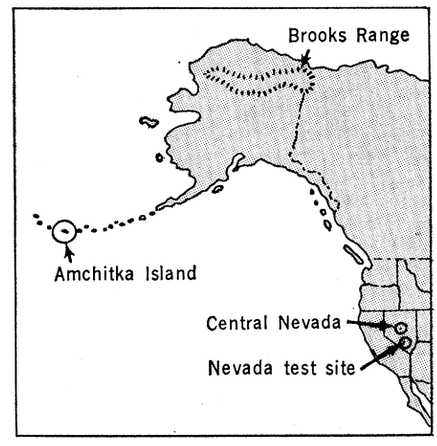
Earthquakes and Nuclear Tests: Playing the Odds on Amchitka



The nuclear test ban treaty of 1963 still stands out as the principal accomplishment in the field of arms control, but, while the treaty eased the universal concern about radioactive fallout, it by no means stopped the testing of nuclear weapons—it simply moved such testing underground. That this would be the case was, of course, clearly understood when the treaty was signed, though the negotiators agreed that they should look to the ultimate goal of extending the ban to underground testing. What most people probably did not understand was that underground tests would eventually be carried on at such high "yields" as to raise fears that they might trigger large, destructive earthquakes and tsunamis, the sea waves that major earthquakes sometimes generate.

Underground testing also raises the possibility of other environmental hazards, such as the release of radioactivity into the atmosphere by accidental "venting," the contamination of groundwater, and the damaging of property by ground shock attributed directly to the nuclear explosion. On the whole, however, the Atomic Energy Commission can claim an excellent safety record for its test program, which it conducts for the Department of Defense. Yet, as the AEC goes to testing in the multimegaton range, a number of scientists are expressing concern that the agency's assurances that the tests will be carried out safely may prove to be unjustified. And, of the possible dangers, the one involving the most unknowns and uncertainties seems to be the earthquake and tsunami hazard.

In October the AEC will detonate a "device" of about 1 megaton on Amchitka Island, in the Aleutians. Amchitka is in an earthquake-prone area and, though the island itself has been well mapped geologically, relatively little detailed geologic information is available for the area offshore.

The test this fall, to be known as Milrow, will be a "calibration" shot, designed not to test a new nuclear warhead but to allow the AEC to determine whether Amchitka is a safe place for two weapons tests at yields which apparently will go up to several megatons. These latter tests are understood to be related to the development of warheads for the antiballistic missile. The 1-megaton Milrow test itself represents a leap forward at the Amchitka site, for the only previous test conducted on the island was the 80-kiloton Long Shot explosion of 1965.

The probability of the Amchitka test series causing a major earthquake and tsunami is considered low by the experts who have been concerned with this question, but, as one put it, "not vanishingly small." This much is conceded by the AEC, but the agency view is that the chance of a destructive and far-reaching disturbance is so slight as to be no cause for public concern.

Tsunami Hazard

Not all the experts see it that way. One of those who does not is Frank Press of M.I.T., a leading seismologist who served on a panel of the President's Science Advisory Committee which last year studied safety aspects of underground testing. Press agrees that the probability of a nuclear test triggering a large earthquake is "very small," and, further, that, if such an earthquake occurred, its effects probably would be confined to the thinly inhabited Aleutians. But, he adds, should an earthquake so induced turn out to be one that causes a destructive tsunami, the consequences could be disastrous. Tsunamis originating in the Aleutians have caused loss of life and heavy property damage in far-distant places, such as Hawaii and Japan.

Concern about the possible triggering of earthquakes by nuclear testing is based partly on observations made after recent tests in Nevada. The largest tests ever carried out at the AEC's Nevada Test Site have been Boxcar, a 1.2-megaton shot in April 1968, and Benham, a 1.1-megaton shot in December. Some intriguing seismic effects having been observed after earlier shots, the Boxcar and Benham events, especially the latter, were instrumented for seismic measurements more heavily than past tests had been.

According to the AEC, each of these shots caused linear fracturing and faulting for a distance of nearly 5 miles on Pahute Mesa, where the tests occurred, thus producing displacements similar to those observed in some earthquakes. Although most, if not all, the displacement is believed to have occurred within seconds of the explosion, the seismic activity continued long after the shots, some 10,000 aftershocks having been recorded during the 4-week period following Benham.

All the aftershocks that have followed Benham and other tests in Nevada have been much smaller than the shocks caused by the shots themselves, which the AEC takes as an encouraging indication that its tests are going to father nothing monstrous. However, seismologists see an evident need for further study of the seismic effects of nuclear events to determine how the effects vary with explosions of different yields and under different geologic conditions—and, above all, to try to learn more about the mechanism by which earthquakes and their aftershocks occur. "Right now, we have very little basis for extrapolations," an earthquake specialist with the U.S. Geological Survey told *Science*. In fact, a principal purpose of the Milrow calibration test is to determine whether the findings from events such as Benham and Boxcar can be applied to Amchitka.

Amchitka is not easily compared with the Nevada Test Site. The Nevada site is deemed by the AEC to be unsuitable for tests of much above 1 megaton. Principally, this is because of the effect of direct ground shock from high-yield explosions on tall buildings in Las Vegas—and on industrialist Howard Hughes, a Las Vegas resident, who

lately has been harrying the AEC about possible environmental hazards.

The Nevada Test Site and the area immediately surrounding it do not constitute a region of high seismicity, although several important active fault systems, such as the San Andreas and Death Valley faults in California, can be found some distance away. North of its original test site, the AEC has developed a Central Nevada site primarily for the testing of weapons larger than Boxcar and Benham and smaller than those to be tested on Amchitka. It, too, is fairly remote from areas of high seismicity and is farther than the original site from Howard Hughes and Las Vegas.

Although no large earthquake is known to have originated on Amchitka Island proper, the Aleutians are part of the circum-Pacific seismic belt and make up one of the most earthquake-prone areas on earth. The Rat Island Earthquake of 1965, which originated 20 miles from Amchitka, was the largest one to occur that year anywhere in the world but caused no seismic or tsunami damage to populated areas.

Contributing to the concern that a high-yield underground explosion might trigger a large earthquake in the Aleutians is the explanation some leading seismologists are now offering about the origin of major earthquakes. In a paper prepared for the April meeting of the American Geophysical Union, James N. Brune of California Institute of Technology said that a study of such events "suggests that in many cases large earthquakes may be considered successions of triggered events rather than smoothly propagating ruptures." Brune noted, for example, that the first event of the Great Alaskan Earthquake of 1964 had a Richter-scale magnitude of only 6.5, whereas the largest event in the sequence had a magnitude of 7.8—an enormous leap on the scale. The deep South American shock of 15 August 1963 also was a succession of several distinct events, he said.

A Nuclear Trigger?

In an interview with *Science*, Brune said, "There is no logical reason why a nuclear explosion couldn't be the initiating event in such a series of events. The larger the explosion, the greater the possibility of its triggering such a series." The same is true, he said, for a naturally occurring earthquake; the bigger it is, the greater the chance of its initiating a series of earthquakes.

According to Melvin L. Merritt of the Sandia Laboratories at Albuquerque, New Mexico, which has taken part in the AEC's seismological studies, the Amchitka tests will be fired at a distance of from 30 to 100 kilometers from the seismic zone associated with the Aleutian thrust fault. Unlike some fault systems, such as the San Andreas fault, which are visible on the earth's surface, the great Aleutian thrust fault is buried deep in the earth. Brune had no comment on the Amchitka tests, as he was unfamiliar with the situation there, but he observed: "I would think that scientists would be very hesitant to fire off a large nuclear explosion 30 kilometers from the San Andreas Fault. One hundred kilometers would be better, but I'd still be a little worried about it."

People in Alaska, having the great 1964 earthquake still in mind, are more than a little worried, despite the AEC's assurances that, even if a test shot should cause an earthquake, the state's populated areas would be unharmed. To protest the Amchitka test series, a "Save Our State" (SOS) group was formed recently in Anchorage, with some of the state's most prominent citizens taking part.

In May, Senator Mike Gravel of Alaska proposed that the President appoint, from outside government ranks, a body of experts to look into the question of nuclear tests and their seismic effects. His proposal was cosponsored by several senators, including Alan Cranston of California and Edmund S. Muskie of Maine. It has been referred to the Joint Committee on Atomic Energy, which, confident from inquiries by its staff that the Amchitka tests will be safely conducted, seems unlikely to take any action that might

A complex array of experimental equipment is deployed for an underground nuclear explosion that occurred at the AEC's Nevada Test Site in 1966. Note the subsidence crater (left of center) from a previous explosion.

delay the tests. Senator Gravel is reluctant to challenge the AEC's plans and has not asked for a postponement of Milrow.

The President's Science Advisory Committee (PSAC) panel on safety aspects of the test program delivered its report late last fall to Donald Hornig, President Johnson's Science Adviser. The report never has been made public, though the chairman of the panel, Kenneth S. Pitzer, president of Stanford and member of PSAC until this past January, says that to edit it and remove classified information would not have been difficult.

While the report did not declare that the Amchitka tests would involve unacceptable risks, the panel members appear to have looked at this test series dubiously. It had no mandate to consider alternative sites for the tests, but some of its members have told *Science* that the consensus within the group was that the north slope of Alaska's Brooks Range would be a safer place than Amchitka for high-yield tests. This area is not earthquake-prone and is mostly uninhabited. Further, the oil industry is currently demonstrating that large-scale drilling projects are feasible in this arctic region, despite its deep permafrost and harsh climate.

The AEC has felt that the north slope is acceptable only as an "insurance" site in case Amchitka cannot be used. It decided against the slope chiefly on the grounds that the costs there would be extremely high and the logistical problems very difficult. Had the agency decided otherwise, it would now probably be fending off criticism from conservationists fearful of the impact that the test program would have on the fragile tundra ecology. Conservation groups also are concerned, however, about the ecological impact of the test program on Amchitka. The island is part of the Aleutian Islands National Wildlife Refuge and is a stronghold of the sea otter, a species once near extinction.

Gordon J. F. MacDonald of the University of California at Santa Barbara, a geophysicist who served on PSAC and the Pitzer committee, says that, if nuclear tests must be conducted on Amchitka for compelling reasons of national security, the precautions observed should include (i) increasing the shot yields gradually and (ii) closely monitoring the shots for seismic effects. Again, the consensus within the committee was that

NEWS IN BRIEF

• **FLORISSANT FOSSIL BEDS NATIONAL MONUMENT**: Congress has acted to preserve 6000 acres of the endangered Florissant fossil beds near Pikes Peak, Colorado, by making the site a national monument. The fossil beds, which scientists claim are "rich" in leaf and insect fossil species, were threatened by a real estate company that planned to bulldoze the site for a housing development (see *Science*, 6 June 1969). While Congress deliberated a bill to establish the monument, a citizen's group sought and obtained a temporary restraining order from a federal Court of Appeals to keep the real estate company from beginning excavation. By 9 August both Houses completed action on the bill to establish the Florissant Fossil Beds National Monument, which was sponsored by Representative Frank Evans (D–Colo.). The measure authorizes $3,727,000 for the Secretary of the Interior to purchase the fossil beds site. The bill still must be signed by President Nixon. Although the fossil beds have been designated as a national monument, the site will not be totally safe from destruction until funds are actually appropriated and the purchase of the land has been assured.

• **BIOCHEMISTRY CONFERENCE MOVED**: The 8th International Congress of Biochemistry, scheduled to be held in September 1970 in Rome, has been transferred to Switzerland. The Italian committee preparing the Rome conference said that student political pressure and a major academic reform bill in Parliament prevented it from devoting sufficient time to organizing the Congress in Italy. Student leaders, complaining of university overcrowding and a rigid faculty hierarchy, had threatened to demonstrate at the conference if it were held in Rome. The Congress is expected to be held from 3 to 9 September 1970 in Lucerne, Interlaken, and Montreux.

• **NEW WOODS HOLE DIRECTOR**: James D. Ebert has been named director of the Marine Biological Laboratory at Woods Hole, Massachusetts. Ebert succeeds H. Burr Steinbach who is retiring from that position in August 1970, but will still remain as dean of the Graduate School of the Woods Hole Oceanographic Institute. Ebert, who is director of the department of embryology of the Carnegie Institution of Washington, will wear two hats. He will continue in his present position with the Carnegie Institution, while assuming new duties at Woods Hole. Ebert, who is a past president of the American Institute of Biological Sciences and a National Academy of Science member, has served as a trustee of the Woods Hole Laboratory since 1964.

• **SULLIVAN NAMED TO PUBLISHERS COUNCIL**: Richard H. Sullivan, president of the Association of American Colleges and a member of the National Science Board, has recently been named managing director of the American Book Publishers Council, a trade association of book publishers. Sullivan, a former president of Reed College in Oregon, was chosen after the industry decided a leading figure from the academic community was needed to promote more interest in books.

• **UNIVERSITY DONATIONS INCREASE**: Despite campus disturbances last year private gift support for higher education has increased substantially. A survey of the Council for Financial Aid to Education shows that gifts to colleges and universities rose in fiscal 1968 to an all-time high—$1.57 billion, an increase of more than 8 percent from the previous year. Gifts for the fiscal year 1967 showed only a 3.3 percent increase over fiscal 1966, which, in turn, showed a decline of 1.2 percent from the previous year.

• **MARINE RESEARCH**: The first comprehensive catalog of U.S. marine research activities has been released by Edward Wenk, Jr., National Council of Marine Resources and Engineering Development executive secretary. *Marine Research–Fiscal Year 1968* contains descriptive summaries of more than 2500 unclassified marine research projects supported last year by federal and nonfederal organizations. The catalog on marine research, which is document number 1969-350-238, may be obtained for $5.50 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

these precautions would be wise, although the risk of triggering a large earthquake would not be eliminated altogether by increasing shot yields gradually. According to Frank Press, even a low-yield shot might be sufficient to release the energy which has naturally accumulated along faults where strains exist. Under its present plans, the AEC obviously will not be increasing shot yields by modest increments. Only three test holes have been drilled on Amchitka, one for this fall's 1-megaton calibration test, the remaining two for the testing of weapons too powerful to be detonated safely in Nevada.

F. R. Tesche, deputy director of the AEC's division of military applications, says that the agency's ad hoc panel on seismology, chaired by James T. Wilson of the University of Michigan, believes that the Amchitka test program does not involve an unreasonable risk. However, in response to inquiries by Senator Gravel, two members of that panel, Clarence R. Allen of Caltech's Seismological Laboratory, and Jack Oliver of Lamont-Doherty Geological Observatory, have endorsed the senator's proposal to establish an independent body of experts on nuclear testing and seismic safety. Furthermore, Allen said, "my confidence in [the safety of the Amchitka tests] would be much increased if our geological and geophysical knowledge of the area were greater, and if we were to progress to the large events by a series of increasing steps."

The AEC is responding to the recommendations for seismic monitoring. According to Tesche, five seismic stations are being established on Amchitka, two others are being set up on neighboring islands, and an as yet undetermined number will be installed on the seabed. The ad hoc panel, he says, is generally satisfied with the seismic network being established. Everything depends, Tesche adds, on the results of Milrow. "If anything coming out of this test is a substantial deviation on the worrisome side, AEC will not be able to continue," he says.

The possibility of large earthquakes and tsunamis being induced by nuclear tests is being cited by advocates of arms control. In an open letter to President Nixon, the Educational Committee to Halt Atomic Weapons Spread in early July urged that the United States seek a treaty banning all underground tests large enough to register above the "threshold" of 4.5, the seismic magnitude produced by a 10-kiloton shot fired in granite. The 1.1-megaton Benham shot, fired in a porous volcanic tuff, produced a seismic magnitude of 6.3. Seismic magnitudes vary widely, however, depending on whether a shot is fired in hard rock, in tuff, or in other material.

A number of prominent scientists, including Jerome Wiesner of M.I.T., George Kistiakowsky of Harvard, and Nobel laureate Polykarp Kusch of Columbia, were among the signers of the letter to Nixon. Among the reasons the letter cited for restricting underground testing were the possibility of accidental venting of radioactivity and the earthquake hazard.

On 31 July, a proposal to restrict testing was submitted by Japan to the Eighteen Nation Disarmament Conference in Geneva. The Japanese would fix the threshold at seismic magnitude 4.75. The concept of a threshold treaty is long familiar, but there has been renewed interest in it since June 1968 when the International Institute for Peace and Conflict Research in Stockholm (SIPRI) released the report of its seismic study group. According to the report, British, Canadian, American, and Soviet research indicates that the world's seismic networks will be able to identify positively nuclear explosions at yields down to 10 kilotons (fired in hard rock), thus distinguishing them from natural earthquakes. The SIPRI finding allows hope of avoiding the troublesome "on-site inspection" issue, on which proposals for banning all underground testing have foundered; the Soviet Union rejects the idea of allowing foreign inspectors to come on its territory to investigate suspicious seismic events.

It appears that the prevailing view among Nixon Administration officials who have considered the matter is that a threshold treaty would be difficult to negotiate—and, if somehow negotiated, hard to monitor without frequent quarrels over disputed interpretations of seismic data. And, further, that it would in any event have far less value as an arms-control measure than a treaty banning all nuclear tests. To stimulate progress in test detection and verification, the United States has proposed that seismic stations throughout the world closely monitor a 40-kiloton shot next month in Colorado demonstrating use of a nuclear explosion to increase recovery of natural gas.

All proposals for banning underground tests now appear to have a low priority on the U.S. arms-control agenda, for the proposed U.S.–Soviet talks on the limitation of strategic arms are still pending and several key nations—Japan, India, Israel, and West Germany—still have not signed the Nuclear Nonproliferation Treaty. Recently, the question of environmental hazards has stimulated increased public interest in the underground testing of nuclear weapons. But unless one of the forthcoming Amchitka shots happens to produce a disaster, the kind of public outcry that contributed to the success of efforts to ban tests in the atmosphere seems unlikely to occur.

—LUTHER J. CARTER

Trouble at NASA: Space Scientists Resign

The resignation of three top space agency scientists and a scientist-astronaut came to public attention recently in the wake of NASA's most glittering success—the Apollo 11 manned lunar landing. The resignations, which NASA officials say represent a "serious loss" to the agency, occur at a time when there is an undercurrent of dissatisfaction among scientists in general over NASA's alleged neglect of important pure science research goals in favor of engineering pursuits and the more glamorous technical aspects of space exploration. But the reasons for the resignations of the space scientists are complicated and seem not to be based on a single motive of disenchantment with NASA policies.

The four scientists leaving the program are Wilmot Hess, science director of the Manned Spacecraft Center in Houston; Elbert King, curator of the Lunar Receiving Laboratory in Houston; Donald Wise, deputy director of Apollo Lunar Exploration at NASA headquarters in Washington; and scientist-astronaut Curtis Michel,