Report of a Greenpeace Scientific Expedition
to Amchitka Island, Alaska—
Site of the Largest Underground
Nuclear Test In U.S. History

NUCLEAR Flashback

THE RETURN TO AMCHITKA

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A Greenpeace Report by Pam Miller

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Greenpeace was compelled to return to Amchitka in June 1996 to conduct an independent investigation of the nuclear detonation sites at Amchitka.

Purpose

Amchitka Island, Alaska was the site of three underground nuclear tests: Long Shot, an 80 kiloton test (80,000 tons TNT equivalent) in 1965; Milrow, a 1 megaton test (1,000,000 tons TNT equivalent) in 1969; and Cannikin, a 5 megaton test (5,000,000 tons TNT equivalent) in 1971. Project Cannikin was the largest underground nuclear test in U.S. history.

Greenpeace was founded by a group of activists who sailed from Vancouver, Canada toward Amchitka Island in an attempt to stop the Cannikin blast through non-violent direct action. Twenty-five years after the founding of Greenpeace, concerns about the legacy of the unstoppable nuclear explosion dubbed Cannikin beckoned us to return to investigate the impacts of nuclear testing at Amchitka.

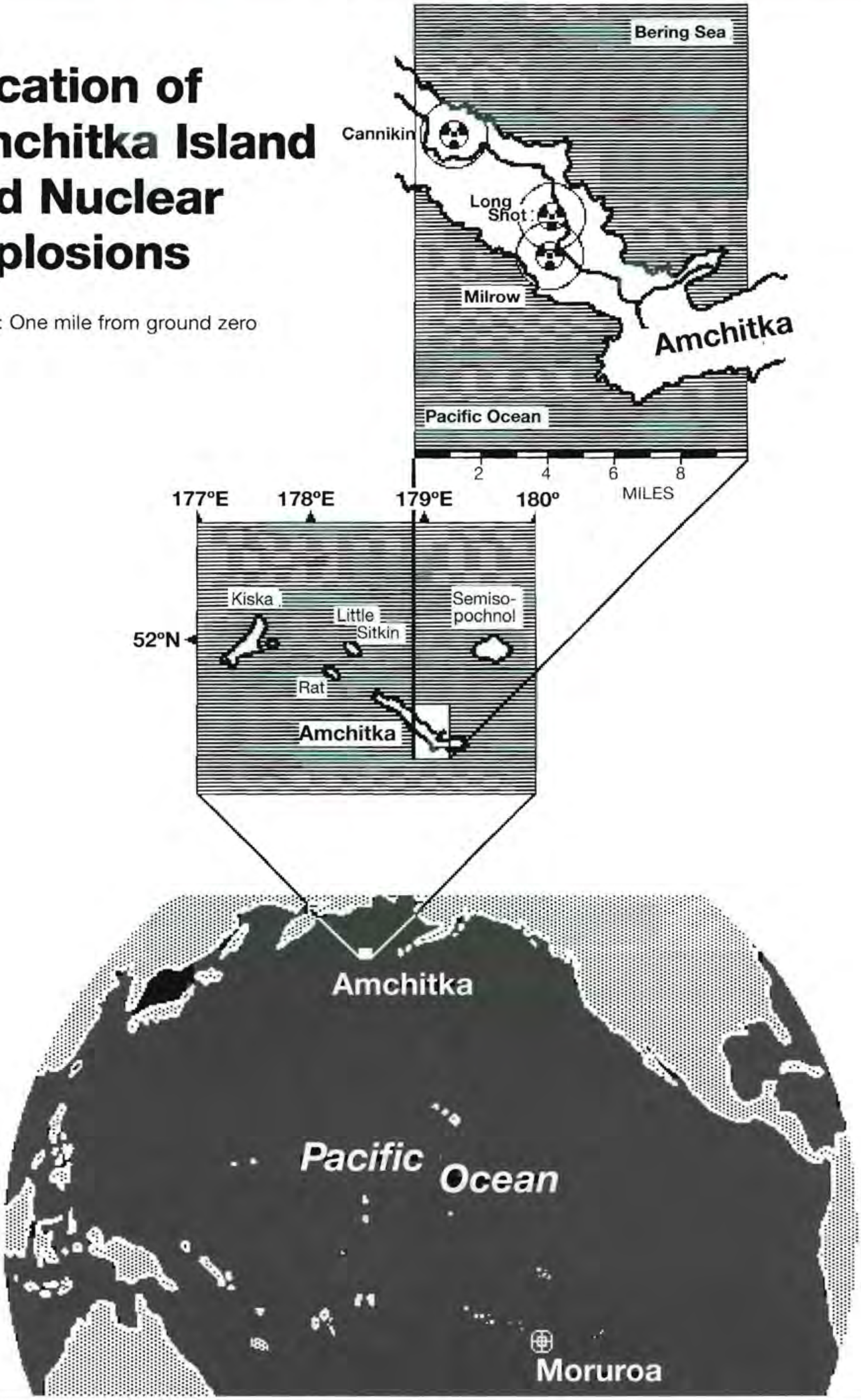
The International Physicians for the Prevention of Nuclear War (IPPNW) calculated the cumulative inventories of radioactive isotopes generated from underground nuclear tests throughout the world. They estimate a fission yield of 0.1 megacurie per megaton explosive yield for strontium-90, 0.16 megacurie per megaton for cesium-137, and unfissioned plutonium-239 at 150 curies per test.

> ***"Assuming a total yield of U.S. underground tests of 37 megatons,... approximately 2.8 million curies of strontium-90, 4.4 million curies of cesium-137, and 110,000 curies of plutonium-239 remain in the environment [using decay-corrected figures]. IPPNW concludes: "Large quantities of radioactive wastes are being explosively injected into fractured underground cavities without serious concern about future containment of the long-lived radioactive materials".[1]***

FIGURE 1

Location of Amchitka Island and Nuclear Explosions

Circles: One mile from ground zero



In June of 1996, Greenpeace sponsored an expedition to Amchitka Island (Figure 1 [map]) to conduct an independent, public-interest, scientific investigation to determine whether radioactivity is leaking from three nuclear test sites. Our review of over 1,100 documents from the Department of Energy suggested that sampling efforts sponsored by the government over the past 25 years have been inadequate to detect the presence of long-lived radionuclides in the environment of Amchitka. Given the level of seismic activity in the Aleutian region, we believe there is a strong possibility that more radioactivity will leak at Amchitka Island. This is the first opportunity for critics of nuclear weapons to access a major nuclear weapons test site and assess its radiological condition without military intervention. Greenpeace encourages open debate, discussion, and investigation of these results.

The original Greenpeace voyage to stop the nuclear test at Amchitka Island became a dramatic focal point for an international movement and inspired protests to a "greater sound and fury."

Conclusions

1 The Cannikin nuclear test site on Amchitka, site of the largest underground nuclear explosion in U.S. history, is leaking long-lived transuranic radioactivity into the Bering Sea via White Alice Creek. Two biological samples taken by Greenpeace researchers from White Alice Creek downgradient from Cannikin reveal the presence of americium-241, a beta decay product of plutonium-241. Americium-241 in the environmental samples indicates the presence of plutonium isotopes in the groundwater-surface water system at Amchitka. One of the two stream samples contained plutonium-239/-240. The plutonium-239 used to trigger the Cannikin fusion explosion (possibly 9-11 pounds of plutonium-239)[2] was co-produced with plutonium-240 and plutonium-241 in a nuclear reactor designed to create weapons-grade plutonium.

2 Cannikin leaks because of a design error that put too large an explosive too close to the land surface so that mechanical containment was breached within two days of the detonation. Leakage from the Cannikin site is probably extensive, involving groundwater pathways through fissures and through the bottom of Cannikin Lake.

3 Aggressive radiological and chemical monitoring is required to define the full extent of Cannikin leakage and to allow evaluation for remedial measures.

4 Long Shot leaks small amounts of long-lived radioactivity and should be added to the list of containment failures.

5 Underground nuclear explosion sites in wet environments leak radioactivity, because the explosions open pathways to and from the blast cavity for groundwater movement. Heat released by the explosion creates and drives advective circulation. Certain radioactive products of nuclear explosions, such as cesium-137 and americium-241, are mobile in groundwater.

6 Those who protested the Cannikin nuclear explosion 25 years ago have been proven right by this Greenpeace study.

The Island of Amchitka and Its Military Legacy

The Island of Amchitka lies along the great Aleutian arc of islands that comprise the emergent bodies of a long submarine ridge connecting North America and Asia. Amchitka is situated nearly half way to Asia, 765 miles west of the tip of the Alaska Peninsula at False Pass and 870 miles east of Petropavlovsk, Kamchatka in the Russian Far East. It is 1340 miles west-southwest of Anchorage. Only the nearby Aleutian island of Amatignak has a more southerly location in Alaska.[3] The Aleutian Islands form the divide between the Bering Sea and the North Pacific Ocean.

The Cannikin nuclear device, a Spartan anti-ballistic missile warhead, suspended over the 5,875 foot shaft in the autumn of 1971. The Cannikin blast, detonated on November 6, 1971, was the largest underground nuclear test in U.S. history at 5 megatons.

Public domain photo/courtesy of U.S. Dept. of Energy

The Aleutian Islands have served as home to Aleut people at least 9,000 years, "a longer continuous existence as an identifiable people in one place than any other people in the world."[4] Russian colonists coming to Alaska for sea otter pelts exploited the indigenous peoples, causing many deaths among the Aleuts. The Russians hunted the sea otter nearly to extinction. Although Amchitka and surrounding waters were still used for subsistence hunting and fishing, Aleuts stopped living there by 1849.[5]

Amchitka is a lush and spongy landscape of maritime tundra, nourished by frequent rains. The island's vegetation is sculpted close to the ground by constant winds. In summer, the voices of Lapland longspurs and gray-crowned rosy finches are heard throughout the Island and extensive kelp beds provide a safe haven for a diversity of fishes, marine birds, sea otters, and harbor seals. Offshore rocks and headlands offer roosting and nesting habitat for peregrine falcons and bald eagles. One hundred and thirty one species of birds have been recorded there with 28 species breeding on the island.[6]

The Cannikin nuclear warhead lowered into the shaft in early autumn 1971.

President William Howard Taft recognized the biological importance of the island when he established it as part of the national wildlife refuge system to protect native birds and fur-bearing animals. Yet a shadow was cast on Amchitka by his 1913 Executive Order that stated: "The establishment of this reservation shall not interfere with the use of the islands for lighthouse, military, or naval purposes."[7]

Amchitka was used as a forward fighter bomber base during World War II to reclaim the Japanese-occupied Aleutian Islands of Kiska and Attu. Troops on Amchitka numbered to 15,000 men. Plans for using Amchitka as a site for nuclear explosions began with Project Windstorm in 1951. The Department of Defense wanted information about the cratering potential of nuclear blasts and planned to detonate two 20 kiloton explosions, one at the surface and one in a shallow shaft. Workers drilled 34 test holes northwest of the location where Cannikin would later be detonated. The project was abandoned to be carried out at the Nevada test site, because the right geological conditions were not found.[8] Amchitka was used over the following years as a Distant Early Warning (DEW line) radar station and White Alice communications site.

Military and Atomic Energy Commission operations have created severe toxic and radioactive waste problems on Amchitka Island. The U.S. Fish and Wildlife Service documented at least 33 toxic waste sites on the island, including areas with massive fuel spills, napalm bomb depositories and other unexploded ordnance, PCBs, solvents, and heavy metals.[9]

History of the Nuclear Testing Program at Amchitka

Long Shot

Amchitka was examined in 1964 by the Department of Defense and Atomic Energy Commission as a remote site for the detonation of underground nuclear tests deemed too large for the Nevada Test Site. Government officials were worried about the proximity of expensive Las Vegas high rise buildings. Secret plans for Project Long Shot on Amchitka Island, known as a Vela Uniform Experiment, began in late 1963.

The purpose of the test was to investigate the U.S. seismic detection ability to distinguish Russian nuclear tests that might be conducted in the Russian Far East. Long Shot was unique in two respects. It was the first underground event planned for an isolated island area, and it was the first nuclear experiment managed by the Department of Defense.[10] In an internal memorandum, military officials expressed worry that "the experiment involves questions relating to a possible violation of the Limited Test Ban Treaty."[11]

Long Shot, an 80 kiloton nuclear explosion, was detonated on October 29, 1965. Scientists measured the seismic energy from the test at 5.75 on the Richter Scale. The Department of Defense (DOD) spent $10 million for the test. Although radioactive leakage in the form of tritium and krypton-85 was detected by scientists a few months after the test in freshwater ponds near surface ground zero, the leak was not made public until 1969.[12] The presence of elevated tritium levels was confirmed in a 1993 groundwater sample collected by the Department of Energy and Environmental Protection Agency.[13] The DOD had not expected the site to leak radioactivity for hundreds of years.

Milrow

Milrow is the code name for the second nuclear test on Amchitka, a one megaton "calibration test" of the AEC, designed to determine whether the island could contain an even larger test of the Spartan anti-ballistic missile warhead.[14] Milrow was detonated on October 2, 1969 at 4,000 feet below the surface of the island.

The blast "turned the surrounding sea to froth" and forced geysers of mud and water from local streams and lakes 50 feet into the air.[15] A large volume of rock, totalling about 6,900 cubic meters, fell from bluffs on the Bering coast.[16] Gene Phillips, Chief of the Barrow Magnetic and Seismological Observatory, wrote to Senator Mike Gravel: "You may be interested in learning that this station not only recorded the Milrow Event, but also detected an alarming influx of earthquakes directly following the test. There is no doubt in my mind that further testing by the AEC could trigger many more earthquakes, not only in Alaska, and no one can predict what disastrous results may be forthcoming."[17] Scientists working for the AEC detected no radioactive leakage from Milrow.

Cannikin

The Cannikin nuclear test conducted on November 6, 1971 cost over $200 million and was the largest underground nuclear explosion in U.S. history. The 730 underground nuclear tests conducted by the U.S. produced a total yield of 37 megatons,[18] and Cannikin's 5 megaton yield alone represents 14% of the total. The purpose of the Cannikin Project was to test the Spartan anti-ballistic missile (ABM) warhead.

Atomic Energy Commission Chairman, James Schlesinger took his wife and two daughters to Amchitka to demonstrate his belief that Cannikin was safe. He stated: "Its fun for the kids and my wife is delighted to get away from the house for awhile."[19] Judge Hart, the Washington judge who reviewed the lawsuits against the AEC quipped that environmentalists' concerns about earthquakes, tsunamis, and radiation were "a tempest in a blinkin' teapot."[20]

The seismic shock from Cannikin registered 7.0 on the Richter scale.[21] The physical effects of the Cannikin blast were by far the most dramatic of the three

Amchitka tests and greater than predicted. A subsidence crater, over a mile wide and 60 feet deep, was formed 38 hours after the test caused by the collapse of the explosion cavity. The blast induced extensive and large volume rockfalls on both the Bering Sea and North Pacific coasts of the island. Rockfalls and turf slides from the bluffs totaled over 35,000 square meters of material.[22] During May of 1972, samples from the Cannikin shaft revealed that about 14,000 cubic feet of radioactive gas containing krypton-85 with concentrations of 200,000 picocuries/liter was venting into the atmosphere. This was the first radiological evidence that Cannikin had breached its containment, yet the venting was not publicly revealed.

Impacts to wildlife were also greater than predicted. Alaska Department of Fish and Game biologist Karl Schneider estimated that 300-800 sea otters were killed from the force of the blast, perhaps as many as 1,000. Schneider based his estimate on pre- and post-shot surveys of sea otter populations that indicate that hundreds were "missing." Although only 23 bodies of sea otters were actually found, weather conditions pushed carcasses away from the shore. Sea otter skulls were fractured by the force of the blast driving their eyeballs through the bone behind their sockets. Some animals suffered from ruptured lungs.

Harlequin ducks were found with their backs broken and legs driven up into their bodies by the pressure of the explosion.[24] Stormy weather precluded an accurate assessment of the numbers of deaths to fish, birds, and marine mammals caused by the blast. In the long term, populations of animal species at Amchitka will recover from the direct physical impacts of the nuclear explosions, but many animals suffered unnecessarily. Studies to assess potential long-term effects from radioactivity on fish and wildlife species have not been done.

A Sea Of Protest

> ***Something must be done to stop the Americans from their insane ecological vandalism.***
> ***— James Bohlen, a Canadian founder of Greenpeace***

In 1971, thousands of people throughout the world were determined to stop the Atomic Energy Commission (AEC) from detonating the largest underground nuclear explosion in U.S. history. Representing 3,500 Aleut residents from the Aleutian and Pribilof Islands, the Aleut League filed a lawsuit to halt the test. Emperor Hirohito of Japan met with President Nixon in Anchorage to express concern for the safety of his country's citizenry. Prime Minister Trudeau of Canada, prompted by the outcry of Canadian citizens, objected strenuously to the test. Editorials in papers such as the Washington Post, New York Times, and Chicago Sun Times urged cancellation of the Cannikin project, citing dangers to the environment and obsolescence of the warhead to be tested. The Cannikin nuclear blast was 385 times the explosive power of the 13 kiloton bomb that devastated Hiroshima; and 250 times the power of the 20 kiloton bomb dropped on Nagasaki.[25]

The Alaska State Medical Association passed a resolution against the test, stating that the nuclear blast "can only result in injury and death to present and future generations."[26] Presenting evidence that the Spartan warhead was outmoded and the Cannikin test unnecessary, Dr. Jeremy Stone of the Federation of American Scientists, representing 2,000 members, testified in opposition to Project Cannikin.[27] The U.S. Supreme Court was presented with a lawsuit filed by the Committee for Nuclear Responsibility and other environmental and human rights groups.

Five federal agencies recommended to President Nixon that the Cannikin test be canceled or postponed. Rather than accept their recommendations, he invoked an Executive Order to suppress comments from these agencies (the Environmental Protection Agency, Council on Environmental Quality, State Department, Office of Science and Technology, and U.S. Information Agency), and the Atomic Energy Commission classified the comments as Restricted.[28] After the explosion, these became known as the Cannikin Papers. When the U.N. Association denounced the Cannikin test for environmental reasons, it also objected to the AEC's secrecy.

Strengthened in their resolve by a powerful grassroots movement and sound scientific information, prominent politicians of the day strenuously opposed the test. The Attorney General of Alaska, John Havelock, declared before Congress that the AEC's environmental impact statement for Cannikin "is little short of sham."[29] Backed with exceptional research by staffer Ms. Egan O'Connor, Senator Mike Gravel of Alaska led the Congressional effort to stop the test. Congresswoman Patsy Mink of Hawaii, Congressman Nick Begich of Alaska, and 31 other Congressional members filed a suit in U.S. District Court seeking the release of secret Cannikin documents.

The Committee for Nuclear Responsibility, with eminent members such as Nobel Laureate Linus Pauling, joined with 7 other international groups to halt Cannikin through legal action. They contended that the test would violate both the 1963 Limited Test Ban Treaty and the National Environmental Policy Act (NEPA). The U.S. Supreme Court with a 4-to-3 vote denied their request to stop the test. Justice William O. Douglas prepared a 13 page dissenting opinion stating that the AEC had not met legal requirements under the NEPA. Justices Brennan and Marshall concurred with Justice Douglas, asserting that there was a "substantial question as to the legality of the proposed test."[30] The AEC responded by exploding the Cannikin nuclear bomb just 5 hours after the Supreme Court's denial on November 6, 1971.

Concern about Cannikin helped spur an international movement for ecological integrity and peace. In October 1971, at the U.S. Consulate in Vancouver, Canada, 9,000 people went to the streets to protest Cannikin, and tens of thousands more throughout Canada and the U.S. demonstrated, testified, petitioned and wrote letters against the test. The Alaska Mother's Campaign Against Cannikin, led by Aleut League Secretary-Treasurer Lillie McGarvey, organized home meetings and sponsored a State Fair booth to gather support in urging President Nixon to cancel the test. Five Navy sailors in Hawaii refused to sail with their ships in protest of Cannikin and were arrested by military officers.

The momentum for the birth of Greenpeace arose from the grassroots movement against the Cannikin test. Motivated by the Quaker tradition of "bearing witness," twelve people set sail from Vancouver to stop the nuclear explosion at Amchitka.

Radio communications of the Greenpeace vessel, the F/V Phyllis Cormack, were monitored by military intelligence. Eighteen crewmen of the U.S. Coast Guard vessel Confidence in Akutan Harbor (Aleutian Islands) signed a statement supporting the Greenpeace protesters.[31] Although stormy weather and postponement of the test prevented the Phyllis Cormack from reaching Amchitka, this first Greenpeace action became a dramatic focal point for an international movement and inspired protests to a "greater sound and fury."[32] An aide to one of the senators against the war in Vietnam was quoted as saying, "I've never seen anything like it. Where we are looking for an issue to revive the ABM debate, the Atomic Energy Commission drops Cannikin in our lap. It's almost enough to enlist every ecology freak in the country."[33]

Lies, Secrets, and Promises of the U.S. Atomic Energy Commission

"All too often [radioactive] damage has been done to ethnic minorities or on colonial lands or both. The main sites for testing nuclear weapons for every nuclear weapons power are on tribal or minority lands."[34]

— Arjun Makhijani, President, Institute for Energy and Environmental Research

"The Cannikin detonation threatens possible destruction or most serious harm to the lives, property, commerce and culture of the Native people living in the Aleutian Island area."[35]

— Iliodor Philemonof, President, Aleut League

"This site was selected—I underscore the point—because of its remoteness and the zero likelihood—virtually zero likelihood of any damage."[36]

— James R. Schlesinger, Chairman, Atomic Energy Commission

Disregard for Aleut People

By exploding nuclear bombs underground at Amchitka Island, the U.S. government disregarded the Aleut people who would suffer most directly should earthquakes, tsunamis, or radioactive leakage occur. Because they depend on the sea for subsistence, Aleuts voiced concern that radioactive leakage would pose a threat to their survival. The AEC ignored them, so the Aleut League filed a lawsuit in September of 1971 to block the Cannikin test, and Aleut villagers filed affidavits that spelled out their concerns stating unequivocally that the Federal government had failed to contact the Aleut people about Cannikin.

"I hear that there is going to be a blast on Amchitka in the fall of this year. Nobody from the Federal government has talked with me about it. I am against the blast because I think it will destroy the food."[37]

"I have been involved in the community government for over 30 years. Conditions in our region are very harsh and during the

winters we have trouble catching food. I am afraid that the blast may cause even more hardships that my people will have to bear. For these reasons I am opposed to the nuclear test."[38]

"I first heard about the blast in the Tundra Times. No person from the Atomic Energy Commission has spoken to me or the Community Council about the test. I am afraid that the blast on Amchitka may cause landslides, tidal waves, or earthquakes. I am also afraid that the fish and wildlife on which we depend may be contaminated."[39]

In response to the suit[40] and only a few days before the Cannikin test, the AEC finally sent representatives to 19 Aleut villages. Yet when the AEC representatives arrived at the villages, they did not listen to the people who most understood the region.

The AEC failed to alleviate the concerns of the Aleut people. Lillie McGarvey, Secretary-Treasurer of the Aleut League and translator for the AEC briefings, stated: "I really don't think anyone was swayed. I think those who were against the blast still are. They still fear the test. They were born and raised in earthquake country."[41]

Some village leaders requested that their people be evacuated to the mainland during the test, but the AEC discounted the Aleuts' fears that something might go wrong. The AEC refused requests by the Aleut people to be moved to safety and never acknowledged the possibility that there might be a mishap with the Cannikin project. The AEC made no arrangements for emergency evacuation of the Aleuts who lived only a few hundred miles downwind from Amchitka.[42]

"No representative of the Atomic Energy Commission has spoken to the village Council about possible safety measures that may be taken in the event of a mishap."[43]

"We who are closer to the blast have concern for the consequences of a miscalculation on the part of the Atomic Energy Commission. Earthquakes continuously happen in this area."[44]

Suppression of Scientific Opposition to Cannikin

Before the Cannikin explosion, officials of the AEC suppressed and ignored scientific sources that cautioned against the blast at Amchitka. Some of the scientists and documents that they chose to disregard are: The Cannikin Papers comprised of recommendations from five federal agencies that advised President Nixon to cancel or postpone the test; Federation of American Scientists who questioned the necessity of the Cannikin project; and multiple affidavits by eminent scientists for an appeal to the U.S. Supreme Court to stop Cannikin.

Cannikin Papers: Cancel or Postpone Explosion

Only portions of the classified documents known as the "Cannikin Papers" were released by the AEC after the blast. In a statement before Congress four days after detonation, Congresswoman Patsy Mink of Hawaii stated: "As evidence that there were serious questions among reputable scientists, we have the Cannikin papers — a group of documents which the administration savagely fought to keep secret from the Congress and the American public. The administration had good reason to fear the wrath of our people if the dangers of this misdeed could be fully disclosed. Authority and funds for Cannikin were obtained from Congress while information on its potential effects was cynically withheld. Nevertheless, the administration had in its possession at the time secret documents which proclaimed the vast destructive dangers of this immense nuclear explosion."[45]

Federation of American Scientists: Question the Purpose of Cannikin

The Federation of American Scientists presented compelling testimony that questioned the fundamental need for Cannikin on the basis that the Spartan warhead was already obsolete. "Basically, Cannikin is a bureaucratic oversight— an experiment that has been waiting to be canceled since, in early 1969, the President changed the rationale for the U.S. ABM away from the anti-Chinese defense."[46] The environmental impact statement for Cannikin did not reveal the yield or purpose of the test. In 1971 before the Cannikin blast, Dr. Jeremy Stone concluded: "This entire episode illustrates the importance of requiring government agencies to explain in their Environmental Impact Statements those true purposes of their activities that might balance the adverse environmental impacts. The key to this entire question is the purpose of Cannikin. The effort to keep this a secret from the American people— when it can, by no stretch of the imagination, now be kept secret from the Soviets— can only sharpen the widening credibility gap in which American governments are increasingly trapped."[47]

Concern About Venting

Critics of the AEC's plan to detonate Cannikin on Amchitka Island had plenty of evidence from past containment failures of underground nuclear tests at the Nevada test site to cause consternation about the AEC's ability to contain a 5 megaton nuclear explosion in a poorly understood area as Amchitka. In 1970, the Baneberry test at the Nevada test site, only a 10 kiloton blast, blew a radioactive plume more than 8,000 feet into the atmosphere. Radioactive debris was detected as far away as North Dakota. Long Shot, an 80 kiloton nuclear test detonated on Amchitka Island in 1965, vented tritium and krypton-85 to the surface a few months after the test, despite Department of Defense assurances that it would be contained for hundreds of years.

The military left behind a legacy of debris, as well as toxic and radioactive waste on Amchitka Island.

According to the Physicians for the Prevention of Nuclear War: "Underground testing has often resulted in prompt releases of radioactivity to the atmosphere, mainly through accidental venting. In the U.S. nuclear weapons testing program between 1957 and 1970, 25.3 million curies of radioactive fission products were released to the atmosphere from 30 under-ground tests. The venting of Baneberry alone, in [December] 1970, injected 6.7 million curies of radioactive fission and act-ivation products into the environment."[49]

Affidavits from Scientists Against Cannikin

In testimony for the suit before the U.S. Supreme Court made public after the Cannikin detonation, scientists predicted that serious long-term consequences of Cannikin may yet occur. In a speech before Congress two weeks after the test, Senator Mike Gravel of Alaska noted: "The potential for radioactive contamination is still present and must be closely watched for the indefinite future... Such a possibility is no idle concern, and only careful monitoring will permit us to know whether a danger is developing."[50]

Located in the Pacific Rim "ring of fire," Amchitka's high seismic activity presents much greater difficulties with containment than the Nevada test site. Dr. Nafi Toksoz a geophysicist from MIT wrote that earthquakes may easily create pathways for radioactivity to migrate into the Bering Sea. "Because of the...active seismic nature of the general area, there is always the likelihood of intermediate and large earthquakes in the general region of Amchitka. The ground displacements and faulting associated with these natural earthquakes could interfere at any time during a period of years with the containment of radioactive products produced by the Cannikin explosion, creating faults which could provide migration paths for the radionuclides to the ocean. The problems relating to containment caused by the admitted occurrence of frequent natural earthquakes in the Amchitka area...were not at all considered by the AEC in the Environmental Impact Statement."[51]

Refuting AEC claims that radioactivity from Cannikin will be trapped within rock melt, Dr. Robert Mueller, a geochemist from the Goddard Space Flight Center, predicted accurately that "rather than remaining trapped, radionuclides will either be dissolved directly in the water or, through the mechanism of exchange, be removed from the interior of the crystals or glass and pass into the water solution. This is especially significant, since migration of radionuclides to the surface is greatly enhanced when they are in water solution."[52]

Geological engineer David Evans, concluded: "Sizeable fractures and fissures will be available after the detonation of Cannikin for the conduction of contaminated groundwater away from the detonation site at a rate and in a concentration considerably greater than the most negative model proposed in the Environmental Impact Statement.[53] The Council on Environmental Quality, citing U.S. Geological Survey calculations, testified that "contaminated water would reach the ocean with a concentration in excess of 10,000 to 100,000 times the permissible concentration for water. This is 100 times greater than the Commission (AEC) indicates is possible under the most adverse conditions..."[54]

Environmental Impact Statement: Public Relations/Not Environment

In its Environmental Impact Statement a year before the blast, the Atomic Energy Commission deliberately withheld or avoided information from scientists about the potential impacts from the Cannikin test. The major public assertions by officials of the AEC included:

1 "The effects of the heat and radioactivity resulting from the explosion will be confined deep underground... A pocket of radioactivity will remain indefinitely. Preliminary calculations of the process predict that only tritium will be discharged into the ocean, and that starting at 145 years after the explosion, lasting for an additional 43 years. The concentration of tritium in the ground

water at the time it is discharged to the ocean should be at a level close to the maximum permissible concentration for water."

2 "The alternative of not testing this particular nuclear explosive would be to make impossible the development of nuclear weapons technology of significance to our national security requirements."

Disseminating an Environmental Impact Statement based more on their wishful thinking than on scientific fact, the AEC officials attempted to manipulate public opinion rather than heed warnings from scientists.

Cannikin Blast Could Not Be Stopped

Nothing would stop the officials of AEC and their associates from moving relentlessly toward their goal, as their desire to explode this huge nuclear warhead was greater than their concern for the safety of people and the environment. A previously classified memo from Philip Coyle of the Lawrence Livermore Laboratory dated September 8, 1971 boasts of the prowess of the Cannikin Project. He glorifies the Cannikin nuclear weapon "emplacement" as the deepest ever attempted at 5,875 feet. The nuclear device is the longest at nearly 300 feet and heaviest at 850,000 pounds. Furthermore, Cannikin was the first to depend upon an active pumping system to keep emplacement hardware dry.[56] General Leslie Groves states: "If there are to be atomic weapons in the world, we must have the best, the biggest, and the most."[57] Cannikin lived up to the expectations of those who are excited about nuclear weaponry.

Although no immediate earthquakes or tsunami disasters occurred as a result of Cannikin, scientists within federal agencies and those testifying for the Committee for Nuclear Responsibility and the Aleut League had presented strong arguments that the AEC "did tamper recklessly with the environment. There was no military need to, but the administration chose to put the lives and property of our people, and those of other nations, on the luck of its wager."[58] Concerns about future radioactive leakage were well founded.

Amchitka: A Wet Site

All three nuclear explosions under Amchitka were "wet," as the bombs were detonated below the Island's water table. These explosions were also below sea level and both the Bering Sea and Pacific Ocean were less than three miles distant from each. The 1963 Limited Test Ban Treaty explicitly bans underwater testing but the Atomic Energy Commission pushed those limitations at Amchitka, especially with the Cannikin Project, which needed an active pumping system simply to keep the bomb dry during emplacement.

A 1994 report by the Government Accounting Office states: "The potential exists for radionuclide movement over time from deep aquifers [within Amchitka] to the Pacific Ocean and Bering Sea."[59] Over 300 radioisotopes may be present in the underground test cavities.[60]

Epidemiological Testing

After pressure from medical professionals in Alaska, the AEC and EPA conducted "human surveillance" radiological studies of blood and urine of people at Atka, the closest Native community to Amchitka. These samples were taken only three weeks before the Cannikin test. Additional sampling was undertaken the following year. Although concentrations of radionuclides did not exceed "dangerous levels as presently understood," elevated levels were found. Yet no follow-up studies were conducted.[61]

The National Arctic Health Science Policy of the American Public Health Association Task Force states: "Particularly among Native people in Alaska, there is an urgent demand for continuous monitoring of radionuclides in air, water, ice, soil and in plants, animals, and man." The lack of information concerning potential exposure among Aleut communities is glaring and unconscionable. Carl Hild, scientist for the Indigenous People's Council for Marine Mammals, expressed concern about the lack of follow-up studies for Aleuts: "I was interested to see that human blood had been sampled for Fe-55 [radioactive iron] and was found to have a mean of 9,000 picocuries/liter, and urine for tritium where levels up to 9,400 picocuries/liter were found. During their pre- and post-shot tests they found that Adak residents had higher tritium levels. It was also frustrating to read that cesium-137 in local tests were higher than at the Nevada test site but lower than levels observed in more northern Arctic villages. With this knowledge, there have been no follow-up studies for the residents in these communities with known elevated levels."[62]

No epidemiological research has been conducted on the hundreds of workers involved in the construction, implementation, and cleanup of the three nuclear tests at Amchitka. Furthermore, documents obtained from the Department of Energy reveal that dosimeter badges and exposure records were "lost." Testimony presented before the Advisory Committee on Human Radiation Experiments by the Alaska State District Council of Laborers (Laborers International Union of North America, AFL-CIO) disclosed that federal and contract workers at the Amchitka nuclear detonation sites have suffered radiation induced illnesses, leukemia, and other radiation exposure-related cancers. Contract workers and their families have been denied access by the federal government to classified information, medical relief, and compensation. Workers at the Amchitka nuclear test site are not protected under the federal Radiation Exposure Compensation Act (RECA) as are workers from the other U.S. nuclear test sites.[63]

Scientific Findings

Containment

The Containment Evaluation Panel established by the Atomic Energy Commission (AEC) in March 1971 defines successful containment of radiation resulting from nuclear explosions as allowing "no radioactivity detectable off-site and no unanticipated release of activity on-site."[64]

A nuclear bomb is exploded underground after it is placed at the bottom of a vertical shaft drilled into the ground. The explosion is said to be "contained" mechanically when the borehole has been plugged. As the shocked and heated material around a blast cavity cools, the material cracks, and the roof of the blast cavity falls. The falling rubble loosely fills the cavity faster than the chimney can collapse from above. When the rubble pile reaches the roof of the chimney, the rubble supports the chimney roof, and the collapse stops.

The strength of a nuclear blast is called "yield" and is measured in tons of TNT. A one-ton yield would be the same as a one-ton blast of TNT, which is 1,000,000,000 calories of explosive energy. As the volume over which any specified degree of blast damage occurs is proportional to length cubed, the length over which that degree of damage occurs is proportional to the cube root (=1/3 power) of the explosive yield. This cube-root scale law applies to all length scales and means that the picture of damage looks the same regardless of yield, but the picture is bigger with a bigger explosive (Figure 3).

For a one-ton blast, whether TNT or nuclear, a blast cavity about 11 feet in diameter would be blown in the ground. With this model of containment, a one-ton explosive would need to be buried 40 feet beneath the earth surface and the top 10 feet of ground would remain more or less intact after the blast.

To scale this model up to the 5,000,000-ton Cannikin explosion, the cube-root scaling factor is (5,000,000 ton)^(1/3) = 171 (where ^ indicates that an exponential follows in parenthesis). So the modeled diameter of the Cannikin blast cavity is scaled up 171 times the 11 feet of a one-ton blast (171x11 feet = 1881 feet). Along with the actual shaft depth for each of the three Amchitka explosions, the 30 "units" of expected chimney collapse depth and the 40 "units" of safe depth are listed in Table 1. According to the model pictured in Figure 3, the blast cavity and collapse chimney are filled with rubble to a height of 30 length units, with 10 length units of more or less intact material above the chimney roof for mechanical "containment."

Using AEC's method of calculating safe depth, where depth = 400 (yield)^(1/3) [cube root of yield], Table 1 shows that Long Shot's shaft depth of 2300 feet was 500 feet more than deep enough to assure that mechanical containment would not be breached by the collapse chimney reaching the ground surface. The Milrow shaft was bored to exactly the safe depth for the reported yield without any added safety factor. The Cannikin shaft was bored 745 feet more than the chimney would have been expected to collapse from a 5,000,000-ton explosion, but almost a thousand feet short of the minimum safe depth. The outcomes of the three explosions are summarized in Table 2.

TABLE 1

Depth Comparisons for the Three Amchitka Nuclear Explosions

Name	Yield (Tons of TNT)	Depth (feet)		
		Actual Shaft	Expected Collapse	* Safe
Long Shot	**80,000**	**2,300**	**1,293**	**>1,724**
Milrow	**1,000,000**	**4,000**	**3,000**	**>4,000**
Cannikin	**5,000,000**	**5,875**	**5,130**	**>6,840**

*Greater than (>) denotes that the Safe Depth calculation actually includes an additional "safety" factor to account for the possibility that the actual yield might exceed the expected yield.

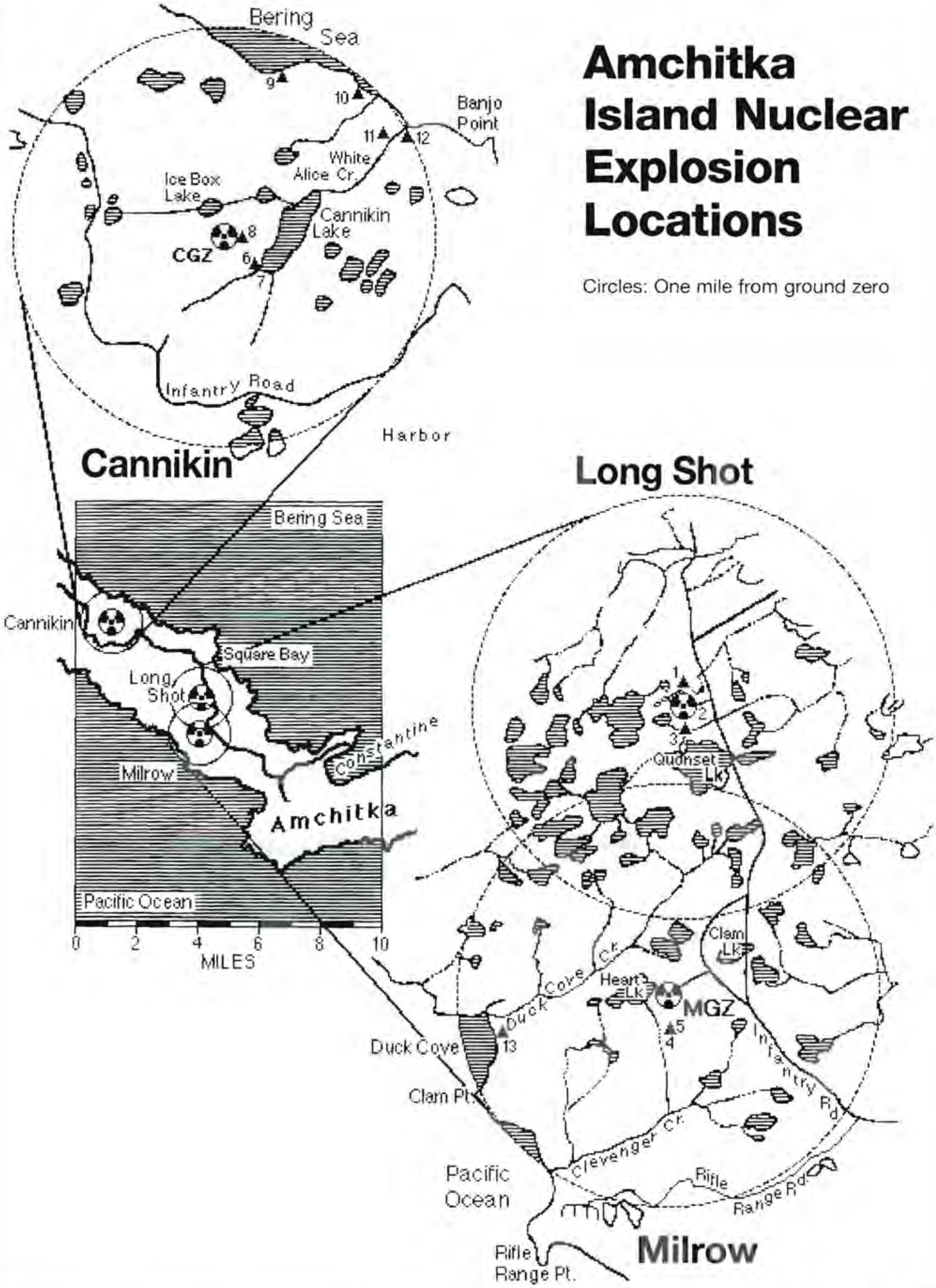
Long Shot

The reported, late venting from the Long Shot explosion almost fits into an exception called a "late-time seep" of a minuscule release of radioactive gas, related to "atmospheric pumping," which can be ignored under the AEC definition for containment as a "not unanticipated release" of radioactivity. The Long Shot explosion did not have to be listed as a failure of radioactive containment, even though it admittedly vented radioactive gas into the atmosphere.

FIGURE 2

Amchitka Island Nuclear Explosion Locations

Circles: One mile from ground zero



Cannikin

The cause of the chimney collapse following the Cannikin explosion has not been explained in the available literature, but when the chimney collapse reached the ground surface east of Cannikin Ground Zero (CGZ) 38 hours after the Cannikin explosion, White Alice Creek disappeared into the newly formed depression. For 10 months, the North and South Forks of White Alice Creek simply vanished into the earth. For three more months, that depression filled to form one of the largest lakes on the island, and then White Alice Creek once again emptied into the Bering Sea.

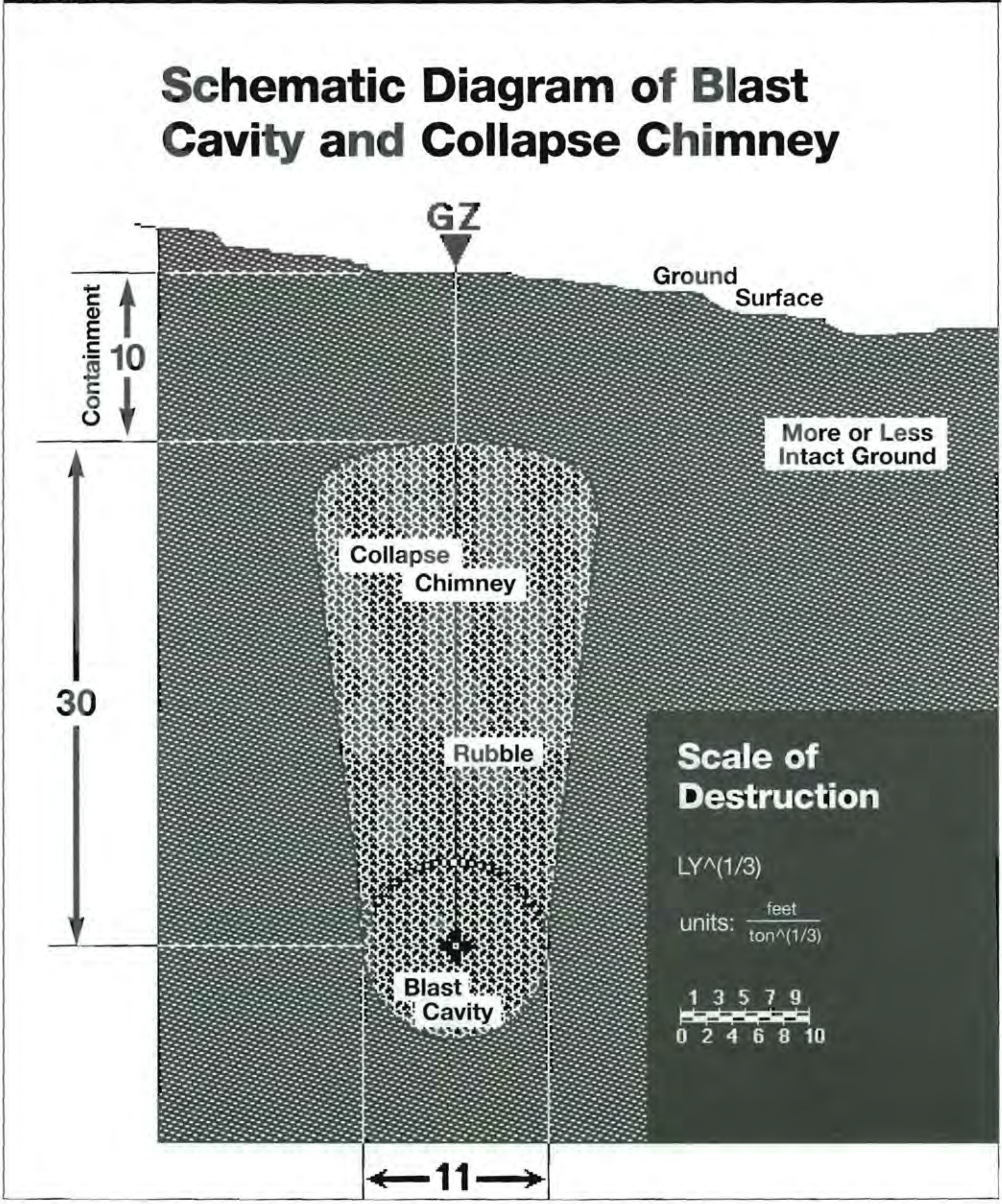
As shown in Table 2, the Cannikin explosion exceeded the yield for which its shaft depth would have safely assured mechanical containment. Having breached mechanical containment, the Cannikin explosion was not listed by the AEC for containment failure because, except for the krypton-85 in 1972 gas samples, monitoring agencies failed to detect leaked radioactivity at the site. In the most recently reported environmental sampling of Amchitka (1993), the EPA collected 52 samples, 16 of which were soil or water samples from the Cannikin environs. EPA detected no radioactivity attributable to the Cannikin explosion.[65] Thus the Cannikin explosion presented a paradox. It was the largest-ever American underground nuclear explosion; it dramatically breached its containment; and yet it seemed, inexplicably, to have contained its radioactivity.

Sampling and Analysis

Our study began with a plan to employ high-resolution gamma spectrometry to identify any significant gamma-emitting, artificial radioactivity in samples collected on Amchitka. This approach screens for most potential radionuclides using a single monitoring test. We required large, clean samples of a medium (algae, moss) that concentrates metal ions. Carefully selected and cleaned samples of moss or algae can be concentrated 50-fold by ashing, allowing

Greenpeace collected moss and algae samples on Amchitka in June 1996 to determine whether the nuclear detonation sites are leaking radioactivity.

FIGURE 3



reasonably low detection levels by ordinary gamma spectrometry. We requested the laboratory perform secondary analyses following positive gamma results, depending on the nature of the radionuclides detected. Technical difficulties with scintillation fluid (repeated clouding of the medium) for our in-field tritium detector prevented us from taking tritium mea-surements from surface water sources.

Sampling

Sample 1 was a moss/algal mat collected from the Long Shot mud pit drainage ditch that the EPA had reported as contaminated (see Figure 2 for locations).

Hand-held radiation detectors yielded low but erratic readings near Long Shot Ground Zero (LSGZ). As the concrete pad at LSGZ was partly moss-covered, this moss, which was subject to airborne fallout rather than aquatic contamination, was collected as Sample 2.

Sample 3 of moss with an oily sheen was collected from a small seep 300 yards south of LSGZ (51° 26'03"N, 179° 10'47"E). It was taken from water from a source pond or stream above LSGZ that was trickling down blast-created fissures to the blast cavity or collapse chimney above it, and then being pushed back upward to a seep below the source.

Another site with a pond above ground zero and seeps below was identified at Milrow. A seep (51°-24'48"N, 179° 10'46"E) with both aquatic moss and green algae was found next to Well No.17, 300 yards south of Milrow ground zero (MGZ). Moss and algae were collected separately at this seep as Samples 4 and 5, respectively.

TABLE 2

Summary of the Three Amchitka Nuclear Explosions

Name	Date (Day/Month/Year)	Yield (Tons)	Containment
Long Shot	**10/29/65**	**80,000**	**venting>1 month radiokrypton & tritium**
Milrow	**10/02/69**	**1,000,000**	**no reported breach**
Cannikin	**11/6/71**	**5,000,000**	**chimney collapse @ 38 hrs; radiokrypton in 1972**

"Containment" in this table refers both to mechanical containment, in which the collapse chimney does not reach the land surface, and to radiological containment.

TABLE 3

Sample Weights

	Weight (grams)				
	Clean		Ash		
Sample #	Wet	Dry	Total	Gamma	Dry-to-Total-Ash Rate
1	1114	125	20.2	20.3	6.2
2	**1908**	**360**	**72.2**	**72.2**	**5.0**
3	2101	284	20.2	20.2	14.1
4	**1811**	**189**	**18.8**	**18.8**	**10.1**
5	1282	77	20.0	19.8	3.9
6	**2762**	**455**	**246.4**	**246.0**	**1.8**
7	562	68	20.3	20.0	3.3
8	**2711**	**519**	**174.7**	**174.8**	**3.0**
9	2364	378	72.3	71.6	5.2
10	**3015**	**392**	**62.7**	**62.5**	**6.3**
11	1754	204	25.7	25.7	7.9
12	**2053**	**270**	**64.1**	**54.7***	**4.2**
13	1130	227	30.8	28.8**	7.4

* 85% used for analysis ** 93% used for analysis

TABLE 4

Gamma Radionuclides [pCi/g(ash)] ± one standard deviation counting error. Half-life [years] is given below the radionuclide.

	Gamma Spectrometry				Alpha
Sample #	Be-7* 0.146	Cs-134 2.065	Cs-137 30.17	Am-241 432.7	
1	105.3±3.3	ND	0.59±0.022	ND**	-***
2	76.2±2.4	0.034±0.002	2.13±0.052	ND	-
3	153.6±4.9	ND	9.96±0.245	0.094±0.040	0.18±0.03
4	59.6±1.9	ND	0.18±0.016	ND	-
5	25.9±0.8	ND	0.19±0.014	ND	-
6	4.4±0.2	ND	0.16±0.006	ND	-
7	3.8±0.2	ND	0.16±0.014	ND	-
8	12.1±0.4	ND	0.13±0.005	ND	-
9	8.8±0.3	ND	0.01±0.006	ND	-
10	7.2±0.2	ND	0.03±0.006	ND	-
11	57.5±1.8	ND	0.86±0.026	0.074±0.024	0.05±0.015
12	38.2±1.2	ND	0.89±0.024	0.041±0.012	<0.03
13	1.4±0.1	ND	0.02±0.009	ND	-

* Back caluclated from analysis date to sampling date.
** "ND" = Not Detected by the described analysis and check procedure.
*** "-" = no alpha analysis performed.

Cannikin Ground Zero (CGZ) was located at its mapped position of (51° 28′17″N, 179° 06′18″E). The North Fork of White Alice Creek was examined for signs of groundwater seepage, but none were found. Along the west side of Cannikin Lake, a seep in the dry bed of the South Fork of White Alice Creek was located at (51° 28′07″N, 179° 06′27″E). Moss (Sample 6) and algae (Sample 7) were taken. Moss was collected as Sample 8 from a small seep below CGZ, 100 yards east (51° 28′17′N, 179° 06′37″E).

Two seeps entering the Bering Sea were identified by low salinometer readings and by the presence of green alga *Enteromorpha*. Sample 9 was collected at (51° 28′51″N, 179° 06′39″E), and Sample 10 at (51° 28′48″N, 179° 07′07″E).

Moss/algal Sample 11 was collected from a seep entering White Alice Creek, approximately 100 yards upstream from the gauging station. Sample 12 was taken from a moss/algal mat in White Alice Falls (51° 28′37″N, 179° 07′25″ E), where White Alice Creek empties into the Bering Sea.

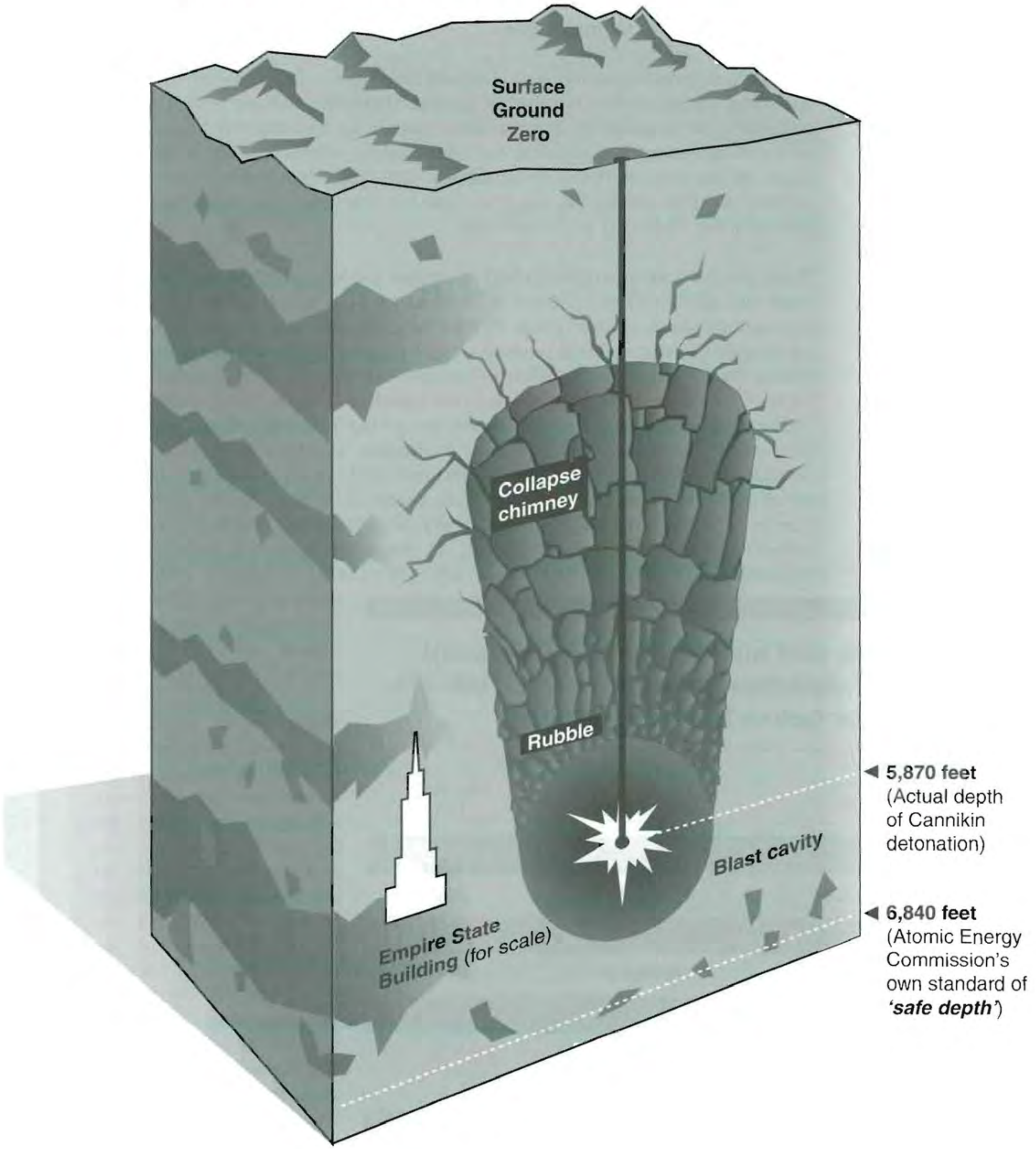
A corresponding Sample 13 of green algae *Ulva* was collected from the Milrow drainage into the Pacific Ocean at the Duck Cove shoreline, about (51° 28′08″N, 179° 09′06″E).

Samples were refrigerated and delivered to the laboratory on June 11. They were dried at 100 degrees Celsius and ashed at 500 degrees Celsius. Wet, dry, and ashed weights are listed in Table 3. Sample gamma emissions were counted for 4000 minutes in June and July on a single, high-purity, energy and efficiency calibrated, spectrally stable germanium detector having a well-known background spectrum and an analytical history with similarly prepared and analyzed moss and algal samples.

FIGURE 4

Cannikin Blast Cavity

This diagram illustrates actual depth of detonation compared with the "safe depth"



Gamma peaks between 55 and 1840 KeV (KeV = thousand electron volts) in the 8,000 channel sample spectra were automatically searched with sensitivity set at 3.0 and with three background channels. For quantitative results, "blank" peaks were subtracted. The number of gamma peaks in each sample spectrum depended primarily on the abundance of natural decay products of the radioactive uranium and thorium decay chains. Some of these peaks appear in the blank (no sample) gamma spectrum of the detector and are then reported as spectral peaks with very low or even negative counts. The number of reported spectral peaks ranged from 41 for Sample 13 to 67 for Sample 8.

For each reported gamma peak in each spectrum, the peak-center energy, calculated energy width, number of counts, standard counting error (random uncertainty) and background counts were reported by the computer software. The software automatically identified the radionuclide responsible for most peaks based on the laboratory's in-house library. The radio-chemical technician then referred to this library to suggest possible identities for each peak not automatically identified by the software.

These gamma results were then checked against previous analyses of comparable moss and algal samples collected in Washington State to flag possible errors in peak identification. Flagged peaks together with unidentified peaks of more than one standard counting error positive were then searched by computer against a custom file based on the Brookhaven National Laboratory's 1995 "Update of the Table of the Isotopes" which appears in the Handbook of Chemistry and Physics. Preliminary candidate radionuclides that turned up in this file search were then cross-checked manually against Walker, Parrington, and Feiner's 14th edition of Nuclides and Isotopes,[66] against Lederer and Shirley's 7th edition of Table of Isotopes;[67] and in the case of peaks having energy in the x-ray region, against J.A. Bearden's "X-Ray Wavelengths Table B, Wavelengths in numerical order of the emission lines and absorption edges" in the aforementioned Handbook of Chemistry and Physics. This cross-check eliminated candidate sources of gamma peaks which were "untenable" for radiological reasons in these particular samples.

These results for all 13 spectra were then compared to reveal patterns and errors in the analysis. The only substantive outcome of the described checking was tentative confirmation of the software identification of americium-241 for the 59.5 KeV peak in the gamma spectra of Samples 3, 11, and 12. These three samples were then submitted to independent confirmation of the presence of Am-241 by chemical extraction of

TABLE 5

Follow-up beta and alpha results [pCi/g(ash)]. One standard deviation counting error. Half-life [years] is given below the radionuclide.

Sample #	Sr-90 29.1	Pu-239/-240 24,100/6,560	Pu-241 14.1
3	--*	0.15±0.02	--
11	<0.61	ND**	<0.08
"***	0.72±0.16	--	--
12	--	0.03±0.01	--
"	--	0.04±0.01	--

* "--"= no analysis for this radionuclide
** " ND" = Not Detected
*** Ditto marks=duplicate analysis

plutonium and americium and then counting of the alpha spectra between 5330 and 5568 KeV (EPA Method EMSL-LV-0539-17 Modified).

Results and Discussion

The radiological results of the 13 sample analyses appear in Table 4, listing short-lived beryllium-7, cesium-134 and -137, and americium-241. All detected radionuclides are listed, except for the naturally occurring members of the uranium-thorium decay chains and naturally occurring potassium-40. The positive gamma results are considered, as follows:

Beryllium-7

Beryllium-7 is a naturally occurring radionuclide resulting from cosmic ray impacts on nitrogen and oxygen atoms in the upper atmosphere. Plants concentrate beryllium-7 from rain. Samples with higher concentrations of beryllium-7 in Table 4 probably took up most of their water from precipitation.

Cesium-134

Cesium-134 is a fission/activation by-product of nuclear reactor operation and is not ordinarily associated with nuclear explosions unless cesium is abundant in the materials near the explosion. With no evidence of a source of Cs-134 on Amchitka and with Sample 2 intentionally and blatantly under atmospheric influences rather than surface or groundwater influence, the Cs-134 in Sample 2 is attributed to fallout from the Chernobyl power reactor accident at the end of April 1986.

Cesium-137

Cesium-137 (Cs-137) is a fission product of both uranium-235 and plutonium-239, and it remains in the environment from nuclear weapons explosions conducted in the atmosphere through the 1960s, and from a few later explosions. Cesium is an alkaline metal that readily forms monovalent (Cs^{+}) ions in water. Cesium is highly mobile in groundwater, as evidenced by the detection of Cs-137 in all 13 samples.

Subtracting the contribution of Chernobyl to the Cs-137 in Sample 2, the samples having the three highest Cs-137 activities (greater than 0.5 pCi/g) in Table 4 (3, 11, and 12) are also the three samples in which americium-241 has been detected. This suggests the possibility of a qualitative association between Cs-137 above 0.5pCi/g(ash) and americium-241, so Cs-137 may be an obvious indicator of the presence of americium-241 in aquatic vegetation.

Americium-241

Americium-241 (Am-241)(half-life of 432.7 years) is the beta decay product of plutonium-241 (Pu-241)(half-life of 14.4 years) which is co-produced with Pu-239 and Pu-240 in nuclear reactors. Plutonium isotopes and Am-241 were dispersed through the atmosphere by above-ground nuclear explosions in the 1960's. For the latitude band 40-50° north, the fallout ratio of americium-241 to Pu-239/-240 is about 0.43.[68]

Pu-239-240 from fallout is routinely reported in biota worldwide. Although Am-241 is readily detectable by alpha spectrometry, often used for plutonium analyses, and gamma spectrometry, routinely employed to analyze for Cs-137 fission product in fallout, there are few reports of Am-241 in biota.

Americium-241 was found in a plankton sample (0.22 pCi/g[dry]) collected from Moruroa Lagoon on June 3, 1987 and reported by the Cousteau Foundation.[69] Moruroa is the site of French underground nuclear explosions in the Pacific Ocean. According to Cousteau, the French Atomic Energy Commission used even smaller safety factors for containment of nuclear explosions than the Americans used at Amchitka. Critics of the French nuclear weapons program have long contended that radioactivity has leaked from several of their underground explosions.

Am-241 is discharged into the Irish Sea from the Sellafield nuclear reprocessing plant. By 1985, Am-241 had become the largest contributor to individual radiation exposure for consumers of Irish Sea fish and shellfish.[70]

Americium-241 is not ordinarily reported in biota contaminated by atmospheric fallout. While Pu-239/-240 is reported in Arctic tundra ecosystems, Am-241 is not.[71] A literature search has failed to reveal any reports of Am-241 in Arctic mosses.

Moss samples collected at 47-48 north in western Washington State in 1996 and processed and analyzed as in the present study have never yielded any gamma peak at the 59.5 KeV energy of Am-241 (automatic software peak search with sensitivity =3.0).

DOE and other government agencies have routinely monitored Amchitka biota over a quarter century since the three underground nuclear explosions on the island. No reports of Am-241 in Amchitka biota have been found, although the government has supplied incomplete data lacking full gamma spectral analyses and there is no indication that they were looking for americium-241.

Americium-241 may be incorporated into food chains only under certain geochemical conditions. Americium has unique thermal-chemical properties which affect its behavior following a hot nuclear explosion in which it is present. Americium is relatively volatile and tends toward divalency at high temperatures. Upon cooling, americium favors trivalency. Compounds formed hot would thus tend to become monovalently positive ions upon cooling and solution in water.[72] Such monovalent americium-compound ions might be expected to mimic cesium ion migration in natural groundwaters. Contrarily, Am-241 released from above-ground nuclear explosions would have cooled before forming compounds. Thus, valency and solubility distinctions can be made between Am-241 released from above- and underground explosions, although the details remain unknown.

One hypothesis to explain the positive Am-241 results of Table 4 is that the americium-241 would be attributable to fallout from above-ground nuclear explosions in the 1960's.[73] The hypothesis is that the wet samples—that is, all but Sample 2—include sediments which to a greater or lesser extent are retained with the biological samples. Further, the detected Am-241 would reside in the particulate sediment fraction which contains Am-241 from fallout, not in the biological fraction contains dissolved Am-241 from leakage. That is, the samples with a larger sediment fraction would be the ones to test positive for Am-241 because the Am-241 is in the sediment and not incorporated into the moss and algae.

This fallout hypothesis has been tested by examining the ratios of dry weight to total ashed weight, which have been listed on the right side of Table 3. A low ratio, such as 1.8 for Sample 6, indicates that the dry sample contained a large fraction of sediment which was not volatilized by ashing. A high ratio, such as 14.1 for Sample 3, indicates little contribution of sediment so that the weight of the sample was greatly reduced by volatilizing the tissue content.

This fallout hypothesis thus implies that if the dry-to-ash weight ratios are arranged in increasing order (so there is more sediment contribution at the beginning of the list), the list would begin with the sample containing the highest Am-241 activity (=Sample 3), which would be followed by the sample having the second highest Am-241 activity (=Sample 11), followed by the sample with the third highest detected Am-241 activity (=Sample 12), followed by the other nine samples with no detectable Am-241.

The list of weight ratios for wet samples in increasing order is as follows:

Sample:	#6	#8	#7	#5	#12	#9	#1
#10	#13	#11	#4	#3			
Dry/Ash:	1.8	3.0	3.3	3.9	4.2	5.2	6.2
6.3	7.4	7.9	10.1	14.1			
Am-241:	ND	ND	ND	ND	0.03	ND	ND
ND	ND	0.06	ND	0.15			

Representatives from Greenpeace collected plant samples on Amchitka Island in June of 1996.

The samples containing the greatest sediment content are thus seen to be the samples with no detectable Am-241 content. The three samples containing detectable Am-241 are arranged in order, with greater Am-241 values corresponding to lesser sediment content. Therefore, the hypothesis that the detected Am-241 is due to fallout and resides in the sediment fraction is rejected. This test supports the conclusion that the detected Am-241 resides within the biological matrix and comes from dissolved Am-241 in leakage rather than from particulate Am-241 in atmospheric fallout.

The government guarantee that there is no possibility that leakage would have gone undetected by government agencies provides a logical test: If any unreported radioactivity which might reasonably result from leakage is detected, this is prima facie evidence that it is in fact leakage.

We have thus considered five kinds of evidence of the source of the detected Am-241:

1) appearance of in situ samples;
2) rare and particular detection of Am-241 in biological samples;
3) explanatory theory accounting for unique, positive Am-241 results;
4) successful test against fallout hypothesis;
5) official definition of detection condition—prima facie evidence.

Based on these considerations, detection of Am-241 at routine monitoring levels in particular biological samples taken from surface- or groundwater flows downgradient from two of the three underground nuclear explosions on Amchitka is here concluded to be detection of radiological leakage from upgradient nuclear explosions.

Americium-241 found in aquatic vegetation demonstrates leakage.

- Am-241 in Sample 3 shows that Long Shot is leaking long-lived radioactivity into the local surface waters.
- Am-241 in Sample 11 shows that Cannikin is leaking long-lived radioactivity from groundwater into surface waters about a mile from ground zero.
- Sample 12 shows that the leakage of Am-241 into the White Alice drainage is large enough to measurably contaminate vegetation in a stream flow of roughly one cubic foot per second. Because of this large flow rate, the detection of Am-241 in Sample 12 is by far the most important radiological result of this study. Given the location of Sample 12 at the base of White Alice Falls just above the high water mark, this result indicates that monitorable Am-241 is leaking from the Cannikin explosion into the Bering Sea.

Although the biological implications of these discoveries at Amchitka are unknown at present, Am-241 (half life of 432 years) is considered to be about as toxic as plutonium, which is highly toxic. In humans, Am-241 is concentrated in the liver where it resides for 40 years (biological half life), and Am-241 accumulates on endosteal surfaces of bone where it is retained for 100 years (biological halflife).[74]

Following the unequivocal detection of Am-241, the laboratory performed further analyses to "fingerprint" the radioactive leakage from Cannikin and Long Shot. Results are summarized in Table 4. These analyses suggest that plutonium-239/-240 accompanies Am-241 in these particular Amchitka sample media at a ratio close to one to one. Plutonium-239 has a half life of 24,110 years.

Because Am-241 is not ordinarily detectable in environmental samples, the ratio of Pu-239/-240 to Am-241 is seldom defined. An exception was Cousteau's plankton sample from the Moruroa nuclear site in French-occupied Polynesia which yielded a ratio of these Pu/Am isotopes of 43. Relative to Cousteau's Moruroan plankton, Greenpeace's moss/alga samples were enriched in americium or depleted in plutonium.

Previous Monitoring Failed to Detect Leakage.

The AEC planned for all radioactivity resulting from the three nuclear explosions at Amchitka to be contained underground, but their designs were flawed because they based them on experience at the relatively dry Nevada Test Site. With the benefit of hindsight, it now seems that those who planned the nuclear explosions under Amchitka might have anticipated Cs-137 and Am-241 leakage in ground water systems. But once the mistake was made, how was it possible that dozens of government radiological survey and monitoring efforts have entirely missed leakage from Long Shot and Cannikin?

Long Shot has long been known to be a little leaky, although it never made the government's containment failure list. In the case of Long Shot, "small" discharges of gaseous radioactivity were detected beginning with traces of radioiodine a month after the explosion. This detection was followed by radiokrypton in soil gas and tritiated surface water a few months later. Tritium has consistently been identified in subsequent radiological monitoring of Amchitka. The list of radionuclides seeping from Long Shot had admittedly grown excessive, as noted by the Atomic Energy Commission in 1973.[75]

Sample 3 of the present study shows that the government's conceptual model of leakage from Long Shot is inadequate and that non-gaseous Cs-137 and Am-241 should be added to the list of leaking radionuclides.

In the case of Cannikin, the explosion was either too large or the borehole was not deep enough to achieve mechanical containment. The mechanical containment failure was evident, with the collapse of the land surface east of ground zero. The Atomic Energy Commission put too much explosive down a shaft that was too short.

After the explosion, government scientists failed to report the significance of the disappearance of White Alice Creek into the blast depression. The blast had created a highly permeable zone down to a great reservoir of heat, and the water was already on its way to radioactivity 38 hours after the explosion. The heat released from Cannikin drove an irregular pattern of advective circulation that carried contaminants from the radioactive source of this heat up into Cannikin Lake and out into the newly blasted hydrological system. Any hopes that the groundwater circulation might have somehow returned to its pre-Cannikin patterns were dashed with the discovery that the surface water discharge from the White Alice drainage basin only regained 80% of its former flow after Cannikin Lake filled.[76] This warned that a large new, groundwater system had been created by the explosion, and the new system was likely to carry contaminants.

Leakage from Cannikin could have been detected by conventional gamma analysis of known indicator vegetation in the White Alice drainage area. Leakage could have been identified on the basis of high Cs-137 or Am-241 detection. A follow-up study could have located and sampled the main points of contaminant discharge, probably yielding radionuclide concentrations tens or hundreds of times those reported in our initial survey and identifying additional co-leaking radioactivity.

If government officials had allowed objective review of the Cannikin explosion after the collapse of the land east of ground zero and the disappearance of White Alice Creek into the abyss, they would have had to admit they made a terrible mistake in the face of strong public opposition.

Review of the literature in light of the present results suggests that radioactive leakage from the Cannikin blast has never been detected or reported, because the government officials deliberately avoided looking for leakage in the new groundwater system that they had created. They simply could not bring themselves to make the statement that "Cannikin is leaking transuranics into the Bering Sea." At least two out of three nuclear explosions at Amchitka and at least 80% of the nuclear yield detonated there is connected to leakage pathways that are delivering long-lived radioactivity to the open environment. Cannikin leaks and because Am-241 has a halflife of 433 years, this leakage will persist for the next few thousand years unless remedial action is taken.

The next step toward remediation is to characterize the main flow pathways along which the Am-241 is migrating and to identify other contaminants in the leakage. Choke points on the main pathways could then be sealed to thwart the flow of contaminants to the open environment. Because this will alter the hydrologic flow again, it will be necessary to monitor the effects of the first round of remediation and to undertake one or two more rounds of remediation, if radioactive leakage from Cannikin is to be reduced to minor levels.

Recommendations

1 Present leakage from the Cannikin, Long Shot, and Milrow explosions should be characterized with the aim of achieving remediation to levels that would not be readily detectable in discharges to the environment.

2 The government should declassify military secrets that affect environmental and human health.

3 A comprehensive critical assessment of pathways and exposure routes of radiological and toxic contamination of Amchitka is urgently needed to identify all major contamination sources. Meaningful involvement in the design and review of scientific studies by the Aleut communities and the general public should be established immediately. EPA should place Amchitka Island on the Superfund National Priorities List to ensure maximum public oversight of cleanup.

4 Epidemiological assessments should be conducted for workers and proximate communities by credible and independent scientists. Workers and other potentially exposed populations should be afforded full disclosure of information on exposure; and granted their right to medical care and compensation.

5 Based on the discoveries made in this first-ever, unrestricted study of an American nuclear weapons test site, all sites of the production, storage, and testing of nuclear weapons should be opened to critical independent environmental monitoring in the public interest. All nuclear weapons test sites should be permanently closed to further nuclear detonations. Steps should be taken immediately to remediate nuclear weapons test sites.

6 Nuclear nations must work quickly to eliminate the 21,000 nuclear weapons remaining in their arsenals. The United States and Russia, with 95% of the remaining nuclear weapons, must take leadership in the elimination of nuclear weapons.

With the signing of the Comprehensive Test Ban Treaty, nuclear powers should now acknowledge that the production, storage, transportation, testing, and continuing threat of nuclear war pose too great a risk to the environment and human health.

Summary

■ In June 1996, Greenpeace returned to Amchitka in the Aleutian Islands of Alaska and conducted the first independent research expedition to a nuclear test site that was not restricted by military intervention.

■ The site under investigation was the site of the Cannikin nuclear detonation, the largest underground nuclear test explosion in U.S. history; and the two other nuclear test sites on the island (Long Shot and Milrow).

■ The nuclear bomb used in the Cannikin test was placed 1,000 feet too close to the surface and breached containment.

■ The Atomic Energy Commission claimed that the nuclear waste from the detonations would be contained for hundreds, if not thousands of years.

■ The Department of Energy has withheld information about leakage from the Cannikin nuclear test site. Sampling reports from the Department of Energy made public over the past 25 years revealed no leakage of radioactivity into the environment from the Cannikin nuclear test.

■ Sampling by Greenpeace in 1996 demonstrates that plutonium-239/240 and americium-241, a decay product of plutonium, are leaking from the Cannikin blast cavity into White Alice Creek and the Bering Sea.

Glossary of Terms

Alpha radiation: radiation comprised of helium atoms that are released with the disintegration of heavy elements such as uranium-238 and radium-226. Because they travel only short distances, alpha particles can do great damage if inhaled or ingested, but cannot penetrate human skin or a piece of paper.

Beta radiation: radiation containing high-speed electrons (elementary particles with a negative electrical charge) or positrons (positively charged particles equal in mass to an electron). Beta particles have relatively small mass and are thus relatively fast. They can penetrate skin, but deposit their energy in a larger volume of tissue and therefore cause less concentrated damage than alpha particles.

Curie: a unit of radioactivity equalling 37 billion disintegrations per second.

Fission: splitting of the nucleus of an atom into two or more parts. Uranium-235 and plutonium-239 are fissioned with the bombardment of neutrons, thus releasing enormous energy and fission products (including such isotopes as cesium-137, strontium-90 and iodine-131).

Fusion: combining or fusing of atomic nuclei usually involving lighter elements such as hydrogen isotopes.

Gamma radiation: electromagnetic radiation capable of travelling long distances and penetrating the entire human body. Gamma rays resemble x-rays, but have higher energy.

Half-life: the amount of time for half the quantity of a radioactive material to decay.

Isotope: a form of an element with differing numbers of neutrons, but equal numbers of protons.

Kiloton: one thousand tons of TNT equivalent.

Megaton: one million tons of TNT equivalent.

Picocurie: one-trillionth of a curie.

Radionuclide: a radioactive isotope.

Transuranic element: an element with an atomic number greater than that of uranium.

Yield: the energy released by a nuclear explosion.

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