the hand sample scale, uranium and thorium remain in equilibrium with each other and increase in concentration directly with increasing strain. Thus, little uranium has been introduced into the system and the four-fold enrichment of both uranium and thorium may be attributed to volume loss with increasing strain. Similar results were found in the Boyertown Mylonite zone developed in Precambrian quartz-feldspar gneiss of the Reading Prong, PA. Uranium in undeformed gneiss is hosted in allanite, titanite, and monazite. In mylonite, uranium is redistributed into the foliation with hematite. Uranium increases from 25 ppm to 50 ppm. Anomalously high radon indoors and in soil gas are also found on the mylonite.

Gundersen, L.C.S., and A.E. Gates, 1989
The concentration of uranium and radon in mylonite zones from Pennsylvania, Maryland and Virginia: A function of chemical and deformational processes [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 499
Mylonites formed in various rock types have consistently moderate-to-high radon and uranium concentrations. Geochemical and geologic studies of shear zones developed in metamorphic and igneous rocks found in PA, MD, and VA have been used to construct a model for radon concentration in mylonites. Several factors contribute to high radon in mylonites. First, uranium concentration increases relative to that of the parent rock. Uranium is removed from its crystalline source in minerals such as titanite and reacts with oxidizing fluids present in the developing mylonite. As shear strain increases, grain size reduction (the breaking down of the minerals) increases and more uranium is mobilized and concentrated in the foliation. Therefore, uranium concentrations increase by two processes: (1) new uranium is brought into the zone by fluids and/or (2) uranium is left in the zone as other elements leave the system, causing volume loss and relative enrichment of uranium. Second, emanation of radon from uranium increases in the foliation. Uranium is removed from a site of low radon emanation (the crystal) to a site of high radon emanation (the foliation). Weathering of mylonites occurs along foliations, exposing the source of uranium even further. Third, the foliation developed during mylonitization increases the permeability of the rock dramatically. This pervasive foliation is mimicked in the soil profile and provides preferred paths for water and air movement, increasing the concentration of radon in both. Shear zones are not the only cause of high indoor radon and some shear zones will not create radon problems. Shears developed in rocks with less than 1 ppm uranium may not produce sufficient radon to cause a problem unless uranium is introduced from another source during deformation. However, shear zones developed in rocks with higher uranium concentrations, such as rocks of granitic composition, have a high probability of causing an indoor radon problem.

Gundersen, L.C.S., G.M. Reimer, and S.S. Agard, 1987
Geologic control of radon in Boyertown and Easton, PA [abs.]:
Geol. Soc. America, Abstracts with Programs, 19(2): 87
Lithologic and structural variations in the Proterozoic metamorphic rocks of Boyertown and Easton, PA are accompanied by distinct variation of radon in soil gas and homes. Lithologies with high uranium consistently have high radon associated with them and can be distinguished from other lithologies with a hand-held scintillometer. Rocks with low uranium do not have high levels of radon, regardless of their permeability. The rock sequence in Boyertown consists of quartz-feldspar gneiss, biotite gneiss, hornblende gneiss, pyroxene gneiss, and graphitic quartzite. Homes and soils on quartz-feldspar gneiss have moderate radon levels (homes- (1 working level (WL) and soils- (1000 pCi/L). Where the quartz-feldspar gneiss is mylonitized along a layer-parallel trend approximately 40 meters wide, radon values become high (homes- 1 WL) and (soils- 1000 pCi/L). Scintillometer and soil gas surveys delineate the mylonite zone within several meters. Pyroxene, hornblende, and biotite gneiss generally have low levels of radon (homes- 0.1 WL) and soils- (400 pCi/L). Moderate levels of radon occur over biotite gneiss where anatectic, coarse-grained, quartz-feldspar pods are locally abundant. ¶In Easton, the rock sequence includes biotite gneiss, quartz-feldspar gneiss, sillimanite gneiss, calc-silicate gneiss, and marble. As in Boyertown, quartz-feldspar gneiss and some biotite gneiss underlie homes and soils with high radon. Fault zones and local occurrences of uranium throughout the sequence correspond with high radon. Helium measured in fault zones was also high, indicating increased permeability. High helium did not consistently accompany high radon where the radon source appeared to be lithologic. On the average, helium is higher over quartz-feldspar gneiss because of the permeable, sandy soil derived from it, and lower over the mafic gneisses because of the clay-rich soils derived from them. These results show that lithology ultimately controls radon distribution by governing both the radon source and the physical characteristics of the soil and can be used predictively in a regional assessment of radon.

Gundersen, L.C.S., G.M. Reimer, and S. Agard, 1988
The correlation between geology, radon in soil gas, and indoor radon in the Reading Prong, *in* Marikos, M. (ed.) Proceedings of the GEORAD Conference: Geological Causes of Radionuclide Anomalies:
Missouri Department of Natural Resources Special Publication 4, p. 91-102

Gundersen, L.C.S., G.M. Reimer, C.R. Wiggs, and C.A. Rice, 1988
Map showing radon potential of rocks and soils in Montgomery County, Maryland:
U.S. Geol. Survey Misc. Field Studies Map MF-2043, 1 plate with text.

Gundersen, L.C.S., and R.R. Schumann, 1989
The importance of metal oxides in enhancing radon emanation in rocks and soils [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(6): A145
Metal oxides formed during weathering, diagenesis, and metamorphism play an important role in the redistribution of uranium and radium in rocks and soils. Examples of enhanced radon emanation due to sorption or coprecipitation of uranium with iron, titanium, and manganese oxides in clayey soils, brittle faults and fractures, ductile shear zones, and coastal plains are presented. Glauconitic sands from the coastal plain of the eastern United States exhibit high radon emanation due to high permeability and siting of radionuclides in pore cements. Brittle faults and fractures in the Conifer, Colorado, area have been hydrothermally altered. Redistribution and precipitation of uranium with iron and manganese oxides have increased the concentration of uranium in the brittle fault zones and enhanced emanation by providing extensive grain and fracture surface coatings containing accessible uranium. In ductile shear zones in a variety of lithologic settings in the Appalachians, the process of mylonitization enhances the radon emanation in a number of ways. The most important of these are the breakdown of low-emanating, uranium-bearing minerals such as titanite and zircon, releasing uranium from these minerals, and the coprecipitation of uranium with hematite and titanium oxides within the foliation. Microprobe analyses and scanning electron microscope imagery have been used in conjunction with analyses of uranium, radium, emanating radon, and soil-gas radon to develop models illustrating the processes that enhance emanation.

Gustafson, P.F., S.S. Brar, U.C. Mishra, 1962
Determination of airborne fission product radioactivity using gamma-ray spectrometry:
Nature [London], 195: 557-559
Nucl. Sci. Abs. 16:29268:
A method for the rapid determination of the radon and thoron daughter content of an air filter shortly after removal from the pump is described. It utilizes gamma-ray measurements in a portion of the energy spectrum in which the spectral shape does not change with time. Afterwards, the contribution to the net counting-rate over a wider energy region from radon and thoron daughter products is removed. In addition to determining the concentration of gross gamma activity due to fission products in terms of pCi/m^3 of air, the concentration of La-140 and Ba-140 was also measured. Beta and gamma measurements were made on the same portion of 50 daily air filters several days after collection. The gross beta count-rates were expressed in pCi/m^3 of air using a Tl-204 source of known activity. The ratio of beta/gamma activity was found to be 1.9 ± 0.15. By using the beta/gamma ratio it was possible to compare the gross gamma results with measurements made at other sites where air-borne radioactivity is expressed in terms of gross beta activity.

Gustafsson, J., and O. Hildingson, 1984
Radon measurements in dwellings using activated charcoal:
Radiation Protection Dosimetry, 7(1-4): 203-206
Chem. Abs. 101:99844s

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Some tests on measuring methods for indoor radon using activated charcoal:
The Science of the Total Environment, 45: 417-423

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Evaluation of characteristics of the passive environmental radon monitor, *in* Health Physics Soc. Ann. Mtg., 30th, Chicago, Ill., May 26-31, 1985:
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Statistical analysis of radon flux measurements, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 124-135, disc., p. 135-136

Hahn, Otto, 1924
Das Emanierungsvermögen feinverteilter Niederschläge als Mittel zur Prüfung von Oberflächen-änderungen [The emanating power of finely-divided precipitates as a means of examination of surface area changes]
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Hahn, Otto, 1924
Untersuchung oberflächenreicher Substanzen nach radioaktiven Methoden und ihre Anwendung auf chemische und radioaktive Probleme [Investigations of substances of large surface area by radioactive methods and their application to chemical and radioactive problems]:
Naturwiss., 12: 1140-1145

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Jour. Heidenmhain Ber. 56: 284-294
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Hahn, Otto, 1929
Die Emaniermethode als Hilfsmittel bei chemischen and physikalisch-chemischen Untersuchungen [The emanation method as an aid to chemical and physical-chemical investigations]:
Naturwiss., 17: 295-296

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Die radioaktiven Substanzen im Dienste chemischer und physikalisch-chemischer Forschung [Employment of radioactive substances in chemical and physical-chemical research]:
Sitzsungs. Ber. Preuss. Akad. Wiss., 26: 5-10

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Radioaktivität und chemische Elementarprozesse [Radioactivity and elementary chemical processes]:
Zeitschrift Electrochemie, 38: 515-518

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Die Verwendung der radioaktiven Elemente and Atomarten in der Chemie [The use of the radioactive elements and atomic species in chemistry]:
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Die Emaniermethode als Hilfsmittel chemischer Forschung [The emanation method as an aid in chemical research]:
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Eos, Am. Geophys. Union Trans., 70(15): 501
Measurements have been made on a variety of natural soils and soil components to determine the levels of the natural radioactive elements present, and the probability of emanation (escape) of the gases radon (^{222}Rn) and thoron (^{220}Rn). Measurements are also being made on the ion-exchange properties of well-characterized natural clays with regard to radium. Efforts are being made to relate these ion-exchange relationships to the question of the mobilization of radium and its precursors in soil.

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Measurement of 226-Ra and 222-Rn in environmental samples:
Health and Safety Lab., New York Operations Office (AEC), N.Y. Conf-727: 142-151
Procedures for determining Ra-226 in human bone ash and in vegetation or vegetation ash are described. Both techniques use Ba-133 tracers. Average radium recovery was determined in 12 samples of bone ash and in nine samples of hay ash and raw tobacco with added Ra-226 and corrected by Ba-133 yields. Recovery from bone ash of Rn-222, Ba-133, and Ra-226 corrected by Ba-133 was respectively: 94.4%, 94.8%, and 99.6%. In vegetation samples recoveries were: Ra-226, 85.6%; Ba,-133, 86.1%; and Ra-226 corrected by Ba-133, 99.5%. A system for radon determinations is presented. With the system 1000 L of air containing a known radon concentration were run with 100% yield.

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Field measurements in the EPA/AEERL Radon R&D Program, *in* Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 2, Symposium Poster Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006b [Springfield, Va., NTIS Order No. PB89-167498], p. 3-87--3- 102.

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Uranium mine ventilation for control of radon and its daughter products, *in* Radiological Health and Safety in Mining and Milling of Nuclear Materials, II:
Vienna Internat. Atomic Energy Agency; 49-60
A problem common to all underground U mines is the inhalation exposure of workmen to Rn gas (Rn-222) and its radioactive decay products. Radiation dosage to pulmonary tissue from breathing air containing Rn is principally from the alpha-emitting decay or daughter products of Rn. For this reason the atmospheric concentration of Rn-daughter products, reported as Mev of potential alpha energy for decay to Pb-210, is the parameter ordinarily used in the U.S. to assess these inhalation exposures. The most common device for the control of exposure is ventilation of working places with air which is free of, or low in, radioactive

contamination. Knowledge of the steady-state concentration of Rn and its daughters in a working place, the volume of the place, and the quantity of uncontaminated air being supplied to it, permits calculation of the quantity of clean air theoretically necessary to reduce the concentration of Rn-daughter products to any other desired concentration. The controlling factor in such a situation is the rate at which Rn emanates in the workplace. Rigid mathemaical definition of ventilation requirements involves a variety of measurements and lengthy calculation; the procedures are briefly reviewed. With certain simplifying assumptions a single exponential equation may be used to estimate ventilation requirements for attaining the desired concentration of Rn daughters in a workplace from single measurements of ventilation rate and steady-state daughter concentration in the place. The development of such an equation and a discussion of limitations in its application are presented. Experience in the application of calculations in practical situations is reported and certain variables which contribute to differences between predicted and actual values are discussed briefly. Ventilation for the control of thoron daughters is briefly explored. The relatively long half life of the intermediate daughter, thorium B (Pb-212), makes modest ventilation rates extremely effective in reducing the potential alpha energy of thoron daughters in a workplace.

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Pennsylvania radon remediation research and demonstration project, *in* Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 1, Symposium Oral Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006a [Springfield, Va., NTIS Order No. PB89-167480], p. 6-67--6-81 and 5-59.

Hassenmueller, Nancy R., 1988
Preliminary evaluation of radon potential of geologic materials in Indiana [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A338
A preliminary evaluation of the radon potential of the geologic materials in Indiana was made in response to the current emphasis on radon as a potential health hazard. Eight major geologic regions were delineated on the basis of similarity of bedrock, Quaternary material, soil permeability, and distribution of uranium and radium in geologic materials. As a result of local variations in the geologic materials of a region, the radon potential ratings for specific areas within a region can range from low to high. ¶Radon is derived from uranium-238 through a complex radioactive decay chain. Uranium concentrations as much as 179 ppm have been measured in the brownish-black organic-rich shale of the New Albany Shale (Devonian and Mississippian), which is 120 to 140 feet thick in southwestern Indiana. Thin brownish-black marine shales of Pennsylvanian age in southwestern Indiana have uranium concentrations as much as 289 ppm. Clasts of brownish-black shale of Devonian and Mississippian age are found in glacial outwash and outwash-fan deposits in northwestern Indiana and glacial tills of the Lagro Formation (Wisconsinan) in northeastern Indiana. A study of the Lagro Formation indicates that the natural radioactivity of the till increases in a northerly direction as shale clasts increase. Part of southern Indiana is characterized by karst topography and *terra rossa* developed on limestone bedrock. Uranium and radium can be concentrated in limestone residuum; therefore, *terra rossa* could produce higher soil-gas concentrations of radon than many other soils.

Hassler, Gerald L., 1940

Soil gas sampling device and method:
U.S. Patent no. 2,210,546, Aug. 6, 1940, 6 p.
[A soil-gas sampling probe having two inflated packers, one above the other near its lower end, creates two separate spaces in a sampling hole. The absolute pressure in the upper space is maintained less than that in the lower space, so that any atmospheric contamination, even that passing through the ground beyond the hole wall, is intercepted in the upper space. An undiluted, contamination-free soil-gas sample is practically guaranteed from the lower space. An analogous arrangement with the same advantages can be used for sampling soil gas rising through the surface of the ground: two concentric cylinders, open on the bottom side only, are pressed on the ground surface, and the pressure in the outer cylinder is maintained less than that in the inner cylinder, from which the soil-gas sample is withdrawn.]

Hataye, Itsuhachiro, 1962
Radiochemical studies on radioactive mineral springs. III. Leaching experiment of radium from basalts and sinter-deposit:
Shizuoka Univ. Liberal Arts and Sci. Fac. Repts., nat. sci. sec., 3(3):
Geophys. Abs. 135-143

Hatuda, Zin'ichiro, 1949
On the radioactive exploration [in Japanese]:
Geophys. Exploration, 2(3): 1-5
Geophys. Abs. 12060:
A review of radioactive exploration, including description of methods and apparatus and discussion of the effects of moisture, temperature, and atmospheric pressure.

Hatuda, Zin'itiro, 1952
A new method of radioactive exploration using nuclear emulsions and comparison with other methods:
Kyoto Univ. Coll. Sci. Mem. Ser. B, 20: 89-94

Hatuda, Zinichiro, 1953
Radioactive exploration [in Japanese with English summary]:
Butsuri-Tanko, 6(3-4): 265-271
Geophys. Abs. 165-325:
[This is a review and bibliography of radioactivity surveying.]

Hatuda, Zin'itiro, 1953
Radon content and its change in soil air near the ground surface:
Kyoto Univ. Coll. Sci. Mem., ser. B, 20(4): 285-307
Geophys. Abs. 160-173:
The concentration of radon in soil air was determined daily for two periods, from October 1944 to October 1945, and from August 1946 to September 1947. In the first series, soil air from depths of 0.6, 1, and 2 m was sucked into tubes and the radon content was determined by the Schmidt type fontactoscope; in the second, soil air from a depth of 1 meter was drawn directly into an ionization chamber through a drying tube which had been evacuated in advance. The averages of the radon contents in the first series were 0.542, 1.17, and 1.92 nCi/L for soil air at 0.6, 1, and 2 m respectively. Changes in content are gradual, especially when meteorological changes are not conspicuous. Concentration of radon in soil air at depths varies with the rising or lowering of atmospheric pressure, as the level of the "equi-concentration surface" is raised as an atmospheric low approaches, and the reverse with the approach of a high. Precipitation usually has the effect of increasing the radon concentration, especially at the shallowest depth, but whether increase or decrease, the change is hyperbolic with depth. A seasonal variation was observed, in general, with an increase during the rainy season and a decrease during the dry season. The effect of temperature was practically negligible.

Felt earthquakes were followed by an increase in the concentration of radon and in one instance were preceded.

Hatuda, Zin'itiro, 1954
Radioactive method for geological exploration:
Kyoto Univ. Coll. Sci. Mem., ser. b, 21(2): 231-271
Geophys. Abs. 162-195:
Radioactive prospecting as here described is the determination of geologic structure by measurements of radioactivity. Four methods are used: determination of radon in soil air, in which soil air extracted from the ground is introduced into an ionization chamber, and the ionization measured; use of a "ground-hole" ionization chamber, involving the measurement of ionization in a hole in the ground into which the central electrode of an electroscope is extended; use of photo plates, with a small sensitive plate attached to the lower end of a long handle inserted in the hole; and Geiger counter measurements. The diffusion of radon in soil may be determined by analogy with electrical conduction. Experimental determinations have been thus made of diffusion near faults. Several field applications of the method have been successful.

Hatuda, Zin'itiro, and Susumu Nishimura, 1956
Variation in radioactivity across igneous contacts:
Kyoto Univ. Coll. Sci. Mem., ser. B, 23(2): 285-295
Geophys. Abs. 172-208:
Distribution of radioactivity across igneous contacts was investigated with a radioscope with a Lauritsen element to test pulverized samples of feebly radioactive rocks and minerals. Variations in radioactivity were found in both wall rock and instrusive rock but the more conspicuous variation was in the intrusive rock. Profiles obtained across contacts were tentatively classified into five types to be modified in the future when more data are available.

Hatuda, Zin'itiro, and Susumu Nishimura, 1958
Variation in radioactivity across igenous contacts (The second report):
Kyoto Univ. Coll. Sci. Mem., ser.B, 25(2): 115-123
Seventy-three traverses were made of the distribution of radioactive elements across igneous contacts. It was found that the profiles of radioactivity are not at random but are reducible to four types presumably corresponding to the conditions under which the contact phenomena took place. In the later stage of solidification of granite magna, the distribution of radioactivity depends upon the migrating power of radioactive elements and may be inferred to show the mode of migration of volatile matter. The several types of radioactive distribution implies the existence of differences in grade of melting of the invading masses, that is, whole or partial melting or, as an extreme, metasomatism in solid state.

Hauksson, Egill, and John G. Goddard, 1981
Radon earthquake precursor studies in Iceland:
Jour. Geophys. Research, 86(B8): 7037-7054

Hauksson, Egill, John G. Goddard, and Sigurdur E. Palsson, 1978
Radon precursor studies in Iceland [abs.]:
Eos, Am. Geophys. Union Trans., 59(12): p. 1196

Hawthorne, A.R., R.B. Gammage, and C.S. Dudney, 1984
Effects of local geology in indoor radon levels, *in* International Conference on Indoor Air Quality and Climate, 3d, Stockholm, August 20-24, 1984; Vol. 2,: Radon, Passive Smoking, Particulates and Housing Epidemiology, Birgitta Berglund, Thomas Lindvall, and Jan Sundell, eds.:
Stockholm, Swedish Council for Building Research, Vol. 2, p. 137-142

[A monitoring study of 40 homes in eastern Tennessee found that about 30% had radon levels >4 pCi/L in the living space and that these elevated levels showed correlation with location on a porous dolomite ridge surrounding Oak Ridge.]

Hayase, Ichikazu, 1959
The radioactivity of rocks and minerals studied with nuclear emulsion. VIII. The radioactive unequilibrium and the radiocolloid of Ogamo and Ningyotoge:
Kyoto Univ. Coll. Sci. Mem., ser. B, 26(2): 153-162
Geophys. Abs. 182-448:
The air in the gallery of the Ogamo mine, Tottori Prefecture, Japan, when measured with photographic plates was found to be anomalously high in radon. In the same gallery a radiocolloid with a high concentration of radium was found in the fault clay, whereas the uranium-bearing mineral of the mine, coffinite, was found to be deficient in radium, that is, it exhibits a disequilibrium condition. In the nearby Ningyotoge mine the same radiocolloid and the same disequilibrium condition of the uranium minerals is present; no measurements were made of the radon content of the air. It is believed that radium, leached from the coffinite or ningyoite, is being concentrated in the fault clay as a radiocolloid and that the radioactive gases come directly from the radiocolloid.

Hayase, Ichikazu, and Tokudo Tsutsumi, 1958
On the emanating power of powdered rocks:
Kyoto Univ. Coll. Sci. Mem., ser. B, 24(4): 319-323
Geophys. Abs. 175-340:
The measurement of the emanating power or radioactivity of such gases as radon, thoron, and actinon emitted from pulverized rocks and soils in their natural state is important in geological age determinations. This paper reports measurements of radioactive gases from rocks and soils by exposing a nuclear emulsion from one to seven days to powdered samples enclosed in an emanation chamber of about 300 mL. It was found that the emanating power is relatively high in rocks showing secondary alteration or weathering, but low in fresh rocks. Thoron and radon were detectable by the difference in their alpha track lengths.

Hée, Arlette, 1948
Le thorium dans les substances faiblement radioactives et dans les roches [Thorium in weakly radioactive substances and rocks]:
Inst. Phys. Globe Strasbourg Ann., new ser., 4(pt. 3): 30-59
Geophys. Abs. 11117:
Previous studies have shown that the ionization produced by substances containing thorium is a function of the thickness and sometimes the age of the specimen, as well as the nature of the substance, and thus cannot be used for estimating the amount of thorium present. The present investigation was aimed at determining the role of thorium in weakly radioactive substances and rocks and the variation, if any, produced by thorium in their radiation. The samples used had equal surfaces but different thicknesses. Measurements were made with an electrometer equipped with a condenser of total radiation but known to register, by virtue of its dimensions, ionization attributable almost exclusively to alpha rays. The method consisted in compensating the ionization current with that of a standard condenser, so that the measured values were obtained directly in electrostatic units. The results showed that in weakly radioactive substances, the apparent effect of thickness is due to the liberation of thoron which depends on the permeability of the medium to gases, as is also the case with thorium minerals. When $Fe(OH)_3$, which facilitates the diffusion of thorium emanation was added to the powdered sample of rocks the previous observation that the effect of thickness is not proportional to the amount of thorium was confirmed. The rocks studied included travertines and arkoses. Results suggested that radioactive prospecting could be aided by a knowledge of the permeability of rocks to radioactive gases.

Hée, Arlette, and René Lecolazet, 1952

Interprétation et utilisation de la mesure du rayonnement pénétrant des roches sur le terrain [Interpretation and utilization of the measurement of penetrating radiation of the rocks on the terrain]:
Annales Géophysique, 8(3): 316-319
Geophys. Abs. 14705:
Measurements made in drill holes give the total penetrating radiation of a rock (Geophys. Abs. 14141), from which the concentration of radioactive substances can be calculated. The uranium equivalent is calculated by means of Eve's formula. If the K_2O and actual uranium content have previously been determined by other methods (chemical analysis and radon method, for instance), the thorium content can be determined with the same order of accuracy as in the very difficult thoron method. An advantage of this method is that it measures the radiation of approximately two tons of rock rather than of a small sample.

Heirendt, Kenneth M., and Lindgren L. Chyi, 1988
An analysis of radon soil gas concentrations in the Serpent Mound area, Ohio [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A338
Passive alpha-track etching method was used to determine radon soil gas concentrations with a precision of 15.7%. Optical grade CR-39 was found superior in precision when compared with industrial grade. Further comparisons found no significant differences between optical grade and a mixture of 90% optical grade and 10% vinyl acetate. ¶In the modeling of the Serpent Mound area, geologic unit and total gamma radiation as measured by a portable scintillation detector are significant in predicting radon concentrations. [Radon concentrations in] Most geologic units were clustered around a mean of 109 pCi/L. The Devonian Ohio Shale has the highest mean of 317 pCi/L and the Silurian Rochester Shale has the lowest at 51 pCi/L. Within the Ohio Shale, strong negative correlation was found between radon concentrations and total gamma radiation but positive correlations were observed for all other rock units. Faulting was found to increase radon emanation to as much as 190% within 10 ft [3 m] of the zone of disturbance. Traverse measurements across the radiometric anomaly indicate that the source of the anomaly is the increased areal exposure of the Ohio Shale. The shape of the anomaly is governed east and west by the eastern-dipping strata, to the south by increased topographical relief, and to the north by the mantle of glacial till.

Henriot, E., 1908
Sur la condensation des émanations radioactives [Condensation of radioactive emanations]:
Le Radium, Feb. 1908, 5(2): 41-
Using a statistical method, it was found that the emanation is completely absorbed by cocoanut charcoal at ordinary temperatures (18°C) and is completely gotten rid of by heating the charcoal to dull redness.

Henry, Mitch E., Maggie Kaeding, and Don Monteverde, 1989
Radon in soil gas and gamma ray activity measurements at Mulligan's Quarry, Clinton, New Jersey [abs.]:
Geol. Soc. America, Northeastern Section, Abstracts with Programs, 21(2): 22
Mulligan's Quarry, Clinton, New Jersey, is located near an area in which elevated (greater than 4 pCi/L) indoor radon concentrations have been measured. As part of a continuing study to evaluate the geologic controls on the distribution of radon in the environment, gamma- ray activities were measured with a hand-held scintillometer and a portable gamma spectrometer. These gamma measurements were compared with one another and with soil-gas radon measurements. Although throughout the quarry, gamma-ray activity (total counts average over 70 per second) is relatively high, large variations in these values (nearly an order of magnitude from 40 to 350 counts per second) occur over small distances (tens of feet). Variations of greater than an order of magnitude also exist in the soil-gas radon concentrations be tween sample sites about fifty feet apart. A positive correlation exists among the three data sets. Areas with anomalously high scintillometer counts are generally coincident with, although somewhat larger than, areas of anomalously high equivalent uranium (eU) determined with the gamma spectrometer. Such areas are also generally coincident with areas displaying anomalously high soil-gas radon concentrations. A few sample locations have a negative correlation between the eU and the soil-gas radon concentration. Data presented herein suggest that if a pre-construction evaluation of the radon hazard potential for a site is desired, a detailed survey should be conducted.

Moreover, measurements of the equivalent uranium in the soil and rock and the concentration of soil-gas radon are both valuable measurements for a thorough site evaluation.

Hernandez, Thomas L., and James W. Ring, 1982
Indoor radon source fluxes: experimental tests of a two-chamber model:
Environment Internat., 8(1-6): 45-57

Hernandez, Thomas L., Harvey M. Sachs, and James W. Ring, 1984
The variation of basement radon concentration with barometric pressure:
Health Physics, 46(2): 440

Herreman, W., 1980
Calculations of the density of liquid radon:
Cryogenics, 20(3): 133-134
Chem. Abs. 93:138129a:

Herzog, Gerhard, 1956
Geophysical prospecting by use of radioactivity surveying:
Mines Mag., 66: 25-28 (Jan.)
[Alpha and beta radioactivity discounted because of "lack of penetration" (Texas Co.).]

Hess, C.T., R.E. Casparius, S.A. Norton, and W.F. Brutsaert, 1980
Investigation of natural levels of radon-222 in groundwater in Maine for assessment of related health effects, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 529-546
We have used an inexpensive radon (^{222}Rn) measurement method using liquid scintillation counting (Gesell and Prichard, 1977; Prichard and Gesell, 1977) to remeasure potable water from 10 sites near Raymond, Maine, to determine the accuracy and reproducibility of earlier measurements (Smith et al., 1961). Duplication or triplication of samples shows a high degree of reproducibility for the liquid scintillation method. Comparison with earlier measurements shows good agreement. We have also measured, in duplication, water from 150 new sites from several counties in Maine: York, Aroostook, Penobscot, Cumberland, Waldo, Lincoln, and Hancock. The sites were characterized in the field for rock and overburden types, well and casing depths, and water temperature; water samples were collected for water chemistry and ^{222}Rn measurement. A hypothesis emerged from analysis of the measured values of ^{222}Rn near Raymond, Maine, that high values (50,000 to 200,000 pCi/L) are associated with granite. This was shown to be correct for several large areas of granite such as the Sebago, Lucern, Waldo, and Waldoboro granites. The presence of high ^{222}Rn concentrations in granite areas hundreds of kilometers from the Raymond area shows that the high ^{222}Rn levels in water are a statewide and perhaps a regional problem rather than a western Maine problem. The groundwater with highest concentrations seems to be in the granites and adjacent metasedimentary rocks lying in the highest grade metamorphic terrain. Nongranitic areas with low-grade metamorphic rocks, as in most of Aroostook County, show low values of ^{222}Rn (200 to 2000 pCi/L).

Hess, C.T., R.L. Fleischer, and L.G. Turner, 1985
Field and laboratory tests of etched track detectors for ^{222}Rn: summer-vs-winter variations and tightness effects in Maine houses:
Health Physics, 49(1): 65-79

Hess, C.T., C.V. Weiffenbach, and S.A. Norton, 1982
Variations of airborne and waterborne Rn-222 in houses in Maine:
Environment Internat., 8(1-6): 59-66

Hess, C.T., C.V. Weiffenbach, and S.A. Norton, 1983
Environmental radon and cancer correlations in Maine:
Health Physics, 45: 339-348

Hess, C.T., C.V. Weiffenbach, S.A. Norton, W.F. Brutsaert, and A.L. Hess, 1982
Radon-222 in potable water supplies in Maine: the geology, hydrology, physics and health effects, *in* Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivian eds., The Natural Radiation Environment:
New Dehli, Wiley Eastern Limited, p. 216-220

Hess, V.F., 1910
Beiträge zur Kenntnis der atmosphärischen Elektrizität XXXIX. Absolutbestimmungen des Gehaltes der Atmosphäre an Radiuminduktion [Contribution to knowledge of atmospheric electricity XXXIX. Absolute measurements of its content in the atmosphere due to generation by radium]:
Wien, Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse, Sitzungsberichte, Abt. IIa, 119(2): 145-195
[Concludes, according to Wright and Smith, 1915, p. 474, that a decrease in pressure was accompanied by an increase in the active deposit, and vice versa.]

Hess, V.F., 1928
The Electrical Conductivity of the Atmosphere and Its Causes:
New York, D. Van Nostrand Co., Inc., 204 p.

Hess, V.F., 1943
On the radon-content of the atmosphere and the radium contents of river water:
Terr. Mag. 48: 203-207

Hess, V.F., V.J. Kisselbach, and H.A. Miranda, Jr., 1956
Determination of the alpha-ray emission of materials constituting the earth's surface:
Jour. Geophys. Research, 61(2): 265-271
Geophys. Abs. 166-304:
Alpha particles from surface materials were measured with a scintillation counter. The surface emissivities, given in terms of alphas/cm^2-min range from 0.00105 to 0.00350 for vegetation, and averaged 0.060 for "acid" igneous rocks, and 0.033 for soils. A correction for exhalation of radon from rocks was determined by heating the rocks to high temperature and "de-emanating" them completely and then determining the buildup of radon after de-emanation. The values determined indicate that alpha-particle emission does not play a very important part in the ionization balance of the lower atmosphere.

Hess, V.F., and G.A. O'Donnell, 1951
On the rate of ion formation at ground level and at one meter above ground:
Jour. Geophys. Research, 56(4): 557-562
Geophys. Abs. 13387:
Observations were made on the lawn at Fordham University with two identical flat ionization chambers to find the rate of ion formation by beta, gamma, and cosmic rays at ground level and at one meter above ground. The total ionizations at the ground and one-meter levels were found to be 11.38 I and 7.40 I. Hess had previously found the value for cosmic rays to be 1.96 I in the same location. Beta and gamma rays were separated by taking readings alternately with and without a 0.31 cm thick aluminum plate in each chamber. Ionization due to beta rays was 2.18 at 0.47 I at ground and one meter above ground; that due to gamma rays was 3.76 and 3.21 I at the same levels. An estimate of 3.58 I for ion formation by alpha particles at ground level was determined from the previously observed rate at one meter due to radon and thoron and their products.

Hess, Victor F. and W. Dudley Parkinson, 1954
On the contribution of alpha rays from the ground to the total ionization of the lower atmosphere:
Am. Geophys. Union Trans., 35(6): 869-871
Geophys. Abs. 159-187:
The contribution of small ions produced by alpha particles near the ground to the total ion content 1 m above the ground is estimated to be in general, rather small, about 5 to 10 per cent. The coefficient of eddy diffusion was assumed to be 0.5 cm/g-s but is not critical.

Hess, Victor F., and Vancour, Roger P., 1950
The ionization balance of the atmosphere:
Jour. Atmospheric and Terrestrial Physics, 1(1): 13-25
[Gamma-ray and airborne α-activity measurements were performed in a garden at Fordham University, New York, N.Y. by means of appropriate ionization chambers. Of a total of 7.21 pairs of ions/cm^3-s ("I") produced in air 1 m above the ground, 1.76 I were due to α rays, 0.40 I to ß rays, 3.15 I to γ rays, and 1.90 I to cosmic rays. The average ^{222}Rn content for November and December was 46 fCi/L.]

Higgins, et al, 1961
Methods for determining Rn-222 and Ra-226:
Am. Water Works Assn. Jour., p. 63

Hildingson, O., 1982
Radon measurements in 12,000 Swedish homes:
Environment Internat., 8(1-6): 67-70

Hildingson, O., J. Gustafsson, and I. Nilsson, 1984
Locating and limiting radon in dwellings:
Radiation Protection Dosimetry, 7(1-4): 403-406
Chem. Abs. 101:99874b

Hilpert, L.S., and C.M. Bunker, 1957
Effects of radon in drill holes on gamma-ray logs:
Econ. Geology, 52(4): 438-455
Geophys. Abs. 170-272:
Discrepancies in duplicate gamma-ray logs of drill holes in uranium deposits in the Todilto limestone near Grants, N. Mex., were found to be caused by contamination by radon and its daughter products. Most contaminated holes were in higher grade ore and contamination increased with elapsed time after drilling. Conditions favorable for radon contamination in drill holes are proximity to uranium deposits and fractured or permeable rocks above the water table. Most drill holes can be decontaminated by blowing them out with compressed air or by filling with water, although in this area water reduced the total thickness-times-grade figures by about 20 percent. Holes should be logged immediately after drilling to avoid most contamination effects.

Hilpman, Paul L., Raymond M. Coveney, Jr., and Charles G. Spencer, 1988
Pennsylvanian black shales may be overrated as radon sources [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A338
Much current radon research is focused on mechanisms of migration from source material to the home, largely based on the assumption that rocks rich in uranium are likely to cause hazardous concentrations of radon whenever adequate pathways to overlying structures are present. In 1984, for example, within the infamous Reading Prong Index House located above gneisses containing 28-55 ppm uranium, radon concentrations >2000 pCi/L of air were detected—far exceeding the U.S. EPA action level of 4.0 pCi/L. In western Missouri and eastern Kansas, uranium concentrations of several black Pennsylvanian shales are nearly twice

the levels (>50-100 ppm uranium) of gneisses below the Reading [Prong] Index House. Accordingly, it seemed appropriate in 1986 to identify the large region of the Midwest underlain by these shales as a potentially high radon risk area. However, more than 200 residences within the Kansas City [Missouri] area have subsequently been tested and radon concentrations above 100 pCi/L have yet to be detected in any structure. Of 48 homes tested exclusively during the winter season, all but seven had readings below the group average of 6.4 pCi/L. Even within limestone mines beneath the City, where commercial underground space is commonly floored by uraniferous black shales, readings average <6.0 pCi/L and none exceed 13.0 pCi/L. On the basis of results thus far, we conclude that shales may be more effective than crystalline rocks [*] in retarding radon emanation. Despite slightly elevated average values for radon in homes of Kansas City, it is inappropriate to project severe contamination levels for the area simply as a function of uranium concentrations in local bedrock. [* "Crystalline rocks" is an inexact term usually meaning igneous or metamorphic rock, as opposed to sedimentary, but sometimes including sedimentary rocks having contiguous crystals, such as marbles and quartzites.]

Himstedt, F., 1903
Über die Ionisierung der Luft durch Wasser [On the ionization of air by water]:
Physikal. Zeitschrift, 4(17): 482-483

Himstedt, 1904
Ann. Physik, 13: p. 573
Ref. U.S. Bureau of Mines Circ. 6072, p. 14
[Identification of radon emanation in natural sources.]

Himstedt, F., 1904
Physikal. Zeitschrift
Ref. U.S. Bureau of Mines Circ. 6072:
[Solubility of emanation in petroleum oils.]

Hinault, J., 1961
Prospection des minerals radioactifs en Guyane Francaise [Prospecting for radioactive minerals in French Guiana (with English abstract)]: in Fifth Inter-Guiana Geological Conf., Georgetown, British Guiana 1959, Proc.:
Georgetown, British Guiana, Geological Survey Department: 239-246
Geophys. Abs. 200-313:
About 5,500 km^2 in French Guiana were explored for radioactive minerals by radiometric and geochemical methods. Only those areas easily accessible by boat were covered. General prospecting was carried out on a kilometric grid, and semi-detailed prospecting on a grid of 260 m in limited zones where anomalies were found. Instruments and techniques are described. The ratemeter, SRAT-GMT-14, proved exceptionally durable, economical, and exact for work in equatorial forests. Geochemical prospecting should become a normal tool, particularly for work in alluvia, in general exploration for uranium in the Guianas. The most important radioactivity anomaly was found at Kaw Mountain. The high surface radioactivity in that locality, however, is associated with only very minor radium. A hypothesis of radon diffusion is suggested to explain the anomaly.

Hinton, Thomas G., and F. Ward Whicker, 1985
A field experiment on Rn flux from reclaimed uranium mill tailings:
Health Physics, 48(4): 421-427

Hinzpeter, M., and H.K. Meyer, 1961
Meteorologische Einflusse auf radioaktive Beimengungen in der Atmosphare [Meteorological influences on radioactive impurities in the atmosphere]
No. 16 in Schriften Reihe des Bundesministers für Atomkernenergie und Wasserwirtschaft. Strahlenschute:

München, Gersbach and Sohn Verlag: p. 76
Nucl. Sci. Abs. 15:27881

Hofmann, Robert, 1905
Über die Absorptionskoeffizienten von Flüssigkeiten für Radiumemanation und eine Methode zur Bestimmung des Emanationsgehaltes der Luft [On the absorption coefficients of liquids for radium emanation and a method for determination of the emanation content of air]:
Physikal. Zeitschrift, 6(11): 337-340
[Ramstedt cites as having carefully studied influence of temp on Rn solubility in water, petroleum and toluene.]

Hofmann, W., F. Steinhäusler, and E. Pohl, 1980
Age-, sex-, and weight-dependent dose patterns due to inhaled natural radionuclides, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1116-1143, disc., p. 1143-1144

Holaday, D.A., 1955
The radon problem in deep-level mining:
Arch. Ind. Health, 12: 163-166
[Citations of radon concentrations in mines?]

Holaday, Duncan A., 1969
History of the exposure of miners to radon:
Health Physics, 16(5): 547-552

Holaday, Duncan A., David E. Rushing, Richard D. Coleman, Paul F. Woolrich, Howard L. Kusnetz, and William F. Bale, 1957
Control of radon and daughters in uranium mines and calculations on biologic effects:
U.S. Public Health Service Pub. 494: 81 p.

Holm, E., C. Samuelsson, and B.R.R. Persson, 1982
Natural radioactivity around a prospected uranium mining site in a subarctic environment, *in* Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:
New York, John Wiley and Sons, p. 85-92
....Transfer of radium to plants [in the subarctic regions] is greater than transfer of uranium....

Holmes, Arthur, W.T. Leland, and A.O. Nier, 1950
Age of uraninite from a pegmatite near Singar, Gaya District, India, with an isotopic analysis of lead:
Am. Mineralogist, 35: 19-28
Age determinations were made by several methods, and necessary corrections for gain of U, loss of Pb, and loss of radon calculated. Four percent radon loss [from uraninite with cracks] throughout the mineral history would have accounted for the apparently low age by AcU/U method of 9.12E8 y in comparison with the assumed correct age of 9.95E8 y.

Holub, R.F., 1982
Time dependent radon diffusion in rocks, *in* Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:
New York, John Wiley and Sons, p. 391-397

Holub, R.F., 1984
Turbulent plateout of radon daughters:
Radiation Protection Dosimetry, 7(1-4): 155-158

Chem. Abs. 101:99840n

Holub, R.F., and B.T. Brady, 1981
The effect of stress on radon emanation from rocks:
Jour. Geophys. Research, 86[B3]: 1776-1784.

Holub, R.F., and P.J. Dallimore, 1981
Factors affecting radon transport and the concentration of radon in mines, *in* Gomez, Manuel, ed., Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, International Conference, Golden, Colo., October 4-9, 1981:
Golden, Colo., Colorado School of Mines, Chap. 154, p. 1022-1028.
"...The laboratory experiments performed involved measurements of diffusion and emanation coefficients, porosity and permeability of representative rock samples. Significant differences have been found when comparing the results of the laboratory permeability determinations to those of the mine determinations. Considerations of underlying principles, however, suggest that the diffusion and emanation coefficients are the same in laboratory and mine. It was also found that moisture content plays a dominant role in radon transport through rock...."

Holub, R.F., and R.F. Droullard, 1978
Radon Daughter Mixture Distributions in Uranium Mine Atmospheres:
U.S. Bur. Mines Rept. Investigations 8316, 20 p.
The Bureau of Mines has made a study of the magnitude of the variations of radon daughter mixtures, with the objective of determining whether these variations reflect the existing physical conditions in uranium mine atmospheres or if they are merely random or systematic errors. To accomplish this, many data have been plotted using a triangular graphing technique which shows that plateout affects Po-218 more than Pb-214 or Bi-214, and that it is impossible to find simple correlations between working level ratios, radon daughter mixtures, and age.

Holub, R.F., R.F. Droullard, T.B. Borak, W.C. Inkret, J.G. Morse, and J.F. Baxter, 1985
Radon-222 and ^{222}Rn progeny concentrations measured in an energy-efficient house equipped with a heat exchanger:
Health Physics, 49(2): 267-277

Hon, Rudolph, and Nancy M. Davis, 1989
Determinations of bulk emanation rates of selected granites by gamma ray spectroscopy [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 496
Bulk radon (Rn-222) emanation rates of eleven selected granites, predominantly from SE New England, were measured by gamma-ray spectroscopy on a 16% efficiency REGE detector. The employed technique compares specific gamma emissions from isotopes that are precursors to the radon stages with those that are subsequent to it. Absolute abundances are obtained through a calibration of absolute efficiencies and by an instrumental neutron activation. Uranium abundances vary from a low of 2 ppm to a high of 46 ppm. Alkaline and peralkaline granites show range between 5 and 10 ppm; whereas peraluminous and two- mica granites give a typical range of 5 to 20 ppm with a few samples yielding as high levels as 46 ppm. Radon emanations appear to be only mildly dependent on the absolute uranium concentrations but are strongly dependent on the fragment sizes used in our experiments. Emanation rates for Rn-222 in bulk sized fragments (>4 inches average dimension) yield rates as high as 20 to 25% (in alkali granites) but a more typical range is less than 10%. With decreasing fragment sizes to less than 100 μm the emanation rates steadily increase up to 40 to 60% and possibly even higher. In contrast the maximum Rn-220 emanation rates for the finest fraction are typically less than 10%. We interpret these results by a very different mode of distribution of uranium and thorium in these rocks. Thorium as a trace element is likely to be found on lattices of resistant accessory minerals whereas uranium is most likely in form of uranium minerals along microfractures. These microfractures then provide a mechanism for the higher Rn-222 release.

Hoogteijling, P.J. and G.J. Sizoo, 1948
Radioactivity and grain size of soil:
Physica, 14: 65-72
By measurements on separated grain size fractions 0-2 μm, 2-16 μm, 16-200 μm of several sedimentary soils, evidence was found for a preference of the radioactive elements for the grain sizes 2-16 μm. From the variation of the activity of the amount of the material, spread each time on the same surface, as well as from the comparison of the radium content with the total activity, we conclude that the composition of the radiation depends on the fineness of the material. The ratios of the concentrations of the various radioactive elements, therefore, must vary with the grain size. It is suggested that this variation is not only related to the mineral composition of the original material but also influenced by the combined processes of solution and adsorption during the process of sedimentation.

Hoogteijling, P.J., and G.J. Sizoo, 1948
Radioactivity and mineral composition of soil:
Physica 14: 357-366
It is demonstrated that in sedimentary sand the radioactive elements are concentrated in the heavy mineral fraction and chiefly bound to the zircon mineral. In clays no relation between the radioactivity and the zircon content could be detected. A correlation between the potassium content and the radioactivity of clays is found. It was proved, however, that the activity can only for a small part be due to the radiation of potassium. The activity of some specimens of typical clay minerals was measured. No evidence was found for a concentration of the radioactive elements in any one of these minerals. It is supposed, that during the chemical transformation of the original minerals into the clay minerals the radioactive elements are at least for a part unbound and spread over the whole material by adsorption to the surface of the precipitating particles.

Hoogteijling, P.J., G.J. Sizoo, and J.L. Yntema, 1948
Measurements on the radon content of ground water:
Physica 14: 73-80
Chem. Abs. 42:6234d; Nucl. Sci. Abs. 1-200:
From eight experimental borings in various parts of Holland, 37 water samples were taken from strainers placed at depths, varying from 5 to 200 m. The radon content and the chlorine content of these water samples, as well as the radioactivity of ground samples from the neighborhood of the strainers was determined. The radon content shows in general a marked decrease with the depth. No correlation of the radon content with the chlorine content or with the radioactivity of the ground could be detected. The presence of a layer of clay or loam tends to increase the radon content of the water beneath it. The mean radon content of the ground water amounts to about 5% of the equilibrium value corresponding to the mean radium content of the bottom. The various factors influencing the radon content of the groundwater are discussed.

Horikawa, Y., 1967
Uranium prospecting by Rn method [in Japanese]:
Geol. Monthly, 159: 24 p.

Horne, J.E.T., and C.F. Davidson, 1955
The age of the mineralization of the Witwatersrand:
Geol. Survey Gt. Brit. Bull. 10: 58-73
[Horne and Davidson described experimental evidence indicating that the rate of radon diffusion was not high enough to account for the discordant results.]

Horrocks, D.L., and M.H. Studier, 1964
Determination of radioactive noble gases with a liquid scintillator:
Analyt. Chem., 36(11): 2077-2079

Hosler, Charles R., 1968
Urban-rural climatology of atmospheric radon concentrations:
Jour. Geophys. Research, 73(4): 1155-1166
Geophys. Abs. 259-507:
Atmospheric concentrations of radon, calculated from filtered radon daughter beta-activity and corrected for radioactive equilibrium departure, were obtained from three sites around Washington, D.C. Measurements made at heights up to 91 m yield diurnal, seasonal, and annual mean radioactivity concentrations and their relationship to meteorological variables. The data indicate that the horizontal distribution of radon is homogeneous during much of the midday period. Radon measurements over about 40 km suggest that the urban area does not act effectively as either a source or sink for Rn.Analyses of the temporal-spatial variations of atmospheric radioactivity indicate that the variation in the concentration of Rn at a given height is mostly a consequence of vertical atmospheric mixing; the effects of advection, changes in emanation rates, and various scavenging processes are slight relative to the effects of vertical mixing.

Hosler, Charles R., 1969
Vertical diffusivity from radon profiles:
Jour. Geophys. Research, 74(28): 7018-7026

Howell, E.P., 1977
Method and apparatus for prospecting for buried mineral deposits:
U.S. Patent No. 4,017,731
Soil gases, such as radioactive decay products, that migrate upwardly through the surface of the earth are collected and measured at a series of dome-shaped plastic shelters 5-20 ft in diameter. Radiant energy heats the soil beneath the enclosed surface area and accelerates the escape of gas through the soil.

Hradil, Guido, 1955
Zur Messung des Emanationsgehaltes der Bodenluft über Strukturlinien [On the measurement of the emanation content of soil air over structural lines]:
Berg- u. Huttenmann. Monatsh., 100(4): 145-147
Geophys. Abs. 163-155:
The presence of fault lines or joints can be revealed by measurement of the emanation content of the overlying soil an average value of 0.35 nCi/L was established from measurement at a depth of 1 m in a garden at Innsbruck, carried on over a 7-month period. The field measurements were made over structural lines perviously determined by Fritsch by his diffusion method, and also at a distance of 20 meters from each station for comparison. Over any crack, the Curie value was found to be consistantly higher than at the corresponding control point, and at intersections the increase was even greater; the average increase was about 70 percent. The findings appear to be reproducible, and independent of outside influences. Applied to the Karwendel range, the method reveals numerous structural lines which are considered to be breaks due to the subsidence of the base of the terraces under the thick glacial cover; the surface effect of such structure is unrecognizable.

Hubbard, L.M., Benjamin Bolker, R.H. Socolow, Darryl Dickerhoff, and R.B. Mosley, 1989
Radon dynamics in a house heated alternately by forced air and by electric resistance, *in* Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 1, Symposium Oral Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006a [Springfield, Va., NTIS Order No. PB89-167480], p. 6-1--6-14.
Understanding the various mechanisms driving radon entry into buildings aids in the development of appropriate diagnostic measurement techniques and in the design of efficient mitigation systems. Environmental parameters such as temperature, wind, and rainfall, and house specific parameters such as air exchange rate, type of heating and cooling system, and leakiness of the sub- structure to the soil gas provide the driving forces and conditions for radon entry. This paper presents field data and analysis which describe the effect of central

heating air distribution systems, electric heating systems, and non-heating conditions on air infiltration into buildings, movement of air and radon around buildings, and the rate of entry of radon-containing soil gas.

Huber, P.B., 1920
Researches on the radioactivity of surface air:
Arch. Sci. phys. nat., 2(5): 508-510

Huck, P.M., J.R. Brown, G. Multamaki, and K.L. Murphy, 1982
Environmental consequences of the placement of radium-barium sludge in tailings areas:
Canadian Mining Metall. Bull., 75(839): 147-153

Hudgens, J.E.R., R.D. Benzing, J.P. Gali, R.C. Meyer, and L.C. Nelson, 1951
Determination of radium or radon in gases, liquids, or solids:
Nucleonics, 9(2): 14-21

Hugi, Th. and F. de Quervain, 1958
Results of the measurement of radioactivity of rocks in the hydroelectric facility tunnels, *in* Survey of Raw Material Resources, Vol. 2: 838-836, United Nations Internat. Conf. on Peaceful Uses of Atomic Energy, 2nd, Geneva, 1-13 Sept. 1958, Proc.:
Geneva, United Nations
[Measurements of gamma-ray activity with portable counters in tunnels were seldom interfered with by radon.]

Hultqvist, Bengt., 1952
Calculation of the ionization due to radioactive substances in the ground:
Tellus, 4(1): 54-62
Geophys. Abs. 13882:
Penetrating gamma radiation from the ground can be expressed by the simple formula I=CXS, where S is the proportion of radioactive element in g/g and C is a constant. Formulas for the ionization when the ground is covered with an absorber of greater density than air, or when the radiation travels through air for long distances, are derived. The ionization from various minerals is calculated and is found to agree in magnitude with measured values. Curves showing the decrease in the ionization as a function of the depth of snow cover, are given for three different values of snow density. The decrease in the dose rate with the altitude above the earth's surface is shown graphically.

Hultqvist, Bengt, 1956
Studies on naturally occurring ionizing radiations with special reference to radiation doses in Swedish houses of various types:
Kungl. Svenska Vetenskapsakademiens Handlingar, Fjarde Serien, 6(3): 125 p.
Stockholm: Almquist and Wiksells Boktryckeri Ab; London: H.K. Lewis and Co., Ltd., 136 Gower Street

Hurley, P.M. and R.R. Shorey, 1952
Discrimination of thoron alpha activity in presence of radon:
Am. Geophys. Union Trans., 33(5): 722-724
Geophys. Abs. 14063:
The short life of ThA is used as a means of discriminating between thoron and radon alpha activity. At low counting rate the count of double alpha pulses due to the rapid decay from Th to ThB indicates the ratio of radium to thorium X in the source solution.

Hurmuzescu, D., 1908
Radioactivity of Roumanian petroleums:
Annal. Scientifiques de l'Univ. de Jassy, 5: 1-31; also Jour. Soc. Chem. Ind., 27: 16

Sci. Abs. 928 (1908); Chem. Abs. 2(13):1878
[The lightest fractions are the most radioactive; the activity decreases with time.]

Hursh, J.B., 1954
Measurements of breath radon by charcoal adsorption:
Nucleonics, 12(1): 62-65

Hursh, John B., 1964
A feasibility study for a new device to measure radon in the breath:
U.S. Atomic Energy Comm. Rept. UR-640: 21 p.
Nucl. Sci. Abs. 18:14130

Hursh, John B., and Arvin Lovaas, 1962
A device for measurement of thoron in the breath:
Rochester, N.Y.U. Atomic Energy Proj., Contract W-7401-eng-49: 28 p.
Nucl. Sci. Abs. 17:14652
A device was developed to measure thoron in the breath of human subjects. It depends upon the adsorption of thoron on a cooled, charcoal particle covered plate which is adjacent to a ZnS coated lucite disk seen by a 5-in.-dia. photomultiplier tube. In its present form it will measure thoron referred to the patient's mouth with a sensitivity of 0.7 counts per min. per pico-curie of thoron per min. with a background of less than 2 counts per min. If a 10 L/min ventilation rate is assumed, the system would detect thoron in concentrations for 1 pCi/L of breath. The minimum level for measurement in 10 min is a breath output of 10 pCi/min. It is also shown that, when used to measure Th-228 in solution, the device has a sensitivity of 1.6 counts per min. per pCi of Th-228.

Hutchinson, J.M.R., P.A. Mullen, and R. Collé, 1986
The NBS radon-in-water standard generator:
Nuclear Instruments and Methods in Physics Research, A247: 385-389
NBS has completed the development of a transfer standard for radon-in-water measurements. This standard can be used to generate and accurately dispense radium-free Rn-222 solutions of known concentration....The standard consists of a polyethylene-encapsulated Ra-226 solution source in a small-volume accumulation chamber and an ancillary mixing and dispensing system which is partially automated with motor-driven syringes....The overall uncertainty of the calibration was estimated to be approximately ± 4%.

Huyskens, Chr. J., J.Th.G.M. Hemelaar, and P.J.H. Kicken, 1985
Dose estimates for exposure to radioactivity in gas mantles:
The Science of the Total Environment, 45: 157-164

Ilyin, L.A., V.A. Knizhnikov, R.M. Barkhudarov, R.M. Alexakhin, B.K. Borisov, and N.Ja. [Ya.] Novikova, 1980
Population doses from natural radionuclides due to certain aspects of human activity, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1446-1456

Ingersoll, John G., 1983
A survey of radionuclide contents and radon emanation rates in building materials used in the U.S.:
Health Physics, 45(2): 363-368

Ingersoll, J.G., B.D. Stitt, and G.H. Zapalac, 1983
A fast and accurate method for measuring radon exhalation rates from building materials:
Health Physics, 45(2): 550-552

International Atomic Energy Agency, 1975
Radon in uranium mining:
Vienna, Internat. Atomic Energy Agency pub. STI/PUB/391: 173 p.

Iokhel'son, S.V., 1958
O vydelenii gornymi porodami radona pri vysokikh temperaturakh [On the liberation of radon from rocks at high temperature]:
Akad. Nauk SSSR Izv., ser. geofiz., 12: 1451-1457
All rocks emanate a certain amount of radon, which as an inert gas occupies voids and capillaries in rocks and spaces in crystal lattices of minerals. The coefficient of radon emanation of a rock, defined by the formula $K_{Rn}=(q_n\text{-}q)/q_n$ x 100% (where q_n and q=amounts of radon before and after heating, respectively), was investigated experimentally by measuring the gamma radiation of various samples before and after heating at different temperatures with time constant, or at constant temperature for different periods of time. The rock types investigated were silicates, hematite-magnetite rocks, carbonates, and caustobioliths. The curves of radon emanation as a function of temperature show that K_{Rn} depends on the composition of the rock and on the thermal properties of the essential rock-forming minerals. Crystalline rocks [*] composed of minerals which do not disintegrate upon heating show a sharp increase in K_{Rn} at a temperature corresponding to the beginning of destruction of the crystal lattice (about 700°C). The intense liberation of radon by carbonates is caused by their dissociation. Caustobioliths give up the largest part of their radon at low heats. Complete liberation of radon takes place at temperatures exceeding the melting temperature (1,700 to 1,850°C), after 5 minutes. If the duration of heating (constant temperature) is increased, the coefficient K_{Rn} increases to a certain limiting value characteristic for each temperature; with increased temperature the time necessary for complete liberation of radon decreases. With repeated heating of heat-resistant rocks, the emanation coefficient remains practically unchanged. These results should be of interest in explaining the kinetics of processes in the earth's crust, in age determinations, in interpreting emanation survey results, and in radiometric analysis of rocks. [* "Crystalline rocks" is an inexact term usually meaning igneous or metamorphic rock, as opposed to sedimentary, but sometimes including sedimentary rocks having contiguous crystals, such as marbles and quartzites.][Translation of author's abstract.]

Ishimori, T., and I. Hataye, 1956
Determination of the RaA and RaF in radioactive spring waters [in Japanese]:
Bull. Chem. Soc. Japan, 77(1): 122-124

Israël, Gerhard W., 1964
New method for direct measurement of the atmospheric thoron content [in German]:
Naturwissenschaften, 51: 134-135
A method for determining the thoron (^{220}Rn) content in air is described. The air was directed over a filter which freed it from ions, fission products of radon and thoron, and aerosols into an ionization chamber. During the aspiration an ionization current was measured, which was composed of the radon and thoron parts of the null effect. After shutting off the air current the ionization current in a few minutes decreased to the thoron part. The measurements showed that the apparatus arrangement could be used for measuring thoron concentrations in the air from 0.1 pCi/L with a precision of 15%.

Israël, Gerhard W., 1965
Thoron (^{220}Rn) measurements in the atmosphere and their application in meteorology:
Tellus, 17: 383-388
Nucl. Sci. Abs. 20(2) 2860:
With new equipment which allows the continuous recording of the atmospheric thoron content down to 5 fCi/L, the thoron content of the atmosphere, at different levels was measured. The measurements were carried out from June until September 1964. The results show a close relation between the thoron content and the meteorlogical variables. The thoron concentration and its decrease with height shows a remarkable diurnal

variation with a maximum at noon and a minimum during the night. The thoron at this station is influenced by wind direction. Rain diminished the thoron content by 50%; the recovery time to reach the initial concentration is about 10 hours. It could be shown that the turbulent diffusion coefficient K increased linearly between 1 m and 4 m. A mean value of K=330± 30 cm^2/s at 1 m level was found.

Israël, Gerhard W., 1966
Meteorological influences on the thoron (Rn-220) content of the atmosphere:
Tellus, 18(203): 633-637
Geophys. Abs. 246-384:
Using the new equipment described in another paper in this issue (ibid, p. 557-561), thoron in the atmosphere was measured at different levels between 1 and 8 m above ground at Mainflingen, Germany, for several months and related to meteorological variables.

Israël, Hans, 1934
Emanation in Boden- und Freiluft [(Radium) emanation in ground and atmospheric air]:
Zeitschrift Geophysik, 10(8): 347-356
Geophys. Abs. 72-2413

Israël, Hans, 1934
Emanation und Aerosol:
Gerlands Beitr. Geophysik, 42: 384-408

Israël[-Köhler], Hans, 1934
Zur Methodik der klimatologischen Emanationsmessungen. I. Über ein neus Emanometer [On the methodology of climataologic emanation measurements. I. On a new emanometer]:
Der Balneologe, 1: 318-327

Israël, Hans, 1943
Radioaktive Messmethoden [Radioactive measurement methods], *in* Reich, R. and von Zwerger, R., eds., Taschenbuch der angewandten Geophysik [Handbook of applied geophysics]:
Leipzig, 373-385

Israël, H., 1951
Radioactivity of the atmosphere, *in* Compendium of Meteorology:
Boston, Am. Meteorol. Soc., 155-162

Israël, Hans, 1959
Der Diffusionskoeffizient des Radons in der Bodenluft (Bemerkungen zur Arbeit von E. Budde: "Bestimmung des Beweglichkeits-Koeffizienten der Radium-Emanation in Lockergesteinen" [The diffusion coefficient of radon in soil air (Remarks on E. Budde's work "Determination of the coefficient of diffusion of radium emanation in porous rocks")]:
Zeitschrift Geophysik, 25(2): 104-108
Geophys. Abs. 180-330
From practically zero at the surface of the earth, radon concentration in soil air exponentially approaches a limiting value a/λ as depth Z increases (a=production of radon per cm^3 of soil air per sec, λ=decay constant of radon). If the "half-value depth" $z=\ln(2)/(\lambda/k)^{-2}$ is calculated on the basis of the values of the diffusion coefficient k determined in the laboratory by Budde (see Geophys. Abs. 174-314), the results do not agree with observed values. Either Budde's laboratory conditions did not truly represent natural conditions, or else other effects besides pure gas-kinetic diffusion are present that lead to exaggeration of the true diffusion phenomenon.

Israël, H[ans], 1961
Der Diffusions-Koeffizient des Radons in Bodenluft [The diffusion coefficient of radon in soil air]:
Zeitschrift Geophysik, 27(1): 13-17
Geophys. Abs. 187-533
The discussion provoked by E. Budde's paper on the diffusion of radon in soil air is continued. (See also Geophys. Abs. 174-314, 180-330, 184-515.)

Israël, H[ans], 1962
Die natürliche und künstliche Radioaktivität der Atmosphäre [The natural and artificial radioactivity of the atmosphere], *in* Israël, H., and Krebs, A., eds., Nuclear Radiation in Geophysics:
New York, Academic Press, p. 76-96

Israël, Hans, 1964
Remarks on the thoron content of the atmosphere:
Jour. Atmos. Terrest. Physics, 26(7): 787-789
Geophys. Abs. 214-273
Methods of measuring the content of thoron in the atmosphere are examined, and Israël's aspiration method is recommended because it not only gives real values of the thoron content but also can be used for registration and research of short time variations in the content. The method employs an ionization chamber into which air is sucked through a filter. The thoron content is measured directly by the ionization current difference during the aspiration and some minutes after finishing the aspiration. The chamber is illustrated.

Israël, H., and F. Becker, 1935
Die Bodenemanation in der Umgebung der Bad Nauheimer Quellenspalte [Soil emanation in the environment of the Bad Nauheim spring fissure]:
Gerlands Beitr. Geophysik 44: 40-55
Geophys. Abs. 78-2791:
The discovery of an abnormally great amount of emanation in a building lying above the issue of the Bad Nauheim spring fissure (occupied by the W.G. Kerckhoff Institute) gives rise to a close examination of the ground emanation near the outlet of the outthrow. The measuring is done according to the usual emanometric method by ground air tests from a depth of 1 m following the course of 6 profiles being vertical to the supposed outthrow stratum, and proves an increase of the emanation to the hundredfold above the issue of the fissure. The course of the individual profiles is being discussed as follows: the cleavage existing throughout in 2 maxima, it cannot be determined positively whether it is due to a cleavage of the outthrow itself, or to the unsettled state of the sedimentary covering stratum. It stands to reason that the cleavage in 2 maxima results from a river bed lying just above the outthrow, considering the more intense wetting of the ground in those parts. The conformity of the course of the outthrow towards the radioactive profiles with the geological particulars resulting from the experts' opinion of spring borings is satisfactory. An exploitation of the extensive ground emanation for therapeutic purposes is being planned. Researches about the percentage of carbonic acid in the ground air also prove an increase through the outthrow. However this statement is somewhat vague, presumably on account of its essentially greater speed of diffusion.

Israël-Köhler, Hans, and F. Becker, 1935
Emanationsgehalt der Bodenluft und Untergrundtektonik [Emanation content of soil air and underground structure]:
Naturwissenschaften, 23(48): 818
Geophys. Abs. 84-3118

Israël-Köhler, Hans, and F. Becker, 1936
Die Emanationsverhaltnisse in der Bodenluft [The proportion of emanation in ground air]:
Gerlands Beitr. Geophysik, 48(1): 13-58

Geophys. Abs. 87-3417:

Theoretical speculation and experimental determinations are given of the condition of emanations in air obtained from the ground, and from the dependency of the pressure of Rn at different depths, the existence, form, and depth of the tectonic heterogeneity can be predicted. Such experiments form a supplementary method of geophysical survey, which can be further augmented by measuring gases (CO_2; CH_4) which do not dissociate. The depth for which geological heterogeneity is perceptible by emanation at the surface is limited by the "prolificness" of the source of interruption. The most reliable analysis is the one based upon the distribution of atmospheric pressure in a relatively short depth. A review of the methods of determining the Th emanation in the ground air and some results of orientating surveys are given. [The following statements are made from comparison of the theoretical considerations with the results of measurements carried out by the author and other investigators: 1. Surveys of emanations in the ground air in connection with the geotectonic structure of the subsoil are examined theoretically and experimentally. From the form of the horizontal and vertical profiles of Ra emanation and from the dependence of concentration on the pressure at various depths conclusions are drawn on the existence, form, and depth of tectonic inhomogeneities. 2. The depth to the layer from which the emanation arises can not be determined definitely, as the emanation changes according to the productiveness of the assumed source. 3. The quantitative conclusions on the depth of the disturbing zone, which are possible theoretically, are greatly limited in practice, owing to the fact that the measurements made close to the surface of the ground are influenced by the inhomogeneities in the upper layer. Most reliable results may be obtained from the analysis of the dependence of the concentration on the air pressure at a depth of a few meters. In conclusion the methods for determining Th emanation in the ground air are discussed and a few measurements which may serve for orientation are quoted.]

Israël, Hans, and S. Björnsson, 1967
Radon (Rn-222) and thoron (Rn-220) in soil air over faults:
Zeitschrift Geophysik, 33(1); 48 p.
Geophys. Abs. 248-401

The Rn-222 and Rn-220 concentration in soil air was surveyed in several profiles across faults in the vicinity of Aachen, Germany, in order to clarify the mechanism of emanation enrichment in soil air over faults. Two different kinds of anomalies were distinguished: anomalies in both Rn-222 and Rn-220 with similar variation in both emanations throughout the profile; and a Rn-222 anomaly over the fault with little or no anomaly in Rn-220. The former type is probably caused by enrichment of the overburden in parent nuclides of the emanations and not by migration of the emanations. The latter, encountered only in dry permeable soil, might be due to upward migration of Rn-222. Results of supplementary surveys over the known strong Rn-222 anomaly at Bad Nauheim are consistent with the latter explanation.

Israël, Hans, S. Björnsson, and S. Stiller, 1962
Emanometrische Messungen von Radon and Thoron in Bodenluft [Emanometric measurements of radon and thoron in soil air (with English and Italian summaries)]:
Annali Geofisica, 15(1): 115-126
Geophys. Abs. 192-314:

The concentrations of radon and thoron in soil air were measured in the summer of 1961 at various depths at two places in Aachen, Germany, using the Satterly method with the Israël emanometer. The results are compared with those of similar measurements made in Bad Nauheim in 1935. The rapid increase of radon concentration and of the radon-thoron ratio agrees qualitatively with the theoretical exponential increase with depth in a homogeneous soil. Details of the results are discussed.

Israël, Hans, M. Horbert, and Gerhard W. Israël, 1966
Results of continuous measurements of radon and its decay products in the lower atmosphere:
Tellus, 18(2-3): 638-642
Geophys. Abs. 246-385:

Using the new equipment described in another paper in this issue (ibid, p. 557-561), the radon content of the atmosphere was measured at different levels between 0.5 and 4 m above ground at Aachen, Germany. Evaluation of simultaneous measurements of the radon daughters with a stepwise progressive filter showed a close relationship of radon and its daughters to meteorological factors.

Israël, Hans, and Gerhard W. Israël, 1966
A new method for continuous measurement of radon (Rn-222) and thoron (Rn-220) in the atmosphere:
Tellus, 18(2-3): 557-561
Geophys. Abs. 246-382:
An aspiration process permitting direct measurement of radon and thoron contributions to the ionization are described briefly, and its use for determination of radon and thoron content of the lower atmosphere is discussed.

Israël, Hans, and Siegfried Stiller, 1963
Climatological aspects of the natural radioactivity:
Zeitschrift Geophysik, 29(2): 51-56
Geophys. Abs. 201-311:
The natural radioactivity of the air (daily means of RaB and ThB) was measured at Aix-la-Chapelle (Aachen), Berlin, and Munich during the period January 1960-August 1961, during the nuclear test ban. The dependence on wind directions and air masses found at Berlin and Aix-la-Chapelle can be explained easily by the "coast effect." Results at Munich were unexpected; maximum values were associated with winds from the east, not from the south as found earlier at the Zugspitze and were four to five times higher than at Aix-la-Chapelle and Berlin; the greater intensity of radiation may be due to emanation from the granite of the Alps, but the reason for the differences in relation to wind direction between Munich and the Zugspitze is not clear. (See also Geophys. Abs. 164-267)

Israelsson, Sven, 1980
Meteorological influences on atmospheric radioactivity and its effects on the electrical environment, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 210-225

Iwasaki, I., and T. Ishimori, 1951
Determination of very low content of radon in natural waters:
J. Chem. Soc. Japan 72: 14-15

Iwasaki, I., T. Katsura, H. Shimojima, and Masaakira Kamada, 1956
Radioactivity of volcanic gases in Japan:
Bull. Volcanology, ser. 2, 18: 103-123
Geophys. Abs. 169-266:
Measurements of the radon and thoron content of the gases from volcanic hot springs and fumaroles in Japan, made with an I.M. Fontactoscope, show that considerable radon and thoron are present in nearly all volcanic gases and that the radioactivity of the thoron is generally stronger than that of the radon in the same gas. The radioactivity of the Japanese gases is never negligible, as in those of Kamchatka, and is often comparable to that of the strongly radioactive mineral springs or to that of the volcanic gases from the island of Vulcano, Italy. The presence of many radioactive elements (Rn, RaA, RaB, RaC, Tn, ThA, ThB) was confirmed, but no actinon was found. Variations in the radioactivity were noted but for the most part the radon content of the most powerful fumaroles is unaffected by changes of season, temperature, precipitation, or atmospheric pressure. From the Tn/Rn ratio in a single gas it is calculated that both elements originated within 10 minutes transportation time from the surface. In the weak, lower-temperature fumaroles accompanied by hot water, there is an excess of Rn and Tn in the gas phase; from this it is concluded that the fumarolic gases are the principal source of the radioactivity of the water. Hot springs far from volcanic centers do not show any

excess of radon in their gas phase; the origin of the radon and thoron in fumarolic gases, therefore, seems to be different from that of non-volcanic radioactive mineral or hot springs.

Iwasaki, Iwaji, Takejiro Ozawa, Minoru Yoshida, Takashi Katsura, Bunji Iwasaki, and Masaakira Kamada, 1962
Chemical composition of volcanic gases in Japan:
Bull. Volcanol, 24: 23-48
Geophys. Abs. 202-260:
This summary of the results of a systematic study of the nature of volcanic gases from lava lakes, fumaroles, and hot springs in Japan includes tabulated radioactivity (radon) measurements. There is no marked difference in the radioactivity of gases between regions of silicic and intermediate rocks, such as has been reported from New Zealand (Belin, Geophys. Abs. 177-322). The periodic variation in radon content of volcanic gases of the Hoko-Zigoku geyser is also tabulated. (see also Geophys. Abs. 192-361).

Iwasaki, Iwaji, Takejuri Ozawa, Minoru Yoshida, Hiroshi Kanda, and Kazuhisa Yamaya, 1968
The change in the radon (Rn-222) and thoron (Rn-220,Tn) contents of the volcanic gases in the Oowakudani District, Hakone Volcano from 1960 to 1967 [in Japanese with English abs.]:
Volcanol. Soc. Japan Bull., ser. 2, 13(1); 21-31
Geophys. Abs. 266-504
Observations of the Rn and Tn contents of hot spring gas from the Bozu-zigoku hot spring pond since 1961 has made it possible to reexamine and improve Kamad's (1961) theory on the mechanism of feeding Rn to volcanic gases. The source area of Rn and Tn in the gas seems to be near the ground surface. The gradual increase in these radioactive components from 1961 to 1965 is explained as due to (1) enrichment of Ra and Th by adsorption on clay minerals from hot spring waters or (2) increase in the effective contact area for feeding Rn and Tn to the gas due to alteration. Decreases observed in 1959 and 1966 are related to repeated earthquake shocks and are due to (1) closing of minute cracks where Ra and Th are enriched hindering extraction of Rn and Tn; or (2) decrease in contact area of source of gas and water. The approximate size of the source volume is estimated.

Jaacks, Jeffrey A., 1984
Meteorological Influence Upon Mercury, Radon and Helium Soil Gas Emissions [Ph.D. Thesis]:
Golden, Colo., Colorado School Mines, 170 p.

Jacobi, R.B., 1949
The determination of radon and radium in water:
Jour. British Chem. Soc., pt. 5: 314-318

Jacobi, W., 1961
The accumulation of natural radionuclides in aerosol particles and precipitation elements in the atmosphere [in German]:
Geofis. pura e appli., 50: 260-277
Nucl. Sci. Abs. 16:33288
The attachment of Rn- and Tn-decay products to the atmospheric aerosol is discussed, taking into account diffusion and electrostatic forces. The computed size distribution of the produced radioactive aerosol agrees with the results of diffusion measurements. The activation of cloud and rain droplets with short-lived decay products is chiefly due to the diffusion of fresh, carrier-free RaA-atoms. The collection efficiency of falling rain droplets for RaA and ThB was measured in model experiments; it is small compared to the activation of cloud elements. A method for the continuous measurement of RaB- and RaC-activity during rainfall is described: the measured, mean specific activity of 30 pCi/cm^3 can be explained by the theory of activation processes.

Jacobi, W., 1962

Die natürliche Radioaktivität der Atmosphäre und Ihre Bedeutung für die Strahlenbelastung des Menchen [The natural radioactivity of the atmosphere and its significance for the radiation protection of man]:
Hahn-Meitner-Institut für Kernforschung, HMI-B21, Berlin: 269 p.
Nucl. Sci. Abs. 17:20240
The behavior and distribution of radon, thorium and their decay products in the atmosphere are considered. A related description of the cycle of natural radioactivity in the atmosphere is given. The inhalation of natural radionuclides is discussed, and the resulting radiation burden to man is estimated. Topics covered include: radionuclides of the radon and thorium decay series, methods of measuring natural radioactivity in the air, radon and thorium given off by the earth's surface, the vertical distribution of natural radioactivity in the air on the basis of the exchange theory, natural radioactive aerosols in the atmosphere, separation processes of natural radioactivity in the atmosphere, and effects of natural radioactivity content in air on man. Results are presented in graphs and tables.

Jacobi, W., 1984
Possible lung cancer risk from indoor exposure to radon daughters:
Radiation Protection Dosimetry, 7(1-4):395-401
Chem. Abs. 101:99873a

Jacobi, W., and K. André, 1963
The vertical distribution of radon 222, radon 220 and their decay products in the atmosphere:
Jour. Geophys. Research, 68(13): 3799-3814
Geophys. Abs. 203-301
Vertical steady-state distributions of radon, thoron, and their decay products were computed assuming constant exhalation of radon and thoron from the ground, no advection, no vertical component of wind velocity, no sedimentation of airborne particles, and uniform rate of washout with altitude. Five different distributions of the turbulent diffusion coefficient were used, corresponding respectively to strong mixing, normal mixing, weak mixing, weak mixing in the lower troposphere, and strong inversion. The computed radon concentrations decrease monotonically with altitude, the gradient being greatest for strong inversion (a tenfold decrease in the first 100 m above ground). Corresponding to extremes in the degree of turbulent mixing, the concentration range is hundredfold near ground level but no more than fivefold in the altitude range 0.5 to 2 km. The surprisingly large amounts of radon found in the lower equatorial stratosphere by Machta and Lucas (see Geophys. Abs. 190-504) are not explainable by turbulent diffusion. Pb-210 concentration gradually increases upward severalfold in the troposphere and then increases sharply in the stratosphere. The results are consistent with observed Pb-210 concentrations if computed for a 20-to-50-day half period of washout in the troposphere and no washout in the stratosphere; vertical turbulent diffusion is sufficient. The ratio of Po-210 to Pb-210 is less than one throughout the troposphere even if there is no washout. Thoron concentration in the atmosphere cannot be determined by measuring thoron decay products.

Jacquet, Ch., 1926
Sur des nouvelles sources radioactives dans le Puy-de-Dôme [On some new radioactive springs in the Puy-de-Dôme]:
Acad. Sci. [Paris] Comptes Rendus, 182: 1398-1400
[Spring radioactivity was studied with relation to the nature of the terrain and the drainage pattern in the Puy-de-Dôme Department.]

Jagitsch, R., 1938
Eine Bemerkung zu der Arbeit von K.E. Zimens: Oberflächenbestimmungen und Diffusionsmessungen mittels radioaktiver Edelgase: [A remark on the work of K.E. Zimens: Surface area determinations and diffusion measurements by means of radioactive inert gases]:
Zeitschrift physikal. Chemie, 192: 56-59

Jagitsch, R., 1939
O. Hahns Emaniermethode als Hilfsmittel zur Untersuchung des strukturellen Aufbaues und der Umsetzungen fester Stoffe [O. Hahn's emanation method as an aid to the investigation of structural composition and of changes in solid matter]:
Ing. Vet. Akad., 1939, (4): 3-9

Jagitsch, R., 1940
Über den Zusammenhang zwischen dem Temperaturinkrement des Emaniervermögens und der Ionenbeweglichkeit in festen Salzen [On the correlation with temperature increment between emanating power and ionic mobility in solid salts]:
Ing. Vet. Akad., 1940, (1): 1-8

Jagitsch, R., 1940
Messungen von Ionenbeweglichkeit inelektronischen Halbleitern mittels der Emaniermethode [Measurements of ionic mobility in electronic semiconductors by means of the emanation method]:
Ing. Vet. Akad., 3: 1-8

Jaki, Stanley L. and Victor F. Hess, 1958
A study of the distribution of radon, thoron, and their decay products above and below the ground:
Jour. Geophys. Research, 63(2): 373-390
Geophys. Abs. 174-312
The respective concentrations of radon, thoron, and their decay products have been measured immediately above the earth and below the ground, and a study of their correlation with meteorological conditions has been carried out. It was found that the concentration of radon and thoron in the vicinity of the earth's surface depends primarily on the dryness of the ground. Measurements at and below the ground level were carried out by an indirect method, collecting the decay products of radon and thoron on the inner surface of an aluminum cylinder charged to -600 volts. From November 16, 1956 to May 7, 1957, 239 experiments were made. It was found that the concentration of thoron below the ground seems to reach a maximum value at a depth of about 75 cm, whereas the concentration of radon shows a continuous increase within the range investigated. Comparison with other experiments shows that the cylinder method can be used for investigating the exhalation of both radon and thoron at the surface of the ground. The mean value obtained for radon is 6 aCi/cm^2-sec. The measurements presented here give the first data on the exhalation of thoron through the air-soil interface.

James, A.C. and J.C. Strong, 1974
Radon daughter monitor for use in mines, *in* Snyder, Walter S., ed., International Radiation Protection Association, Proceedings of International Congress, 3d, 9 Sept.-14 Sept. 1973
Springfield, Va., NTIS

Janssens, A., F. Raes, and A. Poffijn, 1984
Transients in the exhalation of radon caused by changes in ventilation and atmospheric pressure:
Radiation Protection Dosimetry, 7(1-4): 81-86
Chem. Abs. 101:99828q

Jantsky, B., et al., 1958
A characteristic case of uranium mineralization observed in the foothills along the shore of Lake Balatan, *in* Survey of Raw Material Resources, 2: 564-568, United Nations Internat. Conf. on the Peacful Uses of Atomic Energy, 2nd, Geneva, 1-13 Sept. 1958:
Geneva, United Nations
[Emanation tests used to verify uranium as source of anomalies observed by air and carborne surveys.]

Jasinska, M., T. Niewiadomski, and J. Schwabenthan, 1982
Correlation between soil parameters and natural radioactivity, *in* Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:
New York, John Wiley and Sons, p. 206-211

Jaworowski, Zbigniew, Jan Bilkiewicz, Ludwika Kownacka, and S. Wlodek, 1975
Artificial sources of natural radionuclides in the environment, *in* Adams, John A.S., and Lowder, Wayne M., eds., The Natural Radiation Environment II, Symposium proc., Houston, August 7-11, 1972, 3: 809-818:
U.S. ERDA Rept. CONF-720805-P2, Springfield, Va. NTIS

Jech, C., 1962
Release of inert gas from labeled ionic crystals during thermal treatment:
Phys. Status Solidi, 2: 1299-1303
Nucl. Sci. Abs. 17(7):10638:
Release of radon-222 and xenon-133 labels, introduced into samples of a series of alkali metal chlorides by ionic bombardment, is measured during two types of thermal treatment. For a given chloride both gases are released in about the same temperature range, the position of which is dependent on the mass of cation in the chloride. The temperature and time dependence of the release is very similar to the characteristics of thermal recovery of changes induced in chlorides by ionizing radiation. This suggests that release occurs as a result of, or in connection with, the annealing of the radiation damage produced in the surface layers by the ion bombardment.

Jemma, Raimundo J.A., 1962
La prospeccion geofisica del yacimiento uranifero "Rodolfo" en la Provincia de Cordoba [Geophysical prospecting of the uraniferous deposit "Rodolfo" in the Province of Cordoba]:
Anales Primeras Jornadas Geologicas Argentinas, Librart S.R.L., 3: 143-156
Geophysical surveys were undertaken in order to determine the economic possibilities of the Rodolfo uranium deposit in the Punilla Valley near the city of Cosquin. Two methods were applied: measurements of the amount of radon in the soil air and measurements of resistivity by means of deep vertical electric sounding. The former was to determine the continuity of the mineralization along the north-south strip of the mineral zone, and the latter to determine the depth to the crystalline basement and the average groundwater level in the area. The methods were successful in outlining the extent of the deposit. The radon method is recommended for use in exploring vast regions of similar geology where indications of radioacativity have been observed over outcrops.

Jemma, Raimundo, Hugo Olsen, 1965
La Prospeccion emanometrica del yacimiento "Los Adobes": (Provincia del Chubut) [Emanometric prospecting of the Los Adobes deposit (with English abs.)]:
Acta Geol. Lilloana, 5:63-72.
Geophys. Abs. 239-332
The emanometric prospecting method as applied to the sedimentary uranium deposits in the Los Adobes area, Argentina, is described and its advantages cited. Measurements of radon in the soil over possible deposits were made with an emanometer of Ambronn type; the instrument is described and illustrated. The method is advantageous in that it is possible to locate anomalous areas even where the soil cover is some meters thick and where other radioactivity techniques would not be effective. Results compared closely with delimitation of the mineralized zone inferred from borings.

Jensen, C.M., R.F. Overmyer, P.J. Macbeth, V.C. Rogers, and T.D. Chatwin, 1978
Emanating power and diffusion of radon through uranium mill tailings, *in* Seminar on Management, Stabil. Environ. Impact Uranium Mill Tailings, Proc., p. 35-49:
Paris, OECD

Chem. Abs. 93:7916h

Jennings, W.A., and S. Russ, 1948
Radon: Its technique and use:
London, Middlesex Hosp. Press, 220 p.

Jensen, M.L., 1965
Rational and geological aspects of solid diffusion:
Canadian Mineralogist, 8(3): 271-290

Jeter, Hewitt W., 1980
A Modeling Study of Gaseous Rn-222, Xe-133, and He-4 for Uranium Exploration:
Westwood, N.J., Teledyne Isotopes, Inc., U.S. Dept. Energy Rept. GJBX-140 (80), 111 + ix p. + microfiche of 30 p. of computer programs
This work presents one-dimensional mathematical models to simulate the transport of gaseous radon-222, xenon-133, and helium-4 away from uranium ore deposits. The resulting concentrations of indicator nuclides in the overburden are used to infer the detectability of ore deposits by emanation methods. In the case of homogeneous, non-radioactive formations, Rn-222 and some of its daughter products are calculated to be detectable at distances of several tens of meters from a planar uranium ore deposit (1 m thickness, 0.6% U_3O_8, 20% emanation coefficient). When the overlying rock-sediment column is assumed to contain 4 ppm uranium, the masking effect of locally produced radon reduces detection range to 15 m (based on a 5/1 signal-to-background ratio). ...Inhomogeneity in rock formations is simulated by a multiple-layer model. Each horizon may be assigned uranium and thorium concentrations as well as a diffusion coefficient and physical properties. The model has been tested with deep-hole data from a piedmont sedimentary formation located in central Wyoming. Calculated results are highly correlated with measurements of Pb-210 (a solid daughter product of Rn-222). A comparison of fluorimetric uranium data to gamma spectral measurements suggests the migration and deposition of Ra-226 near the water table. Modeling results are improved when this process is taken into account. A constant soil gas velocity of 1×10^{-4} cm/sec causes indicator concentrations to change by several orders of magnitude. If steady upward soil gas motion exists in nature, the detectability of uranium ore by emanation methods will be significantly different from that indicated by pure diffusion models. Barometric influences on gas transport are simulated by time-dependent numerical models. Sinusoidal variations in atmospheric pressure cause sinusoidal changes in gas concentrations which are attenuated with increasing depth. The effect is less than ± 15 percent near the soil surface for Rn-222 and Xe-133, while He-4 exhibits a maximum variation of 0.4 percent.

Jeter, Hewitt W., J. David Martin, and Donald F. Schutz, 1977
The migration of gaseous radionuclides through soil overlying a uranium deposit: a modeling study:
Westwood, N.J., Teledyne Isotopes, Inc., U.S. Dept. of Energy Rept. GJBX-67: 44 p.

Jirkovsky, R., 1962
Kontrol' osnovaniy plotin i issledovaniyo geologicheskikh dislocatsii radioaktivnymi zondai [Control of water dam basements and exploration of geological dislocations by means of radiometric surveys], *in* Geofizyka Jadrowa, Proceedings: Nuclear Geophysicists Conf., Cracow, Sept. 24-30, vol. 4: 871-883

Johansson, G.I., C. Samuelsson, and H. Pettersson, 1984
Characterization of the aerosol and the activity size distribution of radon daughters in indoor air:
Radiation Protection Dosimetry, 7(1-4): 133-137
Chem. Abs. 101:99835q

Johnson, R.H., Jr., D.E. Bernhardt, N.S. Nelson, and H.W. Calley, Jr., 1975

Radiological health significance of radon in natural gas, *in* Stanley, Richard E., and A. Alan Moghissi, eds., Noble Gases, Symposium Proceedings, Las Vegas, Nev., Sept. 24-28, 1973:
U.S. Energy Research and Development Admin. Tech. Inf. Center Rept. CONF-730915: 532-539

Johnson, Raymond H., Jr., Neal S. Nelson, and Abraham S. Goldin, 1982
Natural radiation quality of the environment in the United States, *in* Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:
New York, John Wiley and Sons, p. 180-187
...It is estimated that radon related health effects far exceed those due to cosmic and terrestrial radiation and internal radionuclides. Natural radiation may account for 3.5 to 5.8 percent of normal cancer incidence in the U.S.

Joly, John, 1909
On the distribution of thorium in the earth's surface materials:
Philos. Mag. 17: 760-765
[Gives account (the first?) of the thoron streaming method.]

Jonassen, Niels, 1975
Effect of atmospheric pressure variations on the radon-222 concentration in unventilated rooms:
Health Physics, 29(1): 216-220
[During an investigation of the relation between ^{222}Rn concentration and atmospheric pressure in unventilated rooms, the atmospheric pressure fluctuated too much for the ^{222}Rn concentration to reach a steady state value. According to Clements' 1974 dissertation, the flux density of ^{222}Rn at constant pressure through an interface between an infinitely deep layer of soil with a constant ^{222}Rn production rate and air with no appreciable ^{222}Rn content is proportional to the square root of the diffusion coefficient. If the exhalation of ^{222}Rn from materials such as building materials are to be compared, the diffusion coefficients should be determined while the test system is at constant pressure. In order to meet such a requirement, an investigation is planned where where various building materials will be placed in a pressure chamber and the rate of approach of radioactive equilibrium in the air will be followed by sampling and analyzing air samples while the test system is at constant pressure. Measurements will be repeated at various pressures.]

Jonassen, Niels, 1983
The determination of radon exhalation rates:
Health Physics, 45(2): 369-376

Jonassen, Niels, 1984
Removal of radon daughters by filtration and electric fields:
Radiation Protection Dosimetry, 7(1-4): 407-411
Chem. Abs. 101:99875c

Jonassen, Niels, and William E. Clements, 1974
Determination of radon-222 concentrations by an integrated count method:
Health Physics, 27(4): 347-351

Jonassen, Niels, and J.P. McLaughlin, 1980
Exhalation of radon-222 from building materials and walls, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1211-1224

Jonassen, Niels, and J.P. McLaughlin, 1982
Air filtration and radon daughter levels:

Environment Internat., 8(1-6): 71-75

Jonassen, Niels, and Marvin H. Wilkening, 1970
Airborne measurements of radon 222 daughter ions in the atmosphere:
Jour. Geophys. Research, 75(9): 1745-1752
Geophys. Abs. 284-345
An ion collector suitable for use aboard an aircraft has been developed for the determination of the concentration of radon-222 daughter ions in the lower atmosphere. The operation of the device aboard an aircraft while air samples for radon-222 are collected simultaneously makes possible the determination of the fraction of the total equilibrium value of radon daughter products that exist as small ions in a given environment. Typically, this ratio is of the order of 10 percent with larger values occurring in the early morning hours before eddy diffusion produces a well-mixed lower atmosphere. Vertical profiles show a stable atmosphere; these same quantities remain roughly constant with height in a well-mixed atmosphere.

Jones, W. Mervyn, 1951
Mobility in a sorbed layer. Part I. The flow of gases and vapours through porous media:
Faraday Soc. Trans., 47: 381-392
Theoretical equations are derived for the surface flow of an ideal two-dimensional gas through (a) a hole in a plane sheet, (b) a long circular capillary, and (c) a porous material, the porous material being treated as a bundle of capillaries. The equations express the flow in terms of the dimension of the capillaries, the molecular weight of the gas, and the temperature. The surface flow is not affected by the presence of the vapour phase in the capillaries nor by the roughness of the surface, provided the end conditions and the dimensions of the capillaries remain unaltered. The equations will explain the results of Tomlinson and Flood on the flow of ether and ethyl chloride through porous graphite, when the conditions of the experiment are such that nearly a monolayer is sorbed on the graphite. At lower surface concentrations the effect of a surface field must be taken into account; this is discussed. The results of Carman on the flow of sulphur dioxide through porous silica are also discussed and here the surface field appears to restrict surface mobility for all concentrations examined. It is concluded that in addition to the expressions for Poiseville flow and Knudsen flow which occur in equations for the flow of gases and vapors through fine capillaries, a third expression must be included, namely, that for the flow of sorbed molecules over the surface of the capillaries.

Jost, Wilhelm, 1952
Diffusion in solids, liquids, gases:
New York, Academic Press, Inc., 558 p.

Jurain, George, 1957
Remarques sur la teneur en uranium des eaux des Vosges Méridionales [Remarks on the uranium content of the waters of the southern Vosges]:
Acad. Sci. [Paris] Comptes Rendus, 245(13): 1071-1074
Geophys. Abs. 171-308
The curve representing the distribution of uranium in 170 hot and cold spring waters of the southern Vosges, France, is a characteristic logarithmal curve with a maximum of 0.8 μg/L; content above 2.4 μg/L suggests genetically different conditions. Nearly all the cold waters give results close to these figures. Certain thermal waters (including those of Luxeuil and Reherry) and some cold waters have about 4 μg/L and hot springs of Bains-les-Bains average 7 μg/L. Comparison with radon measurements made between 1900 and 1923 on some of these waters shows little correlation between radon and uranium content.

Jurain, Georges, 1958
Signification géochimique des anomalies de teneur en radon des eaux des massifs cristallins et cristallophylliens [Geochemical signifance of anomalies in radon content of the waters of granitoid and foliated massifs]:
Soc. géol. France Comptes Rendus, 14: 348-350

Geophys. Abs. 177-323

Observations of the anomalous radon content of waters in crystalline massifs, illustrated by examples from the southern Vosges and the Vendee in France, lead to the conclusion that there is a more or less direct relationship between the content of radioactive elements of the uranium-radium family and the radon content of the waters of granitoid or foliated massifs. These particularly high radon contents correspond to the amounts of radiogenic lead (1 μCi of radon corresponds to 0.91 μg Pb-206). Such loss through the waters introduces an error that cannot be neglected in age determinations by the lead-alpha method and in the Pb-206/U-288 as well as in the Pb-207/Pb-206 ratios.

Jurain, Georges, 1960

Moyens et résultats d'étude de la radioactivité due au radon dans les eaux naturelles [Means and results of study of the radioactivity due to radon in natural waters]:

Geochim. Cosmochim. Acta, 20(1):51-82

Geophys. Abs. 183-515

A field method has been developed for the determination of the radon-222 concentration in natural waters. A 30-cm^3 sample of water is taken with a hypodermic syringe and injected into an evacuated tube through a rubber stopper. In a centrally-located laboratory truck it is de-emanated by aeration and agitation into an evacuated 500-cm^3 flask coated inside with a phosphor sensitive to alpha particles. Scintillations are counted at radioactive equilibrium for 15 min. A crew of two can analyze up to 30 samples per day. The concentrations of radon in 655 samples of spring and well waters from 7 lithologic units were determined in 1958 and 1959. For each lithologic unit the results were grouped and plotted on logarithmic probability graph paper. Most of the graphs yielded satisfactory to excellent alignment along straight lines, implying that radon concentrations in waters of a given lithologic unit are distributed lognormally. For two lithologic units that were sampled in both years the mean radon concentrations changed considerably between the first and the second. In 5 of the 7 lithologic units the mean radon concentration was greater than the French standard, 4 nCi/L, for the maximum permissible concentration in drinking water. Because radon anomalies in ground water were found to correlate with uranium-bearing ground, the radon method is recommended in prospecting for uranium.

Jurain, Georges, 1961

Sur la possibilité d'utiliser le dosage du radon des eaux souterraines dans la prospection des gîtes uranifères [On the possibility of using the determination of radon in ground waters in prospecting for uranium deposits]:

Acad. Sci. [Paris] Comptes Rendus, 252(20): 3090-3092

Nucl. Sci. Abs. 15:20953; Geophys. Abs. 186-551

Recent work on radon activity of ground water (see Geophys. Abs. 177-323, 183-515) led to the conclusion that systematic determination of the radon content in such waters could be used to distinguish mineralized and nonmineralized zones in uranium prospecting. This conclusion has now been corroborated by tests in an area that has been surveyed geologically, radiometrically (on 25-m and 5-m grids), geophysically, by trenching and drilling, and geochemically. The method is rapid, accurate, and cheap, and can either replace airborne radiometric reconnaissance surveying or be used in a semisystematic phase of exploration.

Jurain, Georges, 1962

Contribution à la connaissance géochimique des familles de l'uranium-radium et du thorium dans les Vosges méridionales. Application de certains résultats en prospection des gisements d'uranium [Contribution to the geochemical knowledge of the families of uranium-radium and of thorium in the southern Vosges. Application of some results to pospecting of deposits of uranium]:

Sci. de la Terre Mem., 2: 349 p.

Geophys. Abs. 200-306

This study of radioactivity in the rocks of the southern Vosges was designed to contribute to the geochemical knowledge of the uranium-radium and thorium families through a study of an area where the formations encountered present weak concentrations of nonexploitable uraniferous minerals. Furthermore, research was

conducted on radon in waters circulating throughout the diverse formations of the area. The amplitude of the radon variations was then compared with that on massifs containing exploitable uranium deposits. Results obtained have made it possible to establish an effective method of exploration for uranium deposits. The report has five chapters that cover (1) the geology, geography, climate, and previous knowledge on the radioactivity of the rocks and water; (2) a summary of the principal physico-chemical properties of elements of the uranium-radium and thorium families, and methods used for measurements of radioactivity of the rocks of the southern Vosges in the field and laboratory; (3) the content of uranium and thorium of the rocks of the area; (4) research on the content of uranium in the waters and of the radioactivity due to radon and radium; and (5) general conclusions. A bibliography of approximately 275 items is included. The results of analyses are given in tables in an appendix.

Jurić, Mira K., 1961
Determination of alpha-radioactivity in the atmosphere by means of photonuclear plates:
Bull. Inst. Nuclear Sci. "Boris Kidrich" [Belgrade] 12: 43-62
Nucl. Sci. Abs. 16:15005
A method of measuring alpha-radioactivity in the atmosphere is developed, using an electrostatic filter as a collector of aerosols and measuring the collected activity with photonuclear plates. It is found that radon does not remain on the filter (less than 1%) and that the method makes possible the determination of the activity with an error of 25%.

Käding, H., and N. Riehl, 1934
Radioactive Methoden in dienste chemischer und technischer Probleme [Radioactive methods in application to chemical and technical problems]:
Angew. Chemie, 47: 268-270

Kähler, Karl, 1906
Über einige Zerstreuungs und Bodenluftmessungen im Kiel im Herbst 1905 [On some dispersion and ground air measurements in Kiel in the Autumn of 1905]:
Meteorologische Zeitschrift, 41: 253-256

Kahn, Bernd, Geoffrey G. Eichholz, and Frank J. Clarke, 1983
Search for building materials as sources of elevated radiation dose:
Health Physics, 45(2): 349-361

Kaiserman, Ronald Mark, 1984
Lithologic Controls on Groundwater Chemistry in Uranium-Bearing Rocks of the Southern Culpeper Triassic-Jurassic Basin, VA.:
Charlottesville, Va., Univ. Va., Dept. Environmental Sci., M.S. Thesis, 110 p.
Three hundred groundwater samples were collected and analyzed from the Culpeper and Danville Triassic-Jurassic basins, Virginia. In addition to major ions, chemical analyses determined iron, radon-222, and uranium concentrations. Several samples were also analyzed for radium-226 content. Lithologic controls on groundwater chemistry were examined by discriminant analysis and R-mode factor analysis. Discriminant analysis was able to correctly identify 85% of the samples from the Culpeper basin according to lithology. Controls on uranium in solution were examined by multiple regression analysis. From these analyses, it appears that uranium mineralization is likely in this part of the Culpeper Triassic-Jurassic basin. In this area, the most important controls on disolved uranium are bicarbonate concentration, pH, and ionic strength.

Kaku, Koichi, 1954
Distribution of radon in central Kyushu:
Kumamoto Jour. Sci., ser. A 1(3): 86-110, 2(1): 108-118
Geophys. Abs. 169-265

Measurements of radon content were made at 47 hot springs in central Kyushu by use of an I.M. Fontactoscope. Highest observed values were at Musashi Hot Springs (12 Mache units=4.44 nCi/L). Radon content is greatest in areas underlain by granite rocks and least in areas underlain by volcanic rock. Inferences on the geology of the areas are drawn from the "iso-radon" curves and temperature distribution.

Kalkwarf, D.R., P.O. Jackson, and J.C. Kutt, 1985
Emanation coefficients for Rn in sized coal fly ash:
Health Physics, 48(4): 429-436

Kamada, Masaakira, 1953
Radioactivity of volcanic gas:
Tohoku Univ. Sci. Repts, 1st ser., 37(1): 117-124
Geophys. Abs. 159-185:
Presence of radon, radium A, radium B, radium C, thoron, thorium A, and thorium B has been identified in volcanic gases in Japan but actinon has not yet been confirmed. Measurements with an I.M. fontactoscope indicate that the radioactivities of volcanic gases are not negligible and are often comparable to those of gases issuing from strongly radioactive mineral springs. The thoron content of as much as 11,300 Mache units [4.18 μCi/L] for the Shiratori fumarole gas in the Kirishima volcanic region is the world's largest known value. Studies of samples from the Kirishima region indicate that the radon contents of fumarole gases are almost constant, unlike those of the radioactive springs. All fumaroles issued from eruptive rocks. In fumaroles accompanied by hot waters, there was an abnormal partition of radon and thoron, indicating that the origin was in the volcanic gas rather than in the hot water or in ground water near the surface. The Tn/Rn ratio did not differ much from one fumarole to another; their origin then is presumably near the surface. If it is possible to determine An in volcanic gases, the actinon may be used as a tracer to determine more accurately the movement of the gases.

Kametetani, Katsuaki, and Kayoko Tomura, 1976
Concentrations of radium-226 and polonium-210 in tap water, well water and rain water and adsorption of lead-210 in soil [in Japanese]:
Radioisotopes, 25(7): 410-412
Chem. Abs. 86:110975e

Kamiyama, T., S. Okada, and Y. Simazaki, 1973
Exploration of uranium deposits in tertiary conglomerates and sandstones of Japan, *in* Uranium exploration methods, Proceedings of a Panel, Vienna, 10-14 April 1972:
Vienna, Internat. Atomic Energy Agency, pub. STI/PUB/334, p. 45-53, with discussion, p. 54
Prospecting by utilizing the radon content in the air contained in soils has not been used in Japan, but the method has been tested by the Geological Survey of Japan and has proven to be useful. As shown in Fig. 7, the data over a known ore body agreed very well with the shape which was confirmed by drilling.

Kapustin, O.A., and K.B. Zaborenko, 1974
Raschet stepeni vydeleniya radioaktivnykh gazov iz tverdykh tel i opredeleniye koeffitsiyentov diffuzii [Calculation of emanation of radioactive gases from solids and determination of diffusion coefficients]:
Radiokhimiya, 16(5): 611-617; Sov. Radiochemistry, 16(5): 601-606.
Chem. Abs. 35168f; Nucl. Sci. Abs. 22822; May 31, 1976:
Solutions are given for differential equations for the liberation of radium emanation from spherical solids. An examination was made of steady-state and non-steady-state solutions and approximations are given which make possible a numerical solution for a series of cases encountered in practice.

Kapustin, O.A., and K.B. Zaborenko, 1974

Raschet stepeni vydeleniya radioaktivnykh gazov iz tsilindricheskikh tverdykh tel i opredeleniye koeffitsiyentov diffuzii [Calculation of emanation of radioactive gases from cylindrical solids and determination of diffusion coefficients]:
Radiokhimiya, 16(5): 615-625; Soviet Radiochemistry, 16(5): 618-625.
Chem. Abs. 35169g; Nucl. Sci. Abs. 22823; May 31, 1976:
A solution is given for the differential equation which describes the liberation of emanation from a limited solid in the form of a cylinder containing isotopes of radium. Steady-state and non-steady-state conditions were examined. Approximations are given which provide numerical solutions for single crystals or tablets of substances investigated which are used in practice.

Kapustin, O.A., and K.B. Zaborenko, 1978
K teorii emanatsionnogo metoda:
Radiokhimiya, 20(2): 276-283; translated into English as Theory of the emanation method: Soviet Radiochemistry, 20(2): 235-242
Chem. Abs. 88:197876m:

Karim, S.M., 1962
Radioactive fall-out and atmospheric radioactivity:
Pakistan J. Sci., 12(5): 222-235
Phys. Abs. (1962): 24026
After some general considerations about atmospheric radioactivity an account is given of a few experiments to determine the atmospheric radioactivity at Karachi, Pakistan. Air was sampled by suction through a filter paper for 40 min. and the activity was tested by an ionization chamber and a Wulf electrometer. The author's main conclusions are (1) a periodicity of radioactive peaks during February and March 1958 is suspected, (2) rainfall causes reduction in radioactivity, (3) nuclear tests in Russia apparently affected the activity in Karachi, (4) the partial solar eclipse of 19th May 1958 appeared to decrease the radioactivity on that day, and (5) atmospheric radioactivity shows diurnal variation, the maximum being obtained at 2 a.m.

Karol, I.L., 1972
Radioaktivnye izotopy i global'nyl perenos v atmosfere [Radioisotopes and global transport in the atmosphere]:
Gidrometeoizdatel'stvo, Israel Program for Scientific Translations, Jerusalem, 1974. U.S. Dept. Commerce, TT 74-50025

Kaul, A., and H. Muth, 1960
Messungen sehr kleiner Radonkonzentrationen mit Szintillationsanordnungen [Measurements of very small radon concentrations with scintillation apparatus]:
Internat. Congr. Radiology, 9th, Munich, July, 1959, Trans., 2: 1391-1396 Stuttgart, Georg Thieme Verlag

Kawano, M. and S. Nakatani, 1959
The absolute measurement of the concentrations of radioactive substances in the atmosphere, in Tokyo:
Jour. Geomagnetism and Geoelectricity, 10(2): 56-63
Geophys. Abs. 177-326
Concentrations of radioactive substances in the air were measured continuously at Tokyo by the ionization chamber method and compared with those of radon emanated from a radium standard solution to give absolute values. On fine days these concentrations were 0.23-1.2 pCi/L. The ratio of beta plus gamma radiation to total radiation was found to be 5-25 percent; in radon in equilibrium with its decay products this ratio is 2-3 percent; therefore, the radon in the atmosphere is apparently not in equilibrium.

Keane, A.T., H.F. Lucas, F. Markun, M.A. Essling, and R.B. Holtzman, 1986
The estimation and potential radiobiological significance of the intake of ^{228}Ra by early Ra dial workers in Illinois:

Health Physics, 51(3): 313-327

Kearney, P.D., and D.A. Krueger, 1987
Radon-222 flux density measurements using an accumulator: an alternative technique:
Health Physics, 53(5): 525-526

Keefer, D.H., and E.J. Fenyves, 1980
Radiation exposure from radium-226 ingestion, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 839-853

Keith, B., and J.W. Card, 1979
Radon decay products and uranium exploration, *in* Pye, E.G., ed., Geoscience Research Grant Program; Summary of Research, 1978-1979:
Ontario Geol. Survey Misc. Paper No. 87, p. 117-124

Keller, G., K.H. Folkerts, and H. Muth, 1982
Activity concentrations of ^{222}Rn, ^{220}Rn, and their decay products in German dwellings, dose calculations and estimate of risk:
Radiation Environment. Biophys., 20: 263-274

Keller, Gert, and Karl-Heinz Folkerts, 1984
A study on indoor radon, *in* International Conference on Indoor Air Quality and Climate, 3d, Stockholm, August 20-24, 1984; Vol. 2: Radon, Passive Smoking, Particulates and Housing Epidemiology, Birgitta Berglund, Thomas Lindvall, and Jan Sundell, eds.:
Stockholm, Swedish Council for Building Research, Vol. 2, p. 149-154

Keller, G., K.H. Folkerts, and H. Muth, 1984
Special aspects of the radon-222 and daughter product concentrations in dwellings and in the open air:
Radiation Protection Dosimetry, 7(1-4): 151-154
Chem. Abs. 101:99839u

Kellogg, William Crowe, 1957
Observation and interpretation of radioactive patterns over some California oil fields:
Mines Mag., 47(7): 26-28
Geophys. Abs. 170-275
The anomalies measured in airborne radioactivity surveys over the Ten Section oil field and the Tejon Grapevine field in Kern County, California, are explained in terms of the deposition of radioactive salts at the earth's surface by ground water. The movement of ground water is influenced by geology (such as faults, bedding planes, zones of porous and permeable material, or attitude of the strata), so that geologic structure may be revealed by radioactivity anomalies.

Kelly, Roger, 1961
The attachment of inert gases to powders following (n,gamma) events:
Canadian Jour. Chemistry, 39(3): 664-674
It has been found that, when argon, krypton, and xenon are irradiated with neutrons in the presence of various powders, a portion of the inert-gas activity becomes "attached" to the powder. The attached activity was shown to be highly enriched, and to be indistinguishable from adsorbed activity. Expressing the attachment in terms of the attachment efficiency, A = (inert-gas activity attached to target/total inert-gas activity), it was found that A was independent of irradiation time and neutron flux, and for fine powders was also independent of pressure between 0.7 and 700 mm. The use of a very coarse powder or no powder at all led to a decrease

in A, on the basis of which it was estimated that the maximum distance from a surface that attached activity can originate is about 200 mean free paths. The following miscellaneous relations were observed to hold: (i) $A << 1$, (ii) $A_{Ar} > A_{Kr} > A_{Xe}$, (iii) $A_{oxide} > A_{metal}$ (approximate). The results were in general consistent with a mechanism of attachment based on electrical attraction: inert-gas atoms first acquire a high charge due to vacancy cascades initiated by the conversion of capture gamma rays; they then wander about, and, upon approaching a solid surface, are accelerated electrically into it. [A_{Xe} was <3% for crushed quartz tubing and SiO_2 powder.]

Kelly, Roger, 1961
The diffusion of "attached" inert-gas activity:
Canadian Jour. Chemistry, 39(12): 2411-2422
It was shown previously that, when an inert gas is irradiated with neutrons in the presence of a powdered solid, between 0.1 and 14% of the induced inert-gas activity is firmly "attached" to the solid. The manner in which attached inert-gas activity is released at temperatures between 50 and 800°C has now been studied. Release data were assembled for a number of systems, and it was noted that the release was reproducible and apparently a diffusion phenomenon. Several theoretical treatments based on diffusion theory were then explored. Agreement between theory and observation was poor if a constant activation enthalpy was assumed. Agreement was good, on the other hand, with theory that took account of the damaged condition of the solid, and the existence of composition anomalies, in the surface region where the inert-gas activity was attached. The damage and composition anomalies were assumed to lead to a spectrum of activation enthalpies and thence to a simplified diffusive motion involving a single rate-controlling jump. The activation-enthalpy spectra for the systems Ar-Nb and Xe-Nb were found to be identical, extending from about 25 to 47 kcal. The spectrum for Xe-Nb_2O_5 extended from about 28 to 76 kcal, and was, in general, similar to the spectra for Xe-SiO_2, Ar-TiO_2, and Xe-TiO_2.

Kelly, Sherwin F., 1941
Geological studies of uranium-vanadium deposits by geophysical methods:
Mining Congress Jour., 27(8): 27-35
[Emanation haloes near carnotite at Uravan, Colo.]

Kelly, Sherwin F., 1953
Geological studies of uranium-vanadium deposits by geophysical exploration methods:
Precambrian, June
[Anomalous gamma counts were observed in 1940 (by G-M counter) from apparently barren sandstone core as much as 20 ft. above ore stratum (carnotite in Uravan area, Colo.). Attributed to radon migration. Unspecific emanation method suggested for soil gas, drilling, and underground explorations for uranium. (See Mining Congr. Jour. 1941)]

Kerr, J.R.W., D.I. Coomber, and D.T. Lewis, 1962
The use of bismuth radionuclides in analysis. Part III. The determination of radon in waters:
Analyst, 87: 944-948
Nucl. Sci. Abs. 17(6):7974:
A rapid radiochemical method is described for determining radon in water, based on the equilibrium of bismuth-214 with its parent radon. This bismuth isotope is precipitated from solution by n-propyl gallate with inactive bismuth as a carrier. The precipitate of bismuth propyl gallate is collected on a filter, dried, mounted and beta-counted on a conventional instrument. The lower limit of sensitivity is about 20 pCi/L when a simple Geiger assembly is used. The storage in polyethylene containers of water samples taken for analysis is not recommended, as this polymeric material can absorb radon gas from aqueous solutions.

Kerschke, B., 1924

Über die Adsorption der Radium-emanation an Substanzen grosser Oberfläche [On the adsorption of radium emanation by substances of large surface area]:
Diss. Berlin

Ketola, M., and R. Sarikkola, 1973
Some aspects concerning the feasibility of radiometric methods for uranium exploration in Finland, *in* Uranium exploration methods: Proc. of a Panel, Vienna, April 10-14, 1972:
Internat. Atomic Energy Agency STI/PUB/334: 31-41; disc. 41-43
[Rn in streams and rivers ranged up to 0.3 nCi/l, in ground water 3 nCi/l; "In the environment of a scintillometric anomaly detected on the Kesanki fell, which is marked by a circle on fig. 5, radon abundances are encountered which somewhat exceed the background values."]

Key, R.M., R.L. Brewer, J.H. Stockwell, and others, 1979
Some improved techniques for measuring radon and radium in marine sediments and in seawater:
Marine Chemistry, 7(3): 251-264

Key, R.M., N.L. Guinasso, Jr., and D.R. Schink, 1979
Emanation of radon-222 from marine sediments:
Marine Chemistry, 7(3): 221-250

Khademi, B., A.A. Alemi, and A. Nasseri, 1980
Transfer of radium from soil to plants in an area of high natural radioactivity in Ramsar, Iran, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 600-610

Khan, Atika, and Colin R. Phillips, 1985
Dependence of electrostatic diffusion of Rn progeny on environmental parameters:
Health Physics, 49(3): 443-454

Khan, Hameed A., Riaz A. Akber, Ishfaq Ahmad, and Khalid Nadeem, 1980
Field experience about the use of alpha sensitive plastic films for uranium exploration:
Nuclear Instruments and Methods, 173(1): 191-196
Chem. Abs. 93:103293x

Khan, H.A., R.A. Akhwand, K.M. Bukhari, and A. Saddarudin, 1977
The measurement of radon and thoron by solid state nuclear track detectors:
Nucl. Eng. Div., Pak. Inst. Nucl. Sci. Technol., Rawalpindi, Pakistan, Rept. AED-Conf-76-421-031: 10 p [in English]
INIS Atomindex, 8(6), Abs. 296027
Chem. Abs. 87:13228b:

Khaykovich, I.M., 1958
Intensivnost' gamma-izlucheniya radioaktivnykh plastov pri nestatsionarnoy diffuzii radona [Intensity of gamma radiation of radioactive layers for non-steady-state diffusion of radon], *in* Voprosy Razvedochnoy Radiometrii [Problems of Exploration Radiometry]:
Leningrad, Vses. Nauchno-Issled. Inst. Metod. i Tekh. Razveki Inf. Collection no. 1

Khaykovich, I.M., 1961
Raspredeleniye radona v rudnom plaste peresechenom tsilindricheskoy skvazhinoy [The distribution of radon in an ore layer cut by a cylindrical borehole], *in* Voprosy Rudnoy Geofiziki [Problems of Mining Geophysics]:
Moscow, Vses. Nauchno-Issled. Inst. Razved. Geofiziki, no. 2, p. 94-101

Geophys. Abs. 194-296:
This paper investigates mathematically the distribution of radon in a cylindrical borehole piercing an layer of ore, for the case where the diffusion properties of the active ore layer and of the surrounding rocks are equal, as is encountered in some places. Only diffusion, in the steady-state, is developed.

Khaykovich, I.M., and L.A. Khalfin, 1961
Izmemeniye intensivnosti gamma-izlucheniya radioaktivnogo poluprostranstva pri zakriytii ego gasonepronitsayemoy poverkhnostyu [The change in the gamma-ray intensity of a radioactive half-space due to its sealing by a surface impervious to gas], *in* Voprosy Rudnoy Geofiziki [Problems of Mining Geophysics]:
Moscow, Vses. Nauchno-Issled. Inst. Razved. Geofiziki, no. 2, p. 131-134
Geophys. Abs. 194-300

Kikkawa, Kyozo, 1954
Study on radioactive springs:
Japanese Jour. Geophysics, 1(1): 1-25
Geophys. Abs. 164-265:
Amounts of discharge, temperature, chlorine, and radon contents of Zuihozi spring in Arima were measured daily from December 1949 to January 1953. Rainfall increases the radon content, but mixture with ground water at shallow depths during and after rainfall decreases the amount, so there is a complicated relationship. Highest radon contents are associated with cold as well as wet ground. A simple model with a horizontally infinite source of radon beneath the ground surface from which radon diffuses in only one dimension is assumed and equations solved for the steady state, when radon is exhaled freely from the ground surface, and when the surface is closed so perfectly that radon is not exhaled, and the nonsteady state, when exhalation is suddenly controlled (corresponding to the beginning of snow, freezing, or rain). Characteristics of the actual states are approximated by the models.

Kimura, Kenjiro, 1949
Geochemical studies on the radioactive springs in Japan:
Pacific Sci. Assoc., 7th Congr., Proc., 2: 485-499
Geophys. Abs. 159-184:
Geochemical studies have been made of a number of strongly radioactive springs in Japan. The highest radon content, 12,000 Mache units [4.44 μCi/L], was recorded at a small spring at Masutomi; another in the same area maintains a radon content of 5,000 Mache units [1.85 μCi/L]. A spring in the Misasa region contains about 450 Mache units [0.17 μCi/L] of thoron. Springs containing unusually high amounts of polonium, thorium X, actinium X and other radioactive products have also been recorded in the mineral spring regions of Japan. The study of the equilibrium relationships of these radioactive elements indicates that the sources of radon are not too deep in the earth. Tables are given listing the most strongly radioactive springs of the world; depth of radon source estimated from equilibrium relationships; and the radium and thorium X content of 10 springs, the thoron content of 17 springs, and the radium A, B, C, F, and thorium B content of 10 springs.

Kimura, Shigehiko, and Takami Komae, 1980
Applications of environmental radon-222 to some cases of water circulation, *in* Gesell, T.F., and W.M. Lowder, eds., Natural Radiation Environment III:
U.S. Dept. Energy Pub. CONF-780422 (Vol. I), p. 581-599.

King, Chi-Yu, 1975
Radon emanation along an active fault [abs.]:
EOS, Am. Geophys. Union Trans., 56(12): p 1019; see also U.S. Geol. Survey Open-file Rept. 76-875: 4 p. (1976)

King, Chi-Yu, 1976

Anomalous radon emanation on San Andreas fault [abs.]:
Eos, Am. Geophys. Union Trans., 57(12): p. 957

King, Chi-Yu, 1976
Radon emanation on active faults:
U.S. Geol. Survey Open-file Rept. 76-875: 4 p.

King, C-Y, 1976
Radon emanation along an active fault [abs.]:
Eos, Am. Geophys. Union Trans., 57(12): p. 1019
Radon concentration in soil gas has been monitored at 18 sites along an active 60-km segment of the San Andreas fault in central California since May 1975 by a Track Etch method. This method uses a dielectric film that is sensitive to alpha radiation given off by radon. The measured radon emanation shows spatial and temporal variations which appear to correlate with local seismicity.

King, Chi-Yu, 1977
A possible mechanism for anomalously high radon emanation over buried uranium ore bodies [abs.]:
Geophysics, 42(7): p. 1515
Anomalously high radon emanation has often been observed near buried uranium mineralization. The detection of near-surface radon anomalies has been used successfully as a means to find uranium ore bodies that are buried as deep as a few hundred meters. However, the mechanism responsible for the observation is not well understood. In this paper, it is proposed that the observed spatial anomalies are due to the distortion of subsurface radon concentration profile by a small continuous upward flow of crustal gases, caused by the radiogenic gases and heat from the ore bodies.

King, Chi-Yu, 1977
Possible mechanisms for earthquake-related changes in radon emanation from soils [abs.]:
Geol. Soc. America, Cordilleran Sec., Ann. Mtg., 73d, Sacramento, Calif., April 5-7, 1977, Abstracts with programs: p. 447
Several research groups have reported temporal changes of radon emanation that appear to correlate with local earthquakes along active faults. This paper studies some possible mechanisms that might be responsible for such a correlation. One possible mechanism is a change in emanation efficiency of soils resulted from changed local stress conditions. Another is a change in local crustal outgassing rate induced by tectonic pore-pressure changes at greater depth. It can be shown that, for typical soils, the radon concentration profile in soil gas at shallow depths can be significantly perturbed by small changes in outgassing rate. For example, to increase the radon content of soil gas at a depth of 0.7 m by a factor of two requires an increase in outgassing transport velocity by only 3 μm/s.

King, Chi-Yu, 1977
Temporal variations in radon emanation along active faults [abs.]:
Eos, Am. Geophys. Union Trans., 58(6): p. 434
Radon emanation has been monitored at many sites (currently about 60) along several active fault traces in central California since May 1975 by a Track Etch method. In this method, a piece of dielectric film that is sensitive to alpha radiation is exposed to soil air in a shallow capped hole (0.7 m deep) for a period of a week or more. The alpha-particle track density in the film is then used as a measure of the amount of radon emanation during the period. The measured radon emanation shows large temporal variations that are coherent in space over large ranges (tens of km). These variations appear to correlate with regional seismic activities but do not correlate significantly with changes of weather and cosmic-ray conditions, except possibly an annual season effect. Several earthquakes of magnitude 4.0 to 4.6 have occurred in the monitored areas and they were all preceded by anomalous radon emanation at nearby stations for periods of several weeks in a characteristic pattern: a rapid rise to a peak or plateau which is significantly above the background level and

the earthquake occurs shortly after the peak. A possible tectonic cause for the observed preearthquake increase in emanation is increased regional crustal stresses which squeeze out crustal gases at an increased rate. An increased outgassing rate may perturb the radon concentration profile in the soil so that deeper soil gases with much higher radon content are brought up to the detection level. Possible use of the radon data for earthquake prediction is being studied.

King, Chi-Yu, 1978
Anomalous changes in radon emanation in ground water quality [abs.]:
Eos, Am. Geophys. Union Trans. 59(12): p 1196
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.

King, Chi-Yu, 1978
Radon emanation on San Andreas Fault:
Nature [London], 271(5645): 516-519

King, Chi-Yu, 1978
Radon emanation on the San Andreas fault:
Earthquake Information Bull., 10(4): 136-138

King, Chi-Yu, 1979
On radon emanation as a possible indicator of crustal deformation [abs.], *in* Internat. Symposium on Recent Crustal Movements, Palo Alto, Calif., July 25-30, 1977:
Tectonophysics, 52: 120
Radon emanation has been monitored in shallow capped holes by a Track-etch method along several active faults and in the vicinity of some volcanoes and underground nuclear explosions. The measured emanation shows large temporal variations that appear to be partly related to crustal strain changes. This paper proposes a model that may explain the observed tectonic variations in radon emanation and it explores the possibility of using radon emanation as an indicator of crustal deformation. In this model, the emanation variation is assumed to be due to the perturbation of the near-surface profile of radon concentration in the soil gas caused by a change in the vertical flow rate of the soil gas which, in turn, is caused by the crustal deformation. It is shwon that, for a typical soil, a small change in flow rate (3 μm/s) can effect a significant change (a factor of 2) in radon emanation detected at a fixed shallow depth (0.7 m). The radon concentration profile has been monitored at several depths at a selected site to test the model. The results appear to be in satisfactory agreement.

King, C.Y., 1979
Soil-gas radon-concentration data recorded at the time of the Coyote Lake earthquake of August 6, 1979 [abs.]:
Eos, Am. Geophys. Union Trans., 60(46): p. 891
Radon concentration of subsurface soil gas has been monitored since 1975 at an extensive network of stations deployed along several major faults in Central California. The recorded data are examined to see whether radon concentration showed any changes at or before the time of the magnitude 5.7 earthquake which occurred on August 6, 1979 on the Hayward-Calaveras fault near Coyote Lake. Preliminary results indicate that, while no significant changes were recorded at two stations which are closest to the earthquake epicenter, the radon concentration showed a broad-scale increase elsewhere on the Hayward-Calaveras fault between

San Jose and Hollister and along the Hayward fault and its northern extension between Santa Rosa and San Jose, during a period of several months before the earthquake. This episode of increased radon concentration is comparable in duration, amplitude and spatial extent to several earlier episodes, which was previously found to be correlated with local earthquakes of magnitude 4.0 to 4.3.

King, Chi-Yu, 1980
Episodic radon changes in subsurface soil gas along active faults and possible relation to earthquakes:
Jour. Geophys. Research, 85(B6): 3065-3078.
Subsurface soil gas along active faults in central California has been continuously monitored by the Track Etch method to test whether its radon-isotope content may show any premonitory changes useful for earthquake prediction. The monitoring network was installed in May 1975 and has been gradually expanded to consist of more than 60 stations along a 380-km section of the San Andreas fault system between Santa Rosa and Cholame. This network has recorded several episodes, each lasting several weeks to several months, during which the radon concentration increased by a factor of approximately 2 above average along some long, but limited, fault segments ($\approx$100 km). These episodes occurred in different seasons and do not appear to be systematically related to changes in meteorological conditions. However, they coincided reasonably well in time and space with larger local earthquakes above a threshold magnitude of about 4.0. These episodic radon changes may be caused by a changing outgassing rate in the fault zones in response to some episodic strain changes, which incidentally caused the earthquakes. (auth)

King, Chi-Yu, 1980
Radon emanation in tectonically active areas, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 175-181, disc, p. 182-183

King, Chi-Yu, 1985
Impulsive radon emanation on a creeping segment of the San Andreas fault, California:
Pure and Applied Geophysics, 122: 340-352

King, Chi-Yu, 1985
Radon monitoring for earthquake prediction in China:
Earthquake Prediction Research, 3: 47-68

King, Chi-Yu, 1986
Gas geochemistry applied to earthquake prediction: an overview:
Jour. Geophys. Research, 91(B12): 12,269-12,281

King, Chi-Yu, and Ta-liang Teng, 1976
Radon emanation monitoring in Palmdale bulge area [abs.]:
Eos, Am. Geophys. Union Trans., 57(12): p. 899
Radon emanation has been monitored by a Track Etch method at 20 sites in the Palmdale bulge area since March 1976. Seventeen of the stations are located in fault valleys along the "locked" segment of the San Andreas fault from Cuddy Valley (near Gorman) to San Bernardino at spacings of approximately 10 km. The remaining three stations are respectively located on the Big Pine and the Garlock faults 4 km from Gorman, and on the San Gabriel fault at Switzer Camp, south of Palmdale. Several stations occupy locations where ground water is sampled by the University of Southern California for radon content studies. The radon data are studied comparatively toguther with seismic and weather data in search for possible pre-earthquake anomalies. The radon emanation observed so far is comparable with that observed in central California, where no crustal uplift has been reported.

Kinoshita, S., 1908

Condensation of the actinium and thorium emanations:
Philos. Mag. 16(91): 121-131
Actinon and thoron condensation takes place starting at -120°C and completed at -150°C. [However, the vapor pressure is significant at -196°C (ABT).]

Kirchmann, R., M. Darcheville, and G. Koch, 1980
Accumulation of radium-226 from phosphate fertilizers in cultivated soils and transfer to crops, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1667-1672.

Kirikov, A.P., T.N. Bogoslovskaya, and G.V. Gorshkov, 1932
Emaniruyushchaya sposobnost' rud i gornykh porod Tabosharskogo urano-radiyevogo mestorozhdeniya [Emanation capacity of ores and rocks of the Taboshar uranium-radium deposit]:
Vses. Geol.-Razved. Ob"yedineniye Izv., 51(84): 1293-1299
See Geophys. Abs. 62-1961
Auth. Summary:
"...rock and ore samples from the Taboshar deposit were taken and their emanation capacity determined...both in air and water. The samples were placed into hermetically closed glass vessels and the quantity of emanation given off--defined by the circulation method. It was proved that the emanation capacity of ores of the torbernite type approximates 3% in air and is about 4% when emanation is given off into water. Ores enriched along cracks by fine grained-crusts of yellow uranium phosphates approximating, as to their composition, autunite, revealed an emanation capacity of about 15% in air and about 18% in water, as a medium....The emanation capacity of the samples does not depend on the grade of secondary alteration of the samples saturated with some uranium compounds, or others, but on the other hand the emanation capacity proved to be highly dependent on the grade of crumbling of the samples, rising several times if they are reduced to powder...."

Kirikov, A.P., P.N. Tverskoy, and A.G. Grammakov, 1932
K voprosu ob emanatsionnom metode poiskov radioaktivnykh ob"yektov [On the question of the emanation method of searching for radioactive objects]:
Vses. Geol.-Razved. Ob"yedineniye Izv., 51(84): 1269-1282
See Geophys. Abs. 62-1959.
Auth. Summary:
"...This study concerned: the regime of the radio-active emanation in the soil air, its distribution in a horizontal layer at some depth below the surface, and along the vertical, in connection with the possibility of obtaining an areal emanation-survey. This exploration was realized by the method of photographic registration and systematic determination of the radio-activity of the soil air at different depths. The obtained results were compared with those of gamma survey and alpha measurements; they showed that under conditions of constant meteorological factors such a survey is wholly possible and may serve the aims of searching for radioactive objects."

Kirikov, A.P., P.N. Tverskoy, A.G. Grammakov, G.V. Gorshkov, and B.S. Aydarkin, 1934
Radioaktivniye Geofizicheskiye Metody v Primeneniy k Geologii [Radioactive Geophysical Methods in Application to Geology]:
ONTI, Gosgeonefteizdatel'stvo

Kirkham, Don and W. L. Powers, 1972
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Wiley-Interscience: 534 p.
[Ch. 9, Gaseous diffusion in soils, p. 428-461]

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Variation in the radon-concentration field in the atmosphere in the presence of sectors with nonhomogeneous exhalation values, *in* Radioaktivnye Izotopy v Atmosfere i Ikh Ispol'zovanie v Meteorologii:
Moscow, Atomizdat; 57-72
Equations are derived for the two-dimensional and three-dimensional determination from localized sources of the field of Rn concentration, taking into account horizontal wind transfer and vertical turbulent diffusion. An analysis is made of experimental data taken from the literature for the vertical wind profile and the profile of the coefficient of vertical turbulent diffusion in the boundary layer and surface boundary layer of the atmosphere.

Klemic, Harry, 1962
Uranium occurrences in sedimentary rocks of Pennsylvania:
U.S. Geol. Survey Bull. 1107-D, p. 243-288

Kline, S.W., and D.G. Mose, 1989
Causes of elevated indoor radon during winter seasons [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 500
Indoor radon values have been shown to depend on the season of measurement, with winter values generally being highest. Long-term alpha-track basement measurements from 347 metropolitan Washington, DC homes during the winter of 1986/87 and 655 homes during the winter of 1987/88 indicate that radon levels can also vary from winter to winter. The colder 1986/87 winter produced significantly higher median indoor radon in surveyed homes. Most models for explaining seasonal variations deal principally with air exchange between buildings and the out-of-doors. Homes are thought to have more radon in the winter because they are more often closed to conserve heat. Also, soil-to-building flow rates are increased by heated indoor air escaping from the upper part of homes and creating a pressure difference between the building and its substrate. Preliminary data from alpha-track soil radon monitors, indoor radon monitors, and surface gamma-ray spectrometry indicate that indoor radon values in winter are also influenced by intervals of elevated soil-gas radon in the subsurface. Freezing of the upper layer of soil creates a capping effect that reduces the escape of soil-gas radon to the atmosphere, so soil radon concentrations build up to higher-than-normal levels. Thus, periods of frozen ground cause higher concentrations of indoor radon. Since actual radon concentrations in soil gas are apparently higher during such periods, attempts to simulate winter conditions during other seasons through closed-home procedures will probably be less successful in northern latitudes.

Kline, Stephen W., Douglas G. Mose, and Isidore Zietz, 1988
Use of aeroradioactivity maps in indoor radon prediction: A case study from Fairfax County, Virginia and Montgomery County, Maryland [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A337-A338
An indoor radon survey in northern Virginia and southern Maryland in 1987-1988 has accumulated ≈5000 alpha-track (3-month exposure interval) radon measurements. The study area, which contains a diversity of sedimentary, igneous, and metamorphic rocks, is being used to evaluate measurement methods, remediation methods, and methods for radon prediction for communities. Good bedrock, soil, and aeroradioactivity maps are available for the study area. A land-based spectral gamma-ray survey of a number of sites in Fairfax County indicates that there is a general increase in calculated equivalent uranium with increasing total counts of gamma radiation. Analyses for uranium in some soil and rock materials of Fairfax County by neutron activation are in agreement with trends in total count aeroradioactivity averaged over various geologic units. These data indicate that there should be a relationship between total-count aeroradioactivity and soil radon, and hence indoor radon, in this area. Comparison of home locations and their indoor radon values with aeroradioactivity maps of Fairfax and Montgomery Counties shows that total-count aeroradioactivity is a very good discriminator of areas of high potential indoor radon. The results were even better than potential maps based on geology and soil characteristics. Subtle differences in the relationship between the percentage of homes over 4 pCi/L and the aeroradioactivity signal are present between different rock types. The differences

are likely a consequence of using total gamma-ray aeroradioactivity (includes signal components of K as well as daughters of U and Th decay) and to differences in the geology of the surface material. A spectral aeroradiometric survey is expected to produce the best results in regional indoor radon prediction.

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Chem. Abs. 101:99833n

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Geophys. Abs. 178-281:
[Velocity of ground-water flow in the Nybro esker southwest of Kalma, Sweden appears to be 0.1 m/day.]

Kobal, I., J. Kristan, and M. Skofljanec, 1978
Radioactivity of spring and surface waters in the region of the uranium ore deposit at Zirovskivrh:
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Outdoor and indoor radon concentrations in air in the territory of Slovenia, Yugoslavia, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
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New York, Interscience Publs., ch. 30: 816-831
Geophys. Abs. 208-2
The theory underlying the three basic types of age determination in sediments (three natural radioactive series, natural radioactive elements, and cosmic-ray-produced radionuclides), the geochemical considerations involved in the transportation and deposition of the radioactive elements, and practical methods of age determination are discussed. The rate of sedimentation is estimated by dating of the sediment layers; this is discussed briefly.

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New York, Reinhold Pub. Corp. and Washington, Am. Inst. Biol. Sci.: 611-613
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The geochemical behavior of thorium, uranium, and radium in the hydrosphere and the influence of the biosphere on the geochemistry of these elements are reviewed. It is pointed out that existing data are not complete enough to draw definite conclusions.

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Jour. Marine Research, 17: 302-311
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Zur Geochemie des Urans im Östseebecken [On the geochemistry of uranium in the Baltic Sea basin]:
Geochim. et Cosmochim. Acta., 11(1/2): 86-102
Geophys. Abs. 168-262:
The uranium content has been determined for samples of water from 15 rivers flowing into, and 9 places in the Baltic Sea and Skagerrak, and for 3 bottom sediments, and the radium content for samples from 2 rivers and 5 places in the Baltic. The uranium content of river water from regions of igneous rocks is low, averaging 0.5 μg/L, higher for sedimentary rock regions (maximum 12.8 μg/L), indicating that uranium is more easily leached from sediments. The radium content of river water is not in equilibrium with the uranium content; the uranium must be more soluble. The uranium content of the Baltic Sea is variable, ranging from 0.77 to 4.5 μg per l. Correlation with salinity is marked except in the southeastern part and in deep water. Surface water increases in uranium are explained by high content of inflowing river waters, deep water increases by oxygen deficiency. The latter also accounts for the high content of sea bottom sediment (3.2 to 10.3 μg/L); uranium VI is reduced to uranium IV, forming insoluble compounds which settle to the bottom. Detailed study of the distribution of uranium in sediments, supplemented by radiocarbon age determinations, may throw light on past changes in the state of ventilation of the deep basins of the Baltic Sea. The considerable precipitation of uranium on the Baltic Sea shelf indicated by these studies seems to be caused by biologic activity which in turn causes oxygen deficiency.

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Concerning the solubility of rare gases in sea water:
Zeitschrift Naturforschung, 18a: 363-367
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The solubilities of the inert gases were measured in pure water and in sea water within the temperature range from 0 to 25°C. Comparison of the values in pure water and of the solubilities of argon in sea water with data obtained by other authors suggest that the measurements are reliable within the quoted limits of error. The behavior of the inert gases is expressed in a series of regularities which are also graphically shown.

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Mächtigkeitsbestimmung von Deckschichten über Spalten durch Radioaktivitätsmessungen [Depth estimation of overburden above faults by means of radioactive measurements]:
Zeitschrift Geophysik, 4(2): 76-83
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[Calculation of gas diffusion in vein from linear source.]

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Bestimmung des Absorptionskoeffizienten von Radiumemanation in Lösungen und Gemischen [Determination of the absorption coefficient of radium emanation in solutions and mixtures]:
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Löslichkeit der Ra-emanation in wässerigen Salzlösungen [Solubility of radium emanation in aqueous salt solutions]:
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Israel Program for Scientific Translations, Jerusalem, 1971: 337 p.
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Sur le dégagement de l'émanation par le sels de radium à diverses températures [On the release of emanation by radium salts at various temperatures]:
Acad. Sci. [Paris] Comptes Rendus, 145(8): 425-428
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[Emanation of radon from $BaCl_2$ + $RaCl_2$ at fusion temp (830°C.). Ref. Rutherford 1908]

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New observations on the evolution of emanation by radium salts [in French?]:
Le Radium, 6: 321-327

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Production of emanation by radium salts [in French?]:
Le Radium, 7: 266-269.
Chem. Abs. 5(14): p. 2365

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O vydeleniy emanatsiy iz tverdykh ili rasplavlennykh soley, soderzhashchikh radiy [On the liberation of emanation from solids or molten salts containing radium]:
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Przeglad Geofizyczny, v. 9, 17(1): 3-24

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Wykrywanie i konturowanie złoz ropynaftowej i gazu ziemnego metoda wzglednych aktywnosci promieniowania gamma [Detection and contouring of oil and gas deposits by means of the relative effectiveness of gamma radiation]:
Przeglad Geol., 10(12): 661-663
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Results are reported of the use of ground gamma radiation surveys to outline oil pools. A profile across the Rybaki oilfield is given as an example. A photograph shows an excavation being made with a post-hole digger where a reading is to be made.

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Zastosowanie radiometrii powierzchniowej w Polskim przemyslenaftowym [Application of surface radiometry in the Polish oil industry (with English and Russian summaries):
Przeglad Geol., 9(10): 527-530
Geophys. Abs. 198-294:
Ground radioactivity surveys of oil and gas were used in Poland first in 1957. In the period 1957-60 studies were made in known fields of the Carpathians, in the Polish Lowland, and in the Carpathian Foreland. Results were not satisfactory due to differences in surface lithology. The "relative activity" method was developed in 1960; this procedure eliminates surficial effects. The method has had some success in locating oil and gas pools and in finding faults.

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Akad. Nauk SSSR Komiss. opredel. absolyut. vozrasta geol. formatsiy Byull., vypusk 1, p. 22-28
Geophys. Abs. 166-12:
The process of radioemanation from minerals consists of liberation of atoms by radioactive disintegration and diffusion of these atoms through microscopic capillaries in the body of the mineral. The latter factor affects the determination of geologic age. The radioemanations of 57 minerals were investigated by different methods. The results show that the coefficients of emanation of actinon and radon are very nearly equal in most minerals, whereas the coefficients of emanation of thoron and radon are clearly different. This shows

that atoms of thorium and uranium occupy in the lattices of minerals different positions with reference to the system of microcapillaries in minerals. With an increase of temperature the coefficients of emanation increase. After cooling they decrease sharply, probably owing to dislocations of the crystalline lattice. In the opinion of the authors, the Wickman method of computing the coefficient of emanation from the ratios of the lead isotopes is probably erroneous.

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Translation of theses by S.T. Vesselowsky:
1. Bunsen's law is satisfied only in exceptional cases. 2. The velocity of the diffusion of a gas, under given conditions, is independent of whether another gas diffuses in the opposite direction or not. 3. When a gas is moving through a porous body, as a general rule, a jump in the pressure is observed on the boundary surfaces of both the inlet and the outlet ends. 4. The outlet pressure drop for a given surface is always greater than the inlet jump which is observed when the direction of gas flow is reversed, other conditions being equal. 5. In some investigated bodies a negative pressure jump was observed at the inlet surface. 6. The resistance of the porous body changes with the intensity of the gas stream. 7. The variation of the intensity of the gas stream through a porous body is not a linear function of the difference of the pressures acting on the boundary surfaces. 8. When a gas is flowing through a system of two porous bodies which are in good contact with each other, a pressure jump is observed at the contact surface. 9. The pressure jump at the contact is substantially different in the case of a reversed direction of the gas flow. For the same direction of the flow the pressure jump at the contact varies with the changing intensity of the gas flow, but this variation is not linear.

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Report 1974, INIS_mf-3087: 60 p.
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Attachment can be described in terms of 1 or 2 theories, viz. the diffusion theory or the kinetic theory. The diffusion theory is based on the transport of radioactive atoms by means of the process of diffusion. An attachment proportional to the radius R of the aerosol particles for the size range used in these expts., is predicted by this theory. The kinetic theory is based on intermol. collisions as described by the kinetic theory of gases. This theory predicts an attachment that is proportional to R^2. Both these relations have been established by other researchers. However, the author believes that they have not taken several important parameters into consideration in their expts., several such parameters were also not properly controlled in their expts. In the present investigation, the attachment flux for the attachment of 212-Pb [15092-94-1], atoms (of an approx.concn. of 4E3 atoms/cm^3 to monodisperse polystrene (9003-53-6] aerosols (of a radius from 0.5 to 2.5 μm) in the concn. range 1-30 particles /cm^2, was directly measured. Steps were taken to prevent the formation of radiolytic nuclei, and all the relevant parameters were measured during the expts. The attachment between the radioactive atoms and the aerosols was directly proportional to the particle concn. N, as well as to R^2. The sticking probability of atoms to a particle was of the order of 0.1. The results show that the attachment was found; this was attributed to the attachment of radioactive atoms to agglomerate vapor mols.

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Am. Jour. Sci., 252(6): 345-365
Geophys. Abs. 157-133:
The available results on the age of radioactive minerals as determined by the various isotopic ratios Pb-206/U-238, Pb-207/U-235, Pb-207/ Pb-206, Pb-206/Pb-210, and Pb-208/Th-232 are summarized. The probable sources of error are radon leakage, leaching and alteration, uncertainty in the isotopic composition of any common lead, chemical analysis, and instrumental techniques. With sufficient isotopic analyses on the common lead of an area, it is usually possible to make a precise correction for the common lead contribution to the isotopic composition of a radioactive mineral. Radon leakage can be measured under laboratory conditions and extrapolated to the integrated thermal history of the mineral. Chemical and instrumental errors are generally of second-order importance. The occurrence of leaching and alteration can be estimated from the comparison of the lead-lead with the lead-uranium ages. In the most ideal conditions, the uncertainty of the half-life of U-235 may be significant error. It is concluded that the 207/235 and 206/210 ages are the most reliable over the greater range of geologic time. The 206/238 age is generally correct to 5-10 percent and supersedes the 207/235 age in for young minerals. The Pb-208/Th-232 age is considered usable for minerals high in thorium content. The 207/206 age is the least reliable of all.

Kulp, J.L., G.L. Bates, and W.S. Broecker, 1954
Present status of the lead method of age determination:
Am. Jour. Sci., 252: 345-365
Nucl. Sci. Abs. 16:29190:
Nomographs are presented which simplify the calculation of the age of a mineral from the isotopic ratio.

Kunz, C., C.A. Laymon, and C. Parker, 1989
Empirical relationship between soil parameters and indoor radon [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 497

Soil measurements were compared with indoor radon concentrations for several areas in New York State and based on these results the following empirical relationship was developed:

(Indoor radon) $\propto$ (source strength)(depth factor)(permeability)$^{1/2}$

To characterize surficial soil and bedrock regarding the amount of radon likely to enter homes it is necessary to have a measure of the concentration of radon in the soil gas entering the homes (source strength) and a measure of the amount of soil gas that can flow into the homes (permeability). The source strength can be either the soil-gas radon concentration, the total soil radium concentration, or the emanating fraction of radium. The depth factor is the depth of soil to the water table, bedrock, or other low-permeability feature. The distribution of indoor radon concentrations within areas of similar soil types had geometric standard deviations ranging from about 1.5 to 3.0. This limits the ability to predict the indoor level for a particular house. However, it appears that useful estimates of mean indoor concentrations can be made based on soil and bedrock parameters.

Kunz, C., C.A. Laymon, and C. Parker, 1989
Gravelly soils and indoor radon, *in* M.C. Osborne, and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 1, Symposium Oral Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006a [Springfield, Va., NTIS Order No. PB89-167480], p. 5-75--5-86.
Many homes in New York State with above-average concentrations of indoor radon are built on deep, well-drained, gravelly soils. Gravelly soils were studied in three areas where the geometric mean for basement radon-222 concentration ranges from 10 to 20 pCi/L, and at 12 additional State-wide homes with basement radon-222 concentrations greater than 20 pCi/L. The gravelly soils examined in this study contain average to slightly above average concentrations of soil radium-226 (approx. 1.0 pCi/g) and the concentration of soil-gas radon-222 is within the range of average values for soils (approx. 700 pCi/L at 120 cm). The permeability of these soils is high with a geometric mean of approximately 6E-6 cm^2 at a depth of 120 cm. Tests conducted in one study area showed increases in permeability between depths of 30 and 120 cm. The product of a source term (soil radium-226 concentration, emanating radium-226, or soil-gas radon-222 concentration) and the square root of the permeability yields a Radon Index Number (RIN) which is used to predict mean indoor radon-222 concentrations. The RIN which is based on soil parameters agrees well with measured indoor radon-222 concentrations. [This RIN is different from that introduced by Eaton and Scott (1984).]

Kurata, Takayoshi, and Shizuo Tsunogai, 1986
Exhalation rates of ^{222}Rn and deposition rates of ^{210}Pb at the earth's surface estimated from ^{226}Ra and ^{210}Pb profiles in soils:
Geochemical Jour., 20: 81-90

Kurbatov, J.D., 1934
High concentrations of radium and mesothorium I in nature and regularity of their migration:
Jour. Phys. Chemistry, 38(4): 521-532
Geophys. Abs. 67-2180
[Ra and MsTh I in natural waters, determination methods, (non-)effect of sulfate ions, migration of Ra and MsTh I, coprecipitation of Ra and MsTh I with Mn and Fe hydroxides.]

Kurbatov, J.D., 1941
Evaluation of the surface area of catalysts of cubic form by the emanation method:
Jour. Phys. Chem., 48: 851-866
Correct application of the emanation method for evaluating surface area requires the incorporation of radium and thorium X simultaneously in order to determine, from the measurable radon and thoron, that part of the emanation which escape by diffusion and that which escapes from recoil. Assuming as a simple case that the solid consists of separate and perfect cubes, the surface area of the material can be evaluated if the range of

recoil and the percent of recoiled emanation are known. For accurate evaluation of the area, the first factor to be considered is that the parts of the cube—face volumes, edge volumes, and corner volumes—as defined by the value of the range of recoil, R, and the edge of the cube, L, possess different emanating abilities. The signifance of the edge volumes and corner volumes increases as the ratio L/R diminishes. Consequently, the expression 3R/2L, which is used in the literature for the calculation of areas from data on emanating power, has a limited range of applicability. In case one is dealing with well-developed surfaces, such as those of catalysts, the proper expression is $E_mP_R=(3/2)(R/L) - 2/\pi(R/L)^2 + [1/(4\pi)](R/L)^3$. As shown, the upper limit of applicability of this expression is R/L=1/2, which corresponds to 60 percent emanation power. Moreover, any evaluation of surface areas from emanation powers of high value is not reliable, because other physical factors become significant, e.g., the presence of a large number of radium and thorium X atoms with reference to the absolute number of molecules in the individual cubes or the destructive effect of the energy of recoiled emanation upon the cubic unit. It was shown in the examples used that in case the range of recoil is 372 Å, the surface area varies from 0.018 to 9.06 m^2/g when R/L varies from 1000 to 2. Actually, catalysts are composed neither of perfect nor of separate crystals, as is assumed for the derivation of the equation. Crystals are intergrown and form groupings. Consequently, the emanating power and the total surface are less than in the ideal case assumed. Then the accuracy of the method depends upon, among other factors, the extent of this variation, which has been found in a specific case of intergrown crystals to be -6.6 percent.

Kurbatov, L.M., 1940
O radioaktivnosti zhelezo-margantsevykh porod i opredeleniye skorosti ikh obrazovaniya radioaktivnym metodom [On the radioactivity of ferro-manganese rocks and the determination of the speed of their formation by the radioactive method], *in* Internat. Geol. Congress, 17th, Moscow, 1937:
Internat. Geol. Congr. Repts., v. 4, p. 513-522

Kuroda, P.K., P.E. Damon, and H.I. Hyde, 1954
Radioactivity of the spring waters of Hot Springs National Park and vicinity in Arkansas:
Am. Jour. Sci., 252(2): 76-86
Geophys. Abs. 156-137:
The radon content of the waters of Hot Springs National Park has been redetermined, using an I-M type fontactoscope. Thoron was detected in these waters for the first time with the aid of a scintillation tube. The radon content of the hot waters is extremely variable (0.1 to 30 nCi/L; average, 0.8), possibly because each spring has its own radium-bearing tufa as source of radon. The radon content of the cold waters is also extremely variable (0.1 to 7.3 nCi/L) and averages about the same as the hot springs. Radon in spring waters issuing directly from the border of the uranium-vanadium-niobium prospect at Potash Sulphur Springs averages about 15 nCi/L and the radon content is more uniform (6 to 40 nCi/L. Besides having purely scientific interest, such information can be applied to the search for fissionable materials.

Kuroda, P.K., and Y. Yokoyama, 1948
Radioactivity of rain water:
Jour. Chem. Soc. Japan, 69: 791

Kusnetz, H.L., 1964
Measurement of radon and radon-daughter products in mines, *in* Radiological Health and Safety in Mining and Milling of Nuclear Materials, Vol. II:
Vienna, Internat. Atomic Energy Agency: 37-48
Nucl. Sci. Abs. 20268:
Continuing activity in the U and Th mining and milling industry has resulted in the exposure of large numbers of workers to the radioactive elements. Of these products, those most likely to enter the body by inhalation are radon (^{222}Rn) and its daughters, and thoron (^{220}Rn) and its daughters. Accurate measurement of these products is necessary for determining the extent of the workers' exposures. Implementation of control methods, particularly by ventilation, and the evaluation of the efficacy of these controls is dependent on the

ability to measure concentrations of radon, thoron and their daughters. Measurements are complicated by the fact that the contaminants may exist as the parent gas, as the unattached daughter atoms, or as daughter-bearing dust particles in the mine atmosphere. Further, measurement of concentrations underground is difficult because of the probability of instrument contamination. Instrumentation must be rugged enough to withstand field usage, and must be simple enough to be handled and maintained at locations remote from the laboratory. The relatively short half lives of certain of the isotopes preclude any time-consuming sampling and analyzing procedures. Deviations from equilibrium between the parent gas and its respective daughters lead to complexities in interpretation of the measured data. The unavailability of uncontaminated air in the mine increases the problem of measurement and control. Recommended techniques are reviewed for field measurements of these contaminants. For radon, the scintillation effect in a phosphor may be utilized. Thoron may be measured directly by drawing the air stream through an ionization chamber. Concentrations of both of these gases may be estimated by measuring their respective daughter product concentrations. A technique for distinguishing ^{220}Rn daughters from the ^{222}Rn daughters is descibed. A theoretical description for estimating ventilation requirements in mines based on these measurements of daughter concentrations is presented.

Kvasnicka, J., 1980
Radon concentration in the soil air measured by track detectors:
Nuclear Instruments and Methods, 174: 599-604.

Kvasnicka, Jiri, 1986
Radiation data input for the design of dry or semi-dry U tailings disposal:
Health Physics, 51(3):329-336

Labeyrie, Jacques, 1953
Mesure de la concentration des aerosols radioactifs émetteurs α:
Commissariat à l'Énergie Atomique, CEA-335, June 15, 1953: 120 p. [Thesis, Univ. Paris]
Nucl. Sci. Abs. 9:7036:
Techniques used for the quantitative measurement of the concentrations of aerosols carrying short lived (radon or thoron daughters) or long-lived (uranium) alpha radioactive emitters are described. The problem of the determination of radon concentration in air by means of activity determinations on airborne dusts was investigated. Special reference is made to the measurement of the radon active deposit on two types of dust (iron oxide (yellow) and uranium oxide) in small chambers (6 L). Data resulting from determination of radon and thoron concentrations in atmospheric air in the south Paris area using this method are given.

Lahee, F.H., 1955
Program of radioactivity surveys in petroleum exploration:
Nuclear Engineering and Science Congr., Cleveland, preprints, no. 279

Lambert, G[érard], and P[ierre] Bristeau, 1973
Migration des atomes de radon implantés dans les cristaux par énergie de recul [Migration of radon atoms implanted in crystals by recoil energy]:
Jour. de Physique, Colloque C5, suppl. to 34(11-12): 137-138

Lambert, Gérard, Pierre Bristeau, and Georges Polian, 1972
Mise en évidence de la faiblesse des migrations du radon à l'intérieur des grains de roche [Evidence of little radon migration within rock grains]:
Acad. Sci. [Paris] Comptes Rendus, ser. D1972, 274(25): 3333-3336

Lambert, G., P. Bristeau, and G. Polian, 1976
Emission and enrichments of radon daughters from Etna volcano magma:

Geophys. Research Letters, 3(12): 724-726

Lambert, G., T. Grjebine, P. Bristeau, and J.C. Le Roulley, 1973
Excess of polonium 210 at the surface of Apollo 15 fines, *in* Lunar Science Conf, 4th, Houston, March 5-8, 1973, proc. v. 2:
Geochim. Cosmochim. Acta, Suppl. 4, 2: 2183-2188

Lambert, Gérard, Tovy Grjebine, Jean Claude Le Roulley, and Pierre Bristeau, 1972
Alpha spectrometry of a surface exposed lunar rock, *in* Lunar Science Conf., 3d, Houston, Jan. 10-13, 1972, v. 2, Chemical and Isotope Analyses, Organic Chemistry:
Geochim. Cosmochim. Acta, Suppl. 3, 2: 1771-1777

Lambert, G[érard], J.C. Le Roulley, and P[ierre] Bristeau, 1975
Evidence of gaseous radon-222 between fines grains within lunar regolith, *in* Lunar Science Conf., 6th, 1975, proc.:
Geochim. Cosmochim. Acta Suppl. 6, 2: 1803-1809
Chem. Abs. 85:111091e

Lambert, G., J.C. Le Roulley, and P. Bristeau, 1977
Accumulation and circulation of gaseous radon between lunar fines:
Royal Soc. [London] Philos. Trans. ser. A, 285: 331-336

Lambert, Gérard, Pierre Bristeau, and J.C. LeRoulley, 1975
Accumulation and circulation of gaseous radon between lunar fines:
Report 1975, CEA-CONF-3313: 14 p.
INIS Atomindex 1976, 7(12), Abs. No. 245548
Chem. Abs. 85:163900n

Lambert, G. and G. Polian, 1963
On the diffusion at low altitude of continental and oceanic air masses in each hemisphere [in French]:
Acad. Sci. [Paris] Comptes Rendus, 256(20): 4265-4268
Phys. Abs. 21034, 1963
[Measurements at 5 oceanic points give Rn in atmosphere a threefold greater concentration in N vs. S hemispheres—about same as difference in land mass. Thought to be due to equatorial barrier.]

Landa, Edward R., 1983
Leaching of radionuclides from uranium ore and mill tailings:
Uranium, 1: 53-64

Landa, Edward R., 1983
Radon concentrations in the indoor air of earth sheltered buildings in Colorado, in Boyer, L.L., ed., Energy Efficient Buildings with Earth Shelter Protection, Internat. Earth Sheltered Buildings Conf., 1st, Sydney, Australia, August 1-6, 1983, Proc., p. 275-279:
Oklahoma City, Okla., Oklahoma State Univ., Architect. Extension and Univ. Center for Energy Research
Radon concentrations in the indoor air of six residential and three non-residential buildings in eastern Colorado were monitored quarterly using passive, integrating detectors. Average radon concentrations during the 3-month sampling periods generally ranged from about 1 to 9 pCi/L, although one building, a poorly ventilated storage bunker, had concentrations as high as 39 pCi/L. These radon concentrations are somewhat greater than typically reported for energy-efficient, non-earth sheltered buildings. Radium contents and radon emanation coefficients of soils at the building sites, and radon concentrations in water supplies are discussed.

Landa, Edward R., 1987
Radium-226 contents and Rn emanation coefficients of particle-size fractions of alkaline, acid and mixed U mill tailings:
Health Physics, 52(3): 303-310

Landa, Edward R., 1987
Influence of ore type and milling process on ^{222}Rn emanation coefficients of U mill tailings:
Health Physics, 53(6): 679-683

Landa, Edward R., Christine L. Miller, and David M. Updegraff, 1986
Leaching of Ra-226 from U mill tailings by sulfate-reducing bacteria:
Health Physics, 51(4): 509-518
Relatively insoluble sulfate precipitates appear to be a major host for Ra in sulfuric acid-treated U mill tailings. The dissolution of such precipitates by natural processes, such as metabolism by sulfate-reducing bacteria (SRB), creates the potential for release of Ra to contacting waters. Significant leaching of Ra by SRB was achieved in the laboratory during the anaerobic incubation (1 to 119 days) of U mill tailings with pure cultures of Desulfovibrio desulfuricans and mixed cultures containing SRB isolated from the tailings, all grown in a lactate medium at room temperature. While the maximum Ra-226 concentration reached in a sterile media control was 0.44 Bq/L (12 pCi/L), that in the SRB systems was 61 Bq/L (1640 pCi/L) or about 20% of the total inventory in the original tailings sample. The leaching of Ra in SRB systems was accompanied by a decrease in soluble sulfate concentration, an increase in total sulfide concentration, and an increase in the number of SRB. The observed leaching effect does not appear to be due to the action of microbial chelates of to binding to cell walls.

Landa, Edward R., 1982
Leaching of radionuclides from uranium ore and mill tailings:
Uranium, 1(1): 53-64

Lane, A.C., and W.R. Bennett, 1934
From "Science News", Science, 79 (2040): 34-36
Paper read at Boston Meeting of American Assoc. for the Adv. of Science, Dec. 27, 1933-Jan. 2, 1934
[Location of fracture zones by radioactivity of well water. Radioactive water, captured by geologists in wells dug by farmers in Michigan, disclosed the existence of a fault or crack in the earth's deep rocks, although it was masked by a thick overlying layer of earth, according to Prof. Alfred C. Lane and Dr. W.R. Bennett of Tufts College. Water samples, collected and rushed to Purdue University for analysis, showed varying degrees of radio-activity--the closer to the fault the wells, the more active the waters. This was because radioactive substances from deeper within the earth's crust were rising through the crack and charging the water....]

Lane, Alfred C., and W.R. Bennett, 1934
Location of a fault by radioactivity [in English]:
Beitr. angewandten Geophysik, 4(1): 353-357
It is stated by Ambronn that there should be a notable increase of radioactivity in the neighborhood of a fault. The greater radioactivity of waters near a fault near Howell, Michigan, U.S.A. was used to discriminate the fault from a sharp anticlinal. The waters came from shallow wells driven through glacial deposits into sandstone.

Langford, Gerald T., 1962
Radiation surveys aid oil search:
World Oil, 154(5): 114-119
Geophys. Abs. 190-507

In areas of subsurface petroleum accumulation, there is also an increase in the methane content, some of which migrates vertically to the surface. The methane molecules act as carriers of radioactive decay products. When these molecules rise above the water table, they dry out and break down, emitting low-energy gamma rays and Bi-214. These soft rays are the only radiation directly associated with petroleum pools. The sensitivity of the instrument used to detect this characteristic radiation is increased greatly by using two 7-inch thallium-activated NaI crystals. A cosmic ray burst creates a sudden surge of current, such bursts are removed by inserting a gate circuit in the instrument to absorb these surges. The background of hard radiation is reduced by a gate circuit which "clips off" the top two-thirds of the pulse count of the hard rays. As an oil pool is approached, the soft rays increase in number while the hard rays remain constant. [See papers by F.A. Alekseyev and others for a more plausible explanation for the radioactivity pattern noted by Hans Lundberg.]

Langmuir, Donald, and Daniel Melchior, 1985
The geochemistry of Ca, Sr, Ba and Ra sulfates in some deep brines from the Palo Duro Basin, Texas:
Geochim. Cosmochim. Acta, 49(11): 2423-2432

Lapape, A., and W. Geslin, 1954
Radioactivity of some waters with source in the Cauterets and Luz-Saint Savious (High Pyrenees) [in French?]:
Ann. Inst. Hydrol. et Climatol., 25: 27-33

Larson, R.E., R.A. Lamontagne, F.K. Lepple, J.W. Swinnerton, and P.E. Wilkniss, 1975
Atmospheric radon-222, CH_4 and CO over the Pacific Ocean [abs.]:
Eos, Amer. Geophys. Union Trans., 56(12): p 998
[Rn concentrations were less than 1 pCi/m^3 except near land.]

Lassen, Lars, 1961
The attachment of decay products of natural emanations on electrically charged aerosols (suspended matter) [in German]:
Zeitschrift Physik, 163: 363-376
Nucl. Sci. Abs. 15:29529
....Applying this equation to the deposition of natural radioactivity on atmospheric aerosols and assuming that particle size-distribution can be roughly approximated by $N(R) = const.\ R^{-3}$ in the range 10^{-6} cm $< R < 10^{-3}$ cm calculation shows that 90 to 95% of the total natural radioactivity should be attached to particles smaller than $R = 0.05\ \mu m$. It is concluded that the distribution of natural radioactivity on the different particle sizes in atmospheric and artificial aerosols is fundamentally dependent on the diffusion process, including ionic diffusion.

Laubenbakh, A.I., and L.N. Skosyreva, 1958
Ispol'zovaniye vozdushnoy radiometricheskoy s"yemki dlya izucheniya neftyanykh i gazovykh mestorozhdeniy [Use of airborne radiometric survey for study of oil and gas fields]:
Geologiya Nefti, (2): 27-33
Geophys. Abs. 181-429

Lautenschlager, L., 1912
Physikal. Zeitschrift, 13
[Ref. U.S. Bureau of Mines Circ. 6072: Sources of helium in natural gas.]

Lauterbach, Robert, 1953
Zur Frage tektonischer Untersuchungen mit Hilfe emanometrischer Messungen [On the question of structural investigations by means of emanometric measurements]:
Karl Marx Univ. Leipzig wiss., Zeitschrift math.-naturwiss. Reihe, Jahrg. 3, Heft 3: 291-292
Geophys. Abs. 160-167

Microradiological soil-gas surveys, analogous to Lauterbach's micromagnetic technique (see Geophys. Abs. 160-45) can be used to obtain structural information such as the trend of a vein or fault. As the radioactive anomalies are often of the order of only a few meters in size, a network of stations 2 or 3 meters apart, in selected test areas, is desirable. Graphs obtained by plotting these anomalies statistically show good agreement with those based on magnetic and geoelectric measurements.

Lauterbach, Robert, 1968
Radium-Metallometrie zum Nachweis verdeckter tektonischer Bruche [Radium metallometry to indicate hidden tectonic breaks]:
Geophysik u. Geologie, 13: 80-83
Geophys. Abs. 282-407:
Faults and fault zones are regions of lowered pressure. To a slight but continuous extent, elements and compounds of deep chemical facies migrate (by diffusion and flow) to the fault zones and along them to the surface. Radium is one of the elements which form a migration aureole where faults emerge at the surface. Buried faults can also be indicated if the dispersion aureole of radium does not yet extend beyond the hanging wall. Use of gamma spectrometry to measure RaC concentrations is described briefly and the value of this procedure for investigating geologic structure is discussed.

Lawrence, Errol P., 1990
Hydrologic and geochemical processes affecting the distribution of ^{222}Rn and its parent radionuclides in ground water, Conifer, Colorado [M.S. Thesis]:
Golden, Colo., Colorado School of Mines, 181 p., 5 plates
[See abstract below.]

Lawrence, Errol P., Richard B. Wanty, and Paul H. Briggs, 1989
Hydrologic and geochemical processes governing distribution of U-238 series radionuclides in ground water near Conifer, CO [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(6): A144
A 30-mi^2 [78-km^2] area near Conifer, Colorado, underlain by igneous and metamorphic rocks, was studied to determine the processes controlling the distribution of radon (^{222}Rn) and its parent radionuclides in ground water. Specific-capacity pump tests, static water-level measurements, well records, and field observations were used to characterize the ground-water flow regime. Aquifers within the area are fractured and crystalline, and ground water flows under unconfined conditions with calculated transmissivities ranging from 3 to 9300 gallons/day-foot [$4x10^{-7}$ to $1.3x10^{-3}$ m^3/m-s]. Previous studies suggest that aquifer transmissivity may control ^{222}Rn transfer from the rock to the water. In this study, no significant correlations were found between well depth, transmissivity, flow rate, or specific capacity and ^{222}Rn. These hydrogeologic properties are currently being evaluated in the context of aquifer lithology. Water samples from 41 domestic and 5 public water wells and 1 river site were analyzed for major and minor elements, ^{222}Rn, ^{226}Ra, and total uranium. Radon-222 values ranged from 1340 to 139,000 pCi/L [49.6 kBq/m^3 to 5.14 MBq/m^3], with a median value of 6670 pCi/L [247 kBq/m^3]. Concentrations of dissolved uranium ranged from (0.14 to 1200)x10^{-9} [by weight] with a median of 3.1x10^{-9}; preliminary analyses indicate that ^{226}Ra concentrations are <1 pCi/L. Higher uranium concentrations were found in water of higher pH and bicarbonate content. All sampled ground water was sufficiently oxidizing that reduced uranium solids were not supersaturated. Concentrations of uranium and ^{226}Ra do not support the concentrations of ^{222}Rn in ground water. This lack of secular equilibrium in the water and the undersaturation with respect to uranium solids indicate that ^{222}Rn is derived from uranium and ^{226}Ra adsorbed to solid surfaces. Variations in uranium content of the aquifer rocks and aquifer structure are the primary controls on ^{222}Rn abundance in ground water. Results of alpha-track detectors placed in 26 homes where water samples were taken showed that ^{222}Rn in water contributed up to 34% of the ^{222}Rn in indoor air as calculated using the single-cell model of Nazaroff *et al.* (1988)[*q.v.*]. However, some of our data suggest that this model underestimates the contribution of waterborne ^{222}Rn to indoor air.

Lawrence, J.H., W.F. Loomis, C.A. Tobias, and F.H. Turpin, 1946
Preliminary observations on the narcotic effect of xenon with a review of values for solubilities of gases in water and oils:
Jour. Physiology, 105: p 197-
[Ref. Holaday and others, p. 5: partition ratio for Rn water/Rn gas at 20°C=0.23]

Lecoq, J.J., G. Bigotte, J. Hinault, and J.R. Leconte, 1958
Prospecting for uranium and thorium minerals in the desert countries and in the equatorial forest regions of the French Union:
United Nations Internat. Conf. on the Peaceful Uses of Atomic Energy, 2nd, Geneva, Proc., 2: 744-786
Radon anomalies manifested by surface gamma anomalies at Mt. Kaw, French Guiana, follow an important tectonic irregularity for several (at least fifteen) kilometers. They are numerous and sometimes very strong; at seven points we noted 1 to 3 mr/hr.

Ledbetter, Joe O., and Earnest F. Gloyna, 1958
Background radioactivity in Texas waters [Evaluation of the vibrating condenser electrometer for measuring radioactivity in water]:
Sanitary Engineering Laboratory, Civil Engineering Department, Univ. of Texas, Tech Rept. No. 1 to the Water Pollution Control Div., Texas State Dept. of Health [Cont. No. 4413-233]: 53 p.
[Used Nuclear-Chicago dynamic vibrating condenser electrometer and ion chamber; also proportional counter. Range of values in 39 samples (35 surface, 3 rain, 1 sludge from water treatment plant) from 0.144 pCi/L α and 0-928 pCi/L ß. Radon was flushed from samples before counting.]

Lee, F.W., 1928
Supplementary information on radioactive substances and methods for determining their location:
U.S. Bur. Mines Inform. Circ., 6072: 20-25
There is a certain amount of breathing at the surface of the ground due to change of barometric pressure. This tends to dilute the normal concentration of emanation to a depth of from 4 to 6 meters. The helium wells in the United States show only weak radioactivity. Sieveking and Lautenschlager question the connection between helium and radioactivity in springs and gas wells. There is some evidence that these methods may be used for delineating faults. [Anomalously high concentrations of Rn have been found in many natural gas wells of the southwestern U.S.; see Pierce and others, 1964.]

Lee Tan and Yao Chi-lung, 1965
Abundance of chemical elements in the earth's crust and its major tectonic units [in Chinese]:
Acta Geol. Sinica, 45(1): 82-91, in English transl., Internat. Geology Review, 12(7): 778-786 (1970)

LeGrand, Harry E., 1987
Radon and radium emanations from fractured crystalline rocks—a conceptual hydrogeological model:
Ground Water, 25(1): 59-69
["Crystalline rocks" is an inexact term usually meaning igneous or metamorphic rock, as opposed to sedimentary, but sometimes including sedimentary rocks having contiguous crystals, such as marbles and quartzites.]

Lehtimaki, M., G. Graeffe, K. Janka, V. Kulmala, and M. Rajala, 1984
On the behaviour of radon daughters in indoor air:
Radiation Protection Dosimetry, 7(1-4): 165-168
Chem. Abs. 101:99842q

Lehtoviita, Timo, Jussi Holkko, Martti Viljanen, and Eero Slunga, 1985
Radonin merkitys talonrakennustekniikassa. Tutkimuskohteiden rakennustekninen tarkastelu [Radon in building technology. Structural comparison on the research sites]:

Espoo, Finland, Helsinki Univ. Technology, Dept. Civil Engineering, Div. Structural Engineering Rept. 73, 145 p.
Indoor radon concentrations in 45 small houses are compared with their structural characteristics. Measured radon concentrations ranged from 9 to 3541 Bq/m^3. Radon concentrations in soil gas from 13 of the sites ranged from 1 to 241 kBq/m^3. The highest radon levels were measured in houses where the foundation slab was not continuous, and were higher in houses with cellars. In most cases indoor radon levels were high if the radon content of the soil was high.

Lehtoviita, Timo, Jussi Holkko, Martti Viljanen, and Eero Slunga, 1986
Radonin merkitys talonrakennustekniikassa. Maaperan ja rakenteiden radontuotto ja-lapaisevyys [Radon in building technology. Radon exhalation and radon permeability of soil and structures]:
Espoo, Finland, Helsinki Univ. Technology, Dept. Civil Engineering, Div. Structural Engineering Rept. 82, 130 p.
The effects of soil and building structural characteristics on radon entry through basements are given in this treatment of the theoretical bases of radon transfer, laboratory and field experiments, and calculation examples. The main transfer mechanism in clays is duffusion and in coarse sands and gravels is convection. The exhalation of soil and other radon-technical parameters can be defined by the experimental methods developed in this research. Convection is the main radon transfer mechanism into structures. In some cases diffusion must be taken into account. Some building materials can yield radon to indoor air. Theoretical calculations are required when experimental results are analyzed and in radon-technical design.

Lehtoviita, Timo, and Martti Viljanen, 1986
Radonin merkitys talonrakennustekniikassa. Radonin siirtymisen laskenta maanvastaisen rakenteiden lapi [Radon in building technology. The computation of radon transfer through ground based structures]:
Espoo, Finland, Helsinki Univ. Technology, Dept. Civil Engineering, Div. Structural Engineering Rept. 81, 138 p.
This report presents the basic theory of radon transfer from the soil to indoor air. Some calculation methods are presented. Mainly convection and partly diffusion are the transfer mechanisms of radon entry in basement structures, caused by pressure and concentration gradients. The radon transfer can be solved by both analytical and numerical methods. The analytical methods require simple boundary conditions and the material where the transfer occurs must be homogeneous. With numerical methods nonlinear problems can also be solved. A 2-dimensional finite element computer program was developed from a transient heat transfer program for the solution of analogous problems in radon transfer by convection and diffusion. Various examples of radon entry into structures have been computed by both numerical and analytical methods.

Leonard, Robert B., and Victor J. Janzer, 1978
Natural radioactivity in geothermal waters, Alhambra Hot Springs and nearby areas, Jefferson County, Montana:
U.S. Geol. Survey Jour. Research, 6(4): 529-540

Leslie, B.W., D.E. Hammond, and T.-L. Ku, 1989
Disequilibrium of uranium and thorium series radionuclides in an extended flow test of the SSSDP well [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 500
Naturally occurring radionuclides produced in the U-238, U-235, and Th-232 decay series have been measured in 300°C brines produced during a month-long flow test in June 1988 at the Salton Sea Scientific Drilling Project site. Activities (Bq/kg) of Rn-222 (37), Ra-226, -228, -224 (4.2-8.3), and Ac-228 (5) isotopes are high reflecting their large solubilities in the chloride-rich brines and relatively rapid chemical exchange between the brine and host rock. Activities of U-238, U-234, Th-232, and Th-230 are very low (ranging from <0.16 to 0.2 mBq/kg), and activities of Th-228 and Po-210 are intermediate, but are far less than those of their parents. The low activities of U, Th and Po reflect the low solubility of phases containing these isotopes, the rapid sorption of these elements from solution by solid phases, and absence of ligands capable of complexing appreciable amounts of these elements. Comparison of the results from the June 1988 flow test to the much

shorter flow tests (≈1 day) of December 1985 and March 1986 show that although the chemistry (total dissolved solids and major-element concentrations) of the brines produced for each flow test are similar, activities for all radionuclides, except for Rn-222 and its progeny and Ac-228 and its daughter Th-228, are lower by a factor of 2-5 for the extended flow test of June 1988. Radium activities are unrelated to the variations (± 15%) in CO_2 concentration in the different brines. The lower activities of Ra isotopes in the June 1988 flow test indicate that, as flow to the well continues, a mechanism of radium removal may exist and may be related to barite precipitation.

Lester, O.C., 1917
On the calibration and the constants of emanation electroscopes:
American Jour. Science, New Haven, Conn. 4(44): 225-236

Lester, O.C., 1925
A rapid and accurate method of correcting measurements with emanation electroscopes for ordinary changes in temperature and pressure:
Jour. Optical Soc. Am., 11: 637-640
[Ref. Moses, Stehney, and Lucas, 1960.]

Létourneau, E.G., R.G. McGregor, and W.B. Walker, 1984
Design and interpretation of large surveys for indoor exposure to radon daughters:
Radiation Protection Dosimetry, 7(1-4): 303-308

Lewis, Christopher, Philip K. Hopke, and James J. Stukel, 1987
Solubility of radon in selected perfluorocarbon compounds and water:
Ind. Eng. Chem. Research, 26: 356-359

Lewis, D.T., D.I. Coomber, and J.R.W. Kerr, 1963
The use of bismuth radionuclides in analysis, *in* Analytical Chemistry, 1962:
New York, Elsevier Pub. Co.: 274-280
Nucl. Sci. Abs. 18:5241
[Bismuth precipitation used for monitoring natural waters for Rn concentration in range 100-20,000 pCi/L.]

Li Xuanhu, 1984
Progress in the use of the radon method of earthquake prediction in China [in Chinese]:
Guoji Dizhen Dongtai [Recent Developments in World Seismology], No. 9, p. 5-8.

Liinamaa, Paula, and Martti Viljanen, 1984
Radonin merkitys talonrakennustekniikassa. Kirjallisuusselvitys [Radon in building technology. Literature survey]:
Espoo, Finland, Helsinki Univ. Technology, Dept. Civil Engineering, Div. Structural Engineering Rept. 66, 65 p.
This is a review of factors that cause high indoor radon concentrations. The major source of radon is the soil under buildings. Finnish building materials do not contain high radioactive concentrations. The use of radon-rich water may in some individual cases be the major source of indoor radon. Alpha-film measurements of Finnish indoor air have shown that there are great regional and seasonal variations of radon content. The highest concentrations have been measured in houses built on ridges and rough bedrock. The radon problem can be solved by construction and ventilation techniques developed in the U.S.A., Canada, and Sweden, where air-tightening the floor and ventilation of the foundation are thought to be the most efficient solution to the problem. In Finland this type of remedial action is done in only very few cases.

Likes, Richard S., Antonio-Mogro Campero, and Robert L. Fleischer, 1979

Moisture-insensitive monitoring of radon:
Nuclear Instruments and Methods, 159: 395-400

Lind, S.C., J.E. Underwood, and C.F. Whittemore, 1918
The solubility of pure radium sulfate:
Am. Chem. Soc. Jour., 40(3): 465-472

Lind, S.C. and C.F. Whittemore, 1915
The Ra/U in carnotites:
U.S. Bureau of Mines Tech. Paper 88

Lindeken, C.L., 1968
Determination of the degree of equilibrium between radon 222 and its daughters in the atmosphere by means of alpha-pulse spectroscopy:
Jour. Geophys. Research, 73(8): 2823-2827
Geophys. Abs. 216-532
Although radon appears to be a promising tool for studying atmospheric mixing processes, techniques for measuring gaseous radon are cumbersome in comparison to gross alpha- and beta-counting techniques. Equilibrium data are presented here to illustrate the application of alpha-pulse spectroscopy to such measurements. Results of one year's morning and afternoon measurements obtained at Livermore, Calif., are presented. Although instrumentally more complex (so that it does not lend itself easily to portable field operations), alpha-pulse spectroscopy has the advantage that it permits direct observations of the activities on which the calculations are based, and it can be performed in the presence of airborne fission products.

Lindell, Bo, 1984
A radon control program in theory and practice:
Radiation Protection Dosimetry, 7(1-4): 417-425
Chem. Abs. 101:99877e

Lindmark, A., and B. Rosen, 1985
Radon in soil gas--exhalation tests and in situ measurements:
The Science of the Total Environment, 45: 397-404

Lindner, Roland, and Hansjoachim Matzke, 1960
The diffusion of radon in oxides after recoil doping [in German]:
Zeitschrift Naturforschung, 15a: 1082-1086
Nucl. Sci. Abs. 15:14790
The diffusion of radon in the oxides of aluminum, titanium, iron thorium, and uranium was measured by means of the new method of recoil indication (homogeneous distribution of Rn-222 by means of alpha recoil for Ra-226 adsorbed on the grain surface). The activation energy of the gas diffusion at high temperatures lies in the range 40 to 70 kcal/mol. The relationship of these results to the values of the radon method and the cation and anion self-diffusion in the oxides is discussed.

Lindner, R., H. Matzke, and F. Schmitz, 1960
Fission product diffusion and self diffusion in high temperature nuclear fuels:
Zeitschrift Electrochemie 64: 1042-1045 [English trans.] AEC-tr-5206: 11 p.
Nucl. Sci. Abs. 16:24183
The importance of self-diffusion and fission product diffusion to the application of high temperature nuclear fuels is discussed. The self diffusion of uranium in UO_2 was measured and the experimental activation energy was found to be 108 kcal/mole. The diffusion of radioactive fission inert gases Kr-85 and Xe-133 as well as Rn-222 was determined in the oxides of uranium. The diffusion of Xe was also determined in UC and ThO_2 and the

diffusion of Rn was determined in ThO_2. The activation energy for xenon diffusion amounted to 49 kcal in UO2; 20 kcal in U_3O_8; 45 kcal in UC and 30 kcal in ThO_2. Krypton diffusion in UO2 and U_3O_8 gave practically the same values, while the activation energy for radon diffusion in UO2 (59 kcal), U_3O_8 (26 kcal), and ThO_2 (51 kcal) is considerably greater in each case than that of the lighter inert gases.

Lindsay, D.B., G.L. Schroeder, and C.H. Summers, 1981
Polymeric wall sealant test for radon control in a uranium mine, *in* Gomez, Manuel, ed., Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, International Conference, Golden, Colo., October 4-9, 1981:
Golden, Colo., Colorado School of Mines, Chap. 118, p. 790-793

Lindstrom, Richard M., John C. Evans, Jr., Robert C. Finkel, and James R. Arnold, 1971
Radon emanation from the lunar surface:
Earth Planet. Sci. Letters, 11(4): 254-256
Chem. Abs. 111783a

Link, E., and R. Schober, 1926
Das Gas-u. Wasserfach, Journal für Gas Bel. und Wasserversorgung 69: 225-228 (München, R. Oldenbourg)
[Radon in soil gas. (ref. Ambronn, 1928, and Koenigsberger, 1933)]

Link, E., 1941
Significance of the decomposition phenomena of radioactive materials in water economics [in German]:
Das Gas-u. Wasserfach, Journal für Gas Bel. und Wasserversorgung 84: 129-134

Liu, Kuo-Chien, Ko-Ch'in T'ien, Kuo-Hsiang Yao, Huai-Yin Wang, and Chih-Liang Lu, 1959
Ground radioactive methods of prospecting for oil and gas deposits:
Acta Geophys. Sinica, 8(2): 159-166
Geophys. Abs. 193-316
Ground radioactive methods of prospecting for oil and gas have been used in China since 1957. Instruments of the PGR, SG-42, and Yu-PIP No. 1 type were used with the method of point measurements along traverses. Up to the present time the effects of geologic, geomorphic, and regional factors, vegetation, and the presence of hydrocarbons could not be sorted out, but now the errors due to geology and geomorphology (under certain conditions) and regional factors are being calculated. In areas of simple geology, smooth relief, and non-intensive erosion by present streams, it is generally possible to obtain negative radioactive anomalies. The factors affecting the formation of negative radiometric anomalies above oil and gas pools are numerous, but the chief one is the presence of the hydrocarbons, acting as catalysts to cause a decrease in the radioactive element content over the pools. It is suggested that all Chinese organizations that can secure radiometric apparatus should choose some region with respect to its geologic and geomorphic conditions and make test investigations. In this way the efficiency of the radiometric method could be sufficiently enhanced in a short time as to make it one of the best methods of direct prospecting in China.

Liukkonen, E., V. Metag, and G. Sletten, 1975
Recoil escape efficiencies and ranges of actinide recoils from actinide targets:
Nuclear Instruments and Methods, 125( ): 113-117

Lively, R.S., and E.P. Ney, 1987
Surface radioactivity resulting from the deposition of ^{222}Rn daughter products:
Health Physics 52(4): 411-415

Lively, R.S., and D.L. Southwick, 1981
Radon activity in ground waters of seven test areas in Minnesota:

Saint Paul, Minn., Univ. Minnesota Rept. Investigations 25, 60 p.

LKB Resources, Inc., 1977
NURE Aerial Gamma Ray and Magnetic Reconnaissance Survey, Thorpe Area, Newark NK 18-11 Quadrangle:
Huntingdon Valley, PA 19006, LKB Resources, Inc., 55 Buck Road, U.S. Dept. Energy Rept. GJBX-16(78)
[This survey includes an area having the largest density of houses exceeding 200 pCi/L known as of 1988.]

LKB Resources, Inc., 1980
Aerial Gamma and Magnetic Detail Survey of the Reading Prong Area:
Huntingdon Valley, PA 19006, LKB Resources, Inc., U.S. Dept. Energy Rept. GJBX-90(80), 6 vols.
[This survey includes a substantial area of houses found to have indoor radon exceeding 200 pCi/L.]

Lloyd, Larry L., 1983
Evaluation of Radon Sources and Phosphate Slag in Butte, Montana:
U.S. Environmental Protection Agency Rept. EPA 520/6-83-026, 75 p.

Lloyd, Ray D., Gerald B. Folland, Bruce W. Church, and David H. Taysum, 1966?
Gamma-ray emitters in concrete:
Salt Lake City, Utah Univ. Rept. COO-119-233: 97-100
Nucl. Sci. Abs. 20:8742
The content of radionuclides in samples of ready-mix concrete obtained from three local suppliers was determined by gamma-ray counting. Average concentration of gamma emitters in the concrete in pCi per gram was found to be: Ra-226 0.7; Ra-228 0.6; Th-228 0.6; and K-40 7.9 (9 mg K). Retention of Rn-222 activity in the hardened concrete was about 85% that of the Ra-226. The radioactivity of constituents was also measured. Concentration of gamma-ray emitters in gravel was approximately equal to that in the concrete mix, while their concentration was about 40% higher in sand and about 50% lower in cement.

Lobdell, David S., and E F. Buckley, 1954
Gamma ray oil exploration:
Petroleum Engineering, 26(9): B76-B78, B80, B83
[Radioactivity in oil finding. Examples are given of the depression of γ-ray field intensity over several oil fields. See Lundberg, 1952, and abstract below.]

Lobdell, David S., E.F. Buckley, and John W. Merritt, 1954
Gamma ray exploration comes of age:
World Oil, 139(2): 107-112
Geophys. Abs. 159-177
Oil accumulations may be outlined by detecting surface radiation associated with buried hydrocarbons. A greater radiation intensity is found on the edges of pools with a low level of radiation over the main body. Differences may be small. Reconnaissance by helicopter is feasible but conventional airborne surving equipment is too fast and tends to smooth out marginal bands.

Lockhart, Luther B., Jr., 1958
Concentrations of radioactive materials in the air during 1957:
Science, 128(3332): 1139
Geophys. Abs. 175-331
Measurements of the concentration of radon, thoron, and fission products in the air were made daily throughout 1957 at Washington, D.C.; Yokosuka, Japan; Kodiak, Alaska; and Little America, Antarctica, using identical equipment. The averages for the year at each site are tabulated. It can be seen that the bulk of the radioactivity is due to radon and its decay products, derived from radium in the soil. The concentration of radon and thoron is dependent on location of land masses relative to prevailing winds over the collecting site.

Even though the concentration of products was unusually high at Washington in 1957, due to the nuclear tests in Nevada, the artifically produced material amounted to only 1.2 percent of the radon concentration. Similar ratios of fission products to radon were found at the other sites. The thoron concentration is roughly equal to that of the fission products in each case.

Lockhart, Luther B., Jr., 1959
Atmospheric radioactivity levels at Yokosuka, Japan, 1954-1958:
Jour. Geophys. Research, 64(10): 1445-1449
Geophys. Abs. 180-331
The results are presented of measurements of concentrations of some natural radioactive materials and of gross fission products in the air at ground level at Yokosuka, Japan, during the period 1954-58. The data support the conclusions that the concentrations of both natural and fission products vary widely from time to time, that the change in the concentration of the natural radioactivity is related in a general way to the phenomena that control precipitation, and that the trend of the fission-product concentration has been upward during the past few years.

Lockhart, Luther B., Jr. 1960
Atmospheric radioactivity in South America and Antarctica:
Jour. Geophys. Research, 65(12): 3999-4005
Geophys. Abs. 184-525
Information on the concentration of the major natural radioactive species and of gross-fission-product activity in the ground-level air at Lima, Peru; Chaclatay, Bolivia; Rio de Janiero, Brazil; and Little America, Antarctica is reported. The radon content of the air was found to be generally less than that in North America. Thorium seems to be relatively more prevalent in the surface soils there than in North America. In Antarctica the natural activity of the air is extremely low; thoron is a negligible contributor. Fission products are minor contributors to atmospheric radioactivity in the southern hemisphere except in Antarctica, where it assumes relatively more importance compared to the low natural activity present. Seasonal changes in one or more of the radioactive components are evident at each of the sites. These changes are probably related to meteorological factors and the location of soils rich in radioactive elements, whereas changes in the fission product concentration are related to seasonal changes in the mixing rate of air masses.

Lockhart, L.B., Jr. 1962
Atmospheric radioactivity at Washington, D.C., 1950-1961:
U.S. Naval Research Lab. Interim Report: 18 p.
Nucl. Sci. Abs. 16:17916
Seasonal variations inthe short-lived radon and thoron decay products in the air were observed. The short-term variations of these products are sufficiently great to make impractical the direct determination of gross fission products in the associated air masses without removal of the short-lived natural products through decay, unless the fission product concentration is extremely high. The principal sources of fission products in the Washington, D.C. area have been nuclear tests at the Nevada Test Site (U.S.) and at the Soviet test sites (Novaya Zemlya and Semipalatinsk, for example) with much smaller contributions from those at the Pacific Proving Grounds (U.S.). No radioactive debris from any of the Australia or Christmas Island tests (U.K.) were identified in the Washington collections; only traces of activity were detected from any of the nuclear tests in the Sahara (France).

Lockhart, Luther B., Jr. 1962
Natural radioactive isotopes in the atmosphere at Kodiak and Wales, Alaska:
Tellus, 14(3): 350-355
Geophys. Abs. 193-313:
The concentrations of radon and thoron in ground-level air at Kodiak (on Kodiak Island) and Wales (on Seward Peninsula), Alaska, were determined by collection of decay products and measurement of their beta

radioactivity. The monthly averages of radon concentration at Kodiak ranged from 0.7 to 30 pCi/m^3 and reached maxima in late fall and early winter and minima in early summer; toward the end of the decade of measurements, 1950-1960, the mean decreased significantly. Monthly averages of radon concentration during the measurement period 1953-1959 at Wales showed no such decline and ranged somewhat higher, 7 to 50 pCi/m^3; season variations were similar to those Kodiak. Thoron concentrations followed different seasonal patterns; the maxima occurred during summer. At Kodiak, the range of monthly thoron averages was 0.003 to 0.2 pCi/m^3 and the seasonal variation was slight, the minima occurring in spring. At Wales the range was 0.01 to 0.6 pCi/m^3 and the seasonal variation was great, the minima occurring in winter. The concentration of each radionuclide in an air mass is related to the area of land surrounding the measurement site, to the distance of the sea, which is a poor source of nuclides, and to meteorologic factors that tend to disperse or dilute the air mass. Because of the contrast in half life between radon (3.8 days) and ThB (10.6 hr), a thoron measurement is indicative of relatively local soil and meteorologic conditions and is independent of the history of an air mass except for the preceding day or two. Natural atmospheric radioactivity measurements are considered valuable for studying the movement and mixing of air masses.

Lockhart, L.B., Jr., R.A. Baus, R.L. Patterson, Jr., and I.H. Blifford, Jr., 1958
Some measurements of the radioactivity of the air during 1957:
Naval Research Laboratory, Report 5208: 33 p.
This report summarizes measurements made during 1957 on the concentrations of some natural radioactive materials and of gross fission products in the atmosphere at ground level. Among the topics covered are the daily or monthly variations of the concentrations of radon, thoron, and gross fission products in the air at several sites in the Northern Hemisphere, in Brazil, and in Antarctica. In addition, several measurements have been made of the contribution of Be-7 to the radioactivity of the atmosphere and of the relative concentrations of RaD and RaF in the air at ground level at Washington, D.C., and Yokosuka, Japan. It is found that fission-product levels in the Northern Hemisphere are roughly ten times as great as at similar latitude in the Southern Hemisphere. However, the increase in the total radioactivity of the air is negligible when compared with the normal activity levels due to natural radon, thoron, and their descendants.

Lockhart, L.B., Jr., R.L. Patterson, Jr., and W.L. Anderson, 1964
Characteristics of Air Filter Media Used for Monitoring Airborne Radioactivity:
U.S. A.E.C. NRL-6054: 17 p.
Nucl. Sci. Abs. 18:26098
A comparison was made of the more important characteristics of the available filter materials, which are currently in use by various systems for monitoring airborne radioactivity throughout the world. Most of the materials described are commercially available. The filter characteristics measured are such physical properties as tensile strength, thickness, density, ash content, retentivity toward 0.3 μm dioctyl phthalate (DOP) aerosol particles as a function of air velocity, flow rate as a function of pressure drop across the filter, rententivity toward airborne fission products and natural radioactive aerosols (radon daughters) at several air velocities, and the relative rates of clogging by atmospheric dust. The observation of a rapid change in flow with dust loading of some of the filter media suggested the systematic study of such changes as possibly a procedure for monitoring the dust content of the atmosphere.

Lockhart, Luther B., Jr., Robert L. Patterson, Jr., and Allen W. Saunders, Jr., 1966
Airborne radioactivity in Antarctica:
Jour. Geophys. Research, 71(8): 1985-1991
[Rn and Tn inferred by daughter-product collection and ß measurements.]

Loftenius, Christer J., and Rudolph Hon, 1989
Assessment of radon production levels in calc-alkalic plutons [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 496

Near-surface radon levels in areas associated with either peraluminous or peralkalic granitic plutons have been well documented by a number of the previous studies. However, there is a lack of data for calc-alkalic plutons which are the more common of the intrusive types. Our study is focussed on a calc-alkalic suite of rocks within the Sharpners Pond Quartz Diorite Pluton of NE Massachusetts. Geochemical study of 42 samples that includes every lithological type shows a presence of two rock groups: (1) gabbro-diorites with average U: 1 ppm (range: <0.5 to 4.5 ppm), average Th: 4.6 ppm (0.4 to 9.6 ppm), and (2) granites with average U: 5.2 ppm (2.9 to 8.2 ppm), average Th: 16.8 ppm (11.1 to 22.4 ppm). Uranium abundances fail to correlate with most of the major or trace elements, which suggests that a significant portion of U does not appear to be part of the original rock mineralogy, but rather it is in the form of secondary uranium-bearing minerals along open and healed microfractures. Our study of radon emanation rates on 10 selected samples indicates that the bulk sample radon emanation is highly variable (5-25%) supported by 0.5 to 1.5 ppm of the total U present in the rock. In summary: (1) the absolute levels of radon emanation from the bulk samples of calc-alkalic intrusives are lower than those from other types of granites; (2) levels of radon release into a pore space in soils above such intrusions still pose a risk. A significant part of U does not appear to be "locked" in any of the weathering-resistant crystal structures (lack of correlation with Zr, rare-earth elements, etc.) and consequently this U may become free and mobile during the chemical weathering cycle.

Lombardi, Salvatore, and G.M. Reimer, 1989
Radon-222 and helium-4 in soil gas in the Phlegrean Fields, central Italy [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 501
Radon and helium surveys were performed in August 1986 at the Phlegrean Fields in central Italy. The data show a relationship between positive gas anomalies and high gravity values. The gravity values, in turn, are interpreted as due to the presence of magma bodies or the density of pyroclastic calc-aluminum silicates (800–1300 m depth) or nearer surface causes such as circulating hydrothermal fluids and their influence in altering the density of the tuffaceous cover (300–800 m depth). Because the gravity anomalies may be linked to fracture systems due to caldera collapses or regional tectonic stress, the presence of the gas anomalies may point out the existence of more permeable fractures at depth. Helium surveys were performed in a period of seismic activity and seemed related to small geothermal reservoirs and fractures reactivated by inflation. Both gases indicate permeable fracture systems with helium being more sensitive than radon for revealing deeper fractures.

Lombardi, S., and G.M. Reimer, 1990
Radon and helium in soil gases in the Phlegraean Fields, central Italy:
Geophys. Research Letters, 17(6): 849-852
[Radon and helium in soil gases were measured in the volcanic Phlegaraean Fields, which are seismically active and have fracture systems and other tectonic features. Although radon and helium concentrations in soil gas were not in proportion at each sampling point, they had similar areal distributions, suggesting that the distribution is controlled mainly by the fracture system and movement of geothermal fluids.]

Lorenz, Philip J., Orville C. Rodenberg, Larry G. Shalde, Alan C. Antes, and William D. Hess, 1961
Background radioactivity in the Decorah fault region:
Iowa Acad. Sci. Proc., 68: 397-403
Geophys. Abs. 189-500
Nucl. Sci. Abs. 17:3182
A known fault site at Decorah, Iowa, was surveyed for indicative variations in surface radioactivity. Significant increases in gamma ray intensity were found at several locations; at one point the radiation level was 70 percent higher than background. Measurements repeated one year later verified this pattern. A map of radiation contours plotted over an extensive area of Decorah with other supporting evidence indicates a possible fault strike of approximately N55°W. There is no reason to expect that all faults will display a high γ radiation profile. However, if such an increase is generally characteristic of faults in a specific region, a welcome addition to methods of geophysical exploration may be developed.

Löser, Gunter, 1959
Radioaktive Bodenluftmessungen als Beitrag zur Klärung tektonischer Probleme am Südwestrand des Thüringer Waldes [Radioactive soil air measurements as a contribution to clarification of structural problems on the southwest border of the Thüringer Forest]:
Geophysik u. Geologie, 1: 97-103
Geophys. Abs. 189-502
Measurements of soil air radioactivity aid in mapping faults under the soil cover along the southwest border of the Thuringer Wald in Germany. The traces of the Floher, Klinger, Stahlberg, and Messleser faults were clearly evidenced by increases in radon concentration in the overlying soil air. No systematic relationships could be established between depth, throw, dip, and country rock of the faults on the one hand and height and shape of the radioactivity anomalies on the other. The results are reproducible. In wooded areas or areas of thick, moist overburden the measurements were of limited value, however.

Louw, J.D., 1954
Geological age determinations on Witwatersrand uraninites using the lead isotope method:
Geol. Soc. S. Africa Trans. 57: 209-230
[Ref. by de Villiers et al, UNP/1110, vol. 2: p 237 (1958): ....Louw assumed radon loss as the cause of the age discrepancies,...]

Løvborg, L., L. Bøtter-Jensen, E. Mose Christiansen, and B. Leth Nielsen, 1980
Gamma-ray measurements in an area of high natural radioactivity, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 912-926

Løvborg, L., L. Bøtter-Jensen, P. Kirkegaard, and E.M. Christiansen, 1979
Monitoring of natural soil radioactivity with portable gamma-ray spectrometers:
Nuclear Instruments and Methods, 167: 341-348

Løvborg, Leif, Lars Bøtter-Jensen, and Peter Kirkegaard, 1978
Experiences with concrete calibration sources for radiometric field instruments:
Geophysics, 43(3): 543-549
[Gamma output from uranium-enriched concrete calibration pad was variable and consistent with radon losses in dry weather and retention of radon when moist and icy in winter.]

Love, S.K., 1951
Natural radioactivity of water:
Ind. Eng. Chemistry, 43(7): 1541-1544
Geophys. Abs. 13386:
...From the few data available the radioactivity of normal surface and ground water ranges from about 0.1 to 10 pg of radium per liter; the radioactivity of most thermal or mineralized springs is less than 10 ng of radium per liter although values in excess of 0.5 μg/L have been published....[The latter two values may be for radon, rather than radium—ABT]

Lowder, Wayne M., Harold L. Beck, and Wm. J. Condon, 1964
Spectrometric determination of dose rates from natural and fall-out gamma-radiation in the U.S., 1962-63:
Nature [London], 202: 745-749
Nucl. Sci. Abs. 18:25694
Instrumental and analytical techniques are described that were used for spectrometric determinations of dose rates in air from natural and fallout gamma radiation that contributes to environmental radiation levels in the U.S. Emphasis was placed on gamma radiation from K-40, the daughters of Ra-226 and Th-232 in the earth, and the ionizing component of cosmic radiation. The contribution of fallout activity was also determined.

Data are summarized from measurements of both natural and fallout gamma radiation made at over 200 sites throughout the U.S. during 1962 and 1963.

de Luca Muro, F.P., 1947
Anomalías radioactivas del aire telúrico sobre yacimientos de asfaltitas [Radioactive anomalies of the telluric air above asphaltite deposits]:
Bol. Inform. Petroleras, Buenas Aires, 24(277):161-163
Chem. Abs. 2212c
[Air pumped from the soil at a depth of 70 cm attained a max. over the asphaltite deposit.]

Lucas, H.F., 1957
Improved low-level alpha-scintillation counter for radon:
Review Sci. Instruments, 28(9): 680-683
[This paper describes in detail the optimum design and means of preparing alpha scintillation cells for radon counting.]

Lucas, H.F., Jr., and F.H. Ilcewicz, 1958
Natural radium 226 content of Illinois water supplies:
Am. Water Works Assn. Jour., 50(11): 1523-1532
[Used charcoal concentration (in CO_2 bath) + α scintillation chamber.]

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The author's past experience with ground and aerial measurements has shown that there are radioactive lows over oil fields and radioactive highs over their perimeters. He attributes this to the solution of radium minerals from near-surface formations by upward-rising sulfide waters which precipitate radium salt when they encounter downward-percolating oxygen-rich surface waters that oxidize the sulfides to sulfates. These waters are laterally deflected by an oil pool creating a lack of radioactivity above it and a concentration along its edges. [A more plausible explanation was provided by Alekseyev (1959) and by Alekseyev and Gottikh (1965), who inferred that rising hydrocarbon gases lower the adsorption capacity of soil grains above an oil pool and that surface waters carry a significant fraction of the trace elements to the peripheral zone, where they are readsorbed.]

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Unlike regional radon studies from other areas, bedrock geology and gamma radiation show no correlation with radon from soils overlying the Green Pond outlier and the Reservoir fault zone of the N.J. Highlands. Gamma radiation in the Paleozoic sedimentary rocks of the outlier is lower than in the Precambrian gneisses. Sedimentary bedrock shows average gamma radiation of 220.4 counts/s (cps) with a range of 136.0 to 322.8 cps. Gamma radiation from the Precambrian gneisses averages 284.2 cps and range from 240.4 to 575.8 cps. Rare pegmatites from within the Reservoir fault zone yield anomalously high average gamma radiation of 2017.5 cps with a range of 1948.6 to 3493.6 cps. Radon concentrations in soil cover yielded similar averages with wide ranges regardless of bedrock geology. Radon from soil over the sedimentary bedrock of the outlier averaged 517.9 pCi/L with a range of 236.9 to 2695.3 pCi/L. Radon from soil over the gneisses averaged 527.O pCi/L with a range of 240.4 to 1872.3 to pCi/L. The Green Pond outlier and the Reservoir fault zone are covered by the terminal moraine deposits of northwestern N.J. All soil-gas radon samples were taken in glacial till which is poorly sorted, very porous, and in a sandy matrix. The moraine sediments contain erratics composed of all lithologies in the area as well as exotic rock types. Uranium concentrations in the erratics and matrix is highly variable. Radon is a daughter product of uranium and levels in soils are locally governed by the uranium concentrations of each erratic and the matrix. Because glacial till covers the area and is relatively homogeneous, average radon values are similar over all lithologies. Another reason for a lack of a correlation is that the soil is porous, causing radon diffusion and atmospheric dilution. This study shows

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Prospects for the use of helium and radon in geochemical prospecting for deposits of radioactive minerals: a review:
Bol. Mineral, 1977, 4: 35-41
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Mining Congr. Jour., 63(4): 49-52
[Radon is one variable measured.]

Megumi, Kazuko, 1978
Exhalation of radon and thoron from soil surface [in Japanese]:
Kyoto Daigaku Genshiro Jikkensho, Tech. Rept., KURRI-TR-179: 12-14
Chem. Abs. 90:140168u:

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Jour. Geophys. Research, 77(17): 3052-3056
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Emanation and exhalation of radon and thoron gases from soil particles:
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Atmospheric monitoring for alpha emitters using molecular filter membranes:
Arch. Ind. Hygiene and Occupation Med., 10: 372-380
[Contains data on millipore filters. Decay curves for mixtures of alpha emitters given.]

Mercer, Thomas T., 1976
The effect of particle size on the escape of recoiling RaB atoms from particulate surfaces:
Health Physics, 31(2): 173-175
Chem. Abs. 86:35612d

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World Oil, 135(1): 78-80, 82
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The use of radiation-intensity surveys in petroleum exploration is described. Because of the movement of gas and water above oil or gas producing zones, a radioactivity high marking the margin of oil or gas occurrence is postulated. However, because of many variables involved, considerable caution is needed in the interpretation of results of radiation surveys.

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Internat. Geol. Cong., 20th, Mexico City, 1956, Symposium de Exploracion Geoquimica, 2: 283-302
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The operational history of and problems connected with the use of soil chemistry and soil radiation in exploring for oil and gas are reviewed briefly. Examples are given where gamma radiation of surface samples over oilfields with one producing horizon is at a maximum at the margins of the field. For other simple oilfields, corrections are needed to the raw gamma radiation data. The soil radiation method is rarely applicable to complex oilfields with several producing horizons.

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Improvements in or relating to apparatus for measuring the radioactivity of the air, 1962:
British Patent 899,084 (to G.A. Messen-Jaschin)
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An apparatus for measuring the total radioactivity of air is designed which can carry out measurements in a continuous manner. The apparatus comprises a separation chamber, means for flowing an air stream through the chamber, a separating electrode in the form of a band driven through the chamber parallel to the air stream, means for generating ions in the stream and for providing an electrical field in the chamber, and a detector located adjacent the band and beyond the chamber for measuring the radioactivity of particles deposited on the band.

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Leipzig, B.G. Teubner, 541 p.

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[Review of meteorological investigations and radon to 1926]

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The thermal spring at Fojnica, Bosnia, issues from a fault in bituminous Carboniferous shales at the western margin of an extensive terrace of calcareous sinter. Analysis of its water and that of 3 wells in the vicinity shows that the Ca, Mg, and free CO_2 content and temperature decrease with the distance from the fault, but radioactivity increases severalfold. Evidently the water takes up radon generated from uranium that has been precipitated along with iron in the sinter.

Miholić, Stanko, 1958

Radioactive waters from sediments:
Geochim. Cosmochim. Acta, 14(3): 223-233
Geophys. Abs. 175-338
Radon measurements on 107 mineral waters in Yugoslavia show that their radioactivity depends on the geologic age of the sediments through which they flow; those issuing from Carboniferous or Cretaceous strata show a distinctly higher radioactivity, due to the higher uranium content of those sediments. Part of the radioactive substances of the waters is sometimes deposited in sinters around the springs. In these deposits the uranium is not usually in radioactive equilibrium with its daughter elements; particularly in the case of calcareous sinters and ochres, there are more ionium and radium present than necessary for equilibrium. The radioactivity of water passing through such sinters is increased. The thermal water of Visegrad shows the greatest enrichment (by a factor of 7.27).

Miholić, Stanko, 1960
Secondary enrichment of uranium in sediments:
Internat. Geol. Congr., 21st, Copenhagen 1960, Proc., pt. 15: 73-77
Geophys. Abs. 184-521:
Drilling in 1958 at the Fojnica thermal springs and Klokoti mofettes in Bosnia provided new information on the secondary enrichment of sediments in uranium by mineral waters (see also Geophys. Abs. 175- 338). At Fojnica the water issuing from a fault in Carboniferous schists has a radioactivity of 3.640 nCi/L and flows over an extensive sinter terrace. The radioactivity of springs in this terrace increases with increasing distance from the fault, due to secondary enrichment of uranium and radium in the sinter. At Klokoti, carbon dioxide gas from pools in a bog showed a radioactivity of 3.74 nCi/L, whereas drilling yielded gas with a radioactivity of 8.526 nCi/L; in the borehole the gas can reach the surface before much of the radon has decayed.

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Isotopic study of some Colorado Plateau ores:
Econ. Geology, 53(8): 937-948
Geophys. Abs. 176-242:
A number of selected uranium ore specimens from several localities have been analyzed for uranium and lead in both pitchblende and galena phases by isotope dilution techniques, and the lead isotopic abundance determined. It is shown that the hypothesis of hydrothermal deposition of uranium accompanied by old radiogenic lead from the basement at one time about 60 million years ago does not satisfy the isotopic data. A new hypothesis is presented which requires local sources with high U/Th and U/Pb ratios, variable radon leakage, suitable ground water movement, and deposition at the site of H_2S at low temperature. This hypothesis can explain the age discordance and the lead isotope abundances in galena. It is possible from the isotopic data to have all deposition occurring within the last five million years but it does not preclude other periods of deposition such as in Laramide time. The isotopic ages are apparent ages only and bear no direct relation to the time of deposition. The isotopic ratios, however, provide information which may be used to restrict theories of origin.

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Radiation surveys can find oil:
Oil and Gas Jour., 59(7): 124-127
GeoSci. Abs. 3-2052

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London, Inst. Mining and Metallurgy: 135-146

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Radon measurement in uranium prospecting, *in* Uranium Exploration Methods, Proc. of a Panel, Vienna, April 10-14, 1972:
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Lognormal analysis of naturally occurring radionuclides in soil and vegetation of the Hanford area, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 826-831

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Comparison of radon results obtained from track etch films and radon counter methods:
Nucl. Res. Cent. "Democritus" Rept. DEMO 76/4: 11 p.
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The radon content of the atmosphere in the New York area as measured with an improved technique:
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Investigations on natural radiation in the hot spring areas, *in* Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:
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Mishra, U.C., C. Rangarajan, and C.D. Eapen, 1980
Natural radioactivity of the atmosphere over the Indian land mass, inside deep mines, and over adjoining oceans, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 327-346

Misquitta, Neale J., Richard W. Carlton, and Lindgren L. Chyi, 1989
Excessive radon level over abandoned underground coal mine [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(6): A144
Anomalous high radon levels were found in areas with low surface uranium concentrations. Our previous study indicated that excessive radon levels occur over faults in the Serpent Mound area in southern Ohio [see Heirendt *et al.*, 1988]. It is, therefore, suspected that the excessive radon levels in Summit County, Ohio, might be related to induced faults from abandoned underground coal mines. The induced fractures, which resulted from total withdrawal of the coal, might propagate to the surface and serve as conduits for the migration of underground radon to the surface. The hypothesis was tested with 133 passive alpha-track detector assemblies for soil-gas radon. They were buried for 21 days at a depth of 30 inches [1 m] in a series of five traverses over an abandoned coal mine in southern Summit County from directly over the mined-out area to areas adjacent to it. The results indicated that radon levels over the mined-out area are at least twice as high as those over adjacent undisturbed areas. The average radon level over mined-out areas was 112 pCi/L, as compared with 52 pCi/L over the undisturbed areas. The latter is similar to the surface soil-gas radon level of the vicinity. Thus, the 60-pCi/L additional radon over the mined-out area must have come from

underground sources, because radon is not expected to migrate a significant distance over its short half life. The phenomenon that excessive radon levels are found over abandoned coal mines is being explored for the mapping of undocumented abandoned coal mines. [Alternative or additional factors that may have affected the results could be the greater air reservoir volume's response to periodic barometric pressure changes, which have been shown to increase the effective exhalation of radon from greater depths, and a greater drying of the soils overlying the mine site as a result of movement of the mine and atmospheric air through the soil, leading to greater efficiency of the detectors; see Tanner, 1989.]

Mitsch, Barry F., James E. Watson, Jr., and James A. Hayes, 1984
A Study of Radium-226 and Radon-222 Concentrations in Ground Water Near a Phosphate Mining and Manufacturing Facility with Emphasis on the Hydrologic Characteristics of the Area:
Raleigh, NC, Univ. North Carolina, Water Resources Research Inst., Rept. WRRI-UNC 84-216, 69 leaves

Mjachkin [Myachkin], V.I., W.F. Brace, G.A. Soboler, and J.H. Dieterich, 1975
Two models for earthquake forerunners:
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Radon-222 exhalation and its variation in soil air, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 105-116

Moed, B.A., W.W. Nazaroff, A.V. Nero, M.B. Schwehr, and A. Van Heuvelen, 1984
Identifying Areas with Potential for High Indoor Radon Levels: Analysis of the National Airborne Radiometric Reconnaissance data for California and the Pacific Northwest:
Berkeley, Calif., Univ. California Lawrence Berkeley Lab. Rept. LBL-16955, 70 p. [Also published with additional pages i and ii by Bonneville Power Administration, 1985]
Radon-222 is an important indoor air pollutant which, through the inhalation of its radioactive decay products, accounts for nearly half of the effective dose equivalent to the public from natural ionizing radiation. Indoor radon concentrations vary widely, largely because of local and regional differences in the rate of entry from sources. The major sources of indoor radon are soil and rock near building foundations, earth-based building materials, and domestic water; of these, soil and rock are thought to be predominant in many buildings with higher-than-average concentrations. Thus, one key factor in determining radon source potential is the concentration of radium, the progenitor of radon, in surficial rocks and soils. We have analyzed aerial radiometric data, collected for the National Uranium Resource Evaluation Program, for seven Western states with a view towards 1) providing information on the spatial distribution of radium contents in surficial geologic materials for those states, and 2) investigating approaches for using the aerial data,which have been collected throughout the contiguous United States and Alaska, to identify areas where high indoor radon levels may be common. The results showed a range of mean radium concentrations averaged over geologic map units of 0.1-3.6 pCi/g, with an overall mean for the study area of 0.7 pCi/g. Radium concentrations were found to be relatively low in central and western portions of Washington, Oregon, and northern California; they were found to be relatively high in central and southern California. A field validation study, conducted along two flight-line segments near Spokane, Washington, showed close correspondence between the aerial data, in situ measurements of both radium content and radon flux from soil, and laboratory measurements of both radium content of and radon emanation rate from soil samples.

Moeller, Dade W., Dwight W. Underhill, and Gary V. Gulezian, 1980
Population dose equivalent from naturally occurring radionuclides in building materials, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1424-1443

Moffett, D., and M. Tellier, 1978
Radiological investigations of an abandoned uranium tailings area:
Environmental Quality, 7(3): 310-314
Chem. Abs. 89:185427y:

Mogro-Campero, A[ntonio], 1978
Emission of gas from rock samples subjected to stress in the laboratory [abs.]:
Am. Geophys. Union Trans., 59(4): 329

Mogro-Campero, A., and R.L. Fleischer, 1976
Subterrestrial fluid convection: A hypothesis for long-distance migration of radon within the earth:
General Electric Co. Corp. Research and Development, Schenectady, N.Y., Rept. 76CRD133: 4 p.
Scattered observations suggest that radon can migrate through the earth for distances of approximately >100 m, a process of great potential aid in both earthquake prediction and uranium exploration. It is noted that existing theories predict that fluid convection in the earth, driven by the local geothermal gradient, can occur in areas of relatively high permeability. The velocity of fluid flow may be sufficient to transport radon over large distances before it decays. The convection hypothesis also provides a possible explanation of seasonal effects that have been observed in local and general radon emanation into the atmosphere.

Mogro-Campero, A[ntonio], and R[obert] L. Fleischer, 1977
Subterrestrial fluid convection: a hypothesis for long-distance migration of radon within the earth:
Earth Planet. Sci. Letters, 34: 321-325
[See above abstract.]

Mogro-Campero, Antonio, and Robert L. Fleischer, 1980
Search for long-distance migration of subsurface radon, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 72-82, disc., p. 83
Long-distance radon migration is defined as that requiring nondiffusive transport modes. The limitations of diffusive motion are shown by using likely field parameters. Two nondiffusive transport processes are discussed quantitatively: convection driven by the geothermal gradient and flow induced by atmospheric pressure changes. Finally, we treat the problem of experimentally determining if long-range radon migration occurs in a given situation. This includes criteria for selecting anomalous readings in radon surveys and possible reasons for the appearance of such anomalous values.

Mogro-Campero, A., R.L. Fleischer, and R.S. Likes, 1978
Changes in radon concentration of Blue Mountain Lake, NY [abs.]:
Eos, Am. Geophys. Union Trans., 59(12): p 1196

Momeni, M.H., C.E. Dungey, and C.J. Roberts, 1982
Analysis of atmospheric pathways of exposure at Jackpile Mine, *in* Faraday M.A., ed., International Conference on Radioactive Waste Management, Proc., p. 588-594:
Toronto, Canadian Nuclear Soc.

Momeni, M.H., W.E. Kisieleski, Y. Yuan, and C.J. Roberts, 1978
Radiological and environmental studies at uranium mills: a comparison of theoretical and experimental data, *in* Seminar on Management, Stabilization and Environmental Impact of Uranium Mill Tailings, Albuquerque NM, 24-28 July 1978:
Paris, OECD Nuclear Energy Agency

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Radiological impact of uranium tailings and alternatives for their management, in Low-Level Radioactive Waste Management, Health Physics Society Mid-Year Topical Symposium, 12th, February 1979, Proceedings:
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Natl. Acad. Sciences, Natl. Research Council Rept. NAS-NS-3025
[Indexed in Nucl. Sci. Abs. (15:297) under radon.]

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The effect of humidity on the detection of radon:
Health Physics, 31(5): 456-457
Chem. Abs. 86:97743f:

Moore, H.E. and S.E. Poet, 1976
^{210}Pb fluxes determined from ^{210}Pb and ^{226}Ra soil profiles:
Jour. Geophys. Research, 81(6): 1056-1058

Moore, R.B., 1908
Decay of radium emanation dissolved in water:
Royal Soc. [London] Proc., A80: 597-598
Sci. Abs. 1630 (1908)

Moore, W.S., J.H. Chiang, P. Talwani, and D.A. Stevenson, 1977
Earthquake prediction studies of Lake Jocassee: relation of seismicity to radon anomalies in groundwaters:
Eos; Am. Geophys. Union Trans. 58(6): p. 434

Moore, Willard S., and David F. Reid, 1973
Extraction of radium from natural waters using manganese-impregnated acrylic fibers:
Jour. Geophys. Research, 78(36): 8880-8886

Morawska, L., 1982
New method of measurement of radon emanation parameters [Ph.D. thesis]:
Krakow, Poland, Jagiellonian Univ.

Morawska, L., 1983
Influence of sealants on ^{222}Rn emanation rate from building materials:
Health Physics, 44(4): 416-418

Morinaga, Hiroshi, 1958
Radioactive springs in Japan:
Okayama Univ. Balneological Inst. Pamphlet: 11 p.
Geophys. Abs. 178-328
Of the 8,452 springs on record in Japan up to December 1954, 3,719 have been chemically analysed; of these 139, or 3.74 percent, are radioactive. Most of them are radon springs, although some are high in thoron. Tables are given to show the temperatures and the amounts of radon, thoron, and radium in the waters of some of the better known radioactive springs. Extensive medical research is being conducted to determine the therapeutic value of the waters. It has been observed that fluctuations in the chemical contents of spring waters are caused by changes in weather, marked seasonal changes, and changes in the water level of the river.

Morken, D.A., 1961

The effect of inhaled radon on the survival, body weight, and hemogram of the mouse following single exposures:
U.S. A.E.C. Rept. UR-593: 50 p.
Nucl. Sci. Abs. 15:27370

Morris, R.L., and J.W. Klinsky, 1962
Radiochemistry and removal characteristics of radium isotopes in Iowa well waters:
Iowa Acad. Sci. Proc., 69: 396-399
Nucl. Sci. Abs. 18:8243
[Wells with significant Ra are in smaller communities, mostly in southeastern Iowa. Several towns have municipal zeolite softening processes that remove Ra to low levels (as much as 90%).]

Morse, R[obert] H., 1971
Comparison of geochemical prospecting methods using radium with those using radium and uranium, *in* Geochemical Exploration, Proc., Intl. Geochem. Explor. Symp., 3d, Toronto, April 16-18, 1970:
Canadian Inst. Mining Metallurgy Spec. Vol. 11: 215-230

Morse, R.H., 1976
Radon counters in uranium exploration, *in* Exploration for uranium ore deposits, Proceedings of a Symposium on Exploration of Uranium Ore Deposits, Vienna, March 29-April 2, 1976:
Vienna, Internat. Atomic Energy Agency Rept. STI/PUB/434; 229-239
Rapid analytical techniques are available for uranium, radium and radon, each of which is characterized by a different geochemical behaviour and each of which is absolutely specific for uranium. An efficient geochemical exploration programme will be based on a judicious combination of these elements. The battery-operated digital alpha scintillometer combines portability with high sensitivity. Radon and radium can be determined in the field. Thoron is recognized by a rapid drop in count-rate owing to its 54.5-s half-life. At the detailed level of exploration radon in soil gas provides a useful supplement to ground gamma scintillometry. Readings as low as 20 counts/min or lower are significant. High readings due to especially permeable soils are characterized by rapidly falling count-rates because of dilution by thoron. Uranium anomalies are characterized by steady or rising count-rates. Counting beyond the first minute and monitoring any changes is essential. Diurnal radon variations are not critical in Canada. An example is provided from the Bancroft area which compares radon in soil to ground gamma scintillometry. The radon survey shows more detail, in agreement with the geology, than the scintillometer.

Morse, Jerome G., Mahmood H. Rana, and Lauren Morse, 1982
Radon mapping as indicators of subsurface oil and gas:
Oil and Gas Jour., 80(19): 227-246

Moschandreas, D.J., and H.E. Rector, 1982
Indoor radon concentrations:
Environment Internat., 8(1-6): 77-82

Mose, Douglas G., Charles E. Chrosniak, and George W. Mushrush, 1989
State-size radon hazard maps based on zip-code compilations [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(6): A143-A144
Indoor radon measurements are now available for many populated areas in the United States, particularly in the Appalachian Mountain system. A compilation of 1.3 million measurements, using activated charcoal and alpha-track indoor radon monitors, has been gathered from several radon testing companies and grouped according to zip codes. The hypothesis that charcoal monitor data yield zip code averages lower than alpha-track monitor data was found to be incorrect, using Maryland zip code zones. These two measurement methods tend to yield the same average for zip code zones, and the average charcoal measurement was found to be equally likely to be lower than, or higher than, the alpha-track average. A comparison between the geological

provinces in Maryland and the zip-code-based radon hazard map of Maryland reveals the geological control on indoor radon. The Coastal Plain, composed of Cretaceous and younger poorly cemented sedimentary strata, has the lowest average indoor radon. Of intermediate concern for indoor radon is the eastern side of the Piedmont (mainly Paleozoic high-grade metamorphic rocks and granitic rocks), the Blue Ridge (mainly 1 Ga-old high-grade metamorphic and plutonic rocks), and the Plateau Province (flat-lying mid-upper Paleozoic sedimentary rocks). The area that tends to have the most zip code zones with higher indoor radon levels includes the western side of the Piedmont (low-medium-grade metamorphic rocks) and the Valley and Ridge Province (mainly early Paleozoic limestones and shales that were folded in the middle-late Paleozoic, and now form a karst topography). Studies in Maryland and several other States have indicated that zip-code compilations of large numbers of charcoal and alpha-track indoor radon measurements are useful indicators of indoor radon problem areas. If these compilations are superimposed on a geological map, useful radon hazard maps can be quickly constructed for many States.

Mose, Douglas G., George W. Mushrush, David Saum, Mark Messing, Steven Hall, Nick Gromicko, and Robert Dunkle, 1988
Prediction of indoor radon and home remediation in Fairfax County, VA and Montgomery County, MD [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A337
An important goal of the radon studies program in the Center of Applied Science is to develop site-specific criteria for the identification of (a) homesites with a potential indoor radon problem, (b) home construction features that tend to be associated with elevated indoor radon, and (c) the application a particular remediation method, sub-slab ventilation, to reduce indoor radon in different soil types. Out of a study group of ≈1500 homes in which radon gas was measured during an entire year using four seasonal intervals in each home, a set of 150 homes was studied to determine the relationship between homesite soil radon, soil permeability, and indoor radon. Another set of 150 homes was used to test the effectiveness of sub-slab ventilation. Our study shows that in more than 80% of the homes, the pre-remediation indoor radon could be estimated by measuring the soil radon (Terradex soil monitors, buried at 1 m within ≈5 m of the home for 1-3 months) and the soil permeability (simplified water percolation test). We found that basement wall construction, home heating system, and other factors show a correlation with indoor radon. Finally, we found that a simple sub-slab ventilation system reduced indoor radon to less than 2 pCi/L in most homes, in spite of differences in pre-remediation indoor radon, soil radon potential, or home construction factors. It thus appears that while indoor radon is often predictable by homesite (or regional) criteria and home construction criteria, all homes (at least in the northern Virginia and central Maryland study area) can be adequately remediated by simple sub-slab ventilation to effectively eliminate the home health risk due to radon.

Mose, D.M., C.E. Chrosniak, G.W. Mushrush, and S.L. Davis, 1989
Relationships between radon in water, indoor radon and cancer : A case study in Virginia and Maryland [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 500
Year-long indoor radon measurements have been made in the homes of ≈1500 VA and MD residents from which radon was also measured in drinking water. About 85% of the homes have municipal water, and these had no detectable radon (lower limit of detection is ≈100 pCi/L). Almost all of the water samples from private wells had detectable radon (range up to ≈10,000 pCi/L; median ≈2000 pCi/L). A correlation cannot be demonstrated between drinking water radon and indoor radon, indicating that other factors (e.g., home construction and use) are important. Based on a questionnaire (time in home, cancer if any and when found, etc.), there is a positive correlation between the percentage of people who develop cancer (all types except lung cancer in long-term smokers) and the radon concentration in the drinking water, and the correlation is more pronounced with increasing length of exposure. In the study area, ≈15% of the homes use private water wells; a simple population study shows that the incidence of cancer related to drinking water may exceed the incidence of cancer from inhalation of airborne radon. We recommend that increased attention be given to radon in water, and to associated radionuclides (Ra and Po). We also recommend that 1000 pCi/L for radon in drinking water be used as a national "action level" even though data show there is some risk at the 100-1000

pCi/L level. We note that the large numbers of homes now in the 100 to 1000 pCi/L range, some of which are served by public water systems, makes a "no-risk" action level of 100 pCi/L unreachable.

Moses, Harry, 1961
Multiple regression equations relating meteorological variables with eight-hour average radon concentrations, *in* Argonne National Laboratory, Radiological Physics Division semiann. report, January through June 1961:
U.S. A.E.C. Rept. ANL-6398: 86-95
Nucl. Sci. Abs. 16:2869:
The screening technique of multiple regression analysis is used to relate observed eight-hour average radon concentrations in air with weather conditions in the immediate vicinity. The effects of vertical diffusion and precipitation on radon concentration are taken into account. Improvement of the analysis by additional variables is discussed.

Moses, Harry, F.C. Kulhanek, and G.A. Zerbe, 1957
Meteorology. II. Concentration of atmospheric radon, *in* Radiological Physics Div. Semiann. Rept. January through June 1957:
Argonne Natl. Laboratory Rept. ANL-5755, p. 70-77

Moses, Harry, Henry F. Lucas, Jr., and Gunther A. Zerbe, 1962
The effect of meteorological variables upon radon concentration three feet above the ground, *in* Radiological Physics Division Semiann. Rept., July through December 1961:
Argonne Natl. Laboratory Rept. ANL-6474, p. 58-72
Nucl. Sci. Abs. 16:30185
Case studies based on a time-series comparison of radon and pertinent meteorological variables for periods of clear weather, extremely windy weather, unusually moist ground, and snow cover are presented. A climatological summary is given of the radon measurements as shown by relative frequency diagrams for the four season, time of day, and various ground conditions.

Moses, Harry, A.F. Stehney, H.F. Lucas, Jr. 1958
The effect of meteorological variables upon the vertical and temporal distributions of atmospheric radon, *in* Radiological Physics Division Semiann. Rept., January through June 1958:
Argone Natl. Laboratory Rept. ANL-5919, p. 102-112

Moses, H., A.F. Stehney, and H.F. Lucas, Jr., 1959
The effects of meteorological variables upon the vertical and temporal distribution of atmospheric radon, *in* Radiological Physics Div. Semiann. Rept. July-Dec 1958:
Argonne Natl. Laboratory Rept. ANL-5967, p. 165-182

Moses, Harry, Andrew F. Stehney, and Henry F. Lucas, Jr., 1960
The effect of meteorological variables upon the vertical and temporal distributions of atmospheric radon:
Jour. Geophys. Research, 65(4): 1223-1238

Moses, Harry, and G.A. Zerbe, 1957
Meteorology II. Concentration of atmospheric radon, *in* Radiological Physics Div. Semiann. Rept. July through Dec 1957:
Argonne Natl. Laboratory Rept. ANL-5829, p. 200-203
[Concentrations of atmospheric radon appear to undergo an annual cycle.]

Mowris, R.J., and W.J. Fisk, 1987
Modeling the effects of exhaust ventilation on radon entry rates and indoor radon concentrations:
Berkeley, Calif., Univ. Calif. Lawrence Berkeley Laboratory Rept. LBL-22939, 20 p.

Muchemblé, Georgette, 1952
Observations sur les eaux souterraines radioactives du nord de la France et la radioactivité des roches encaissantes [Notes on radioactive underground waters of northern France and the radioactivity of the enclosing rocks]:
Annales Inst. Hydrologie et Climatologie, 23(72): 29-64
Geophys. Abs. 164-269:
The radon and radium content of several sources of mineral waters of northern France and of geologic formations containing them were determined by Lepape's method. The greatest radium content, 230 pg/L of water, was found in fossil chlorine water of the Bruay region; a much lower radium content was found in the rocks. The most radioactive substances are concluded to be the fossiliferous marine deposits, rich in organic detritus.

Muehleisen, Richard, and Ulrich Boesenberg, 1977
Increase of radioactivity in closed rooms [in German]:
Staub-Reinhalt Luft, 37(2): 68-70
Chem. Abs. 86:129567v
[Ionization rates in room air can be raised by factors of 10 to 30 when closed, probably because of increased emanation and concentration of radon and its progeny. The effect should be investigated because of its health implications.]

Muessig, K[arl] W., 1989
Correlation of airborne radiometric data and geologic sources with elevated indoor radon in New Jersey, *in* Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 1, Symposium Oral Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9- 89/006a [Springfield, Va., NTIS Order No. PB89-167480], p. 5-1--5-12.

Muessig, Karl W., 1989
Uranium cycling in the crust and its relationship to radon hazards in New Jersey [abs.]:
Geol. Soc. America, Northeastern Section, Abstracts with Programs, 21(2): 53
Information accumulated from uranium resource occurrences and more recently on indoor radon problems indicate that anomalous concentrations of uranium and associated elevated radon occur in all of the New Jersey geological provinces. A model of uranium cycling in the crust, involving partial melting, hydrothermal activity, deformation and later fluid movement, is proposed to explain the varied mineralization styles throughout the lithologic column. It also explains the more pervasive uranium enrichment in the western parts of the provinces. The oldest recognizable concentrations of uranium occur in the Precambrian metamorphosed granites and volcanic-sedimentary rocks of the Reading Prong. Widespread enrichment of uranium is characteristic of the granites. Other smaller but more concentrated uranium occurrences are found in the metavolcanics and sediments. Metamorphism, partial melting, hydrothermal activity and deformation were important in recycling and concentrating uranium. Cambro-Ordovician cover rocks in the Valley and Ridge and Reading Prong host equally varied uranium mineralization. Residual uranium-rich minerals are found in the basal Cambrian quartzite. Hydrothermal deposits of uranium cause severe radon problems in some Cambro-Ordovician dolomites. Uranium was also incorporated into the marine shales of the Martinsburg and Jutland Formations during sedimentation and was reconcentrated during diagenesis and hydrothermal activity. The dominant repository for uranium in the Triassic rocks of the Piedmont Province is the lacustrine black shales of the Lockatong Formation. Diagenesis induced the secondary migration of uranium and small secondary deposits are associated with severe radon problems in the arkosic sandstones of the Stockton Formation. These appear to be related to structures and later fluid movements.

Müller, Ferdinand, 1927

Radioaktivitätsmessungen als geophysikalische Aufschlussmethode [Radioactivity measurements as a geophysical information method]:
Zeitschrift Geophysik, 3: 330-336

Müller, Ferdinand, 1931
Zeitschrift Geophysik, 7: 241-
[Radon in soil gas.]

Müller, Hans, 1930
Die Emaniermethode als Mittel zur Untersuchung oberflächenarmer Salze [The emanation method as a means to the investigation of salts of low surface area]:
Zeitschrift physikal. Chemie (A), 149: 257-278
[Ref. Wahl and Bonner, 1951, p. 290. Adsorption of radon on chabazite was approx. inversely proportional to amount of water adsorbed.]

Mumme, I.A., 1959
Ground scintillation survey-Radium Hill area:
South Australia Dept. Mines Mining Review, 108: 62-65
Geophys. Abs. 182-274
A ground scintillometer survey in an area just west and southwest of Radium Hill mine revealed several anomalous radioactive areas, and uranium mineralization is shown to be associated with five of them. Geologic mapping is recommended to determine the economic possibilities, and a radon gas detection survey is recommended in the large areas of alluvium where uraniferous deposits may be concealed.

Murphy, J. A., 1977
Georadiological surveying for oil and gas and subsurface structure contour mapping:
U.S. Patent no. 4,059,760 App. 7/6/76, iss. 11/22/77
Geophysics 43(4): p. 845

Musin, Ya.A., S. Idrisova, V.A. Kabo, N.U. Musin, and A.M. Fedorov, 1985
Mechanism of radon anomalies in the period preceding earthquakes [in Russian], *in* Varshal, G.M., ed., Gidrogeokhim. Predvestniki Zemletryasenii [Hydrogeochemical Precursors of Earthquakes]:
Moscow, Nauka, p. 62-70
Chem. Abs. 104:22211n

Mustonen, R., 1984
Methods for evaluation of radiation from building materials:
Radiation Protection Dosimetry, 7(1-4): 235-238
Chem. Abs. 101:99848w
[Included Rn exhalation]

Nair, N.B., C.D. Eapen, and C. Rangarajan, 1982
High radon levels detected in some non-uranium mines in India, in Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:
New York, John Wiley and Sons, p. 114-118

Nakai, Toshio, 1940
Radium content of mineral springs in Japan:
Japan Chem. Soc. Bull., 15, supp.: 333-426
[Analytical method: emanation, for both Rn and Ra, using electroscope. Samples were collected in flasks of 2l capacity; I could not ascertain susceptibility to Rn loss except that a trial (p. 335) showed a loss of 16%

between a sample that was taken from a spring source and one from the surface (of the bath using the source); temp. not given.]

Narasimhan, T.N., Y.W. Tsang, and H.Y. Holman, 1990
On the potential importance of transient air flow in advective radon entry into buildings:
Geophys. Research Letters, 17(6): 821-824
[Numerical modeling by an integral finite difference method was used to model the temporal variations of air flux within homogeneous soil surrounding a basement during periodic variations of barometric pressure and a persistent 5-Pa underpressure in the basement. The basement walls were assumed to be impermeable, the basement was assumed to be barren earth, and the water table was assumed to be 5 m below the basement floor. In the absence of barometric pumping, the air flow into the basement was computed to be proportional to the soil permeability over the range $0.153–15.3x10^{-12}$ m^2. Barometric pumping with a period of 0.5 hr and peak-to-peak amplitude of 100 Pa amplified the air flow by a factor of ≈70 for the lowest permeability and by a factor of ≈4 for the highest permeability; flow into the basement during increasing barometric pressure slightly exceeded flow into the ground during decreasing pressure for the lowest permeability, but for the highest permeability flow into the basement was several times greater than flow into the ground; and air flow through the vertical plane below the basement wall changed direction for the lowest permeability but was always toward the basement for the highest permeability. Barometric pumping of 500-Pa peak-to-peak amplitude and 24-hr period amplified the air flow into the basement by a factor of ≈29 for the lowest permeability and a factor of ≈3 for 1.53x10-m^2 permeability, but reduced air flow into the basement by a factor of ≈3 for the highest permeability. The results show that with short-period barometric pumping, advective movement of soil air into a basement can be significant even if the soil's permeability is low enough to be negligible under steady-state conditions.]

Nason, Richard, and Bernard L. Cohen, 1987
Correlation between ^{226}Ra in soil, ^{222}Rn in soil gas, and ^{222}Rn inside adjacent houses:
Health Physics, 52(1): 73-77

Nathwani, J.S., and C.R. Phillips, 1978
Rates of leaching of radium from contaminated soils; an experimental investigation of radium bearing soils from Port Hope, Ontario:
Water, Air, Soil Pollution, 9(4): 453-465

National Council on Radiation Protection and Measurements, 1975
Natural Background Radiation in the United States:
Washington, D.C., National Council on Radiation Protection and Measurements Rept. No. 45, 163 p.
Committee chairman: J.H. Harley; members: R.B. Holtzman, W.M. Lowder, D.W. Moeller, A.B. Tanner, N.A. Wogman; consultants: Z.G. Burson, D.T. Oakley. [This report was superseded by Report No. 94.]

National Council on Radiation Protection and Measurements, 1984
Exposures from the Uranium Series with Emphasis on Radon and Its Daughters:
Bethesda, Md., National Council on Radiation Protection and Measurements Rept. No. 77, 131 p.
Committee chairman: J.H. Harley; members: N.H. Harley, J.W. Healy, G.V. LeRoy, E.G. Létourneau

National Council on Radiation Protection and Measurements, 1984
Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States:
Bethesda, Md., National Council on Radiation Protection and Measurements Rept. No. 78, 204 p.
Task group chairman: N.H. Harley; members: F.T. Cross, B.D. Stuart; advisors: V.E. Archer, D.A. Morken; consultant: J.H. Harley

National Council on Radiation Protection and Measurements, 1987

Ionizing Radiation Exposure of the Population of the United States:
Bethesda, Md., National Council on Radiation Protection and Measurements Rept. No. 93, 87 p.
Committee chairman: W.K. Sinclair; members: S.J. Adelstein, M.W. Carter, J.H. Harley, D.W. Moeller
[Figure 8.1 shows radon as contributing 55% of the total average dose equivalent to the U.S. population.]

National Council on Radiation Protection and Measurements, 1987
Exposure of the Population in the United States and Canada from Natural Background Radiation:
Bethesda, Md., National Council on Radiation Protection and Measurements Rept. No. 94, 209 p.
Committee chairman: J.H. Harley; members: R.B. Holtzman, W.M. Lowder, D.P. Meyerhoff, A.B. Tanner, N.A. Wogman; consultants: B.S. Pasternak, J.K. Soldat, J.A. Young

National Council on Radiation Protection and Measurements, 1987
Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources:
Bethesda, Md., National Council on Radiation Protection and Measurements Rept. No. 95, 99 p.
Committee chairman: D.W. Moeller; members: R.J. Guimond, J.W.N. Hickey, E.A. Miller, G.D. Schmidt
[According to sec. 5.2, use of information in International Commission on Radiological Protection Publication 32 concerning conversion of dose to dose equivalent, the dose delivered to the lungs of an average smoker per year by Po-210 is about 13 mSv (1.3 rem), probably the greatest single contributor to the population dose equivalent of all radiation sources, including natural background sources and medical radiation.]

National Council on Radiation Protection and Measurements, 1988
Measurement of Radon and Radon Daughters in Air:
Bethesda, Md., National Council on Radiation Protection and Measurements Rept. No. 97, 174 p.
Committee chairman: N.H. Harley; members: I.M. Fisenne, J.H. Harley, R.G. McGregor, A.V. Nero, M.H. Wilkening

National Council on Radiation Protection and Measurements, 1989
Control of Radon in Houses:
Bethesda, Md., National Council on Radiation Protection and Measurements Rept. No. 103, 90 p.
Committee chairman: D.W. Moeller; members: C.T. Hess, E.F. Maher, A.G. Scott; consultants: R.J. Guimond, J.H. Harley

Naumov, G.B., and O.F. Mironova, 1960
Oxidation-reduction equilibrium in the system uranium-iron in a carbonate environment and its significance to geochemistry [in Russian]:
Geokhimiya (3): 286-293, in translation
From GeoSci. Abs. 4-619:
The experimental investigations already accomplished show that the oxidation-reduction equilibrium in the system U-Fe in a carbonate, neutral, and weakly alkaline environment is almost completely shifted in the direction of U oxidation and the Fe reduction. Such equilibrium may occur under natural conditions, in particular in hydrothermal U-bearing solutions.

Nazaroff, W.W., and S.M. Doyle, 1985
Radon entry into houses having a crawl space:
Health Physics, 48(3): 265-281
The transport of ^{222}Rn from soil, through a vented crawl space, and into the living space of single-family residences was studied. Two houses were monitored in detail for periods of 5 and 7 weeks. With crawl space vents open, the average indoor ^{222}Rn concentrations were 1.2 and 0.6 pCi/L (44 and 22 Bq/m^3); with vents sealed the averages rose to 2.2 and 1.0 pCi/L (81 and 37 Bq/m^3). The data suggest that, of the Rn released into the crawl space from the soil beneath the house, a significant fraction, perhaps 50% or more, enters the living space. The effects of 3 meteorological parameters--wind speed, indoor-outdoor temperature difference,

and rate of barometric pressure change--on Rn concentration and entry rate were examined. In 1 of the houses a higher temperature difference corresponded to a higher indoor concentration, suggesting that the increased infiltration rate is more than compensated by an increase in the Rn entry rate. On the other hand, a high wind speed tended to reduce the indoor concentration, presumably by increasing both cross-ventilation of the crawl space and the infiltration rate of the living space. Results suggest that Rn transport into the crawl space of at least 1 of the houses occurred by pressure-driven flow, rather than solely by molecular diffusion. The diffusion coefficient of ^{222}Rn through polyethylene sheeting, such as was present on the ground beneath this house, was measured in the laboratory and found to range from 0.65 x 10^{-7} cm^2/s at 11°C to 1.6 x 10^{-7} cm^2/s at 25°C, implying that the maximum diffusive flux through the sheet was many times smaller than necessary to account for the rate of Rn entry into the house. A third house was studied using a tracer gas injected into the crawl space at a controlled rate. The fraction of air leaving the crawl space that entered the living space ranged from 0.3 to 0.65, in good agreement with the results for Rn transmission in the other 2 houses, assuming that the ^{222}Rn flux into the crawl space was comparable to that which would have resulted from molecular diffusion from soil having a ^{222}Rn diffusion length of 1.0 m. By sealing leaks in the floor of this house, the average infiltration rate was reduced by 25%, but the indoor concentration of the tracer gas remained constant.

Nazaroff, W.W., H. Feustel, A.V. Nero, K.L. Revzan, D.T. Grimsrud, M.A. Essling, and R.E. Toohey, 1985
Radon transport into a detached one-story house with a basement:
Atmospheric Environment, 19(1): 31-46
We describe the results of a five-month study during which the ^{222}Rn (radon) concentration, air-exchange (or ventilation) rate, and the weather and radon source parameters were continuously monitored in a house near Chicago, with a view to accounting for the radon entry rate. The results suggest that the basement sump and perimeter drain-tile system played an important role in influencing the radon entry rate and that pressure-driven flow was more important than diffusion as a mechanism for radon entry. For the first 15 weeks of the study period the mean indoor radon concentration and air-exchange rate were 2.6 pCi/L (96 Bq/m^3) and 0.22 /h, respectively; both parameters varied over a wide range. Radon concentration measured at the sump cover varied bimodally between 0 and 10 pCi/L (0-400 Bq/m^3) and 300-700 pCi/L (10,000-30,000 Bq/m^3). These two modes corresponded well to periods of low and high indoor radon concentration; average indoor concentrations for these periods were 1.5 and 6.5 pCi/L (55 and 240 Bq/m^3), respectively. For data sorted into two groups according to radon activity at the sump, the indoor radon concentration showed little dependence on air-exchange rate. This result is accounted for by a model in which the radon entry rate, determined by mass balance, has two components--one diffusive, the other a pressure-driven flow component which is presumed to be proportional to the air-exchange rate. In fitting this model to the data we found that (1) the flow component dominated the diffusive component for periods of both high and low activity at the sump and (2) the magnitude of the diffusive component agreed well with the expected contributions of radon emanating from concrete and soil and diffusing into the house. To account for the flow component, we hypothesize that pressure drives air carrying a high concentration of radon generated in the soil, either through the bulk of the soil or along the outside of the basement walls, then into the basement through cracks and openings. During the final six weeks of the study, measurements were made with the water level in the sump maintained first below, then above the entrance of the pipe connected to the perimeter drain tile system. Average indoor radon concentrations during these two periods were 10.6 and 3.5 pCi/L (390 and 130 Bq/m^3), respectively. The relatively high latter value compared with the mean for the first 15 weeks, combined with the observation of intervals of high airborne alpha activity at the sump during this period, suggest that the level of water in the sump does not, by itself, account for the variation in alpha activity at the sump that we had previously observed. Fireplace operation substantially increased the air-exchange rate, but had only a small effect on indoor radon concentration, providing corroborative evidence that pressure-driven flow is an important mechanism for radon entry into this house.

Nazaroff, W.W., S.R. Lewis, S.M. Doyle, B.A. Moed, and A.V. Nero, 1986
Experiments on pollutant transport from soil into residential basements by pressure-driven air flow:

Berkeley, Calif., Univ. California Lawrence Berkeley Lab. Rept. LBL-18374, 26 p.

Nazaroff, W.W., B.A. Moed, and R.G. Sextro, 1988
Soil as a source of indoor radon: generation, migration, and entry, *in* Nazaroff, W.W., and A.V. Nero, eds., Radon and Its Decay Products in Indoor Air:
New York, John Wiley and Sons, p. 57-112

Nelson, Roger A., 1987
Measurement uncertainties of long-term ^{222}Rn averages at environmental levels using α track detectors:
Health Physics, 53(5): 447-453

Nelson, Roger A., Kenneth R. Baker, and W. John Smith II, 1985
Ambient radon concentrations around the inactive uranium mill tailings facility at Durango Colorado:
Albuquerque, N.Mex., Jacobs Engineering Group, Inc., Unpub. manuscript, 29 p.
[See above paper.]

Nelson, Roger A., W. John Smith, and Kenneth R. Baker, 1985
The range and variability of radium concentration and emanating fraction in uranium mill tailings and their impact on radon barrier design, *in* Symposium on Waste Management, Tucson, Ariz., March 24, 1985, Proc.:
Tucson, Ariz., Arizona Board of Regents, Arizona Univ., College of Engineering, File No. TI86006918, Rept. CONF-850314, Vol. 3, p. 197-200

Nelson, R.A., R.P. Schoenfelder, and K.R. Baker, 1985
An evaluation of the suitability of Terradex Track-Etch detectors for environmental Rn-222 measurement [abs.]:
Health Physics Soc., 30th Ann. Mtg., Abstracts

Nero, Anthony V., Jr., 1985
Indoor concentrations of radon-222 and its daughters: sources, range, and environmental influences, Chap. 4, *in* Gammage, Richard B., and Stephen V. Kaye, eds., Indoor Air and Human Health:
Chelsea, Mich., Lewis Publishers, Inc., p. 43-67

Nero, A.V., and W.W. Nazaroff, 1984
Characterising the source of radon indoors:
Radiation Protection Dosimetry, 7(1-4): 23-39
Average indoor radon concentrations range over more than two orders of magnitude, largely because of variability in the rate at which radon enters from building materials, soil, and water supplies. Determining the indoor source magnitude requires knowledge of the generation of radon in source materials, its movement within materials by diffusion and convection, and the means of its entry into buildings. This paper reviews the state of understanding of indoor radon sources and transport. Our understanding of generation rates in and movement through building materials is relatively complete and indicates that, except for materials with unusually high radionuclide contents, these sources can account for observed indoor radon concentrations only at the low end of the range observed. Our understanding of how radon enters buildings from surrounding soil is poorer; however, recent experimental and theoretical studies suggest that soil may be the predominant source in many cases where the indoor radon concentration is high.

Nero, A.V., R.G. Sextro, S.M. Doyle, B.A. Moed, W.W. Nazaroff, K.L. Revzan, and M.B. Schwehr, 1985
Characterizing the Sources, Range, and Environmental Influences of Radon-222 and its Decay Products:
The Science of the Total Environment, 45: 233-244
[Original pub.: Berkeley, Calif., Univ. Calif. Lawrence Berkeley Lab. Rept. LBL-19869 (EEB-Vent 85-9), 12 p.]

Nero, A.V., M.B. Schwehr, W.W. Nazaroff, and K.L. Revzan, 1986

Distribution of airborne radon-222 concentrations in U.S. homes:
Science: 234(4779): 992-997. [Orig. pub.: Lawrence Berkeley Lab. Rept. LBL-18274, 1984]
We have developed a frequency distribution of ^{222}Rn concentrations in U.S. single-family homes by systematically appraising available data using lognormal representations and explicitly considering differences in selection of homes and season of measurements. Results are quite robust, showing a dependence on the specific aggregation approach that is modest and consistent with expectations. Considering the resulting distributions, as well as identifiable sampling uncertainties, the distribution of annual-average ^{222}Rn concentrations in single-family residences can be characterized by a geometric mean of 0.9± 0.1 pCi/L (34± 4 Bq/m^3) and a geometric standard deviation of 2.8 ± 0.2. It appears that concentrations in approximately one million U.S. homes exceed 8 pCi/L, which -- for long-term occupants -- corresponds to an added individual lifetime risk of lung cancer of about 2%.

Newby, I.J.N., 1973
A practical investigation of the parameters controlling radon emanations from an impermeable uraniferous ore [Master's thesis]:
Queen's University, Kingston, Ontario, Canada: 149 p.

Newton, R., and G.F. Round, 1961
The diffusion of helium through sedimentary rocks:
Geochim. Cosmochim. Acta, 22(2/4):106-132
[Elaborate analytical approach to one-dimensional diffusion in multi-layered medium.]

Ney, E.P., and Lively, R.S., 1989
Boundary conditions affecting radon estimation based upon daughter deposition, in Osborne, M.C., and Harrison, Jed, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 1, Symposium Oral Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006a [Springfield, Va., NTIS Order No. PB89-167480], p. 4-65--4-68.

Nicolaysen, L.O., 1957
Solid diffusion in radioactive minerals and the measurement of absolute age:
Geochim. Cosmochim. Acta, 11: 41-59

Nielson, Kirk K., and Vern C. Rogers, 1980
Radon flux through multilayered covers over uranium mill tailings:
Am. Nuclear Soc. Trans., 34: 131-132

Nielson, K.K., and V.C. Rogers, 1982
Theoretical modeling of CO_2, krypton, and radon diffusion coefficients for low-level waste sites:
Am. Nuclear Soc., Trans. 41:56

Nielson, K.K., and V.C. Rogers, 1989
Radon generation, absorption and transport in porous media — the RAETRAN model [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 497
A new mathematical model has been developed to describe the generation and transport of radon gas in soils. It is aimed at describing radon sources and their availability for entry into the indoor environment from sub-structure soils. The model is a multiregion, one-dimensional analytical model. It combines individual mathematical descriptions of radon emanation, diffusive transport, and advective transport in both gas- and liquid-filled pore space. It explicitly considers the equilibrium absorption of both radon and radium in the liquid phase and of radon adsorption on solid surfaces. The model is implemented in a Fortran code, RAETRAN, which computes radon fluxes and distributions for prescribed source concentrations, pressure

gradients, concentration boundary conditions, moistures, and a variety of soil properties. The code uses defining properties for any number of regions. Defining properties may include the soil thickness, porosity, radium concentration, emanation coefficient, moisture, grain size distribution, diffusion coefficient, gas permeability, temperature, and applied pressure gradient. For cases in which suitable input values of soil gas permeability, diffusivity, or radon emanation coefficient are not known, the code computes appropriate values from empirical correlations with the soil particle size distribution, moisture content, and porosity. By unifying the theories of radon generation and transport, the model avoids previously required approximations and inconsistencies, and correctly describes radon source strengths and availabilities. It has been applied in describing experimental systems and sensitivity testing of the source parameters that affect indoor radon concentrations.

Nielson, K.K., V.C. Rogers, and G.W. Gee, 1984
Diffusion of radon through soils: a pore distribution model:
Soil Sci. Soc. America Jour., 48(3): 482-487
Chem. Abs. 101:45240y:

Nikitin, B.A., 1937
Trav. Inst. État Radium, U.R.S.S., 3: 228
Chem. Abs. 31:4590 (1937)
[Cited by Bagnall on solubility of $RaCO_3$.]

Nikitin, Boris, and Otto Erbacher, 1932
Ein Beitrag zur Gultigkeit des Massenwirkungsgesetzes I. Die Löslichkeit von Radiumsulfat in Schwefelsaure- und Natriumsulfat- Lösunge [A contribution on the validity of the law of mass action. I. The solubility of radium sulfate in sulfuric acid and sodium sulfate solutions]:
Zeitschrift physikal. Chemie, 158: 231-236

Nikitin, B.A., and E.K. Gerling, 1938
O vydelenii radona iz uranovykh mineralov [On the liberation of radon from uranium minerals]:
Radievyy Inst. Trudy, 4: 318-322
Geophys. Abs. 103-5818

Nikitin, B.A., and E.M. Joffe, 1944
Adsorption of radon on charcoal under dynamic conditions [in French?]:
Acad. Sci. U.R.S.S., Cl. Sci. Chim., p. 210-215

Nikitin, Boris, and Paul Tolmatscheff [Tolmachev], 1933
Ein Beitrag zur Gultigkeit des Massenwirkungsgesetzes. II. Quantitative Bestimmung der Löslichkeit des Radiumsulfats in Natriumsulfatlösungen und in Wasser [A contribution on the validity of the mass-action law. II. Quantitative determination of the solubility of radium sulfate in sodium sulfate solutions and in water]:
Zeitschrift physikal. Chemie, A167: 260-272

Nogami, H.H., and P.M. Hurley, 1947
Experimental test of predicted adsorption of alpha-rays in minerals [abs.]:
Geol. Soc. America Bull., 58(12), pt 2: p. 1214
Geophys. Abs. 9852:
It was desired that the Bragg-Kleeman rule, giving the approximate range and thus the absorption of the various alpha rays from the U and Th series in different media, be checked experimentally to see if it was sufficiently accurate to make the correction for the "stopping power" of the minerals. For this purpose a number of pulverized mineral samples, previously analyzed for U and Th by Rn and Tn measurement, were tested for total emission from a plane surface of the powder on a source plate, the thickness of source exceeding the

maximum alpha-ray range. The theoretical emission from each sample was computed from the Rn-Tn value, assuming the stopping power of the mineral to be proportional to the sum of the atomic fraction times the square root of the atomic weight of the elements in the mineral. It was found that the observed emission agreed with the predicted emission with 4 percent, over a range of mineral densities.

Noguchi, Masayasu, and Hiroshi Wakita, 1976
Radon. Recent development in its measurement and its application to earthquake prediction: [in Japanese]:
Oyo Butsuri, 45(5): 453-458
[Review with 21 references.]

Noguchi, Masayasu, and Kiroshi Wakita, 1977
A method for continuous measurement of radon in ground water for earthquake prediction:
Jour. Geophys. Research, 82(8): 1353-1357
Chem. Abs. 86:177004f

Norinder, Harald, Reinhards Siksna, and Arvids Metnieks, 1952
Radon and thoron contents of the soil-air at Almunge:
Geol. Fören., Stockholm Förh., 74(4): 450-454
Geophys. Abs. 14555
Measurements of the radioactivity of soil air were made at the Institute of High Tension Research of Uppsala University. Air from the soil was sucked into an ionization chamber through a pipe driven into clefts in a pegmatitic facies of thorite-containing canadite. After collecting the air in the ionization chamber, the chamber was connected with a bifilar Wulf electrometer and the radioactivity of the air in the chamber determined by the electrical leak produced. Radon and thoron activities were distinguished by the difference in the disintegration periods. The shape of the ionization curve may indicate the presence of thorium minerals but the relation of the primary sources cannot be calculated from the emanations because of the various uncertainties involved.

Norinder, Harald, Arvids Metnieks, and Reinhards Siksna, 1953
Radon content of the air in the soil at Uppsala:
Arkiv Geofysik, 11(5-6): 571-579
Geophys. Abs. 153-14556
Measurements of the radon content of the soil air, carried out at the Institute of High Tension Research of Uppsala University from August 1950 to October 1951, were made to determine if the locality was very rich in emanation. All measurements were made with an ionization chamber and electrometer of the Wulf bifilar type, the calibration of which was determined by calculation rather than by use of a radium standard; without absolute values, the radon measurements at Uppsala cannot be compared directly with the values found by investigators in other countries. The measurements verified an abnormally high radon content from 1 to 6 nCi/L at a depth of 90 cm. Air in basement rooms of the Institute had radon content as high as 0.5 nCi/L. Thoron measurements showed a Rn/Tn ratio between 1.5E3 and 10E3.

Norton, S.A., W.F. Brutsaert, C.T. Hess, et al, 1978
Geologic controls on natural levels of Rn-222 in ground-water in Maine [abs.]:
Geol. Soc. America, Abstract Programs, 10(2): p. 78

Novikov, G.F., 1966
Vliyaniye emanirovaniya toriyevykh rud na radiometricheskikh izmereniya [Effect of emanation of thorium ores on radiometric measurements]:
Leningrad Gornyy Inst. Zapiski, 51(2): 114-124

Nozaki, Yoshiyuki, 1986

^{226}Ra-^{222}Rn-^{210}Pb sytematics in seawater near the bottom of the ocean:
Earth Planet. Sci. Letters, 80(1): 36-40

Nussbaum, Elmer, 1962
Diffusion of radon and tritium through semipermeable materials: Technical progress report:
Upland, Indiana, Taylor Univ. Rept. TID-15160: 27 p.
Nucl. Sci. Abs. 16:12113, 1962
The rates at which radon and tritium are diffused through sheets of rubber vulcanizates, plastic films, and papers were investigated. A modified reaction flask, with semipermeable membrane interposed between glass hemispheres, was used in the diffusion studies. Samples containing radon or tritium were assayed for gamma activity. Data from typical experiments are tabulated. Results indicate that the diffusion of tritium proceeds more slowly than radon at the same temperature through all rubber vulcanizates tested, but more rapidly through certain plastic films and wax-coated papers. The diffusion of radon and tritium through semipermeable materials was found to be directly related to temperature, but there appears to be a wide variation in the effectiveness of change in temperature on transmission rates.

Nussbaum, E., and John B. Hursh, 1958
Radon solubility in fatty acids and triglycerides:
Jour. Phys. Chemistry, 62: 81-84

Nussbaum, E., Oana, Shinya, and Kazuo Kuroda, 1940
Geochemische Untersuchungen der Vulkane in Japan. XXIV. Radongehalt von Mineralwasser in Masutomi [Geochemical investigations of volcanoes in Japan. XXIV. Radon content of mineral water in Masutomi]:
Japan Chem. Soc. Bull, 15(12): 484-486
[Measurement of Rn content of 7 thermal waters (18.8-32.3°C) in both July 1939 and October 1940 gave differences by factors of about 1/3, 1/40, 1/3, 4, 1/10, 1/300 and 1/10. Boyle's law and Henry's law corrections were not made.]

O'Brien, Keran, 1980
Human dose from radiation of terrestrial origin, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1163-1210

Ochiai, Toshiro, 1951
Radioactive exploration on the faults [in Japanese with English summary]:
Geophys. Exploration, 4(2): 78-83
Geophys. Abs. 148-13487:
In an experiment in the fault zone at Manazuru, Kanagawa-ken in 1951, radioactive intensity was measured by boring a hole in the ground and putting into it a Geiger-Müller counter. Results of the experiment clearly indicate that the place where the maximum radioactivity was shown agreed well with the place where a fault crosses, and that an area about 200 m wide has a greater radioactive intensity.

Okabe, Sigeru, 1956
On some relations between the hot spring and radioactivity:
Kyoto Univ. Coll. Sci. Mem., ser. A, 28(1): 39-71
Geophys. Abs. 169-264:
Rapid and violent fluctuations of the radon content of hot spring water were observed at several places in Japan by a method that involved bottling samples of the water and after 3 hours, during which the radon reached equilibrium with its daughter products, measuring the activity of the precipitate formed when sulfuric acid and barium nitrate were added. The variations are believed due to the differences in the amounts of radon contributed to the thermal waters by underground cavities containing radioactive liquids. Observations at

several places indicate a correlation between a high radioactive background and the occurrence of hot springs, and between radioactivity and temperature. The source of the radon is presumed to be at a shallow depth and not connected with the original source of the spring water.

Okabe, Sigeru, 1956
Time variation of the atmospheric radon-content near the ground surface with relation to some geophysical phenomena:
Kyoto Univ. Coll. Sci. Mem., ser. A, 28(2): 99-115

Okabe, Sigeru, 1957
On some relations between atmospheric ions and natural radioactivity:
Kyoto Univ. Coll. Sci. Mem., ser. A, 28(3): 231-252
Geophys. Abs. 173-335:
The distribution of alpha-particles in the air near the ground was determined by measurement with a nuclear plate camera. The density of alpha-particles in the lower layer of air was found to be small and the application of the theory of eddy diffusion to these particles is believed to be wrong. A correlation between atmospheric radioactivity and the atmospheric ions was found to exist at night but not during the day. The ratio of atmospheric ions ionized by atmospheric radioactive substances to the total number of ions was calculated to range from 0 to 80 percent. The mean correlation coefficient between earth radiation and atmospheric ions was estimated to be 0.62. The percentages of ions formed by earth radiation and by atmospheric radioactivity are presumed to be 60 to 79 percent and 10 to 20 percent respectively.

Omes', S.P., Yu.V. Bondarenko, N.I. Zakharova, and F.P. Borkov, 1963
Ob izuchenii gamma-polya nad neftyanymi i gazovymi mestorozhdeniyami [On the study of the gamma-field over oil and gas fields], *in* Yadernaya Geofizika [Nuclear Geophysics]:
Moscow, Gostoptekhizdat, p. 233-245

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A model for the temporal and spatial variation of radon concentration as seismic precursor [abs.]:
Eos, Am. Geophys. Union Trans., 60(32): 589-590

Oshima, Yoshio, Naoharu Yamada, and Masaaki Mifune, 1954
Radon content of hot springs in Tottori prefecture, Japan [in Japanese with English summary]:
Okayama Univ. Balneological Lab. Repts., 14: 1-4
Geophys. Abs. 158-194:
The radon content of 166 water samples from hot springs in Iwai, Tottori, Yoshioka, Mamamura, Togo, Sekigane, Misasa, and Kaike was measured with an I.M. Fontactoscope. Sixty-six contained more than 3 nCi/L, the highest being 115 nCi/L at Hisui-no-Yu in Misasa. The radon content was higher in springs which issue from granite than those in other districts. No definite relation between radon content and temperature of water was determined. Radon content was generally high in "simple" thermal waters or in weak sodium chloride springs, but low in sulfated springs or in saline springs that had a comparatively high sulfate content.

Ospanov, A.B., 1985
Characteristic of earthquake prediction from radon anomalies in ground waters [in Russian], *in* Varshal, G.M., ed., Gidrogeokhimicheskiy Predvestniki Zemletryasenii [Hydrogeochemical Precursors of Earthquakes]:
Moscow, Nauka, p. 74-81
Chem. Abs. 104:22213q

O'Sullivan, M.J., and R. McKibbin, 1986
Heat transfer in an unevenly heated porous layer:
Transport in Porous Media, 1(3): 293-312

Otton, James K., 1987
Indoor radon—Geologic controls in Pacific Northwest [abs.]:
Geol. Soc. America, Abstracts with Programs, 19(2): 122
Three-month, wintertime, indoor radon measurements of over 16,000 residences in selected areas of the northwest U.S. by the Bonneville Power Administration show higher radon values (more than 10 percent of homes greater than 5 pCi/L) in townships in the Spokane and Rathdrum Prairie areas (SRP) of northeast Washington and northern Idaho, the Milton-Freewater area (MF) in eastern Oregon, several communities along the lower Columbia River (LCR), and several communities along the Willamette River valley (WRV) in western Oregon. Maximum values approach 100 pCi/L near Spokane; of the 24 values exceeding 25 pCi/L in the entire dataset more than half are from SRP. Throughout the SRP area, soils have relatively high soil uranium contents compared with the rest of the Northwest (2-3 ppm equivalent uranium estimated from aeroradiometric data), and the soils are typically rapidly to very rapidly permeable because they are developed on coarse glacio-fluvial outwash. Rapidly permeable soils permit more radon-bearing gas to enter into structures. Persistent low values occur in the Puget Lowland from Seattle northward to Everett (for example, in T27N, R4E, 1165 homes averaged 0.46 pCi/L radon with a maximum value of 2.84 pCi/L); however the southern suburbs of Seattle show higher values in four townships (in T19N-R2 to 5E, 247 homes averaged 1.48 pCi/L with a maximum of 17.71 pCi/L). Although no significant differences can be seen in the permeability of the soils from north to south across this area, the average equivalent uranium value for soils increases systematically from about 0.5 ppm at the latitude of T32N to 1.5 ppm at the latitude of T19N. In the other areas (LCR, WRV and MF), higher indoor radon values usually correspond to rapidly permeable soils and higher soil uranium contents. These data suggest that most higher indoor radon levels in the Pacific Northwest are associated with rapidly permeable soils and soil uranium concentrations about 1.5 ppm and above. Overall, however, indoor radon levels in the Pacific Northwest are regionally low compared with other areas under examination in the U.S.

Otton, James K., 1987
Potential for indoor radon hazards: A first geologic estimate, *in* Radon and the Environment, Conference Proceedings, Mahwah, N.J., May 8-10, 1986, Makofske, William J., and Michael R. Edelstein, eds.:
Mahwah, N.J., Ramapo College of New Jersey, Inst. for Environmental Studies, p. 28-33

Otton, J.K., 1987
Significant accomplishments of research programs, 1986. Radon hazards in the United States: the role of geology:
U.S. Geol. Survey Yearbook, Fiscal Year 1986, p. 38-41

Otton, J.K., 1987
Some thoughts on the role of site modification in the indoor radon problem, *in* International Symposium on the Natural Radiation Environment, 4th, Lisbon, Portugal, December 7-11, 1987:
Lisbon, Commiss. European Communities, U.S. Dept. Energy, and Dept. Proteccao e Seguranca Radiol. [Portugal], Book of Abstracts, no. 127

Otton, J.K., 1988
Radon potential of rocks and soils: a Fairfax County case history [abs.], *in* Proceedings of the 1988 Symposium on Radon and Radon Reduction Technology, Denver, Colorado, Oct. 19-22, 1988:
U.S. Environmental Protection Agency, Washington, D.C.

Otton, J.K., 1989
Mapping the radon potential of rocks and soils:
The Professional Geologist, 26(5): 8; also Virginia Minerals, 35(1): 2-3

Otton, J.K., 1989

Using geology to map and understand radon hazards in the United States:
U.S. Geol. Survey Yearbook, Fiscal Year 1988, p. 52-54

Otton, J.K., 1990
Origin of sedimentation and uranium in the Boston Peak Fen, north-central Colorado [abs.], *in* Society for Wetland Scientists Ann. Mtg., 11th, Breckenridge, Colo., June 6, 1990:
The Boston Peak fen is located in the upper Laramie River valley 75 km west of Fort Collins, Colorado. The depression that hosts the wetland formed shortly after Late Pleistocene glacial ice retreated from the valley floor. Unstable Tertiary sediments and moraine on the valley wall slumped onto the valley floor and dammed part of it. Water ponded in the 10-15 m deep depression and clay and silt accumulated. About 10,000 years ago, pond weeds became established, and organic productivity increased. About 3,000 years ago, downcutting of the spillway and infilling of the pond created conditions shallow enough for the establishment of peat-forming sedges. Up to 3.5 m of peat has accumulated. Recently, shrubs and willows have invaded the wetland. Initially, uranium derived from spring and shallow ground waters was adsorbed from the water by organic matter in the sediment to form layers ranging in uranium content from 10 to 150 ppm. As the wetland developed, ground-water recharge zones (spring pools, marginal seeps) became point sources of metal input, and as much as 3,300 ppm uranium accumulated locally in the peat.

Otton, James K., and Joseph S. Duval, 1990
Geologic controls on indoor radon in the Pacific Northwest [abs.], *in* The 1990 International Symposium on Radon and Radon Reduction Technology, Atlanta, Ga., 19-23 February 1990:
Preprints, Vol. III, no. VI-5
Indoor radon data for some townships in the Pacific Northwest (Washington, Oregon, Idaho, western Montana, and western Wyoming) have been compared with aerial gamma-ray data which show the radium content of surface materials. Surface radium measurements provide a first-order estimate of the average levels of indoor radon where soils have low to moderate intrinsic permeability. Areas with significantly higher average indoor radon are almost all characterized by soils that have higher permeabilities, based on county soil descriptions. The permeability effect is greatest in the dry areas (less than 50 cm annual precipitation) in the eastern part of the study area. In the wet Puget lowland, elevated indoor radon levels occur only in houses on soils with extremely high permeability. Some of the areas above the general trend are also characterized by steep slopes.

Otton, James K., and Linda C.S. Gundersen, 1988
Geologic assessments of radon potential at county scales [abs.], *in* Radon in the Northeast: Perspectives and Geologic Research (conference), Troy and Albany, New York, May 31-June 2, 1988:
Northeastern Environmental Science, 7(1): 7-8
[Assessments of indoor radon potential have been made for Fairfax County, Va. (Otton and others, 1988) and for Montgomery County, Md. (Gundersen and others, 1988) using mainly indirect data, such as aeroradiometric surveys, geologic maps, and soil surveys, and supplementary measurements of radon in soil gas. Maps delineating areas of radon potential in five tiers or three tiers, respectively, have been published and show excellent correspondence between rock and soil types and indoor radon data in both counties.]

Otton, James K., R. Randall Schumann, Douglass E. Owen, and Alan F. Chleborad, 1988
Geological assessments of radon hazards: A Colorado case history [poster abstract], *in* Marikos, Mark A., and Robert H. Hansman, eds., Geologic Causes of Natural Radionuclide Anomalies, Proceedings of the GEORAD Conference, St. Louis, Mo., April 21-22, 1987:
Rolla, Mo., Missouri Dept. Nat. Resources, Div. Geology and Land Survey Spec. Pub. No. 4, p. 167
A preliminary geologic assessment of radon hazards must often rely on existing data to characterize those geologic features that are likely to influence indoor radon levels indirectly. The features believed to be the most important are the radium content and permeability of the soil and substrate (surficial materials, weathered and unweathered bedrock) at or near the ground surface. Because no databases exist that can provide direct information on the distribution of these features, interpretations of geological, geochemical, and

geophysical data form the basis for assessment. These principles are illustrated in a recently compiled preliminary assessment of radon hazards in the State of Colorado. Key databases used include the NURE aeroradiometric flight-line data (most of the State was flown at a 3-mile [5-km] flight-line spacing; several areas were flown at a 1-mile spacing), uranium occurrence compilations (Colorado has been intensively explored for uranium), and soil permeability estimates from Soil Conservation Service mapping (less than half the State is covered but more than 90% of the State's population lives in the covered areas). ¶Colorado has long been known to have high natural-background radioactivity. Uranium concentrations in soils across the State probably average just below 3 ppm, as estimated from examination of NURE flight-line data, so most soils across the State are expected to have several hundred pCi/L of radon in the soil gas. Thus, in virtually all areas of the State a significant percentage of homes (10-30%) are expected to have elevated (>4 pCi/L) indoor radon levels. The area considered to have the highest risk includes all the Front Range of Colorado, from Pueblo north to the Colorado-Wyoming State line. This area is underlain by granitic, metamorphic, volcanic, and sedimentary rocks, including several moderately (3-6 ppm uranium) to highly (>6 ppm uranium) uraniferous granites and many smaller uranium occurrences and deposits. Soils over the granites, many metamorphic rocks, and alluvium are typically highly permeable, and the rocks are, in many areas, highly fractured.

Otton, J.K., R.R. Schumann, D.E. Owen, Nelson Thurman, and J.S. Duval, 1988
Map showing radon potential of rocks and soils in Fairfax County, Virginia:
U.S. Geol. Survey Misc. Field Studies Map MF-2047, scale 1:48,000

Ovchinnikov, A.K., Yu.V. Khromov, and A.V. Fomin, 1970
Novaya radiometricheskaya apparatura dlya poiskov i razvedki mestorozhdeniy radioaktivnykh rud [New radiometric apparatus for prospecting for and exploring radioactive ores]:
Razvedka i Okhrana Nedr, (9): 36-39
Geophys. Abs. 295-518:
...The "Radon" field scintillation emanometer is for measuring concentrations of radon and thoron in soil, air, or water samples, and for dosimetric measurements....

Owczarski, P.C., D.J. Holford, H.D. Freeman, and G.W. Gee, 1989
Effect of soil porosity, permeability, and water content on radon flux from soil surfaces [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 500
A computer code, RN3D*, was used to study the effects of varying the water content of five homogeneous soil types (gravel, sand, silt, clay, and loam) on the transport of radon from soil surfaces. Dry soil air permeabilities ranged from 10^{-3} to 10^{-9} m/s. Total porosities ranged from 0.27 to 0.54. Temperature (20°C) and radium content were assumed to be the same for all soils. Surface fluxes and concentrations were computed for zero (steady state), steadily increasing and decreasing, and sinusoidal (e.g., diurnal) changes in atmospheric pressure. These pressure changes drive the advective radon transport, which shows a net enhancement for sinusoidal changes. The magnitude of this enhancement for the five soil types was studied by varying the water content from dry to saturated. Water fills soil pores and affects the radon emanation coefficient, air-filled porosity, soil permeability, and ultimately the effective diffusion coefficient of radon. The effective radon diffusion coefficient in m^2/s varies between 10^{-5} times the soil tortuosity at dryness to 10^{-9} times the soil tortuosity when water-saturated. Radon flux is affected as much by varying soil water content as it is by varying soil type (i.e., porosity and permeability). (*RN3D is a three-dimensional finite-element code that has been developed by D.J. Holford at New Mexico Tech and the Pacific Northwest Laboratory to simulate the transport of radon gas within and from unsaturated soils with or without parallel, partially penetrating cracks and other heterogeneities.)

Owen, Douglass E., 1989

Characterization of radon: Constraints of scale, Sec. O, *in* Duray, John R., *et al.*, eds., Proceedings of the Technical Exchange Meeting on Assessing Indoor Radon Health Risks, Grand Junction, Colo., September 18-19, 1989:

Grand Junction, Colo., U.S. Dept. Energy, Grand Junction Projects Office, Tech. Measurements Center, Rept. CONF-8909190, 2 p.

The size of the area to be assessed for radon determines the constraints on the techniques to be used and the data that are applicable. Studies of large land areas (small map scales) have by their very nature much less detail, and are therefore less constrained. At these scales many parameters can be generalized, averaged, or interpolated. Conversely, the smaller the land area, or the larger the map scale, the greater the constraints. The greater detail required to adequately characterize a small area necessitates collecting data that are more specific. As one investigates smaller areas or specific processes (even approaching the molecular level) the number and detail of parameters that must be taken into consideration increases, and the task of assessing radon becomes more complicated. ¶A radon assessment of several counties or a whole State can make used of generalized geologic and soils maps. A radon assessment of a single home site, however, may need new detailed geologic mapping and soils investigations. For example, Gundersen (1989 ["Anomalously high radon..."]) has shown that localized shearing in rocks can mobilize and concentrate uranium, producing elevated radon levels. Localization may be such that houses next to each other have order-of-magnitude differences in their indoor radon levels. Most areas in the country do not have detailed enough geologic mapping to delineate such shear zones. ¶For information on regional permeability, Soil Conservation Service (SCS) maps are adequate. However, there is too much variability in soils to reliably use SCS soil maps to characterize the soil at a single home site, and soil profiles and soil characteristics will need to be determined specifically for that site. ¶Aerial radiometric data may or may not be suitable for use in radon assessments, depending upon the scale of the assessment. Most of the aerial radiometric surveys available for the U.S. were flown during the National Uranium Resource Evaluation (NURE) program. The NURE surveys were generally flown at a height of 125 m above the ground, with a spacing of 5 or 10 km between flight lines. The radius of investigation is two times the height, yielding actual ground coverages of 10% and 6%, respectively. At a small map scale, e.g., 1:250 000, this is probably adequate, but for large map scale studies the chance is remote that a flight line passed directly over the site that is to be characterized. A limitation of both ground and aerial γ-ray surveys, in certain cases, is that approximately 90% of the measured γ-ray signal originates within 30 cm of the surface of the ground. Therefore, in areas where radionuclides in the soil may have been leached from near the surface and redeposited below 30 cm, the γ-ray survey will give a low reading. The soil zone below 30 cm, however, is still within radon migration range of a home [with a basement—ABT]. Gamma-ray surveys also assume secular equilibrium between uranium [or radium] and its various daughters in the soil, which is not always a valid assumption and could result in an over- or underestimate of actual near-surface uranium content in some cases. ¶The following is a list of characterization scales (after Schumann) demonstrating the effect of scale on characterization methodology. Ideally, in order to properly characterize an area, something must also be known about the processes involved and the geologic and soil characteristics from two steps lower on the list. For example, in characterizing a State (1) for radon potential, information on a county scale (2) and small-scale bedrock and SCS soil maps (3) must be used. <u>Characterization scales:</u> (1) Region/State; (2) County(ies)/township(s); (3) Bedrock/soil units; (4) Single building site and (a) house construction characteristics; (5) Macroscopic soil properties, (a) soil profiles, (b) permeability, and (c) meteorologic effects; (6) Molecular-scale properties of soil particles and radon, (a) location of radium, and (b) radon emanation [emanating power].

Owen, Douglass E., 1990

The use of radon-222 as an indicator of ground-water input and for flow-rate determinations at Boston Peak Fen, Larimer County, Colorado [abs.], *in* Society of Wetland Scientists Ann. Mtg., "Wetlands- The next decade," Breckenridge, Colorado, June, 1990:

Abstracts, p. 57

[See abstract below.]

Owen, D.E., 1990
The use of radon-222 as an indicator of ground water input and for flow-rate determination at Boston Peak Fen [abs.], *in* Environmental Forum 1990: Geoscience investigations that emphasize chemical, physical, and biological ecosystem processes:
U.S. Geol. Survey Open-file Rept. 90-288, p. 21
Radon-222 (Rn), a naturally occurring radionuclide (part of the Uranium-238 decay series), is found in detectable amounts in most ground water. Rn can readily be separated from water samples in the field and measured in an alpha scintillation counter. Because Rn has a half life of 3.8 days, it makes an excellent indicator of recent minerotrophic water input. After 15 days, only 6% of the original Rn concentration remains. Therefore, Rn can be used to determine whether pools present in a wetland have a strong connection to the ground-water system or are being fed by waters moving slowly through the peat. Radon can also be used as a natural tracer to determine the flow rate of water from point sources, such as spring pools. The test procedure involves digging small pits at regular intervals away from the spring pool and leaving them undisturbed for at least 26 days, before measuring their water Rn concentration. The decay curve of Rn is used in conjunction with the spring pool (source) Rn concentration, to calculate a flow rate from the point source. I calculated flow rates between 4.5 and 5.2 cm/day for water movement from several spring pools in the Boston Peak fen.

Owen, Douglass E., Sigrid Asher-Bolinder, and R. Randall Schumann, 1988
Assessment of natural phenomena producing fluctuations and variations in soil-gas radon-222 concentrations [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A354
Although a correlation between soil-gas radon-222 concentrations and local geologic-pedologic setting has been identified and documented by several researchers, less is known quantitatively about the influence of climatic and meteorological phenomena on soil-gas radon concentrations. Assuming that over a year the geology and soil characteristics remained essentially constant, we selected and monitored a single site on the Denver Federal Center, Colorado, near a weather station from which hourly meteorological data were acquired. The site is little disturbed, unwatered [unirrigated], and mowed only twice a year, and thus favors the investigation of natural phenomena. Soil moisture conditions caused by precipitation and evaporation have a profound effect on soil-gas radon concentrations. Addition of soil moisture changes the effective gas permeability of the soil by occupying pore space and causing the swelling of expandable clays. Moisture-saturated layers also can produce capping effects. At the site, the larger seasonal variations in soil-gas radon concentrations are attributed mostly to changes in the soil moisture regime. The day-to-day smaller-scale fluctuations in soil-gas radon concentrations are attributed to changes in barometric pressure, soil and air temperature, soil moisture, and wind. Interrelation of these factors makes it difficult to determine the magnitude and individual influence of any one factor. Through an understanding of the geology and pedology of a site and of their interaction with climatic and meteorologic parameters, it may become possible to make predictions about ranges of radon-222 concentrations that can be expected during the course of a year.

Owen, Douglass E., R. Randall Schumann, and James K. Otton, 1988
Reconnaissance of Colorado Front Range bogs for uranium and other elements, *in* USGS Research on Energy Resources–1988; Program and abstracts:
U.S. Geol. Survey Circular 1025, p. 42-44
Alpine bogs or mountain wetlands in the Colorado Front Range commonly form along spring lines in valley floors and in areas where drainage is restricted by moraines, slides, and beaver dams. The bogs generally lie between 7000 and 10000 feet [2100 and 3000 m] elevation and are geologically young (late Pleistocene or early Holocene to late Holocene). The alpine bogs are classified botanically as fens (sedge, grass, or reed-dominated minerotrophic peatlands), as carrs (wetlands that occur on organic soil composed of minerotrophic peat with greater than 25% shrub cover), as bogs (where sphagnum moss is dominant), or as a combination of these. These bogs or wetlands contain peat and organic-rich muck from a few decimeters to several meters thick. Peat has a great affinity for highly charged cations such as uranyl (UO_2^{2+}) that can be complexed and

carried in local ground water. The geochemical enrichment factor between peat and uranium-bearing ground water can approach or exceed 10^4. As the bog sediments are geologically young, the uranium is in gross disequilibrium with its daughters, and the resultant low gamma radioactivity makes these occurrences undetectable by ground and aerial γ-ray surveys. ¶Reconnaissance auger sampling of bogs was conducted in the Colorado Front Range from the South Park area to the Colorado–Wyoming State line. Samples were dried and analyzed for elemental uranium and thorium using a delayed-neutron activation technique. In addition, some samples were analyzed for 44 elements using inductively coupled plasma–optical emission spectrometry. Most of the bogs have uranium concentrations in the 10-100 ppm range; however, samples from several of the bogs have uranium concentrations as high as 1000-3000 ppm on a dry-weight basis. Some of the bog samples show concentrations of between 100 and 1000 ppm for Ba, Mn, Sr, and Zn. Bi, Cr, Co, Cu, Ga, Pb, Ni, Sn, and V were found in concentrations between 10 and 100 ppm on a dry-weight basis in some of the samples. These elements are not necessarily associated with high uranium concentrations. ¶Some of the bogs, in addition to being mined for peat, may contain enough uranium to be of commercial interest. Furthermore, uraniferous bogs are of environmental concern because of the previously unrecognized risk to local water quality. Uranium (and other metals) could be remobilized from the peat during interaction with acid mine drainage or during oxidation following a lowering of the water table or draining of the bogs. Because of the results of this reconnaissance study and the importance of these wetlands as natural filters, in a region where a high percentage of the water for domestic use comes directly or indirectly from the wetlands, a multidisciplinary approach has been initiated to investigate the processes involved in the migration and trapping of uranium and other elements.

Ozerkov, E.L., 1971
Rastvorimost' i vysalivaniye radona iz vodnykh rastvorov NaCl [Solubility and salting-out of radon from sodium chloride aqueous solutions]:
Novyye Issled. v Khimii, Metallurgii i Obagashchenii, (3): 83-87

Pacelli, Marino, 1962
On the radioactivity of Italian thermal springs:
Ann. Med. Navale (Rome), 67: 109-112
Nucl. Sci. Abs. 17:20200

Paredes, Carmela Hernandez, 1984
Determination of radioactivity in and radon emanation coefficient of selected building materials and estimation of radiation exposure from their use [Ph.D. Thesis]:
West Lafayette, Ind., Purdue Univ., 183 p. [Univ. Microfilms]

Paschoa, A.S., J.A. Torrey, and M.E. Wrenn, 1985
Reducing radon exhalation from covered tailings: optimization or cost effectiveness?:
The Science of the Total Environment, 45: 187-194

Paschoa, A.S., M.E. Wrenn, and J.A. Torrey, 1984
A mathematical model of indoor radon and daughters:
Radiation Protection Dosimetry, 7(1-4): 139-142
Chem. Abs. 101:99836r:

Parthasarathy, K.S., 1976
Decay products of radon-222 in the living environment:
Health Physics, 31(2): 187-188
Chem. Abs. 86:23103a:

Partington, J.R., 1957

Discovery of radon:
Nature [London], 179: p. 912

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Paul, A.C., V.S. Londhe, and K.C. Pillai, 1980
Radium-228 and radium-226 levels in a river environment and its modification by human activities, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
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Paul, A.C., P.M.B. Pillai, S. Komalan Nair, and K.C. Pillai, 1984
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Jour. Environ. Radioactivity, 1(1): 51-65

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Geophys. Abs. 14738
This paper gives the results of a general survey of the radioactivity of Switzerland. Payot and Jaquerod measured the radioactivity of 570 spring waters and 12 gases by means of an electrometer (± 10% accuracy) and of approximately 100 rocks by means of a Geiger-Müller counter (± 20% accuracy). Extensive tables present their data, with 167 additional spring-water measurements made by others in Switzerland and neighboring countries. In general, radioactivity is found to be weak, and no uranium deposits are believed to exist. Radioactivity is associated with granites, gneisses, pegmatites, and Triassic and Liassic bituminous schists. If exploitation of rocks with low uranium content should ever be envisaged, possible regions would be the center of the Hercynian massif or the upper valleys of the Rhone and the Aare, the Tessin [Ticino] with its bituminous schists, and perhaps the Grisons [Graubunden]. Radioactive springs of undetermined origin are aligned between the Jura and the Molasse basin, but they do not seem to originate in the bituminous beds.

Peacock, J.D., and R. Williamson, 1961
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Three different techniques were tried for measuring the radon from soil: sucking the soil air through filter paper and counting the alpha radioactivity of radon decay products on the filter; implanting an alpha-sensitive scintillation probe in slim holes 2-3 ft. deep; and sucking the soil air into a 2 x 8.6 x 8.6-cm chamber between a pair of opposed alpha scintillation probes. The filter technique was rejected because of low sensitivity and handling difficulties; the in-hole probe technique was feasible but entailed slower hole preparation (20-30 versus ½ minute) than the alpha-chamber technique. Maximum counts were attained 1 hr. after covering of the prepared holes; in practice, 2 hrs. were allowed. Field measurements were made over known uranium-bearing veins in southern Scotland, where counting rates ranging from 2 to 9,000 counts per minute contrasted with instrumental background counting rates usually not exceeding 20 counts per minute. Counting rates above background of less than 100 counts per minute were not significant. Daily fluctuations were sufficiently large that the maximum counting rate exceeded the minimum by a factor of 50 at one of two sites monitored over a period of several weeks; the monitoring of control stations is advised during surveys. Two anomalies, of 248 and 660 counts per minute maximum activity respectively, were checked by trenching. The first did not reveal uranium-bearing material in the underlying rock. The second trench exposed a small uraniferous

fracture filling in hornfels at 6½ ft. depth. The method is recommended for delineating favorable zones in known uranium-bearing areas where soil cover masks direct radiation from the radioactive deposits.

Peake, R. Thomas, and L.C.S. Gundersen, 1989
An assessment of the radon potential of the U.S. Coastal Plain [abs.]:
Geol. Soc. America, Northeastern Section, Abstracts with Programs, 21(2): 58
Radon data collected during recent indoor radon surveys and data obtained from commercial radon measurement companies have produced indoor radon data which can be compared with geology in the U.S. Coastal Plain. Survey data are available for Tennessee, Alabama, New Jersey, and Florida. Indoor radon data from several radon testing companies for other Coastal Plain States are also available to the Environmental Protection Agency. We estimate that the screening indoor radon average in the Coastal Plain is approximately 0.9 pC/L and that less than 10% of the homes will have screening radon concentrations above 4 pCi/L. These values may be higher in the Mid-Atlantic Coastal Plain, and slightly lower in the Southern Coastal Plain. Even though the Coastal Plain region may have low radon potential, there are areas in the Coastal Plain in which as many as 30% of the homes contain or may contain screening radon concentrations greater than 4 pCi/L. The homes with the highest indoor radon concentrations in the Coastal Plain are likely to be sited on phosphatic or glauconitic lithologies or on Cretaceous chalks and carbonaceous shales. House construction can influence radon screening measurements and is a critical component of our analysis. The concept of integrated radon potential (IRP) may be a useful method for factoring in the house construction component.

Peake, R.T., L.C.S. Gundersen, and C.R. Wiggs, 1988
The Coastal Plain of the eastern and southern United States--An area of low radon potential [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A337
Six important parameters: geology, radon in soil gas, indoor radon, equivalent uranium, permeability, and housing construction all indicate that the Coastal Plain from New Jersey to Texas is an area of low radon potential. In general, the data suggest that the Inner Coastal Plain (mainly Cretaceous and Tertiary sediments) is slightly higher in radon potential than the Outer Coastal Plain (Eocene sediments). Grab samples of radon in soil gas measured at 1-m depth averaged between 700-1000pCi/L. Data from the joint State/Environmental Protection Agency Indoor Radon Surveys (winter 1986-1987) show a median concentration for the Alabama Coastal Plain of 0.6 to 0.7 pCi/L (average 0.9). Other data sets for New Jersey, Tennessee, and Florida are similar. In Tennessee, the geometric mean (GM) for indoor radon is 0.8 pCi/L (average 1). The New Jersey Outer Coastal Plain has a GM for indoor radon of 1.2 pCi/L (average 1.8) and the Inner Coastal Plain has a GM for indoor radon of 1.4 pCi/L (average 2.5). The GM for indoor radon in Florida is 1.2 pCi/L. Aeroradiometric data from the National Uranium Resource Evaluation Program show that equivalent uranium signatures for most of the Eocene sediments are typically 1.5 ppm. Higher values are found in Tertiary phosphorites (varying between 1 and 8 ppm) and Cretaceous chalk units (averaging 3 ppm). Soils overlying Cretaceous chalks yield radon concentrations up to 5000 pCi/L, but their permeability is low. Permeability of the Coastal Plain as a whole is in the 0.6-to-2 inches/hour range (considered moderate). A final and vital factor in the understanding of radon potential is the common construction practice of slab-on-grade buildings in the Coastal Plain. The absence of a basement significantly reduces the amount of radon that may enter a home and may be one of the most important factors to consider in radon potential assessments.

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Urbana, Illinois Univ., Dept. of Gen. Engineering, Progress Rept., June 1961 thru May 1964, Research Grant No. AP00134-01/2/3: 68 p.

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Jour. Geophys. Research, 70(20): 5279-5290

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Natural environmental radioactivity from radon 222:
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Radium-226 and radon-222 have been measured using a deemanation method in which the gaseous daughter, radon-222, is collected and analyzed by an alpha-scintillation method. "Emanating radium-226" from particles of soil in clay type soils varied from 0.342 pg per g of dry soil to 0.690 pg/g. Sandy soils varied between 0.147 to 0.244 pg/g. Highest activity measured was 14.3 pg of "emanating radium-226" per gram of dry soil containing uranium ore. Emanation from ground in Champaign County, Ill., for 216 measurements, was (140± 73) aCi of radon-222/cm^2-sec. Other soils released similar values of radon-222 except at locations where uranium-238 is available in commercially significant amounts. Release of radon-222 from the leaves of corn (Zea mays L.) about midday and near the growth peak was approximately 2.6 times that of the soil under the corn at Argonne National Laboratory in one series of six tests. Radon-222 concentration in the atmosphere were measured in eight series of 24-hour tests, to elevations of 16 m. Values of concentration of various times of the day are presented for the normal environmental levels.

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Soil concentrations of emanating radium-226 and the emanation of radon-222 from soils and plants:
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Values of radon-222 emanation from soils and concomitant variation of factors affecting the rate of emanation are reported. Measured values of radium-226 in the soil capable of giving rise to diffusing radon varied 70-fold in different geological regions but were uniform in Champaign County, Illinois, where the content was (0.64± 0.09) pg of "emanating Ra-226" per g of soil. The emanation rate of radon-222 from soils into the atmosphere varied 1,000-fold among geographic regions but was also uniform in Champaign County, averaging (140± 73) aCi/cm^2-sec. Thus Rn-222 may be used as a cost-free tracer in vertical diffusivity studies in Champaign County.

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Mesure de la radioactivité de l'air dans l'Antarctique [Measurement of the radioactivity of the air in the Antarctic]:
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This is a preliminary report on measurements of atmospheric radioactivity made by the Belgian Antarctic Expedition of 1957-1958. Mean artificial radioactivity was found to be 2E-14 counts/m^3. Natural nuclides ThB (Pb-212) and RaB (Bi-214) were measured directly; the latter can be considered to be in equilibrium with atmospheric radon. A nuclide having a half life greater than 10 days, provisionally attributed to polonium,

was also detected. Measured values were: RaB<1E-12 counts/m^3, ThB<5E-14 counts/m^3, and Po=1E-16 counts/m^3. Both the artificial and natural radioactivity are very low; the latter is comparable to that measured above oceans, and several times weaker than the mean radioactivity over other continents. The absence of radon indicates that the time of diffusion across the ice cap is much longer than 3.8 days. The presence of Po and therefore of RaD (Bi-210) opens interesting possibilities for ice chronology during the last hundred years, supplementing those offered by tritium.

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The radiation exposure during the inhalation of air containing radon depends not only on the concentration of the emanation, but also on their content of solid decay products of the radon. A method for the determination of the content of the decay products of the air and the values (for radon) used for the calculation are reported. Moreover the additional radiation exposure received by the lung tissue and the blood from the decay products which are inhaled and filtered by the lung has been calculated. The calculated values for the radon inhalation therapy in the thermal gallery of Badgastein/Bockstein (Austria) are given as numerical examples. It has been shown that the radiation hazards of the patients are negligible in any case.

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Radioaktive Luftmessungen im Raum von Badgastein and Böckstein [Radioactive measurements of the air in Badgastein and Böckstein]:
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[Account of first expriments to determine directly the volume of emanation (Rutherford, 1908)]

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Sur la solubilité de l'émanation du radium dans les liquides organiques [On the solubility of radium emanation in organic liquids]:
Le Radium, 8(7): 253-256
[Ref. U.S. Bureau of Mines Circ. 6072, p. 15]

Ramstedt, Eva, 1919
Sur la diffusion de l'émanation du radium dans l'eau [On the diffusion of radium emanation in water]:
Meddelanden från Kungl. Vetenskapsakademiens Nobelinstitut, 5(5): 1-14
[D=0.820 cm^2/day (14°C); D*sqr(m)=12.2 (14°C); Molecular 'rayon' (mean free path?) 0.185 nm]

Ramstedt, Eva, 1919
Diffusion der Radiumemanation in Wasser [Diffusion of radon in water]:
Chem. Zentralblatt, 90(1): p. 994

Rankin, M.O., D.P. Brown, C.D. Boyne, and W.G. Spear, 1962
Air-monitor and protection--a coincidence-count alpha particle air monitor:
Contract [AT(4501)-1350]: 11 p.
Nucl. Sci. Abs.-17, No. 7, 10532
The detection of the Pu-239 maximum permissible air concentration (MPC) of 2E-12 $\mu Ci/cm^3$ is complicated by a varying background of natural alpha emitters. The air concentration of radon and thoron, in particular, varies considerably with atmospheric conditions. Since one MPC of airborne Pu-239 is only 4.44E-6 dpm/cm^3, it is necessary to integrate the activity on a fixed filter to obtain adequate measurement sensitivity. Radon and thoron are also collected on the filter, and at times may accumulate to several hundred times the required detection level of Pu-239. An instrument using coincidence counting techniques was developed to measure the Pu-239 air concentration levels. In the decay chain for radon, RaC decays by beta emission to RaC' which decays by alpha emission with a half life of 163 μs; and in the similar thoron chain, ThC decays by beta emission to ThC' which decays by alpha emission with a half life for 0.3 μs. Delayed coincidence-counting techniques are used to identify counts due to natural alpha count to provide a measurement of Pu-239. The developed instrument can detect continuous airborne Pu-239 concentrations of 2E-11 $\mu Ci/cm^3$ in about 90 minutes and 2E-12 $\mu Ci/cm^3$ in about 900 minutes. These detection levels can be obtained with background Ra-Th concentration levels of 2E-10 $\mu Ci/cm^3$.

Rannou, A., C. Madelmont, and H. Renouard, 1985
Survey of natural radiation in France:
The Science of the Total Environment, 45: 467-474

Rannou, A., F. Posny, J.M. Guezengar, and C. Madelmont, 1984
Study of natural irradiation in dwelling places in France:
Radiation Protection Dosimetry, 7(1-4): 317-320
Chem. Abs. 101:99866a:

Ratner, A.P., 1937
Some notes on the mechanism of emanation [in Russian]:
SSSR, Gosudarstvennyy Radiev. Inst. Trudy, 3: 135-139, with English summary, p. 139-140
Chem. Abs. 31: 4586-4587 (1937)

Reimer, G. M., 1980
Use of soil-gas helium concentrations for earthquake prediction: Limitations imposed by diurnal variations:
Jour. Geophys. Research, 85(B6): 3107-3114

Reimer, G. Michael, 1986
Helium soil-gas survey of the Aurora uranium deposit, McDermitt caldera complex, Oregon:
Jour. Geophys. Research, 91(B12): 12,355-12,358
Two soil gas helium surveys were carried out in a section of the McDermitt caldera complex of mineralized volcanic rocks in Oregon. A regional helium anomaly was found and is thought to be associated with uranium-rich tuffaceous fill of the caldera and the Aurora uranium deposit, which occurs near the northeastern rim of the caldera. Local hydrology may have an effect on the displacement of the helium anomaly from the uranium deposit and be a carrier of helium from sources at depth. This study suggests that helium surveys may be useful in a volcanic environment by helping to select areas for exploratory drilling for uranium deposits.

Reimer, G.M., 1988
An integrated approach to assess potential radon content of soils using geologic, gamma-ray and soil-gas data [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A354
Various singular techniques of evaluating the radon potential of geographic areas have been used but data from field studies suggest that an integrated approach may give more reliable estimates. Many techniques are indirect in that they do not actually measure the in-situ radon concentration. For example, knowledge of geologic lithologies provides estimates of the uranium concentration; spectral gamma-ray measurements typically analyze for Bi-214, a daughter of radon-222, in the upper portion of the surface. Even direct measurement of soil-gas radon has limitations because of diurnal, seasonal, and permeability effects. Gamma-ray and geologic data may be known for many areas, although their integration may be hampered by having different scales or degrees of resolution, but it is very unlikely that a soil-gas radon data base exists. Field studies must include the collection and analysis of soil-gas radon at a scale determined to be compatible with the overall resolution required. Results from Frederick County, Maryland show how data from different scales are combined and interpreted. Soil development in some areas created low uranium or radium concentrations in the upper soil horizon giving a lower gamma-ray reading than would be anticipated for the known lithology. Radon concentrations in regions that are structurally complex can be higher than from similar but undisturbed lithology. Interpretation of the combined data provides the most accurate estimates of radon potential and compares well with known indoor radon concentrations.

Reimer, G.M., 1988
Radon soil-gas survey in Prince Georges County, Maryland:
U.S. Geol. Survey Open-file Rept. 88-52, 10 p.
Soil-gas samples collected along a traverse in Prince Georges County, Maryland were analyzed for radon. The traverse included principal lithologies and areas for which aeroradiometric measurements showed various intensities. Although, in the past, this region in the Coastal Plain province had not been considered to possess the type of geologic setting or aeroradiometric signature that would contribute to significant indoor accumulations of radon, the measured soil-gas concentrations of up to 2500 pCi/L indicate that the potential exists for indoor accumulations in excess of the 4 pCi/L [action] level established by the U.S. Environmental Protection Agency. The higher levels of soil-gas radon were found in some of the Tertiary sediments with the lower concentrations in the Cretaceous and Quaternary sediments. Geologic relationships are thought to be the controlling factors for the radon soil-gas concentrations. Although very few indoor radon data are available for Prince Georges County, they, too, indicate levels exceeding the 4 pCi/L guideline in areas underlain by some Tertiary formations but less for the Cretaceous and Quaternary formations.

Reimer, G.M., 1990

Helium soil-gas survey of the Crownpoint area, New Mexico: Consideration of the regional distribution, *in* Durrance, E., ed., Geochemistry of Gaseous Elements and Compounds,:
Athens, Greece, Theophrastus Publications, p. 449-456.

Reimer, G.M., 1990
The occurrence and transport of radon in the natural environment:
Geophys. Research Letters, 17(6): 799
[This is a foreword to a collection of papers derived from two sessions, on the topic of the title, at the annual spring meeting of the American Geophysical Union, Baltimore, Maryland, 10 May 1989.]

Reimer, G.M., 1990
Reconnaissance techniques for determining soil-gas radon concentrations: An example from Prince Georges County, Maryland:
Geophys. Research Letters, 17(6): 809-812
Preliminary field measurements of soil-gas radon (Rn) concentrations can provide an intitial assessment of the Rn potential in any location and aid in designing a larger or more detailed sampling program. Radon reconnaissance requires some special considerations because a large area must be covered in a short period of time and analyses must be made soon after collection because of Rn decay. A simple approach to collection and field analysis consists of a small-diameter probe pounded into the ground to a depth of at least 0.75 m. Analysis is by an alpha scintillometer. Soil-gas samples collected along a traverse in Prince Georges County, Maryland, demonstrate the utility of the technique. Although this region in the Coastal Plain province might be considered to possess the type of geologic setting that would not contribute to significant Rn potential, the reconnaissance sampling revealed Rn soil-gas concentrations of up to 2500 pCi/L, indicating that the potential exists for indoor accumulations in excess of 4 pCi/L.

Reimer, G.M., J.M. Been, and S.L. Szarzi, 1989
Technique for rapid field assessment of radon soil-gas concentrations, *in* Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 2, Symposium Poster Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9- 89/006b [Springfield, Va., NTIS Order No. PB89-167498], p. 3-51--3-54.

Reimer, G.M., C.G. Bowles, D.G. Murrey, and J.M. Been, 1979
Helium in soil-gas and helium/radon in ground water in the vicinity of a south Texas uranium roll-type deposit:
U.S. Geol. Survey Open-file Rept. 79-1625: 12 p.
Chem. Abs. 93:153379a

Reimer, G.M., and L.C.S. Gundersen, 1989
A direct correlation among indoor Rn, soil gas Rn and geology in the Reading Prong near Boyertown, Pennsylvania:
Health Physics, 57(1): 155-160

Reimer, G.M., and R.S. Rice, 1977
Linear-traverse surveys of helium and radon in soil gas as a guide for uranium exploration, central Weld County, Colorado:
U.S. Geol. Survey Open-file Rept. 77-589: 10 p.

Reiter, Reinhold, 1955
Der Emanationsgehalt der Luft in den nordlichen Kalkalpen in Abhängigkeit von atmosphärischen Schichtung und Windrichtung [The emanation content of the air in the northern Bavarian Alps in relation to stratification of the atmosphere and wind direction]:

Naturw. Jahrg. 42(23): 622-623
Geophys. Abs. 164-267:
According to measurements carried on from mid-August to late September 1955, the emanation content of the air on the Zugspitzplatte (2,580 m above sea level) showed a notable increase during temperature inversions. Under such conditions, 530 counts per minute were counted, in contrast to 335 counts per minute for thoroughly mixed air. Furthermore, the emanation content varied appreciably with wind direction. Winds with a southerly component, coming from an area of primitive rocks, contained 4.3 times as much radon as those from the northern quadrants; in one instance the radon content, during a southeasterly wind, increased by a factor of 7.3.

Reiter, Reinhold, 1956
Schwankungen der natürlichen Radioaktivität der Luft, Messungen in 2600 m Seehöhe in den Nordalpen [Variations of the natural radioactivity of the air, measurements at an elevation of 2,600 m above sea level in the northern Alps]:
Zeitschrift Naturforschung, 11a(5): 411-418
Geophys. Abs. 165-303
This is a more complete report on investigations of atmospheric radioactivity carried out on the Zugspitzplatt in the northern Alps (see Geophys. Abs. 164-267]. Besides emphasizing the dependence of radon content of the air on geology and wind direction, it includes consideration of the effect of humidity (radioactivity is often extremely high with humidity more than 80 percent), relation to electrical conductivity and number of condensation nuclei per volume (conductivity increases with radioactivity), and the possible effect of the radioactivity on rainfall and organisms.

Reiter, Reinhold, 1957
Schwankungen der Konzentration und des Verhaltnisses der Radon- und Thoronabkommlinge in der Luft nach Messungen in den Nordalpen [Variations in concentration and ratios of radon and thoron derivatives in the air according to measurements in the northern Alps]:
Zeitschrift Naturforschung, 12a(9): 720-731
Geophys. Abs. 171-307:
A total of 672 measurements of natural radioactivity of the air were made from April 1956 to April 1957 in the north-south trending Loisach valley in the northern Alps. Radioactivity was found to be high when upper air currents were from the south, regardless of season. Local winds in the valley have no systematic effect. The effect of snow and ice cover on the amount of thoron derivatives is great. The ratio of radon-series products to thoron-series products corresponds in summer to the uranium:thorium ratio in the region from which the upper air currents blow. Wind velocity and relative humidity have no effect on mean values of radioactivity in the air. Radioactivity increases with decrease in pressure, owing not to increased exhalation from the ground but to simultaneous veering of the high winds to the southerly direction. The activation and filtration method, both of which were used in these measurements, are compared. The effect of variation of the natural radioactivity of the atmosphere on ionization at 700 to 3,000 m altitude is discussed, on the basis of records of atmospheric electricity at 7 stations during 8 months; when radioactivity is below average (500 to 1,000 impulses per minute), the electric field intensity increases at all stations and conductivity decreases; when radioactivity is average (1,000 to 1,500 impulses per minute), the potential values fluctuate unsystematically around the mean; but when radioactivity is above average the field strength at all stations is distinctly to strongly reduced and conductivity correspondingly increased.

Reiter, R., 1957
Variations of natural air radioactivity at the valley level of the Northern Dolomite Alps [in German]:
Meteorol. Rundschau, 10: 2 [?]
Nucl. Sci. Abs. 16:31972:
In order to determine whether large variations of the natural air radioactivity occurs at the valley level of the Northern Dolomite Alps, measurements were carried out from April to November 1956 on rainless days at

the valley station for Farchant. The results obtained are shown graphically as a function of the mean wind direction over the Alpine crest. The results show clearly how the accumulation range of the measurement points for the individual principal directions are shifted to the southern half as the wind rose according to high radioactivity values. The results also show that extreme fluxations of the natural air activity are very frequent at the valley level. These results show that the natural radioactivity permits extensive investigations of wind and circulation behavior. The observations also have significance for health, climatic, and bioclimatic questions. The fluxations found in the natural air radioactivity indicate corresponding variations of the ionization.

Reiter, R., 1958
Natural and artificial air radioactivity in the Alps at different heights [in German]:
Ber. deut. Wetterdienstes, 54: 38-53:
Nucl. Sci. Abs. 16:26724:
Since 1956, the natural radioactivity of the atmosphere has been determined several times a day in a valley of the North Alps (Farchant, elevation 675 m) whereby the disintegration products of radium and thorium emanation have been measured separately. In addition the artificial radioactivity of the air has been observed at several hours a day since the beginning of 1957. Another station simultaneously carries out records at 1780 and/or 2650 m above sea level. Both stations are situated at a horizontal distance of only a few kilometers. The data obtained with these stations and particularly their comparison result in an insight in the vertical distribution of the natural and artificial substances in the atmosphere under different meteorological conditions and particularly with a view of the specific meteorology and geology of the Alps.

Reiter, R., 1959
Metorologically and geologically limited distribution ranges of natural radioactivity in aerosols of the northern Alps from the latest measurements [in German]:
A. Aerosol. Forsch. u. Therap., 7: 1-16
Nucl. Sci. Abs. 16:27462
An investigation was made of the variation of natural radioactivity of aerosols in the region of the northern Alps. Meteorological and geological conditions were determined. Methods used in the study are described. Geographic relations are outlined. The dependence of the natural radioactivity of aerosols on wind direction over the Alps was studied. Effects of air moisture, wind velocity, and air pressure are discussed. Results are presented in graph form.

Reiter, R., 1960
Natural and artificial radioactivity in the Highlands. Studies of the extent and origin, and variations with time and location of radioactivity of aerosols in the Northern Alps and their effects on radioactivity of precipitation, snowfall, and grasses [in German]:
Stuttgart, Friedrich-Karl Schattauer-Verlag: 79 p.
Nucl. Sci. Abs. 16:31982
A complete and clear report is given of studies made over a period of several years of the natural and artificial radioactivity aerosol in the Alps. The transient and spatial variations of the aerosol activity and their relationships to local and regional meteorological processes and conditions were studied. Special emphasis was given to problems present in the Alpine region, to the solution of these problems and to those results which have more than regional significance. The measurements made were determinations of the artificial radioactivity in precipitation and grasses, and the radioactive deposition from snow and ice surfaces. The measurement results are shown in tabular and graphical form and the practical consequences are discussed.

Reiter, R., 1960
Recent results from alpine air radioactivity measurements [in German]:
Zentr. Biol. Aerosol Forsch, 9: 195-219
Nucl. Sci. Abs. 16:31978:

By means of various diagrams, the transient pattern of the natural and artificial radioactivity and of air impurities in 1959 at a valley and a neighboring mountain station was represented and described. It was shown that the air layer near the ground added more long-lived radioactive substances by repeated eddying up from the ground than from greater heights. The daily pattern of the components of the air radioactivity at the mountain and valley stations was described. The effect of vertical temperature gradients on the vertical distribution of natural and artificial radioactive substances was thoroughly represented. Conclusions on the half-value height of the natural radioactive elements and therefore on the velocity of vertical material exchange were given. The application to the estimation of the transport velocity of contaminated particles from the mountain to the valley was indicated. From the vertical concentration variation of the RaB, the exchange coefficient was calculated as a function of temperature stratification. The correlation between natural or artificial air activity and relative humidity, as well as air pollution, was described by means of diagrams. Whereas natural radioactive particles were bound to the large aerosols of the valley air, artificial radioactive elements were not. These were specially concentrated by atmospheric descending movements at the mountain station. The activity values originating in the passage of a radioactive cloud from the French research in the Sahara were described using some motion diagrams.

Reiter, R., 1961
Some results on the behavior of thorium B in the lower atmosphere from measurements at a valley and mountain station of the Northern Alps [in German]:
Zentr. Biol. Aerosol. Forsch., 9: 448-467
Nucl. Sci. Abs. 16:31979:
After a discussion of the various half lives of radon and thoron decay products and their significance in vertical distribution in the upper atmosphere, the monthly average and monthly extremes of ThB concentrations measured in the air at the Farchant Station (675 m NN) and at the mountain station Wankgipfel (1780 m NN) were reported in tabular form for the year 1959 and the first half of 1960. The table contains, for comparison, the simultaneously measured values of the RaB concentration and the concentration of fission products in the air. It is shown that after a decay time of 48 hrs., under certain circumstances, significant masses of ThB and decay products still remain on the exposed filters, which can more or less strongly impair the determination of the fission products. This is no longer the case after a decay time of 120 hrs. The annual trend of the ThB concentration deviates significantly from that of the RaB concentration. The type of deviation leads to the conclusion that the ThB formed in the valley cannot reach the mountain station. The vertical motion is much too long in comparison with the decay time of the ThB. Also the daily pattern of the ThB deviates significantly from that of the ThB. The minimum on ThB was measured at night, in contrast to the RaB. This indicates that a given minimum turbulence in the air layer near the ground is necessary in order to eddy up the ThB concentration with the wind velocity leads at both stations to the same results. A relationship between ThB and the relative humidity as well as the degree of air pollution could be detected at neither of the stations. Sharp increases of the ThB level were observed at the time of the snow melting, whereas in the winter the ThB concentration is very low because of the impedance in exhalation. It is assumed that the ThB emission from near mines yields a noticeable contribution.

Renoux, A., 1963
Study of the charge of small radioactive ions and their fixation on atmospheric aerosols [in French]:
Acad. Sci. [Paris] Comptes Rendus, 256: 478-480
Nucl. Sci. Abs. 17:16271:
It was established that during the decay of radon in the air, a certain number of electrically neutral recoil atoms, in addition to positively charged atoms, appear. The time of fixation of the latter on natural aerosols was determined, and the contact time of these aerosols and of radon in the atmospheric air was evaluated.

Renoux, André, 1965
Radioactive ions in the atmosphere [in French]:
Comm. Énergie atomique, Rept. CEA-R-2771: 86 p.

Chem. Abs. 64:261f

Ridland, G.C., 1945
Use of the Geiger-Müller counter in the search for pitchblende-bearing veins at Great Bear Lake, Canada:
Am. Inst. Min. Metall. Engineers Trans., 164: 117-124

Riedel, Donald W., 1980
Estimates of uranium content and radon flux for uranium mine dumps based on borehole radioactivity logs:
Denver, Colo., Kilborn/NUS, Inc., Rept. NUREG/Cr-1549: 37 p., NTIS
Chem. Abs. 94:38206a:

Riehl, Nikolaus, 1961
Effect of high energy radiation on the surface of solid bodies [in German]:
Kerntechnik, 3: 518-521
[Cited by Zimen and Mertens (1971) as explaining high emanating power of hydroxides, carbonates, and similar systems]
Nucl. Sci. Abs. 16(10): p. 1571 [1962] abs. 12195
....One recoil atom from ThC "shoots away" from a gold surface about 100 Au atoms.... but "electron microscopy revealed no spikes or "craters" on the surface after irradiation, but alpha particles caused smoothing.

Robertson, John B., 1969
Diffusion from a gaseous source in a porous medium--a field and theoretical comparison, *in* Geological Survey Research 1969, Chap. D:
U.S. Geol. Survey Prof. Paper 650-D; D265-D273
Small volumes of air containing a radioactive krypton-85 tracer were injected into fine-grained sediments at the National Reactor Testing Station, Idaho. Dissipation of the Kr-85 gas away from the injection points was observed by recording the gamma radioactivity in the holes. A mathematical model was adapted from a heat-flow analogy to estimate the amount of molecular diffusion occurring in the system. The observed field data match the theoretical diffusion curves closely, indicating that most of the observed outflow was due to diffusion.

Roffman, Amiram, 1972
Short-lived daughter ions of radon-222 in relation to some atmospheric processes:
Jour. Geophys. Research, 77(30): 5883-5899

Rodgers. John C., 1982
Quantifying the radon impacts of passive solar heating, *in* Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:
New York, John Wiley and Sons, p. 598-603

Roessler, C.E., R. Krautz, W.E. Bolch, Jr., and J.A. Wethington, Jr., 1980
The effect of mining and land reclamation on the radiological characteristics of the terrestrial environments of Florida's phosphate regions, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1476-1493

Roessler, C.E., G.S. Roessler, and W.E. Bolch, 1983
Indoor radon progeny exposure in the Florida phosphate mining region: a review:
Health Physics, 45(2): 389-396

Rogers, A[llen] S., 1953

Physical behavior of radon, *in* U.S. Geological Survey, Geologic investigations of radioactive deposits, semiannual progress report, June 1 to November 30, 1953:
U.S. Geol. Survey Rept. TEI-390: 274-276
[Radon in surface streams: related to springs and lithology; flushed rapidly from stream; exploration possibilities.]

Rogers, A.S., 1954
Physical behavior of radon, *in* U.S. Geological Survey, Geologic investigations of radioactive deposits, semiannual progress report, December 1, 1953 to May 31, 1954:
U.S. Geol. Survey Rept. TEI-440: p. 241
[Radon influx in Weber River.]

Rogers, A.S., 1954
Physical behavior of radon, *in* U.S. Geological Survey Geologic investigations of radioactive deposits, semiannual progress report, June 1 to November 30, 1954:
U.S. Geol. Survey Rept. TEI-490: 294-26
[Radon in well waters (N. Salt Lake). Increase in background from 350 pCi/L in south to 1400 pCi/L in N. Becks Hot Springs minimum 1,350 pCi/L. Rn in plants.]

Rogers, A.S., 1955
Physical behavior of radon, *in* U.S. Geological Survey, Geologic investigations of radioactive deposits, semiannual progress report, December 1, 1954 to May 31, 1955:
U.S. Geol. Survey Rept. TEI-540: 270-271
[Radon in well waters, North Salt Lake area, Utah (Rogers). Analyses of brines, Texas and Oklahoma Panhandle gas fields.]

Rogers, A.S., 1955
Physical behavior of radon, *in* U.S. Geological Survey, Geologic investigations of radioactive deposits, semiannual progress report, June 1 to November 30, 1955:
U.S. Geol. Survey Rept. TEI-590, 337-343
[Radon, radium, and uranium in well and spring waters, North Salt Lake area, Utah. Radon in spring, well, stream, and reservoir waters, Huntsville, Utah, area. Radon in drill hole air near Grants, N. Mex. Radon in drill hole water, Central and Northern Florida. Radon in drill hole air and water, Black Hills area, South Dakota.]

Rogers, Allen S., 1955
Geological significance of radon in stream and well waters [abs.]:
Geol. Soc. America Bull, 66(12): p. 1609
The distribution of radon in mountain streams near Salt Lake City, Utah, was used to locate points where relatively large amounts of radon-bearing ground water enter the stream, although other evidence of spring activity may be lacking. These points of influent ground water are marked by abrupt anomalous increases in the radon content of the stream waters (as much as two orders of magnitude within a linear distance of 50 feet). The abnormal concentration of radon is rapidly dissipated to the atmosphere; the rate is an exponential function of various slopes with respect to distance of stream flow. Major increments of addition of ground water to stream flow can be estimated on the basis of radon concentrations in stream and related spring waters. The radon content of the stream waters can generally be related to specific stratigraphic horizons in different drainage areas. Contours of radon concentrations in waters from 130 wells show well-defined, linear highs over two known faults in unconsolidated valley fill. Several additional parallel highs suggest a series of en echelon faults not otherwise evident. An observed regional variation in the general radon background is attributed to a corresponding variation in the sediments. In the area of high background the sediments are derived from adjacent highlands of schist and gneiss; in the low background region a conglomerate is the source. In all waters studied radon is unsupported by radium in solution.

Rogers, Allen S., 1956
Applications of radon concentrations to ground-water studies near Salt Lake City and Ogden, Utah [abs.]:
Geol. Soc. America Bull, 67(12): 1781-1782
Contours of equal-radon concentrations in waters from 130 wells in an area of 15 square miles north of Salt Lake City, Utah, show well-defined, linear highs over two known faults in unconsolidated valley fill. Several additional parallel highs suggest a series of en echelon faults or fractures not otherwise evident from surface expression. In the North Ogden, Utah, area, where radon was measured in water from 300 wells in 20 square miles, the extension of five faults from bedrock into the area of valley fill is suggested by the alignment of linear zones of high radon concentrations. The radon concentrations range from 250 to 2300 pCi/L in the area north of Salt Lake City, and from 100 to 2800 pCi/L in the North Ogden area. An observed regional increase in the general radon background north of Salt Lake City is attributed to a corresponding variation in the sediments in the aquifers. In the low background region (200-300 pCi/L) the sediments were derived from sedimentary rocks in the adjacent mountains. In the region of high background (600-800 pCi/L) the sediments were derived largely from schists and gneisses. No correlation was observed in either area between the radon content of the ground water and depth (10 feet to 800 feet) or rate of discharge of the well. In all waters studied radon is unsupported by radium in solution and is essentially constant with time (up to 1 year).

Rogers, Allen S., 1958
Physical behavior and geologic control of radon in mountain streams:
U.S. Geol. Survey Bull. 1052-E: 187-211

Rogers, Allen S., and Allan B. Tanner, 1956
Physical behavior of radon, *in* U.S. Geological Survey, Geologic investigation of radioactive deposits, semiannual progress report, December 1, 1955 to May 31, 1956:
U.S. Geol. Survey Rept. TEI-620 [Oak Ridge, Tenn., Tech. Inf. Extension]
[Radon in well waters from North Ogden, Utah, area. Alpha logging of drill holes anomalously high in radon conc.]

Rogers, V.C., and K.K. Nielson, 1981
A complete description of radon diffusion in earthen materials:
Uranium Mill Tailings Management, 4: 247-263
Radon migration in porous, earthen materials is characterized by diffusion in both the air and water components of the system as well as the interaction of the radon between the air and water. The size distribution and configuration of the pore spaces are also key parameters of the diffusion model. Calculations based on the model yield radon diffusion coefficients that do not depend upon radon diffusion measurements. The diffusion coefficients are expressed in a form suitable for use in simple homogeneous-medium diffusion expressions for predicting radon transport and compare well with measured values of the diffusion coefficients.

Rogers, V.C., and Nielson, K.K., 1989
Radon emanation and transport in porous media, *in* Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 1, Symposium Oral Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006a [Springfield, Va., NTIS Order No. PB89-167480], p. 5-45--5-58.
A unified model of radon emanation and transport has been developed that combines the RAECOM model for diffusive transport with new mathematical models of advective transport, moisture effects, and radon emanation. The model accounts for advective depletion in radon source regions, and for the effects of varying moistures on radon emanation, diffusion, and advective transport rates. Radon transport in gas- and water-filled pore space is characterized, and exchange between the phases is considered. Correlations are also given for diffusion and permeability coefficients. The model provides a comprehensive assessment of source potentials for indoor radon accumulation based on soil moistures, radium, emanation [coefficient], and advection of soil gas.

Rogers, V.C., K.K. Nielson, and D.R. Kalkwarf, 1984
Radon attenuation handbook for uranium mill tailings cover design:
Salt Lake City, Utah, Rogers and Associates Engineering Corporation, U.S. Nuclear Regulatory Commission Rept. NUREG/CR-3533, 85 p.

Rogers, V.C., K.K. Nielson, G.B. Merrell, and D.R. Kalkwarf, 1983
The effects of advection on radon transport through earthen materials:
Salt Lake City, Utah, Rogers and Associates Engineering Corporation, U.S. Nuclear Regulatory Commission Rept. NUREG/CR-3409, 54 p.

Rogers, V.C., R.F. Overmyer, C.M. Jensen, and G.M. Sandquist, 1979
Moisture effects on radon diffusion:
Am. Nuclear Soc. Trans., 33: 174-175

Rogers, V.C., R.F. Overmyer, and K.K. Nielson, 1979
Radon attentuation through cover materials, *in* Symposium on Uranium Mill Tailings Management, Ft. Collins, Colo., November 1979:
Ft. Collins, Colo., Colorado State University

Rogers, V.C., B.J. Thamer, R.F. Overmyer, and B.W. Sermon, 1980
A new laboratory techmique for measuring diffusion coefficients of mill tailings covers:
Am. Nuclear Soc. Trans., 34: 132-133.
Chem. Abs. 93:155300s:

Rogover, B.G., 1935
Radioactive method of prospecting and its role in locating the deposits of raw materials in the Union [in Russian]:
Razvedka i Okhrana Nedr, (3): 4-7
Geophys. Abs. 75-2596

Rogozen, Michael B., 1982
Dynamic simulation of radon daughter concentrations in apartments using solar rockbed heat storage:
Environment Internat., 8(1-6): 89-96

Róna, Elisabeth, 1917
Diffusionsgrösse und Atomdurchmesser der Radiumemanation [Magnitude of diffusion and atomic dimensions of radon]:
Zeitschrift physikal. Chemie, 92(2): 213-218

Rosa, Guiseppe, 1936
The retention of RaA, RaB, and RaC on dust particles:
Gerlands Beitr. Geophys, 46: 394-399

Rose, A.W., 1978
Geochemical exploration for uranium in Pennsylvania:
Earth Miner. Sci., 47(7): 49-52
[Ore guides, haloes, U-238, Rn-222, ground-water.]

Rose, Arthur W., 1980
Regional and local anomalies of uranium and thorium in rocks near sandstone-type uranium deposits in Pennsylvania and Colorado:

Pennsylvania State Univ., U.S. E.R.D.A. Rept. GJBX-126(80)

Rose, Arthur W., and Lisa A. Korner, 1979
Radon in natural waters as a guide to uranium deposits in Pennsylvania, *in* Watterson, John R., and Theobald, Paul K., eds. Geochemical Exploration 1978, International Geochemical Exploration Symposium, 7th, Golden, Colo., April 17-19, 1978, Proc.:
Rexdale, Ont., Canada, Assoc. Exploration Geochemists: 65-76

Rose, Arthur W., Ronald L. Schmiermund, and Dennis L. Maher, 1977
Geochemical Dispersion of Uranium Near Prospects in Pennsylvania:
Pennsylvania State Univ., U.S. E.R.D.A. Rept. GJBX-59(77)

Rose, Arthur W., and John W. Washington, 1989
Controls of seasonal variability in Rn content of soil gas [abs.]:
Geol. Soc. America, Northeastern Section, Abstracts with Programs, 21(2): 63
Measurements of soil gas radon over a one-year period at five sites in central Pennsylvania show a large seasonal variation. The radon (^{222}Rn) concentrations reach values of 1500 to 4000 pCi/L in summer at depths of a meter or more. Winter values are only 1/3 to 1/10 of the summertime high values. The seasonal decrease is most pronounced in deep soils (greater than 1 meter). In summer the depth profiles approximate a diffusional-type pattern, but during other periods of the year the depth profiles are irregular, often showing peaks in the middle part of the profile. Thoron (^{220}Rn) shows patterns over time similar to ^{222}Rn. Depth profiles of thoron are not clearly diffusionally controlled at any time of the year. Presumably the muting of the diffusion pattern for thoron is related to its short half-life. The radon variability both with time and depth correlates with soil moisture as determined by resistance blocks, tensiometers, neutron moisture gauge, and visual observation. In summer the soils are usually dry due to high evapotranspiration; in late fall the soils are relatively wet because of low evaporation and perhaps increased precipitation. The exact relationship between the low winter radon values and high moisture is not clear, but appears to involve inhibited diffusion through water-filled pores or adsorption-like effects. Several other researchers have reported similar seasonal effects in humid-region soils, but in semi-arid regions, high radon is reported in winter or early spring, apparently during periods of high moisture. Evidently several processes cause seasonal variability in soil-gas radon values.

Rose, A.W., J.W. Washington, and D.J. Greeman, 1988
Variability of radon with depth and season in a central Pennsylvania soil developed on limestone:
Northeastern Environmental Science, 7(1): 35-39.

Rosen, A., and Ya. Shevlov, 1952
Nekotoriye sootnosheniya pri diffuzii gazov v tverdom tele [Some correlations valid in the diffusion of gases in a solid body]:
Akad. Nauk SSSR Doklady, 87(5): 817-820

Rosen, R., 1957
Note on some observations of radon and thoron exhalation from the ground:
New Zealand Jour. Sci. Technology, sec. 5, 38(6): 644-654
Geophys. Abs. 170-269
Measurements of radon exhalation from the ground have been made by a modified induction method, in which the decay of products on the collector wire is recorded by a gauze cylindrical ion chamber situated around the wire. Measurements from June to August 1955 (at a site in Wellington, New Zealand) showed an average exhalation rate of approximately 0.2 aCi/cm^2-s. During periods of decreasing atmospheric pressure, there was usually a slight increase in the exhalation rate. There was a marked decrease during rainfall. The results also indicated a diurnal variation in the exhalation rate. The radon thoron ratio was found to be about 1.5.

Rosholt, John N., 1958
Radioactive disequilibrium studies as an aid in understanding the natural migration of uranium and its decay products, *in* United Nations Internat. Conf. on the Peaceful Uses of Atomic Energy, 2nd, Geneva, 1958, Proc., 2: 230-236
Geophys. Abs. 178-319
Equilibrium in natural uranium and thorium series is set up after a lapse of 500,000 years, provided losses of neither parent nor daughter elements occur. Such losses result in deviations of four general types; daughter deficiency, thorium-230 deficiency, exclusive radium-actinium isotope occurrences, and daughter excess. Radioactive age determinations can be made on a basis of the ratio of parent uranium to intermediate daughter products provided no deviations of the type outlined above have taken place, and also provided that the parent uranium was free of decay products and the rate of deposition was not too slow compared with the rate of growth of daughter products.

Rosholt, John N., Jr. 1959
Natural radioactive disequilibrium of the uranium series:
U.S. Geol. Survey Bull. 1084-A: 1-30

Rothé, Klaus, 1959
Problematik radiometrischer Messungen über Ölstrukturen [Problems of radiometric measurements over oil structures]:
Geol. Gesell. Ber., 4(2/3): 183-187
Geophys. Abs. 184-528
A number of oil structures in East Germany have been investigated in order to determine whether radiometric measurements made at the surface can delineate anomalies that indicate the presence of oil. The first tests were made on the old Fallstein oilfield, and in the Diesdorf-Waddekath area. A counting apparatus was carried along foot traverses. The intensity of radioactivity was averaged for every 20 m of traverse in order to eliminate any very local effects. An accuracy of 0.2-0.5 μR/hr was found to be sufficient. The results show that such radiometric measurements on the ground can definitely be used for oil prospecting. [Armstrong and Heemstra (1973): Rothé calculated that the surviving radium in ground water moving up at a rapid pace of about 1 inch per year from a depth of nearly 800 feet would be reduced to 2 percent of the original.]

Roubault, Marcel, René Coppens, and Georges Jurain, 1959
Sur la teneur en radon des eaux froides de certains regions de France [On the radon content of the cold waters of certain parts of France]:
Acad. Sci. [Paris] Comptes Rendus, 238(5): 715-717
Geophys. Abs. 176-298:
Field measurements of the radon content of natural waters were made in various part of France with the aid of a truck-borne laboratory. Analyses were made of 344 cold well and spring waters currently being consumed by humans and animals. A large number showed high radon contents. In a region some kilometers south of a strongly uraniferous zone, 2/3 of the wells had radon contents exceeding the tolerable dose (4 nCi/L): 1/6 had more than 10 times the limit. In a second area far from any uranium deposit, 2/3 of the springs were over the limit, but none by as much as 10 times. Geological and geochemical interpretation will be given later. In the meantime, it is suggested that the "tolerable dose" be reexamined, inasmuch as these waters have always been drunk by the populations of these regions with no apparent ill effects.

Rowland, R.E., J. Jowsey, and J.H. Marshall, 1958
Radon escape from bone mineral:
Radiation Research 8: 298-306

Rowland, R.E., and Marshall, J.H., 1959

Radon retention of embedded and sectioned bone, *in* Radiological Physics Division semiannual report, July through December, 1958:
Argonne Natl. Lab. Rept. ANL-5967, p. 50-52
[Beagle bones embedded in methyl methacrylate, cross-sectioned, and sealed in glass tubes; measured by gamma radiation at appropriate equilibrium.]

Royds, T., 1909
The grating spectrum of radium emanation:
Philos. Mag. 17-6: 202-204

Rubin, R.M., 1978
Literature Survey on Radon Distribution in Soil and Air; Final Report:
U.S. Dept. Energy Rept. GJBX-110(80), 63 p.

Rubin, R.M., D. Leggett, and M.B. Wells, 1980
National uranium resource evaluation. Effects of overburden, biomass, and atmospheric inversions on energy and angular distributions of gamma rays from U, K, Th, and airborne radon sources:
Ft. Worth, Tex., Radiation Research Associates, Inc., Rept. RRA-T8012, for U.S. Dept. Energy, Rept. GJBX-141 '81: 259 p.
[Radiation transport calc. using ANISN S_n discrete ordinates code and a point kernel code. P. 40-42 treat Rn diffusion from source layer with active overburden but apparently use bulk concentrations with boundary-value error.]

Rudolph, P.S., 1965
Apparatus for the collection and purification of radon:
Review Sci. Instruments, 36(1): 75-77

Rudorf, G., 1909
Über einige numerische Konstanten der Radiumemanation und deren Beziehung zu denen der Edelgase: [On several numerical constants of radon and their relation to those of the noble gases]:
Zeitschrift Elektrochemie 15: 748-749

Rumbaugh, James O., III, and Richard R. Parizek, 1983
Effect of fracture permeability on radon-222 concentration in ground water of the Reading Prong, Pennsylvania [abs.], *in* Geological Soc. America Ann. Mtg., 96th, Indianapolis, Ind., Oct. 31-Nov. 3, 1983:
Geol. Soc. America, Abstracts with Programs, 15(6): 675

Rumelin, G., 1907
The rate of transformation of the radium emanation:
Philos. Mag. ser. 6, 14: 550-553
Two sealed glass tubes of different volume contained, at t=0, a homogeneous mixture of air and Rn. The smaller volume was introduced in an ion electroscope (G-L) at t and the larger at about t_2.

Rundo, John, and R.E. Toohey, 1983
Radon in homes and other technologically enchanced radioactivity, *in* Natl. Council on Radiation Protection and Measurements, Proc. 19th Ann. Mtg., p 17-26.
Chem. Abs. 101:99888j

Rushing, David E., W.J. Garcia, and D.A. Clark, 1964
The analysis of effluents and environmental samples from uranium mills and of biological samples for radium, polonium, and uranium, *in* Radiological Health and Safety in Mining and Milling of Nuclear Materials:

Vienna, Internat. Atomic Energy Agency: 2: 187-230

Russ, Sidney, 1909
The diffusion of actinium and thorium emanations:
Philos. Mag. 17(6): 412-422
[1. The diffusion of actinium emanation in gases such as air, hydrogen, carbon dioxide, sulphur dioxide, and argon shows no considerable deviation from the ordinary laws of diffusion. 2. The variation with pressure of the coefficients of diffusion of the actinium and thorium emanations appears to be quite regular down to pressures of a few centimeters.]

Russell, W.L., 1944
The total gamma-ray activity of sedimentary rocks as indicated by Geiger-counter determinations:
Geophysics 9(2): 180-216
[Use of gamma measurement to detect oil. Determined gamma ray intensities of 510 rock samples.]

Russell, W.L. and S.A. Scherbatskoy, 1951
The use of sensitive gamma ray detectors in prospection:
Econ. Geology, 46: 427-446

Rutherford, E., 1900
Über eine von Thoriumverbindungen emittierte radioaktive Substanz [On a radioactive substance emitted from thorium compounds]:
Physikal. Zeitschrift, 1(32): 347-348
[Detailed in Philos. Mag., Jan. 1900.]

Rutherford, Ernest, 1901
Einfluss der Temperatur auf die 'Emanationes' radioaktiver Substanzen [Influence of temperature upon the 'emanations' of radioactive substances]:
Physikal. Zeitschrift, 2(29): 429-431
[On emanating power.]

Rutherford, Ernest, 1904
Radio-activity:
Cambridge, Univ. Press: 399 p.

Rutherford, Ernest, 1906
Absorption of the radio-active emanations by charcoal:
Nature [London], 74(1930): 634
[This is a letter pointing out the absorption of radium emanation by cocoanut charcoal.] "...If a slow current of air, mixed with the emanation of radium, thorium, or actinium, is passed through a tube filled with charcoal, the issuing gas is completely deprived of emanation. This occurs at ordinary temperatures....It makes no difference whether the charcoal has been initially heated to get rid of absorbed air or whether it has already absorbed its full quantity. At low pressures of the gas, using charcoal which has been previously heated, the removal of emanation takes place rapidly. This is probably due to the rapid absorption of the gas which carries the emanation with it. The charcoal retains the emanation at ordinary temperatures, for I have found that the emanation retained in a charcoal tube open to the air loses its activity at the normal rate observed in sealed vessels. The greater part of the emanation is released by heating the charcoal below a red heat. I have not yet settled whether the release of the emanation is due to an alteration in the absorptive power of the charcoal for the emanation at high temperatures, or whether the emanation is mechanically carried away by the rush of air which takes place when the charcoal is heated...."

Rutherford, Ernest, 1908
Experiments with the radium emanation. (1) The volume of the emanation:
Philos. Mag. 16-6: 300-312
[The emanation had a "sensible" vapor pressure even below the temperature of complete condensation (-150°C).]

Rutherford, Ernest, 1909
Condensation of the radium emanation:
Philos. Mag. 17-6: 723-729
[Absolute boiling pt. of Rn, 208 K; density at boiling pt. 5?]

Rutherford, Ernest, 1913
Radioactive substances and their radiations:
Cambridge Univ. Press., 699 p.

Rutherford, E[rnest] and H[arriet] T. Brooks, 1901
The new gas from radium:
Royal Soc. Canada Trans. 7(3): 21-25
[Investigated temperature effect on the emanating power of radium and thorium preparations. Obtained diffusion coefficient of .08 to .15 (T not specified)]

Rutherford, Ernest, and T. Royds, 1908
Spectrum of the radium emanation:
Philos. Mag. 16-6: 313-317
[About 30 more intense lines and a total of >100 lines were found.]

Rutherford, E., and Frederick Soddy, 1902
The radioactivity of thorium compounds. I. An investigation of the radioactive emanation:
Chem. Soc. [London] Jour. Trans., 81: 321-350

Rutherford, Ernest and Frederick Soddy, 1903
Philos. Mag. 5-6: p. 361-
[Condensation of radium emanation from gas mixtures at -150°C. First paper.]

Rutkowska, Krystyna, 1965
Quantitative and qualitative determination of natural alpha-active aerosols by means of nuclear emulsion [in Polish]:
Prace Centr. Inst. Ochrony Pracy, 15: 181-195
A method for measuring the concentration of natural alpha-active aerosols in air by means of an impactor and nuclear emulsion, assuming that a radioactive equilibrium between radon and its daughters exists in the air is discussed. A method of separating, in the emulsion, traces of alpha particles derived from the decay of ^{212}Po and ^{214}Po by calibrating the nuclear emulsion is also discussed. The results of a series of measurements were interpreted by two different methods in order to verify whether the simplified method is admissible for interpreting microscopic measurements of the lengths of tracks of the alpha particles.

Sachs, H.M., D. Harrje, H.W. Prichard, K. Gadsby, and David I. Jacobson, 1983
Radon concentrations and ventilation rates in eastern Pennsylvania houses, *in* Janssen, J.E., ed., Proceedings of the Engineering Foundation Conference on Management of Atmosphere in Tightly Enclosed Spaces:
Atlanta., Ga., Am. Soc. Heating, Refrigeration and Air Conditioning Engineers, Spec. Pub.
[Measurements were made in 37 houses, all on sedimentary occurrences.
From Table I:
Rn in air (pCi/L)

		#	Living Area		Outer Cellar	
			Geom.Mean	1 Std.Dev.	Geom.Mean	1 S.D.
I	All houses	30	4.6	1.4-15.8	6.5	1.7-24.8
II	<10-15 yr old	12	10.6	2.7-4.0	13.7	3-73
III	>10-15 yr old	16	2.9	1.3-6.2	4.0	1.8-9.1]

Sachs, H.M., T.L. Hernandez, and J.W. Ring, 1982
Regional geology and radon variability in buildings:
Environment Internat., 8(1-6): 97-103

Saito, Yasutoshi, 1971
Escape of thoron from thorium dioxide [in Japanese]:
Funtai Oyobi Funmatsuyakin, 17(17):300-306
Chem. Abs. 76:147881r:

Sakakura, A.Y., Carolyn Lindberg, and Henry Faul, 1959
Equation of continuity in geology with applications to the transport of radioactive gas:
U.S. Geol. Survey Bull. 1052-I: 287-305

Samuelson, Alan C., David Ober, Thad Godish, David Govaer, and Alice Bennett, 1988
Air and water radon investigations in east-central Indiana [abs.]:
Geol. Soc. America, Abstracts with Programs, 20(7): A338
The Radon Working Group at Ball State University [Muncie, Indiana] has initiated a study of radon levels in both air and groundwater in homes in east-central Indiana. The air data are collected for two-day periods in charcoal canisters placed in the center of the lower floor in private homes. The data are correlated with outside temperatures, house construction characteristics, and soil types on which the home is founded with the latter producing the most striking correlation. All of the highest radon levels (over 3.25 pCi/L) are in homes founded on a subsoil consisting of glacial sand and gravels of high porosity, and including gravels of Precambrian granite pebbles. The water data are collected from groundwater wells and measured by scintillation techniques. The data are correlated with values for other elements, geographic location, well depth, and aquifer type with the latter two factors producing the most positive correlation. To date, most of the higher radon levels (>300 pCi/L) are found in groundwaters coming from wells that are >24 m deep that are in Silurian carbonates. Wells that are drawing from the glacial sand and gravels typically have lower radon levels.

Samuelsson, C., and H. Pettersson, 1984
Exhalation of ^{222}Rn from porous materials:
Radiation Protection Dosimetry, 7(1-4): 95-100
Chem. Abs. 101:99830j

Sanchez Serrano, E., 1952-53
La radiactividad de algunas aguas naturales españolas [The radioactivity of several Spanish natural waters]:
Bol. Radiactividad, 25: 24-27
Geophys. Abs. 158-192
The results of radon measurements made on 30 natural waters in Spain, most of them hitherto unpublished, are listed. With the exception of three samples from Valdemorillo (Madrid) which contained 130.5, 166.5, and 174.4 nCi/L, radon contents measured were less than one or at most a few nCi/L.

Sanchez Serrano, E., 1952-53
Bibliografia anotada (1904-1954) sobre radiactividad de aguas naturales españolas [Annotated bibliography (1904-1954) on radioactivity of Spanish natural waters]:

Bol. Radiactividad, 25: 28-65
Geophys. Abs. 158-193
An annotated bibliography covering the first 50 years of radioactivity studies on natural waters in Spain, most of which have been made by the Instituto de Radiactividad in Madrid. Entries are arranged chronologically.

Sanderson, J.C., 1911
The probable influence of the soil on local atmospheric radioactivity:
Am. Jour. Sci., 32(189): 169-184
[Emanating powers of several thorium minerals.]

Sarcia, J.A., 1958
The uraniferous province of northern Limousin and its three principal deposits, *in* United Nations Internat. Conf. on the Peaceful Uses of Atomic Energy, 2nd, Geneva, Proc., 2: 578-591
[Les Sagnes deposit, (p. 579): Exploratory mining follows a simple scheme. The veins are traced from the entrance until radon concentrations become too high....[then chip samples are taken]....Margnac deposit (p. 584): The first investigation of radon concentrations has come to an end; it located very precisely the prolongation of the ore bodies of Margnac III-IV, something that it was not possible to achieve heretofore by any other method. No other mention of radon.]

Sarmiento, J.L., W.S. Broecker, and P.E. Biscaye, 1978
Excess bottom radon 222 distribution in deep ocean passages:
Jour. Geophys. Research, 83(10): 5068-5076

Sato, Konosuke, 1956
Some problems of prospecting for radioactive minerals [in Japanese with English summary]:
Butsuri-Tanko, 9(1): 1-4
Geophys. Abs. 166-314
A review of methods and techniques of prospecting and the geologic interpretation of radioactivity anomalies.

Sato, M., 1953
The existence of radium B, radium C, and thorium B in the Misasa hot springs:
Repts. Baleneol. Lab. Okayama Univ., 13: 5-8

Satterly, John, 1908
The amount of radium emanation in the atmosphere:
Philos. Mag. 16-6: 584-615

Satterly, John, 1910
On the amount of radium emanation in the lower regions of the atmosphere and its variations with the weather:
Philos. Mag. 20: 1-36
["Absorption" by cocoanut charcoal; observed pressure, wind velocity, etc.; corr. w/pressure. See review of early results on pp. 29-32. Contradictory results.]

Satterly, John, 1910
Some experiments on the absorption of radium emanation by cocoanut charcoal:
Philos. Mag. 20: 778-78

Satterly, John, 1911
Cambridge Philos. Soc. Proc., 16: 336-355(364?)
[Cullen, 1946, refers to Satterly, saying "some of the radon produced is occluded in the solid, but about one-seventh of it finds its way into....soil gases."]

Satterly, John, 1912
A study of the radium emanation contained in the air of various soils:
Cambridge Philos. Soc. Proc., 16, pt. 4: 336-355

Satterly, John, 1912
Nature [London], 89: 208 [presented at Cambridge Philos. Soc., March 11, 1912]
Average Rn in gravelly soil at depths from 100 to 200 cm: 200 pCi/L ....As the actual radium content is more likely to be seventy times this it follows that little of the emanation generated in the solid particles of the soil can escape into the air around them.

Satterly, John, 1912
The radium content of various fresh and sea waters and some other substances:
Cambridge Philos. Soc. Proc. 16: 360-364

Satterly, John, 1912
The quantities of radium and thorium emanations contained in the air of certain soils:
Cambridge Philos. Soc. Proc., 16, Pt. 6: 514-533

Satterly, J., and J.C. McLennan, 1918
The radioactivity of the natural gases of Canada:
Royal Soc. Canada Trans., 12, sec. 3: 153-160

Saum, D., 1989
Radon mitigation performance monitoring in three houses, in Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 2, Symposium Poster Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006b [Springfield, Va., NTIS Order No. PB89-167498], P. 3-103--3-120.

Sax, N. Irving, and Jack J. Gabay, 1960
Public health aspects of environmental radiation: 81 p.
Nucl. Sci. Abs. 16:19181;
Preliminary results are reported for a long-range study of the effects upon naturally occurring radioactive materials. A miniature community ingestion and excretion study for the ingestion of radium was carried out with ten individuals, comprising five married couples, participating. Results are reported from investigations of analytical methods, the ambient radon content of the air in homes, whole-body counting, external dose measurements, and special samples analysis.

Scarpa, O., 1910
The ionization of the air in the vicinity of some springs in the Isle of Ischia:
Atti. del r. ist. d'incoragg. di Napoli, 6: 39-42

Scheminzky, F., and W. Grabherr, 1951
Über uran anreichernde Warzen- und Knopfchensinter an Osterreichischren Thermen, insbesondere in Gastein [On uranium enriched mamillary and knobby sinter in Austrian hot springs, especially in Gastein]:
Tschermaks Mineralogische und Petrographische Mitteilungen, 2(3)

Schery, S.D., 1989
Measurements and modeling of desorption of radon from porous materials [abs.]:
Eos, Am. Geophysical Union Trans., 70(15): 497

Measurements have been made of the sorption coefficient for trace amounts of radon in air on a variety of soils and rocks. At low moisture and temperature many sorption coefficients are significant, but they generally decrease rapidly with increasing temperature and moisture. Although not pervasive, there could be places at the earth's surface where desorption is important for releasing radon to the atmosphere. The top several centimeters of dry, unvegetated soil in arid or semi-arid climates, and loose rocks upon such soil, might be situations where desorption is important. Transport calculations predict patterns of radon release that can possess subtle features. Change in the sorption coefficient may have no net effect on the steady-state release of radon for some situations (for example, small, isolated rocks). More typically, there is a complicated time-dependent release of radon governed by the size of a sample, the thermal diffusivity, the porosity, the effective diffusion coefficient, and the time dependence of boundary conditions.

Schery, S.D., and D.H. Gaeddert, 1982
Measurements of the effect of cyclic atmospheric pressure variation on the flux of ^{222}Rn from the soil:
Geophys. Research Letters, 9(8): 835-838

Schery, S.D., D.H. Gaeddert, and M.H. Wilkening, 1982
Transport of radon from fractured rock:
Jour. Geophys. Research, 87(B4): 2969-2976.

Schery, S.D., D.H. Gaeddert, and M.H. Wilkening, 1984
Factors affecting exhalation of radon from a gravelly sandy loam:
Jour. Geophys. Research, 89(D5): 7299-7309.

Schery, S.D., and A.G. Petschek, 1983
The question of the effect of thermal gradients in soil:
Earth Planet. Sci. Letters, 64: 56-60

Schery, S.D., and Siegel, D., 1986
The role of channels in the transport of radon from the soil:
Jour. Geophys. Research, 91(B12): 12366-12374
Chem. Abs. 106:7745n:

Schery, Stephen D., and Stewart Whittlestone, 1987
Progress in measurements of sorption of radon on porous materials and implications for the release of radon at the Earth's surface:
Socorro, N. Mex., New Mexico Inst. Mining Technol., Physics Dept., unpub. rept., 20 p.

Schlundt, H., 1907
Electroscopic determination of the radium present in some "tufa" deposits from Hot Springs, Arkansas:
Am. Electrochem. Soc. Trans. 12: 247-252
Sci. Abs. 1101 (1908)
The amounts of radium found in various samples of tufa vary from 0.01 to 1927 pg per g of tufa. No correspondence exists between the content of radium emanation in the waters of the springs and the radium present in the deposited tufa.

Schlundt, H., 1935
The radioactivity of the spring water on the Hot Springs Reservation, Hot Springs, Arkansas:
Am. Jour. Sci., 30: 45-50

Schlundt, Herman, and R.B. Moore, 1909
Radioactivity of the thermal waters of Yellowstone National Park:

U.S. Geol. Survey Bull. 395, 35 p.

Schmeling, Per, and Fred Felix, 1961
Experimental methods and equipment for diffusion measurements of radioactive rare-gases in solid (rare-gas diffusion in solids 7):
Berlin, Hahn-Meitner Inst. für Kernforschung Rept. HMI-B-19: 42 p.
Nucl. Sci. Abs. 16:10528, 1962
A literature survey is given on the methods and equipment used for the measurement of release of radioactive rare gases in solids, with a discussion of advantages or disadvantages. Continuous methods with sweepgas or circulation and various discontinuous methods are discussed and apparatus used for Hahn emanation-, DAD-, or PAD-experiments are described. In addition, references are given concerning sampling, purifying, and measuring of radioactive rare gases as well as materials to be used for measuring rare-gas diffusion at high oxygen-sensible systems.

Schmid, Ekkehard, 1931
Der Gehalt der Freiluft an Radiumemanation und deren vertikale Verteilung in der Nähe des Erdbodens [The content of radium emanation in free air and its vertical distribution in the vicinity of the Earth's surface]:
Wien, Ber. Abt. 2a, 140: 27-48

Schmid, Ekkehard, 1932
Messungen des Radium-Emanations-Gehaltes von Kellerluft [Measurements of the radium-emanation content of cellar air]:
Zeitschrift Geophys. 8(5): 233-242
[Trans. (ABT) In the present work the radium emanation content of cellar air will be investigated. The emanation content shows strong fluctuations in noticeable correlation with falling presure. By (investigation) of the exhalation this correlation stood out more plainly. It is established that the correlation is due exclusively to the ventilation of the cellar with outdoor air.]

Schmidt, W., 1926
The distribution of radioactive substances in the air:
Physikal. Zeitschrift, 27: 371-378
See Chem. Abs. (1927) 1056-1
[Theoretical rate of exhalation of radon from the earth.]

Schmied, Hannes, 1985
Combined stack effect in houses and eskers explaining transients in radon source:
The Science of the Total Environment, 45: 195-201

Schmitz, J., and M. Urban, 1984
Mine dumps as a source of radon impact on buildings:
Radiation Protection Dosimetry, 7(1-4): 63-67.
Chem. Abs. 101:99824k

Schoeneich, Krzysztoff, 1960
Radiogeologiczne metody rozpoznawania z powierzchni nieciagłości tektonicznych nad nie rozcietymi złozami kopaliny [Radiogeological methods of surficial detection of tectonic discontinuities over unfaulted mineral deposits]:
Przeglad Geol., 8(12): 649-651
Geophys. Abs. 185-506

Radiogeologic methods are particularly useful in detecting faults within horizontal sediments that are overlain by thin Quaternary deposits. An emanometer of the type used in exploration for radioactive minerals was used to locate such faulting in the phosphorite at Annopol on the Vistula River.

Schroeder, Gerald L., 1964
Radon-222 in mine atmospheres:
Science, 145(3663): p. 727
Geophys. Abs. 214-272:
The measured flux of Rn-222 into the atmospheres of several mines is greatest during periods of falling barometric pressure. Flow of interstitial gas from the mine rock into the mines and relatively high radon concentration gradients in the shallow rock layers forming the mine interiors are infered to result from the falling pressure.

Schroeder, G.L., 1977
Falling barometer nullifies rock sealant effectiveness:
Mining Engineering, 29(6): 38-39

Schroeder, G.L., M.M. Costello, and A.R. Lewis, 1962
Behavior of radon in soil gas, *in* Evans, Robley D., Radium and mesothorium poisoning and dosimetry and instrumentation techniques in applied radioactivity. Annual progress report:
Massachusetts Inst. Technology Radioactivity Center Rept. TID-16349: 79-90
Nucl. Sci. Abs. 16:28701

Schroeder, Gerald L., Hobart W. Kraner, and Robley D. Evans, 1965
Diffusion of radon in several naturally occurring soil types:
Jour. Geophys. Research, 70(2): 471-474
Geophys. Abs. 219-317
Experimental values of the diffusion coefficient for Ra-222 (radon) in several naturally occurring soils are presented; 0.03 cm^2/s appears to be a fair approximation of the true value for moderately dry, sandy soils. In at least the upper 30 cm of some soils convection and diffusion are the mechanisms which remove radon from these shallow layers. Concentrations of Rn-220 (thoron) in several soil and rock environments are listed.

Schultz, Arthur P., and Calvin Wiggs, 1989
Geol. Soc. America, Northeastern Section, Abstracts with Programs, 21(2): 65
Preliminary results of a radon study across the Great Valley of West Virginia [abs.]:
As part of the U.S. Geological Survey's radon program, a study of the distribution of radon in areas underlain by folded, faulted, and cleaved limestones, dolomites, and shales of the Great Valley of West Virginia was undertaken. Radon soil-gas measurements and scintillometer measurements of soil and bedrock were made on a 20-km traverse approximately perpendicular to regional strike. Radon values generally vary with changes in rock type. Soil-gas values on the traverse are 500 to 1,500 pCi/L for soils above the Cambrian through Middle Ordovician Tomstown dolomite, the Waynesboro Formation, the lower and middle parts of the Elbrook Formation, the Conococheague Formation, the Beekmantown Group and Middle Ordovician limestones and dolomites; 1500 to 2800 pCi/L for soils above the upper part of the Cambrian Elbrook Formation and the Middle Ordovician Martinsburg Formation; and 2800 to 4000 pCi/L for soils above a limited stratigraphic interval in the lower part of the Cambrian Conococheague Formation. In areas underlain by limestone and dolomite, where soil-gas values are high, scintillometer readings on outcropping bedrock were generally low. The high soil-gas readings may indicate concentration of uranium minerals during carbonate solution of adjacent bedrock and soil-forming processes. Outcrop scintillometer readings for shaly and sandy carbonate rocks were generally higher than those for adjacent limestones and dolomites. Except for high spot anomalies, the variation in soil-gas values is similar to the variation in aeroradioactivity values.

Generally low radon soil-gas values were found above mapped faults. In one case, an area of high soil-gas values appears to be related to a zone of impermeable clay within a thick *terra rossa* developed on limestones.

Schumann, G., 1956
Untersuchung der Radioaktivität der Atmosphäre mit der Filter Methode [Investigation of the radioactivity of the atmosphere by the filter method]:
Archiv Meteorologie, Geophysik u. Bioklimatologie, 9(2): 204-223
Geophys. Abs. 165-304:
Nongaseous radioactive substances in the air are trapped by aerosols and can be collected with them in filters. By placing the filter inside a counter, absolute activities may be measured. The radioactivity of the atmosphere at Heidelberg has been studied by the filter method at two stations 565 and 130 m above sea level. The decay curves give beyond the radon daughter products, the contributions of the thorium series, fission products from atomic bomb tests, and of RaD (Pb-210). A consistent interpretation is obtained only when all weather factors are considered at the same time. The filter method was also used to study air from the ground in tunnels and boreholes, and a fault was located.

Schumann, G., 1963
Investigation of radon daughters:
Jour. Geophys. Research, 68(13): 3867-3869
Geophys. Abs. 203-303:
A Goetz aerosol spectrometer and low-level counting techniques were used to study the size distribution of aerosol particles having attached Pb-214 and Bi-214. Particles as small as 25 nm in radius could be measured. The values obtained fall between theoretical size distributions given by Lassen (1962) and by Junge (1955), but the number of measurements is insufficient to warrant conclusions about the distributions.

Schumann, R.R., 1990
Hydrologic setting of the Boston Peak fen, *in* Environmental Forum 1990: Geoscience investigations that emphasize chemical, physical, and biological ecosystem processes:
U.S. Geol. Survey Open-file Rept. 90-288, p. 20
The Boston Peak fen is a montane lakefill wetland with ground water hydrology characterized by a confined, locally artesian aquifer overlain by an unconfined aquifer. Clayey glacial and postglacial lake sediments act as an aquiclude separating underlying glaciofluvial sands from overlying peat. Faults and fractures in the surrounding crystalline rocks [*] act as conduits for uranium-rich waters that enter the wetland as seeps and springs, providing the primary water input to the wetland. Concentrations of uranium in the wetland are largely confined to areas along the margins and base of the wetland deposits, and along preferred ground water flow paths. Twenty piezometer stations consisting of 40 wells were used to measure hydraulic conductivity of wetland deposits, monitor water tables, and characterize ground water flow within the wetland. Seasonal water table fluctuations are unequal across the wetland and are reflected in the distribution of plant types: The area with the greatest seasonal water table fluctuation is a willow carr, whereas the area with consistently higher water tables is a sedge-dominated fen [†]. [* "Crystalline rocks" is an inexact term usually meaning igneous or metamorphic rock, as opposed to sedimentary, but sometimes including sedimentary rocks having contiguous crystals, such as marbles and quartzites. † See Owen *et al.*, 1988, for classifications of some wetlands.]

Schumann, R. Randall, Sigrid Asher-Bolinder, and Douglass E. Owen, 1989
Factors influencing seasonal variations in soil-gas radon concentrations in a fine-grained soil [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(2): 65
Although geologic and soil characteristics are primarily responsible for determining the concentration of radon-222 in a given soil, soil-gas radon concentrations at a site fluctuate under the influence of meteorologic factors. A long-term soil gas monitoring site was established at the Denver Federal Center (DFC), Colorado, to investigate causes of non-geologic variations in measured soil-gas radon concentrations. The dry climate

and smectitic soil at the DFC site interact to form an extensive system of desiccation cracks that imparts significant permeability to what would otherwise be an almost impermeable soil. Moisture capping occurs when precipitation infiltrates the uppermost soil layers, causing the clays to swell and cracks to close, and radon accumulates to elevated levels beneath the capping layer. The capping effect is further enhanced during the winter, when moisture in the surface layer freezes. Radon concentrations in soil gas at the DFC site vary by as much as an order of magnitude between seasons, and by as much as 200 percent in response to day-to-day weather variations. The most important weather factors affecting soil-gas radon concentrations at the DFC site are: 1) precipitation (as it affects soil moisture); 2) barometric pressure; and 3) temperature, wind, and other factors. Effects of lower-ranked factors are more noticeable in the absence of higher-ranked ones, because the more dominant weather factors tend to overshadow the effects of those factors with weaker influences. The results of this study suggest that radon surveys based on soil gas data could be misinterpreted if seasonal and weather-related variations are not considered. Additional data from other soil types and climatic zones should be collected to provide a better base for interpretation of radon data.

Schumann, R.R., L.C.S. Gundersen, S. Asher-Bolinder, and D.E. Owen, 1989
Anomalous radon levels in crystalline rocks near Conifer, Colorado [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(6): A144-A145
An area near Conifer, Colorado, with known elevated indoor radon levels was investigated to determine the geologic factors controlling radon concentrations in rocks, soils, and water in crystalline rocks [*] of the Front Range. More than 200 soil-gas radon concentration and 300 surface gamma radioactivity measurements were made along traverses and grids in an approximately 75 km^2 area and correlated with observations of geologic and structural features. Locally uranium-rich (containing as much as 18 ppm equivalent uranium) granites and gneisses provide sources for radon, especially where these rocks are fractured and/or intensely weathered or altered. Soil-gas radon concentrations greater than 5000 pCi/L [185 kBq/m^3], compared with a median concentration for the study area of 600 pCi/L [22 kBq/m^3] were measured in proximity to sheared and altered zones. Faults, shears, and fractures provide the necessary permeability for movement of soil gases, as well as providing pathways for percolation of water through the rocks, enhancing the weathering process. Redistribution of uranium by weathering, from sites of low emanation within mineral grains to sites of higher emanation on grain surfaces and grain coatings, occurs by two processes: (1) as mineral grains are physically broken down, more uranium is exposed as grain size decreases and surface area-to-volume ratio increases; and (2) chemical weathering of the rocks produces Fe, Mg, and Mn coatings on mineral grains and fracture walls that tend to preferentially adsorb uranium. These zones may be relatively enriched in uranium as other elements are leached from the system. Some uranium enrichment may occur along fractures and shears through contact with uranium-bearing near-surface ground waters. [* "crystalline rocks" is an inexact term usually meaning igneous or metamorphic rock, as opposed to sedimentary, but sometimes including sedimentary rocks having contiguous crystals, such as marbles and quartzites.]

Schumann, R.R., and D.E. Owen, 1988
Relationships between geology, equivalent uranium concentration, and radon in soil gas, Fairfax County, Virginia:
U.S. Geol. Survey Open-file Report 88-18, 27 p.

Schumann, R.R., D.E. Owen, and S. Asher-Bolinder, 1989
Weather factors affecting soil-gas radon concentrations at a single site in the semiarid western U.S., in Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 2, Symposium Poster Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006b [Springfield, Va., NTIS Order No. PB89-167498], p. 3-1--3-13.
Concentrations of radon-222 in soil gas, measured at a long-term radon monitoring site on the Denver Federal Center (DFC), Colorado, vary by as much as an order of magnitude in response to short- and long-term weather variations. The primary weather factors influencing soil-gas radon concentrations are precipitation and barometric pressure, with lesser effects attributed to temperature and, possibly, wind. Soil characteristics

are highly significant in determining the magnitude and extent of the soil's response to weather changes. The soil at the DFC site is clay rich and develops an extensive system of desiccation cracks that impart a moderate permeability to what would otherwise be a relatively impermeable soil. A capping effect caused by frozen or unfrozen soil moisture is a primary radon concentrating mechanism.

Schumann, R. Randall, R. Thomas Peake, Kevin M. Schmidt, and Douglass E. Owen, 1990
Correlations of soil-gas and indoor radon with geology in glacially derived soils of the northern Great Plains, *in* The 1990 International Symposium on Radon and Radon Reduction Technology, Atlanta, Ga., 19-23 February 1990:
Preprints, Vol. III, no. VI-3, 14 p.
A higher percentage of homes in parts of the northern Great Plains underlain by soils derived from continental glacial deposits have elevated indoor radon levels (greater than 4 pCi/L) than any other area of the United States. Soil-gas radon concentrations, surface radioactivity, indoor radon levels, and soil characteristics were studied in areas underlain by glacially derived soils in North Dakota and Minnesota to examine the factors responsible for these elevated levels. Clay-rich till soils in North Dakota have generally higher soil-gas radon levels, and correspondingly higher indoor radon levels, than the sandy till soils common to west-central Minnesota. Although the proportions of homes with indoor radon levels greater than 4 pCi/L are similar in both areas, relatively few homes underlain by sandy tills have screening indoor radon levels greater than 20 pCi/L, whereas a relatively large proportion of homes underlain by clayey tills have screening indoor radon levels exceeding 20 pCi/L. The higher radon levels in North Dakota are likely due to enhanced emanation from the smaller grains and to relatively higher soil radium concentrations in the clay-rich soils, whereas the generally higher permeability of the sandy till soils in Minnesota allows soil gas to be drawn into structures from a larger source volume, increasing indoor radon levels in those areas.

Sciocchetti, G., and F. Scacco, 1980
Results of a national survey on natural radioactivity in Italy, *in* Natural Radiation Environment III, Gesell, Thomas F.,and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1107-1114, disc., p. 1114-1115

Sciocchetti, G., F. Scacco, P.G. Baldassini, C. Batella, M. Bovi, and L. Monte, 1985
The Italian national survey of indoor radon exposure:
The Science of the Total Environment, 45: 327-333

Sciocchetti, G., F. Scacco, P.G. Baldassini, L. Monte, and R. Sarao, 1984
Indoor measurements of airborne natural radioactivity in Italy:
Radiation Protection Dosimetry, 7(1-4): 347-351
Chem. Abs. 101:99871y

Scott, Robert C., and Franklin B. Barker, 1962
Data on uranium and radium in ground water in the United States, 1954 to 1957:
U.S. Geol. Survey Prof. Paper 426: 115 p.

Seismological Brigade of Hebei Province, Group of Hydro-chemistry, 1975
Studies on forecasting earthquakes in the light of the abnormal variations of Rn concentration in ground water [in Chinese]:
Acta Geophysica Sinica [Peking], 18(4): 279-283
[Authors: Liu Po Li, Wan Di Kun, Wan Tsen Min.]

Seismological Brigade of Peking, Group of Hydro-Chemistry, 1977
An experimental study of the relation between rock rupture and variation of radon (Rn) content [in Chinese]:

Acta Teophysica Sinica [Peking], 20(4): 277-282 [in English Transl.] Chinese Geophysics, 1(2): 361-367 (1978)(Earthquake Research in China: 2)

Semenov, G.S., 1961 [1962]
Nekotoryye rezul'taty issledovaniy sostave yestestvennogo gamma-polya nad gazovymi mestorozhdeniyami Bukharo-Khivinskoy depressii [Some results of investigation of the composition of the natural gamma field over gas deposits of the Bukhara-Khiva depression], *in* Yadernaya Geofizika [Nuclear Geophysics]:
Moscow, Gostoptekhizdat, p. 154-159
Geophys. Abs. 199-285

Semkow, T.M., 1989
Alpha-recoil emanation theory applied to radon release from solids:
Eos, Am. Geophys. Union Trans., 70(15): 496
The alpha-recoil is presented as a major mechanism for radon release from solid materials. The theory is developed for radon emanation from geometrical shapes: spheres and cylinders having variable thickness of precursor-radium-containing material. Subsequently, a sphere-pore model of emanation from solid grains (like minerals, soils, etc.) is described, which includes processes like pore overlap, radon embedding, water effect and edge effects. Using such a model it is shown how the radon emanating-power measurements can give a clue to the radium distribution and surface properties of the samples. In particular it is shown that for surface radium distribution the emanating power is independent of the grain size but the total radium concentration varies with the reciprocal of the grain size. The reverse is true for radium distributed uniformly through the volume of the grain. It is also shown how the information about pore density, pore length and thickness of radium-containing material can be deduced from measurements of the water effect on the emanating power as well as from measurements of the pore-size distribution. In addition, implications are made with respect to uranium and thorium transport.

Senior, Lisa, and Karen L. Vogel, 1989
Geochemistry of radium-226, radium-228, and radon-222 in the ground water of the Chickies Quartzite, southeastern Pennsylvania [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(6): A145
Elevated radium activities in ground water of the Chickies quartzite were detected in 1985. Between 1986-88, the U.S. Geological Survey sampled 160 wells penetrating the Chickies Quartzite to determine the magnitude and distribution of ground-water radium-226, radium-228 and radon-222 activities and to characterize the geochemical environment associated with elevated radium. The Chickies Quartzite is a Cambrian basal conglomerate, quartzite, and slate that crops out in the Piedmont of southeastern Pennsylvania. Water-sample analyses included determination of dissolved ^{226}Ra, ^{228}Ra, ^{222}Rn, uranium, and major and minor ions. Activities of up to 41 pCi/L ^{226}Ra, $\approx$60 pCi/L ^{228}Ra, and 32,280 pCi/L ^{222}Rn were measured. Nonparametric Spearman rho correlations show that dissolved radium activity relates negatively to pH and postively to dissolved organic carbon concentration. These factors may favor radium mobility by promoting a decrease in adsorption and an increase in solubility. Radium activities were greatest in acidic ground water in the conglomerate and quartzite (median pH of 5.0 and 5.2, respectively) and least in more neutral water in the slate (median pH of 6.4). Ra-228 activity exceeds ^{226}Ra activity in most water samples. Results of solid-phase analysis indicate that the conglomerate may contain more thorium and uranium than the quartzite. A trend of increasing median ^{222}Rn activities in ground-water samples from the slate to the quartzite to the conglomerate also suggests a trend of increasing uranium content in those lithologies. Rn-222 activity does not correlate with ^{226}Ra or uranium in solution. Observed distributions of radium isotopes and ^{222}Rn activities in ground water reflect geochemical controls on solubility and adsorption and variable distribution of parent thorium-232 and uranium-238 in the formation.

Serdyukova, A.S., and V.P. Doshchechkin, 1969

O vozmozhnosti gamma-spektroskopii v karotazhe skvazhin pri nalichii v nikh radona [On the possibility of gamma spectroscopy in logging in the presence of radon in the boreholes):
Vyssh. Ucheb. Zavedeniya Izv., Geologiya i Razved., 12: 134-137
Geophys. Abs. 285-553:
It is shown that to distinguish the part of gamma radiation of ores from the total radiation (ore plus radon), the energy intervals 180-230 and 580-630 keV, and also 500-550 and 580-630 keV, should be used in the measurements. In theory other pairs of energy intervals could be used. Comparison of data of spectral gamma logging using the 180-230 and 580-630 keV intervals with the results of logging on the basis of total gamma radiation in the absence of radon gave satisfactory convergence, which means that spectral gamma logging can be recommended for determining the uranium content in ores.

Serdyukova, A.S., and V.P. Doshchechkin, 1969
Sravitel'noye issledovaniye spektrov gamma-izlucheniya uranovoy rudy i radona, nakhodyashchegosuya v skvazhine [Comparative investigation of the gamma-ray spectrums of uranium ore and radon located in a borehole]:
Vyssh. Ucheb. Zavedeniya Izv., Geologiya i Razved., 9: 112-117
Geophys. Abs. 285-551:
As a result of investigations on models and in place, it is established that the differential apparatus spectrums of gamma radiation from uranium ores and radon in a borehole are sharply different in the low energy range (less than 350 keV) and in the region of the peak corresponding to the energy of primary gamma radiation of 609 keV. These differences make it possible to use gamma-ray spectrometry to distinguish the fraction of gamma radiation of the ore from the total (radon + ore) gamma-ray measurement.

Serdyukova, A.S., and Yu.T. Kapitanov, 1969
Izotopy Radona i Korotkozhivushchiye Produkty ikh Raspada v Prirode:
Moscow, Atomizdat; translated into English as Radon Isotopes and Short-lived Products of Their Disintegration in Nature: New Delhi, Indian Nat. Scientific Documentation Centre [Washington, U.S. Bur. Mines and Nat. Sci. Foundation trans. T72-51014, 379 p.]

Serdyukova, A.S., Yu.T. Kapitanov, and M.P. Zavodskaya, 1965
Opredeleniye koeffitsiyentov diffusii po velichine kontsentratsii radona v vozdukhe gornyhh porod i tupikovykh vyrabotok [Determination of coefficients of diffusion by magnitude of the concentration of radon in the air of mines and blind workings]:
Akad. Nauk SSSR, Izv., Fizika Zemli, 7: 123-127

Serdyukova, A.S., A.F. Zima, V.I., Skosyrev, and T.A. Trofimova, 1977
Combined use of emanation and gamma-ray spectral methods for evaluating possible radiometric anomalies [in Russian]:
Vyssh. Ucheb. Zaved. Izv., Geologiya i Razvedka, 20(12): 116-123
Chem. Abs. 88:123930c

Servant, J., 1966
Temporal and spatial variations of the concentration of the short-lived decay products of radon in the lower atmosphere:
Tellus., 18(2-3): 663-671
Geophys. Abs. 246-388:
The concentration of radon in the lower atmosphere was measured above a plateau and at different latitudes and longitudes over continents and oceans to determine its general distribution in the lower atmosphere. The maximum (75,000 pCi/m^3), above the continents, is greater by a factor of 7.5E4 than the minimum (1 pCi/m^3), above the oceans. Factors controlling the variation over land and sea are discussed.

Servant, J., and Olga Tanaevsky, 1961

Mesures de la radioactivité naturelle dans la region Parisienne [Measurement of natural radioactivity in the Paris region]:
Annales Geophysique, 17(4): 405-409
Geophys. Abs. 189-491
The methods of measuring natural radon emanation on or at various levels above the ground are described, and the results of measurements at Quai Branly and the Eiffel Tower in Paris are discussed and illustrated in tables and graphs. Measurements at the ground were begun and have continued without interruption to the present time. Comparison between the monthly mean of radon for 1955 and 1960 at Paris and at Saclay shows that it was weak from 1955 through 1958 but became more elevated in 1959 and 1960. Results demonstrate that radon accumulation above the ground is favored by intense fog, stable air, and temperature inversion due to radiation or subsidence. The accumulation is of the same order on plateaus as in valleys.

Setter, L.R., and C.P. Straub, 1958
The distribution of radioactivity from rain:
Am. Geophys. Union Trans. 39: 451-458

Severne, B.C., 1978
Evaluation of radon systems at Yeelirrie, Western Australia:
Jour. Geochem. Exploration, 9(1): 1-22.

Sextro, Richard G., 1985
Understanding the origin of radon indoors--Building a predictive capability, from Conference on Characterization of Contaminant Emissions from Indoor Sources, Chapel Hill, NC, May 13-15, 1985:
Lawrence Berkeley Lab. Rept. LBL-20210, 21 p. [submitted to Atmospheric Environment]
Indoor radon concentrations one to two orders of magnitude higher than the U.S. average of ≈ 40 Bq/m^3 (≈ 1 pCi/L) are not uncommon, and concentrations greater than 4000 Bq/m^3 have been observed in houses in areas with no known artificially enhanced radon sources. In general, source categories for indoor radon are well known: soil, domestic water, building materials, and outdoor air. The latter two source categories have generally been found to have low radon source strengths. Domestic water supplies also typically contribute little to airborne radon concentrations, although in certain localities water has been identified as a significant source. Soil, on the other hand, is thought to be a major source of indoor radon, either through diffusive (usually a minor component) or bulk flow of soil gas. While soil gas flow into residences has been demonstrated, no general understanding of the important factors affecting the source strength of radon from soil has yet emerged. Preliminary work in this area has identified a number of likely issues, including the concentration of radium in the soil, the emanating fraction, soil type, soil moisture content, and other factors that would influence soil permeability and soil gas transport. A predictive capability is needed that would help identify geographical areas having the potential for high indoor concentrations. The development of such a capability will require additional scientific study of the soil-related factors discussed above, along with an exploration of existing data bases that might provide indicators of radon concentrations. In addition to soil-specific factors, and examination of the coupling between the soil and the living space provided by various building types and substructures is needed and the role of local meteorology--rainfall, wind loading, barometric pressure changes, and building thermal loads--must be assessed.

Sextro, R.G., B.A. Moed, W.W. Nazaroff, K.L. Revzan, and A.V. Nero, 1987
Investigations of soil as a source of indoor radon, *in* Hopke, Philip K., ed., Radon and Its Decay Products; Occurrence, Properties, and Health Effects:
Washington, Am. Chem. Soc. Symposium Ser. 331, p. 10-29
The predominant source of indoor radon in most single-family housing in the U.S. is the soil adjacent to the house substructure. We have examined factors influencing the production and transport of radon in soil and into buildings. A number of important parameters have been identified and their effect on radon production and migration assessed, including radium concentration, moisture content, air permeability, and grain size

distribution of soils. The potential regional variations in parameters affecting radon have been evaluated by examining geographic data, including surface radium concentrations and general soil data. We have also investigated factors influencing radon migration into individual dwellings. Coupling between the building shell and the surrounding soil has been demonstrated experimentally, and pressure-field mapping and soil permeability measurements have been carried out.

Sextro, R.G., Nazaroff, W.W., and Turk, B.H., 1989
Spatial and temporal variation in factors governing the radon source potential of soil, *in* Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 1, Symposium Oral Papers: Research Triangle Park, N.C.
Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006a [Springfield, Va., NTIS Order No. PB89-167480], p. 5-61--5-74.
Soil is the predominant source of radon in most U.S. homes, particularly for those homes with elevated indoor concentrations. Three factors help govern the indoor radon concentration, the radon production rate in the soil, the air permeability of the soil surrounding the building substructure, and the coupling between the soil and the building. In order to evaluate the spatial and temporal variability of the first two factors, soil permeabilities and soil gas radon concentrations have been measured at different locations and as a function of time. The spatial variabiltiy in permeability measurements at an individual homesite was seen to range from approximately a factor of ten to more than four orders of magnitude. Similarly, spatial variations in soil gas radon concentrations are less than a factor of two at some homesites to a factor of about 200 at others. The temporal changes in permeability and soil gas radon at a given sampling location are somewhat smaller, yielding variations ranging from less than a factor of two to a factor of about 90 in the case of permeability, and from less than a factor of three to a factor of about 40 for soil gas radon concentrations. A method of combining measurements of soil gas radon and air permeability to provide a characteristic parameter - the radon source potential - has been developed and is briefly reviewed. Calculated indoor radon concentrations, based on measured values of radon source potential at a few sample homesites, correlate with the measured indoor radon concentrations.

Shapiro, Mark H., Rebecca Kosowski, and Daniel A. Jones, 1978
Radon series disequilibrium in Southern California coastal air:
Jour. Geophys. Research, 83(C2): 929-933
Chem. Abs. 88:176294e

Shapiro, M.H., J.D. Melvin, N.A. Copping, T.A. Tombrello, and J.H. Whitcomb, 1980
Automated radon-thoron monitoring for earthquake prediction research, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 137-152, disc., p. 153

Shapiro, M.H., J.D. Melvin, T.A. Tombrello, and M.H. Mendenhall, 1981
Relationship of the 1979 southern California radon anomaly to a possible regional strain event:
Jour. Geophys. Research, 86(B3): 1725-1730

Shapiro, M.H., J. Melvin, T.A. Tombrello, and J.H. Whitcomb, 1977
Preliminary data from the Caltech automated radon-thoron monitor [abs.]:
Eos, Am. Geophys. Union Trans., 58(6): p. 434
We have designed, built and deployed a fully automated radon-thoron monitor for use in earthquake prediction studies. The device uses aerosol filtration techniques to sample the radon and thoron daughter isotopes ^{214}Pb, ^{214}Bi, and ^{212}Pb from boreholes, tunnels or mineshafts. Design features include high sensitivity, wide dynamic range, fully automated microprocessor control of all operations, real time data collection with computer controlled data call-up systems, and low unit cost. The unit was placed in operation at a field site in Pasadena in mid-December 1976. From mid-December to mid-February ambient ground level air was sampled three

times daily. During the period of ambient air operation, a sharp decline in radon occurred prior to a 3.2-M earthquake in the Newhall area. The unit was then placed over a newly drilled 24-m borehole. Preliminary data from the borehole operation will be presented.

Shapiro, M.H., J.D. Melvin, T.A. Tombrello, and J.H. Whitcomb, 1978
Data from the Caltech automated radon-thoron monitors [abs.]:
Eos, Am. Geophys. Union Trans., 59(12): p. 1196

Shapiro, M.H., J.D. Melvin, T.A. Tombrello, and J.H. Whitcomb, 1979
Southern California radon anomaly [abs.]:
Eos, Am. Geophys. Union Trans., 60(46): p. 883

Sharkov, Yu.V., 1959
Poiski mestorozhdeniy atomnogo syr'ya [Exploration for deposits of atomic raw materials]:
Priroda, 48(12): 13-21
[Discussion of emanation methods, p. 19. Radium in ground water, p.19-20. p. 19, col. 2, 3d full para.: "Radium quickly enough is captured by clay particles of the ground and usually is not dispersed in underground waters farther than several tens of meters from the deposit. Radon is removed in tens, more rarely the first hundred meters. Migrating farther than these is uranium, which sometimes is carried by ground water to the surface and flowing into streams, rivers, swamps, and lakes, forms aureoles of many kilometers' extent. In addition, uranium is more easily detected in waters than radon or radium...."]

Shashkin, V.L., and M.I. Prutkina, 1970
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[Thorium was determined by the thoron method in Japanese springs. (Ann. Rev. Nuclear Sci. 1, 471)]

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[P. 184:, Ch. VII: 1. Radiations measured at the surface or just above it come from within 0-0.3 feet in loams, 0.6-1.5 feet in sands, and 2 feet in peat. 2. The radon content of sandy soils decreases with increasing coarseness of sands. 3. The radon content of holes drilled on top of dunes and near road cuts is lower than that of holes drilled on the sides of dunes and dunes and away from road cuts. 4. Radiation intensity decreases in lime-rich sandy soils, and increases in sands with increasing limonite stain. 5. Ground water data and airborne radium data show a good general correspondence. 6. Factors have been developed to make necessary soil corrections, and their validity is suggested. 7. Mapping of probable faults has been feasible by airborne radium data in the Redwater Area and l'Assomption Prospect, Quebec. 8. The existence of an anomalous low, bordered by scattered areas of highs, at Redwater Oil Field is suggested. P. 185: 9. A radiometric anomaly associated with the Ten Section Oilfield, California, has been described and evaluated. 10. A mechanism to explain the formation of radiometric anomalies based on the probable presence of fractures in rocks is proposed. 11. The processes of formation of geochemical anomalies are dynamic.]

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Scintillation-counter data from Ten Section Oilfield, 10 miles southwest of Bakersfield, Calif., have been evaluated. The results show an anomalous low at the surface above the Ten Section pool that is coincident with a hydrocarbon low. It is suggested that this coincidence is due to migration of oil through fractures. Two other lows were found; one is due to soils rich in lime and organic matter and the other is unexplained. [Another report on Ten Section said that the radiometric anomaly was unrelated--ABT].

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The principles of radioactivity surveying and gamma-ray spectrometry are reviewed briefly, and a gamma-ray spectrometer with modifications applied to achieve an airborne instrument is described. The application of the method to a survey over the l'Assomption Prospect, Quebec, about 25 miles north of Montreal, is discussed. A number of faults were detected by the survey, and their presence was confirmed by data from well logs and other geophysical means. The application of airborne-radioactivity surveying to soil mapping, mineral exploration (particularly sulfides), geologic mapping, and to the mapping of oil-bearing structures is discussed also.

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[Belgrade] Zavod. Nukl., Sirovine, Sek. Ist. Nukl. i Dr. Mineral. Sirovina Radozi, 1(2): 97-104
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[Radon migration discussed.]

Steele, S.R., 1985
Anomalous radon emanation at local and regional distances preceding earthquakes in the New Madrid Seismic Zone and adjacent areas of the central mid-continent of North America:
Pure and Applied Geophysics, 122: 353-368

Stefanizzi, A., 1950
On the radioactivity of atmospheric precipitates:
Jour. Geophys. Research, 55(4): 373-378
Geophys. Abs. 12764
Determination of the radioactivity of 33 samples of atmospheric precipitates (snow and rain) showed that snow usually has a greater activity than rain, that rain in thundershowers is more active than ordinary rain, and that at least a certain amount of activity is acquired during fall from clouds to ground level. Decay products of thoron were also found in precipitates.

Stehney, A.F., W.P. Norris, H.F. Lucas, Jr., and W.H. Johnston, 1955
A method for measuring the rate of elimination of radon in breath:
Am. Jour. Roentgenol. Radium Therapy Nuclear Med., 73: 774-784

Stein, L., J.A. Shearer, F.A. Hohorst, and F. Markun, 1977
Development of a radiochemical method for analyzing radon gas in uranium mine atmospheres:
NTIS, PB Rept. PB-269900: 75 p.

Steinberg, M., and B. Manowitz, 1958
An adsorption process for recovery of fission product noble gases:
Brookhaven Natl. Lab. BNL493 (T-115)
[Discusses recovery by adsorption on charcoal:....To increase the capacity of charcoal for noble gases at the low concentrations [0.09 ppm by vol Xe and 1.14 ppm Kr] in question, the beds must be operated at low temperatures -- down to -196°C. Operation at room temperatures requires large pieces of equipment. ...The adsorptive activity of charcoal is highly variable, depending on the type used, and tends to decrease after a number of cycles; small amounts of water also decrease it....The one overriding disadvantage is that ever-present danger of a possible uncontrollable combustion and explosive reaction when quantities of oxygen are present in the bed at low temperatures....]

Steinhäusler, Fritz, 1985
European radon surveys and risk assessment, Chap. 7, *in* Gammage, Richard B., and Stephen V. Kaye, eds., Indoor Air and Human Health:
Chelsea, Mich., Lewis Publishers, Inc., p. 109-129

Steinhäusler, F., W. Hofmann, E. Pohl, and J. Pohl-Ruling, 1980
Local and temporal distribution pattern of radon and daughters in an urban environment and determination of organ-dose frequency distributions with demoscopical methods, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1145-1161, disc., p. 1161-1162

Steinhäusler, F., and E. Pohl, 1973
Concentration of radon-222, radon-220, and their daughters in the air, the dependence on meteorological variables and contribution to the radiation dose for the inhabitants of a radon spa:
Proc. Internat. Radiat. Prot. Assoc. Eur. Congr. Radiat. Prot., 2nd: 397-400

Stenstrand, K., M. Annanmaki, and T. Rytomaa, 1979
Cytogenetic investigation of people in Finland using household water with high natural radioactivity:
Health Physics [England], 36(3): 441-444

Sterrett, Elton, 1944
Radon emanations outline formations: Oil Weekly, 115(4): 29-32
Geophys. Abs. 119-7722

Stevens, D.N., G.E. Rouse, and R.H. De Voto, 1971
Radon-222 in soil gas: three uranium exploration case histories in the western United States, *in* Geochem. Exploration, Proc. Intl. Geochemical Expl. Symposium, 3d, Toronto, April 16-18, 1970:
Canadian Inst. Mining Metallurgy, Spec. Vol. 11: 258-264

Stieff, L.R., 1981
Studies of an Improved Polonium-210 Analytical Procedure and the Distribution and Transport of Uranium and its Alpha Emitting Daughters Using Nuclear Emulsions; Final Report:

Kensington, Md., Stieff Research & Development Co., Inc., U.S. Dept. Energy Rept. GJBX-144 (81), 120 p.
[An extension of study reported by Stieff, Balkissoon, and Barbera, 1981.] ...Microscopic examination of exposed and developed nuclear emulsion plates on which non-ore core samples were dispersed confirms the original observation that U-238 and its long-lived daughters U-234, Th-230 and Ra-226, deposit on grain surfaces in very low concentrations (U-238 in sub-picogram amounts). Many of these atoms are bound to the surface so lightly that they, as well as Rn-222, are free to enter the underlying emulsion where their decays are recorded as three, four and five branched alpha track stars. Abundant evidence for the recent transport of Ra-226 is confirmed by the presence of alpha stars on grain surfaces and the presence of numerous small mineral grains having both high relief and high specific alpha activity (possibly barite). In the ore zones as well as in some of the weakly mineralized zones, concentrations of alpha activity usually associated with minerals containing significant amounts of uranium were observed. Abundant evidence for the recent separation, transport and redeposition of Ra-226 has also been obtained. On the basis of both alpha star populations and possibly the presence of numerous barite grains containing Ra-226, unsupported Ra-226 appears to be more mobile than Rn-222 and is widely distributed. These observations confirm tentative conclusions made in the preliminary study (Stieff, et al, 1981)....Neither the Po-210 drill core data reported earlier in the preliminary study nor the results of the nuclear emulsion studies of the same cores reported in this paper provide any supporting evidence for the predicted Po-210 concentration gradient produced by the decay of mobile, unsupported Rn-222 either in transit to the surface or even in transit over short distances from pronounced Po-210 highs. The Po-210 analyses and microscopic studies suggest that observed Rn-222 and Po-210 surface anomalies may be associated with widely dispersed, very low concentrations of Ra-226 or its longer lived parents including uranium. These members of the uranium decay chain may be distributed around the ore at depth as halos or as weak zones of uranium mineralization. Should this tentative conclusion be supported by more comprehensive field and laboratory investigations, the exploration geologist may find that Ra-226/Po-210 can be used in the field as an effective radiochemical technique in the search for uranium.

Stieff, L. R., 1981
Transport and Distribution Studies of Uranium and Its Alpha-Emitting Daughter Products on Drill Core from the Red Desert and Copper Mountain Test Sites, Wyoming, Using Nuclear Emulsions and Po-210; Final Report:
Kensington, Md., Stieff Research and Development Co., Inc., U.S. Dept. Energy Rept. GJBX-112(82), 125 p.
The work on the transport and distribution of uranium and its alpha-emitting daughter products in soil and drill-core samples from the Red Desert and Copper Mountain Test Sites, Wyoming, has been divided into three closely related parts: 1) detailed Po-210 measurements of soil and drill core to study both the vertical and horizontal-surface gradients of Rn-222 and Po-210 (Stieff et al., 1981); 2) detailed nuclear emulsion studies of the same Red Desert and Copper Mountain soil and drill-core samples (Stieff, 1981); and 3) Po-210 measurements and nuclear-emulsion studies on additional Red Desert and Copper Mountain drill-core samples as well as U_3O_8, Ra-226, and Pb-210 measurements for secular equilibrium (this paper). Measurements of Po-210 in the sequential decay, Rn-222 (3.8 days)—>Pb-210 (22 years)—>Po-210 (138 days), provide an indirect means of estimating the number of Rn-222 atoms that have decayed in a sample over the last 80 to 100 years. This estimate includes not only the supported Rn-222 produced by the decay of the Ra-226 in the sample but also the unsupported Rn-222 which has decayed in the sample while in transit during that time interval. Many Po-210 highs have been observed in cores from the Red Desert and Copper Mountain test sites; some are directly associated with uranium mineralization. To date, evidence has not been found in the Bendix Field Engineering (BFEC) core samples for a Po-210 concentration gradient produced by the decay of mobile, unsupported Rn-222 either in transit to the surface or even in transit over short distances (10 feet) from pronounced Ra-226/Po-210 highs. In fact, with only a few exceptions, all of the Po-210 observed in those cores on which Ra-226 measurements have been made can be attributed to the decay of the Ra-226 in the sample. Only an few samples have excesses of Po-210 above the Ra-226 secular equilibrium value that could possibly be attributed to the decay of unsupported Rn-222 in transit. The microscopic examination of exposed and developed alpha-sensitive nuclear-emulsion plates on which finely ground samples of unmineralized drill core were dispersed suggests that a significant fraction of the U-238

in the sample, as well as its long-lived daughters U-234, Th-230, and Ra-226, deposits on grain surfaces in very low concentrations (U-238 in sub-picogram amounts). Many of these long-lived daughters are bound to the surface so lightly that they, as well as Rn-222, Ra-226, and Th-228, are free to enter the underlying emulsion where their decays are recorded as single alpha tracks and as three-, four, and five-branched alpha-track stars, respectively. Many of the four-and five-branched stars originate from a geometric point source suggesting that, at least in nuclear emulsions, the movements of Rn-222 and Ra-226 due to recoil and diffusion are not major processes. Abundant evidence is found in almost every drill core and soil sample for the recent transport of Ra-226. The transport of radium is confirmed by the presence of alpha stars on grain surfaces and in the emulsion and by the presence of numerous small mineral grains, possibly barite, having both high relief and high specific alpha activity. In the ore zones, concentrations of alpha activity usually associated with minerals containing significant amounts of uranium are observed, and evidence for the recent separation, transport and redeposition of Ra-226 in the ore zone samples can be seen. This suggests that at least some of the unsupported Ra-226 observed in the overlying sediments and soil may be derived from the ore zones. On the basis of both alpha star populations and the presence of numerous alpha-active grains containing unsupported Ra-226, the Ra-226 appears to be more mobile than Rn-222 and is widely distributed. The Po-210 analyses and microscopic studies suggest that observed Rn-222 and Po-210 surface anomalies may be associated with widely dispersed, very low concentrations of Ra-226 or its longer-lived parents including uranium.

Stieff, Lorin R., 1984

A feasibility study of the prompt Pb-214, Bi-214 gamma method for measuring radon transport gradients, *in* Symposium on Uranium Mill Tailings Management, 6th, Fort Collins, Colo.:

Colorado State Univ., Civil Eng. Dept., Geotech. Eng. Program, Proc., p. 307-316

An experiment has been performed to determine the feasibility of measuring the prompt Pb-214/Bi-214 gamma decay in freshly collected tailings samples as a method of studying the undisturbed state of secular equilibrium between Ra-226 and Rn-222 at the time of and immediately preceding sample collection. Tailings pile core samples were collected from four layers of the sandbox, a special test area within the Grand Junction tailings pile, and immediately sealed in aluminum cans. Starting within 11 to 30 minutes of collection a series of gamma spectral measurements using both NaI and Ge(Li) detectors were made to follow the prompt decay and subsequent buildup of Pb-214 and Bi-214. By observing the difference between the gamma count rate extrapolated to the time of sample collection and the final equilibrium count rate, a measure of the net loss or gain, if any, of Rn-222 that occurred in the sample during the 2 to 3 hours that preceded sample collection was obtained. Using this technique, it was found that at the time of collection the two samples nearest the surface contained essentially unsupported Rn-222, one sample contained a net excess of Rn-222, four samples showed a net deficiency, and one sample contained Rn-222 and Ra-226 essentially in secular equilibrium. Although much additional work remains to be done, this preliminary data suggests that a technique may be developed to measure directly undisturbed radon transport gradients in uranium mill tailings piles, in different types of tailings pile covers, and in laboratory experiments.

Stieff, L.R., I.L. Balkissoon, and F.M. Barbera, 1981

A Preliminary Study of the Transport and Distribution of Radium, Radon, and Their Alpha Emitting Daughters Using Nuclear Emulsions and Polonium-210; Final Report:

Kensington, Md., Stieff Research and Development Co., Inc., U.S. Dept. Energy Rept. GJBX-144(81), 161 p.

The principal objective of this preliminary study was to develop data on the concentration and distribution of radium and radon and their alpha emitting daughter products as a means of examining several possible Rn-222 transport models. Semi-quantitative Po-210 measurements have been made on a limited number of near surface soil samples collected over or in the vicinity of known uranium ore deposits and on closely related diamond drill cores. These Po-210 measurements provide an indirect way of estimating the Ra-226/Rn-222 content of the samples and a way of estimating the long term Rn-222 flux to which the samples have been exposed. Also, the physical distribution of uranium and some of its alpha emitting daughter products in these same samples has been studied in a qualitative way using alpha sensitive nuclear emulsion techniques. Microscopic examination of nuclear emulsion plates on which non-ore zone core samples were dispersed suggests that U-238 and its long-lived daughters U-234, Th-230, and Ra-226, deposit on grain surfaces in very low concentrations (U-238 in sub-picogram amounts). Many of these atoms are bound to the surfaces so lightly that they, as well as Rn-222, are free to enter the underlying emulsion where their decays are recorded. Concentrations of alpha activity usually associated with discrete uranium minerals were not observed. On the basis of alpha star counts in the emulsion, Ra-226 appears to be more mobile than Rn-222. Measurements of Po-210 in the sequential decay, Rn-222 (3.8 days)—>Pb-210 (22 years)—> Po-210 (138 days), provide an indirect means of estimating the number of Rn-222 atoms that have decayed in a sample over the last 80 to 100 years. Many Po-210 highs have been observed in the Red Desert cores, some directly associated with uranium mineralization. To date, evidence has not been found for a Po-210 concentration gradient produced by the decay of mobile, unsupported Rn-222 either in transit to the surface or even in transit over short distances from pronounced Po-210 highs. The Po-210 analyses and microscopic studies suggest that observed Rn-222 and Po-210 surface anomalies may be associated with widely dispersed very low concentrations of Ra-226 or its longer lived parents including uranium which surround the ore as halos or as weak zones of uranium mineralization. The Po-210 sub-surface soil anomaly map from this study has also been compared with earlier surface anomaly maps from the same area based on helium, radon by Track-Etch and uranium surveys. Although direct comparison of the data from the two surveys is limited due to differences in sampling intervals between the two survey grids, the closest agreement is observed with the results of the Track-Etch survey. Selective chemical leaching experiments undertaken in an effort to enhance the mobile Rn-222/Po-210 signal were not successful. The results of these studies suggest that if the samples contained unsupported Rn-222 which had decayed in the samples while the radon was in transit, the selective leaching procedures used in this study were unable to preferentially concentrate this Po-210 fraction.

Stieff, L.R., M.N. Girhard, T.W. Stern, 1950
A preliminary report on methods of determining the age of Colorado Plateau carnotite:
U.S. Geol. Survey Rept. TEI-108
[Describes experimental work on emanating power as a function of relative humidity.]

Stieff, L.R., C.B. Stieff, and R.A. Nelson, 1987
Field measurements of in situ ^{222}Rn concentrations in soil based on the prompt decay of the ^{214}Bi counting rate:
Nuclear Geophysics, 1(2): 183-195
Indirect field measurments of the in situ Rn-222 concentations in sealed samples of soil have been made based on the prompt decay of the Bi-214 counting rate in the 2-hr interval immediately following sample collection. Subsequent Bi-214 measurements yield estimates of the Rn-222 lost during sample collection and the concentration of Ra-226 in the samples. These data may be used in the measurement of in situ Rn-222 concentration gradients, the characterization of the state of Ra-226/Rn-222 equilibrium in soil samples, and calculation of Rn-222 surface flux.

Stoenner, R.W., Raymond Davis, Jr., Elinor Norton, and Michael Bauer, 1974
Radioactive rare gases, tritium, hydrogen, and helium in the sample return container, and in the Apollo 16 and 17 drill stems, *in* Lunar Science Conf., 5th, Houston, Texas, March 18-17, 1974:
Geochim. Cosmochim. Acta., Suppl. 5, 2: 2211-2229

Stoenner, R.W., Richard M. Lindstrom, Warren Lyman, et al., 1972
Argon, radon, and tritium radioactivities in the sample return container and the lunar surface; Lunar Science Conf., 3d, Proc.
Geochim. Cosmochim. Acta, Suppl. No. 3, 2: 1703-1717

Stoklasa, J. and V. Zdobnikcy, 1913
Acad. Sci. [Paris] Comptes Rendus, 157: 1082
[Suggests (according to Karim et al., 1958) that "radon in the soils influence the development of plants." Influence is supposedly good up to a point.]

Stothart, R.A., 1948
Tracing wildcat trends with radon emanations:
World Oil, 127 10: 78-79
Geophys. Abs. 138-11328
Radon emanation surveys, which had been used effectively as a check method for determining fault trends and productivity limits (see Geophys. Abs. 112, No. 6818, and 119, no. 7722), now offer a means for determining desirable areas for wildcatting when known production in an area affords a correlation base.In the upper Gulf Coast, for example, wells are relatively closely spaced over large areas and there are sufficient producing wells to establish radon-time relations for the area. Radial surveys may be run and the variations in radon emanations when correlated with another set from within 10 miles may be used to delimit shoreline conditions too low in relief to be accurately outlined by other geophysical methods. A series of such intersecting traverses may develop trends which when interpreted in the light of past experience may indicate areas best suited to exploration with the drill. It is noted that radon emanation surveys were apparently discredited when tests made in the areas of the 1945-46 atomic bomb explosions and resurveys of previously surveyed regions showed discrepancies. These were later determined to be only surface effects, and a method of making measurements in test holes was devised to overcome the difficulty.

Stothart, R.A., 1950
Reef surveying with radioactivity:
World Oil, 130(1): 61
Radioactivity in oil finding.

Stothart, R.A., 1954
World Petroleum, April
Radioactivity in oil finding.

Stoute, J. R. D., G. C. H. Groen, and T. J. H. De Groot, 1984
Characterization of indoor atmospheres:
Radiation Protection Dosimetry, 7(1-4): 159-163
Chem. Abs. 101:99841p

Stranden, Erling, 1985
The radiological impact of mining in a Th-rich Norwegian area:
Health Physics, 48(4): 415-420

Stranden, E., and A.K. Kolstad, 1985
Radon exhalation from the ground; method of measurements and preliminary results:
The Science of the Total Environment, 45: 165-171

Stranden, E., A.K. Kolstad, and B. Lind, 1984
The influence of moisture and temperature on radon exhalation:
Radiation Protection Dosimetry, 7(1-4): 55-58
Chem. Abs. 101:99822h:

Strashnikov, N.S., and N.Z. Nasyrova, 1959
Temperature dependence of emanation of minerals [in Russian] *in* Optika. Yadernye Protsessy [Optics. Nuclear Processes], p. 3-13
Nucl. Sci. Abs. 16:31981

Strassmann, F., 1931

Über einige neue Anwendungs-Möglichkeiten der "Emaniermethode" [On some new possible applications of the "Emanation method."]:
Naturwissenschaften, 19: 502-504

Strassmann, F., 1934
Relation between lattice structure and gas permeability of organic salts according to the emanation method of Hahn [in German]:
Zeitschrift physikal. Chemie B., 26: 362-372
Chem. Abs. 28(22):col. 7150-7151

Straus, Joe M., and G. Schubert, 1977
Thermal convection of water in a porous medium: effects of temperature- and pressure-dependent thermodynamic and transport properties:
Jour. Geophys. Research, 82(2): 325-353

Strong, J.C., and M.J. Duggan, 1973
The effect of the presence of thoron daughters on the measurement of radon daughter concentrations:
Health Physics, 25(3): 299-300

Strong, Kaye P., Desmond M. Levins, and Anthony G. Fane, 1981
Radon diffusion through uranium tailings and earth cover, *in* Gomez, Manuel, ed., Radiation Hazards in Mining: Control, Measurement, and Medical Aspects, International Conference, Golden, Colo., October 4-9, 1981:
Golden, Colo., Colorado School of Mines, Chap. 107, p. 713-719

Strong, K.P., and D.M. Levins, 1982
Effect of moisture on radon emanation from uranium ore and tailings:
Health Physics, 42:27-

Strutt, R.J., 1904
A study of the radio-activity of certain minerals and mineral waters:
Royal Soc. [London] Proc., 73(491): 191-197
[Heated samarskite, fergusonite, pitchblende, malacone, monazites and zircon to redness; found decays of emanations in range 4.05-3.48 d. Zircon and 1 of 3 monazites yielded very little emanation.]

Styra [Styro], B.I., T.N. Nedveckaite, and E.E. Senko [Sen'ko], 1970
New methods of measuring thoron (radon 220) exhalation:
Jour. Geophys. Research, 75(18): 3635-3638 [in Russian, 1969 (pub. 1972) in Inst. Eksp. Meteorologii Trudy, no. 25, pt. 2, p. 109-116]
Geophys. Abs. 288-385

Styro, B., and K. Stelengis, 1975
Quantitative evaluation of long-lived radon-222 decay products of nonemanation origin in the ground-level layer of air [in Russian]:
Metorol. Aspekty Radioakt. Zagryaz. Atmos., Tr. Mezhdunarod. Simp. 1973 [Pub. 1975], 157-161
Chem. Abs. 86:198286:

Subba Ramu, M.C., and K.G. Vohra, 1969
Investigations on radioactive equilibrium in the lower atmosphere between radon and its short-lived decay products [with Russian summary]:
Tellus, 21(3): 395-403
Geophys. Abs. 279-379:

Variations in the degree of equilibrium between radon and its short-lived decay products were studied at 2 m above the ground at a selected location near Trombay, Bombay, India, and correlated with various meteorological parameters. The degree of equilibrium ranged from 4 to 100 percent, depending on meteorological conditions. The application of these results to study of mixing processes in the lower atmosphere is discussed.

Sugihara, T., 1953
The detection of a radioactive spring by ground water:
Repts. Balneol. Lab. Okayama Univ., 9: 37-42

Sugihara, T., and M. Mifune, 1953
Radon content of waters and earth temperatures in Fukudame Kitadani Village, Tottori Prefecture, Japan:
Repts. Balneol Lab. Okayama Univ., 9: 28-31

Sultankhodzhayev, A.N., I.G. Chernov, and T. Zakirov, 1977
Gidrogeoseysmologichoskiye predvestniki gazliyskeog zemletryaseniya [Hydrogeoseismological advance signs of the Gazli earthquake]:
Akad. Nauk Uzbek. SSR, Dokl., 7: 51-53
Chem. Abs. 87:28686y:

Sultankhodzhayev, A.N., S.U. Latipov, T. Zakirov, and L.A. Khamidov 1977
O vozmozhnosti prognozirovaniya mesta vozniknoveniya sil'nykh zemletryaseniy po variatsii radona. [On the possibility of predicting the point of origin of strong earthquakes by the variation of radon]:
Uzbek. Geol. Zhur., 3: 39-43

Sultankhodzhayev, A.N., V.G. Tyminskii, V.I. Ulomov, I.S. Faizullin, 1974
Ob ispol'zovanii radona dlya prognozirovaniya zemletryaseniy [Use of radon to forecast earthquakes]:
Akad. Nauk Uzbekskoy SSR, Uzbekskiy Geol. Zhur., 18(2): 44-49
Chem. Abs. 82:6157w
[The authors inferred a direct relation between rock deformation and the radon concentration in waters.]

Surbeck, H., and Piller, G., 1989
A closer look at the natural radioactivity in soils, *in* Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 1, Symposium Oral Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006a [Springfield, Va., NTIS Order No. PB89-167480], p. 5-13--5-26.
Enhanced indoor radon levels are frequently found in the western part of the Swiss Jura Mountains, a karst region. The Ra-226 activity in the limestone bedrock is low (20 Bq/kg). In the thin soil overburden the Ra-226 concentration is 2 to 3 times higher than in soil samples from the Swiss Plateau but on the average still below 100 Bq/kg. It is supposed that the radon problem in this region is due to the high permeability of the karst bedrock. A sampling device for radon in soil gas measurement is described that permits a coarse in-situ soil permeability determination. Specific activity vs. grain size measurements for some Swiss soils and the high activities found in heavy minerals are presented and a possible aeolian origin of the soils in the western Jura is discussed.

Swedjemark, Gun Astri, 1980
Radon in dwellings in Sweden, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1237-1258, disc., 1258-1259

Swedjemark, Gun Astri, 1982

Buildings with enhanced radioactivity in Sweden, *in* Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:
New York, John Wiley and Sons, p. 535-542, disc., 542-543
The Ra-226 content of various house building materials and the radon levels indoors in Sweden have been evaluated. In houses built entirely of alum shale concrete the indoor radon levels were between 5 and 32 pCi/L, and the indoor absorbed dose rates from gamma radiation were 35-69 μr/hr. Houses built in regions with enhanced radium content showed higher radon levels indoors. Various countermeasures have been adopted to reduce the indoor radon levels.

Swedjemark, G.A., 1984
Temporal variations of the radon concentration indoors:
Radiation Protection Dosimetry, 7(1-4): 255-258
Chem. Abs. 101:99853u

Swedjemark, G A., and L. Mjoenes, 1984
Radon and radon daughter concentrations in Swedish homes:
Radiation Protection Dosimetry, 7(1-4):341-345
Chem. Abs. 101:99870x

Sykes, Lynn R., and C. Barry Raleigh, 1975
Premonitory effects of earthquakes, Part 7, pp. 858-863, *in* American Seismology Delegation, Earthquake Research in China:
Eos, Trans. Am. Geophys. Union, 56(11): 838-881

Szabó, A., 1954
The radioactivity of mineral waters in the Romanian Peoples Republic II. The content of radon and metallic radium at Baile Herculane [in Romanian]:
Acad. Repub. Pop. Romine, Studii Cercetari Stiint, 5: 45-56 [French summary]

Szabó, Arpád, 1957
Concentrarea in radon si radiu metalic a izvoarelor si depozitelor minerale de la Baile Borsec si Toplita (Transilvania), VIII [Concentration of radon and metallic radium in mineral springs and their mineral deposits at Baile Borsec and Toplitsa (Transylvania), part 8] [in Romanian]:
Acad. Romine Bul. stiint., sec. de stiinte matematice si fizice, 9(2): 537-544
Geophys. Abs. 178-327:
In his investigations of radioactivity of mineral springs and their deposits in Transylvania, Rumania, Szabo finds that the water from Pierre Curie spring at Borsec has 19.91 Mache units [7.4 nCi/L] of radon and 8.2 pg Ra/L. Radioactivity of the springs "Horea," "Closca," "Caprei," and "Templului" varies from 2.5 to 3.5 Mache units [0.9 to 1.3 nCi/L]. Deposits of tufa were found to contain (1-6) pg per g of dry mineral at 100°C. The source of the radioactivity found is considered to be the mica schist which contains grains of radioactive ore, and through which the spring water runs.

Szabó, Arpád and Ioan Bányai, 1963
Contributii la cercetarea radiogeologica a Carpatilor Orientali [Contributions to radiogeological studies in the Eastern Carpathians [in Romanian with Russian and French abstracts]:
Acad. Romine Studii si Cercetari de Geologie, 8(2): 303-325
Geophys. Abs. 206-263
The history of research during the last 35 years on natural radioactivity in the eastern Carpathians is reviewed. The importance is emphasized for radioactivity research in this area to elucidate the geogehmical processes that take place in the crust of the Earth. Experimental material tabulated includes radioactivity data from 102 sources of water, 9 of natural gas, 30 of therapeutic muds and mineral deposits, and 36 varieties of rocks from

the eastern Carpathians. The geology of the zone is discussed also including that of the deposits sampled for radioactivity studies. The conclusion specifies in detail the diverse possibilities and perspectives of radiogeologic research, and the precise objectives of future research in studies of important economic problems of this region.

Szabó, A., and B. Gavril, 1954
The radioactivity of mineral waters in the Romanian Peoples Republic. Radiological study of mineral waters and sulfur muds at Baile Sumneseni-Cluj [in Romanian]:
Acad. Repub. Pop. Romine, Studii Cercetari Stiint. 5: 57-64

Szabó, A., and A. Soo, 1957
Étude de la concentration en radon, radium et uranium des eaux minerals et des tufs calcaires de Singeorz-Bai (region de Cluj) [Study of the concentration of radon, radium, and uranium of the mineral waters and calcareous tufas of Singeorz-Bai (Cluj region)][with English summary]:
Acad. Repub. Pop. Romine, Bull. Sci., Sect. Sci. Math. et Phys., 9(1): 159-163

Szarzi, S.L., G.M. Reimer, and J.M. Been, 1990
Soil-gas and indoor radon distribution related to geology in Frederick County, Maryland [poster abs.], *in* Indoor Radon and Lung Cancer: *Reality or Myth?*, Hanford Symposium on Health and the Environment, 29th, Richland, Washington, October 15-19, 1990:
Richland, Wash., Battelle Pacific Northwest Laboratories, Final Program, p. 95-96
The two major physiographic provinces that occur in Frederick County, Maryland, are the Piedmont and the Blue Ridge. Soil-gas measurements were taken for a study designed to show the relationship between geology and soil-gas radon concentrations. The local geology causes varied soil-gas concentrations that contribute to radon availability for indoor accumulations. The western part of the county, where quartzites form the core of ridge and mountains, has a mean soil-gas radon concentration of 26 kBq/m^3 (700 pCi/L). The eastern part of the county, containing the phyllites of the Piedmont Province, has a mean soil-gas concentration of 59 kBq/m^3 (1600 pCi/L). In the southeast part of the county, where soil-gas radon concentrations exceeded 75 kBq/m^3 (2000 pCi/L), the average indoor radon concentration (from charcoal canister measurement) was 1.9 kBq/m^3 (50 pCi/L). This observation supports previous work showing that the soil-gas radon concentration is a primary component in determining the coupling characteristics of radon transport between soils and homes. Data acquired by studies such as these throughout the United States are essential to identify regional radon "hot spots" which may produce elevated indoor radon levels of unquestioned risk.

Taipale, T.T., and K. Winqvist, 1985
Seasonal variations in soil gas radon concentration:
The Science of the Total Environment, 45: 121-126

Tajima, Eizo and Tadayoshi Doke, 1956
Airborne radioactivity:
Science, 123(3189): 211-214
Geophys. Abs. 165-302:
Measurements of airborne radioactivity in Japan from March 16 to May 4, 1955 showed the presence of radon daughter products of the order of 0.1 pCi/L, assuming they were in equilibrium, and activity with a half-life of 10 to 12 hr, which is compatible with activity due to thoron daughter products. The concentration of radon daughter products was larger at night than in the daytime because of temperature inversion. Artificial radioactivity, including alpha emitters, was also detected and apparently consists of two or more components of different origins.

Talwani, Pradeep, W.S. Moore, and Jin Chiang, 1978
Geochemical research related to earthquake prediction at Lake Jocassee, South Carolina [abs.]:

Eos, Am. Geophys. Union Trans., 59(12): p. 1196

Tanaevsky, Olga, and Étienne Vassy, 1955
Variations de la radioactivité naturelle et artificielle de l'atmosphère [Variations of the natural and artificial radioactivity of the atmosphere]:
Acad. Sci. [Paris] Comptes Rendus, 241(1): 38-40
Geophys. Abs. 163-166:
Continuous registration of radioactivity 4 meters above the ground shows that when the air is calm radon accumulates but it is dissipated with the slightest wind. Radioactivity, with long half-life indicating artificial origin, was observed in rainwater.

Tanaevsky, Olga, and Etienne Vassy, 1955
Radioactivité naturelle et artificielle de l'atmosphere [Natural and artificial radioactivity of the atmosphère]:
Annales Géophysique, 11(4): 486-490
Geophys. Abs. 165-305:
Measurements of the radioactivity of air samples taken at a height of 4 m above the ground have been made since December 1953 at Val-Joyeux. The activity recorded, except for one case, has been due to the daughter products of radon and thoron. No annual periodicity is observable in the activity. An accumulation of atmospheric radon generally is observed when the atmosphere is calm, but it disappears with the slightest wind. The correlation or lack thereof of the observed activity due to radon and barometric pressure, wind, temperature, precipitation, and industrial contamination are discussed. Measurements of radioactivity of precipitation were begun in January of 1955. The precipitation of April 6-7, 1955 was particularly radioactive, but was less than half of the "tolerance dosage" of 2 nCi/L of water. The radioactivity was evidently due to the nuclear explosions of March 1955.

Tanaka, Fujio, and Yasuyuki Maki, 1982
Automatic monitoring of radon daughter concentration in soil air by electrode collector, *in* Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:
New York, John Wiley and Sons, p. 343-349

Taniguchi, H., and P. Vasudev, 1980
Radon and radon daughters due to natural uranium occurrences in a rural Ontario community, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1623-1632

Tanner, Allan B., 1956
Physical behavior of radon, *in* U.S. Geological Survey, Geologic investigations of radioactive deposits, semiann. progress report, June 1 to November 30, 1956:
U.S. Geol. Survey Rept. TEI-640: 285-286
[Partitioning of radon in naturally-occurring binary water-gas systems. New reflux condenser for field use.]

Tanner, Allan B., 1957
Physical behavior of radon, *in* U.S. Geological Survey, Geologic investigations of radioactive deposits, semiann. progress report, December 1, 1956 to May 31, 1957:
U.S. Geol. Survey Rept. TEI-690:532-533
[Radon emanation from rock. Core holder for emanating power studies. Calculations of radon migration into drill holes.]

Tanner, Allan B., 1957
Physical behavior of radon, *in* U.S. Geological Survey, Geologic investigations of radioactive deposits, semiann. progress report, June 1 to November 30, 1957:

U.S. Geol. Survey Rept. TEI-700: 243-246
[Radon in soil gas, Karnes County, Texas. Apparatus for counting radon in soil gas.]

Tanner, Allan B., 1958
Physical behavior of radon, *in* U.S. Geological Survey, Geologic investigations of radioactive deposits, semiann. progress report, December 1, 1957 to May 31, 1958:
U.S. Geol. Survey Rept. TEI-740: 275-276
[Radon and thoron anomalies in soil gas and water, Clay Co., Fla.]

Tanner, Allan B., 1958
Physical behavior of radon, *in* U.S. Geological Survey, Geologic investigations of radioactive deposits, semiann. progress report, June 1 to November 30, 1958:
U.S. Geol. Survey Rept. TEI-750, 3 p.
[Radon in well waters, Tooele Co., Utah]

Tanner, Allan B., 1958
Increasing the efficiency of exploration drilling for uranium by measurement of radon in drill holes, *in* United Nations Internat. Conf. on the Peaceful Uses of Atomic Energy, 2d, Geneva, Sept. 1958, Proc., v. 3, p. 42-45:
Geneva, United Nations
[Through the influence of atmospheric pressure changes, Rn-222 tends to migrate from uranium ore into drill holes. Under appropriate geologic conditions advantage may be taken of this tendency by increasing the distance between exploration drill holes without increasing the likelihood of missing bodies of ore. Where there is sufficient fracturing or permeability of the rock constituting the ore horizon, anomalous concentrations of radon may be observed many meters from uranium ore, in contrast with the extremely local information derived from γ-ray logs or from analysis of drill cuttings or cores. If there are errors, caused by excess radon, in γ-ray evaluation of many holes in an area, there is reason to believe that this method is appplicable. Radon measurement may be accomplished either upon samples of drill-hole air taken at the ore horizon or by direct measurement of α radiation in the hole. Samples of air from the ore horizon in 11 drill holes on a line traversing a uranium ore body in limestone near Grants, New Mexico, were analyzed for radon with field equipment. Anomalous concentrations of radon were observed not only in samples from holes that penetrated ore, but also in samples from holes located from 30 to 60 m from the nearest ore.]

Tanner, Allan B., 1959
Meteorological influence on radon concentration in drillholes:
Mining Engineering, 11(7): 706-708; also in Am. Inst. Mining Metall. Petroleum Engineers Trans., v. 214 (1959)
Geophys. Abs. 181-413:
The concentration of radon-222 in drill holes in uraniferous limestone near Grants, New Mexico, was observed to change markedly with different meteorological conditions. Continuous records of wind velocity, surface temperature, and atmospheric pressure were obtained for a 20-day period during which a series of analyses was made for the radon content of air collected at several depths in at 106-mm diameter drill hole. More limited investigations were made in several other drill holes. An inverse relation was inferred between trends in atmospheric pressure and the total amount of radon in a hole. Pressure changes of 10 mm Hg over a period of about a day resulted in approximately two-fold changes in the total amount of radon in the hole. The relation is believed to be a manifestation of "earth breathing." The effects of wind differed greatly for different holes. No significant effect was observed when a 6.3-to-7.2 m/s wind blew over an open hole for 4 hr; an 11-to-16 m/s wind, blowing over another open hole of the same diameter and approximately the same depth for 6 hr, caused a reduction in the total amount of radon in the hole by a factor of about 400. [Venturi effects were unlikely. The most reasonable explanation for the marked difference was that at the higher wind velocity the air in the drill hole was excited as in a closed-end organ pipe (fundamental frequency about 3 Hz), and effectively increased the diffusion coefficient in the hole.] No correlation was noted between surface temperature and the behavior of radon in the drill holes.

Tanner, Allen [Allan] B., 1960
Usefulness of the emanation method in geologic exploration, *in* Geological Survey Research 1960:
U.S. Geol. Survey Profess. Paper 400-B, p. B111-B112
Geophys. Abs. 183-520:
Exploration for radioactive materials or geologic features by measurement of one or more of the emanation isotopes, radon, thoron, and actinon, contained in soil gas near the surface of the Earth, is called the emanation method. Because techniques for emanation measurement are more sensitive and more specific than field γ-ray meaurements, emanation surveying, particularly that using ^{222}Rn, has been practiced since the 1920's. However, it has become apparent that most "radon" anomalies described in the literature probably are not caused by [migration of] the short-lived radon but by radium and other intermediate decay products of uranium in solution. This type of anomaly tends to be displaced in the direction of ground-water movement; therefore, it is inaccurate in locating geologic features unless the features are large compared with the thickness of overburden.

Tanner, Allan B., 1964
Physical and chemical controls on distribution of radium-226 and radon-222 in ground water near Great Salt Lake, Utah, Chap. 14, *in* Adams, John A.S., and Wayne M. Lowder, The Natural Radiation Environment:
Chicago, Chicago Univ. Press, p. 253-276

Tanner, Allan B., 1964
Radon migration in the ground, a review, Chap. 9, *in* Adams, John A.S., and Wayne M. Lowder, The Natural Radiation Environment:
Chicago, Chicago Univ. Press, p. 161-190

Tanner, Allan B., 1980
Radon migration in the ground: a supplementary review, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 5-56.
...Water is the most important agent in enabling radon isotopes to escape from solid material: Water absorbs kinetic energy of the recoil atom of radon; it is an active agent in altering and hydrating mineral surfaces, thus enhancing their emanating power; and it decreases the adsorption of radon on mineral surfaces. Once in rock and soil pores, radon atoms migrate by diffusion and by transport in varying proportions. In diffusion and transport calculations, it is desirable to use the radon concentration in the interstitial fluid as the concentration parameter and to include porosity explicitly. Most values of diffusion coefficient in the literature are for an effective diffusion coefficient, equal to the true diffusion coefficient divided by porosity, and should be corrected before applying boundary conditions. The transport component is important in dry, permeable soils in the upper layers, but is much reduced below depths of several tens of meters. Research in disequilibria among radionuclides of the uranium and thorium series suggests that much assumed migration of ^{222}Rn is, in fact, a more general migration of uranium and radium isotopes.

Tanner, Allan B., 1986
Geological factors that influence radon availability, *in* Indoor Radon, Proceedings of the APCA International Specialty Conference , Philadelphia, Pa., February 24-26, 1986:
Air Pollution Control Assoc., P.O. Box 2861, Pittsburgh, PA 15230, Pub. SP-54, p. 1-12
There is great need for the characterization of localities with respect to their potential for supplying radon to structures, especially where the number of existing structures is insufficient for valid sampling. Although the interaction between a structure and the ground is not quantitatively known, it is practical to assume that the ground can be characterized as to the rate at which radon can be drawn from it by a structure: a measure of radon availability. Radon availability is related mainly to the concentration of radon in the spaces in rock fractures and soil pores and to the permeability of the ground to gases. The fraction of radium disintegrations producing radon that reaches those spaces usually falls within the range of 0.15 to 0.55. Permeability and the

diffusion coefficient are reduced markedly as the sizes of those spaces are reduced and as the proportion of the spaces filled by liquids is increased. Coupling this knowledge with that of the geology, soil, hydrology, and topography of a locality should permit qualitative evaluation of radon availability. Rock types that usually have above-average concentrations of radon in the pore and fracture spaces include granites, some gneisses, phosphatic rocks, marine shales, and some recrystallized limestones and dolomites. Construction of buildings in contact with such rocks, if fractured, requires special radon barriers. Residual soils, notably *terra rossas*, are often enriched in radium. Ground with coarse grain size (such as gravels and coarse sands), particularly if well-drained, is highly permeable and apt to make more radon available than would be expected on the basis of its radium content. At the other extreme, muds and clays tend to be of low permeability, especially if wet. Ground that does not pass a percolation test should have low radon availability unless enriched in radium. Buildings located on hillsides and ridges are more apt to be located on soils that are coarser and better drained than those in adjacent valleys. Other things being equal, radon availability should be greater on hillsides and ridges.

Tanner, Allan B., 1988

Measurement of radon availability from soil, *in* Marikos, Mark A., and Robert H. Hansman, eds., Geologic Causes of Natural Radionuclide Anomalies, Proceedings of the GEORAD Conference, St. Louis, Mo., April 21-22, 1987:

Rolla, Mo., Missouri Dept. Nat. Resources, Div. Geology and Land Survey Spec. Pub. No. 4, p. 139-146.

A method is under development to evaluate the intrinsic ability of the ground at a specific site to be a source of indoor radon. Radon availability, a quantity that indicates a practical upper limit to the amount of radon that can be drawn into a structure from the soil, is here defined as the radon concentration in the soil pores multiplied by the mean one-dimensional migration distance of radon in a homogeneous soil. This distance is calculated from the effective diffusion coefficient and a steady-state convection velocity calculated from the gas permeability of the soil in question, by using an arbitrary standard driving-pressure difference. From estimated extreme ranges of radon concentration, effective diffusion coefficient, and gas permeability, radon availability values should range from 10 Bq/m^2 ($3x10^2$ pCi/m^2) to 10^8 Bq/m^2 ($3x10^9$ pCi/m^2), although it is unlikely that the higher end of the range would be realized. A practical method of determining radon availability is based on analyzing the radon concentration in air drawn from a small augered hole in the ground, simultaneously measuring permeability in situ, and estimating the effective diffusion coefficient by means of soil type and moisture content. Measurements are being made in places where indoor radon concentrations are known, in order to test the utility of the method and the spatial and temporal variations of radon availability.

Tanner, A.B., 1988

A tentative protocol for measurement of radon availability from the ground, *in* Natural Radioactivity, International Symposium on the Natural Radiation Environment, 4th, Lisbon, Portugal, December 7-11, 1987, Proceedings:

Radiation Protection Dosimetry, 24(1/4): 79-83

A procedure is being tested in order to determine its suitability for assessing the intrinsic ability of the ground at a particular site to supply ^{222}Rn to a basement structure to be built on the site. Soil gas is sucked from a borehole probe through an alpha scintillation chamber and flow meter by a pump. The permeability of the soil is calculated from the flow rate and the pressure difference between the atmosphere and the borehole at the intake point. The diffusion coefficient is estimated from the water fraction in the soil pores. The upward migration distance for radon in such soil during one mean life is computed for an arbitrary steady pressure difference. This mean migration distance, multiplied by the measured radon concentration, gives the "radon availability number." Measurements at sites of known indoor radon concentration suggest that numbers below 2 kBq/m^2 indicate little chance of elevated indoor radon and above 20 kBq/m^2 indicate that elevated indoor radon is likely. The range of uncertainty and the point-to-point and seasonal variations to be expected are under investigation.

Tanner, Allan B., 1988
A tentative protocol for measurement of radon availability from the ground:
Northeastern Environ}ental Science, 7(1): 58-62
[A slightly revised version of the above paper.]

Tanner, A.B., 1989
A tentative protocol for measurement of radon availability from the ground, *in* Osborne, M.C., and Harrison, Jed, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 2, Symposium Poster Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006b [Springfield, Va., NTIS Order No. PB89-167498], p. 3-15--3-24.

Tanner, Allan B., 1989
The source of radon in houses, *in* Harley, N.H., ed., Radon. Proceedings of the Twenty-Fourth Annual Meeting of the National Council on Radiation Protection and Measurements, Washington, D.C., 30-31 March 1988:
Bethesda, Md., Natl. Council on Radiation Protection and Measurements, Proc. ser., no. 10: 159-168

Tanner, A.B., 1989
Error in measuring radon in soil gas by means of passive detectors [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 497
Passive detection of radon isotopes depends on diffusion of radon atoms from the sites of their generation to the location of the detecting or collecting device. Examples of passive detectors are alpha-track and electret detectors, charcoal-canister and organic-liquid radon collectors, and gamma-ray detectors placed in nonradioactive permeable material thick enough to shield the detector from direct gamma rays from radon sources in the soil. Because some radon decays *en route* to a passive detector in soil, the radon concentration measured by the detector must be less than the radon concentration in the interstitial spaces of the soil where the concentration is undiminished by diffusion to the detector cavity. The maximum radon concentration measured by a passive method can be modeled by diffusion from an isotropic, homogeneous medium inward along the radii of a spherical cavity. The approximate minimum radon concentration can be modeled by diffusion along radii of a cylindrical cavity. Analytic solutions for diffusion in these models indicate that at less than about 80 percent water saturation there is little underestimation of the true soil-gas ^{222}Rn concentration if the detector cavity diameter is less than about 5 cm, but the underestimation is serious in a cavity 1 m in diameter. The degree of underestimation is strongly dependent on the degree of water saturation of the soil pores; thus, some observed fluctuations of radon concentration in soil gas measured by passive detectors may be due entirely to variation in the water content of the soil.

Tanner, Allan B., 1990
The role of diffusion in radon entry into houses, *in* The 1990 International Symposium on Radon and Radon Reduction Technology, Atlanta, Ga., 19-23 February 1990:
Preprints, Vol. III, no. V-2, 9 p.
Pressure-driven flow of radon-bearing soil gas is commonly accepted as the usual mechanism whereby radon moves from outside house foundations to cause elevated indoor radon concentrations. It is less clear how radon moves to the backfill-and-subslab zone just outside the foundation. Fourteen houses having elevated indoor radon concentrations were investigated by the U.S. Environmental Protection Agency and its contractors. The permeability of the ground to gas flow was measured next to and several meters from each house foundation. For 6 of the 14 houses none of the intrinsic permeability values exceeded 7.6×10^{-12} m^2, below which diffusion is likely to be the dominant mechanism of radon movement. Because it can be significant in unsaturated soils of moderate-to-low permeability, diffusion should not be ignored in considering radon movement to house foundations.

Tappan, J.T., 1989

Passive radon reduction techniques for existing and new structures, *in* Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 1, Symposium Oral Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9-89/006a [Springfield, Va., NTIS Order No. PB89-167480], p. 7-29--7-50.
[Open land was evaluated for a planned major residential development near Carefree, Arizona. Portable gamma survey of the granitic terrane indicated about twice normal background (20 μR/hr). Elevated indoor radon (to 6.5 pCi/L) was present with the house heating system on for a 14-hr period, but not with the house heating system off for a 14-hr period during which the indoor temperature was lower than the outdoor temperature.--ABT]

Taskayev, A.I., V.Ya. Ovchenkov, and R.M. Aleksakhin, 1978
Forms of Ra-226 in the horizons of soils with a high concentration of this isotope [in Russian]:
Soviet Soil Sci., 10(1): 45-50

Taylor, S.R., and S.M. McLennan, 1981
The composition and evolution of the continental crust: rare earth element evidence from sedimentary rocks:
Royal Soc. [London] Philos. Trans., A301(1461): 381-399

Teng, Ta-liang, 1978
Geochemical measurements pertinent to earthquake prediction [abs.]:
Eos, Am. Geophys. Union Trans, 59(12): p. 1196

Teng, Ta-liang, 1980
Some recent studies on groundwater radon content as an earthquake precursor:
Jour. Geophys. Research, 85(B6): 3089-3099

Teng, T.L., and R.P. McElrath, 1976
Response of groundwater radon content to solid tidal strain [abs.]:
Eos, Am. Geophys. Union Trans., 57(12): p. 899

Teng, T.L., T.L. Ku, and R.P. McElrath, 1975
Groundwater radon measurements along San Andreas Fault from Cajon to Gorman [abs.]:
Eos, Am. Geophys. Union Trans., 56(12): 1019

Teng, Ta-liang, and Liang-Fang Sun, 1986
Research on groundwater radon as a fluid phase precursor to earthquakes:
Jour. Geophys. Research, 91(B12): 12,305-12,313

Teng, Ta-liang, Liang-fang Sun, and John K. McRaney, 1981
Correlation of groundwater radon anomalies with earthquakes in the greater Palmdale Bulge area:
Geophys. Research Letters, 8(5): 441-444

Terilli, Terence B., and Naomi H. Harley, 1987
Indoor ventilation rates for ^{222}Rn:
Health Physics, 52(6): 801-803

Teuscher, Ernest Otto,and Ernst Budde, 1957
Emanationsmessungen im Nabburger Flussspätrevier. I. Geologischer Teil (Neuere Untersuchungen auf Bayerischen Flussspätvorkommen); II. Geophysikalischer Teil (Rn-Messungen auf Flussspätgangen)

[Emanation measurements in the Nabburger fluorspar district. 1. Geological part (New investigations on the Bavarian fluorspar occurrences) 2. Geophysical part (Radon measurements on fluorspar veins)]:
Geol. Bavarica, no. 35, 59 p.
Geophys. Abs. 174-317:
Radioactivity observed in different fluorspar veins in Bavaria stimulated intensive soil-gas emanation surveys in which more than 60 profiles between 40 and 100 m long were made across 24 different fluorspar zones. The geology of the various fluorspar districts and the interpretation of the results of the survey in the Nabburger district are presented in the first part of the paper. The results appear to be correlated with physical properties; thus the method is found suitable for fine-scale surveying, such as tracing known fractures and veins, particularly when overburden and vegetation cover are of uniform and moderate thickness. Best results were obtained when samples were taken at least one meter apart and at equal depths. Although accuracy is not as great as that of trenching or boring, further refinement of the method would hardly pay. The second part of the paper gives details of the measurements and describes examples typical of different combinations of vein and country rock: light veins (inactive zones) in active country rock; dark veins (stained by radioactivity) in more active country rock; and fractures filled with dark spar in active country rock.

Tewari, S.G., and N.S. Bhalla, 1976
Lognormal distribution of radon in soil—an analysis:
Indian Jour. Pure Appl. Physics, 14(7): 566-570
Chem. Abs. 86:7321q:

Thamer, B.J., 1984
The determination of the diffusion coefficient of radon in a porous material by injecting radon and measuring the exhalation:
Jour. Nuclear Material, 120(2-3): 166-173
Chem. Abs. 101:96780g:

Thamer, Burton J., Nielson, Kirk K., and Felthauser, Karen, 1981
The effects of moisture on radon emanation (including the effects on diffusion):
Salt Lake City, Utah, Ford, Bacon & Davis Utah Inc. Rept. FBDU-315-2, U.S. Bur. Mines Open-file Rept. OFR184-82, 211 p. [Springfield, Va.: Natl. Tech. Inf. Service Cat. No. PB83-136358]
Radon emanation coefficients of 0.02 to 0.55 were measured at moisture contents ranging from dry to saturation in eighteen different ores. The emanation coefficients rose from a minimum when dry to a plateau usually starting at 5-20 percent of saturation. A model, using measured pore-size distributions, suggested that the radium mineralization may be confined to annular layers about 0.02 μm thick around pores. Radon's diffusion coefficient was determined as a function of moisture. The techniques involved comparing a disc's exhalation as a function of time whether or not the disc had a distributed source. The model was free of approximations and included the effects of porosity and adsorption. An increase of diffusion coefficient with moisture for one or two ores was explained in terms of a model's equation for the diffusion coefficient in terms of both volume and surface diffusion. Radon's adsorption coefficient was determined on a uranium ore.

Thomas, C.D., M.K. Gainer, and T.W. Ball, 1955
Relation of radon to non-active air contamination:
Nature [London], 175: 4460-4472

Thomas, Donald M., Kevin E. Cuff, and Malcolm E. Cox, 1986
The association between ground gas radon variations and geologic activity in Hawaii:
Jour. Geophys. Research, 91(B12): 12,186-12,198

Thomas, D.M., and M. Gaspari, 1989
Groundwater radon and radium activities in Hawaii [abs.]:

Eos, Am. Geophys. Union Trans, 70(15): 500
A survey of groundwater radon and radium activities has been conducted on four of the major islands of the Hawaiian chain (Kauai, Oahu, Maui, and Hawaii). The water sources sampled included drinking-water wells drawing upon basal aquifers, dike-impounded water supplies, and a deep, high-temperature, geothermal well. Although the radon activities detected have been well below levels that are considered to pose a public health hazard, this limited survey has shown that radon activities in basal groundwaters span a range of more than two orders of magnitude. Even more surprising is that the highest radon activities found were not associated with hot geothermal fluids on the island of Hawaii, but were found on the oldest island of the group, Kauai, where no geothermal systems are known (or suspected) to exist. There is no evidence to suggest that the high values found are associated with the depth of the water source and we are currently analyzing samples of the source rocks to determine whether they have unusually high concentrations of uranium and thorium parent nuclides. Although radium in the cold groundwaters do not span as large a range of concentrations as does the radon, the radon-rich groundwaters show nearly a factor of ten enrichment in radium. Radium concentrations in the geothermal fluids from the island of Hawaii are, however, substantially higher than those in normal groundwaters and exceed even the highest Kauai values by a factor of approximately 7. Further analyses of both normal and geothermal groundwaters and source rocks are continuing. The results of these studies will be Presented along with our working hypothesis for radon and radium geochemistry in basal island aquifers.

Thomas, Jess William, 1968
Determination of radon progeny in air from alpha activity of air samples:
U.S. Atomic Energy Comm. Rept. HASL-202: 27 + 7 p.

Thomas, Jess William, 1971
Thoron determination by the two-filter method:
U.S. Atomic Energy Comm. Rept. HASL-TM-71-1: 26 p.
Studies were made of the validity and sensitivity of the 2-filter method for detn. of ^{220}Rn so that its usefulness for mine inspection and other work could be judged.

Thomas, Josef,
Controlling transmutation products of radon in the atmosphere:
Inst. Industrial Hygiene and Radiation Protection, Prague, Jaderna energie, 7: 408-410 [in Czech]
Biological effects of inhaled radon decay products in the first approximation are proportional to the latent energy of alpha radiation of all decay products of radon. It is possible to determine this value by a method using beta radiation of decay products of radon. Detection efficiency seems to be changed with time only; however the change is insignificant even in various degrees of equilibrium disorder of radon transmutation products. The method is a modification of Kusnetz's method for alpha radiation of transmutation products of radon.

Thompkins, R.W., and Ku-Chuan Cheng, 1969
The measurement of radon emanation rates in a Canadian uranium mine:
Canadian Mining and Metall. Bull, 62(692): 1356-1362
Geophys. Abs. 287:338:
Radon gas emanates into uranium mines from the rock walls or from the faces of broken ore lying in the stope. It is the source of the radon daughters, which in turn are the elements that produce physiological damage in the lungs and which are the source of the definition of a working level of radiation. Knowledge of the rate of emanation is essential to the design of mine ventilation systems for uranium mines. This paper describes the method being used at Elliot Lake to measure the emanation of radon gas.

Thompson, Thomas, and Per Ake Wibert, 1963
Some observations of variations of the natural background radiation:
Tellus, 15(3):313-318

Geophys. Abs. 207-301:
Ionizing radiation has been measured at 25 stations in Sweden since mid-1960, using high pressure ionization chambers. Its variation during October 1960 is shown in a graph, and correlated with precipitation. Various factors affecting the natural radioactivity (Ra-226 series) of precipitation are discussed; its average specific activity is calculated to be 15-30 pCi/g.

Tianshan, Ren, Lin Lianqing, Chen Zhipeng, Li Guiyuan, and Chen Amin, 1987
Indoor ^{222}Rn measurements in the region of Beijing, People's Republic of China:
Health Physics, 53(3): 219-225

Tidjani, A., J.L. Seidel, M. Monnin, and D.B. Isabelle, 1987
Realization of a simulator for radon-222 underground migration studies:
Nuclear Instruments and Methods in Physics Research, Sec. A, A255(1-2): 423-425.
Chem. Abs. 106:184693q:

Tikhomirov, V.V., 1972
O vzaimootnoshenii geliya i radiya v plastovykh vodakh Bukharo-Karshinskogo artezianskoga basseyna [Interrelation betwen helium and radon in ground water of the Bukhara-Karshi artesian basin]:
Sovyetskaya Geologiya, 12: 147-150

Timofeyev, A.N., 1959
K teorii gamma-razvedki [On the theory of gamma prospecting]:
Akad. Nauk SSSR Izv. ser. Geofiz., (12): 1873-1875
Geophys. Abs. 181-432:
Radon emanating from a uranium deposit overlain by porous nonradioactive material can move by diffusion and convection toward the surface and form a radon halo far above the deposit. This may cause a large increase in the intensity of the gamma field and lead to an incorrect interpretation of the uranium deposit. A mathematical analysis of diffusion and convection of radon under such conditions is carried out, and a formula derived for the variation of gamma radiation anticipated under such conditions.

Tiratsoo, E.N., 1949
The radioactivity of sediments, pts. 1-4:
Petroleum, 12(3): 61-65; 5:117-122; 7:166-169; 12:313-315
Geophys. Abs. 12214
Various laboratory methods for determining the radioactivity of rocks are described, including the ionization chamber techniques in which the radon or thoron content of a rock sample is measured by releasing its gases by fusion, solution, or boiling, and passing them into the chamber for discharge in an electroscope, and the determination of potassium content in rocks and liquids by measuring beta radiation. Absorption coefficients for gamma rays in rock can be calculated from measurements made with Geiger-Muller counters of the radiation passing from a known source through progressively increased thicknesses of rock samples until no further change in count is observed. Coefficients for sandstone, shale, marl, and limestone are 0.34, 0.34, 0.11, and 0.24 for energies of about 1.50 MeV.

Titaeva [Titayeva], N.A., R.M. Alexakhin, A.I. Taskaev, and V.I. Maslov, 1980
Migration of heavy natural radionuclides in a!xumid climatic zone, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 724-737

Titayeva, N.A., V.Ya. Ovchenkov, and T.I. Veksler, 1975
Povedeniye radiya v kontinental'nom osadochnom protsesse (dlya usloviy gumidnogo klimata) [The behavior of radium in continental sedimentation processes (under humid climatic conditions)]:

Geokhimiya, (9): 1372-1379

Titayeva, N.A., A.I. Taskayev, V.Ya Ovchenkov, R.M. Aleksakhin, and Shuktomova, I.I., 1977
Osobennosti formirovaniya izotopnogo sostava U, Th, Ra pochv pri dlitel'nom kontakte s radioaktivnimi plastovymi vodami [Peculiarities of the formation of the isotopic composition of U, Th, Ra in soils during a protracted contact with radioactive stratal waters]:
Geokhimiya, 9: 1368-1375
The heightened content in chlorcalcic stratal waters of oil and gas deposits may lead to radioactive contamination of soils in the process of well drilling and exploitation. The study of soddy-meadow and soddy-podzolic soils having for a long time contact with stratal waters in an old oil-field shows a substantial increase of gamma-activity at the expense of contamination by all products of decay of natural radioactive series not being backed by parental ^{238}U, ^{235}U, and ^{232}Th. The presence of relatively short-lived products of ^{232}Th decay in stratal waters allows to conclude that the enrichment of waters in radioactive isotopes occurs continuously at the expense of aquifer rocks.

Tobailem, Jacques, 1955
Mesures précises de périodes radioactives [Precise measurements of radioactive half-lives]:
Jour. Physique et Radium, 16(1): 48-53
Geophys. Abs. 162-186:
Half-lives of several radioactive elements have been precisely determined with an apparatus consisting of two different ionization chambers connected to an electrometer tube. One obtains a precision of the order of 1 percent for half-lives of the order of several years and of the order of 0.1 percent for half-lives of the order of several days. The following results have been obtained: Co-60:5.27± 0.7 years; Rn-222: 3.825± 0.005 days; Ac-227: 21.6± 0.4 years; Ga-67: 77.9± 0.3 hours; Na-24: 14.90± 0.05 hours; Cu-64: 12.8± 0.03 hours; and Au-108: 2.686± 0.005 days.

Tobailem, Jacques, 1955
Mesure de la period du RaD [Measurement of the half-life of Pb-210]:
Jour. Physique et Radium, 16(3): 235-236
Geophys. Abs. 162-187:
The half-life of Pb-210 was redetermined with a differential twin ionization chamber. The results, $t = 19.40 \pm 0.35$ years, corresponding to $\lambda = 1.13 \pm 0.02E\text{-}9/s$ confirms the previous determination by the Curies made in 1929.

Toohey, R.E., M.A. Essling, J. Rundo, and Hengde Wang, 1984
Measurements of the deposition rates of radon daughters on indoor surfaces:
Radiation Protection Dosimetry, 7(1-4): 143-146
Chem. Abs. 101:99837s

Torgersen, Thomas, 1980
Controls on pore-fluid concentration of ^{4}He and ^{222}Rn and the calculation of $^{4}He/^{222}Rn$ ages:
Jour. Geochem. Exploration, 13; 57-75

Tóth, Árpád, 1960
Vízben oldott rádium- és radontartalom maghatározása torziós száles elektrométerű emanométerrel [Determination of the amount of radium and radon dissolved in water with an emanometer on the principle of a torsion fiber electrometer (with German summary)]:
Geofiz. Kozlemenyek, 8(4): 279-290
Geophys. Abs. 185-496:
A method and apparatus are described that can be used in the field for determining the dissolved radon content of water and in the laboratory for determining both radium and radon. The apparatus consists of an ionization chamber coupled to a torsion electrometer and a compensator.

Tóth, Árpád, 1965
Radon measurements by scintillation methods [in Hungarian]:
Magy. Fix. Folyoirat, 13: 129-155
Nucl. Sci. Abs. 20:2152
Scintillation methods were found very useful for determining ^{222}Rn, ^{220}Rn, and ^{219}Rn for purposes of radiation protection, raw material prospecting, geophysical and physico-chemical studies, etc. The measurements are usually carried out at a very low level of activity. These alpha counters present the advantage of being inexpensive, unaffected by humidity, cosmic, and gamma radiation; they do not require a special filling gas and possess a resolution better than 2 msec. The ZnS scintillating layer may be easily replaced. A novel counting system based on ZnS(Ag) scintillator was developed; it operated reliably for periods of 8 hours per day without changing the background as a result of electric noise under conveniently reached conditions. Activities as low as 0.2 pCi of ^{222}Rn could be determined within 2 hours with an accuracy of ± 20%. The construction details given illustrate that the needed components, such as multipliers, pulse recorders, integral discriminating circuits, etc., may be procured easily, without any major changes in the electronics.

Tóth, Á., 1984
A simple field method for determination of ^{220}Rn and ^{222}Rn daughter energy concentrations in room air:
Radiation Protection Dosimetry, 7(1-4): 247-250
Chem. Abs. 101:99851s

Tóth, Á., I. Fehér, S. Novotny Lakatos, L. Koszorus, and B. Keszthelyi, 1980
Distribution of natural radioactive isotope concentrations and emanation factors measured on concrete and brick samples produced in Hungary, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1396-1406

Tovedal, H., 1984
Radon measurement activities and instruments designed at Studsvik Energiteknik AB:
Radiation Protection Dosimetry, 7(1-4): 215-218
Chem. Abs. 101:99845t

Trembaczowski, Emanuel, 1951[1953]
Promieniotwórczość wód na Sławinku pod Lublinem [Radioactivity of the waters in Sławinek near Lublin]:
Marii Curie Skłodowska Uniw. Rocz., Dzial AA, 6(2): 15-24
Geophys. Abs. 156-138
The radioactivity of water from Sławinek sources near the city of Lublin, Poland, was measured with an emanometer, consisting of a gold leaf electrometer and an ionization chamber. The sensitivity of the electrometer was 1.34 volt per scale division. The procedure for the measurements and their theory is discussed and the formula for radioactive intensity is derived. The radioactivity of the water in the well of the source was found to be 1.63 Mache units [600 pCi/L]; similar to that found in several other European sources.

Trembaczowski, Emanuel, 1953
Promieniotwórczość wód Lubelszczyzny [Radioactivity of waters in Lublin province]:
Acta Geophys. Polonica, 1(2): 126-142 [with German summary]
Geophys. Abs. 156-139:
In 1952, radioactivity measurements were made on 57 different waters from 24 places in the province of Lublin. An emanometer was used, consisting essentially of a gold leaf electrometer and an ionization chamber. The results are presented in a table. In most places the activity did not exceed 1 Mache unit [370 pCi/L], but one spring showed 5.4 Mache units [2.0 nCi/L].

Tripp, R.M., 1944

Analytical and experimental data concerning a solid hydrocarbon survey of the Fort Collins anticline:
Geophysics, 9(3): 367-387
Geophys. Abs. 119-7726:
[Includes discussion of radioactive highs over structures.]

Tripp, R.M., 1945
Thermodynamics of a gas migrating vertically through the sedimentary column:
Geophysics, 10: 229-237
Geophys. Abs. 8132:

Tripp, R. Maurice, 1945
Measurement of soil-air ions over the Fort Collins anticline:
Geophysics, 10: 238-247

Trombe, Félix and Charlotte Henry la Blanchetais, 1947
Ionisation--Sur la présence de radiations pénétrants telluriques dans la rivière souterraine de Saint-Paul, Hâute-Garonne [Ionization--On the presence of a penetrating telluric radiation in the subterranean river of Saint-Paul, Haute-Garonne]:
Acad. Sci. [Paris] Comptes Rendus, 224(3): 207-209
Geophys. Abs. 132-9858:
The water of this subterranean river has a temperature slightly higher than that of several adjoining streams in the same region. Having established this fact, the authors measured the electric conductivity of the air in the caverns along this river and found it higher than normal. They also determined the intensity of the penetrating radiation of the water, using for this purpose Kohlhorster's apparatus. They found that the intensity of radiation was quite pronounced approaching the radioactivity of the uraniferous deposits of Lachaux. It appears probable that the water of the river, coming from a great depth, brings to the surface radioactive gases dissolved in it. An exploration of the caverns of this river for radioactive substances appears to be promising.

Tsivoglou, E.C., and H.E. Ayer, 1953
Emanation of radon in uranium mines and its control by ventilation:
Arch. Industrial Hygiene and Occupational Medicine, 8:125-132

Tsivoglou, E.C., H.E. Ayer, and D.A. Holaday, 1953
Occurrence of nonequilibrium atmospheric mixtures of radon and its daughters:
Nucleonics, 11(9): 40-45

Tso, Man-yin W., and Chung-chuen Li, 1987
Indoor and outdoor ^{222}Rn and ^{220}Rn daughters in Hong Kong:
Health Physics, 53(2): 175-180

Turekian, Karl K., and Karl Hans Wedepohl, 1961
Distribution of the elements in some major units of the Earth's crust:
Geol. Soc. America Bull., 72(2): 175-192

Turekian, K.K., Y. Nozaki, and L.K. Benninger, 1977
Geochemistry of atmospheric radon and radon products:
Annual Review of Earth and Planet. Sci., 5: 227-255

Turf, J., 1963
La mesure continue de la radioactivité naturelle de l'air [The continuous measurement of the natural radioactivity of the air]:

Ciel et Terre, 79(3-4): 57-67, and (5-6): 141-154
Geophys. Abs. 203-306:
The first part describes the method of continuous measurement of the natural radioactivity of the air used at Dourbes, Belgium, the reduction of the recorded values and the determination of the radon thoron ratios. The second part presents the mean daily values obtained from such measurements made in March through August 1961, and gives graphs of the variation of natural radioactivity as a function of temperature, atmospheric pressure, wind velocity, rainfall, and relative humidity, and graphs of the diurnal variation of radon and thoron for each of the six months in question. The results show that (1) the diurnal maximum is reached shortly after sunrise; (2) the time interval between sunrise and the maximum varies seasonally, being shorter when the days are longer; (3) the natural radioactivity varies seasonally, with a maximum in June; and (4) the diurnal minimum occurs in the afternoon with hardly any change between 12 and 18 h. The general conclusion drawn from this study is that the method of continuous measurement of natural radioactivity described here makes it possible henceforth to study in detail the correlation of radioactivity with meteorological phenomena.

Turk, B.H., R.J. Prill, W.J. Fisk, D.T. Grimsrud, B.A. Moed, and R.G. Sextro, 1987
Radon and remedial action in Spokane River Valley homes. Volume 1: Experimental design and data analysis:
Berkeley, Calif., Univ. California Lawrence Berkeley Laboratory Rept. LBL-23430, 25 p.

Turk, B.H., Prill, R.J., Sextro, R.G., and Harrison, Jed, 1989
Intensive radon mitigation research: lessons learned, *in* Osborne, M.C., and Jed Harrison, Symposium Cochairmen, The 1988 Symposium on Radon and Radon Reduction Technology, Proc., Vol. 1, Symposium Oral Papers:
Research Triangle Park, N.C., Radian Corp., U.S. Environmental Protection Agency Pub. EPA/600/9- 89/006a [Springfield, Va., NTIS Order No. PB89-167480], p. 6-25--6-44.

Turkevich, Anthony L., James H. Patterson, Ernest J. Franzyrote, Kenneth P. Sowinski, and Thanasis E. Economou, 1970
Alpha radioactivity of the Lunar surface at the landing sites of Surveyors 5, 6, and 7:
Science, 167(3926): 1722-1724

Turner, R.C., 1962
Radioactivity and hardness of drinking waters in relation to cancer mortality rates:
Brit. Waterworks Assoc. Jour., 44: 613-629
Nucl. Sci. Abs. 17:20255:
A study of mortality rates for cancer of different sites and for a number of other diseases did not reveal any correlation between area mortality and the widely different amounts of Ra-226 and its daughter products known to be present in the drinking waters available in England and Wales. The areas of Wales that show surplus mortality from gastric cancer possess drinking water supplies with very low contents of natural radioactivity. Surplus gastric cancer tends to appear in regions having soft drinking waters derived from surface drainage, and often having a low pH at their source. Surplus mortality rates due to diabetes mellitus among females and to vascular lesions affecting the central nervous system in both sexes, also appear in the soft water regions of England and Wales. This trend is not displayed by cancer of other sites nor does it appear in the mortality data for a number of other diseases.

Turner, R.C., J.M. Radley, and W.V. Mayneord, 1961
Naturally occurring alpha-activity of drinking waters:
Nature [London], 189(4762): 348-352
Geophys. Abs. 185-495:
The results of measurement of the natural alpha activity due to Ra-226 in 71 drinking waters in Great Britain, together with values for short-lived Rn-222 and Ra-224 (ThX) where present, are tabulated. The highest

values of long-lived alpha-activity are in spa waters. Next highest are those in waters from boreholes in strata other than chalk. Waters from chalk are still lower, and the least active are surface waters even though many are derived from areas of Precambrian or granitic rocks.

Tutarova, A.B., 1971
Fonovaya radioaktivnost' podzemnykh vod Ukrayny [Background radioactivity of the ground waters of the Ukraine]:
Geol. Zhur., 31(1): 91-97
Geophys. Abs. 298-585

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Distribution of helium and radon in subsurface waters in the artesian basin in the Tashkent Region [in Russian]:
Uzbek. Geol. Zhur., 12(1): 46-49
Chem. Abs. 30002u

Tyukhtin, M.I., 1974
Vliyaniye Rn i Tn v prizemnom sloye atmosfery na gamma-spektral'nyye opredeleniya U i Th [Effect of radon and radon-220 in the surface atmospheric layer on the gamma-spectroscopic determination of uranium and thorium:
Zapiski Leningradskogo Gorn. Inst., 64(2): 94-96
Chem. Abs. 84:62820k:

Ueji, Torajiro, 1958
Some results obtained by the measurements of radioactivity in a certain bath-room of radioactive spring in Hyogo Prefecture, Japan [in Japanese with English abstract]:
Balneol. Soc. Japan Jour., 9(2/3): 52-57
Geophys. Abs. 186-547:
The results of radioactivity measurements with a scintillation counter of the water and air in a hot spring bathhouse are reported. It was found that the higher the temperature of the mineral water in the bathtub, the larger the radon emanation from the water. Readings of the counts in the air of the bathhouse proved to be irregular but were generally higher on the floor than in the upper parts of the room.

Ueji, Torajiro, 1960
Radioactive mineral springs in Mt. Rokko and its environs near Kobe, Japan [in Japanese with English abstract]:
Balneol. Soc. Japan Jour., 11(2/3): 29-33
Geophys. Abs. 186-548:
The results of an investigation of the radioactivity, temperature, and geologic relations of 65 mineral springs in the Mt. Rokko, Japan, area are reported. Radioactivity was found to be higher in springs of lower temperature. Zuihorji and Kurakuen springs have the highest radioactivity; both issue from biotite granite.

Ulbak, K., N. Jonassen, and K. Baekmark, 1984
Radon exhalation from samples of concrete with different porosities and fly ash additives:
Radiation Protection Dosimetry, 7(1-4): 45-48
Chem. Abs. 101:99820f

Ulomov, V. I. and B. Z. Mavashev, 1967
O predvestnike sil'nogo tektonicheskogo zemletryaseniyna [A precursor of a strong tectonic earthquake:
Akad. Nauk SSSR Doklady, Earth Sci. Sec., 176(2): 319-321
Stabilization of the concentration of radon, preceded by a rapid and turbulent increase of its normally low concentration in thermal waters of the deep Canomnian aquifer, fed partly by abyssal waters in the Tashkent basin, proved to be a forerunner of major earthquakes.

Umemoto, S., 1952
Radon content of Misasa hot springs, Japan [in English]:
Repts. Balneol. Lab., Okayama Univ., 7: 6-7

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Relation between radon and radium B in some radioactive springs:
Okayama Daigaku Onsen Kenkyôsho Hôkoku, 18: 24-25

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Health and Safety Laboratory manual of standard procedures, revised: NYO-4700: 454 p.
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[Procedure for sampling and determination of radon.]

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Preliminary Reconnaissance for Uranium in Maryland and Pennsylvania:
U.S. Atomic Energy Comm. Rept. RME-4103

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Russian Papers on Measurements of Terrestrial Radioactivity, with a Supplementary Chapter on Radioactive Substances and Methods for Locating Them (by F. W. Lee):
U.S. Bur. Mines Inf. Circ. 6072, 27 p.
[Translations by A. Seletzky:]
Bogoyavlenskiy, L.N., and A.A. Lomakin, Experiments on highly penetrating radiations from the Earth
Bogoyavlenskiy, L.N., Radiometric exploration of oil deposits
Cherepennikov, A., Some measurements of the radioactivity of gases and water of the Ukhta oil-bearing region and of medicinal mud and brine fron the salt lake of the Tinakee Station

U.S. Department of Energy, 1979
National Uranium Resource Evaluation, Interim Report:
U.S. Dept. Energy, Grand Junction Operations Office, Rept. GJO-111(79), 155 p.
[Plate 5: Areas identified as favorable but with insufficient basis for estimation of potential uranium resources (smaller scale copy of Preliminary Map No. 30, 1-1-79, same title)]

U.S. Environmental Protection Agency, 1975
Preliminary findings, radon daughter levels in structures constructed on reclaimed Florida phosphate land:
U.S. Environmental Protection Agency, Office of Radiation Programs Tech. Note ORP/CSD-75-4, 32 p.

United Sates-Euratom Joint Research and Development Program, 1962
The diffusion of inert gases in solid bodies:
Quarterly Report no. 1, Contract 094-62-9RDD: 8 p. [A translation]
Nucl. Sci. Abs. 17:22169:
The diffusion of argon in KBr and KCl and xenon diffusion in ThO_2, UC, and UO_2 received further investigation. Alterations were made to the apparatus to permit study of the initial processes in KCl diffusion experiments. Tests on normal and NH_4NO_3-doped tablets of 8 tons pressure tension revealed that the NH_4NO_3—compounded tablets yield a greater percentage of inert gas. Inert gas yield obtained from a natural UO_2 crystal of Bröggerit mineral was much greater than that from artificial crystals. Longer irradiation apparently increased the xenon yield from UC.

United States-Euratom Joint Research and Development Program, 1961
Diffusion of rare gases in solids:
Final report, Contract 064-61-RDD; 44 p. [Translation]

Nucl. Sci. Abs. 17:22170:
The evaluation of post-activation diffusion (PAD) measurements, the experimental methods used for the diffusion measurements, and the of the radioactive rare gases are described. Experimental results of PAD measurements are given in the form of release curves and activation energies. Deviations from the ideal case of pure volume diffusion were observed with polycrystalline and sintered material and are discussed in a survey of parameters affecting the rare gas release from the solids.

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Air Pollution. Hazards of Indoor Radon Could Pose a National Health Problem. Report to the Pennsylvania Congressional Delegation, House of Representatives:
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Indoor Radon. Limited Federal Response to Reducing Contamination in Housing. Report to the Honorable Frank R. Lautenberg, U.S. Senate:
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NBS Technical News Bull. 34: 160-163
[Application to breath testing; description of apparatus.]

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Public Health Reports, U.S., 41(37): 1937-1939

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First measurements of atmospheric radioactivity at Santa Fe:
Anales Soc. Cient. Santa Fe, 5: 30-34, 48-53
Chem. Abs. (1935) 2839

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Determination of the thorium content of rock:
Jour. Chem. Physics, 4: 34-39
Geophys. Abs. 85-3158

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Determination of the radium content of rocks:
Jour. Chem. Physics, 4: 40-48
Geophys. Abs. 85-3159

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Survey on natural radiation in houses in Belgium:
Radiation Protection Dosimetry, 7(1-4): 275-278
Chem. Abs. 101:99858z

Uzumasa, Yasumitsu, 1965
Chemical investigations of hot springs in Japan:
Tsukiji Shokan Co., Ltd., 189 p., 535 refs.
[Essential reference and review. Ch. 5 - Radioactivity, 111-124.]

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Soil and regional uranium as controlling factors of indoor radon in eastern Pennsylvania:
Princeton, NJ, Princeton Univ. Center for Energy and Environmental Studies Rept. PU/CEES-145, 68 p.
High indoor radon concentrations in eastern Pennsylvania are associated with specific geological environments. For example, houses on the Beekmantown formation in the Great Valley [which extends approximately from Harrisburg to Easton] are likely to have high concentrations. Since the geology of uranium distribution is better known than that of radon, this study tested the utility of uranium data as predictors of radon concentrations. Neither available uranium data nor National Uranium Resource Evaluation (NURE) data proved good predictors in this region. We implemented protocols for uranium analysis in soils by paper chromatographic separation for fluorimetry. Analysis of 40 samples from the region showed that average values were relatively high (3.5 mg/kg bulk), and that uranium concentrations in soils were not robust predictors of radon in nearby houses.

Van der Lugt, G., and L.C. Scholten, 1985
Radon emanation from concrete and the influence of using flyash in cement:
The Science of the Total Environment, 45: 143-150

Van der Weijden, C.H., M. Van Leeuwen, and A.F. Peters, 1985
The adsorption of U(VI) onto precipitating amorphous ferric hydroxide:
Uranium, 2(1): 53-58

Vankova, Vera, 1956
Nekolik poznamek k pouziti radiometricke aparatury v terenu [Some remarks on the utility of radiometric equipment in the field]:
Ceskoslovensky Casopis pro Fysiku, 6(4): 488-491
Geophys. Abs. 168-276:
Profiles of total gamma-ray intensity measured with a Geiger counter in shallow pits in the surface soil placed 10 m apart in line across known faults show a small positive anomaly over one fault, none over others, and a negative anomaly over water-logged ground in the vicinity of a known fault zone. It is concluded that equipment used cannot locate faults where even their approximate position is unknown in advance. In the appended discussion (p. 491-492), J. Backovsky and R. Seidl state that the method is less suitable for the search for faults than for their precise localization under favorable conditions.

Várhegyi, András, István Baranyi, and György Somogyi, 1986
A model for the vertical subsurface radon transport in "geogas" microbubbles:
Eötvös Loránd Geophys. Inst. (Hungary) Geophys. Trans., 32(3): 235-253
Based on the concept of "geogas" [introduced by Kristiansson and Malmqvist, 1982, *q.v.*] rising in the form of microbubbles from deeper regions, the authors have developed a new model for the transport of radon released from deep sources, and a method for its detection. The advantage of the new model compared with the earlier ones is the elimination of the well-known problems of the radon emanation research methods (penetration depth, reproducibility, etc.), and it provides a qualitative and quantitative description of the transport mechanism, which is realistic from both geological and physical viewpoints. The authors emphasize the role of groundwater and gases of deep origin in the movement of radon, briefly discussing possible sources of these gases. The problems of detecting the radon below the water-table with track detectors are reviewed and the connection between the rock physical parameters (tortuosity, porosity, grain size distribution) and transport characteristics is investigated in detail. Assuming different geological conditions and rock physical parameters, theoretical vertical radon concentration and track production profiles were calculated. Finally detectability of deep radon sources depending on geological conditions is analysed and methodological recommendations are made for the more efficient use of the radon emanation uranium exploration methods. [Surface interaction between bubbles and the losses of momentum after hitting grains were apparently not taken into account.]

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The influence of the nature of the carrier on the emission of radon:
Acad. Sci. [Paris] Comptes Rendus, 183: 1277-1279
Chem. Abs. (1927) 856-2:
The relation of the quantity of radon emitted in 24 hours from radium included in several salts and carbon to the accumulated radon is given.

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Analiticheskaya khimiya radiye [Analytical chemistry of radium] [in Eng. trans.]:
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Israel Program for Scientific Trans., Jerusalem, 1971: 142 p.
U.S. Dept. Commerce, NTIS, TT70-50093

Viljanen, Martti, Eero Slunga, Timo Lehtoviita, and Pekka Kanerva, 1987
Radon merkitys talonrakennustekniikassa. Radontekninen suunnittelu [Radon in building technology. Radontechnical design]:
Espoo, Finland, Helsinki Univ. Technology, Dept. Civil Engineering, Div. Structural Engineering Rept. 88, 147 p.
This report on the design of buildings, their foundations, and ventilation can be used for both new design and remedial action. A radon-technical classification of foundation soil is proposed with instructions for defining low, normal, high, and very high radon classes on the basis of radon content and air permeability of the soil.

Vincenz, S.A., 1959
Some observations of gamma radiation emitted by a mineral spring in Jamaica:
Geophys. Prospecting, 7(4): 422-434
Geophys. Abs. 181-412
The decay rate of gamma radiation emitted by a mineral spring in Jamaica, West Indies, has been measured by means of portable rate meters. The results of the measurements, supported by auxiliary tests, suggest that the radioactivity is due chiefly to radon-222. The intensity of gamma radiation is inverse to the rate of water discharge. Investigation of the effect of rainfall and of earthquakes leads to the conclusion that the radon, or radon-charged water, is derived from appreciable depths by way of conduits. The source is probably a region containing disseminated uranium (perhaps in the Lower Eocene or Cretaceous shales) rather than a high-grade uranium deposit.

Vincenz, S.A., 1964
A note on the radioactivity of Jamaican bauxite and Terra Rossa:
Overseas Geology and Mineral Resources, 9(3): 295-301
Geophys. Abs. 211-268:

It is concluded from observation of gamma-ray activity of Jamaican bauxite and *terra rossa* that the radioactive source is ionium and radium associated with the ferruginous fraction in the bauxite. A possible mechanism for the concentration of ionium and radium might be the initial removal of these elements from the terra rossa by high carbonate waters and then, as a result of adjustment in the pH values of the water, their re-adsorption in the *terra rossa*. Although the radioactive fraction has been derived from a pre-existing Tertiary uranium source, the process of its deposition and concentration is still taking place today. The ultimate source of the deposits should be sought in rocks of igneous origin. [The term "*terra rossa*" signifies a reddish-brown residual soil, here used to indicate noncommercial grades of Jamaica bauxite. See Kukoc, 1980.]

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The assumption that radon anomalies near the surface are due to increased radon diffusion from an underground source is questioned; the small radon diffusion coefficient and the thickness of the fine-grained weathered layer or crevice fillings would largely prevent diffusion of radon to the surface. Radon profiles were measured over faults with relatively thick and very dense covers, and soil samples were taken at various depths at each measuring point and measured with a Geiger counter after a storage time several times longer than the half life of radon. The conditions of the tests exclude the effect of diffused radon, yet both methods showed a maximum over the faults. It is concluded that radon accumulates near the surface with the aid of ground water, charged with both stable and active cations, which is carried upward by capillarity and evaporates near the surface. In clays the cations are accumulated by ion exchange. Three mechanisms causing radon anomalies are therefore possible: 1) accumulation of uranium and radium by ion exchange; 2) accumulation of uranium and radium by ion exchange, and radon diffusion; and 3) radon diffusion alone (in rare cases).

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Geophys. Abs. 74-2533

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Nonequilibrium concentrations of radon daughters in a ventilated mine:
Repts. CRT-1029, AECL-1296
Nucl. Sci. Abs. 15:29537

Vohra, K.G., M.C. Subbaramu, and A.M. Mohan Rao, 1964

Measurement of radon in soil gas:
Nature [London], 201(4914): 37-39
Geophys. Abs. 211-270:
A method of measuring the Rn-222 present in soil gas down to about 50 pCi/m^3 is described. For this method about 50 L of soil gas is pumped into a balloon, and after 3 hr the daughter products Pb-214 and Bi-214 are assumed to have been collected on the aerosols, which are then filtered out and estimated by the beta-activity of the filter. This method is insensitive to thoron whose daughters have a very low beta-activity after 3 hr.

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Tellus, 18(2-3) 672-678
Geophys. Abs. 246-389:
Experiments have been made with natural radon in the air to show that radon daughter products behave as single ions of high mobility in dry air whereas they are attached to cluster aerosols formed in the presence of certain charges and vapors. This mechanism is of fundamental importance in understanding the nature of radon daughter products in the air under different environmental conditions.

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Physikal. Zeitschrift, 5(5): 130-134
[Ramstedt (1911) cites these as first results of solubility of Rn in liquids. Ref. U.S. Bureau of Mines Circ. 6072, p. 14.]

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Radioaktivnost travertine u Niskoj Banji [Radioactivity of travertine at Niska Banja (with English summary)]:
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Geophys. Abs. 188-475:
Radium is deposited in the travertine at Niska Banja without its parents ionium and uranium. The radium content decreases with depth in the travertine. The radioactivity of the travertine is independent of the accessory minerals and of the content of Mn, Fe, Al, and hydrated Si oxides. Studies using photonuclear plates indicate that the radioactive elements are distributed in all the mineral fractions. The thorium content of the travertine was also measured.

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U.S. Geol Survey Profess. Paper 455-A, 28 p.
[Plate 1: Geographic distribution of uranium-bearing veins in the conterminous U.S.]

Walker, R.Y. and Samuel R. Litzenberg, Jr., 1959
New exploration technique shows promising results:
World Oil, 148(5): 134-137
Geophys. Abs. 184-529:
The emission technique of oil exploration, based on the radiation and detection of low energy (soft) gamma rays from the subsurface, has been field tested in producing areas of Texas, Louisiana, New Mexico, and Oklahoma with good results. This method is particularly useful in outlining the productive limits of fields. Faults are also detected by the gamma radiation from radon gas that passes along the fault plane. The direction of dip of the fault can be determined by the leakage of radon upward from the fault plane on the downdip side.

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Methodische Probleme und Ergebnisse emanometrischer Untersuchungen im Baskischen Gebirge [Methodical problems and results of emanometric investigations in the Baskisch Mountains]:
Münster Univ., Dissertation

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Radon and its daughter products in mine atmospheres, and introduction to its occurrence, detection and control:
Camborne [Cornwall] School of Mines Jour., 77: 38-42
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Wanty, Richard B., Paul H. Briggs, and Susan L. Johnson, 1989
Influence of water-rock reactions on the availability of radon-222 and its parent radionuclides to ground water [abs.]:
Geol. Soc. America, Northeastern Section, Abstracts with Programs, 21(2): 73-74
A study of ground-water chemistry was performed near Glen Gardner, New Jersey, to determine the availability of radionuclides to ground water. Radon-222 (^{222}Rn), radium-226 (^{226}Ra), and total uranium (U) were measured, in addition to a comprehensive analysis of inorganic constituents. Water chemistry was compared with aquifer lithology, and constraints were placed on the solubility and chemical residence of the radionuclides. Water samples were drawn from two aquifer units: a hornblende granite (HG) and a mylonitized hornblende granite (MG). Water in the MG is distinguished from that in the HG by its generally lower pH (avg. for MG=5.4, avg. for HG=6.4), higher dissolved oxygen (MG_{avg}=5.8 ppm; HG_{avg}=3.7 ppm), and lower dissolved CO_2. Low-pH waters from either rock type generally have higher concentrations of trace metals such as Fe and Cu, suggesting that adsorption reactions are important in limiting trace-metal mobilities. Aqueous ^{222}Rn values for the MG (avg. 4400 pCi/L) were only slightly higher than those for the HG (avg. 2550 pCi/L). Aqueous uranium concentrations were low, all less than 4.9×10^{-9}; nearly half the samples were below the level of detection ($\approx 0.1 \times 10^{-9}$). No clear distinction exists between waters drawn from the two rock types as far as ^{222}Rn or U contents are concerned. Although the ^{226}Ra analyses are incomplete, preliminary indications suggest low aqueous ^{226}Ra values. In accord with previous studies, the radioactivity of ^{222}Rn in

water is always higher than that of its parents, so the water itself is not in secular equilibrium. This condition requires ^{226}Ra be located close to the water-rock interface so that ^{222}Rn, when produced, can be transferred rapidly to the aqueous phase. Chemical model calculations indicate that U minerals are not supersaturated in any of the samples, suggesting that adsorption processes play a key role in limiting the mobility of U. The same is expected for ^{226}Ra. This observation concurs with the trace-metal results. These results demonstrate the importance of examining water-rock interactions in understanding the mechanisms controlling radionuclide mobility.

Wanty, Richard B., and Linda C. Gundersen, 1987
Factors affecting radon concentrations in ground water—Evidence from sandstone and crystalline aquifers [abs.]: Geol. Soc. America, Abstracts with Programs, 19(2): 135

Geochemical and hydrologic processes control radon concentrations in ground waters. Radon is derived from the successive radioactive decay of uranium [^{222}Rn], thorium [^{220}Rn], and radium [^{222}Rn], but its ground-water concentration is commonly not strongly correlated with those of its parent elements. This phenomenon is explained by varying mobilities of uranium, radium, and radon under different chemical conditions, and by the fact that waters are rarely in secular equilibrium. Highest ground-water radon levels are usually found in rocks locally enriched in uranium, inferring a major contribution to dissolved radon by parent nuclides in the solid phase. Ground-water flow rates are usually slow enough that radon, with a 3.8-day half-life, is not carried far from its source. Ground-water samples from sandstone aquifers in the Miocene Oakville Formation in south Texas, and the Late Cretaceous Lance Formation in northeastern Wyoming show that aqueous chemical changes along the flow path influenced the radon content by dissolving or concentrating uranium and radium in the rocks. Aqueous concentrations of radium and radon are highest along redox boundaries where uranium is concentrated in the rocks. Investigations of two fracture-controlled aquifer systems in Proterozoic metamorphic rocks of the Reading Prong in eastern Pennsylvania are currently being performed. Rock types in the Pennsylvania study areas consist of moderate-to-steeply dipping granitic gneisses with or without hornblende gneiss and amphibolite. Preliminary results show that general chemical properties of the ground water such as pH, dissolved oxygen, and ionic strength vary with local rock type, as do radon concentrations. Higher radon levels occur in rock units enriched in uranium, an in sheared zones having locally increased water-rock contact. The Pennsylvania ground waters have uniformly higher radon levels than the other two areas, possibly because of lower water/rock ratios, more widely and evenly dispersed uranium content, or different mineral residences of the radioactive parents.

Wanty, Richard B., and Linda C.S. Gundersen, 1988
Groundwater geochemistry and radon-222 distribution in two sites on the Reading Prong, eastern Pennsylvania, *in* Marikos, Mark A., and Robert H. Hansman, eds., Geologic Causes of Natural Radionuclide Anomalies, Proceedings of the GEORAD Conference, St. Louis, Mo., April 21-22, 1987:
Rolla, Mo., Missouri Dept. Nat. Resources, Div. Geology and Land Survey Spec. Pub. No. 4, p. 147-156

High levels of indoor radon-222 have been found in houses built on the Reading Prong, a continuous exposure of Proterozoic metamorphic rocks trending northeastward from Reading, Pennsylvania. The radon-222 is derived from radioactive decay of uranium-238, with which these rocks are enriched. Radon-222 is present also in the groundwater in these fractured crystalline [non-sedimentary] aquifers. Groundwater samples were taken from 31 domestic supply wells in two areas and were analyzed for total uranium, radon-222, and radium-226. The highest radon-222 and uranium concentrations were in water from mylonitized [metamorphosed under conditions of ductile shear] quartz-feldspar gneiss. Radon-222 concentrations as high as 100,000 pCi/L and total uranium concentrations as high as 200 pCi/L were measured. Radium-226 concentrations ranged from 0.1 to 10.1 pCi/L, but seldom exceeded 1 pCi/L. Secular equilibrium between radon-222 and uranium-238 is not attained in any of the samples. In every case, radon-222 activity greatly exceeds that of uranium 238; thus, the source of the dissolved radon-222 lies ultimately in solid-phase uranium-238. Likewise, radium-226 activity is lower than that of radon-222 in every sample. Data suggest that uranium concentrations in oxidized groundwater are independent of major chemical parameters such as pH and carbonate concentration, but depend strongly on aquifer rock type. Reduced groundwater, restricted to two narrow zones of mafic gneiss, contains uniformly lower uranium concentrations (<1 pCi/L); therefore, aquifer rock type appears to be the dominant factor in determining the radon-222 potential of groundwater in the two studied sites in the Reading Prong.

Wanty, R.B., L.C.S. Gundersen, and R.R. Schumann, 1990

Geological factors affecting radionuclide mobility [abs.], *in* Gough, L.P. (ed), Proceedings of the USGS Environmental Forum 1990:

U.S. Geol. Survey Open-file Rept. 90-288, p. 15-16

A research program funded by the U.S. Geological Survey, Department of Energy, and the Environmental Protection Agency is being conducted to investigate the geologic factors affecting radionuclide mobility in the natural environment. The primary focus of the program is Radon-222 (^{222}Rn) in soil gas and ground water, and the contribution of ^{222}Rn in each of these media to indoor airborne ^{222}Rn. When present in indoor air, ^{222}Rn is a suspected carcinogen. ^{222}Rn is a daughter in the uranium-238 (^{238}U) radioactive decay series; its immediate parent radionuclide is radium-226 (^{226}Ra). Our results show that an integrated approach, including geologic, geochemical, and pedologic studies, is the most effective in understanding ^{222}Rn distribution in the environment. We hope to gain a reliable means of predicting areas likely to have problems with high levels of ^{222}Rn by examining the processes governing the mobility of ^{222}Rn as well as its radioactive parents. ¶Studies have been performed in a number of areas around the United States, including the Reading Prong, Pennsylvania, the Piedmont and Valley and Ridge of the Appalachian Mountains, the Atlantic Gulf Coastal Plain, the northern Great Plains, and the Rocky Mountains. Our major conclusion is that there is a strong correlation between local geology and the potential for high ^{222}Rn in soil gas or ground water. ¶In the Piedmont and Reading Prong, shear zones (in particular mylonite zones) produce high ^{222}Rn concentrations because uranium is redistributed during ductile deformation from resistate minerals, which have a low degree of emanation, to more highly emanating sites in foliations and associated fractures. Uranium commonly is associated with iron and titanium oxide grain coatings. The high emanation of ^{222}Rn from the rocks to the soil gas or ground water causes the very high concentrations of ^{222}Rn found in soils, ground water, and homes associated with shear zones. ¶In areas underlain by sedimentary rocks, variable ^{222}Rn concentrations have been found in soil gas. For instance, in the northern Great Plains, several types of continental glacial deposits were found to have high concentrations of ^{222}Rn in soil gas, resulting in a large proportion of homes with high indoor ^{222}Rn levels in Iowa, North Dakota, and Minnesota. In the Coastal Plain of the eastern and southern U.S., generally low concentrations of ^{222}Rn are found in soil gas and homes. High soil-gas Rn occurs in glauconitic sandstones, phosphatic claystones and sandstones, black shales, and heavy mineral sand deposits. ¶Soil and weather characteristics have a marked influence on radon generation and mobility in soils. Results of a study at the Denver Federal Center (DFC) showed that as much as a tenfold difference in soil radon concentrations may occur seasonally as a result of moisture capping effects and formation and destruction of desiccation cracks in the soil. Shorter term, two- to threefold variations in soil radon concentrations can occur in response to precipitation, barometric pressure, and other weather factors. Soil type is important in determining the magnitude of the soil's response to weather factors. Smectitic soils such as those found at the DFC site are most susceptible to the moisture capping effects noted in the study. ¶Investigations of ^{222}Rn in ground water supplies have shown that extremely high levels of dissolved ^{222}Rn occur in some areas. Equally important is the finding that high levels of uranium and radium also may exist in these areas. When present in high enough concentrations in drinking water, these elements pose a threat to human health. Adsorption processes appear to be the major control on the concentrations of uranium and radium, but radon concentrations seem to be limited by the degree of emanation from the rock to the water as it is produced by radioactive decay of radium. ¶Future studies of radon in rocks and soils will concentrate on radon emanation and the climatic and geochemical parameters that most affect it. A nationwide study of granites and associated shear zones will attempt to further evaluate some of the most severe radon problems in the U.S. Studies of radionuclides in ground water will be directed toward a more thorough understanding of the geology, petrology, geochemistry, and hydrogeology of the rock-water system, and the chemical and physical factors influencing ^{222}Rn sources. In addition, a more reliable method for estimating the contribution of radon in domestic water to indoor air will be evaluated.

Wanty, Richard B., Susan L. Johnson, Paul H. Briggs, and Linda C.S. Gundersen, 1989
Geochemical constraints on radionuclide mobility in ground water from crystalline aquifers in Montgomery County, MD [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(5): 156
Ground waters in uraniferous rocks may have high concentrations of uranium or its progeny radium (^{226}Ra) and radon (^{222}Rn). Therefore, it is important to understand the processes that control the mobilities of these elements, as they pose a possible health problem when present in drinking water. Through an understanding of the behavior of these elements in the rock-water system, a predictive capability can be developed for identifying other areas that may have a problem with radionuclides in ground water. Thirty-one ground-water samples were collected from four areas in Montgomery County, Maryland, and analyzed for uranium, radon, pH, and major and trace cations and anions. The four areas provided samples from five crystalline aquifers of various uranium content. The primary control on ground-water chemistry is the aquifer rock type; distinctly different pH's and major-element chemistries are seen in the different aquifers. All but one water sample had less than $1x10^{-10}$ (0.1 ppb) uranium, indicating that uranium is tightly bound in the solid phase. Autoradiographs support the water analyses and show that uranium is distributed within minerals rather than localized at mineral surfaces. Radon-222 in the samples varied from <100 pCi/L to 6670 pCi/L. Aquifers with generally higher dissolved ^{222}Rn correspond to rock units identified as having moderate or high risk for indoor radon problems. Aquifers identified as having low risk for high indoor ^{222}Rn have, on average, ten times lower dissolved ^{222}Rn. Our results indicate that a fundamental knowledge of the geology and hydrology is essential to develop an efficient and reliable means of identifying new areas likely to have a problem with radionuclides in ground water. This approach is much more efficient than random screening based on statistical searches using geographic variables that do not depend on areal geology.

Wanty, Richard B., Donald Langmuir, Cynthia A. Rice, and Paul H. Briggs, 1990
Geochemical controls on uranium mobility in crystalline-rock aquifers [abs.], *in* Materials Research Society Fall Meeting, Boston, Mass., November 26-December 1, 1990:
Materials Research Soc., Pittsburgh, Pa., Final Program and Abstracts, p. 473
Approximately 140 ground-water wells in crystalline-rock aquifers from Pennsylvania, New Jersey, Maryland, and Colorado were analyzed for all major cations and anions, and uranium, to evaluate the mobility of natural uranium in ground waters. Field-measured pH ranged from 4.4 to 9.4; estimated Eh ranged from -0.13 to +0.83 V. Modelling with [USGS computer program] PHREEQE revealed that uraninite or coffinite may be near saturation in reducing waters, which limits uranium concentrations to $<1x10^{-9}$ (1 ppb; detection limit is 0.05 ppb). However, uranium minerals are below saturation in all oxidizing ground waters. Uranyl carbonate complexes are the dominant uranium species in the oxidizing waters. Autoradiographs of rock samples from these areas show that uranium is concentrated along fracture boundaries and ferric-oxide grain coatings. Because uranium minerals are undersaturated, uranium mobility probably is limited by adsorption onto ferric oxides and lesser amounts of manganese oxides. Uranium concentrations in the ground waters (<0.05 to 1200 ppb) are comparable with the results of published experimental studies of uranium adsorption onto various ferric oxides in the pH range of the water samples. Consistent with the experimental studies, higher dissolved uranium occurs in alkaline carbonate-rich waters, suggesting that as expected, the formation of uranyl carbonate complexes inhibits adsorption. Preliminary calculations of uranyl adsorption onto goethite using [USEPA computer program] MINTEQA2 show that in low-carbonate waters (<50 ppm ΣCO_3), the ratio of adsorbed:dissolved uranium is greater than 10:1. In alkaline waters, adsorption is less, and higher aqueous uranium concentrations are predicted. These results are important to understand the migration of uranium from the radioactive waste repositories in oxidizing ground-water systems where the uranium minerals rarely attain saturation. In oxidized water-rock systems, the slow escape of uranium from a breached repository may be compensated for by its continual adsorption onto mineral surfaces in the rock.

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Barrier technique for separate measurement of radon isotopes:
Review Sci. Instruments, 48(11): 1440-1441

Warren, Roy K., 1977
Recent advances in uranium exploration with electronic alpha cups:
Geophysics, 42(5): 982-989

Washington, J.W., and A.W. Rose, 1989
Effects of variation in soil temperature and moisture on radon in soil gases [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(6): A145
Radon in soil gases partitions between the air and water phases of soil. The partition ratio, Rn(air)/Rn(water), depends strongly on temperature, ranging from 1.87 at 0°C to 2.73 at 10°C, 3.88 at 20°C, and 4.93 at 30°C. For a soil with a given emanation coefficient, radium, and porosity, radon concentration in the air phase increases by a factor of nearly 4 at 20°C as the moisture saturation increases from 0 to 100%. At conditions near saturation, changes in temperature and moisture can cause large changes in radon in the air phase. For example, cooling from 20°C and 99% saturation to O.l°C and 50% saturation decreases radon in the air phase to about 37% of its initial value. In contrast, changes of temperature and moisture in the dry region have relatively little effect. Because of these effects, soils in humid regions that experience sub-freezing temperatures are characterized by significant seasonal variations in radon content. This behavior is observed for some soils from central Pennsylvania which typically are near saturation and 0°C to 3°C at 0.5 m and deeper during winter, and at 15°C to 20°C with moisture saturation of about 0.8 during summer. The lowest radon values are in the winter for these soils, which are dominated by temperature effects. In contrast, reported seasonal variations for soils that are less moist and remain well above freezing typically show highest radon in winter, interpreted to result from the increased soil moisture during winter. Radon entering homes is also expected to vary as a function of climate.

Washington, J.W., A.W. Rose, and D.J. Greeman, 1989
Effect of inhomogeneity of soil properties on radon transport in soil gases [abs.]:
Eos, Am. Geophys. Union Trans., 70(15): 497
Past concepts and models of radon in soil gas have assumed a depth distribution determined by diffusion and flow in soil with uniform radium content, emanation coefficient, porosity. diffusion coefficient, moisture content, and permeability. Measurements for six soil profiles in Pennsylvania and North Carolina show large variations in these properties; also, variation of moisture content with time causes variation of other properties with time. Field permeability measured with a 10-cm diam. ring pushed 10 cm into pit walls commonly varies by xlO to x50 within a profile. The A horizon usually has much higher permeability than the B horizon. Diffusion coefficients measured in the field show a similar large range, correlating with permeability. Radium commonly varies by x2 within profiles. Moisture content varies widely with depth, and is generally much higher in winter than in summer. Emanation coefficients measured in the lab at a range of moisture tensions show values as low as 0.03 for near-saturated conditions, compared with values of 0.10 to 0.40 for disaggregated soils suspended in water. Both models and observations of radon activity in soil gas reflect these inhomogeneities by complex vertical profiles that change with time.

Wathen, John B., 1987
The effect of uranium siting in two-mica granites on uranium concentrations and radon activity in ground water, *in* Graves, Barbara, ed., Radon, Radium, and Other Radioactivity in Ground Water. Hydrogeologic Impact and Application to Indoor Airborne Contamination. National Well Water Association Conference, Somerset, N.J., April 7-9, 1987, Proceedings:
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Meteorological influences on soil-gas release: As applied to mineral exploration and earthquake prediction [Master's thesis]:
Golden, Colo., Colorado School of Mines
[Indexed under Rn]

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Field-determination of vertical permeability to air in the unsaturated zone:
U.S. Geol. Survey Profess. Paper 1051, 41 p.
The vertical permeability to air of layered materials in the unsaturated zone may be determined from air pressure data obtained at various depths during a period when air pressure is changing at the land surface....

Weeks, Edwin P., Douglas E. Earp, and Glenn M. Thompson, 1982
Use of atmospheric fluorocarbons F-11 and F-12 to determine the diffusion parameters of the High Plains of Texas:
Water Resources Research, 18(5): 1365-1378

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Radon measurement in uranium prospecting:
[Finland] Comm. Geol. Bull., 188: 23-40

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U.S. Geol. Survey Open-file Rept. 77-82; 139 p.

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Vapour pressure and condensation of radon at low temperatures:
Royal Soc. [London] Proc., A150: 395-410

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The measurement of radioactivity alpha in the air of some places of low Silesia district:
Nukleonika, 6: 801-812
The results of measurements of alpha radioactivity in the air of Low Silesia District are given. The method of measurement and the construction of the apparatus are described.

Westphal, Warren H., and Sylvan Rubin, 1964
Techniques of on-site inspection:
Geophysics, 29(2): 250-258
Geophys. Abs. 210-205:
Radon is continuously produced by decay of naturally occurring uranium in many minerals. It gradually diffuses upward and is exhausted into the atmosphere. It can be detected by collecting soil gas in an ionization chamber or by filtering from the air particulate material which has collected radioactive decay products of the short-lived radon (Budde, 1958). A strong seismic disturbance may modify the rate of diffusion of radon through the ground or change the concentration in surface gas samples. A study of effects of underground explosions on the surface-concentrations and flow of radon (Evans et al., 1962) showed that significant changes did indeed occur in the epicentral area of underground nuclear events. These changes persisted only a few days in relatively undisturbed alluvium, but were measured for a few months in the welded tuff of Rainier Mesa where considerable fracturing occurred. There was no mapping of the normal levels of radon in soil over sizeable areas of the Nevada Test Site, and it is not known if the variations could be interpretable in an on-site inspection.

Weszelszky, J.V., 1927
The exact determination of radium emanation [in German?]:
Physikal. Zeitschrift 28: 757-761
Chem. Abs. (1928) 2708-9:
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Chem. Abs. 101:99869d

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Composition and properties of natural radioactive aerosols. A quantitative expansion of the research of Elster and Geitel [in German]:
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Nucl. Sci. Abs. 17, No. 6, 8419:
The influence of an electric field, acting on the deposition of natural radioactive aerosols, was investigated. At an overall aerosol concentration of 10^4 particles per cm^3 only 3 percent of the Ra-Ar activity exists in an atom-disperse state. 90 percent of the radon decay products are attached on particles with a radius $<10^{-5}$ cm. The size spectrum of natural-occurring radioactive aerosols was calculated. The result is in good agreement with experience.

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Am. Geophys. Union Trans., 37(2): 177-180
Geophys. Abs. 165-299:
The vertical distribution of radon decay products in the lower atmosphere has been measured during airplane flights, using both negative-wire and precipitator methods of sample collection. Data taken by the wire method show a very gradual decrease in activity with height, with considerable activity found to exist at 16,000 ft (MSL). The precipitator results indicate an approximately linear decrease with altitude, with no appreciable activity found in samples collected by this method above about 11,000 ft. Measurements made at four ground stations in the altitude interval 4,620 to 10,297 ft gave similar results. The mean value for the coefficient of eddy diffusion in the atmosphere calculated from the precipitator data was 7 ± 4 m^2/s for the plane flights and 11 ± 7 m^2/s for the ground stations.

Wilkening, Marvin H., 1959

Daily and annual courses of natural atmospheric radioactivity:
Jour. Geophys. Research, 64(5): 521-526
Geophys. Abs. 177-324:
Measurements of the radon-decay products in the atmosphere over a 6 year period have been made with a monitor which precipitates fine airborne particulate matter over a moving metallic tape. A calibration of the apparatus showed that the mean value for radon content at Socorro, New Mexico, is 2.4 aCi/L, with an average diurnal fluctuation of a factor of 3.1 between maximum and minimum. The diurnal variation is attributed to the amount of vertical mixing due to eddy diffusion in the lower atmosphere. The gustiness in air motion near the ground is taken as a measure of the mixing that occurs, and it is measured with a hot-wire anemometer. An annual variation in the atmospheric radioactivity is found which gives values during the fall months that are about twice those during the spring. This variation can also be explained in terms of the mixing that occurs at low levels as judged from mean wind-speed data. Values for the coefficient of vertical diffusion are calculated from measurements of the exhalation rate of radon from the ground and the concentration of radon near ground level as determined from the monitor data. The mean value of the height-independent diffusion coefficient is 6.7E4 cm^2/s. Maximum values of as high as as 55E4 cm^2/s are found in the late afternoon of the month of April. Minimum values of the order of 2.0E4 cm^2/s are found in the early morning hours in the fall months. [See Philip, J.R., 1959, for refutation of this treatment of eddy diffusion in the lower atmosphere. Philip says that the steady-state approximation is not valid.]

Wilkening, Marvin H., 1970
Radon 222 concentrations in the convective patterns of a mountain environment:
Jour. Geophys. Research, 75(9): 1733-1740
Geophys. Abs. 284-343:
Radon-222 concentrations have been measured in a mountain environment to learn more about its distribution and to test its usefulness in the study of certain features of convective cloud systems over a mountain range. When the atmosphere is in a quiescent state, radon concentrations are found to vary from 0.43 pCi/L at 40 m over a basin near the mountain ridge to 4 fCi/L at altitudes of nearly 8 km [above mean sea level], while the distribution over a mountain ridge follows that of potential temperature. Two important mechanisms in the transport of radon from the canyons to higher levels are mountain slope heating and turbulence created by lee waves. A radon excess of 25 percent observed in cumulus humilis clouds formed in the clear air above the mountains appears to have been supplied by updrafts below the cloud. A similar observation is made for cumulus congestus. Full-scale cumulonimbus systems may have an estimated total Rn-222 content of the order of 1.5 Ci in a volume of about 50 km^3.

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Radon-222 from the Island of Hawaii: deep soils are more important than lava fields or volcanoes:
Science, 183: 413-415

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Radon 222 concentrations in the Carlsbad Caverns, *in* International Symposium on Areas of High Natural Radioactivity, Poços de Caldas, Brazil, June 16-20, 1975:
Rio de Janeiro, Academie Brasileria de Ciências, p. 183

Wilkening, Marvin H., 1980
Radon transport processes below the Earth's surface, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:
Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 1, p. 90-103, disc., p. 103-104

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Radon in atmospheric studies: a review, in Vohra, K.G., U.C. Mishra, K.C. Pillai, and S. Sadasivan, eds., Natural Radiation Environment:

New York, John Wiley and Sons, p. 565-574

Wilkening, Marvin, 1985
Radon transport in soil and its relation to indoor radioactivity:
The Science of the Total Environment, 45: 219-226

Wilkening, Marvin H., and William E. Clements, 1975
Radon-222 from the ocean surface:
Jour. Geophys. Research, 80(27): 3828-3830

Wilkening, Marvin H., and John E. Hand, 1960
Radon flux at the earth-air interface:
Jour. Geophys. Research, 65(10): 3367-3370
Geophys. Abs. 183-514:
The radon content of the atmosphere and of the soil gases escaping to the earth's surface has been measured in the vicinity of Socorro, N. Mex., by means of a radon condenser that uses a trap cooled by liquid oxygen. The average radon content of the atmosphere at ground level was found to be 0.24 pCi/L, and radon flux at the earth-air interface to be 90 aCi/cm^2-s. The well-known diurnal variation of atmospheric radon was clearly evident; the radon content built up in the early evening, then rapidly decreased when the inversion was broken in the morning. The radon flux at the earth-air interface, on the other hand, appeared to be relatively constant over a diurnal period. Diffusion theory is used to derive an expression for the radon flux in terms of the concentration of radium in the soil at depth. The measured value is consistent with a radon concentration produced by 1.1 pg radium per g soil, assuming the local soil density to be 1.7 g/cm^3. This value (accuracy about 50 percent) is within the range reported for rock types in the area. [Used D=0.072 cm^2/sec, EP of 7.5% based on Boltwood (1908)]

Wilkening, M.H., M. Kawano, and Carlton Lane, 1966
Radon-daughter ions and their relation to some electrical properties of the atmosphere:
Tellus, 18(2-3): 679-684
Geophys. Abs. 246-390
Radon and its short-lived daughters in the atmosphere form positive ions at the moment of decay, which are shown to fall in the "small ion" category. There are on the average only three of such ions per 100,000 ordinary small ions in the atmosphere. A correlation coefficient of +0.8 is obtained between the radon-daughter ion concentration and total small-ion content over a small-ion concentration range of 100 to more than 1,200 ions per cm^3. An interesting application of the use of radon-daughter ions in the atmosphere is study of the electrical environment of a thunderstorm.

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Air exchange and ^{222}Rn concentrations in the Carlsbad Caverns:
Health Physics, 31: 139-145

Wilkinson, P., and P. J. Dimbylow, 1985
Radon diffusion modelling:
The Science of the Total Environment, 45: 227-232

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Theoretical aspects of the design of a passive radon dosemeter:
The Science of the Total Environment, 45: 433-440

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U.S. Geol. Survey Open-file Rept. 84-0939, p. 708-713.

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World Oil, 144(5): 126-128
Geophys. Abs.169-273:
Radioactive gases that migrate upward from a buried fault may be detected by gamma-ray surveys at the surface.

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Mapping the radon risk of our environment, *in* International Conference on Indoor Air Quality and Climate, 3d, Stockholm, August 20-24, 1984; Vol. 2: Radon, Passive Smoking, Particulates and Housing Epidemiology, Birgitta Berglund, Thomas Lindvall, and Jan Sundell, eds.:
Stockholm, Swedish Council for Building Research, Vol. 2, p. 85-92

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Am. Ind. Hyg. Assoc. J., 22: 409-415

Wilson, W., 1909
On the radio-active products present in the atmosphere:
Philos. Mag., ser. 6, 17: 321-325
[Variation of ionization with pressure.]

Wilson, W., and W. Makower, 1907
Note on the rate of decay of the active deposit from radium:
Philos. Mag., ser. 6, 14: 404-408
[Differential ion chamber arrangement for verifying the fact that different nuclear species were sources of alpha and beta-gamma radiations from radon daughters.]

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Zeitschrift des intern. vereins der Bohrengenieure und Bohrtechniker, Wien 32:57-58
[Radioactivity exploration applied to uranium mining]

Witte, H., 1926
Bestimmung des Radium-Emanationsgehaltes von Erd und Quellengasen in Bad Brambach [Determination of the radium-emanation content of soil and spring gases in Bad Brambach]:
Zeitschrift Geophysik 2: 181-187

Wolfs, F., H. Hofstede, R.J. De Meijer, and L.W. Put, 1984
Radon daughter concentrations in and around dwellings in the northern part of the Netherlands:
Radiation Protection Dosimetry, 7(1-4): 287-290
Chem. Abs. 101:99861v

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Geophys. Research Letters, 1(8): 359-362
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Elsevier Scientific Pub., Co., Amsterdam-Oxford-New York: p. 5-36

Wollenberg, H.A., and K.L. Revzan, 1990
Radium regionalization in California:
Geophys. Research Letters, 17(6): 805-808
[Under the assumption that ^{226}Ra is in equilibrium with ^{238}U in California rocks and soils, comparison of data on the uranium concentration in the rocks and soils with ^{214}Bi γ radiation data from the National Aerial Radiometric Reconnaissance project of the National Uranium Resource Evaluation Program indicated a significant discrepancy in the radium concentration estimates in central California. In three 1°x2° quadrangles, the aeroradiometric radium estimates were higher by as much as a factor of 2 than those obtained by weighting the radium concentrations of rocks according to their areas of exposure. A traverse by a ground-borne γ-ray spectrometer across two strong aeroradiometric anomalies in the San Jose quadrangle failed to confirm the anomalies, perhaps because of atmospheric inversion. Field checking of the aeroradiometric data is urged before using them to predict indoor radon potential.]

Wollenberg, H.A., and A.R. Smith, 1984
Naturally occurring radioelements and terrestrial gamma-ray exposure rates: An assessment based on recent geochemical data:
Berkeley, Calif., Univ. Calif. Lawrence Berkelgy Lab. Rept. LBL-18714, 79 p. [Submitted to Environmental Geology and Water Resources]
A survey of the geochemical literature and unpublished data has resulted in the cataloging and characterization of the concentrations of the naturally occurring radioelements, U, Th, and K and their associated rock types. The purpose of this work is to aid in the planning and interpretation of airborne gamma-radiation environmental surveys of proposed and operating nuclear power reactors and other nuclear energy related sites. A data base of over 2500 entries has been assembled, and formulas relating gamma-ray exposure rates to radioelement concentrations have been applied to these data. The resulting tabulation and histograms illustrate the broad range of radioactivities encompassed by the various rock types. The gamma-ray exposure rates of igneous rocks generally vary with their silica contents, and, with the exception of shale, sedimentary rocks have lower K/U and K/Th ratios than most igneous rocks. By considering together radioelement ratios, relative abundances, and total gamma radioactivities, the general lithology of overflown terranes may be distinguished by airborne multi-spectral gamma surveys. In the course of this investigation an appreciable difference was noted between the overall mean terrestrial gamma-ray exposure rate calculated from rock radioelement concentrations (≈ 8 μR/hr) and the mean exposure rate from field measurements over soil (5.1 μR/hr). This difference may be explained by effects of the differences in density of rock and soil, the moisture content of soil, and the apparent depletion of U in unsaturated near-surface material.

Wollenberg, Harold, Tore Straume, Alan Smith, and Chi-Yu King, 1977
Variations in radon-222 in soil and ground water at the Nevada test site:
Univ. of Calif., Lawrence Berkeley Lab. Rept. LBL-5905; 6 p.
To evaluate their utility as an earthquake predictor, variations in ground water and soil gas were measured following underground explosions of the Nevada Test Site. Rn-222 fluctuations in ground water were observed during aftershocks following the Oroville, California earthquake of August 1, 1975. If such fluctuations are produced by ground shaking, they might be attributed to changes in earth strain prior to the aftershocks. Well waters were periodically sampled and soil-gas Rn-222 monitored prior to and following underground explosions of varying strength. Soil gas Rn-222 contents were measured by the alpha-track method; well water Rn-222 by gamma-ray spectrometry. There was no clearly identifiable correlation between well-water Rn-222 fluctuations and individual underground tests. A prominent variation in soil-gas Rn-222 corresponded to a pair of underground tests in alluvium; there was no apparent correlation between Rn-222 emanation and other explosions. Markedly lower soil-gas Rn-222 contents following the alluvium tests were probably caused by consolidation in response to ground shaking.

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Gas-u. Wasserfach., 99(14): 322-324
Nucl. Sci. Abs. 15:20982

Wright, J.R., and O.F. Smith, 1915
The variation with meteorological conditions of the amount of radium emanation in the atmosphere, in the soil gas, and in the air exhaled from the surface of the ground, at Manila:
Phys. Review, ser. 2, 5(6): 459-482

Wrixon, A.D., L. Brown, K.D. Cliff, C.M.H. Driscoll, B.M.R. Green, and J.C.H. Miles, 1984
Indoor radiation surveys in the U.K.:
Radiation Protection Dosimetry, 7(1-4): 321-325
Chem. Abs. 101:99867b
[Substantial variation was found in indoor exposure, especially that due to radon progeny. Geologic influence was important.]

Wruble, D.T., S.D. Shearer, D.E. Rushing, C.E. Sponagle, 1964
Radioactivity in waters and sediments of the Colorado River Basin, 1950-1963:
Radiological Health Data, 5(11): 557-567

Yagoda, H., 1949
Radioactive measurements with nuclear emulsions:
New York, John Wiley and Sons, Inc., 356 p.

Yaniv, A., and D. Heymann, 1972
Radon emanation from Apollo 11, 12 and 14 fines [abs.], *in* Lunar Science, III:
Lunar Science Inst. Contrib. No. 88: 816-818

Yano, N., 1961
Measurement of natural radioactive dust in the atmosphere by electric precipitator:
[Japan] Papers in Meteorology and Geophysics, 12(3-4): 277-293
Geophys. Abs. 198-286:
An automatic continuous recording system for measurement of natural radioactive dust in the atmosphere is described. The system measures alpha- and beta-rays simultaneously, and sampling time can be adjusted arbitrarily to the half life of radioactive elements. Moreover, it measures radioactive elements with half life as short as that of Po-218. The radon amount may be estimated from the value of the Po-218 provided an equilibrium exists between the isotope and the radon, but since such equilibrium does not exist in the atmosphere the nonequilibrium can be estimated from the decay curve of the alpha ray. Field observatons made in May and June, 1961 in Tokyo and in July, 1961 at Karuizawa show that vertical diffusion is predominant over the diurnal variation of radioactivity and that air temperature and humidity are not direct causes of that variation. Dust particles do not affect the radioactivity.

Yanokura, Minoru, Kimiko Horiuchi, Hiromichi Nakahara, and Yukio Murakami, 1978
Determination of radioactive rare gases by solvent extraction followed by gamma-ray spectrometry:
Chem. Letters, 10: 1131-1134
Chem. Abs. 89:208593r:

Yarborough, Keith A., 1980
Radon- and thoron-produced radiation in National Park Service caves, *in* Natural Radiation Environment III, Gesell, Thomas F., and Wayne M. Lowder, eds.:

Springfield, Va., NTIS, U.S. Dept. Energy Rept. CONF-780422, Vol. 2, p. 1371-1395

Yastrebov, M.T., 1958
Yestestvennaya radioactivnost' zonal'nykh pochv evropeyskoy chasti SSSR [Natural radioactivity of zonal soils of the European part of the USSR]:
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Geophys. Abs. 175-339

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Radonovyye vody obramleniya i krayevykh uchastkov Irkutskogo amfiteatra [Radon-bearing waters of the bordering and marginal regions of the Irkutsk Amphitheater]:
Akad. Nauk SSSR, Sib. Otdel., Geol. Geofiz., (9): 56-61

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Gaithersburg, Md., Natl. Inst. Standards and Technology Rept. NISTIR 89-4106, 62 p.

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Studies on radioactive springs in Japan. IV. Determination of thoron and radon by induced activity [in Japanese]:
Jour. Chem. Soc. Japan (Pure Chem. Sect.), 77(2): 370-375

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A method for determing concentrations of Rn-220 in the field:
Health Physics, 51(3): 343-348

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Use of the emanation method to study processes occurring in heated solids [in Russian]:
Radiokhimiya, 1:336-345, in English translation, U.S. Atomic Energy Commiss. AEC-tr-4554
Nucl. Sci. Abs. 15:16973

Zaborenko, K.B., and O.A. Kapustin, 1978
Calculations of polytherms of emanation using an empirical function [in Russian]: Radiokhimiya, 20(2): 284-289; Soviet Radiochemistry [English transl.], 20(2), 242-

Zaborenko, K.B., T.E. Os'kina, and N.A. Chernova, 1974
Investigation of the diffusion mobility of ^{220}Rn in thorium by the emanation method:
Soviet Radiochemistry [English transl.], 16(5): 614-617 Trans. from Radiokhimiya, 16(5): 625-629
Nucl. Sci. Abs., May 31, 1976, p. 2263:
It was established that there is a correlation between self-diffusion and ^{220}Rn diffusion parameters in the thorium lattice and this made it possible to use the emanation method to find the Tamman temperature $\tau = 950$ K, to separate out energetically nonequivalent temperature sections with different diffusion mobilities, and to determine more accurately the phase transition point of thorium from a face-centered to a body-centered cubic structure (1630 K). By the emanation method it was shown that thorium belongs to the group of metals with anomalously low diffusion parameters in the high temperature phases. By means of the emanation method we obtained the temperature dependence of the diffusion coefficient of ^{220}Rn in a face-centered cubic lattice of thorium with an activation energy of 61± 9 kcal/g-atom for P=0.95 with F=11, which is considerably lower than the activation energy of self-diffusion of thorium. A hypothesis is put forward on the charge of diffusing radon in thorium. It was shown that the change in the surface must be taken into account in the calculation of the diffusion parameters of an inert gas in a solid by the emanation method.

Zaborenko, K.B., R. Tetner, and L.L. Melikhov, 1963

Use of the emenation method in the study of calcium silicate hydrates [in Russian]:
Radiokhimiya, 5(3): 360-369

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A time-dependent method for characterizing the diffusion of ^{222}Rn in concrete:
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Über die Nachlieferung von Radiumemanation aus dem Erdboden [On the supply of radium emanation from the soil]:
Terrestrial Magnetism Atmos. Electricity, 40: 281-294
Geophys. Abs. 81-2972:
The amount of radon given off from the soil was measured by the method of P. Zupancic (1934) with certain improvements. During December 1933 to October 1934, 150 measurements were made at two points in a meadow near Hötting; observations were made alternately at these. The average value is 43.5 aCi/cm^2-s. Considering the fact that very few measurements were made in the autumn, it must be concluded that the annual average is nearly 50 aCi/cm^2-s. This amount of exhalation agrees well with the results of Smyth (Dublin) and Wright and Smith (Manila) who obtained 73 and 20.5 aCi/cm^2-s, respectively. It is interesting to note that P. Zupancic in the garden of the Institute in Innsbruck obtained an average exhalation of 23 aCi/cm^2-s (December-July) that is, about half as much as the author on the meadow in Hötting where the soil was never mixed with fragments of brick, etc. It was found that the meteorological factors governing the exhalation of radon are not the same in different seasons of the year. In winter the influence of snow or ice on the ground prevails. The exhalation increases rapidly when the snow is melting. In spring rather large variations in the amount of exhalation were found corresponding to large differences of temperature, etc. A lawn-covered area gives off less radon than an area of the same soil without lawn. The highest values of exhalation were found in July and August. The relationship of exhalation to different meteorological factors is discussed. Wind decreases the amount of exhalation measured. This may be due to the removal of radon within the collecting vessel by the small rapid changes of barometric pressure during high winds. The daily variation of exhalation was studied and found in good agreement with the curve of P. Zupancic. Simultaneous measurements of the radon-content of open air showed a daily variation similar to that of the exhalation. [Graphs (p. 243) showing meteorological factors, rate of Rn exhalation, and Rn concentration, appear to me (ABT) to show correlation between falling pressure and greater rates of radon exhalation].

Zeldes, H., and A.R. Brosi, 1950
Decontamination of xenon from radon:
Oak Ridge National Lab. Rept. ORNL-793, [Declassified Jan. 5, 1956]
Nucl. Sci. Abs. 10-4322:
The feasibility of rapidly decontaminating liter amounts of Xe from Rn by factors of at least 10^6 using a simple gas chromatography technique has been demonstrated. The separation has been achieved in a single pass through a small synthetic hydroxyapatite column with high recovery. A method is also indicated for quantitatively recovering the Xe in a given sample in decontaminated form.

Zézsi, Zoltán, 1963
Studies on the determination of the radioactive materials content of natural waters [in Hungarian]:
Fiz. Szemle, 13: 298-304
Nucl. Sci. Abs. 18:12378:
....Integrating-pulsed ionization chambers were used for determining the Ra and Rn concentrations in waters....No generally valid laws could be developed....U concentrations of the order of 10 alpha/liter could not be correlated with presence of U-rich ores in the surrounding area.

Zhang, Zhe, 1984

Use of ventilation pressure in controlling radon pollution in uranium mines [in Chinese]:
Youkuangye, 3(1): 56-59, 72
Chem. Abs. 101:99885f

Zielinski, R.A., C.A. Bush, and J.N. Rosholt, 1986
Uranium series disequilibrium in a young surficial uranium deposit, northeastern Washington, U.S.A.:
Applied Geochemistry, 1: 503-511
[This report describes a uranium deposit of such recent age that very little time has elapsed for a buildup of Ra-226. Consequently, the emanation of Rn-222 and its gamma-emitting decay products is very much lower than would be expected from uranium ore.]

Zielinski, Robert A., and James K. Otton, 1989
Geologic controls on uranium in water and surficial sediments, Lake Tahoe area, Nevada [abs.]:
Geol. Soc. America, Abstracts with Programs, 21(6): A146
Anomalously uraniferous water and stream sediments occur in several drainages in the west-central Carson Range, near the eastern shore of Lake Tahoe. Uranium contents of water from 17 streams and springs in the area average $17\pm 14x10^{-9}$ [by weight] compared with a reported regional average of approximately $5x10^{-9}$. Organic-rich valley-fill sediments in an upland fen average $1500x10^{-6}$ (ppm) on a dry weight basis, and sediments in a wet meadow near the lake shore average $800x10^{-6}$. Uranium concentrations as high as several thousand ppm were recorded at some localities. Present or future contamination of local domestic water supplies is the main concern. Factors that contribute to the leachability of uranium from granodiorite bedrock include anomalous average uranium contents ($7.2\pm 4.3x10^{-6}$), extensive fracturing and shearing related to local high-angle normal faulting, and extensive thick covers of permeable granulated bedrock formed by physical weathering. Organic-rich sediments accumulate in response to bedrock topography and along low-gradient sections of streams and delta plains. Controls on the fixation of uranium in the sediments include the concentration of dissolved carbonate and organic-acid complexing agents, the amount and humification of solid organic matter, and local redox conditions. The latter may vary seasonally with water-table fluctuations in wet meadow sediments. In contrast with uranium, decay products such as radium and radon are largely retained in the bedrock. Buildup of decay products in the young surficial sediments is minimal because of the recency of uranium emplacement.

Zielinski, Robert A., and John N. Rosholt, 1978
Uranium in waters and aquifer rocks at the Nevada Test Site, Nye County, Nevada:
U.S. Geol. Survey Jour. Research, 6(4): 489-498

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Angewandte Radioaktivität [Applied radioactivity]:
Berlin, Springer-Verlag: 124 p.
[Application to self-diffusion and solid diffusion, p. 73-74. Reference to Paneth's estimation of surface area of powders and other solids, p. 74 (Paneth, 1948, Jour. de Phys. Chem. 45: 205)]

Zimen, K.E., and P. Mertens, 1971
Nuclear recoil in solids and the knock-out effect:
Zeitschrift Naturforschung, ser. A, 26(4): 773-775

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Zur Emaniermethode. 1. Das thermische Verhalten der Erdalkalicarbonate. 2. Die Möglichkeit der Bestimmung von Diffusionskonstanten und von Korngrössen aus dem Emaniervermögen [On emanating method. 1. The heat content of the alkaline earth carbonates. 2. The feasibility of measurement of diffusion and of grain size by the emanating power]:
Zeitschrift Electrochemie, 44: 590-594

Zimens, K.E., 1942
Die praktische Durchführung von EV-Messungen [The practical accomplishment of EP (Emanating power) measurements)]:
Zeitschrift physikal. Chemie (A), 191: 1-53

Zimens, K.E., 1942
Oberflächenbestimmungen und Diffusionsmessungen mittels radioaktiver Edelgase. II. Die Auswertung von EV-messungen [Surface area determinations and diffusion measurements by means of radioactive inert gases. II. The utilization of EP (emanating power) measurements]:
Zeitschrift physikal. Chemie (A),191: 95-128

Zimens, K.E., 1943
Surface area determinations and diffusion measurements by means of radioactive inert gases. Part III. The process of radioactive emission from disperse systems. Conclusions pertaining to the evaluation of EP (emanating power) measurements and the interpretation of results [in German]:
Zeitschrift physikal. Chemie, 192(1/2): 1-55, in English translation, East Orange, New Jersey, Assoc. Tech. Services, no. 43G7G, 38 p. [1955]

Zor'kin, L.M., A.N. Sultankhodzhayev, V.G. Tyminskiy, A.I. Spiridonov, and S.U. Latipov, 1974
Interrelation between helium and radon in stratal waters [in Russian]:
Uzbek. Geol. Zhur, 6: 40-44; Soviet Hydrology [English transl.], 1974, 6: 405-409

Zupancic, P. Reginald, 1934
Messungen der Exhalation von Radiumemanation aus dem Erdboden [Measurements of the exhalation of radium emanation from the ground]:
Terrestrial Magnetism Atmos. Electricity, 39(1): 33-46
Geophys. Abs. 66-2138:
The amount of radon given off from the soil was measured by a new method. An area of 2800 cm^2 of lawn as covered by a zinc cylinder filled with air completely free of radon at the beginning of each experiment. Twelve or 24 hours later the air from the cylinder after thorough mixing was introduced in an ionization-vessel calibrated in curies and measured in the usual way. From this measurement the amount of radon exhaled from the soil per square centimeter and second can be calculated. The average amount of this exhalation of radon as observed in the period December 1932 to July 1933, was 23 aCi/cm^2-s. Within the period mentioned the minimum of exhalation was found in January and the maximum in June. The exhalation during the day is about 1.5 times as much as in the night hours. The maximum value of exhalation during the observation period of about six months exceeds the minimum by about 100 times. Exhalation of radon is mainly governed by the temperature of the soil, increase of this temperature causing an increase of exhalation of radon. Freezing of the soil decreases the amount of exhalation almost to zero. Atmospheric pressure and its variations seem to be of secondary importance.