The History of Uranium Mining and the Navajo People

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From World War II until 1971, the government was the sole purchaser of uranium ore in the United States. Uranium mining occurred mostly in the southwestern United States and drew many Native Americans and others into work in the mines and mills. Despite a long and well-developed understanding, based on the European experience earlier in the century, that uranium mining led to high rates of lung cancer, few protections were provided for US miners before 1962 and their adoption after that time was slow and incomplete. The resulting high rates of illness among miners led in 1990 to passage of the Radiation Exposure Compensation Act.

Above right: Navajo miners near Cove, Ariz, in 1952. Courtesy of the Navajo Nation Museum, Window Rock, Ariz (NG6-52).

IN 1990, THE US CONGRESS passed the Radiation Exposure Compensation Act (RECA). This act acknowledged responsibility for the historical mistreatment of uranium miners by the US government, the sole purchaser of uranium from 1948 to 1971,[1–3] and made provision for financial compensation to miners with diseases that could be related to their mining experience. Ten years later, in June 2000, the US Congress passed and the president signed legislation amending the original law to correct for what were widely perceived as areas of unfairness in the original legislation.[4]

In this report, we tell briefly the history of US uranium mining leading to the RECA. We leave the post-1990 experience to another report. The 100-year legacy of deaths from uranium mining spanning the European and the US experiences, the 30-year struggle to obtain reparations, the controversy following passage of the RECA, as well as the recent debate over amending the RECA, all raise critical questions about how to protect workers, how to compensate those who become ill, and the tradeoff between national security and the environmental health of workers and communities. Our lens for examining this history is the experience of the Navajo People. We choose this approach for several reasons: we are more familiar with this experience than that of White and Hispanic miners; environmental justice encourages a look at the environmental experience of minority communities[5,6]; minority miners are among the least-advantaged populations with respect to workplace safety[7]; and, perhaps most importantly, Navajo uranium activists themselves have been at the forefront of advocating for compensation and justice, and we are fortunate to be able to draw directly upon their knowledge and experience.[1,8]

THE EARLY EUROPEAN EXPERIENCE

Before the US nuclear program, uranium-bearing ore had been mined for centuries in Schneeberg (Germany) and Jachimov (Czechoslovakia) for metals and the manufacture of uranium dyes. An association, long observed, between these mining activities and a lung disease, then called *Bergkrankheit*, was first reported in detail in 1879.[9–12] The investigators reported that 75% of all deaths among miners were due to this disease. Later follow-up[10] reduced this extraordinary estimate by about a third, provided detailed histological descriptions of the cancers, and also discussed a high prevalence of nonmalignant lung disease. An imprecise retrospective estimate suggests that these miners were exposed to roughly 30 to 150 working levels (see "Measuring Radon in the Mines" below) while they were mining.[12] In 1926, clinical evaluation defined the histopathology of the lung cancer in miners.[11] By 1932, Germany and Czechoslovakia had designated cancer in these miners as a compensable occupational disease.[2]

THE MINING BOOM IN THE UNITED STATES

After its initial dependence on foreign sources, the US Atomic Energy Commission (AEC) announced in 1948 that it would guarantee a price for and purchase all uranium ore that was mined in the United States. This initiated a mining "boom" on the Colorado Plateau in New Mexico,

Utah, Colorado, and Arizona that replaced a more limited mining industry centered first on radium and then vanadium, which are found in the same easy-to-mine, soft sandstone ore.[12,13] The US government remained, by law, the sole purchaser of uranium in the United States until 1971, but private companies operated the mines.[14] Purchases of uranium by the AEC dropped in the late 1960s when the US government decided it had acquired enough. Commercial purchases rose, however, to roughly replace AEC purchases by 1971 and remained strong into the 1980s.[15,16]

By 1958, there were 7500 reports of uranium finds in the United States with over 7 000 000 tons of ore identified.[1] During the peak in the mid-1950s, there were about 750 mines in operation.[17] The Navajo Reservation, situated on one corner of the uranium-mining belt, was swept into the boom.[1] Uranium was discovered in Cove, Ariz, and then elsewhere in the reservation.[18] Eventually, 4 centers of mining and milling operated on reservation land near Shiprock, NM (including the Carrizo Mountains, near Cove), in Monument Valley, Utah, and at Church Rock, NM, and Kayenta, Ariz (see Figure 1). In addition, many Navajo People traveled to mines off the reservation seeking work; they often moved their families with them and lived in mine camps (T. Benally, oral communication, 1999). Uranium production in the northern and western Carrizo Mountains of the Navajo Nation, begun in 1948, peaked in the years 1955 and 1956 and declined to zero again by 1967.[3,19] More than 1000 abandoned uranium mines shafts are now estimated to lie on Navajo land (P. Charley, oral communication, 1995).

THE NAVAJO PEOPLE AT THE START OF URANIUM MINING

Navajo men gravitated to work in the mines, which were near their homes and about the only job available. For many Navajo families, uranium mining represented a first contact with the broader US wage economy. These Navajo families were thankful at the time that they had employment.[20,21]

Miners were paid minimum wage or less. Copies of pay stubs provided by a Navajo miner from 1949 show an hourly wage of $0.81 to $1.00 (D. Crank, written communication, 1998). The jobs that they held included blasters, timber men (building the wooden supports in the mines), muckers (who dug the blasted rock), transporters, and millers. Navajo miners report that the bosses were usually White and that the foremen did not spend as much time in the mines as did the Navajo laborers. Mines ranged from pickax and wheelbarrow to heavy equipment. Navajo miners reported working as little as a few months to 10 years or more in uranium mines.[1,8]

When uranium mining began, the predominant modes of transportation for Navajo People were by horse and wagon or by foot on the reservation, the Navajo language had no word for radiation, few Navajo People spoke English, and few had formal education. Thus, the Navajo population was isolated from the general flow of knowledge about radiation and its hazards by geography, language, and literacy level.[1,8] Today, the miners and their families say that they had no idea that there were long-term health hazards associated with uranium mining. Virtually all of the Navajo miners report that they were not educated about the hazards of uranium mining and were not provided with protective equipment or ventilation.[22]

Today, many Navajo People note that the Treaty of 1868 be-

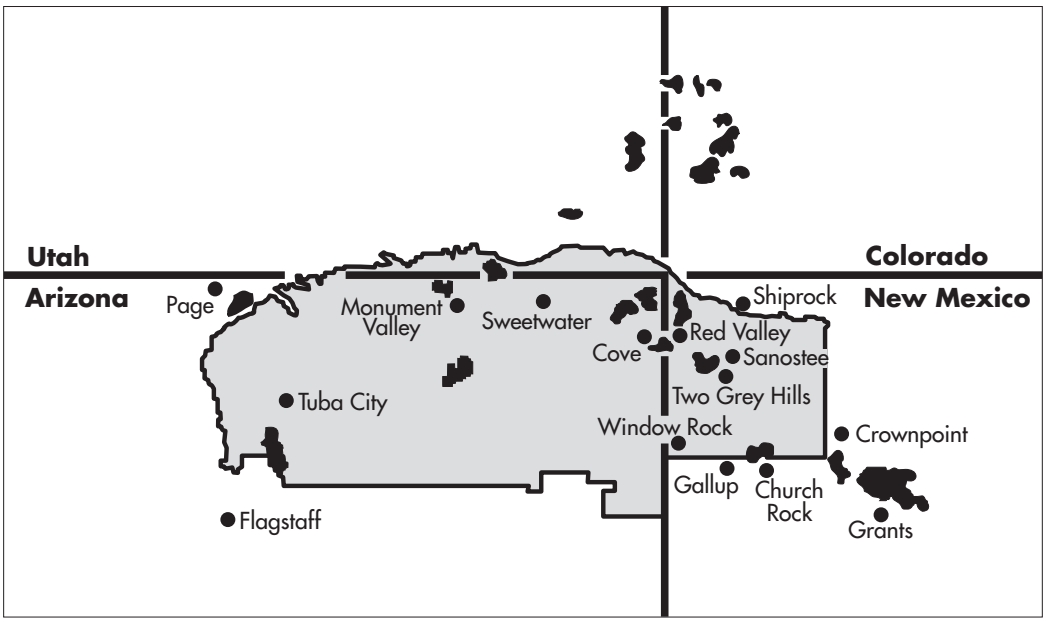
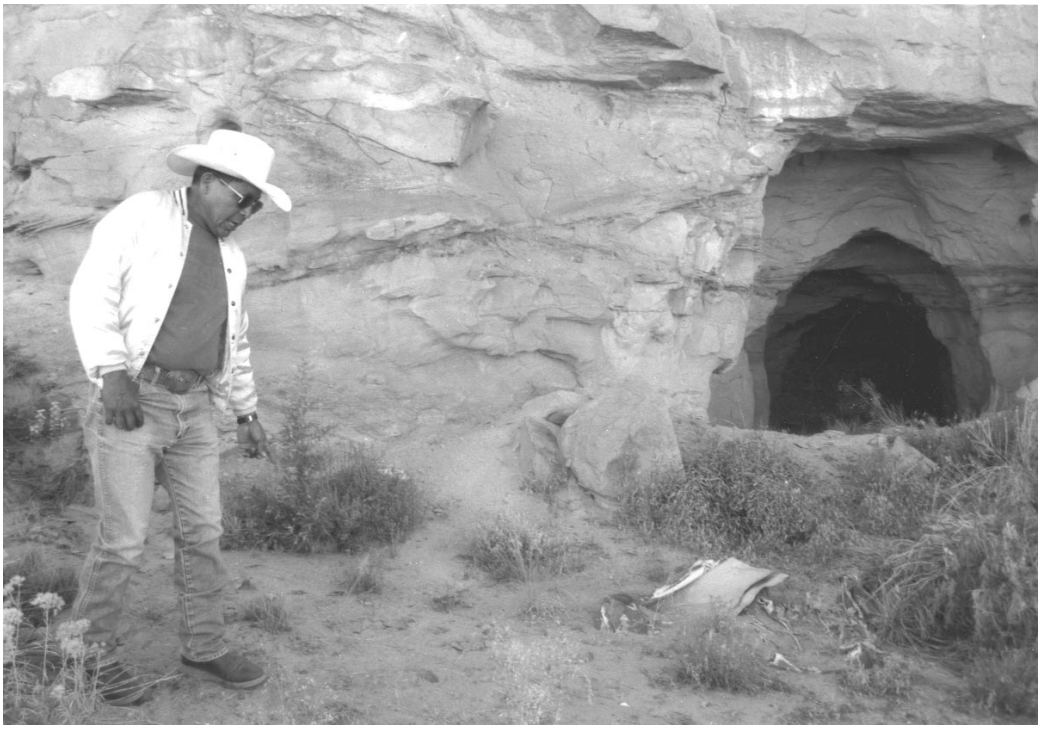


FIGURE 1—Map of the Navajo Nation, with key towns and uranium mining areas marked in black.



Former miner Joe Ray Harvey at an abandoned uranium mine near Cove, Ariz, 1995.

tween the Navajo Tribe and the US government assigned the Bureau of Indian Affairs to care for Navajo economic, educational, and health services. They view this as a special trust relationship that carried particular responsibilities, including safeguarding the health of the Navajo People.[8] However, government-provided health care for Navajo People has been fraught with problems. From the 19th century through the 1940s it focused more on eliminating the role of native healers, or medicine men, than on curing widespread infectious disease. Thus, uranium mining–related disease arose in a context of other public health failures.[23]

THE CAUSAL AGENT FOR LUNG CANCER

Although it was unknown to the Navajo People, by the late 1930s there was no scientific doubt that uranium mining was associated with high rates of lung cancer.[24] The debate was about the causal agent. A ventilation project begun in Jachimov, Czechoslovakia, by the Ministry of Public Works in 1930 provides clear evidence that policymakers at the time thought that radon was hazardous. This effort was reported to have reduced radon from unventilated levels of 320 to 8950 pCi/L (0.32–8.9 working levels) to below 350 pCi/L (0.35 working levels) by use of ventilation.[25]

A 1942 review by Wilhelm Hueper[26] suggested that radiation was the causal agent. A 1944 review by Egon Lorenz,[11] however, concluded that radiation could not be the causal agent since x-rays giving doses comparable to those from the radon gas did not have the same effect in animals. This was a correct but—as was shown later—incomplete analysis. Scientific opinion was, in the mid-1940s, not clear and somewhat divided as to the agent responsible for elevated lung cancer rates among uranium miners.

Work by William Bale and John Harley, based on what became Harley's 1952 PhD thesis,[27,28] finally resolved the question of how radon could cause such high rates of lung cancer. Bale reported first in 1951 in an influential memorandum[29] that it was the radon daughter isotopes that contributed the bulk of the radiation to the lung. Unlike radon gas, the radon progeny or daughters can be retained in the lung adjacent to sensitive cells for periods of time as long as their radioactive half-lives, delivering high doses of radiation. This explanation, coincident with the expansion of uranium mining in the United States, was a singular achievement since the causal links of few other toxins were understood at that time.

MEASURING RADON IN THE MINES

Early measurements were of the concentration of radon in the air in mines—typically measured in picocuries per liter. Harley's work focused on the radon daughters and led to the definition of a working level as the measure of the energy released by radon daughters. This provides a physical measure that is closely related to the mechanism for biological damage. One working level is a concentration of radon decay products that will release 1.3 million electron volts per liter of air. Depending on ventilation and the amount of dust, a particular concentration of radon in the air can correspond to different working levels.[17,30] At equilibrium (expected with poor ventilation), 1 working level corresponds to 100 pCi/L in air.

The commonly reported measure of exposure (which depends on both the amount of radioactivity and duration) is "working level months." One working level month is equal to spending 170 hours (1 month of working hours) exposed to 1 working level.

THE PUBLIC HEALTH SERVICE STUDY

In 1950, the US Public Health Service (PHS) began a study of uranium miners in the Colorado Plateau, through concerns that the European experience implied that radon in US mines would cause lung cancer.[2,31–34] The study measured both radon in mines and health outcomes (i.e., lung cancer). It failed to inform miners of the risks being studied[2] and initially focused its attention on White miners, although the first full report did give mortality rates for non-White populations as well.[32] In 1984, Jonathan Samet and collaborators made a full analysis of the Navajo population.[35]

Victor Archer headed the PHS medical team. He has been quoted as saying, "We did not want to rock the boat. We had to take the position that we were neutral scientists trying to find out what the facts were, that we were not going to make any public announcements until the results of our scientific study were completed."[36(p46)] There were some pamphlets given to miners in 1959 that mentioned a risk of lung cancer, but they minimized the level of concern,[2] and it is unclear how widely these materials were disseminated or what was the literacy and English comprehension of the miners who received them.

The PHS protocol is ethically troubling. The centerpiece of the Nuremberg Code, promulgated in 1947 and widely publicized, was provision of informed consent to persons enrolled in research studies. The PHS study clearly violated a central tenet of the standard of care of the time as well as the standards of today. Notably, the uranium miner study also took place after the start of the better-known Tuskegee Study of Black men with syphilis, which was also run by the PHS. However, the Tuskegee study did not come to public view until 1972.[37]

OTHER RELATED DISEASES

New knowledge about other health hazards of mining also emerged. Silicosis and its causes became a prominent concern after large numbers of deaths, disproportionately among Black miners, at Hawks Nest, WVa.[7] The hazards of coal mining and "black lung disease" became a national concern in the mid-1960s.[38,39] Serious respiratory disease became viewed generally as a plausible hazard of mining. Furthermore, there were clear observations in the early European experience and in the PHS study that other respiratory illnesses, including silicosis, tuberculosis, pneumonia, and emphysema, were causing deaths in uranium miners at rates approaching those from lung cancer. For the Navajo cohort in the PHS study, the death rate from nonmalignant respiratory disease was essentially the same as the death rate from lung cancer.[40]

THE RESPONSE TO THE HAZARDS OF URANIUM MINING

Some US officials and scientists advocated ventilation requirements in US mines as a proactive, preventative measure during the 1950s, on the basis of their knowledge of European experience. Duncan Holaday, an industrial hygienist with the PHS, has generally been recognized as the most prominent advocate for ventilation. He led the effort to obtain measurements of radon in the mines, and he used the data to argue forcefully within the government that ventilation would be effective and was feasible.[41] His arguments achieved only limited success, as there was government resistance to requiring ventilation and his views were not made public at the time.[42]

The AEC was an obstacle. In the late 1940s, controversy erupted in the New York Operations Office over the hazards from beryllium and uranium mining. The AEC wrote worker health requirements in contracts with companies that handled beryllium. After conflicting recommendations from staff, it chose not to establish such requirements for uranium. It claimed to lack legal authority, but it did not explain the legal difference between uranium and beryllium. The AEC did not lack knowledge: records of a January 25, 1951, internal meeting of AEC and PHS staff reveal that, on the basis of early measurements, they believed that radon was present in levels that would cause cancer and that ventilation could abate the hazard. Public acknowledgment of this problem was apparently squelched. For instance, Hueper, the scientist who wrote the 1942 review and who was then at the National Cancer Institute, was forbidden to speak in public about his concerns about the health hazard of radon in uranium mines. It is reported that he was even forbidden to

travel west of the Mississippi, lest he say too much to the wrong people.[2]

EDUCATION AND STATE EFFORTS AT VENTILATION

Rather than create federal requirements, federal officials tried to encourage states and mine owners to improve conditions. They conducted several public forums for mine operators and state government officials about the hazards of uranium mining, including an early forum in 1951. A 1957 report by Holaday and colleagues[41] laid out an approach for controlling radon in mines. They proposed a tentative threshold exposure value of 1 working level, but they stopped short of making a definitive recommendation because of what, in hindsight, looks like an exaggerated concern about uncertainties in interpreting radon measurements. The report showed that radon concentrations in most of the 157 mines tested were above levels that required ventilation and went on to discuss mechanical ventilation (natural ventilation was found to be insufficient). The public education efforts culminated with a presentation to the Governor's Conference (of southwestern states) in 1960. The states did adopt guidelines for radon at levels equivalent to 1 working level, and in 1958 New Mexico adopted a policy clearing all areas that exceeded 10 working levels. There was, however, limited enforcement of state regulations in the period before federal regulations appeared at the end of the 1960s.[1,12]

RADON LEVELS IN THE MINES

Depending on which measurements are considered and what credence they are given, one can draw different conclusions about the effect of state regulation. Estimates of average exposures to miners over the 1960s show only a moderate decline that can be attributed to the gradual installation of better ventilation.[17(annex E1)] However, levels reported as percentage of measurements in excess of 10 working levels declined very gradually from 1950 to 1960, fell precipitously from 1960 to 1962, and then continued a gradual decline into the 1970s.[14] The sharp decline from 1960 to 1962 corresponds to the institution of government inspection and the choice by one state, New Mexico, to close mines that exceeded the 10-working-level limit. It is likely that reductions in radon levels were mostly confined to larger mines that were inspected more often and that were run by companies with more resources to install ventilation. Further, it does not necessarily follow from this record that ventilation was always used when inspectors were absent, and for very many mines, there are no records at all.

Levels of radon measured in mines on the Navajo Reservation were lower. This was attributed to the mines being smaller and having better natural ventilation.[12] It is not clear to us, however, whether the inspection rates and installation of ventilation that led to progressive declines in radon levels elsewhere were mirrored in Navajo mines.

A STATISTICALLY SIGNIFICANT ASSOCIATION

By 1959, the PHS study of US uranium miners had shown that there was a statistically significant association between uranium mining and lung cancer for White miners, a result that was reported in the literature in 1962.[31] The reason for excluding minority miners (who were included in the field study) from the analysis was apparently a scientific desire to report on a homogeneous population. The study sought mathematical precision of the association, rather than the more general fact that uranium mining led to exposure to radon that caused lung cancer.

Later in the 1960s, it became apparent that smoking was a modifier of risk and that most of the lung cancers in White miners were among smokers. This did not change the strong association with radon exposures, but it added a complication that coincided with the US Surgeon General's 1964 report on smoking and health,[43,44] marking the key turning point in public awareness of the hazards of smoking.

NAVAJO PEOPLE AND SMOKING

A 1968 survey of cigarette use by southwestern Native Americans[45] reported that only 4.4% of male Native Americans smoked more than 1 pack per day, while some 33.3% of the male non-Indian population smoked more than 1 pack per day. Today, only 4% of Navajo men over age 60 report being current smokers.[46] In a study of Navajo uranium miners, 58.9% were reported to be never smokers. Ex-smokers and light smokers (<1 pack per day) made up 37% of these Navajo uranium miners.[40]

Tobacco is used for ceremonial and cultural purposes on a regular but limited basis by much of the Navajo population. Conse-

quently, records in which Navajo People represent themselves as "smokers" may refer to such usage. The amount of tobacco smoked would likely be far less than 1 pack-year (packs smoked per day times years of smoking) over a lifetime for most Navajos who smoked only for this purpose (T. Benally, oral communication, July 1998), although we know of no quantification of ceremonial smoking.

NAVAJO PEOPLE BEGIN TO ORGANIZE

In the early 1960s, after about 10 years of mining, the first cases of lung cancer began appearing in Navajo uranium miners. The affected Navajo communities looked for the cause of this heretofore rare to nonexistent disease. In the 1960s, Navajo widows came together and talked about their husband's deaths and how they had died. The process that they initiated, which included steep learning curves about science, politics, and organizing, would culminate some 30 years later in the passage of the RECA.[1,8,47] To visit the homes of the widows in Cove, Ariz, today, to see the lack of telephones, the wood stoves, and the remoteness of the community, is to marvel at the fact that their complaint ever reached Washington, DC. To our knowledge, their story is still largely oral and unrecorded in any detail. However, Peter Eichstaedt[1] relates that Harry Tome, of Red Valley, a tribal council member and later employee of the minerals department of the tribe, was one of those who noticed the problem in the early 1960s. Tome later became a leading advocate on the issue.

FEDERAL REGULATIONS ARE ESTABLISHED

National regulations for uranium mining were first debated in the US Congress in 1966 before the Labor Subcommittee of the Senate Committee on Labor and Public Welfare, but little attention was initially paid to the problem.[1] A story by J.V. Reistrup in the *Washington Post* started the newspaper coverage, which registered a sharp peak in 1967.[1,13,14] This preceded the more dramatic uprising of unionized coal miners in Appalachia that climaxed in 1968 and 1969. The coal miner strike, involving tens of thousands of miners, received prominent national coverage and was not subject to the national security issues that cloaked uranium mining. The coal strike led to the passage of both regulations on conditions in the mines and a compensation system for disabled coal miners.[38]

The connection between the labor unions and the Navajo miners was complex. Anthony Mazzocchi, formerly of the Oil Chemical and Atomic Workers International, argued before Congress that the research studies should include results for Navajo miners, not just for Whites, but Navajo People did not testify directly in this first congressional debate.[1] While some Navajo miners were members of unions if they worked in the many off-reservation mines, there was apparently no unionization of miners on the reservation itself (A. Mazzocchi, oral communication, March 2001). None of the miners that we spoke to recalled unions operating in reservation mines, and one of our colleagues recalls being fired for suggesting that the workers needed a union (T. Benally, oral communication, 2000). The Navajo Tribal Council had even outlawed union activity on the reservation in 1958, and there were only 300 union members on the reservation by 1971.[48] Thus, while the unions were a source of information and advocacy, they were not involved in the organizing of the Navajo People, which proceeded primarily on the reservation at the community level.

The standard that was finally set for radon in mines, 0.3 working levels, was established on January 1, 1969.[1] It is essentially the standard that applies today, reformulated as 4 working level months per year. Mazzocchi noted in 1977 that violations of the existing standard occurred even after advance notice was given of pending inspections.[49] In 1987, the National Institute of Occupational Safety and Health (NIOSH) proposed lowering the standard to 1 working level month per year, a recommendation that has yet to be implemented. NIOSH asserted that the more stringent standard was both necessary to protect health and feasible with available technology.[33]

NAVAJO ADVOCACY IN THE 1970S AND 1980S

Tome, the early Navajo advocate, prompted the *Albuquerque Tribune* to run a cover story in 1973 that led to the first legislation in the US Congress aimed at compensation, designed to extend black lung benefits to uranium miners. The bill never passed, despite Tome's dogged lobbying efforts over a number of years. In 1978, Tome began working with Stuart Udall, secretary of the interior under President John F. Kennedy. Ultimately, Udall filed 2 lawsuits in 1979 seeking damages for uranium

miners. One was aimed at the mining companies; the other was filed against the US Department of Energy (formerly the AEC).[1]

LEGAL CHALLENGES IN THE 1970S AND 1980S

The case against the mining companies was thrown out of court in 1980 on the basis of the mining companies' argument that workers were covered by workers' compensation, which precludes lawsuits against the workers' employer for occupational health and safety injuries or illness.[50,51] Ironically, many miners with illnesses were either denied claims under the state workers' compensation systems or never filed claims.[13] Mining companies have largely avoided liability to date; a rare exception was a court ruling against a uranium mill in Colorado in which members of the community, rather than workers, sued for damages.[52]

The suit filed by Udall in federal district court in Arizona, *Begay v United States*, seemed a more promising route to gain compensation for uranium miners.[53] Udall hoped that the trust relationship between the Navajo Tribe and the United States might overcome the judicial bias in favor of federal immunity from lawsuits. However, the court ruled in 1984 that the US government was immune.[54] The decision cited national security as the government's interest. The court did indicate that federal legislation would be necessary and that the situation "cries for redress."[2(p577)] The Advisory Committee on Human Radiation Experiments later concluded that "there is no obvious national security or other ground on which to justify the continued exposure of miners to the radon hazard."[2(p577)]

CONGRESSIONAL HEARINGS ON COMPENSATION

In 1979, congressional hearings were held in Grants, NM. A large number of White and Navajo uranium miners testified, offering heartfelt and tragic stories. Leading the Navajo delegation was Tome. The legislation under consideration in 1979 was still modeled after black lung benefits; that is, a small monthly stipend.[1] In 1980, congressional hearings considered creating an exemption to make the United States liable for damages to uranium miners. The proposed eligibility criterion for miners was 1 year of work in the mines.[55] The hearings the following year focused on creating exemptions for populations living downwind from the atomic bomb tests.[56] In 1982, Navajo People showed up in force at a Senate hearing in Salt Lake City, Utah. The Navajo miners were last on the agenda, and Senator Orrin Hatch observed that the hearing was about fallout victims and that workers' compensation would be taken up later. The Navajo miners were allowed to testify anyway, and Leo Redhouse, Sam Jones, Harold Tso, Harry Tome, and Perry and Harris Charley again gave highly personal accounts of Navajo suffering.[57]

DOSE–RESPONSE RELATIONSHIPS

While organizing progressed and hearings were held in the 1980s, new information about miners, radon, and lung cancer appeared. An important secondary literature reviewed and combined studies to define more precisely the dose–response relationship. This continuing effort is conducted by the Committee on the Biological Effects of Ionizing Radiation (BEIR) of the National Academy of Sciences/Institute of Medicine. The BEIR IV report, published in 1988,[30] combined 4 studies of miners: the Colorado Plateau study and studies from iron miners at Malberget in Sweden, uranium miners in Ontario, and uranium miners at the Eldorado Mine in Beaverlodge, Saskatchewan. It determined that risk depended on time since exposure and current age. The BEIR VI report, published in 1999,[17] reviewed 11 studies of miners including the 4 previous ones. It determined that risk also depended on the intensity or duration of exposure and it created 2 models, an "exposure–age–duration" model and an "exposure–age–concentration" model, to reflect this dependence. Both BEIR IV and BEIR VI contained substantial discussion of the joint effects of radon exposure and smoking.

Smoking is a complicating factor in determining the risk of lung cancer from radon exposure among uranium miners. In the Colorado Plateau study cohort, about 84% of miners were either current or ex-smokers.[58] By the mid-1960s, it had been recognized that most of the uranium miners who developed lung cancer were smokers. BEIR IV[30] suggested that smoking and radon exposure result in a greater than additive, but less than multiplicative, risk of lung cancer. This conclusion was strengthened by the analysis in BEIR VI,[17] which included direct evidence of increased cancer incidence among never smokers. A recent case–control study of Navajo uranium miners reports that adjustment for smoking status did not change the strong re-

lationship between lung cancer and mining uranium.[59]

As a result of smoking rates below those of the general population, lung cancer rates have remained comparatively low in Native American populations in the Southwest. Samet et al. found that age-adjusted annual mortality rates for lung cancer among New Mexico Native Americans (which included many Navajo People) rose from 5.3 per 100 000 in 1958 to 1962 to 10.8 per 100 000 in 1978 to 1982.[60] By comparison, the rate for the White population rose from 38.5 per 100 000 to 70.4 per 100 000 during the same period.[60]

The rate for the Navajo People may in fact be even lower than for Native Americans in general. For 1991 to 1993, the age-adjusted lung cancer mortality rate for Native Americans living in the Indian Health Service–designated "Navajo area" was 4.8 per 100 000 (A. Handler, Indian Health Service, written communication, November 24, 1997).

HEALTH CONSEQUENCES AND THE DOSE–RESPONSE MODEL

It has been estimated that 500 to 600 of the thousands of uranium miners who worked between 1950 and 1990 died of lung cancer, that most of these deaths were associated with radon exposure, and that a similar number would die after 1990.[42] A 2000 study of Navajo miners reports that there were 94 lung cancer deaths documented from 1969 to 1993, that 63 of these individuals were former uranium miners, and that uranium miners had a relative risk of 28.6 compared with controls.[59] Frank Gilliland et al. point out that this appears to be a "unique example of exposure in a single occupation accounting for the majority of lung cancers in an entire population."[59(p278)]

THE FINAL PUSH TO PASS THE RECA

In the 1980s, Perry Charley (who with his father had testified at the Senate hearing in Utah) and Phil Harrison, both of whose fathers became ill from working in the mines, carried on with organizing. Charley assisted Udall with *Begay v United States* before helping to start the Red Mesa/Mexican Water Four Corners Uranium Committee in 1985. Harrison was elected president of the Uranium Radiation Victims Committee, based in Red Valley and Cove, in 1982.[47] Organizing, combined with the status of the Navajo People as a sovereign nation, provided the foundation for passage of the RECA, which finally occurred in 1990.[1] An estimated 10 000 workers were employed in uranium mining, and about a quarter of them were Navajo. About 40% (3975) have applied for compensation as of March 21, 2001.[61]

CONCLUSIONS

This history details how the federal government deliberately avoided dealing with a health disaster among Navajo uranium miners, even though uranium mining was considered very much a federal matter. For up to 2 decades after the harmful effects of uranium mining were known, protective safeguards were not implemented. The position of scientists in the government who were knowledgeable and who often argued for protection was seriously compromised. We are hardly the first to conclude that these delays represent a gross violation of the rights of the miners.[1–3,8,20] Federal regula-

Navajo miners near Cove, Ariz, dump tailings over the side of a mesa in 1952. Photograph by Milton "Jack" Snow, courtesy of the Navajo Nation Museum, Window Rock, Ariz (NG6-67).

tions for ventilation came nearly 20 years after the need was clear, and only when many miners were obviously sick and dying. The revisions proposed by NIOSH have still not been implemented. Earlier efforts at educating mine owners and state officials and notification of miners were half-hearted at best. Compensation for those who were sick or died came only another 20 years later, after hundreds had died. Even when compensation was belatedly provided, it was given in a grudging and capricious fashion. The Navajo People suffered along with White miners from these failures. In addition, they were even more poorly informed and hampered from protecting themselves. Their position with respect to the rules and implementation of the RECA was even worse.

The one bright spot in this history is the view it affords of communities and labor organizations that identified problems, organized themselves to learn about them, and formed alliances to address them. Government bureaucracies and scientific communities should learn to listen to them and respond appropriately and in a timely fashion. ■

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D. Brugge, who took the lead role in writing the manuscript, wrote first drafts and made most editing changes. He was particularly responsible for the Navajo history. R. Goble read, commented on, and edited earlier drafts. He wrote the first drafts of and was primarily responsible for the health physics.

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References

1. Eichstaedt PH. *If You Poison Us.* Sante Fe, NM: Red Crane Books; 1994.

2. Advisory Committee on Human Radiation Experiments. *Final Report: Advisory Committee on Human Radiation Experiments.* Washington, DC: US Government Printing Office; October 1995.

3. Moure-Eraso R. Observational studies as human experimentation: the uranium mining experience in the Navajo Nation (1947–66). *New Solutions.* 1999;9:163–178.

4. Woolf J. Bill may finally compensate sick Navajo uranium workers. *Salt Lake Tribune.* July 25, 2000:A1.

5. Institute of Medicine. *Toward Environmental Justice: Research, Education and Health Policy Needs.* Washington, DC: National Academy Press; 1999.

6. Bullard RD, ed. *Unequal Protection: Environmental Justice and Communities of Color.* San Francisco, Calif: Sierra Club Books; 1994.

7. Cherniack M. *The Hawk's Nest Incident: America's Worst Industrial Disaster.* New Haven, Conn: Yale University Press; 1986.

8. Brugge DM, Benally T, Harrison P, Austin-Garrison M, Fasthorse-Begay L. *Memories Come to Us in the Rain and the Wind: Oral Histories and Photographs of Navajo Uranium Miners and Their Families.* Boston, Mass: Tufts School of Medicine; 1997.

9. Härting FH, Hesse W. Der Lungenkrebs, die Bergkrankheit in den Schneeberger Gruben. *Vierteljahrsschrift für gerichtliche Medicin und öffentliches Sanitätswesen.* 1879;30: 296–308; 31:102–129, 313–337.

10. Arnstein A. Über den sogenannten "Schneeberger Lungenkrebs." *Verhandlung der Deutschen Pathologischen Gesellschaft.* 1913;16:332–342.

11. Lorenz E. Radioactivity and lung cancer; a critical review of lung cancer in the miners of Schneeberg and Joachimsthal. *J Natl Cancer Inst.* 1944; 5:1–15.

12. Holaday DA. History of the exposure of miners to radon. *Health Physics.* 1969;16:547–552.

13. Ringholtz RC. *Uranium Frenzy: Boom and Bust on the Colorado Plateau.* New York, NY: WW Norton & Co; 1989.

14. Pearson J. Hazard visibility and occupational health problem solving: the case of the uranium industry. *J Community Health.* 1980;6:136–147.

15. New Mexico Energy Institute. *Uranium Industry in New Mexico.* Albuquerque: Public Finance Research Program, University of New Mexico Energy Resources Board; November 1976. Report 76–100B.

16. *United States Mining and Milling Industry: A Comprehensive Review. A Report to the Congress From the President of the United States.* Washington, DC: US Dept of Energy; May 1984.

17. Committee on the Biological Effects of Ionizing Radiation. *Health Effects of Exposure to Radon (BEIR VI).* Washington, DC: National Academy Press; 1999.

18. Brugge D, Benally T, Harrison P, et al. The Navajo Uranium Miner Oral History and Photography Project. In: J. Piper, ed. *Dine Baa Hane Bi Naaltsoos: Collected Papers From the Seventh Through the Tenth Navajo Studies Conferences.* Window Rock, Ariz: Navajo Nation Historic Preservation Department; 1999:85–96.

19. Stern J. *Archival and Ethnographic Investigations Relating to Ten Priority II and Eight Priority III Project Areas Associated With the Navajo Abandoned Mine Lands Reclamation Department's Sweetwater Program Area.* Window Rock, Ariz: Navajo Abandoned Mine Lands Reclamation Department; September 9, 1992. Publication NNAD 92–021.

20. Brugge D, Benally T. Navajo Indian voices and faces testify to the legacy of uranium mining. *Cultural Survival Q.* 1998;22:16–19.

21. Brugge D, Benally T, Yazzie E. Into the nuclear age as a hand mucker:

interview with Navajo George Tutt, former uranium miner. *New Solutions.* 1999;9:195–206.

22. Dawson S. Navajo uranium workers and the effects of occupational illness: a case study. *Hum Organ.* 1992; 51:389–397.

23. Tennert RA, Litchford M. *White Man's Medicine: Government Doctors and the Navajo, 1863–1955.* Albuquerque: University of New Mexico Press; 1998.

24. Peller S. Lung cancer among mine workers in Joachimsthal. *Hum Biol.* 1939;11:130–143.

25. Behounek F. 1970. History of the exposure of miners to radon. *Health Physics.* 1970;19:56–7.

26. Hueper WC. *Occupational Tumors and Allied Diseases.* Springfield, Ill: Charles C. Thomas; 1942.

27. Harley JH. Sampling and measurement of airborne daughter products of radon [reprinted in *Health Physics.* 1980; 38:1067]. *Nucleonics.* 1953;11:12–15.

28. Harley JH. *Sampling and Measurement of Airborne Daughter Products of Radon.* [doctoral dissertation]. Troy, NY: Rensselaer Polytechnic Institute; 1952.

29. Bale WF. Memorandum to the files, March 14, 1951: hazards associated with radon and thoron. *Health Physics.* 1980;38:1062–1066.

30. Committee on the Biological Effects of Ionizing Radiation. *Health Risks of Radon and Other Internally Deposited Alpha-Emitters (BEIR IV).* Washington, DC; National Academy Press; 1988.

31. Archer VE, Magnuson HJ, Holaday DA, Lawrence PA. Hazards to health in uranium mining and milling. *J Occup Med.* 1962;4;55–60.

32. Lundin FE, Wagoner JK, Archer VE. *Radon Daughter Exposure and Respiratory Cancer Quantitative and Temporal Aspects.* Washington, DC: US Dept of Health, Education and Welfare; 1971. NIOSH-NIEHS Joint Monograph No. 1.

33. *Criteria for a Recommended Standard for Occupational Exposure to Radon Progeny in Underground Mines.* Washington, DC: National Institute of Occupational Safety and Health; 1987. DHHS (NIOSH) publication 88–101.

34. Donaldson AW. The epidemiology of lung cancer among uranium miners. *Health Physics.* 1969;16:563–569.

35. Samet JM, Kurtvirt DM, Waxweiler RJ, Key CR. Uranium mining and lung cancer in Navajo men. *N Engl J Med.* 1984;310:1481–1484.

36. Ball H. *Cancer Factories: America's Tragic Quest for Uranium Self-Sufficiency.* Westport, Conn: Greenwood Press; 1993.

37. Rothman DJ. *Strangers at the Bedside: A History of How Law and Bioethics Transformed Medical Decision Making.* New York, NY: Basic Books; 1991.

38. Smith BE. *Digging Our Own Graves: Coal Miners and the Struggle Over Black Lung Disease.* Philadelphia, Pa: Temple University Press; 1987.

39. Rosner D, Markowitz G. *Deadly Dust: Silicosis and the Politics of Occupational Disease in Twentieth-Century America.* Princeton, NJ: Princeton University Press; 1991.

40. Roscoe RJ, Deddens JA, Salvan A, Schnorr TM. Mortality among Navajo uranium miners. *Am J Public Health.* 1995;85:535–540.

41. Holaday DA, Rushing DE, Woolrich PF, Kusnetz HL, Bale WF. *Control of Radon and Daughters in Uranium Mines and Calculations on Biological Effects.* Washington, DC: Public Health Service; 1957. Public Health Service publication 494.

42. *Hearings Before the Senate Committee on Labor and Human Resources,* 101 Cong, 2nd Sess (1990) (testimony of V.E. Archer).

43. *Report of the Advisory Committee to the Surgeon General of the Public Health Service: Smoking and Health.* Washington, DC: Public Health Service; 1964. PHS Publication 1103.

44. Parascandola M. Cigarettes and the US Public Health Service in the 1950s. *Am J Public Health.* 2001;91:196–205.

45. Sievers ML. Cigarette and alcohol usage by southwestern American Indians. *Am J Public Health.* 1968;58: 71–82.

46. Mendlein JM, Freedman DS, Peter DG, et al. Risk factors for coronary hearth disease among Navajo Indians: findings from the Navajo Health and Nutrition Survey. *J Nutr.* 1997;127 (suppl 10):2099S–2105S.

47. Dawson SE, Perry PH, Harrison P. Advocacy and social action among Navajo uranium workers and their families. In: Toba Schwaber Kerson and Associates, eds. *Social Work in Health Settings: Practice in Context.* 2nd ed. New York, NY: Haworth Press; 1997: 391–407.

48. Jorgensen JG, Clemmer RO, Little RL, Owens NJ, Robbins LA. *Native Americans and Energy Development.* Cambridge, Mass: Anthropology Resource Center; undated.

49. *Federal Mine Safety and Health Amendments Act of 1977: Hearings Before the Subcommittee on Labor of the Senate Committee on Human Resources,* 95th Cong, 1st sess (1977) (testimony of A Mazzocchi and S Wodka).

50. Schwartz RM. *The Legal Rights of Union Stewards.* Boston, Mass: Work Rights Press; 1988.

51. Boden L. Workers' compensation. In: Levy B, Wegman D, eds. *Occupational Health: Recognizing and Preventing Work-Related Disease and Injury.* 4th ed. Boston, Mass: Lippincott, Williams & Wilkins; 2000:237–256.

52. Zubeck P. Jurors rule against mill: company ordered to pay $2.9 million. *Colorado Springs Gazette.* July 17, 1998:1–4.

53. *Begay v United States,* 591 F Supp 991, 1007 (D Ariz 1984).

54. Udall SL. *The Myths of August: A Personal Exploration of Our Tragic Cold War Affair With the Atom.* New York, NY: Pantheon Books; 1994.

55. *Radiation Exposure Compensation Act of 1979: Joint Hearing Before the Subcommittee on Health and Scientific Research of the Senate Committee on Labor and Human Resources and the Committee on the Judiciary,* 96th Cong, 1st sess (June 10, 1980).

56. *Radiation Exposure Compensation Act of 1981: Hearing Before the Senate Committee on Labor and Human Resources,* 97th Cong, 1st sess (October 27, 1981).

57. *Radiation Exposure Compensation Act of 1981—Part 2: Hearing Before the Senate Committee on Labor and Human Resources,* 97th Cong, 2nd sess (Salt Lake City, Utah, April 8, 1982).

58. Roscoe RJ. An update of mortality from all causes among white uranium miners from the Colorado Plateau Study Group. *Am J Ind Med.* 1997;31:211–222.

59. Gilliland FD, Hunt WC, Pardilla M, Key CR. Uranium mining and lung cancer among Navajo men in New Mexico and Arizona, 1969 to 1993. *J Occup Environ Med.* 2000;42:278–283.

60. Samet JM, Wiggins CL, Key CR, Becker TM. Morbidity from lung cancer and chronic obstructive pulmonary disease in New Mexico, 1958–82. *Am J Public Health.* 1988;78:1182–1186

61. Radium Exposure Compensation Program. Available at: http://www.usdoj.gov/civil/torts/const/reca/awards.htm. Accessed June 10, 2002.