


# From Calamity Mesa to Boyertown, PA:

## Risk, Radon, and Regulation in Cold War America

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In the boom uranium mining industry in the American Southwest during the post-war 1940s and 1950s, the first casualty was occupational safety. That lapse engendered a harsh legacy: roughly fifty percent of the miners developed lung cancer over the next ten to twenty years, an outcome to which their excessive exposure to the decay products of radon gas emitted by the uranium ore may have contributed. Several decades later, in the mid-1980s, radon returned to the realm of public health and public policy when the high levels of radon gas found in private homes in Pennsylvania and New Jersey set off an indoor radon scare and compelled the Environmental Protection Agency (EPA) to set radon standards for residential environments. This paper employs these two radon exposure crises as a heuristic for examining the multiplicity of social, economic, political, and cultural concerns that are mobilized around a scientifically-informed regulatory decision.

## Radon Risks in Colorado Mines and Pennsylvania Suburban Homes

The inside of a uranium mine on the Colorado Plateau in the 1950s might seem literally and figuratively very far from a basement of a suburban home in 1980s Pennsylvania, and yet these two contexts became linked in dual crises involving radon, risk, and regulation. These related events at the beginning and the end of the Cold War illustrate connections between conceptions of risk and danger, contested scientific data, risk communication, and changing expectations of governance. In the first case, the uranium mining industry in the American Southwest during the postwar 1940s and 1950s, exposures to the decay products of radon gas emitted by uranium ore were implicated in the subsequent pulmonary pathologies of underground miners. In the second case, which occurred in the mid-1980s, radon made another appearance in the realm of public health and public policy when private homes in Pennsylvania and New Jersey were found to have high levels of radon gas. The Environmental Protection Agency (EPA) set standards for residential environments in response to this radon crisis. Significantly, EPA used epidemiological studies of uranium miners, including those who worked in American mines during the 1940s, 1950s, and 1960s and who were tracked over several decades by a U.S. Public Health Service study, as a fundamental data set. In this paper, these two radon exposure crises, linked by a shared radioactive element and a set of scientific data, are employed as a heuristic for examining the multiplicity and complexity of social, economic, political, and cultural concerns that are mobilized around a scientifically-informed regulatory decision.

## Elephant Country: U.S. Uranium Mining, 1945-1960

In the uranium mining industry in the American Southwest during the postwar 1940s and 1950s, the highest priority for all involved was to fuel U.S. nuclear ambitions as rapidly as possible. To increase domestic production, on March 1, 1951, the Atomic Energy Commission (AEC) announced a bonus of $3.50 a pound for up to 10 000 pounds of uranium from a new deposit — in other words, a maximum of $35 000 (a substantial increase over the previously offered bonus of $10 000, which was never collected by anyone) — but the ore had to be delivered and the bonus collected by March 1, 1954. The critical considerations were speed, efficiency, and volume. There were plenty of legitimate reasons for the AEC, which was the sole buyer of uranium in the U.S., to be concerned about national security and the state of the nuclear arsenal in 1951 and therefore to create economic incentives for rapid uranium mining: the Soviet's acquisition of the atomic bomb in 1949, the implications of the Korean War as a possible sign of more active aggression from the Soviet Union, and concerns about similar proxy warfare in Africa that might end U.S. uranium acquisition from the Belgian Congo. Between 1951 and 1957, the AEC paid the highest average prices for uranium that it would ever offer: between $10.00 and $12.30 per pound [22], [23].

This imperative for rapid production was understood in the field. Interviewed in 1970, George Morehouse, a field geologist who worked for the AEC from 1951 to 1958, said, "We must remember this was in 1951. Our instructions as a government employee at that time were to help promote the production of uranium any way we could. We had to assist the miner and the operation even to the point where we would help them plan their drilling operation. Several projects were designed where even the government would come in and drill for the small producer ahead of their working areas, to supply them with a four to six month reserve of ore … But our object was to assist those in industry to produce more ore. It was in very short supply at that time. That was my job" [16].

Ernie Gordon, a mining engineer with the AEC, recalled that, "The main thing was the country's need for more uranium. We had to be self sufficient. At least the powers that be in Washington felt we had to be self sufficient. Or at least as much so as possible. And if not in this country at least in the free world. Most known uranium in the States existed on the Colorado Plateau and therefore the effort was made, the strongest effort was made there. When you're looking for elephants go to elephant country" [9].

The uranium industry boom that was cultivated by the AEC

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in the Four Corners area was fast-paced and disorderly. Many inexperienced miners came into the area. Small claims — especially in Colorado — were worked out quickly by two or three men who then moved on, and there was very little meaningful oversight of safety conditions in the mines [1], [19], [21], [23]. In the early 1950s, these unregulated conditions and the rapid retrieval of ore benefited not only the AEC and U.S. national security interests, but also, from a financial standpoint, the miners themselves. But even when the states put in place a patchwork of regulations in the mid-1950s, safety measures to protect against occupational exposures to radon and its byproducts — including installing mine ventilation systems, making sure that those ventilation systems were in fact in use during working hours, gaining the cooperation of the miners to keep working areas of the mines ventilated, limiting working hours in the mines, and requiring respirators — were expensive (and in the case of some of the small mines, prohibitively so) and, perhaps even more importantly, time consuming both to put into place and to police.

Despite of a lack of scientific consensus on the specific hazards of radon and radon daughter exposure, the Public Health Service (PHS) and the Southwestern state departments of health believed that radon levels in the mines were a serious concern [4], [19], [21], [22]. It was generally known that the process of blasting and digging for uranium ore released appreciable amounts of radioactive radon-222 gas, a product of the radioactive decay of radium-226. William Bale, a radiobiologist who worked for the AEC's Division of Biology and Medicine, confirmed in an internal AEC memo in 1951 that radon's first four radioactive daughter products, the most damaging of which are polonium-218 and polonium-214, are the greatest source of radon's threat [3]. These radon daughters, either attached to particulate matter or moisture in the mine or unattached and diffused through the air, are breathed in or ingested by miners, and are retained in the lung where they emit alpha radiation. A few steps down the decay chain is radioactive lead-210, an element with a half-life of twenty-two years. Lead-210 builds up in the soft tissues and ultimately lodges in the skeletal system and the bone marrow where it begins the process of decay to lead-206, a stable isotope. The damage to lung tissue comes primarily from these internalized alpha-emitters in the bones and lungs, although uranium miners are also exposed to gamma radiation.

In the summers of 1950 and 1951, at a time when the American Conference of Government Industrial Hygienists[1] suggested a maximum allowable radon concentration of ten picocuries per liter (pC/l) of air, samples of radon gas collected by the PHS from around fifty mines showed a median concentration of 3100 (pC/l), and the highest measured concentration was 110 000 (pC/l). Correspondingly high levels of radon daughters were found in these mines at the times these samples were taken [12].

In a letter from January 1951, Duncan Holaday, a senior sanitary engineer for the Industrial Hygiene Division of the PHS, wrote to the Director of the Division of Industrial Hygiene of the Colorado Board of Health: "With the knowledge at hand, it is impossible to select a safe concentration of radon, but this situation cannot be allowed to continue until we have enough information to select a maximum allowable concentration for radon" [13]. In other words, even if scientific work could not point to a precise, demonstrably "safe" standard, Holaday felt that these levels were not within the realm of acceptability and that waiting until it was clearer where the upper limit of exposure could be reasonably set would cost at least some miners their lives.

The problem that Holaday and his colleagues were facing included all the usual elements we see in matters to be decided by regulatory science: there was a lack of scientific consensus and a dearth of specifically applicable data, time was a problem both from the point of view of bureaucratic action and human health, and political and cultural factors weighed heavily in the direction of sacrificing occupational safety.

In the particular case of radiation safety in uranium mines, the values and priorities on which the regulatory ethos was based — represented primarily by PHS officials, mining safety engineers, and state health and mining experts — were so different from those underlying the hard-rock mining ethos that the collision of the two created difficulty, even incommensurability, in communicating about risk and danger. For example:

- While the establishment risk culture conceptualized health problems with long time horizons, uranium miners were generally more focused on immediate rewards, particularly financial ones, and more immediate and visible dangers, like mining accidents.
- While the expert risk culture took a conservative (in the literal sense) view of human health and life, the miners assumed danger was part of an occupational environment and that each worker was responsible for his or her own fate.
- While the PHS and the upper level management at the larger mining companies agreed that reliable authority came from expert sources and that occupational hazards were in need

[1]The American Conference of Government Industrial Hygienists was not a regulatory body, so their maximum allowable concentration was merely a recommendation given without benefit of the enforcement muscle that would have been required to influence actual practice or conditions in the field.

of expert and/or scientific assessment, the miners were frequently suspicious of expertise and expert attempts to control behavior, working conditions, and health outcomes.

Although both groups were aware of danger and risk, miners and small mine operators tended to focus on palpable hazards or danger, while the experts tended to prioritize probabilistic, long-term risks.[2]

As mentioned above, the states involved set regulations for radiation in mines in the mid-1950s, but enforcement came later and varied greatly in its frequency and effectiveness. But even in the best case, the typical mine was inspected by state agencies once or twice a year.[3] So in practice, the attitudes of the miners themselves were quite important because their cooperation was necessary to keep the mines properly ventilated during all hours of operation. In the absence of frequent inspections, and until the miners could be convinced to focus as much on radiation hazards as they did on other dangers in the mine, radiation safety would continue to be an issue, regardless of regulations and standards.

[2]This analysis is based on readings of a large collection of primary documents, including but not limited to oral histories conducted with uranium miners, PHS publications and internal documents, Bureau of Mines reports, and AEC mine inspection reports. The extended argument and evidence can be found in the author's forthcoming dissertation.

[3]There are 147 boxes of Bureau of Mines inspection reports for these states during this time period archived in the National Archives and Records Administration (NARA), Rocky Mountain Region in Denver, CO (National Record Group 70, Records of the Bureau of Mines). The author looked closely at around 200 individual reports on uranium mines in various localities and in various years during these decades and made a cursory survey of about 200 others in the course of her research, enough to ascertain that the volume of these materials is largely a factor of the sheer number of different kinds of mines operating in the Southwest rather than an indication that any individual mine was inspected that frequently. On average, mines were inspected by the agency once or twice a year.

Although the radon and radon daughters levels in the uranium mines — on average — dropped as time went by and awareness of the problem grew among state officials and miners alike [4], [21], [25], the federal government did not establish a standard until 1970, when the Bureau of Mines established "one Working Level (WL)," or twelve working level months per year, as the federal exposure limit for underground mines. The Working Level was a unit developed by the PHS in 1957 for documenting exposure to radon daughters and, for our purposes, is approximately 100 picoCuries per liter (pC/l).[4] By the time the federal standard was set, however, the uranium industry as a whole was in a trough. Between the late 1960s and 1972, the price for uranium ore hovered between $6 and $8 a pound, a considerable drop from the boom prices of the 1950s [24]. With the cost of finding uranium ore estimated at $2 per pound, a figure that excluded all production costs, falling prices made uranium mining and production in the United States less and less economically viable [24]. As a result, the new regulations affected fewer miners.

Throughout the 1950s, 1960s, and early 1970s, radiation safety in American uranium mining was pursued through a complicated universe of tangling, intermeshing, and changing contingencies: the limitations of multiple state and federal government agencies, incomplete and inconclusive scientific and medical evidence, the culture and priorities of the mining population, and the national security demands of the Cold War. The federal standard was as much a product of these issues as any of the previous state regulations and expert debates. Public Health Service physician Victor Archer commented on the 1 WL standard at the time it was established in 1970: "This 1 WL, which is presently considered a safe level for uranium miners, I don't really think it's a safe level, but I think it is a level at which the lung cancer produced is tolerable by our society" [2]. Through this remark, Archer gestured both toward the idea that there was no threshold that would ensure complete safety and the more complex notion that "1 WL" was, in effect, a flattened symbol that referenced a whole constellation of political, cultural, sociological, and economic concerns yet at the same time remained "silent" about them. By co-opting scientific authority and the language of safety, this standard gained the guise of objectivity, even though it continued to be freighted with subjective considerations. As those considerations changed, so did the standard.

[4]In an industrial context, radon gas is measured in units called "working levels." One working level is a concentration of radon decay products that releases 1.3 million electron volts per liter of air. At equilibrium, one working level is approximately 100 pC of radon gas per liter of air. The measure of worker exposure is usually reported in "working level months." One working level month means 170 hours of exposure to one working level, reflective of one average month of work with miners on the clock about 42.5 hours a week.

To return to the 1950s, the question of which agency or agencies (and at what level—state or federal) would be responsible for radiation safety in the mines — some of which were privately operated and others of which operated under AEC leases — was batted around between the AEC, the state and federal Bureaus of Mines, the U.S. Public Health Service, and the state Departments of Health. Meanwhile, a systematic, ongoing epidemiological study of the uranium miners began in earnest in 1954. Conducted by the PHS in cooperation with the state health departments of Utah, New Mexico, Arizona, and Colorado and headed by Senior Sanitary Engineer Duncan Holaday, this controversial study tracked around 3500 uranium miners who had agreed to at least one physical examination between 1950 and 1960 [27].

Because radiation-induced lung cancer typically has a ten to twenty year latency between exposure and appearance of the pathology, the first uranium miner deaths from pulmonary malignancies occurred in this cohort in the late 1950s. By 1973, 144 of the Colorado Plateau miners in the Public Health Study had died of lung cancer [14]. Victor Archer, who remained one of the study's key researchers through the 1970s and 1980s, reported that by 1990, around 600 miners had died of lung cancer that that 600 more were expected to die within the next decade. To date, over 4700 miners or their survivors have been compensated under the Radiation Exposure Compensation Act (RECA) for lung cancer and other disabling pulmonary pathologies [20].[5]

## *A Citizen's Guide to Radon:* Indoor Radon and EPA, 1985-1991

When the EPA was faced with setting standards for indoor radon in the 1980s, it relied heavily on the PHS uranium miner study data on mortality and its link to radon exposure. But with the passage of three decades, the political, social, and risk contexts had changed: the environmental movement and a constellation of related concerns both reflected and suggested a new conceptualization of the regulatory state; chronic risk had become an increasingly central concern; risk assessment was an accepted, if embattled, tool of regulatory agencies; and the locus of concern about radon had moved from the mine to the home.

The indoor radon issue became newly prominent in the national media in January 1985 [15]. The Pennsylvania Department of Energy Resources evacuated Stanley Watras and his family after discovering extremely elevated levels — 2700 pC/l — of radon gas in their Boyertown, PA, home. Watras, a senior construction engineer at the Limerick Generating Station, a nuclear power plant near Pottstown, PA, had requested the sampling because he had inexplicably and repeatedly set off the radiation detectors at his workplace in December 1984 — before entering the plant — leading him to suspect that the contamination source was his own home [26]. By early July, the Watras family had returned to their house after the completion of a $32 000 radon remediation project funded by the Philadelphia Electric Company [6], [26]. In the meantime, the Watras case had become something of a cause célèbre in the national media, and therefore among Environmental Protection Agency and Department of Energy officials who dealt with radon research and policy, politicians and activists who concerned themselves with issues of indoor air pollution, and scientists who were studying the effects of radon exposure on human populations [6], [10].

The decay products of radon were known carcinogens, but before 1985, residential radon policy in the United States almost exclusively concerned problems actively, if sometimes unwittingly, *created* by human beings, like houses built over uranium or phosphate tailings, or buildings that used uranium mining waste in their actual materials [6]. Until the Watras incident, no one had measured such high levels of naturally-occurring radon in a residence in the United States, and the indoor residential radon problem was frequently presented as though it was relatively new, an unwanted and possibly dangerous side effect of the more energy efficient construction and retrofitting of houses that began in the 1970s. Those concerned with indoor air pollution often emphasized the efficiency/radon link, despite considerable uncertainty about its validity [18].

In early 1985, the combination of increasing concern about indoor air quality in general and the publicity surrounding the Watras case in particular put pressure on state and federal government agencies to respond with a coherent statement or set of standards that could guide the homeowner with regard to radon [15]. Furthermore, the Reagan administration highlighted residential radon as a politically convenient environmental problem: it did not involve regulating industry or manufacturing, and the financial onus for remediation was on the homeowner. But the fact that radon had always existed and was emanating from the ground itself and collecting in private residences posed particular challenges in managing and communicating its dangers. These fell into the purview of the EPA.

Problematically, while high exposures to radon gas, like those sustained by uranium miners in the American Southwest in the 1940s and 1950s, were at this point known to be a causal factor in excess lung cancers and chronic pulmonary pathologies, there was no scientific consensus in 1985 about the risks of low-level radon exposures in a domestic environment, a circumstance that exposed any radon guideline or standard to controversy.

Although the arena of greatest uncertainty had moved from higher to lower level exposures, this situation roughly paralleled the sort of scientific uncertainty faced in the early 1950s regarding radon in the uranium mines, a circumstance which at that time became part of the justification for slow and incoherent regulation. In the case of indoor radon, however, the response to this conundrum was markedly different. What *was* the same was the complexity of the non-scientific contingencies and considerations that were mobilized by this question — although of course they were different this time — and the

[5]For more on the particular difficulties Native American uranium miners faced in getting compensation, see [8]. Eichstaedt's work discusses uranium mining specifically as it was experienced by Native Americans, especially Navajo. For various reasons that Eichstaedt details, Native American miners typically occupied an especially vulnerable position within the industry.

tendency of critics to attack government agency decisions using naïve assumptions about science and the transfer of scientific knowledge.

In 1985, the most comprehensive scientific report on the biological effects of low-level radon exposure was *Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States*, by the National Council on Radiation Protection and Measurement (NCRP). This study looked closely at both experimental animal studies and epidemiological studies of four groups of underground miners, including the PHS cohort from the United States, and cohorts from Canada, Czechoslovakia, and Sweden. In its summary assessment of the failures of the available mining studies, the report was clear about the limitations of the data. "All of the studies reported so far suffer from defects," the committee wrote. "Primarily, exposure conditions are not well known and in some instances the follow-up time for miners is too short" [17]. There were also concerns about how accurately one could extrapolate from a homogenous group of workers to a diverse population, and from a mine environment to other environments. Nonetheless, the epidemiological studies of miners indicated that excess lung cancers occurred at cumulative exposure levels of 100 working level months (WLM) and above [17].

While there were uncertainties, radon was unusual among known carcinogens because human epidemiological data existed from those uranium miner studies (whereas with most carcinogenic substances the best data available came from experimental animal studies), and because there was a confirmed relationship between radon decay product exposures at relatively high levels and lung cancer. Although this was highly suggestive, there were still many unanswered questions about radon's dangers in a residential environment, especially where lower-level exposures (under 60 WLM cumulative lifetime exposure) were concerned [17]. As the NCRP noted, scientific work remained to be done on the validity of extrapolating from higher exposures to lower, from underground mines to other environments, and from a population of adult men to a population including men, women, and children of all ages.

But the Watras incident publicized the fact that there were houses in the United States — although no one knew how many or had developed a reliable protocol for identifying them — where the radon levels were high enough to raise the occupants' risk of lung cancer. To a greater degree than was the case three or four decades earlier, many groups of Americans expected guidance from the government about (and often regulation of) environmental hazards. EPA felt political pressure to suggest without delay guidelines that would protect homeowners in a similar situation, but it was also dealing with a hazard that was generally understood to pose some risk in any, even the smallest, amount. (The relative public apathy that EPA and the PHS encountered in the following years were not anticipated [11], [26]. On the contrary, the agencies were concerned initially about the possibility of public hysteria and panic.)

By August 1986, EPA had produced two brochures that dealt exclusively with radon: *Radon Reduction Methods: A Homeowners Guide* and *A Citizen's Guide to Radon: What It Is and What to Do About It.* The latter had an initial run of over a million copies, the largest of any government statement on radon [6]. Both publications recommended testing for radon levels in the home and then, if necessary, installing a radon remediation system, the most common of which was a vent pipe system and a fan, which pulled radon from beneath the house and vented it to the outdoors [28], [29]. Contemporaneously with the publication of *A Citizen's Guide to Radon*, EPA made an official announcement that set four pC/L as the upper acceptable residential radon limit and estimated that 8 million homes in the United States had radon levels in excess of this level.

Criticism of EPA's indoor radon standard came swiftly from two major and completely opposed camps, each with its own agenda: the first — composed primarily of scientists and officials from other government agencies — argued that EPA had set a ridiculously low standard for radon based on inconclusive scientific evidence and was overreacting to a threat that was at most minor; the second — scientists as well as representatives of environmental groups and radon remediation companies — argued that *any* exposure to radiation was harmful and that since radon was a "known carcinogen," EPA should have set the standard lower and was therefore being neglectful and recklessly endangering the lives of unwitting American citizens [5], [6], [7]. On the whole, however, there were more voices that piped up to criticize EPA for being overly cautious — something of an irony in this American radon narrative in which the consistent charge had historically been that government regulation was far too lax.

By the late 1980s, public tolerance for risks from radiation was perceived to be very low. Deaths from accident or pathology increasingly had to be accounted for, traced to a cause, and — if humanly possible — mitigated against. Consequently, public health and environmental officials were expected to set, in a timely fashion, a standard based on uncertain data. Importantly, the affected group was one with some political and social clout — middle-class, suburban property owners.

The EPA was expected both to defend its standard and to communicate it to the American home-owning public in a way that would move them to action, a project that proved challenging. To return for a moment to Victor Archer and his observation, EPA's four picocurie standard shared with its older cousin the 1 WL the characteristic of saying less about "safety" than about what level of lung cancer is tolerable by our society and in whose lungs. By this time, however, multiple changes had occurred in the way risk was conceptualized and perceived, changes for which the professionalization of risk assessment and its increasing use by government agencies was a signpost.

## Social, Economic, and Political Concerns Mobilize to Affect Policy

These two linked radon exposure crises serve as a useful heuristic for examining the kinds of social, economic, political, and cultural concerns that are mobilized around a scientifically-informed regulatory decision. At the heart of both questions was the radon problem itself. The ambiguous danger posed by this naturally-occurring and weakly-radioactive element in two politically-charged contexts — the uranium mine and the suburban basement — created two complex regulatory problems for which there were no obvious and uncontroversial solutions and in which multiple actors had a stake. Although a more extended treatment could unpack these narratives in greater detail, even this brief examination of these two cases indicates that a range of extra-scientific concerns during this period had a significant impact on radon policy — both the standards themselves and their implementation and enforcement — in the United States. More broadly, the arc of these events is suggestive of changes in the level and character of public concern about radiation risks, of shifts in the nature and the reach of governance, and of developments in the ongoing and controversial effort to quantify risk in a meaningful way.

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## References

[1] M.A. Amundson, *Yellowcake Towns: Uranium Mining Communities in the American West.* Boulder, CO: Univ. Press of Colorado, 2002.

[2] V. Archer, Taped interview conducted by G. Brolin, Uranium Industry Project, California State University, Fullerton Center for Oral and Public History, Fullerton, CA, Aug. 4, 1970.

[3] W.F. Bale, *Measurements of Air-Borne Radioactivity in a Colorado Plateau Mine*, AEC Internal Memo, Nuclear Testing Archive, Nevada Site Office, Department of Energy, Las Vegas, NV, document accession number: 0727676, July 17, 1961.

[4] H. Ball, *Cancer Factories: America's Tragic Quest for Uranium Self-Sufficiency.* Westport, CT: Greenwood, 1993.

[5] M.W. Browne, "Scientist says low radon levels may be harmless," *New York Times*, section 2, p. 7, Sept. 28, 1988.

[6] L.A. Cole, *Element of Risk: The Politics of Radon*, Washington, DC: American Association for the Advancement of Science Press, 1993.

[7] E. Eckholm, "Radon: The threat is real, but scientists argue over its severity," *New York Times*, sect. 3, p. 7, Sept. 2, 1986.

[8] P.H. Eichstaedt, *If You Poison Us: Uranium and Native Americans.* Santa Fe, NM: Red Crane Books, 1994.

[9] E. Gordon, interview conducted by R. Gibbs and G. Brolin, Uranium Industry Project, California State University, Fullerton, Center for Oral and Public History, Fullerton, CA, July 31, 1970.

[10] W.R. Greer, "Radioactive gas alters lives of Pennsylvanians," *New York Times*, sect. 1, p. 10, Oct. 28, 1985.

[11] M. deCourcy Hinds, "Radon: Making the public pay attention," *New York Times*, sect. 1, p. 56, Sept. 24, 1988.

[12] D.A. Holaday *et al., Investigation of Radon and Radon Decay Products in the Uranium Mines of the Colorado Plateau*, Federal Security Agency, Public Health Service, Division of Occupational Health, internal rep., Nuclear Testing Archive, Nevada Site Office, Dept. of Energy, Las Vegas, NV, document accession no. 0723955, 1952.

[13] D.A. Holaday, Letter to J. Jacoe, Jan. 30, 1951, Papers of Stewart Udall, Special Collections, University of Arizona, Tucson, AZ (AZ 372, Box 238, Folder 9).

[14] M. Ivins, "Uranium mines in West leave deadly legacy," *New York Times*, p. 1, May 20, 1979.

[15] A. Mazur, "Putting radon on the public's risk agenda," *Science, Technology, and Human Values*, vol. 12, pp. 86–93, Summ./Aut. 1987.

[16] G.E. Morehouse and J.L. Chapman, interview by R. Gibbs, Uranium Industry Project, California State University Fullerton, Center for Oral and Public History, Fullerton, CA, July 31, 1970.

[17] National Council on Radiation Protection and Measurements, *Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States*, NCRP, rep. no. 78, Bethesda, MD, May 31, 1984.

[18] A.V. Nero, Jr., "Controlling indoor air pollution," *Scientific American,* vol. 258, pp. 42–48, May 1988.

[19] R.N. Proctor, *Cancer Wars: How Politics Shapes What We Know and Don't Know About Cancer.* New York, NY: Basic, 1995.

[20] *Radiation Exposure Compensation Act, Claims to Date Summary*; http://www.usdoj.gov/civil/omp/omi/Tre_SysClaimsToDateSum.pdf, accessed Feb. 4, 2008.

[21] R.C. Ringholz, *Uranium Frenzy: Boom and Bust on the Colorado Plateau*. New York, NY: Norton, 1989.

[21] S.I. Schwartz, Ed., *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940.* Washington, DC: Brookings Institution Press, 1998.

[23] G.L. Shumway, *A History of the Uranium Industry on the Colorado Plateau*, Ph.D. diss., University of Southern California, 1970.

[24] G. Smith, "Uranium: Bad times," *New York Times*, p. F1, F9, Jan 20, 1972.

[25] Summary Analysis of Hearings, U.S. Congress, Subcommittee on Research, Development, and Radiation, Joint Committee on Atomic Energy, *Radiation Exposure of Uranium Miners*, 90th Congress, 1st session, Dec. 1967.

[26] U.S. Congress, House, Subcommittee on Natural Resources, Agricultural Research and Environment of the Committee on Science and Technology, *Hearing on Radon and Indoor Air Pollution*, 99th Congress, 1st session, Oct. 10, 1985.

[27] U.S. Department of Health, Education, and Welfare, *Governors' Conference on Health Hazards in Uranium Mines: A Summary Report*, Public Health Service Publication 843, Washington, DC, 1961.

[28] U.S. Environmental Protection Agency, Office of Air and Radiation. U.S. Department of Health and Human Services, Centers for Disease Control, *A Citizen's Guide to Radon: What It Is and What to Do About It*, Aug. 1986.

[29] U.S. Environmental Protection Agency, Office of Air and Radiation. U.S. Department of Health and Human Services, Centers for Disease Control, *Radon Reduction Methods: A Homeowner's Guide*, Aug. 1986.

[30] U.S. Bureau of Mines, Radiation Protection in Uranium Mines (film), 1960; http://www.archive.org/details/Radon_in_mines.