U.S. NEWS

Nuclear Waste Piles Up—in Budget Deficit

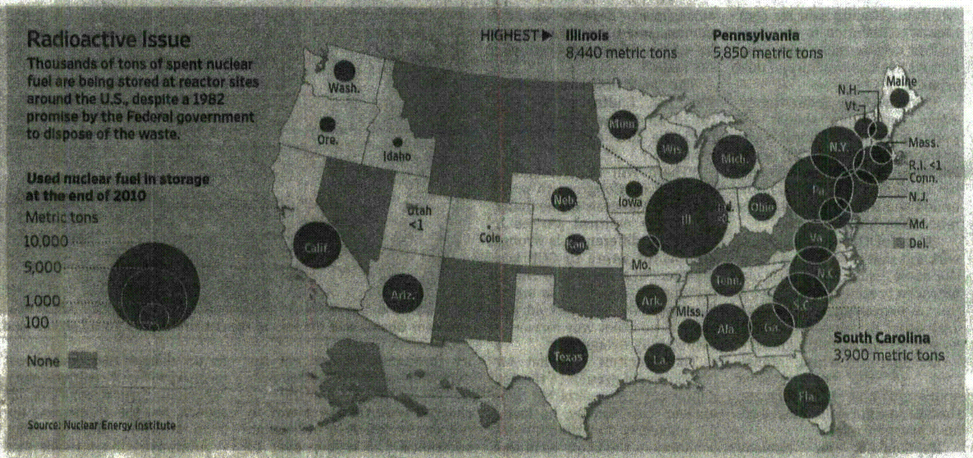
Tab for Disposal, in the Tens of Billions, Is on Taxpayers as U.S. Searches for a Site and Dedicated Fund Proves Illusory

BY MARK MAREMONT

Imagine a football field packed 20 feet high with highly radioactive nuclear waste. That's about the volume of the 65,000 metric tons of spent nuclear fuel stranded at dozens of nuclear sites across the U.S.

It isn't just a potential public health hazard, as Japan's recent nuclear disaster showed, but a growing burden on the federal government's groaning finances.

A decades-old promise to dispose of the waste has become another unfunded liability, starting with a $25 billion ratepayer fund gone astray and $16 billion or more in estimated legal judgments to compensate utilities for their storage expenses. The costs of the ultimate disposal project also are sure to rise, with no plan in sight to replace the now-canceled plan to entomb the waste at Nevada's Yucca Mountain.



In a draft report issued late last month, a presidential panel recommended overhauling the waste-disposal project to make it more self-financing. But that would increase the federal budget deficit, a long shot in light of current deficit politics. The Obama administration has requested no funding for the disposal program in its fiscal 2012 budget, officials say.

Former waste-project officials say that the lack of assured long-term funding is a critical flaw in a decades-long capital project, and that over the years it exposed the Yucca Mountain plan to political meddling and budget cuts that added delays and contributed to its demise.

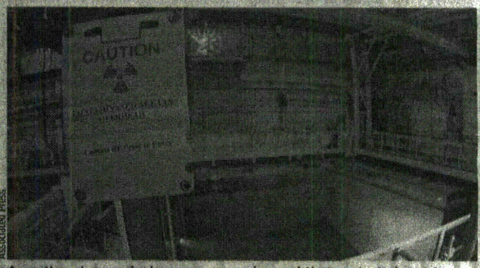
The project's funding arrangement is "fundamentally broken," said Ward Sproat, who headed the civilian nuclear-waste program during the latter part of President George W. Bush's administration. He said overhauling it was "absolutely essential."

Damien LaVera, a spokesman for the Department of Energy, said that "we fully intend to meet our contractual obligations for long-term disposal of these materials." He noted the panel's final report wasn't due until January, and said, "We are committed to finding a sustainable approach to assuring safe, secure, long-term disposal of used nuclear fuel and nuclear waste."

When the federal government took responsibility for nuclear-waste disposal three decades ago, taxpayers weren't supposed to be on the hook. Under a "polluter pays" doctrine, the 1982 law required nuclear utilities to shoulder the cost through an annual fee paid to the federal government. The fee was to be deposited in a newly created Nuclear Waste Fund that the U.S. Department of Energy could tap to fund the storage project.

The fee, which ultimately comes from nuclear-electricity customers as a surcharge of 1/10th of a cent per kilowatt hour, now amounts to about $750 million a year. Counting past expenditures and interest earned, the fund's balance is about $25 billion.

But that cash doesn't really exist. Since the Balanced Budget and Emergency Deficit Control Act of 1985, Congress and successive administrations have changed the plan so that the fees paid by utilities essentially are treated like taxes and go into the government's general coffers.



A caution sign marked an area around a pool that protected spent nuclear fuel at the Indian Point power plant in Buchanan, N.Y., in 2007.

Because the government failed to start taking spent fuel as promised beginning in 1998, utilities are suing it to cover their additional storage costs. Federal officials have estimated it will cost $16.2 billion to pay legal judgments owed to utilities by 2020—assuming the U.S. is able to start taking waste from utilities starting then—and $500 million a year after that.

A group of state regulators and the Nuclear Energy Institute, a trade organization, are suing the Department of Energy, seeking to suspend collection of the annual fees utilities pay into the waste fund. "There's no sense paying a fee if you're not getting a program for it," said NEI's Steven Kraft.

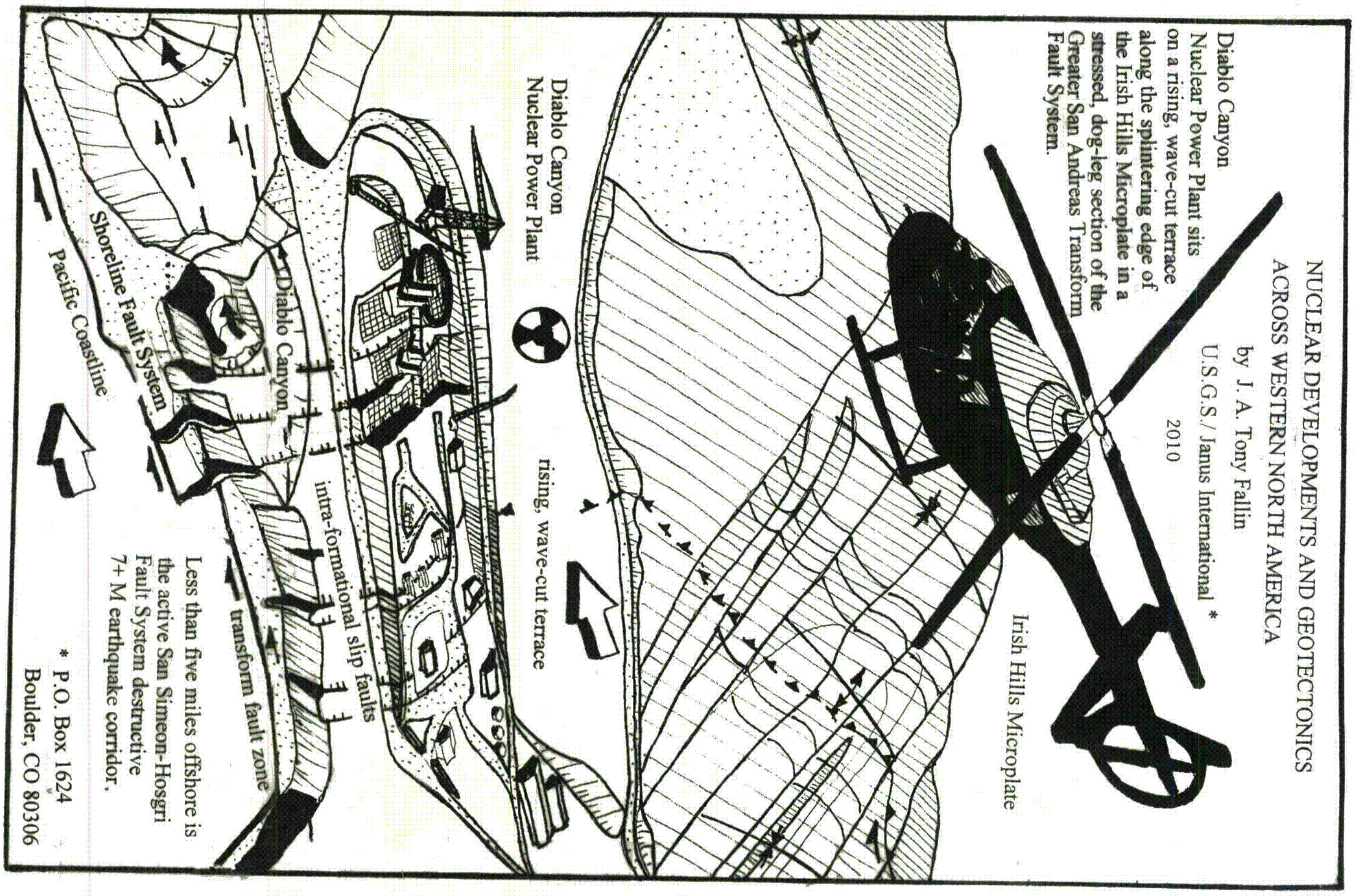
The draft report issued July 29 by the panel, the Blue Ribbon Commission on America's Nuclear Future, said the U.S. nuclear-waste disposal program had "all but broken down" and suggested a series of fixes. One recommendation was an overhaul of what it called the "dysfunctional" Nuclear Waste Fund arrangement.

The panel was formed last year by President Barack Obama, after the administration's decision to halt the Yucca Mountain project. The panel includes former elected officials from both major parties, along with academic experts and representatives of industry and labor.

One of the panel's proposals was to cut the annual fees collected from utilities to match the level of federal spending on the program. Uncollected funds would go into utility-run trust funds, to be tapped when needed for the waste project.

That would put the project onto sounder fiscal footing, the panel said, but would add to the near-term federal deficit because some of the utility fees wouldn't be counted as current revenue. Still, the panel draft report said, "the bill will come due at some point," because the government is contractually bound to remove the spent fuel.

Legal challenges to the Yucca decision are pending. If the plan is dead and the government has to find a new site, the ultimate cost of disposal almost certainly will rise.



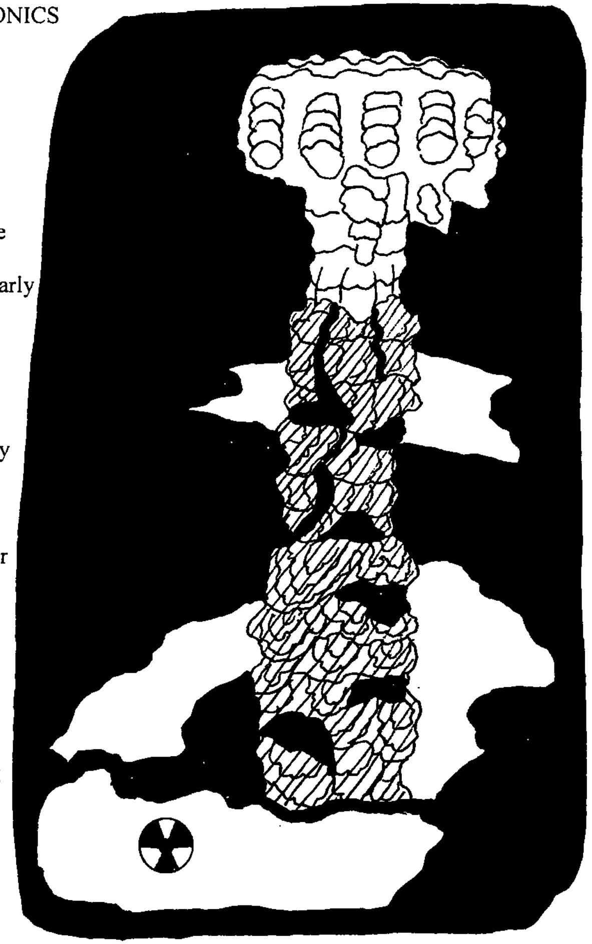
NUCLEAR DEVELOPMENTS AND GEOTECTONICS

ACROSS WESTERN NORTH AMERICA

by J. A. Tony Fallin, U.S.G.S./ Janus International

Introduction

The Nuclear Age in North America is a little more than 100-years-old, having begun during the early 20th Century with the study of atomic physics, and the discovery that radioisotopes like uranium-235, and plutonium-239 produce large amounts of energy during nuclear fission. Controlled nuclear fission was subsequently achieved in a small atomic reactor at the University of Chicago, leading to the development of the atomic bomb during World War II (WW II) in the 1940s. Post-WW II development of nuclear energy has continued ever since, generating millions of tons of radioactive waste (radwaste), while also expanding military arsenals, powering naval vessels, manufacturing medical isotopes, advancing atomic research, and producing large volumes of steam for seawater desalinization, and electric power generation.

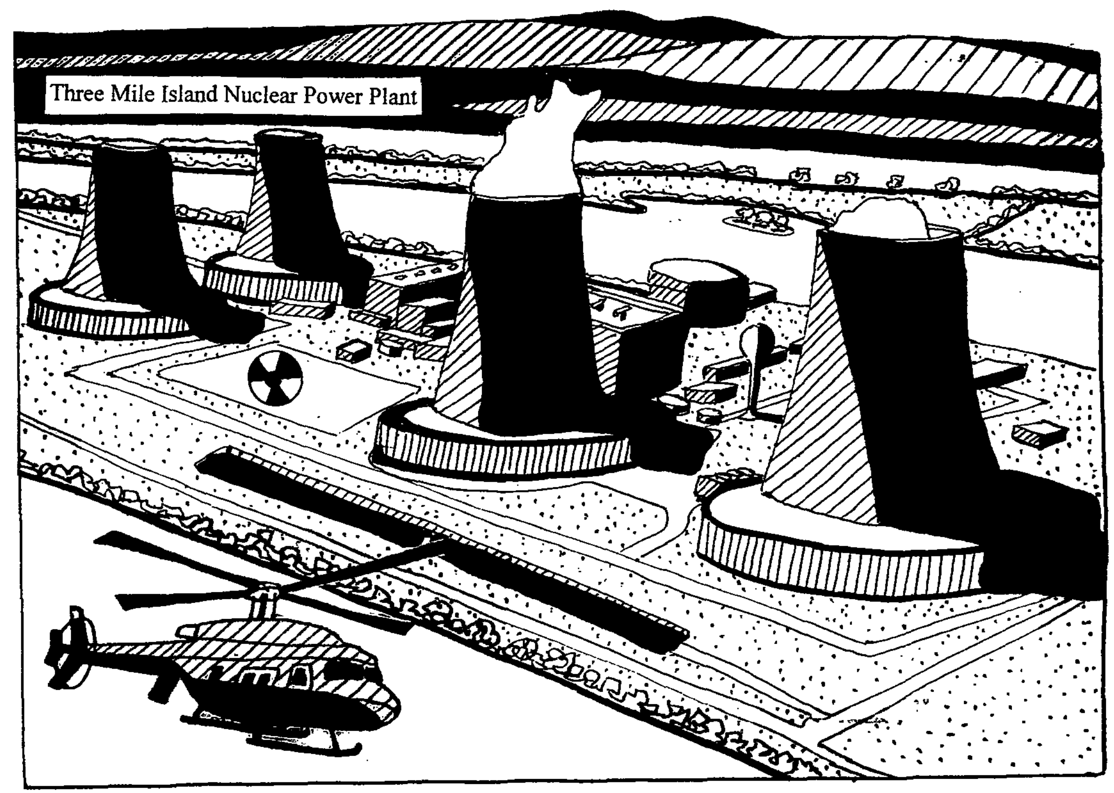


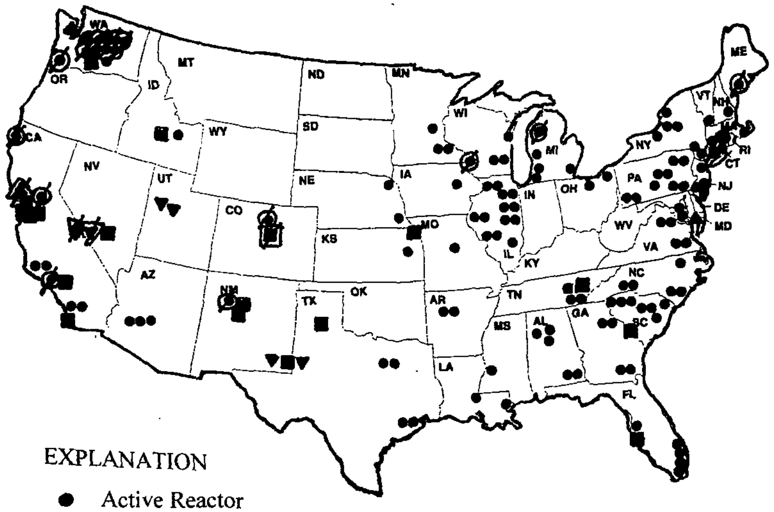
The Nuclear Age comes in with a BANG! A plutonium-239 fission bomb explodes over Nagasaki, Japan, in August, 1945

The post-WW II production of nuclear energy, and radwaste was managed almost exclusively by the Federal Government until 1954, when the U.S. Congress passed an act allowing private industry to assume control of commercial nuclear reactor research, and development. Ten years later, almost 200 American-built atomic reactors were operating across the United States, with more than half being used

for nuclear testing, and research, but also with 42 of the atomic power systems propelling naval vessels, and 18 others being used to produce steam at nuclear power plants.

The number of power plant reactors in the United States then grew to 110, before an 1979 partial core meltdown at the Three Mile Island Nuclear Power Plant in Pennsylvania prompted a 30-plus year moratorium on further reactor siting across the nation. Today, 104 of the 110 atomic reactors continue to operate in the U.S., while plans for at least 26 more units await Federal approval for further development. The reactors are generating upwards to 20 percent of the nation's electric power, and 70 percent of the emission-free energy in the country, while also producing thousands of tons of long-lived, high-level radwaste annually in the form of spent reactor fuel rods. With no national repository available at present, upwards to 80,000 short tons of radwaste are being stockpiled temporarily at 127 nuclear power plants, and other sites. The high-level radwaste is often submerged in open pools of water for up to five years, prior to being processed, and sealed in dry, steal and concrete casks while awaiting transport to a long-term storage facility.



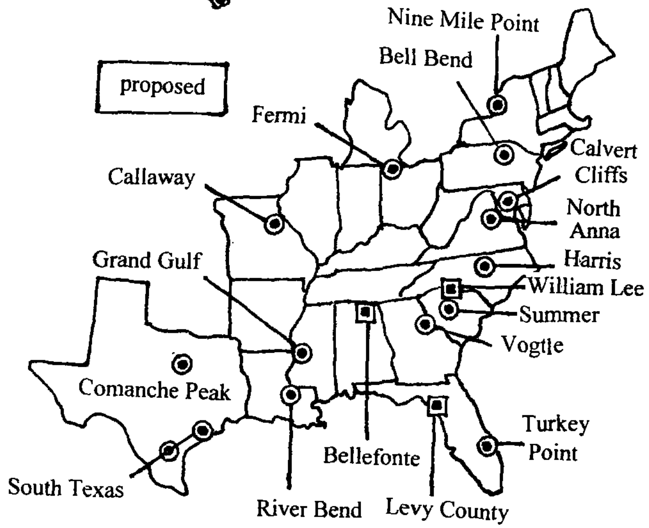


Map showing selected nuclear facilities across the United States

EXPLANATION

- ● Active Reactor
- ■ Active Lab/Plant/Test Site
- ▼ Active Radwaste Repository
- ▲ Active Naval Shipyard

Decommissioned/Discontinued Site



Today, 104 nuclear power plant reactors operate in the U.S., while plans for at least 24 more units await Federal approval for further development.

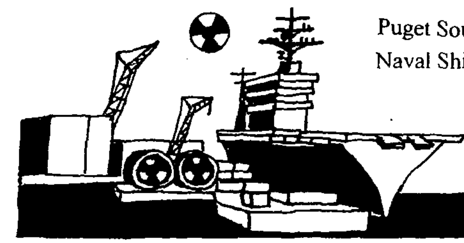
The vast majority of nuclear facilities in the United States today, excluding regional uranium mills, and thousands of uranium mines, are located east of the Rocky Mountains, with most being on relatively stable tectonic terrane, but many also over fresh-water aquifers. The eastern facilities include nuclear research institutions, National Laboratories, military installations, uranium enrichment facilities, private corporations, and radwaste storage sites, as well as 100 nuclear reactors at electrical power plants.

West of the Rocky Mountains, on much more active geotectonic terrane, are 25 other nuclear facilities, five of which function now only as radwaste storage sites after early operational shutdowns, or closures. Essentially all of the Western facilities are located over fresh-water aquifers, with most also lying on, or near active faults in earthquake corridors. Some of the nuclear facilities also sit in the shadow of active volcanos, while others are located along stretches of eroded coastline where they are subject to tsunamis, rogue waves, and seasonal storm surges. The active faults, and earthquake corridors reflect the effects of the Pacific Seafloor Plate wrenching western parts of the continental margin northwest as it collides obliquely with the North American Plate. Vulcanism in the Pacific Northwest is being generated inland from the active Cascadia Subduction Trench, i.e., where the continent is overriding Pacific seafloor microplates.

By geotectonic province, nuclear facilities that are located west of the Rocky Mountains in the United States include:

Olympic Peninsula Microplate

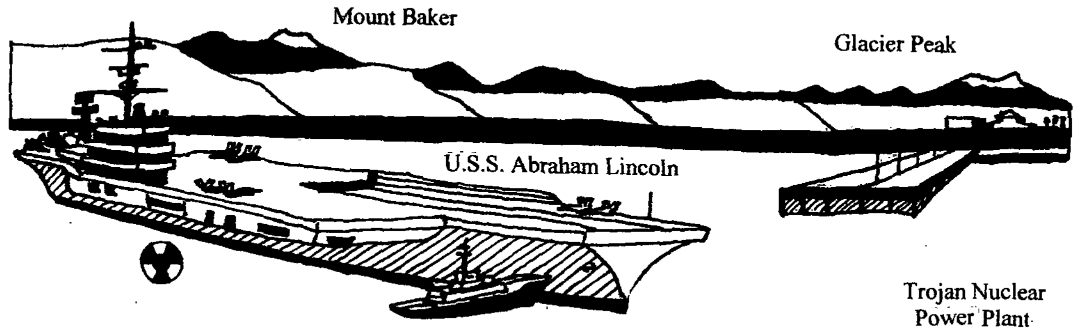
Puget Sound Naval Ship Yard, Washington



Puget Sound Naval Shipyard

Cascade Mountains Microplate

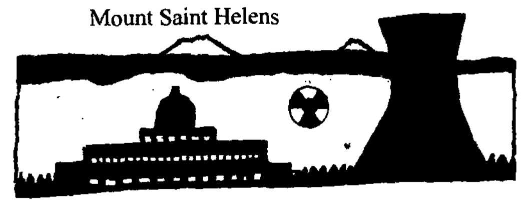
Naval Station Everett



Coastal Ranges Microplate

Trojan Nuclear Power Plant, Oregon*

Trojan Nuclear Power Plant



* Facility decommissioned, or closed, but with radwaste still stored on-site, 01-01-10

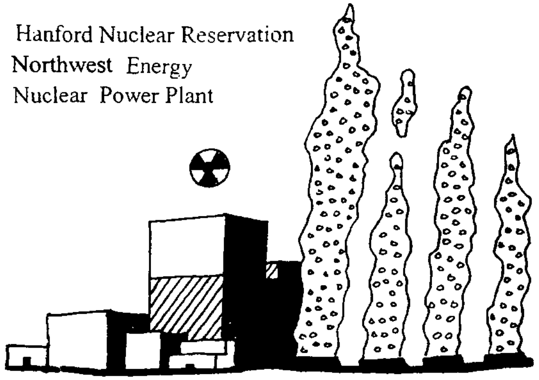
Columbia Plateau Microplate

Hanford Nuclear Reservation, Washington

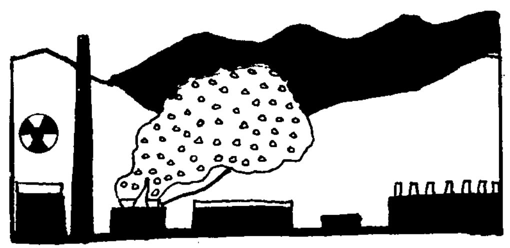
Snake River Plain Microplate

Idaho National Engineering, and Environmental Laboratory

Hanford Nuclear Reservation
Northwest Energy
Nuclear Power Plant



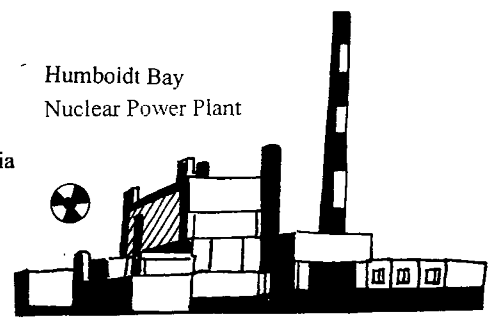
Idaho National Engineering
and Environmental Laboratory



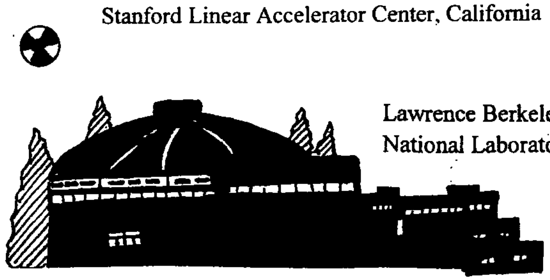
Greater San Andreas Transform Fault System Microplates

Humboldt Bay Nuclear Power Plant California*
Lawrence Berkeley National Laboratory, California
Lawrence Livermore National Laboratory, California
Vallecitos Radiation Laboratory, California
Stanford Linear Accelerator Center, California

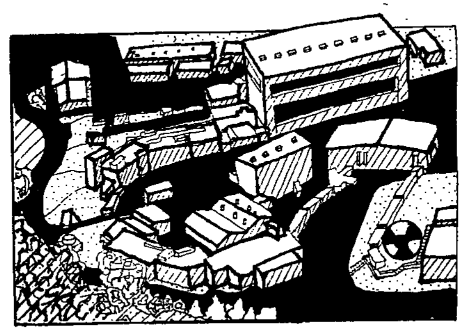
Humboldt Bay
Nuclear Power Plant



Lawrence Berkeley
National Laboratory



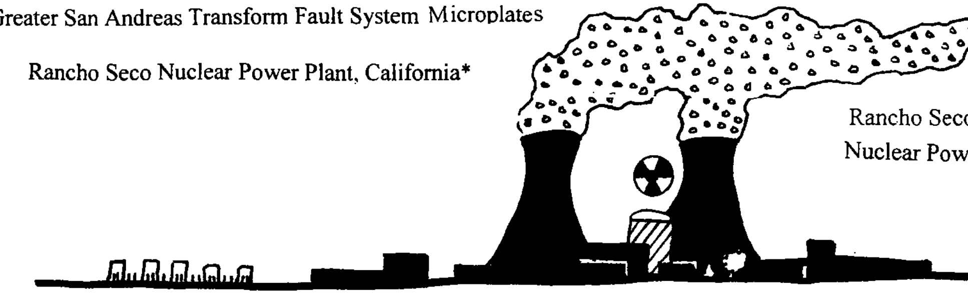
Stanford Linear Accelerator Center



Vallecitos Radiation Laboratory

Greater San Andreas Transform Fault System Microplates

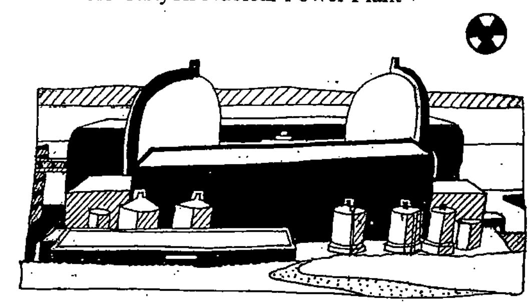
Rancho Seco Nuclear Power Plant, California*



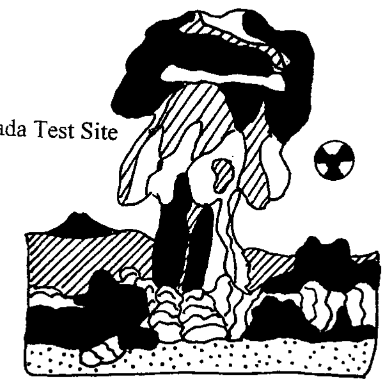
Rancho Seco
Nuclear Power Plant

Diablo Canyon Nuclear Power Plant, California
Santa Susana Field Laboratory, California*
General Atomics Corporation, California
San Onofre Nuclear Power Plant, California
Nevada Test Site
Yucca Mountain Repository, Nevada
Beatty Chemical, and Low-Level
Radwaste Repository, Nevada*

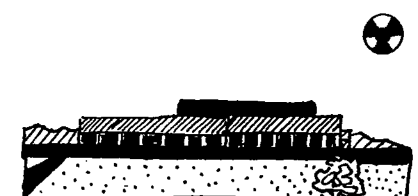
Diablo Canyon Nuclear Power Plant



Nevada Test Site

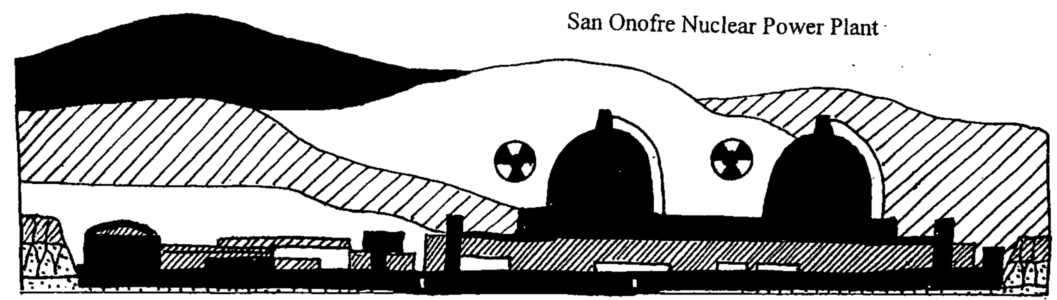


Yucca Mountain Repository



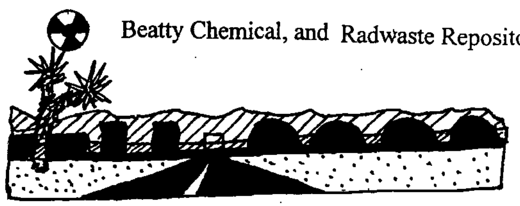
Field Operations Center

San Onofre Nuclear Power Plant



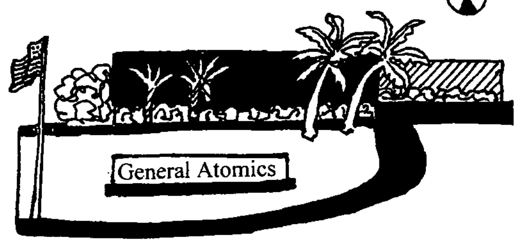
Greater San Andreas Transform Fault System Microplates

Beatty Chemical, and Radwaste Repository



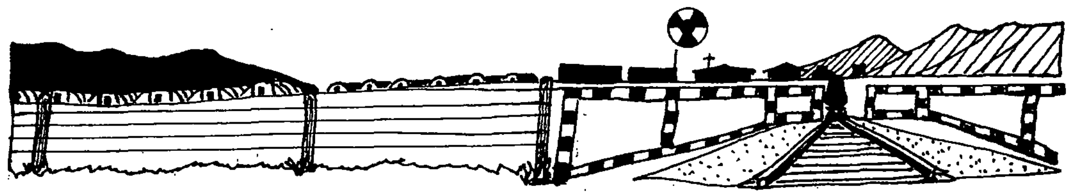
Great Basin Extensional Corridor

General Atomics Corporation

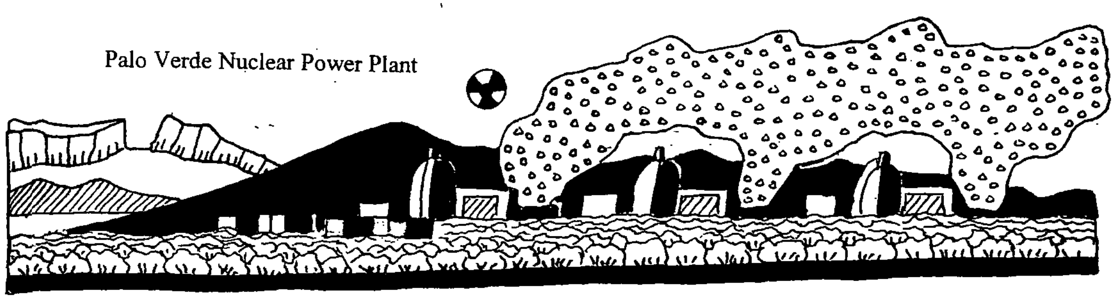


Tooele Army Depot, Utah
Envirocare Radwaste Repository, Utah
Palo Verde Nuclear Power Plant, Arizona

Tooele Army Depot



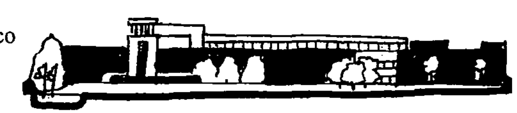
Palo Verde Nuclear Power Plant



Rio Grande Rift Extensional Corridor

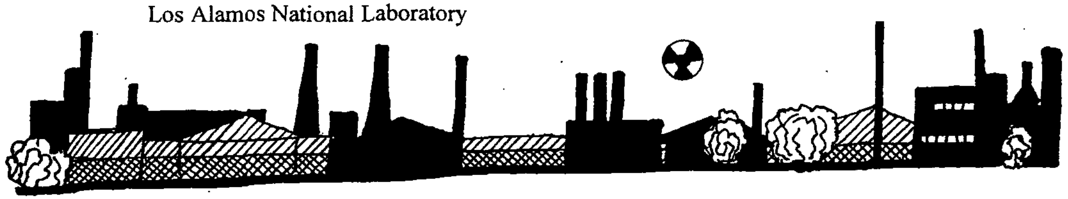
Los Alamos National Laboratory, New Mexico
Sandia National Laboratory, New Mexico
White Sands Missile Range, New Mexico

Sandia National Laboratory



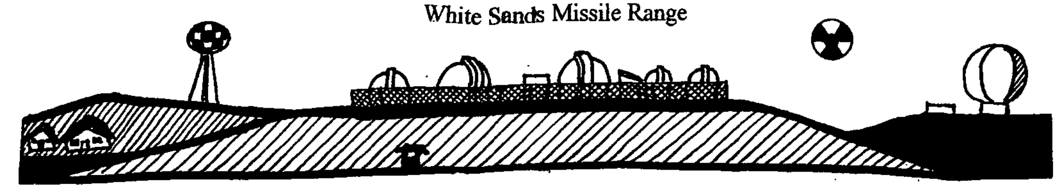
Rio Grande Rift Extensional Corridor

Los Alamos National Laboratory



Rio Grande Rift Earthquake Corridor

White Sands Missile Range



Mustang Radar Installation

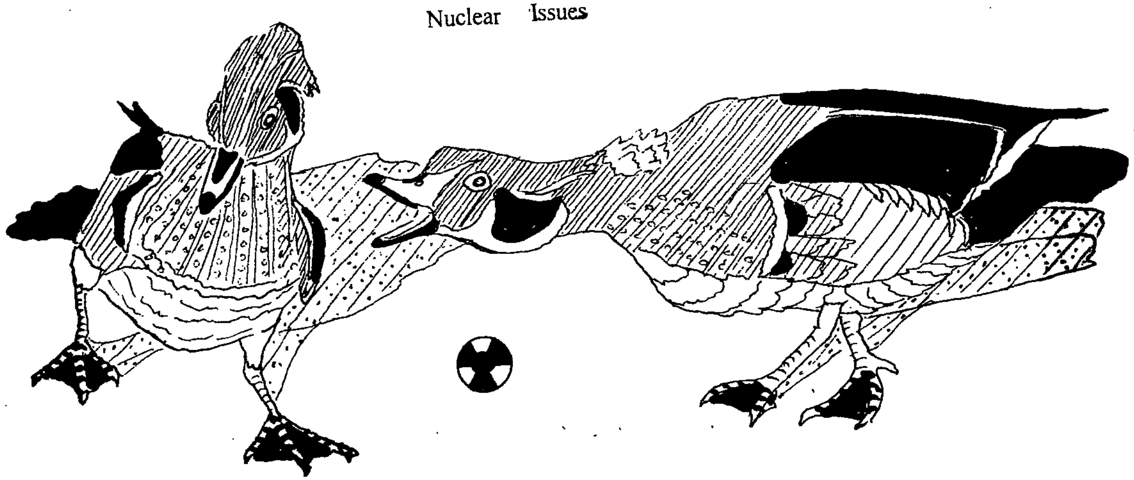
Nuclear Issues

Proponents of nuclear development often note that it takes far less uranium-235 than it does other forms of fuel, or explosive to produce any given amount of energy. For example, one pound of uranium-235 produces the same amount of heat energy during fission as three million pounds of coal, 12 million barrels of oil, or 34 million cubic feet of natural gas during combustion. In addition, a short ton of uranium-235 will produce the same amount of explosive energy as 16 million short tons of dynamite, making the isotope attractive, in some respects, for both nuclear power generation, and nuclear weapons production.

Nonetheless, there remain a number of disadvantages to developing nuclear power, and nuclear weapons as well. There are, for example, relatively high facility, and operation costs, limited fuel reserves, and long-lived radwaste processing, packaging, transport, and long-term storage to be considered, along with irresponsible nuclear site development, licensing, and operations procedures, plus deadly radiation health dangers induced by medical applications, accidents, natural disasters, and acts of terrorism.

High Facility, and Operation Costs

The costs of nuclear research, and development are relatively high when compared to other available options in the private sector. Even with U.S. Government subsidies, nuclear power plants, National Laboratories, uranium enrichment plants, military weapons test sites, and naval shipyards all cost billions of dollars to plan, site, construct, license, manage, operate, and dismantle as a rule, especially when expenses for vanishing fuel supplies, plus long-term radwaste storage, and environmental site remediation are factored into the bill.



"I believed in nuclear power but after seeing the NRC in action, I am convinced a serious accident is not likely, but inevitable.... They are asleep at the wheel!"

George Galatis, Senior Nuclear Engineer

"There is enough soil contaminated with radionuclides and other chemicals on the Hanford Nuclear Reservation to cover the District of Columbia up to the U.S. Capitol rotunda."

U. S. Department of Energy

"The metal canisters that have been accepted to store high-level radwaste at Yucca Mountains, and their protective drip shield are badly designed. They will corrode, and that will lead to radwaste leakage."

Paul Craig, Physicist

"Nuclear power is too costly and too risky!"

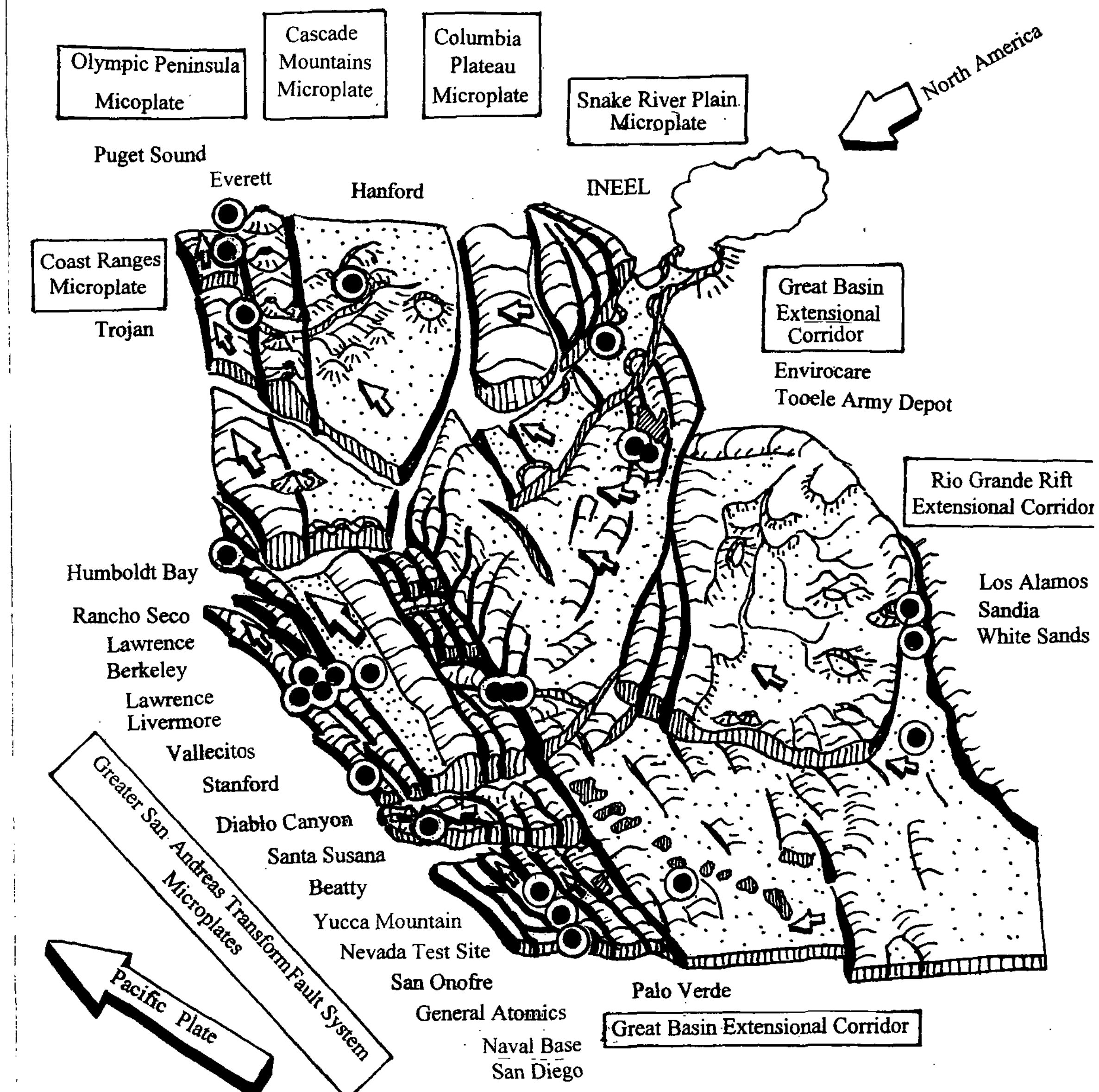
World Bank

"The failure of the U.S. nuclear power program is the largest managerial disaster in U.S. business history involving $1 trillion in wasted investment and $10 billion in direct losses to stockholders."

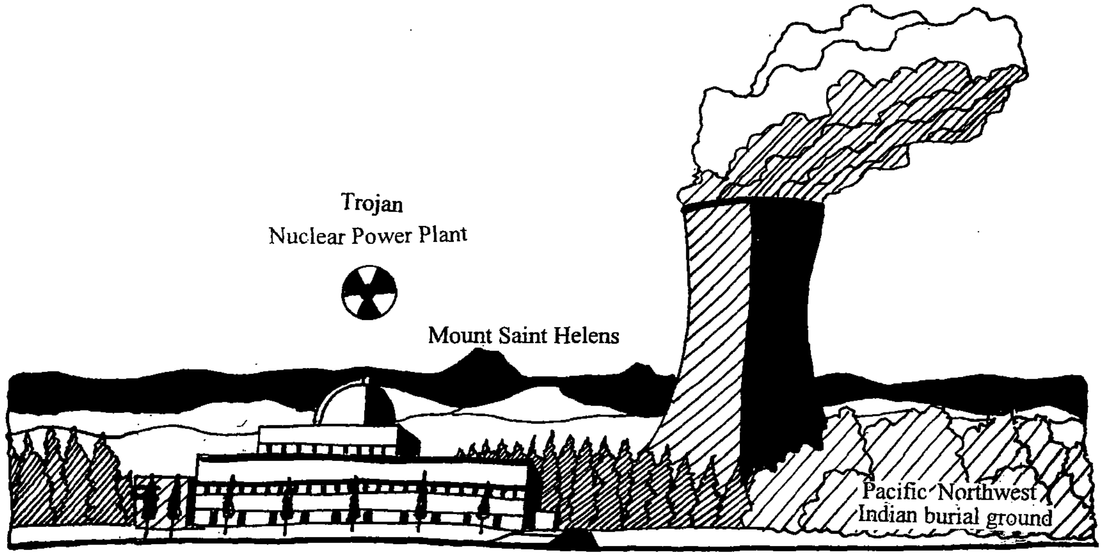
– Forbes Business Magazine

"If the United States were to stop using nuclear energy tomorrow, and begin divesting itself of nuclear weapons, it would still need National Labs and Administrative complexes for centuries to come to oversee the dismantlement of its nuclear program and to operate and monitor its radwaste repositories."

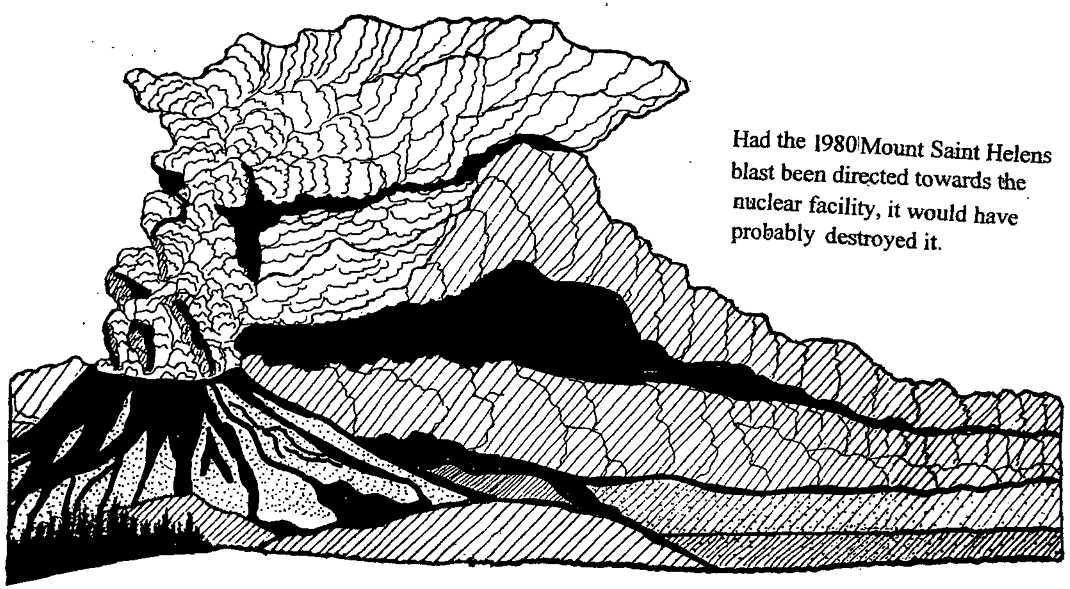
U.S. Department of Energy



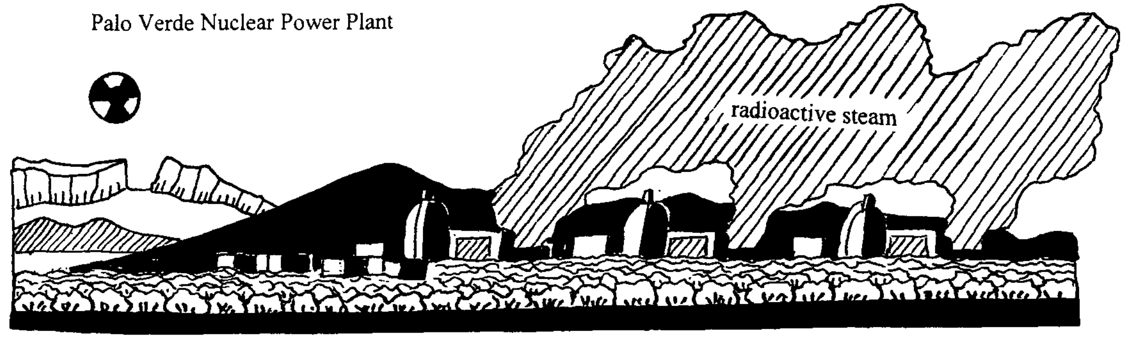
NUCLEAR DEVELOPMENTS AND GEOTECTONICS ACROSS WESTERN NORTH AMERICA



Cradle-to-the-grave expenses for Portland General Electric's controversial Trojan Nuclear Power Plant in Oregon, for example, approached one billion dollars, even when the plant operated with just one atomic reactor, and was decommissioned early after repeated equipment malfunctions, public complaints, and the discovery of a nearby active fault. Further south, Arizona Public Service's Palo Verde Nuclear Power Plant

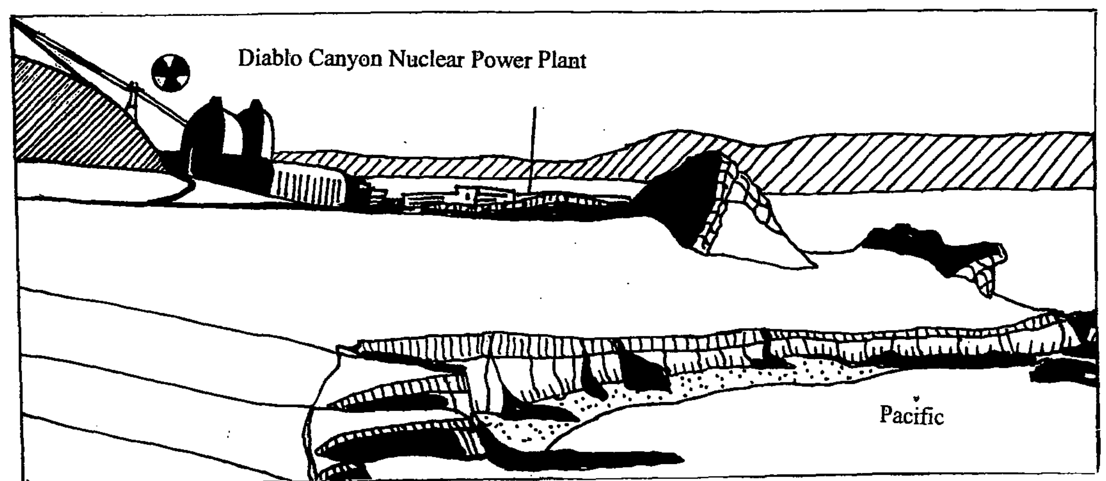


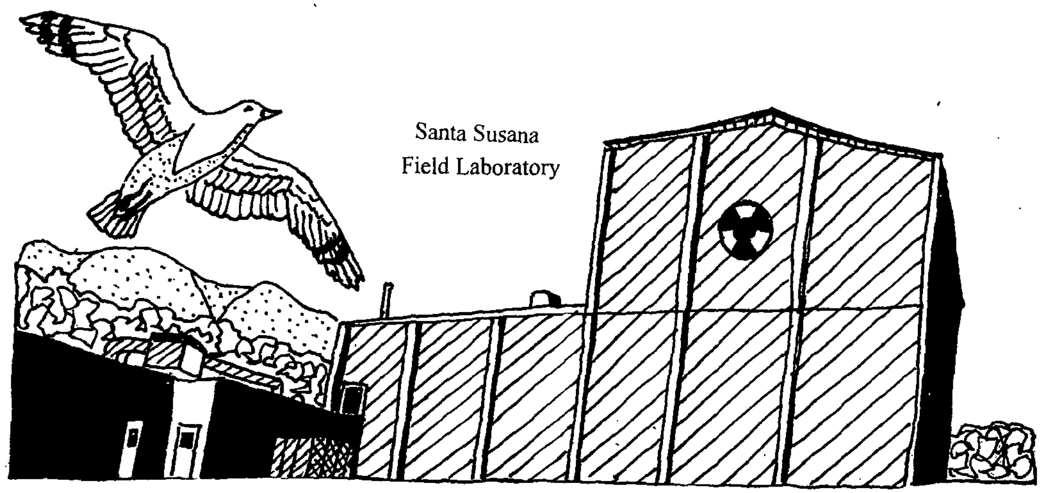
Had the 1980 Mount Saint Helens blast been directed towards the nuclear facility, it would have probably destroyed it.



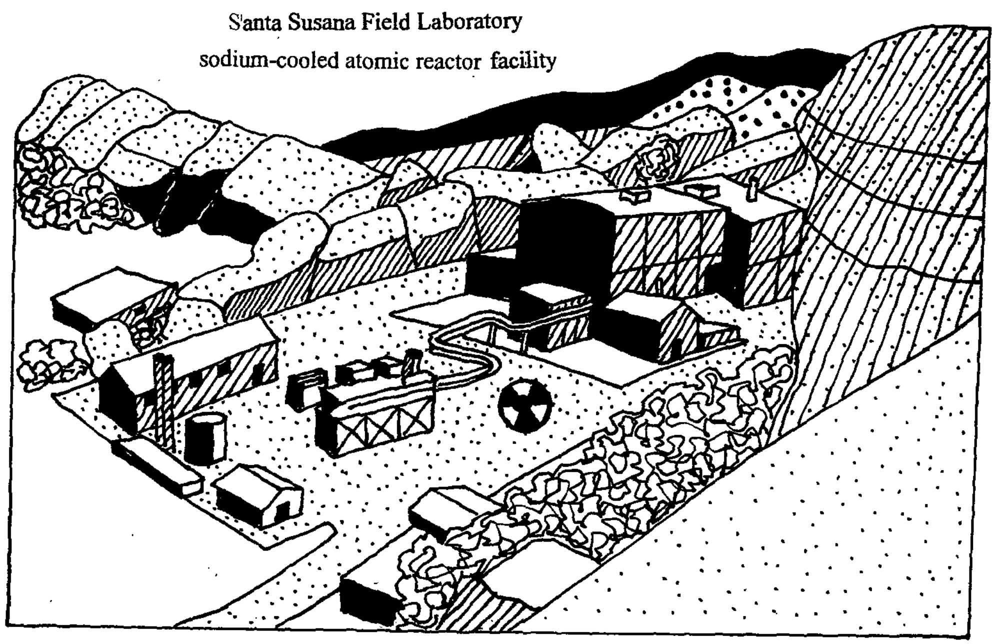
with three atomic reactors has thus far cost more than 9 – billion dollars to build, and operate, or what several fossil-fuel, and passive-energy plants might cost in comparison. The Palo Verde facility has rarely operated at full capacity owing to repeated steam generator radiation leaks, and to other problems requiring expensive plant shut-downs, and repairs.

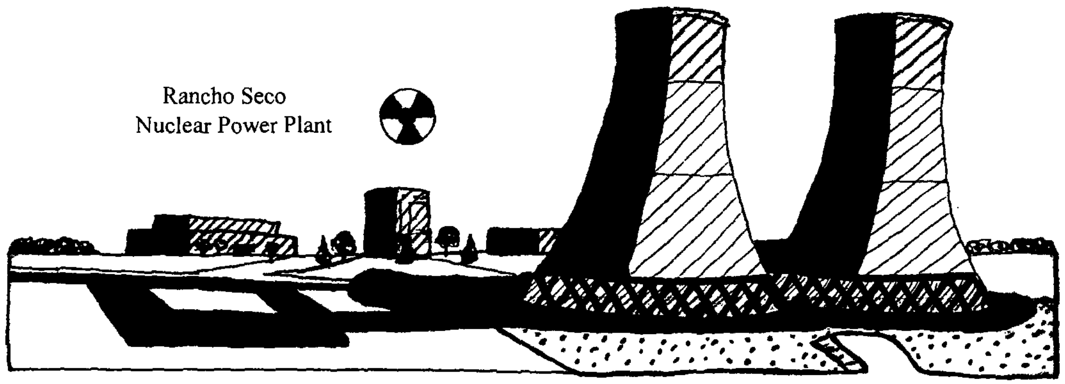
Similarly, Pacific Gas and Electric's Diablo Canyon Nuclear Power Plant and Southern California Edison's San Onofre Nuclear Power Plant on the destructive Pacific Coastline of California have each cost several billion dollars to build, and operate to date. Notably, both of the facilities required expensive structural design and construction upgrades prior to start-up to limit inevitable earthquake damage after the discovery of active transform faults near them. In addition, the San Onofre Plant has had to replace one of its reactors, raising its overall cost for Southern California consumers even more.





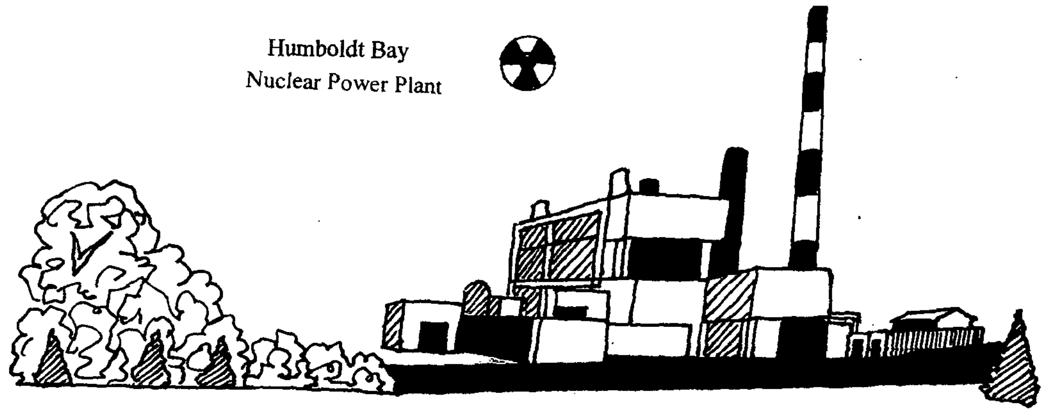
Still other nuclear facilities in California with a record of costly atomic reactor problems, or other equipment malfunctions include the Santa Susana Field Laboratory, plus the Rancho Seco, and Humboldt Bay Nuclear Power Plants. At the multi-billion dollar Santa Susana Field Laboratory, an early sodium-cooled nuclear reactor test failed, leading to a partial core meltdown, and the consequent venting of radiation over San Fernando Valley, and the Greater Los Angeles Basin.



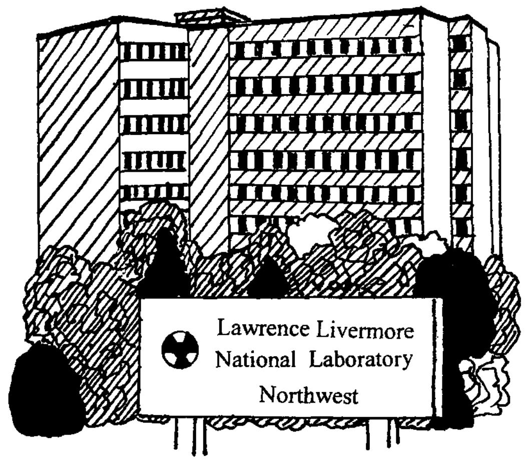


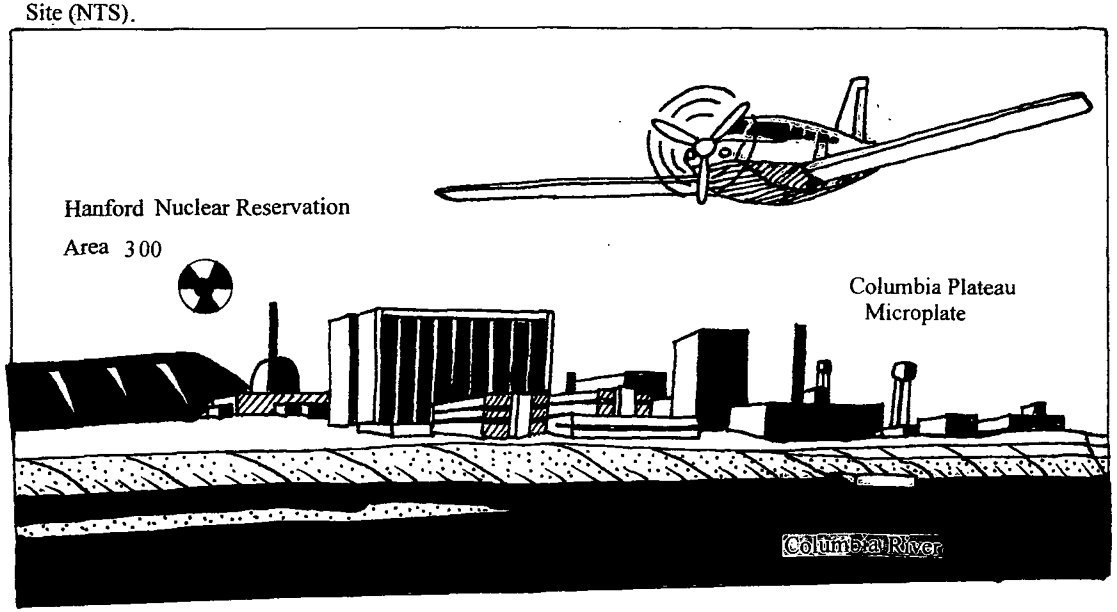
Sacramento Municipal Utility Company's Rancho Seco Nuclear Power Plant was also beset with equipment malfunctions prior to its early closure. One incident at the plant involved the unscheduled shut-down of the reactor's cooling system while the facility was still operating, leading to a near core meltdown. Ultimately, consumers in Sacramento, California, elected to import electricity from other sources rather than continue bearing the costs of stress, and worry about accidents at the Rancho Seco site.

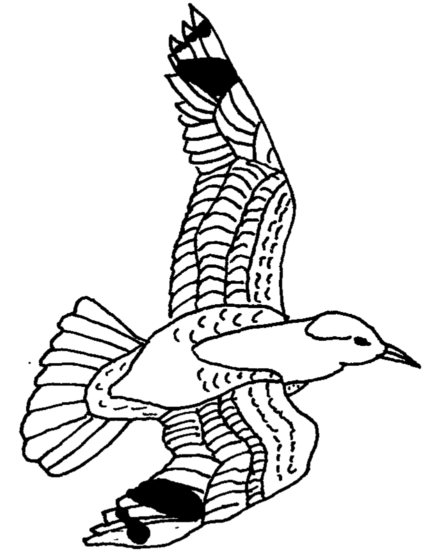
Radiation leaks from an uncontained reactor cooling system, plus earthquake damages, and tsunami dangers all combined to help shut down Pacific Gas and Electric's Humboldt Bay Nuclear Power Plant early in Northern California. The plant site is located over an active fault trace of the Greater San Andreas Transform Faul System, and is shaken regularly by earthquakes, with one offshore temblor knocking transformers off their bases, and buckling steam pipes at the facility, while also collapsing a freeway overpass, and imparting other structural damage to homes, and buildings in nearby Eureka, California.



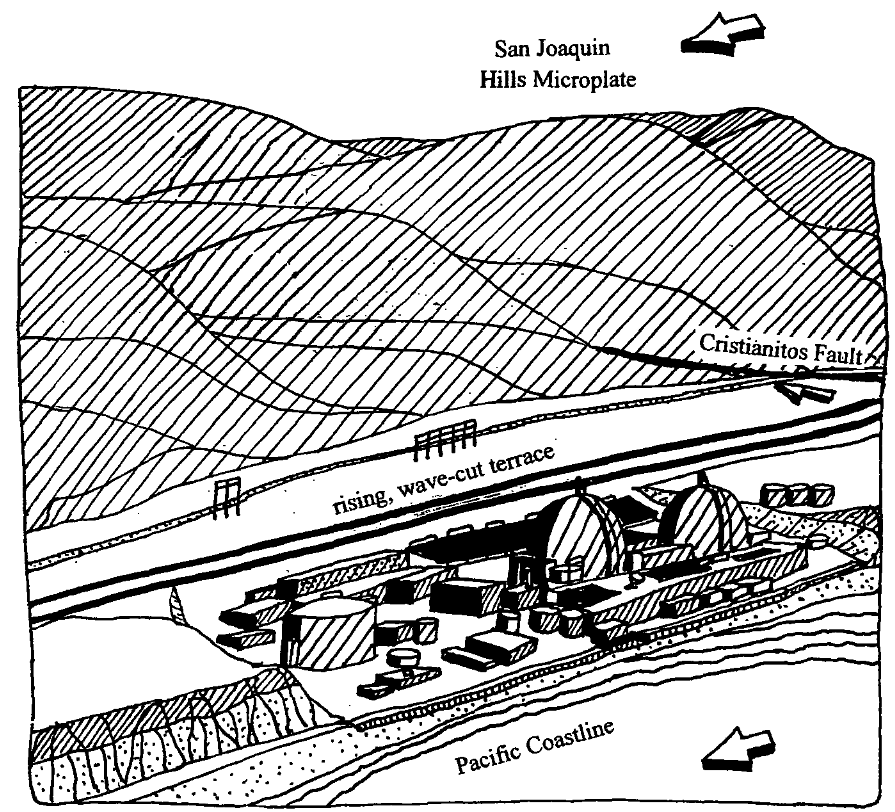
The costs of just managing, and running nuclear facilities across the West are also relatively high, with annual operating budgets reaching, or exceeding one billion dollars regularly at several locations, including Lawrence Livermore National Laboratory in California that manages the nation's nuclear weapons program; Los Alamos National Laboratory in New Mexico that designs, and helps manufacture atomic weapons; and Idaho National Engineering, and Environmental Laboratory (INEEL) that tests nuclear reactors, and processes U.S. Navy reactor fuel rods, while also providing temporary storage for associated high-level radwaste. All of the National Labs are at least 50-years old, and have had to undergo expensive site remediation for chemical, and radioactive contamination during their operational lives, much the same as the Hanford Nuclear Reservation in Washington; Santa Susana Field Laboratory in California; Tooele Army Depot in Utah; and the Nevada Test Site (NTS).





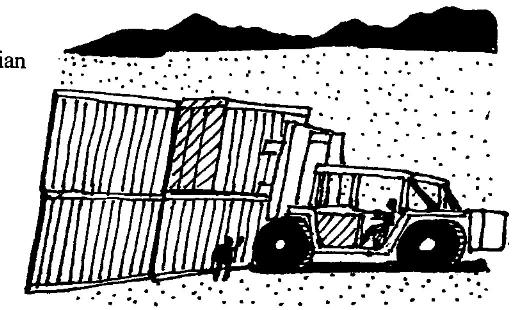


The San Onofre Nuclear Power Plant is located midway between Los Angeles and San Diego on the rising, northwest -moving San Joaquin Hills Microplate.



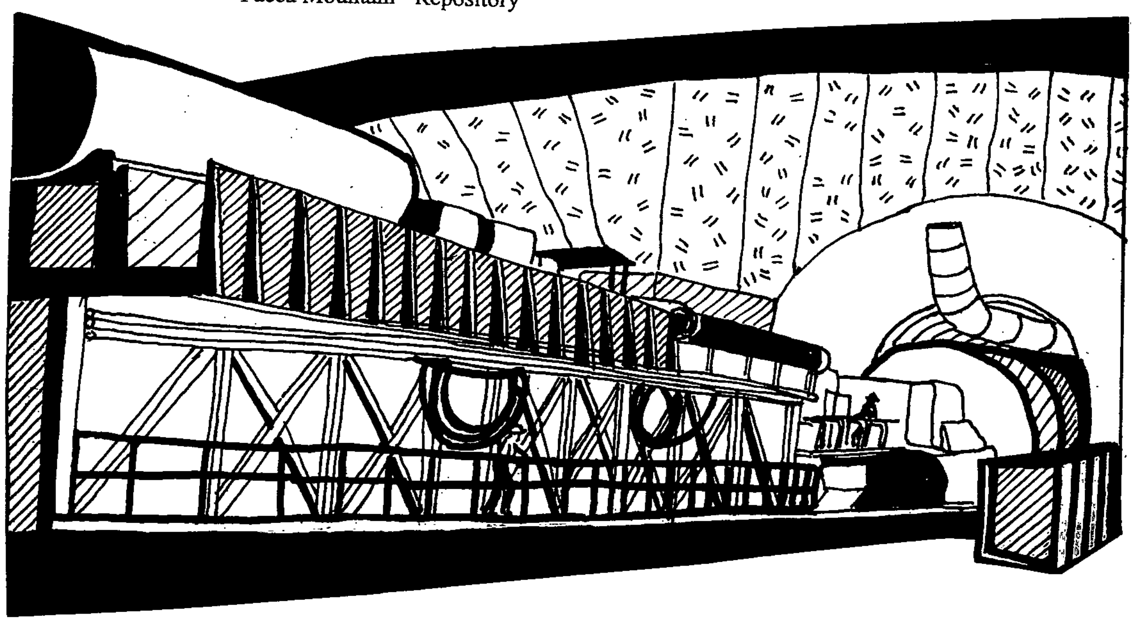
At the contested Yucca Mountain Repository next to the Nevada Test Site, construction costs reached $13.5 billion before the Federal Government decided not to use the site for radwaste storage in 2009. And already, alternatives for a national high-level radwaste repository site are being proposed, including areas on the stable Canadian Shield west of the Mesabi Iron Ore Range in northern Minnesota.

The Nevada Test Site is presently being cleaned up at some locations, with remediation efforts projected to last at least through 2048, and budgeted in the billions of dollars.



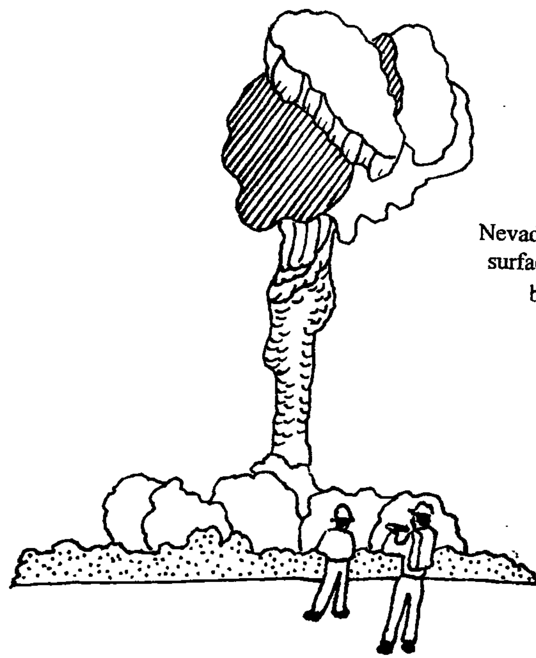
The Yucca Mountain Repository was designed initially to accept a 30-year backlog of spent reactor fuel rods from U.S. nuclear power plants, plus other high-level radwaste from Hanford, and INEEL. Delivery of the back-logged radwaste was scheduled to be made with 16,000 deliveries over a 39-year period at a cost of over one billion dollars for handling, packaging, transport, and storage.

Yucca Mountain Repository

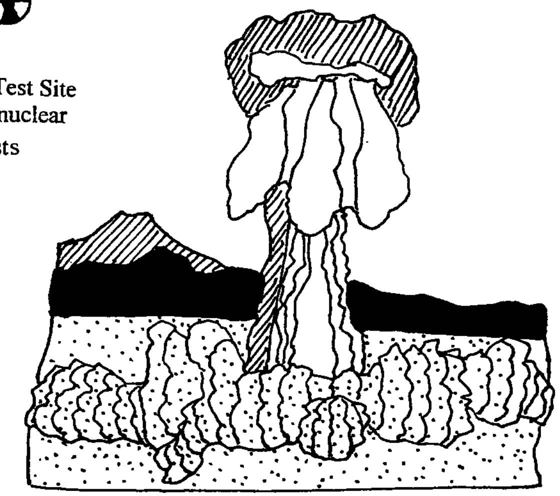


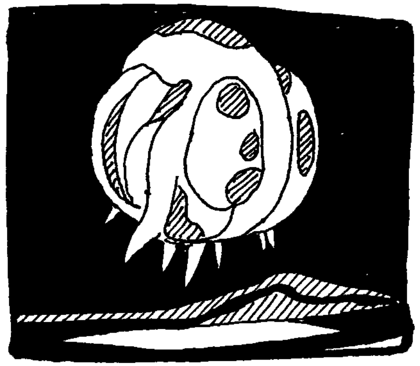
Military expenses for atomic research, and development, plus nuclear installations, test sites, munitions, weapons, and delivery systems like ballistic missiles, and a nuclear-powered navy are at least an order of magnitude larger than those in the private sector. Already, the U.S. Government, and Military have spent more than six trillion dollars developing, and utilizing atomic power. Very large expenditures began during World War II in the 1940s with the Manhattan Project, and the development of the atomic bomb. Major Western nuclear facilities involved in the project included Lawrence Radiation Laboratory (now Lawrence Berkeley National Laboratory), the Hanford Nuclear Reservation, Los Alamos National Laboratory, and White Sands Missile Range, all of which were under U.S. Military supervision during the War.

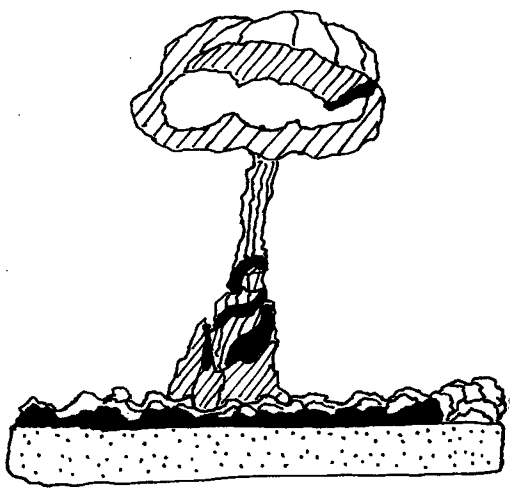
Post-WW II military development, and use of atomic power have continued ever since, with hundreds of billions of dollars being spent on uranium-235, and plutonium-239 production at the Hanford Nuclear Reservation; atomic bomb tests at the Nevada Test Site; nuclear weapons design, and manufacture at Lawrence Livermore, Sandia, and Los Alamos National Laboratories; atomic reactor research at Idaho National Engineering Laboratory (now INEEL); rocket engine, and reactor tests at Santa Susana Field Laboratory;

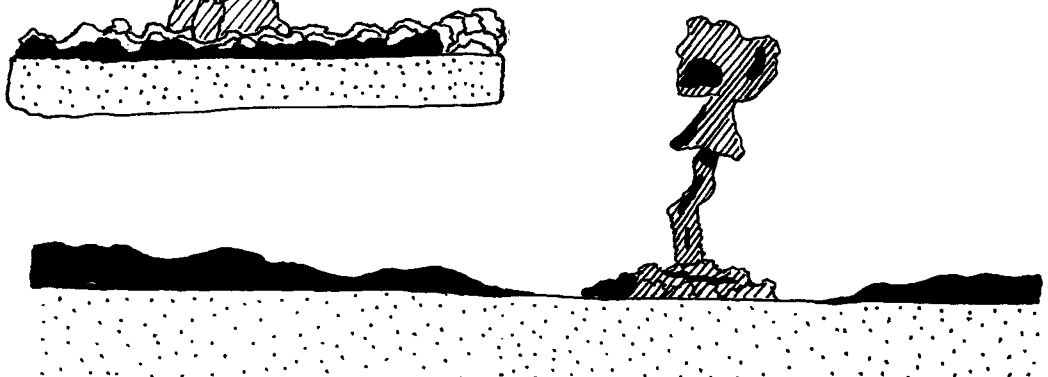


Nevada Test Site surface nuclear blasts



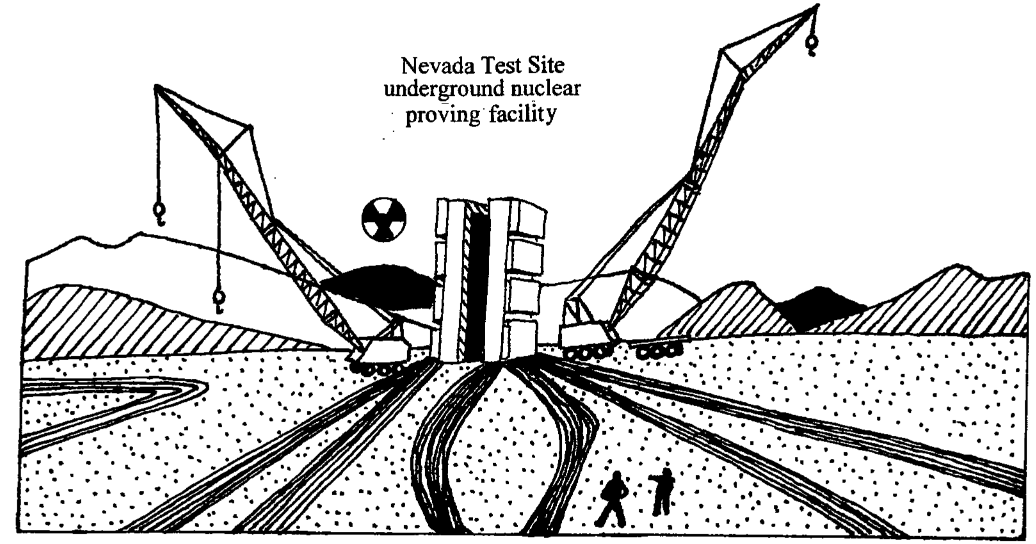






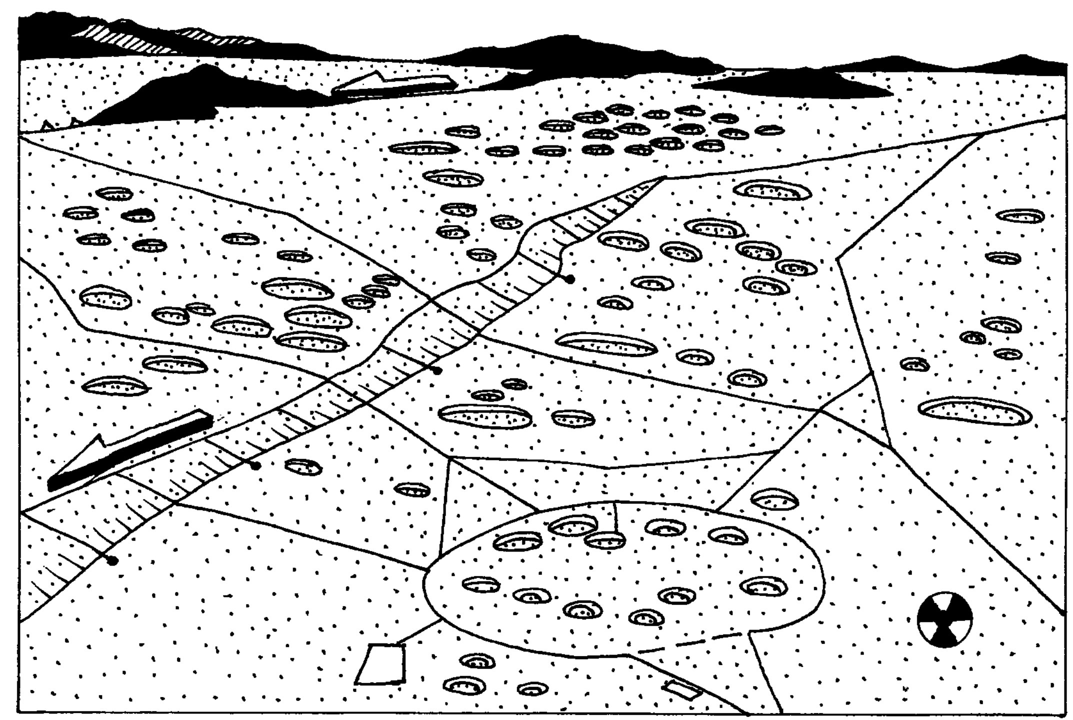
The Nevada Test Site was established after World War II as a U.S. Government proving ground for nuclear weapons.

Nevada Test Site underground nuclear proving facility



Nevada Test Site

Yucca Flat , where numerous underground atomic test have been performed.



atomic particle studies at Lawrence Berkeley National Laboratory, and the Stanford Linear Accelerator Center; nuclear missile tests at White Sands Missile Range; and the early development of the U. S. Navy nuclear fleet. As a consequence, the U.S. Military is well equipped with nuclear weapons today, including self-propelled nuclear howitzers, and guided missiles with multiple nuclear warheads.

Limited Fuel Reserves

With the Cold War between the U.S., and Soviet Union ending during the early 1990s, nuclear disarmament programs have been continued by the military, many aimed at reducing nuclear weapons' stockpiles, and converting weapon's-grade uranium-235 into atomic reactor fuel, if only to reduce demands temporarily for the vanishing isotope. As the most common energy producing element in atomic reactors, and many nuclear weapons, uranium-235 accounts for less than one percent of all uranium found in nature. Still, it is the only natural isotope that fissions readily to produce chain reactions in reactors. Quite often, it takes more than 300,000 short tons of uranium ore to produce just one short ton of uranium-235. The isotope occurs with uranium-238, which accounts for more than 99 percent of all uranium found in nature, and it requires expensive processing to separate the two isotopes into concentrations that can be used to fabricate nuclear reactor fuel, or weapons'-grade nuclear material.

More specifically, uranium ore assaying less than one percent uranium-238, and only minute traces of uranium-235, is commonly milled, and concentrated before being placed in a sulfuric acid bath, and converted to uranium oxide, or "yellow cake". Enrichment plants mix the yellow cake with fluorine gas to produce uranium hexafluorine gas, before removing varying amounts of uranium-238 from the feedstock with expensive gas-diffusion, or centrifuge separation systems. Fuel fabrication plants then convert the hexafluorine gas into black, uranium dioxide powder prior to compressing the enriched product into pellets for insertion into hollow zirconium, or stainless steel reactor fuel tubes, or molding the powder to fit nuclear weapons' designs. As a rule, enriched reactor fuel pellets contain upwards to five percent uranium-235, while weapons'-grade material is often enriched to 90 percent concentration levels of the fissionable isotope.

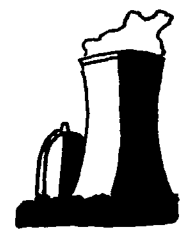
How long will ***global uranium*** *deposits fuel the world's nuclear reactors at present consumption rates?*

Steve Fetter, dean of the University of Maryland's School of Public Policy.

If the Nuclear Energy Agency (NEA) has accurately estimated the planet's economically accessible uranium resources, reactors could run more than 200 years at current rates of consumption.

Most of the 2.8 trillion kilowatt-hours of electricity generated worldwide from nuclear power every year is produced in light-water reactors (LWRs) using low-enriched uranium (LEU) fuel. About 10 metric tons of natural uranium go into producing a metric ton of LEU, which can then be used to generate about 400 million kilowatt-hours of electricity, so present-day reactors require about 70,000 metric tons of natural uranium a year.

According to the NEA, identified uranium resources total 5.5 million metric tons, and an additional 10.5 million metric tons remain undiscovered—a roughly 230-year supply at today's consumption rate in total. Further exploration and improvements in extraction technology are likely to at least double this estimate over time.



Using more enrichment work could reduce the uranium needs of LWRs by as much as 30 percent per metric ton of LEU. And separating plutonium and uranium from spent LEU and using them to make fresh fuel could reduce requirements by another 30 percent. Taking both steps would cut the uranium requirements of an LWR in half.

Two technologies could greatly extend the uranium supply itself. Neither is economical now, but both could be in the future if the price of uranium increases substantially. First, the extraction of uranium from seawater would make available 4.5 billion metric tons of uranium—a 60,000-year supply at present rates. Second, fuel-recycling fast-breeder reactors, which generate more fuel than they consume, would use less than 1 percent of the uranium needed for current LWRs. Breeder reactors could match today's nuclear output for 30,000 years using only the NEA-estimated supplies. ■

March 2009 www.SciAm.com/asktheexperts

There are already approximately 1500 active atomic reactors powering naval vessels, and electrical generation plants worldwide today, with still others planned, or under construction. Combined, the active atomic reactors are consuming the world's proven uranium-235 reserves at depletionary rates that will make the isotope much more expensive to mine and process by 2050. Accordingly, limited reactor fuel reserves are a very real concern of the trillion-dollar nuclear power industry.

Alternative designs of nuclear reactors that have shown promise in addressing the problem of diminishing uranium-235 fuel reserves include Training, Research, Isotopes, General Atomics (TRIGA) models. Powered by radwaste and produced by General Atomics in San Diego, California, TRIGA reactors use closed-circuit, super-heated helium gas jets to propel small , electricity-generating turbines.

Scientists at Los Alamos National Laboratory in New Mexico have also developed small, portable reactors that use much more plentiful uranium-238 for fuel. The U-238 reactors can be adapted to generate enough electricity from heat and steam to satisfy the power demands of small cities, while producing very little radwaste and being far less expensive to purchase and operate than multi-billion dollar nuclear power plants.

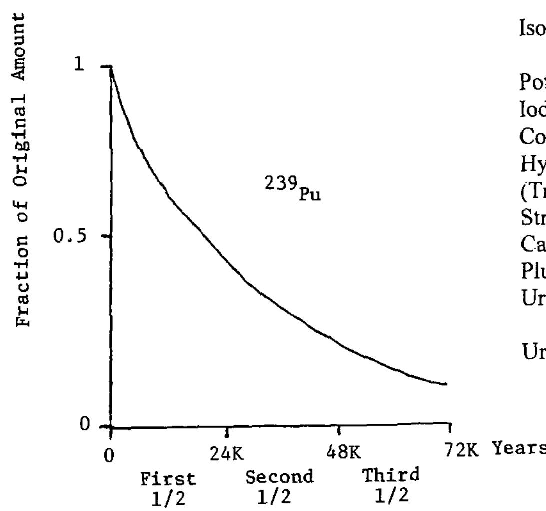
Then there are those who suggest and promote replacing outdated U-235 reactors with thorium liquid-fuel reactors powered by molten fluoride salt containing thorium. Worldwide, there is four times as much thorium as uranium. Easier to handle and process, thorium "breeds" its own fuel, i.e., uranium-233, continuously and can produce about 90 times more energy than similar quantities of uranium-235. Thorium reactions produce no plutonium or other bomb-making, raw materials and generate much less radwaste than uranium-235 reactions. Moreover, radwaste from thorium reactors is relatively short-lived, requiring only centuries, rather than millennium for safe storage. Finally, thorium reactors have much lower risks of uncontrolled reactions and expel xenon gas from their molten fuel, rather than allowing buildups that interfere with reactor functions like uranium-235 fuel rods.

Radioactive Waste Concerns

Growing accumulations of radioactive waste pose another disadvantage to nuclear development, especially long-live radwaste requiring long-term disposal, and monitoring for a wide range of materials, some requiring more attention than others, but all needing responsible handling, packaging, transport, and storage in the end.

The fission of uranium-235 in atomic reactors produces a number of different radioisotopes, including strontium-90, and cesium-137 that dominate in most high-level radwaste fractions left over from reactor fuel rod processing, and that require about 600 years of isolation before their cumulative half-life decay rates render them relatively harmless. As another trace product of atomic reactor chain reactions, plutonium-239 poses dangers for a much longer period of time, having a half-life of about 24,000 years, and requiring an even

PLUTONIUM HALF-LIFE DECAY



HALF-LIFES OF SELECTED RADIOISOTOPES

Isotope	Half-Life	Particle Emissions
Potassimu-42	12.4 hours	Alpha, Beta
Iodine-131	8 days	Beta, Gamma
Cobalt-60	5.27 years	Beta, Gamma
Hydrogen-3 (Tritium)	12.5 years	Beta
Strontium-90	28 years	Beta
Carbon-14	5370 years	Beta
Plutonium-239	24,000 years	Alpha, Gamma
Uranium-235	710 million years	Alpha, Gamma
Uranium-238	4.5 billion years	Alpha, Gamma

longer period of isolation when incorporated in radwaste. In contrast, low-level radwaste containing tritium, a radioactive form of hydrogen, requires only a few decades of isolation, with its half-life being just 12.5 years.

As a rule, radwaste occurs in bulk mixtures containing both high-, and low-level components that require sorting prior to disposal, or storage in separate types of repositories. Selected types of mixed, bulk radwaste include uranium mine, and mill tailings; nuclear lab equipment, tools, chemicals, clothing, and effluents; spent reactor fuel rods, and chemical washes from reactor fuel rod processing plants; decommissioned atomic reactors, and other contaminated nuclear site debris, including glove boxes, air vents, steam pipes, and other equipment; discarded medical radioisotopes, and x-ray machines; plus millions of tons of sediments, and trillions of gallons of water contaminated by radioactive explosions, dumps, spills,

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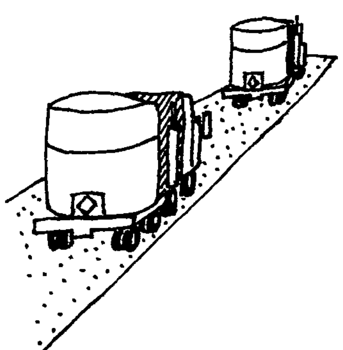
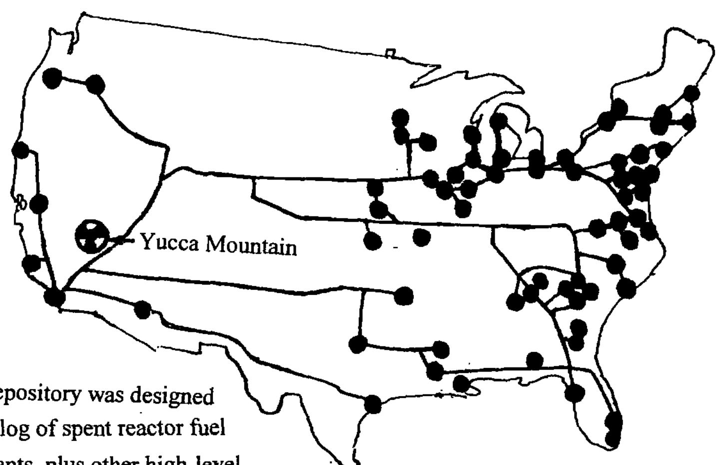
Today, more than 80,000 short tons of high-level radwaste are stored temporarily at 127 nuclear power plants and other temporary repositories across the nation.





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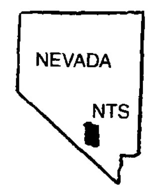
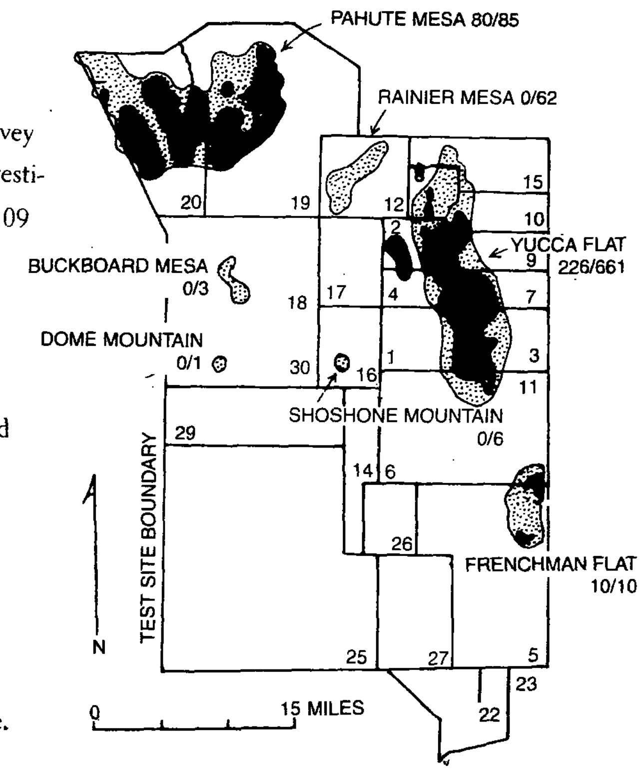
fallout, well injections, and leaks. Accordingly, one short ton of uranium-235, today, is also commonly equal to millions of short tons of radwaste.

Already, billions of short tons of uranium mine ore, and mill tailings have been produced across the West. However, only small portions of the tailings have thus far been isolated, and treated over clay mats, and plastic liners prior to being covered with clay, or asphalt to limit their radioactive emissions, and to contain other environmental contamination by runoff, and erosion.

At the Nevada Test Site, billions of tons of soils, and sediments, plus trillions of gallons of ground water have also been contaminated by hundreds of above-, and below-ground nuclear explosions, making it the most contaminated area in the Western Hemisphere. In addition, the above-ground atomic blasts at the NTS spread radwaste in the form of "black rain", or radioactive fallout far beyond the site's boundaries during the late



U.S. Geological Survey Water Resources Investigations Report 96-4109



Map showing principal underground bomb test areas within the Nevada Test Site. Stippled pattern shows areas where bombs detonated above the water table, and black areas are where bombs detonated below the water table. Figures separated by a slash (e.g., 80/85) give the number of tests above/below the water table.

Radionuclide Contamination at the Nevada Test Site

Over 925 nuclear tests were conducted at the Nevada Test Site between 1951 and 1992 and resulted in the emplacement into the subsurface of several hundred million curies of radioactivity, including significant quantities of tritium, plutonium, and fission products.

Many of these tests were conducted at or below the groundwater table. Nevada officials contend that the site contains more contaminated media than any other site in the DOE complex.

DOE has no plans to remediate the subsurface in and around the underground tests because "cost-effective remediation technologies have not yet been demonstrated."

Isotope Inventories from Underground Testing at the Nevada Test Site

Location	Isotope	Inventory (10^6 curies) (Numbers are rounded)
Pahute Mesa	Tritium	69.9
	Cesium-137	1.95
	Strontium-90	1.56
	Krypton-85	0 13
	Plutonium-241	0.09
	Samarium-151	0.07
	Europium-152	0.03
	Plutonium-239	0.02
	Europium-154	0.02
	Others (34 isotopes)	0.05
	Total Pahute Mesa	73.8
Non-Pahute Mesa	Tritium	30.7
	Potassium-40	24 7
	Cesium-137	1.48
	Strontium-90	1.19
	Plutonium-241	0.10
	Krypton-85	0.09
	Europium-152	0.06
	Samarium-151	0.05
	Europium-154	0 05
	Plutonium-238	0.03
	Plutonium-239	0.01
	Others (32 isotopes)	0 04
	Total Non-Pahute Mesa	58.5

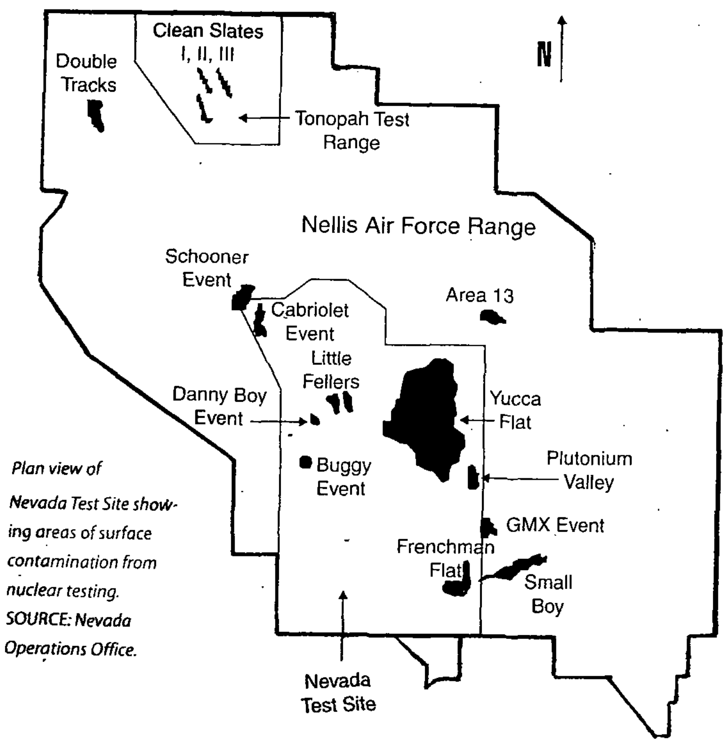
SOURCE: Presentation to the committee by Robert Bangerter, DOE-Nevada Operations Office, December 15, 1998.

Surface Contamination at Nevada Test Site

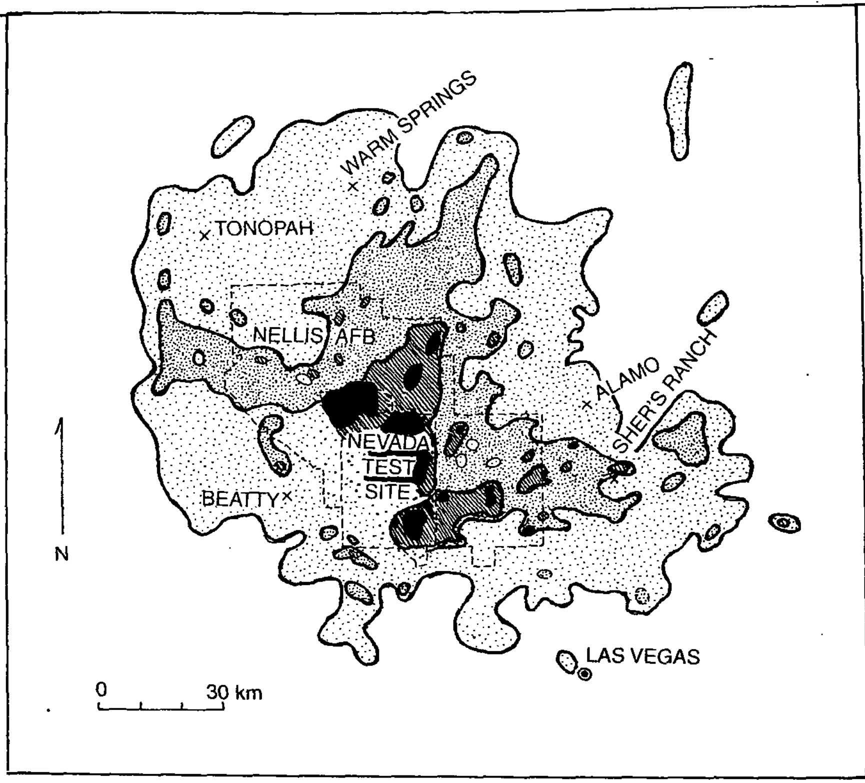
There is a significant amount of surface and shallow surface soil contamination that resulted from above-ground and near-surface nuclear detonations, safety shot tests, rocket engine development, and underground nuclear testing at the Nevada Test Site. The primary contaminants include americium, plutonium, depleted uranium, and metals such as lead. The contamination is found on parts of the test site, the Tonopoh Test Range, and the Nellis Air Force Range.
The safety shot tests resulted in dispersion of contaminants in excess of 40 picocuries per gram over more than 1,200 hectares (3,000 acres). This contaminated acreage increases to 11,000 hectares (27,000 acres) when atmospheric and near-surface tests are included.

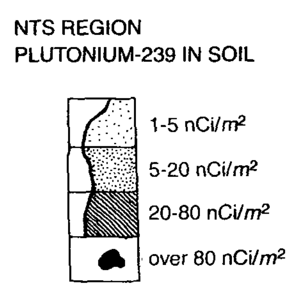
When warranted, cleanup of the Soils Sites Area will consist of excavation and disposal elsewhere on the site. Few of these sites have been characterized because of funding constraints.

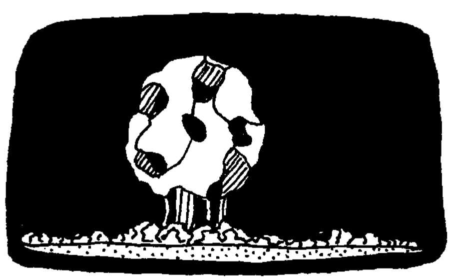
Tritium is very mobile in groundwater, and large plumes of tritium have been detected from many of the underground tests. It has long been argued that most other radionuclides, and especially plutonium, are relatively immobile due to their low solubilities in groundwater and strong sorption onto mineral surfaces. However, recently published work challenges this conventional view.



Plan view of Nevada Test Site showing areas of surface contamination from nuclear testing. SOURCE: Nevada Operations Office.







Map showing plutonium concentrations in soils surrounding the Nevada Test Site, deposited in fallout from atmospheric bomb tests.

Paths taken by more than one nuclear cloud across the United States carrying radioactive fallout.

1940s, and 1950s, covering much of the United States ultimately with millions of Curies of radiation. By comparison, the Three Mile Island partial reactor core meltdown in 1979 vented less than 33 Curies of radiation over downwind areas next to the nuclear power plant.

Wide spread radionuclide contamination at the NTS is particularly concentrated today in a large volcanic caldera complex that occupies the northwest corner of the site, and below Yucca Flat further south where numerous underground atomic test have been performed. There are also smaller, more concentrated zones of radioactive, and chemical contamination along the Test Site's east boundary, and in the adjacent Area 51 where the U.S. Military has experimented with Top Secret nuclear-, and jet-propelled aircraft for decades.

The second most contaminated area in the Western Hemisphere is the Hanford Nuclear Reservation in south-central Washington where plutonium-239 was produced for the first atomic bomb in seven breeder reactors bordering the Columbia River. Preliminary environmental remediation studies in the 1980s revealed more than 1000 contaminated sites on the Reservation, including plutonium breeder reactors, and separation plants; unlined radwaste dumps, trenches, and cribs; and leaky radwaste storage tank farms. Subsequently, the U.S. Department of Energy (US-DOE) published a report stating that "... there are enough sediments

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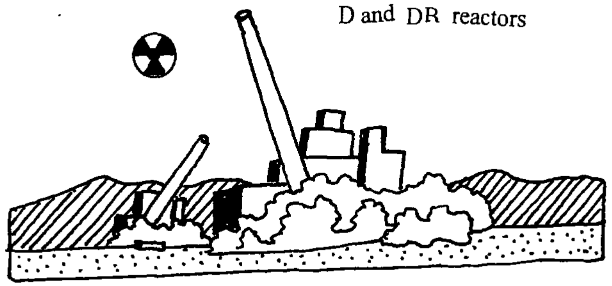
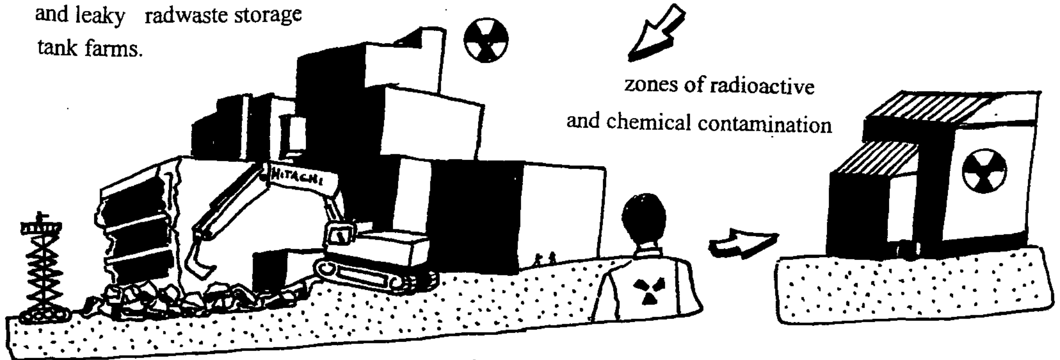
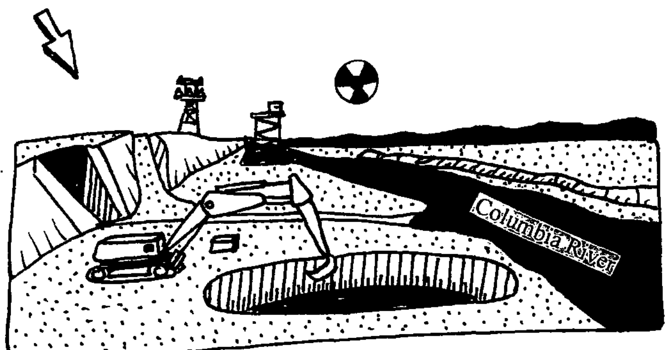
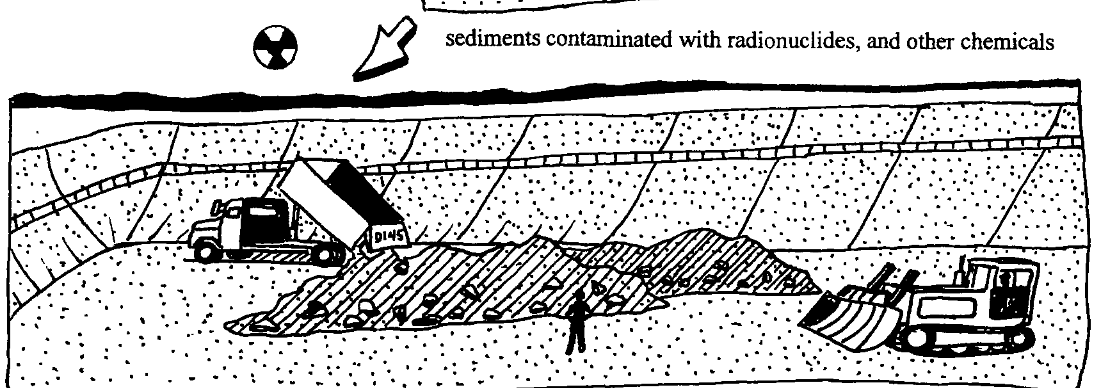




As a consequence, the site is presently being cleaned up at some locations, with remediation efforts projected to last at least through 2048, and budgeted in the billions of dollars.

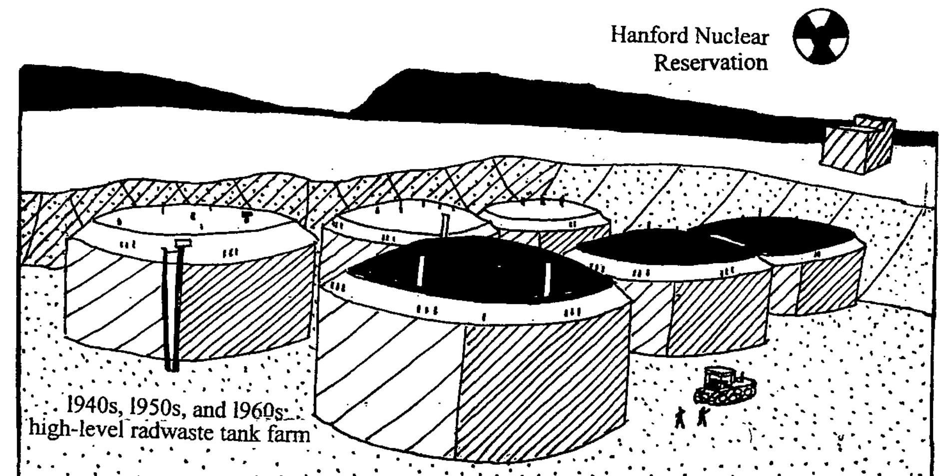


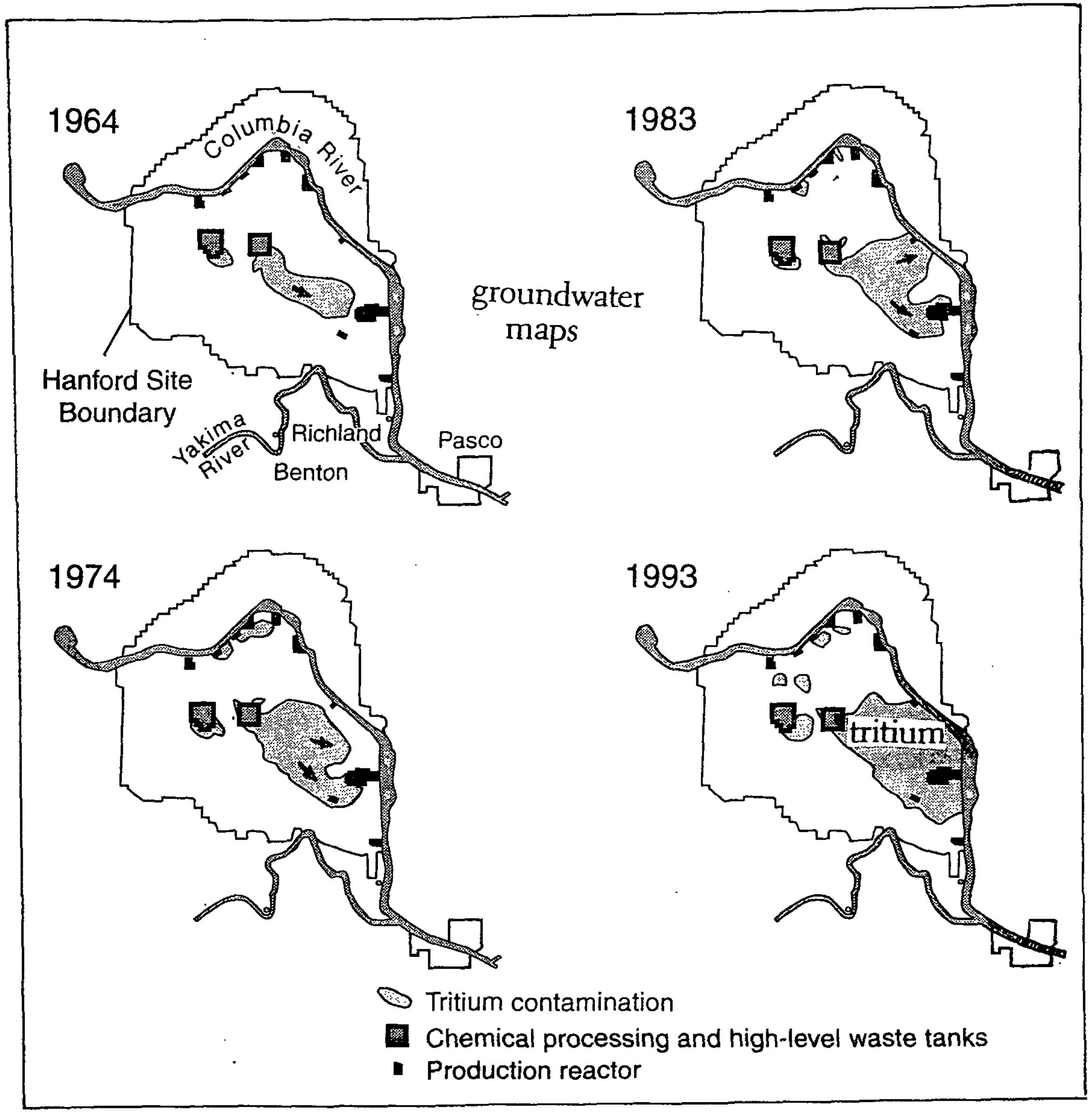


contaminated with radionuclides, and other chemicals under the Hanford Nuclear Reservation to cover the District of Columbia up to the U.S. Capitol dome rotunda." Trillions of gallons of surface-, and ground-water have also been contaminated with radionuclides, and other chemicals by operations at Hanford.

During the late 1940s, 1950s, and 1960s, for example, breeder reactors at Hanford pumped millions of Curies of radiation into the Columbia River as cooling-water return flow, defining an 100-mile-long plume of riverbed plutonium-239 that stretches downstream towards Portland, Oregon. During the same time period, plutonium separation plants on the Reservation were pumping trillions of gallons of water containing radionuclides, and other chemicals into bounding ponds, and unlined trenches, allowing tritium, and other soluble elements to contaminate both sediments, and groundwater below the dump sites. As a result, there is a plume of contaminated groundwater that covers more than200-square miles under the Reservation, and that connects hydraulically with the Columbia River at a number of radioactive spring sites today. The contamination plume is restricted largely to upper parts of an otherwise shallow, unconfined, regional, fresh-water aquifer, and contains nitrates, plus industrial solvents, as well as tritium, and other radionuclides in it.

Notably, leaky, high-level, liquid radwaste storage tanks have also contaminated sediments, and groundwater supplies at Hanford. Combined, the leaky tanks have introduced upwards to one million gallons of high-level radwaste into the porous, and permeable alluvial floodplain sand, and gravel deposits that surround them.

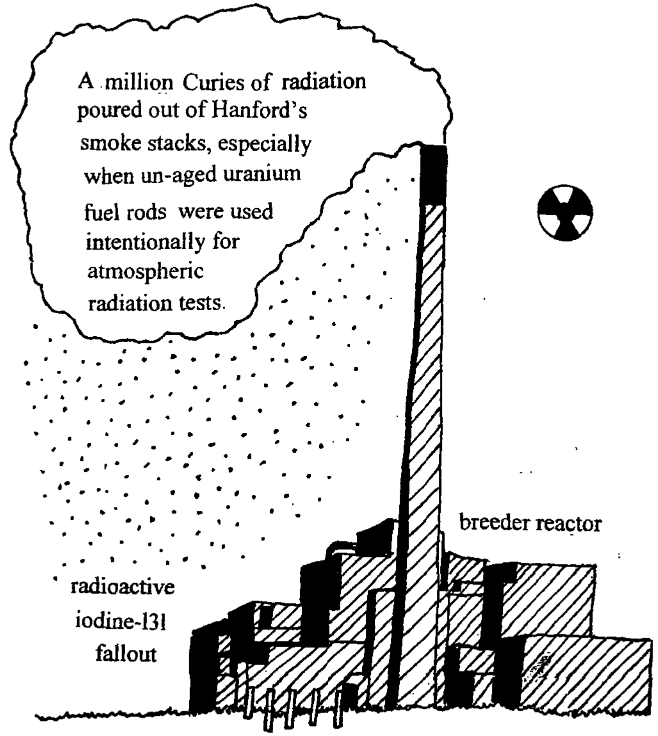


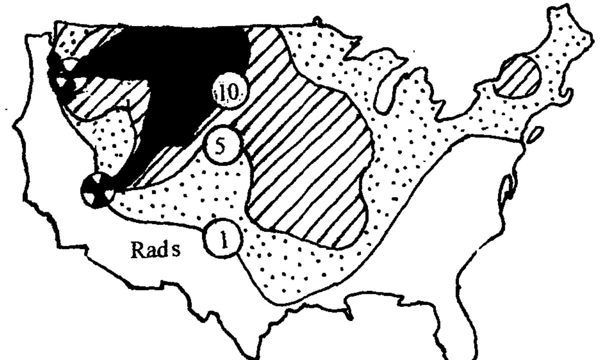


The Hanford Nuclear Reservation produced trillions of gallons of chemical waste, and low- to intermediate radwaste that were poured directly into unlined pits, cribs, trenches, and ponds on the Reservation, contaminating large volumes of sediments, and groundwater in the process.

The high-level radwaste is composed largely of a nitrate wash solution carrying cesium-137, and strontium-90, plus tritium, and other radionuclides, including plutonium-239. First to drop out of the nitrate wash solution when it leaks into the floodplain deposits is plutonium-239, followed by cesium-137, and strontium-90. Being much more soluble in water, the tritium, and nitrate wash are prone to flush further downward in damp sediment zones to the regional aquifer.

Finally, it should be noted that radioactive fallout from stack emissions at Hanford have released more than a million Curies of radiation on the environment. Many of the contaminating stack emissions occurred when un-aged, or "green" uranium-235 fuel rods were used intentionally for atmospheric tests on the Reservation during the late 1940s, and 1950s. The tests blanketed the northern United States, and southern Canada with radioactive iodine, and other isotopes, inducing downwind sickness, and death in their wake around the nuclear facility.

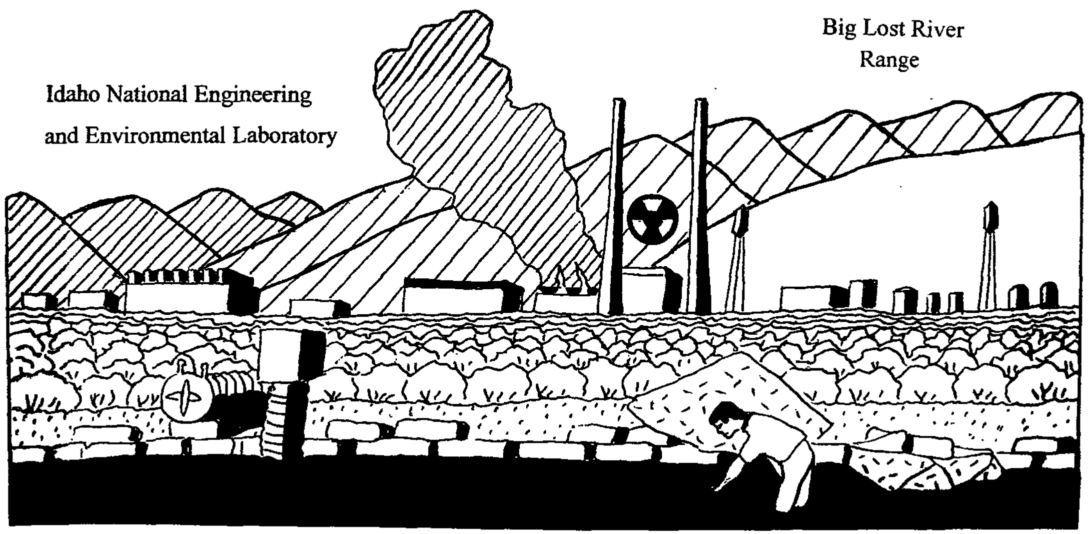




Radioactive fallout from above-ground atomic bomb blasts at the Nevada Test Site and "Green Run" atmospheric tests at Hanford sickened, and killed both livestock, and humans downwind from the nuclear facilities Radioactive iodine-131 poisoning after the Hanford tests concentrated in the thyroid glands, disrupting body metabolism, and bone growth. Higher incidences of miscarriages, birth defects, and cancer deaths in the downwind human population followed.

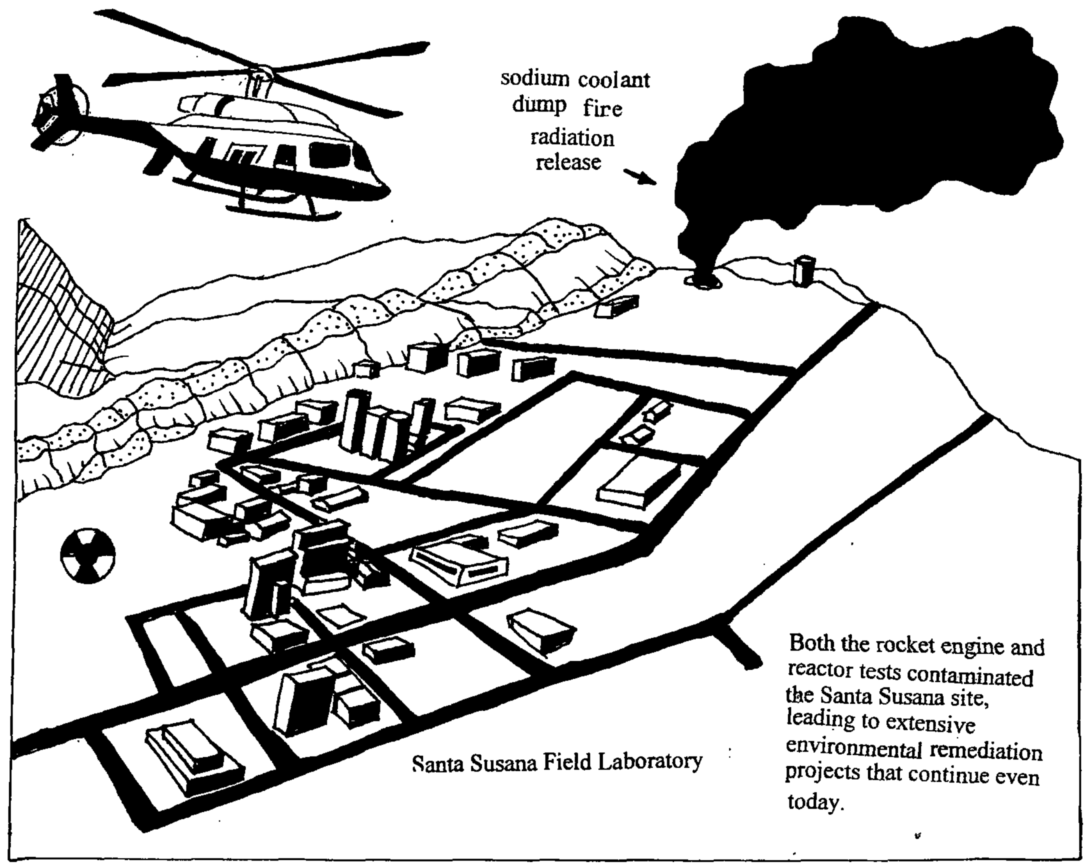
Other Western nuclear facilities that have produced large volumes of radioactive, and chemical waste include INEEL, Santa Susana Field Laboratory, Lawrence Livermore National Laboratory, Tooele Army Depot, and Los Alamos National Laboratory. At INEEL, more than one trillion gallons of liquid radioactive, and chemical waste were well-injected annually into the fresh-water Snake River Plain Aquifer System over one 20-year-long period of operation. The liquid waste was largely a product of spent reactor fuel rod processing, and nuclear lab effluents, with radioactive fractions containing relatively large volumes of tritium-3, plus smaller amounts of longer-lived strontium-90, and cesium-137.

There are also a number of solid radwaste dump sites at INEEL that have required, or that are requiring, remediation, with at least one site needing special robotic equipment to reclaim pit deposits contaminated with plutonium-239 that was imported originally from the decommissioned, and dismantled Rocky Flats Nuclear Weapons Plant in Colorado. As at Hanford, and the Nevada Test Site, overall environmental remediation at INEEL is presently projected to last through 2048, or to about the same time that uranium-235 reactor fuel becomes rarer, and much more expensive to mine, and develop. More than 400 million Curies of high-level liquid, and solid radwaste are already being stored at the Hanford, and INEEL sites, all awaiting transfer to a national repository as it is developed, licensed, and opened.

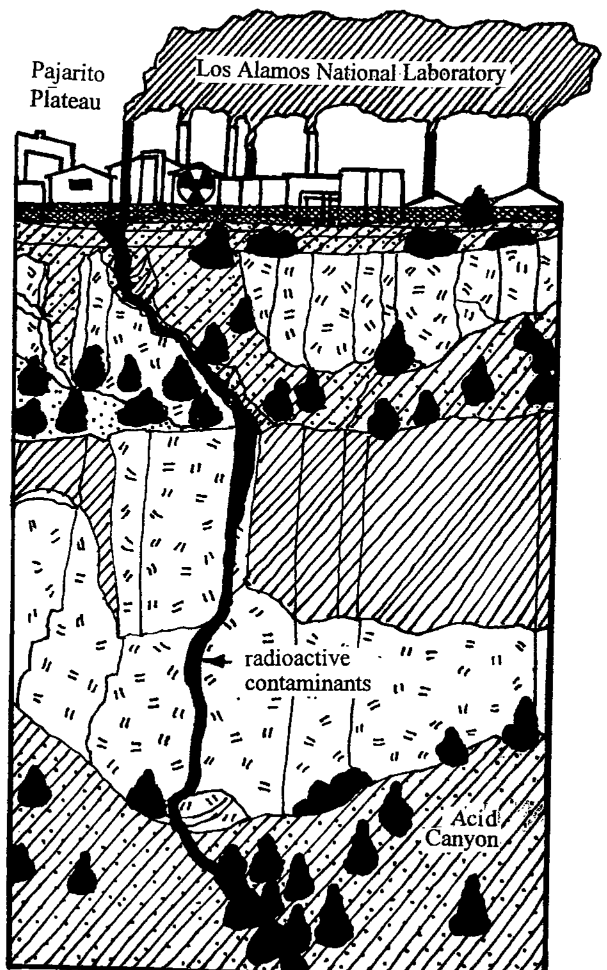


Soils, lakes, and groundwater were all contaminated with radionuclides, and industrial solvents during Santa Susana Field Laboratory operations in Southern California. Radionuclide contamination resulted from reactor accidents spreading radioactive fallout over the site, and from irradiated sodium reactor coolant leaks at unlined dumps seeping into sediments, and groundwater below the nuclear facility.

More than one million gallons of trichloroethylene (TCE) were also lost to solvent spills during rocket engine tests at the Santa Susana Complex. Seeping into soils, and sediments, the TCE moved downwards into a shallow, fresh-water aquifer below the site, contaminating upwards to one trillion gallons of groundwater. Some of the contaminated groundwater has since been pumped, and treated above ground, before being re-injected, and monitored further around the closed facility.



Spills, and leaks of both radioactive, and other chemical waste have also contaminated sediments, and groundwater at Lawrence Livermore National Laboratory, Tooele Army Depot, and Los Alamos National Laboratory. Aviation fuel, and solvent spills during U.S. Naval airbase operations contaminated sediments, and groundwater below the Lawrence Livermore site even before the National Laboratory was built. Site remediation began later after Lab spills added radionuclides, and other chemicals to the contaminated zones as well. To date, more than a billion gallons of contaminated groundwater have been pumped, and treated at ground surface before being re-injected into the aquifer system below the Lawrence Livermore facility. Upwards to 12 pounds of plutonium have also been lost at the National Laboratory.



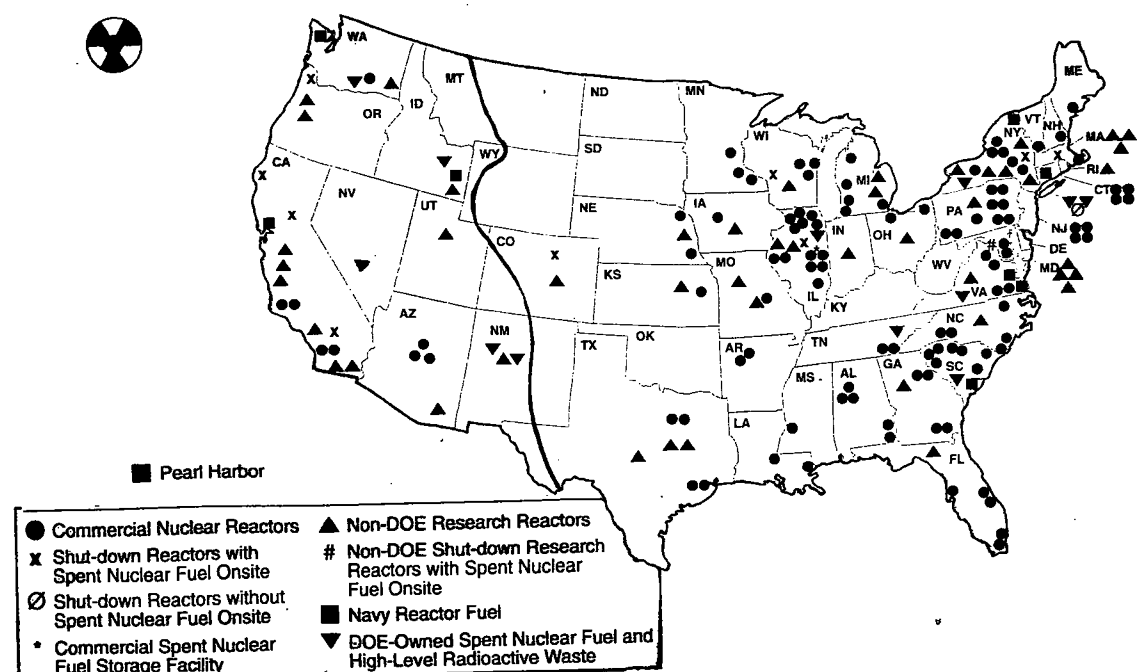
At Tooele Army depot, billions of gallons of groundwater have also been pumped, and ated above ground to remove industrial solvents, munitions chemicals, and radionuclides from a shallow, fresh-water, alluvial basin aquifer. Clean-up at the Depot was mandated after the site was assessed, and added to the U.S. Environmental Protection Agency's Superfund National Priority List.

Plutonium-239, and other radionuclides, plus TCE, and other chemicals have all migrated down canyons bordering Los Alamos National Laboratory after leaking from unlined dump

sites, and flowing from lab drains into the canyons. In addition, some of the contaminants have also entered fresh-water aquifers below the nuclear facilitly before moving down-gradient, and re-surfacing at radioactive springs both onsite, and offsite beside the Rio Grande. The Los Alamos compound is also serving as a temporary repository for high-level radwaste that was generated by its Omega test reactor up to the 1990s, and that is presently being generated at other lab facilities at the site.

Depending on their size, reactors at commercial power plants today use between 50, and 150 short tons of uranium dioxide fuel during annual operations usually.Reactor fuel rods at many of the plants are replaced every year, with "spent", or used fuel assemblies being place underwater in specially designed storage pools for several years to allow them to cool off as short-lived fission products in them decay. Once the reactor rods have "cooled down", uranium dioxide fuel in them may be reprocessed for later use. High-level radwaste containing strontium-90, cesium-137, barium-140, plutonium -239, and other radioisotopes are removed from the fuel as it is reprocessed. Then it is diluted, and mixed with hot calcinating cement for long-term dry storage in steal casks that are also coated with cement.

Locations of Spent Nuclear Fuel and High-Level Radioactive Waste Destined Ultimately for Geologic Disposal

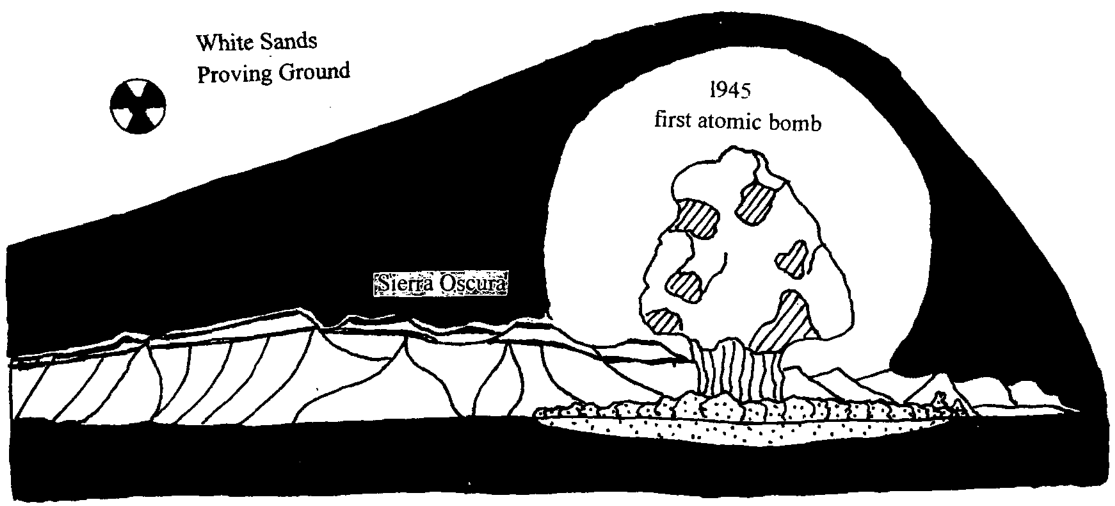


Today, more than 80,000 short tons of high-level radwaste are stored temporarily at 127 nuclear power plants and other temporary repositories across the nation. Add much larger backlogs of U.S. Military high-level radwaste from naval reactors, plus other sources to arrive at almost 200,000 short tons of processed radioactive material awaiting secure, long-term storage in the United States alone.

Development, Licensing, and Operational Concerns

Virtually all nuclear facilities across the Western U.S. have been developed during pro-nuclear Federal Administrations, beginning with the Manhattan Project during World War II when sites like the Hanford Nuclear Reservation, Los Alamos National Laboratory, and the White Sands Missile Range were selected with very little regard being given to their geotectonic setting, or to any negative impact that the facilities might have on the environment. The goal was to build, develop, and test atomic bombs in remote, and secure "out-of-sight, out-of-mind" locations as fast as possible. Irresponsible management and operational practices even included intentional releases of millions of Curies of radiation into the open atmosphere, and across the nation.

Unfortunately, things did not improve immediately after WW II as the U.S. Military continued to expand its nuclear arsenal during the Cold War between the U.S., and U.S.S.R. by setting off hundreds of above-ground atomic explosions at the Nevada Test Site. The nuclear explosions blanketed the country with



still more radioactive fallout bearing millions of Curies of radiation. Then came the early Cold War development of a nuclear-powered navy, and intercontinental ballistic missiles carrying multiple nuclear warheads, plus the construction of first-generation commercial nuclear power plants without steel containment vessels, or concrete shields.

A second generation of commercial nuclear power plants with both containment vessels, and shields followed, often endorsed by pro-nuclear Federal Review Boards even when the plant sites failed to meet National Regulatory Commission stipulations that they be located away from active faults, and other major

Nuclear Power Station

Geotechnical Considerations in Site Selection

NRC Criteria

The NRC has developed specific geologic and seismologic siting criteria (10 CFR Part 100, Appendix A), which require, in general terms:

1. Establishment of the maximum level of earthquake shaking that might conceivably be experienced by the plant;
2. Determination of the potential for surface faulting within 5 miles of the site;
3. Effect of shaking or loading on the performance of foundation soils;
4. Impact of any other geologic hazards near the site (subsidence, fissuring, and collapse).

The maximum level of earthquake shaking that could conceivably be expected at the site is called the Safe Shutdown Earthquake (SSE). The plant is designed to withstand at least this level of shaking and still be able to shut down operation without an accident. The SSE is a maximum credible seismic event that is conservatively determined after a complete study is made of the seismology, structural geology and tectonics within a 200-mile radius of the site.

The NRC criteria require that the potential for surface faulting be precluded within a 5-mile radius of the site. To accomplish this, any faults within a 5-mile radius must be demonstrated to:

a. have not moved once within the last 35,000 years, or
b. have no multiple movements within the last 500,000 years, or
c. have no logical connection to a fault beyond the 5-mile radius which might be considered capable of movement, and
d. have no demonstration of active seismicity.

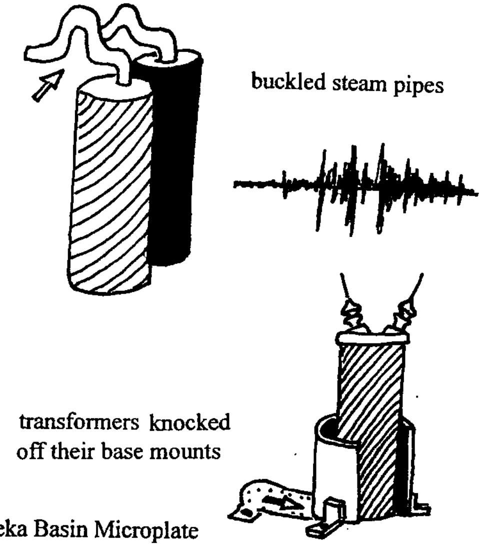
As a result, it becomes highly important that a potential nuclear site have consistent Quaternary stratigraphy relatively close to ground surface in order to determine minimum age on faults within the 5-mile radius and, in some cases, even beyond.

A comprehensive analysis of the foundation soils is required by the NRC for Preliminary Safety Analysis Studies to preclude the possibility of differential settlements, excessive consolidation, liquefaction during the Safe Shutdown Earthquake, or any other foundation phenomena that might endanger the integrity of the plant. The foundation studies also include such considerations as subsidence due to decreases in ground-water level, collapse of soils, and the effects of man-made hazards such as mining or withdrawal of oil. Besides immediate impacts of such conditions, all of these investigations must also consider possible long-term changes over the projected 40-year life of the plant.

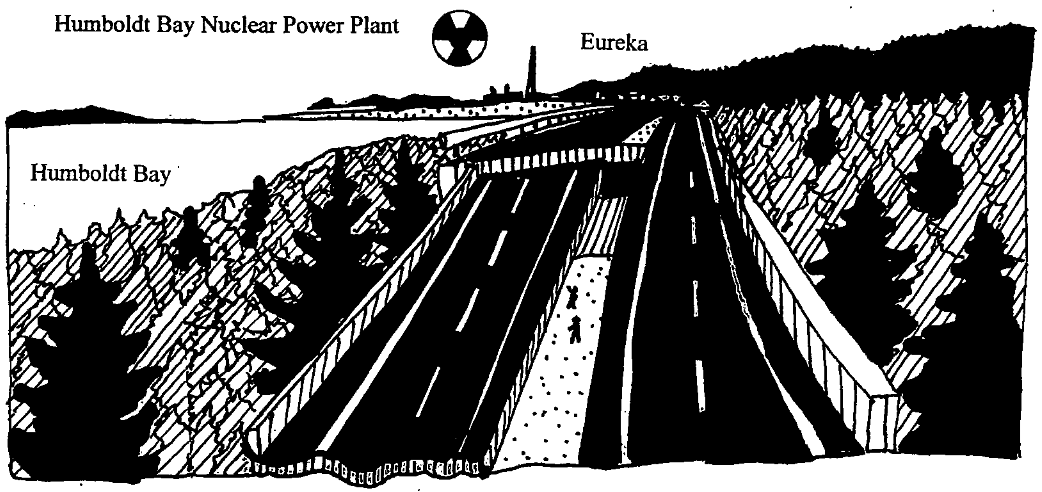
geologic hazards. As a result, six out of eight commercial nuclear power plants west of the Rocky Mountains today are located near, or over active faults in associated earthquake corridors. Also, half, or four out of eight of the commercial nuclear power plants have already been shutdown, decommissioned, and dismantled after public complaints about their vulnerable geotectonic settings, plus a number of equipment malfunctions, and operator errors that led to releases of radioactive fallout over areas surrounding the nuclear facilities.

Geotectonic Hazards, and Natural Disasters

Prior to its early closure, earthquakes had already buckled steam pipes, jammed doorways, and knocked transformers off their base mounts at the Humboldt Bay Nuclear Power Plant near Eureka in Northern California. One offshore temblor also raised the Pacific seabed up to five feet in elevation south of the plant, while collapsing a nearby highway overpass, and knocking homes off their foundations in Eureka.

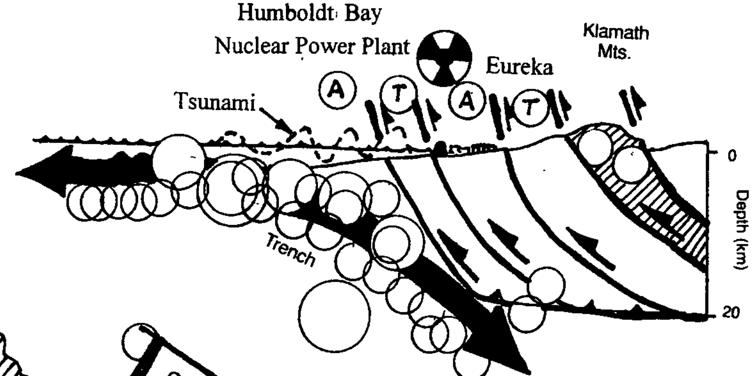


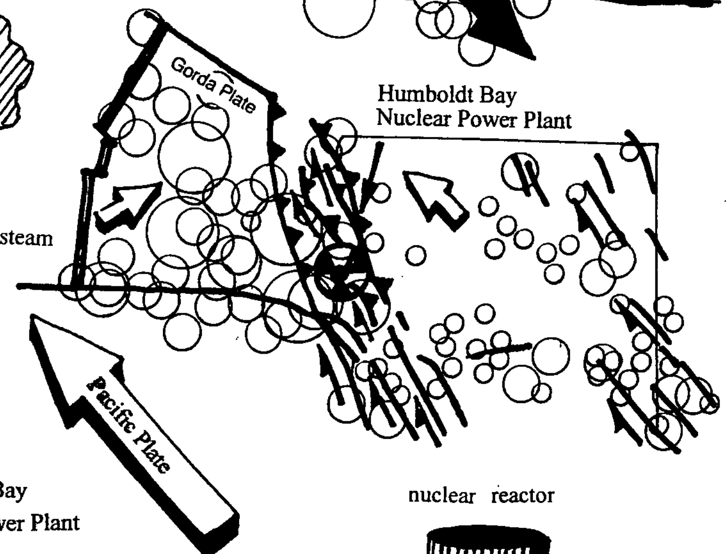
EARTHQUAKE DAMAGE

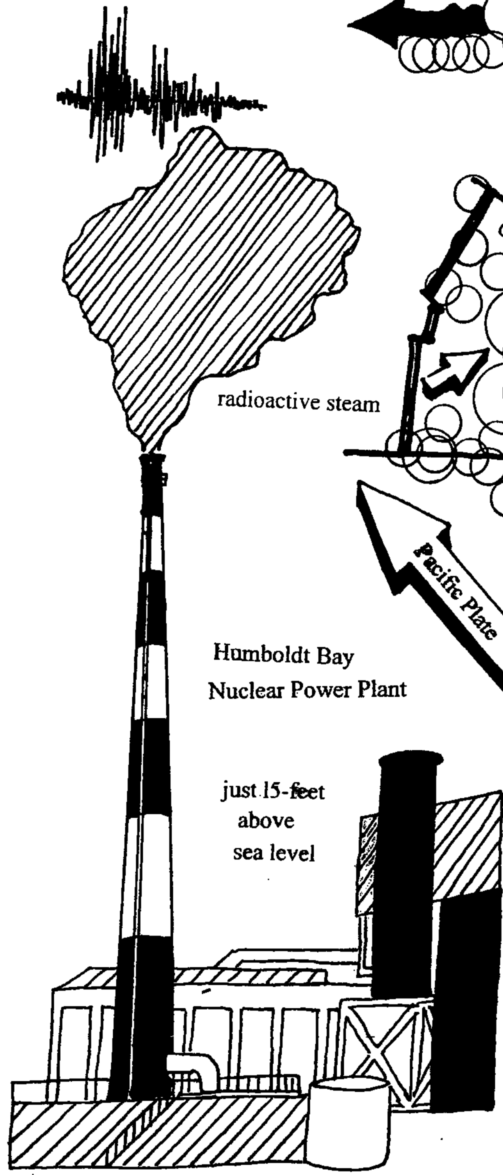


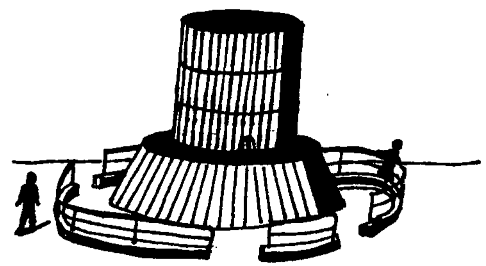
collapsing highway overpass

Major 7+ M earthquakes are a very real threat to the Humboldt Bay Nuclear Power Plant site.





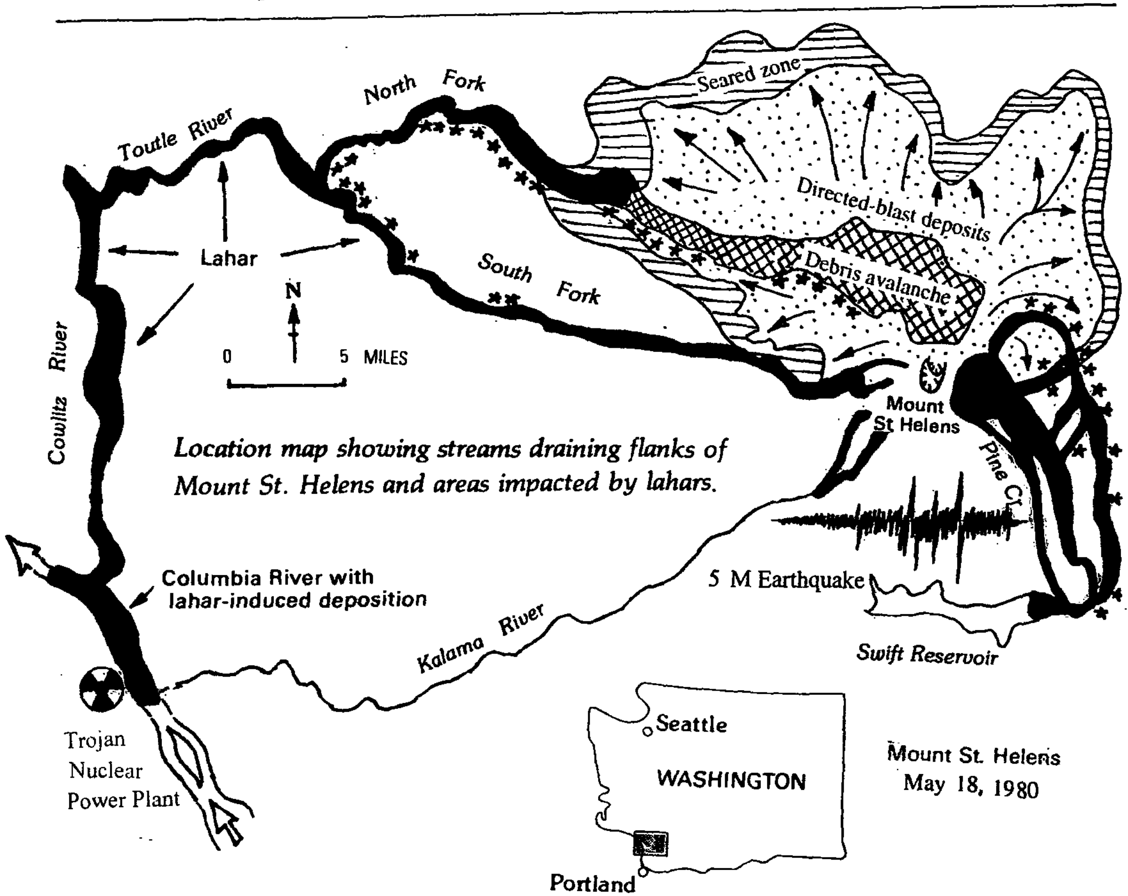


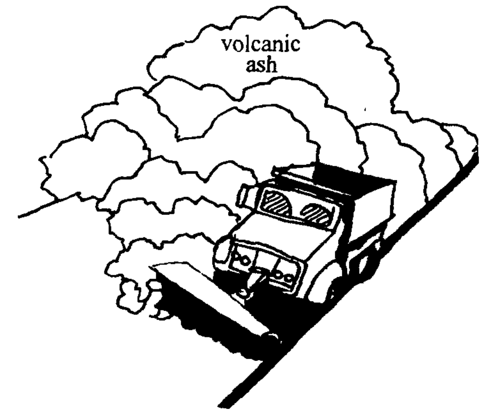


After early closure, the Humboldt Bay nuclear facility is being dismantled.

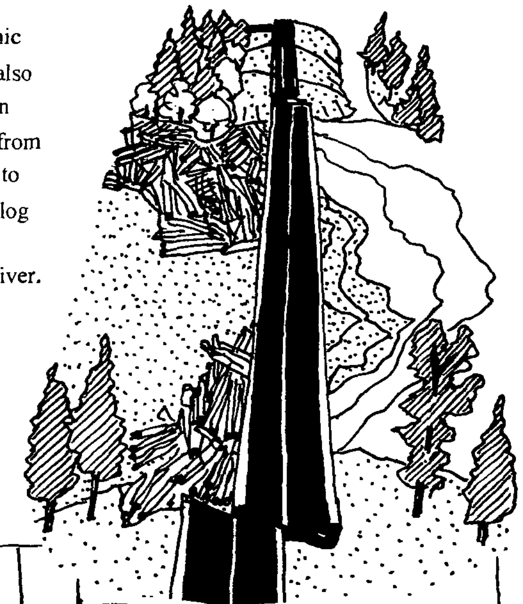
Earthquakes of 5 M, or larger also jolted the Trojan Nuclear Power Plant in Oregon, and the Santa Susana Field Laboratory in California prior to their closures. The earthquakes were associated with Mount Saint Helen's 1980 volcanic eruption 35-miles east of the Trojan facility, and with blind thrust offsets in the Greater San Andreas Transform Fault System below the Santa Susana Field Laboratory.

Mount Saint Helen's erupted with the equivalent force of 22,000 Hiroshima-size atomic bombs in 1980, and prompted Oregon voters to ban further nuclear power plant construction in the state after blanketing both the Trojan site, and the downwind Hanford Nuclear Reservation in Washington with volcanic ash. In addition, the eruption generated enormous mudflows that moved down slope to the Trojan Nuclear Power Plant site, while also activating fault traces even closer to the nuclear facility.

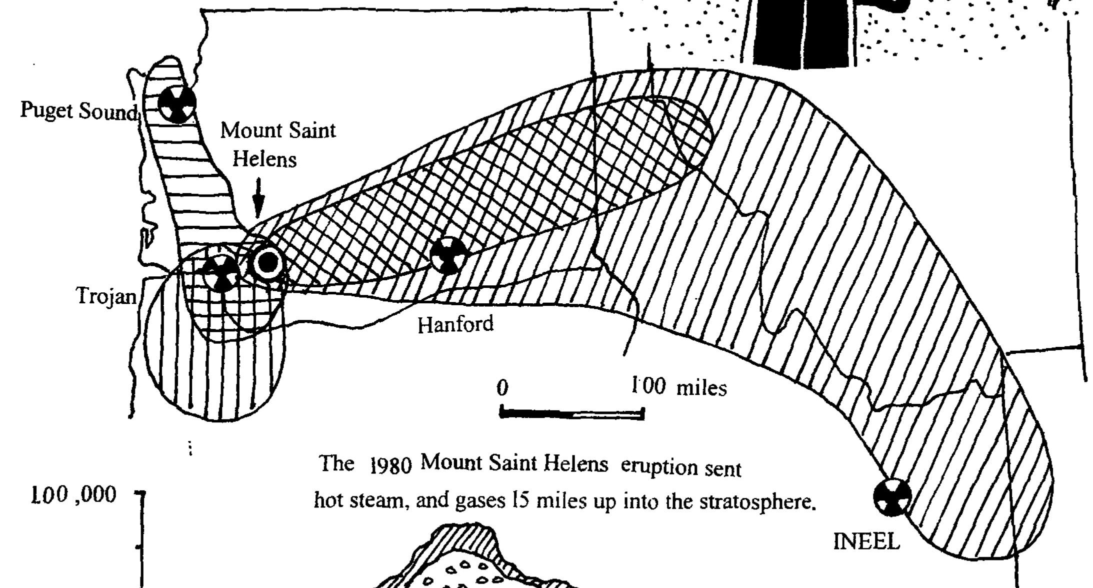




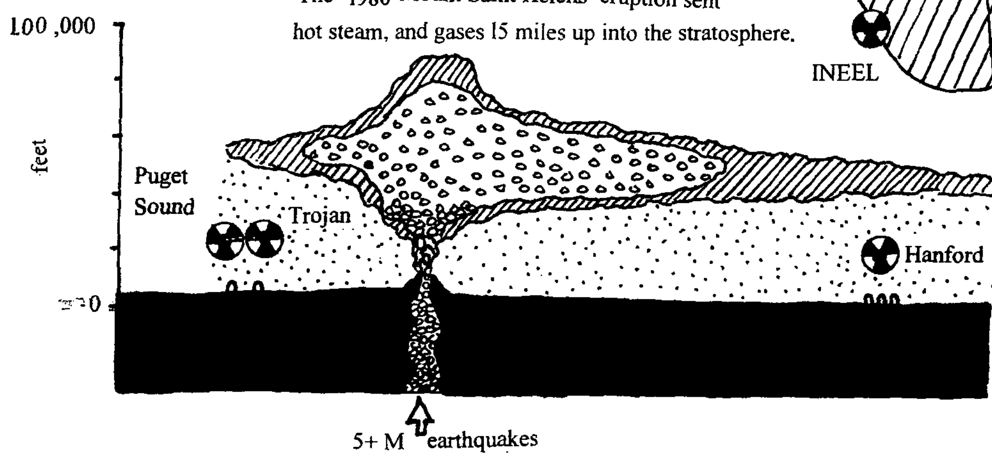
A cataclysmic debris flow also moved down slope away from the volcano to ultimately clog part of the Columbia River.



More than one half billion tons of volcanic ash blanketed a five state area, measuring up to five-feet-thick in places.



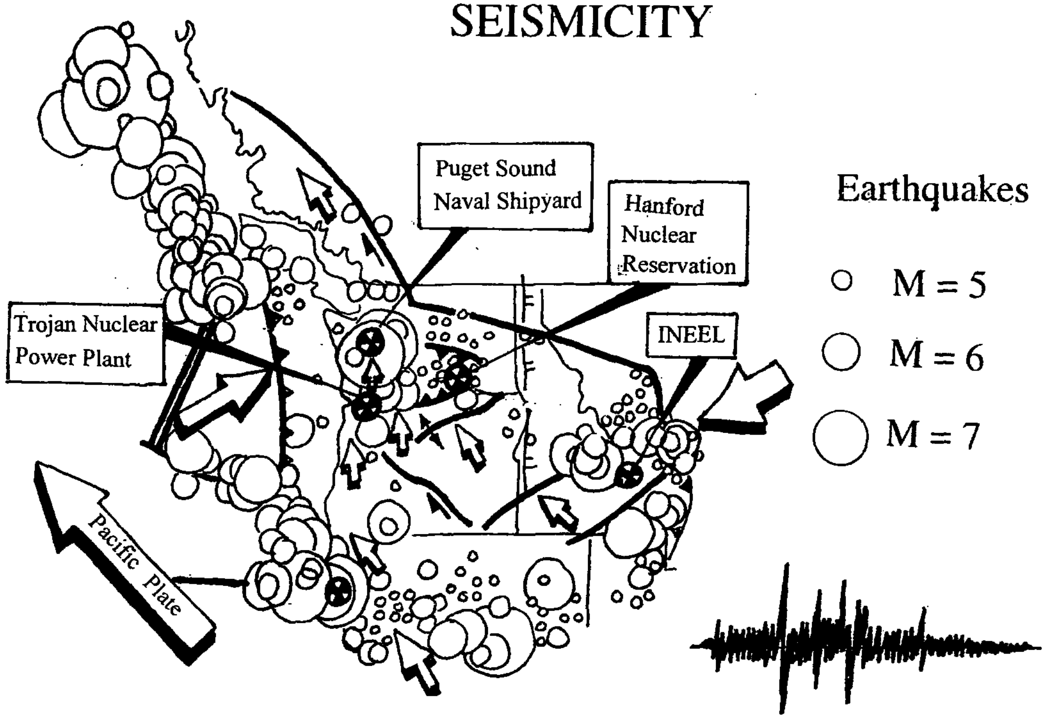
The 1980 Mount Saint Helens eruption sent hot steam, and gases 15 miles up into the stratosphere.



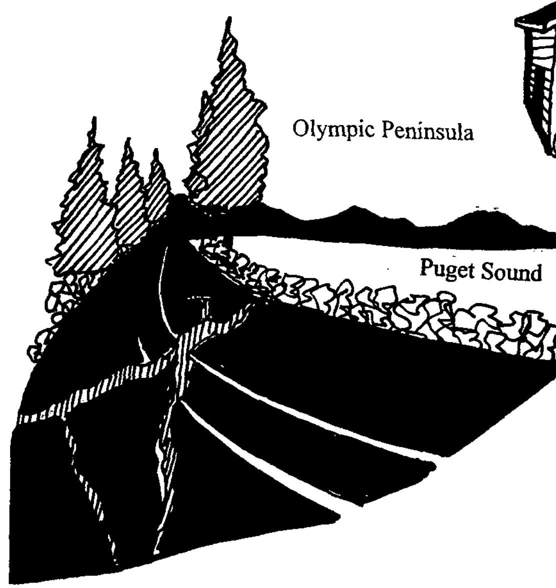
Two major earthquakes rocked the Santa Susana Field Laboratory during its operational life, both with epicenters just east of the facility in the San Fernando Valley. The quakes caused billions of dollars worth of damage, collapsing freeways, parking garages, municipal buildings, hospitals, and other structures in the Valley, while also killing more than 100 people, and leaving more than 10,000 other local residents homeless.

Other Western nuclear facilities that have been rattled by major earthquakes include the Puget Sound Naval Shipyard in Washington, and Idaho National Engineering, and Environmental Laboratory. Located inland from the active Cascadia Subduction Trench, Puget Sound is particularly vulnerable to deep-focus tremors, and was the epicenter of the 2001 Nisqually Earthquake (6.8 M) that shook the entire region under, and around the Shipyard, turning unstable shoreline sediments to quicksand in places.

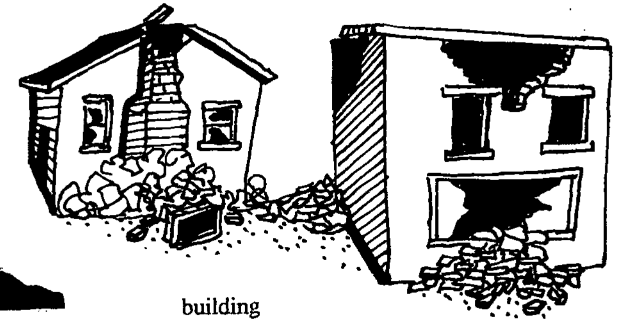
SEISMICITY



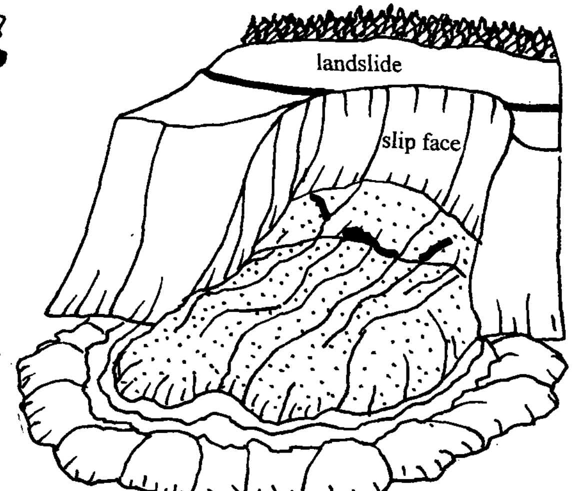
2001
Nisquali Earthquake damage

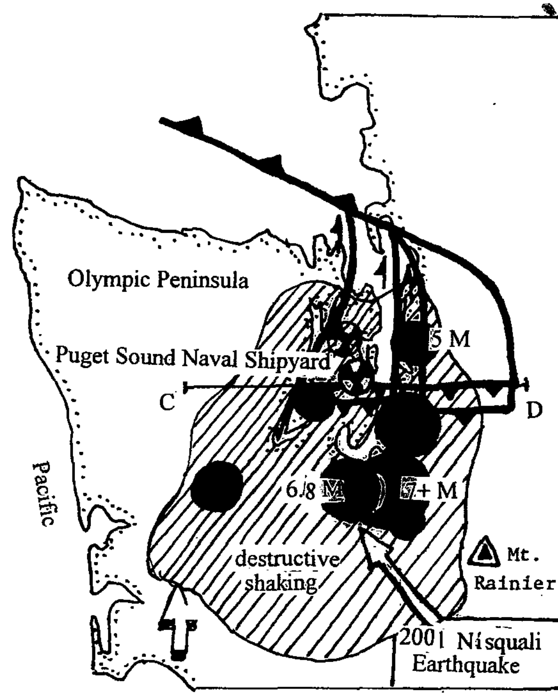


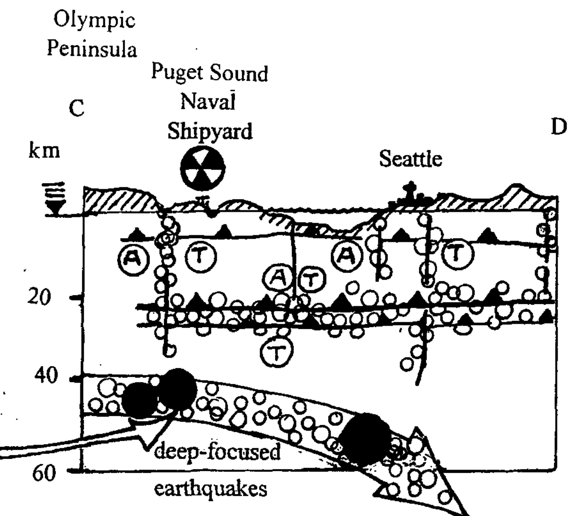
sediment liquefaction



building
rubble

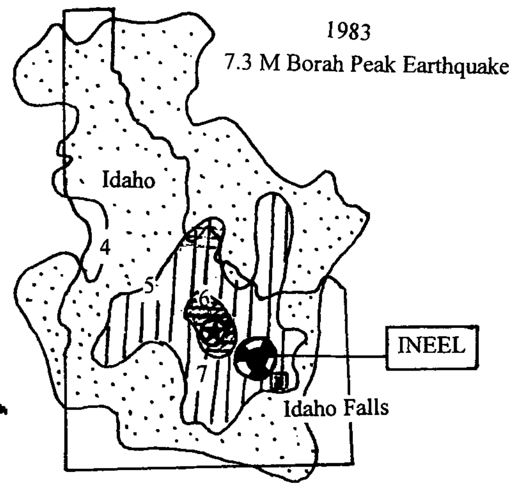


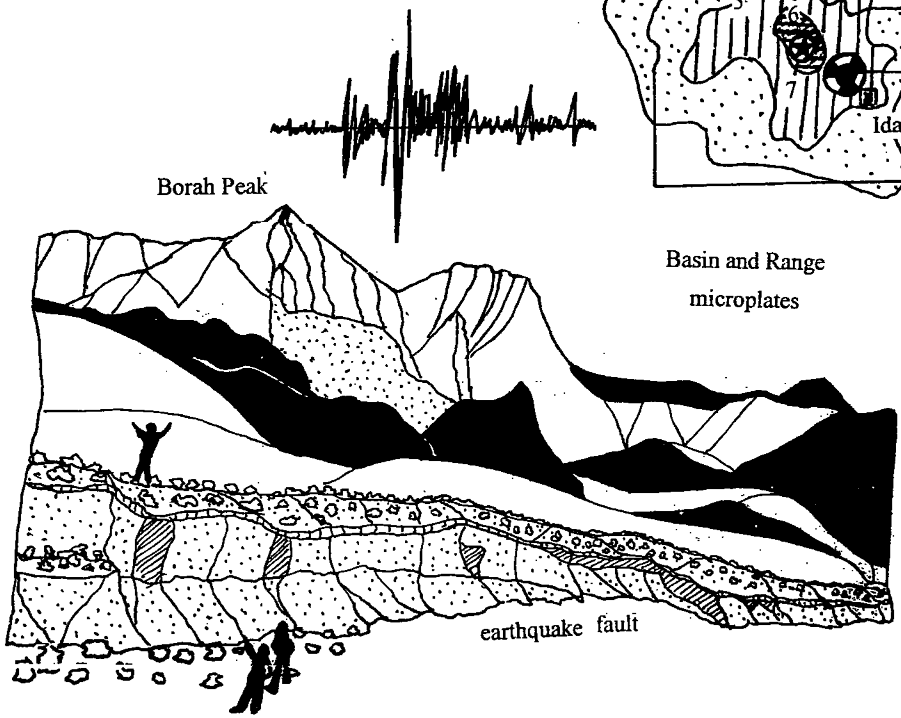




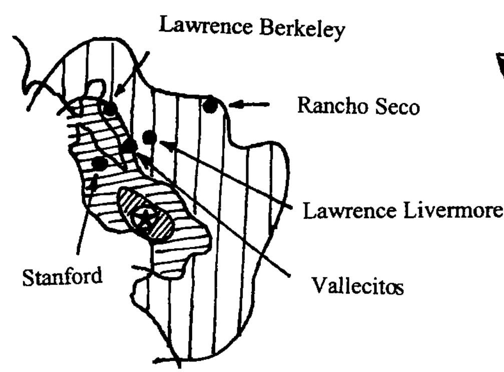
The 1983 Borah Peak 7.3 M Earthquake epicenter was only 35 miles northwest of INEEL. Although dampened, ground waves from the quake still shook many structures on the nuclear reservation with forces measuring more than 5 M on the Richter scale. INEEL is also located just east of Recent volcanic vents at Craters of the Moon National Monument on the Snake River Basalt Plain, and west of the Yellowstone Hot Spot where two near-surface magma chambers are venting thermal waters, and gases out of thousands of hot springs, and geysers in a giant, volcanic caldera complex. Any major eruption at either Craters of the Moon, or Yellowstone stands to endanger INEEL operations significantly.

The 7.3 M 1983 Borah Peak Earthquake was generated as the Big Lost River Fault shifted, doubling river, and spring flow in the region for more than a year. The earthquake shook INEEL with strong 5+ M ground waves.

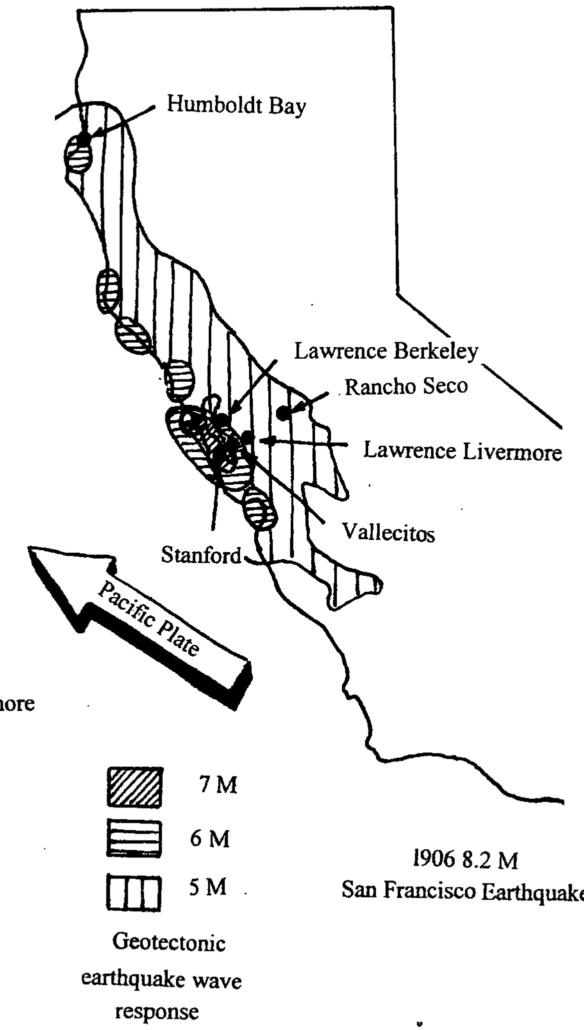




Then there is the Greater San Andreas Transform Fault System of California, and western Nevada to consider, where earthquakes occur daily, and where major quakes often shake several different nuclear sites at one time. For example, the 1989 Loma Prieta 7.1 M Earthquake that killed more than 80 people, collapsed freeways, destroyed parts of the San Francisco's Marina District, and did billions of dollars in damages rocked all four major nuclear facilities in the San Francisco Bay Area, including Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, VallecitosRadiation Laboratory, and the Stanford Linear Accelerator Center. In addition, the Loma Prieta Earthquake increased ground-water flow into the Humboldt Bay Nuclear Power Plant's underground reactor caisson from 6,000 to 10,000+ gallons per day more than 250 miles north of the temblor's epicenter.

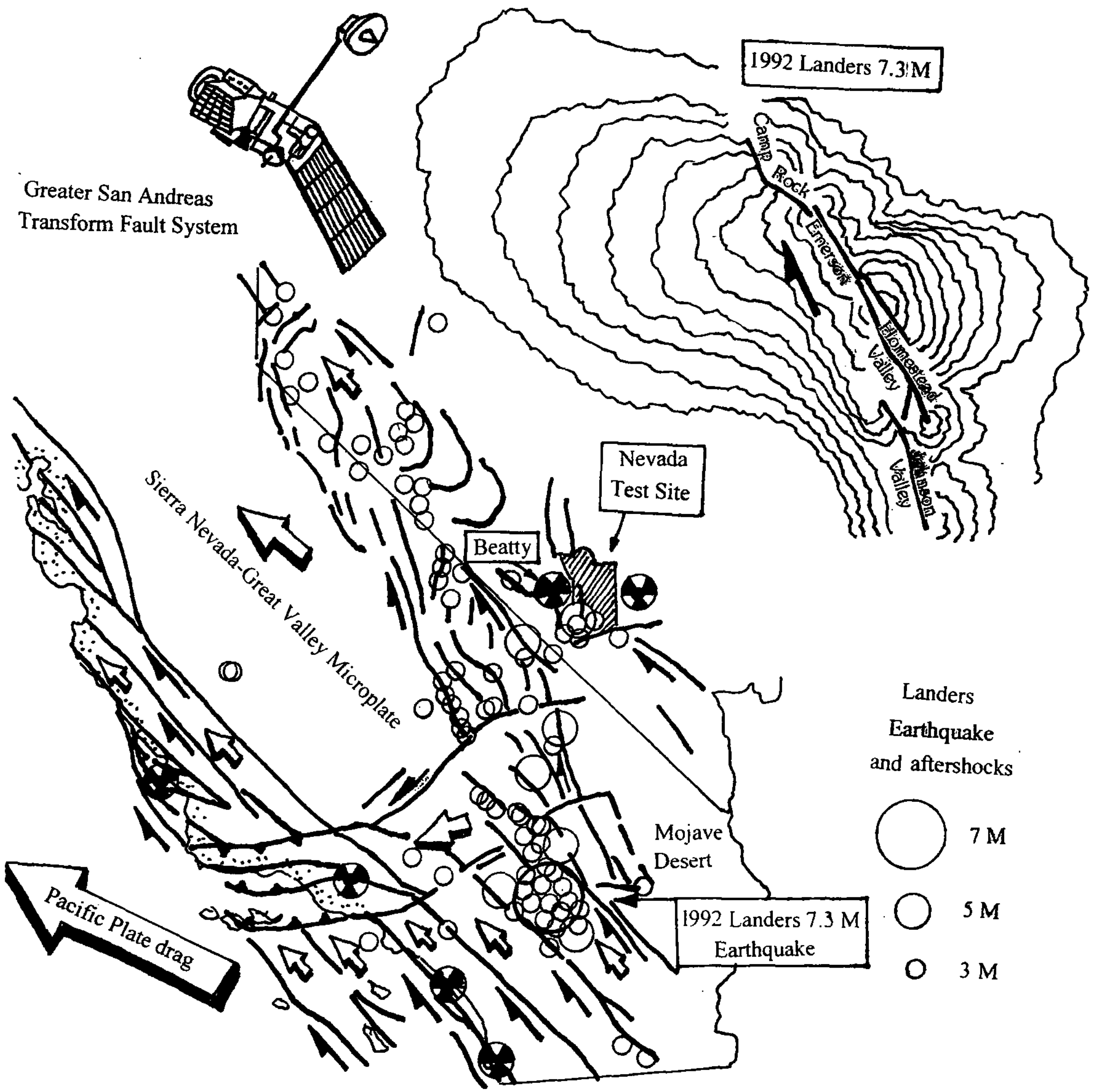


1989 7.1 M
Loma Prieta Earthquake

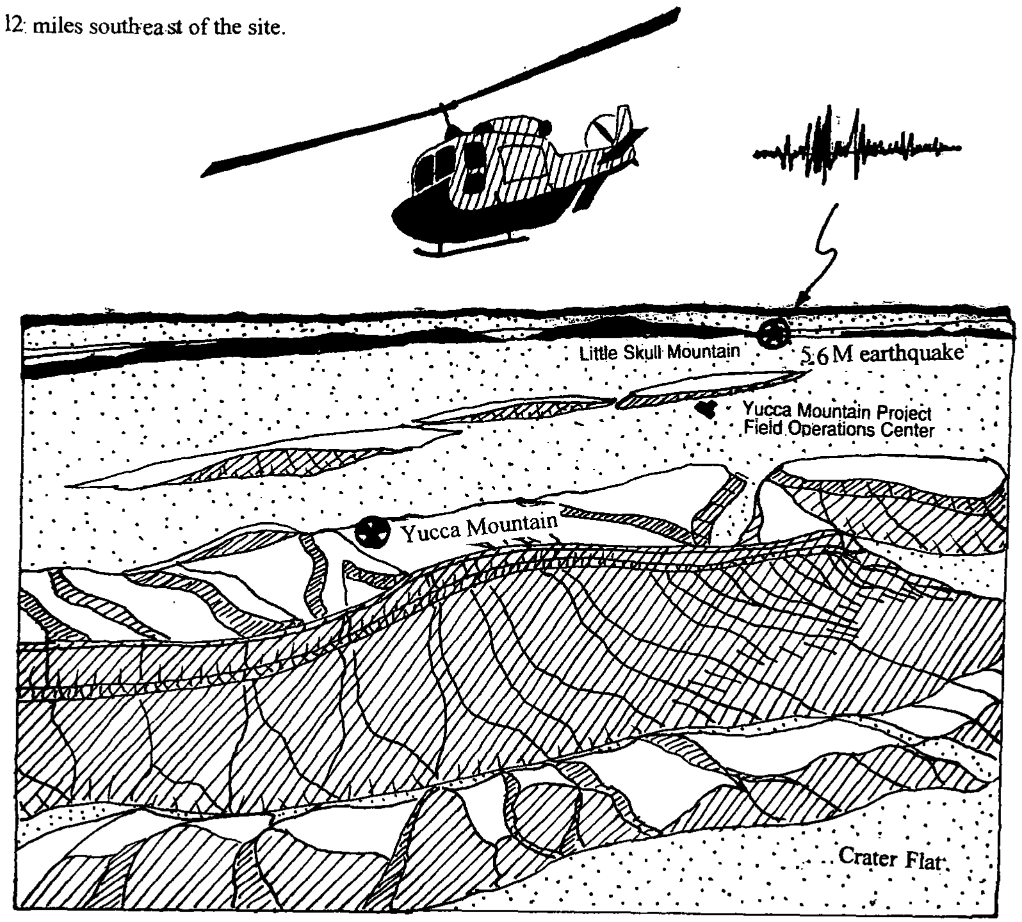


1906 8.2 M
San Francisco Earthquake

Similarly, the 1992 Landers 7.3 M Earthquake in Southern California's Mojave Desert generated aftershocks up the east side of the Sierra Nevada-Great Valley Microplate that were felt at the Nevada Test Site, and Beatty Chemical and Radioactive Waste Repository, too. In total, the Landers Earthquake aftershock corridor measured more than 300-miles-long, and stretched all the way north to the California-Oregon border.



Northwest drag by the Pacific Seafloor Plate keeps all of the Greater San Andreas Transform Fault System under constant stress today, and multiple displacements with associated aftershocks are common along parts of the system after a major offset, and associated earthquake occur. Significantly, a number of small earthquakes have also been recorded on, and around the Nevada Test Site immediately after underground nuclear blasts have induced local fault offsets in eastern extensions of the Greater San Andreas System. In essence, the quakes denote temporary releases of crustal tension in the stressed terrane. Still, larger quakes that are not associated directly with nuclear blasts also shake the NTS periodically. For example, a 5.6 M quake damaged surface facilities at the Yucca Mountain Repository in 1992 as a wrench zone detachment fault shifted 12 miles southeast of the site.

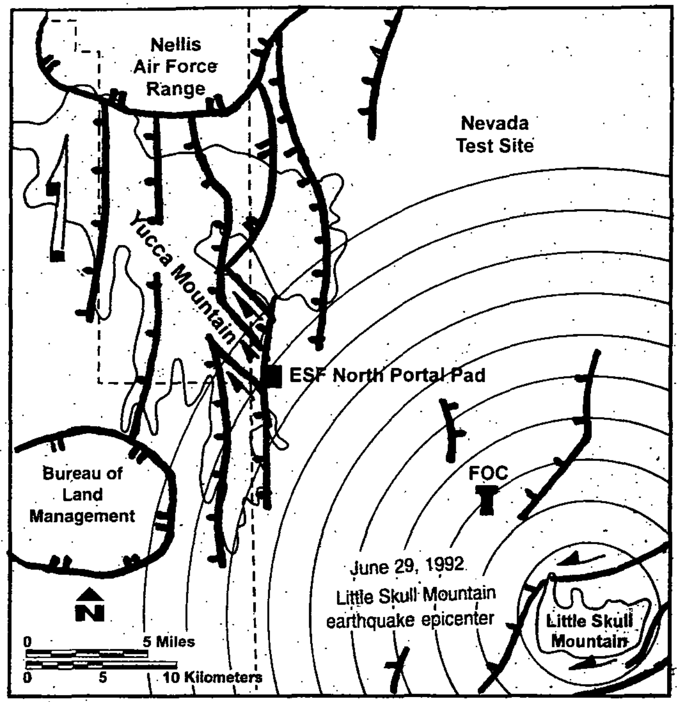


Damage to FOC from '92 quake cited

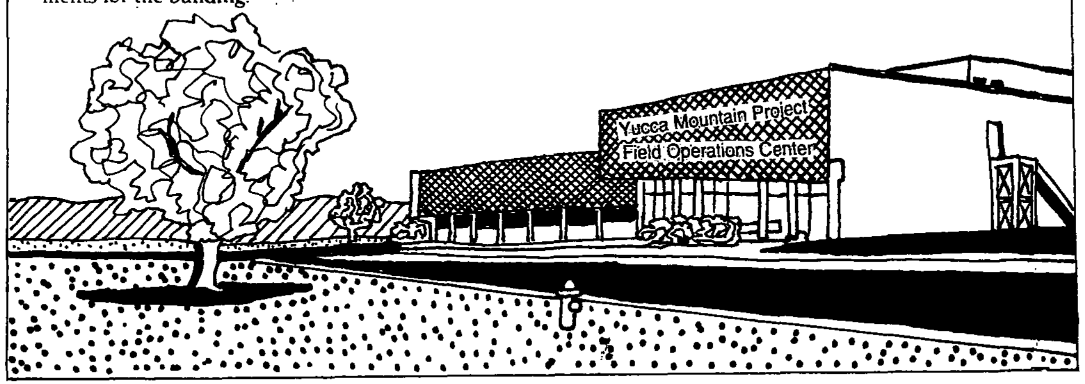
On June 29, 1992, a moderately powerful earthquake rocked the Yucca Mountain Project Field Operations Center, or FOC, located in Area 25 of the Nevada Test Site. Its epicenter was Little Skull Mountain, Nevada, located about six-and-a-half kilometers (four miles) from the FOC, and 19 kilometers (12 miles) from Yucca Mountain.

Seismologists experienced little trouble establishing the magnitude of this particular tremor (known as the Little Skull Mountain earthquake), which registered at 5.6 on the Richter Scale.

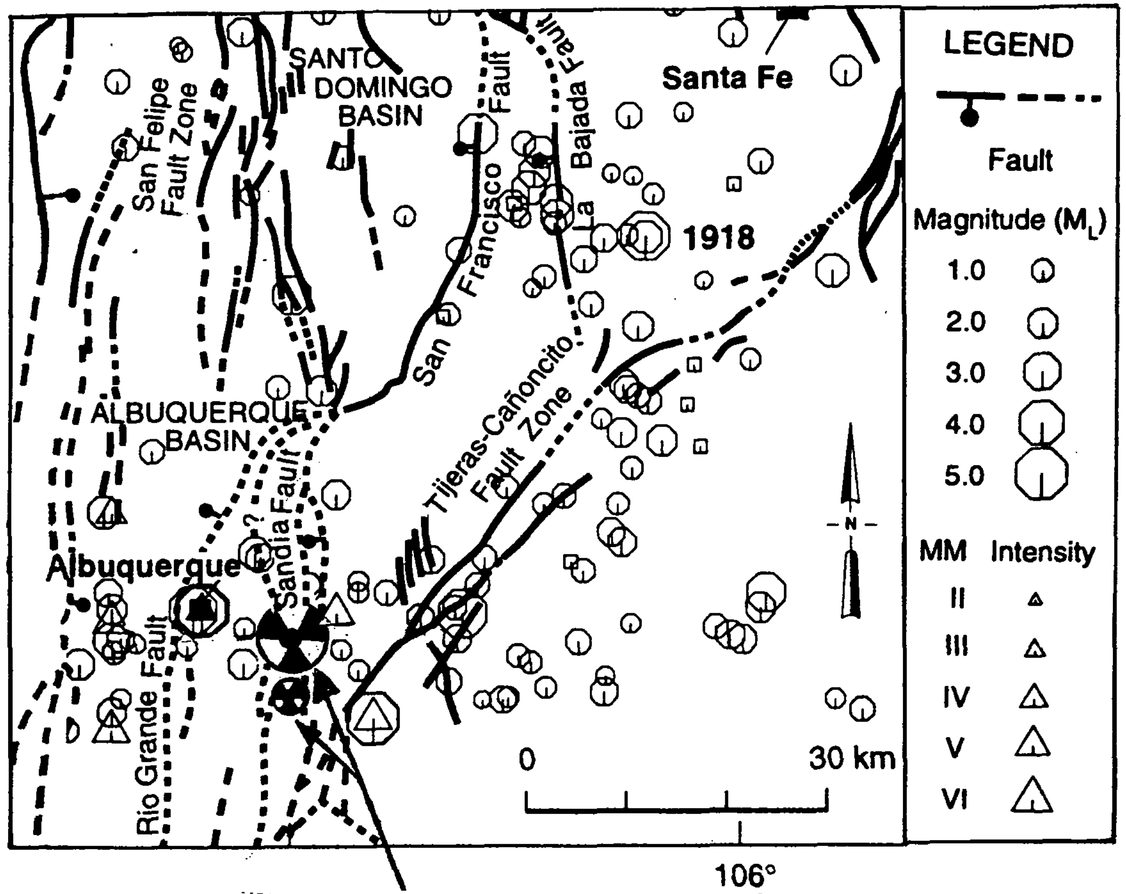
The extent to which the FOC was damaged by the Little Skull Mountain earthquake has been determined, and the bill for all necessary repairs came in at $40,000. The cost of repairs breakdown: repairs to broken windows totaled $23,000. Repairs to damaged stairwells cost $6,500. Another $9,500 covered miscellaneous painting, interior caulking, floor and ceiling tile replacement, and air conditioning duct repairs. This amount also included the cost of structural damage assessments for the building.



FOC and Yucca Mountain repository damaged by the Little Skull Mountain earthquake

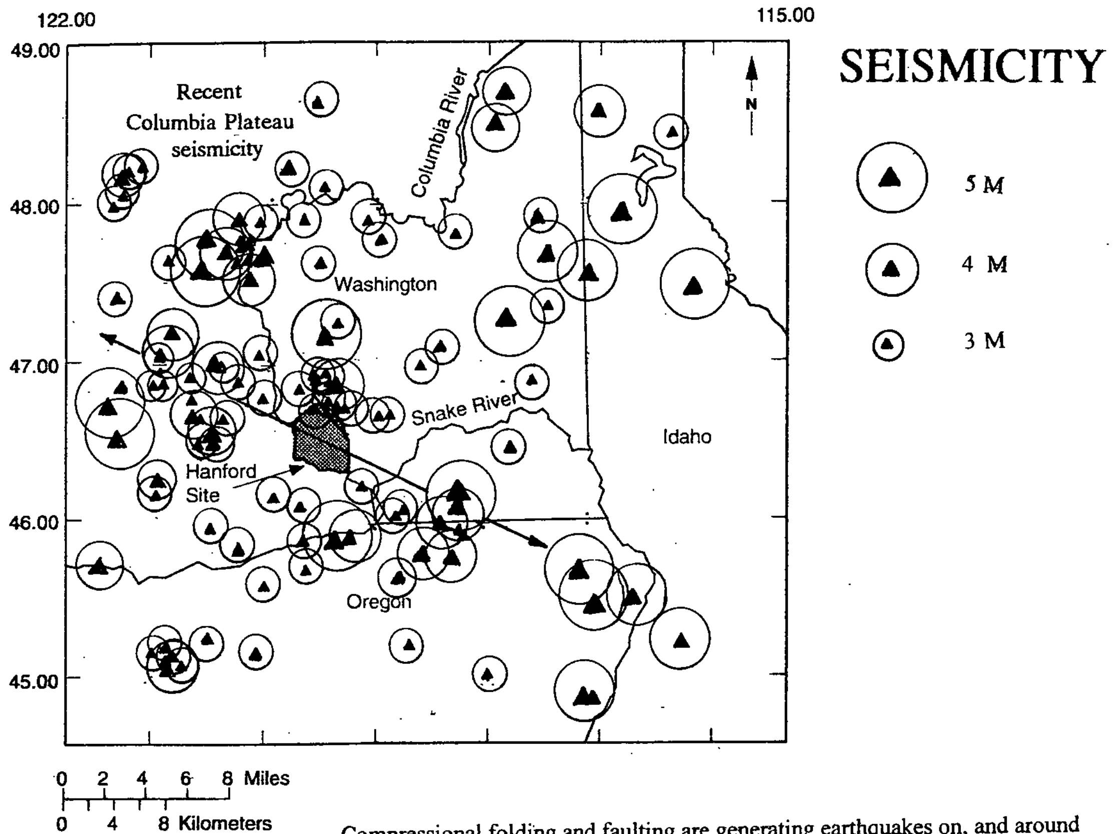


Extensional faulting in response to Pacific Seafloor Plate drag along the west margin of North America is also generating earthquakes across the Great Basin, and along the Rio Grande Rift. In turn, the earthquakes are shaking nuclear facilities like the Tooele Army Depot and Envriocare Radwaste Repository in western Utah, and Los Alamos and Sandia National Laboratories in New Mexico. The faulting and earthquakes occur less frequently, and are generally less severe in areas further removed from the effects of Pacific Plate drag. Still, 5+ M temblors have been recorded in the more insular regions, and can be expected to continue occurring until the Pacific Plate's sideswipe collision with North America ends.

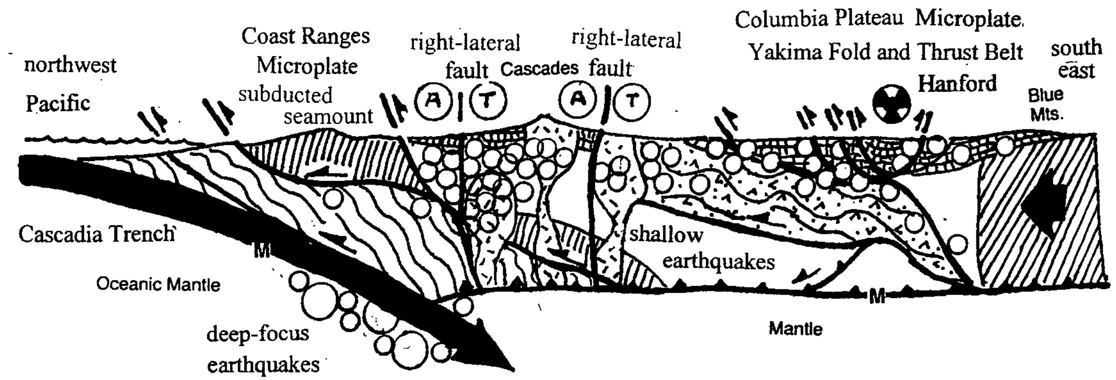


Sandia National Laboratory

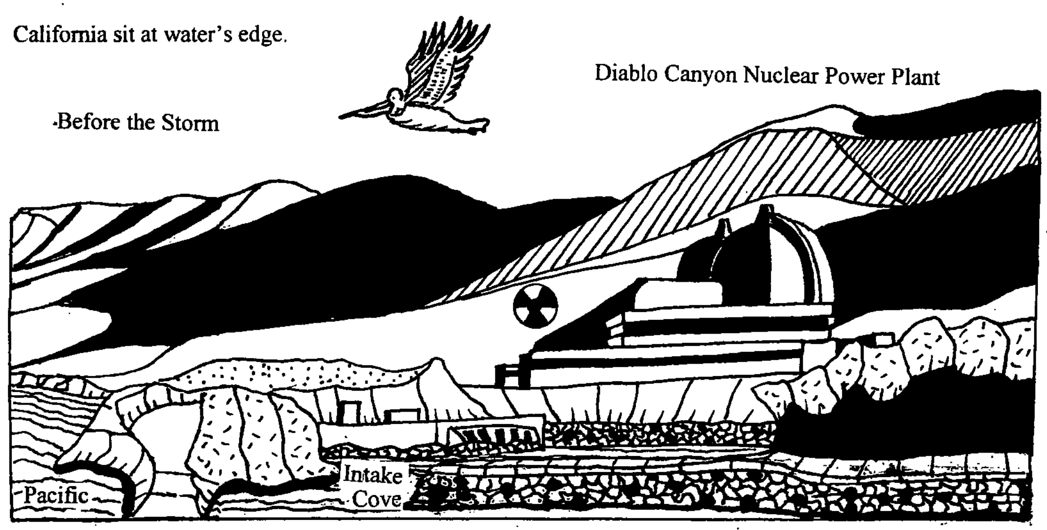
Finally, compressional folding and faulting are generating earthquakes on, and around the Hanford Nuclear Reservation, while also giving form to the Yakima Fold and Thrust Belt in south-central Washington. The earthquakes are generally of small magnitude, rating 4 M, or less on the Richter scale, and have relatively shallow focuses, reflecting the effects of near-surface basalt flo·· deformation over thicker, less brittle volcaniclastic deposits at depth. Notably, the deformation is also occurring in response to regional compression of the Columbia Plateau Microplate by the Pacific Plate's oblique collision with North America.



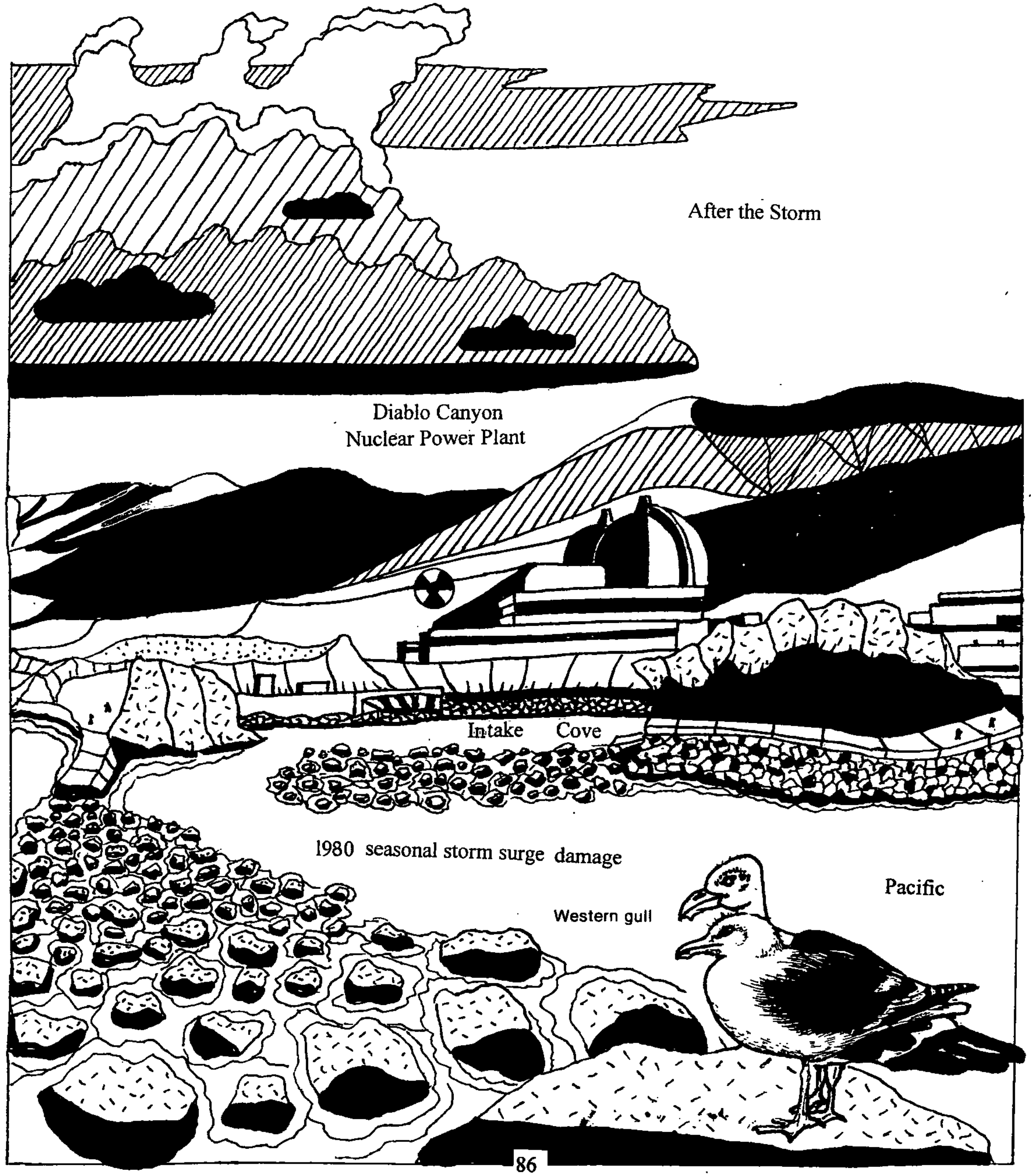
Compressional folding and faulting are generating earthquakes on, and around Hanford. The earthquakes have relatively shallow focuses, reflecting the effects of near-surface basalt flo·· deformation over thicker, less brittle volcaniclastic deposits at depth.



Tsunamis, rogue waves, and seasonal storm surges are all viable threats to nuclear sites bordering the Pacific coastline of Western North America. Geologic studies just south of the Olympic Peninsula in Washington, for example, indicate large tsunamis traveling several hundred miles per hour have hit the region repeatedly over the last 5000 years. In 1700, for example, a 9 M Cascadia Trench earthquake generated a tsunami that not only swamped inland forests just north of the Trojan Nuclear Power Plant site in Oregon, but also traveled across the Pacific, and hit the coast of Japan. More recently, smaller tsunamis, rogue waves, and seasonal storm surges have also pounded the Pacific coastline regularly with 10- to 15-feet-high seas, exposing ocean-bounding nuclear facilities even more to some of nature's more destructive forces. Both the Humboldt Bay and San Onofre Nuclear Power Plant sites in California are just 15-feet above sea level, while the Puget Sound Naval Shipyard in Washington, and Intake Cove at Diablo Canyon Nuclear Power Plant in California sit at water's edge.

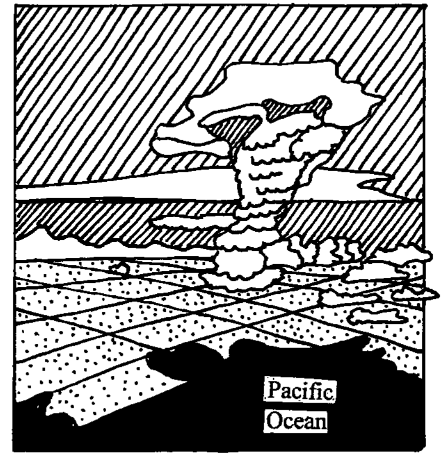


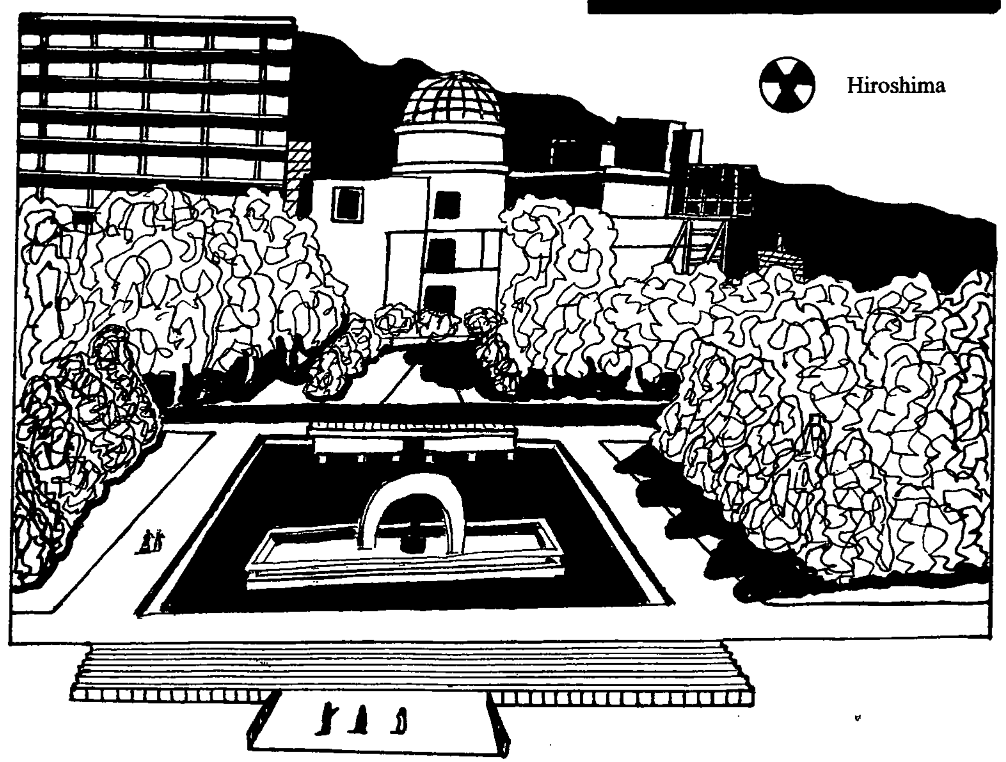
The Diablo Canyon Nuclear Power required expensive structural design and construction upgrades after start-up to limit the effects of some of nature's more destructive forces, including the inevitable seasonal storm surges that pound the ocean-bounding facility regularly with 10- to 15-feet-high seas.

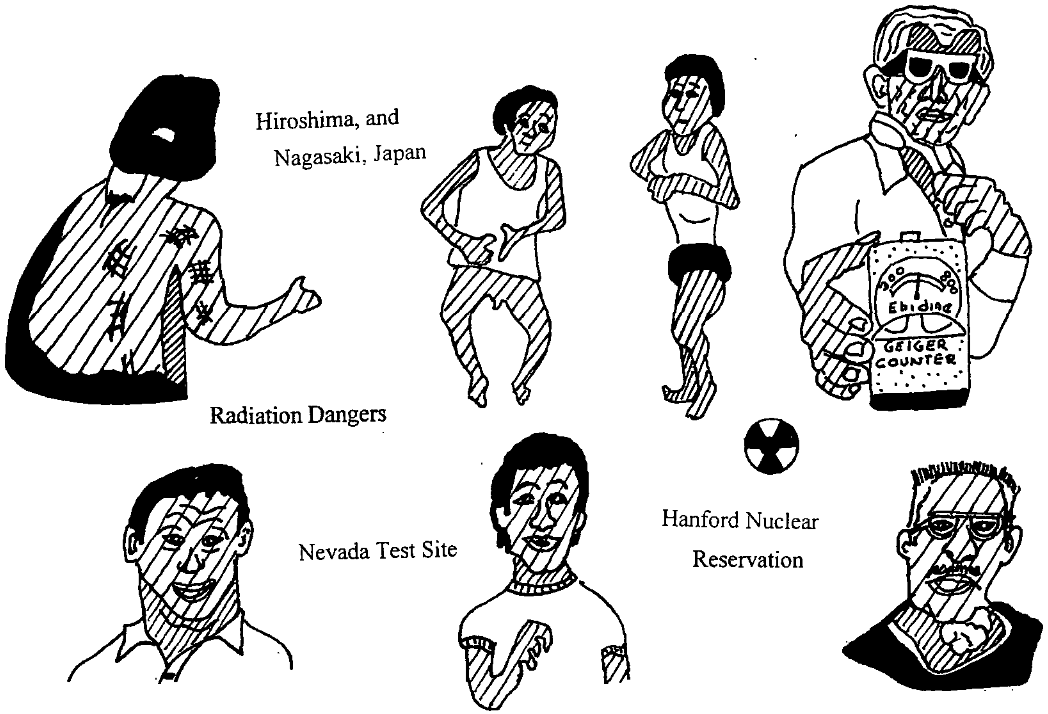


Radiation Dangers

The disadvantages of nuclear development become even more personal at a human level when radiation dangers are considered. More than 120,000 people were vaporized, or otherwise killed by radiation when atomic bombs were dropped on Hiroshima, and Nagasaki, Japan, near the end of World War II. Even more Japanese suffered from radiation burns, and radiation sickness after the air raids, with their body cells, and organs damaged, if not completely destroyed, by subatomic particle bombardment. The radiation burns were treated with balms, and salves, when skin grafts were not







required. Radiation sickness symptoms included lóss of appetite, and vigor, internal hemorrhaging, hair loss, and immune system failure, with treatment often limited to blood transfusions, and the injection of antibodies to help fight infections. Later to come were miscarriages, birth defects, and various types of cancer, many irreversible, and incurable.

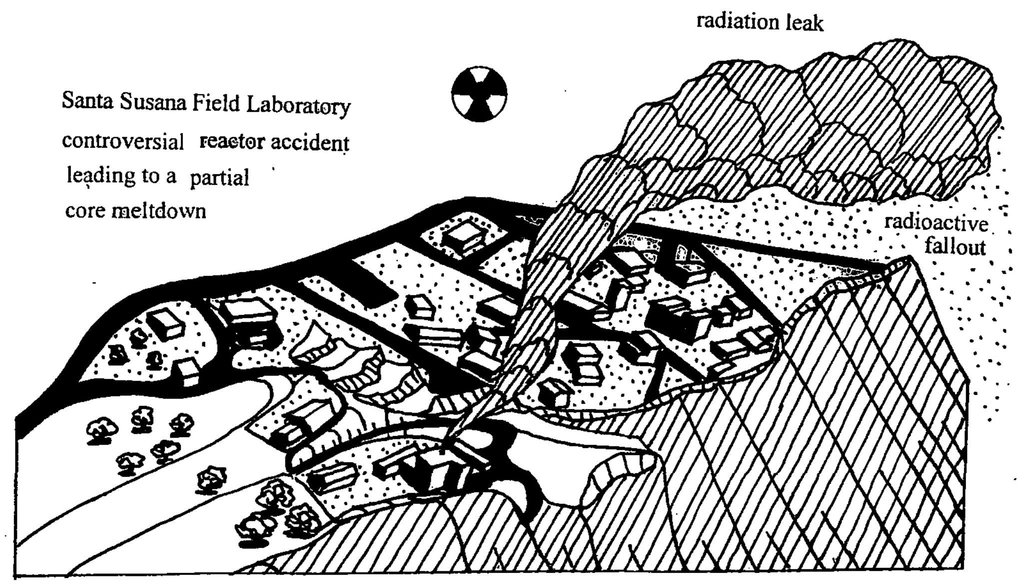
Similarly, many Americans across the West and elsewhere have also been sickened, if not killed, by radiation releases from atomic reactors, and atomic bomb explosions. Particularly hard hit during the 1940s, and 1950s were populations living, and working on, or downwind from nuclear facilities like the Hanford Nuclear Reservation in Washington, and the Nevada Test Site, where millions of Curies of radiation were released intentionally into the atmosphere during atomic bomb blasts, and other nuclear experiments.

Quite often, children were the most susceptible to radioactive iodine-131 poisoning after Hanford's "Green Run" atmospheric tests that covered downwind grazing lands with the radioisotope during early post-WW II years. In essence, dairy cows ingested the iodine-131 while feeding on pastures contaminated with radioactive fallout. The radioisotope was then passed on to the children when they drank the cows' milk, and

concentrated in the youngsters' thyroid glands, disrupting body metabolism, and bone growth. Higher incidences of miscarriages, birth defects, and cancer deaths in the downwind human population followed after the Hanford tests.

Radioactive fallout from above-ground atomic bomb blasts at the Nevada Test Site during the late 1940s, and 1950s also sickened, and killed both livestock, and humans downwind from the nuclear facility. Soon after the tests began, nearby ranchers began to complain about livestock deaths, miscarriages, and birth defects, too. The came higher numbers of cancer deaths among the general human population living downwind in heavy radioactive fallout zones, including those of John Wayne, and others who worked on a contaminated movie set near Saint George, Utah, during the 1950s.

Further west, researchers were also being exposed to high doses of radiation during sodium-cooled atomic reactor tests at the Santa Susana Field Laboratory in Southern California. After one failed test led to a partial reactor core meltdown, and the release of radiation over Los Angeles Basin, almost all researchers involved in the incident died ultimately of cancer.

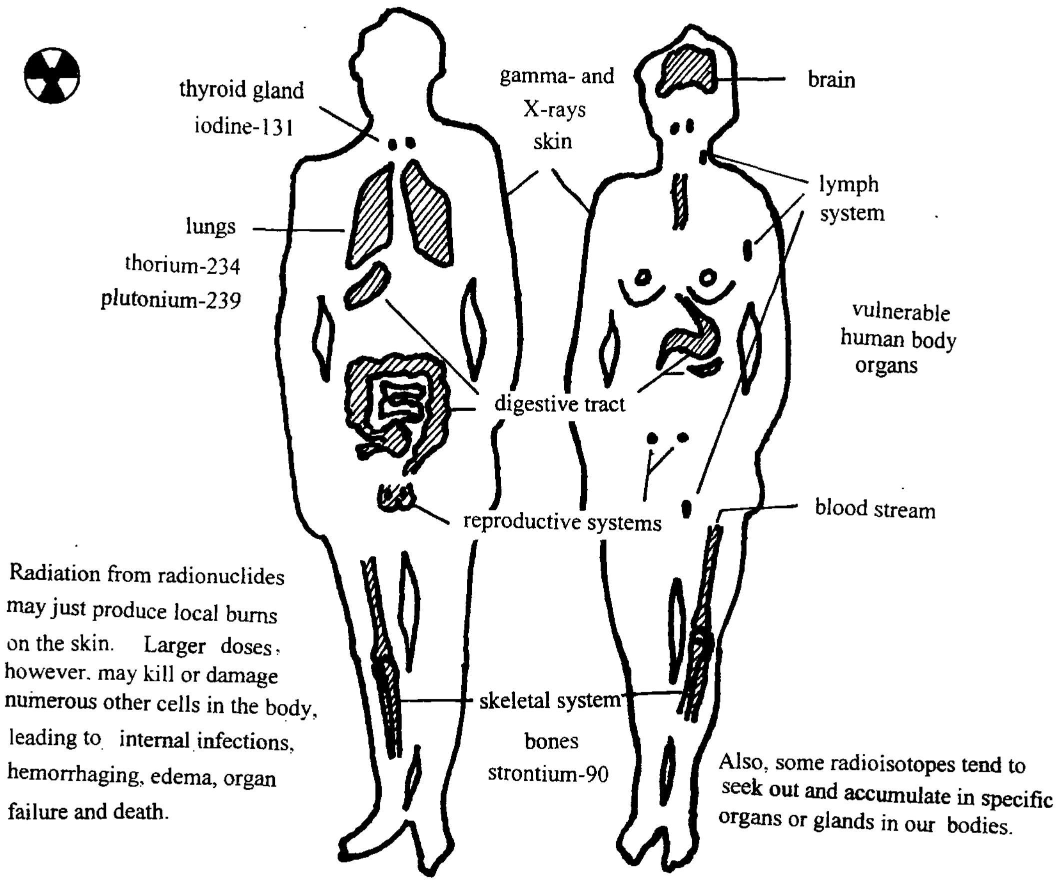


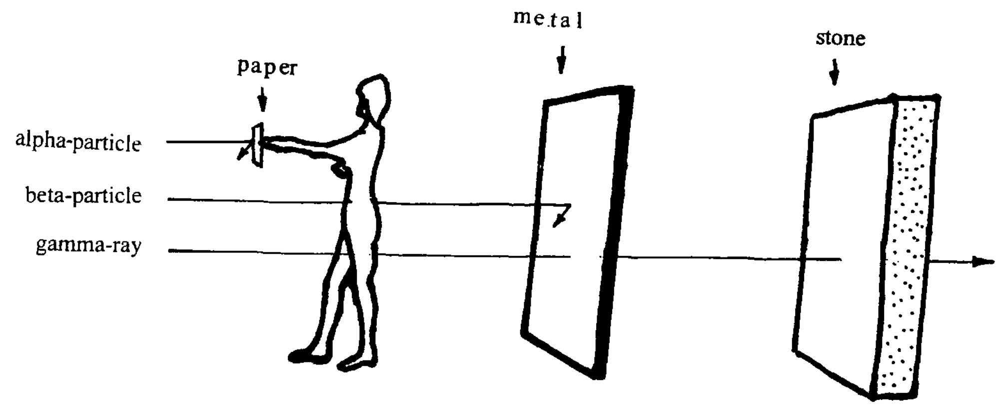
In overview, humans are susceptible in various ways to a number of different types of radiation. The radioactive decay and fission of radioisotopes produces pulses of electromagnetic energy or photons that travel at the speed of light and that have both high gene-, and cell-damaging potential in the form of gamma-rays. Additional products of radioactive decay and fission include alpha-, and beta-particles, plus X-rays and other subatomic pieces of matter, all of which can damage human tissue, while altering cell growth, too.

In nature, different radioisotopes emit different types and amount of subatomic particles and energy. For example, uranium-238 emits a slow-moving alpha particle composed of two protons and two neutrons, plus gamma- and X-rays as it decays to form thorium-234. The instable thorium atom then emits a beta particle composed of a small, fast-moving electron, plus gamma- and X-rays to form protactinium-234. Half-lives, or decay rates of different radioisotopes vary, with some occurring in micro-seconds, and others spanning millions of years.

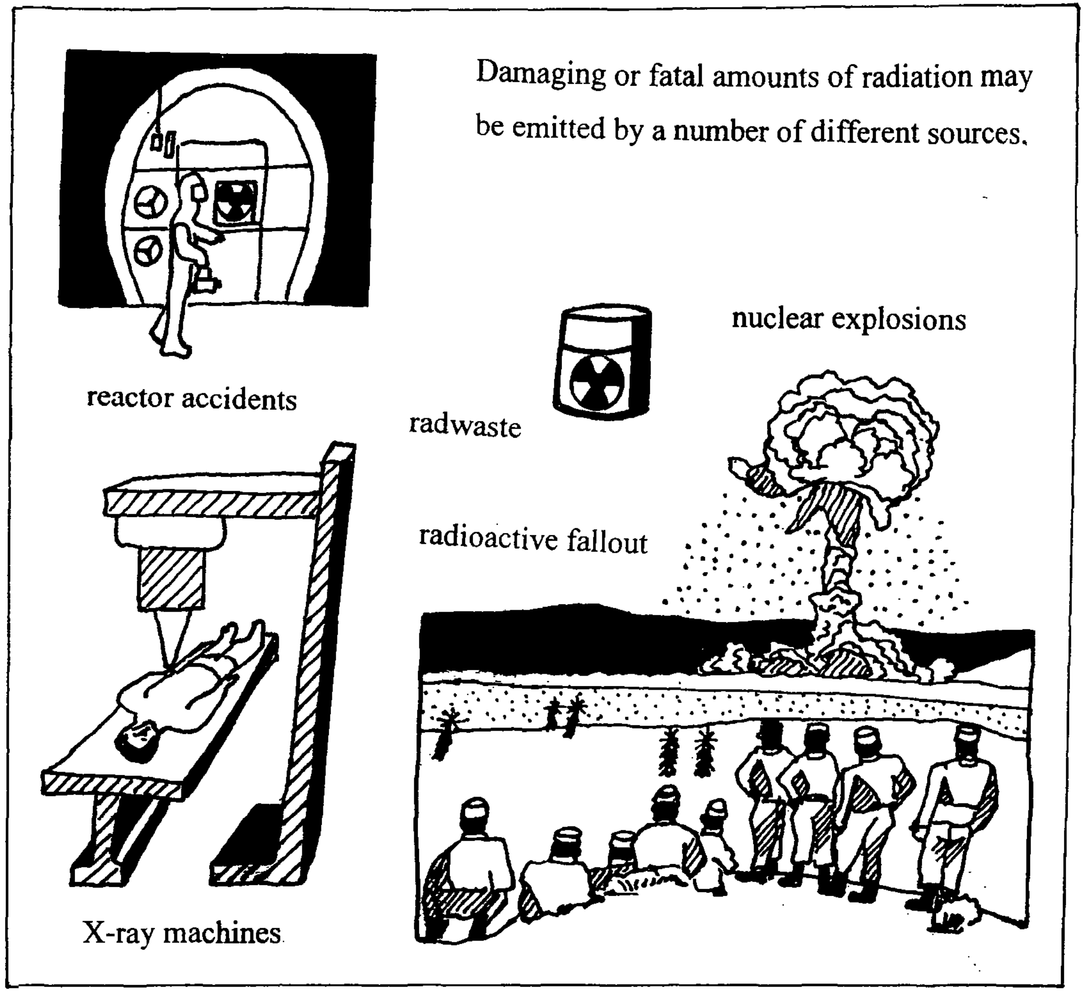
Radiation from radionuclides affects the human body in many different ways. In small doses, it may just produce local burns on the skin. Larger doses of radiation, however, may kill or damage numerous other cells in the body, including those in the blood stream and digestive tract, leading to internal infections, hemorrhaging, edema, organ failure and death. Also, some radioisotopes tend to seek out and accumulate in specific organs or glands in our bodies. For example, radioactive iodine-131 is often absorbed by the thyroid gland in the human endocrine system, while strontium-90 concentrates in our bones or skeletal system. Other organs in the human body that are especially vulnerable to specific radioisotopes or radiation include our lungs, skin, brain, and digestive tract, as well as our lymph and reproductive systems.

Damaging or fatal amounts of radiation may be emitted by a number of different sources, including nuclear explosions, radioactive fallout, uranium mines, X-ray machines, subatomic particle accelerators and radwaste piles, plus industrial and medical radioisotopes. To date, atomic bomb explosions and associated fallout have probably been the biggest radiation killers in the Nuclear Age, followed by uranium mines, atomic





In nature, different radioisotopes emit different types and amount of subatomic particles and energy.

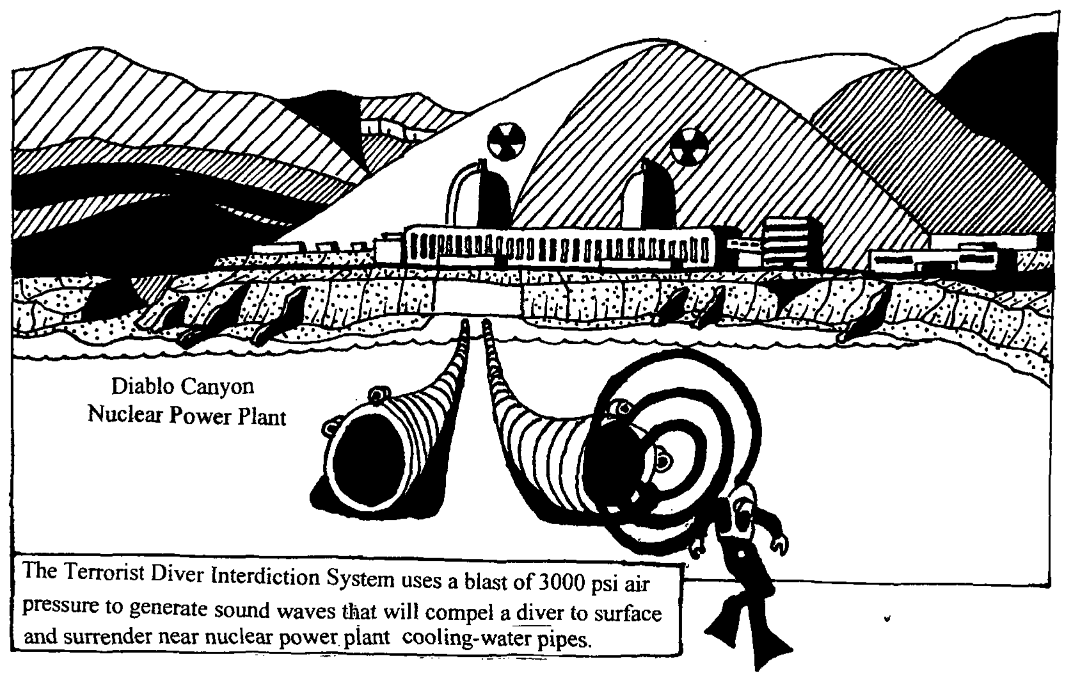


reactor accidents, radwaste spills and medical isotopes. There have been inceasing concerns in recent years, however, that terrorists may spread radionuclides on large segments of the general human population by poisoning municipal water supplies, or in other ways killing even more people than have already been killed by wartime atomic blasts and associated radioactive fallout.

Terrorists' attacks on vulnerable U.S. nuclear power plants that lead to reactor core meltdowns, and major radioactive disasters must also be considered. Already, all of the nation's nuclear facilities have been proven vulnerable to suicide, and accidental airplane crashes. In addition, a series of ground-

based exercises by the National Regulatory Commission between 1991, and 2001 showed that mock attackers were able to achieve simulated reactor meltdowns at nearly half of the nation's commercial nuclear power plants.

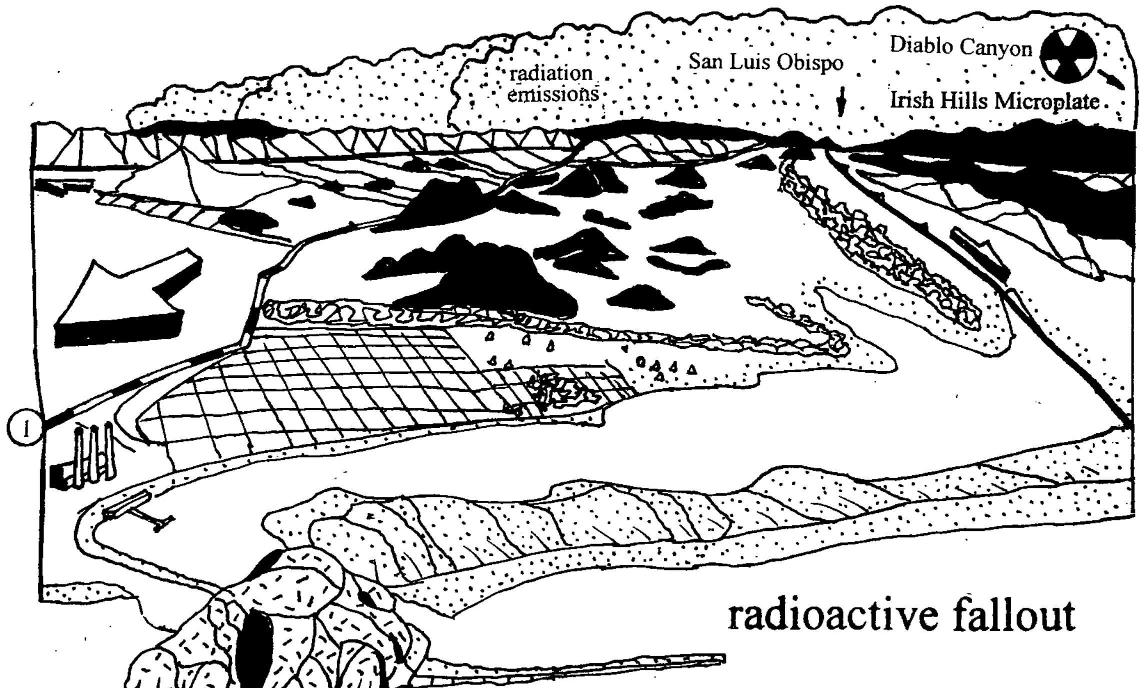
Also vulnerable during the mock terrorists' attacks were reactor cooling water intake, and outflow pipes; spent nuclear fuel rods stored in cooling pools; and radwaste transport routes. The reactor cooling-water intake, and outflow pipes can be sabotaged by experienced underwater divers at a number of commercial reactor sites across the nation. Studies by the American Federation of Scientists, and other professional groups have also shown that overheated, ruptured fuel rods in a drained power plant cooling pool will catch fire, and burn for days. Such fires can release up to five times more radiation into the atmosphere than the 1986 Chernobyl reactor meltdown in Russia, or upwards to 600 million Curies in radioactive fallout, making an area the size of New York uninhabitable for at least 30 years. Almost 60 percent of the U.S. population lives within 75 miles of one of the nation's 127 spent fuel repositories in 44 different states.

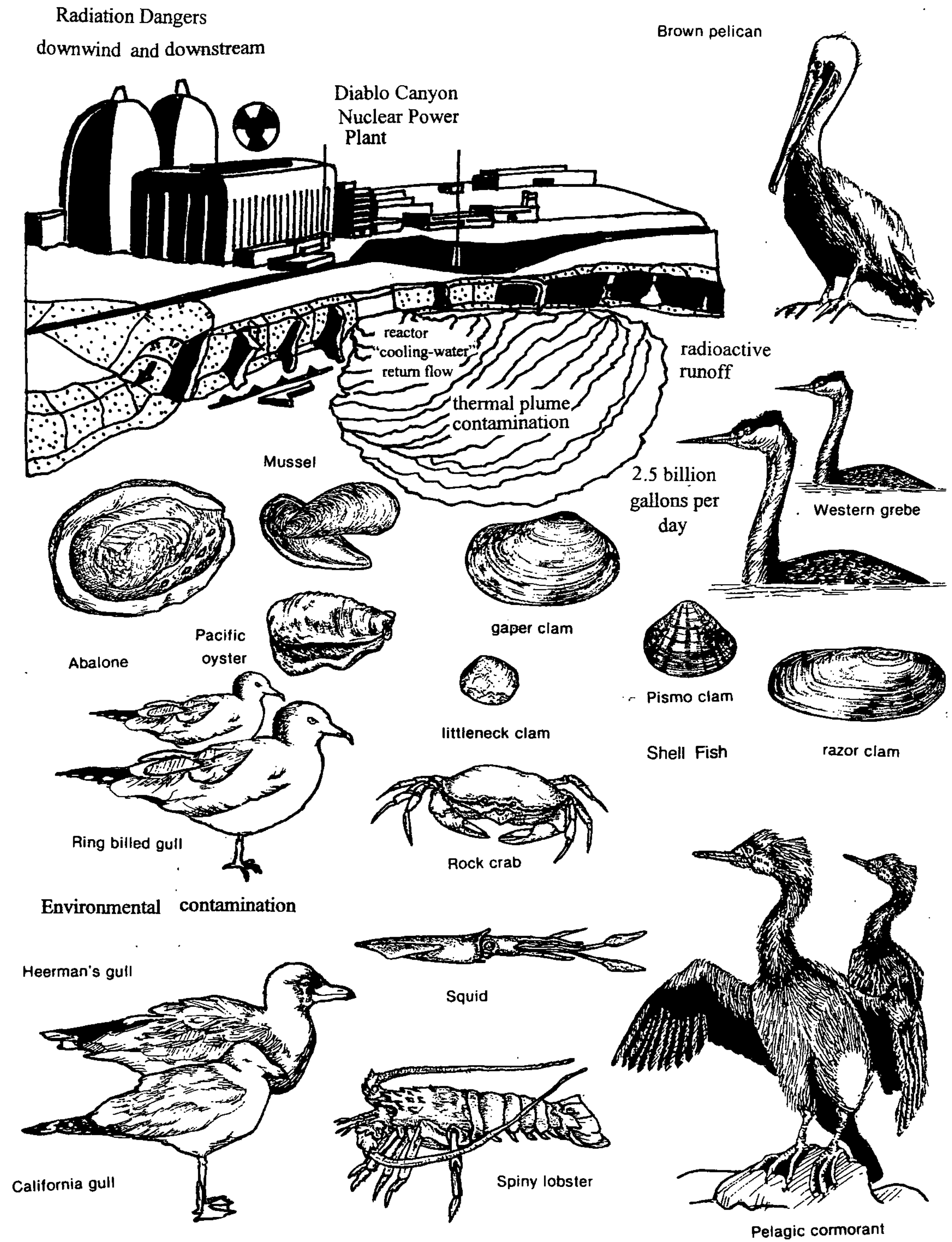


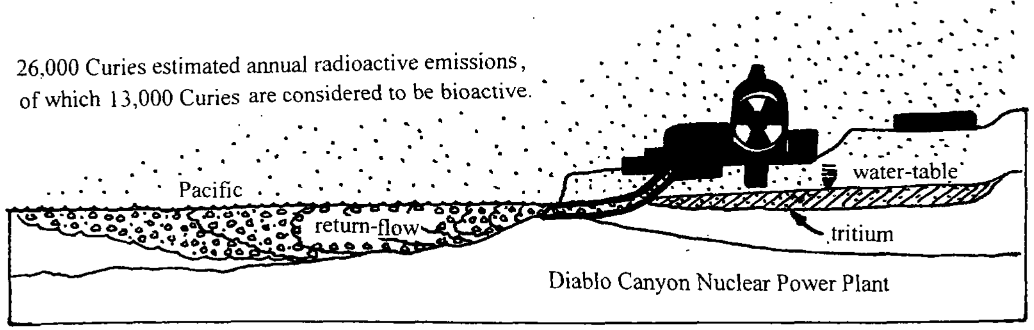
The Terrorist Diver Interdiction System uses a blast of 3000 psi air pressure to generate sound waves that will compel a diver to surface and surrender near nuclear power plant cooling-water pipes.

Operational radiation leaks and emissions from nuclear power plants across the West and elsewhere also pose significant dangers, and are far more common than most people know. Still, the leaks and emissions occur regularly during "normal" plant operation procedures, and are often played down by plant operators, if even reported at all. Add to the leaks and emissions the effects of thermal pollution from reactor "cooling-water" return flow, and the negative environmental impact of individual nuclear power plants becomes even more significant.

At the Diablo Canyon Nuclear Power Plant just west of San Luis Obispo in Southern California, a nuclear operations chief has noted that the facility's estimated annual radioactive emissions may peak at 26,000 Curies, half, or 13,000 Curies of which are considered to be bioactive. This is to say that over a projected 30-year operational life, the nuclear power plant will emit well over one half million Curies of radiation, half of which will be dangerous to human beings and other living organisms, some for hundreds, if not thousands, of years to come.







Put in perspective again, the 1979 reactor core meltdown accident at Three Mile Island in Pennsylvania released only about 30 Curies of radiation into the atmosphere by most estimates. One Curie of radiation equals 37 billion nuclear disintegrations per second.

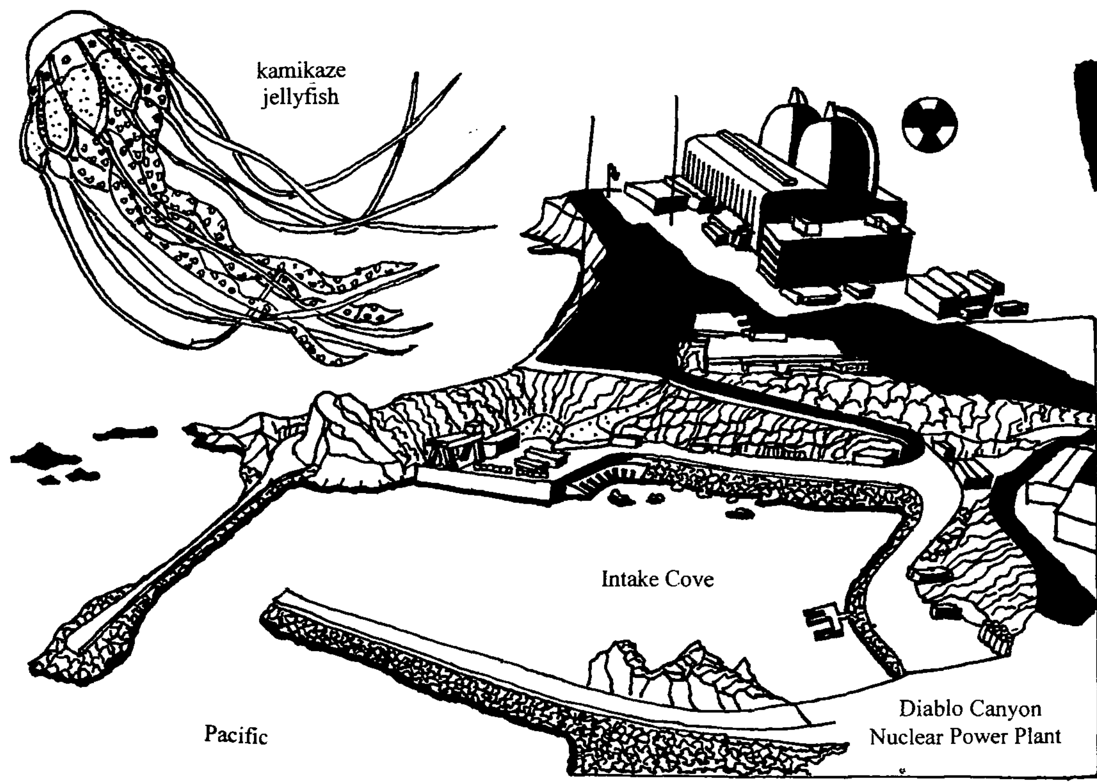
Some of the Diablo Canyon radiation emissions are undoubtedly contained in the plant's daily 2.5 billion gallons of heated reactor "cooling-water" return-flow to the Pacific. Here, thermal heat from the return-flow alone is credited with decimating shell fish and other marine organisms just offshore from the plant, including very large numbers of abalone that supported a thriving commercial fishing industry in the region before Diablo Canyon facility operations began.

The effects of tritium and other radionuclides in the return-flow extend beyond the thermal plumes when absorbed by commercial game fish, plus other sea mammals and birds. On land, reactor return-flow to rivers, estuaries and bays also poses radiation dangers to humans, plus other flora and fauna. For example, upwards to 90 percent of San Francisco's East Bay community was estimated to be impacted negatively by reactor "cooling-water" releases from the Rancho Seco Nuclear Power Plant southeast of Sacramento before the facility's early closure by consumer vote and demand.

In 2000, Pacific Gas and Electric was found to have withheld both reactor in-flow and return-flow damage effects at Diablo Canyon Nuclear Power Plant for 20 years, including records addressing the catastrophic obliteration of abalone, and other marine life in the bounding Pacific. This came after P.G. & E. was fined $14 million for failure to meet State and Federal Clean Water Act laws at Diablo Canyon in 1997 ... and before a later counter-attack on the nuclear facility by kamikaze sea organisms themselves.

More specifically, thousands of basketball-size Moon Jellyfish congregated at Intake Cove below the nuclear plant in 2008, and succeeded where abalone fishermen and tens of thousands of dry land protestors had all previously failed. Clogging the facility's reactor cooling-water intake pipe filters, the jellyfish shut one of Diablo Canyon's two reactors down completely and reduced the other reactor's output capacity to half-power for more than a week.

Human radiation dangers from contaminated ground water exist also around a number of nuclear power plants across Western North America. Indeed, highly-mobile tritium has filtered downward below every facility built, to date. Entering shallow aquifer zones dissolved in water, the tritium the spreads laterally at water-table depths, remaining mostly in upper parts of unconfined ground-water systems as a rule.



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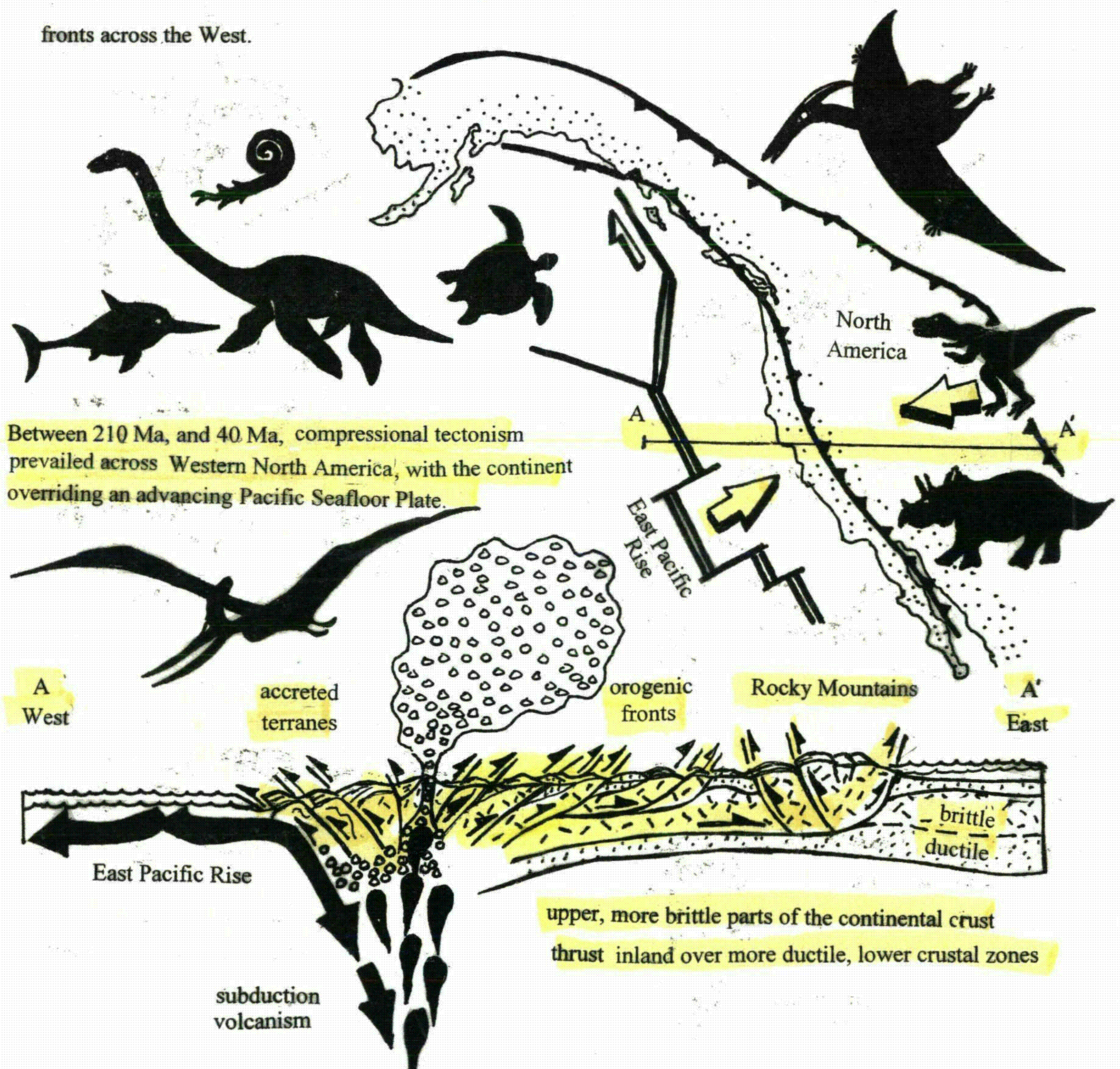
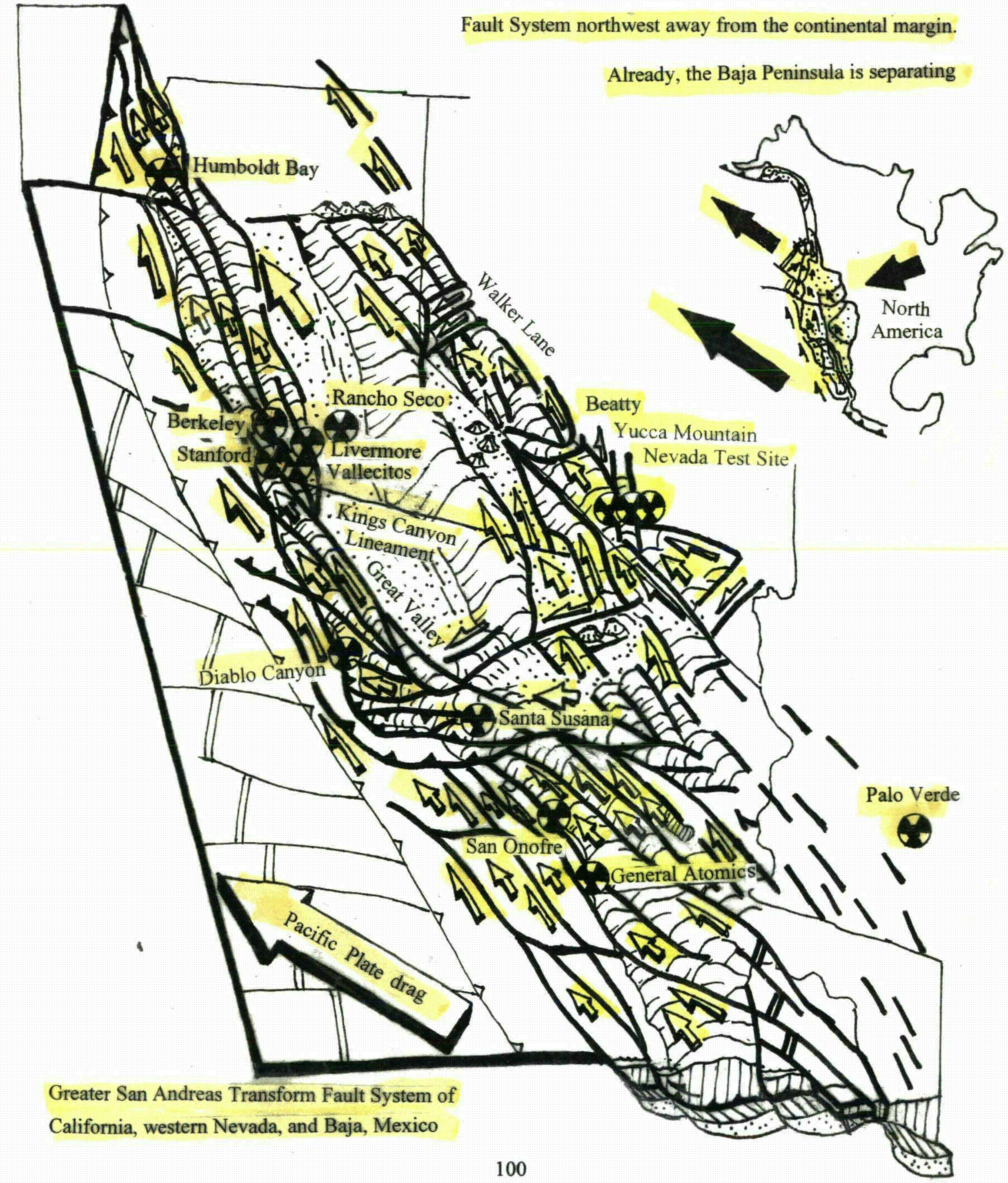
Geotectonic Setting of Western North America

The geotectonic setting of Western North America is perhaps best described as a work in progress. Between 210 Ma, and 40 Ma, compressional tectonism prevailed across the region, with the continent overriding an ~~advancing~~ Pacific Seafloor Plate. The head-on collision induced subduction volcanism, accreted new terranes to the continental margin, and thrust upper, more brittle parts of the continental crust inland over more ductile, lower crustal zones, giving form to the Rocky Mountains, and other orogenic fronts across the West.

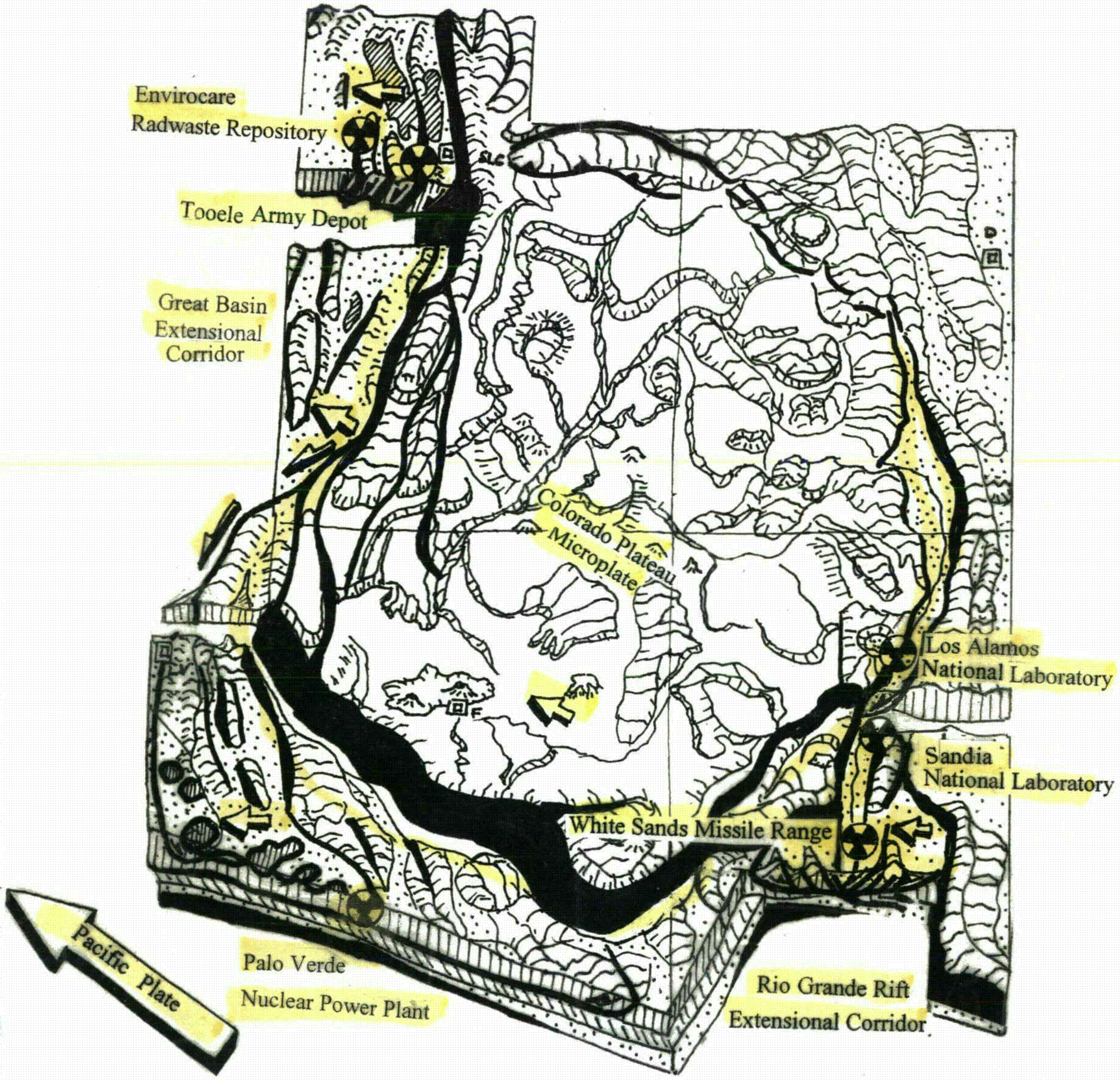


More recently, with the continent overriding the East Pacific Rise, the collision between North America, and the Pacific Seafloor has changed, becoming more oblique, or sideswiping in nature. As a consequence, the Pacific Plate is now wrenching microplates in the Greater San Andreas Transform Fault System northwest away from the continental margin. Already, the Baja Peninsula is separating



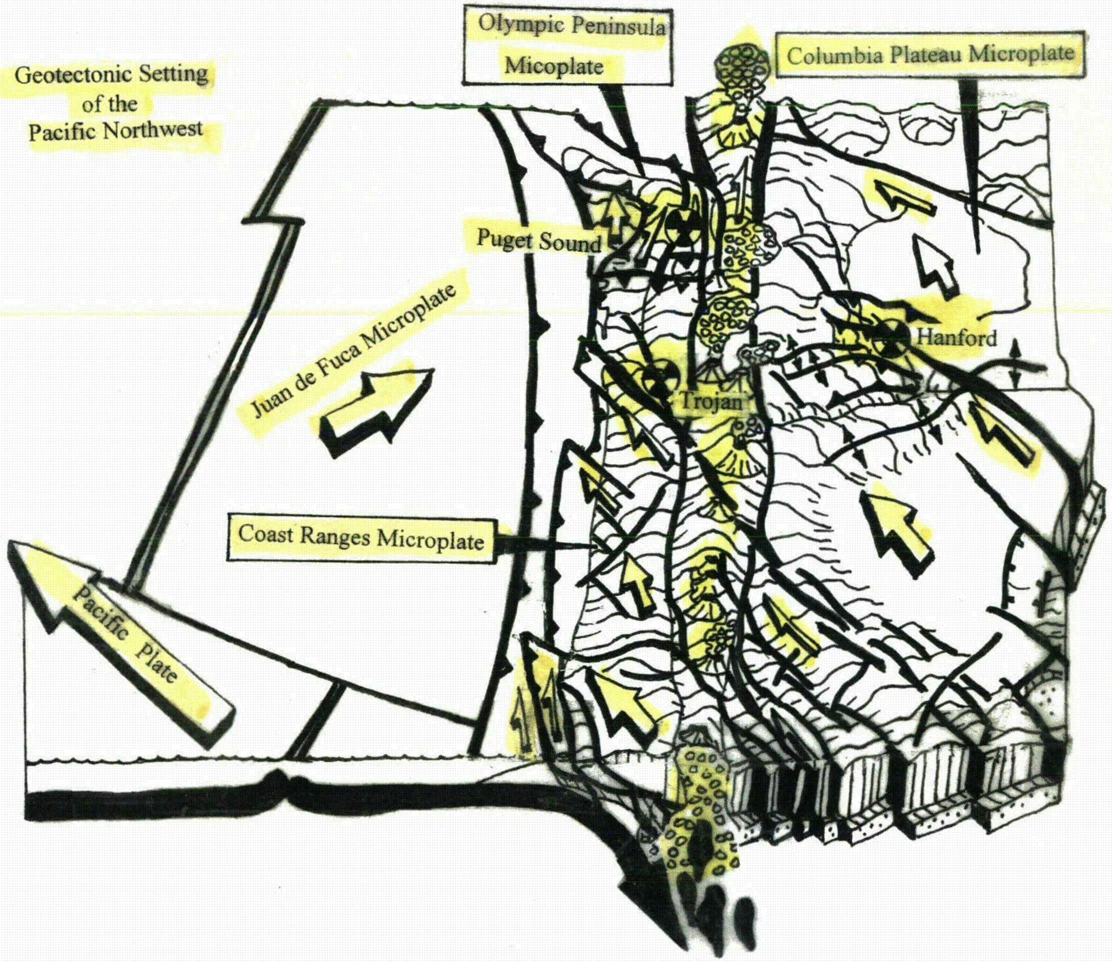
Greater San Andreas Transform Fault System of California, western Nevada, and Baja, Mexico from the Mexican mainland as splintering microplates in the Coastal Ranges, and Walker Lane move outwards towards the Pacific with the Sierra Nevada-Great Valley Microplate, too.

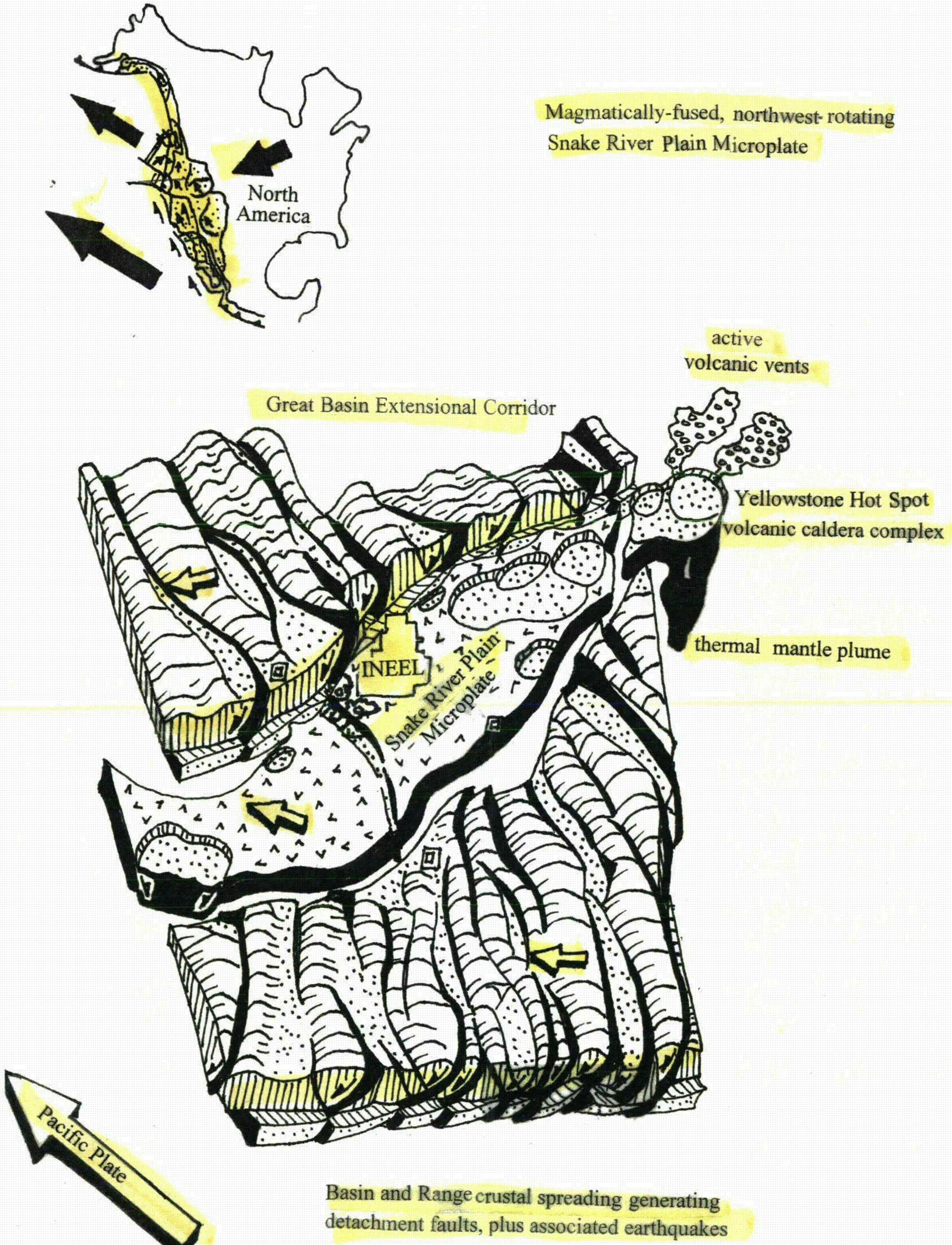
Further inland, both the Great Basin, and Rio Grande Rift are also being wrenched apart in response to the Pacific Plate's drag along the western continental margin. Concomitantly, the more integral Colorado Plateau Microplate is rotating clockwise to the northwest, but at a slower rate than the

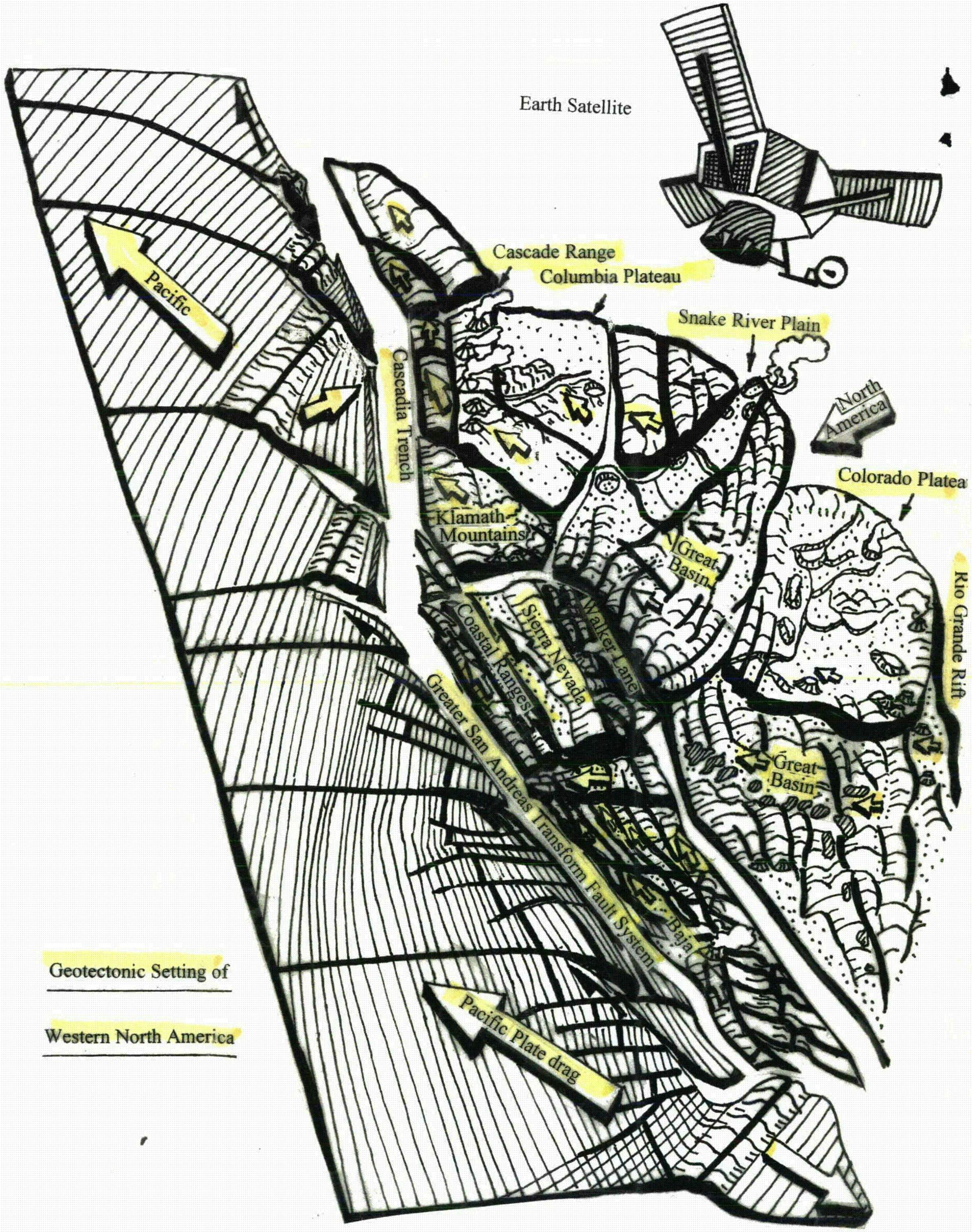


continental crust is being extended across the Great Basin, and in the Greater San Andreas Transform Fault System.

In the Pacific Northwest, the Coastal Ranges, Cascade Mountains, Olympic Peninsula, and Vancouver Island Microplates are all being pushed northward on the landward, transpressive side of the Cascadia Subduction Trench. Further inland, the more insular Klamath Mountains, Snake River Plain, Idaho Batholith, and Columbia Plateau Microplates are moving more northwest, just like the splintering microplates in the Greater Queen Charlotte Transform Fault System of northwest Canada, and Alaska.



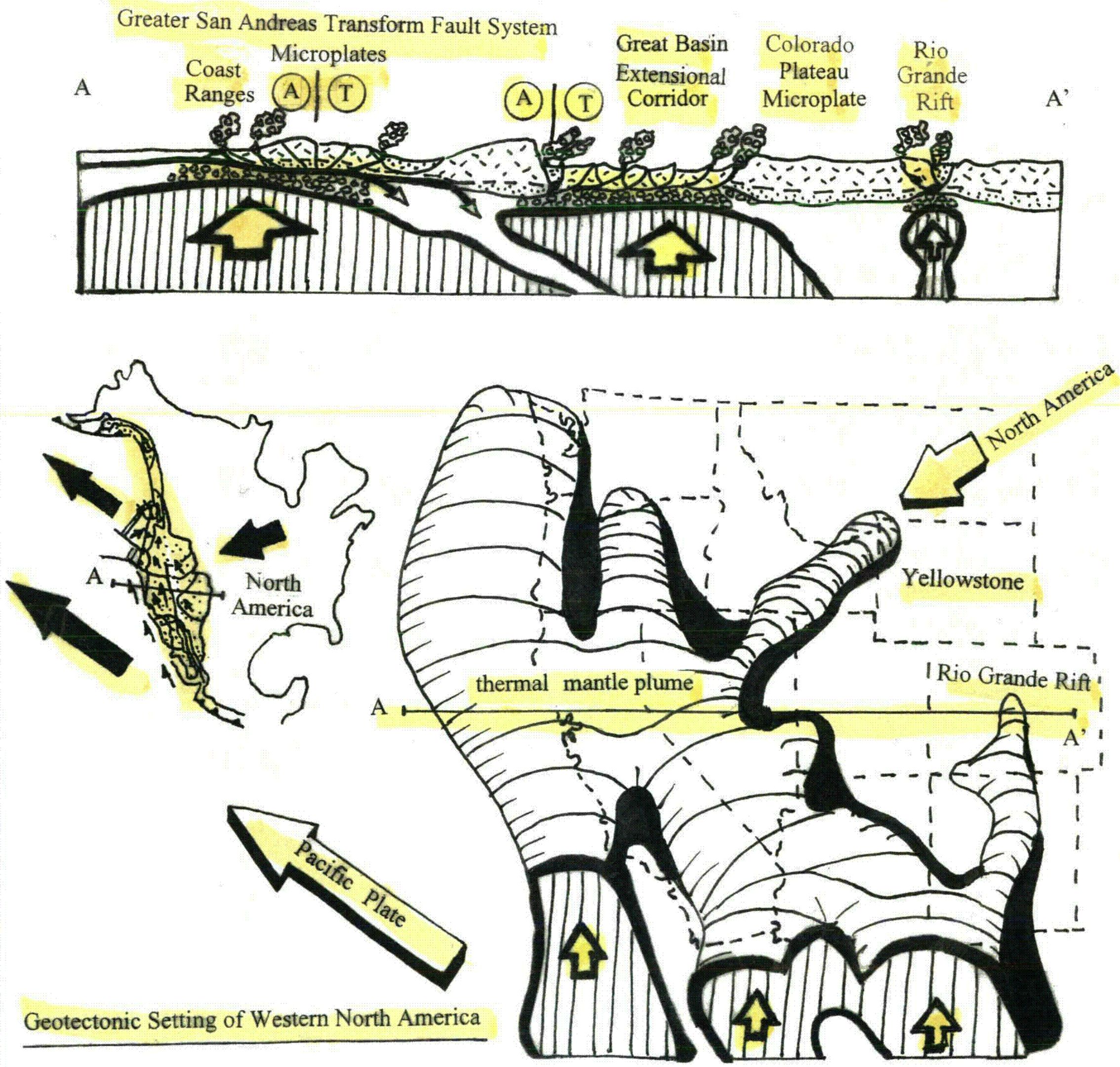




Geotectonic Setting of

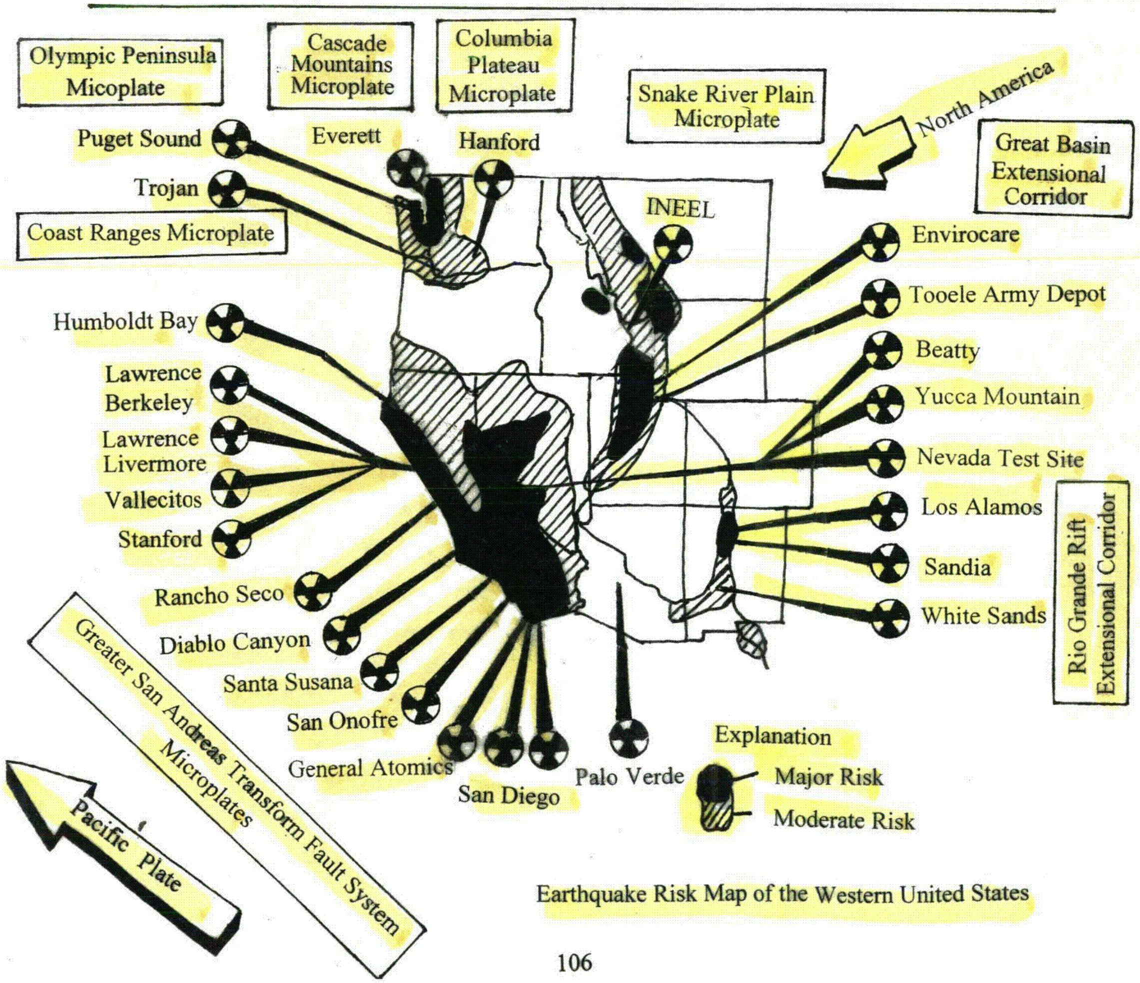
Western North America

All mobile microplates along the western margin of North America are underlain by a rising thermal mantle plume that is composed of buoyant, re-melted, basaltic seafloor in a more dense olivine peridotite mineral suite. The plume has elevated the microplates more than 10,000 feet in places, while also intruding and distending the continental crust more than 120 miles across parts of the Great Basin since 5 Ma. Regional detachment faulting, plus semi-horizontal sub-thrusting, and shearing are occurring during the crustal extension, and wrenching processes, too.



Geotectonic Setting of Western North America

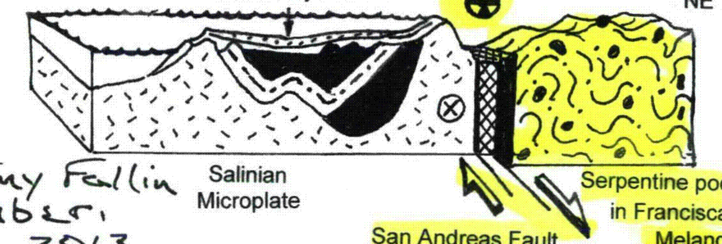
Unsurprisingly, well-defined earthquake epicenter corridors lie along many splintering microplate boundaries, especially in the Greater San Andreas Transform Fault System, and along the Wasatch Front Detachment Fault zone where Great Basin extension is outpacing Colorado Plateau Micropate rotation to the northwest. The earthquakes are generally larger in magnitude, and occur more frequently closer to the sideswiping Pacific Plate than further inland in more insular, less stressed parts of the Colorado Plateau, Rocky Mountains, and Rio Grande Rift. Other well-defined earthquake epicenter corridors across the West lie just inland from more active parts of the Cascadia Subduction Trench in the Pacific Northwest; around the Yellowstone Hot Spot where rising magmas are elevating ground surface; and in a crustal extension zone north of Yellowstone along the ancestral Rocky Mountains Overthrust Belt.



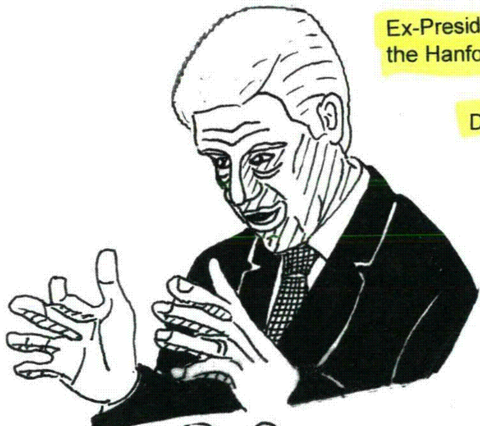
Earthquake Risk Map of the Western United States

Allison - A little background on some of my own experiences with nuclear power plant site investigation as penned to Anna Banana, one of my charges - J.A. Tony Fallin November, 2013

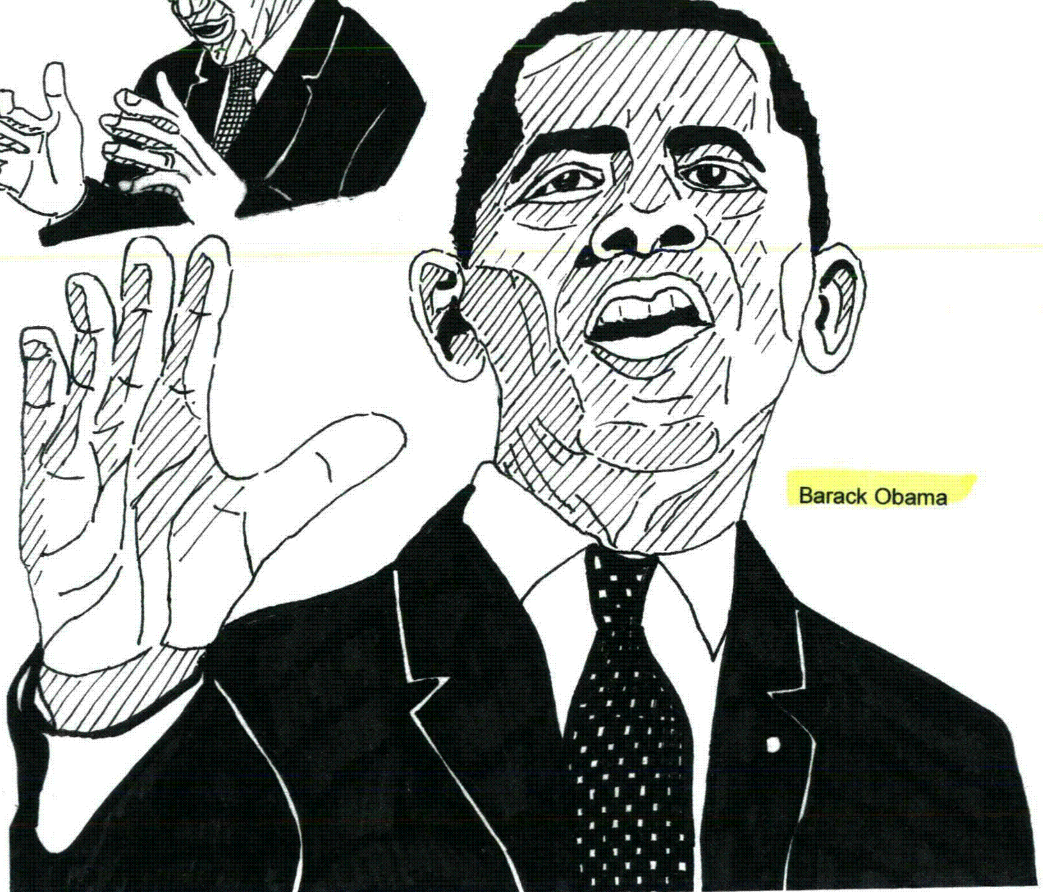
One of Barack Obama's first questions after being inaugurated as President of the United States was: WHAT IS HANFORD!?! The answer was: "America's little Chernobyl, unknown even to many incoming U. S. Presidents, swept under the rug and kept hidden from sight since World War II, the place where plutonium for the first atomic bomb was "bred" in nine nuclear reactors along the banks of the Columbia River in Washington, second only to the Nevada Test Site as the most contaminated piece of earth in the Western Hemisphere, a nuclear facility that released millions of Curies on the environment, beyond containment and the control of Man!"



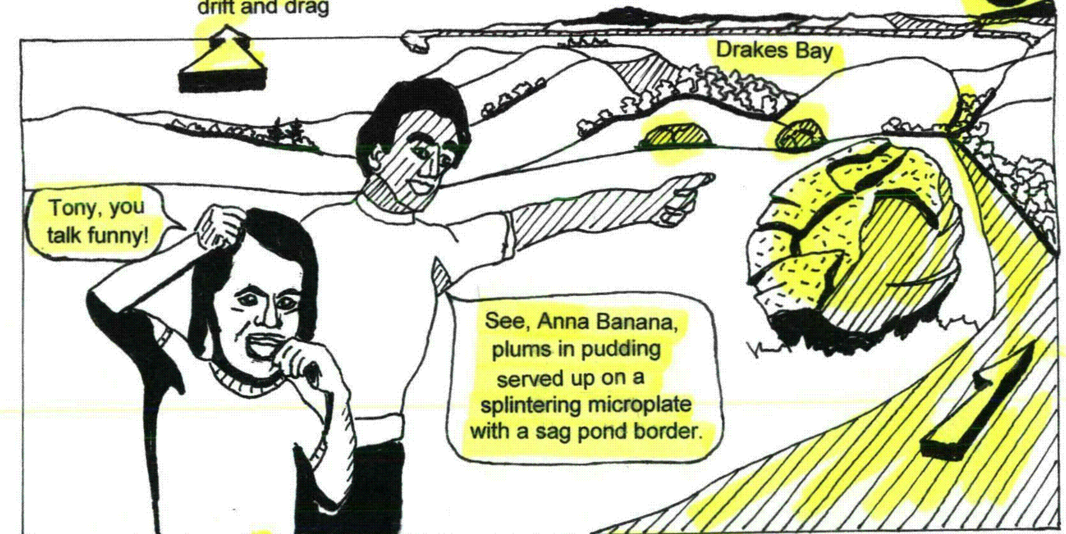
Ex-President Bill Clinton rues being mis-informed and creating the Hanford Reach National Monument just before leaving office.



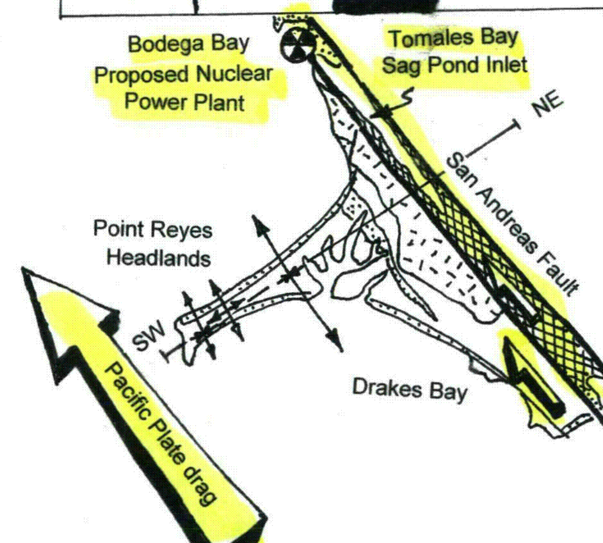
DON'T TAKE YOUR CHILDREN TO HANFORD!

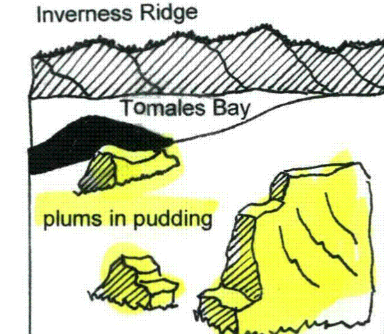


Barack Obama



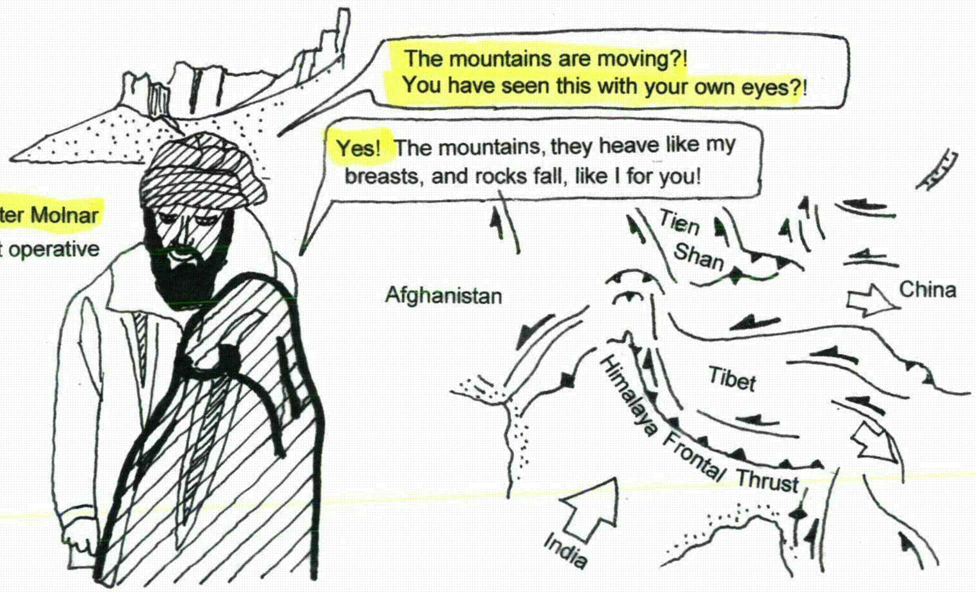
Point Reyes Headlands from Inverness Ridge





Dear Anna Banana, et al.

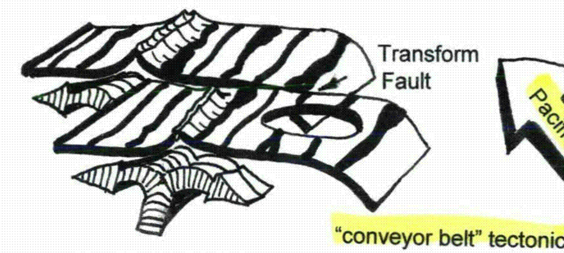
It is the mid- 1970s in Afghanistan, where push comes to shove, forming the Himalaya and other mountain chains. Looking deep into her hornblend eyes, CIA-not operative Peter Molnar advances the science of plate tectonics by capturing the heart of yet another, fair maiden.

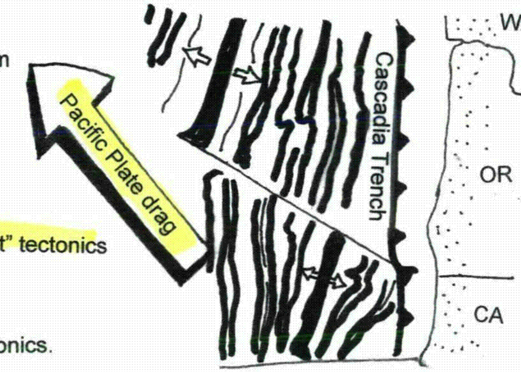


Already, young Peter has captured many other maiden's hearts, both at Oberlin College as an undergraduate student during the early to mid-1960s and as a graduate student at Columbia University while studying geophysics, 1965-1970, with Jack Oliver, Lynn Sykes and others. Indeed, even as a post-doctoral researcher at Lamont and then Scripps, Peter was a ladies' man, leading to a brief marriage with Tanya Atwater as the two tracked and timed the Pacific seafloor plate's northwest drift and drag past the North American plate in its late appointment for subduction in the Alaska, Japan and other circum-Pacific trenches.

bare-footed, bead- wearing, flower-child

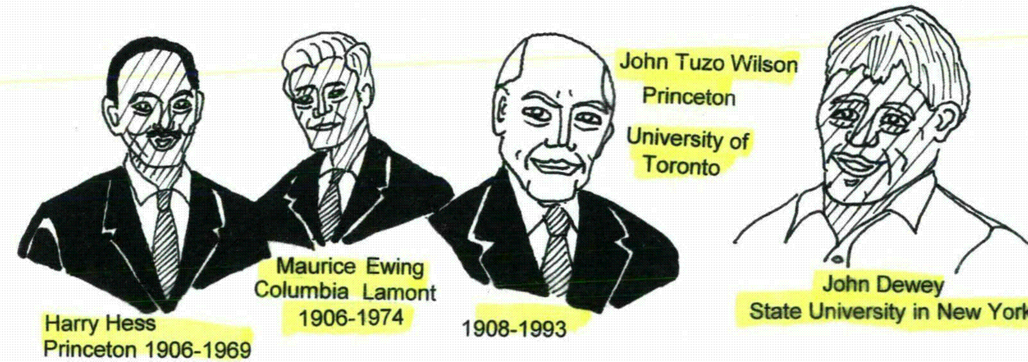
Out of MIT and U.C.-Berkeley shortly before Scripps, bare-footed, bead-wearing, flower-child Tanya had joined the "Plate Tectonic Revolution" earlier in the 1960s with Peter and a host of others, me included. As such, she mapped





Some of Tanya's early "takes" on plate tectonics.

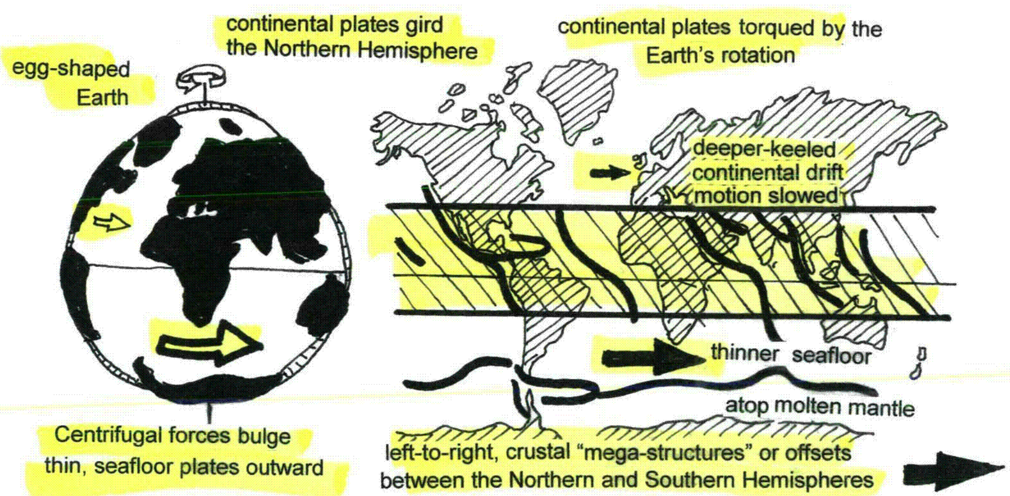
and dated linear, Pacific-seafloor, magnetic anomalies when not studying the works and thoughts of other mentors of ours' in the emerging frontier, including Princeton 's Harry Hess and Fred Vine at Cambridge; Princeton's John Tuzo Wilson at the University of Toronto; Maurice Ewing at Woods Hole; Robert Dietz at Scripps; and John Dewey at the State University in New York.



Of course, the concept of continental drift was already a half-century old, having been proposed by German meteorologist Alfred Wegener near the turn of the 20th Century. But only in the mid-20th Century did North American geologists and universities begin to support the theory of plate tectonics as more and more data was accumulated, showing it to be true.

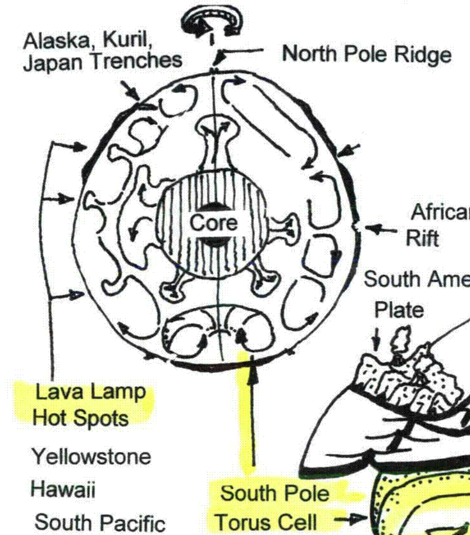
I was first introduced to the concept of plate tectonics in the early-1960s when attending National Science Foundation summer institutes in geology as a high school student. Released from a static world of dry science and cold rocks, I had suddenly a dynamic and evolving planet to explore, with boundless frontiers beckoning! And what an adventure lay in store.

At the University of Texas in Austin in the mid-1960s, Caltech's Ralph Kehle spoke of "conveyor belt" seafloors to others and me, as U.T.'s Bill Muehlberger brought us satellite imagery from N.A.S.A. to view and interpret after consulting with the first U.S. Astronauts aiming for the moon. This led to some of us speculating that the Earth would prove to be egg-shaped, even before satellite images showed the same to be true. It just had to be, with thick continental plates girding the Northern Hemisphere and little but thin, seafloor plates over molten mantle dominating further south.

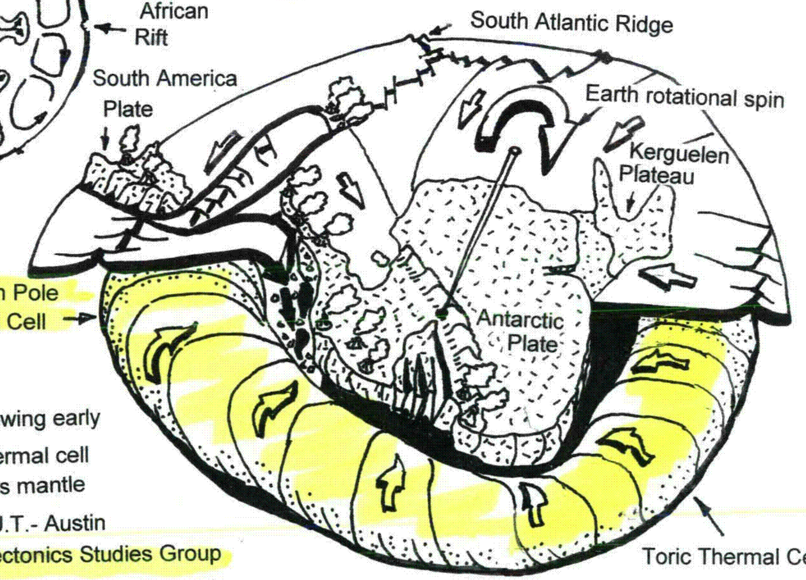


Centrifugal forces, alone, would bulge the thin, seafloor plates outward, especially under shallow, ocean areas without much seawater cover or other overburden! In addition, I noted that continental plates were torqued by the Earth's rotation atop a more-forgiving, molten mantle, with their deeper-keeled tectonic drift or motion slowed and otherwise affected relative to thinner, seafloor plates. Among other things, this has defined a number of left-to-right, crustal "mega-structures" or offsets between the Northern and Southern Hemispheres, including a listric displacement of the American plates and of the Mid-Atlantic seafloor, spreading ridge that I reported on later at the National Meeting of the American Association for the Advancement of Science on the U.C.-Berkeley Campus.

Also, when Princeton's John Maxwell moved to Austin, Texas, and introduced U.T. graduate students to his own studies of ophiolites and seafloor subduction zones around the world, I was given the opportunity to research the geotectonic setting of Antarctica over a three month period in 1970. This led

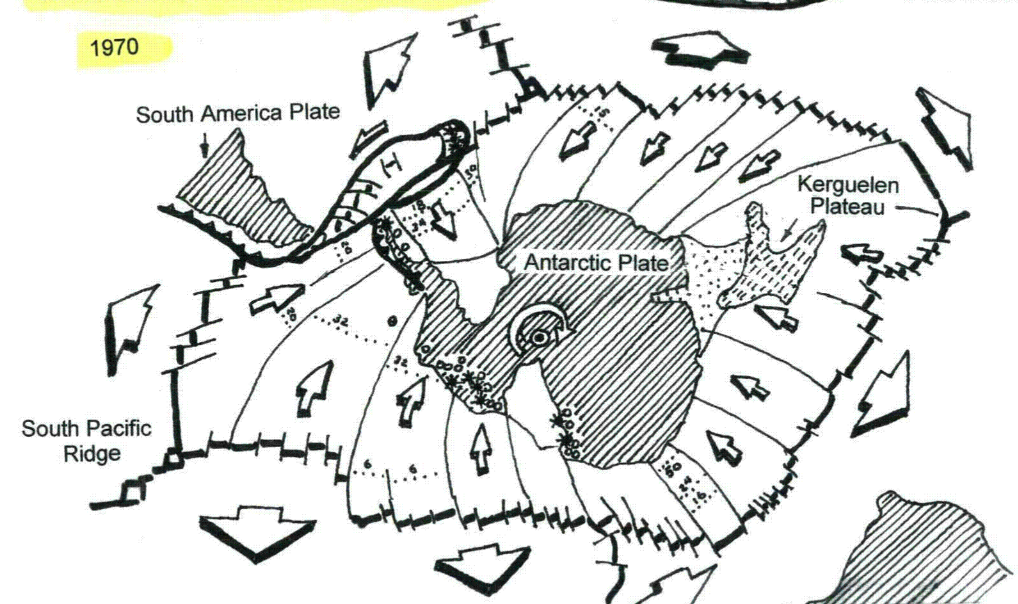


Antarctica has been trapped over a toric- or doughnut-shaped, polar, thermal cell in the upper mantle since near the outset of the Mesozoic Era, or for more than 200 million years.

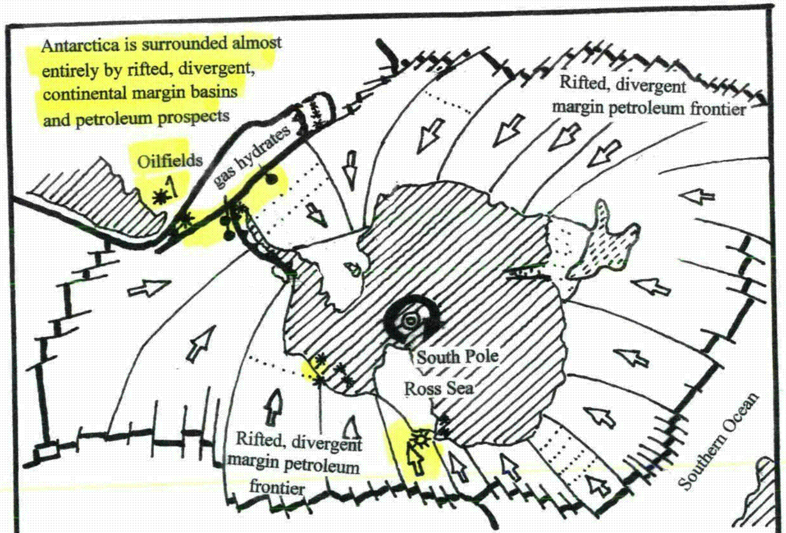


Cartoon diagrams showing early speculations about thermal cell geometry in the Earth's mantle by J. A. Tony Fallin, U.T.- Austin
John Maxwell Plate Tectonics Studies Group

1970

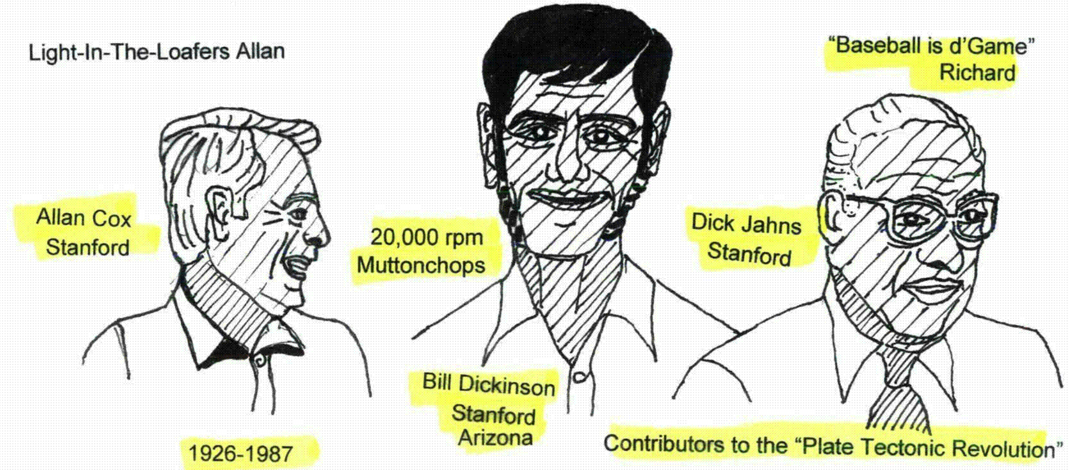


ultimately to my suggesting that the southern plate has been trapped over a toric- or doughnut-shaped, polar, thermal cell in the upper mantle since near the outset of the Mesozoic Era, or for more than 200 million years. Encircled almost entirely by offset, spreading, seafloor centers and having only one, short subduction trench offshore from the Antarctica Peninsula, the polar plate is bound mostly by a divergent, rifted, continental margin with a unique, dynamic history of its own.



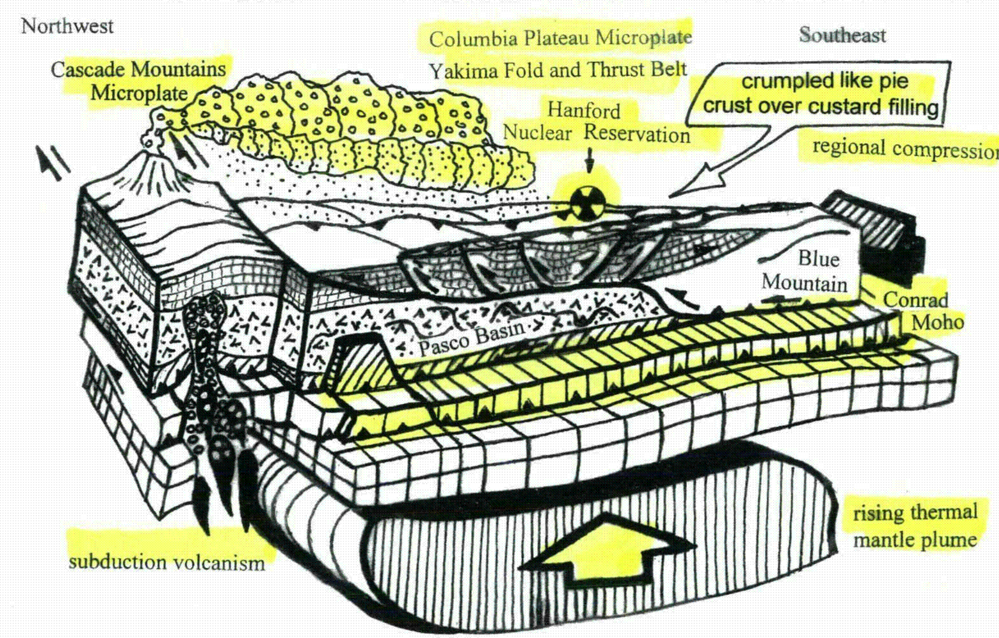
Of course, even with extreme weather, ice bergs and heavy seas, Antarctica's offshore, divergent and rifted, continental margin at the South Pole must also be considered a petroleum frontier. Surrounded by krill-rich seas and locked in polar position for at least 200 million years, the Southern Continent also has an older history of more tropical climes, suggesting its offshore source beds have generated both oil and gas from multiple types of kerogen. Already, oil and gas wells have been completed in Malvinas Basin offshore Tierra del Fuego below the Southern Ocean and natural gas shows have been detected in rift basin deposits below Ross Sea. Having mastered the North Sea and Arctic exploration and development, Big Oil will undoubtedly give more attention to South Pole petroleum prospects as well.

I completed course work for a Masters Degree in Geological Sciences at U.T.-Austin in January, 1972, and elected to take a year off from diminished institutional life in Santa Fe, New Mexico, before moving to the West Coast San Francisco Bay Area. I was contemplating the PhD program at Stanford, then a hot bed for continental drift studies, with Allan Cox, Bill Dickinson, Ben Page, Bob Compton, Dick Jahns and Konrad Krauskoph all active faculty and contributors to the "Plate Tectonic Revolution". But then came an offer from FUGRO, International, Consulting Engineers and Geologists, that was all, but impossible to refuse.

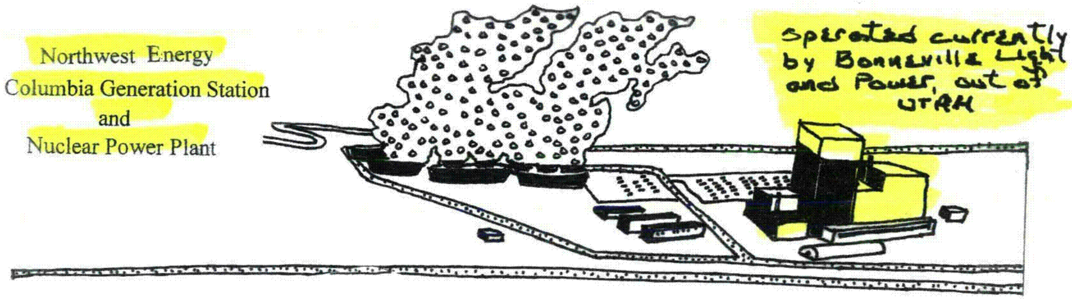


At the time, FUGRO's clients were providing up to million dollar contracts from Big Utility coffers to investigate the geology of proposed nuclear power plant sites across western North America and on Caribbean Islands. Soon, I was flying all over the West to do field studies in active, tectonic terrane, when not helping to plan, budget and staff specific projects at FUGRO's San Francisco Bay Area Office or making client presentations in big city skyscrapers.

One of the first projects that I worked on was located on the Hanford Nuclear Reservation in south-central Washington. Bordering the Columbia River, the Reservation sat in the heart of the active Yakima Fold and Thrust Belt atop

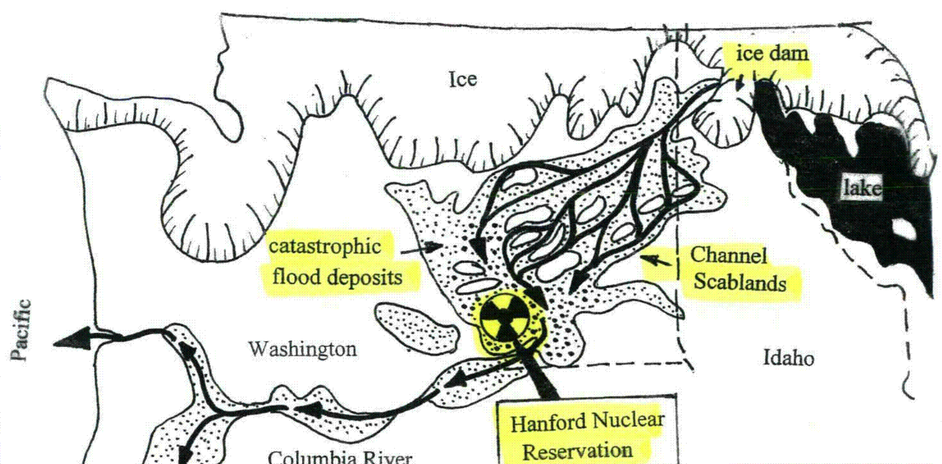


Hanford Nuclear Reservation, Washington



catastrophic, floodplain deposits of boulders, gravel, sand and silt just east of Mount Saint Helens and other active volcanoes in the Cascade Mountain Range.

Floodplain deposits that mantle the deforming basalt flows, and that give form to the contaminated aquifer below Hanford, accumulated mostly when catastrophic deluges inundated the region during waning stages of the last Ice Age. In essence, ice dams broke upstream in what is the Panhandle of Idaho today, allowing lakes behind the dams to flush over central Washington, and form the Channel Scablands before depositing some of their sediment load over the Hanford area. Later, the flood waters breached growing, downstream ridges in the Yakima Fold, and Thrust Belt to drain out to the Pacific, leaving most of the catastrophic flood deposits behind to record their passing.

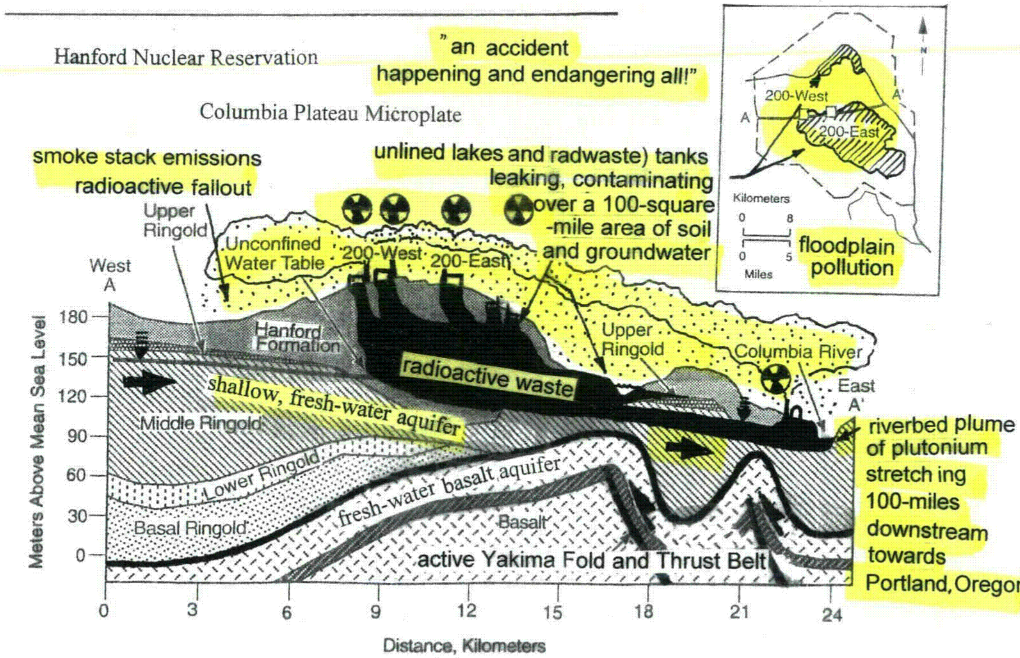


Floodplain deposits below Hanford accumulated mostly when catastrophic deluges inundated the region during waning stages of the last Ice Age.

Washington Public Power and Supply System (WPPSS or "Whoops!") would eventually place yet another nuclear reactor on the Reservation with the pro-Nuclear Regulatory Commission's (NRC's) blessing, no matter FUGRO's expressed concerns about the area's overall geologic setting. Already, at least nine reactors had been built on the Reservation, most to generate or "breed" plutonium for the world's first atomic bomb.

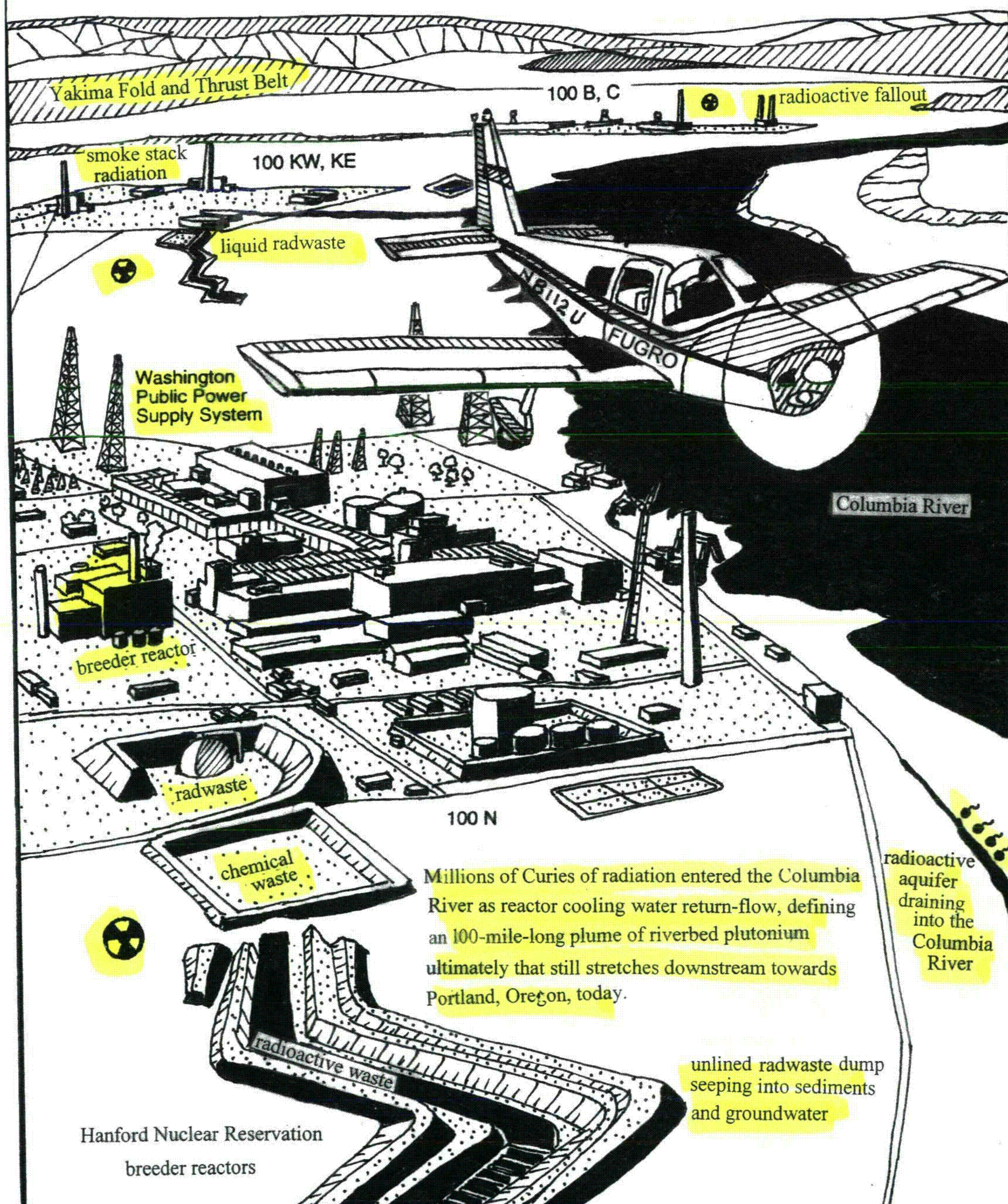
To some of us who investigated it in the field, Hanford was not so much an "accident waiting to happen" as an "accident already happening and endangering all!" The nuclear facility had already vented millions of Curies of radiation on the environment in the form of smoke stack emissions and resultant fallout as well as reactor cooling water pumped directly back into the Columbia River. In fact, there was a plume of plutonium in the riverbed sediments that stretched already 100-miles downstream towards Portland,Oregon.

In addition, the facility's high-level, radioactive waste (radwaste) tanks were leaking, contaminating over a 100-square-mile area of soil and groundwater below the Reservation, as lower-level radwaste was also pored directly into unlined lakes and pits on the grounds as well, adding still more pollution to the region. In total, the US-DOE estimated that there was enough contaminated soil on the Reservation to cover Washington, D.C. up to the US Capitol rotunda!

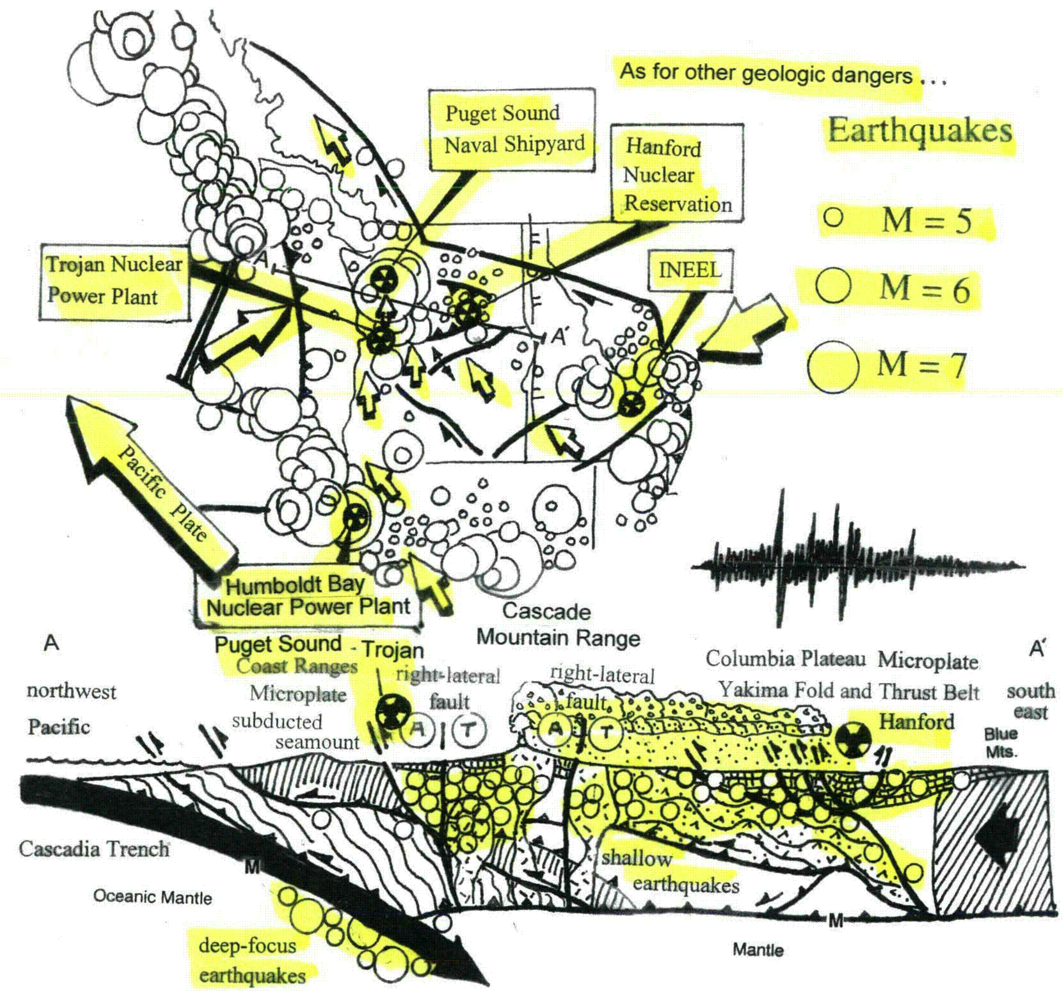


The nuclear facility had already vented millions of Curies of radiation on the environment ...

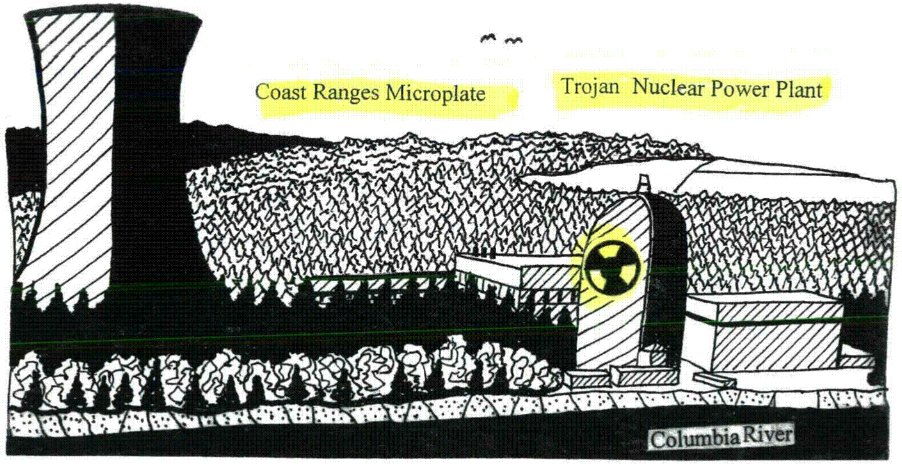
Hanford's nuclear facilities have produced large volumes of liquid, gaseous, and solid radwaste, much of which have been released directly out into the surrounding environment.

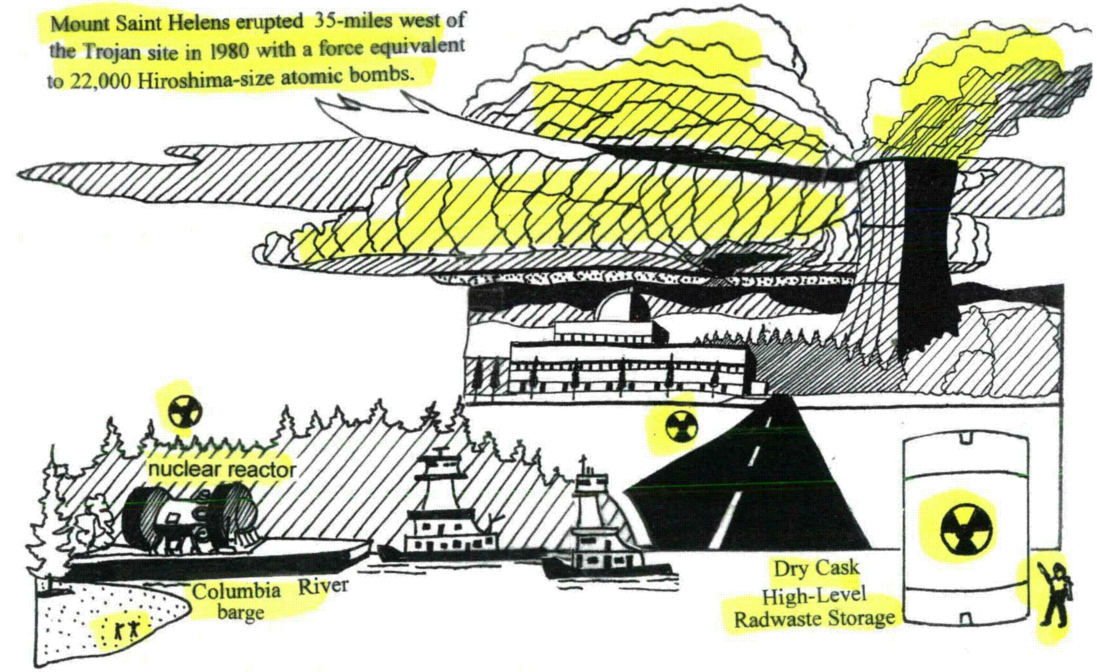


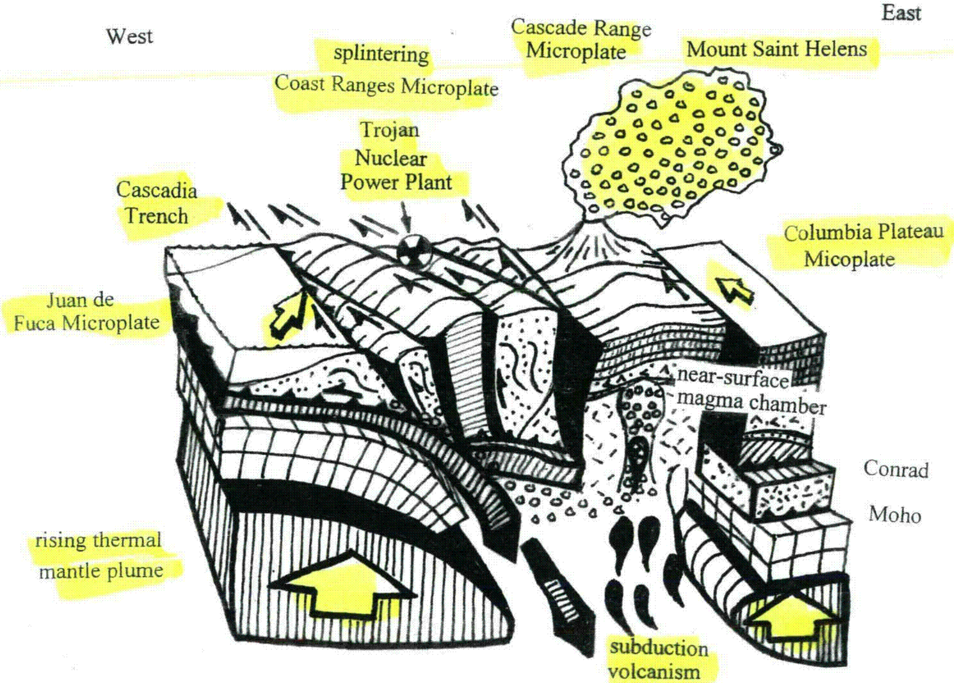
Downwind human and livestock populations had already suffered numerous health problems and even pre-mature deaths from the Reservation's radioactive emissions. And most, if not all, plants and animals on the Reservation were radioactive as well. As for other geologic dangers, it would be less than ten years before Mount Saint Helen's 1980 eruption turned day into night and covered some parts of the Reservation with up to five-feet-thick drifts of ash. Also, shallow earthquakes below the facility continued to occur, reflecting active crustal stresses from Pacific Plate drag being released periodically as near-surface basalt flows crumpled over softer volcanic ash deposits like pie crust over custard filling. It was just not a comfortable or safe place to be!



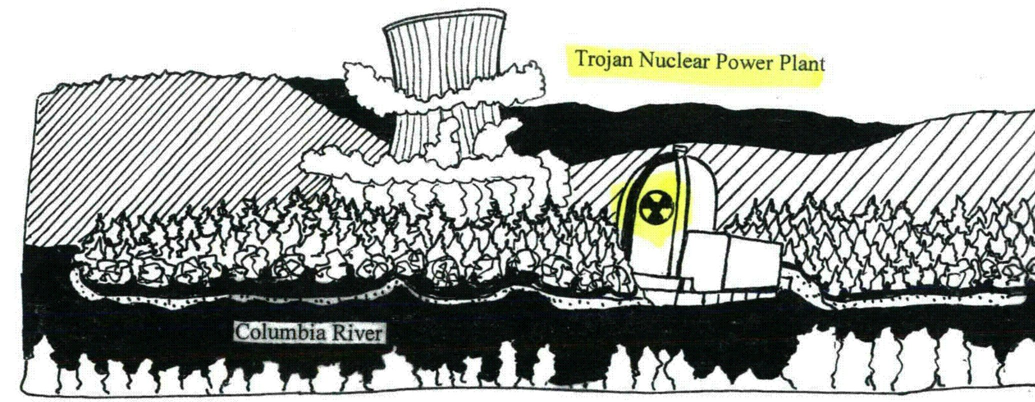
Immediately west of Mount Saint Helens was Portland General Electric's proposed Trojan Nuclear Power Plant site that also fronted the Columbia River and sat atop active faults connected to the Cascadia subduction trench. Soon, things would pick up around it as well !

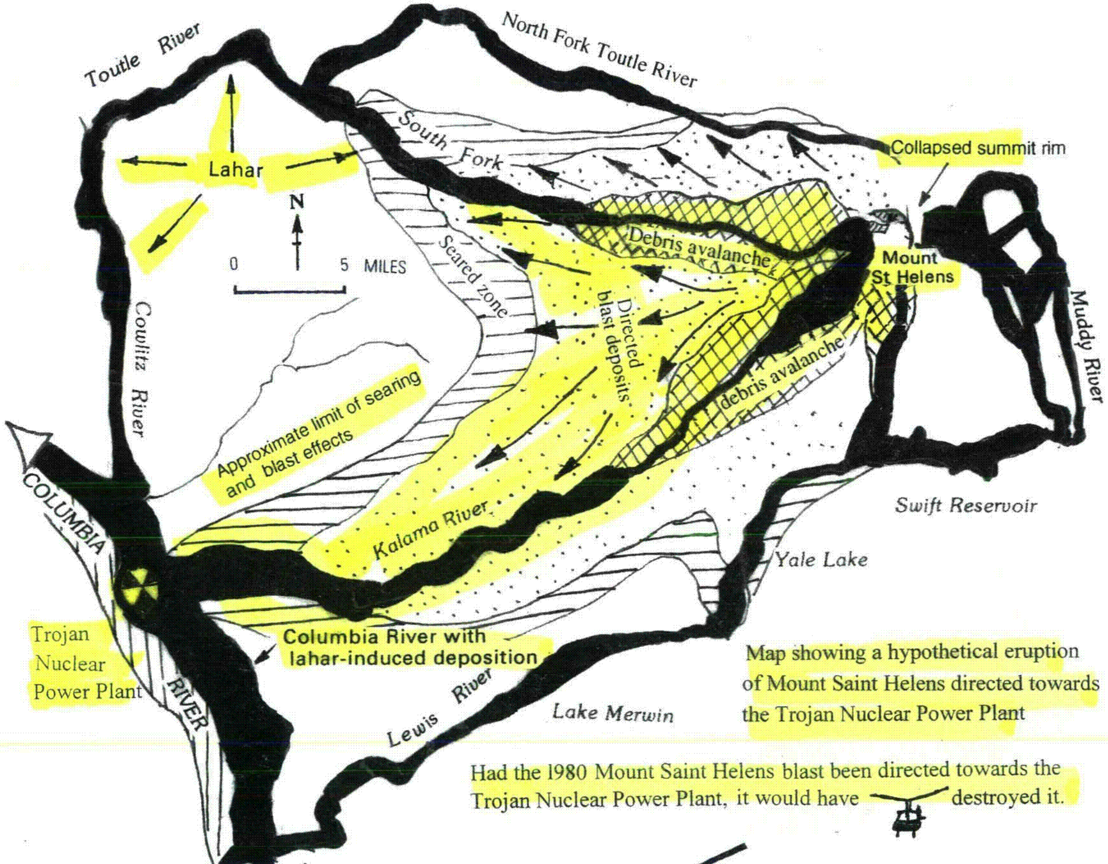






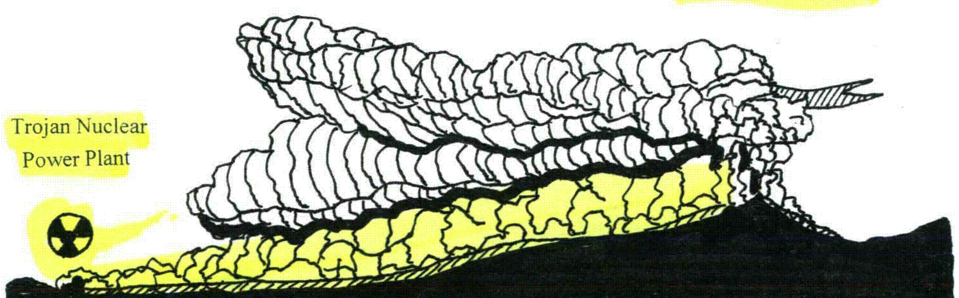
The controversial Trojan Nuclear Power Plant was constructed during the 1970s on a Pacific Northwest Indian burial ground, only to be shut down early and dismantled. During its abbreviated operational life, the facility experienced repeated radiation leaks from cracked steam pipes and was jolted regularly by 5 M earthquakes generated during eruptions of Mount Saint Helens in the 1980s just 35 miles to the east. Notably, Oregon voters banned further nuclear power plant construction in the State after the eruptions.



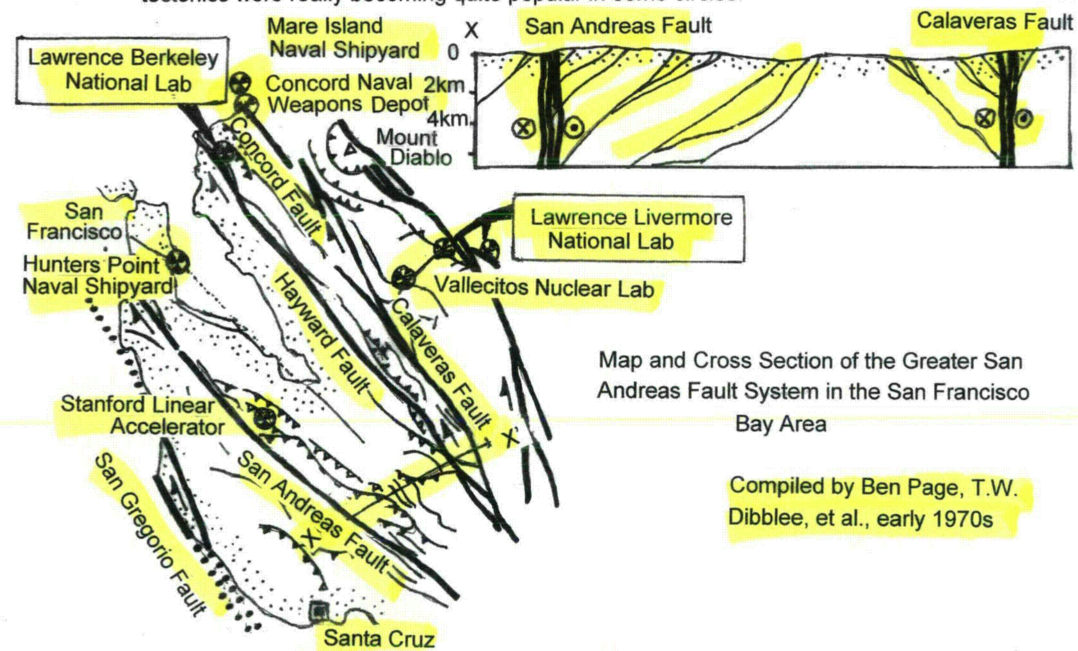


Map showing a hypothetical eruption of Mount Saint Helens directed towards the Trojan Nuclear Power Plant

Had the 1980 Mount Saint Helens blast been directed towards the Trojan Nuclear Power Plant, it would have destroyed it.



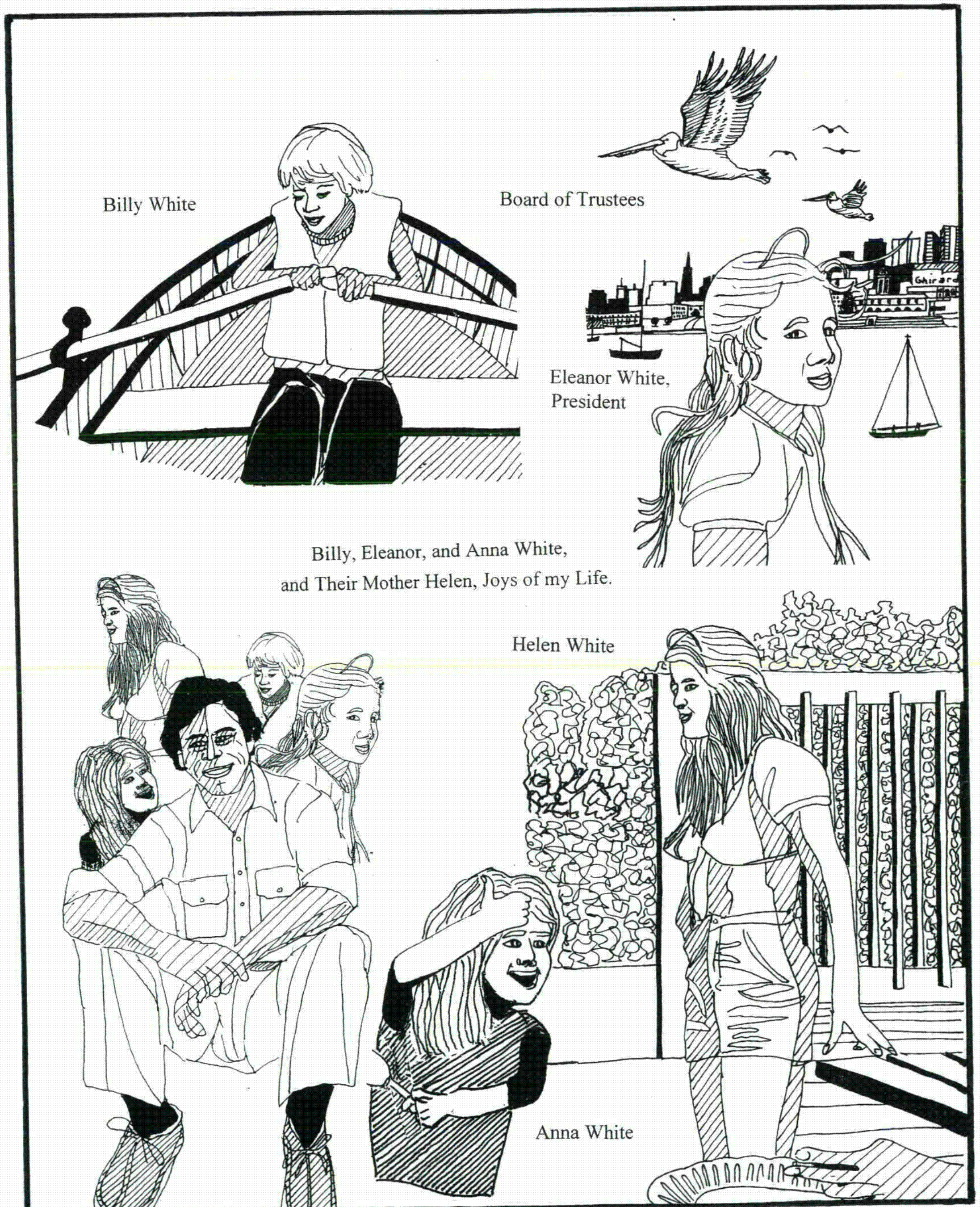
Returning to the San Francisco Bay Area from Hanford on a "10 and 4" schedule, i.e., "nine days on the 'Rez', one day in the air travelling, four days off", I began to research "All Things Nuclear" at Stanford, U.C. Berkeley, and the U.S.G.S. - Menlo Park, when not sprinting for the Pacific coastline and other wilderness areas just to get away from death-wish crowds. Soon, I would meet a young mother, Helen White, and her three children, Billy, Eleanor and Anna, whose family were close friends with Ben Page at Stanford. Ben and others were already mapping the Greater San Andreas Fault System in California, with Ben also serving as the first Editor-in-Chief of the new, bi-monthly, technical journal, "Tectonics". Continental drift and regional tectonics were really becoming quite popular in some circles.



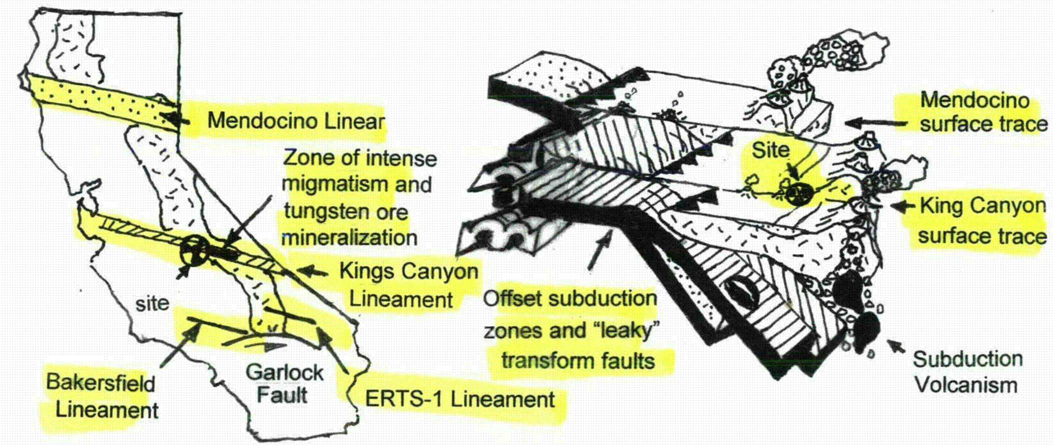
Map and Cross Section of the Greater San Andreas Fault System in the San Francisco Bay Area

Compiled by Ben Page, T.W. Dibblee, et al., early 1970s

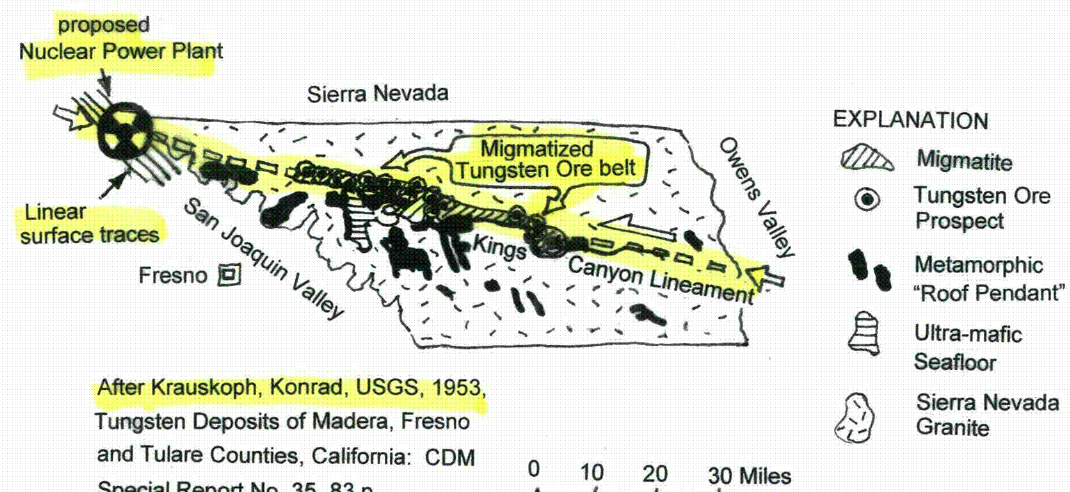
It was through Ben that I first got to know other members of the Sanford faculty in the geology department better, especially after FUGRO completed its Preliminary Safety Analysis Report (PSAR) for the Hanford project and began to re-focus its work on proposed PG&E and SoCal Edison nuclear power plant sites in California. Already, Tanya Atwater had made a name for herself by publishing findings from her northeast Pacific spreading seafloor studies in the December 1970 issue of the Geological Society of America (GSA) Bulletin and Caltech's Don Anderson had gotten his block diagram interpretation of the Greater San Andreas Fault System profiled in a 1971 issue of "Scientific American". In addition, Bill Dickinson at Stanford was organizing Penrose Conferences to address the Greater San Andreas Fault System and other West Coast plate tectonic issues, allowing for more or less open forums in a "Think Tank" atmosphere. On the sidelines, with million-dollar budgets for field investigations, I soaked up emerging thoughts and concepts like a sponge.



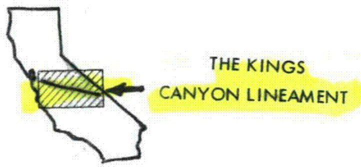
Schematic map and block diagram showing the Kings Canyon Lineament as the now-passive, surface expression of a subducted, "leaky" transform fault system cutting obliquely across Central California



The first PG&E project that I would work on with FUGRO was a proposed nuclear power plant site north of Fresno, California, along the boundary between the San Joaquin Valley and Sierra Nevada. Two of my U.T.- Austin Graduate School peers, John Everett and Will Reid, had already helped establish Earth Satellite Corporation outside Washington, D.C., making EARTHSAT space imagery readily available to me. Soliciting images of Southern California, I soon had a synoptic view of the proposed nuclear power plant site and surrounding terrain that showed a distinct, west-northwest-trending lineation cutting directly under our study area, Nevada to Pacific!

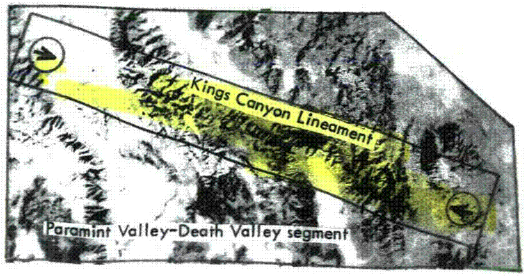


After Krauskoph, Konrad, USGS, 1953, Tungsten Deposits of Madera, Fresno and Tulare Counties, California: CDM Special Report No. 35, 83 p.



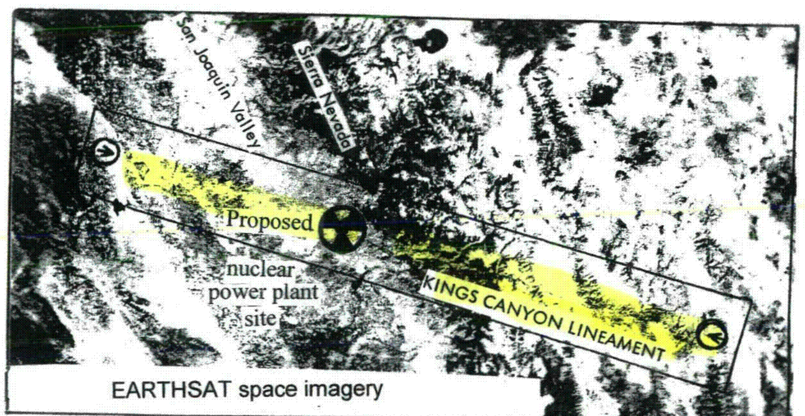
THE KINGS CANYON LINEAMENT:
A Cross-Grain ERTS-1 Lineament In Central California

1974 NEW BASEMENT TECTONICS
CONTRIBUTION NO. 9

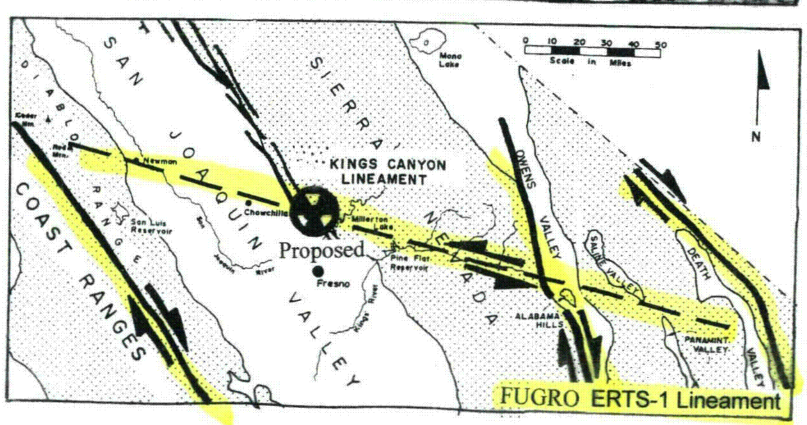


J.A. Tony Fallin
Gary J. Anttonen
Edward A. Danehy

FUGRO, Inc.
Redwood City, California



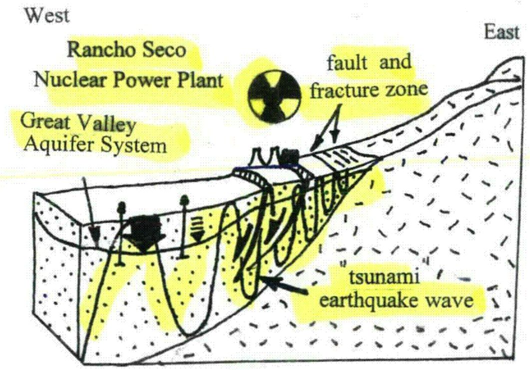
EARTHSAT space imagery



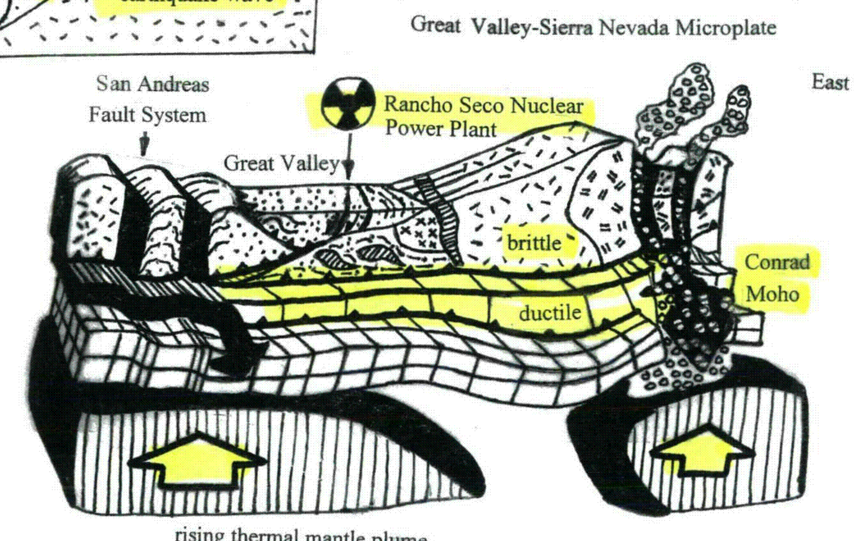
FUGRO ERTS-1 Lineament

Ultimately, we named the feature the Kings Canyon Lineament and interpreted it to be the passive, surface expression of a once-active, "leaky", transform, seafloor, ridge fault that was subducted below an offset Sierra Nevada magma chamber during the Late Mesozoic Era. As such, the lineament posed no serious geologic threat to the area that we were investigating, but did offer fodder for a "Plate Tectonic Revolution" report. Accordingly, Stanford alumnae Ed Danehy and Gary Antonnen at FUGRO drafted a technical paper with me that was presented later at The First International Conference for the New Basement Tectonics in Salt Lake City, Utah in 1974. Notably, the illustrations that I drafted for the report were influenced by earlier works of Tanya Atwater at Scripps and Jack Oliver at Columbia University.

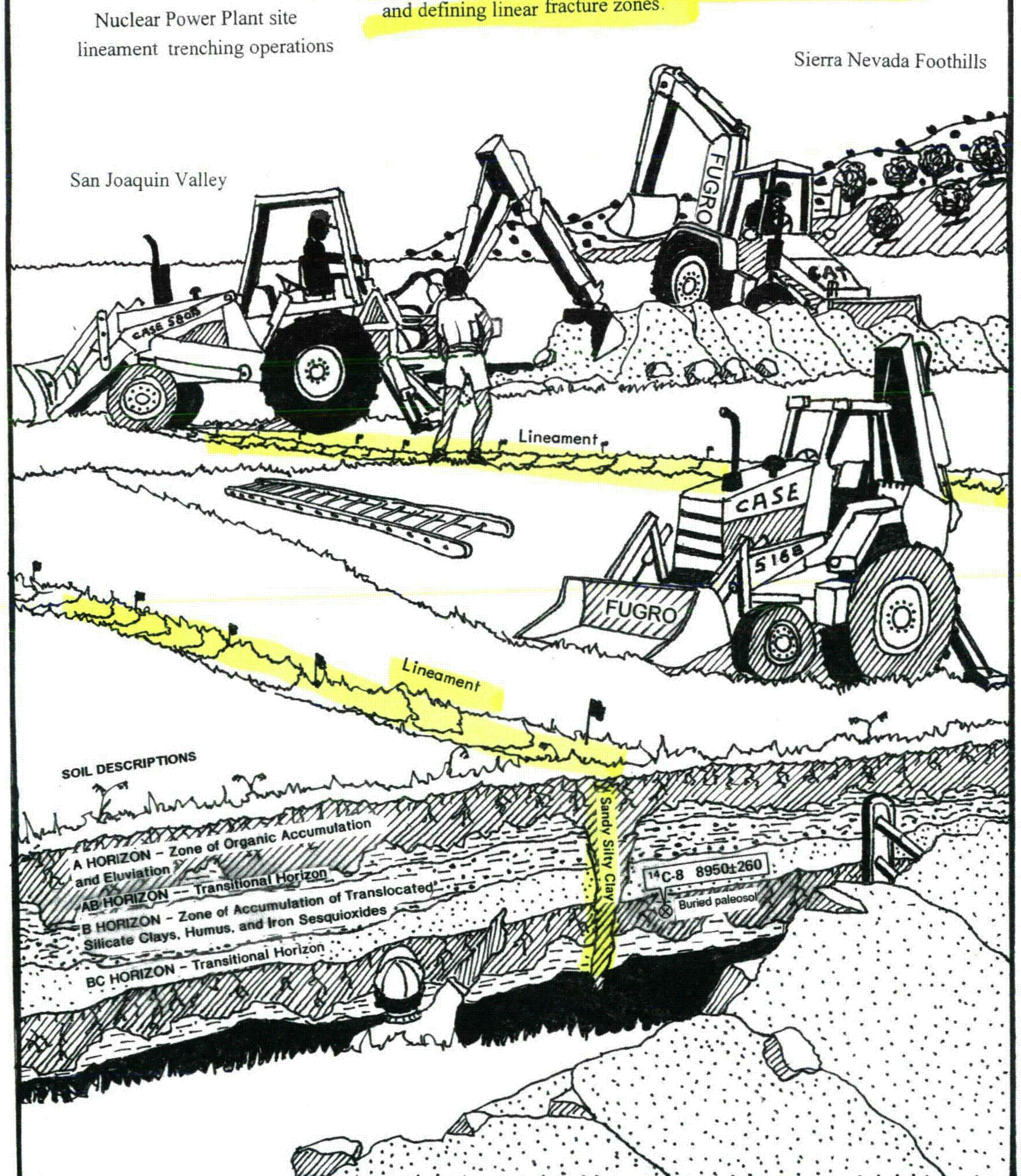
We also trenched other lineaments at the proposed PG&E site that paralleled the boundary between the San Joaquin Valley and Sierra Nevada, and that proved to be "healed" fissures with no visible signs of vertical offset. It was my feeling that the lineations formed as earthquake waves from the San Andreas Fault System to the west "shoaled" on shallow, Sierran bedrock, prompting overlying sediments to



Block diagrams showing earthquake fault and fracture zones paralleling the Sierra Nevada front in the Great Valley



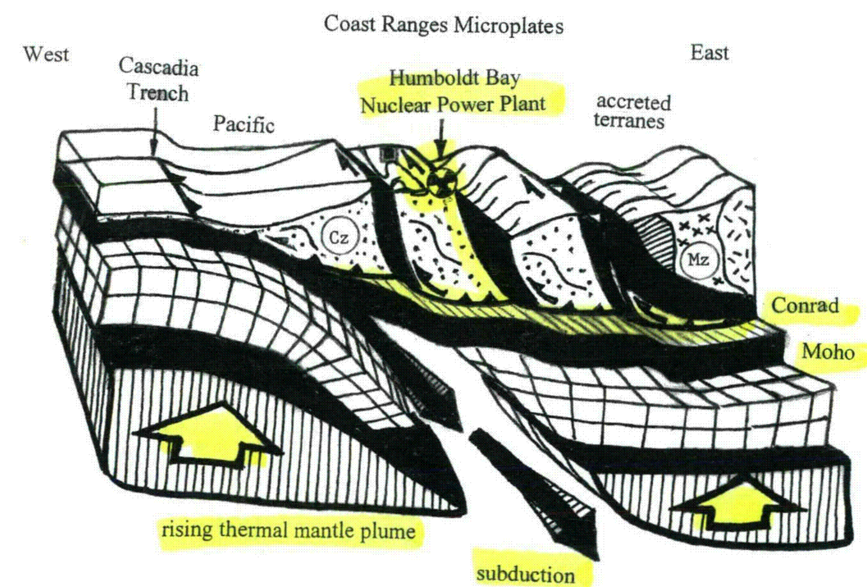
In the Great Valley of California, "tsunami" earthquake waves shoal on Sierra Nevada basement rocks, prompting sediment compaction and defining linear fracture zones.



compact and fissure parallel to the mountain front. Further north, the lineaments extended more into the Great Valley, becoming down-faulted in thicker sedimentary sections, with some of the traces projecting towards the proposed, Sacramento Municipal Utility, Rancho Seco Nuclear Power Plant site.

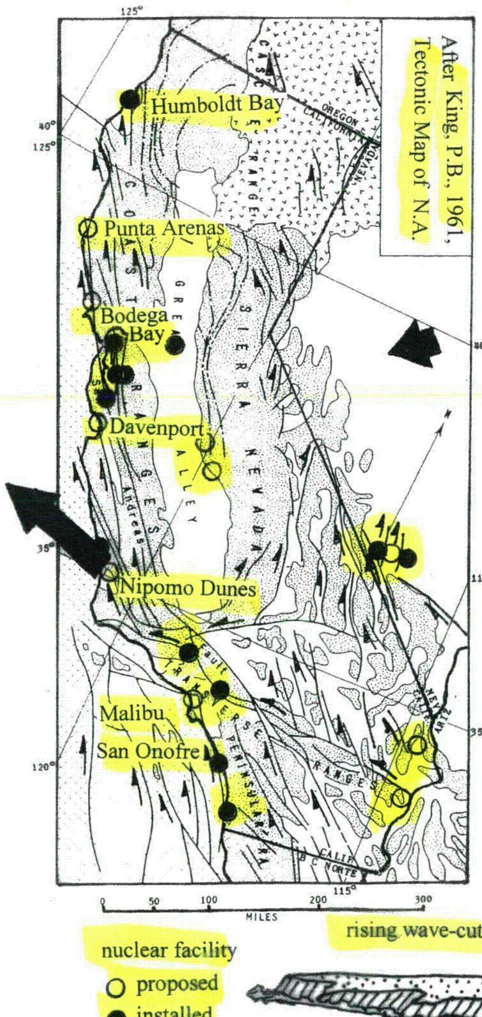
Stanford graduate Mary Gillam and I also mapped Ice Age terraces along Sierra Nevada drainages, but found no signs of faulting in the region, either. Soon afterwards, however, PG&E decided to discontinue the site investigations, if only to attend to problems arising at other nuclear facilities and proposed sites in the California. In short, I got the impression that the Public Utility was having second thoughts about its commitment to nuclear power after making some bad judgements by selecting sites along the active, San Andreas Fault System to investigate and build on earlier.

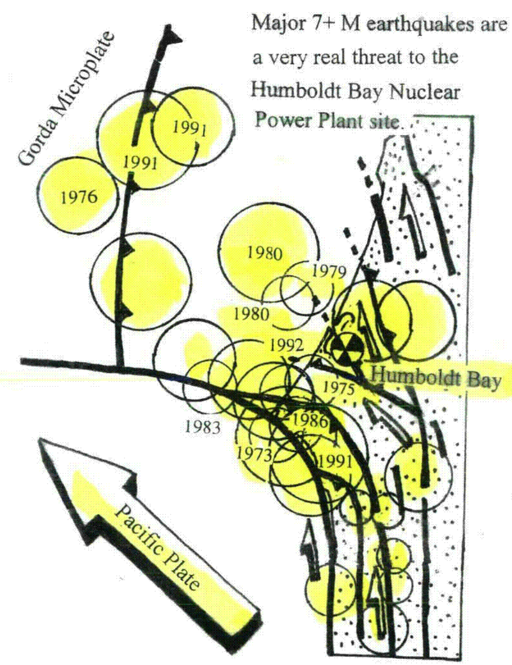
PG&E's Humboldt Bay Nuclear Power Plant, for example, was being stressed and shaken slowly to pieces after being constructed directly over an active, northern extension of the San Andreas Fault System and its associated, earthquake corridor. Built just 15 feet above sealevel beside Humboldt Bay, the nuclear facility was nearly breached by a 12-feet-high tsunami during its first year of operation. The plant's unconfined reactor was also placed in a leaky caisson that extended up to 50-feet-below the local water table and had to be pumped continually by design. Shaken repeatedly by earthquakes, the reactor malfunctioned and vented radioactive fallout from a tall smoke stack regularly, giving it the dubious distinction of being labeled as one of

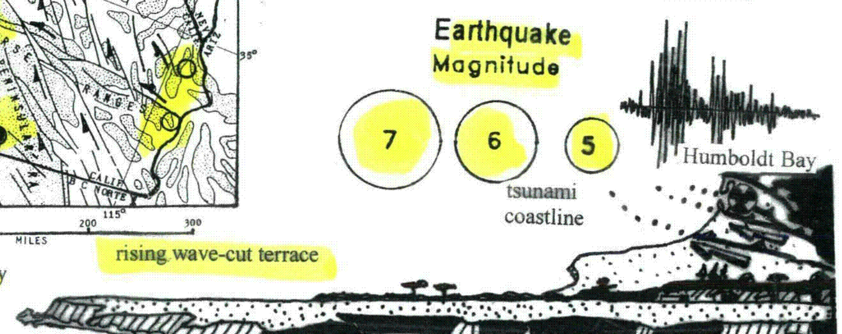


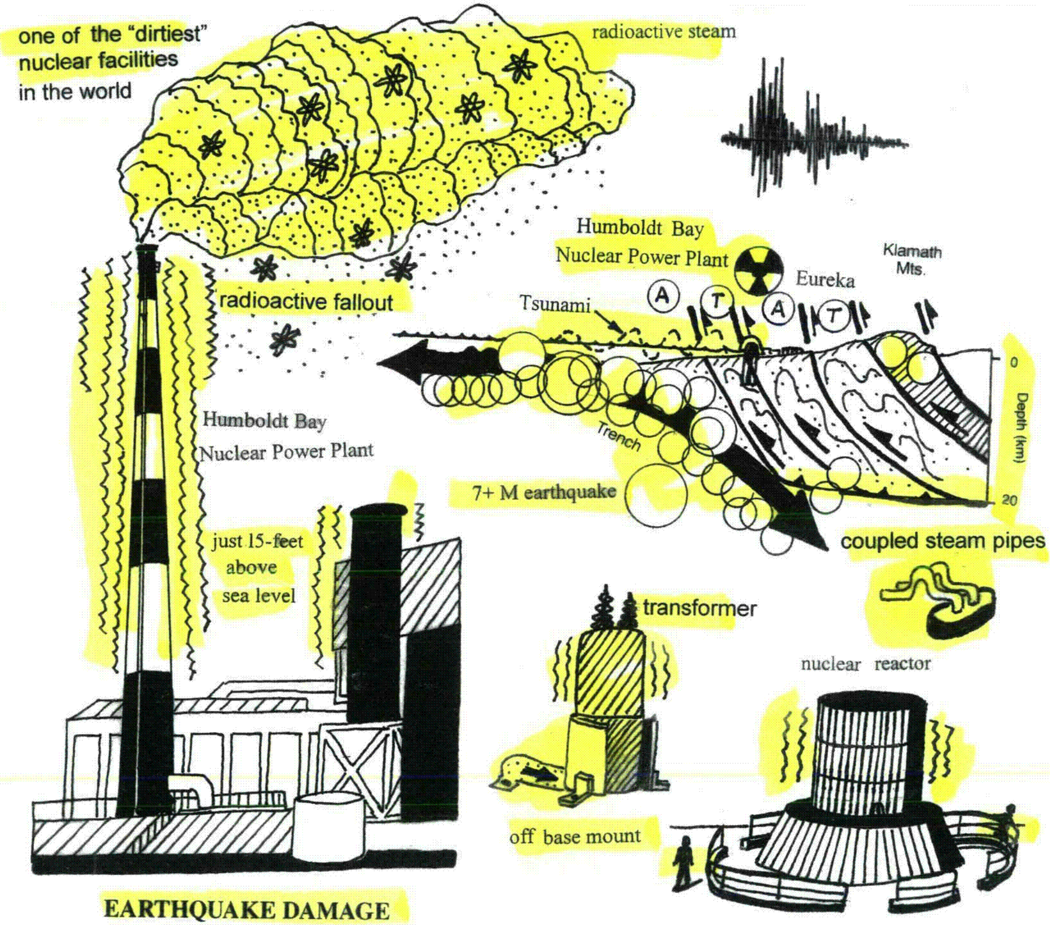
the "dirtiest" nuclear facilities in the world. The earthquakes jammed doorways, coupled steam pipes and knocked transformers off their base mounts at the facility, while also collapsing a nearby, freeway overpass, leading ultimately to an early shut-down and closure.

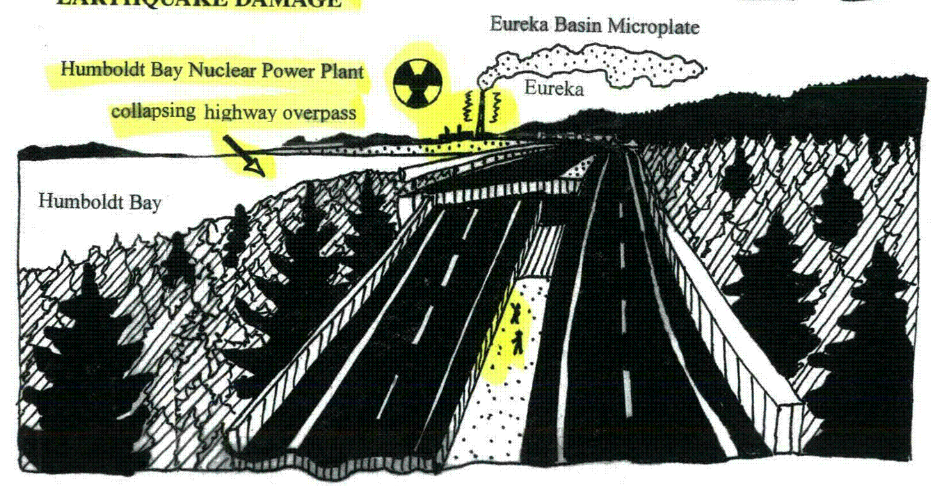
Further south, PG&E's proposed nuclear power sites at Punta Arena, Bodega Bay, Davenport near Monterey and Nipomo Dunes all failed to pass muster, if only for being located on or next to the San Andreas Fault trace, too. Still, PG&E continued to claim that it had learned its lesson at Humboldt Bay, active fault traces be damned!



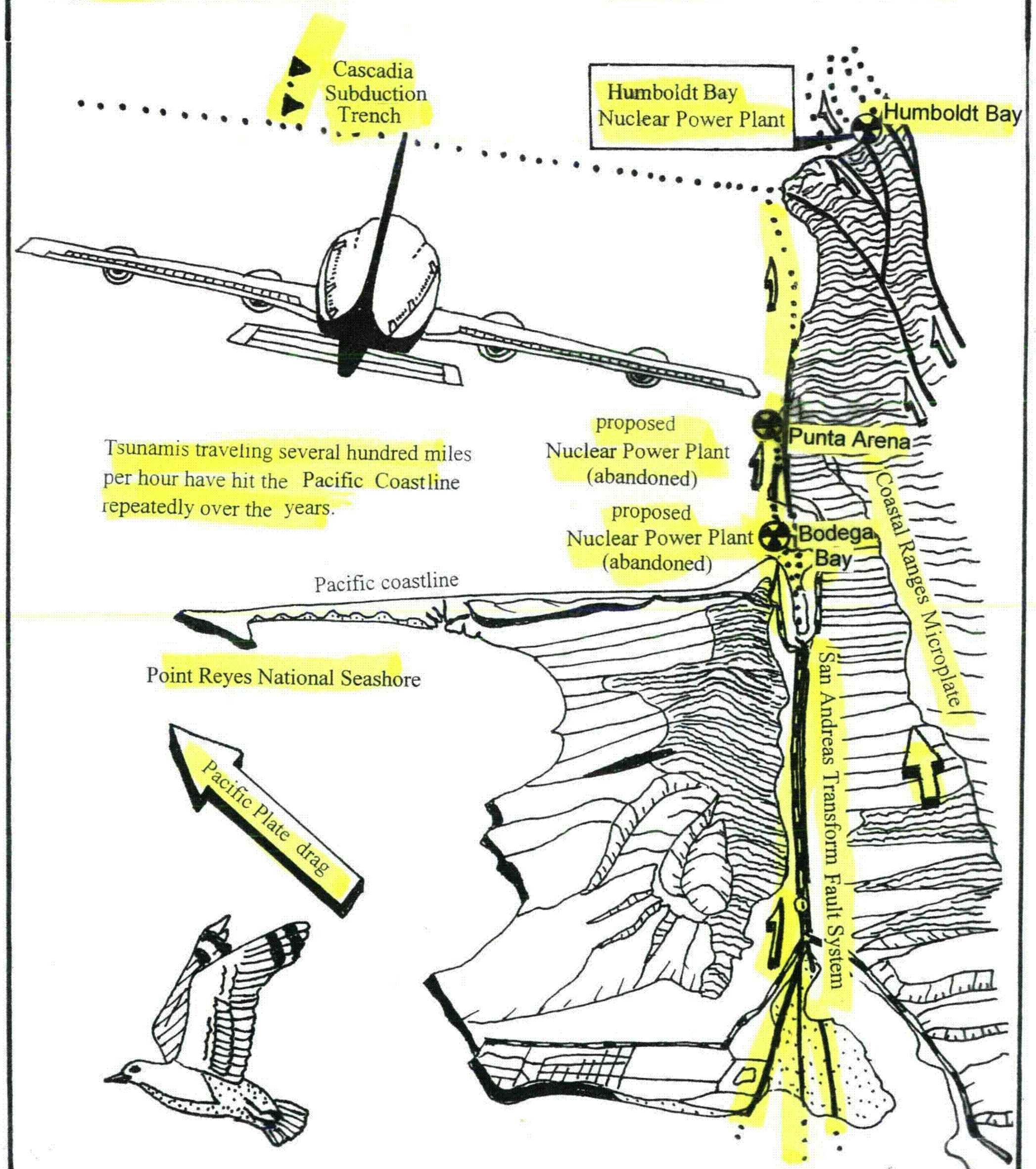




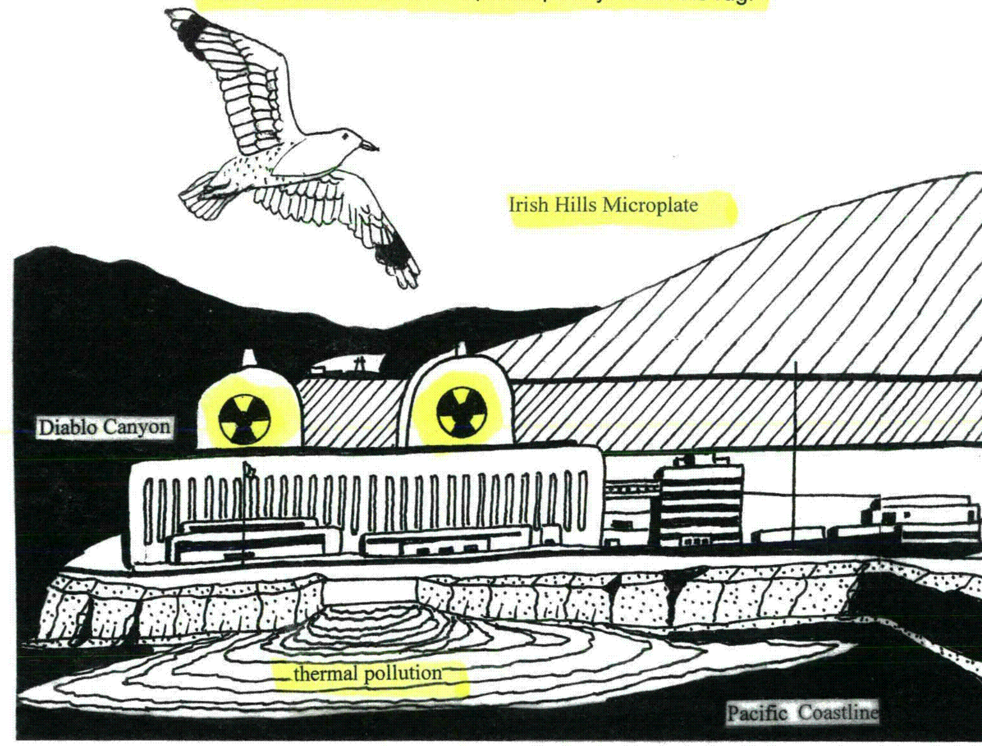




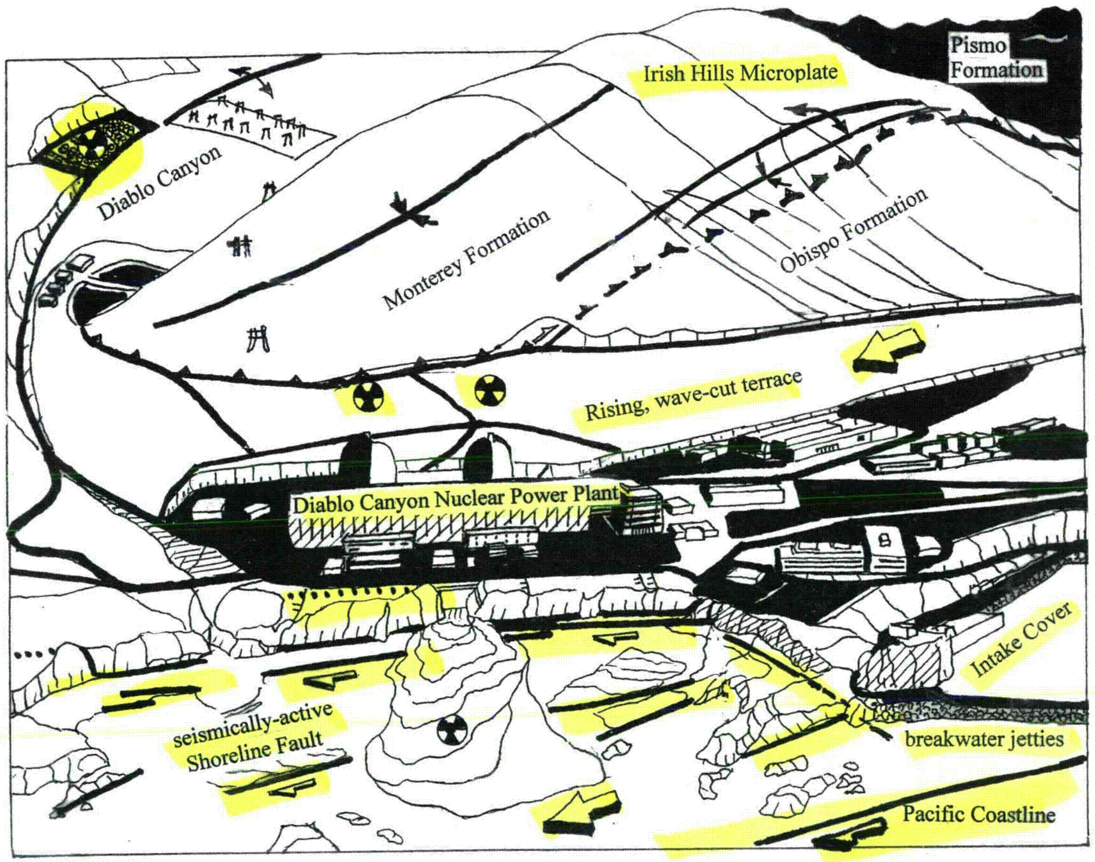
The Humboldt Bay Nuclear Power Plant site in Northern California is located directly over the active Little Salmon Fault in northern extensions of the Greater San Andreas System. Home to high-level radwaste and a decommissioned nuclear reactor, the site was almost breeched by a tsunami.

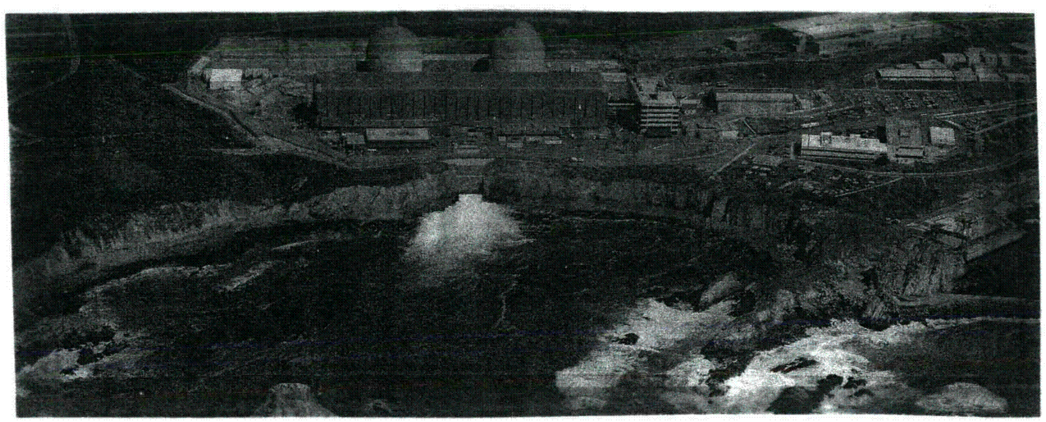


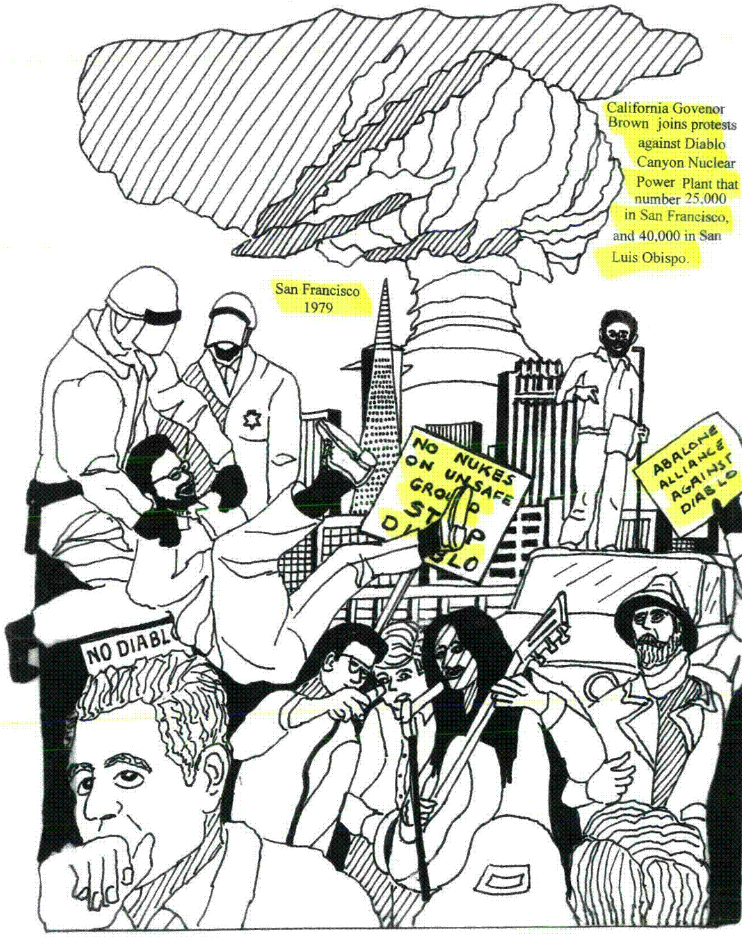
Slipping by pro-nuclear, Federal 'NRC' Review Boards in Southern California, with tens of thousands of citizens protesting them, were PG&E's Diablo Canyon Nuclear Power Plant just west of San Luis Obispo and SoCal Edison's San Onofre Nuclear Power Plant midway between Los Angeles and San Diego. Both of the southern nuclear facilities fronted the tsunami-prone Pacific with two-billion-gallon-per-day, cooling-water intakes and out-flow systems extending out to sea. In addition, both of the plants began operating during the mid- to late 1980s, with a lot of their geologic liabilities being down-played, if not swept completely under the rug.



My own involvement with assessing the plants' geologic settings while working with FUGRO in the early 1970s was peripheral, at best, and my cautionary warnings about my perceived fault, earthquake and tsunami dangers were largely, if not completely, ignored by a pro-development crowd. To be sure, structural up-grades were made eventually by adding more rebar and concrete to both facilities after Big Utility engineering departments recommended them. But the concept of concrete and other structures being stressed repeatedly to failure or even tilted on their side and destroyed by seismic events was more than most wanted to consider, let alone accept. Denial and death-wish, cultural tendencies were wide-spread.





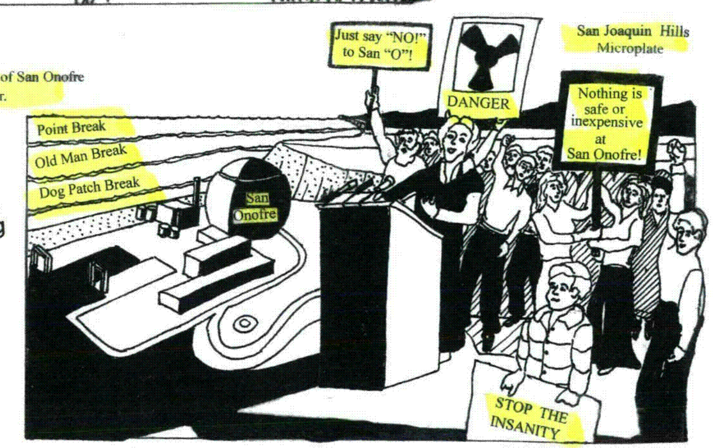


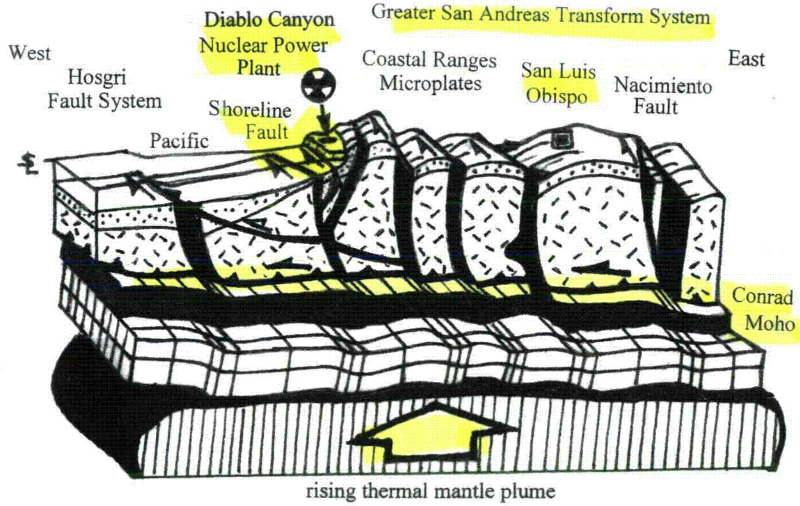
Tens of thousands of citizens protest PG&E's Diablo Canyon Nuclear Power Plant just west of San Luis Obispo and SoCal Edison's San Onofre Nuclear Power Plant midway between Los Angeles and San Diego.

Both of the nuclear facilities front the tsunami-prone Pacific fault, earthquake and tsunami dangers.

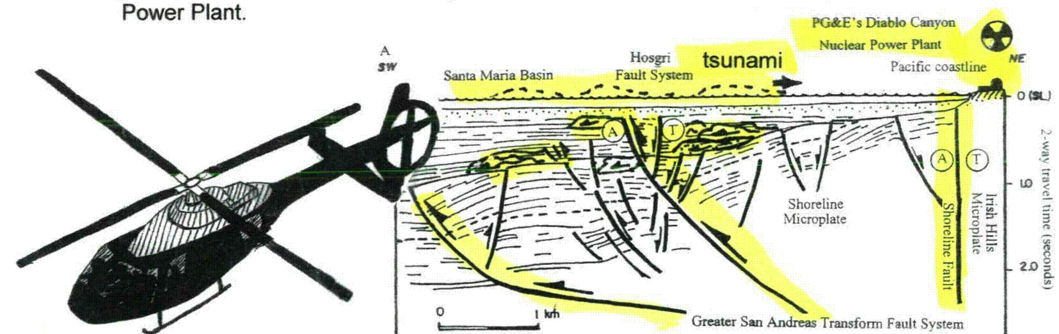
Slipping by pro-nuclear Federal NRC Review Boards with NRC criteria precluding the construction of any nuclear power plant with an active fault within five miles from it.

Protestors gather at the confinement dome of San Onofre Nuclear Power Plant Unit Number 1 reactor.



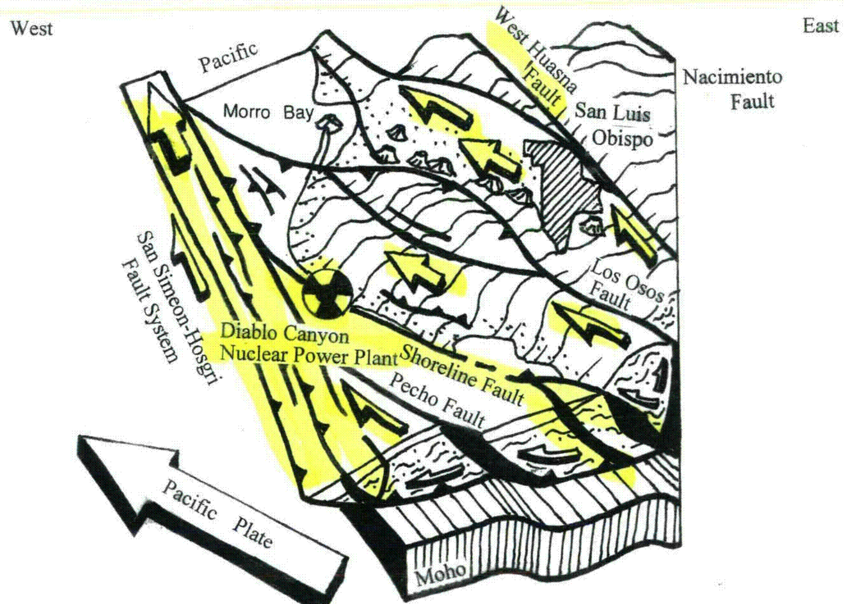


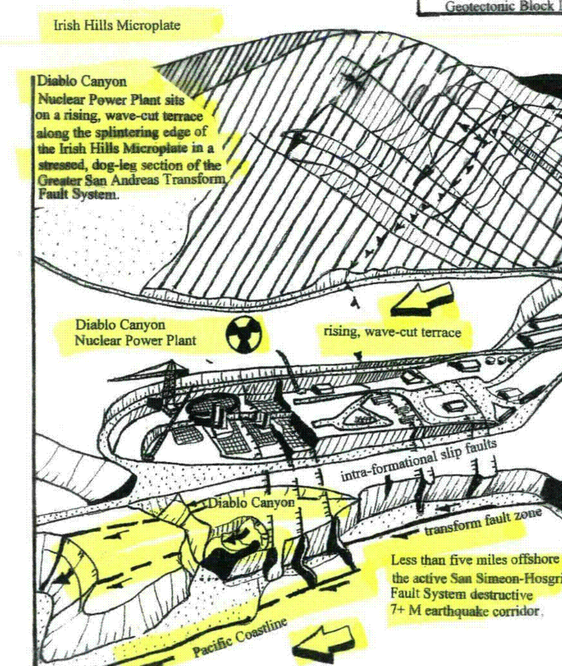
When I first viewed the Diablo Canyon site on aerial photographs in the early 1970s at FUGRO's Long Beach headquarters, I mentioned immediately that low-tide lineations bordering the plant just offshore suggested that the facility sat on the edge of a rising, tectonic block, or microplate in the Greater San Andreas Fault System, only to be met with stony silence. SoCal Edison's stance was that if the plant was re-designed to withstand a 7+ M Hosgri event, it could withstand any event the border fault might offer. And that was all people had to know! Ben Page at Stanford would map and publish a cross section of the same structure in "Geology" in the late 1970s. And just over three decades later, the USGS would also "discover " the Shoreline Fault using seismic-epicenter mapping, prompting more investigations of it as a possible "fatal flaw" to re-licensing of the ever-controversial Diablo Canyon Nuclear Power Plant.

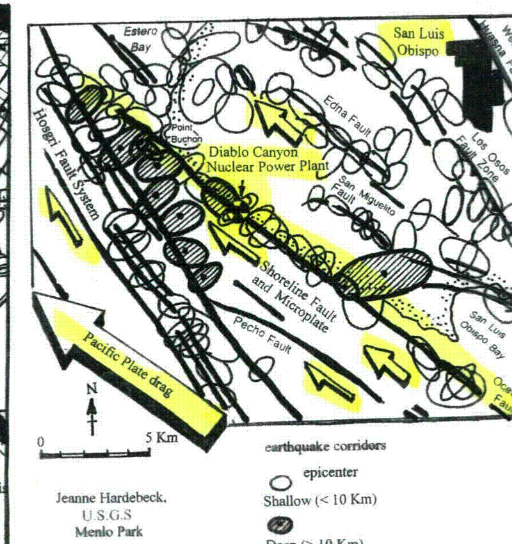


Geotectonic Block Diagram and Seismic Cross Section of the Diablo Canyon Area, California

Construction of the Diablo Canyon plant began in1968, or just one year before Shell Oil Company geologists announced the offshore, seismic-line discovery of the active, 7+ M-capable Hosgri Fault zone lying within five miles of the site. At the time, NRC criteria precluded the construction of any nuclear power plant with an active fault within five miles from it. Bordering the Hosgri Fault were active, submarine slide scarps boding tsunami-generating potential as well. With construction and re-design costs sky-rocketing, more concrete with rebar-reinforcement was installed.

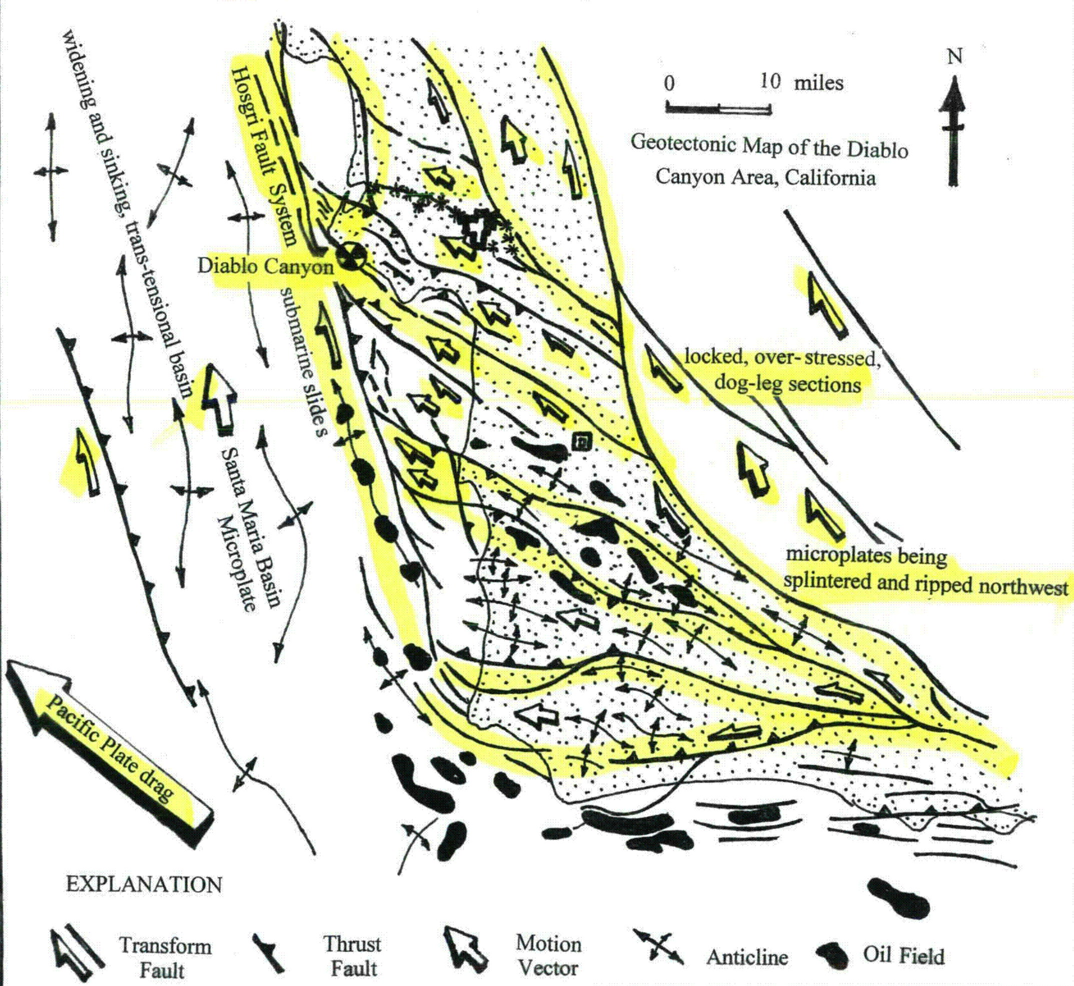






From a geotectonic perspective, the Diablo Canyon Nuclear Power Plant sits atop the rising Irish Hills Microplate in a stressed and rotating dog-leg part of the Greater San Andreas Transform Fault System. As at the San Onofre site on the Pacific Coastline, the Diablo Canyon area also has a number of stair-stepping, wave-cut terraces around it that document a history of jolting uplifts and transform offsets interspersed with more quiescent periods of wave-cut terrace development. In total, U.S.G.S. geologist Wallace Hall documented eight wave-cut terrace levels near Diablo Canyon in 1973 (See U.S.G.S. MF-511) at elevations of 10-, 16- 40-, 100-160-, 190- 370- and 600-feet. More recent studies show at least four other levels dating back to 755 Ka. Overall, the Irish Hills Microplate has risen well over 2000 feet above sea level since 5 Ma, while being rotated clockwise to its present-day northwest-striking orientation.

Greater San Andreas Transform Fault System

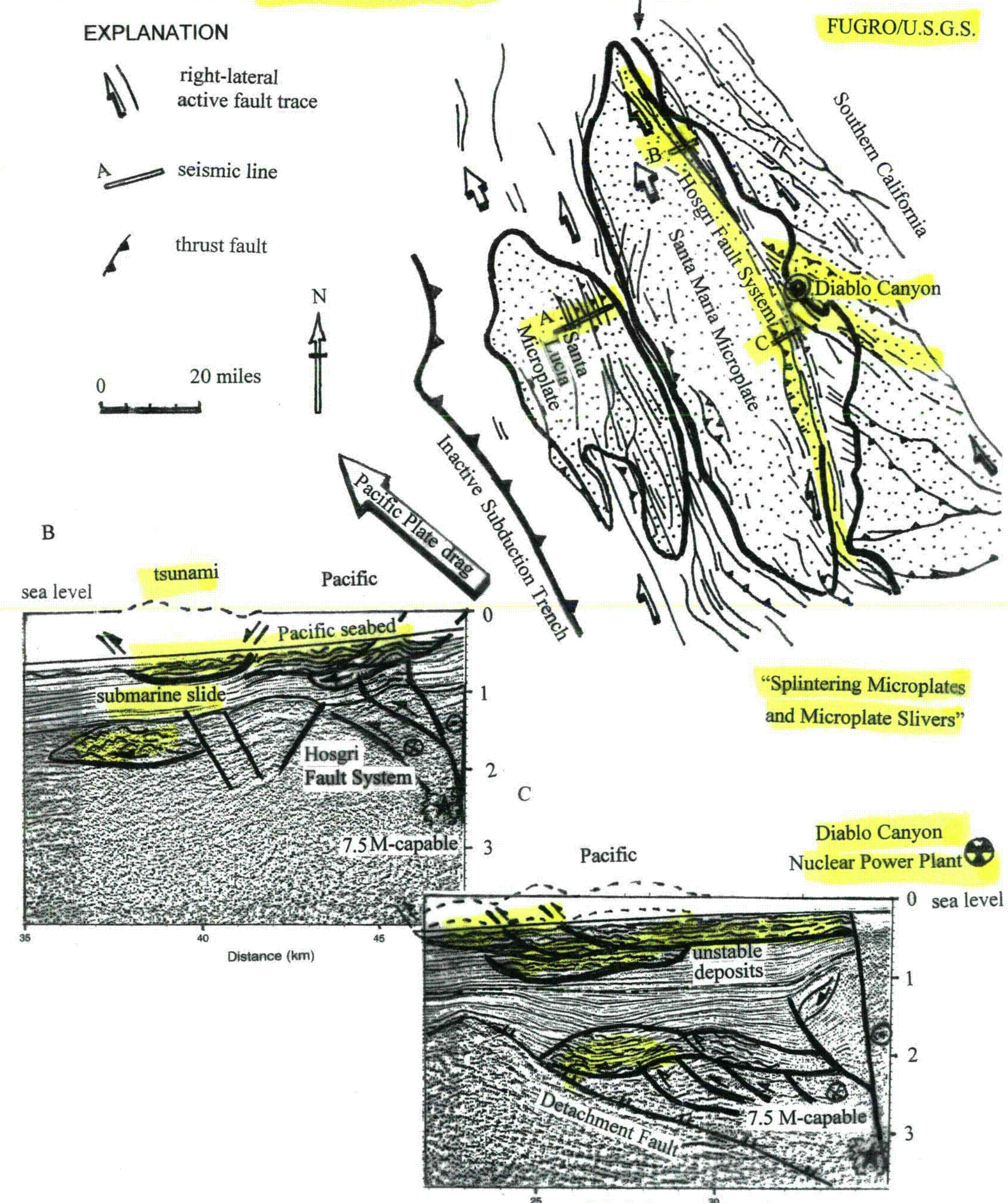


J. A. Tony Fallin, U.S.G.S./ Janus International

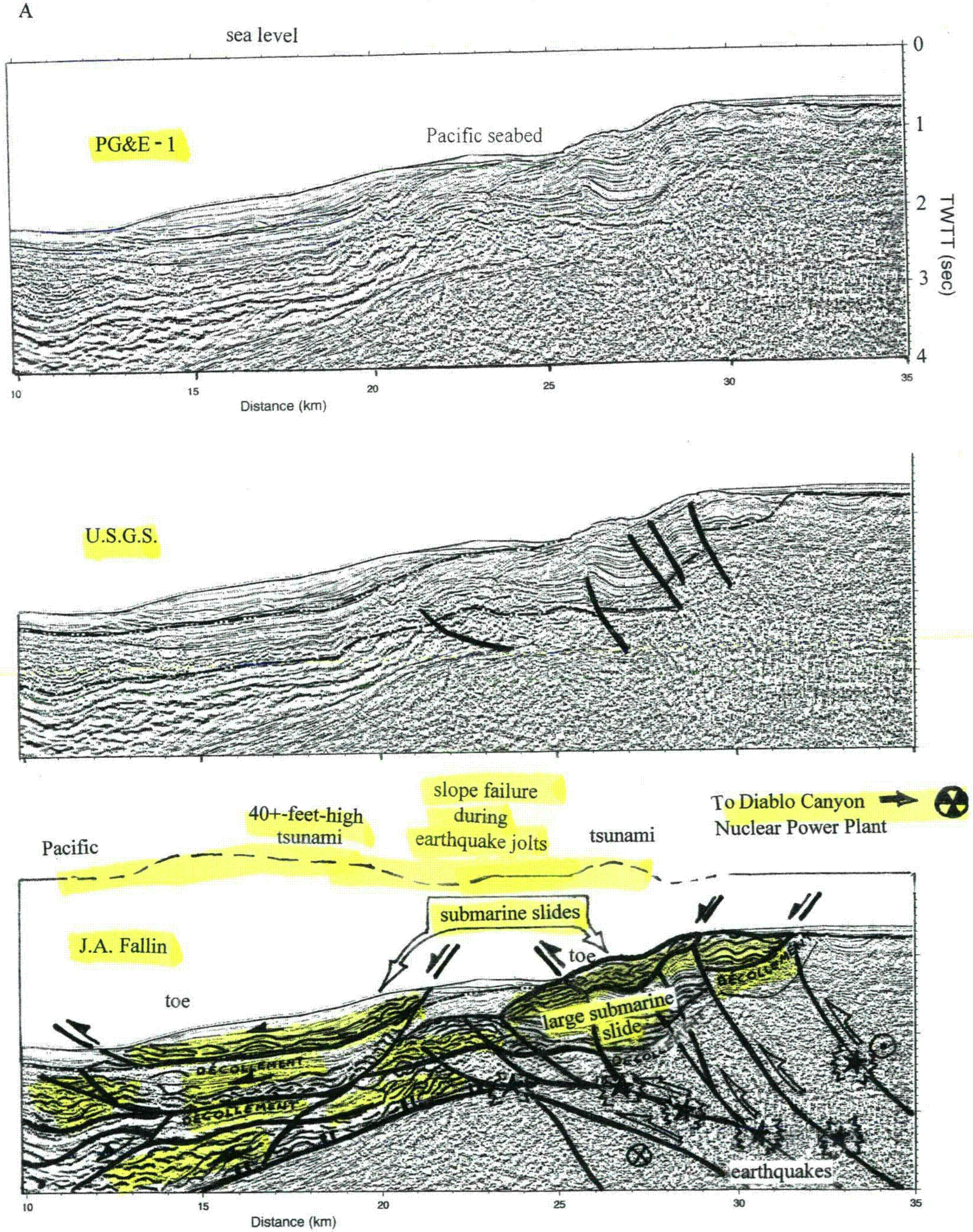
U.S.G.S. Bulletin 1995 series

tsunami-, and storm-prone Pacific Coastline

FUGRO/U.S.G.S.



U.S.G.S. Bulletin 1995 series



At San Onofre, the addition of two, new reactors beside an older one in the early 1970s prompted further geological surveys around the facility, especially after a shear zone was uncovered beneath one of the new, proposed, reactor sites. Neotectonics consultant and U.C.- Berkeley alumn Roy Shlemon responded and demonstrated conclusively that the Cristianitos Fault did not displace 125,000-year-old terrace deposits where it was exposed in a shoreline outcrop one mile south of the reactors. Using this alone as evidence, SoCal Edison declared the entire fault line inactive and its site safe, no matter the Cristianitos offset had an active seismic history along other parts of its trace that had been discussed with the utility one week earlier at FUGRO's Long Beach headquarters in a conference I happen to attend.

In addition, no mention of a covered, horizontal, sole fault running below the San Onofre site was made in SoCal Edison's report to the NRC, even with seismic lines having suggested its possible existence. And somehow, a pro-nuclear NRC was also willing to allow the addition of two, new reactors being placed on the San Onofre

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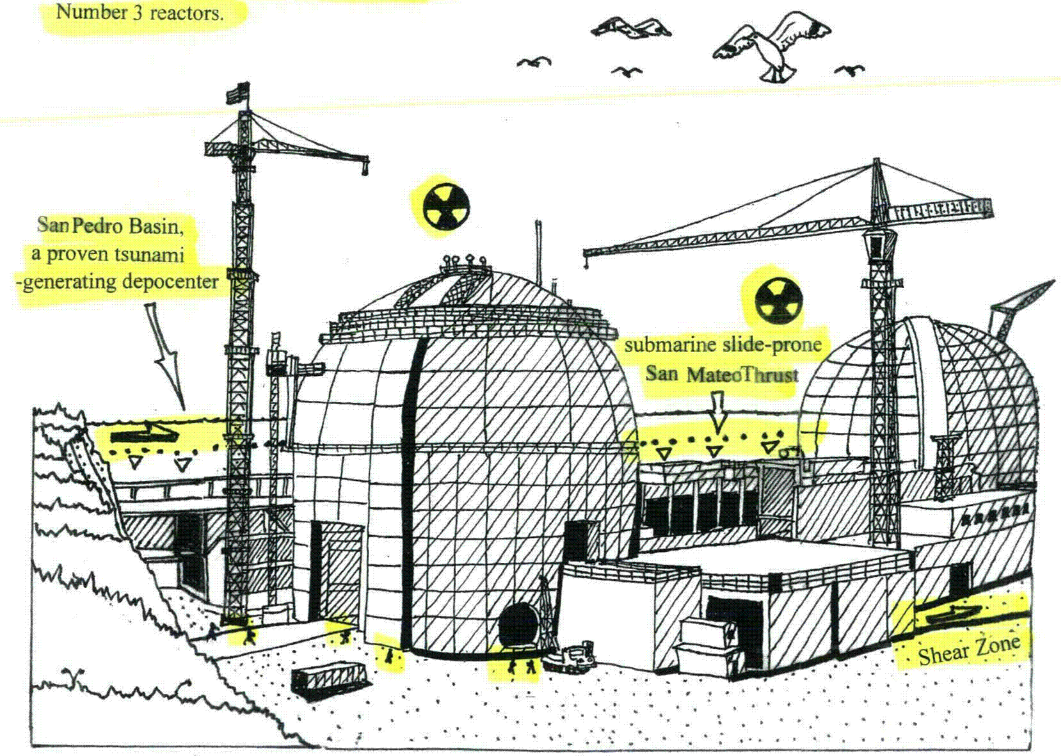
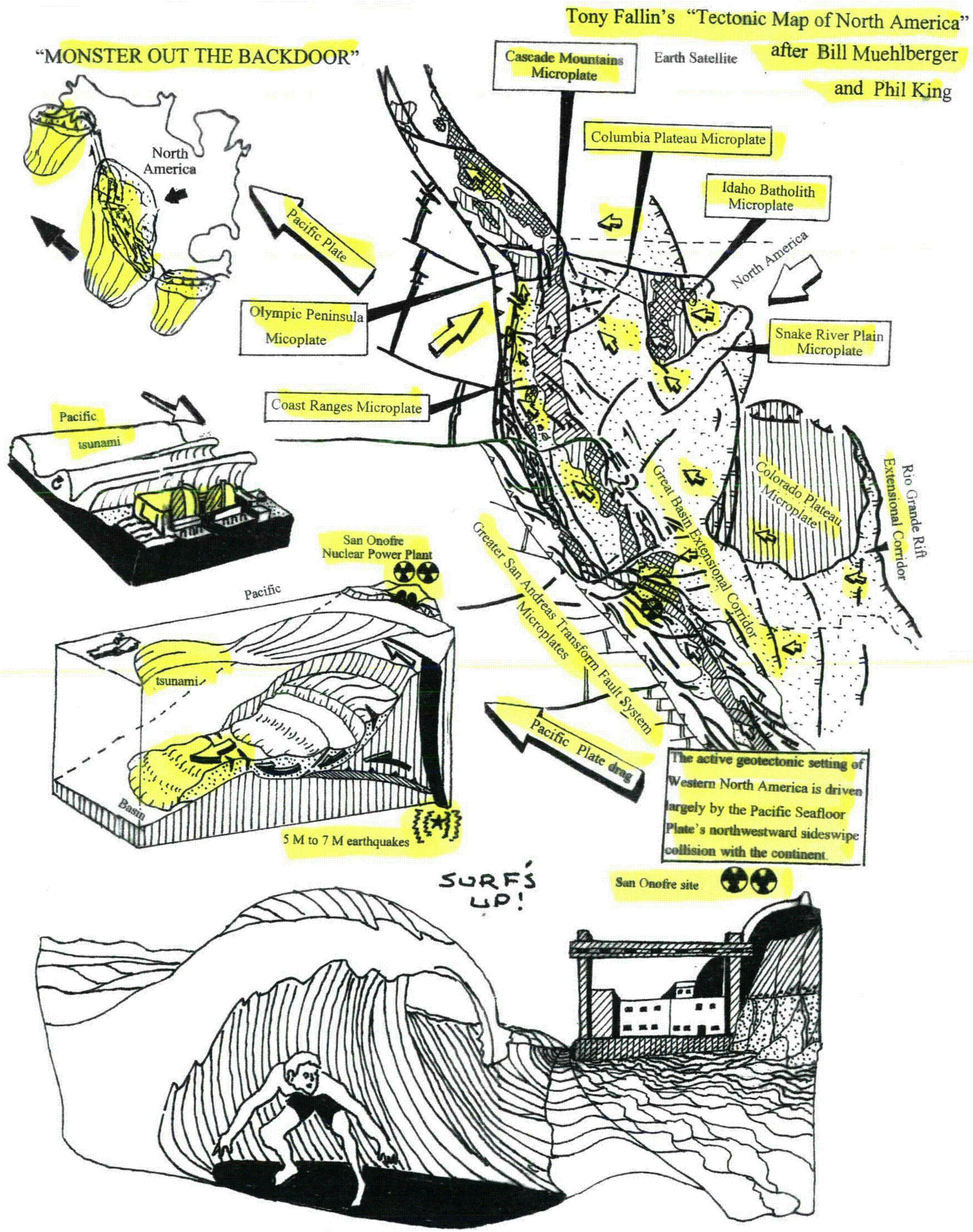
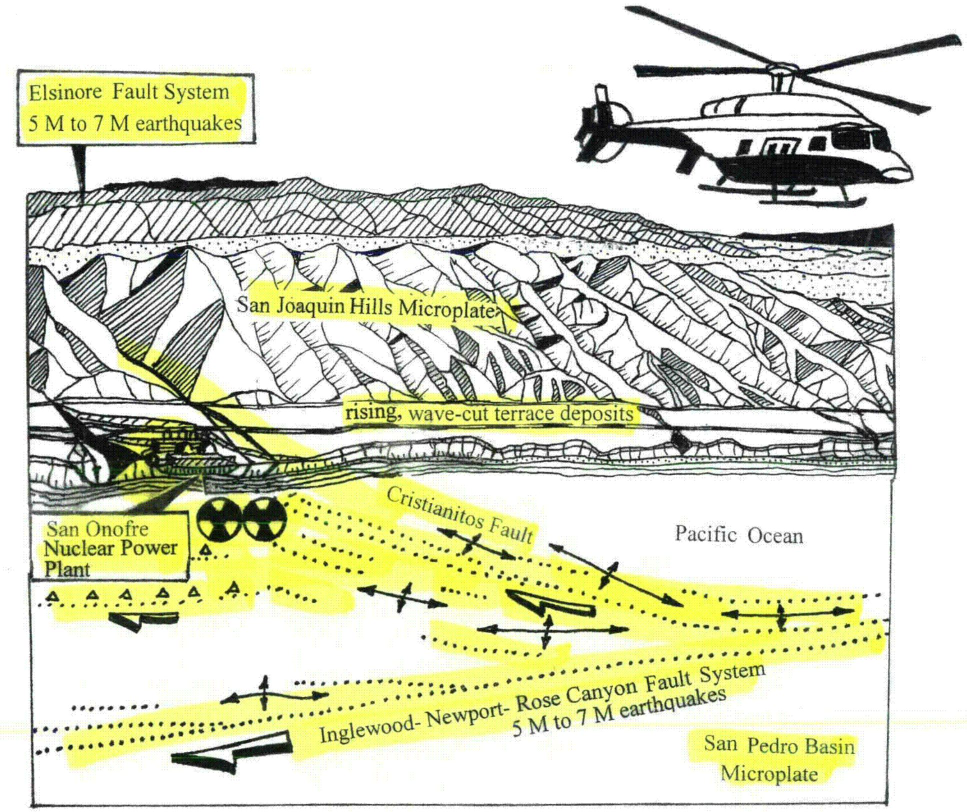
1970s construction of the San Onofre Nuclear Power Plant Unit Number 2 and Unit Number 3 reactors.

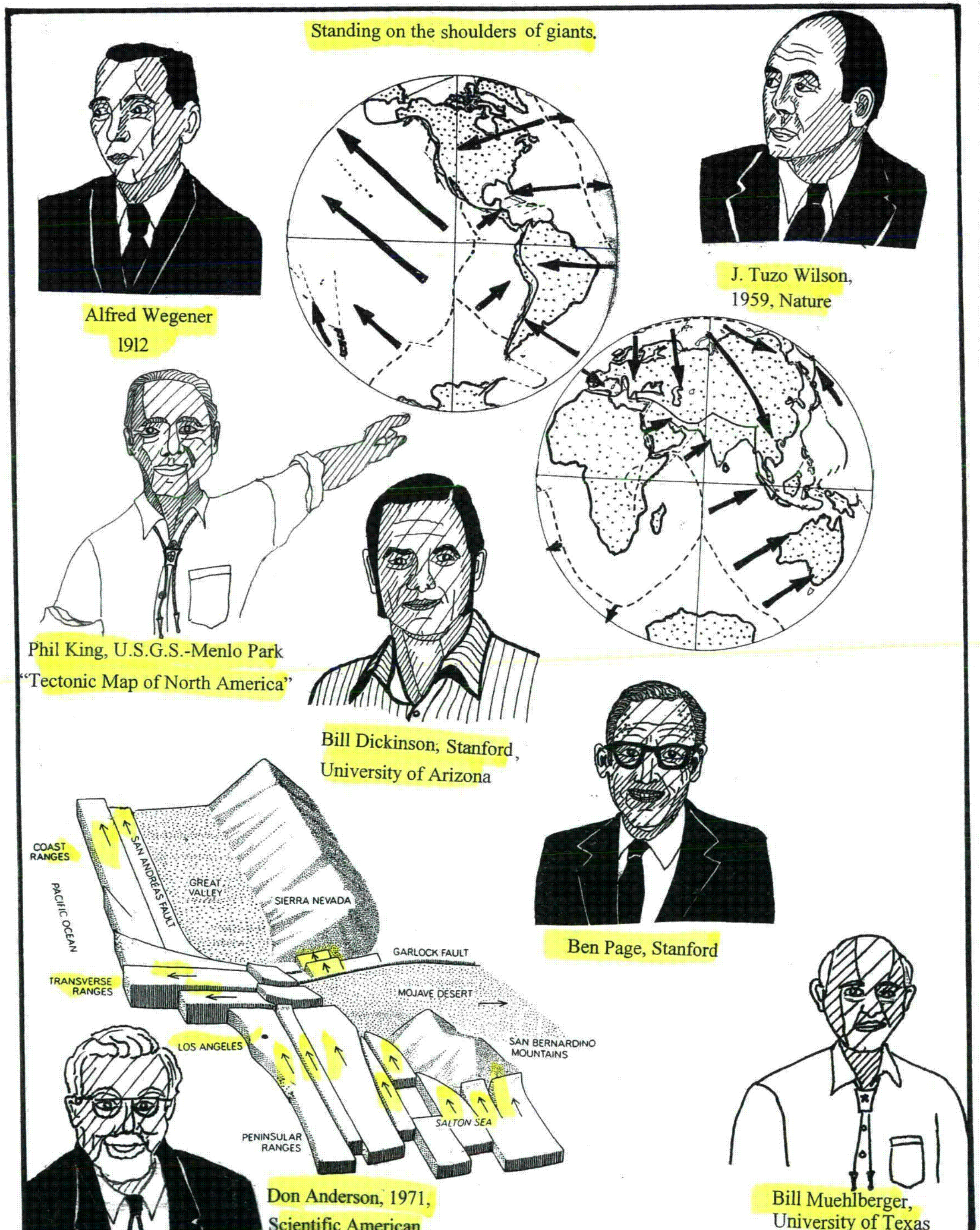


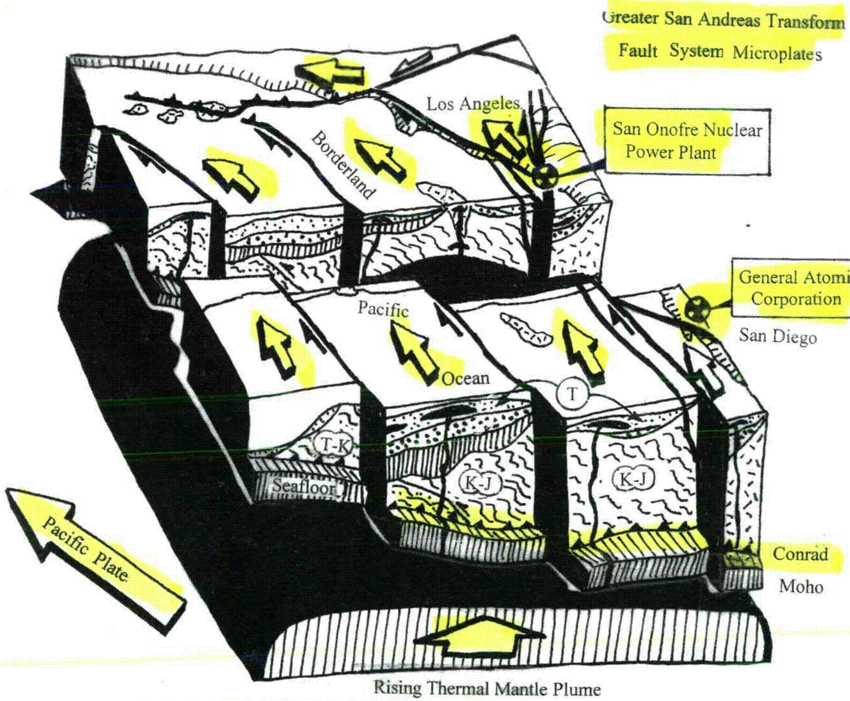




site, even with traces of the 7+ M-capable, Newport-Inglewood-Rose Canyon Fault System and bounding, submarine slides with tsunami-generating potential lying just offshore within five miles of the nuclear complex.

From a plate tectonic perspective, both Don Anderson at Caltech and J. H. Veder et al., at the USGS had shown the San Onofre site to be located on the edge of an active tectonic block or microplate in the Greater San Andreas Fault System, with Don's work profiled in a 1971 issue of "Scientific American" and J. H. Verder, et al.'s views outlined in a 1971 USGS Miscellaneous Investigation addressing the geology of Southern California's borderlands under the Pacific. More detailed investigations of the Newport-Inglewood-Rose Canyon Fault System by Western Geophysical for the San Onofre project were to follow, showing a complex, maze of anastomosing fault traces bordering the Southern California coastline, prompting me to thereafter use the term "splintering microplates and microplate slivers" when describing the Greater San Andreas Fault System and related structures across much of Western North America.





After Veder, J.H. , et al., 1971, U.S.G.S. MF-624; Howell, G.W., and Veder, J.H., 1981, in The Geotectonic Development of California, Ernst, W.G., Editor, Prentice Hall, New Jersey

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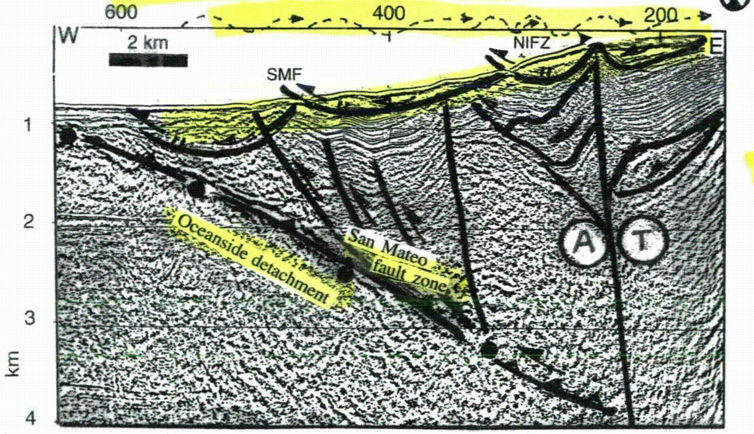
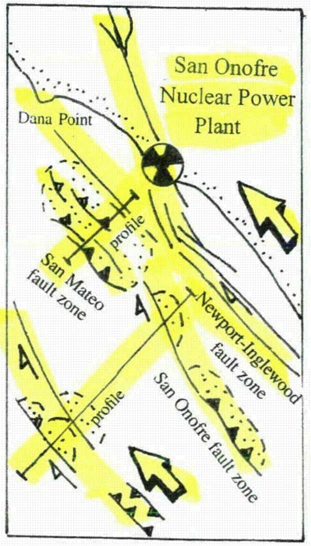
In essence, microplate border faults were splaying out up-section in less-consolidated sediments within the transform terrane, placing some parts of the Newport-Inglewood-Rose Canyon Fault zone, plus associated scarps with tsunami-generating potential, much closer to the San Onofre Nuclear Power than had been known previously. Further north, similar structures would also appear offshore from the Diablo Canyon Nuclear Power plant and offshore from the San Francisco Bay Area as still more oceanic, seismic surveys were made.

At depth on the seismic lines, there was also abundant evidence of sole-fault offsets between subducted seafloor and overlying sediments along the Pacific coastline and along the Conrad Seismic Discontinuity below the Great Valley and Sierra Nevada. In some respects, the offsets appeared related to what Albert "Bert" Bally was mapping on seismic lines across the Canadian Rockies further north, and I developed a series of block diagrams showing the features for areas where I was working, incorporating earlier works by Ben Page, Bill Dickinson, Don Anderson, and others in the process.

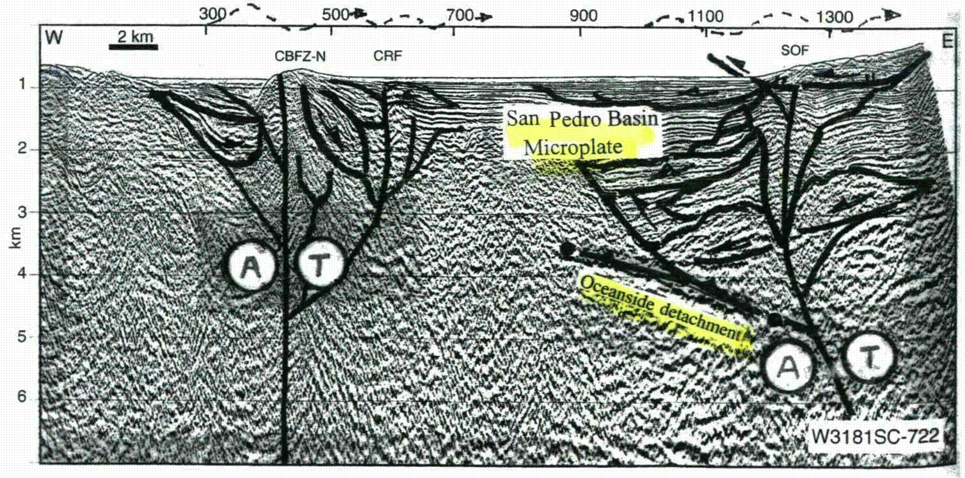
Just offshore from the San Onofre site is
submarine slide-prone San Pedro Basin,
a proven tsunami-generating depocenter,
and bounding, 7+ M-capable,
Newport-Inglewood-Rose Canyon Fault System



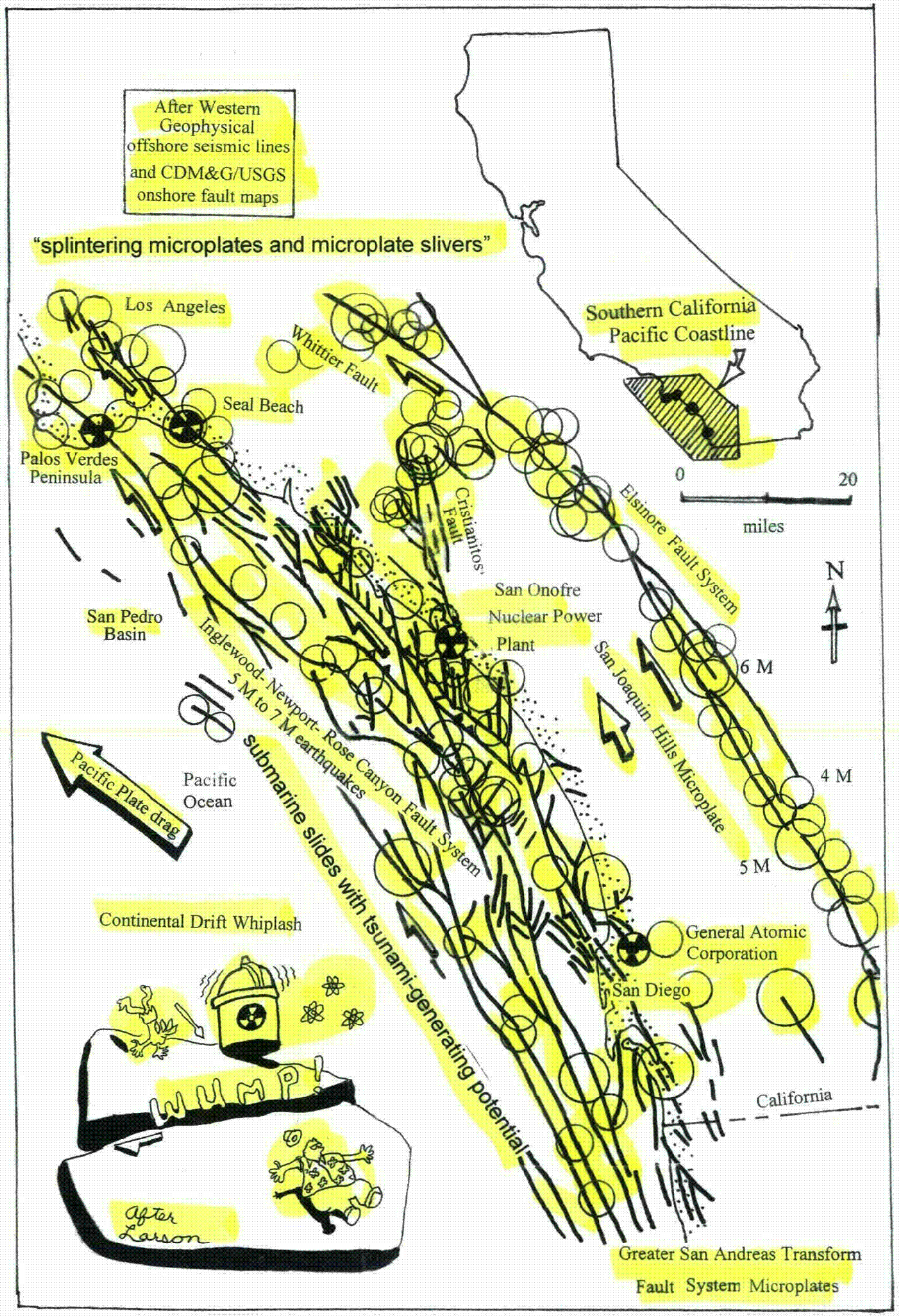


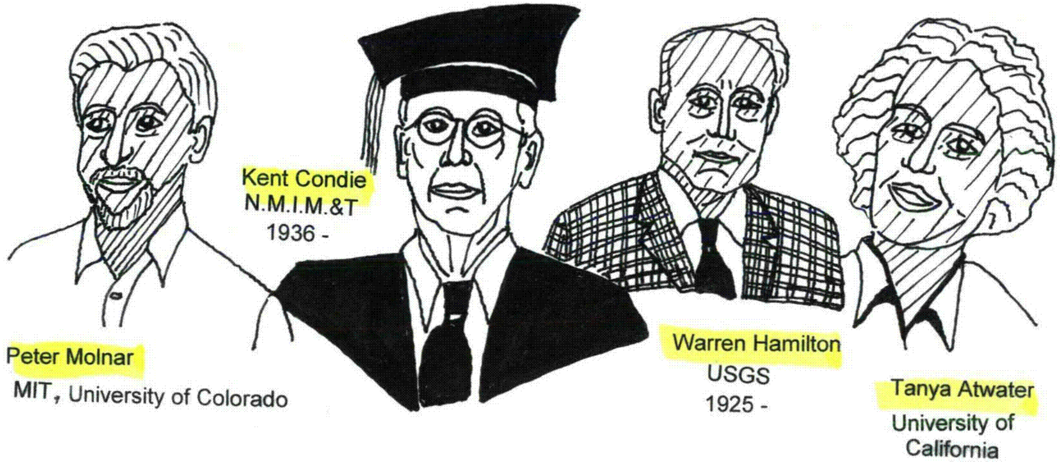
Migrated and depth-converted WesternGeco multichannel seismic profile 406 (W375SC) across the Newport-Inglewood fault zone (NIFZ) and San Mateo fault (SMF). Dots delineate the strong reflector associated with the Oceanside detachment.

2009, GSA Special Paper 454



Migrated and depth-converted, WesternGeco, multichannel seismic profile 722(W3181SC) across the San Onofre fault (SOF), the northern section of the Coronado Bank fault zone (CBFZ-N), and the buried southern end of the Carlsbad Ridge fault (CRF).

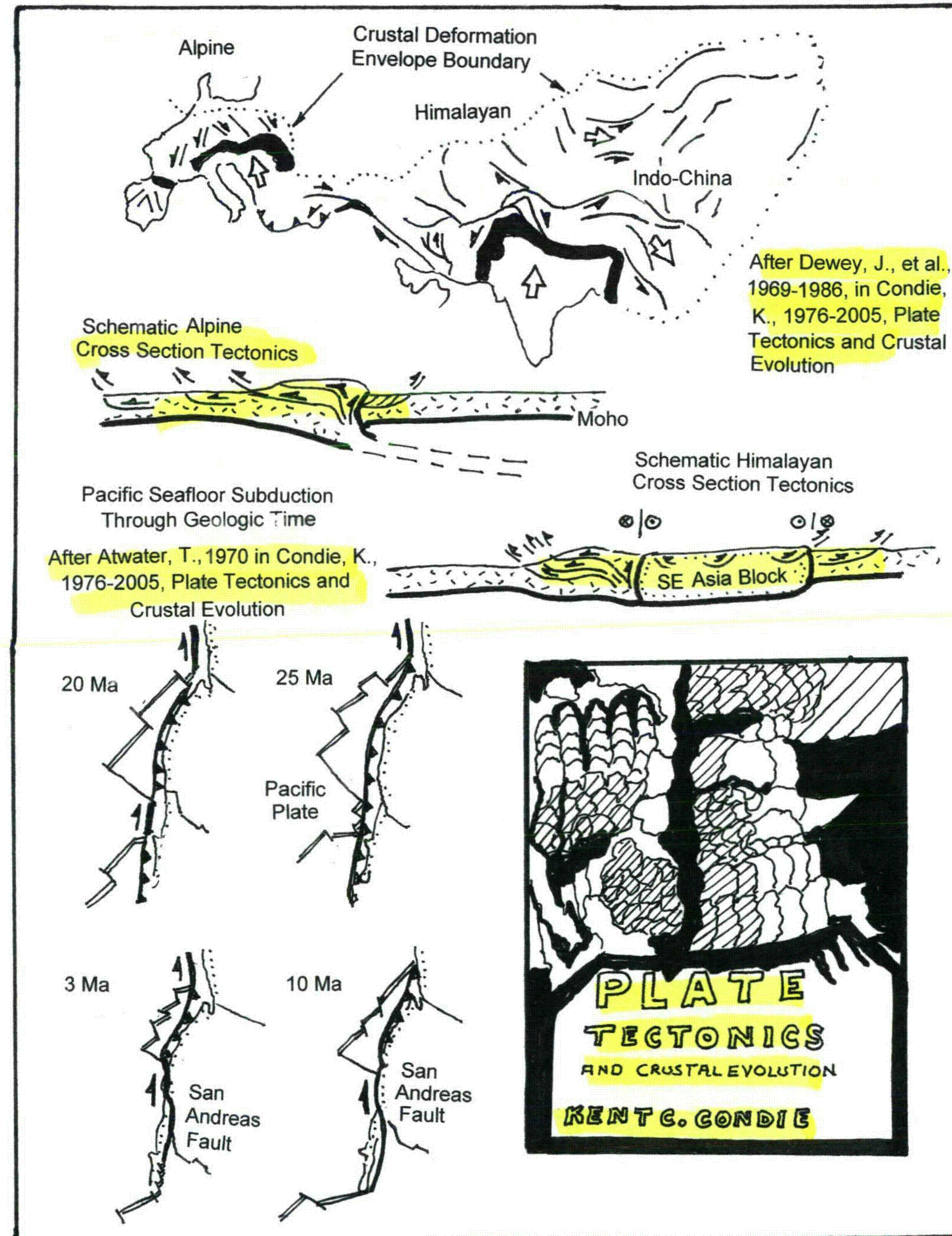


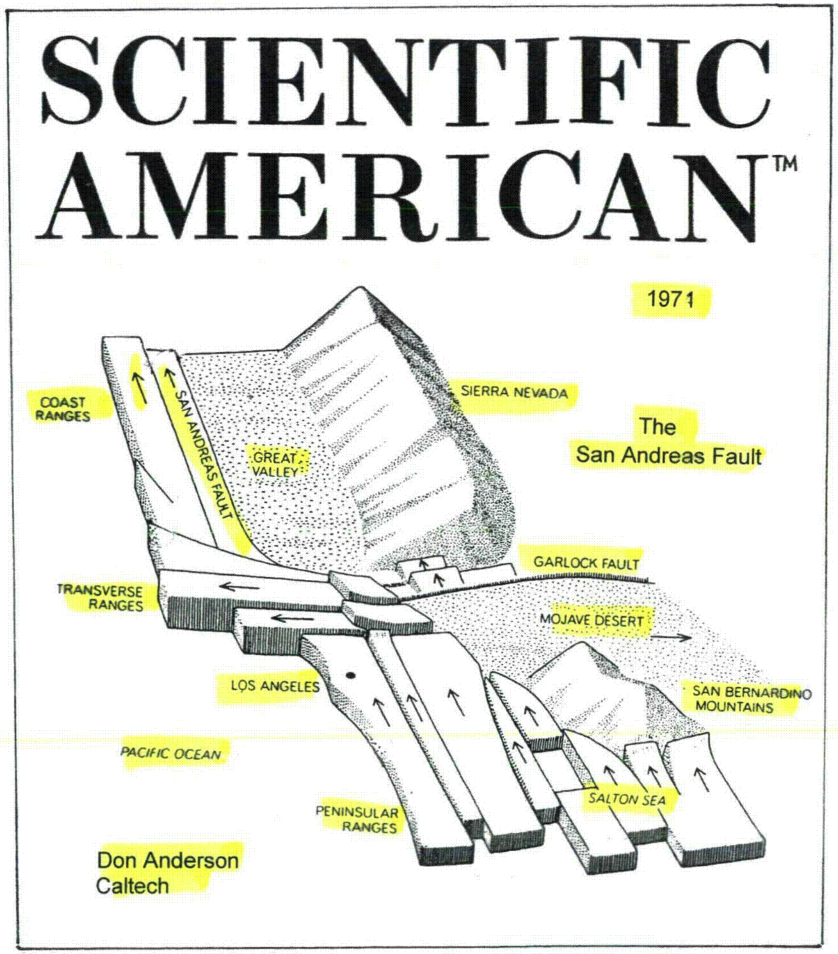


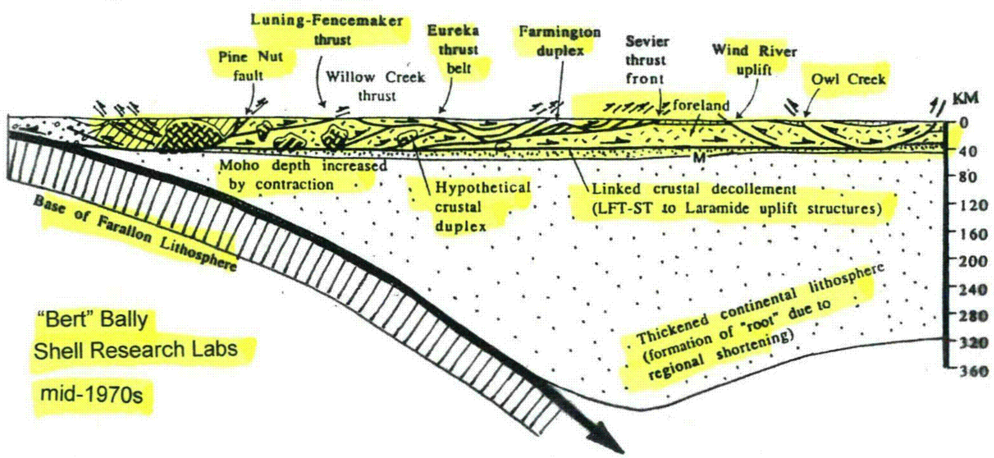
As the mid-1970s arrived, others involved with the "Plate Tectonic Revolution" continued to stay active. Peter Molnar and Tanya Atwater, per the grapevine, had taken a sabbatical in Russia, spawned a child and then gone their separate ways, Peter to MIT and Afghanistan; Tanya to teach at UC- Santa Barbara. Working with first-generation Landsat imagery, Peter would use synoptic views from space to suggest large-scale, crustal deformation, including eastward, transform displacement of Indo-China during the docking of India with Asia and the Himalayan Orogeny.

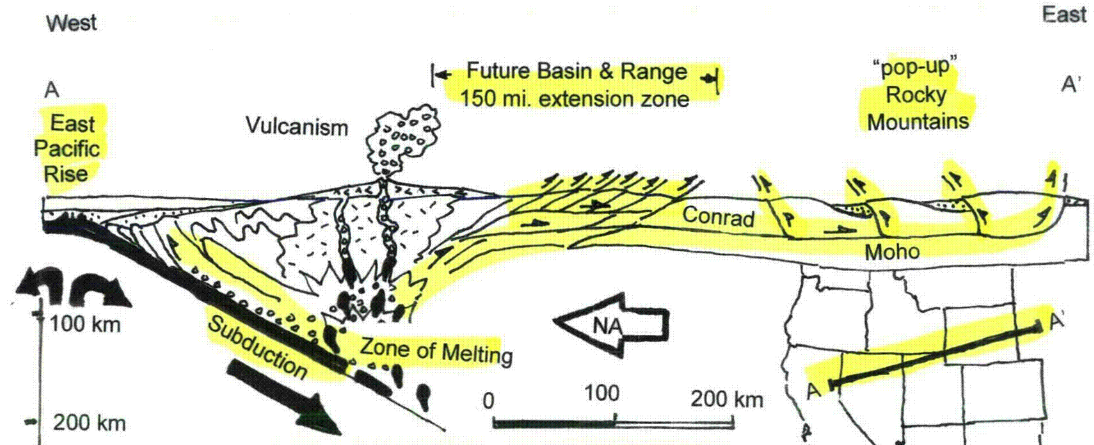
While Peter was busy in Asia, Kent Condie at New Mexico Institute of Mining and Technology in Socorro was putting the finishing touches on his 1976 opus Plate Tectonics and Crustal Evolution. As a compendium of others' and his own emerging thoughts on plate tectonic theory, Kent's work would continue to evolve in future editions, helping those of us working on our own related projects to stay in touch with what others were doing in the "Plate Tectonic Revolution", too.

I was particularly interested in what others were encountering in the field and on deep seismic lines when focusing on large-scale, crustal deformation. Already, Warren Hamilton, et al., at the USGS had suggested large-scale, Laramide deformation and plutonism across Western North America where I was working, even implicating regional sub-thrusts stretching from the Sierra Nevada to the Rocky Mountains' eastern front to explain the latter's "pop-up" origin. Profiled first in mid- to late-1960s reports, Warren, et al.'s work would later be adapted and used by Colorado School of Mines' L.T. Grose in the "Tectonics" section of RMAG's Geologic Atlas of the Rocky Mountains Region. Following suit would be "Bert" Bally at Shell Research Labs reporting on detailed, seismic-line studies of the Rocky Mountains in the mid-1970s showing mid-crustal sub-thrusting cutting below transform and other terranes, while also extending hundreds of miles in-board within North America's western, continental plate boundary.









Cross section showing the geotectonic setting of Western North America during Laramide deformation, ~40 Ma

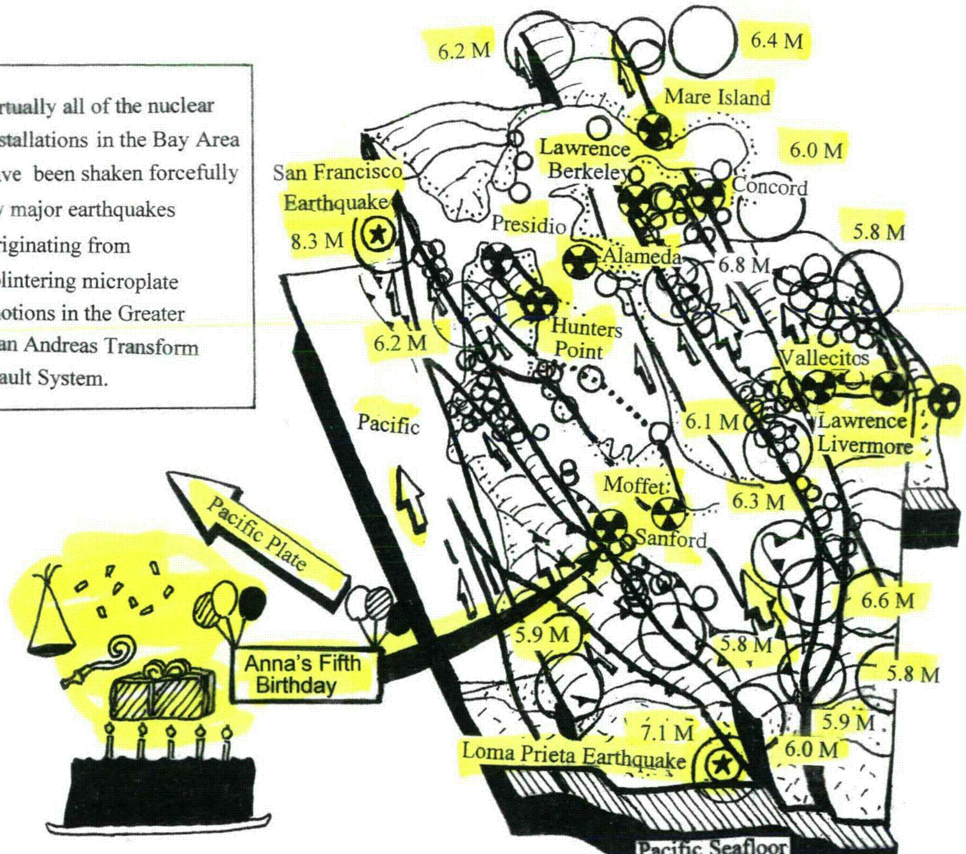
After Hamilton, W., 1965-1969, and Grose, L.T., 1972, Tectonics in RMAG Geologic Atlas of the Rocky Mountains Region: Denver, CO

Implicit in all of the crustal studies that I scanned during the mid-1970s was the fact that the Earth's thin, outer shell is little more than putty and Graham crackers when responding to much more massive, thermal-cell, convection currents in the Earth's mantle! Saturated, near-surface sediments turn to mush, while more brittle, crustal stratae snap, crackle and pop under the enormous pressure of mantle, thermal-cell convection below them, when not being consumed in subduction zones or otherwise stressed and deformed. The "Plate Tectonic Revolution" was really beginning to address thin, seafloor-plate subduction and thicker, crustal-plate deformation in dynamic settings where the earth's crust was continually evolving.

This was very much in agreement with what I was discovering as well. In essence, I viewed Western North America as a work in constant progress, with its underlying crustal plate in a state of perpetual stress. Sitting atop an uplifting, lubricating and propelling mantle, thermal plume, much of the West, from my own perspective and findings in the field with FUGRO, was being sheared, extended or rotated northwest in its sideswipe collision with the Pacific Plate. This is to say I viewed myself and others in the region as living amidst a sea of splintering microplates and microplate slivers, all with associated earthquake corridors and deep, sole-thrusts as well as more vertical transform boundaries around them! Indeed, this was what deep seismic data, surface structures, well cores and shallow as well as deep, crustal earthquake epicenter zones all suggested to me.

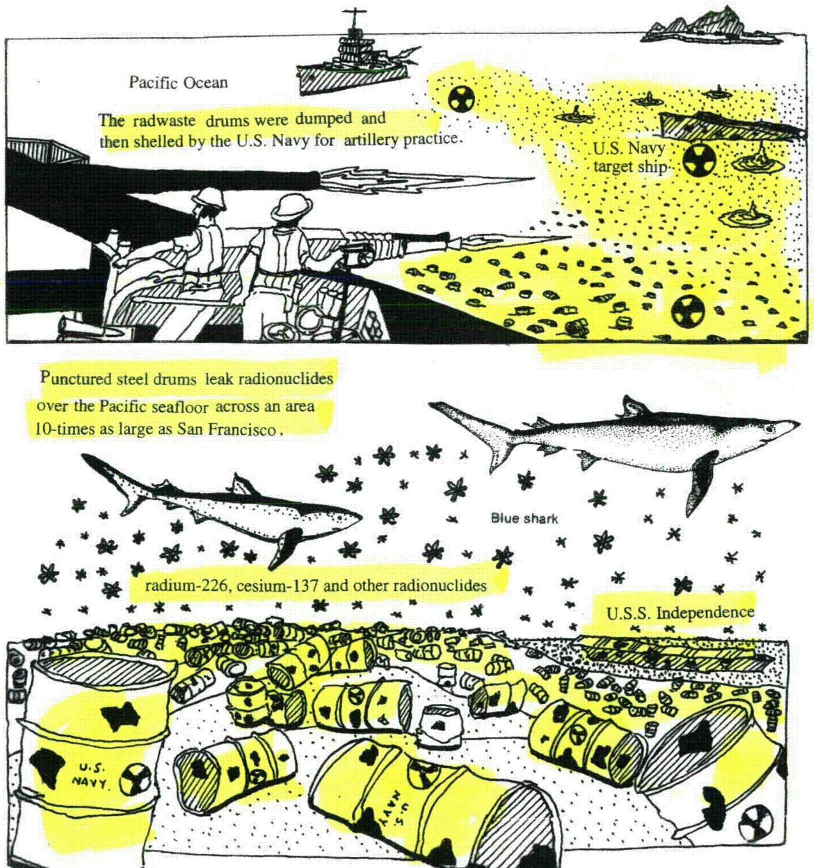
Returning to the San Francisco Bay Area from FUGRO's Long Beach headquarters in the spring of 1974, I opted for a little "quality, family time" with Helen, Billy, Eleanor and Anna during the spring of 1974. The kids were already outward-bound, much to my liking, with Billy even hunting squirrels on Stanford lands and reminding me of me during my own youth. Anna's fifth birthday was at hand April 23 and Helen had planned a party in Portola Valley, selecting unbeknownst to her, a park and sag pond area located directly over an active trace of the San Andreas Fault. All of Helen's family would be at the gathering and it would take an Act of God or Mother Nature to change things. With my hair beginning to turn prematurely gray, I mentioned earthquake dangers only briefly, then hoped that both God and Mother Nature would let us enjoy the day! I felt like Colin Wilson's <u>The Outsider</u>, "…knowing too much, seeing too deeply" and with responsibilities in hand, could never rest easily.

Virtually all of the nuclear installations in the Bay Area have been shaken forcefully by major earthquakes originating from splintering microplate motions in the Greater San Andreas Transform Fault System.

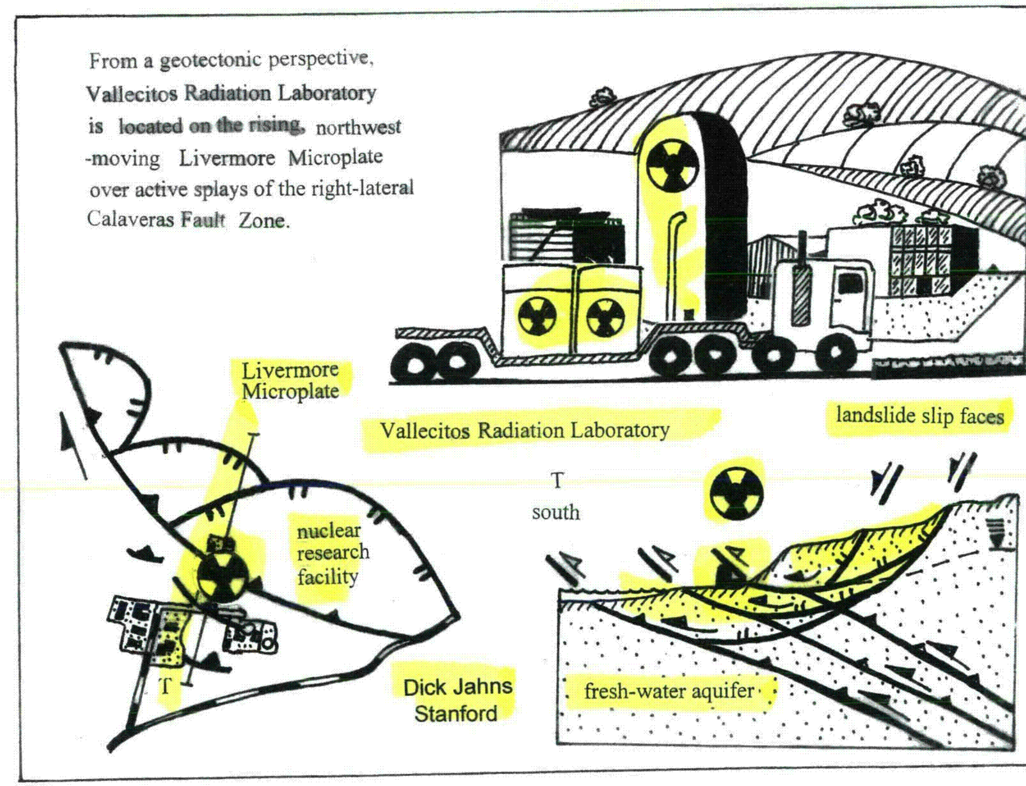


San Francisco Bay Area
Greater San Andreas Transform Fault System

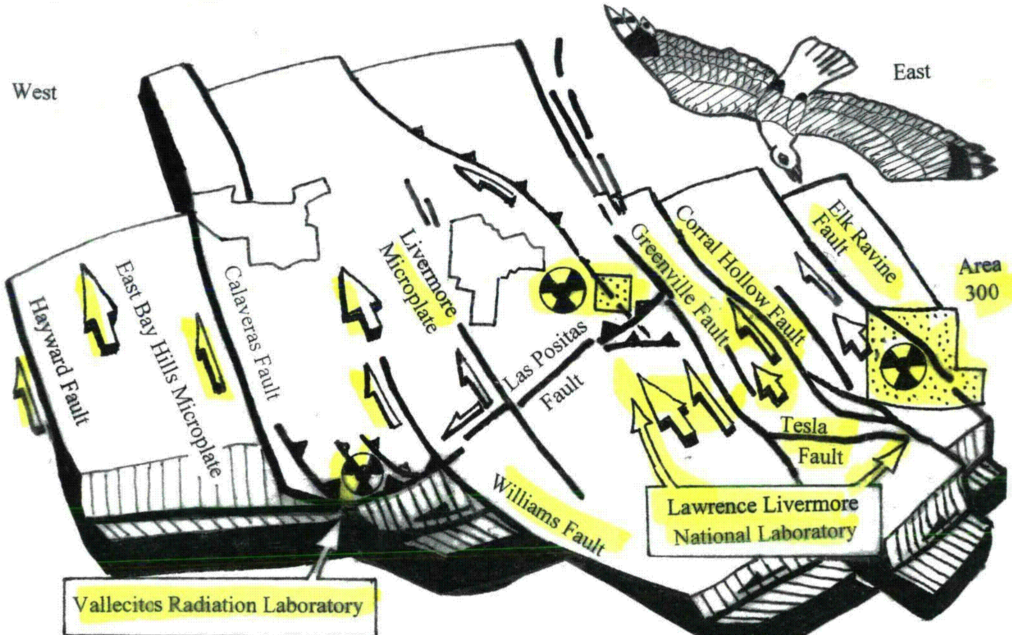
I was between million-dollar, PSAR field projects with FUGRO and had a little time to investigate the geotectonic setting of several nuclear facilities in the San Francisco Bay Area. There were at least seven, major sites in the area with reactors, atomic accelerators, atomic arms or radwaste on them, some of which had already been investigated by Ben Page and Dick Jahns at Stanford. Included on the short list were the Stanford Linear Accelerator Center (SLAC), the Lawrence Berkeley and Lawrence Livermore National Labs (LBNL, LLNL), Vallecitos Nuclear Lab, Mare Island Naval Shipyard, Hunters Point Naval Shipyard, and the Concord Naval Weapons Depot. The Navy had also dumped 47,000 barrels of mixed- and high-level radwaste from its cyclotron research lab at Hunters Point in the Pacific Ocean just west of San Francisco, shelling the barrels to make them sink and releasing their radionuclides on the environment without considering the consequences of their actions. Hello seafood in San Francisco and other West Coast markets!

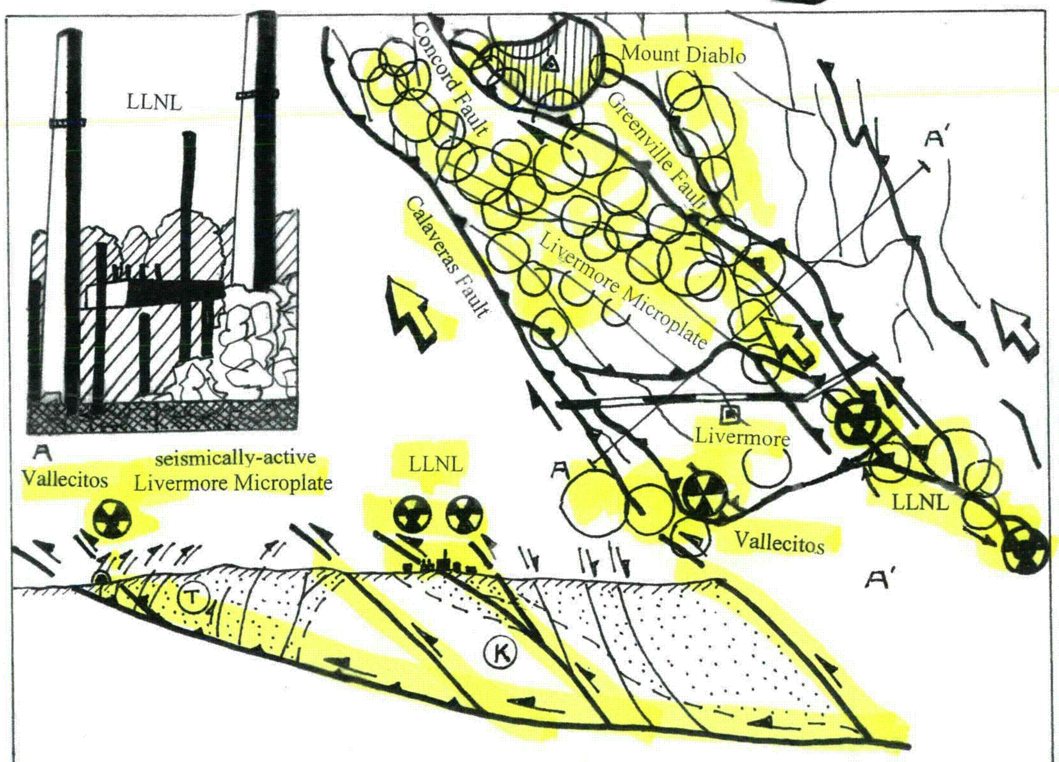


Dick Jahns was said to have returned to Stanford shaking his head in somewhat disbelief after mapping "stacked" or superimposed landslides and secondary thrust faults below the Vallecitos nuclear reactor in the East Bay Area. And yet, he still gave the facility a vote of confidence befitting the late-1950s-early 1960s Atomic Age fervor that was stirring the country when it came to recommending it for a operating license.

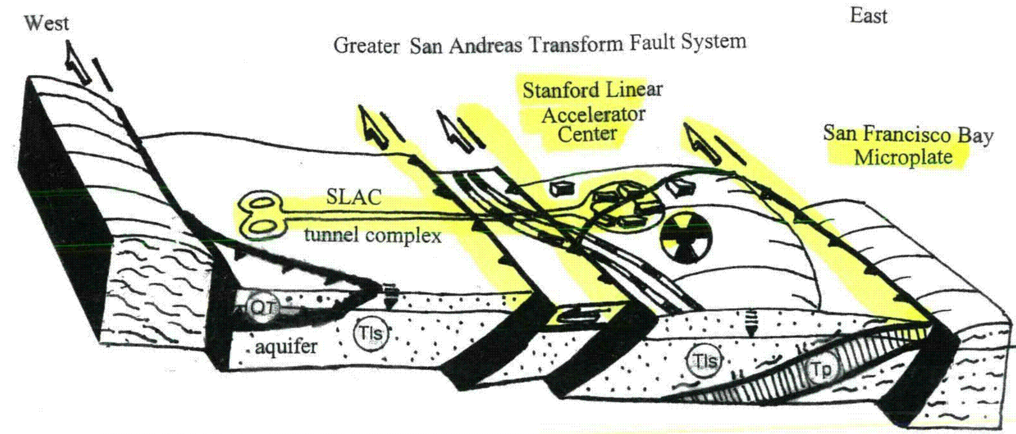


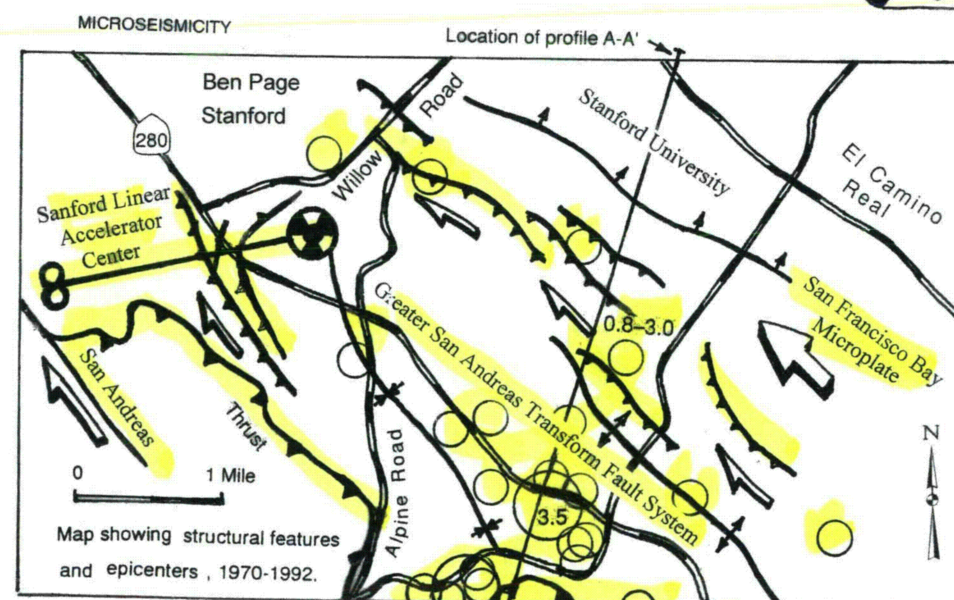
Immediately east of Vallecitos were Lawrence Livermore National Lab and the Lab's offset Area 300. Cross-cut by active, transform faults, both the Lab and Area 300 were also underthrust at depth by the same system that cropped out at Vallecitos per my own interpretations of east-west seismic lines running below the nuclear complexes. Sitting atop contaminated, fresh-water aquifers, Vallecitos Nuclear Lab and the Lawrence Livermore facilities were all located along the south boundary of what I referred to as the "Livermore Microplate", one of the more seismically-active tectonic blocks in the Greater San Francisco Bay Area.

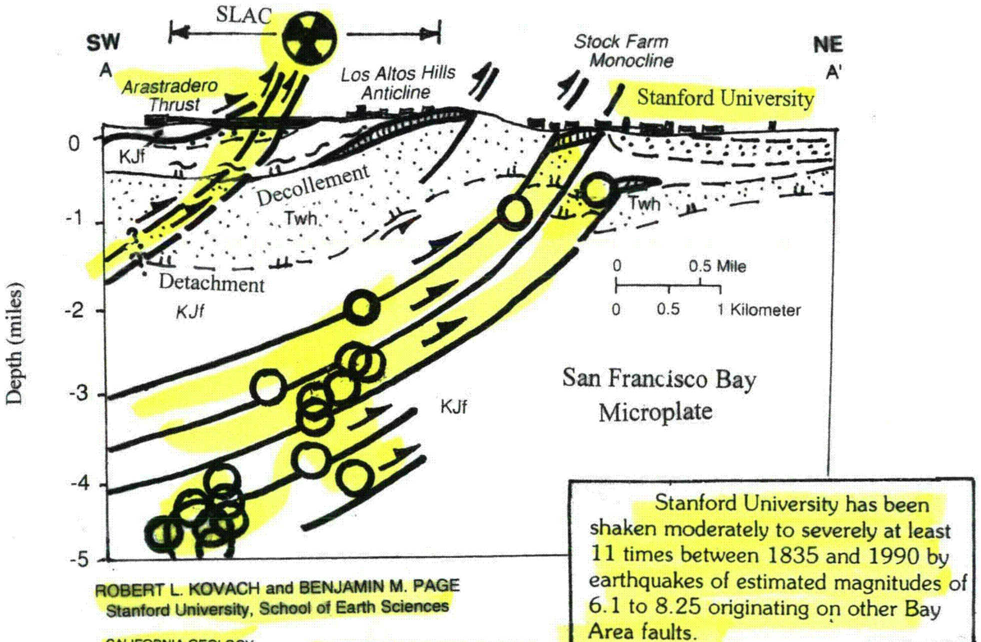




In the late-1960s and early 1970s, Ben Page mapped active fault traces and what he referred to as "tectonic domains" around the Stanford Linear Accelerator Center or SLAC, and the Lawrence Berkeley National Lab or LBNL complex, both of which I was interested in learning more about, too. After finding San Andreas Fault thrust splays running directly below the SLAC nuclear facility, Ben also plotted active



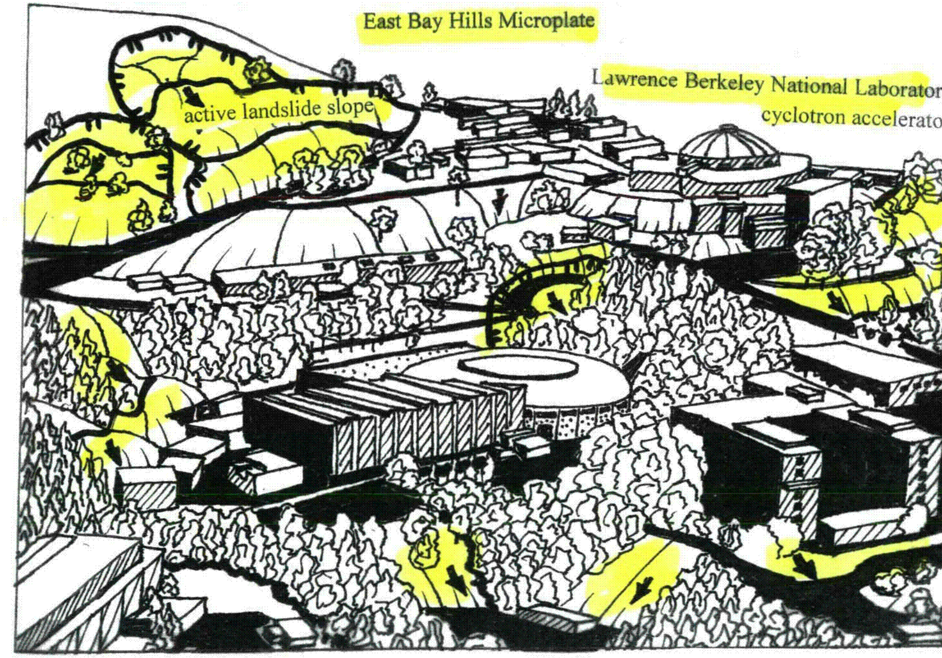




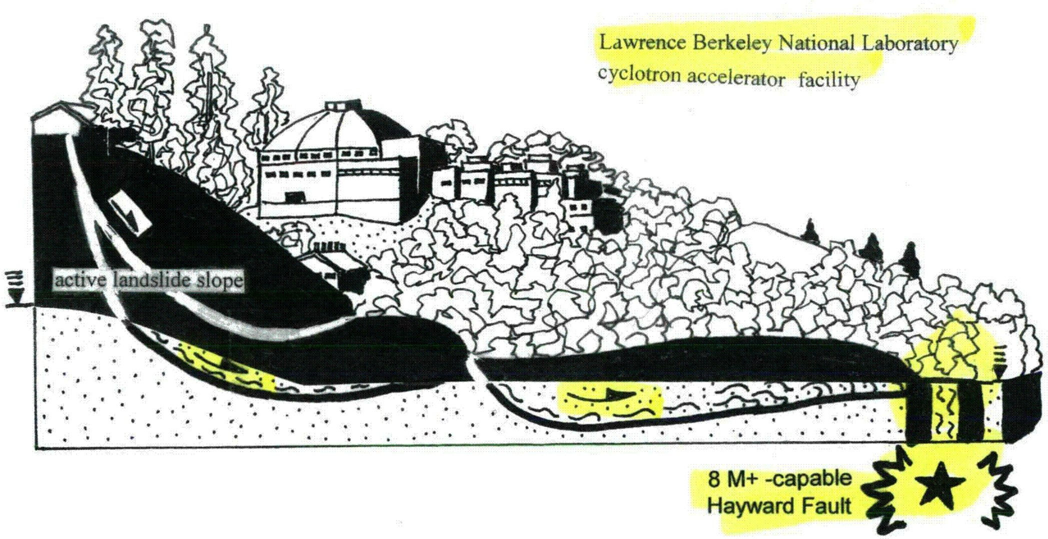
ROBERT L. KOVACH and BENJAMIN M. PAGE
Stanford University, School of Earth Sciences

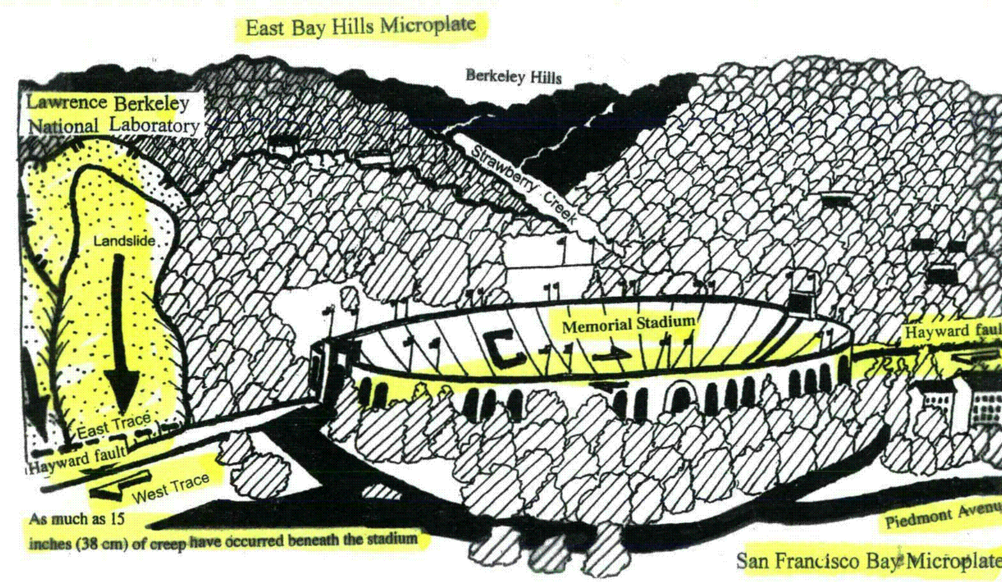
CALIFORNIA GEOLOGY
JULY/AUGUST 1995
Volume 48/Number 4

Hypocenters projected onto vertical geological section

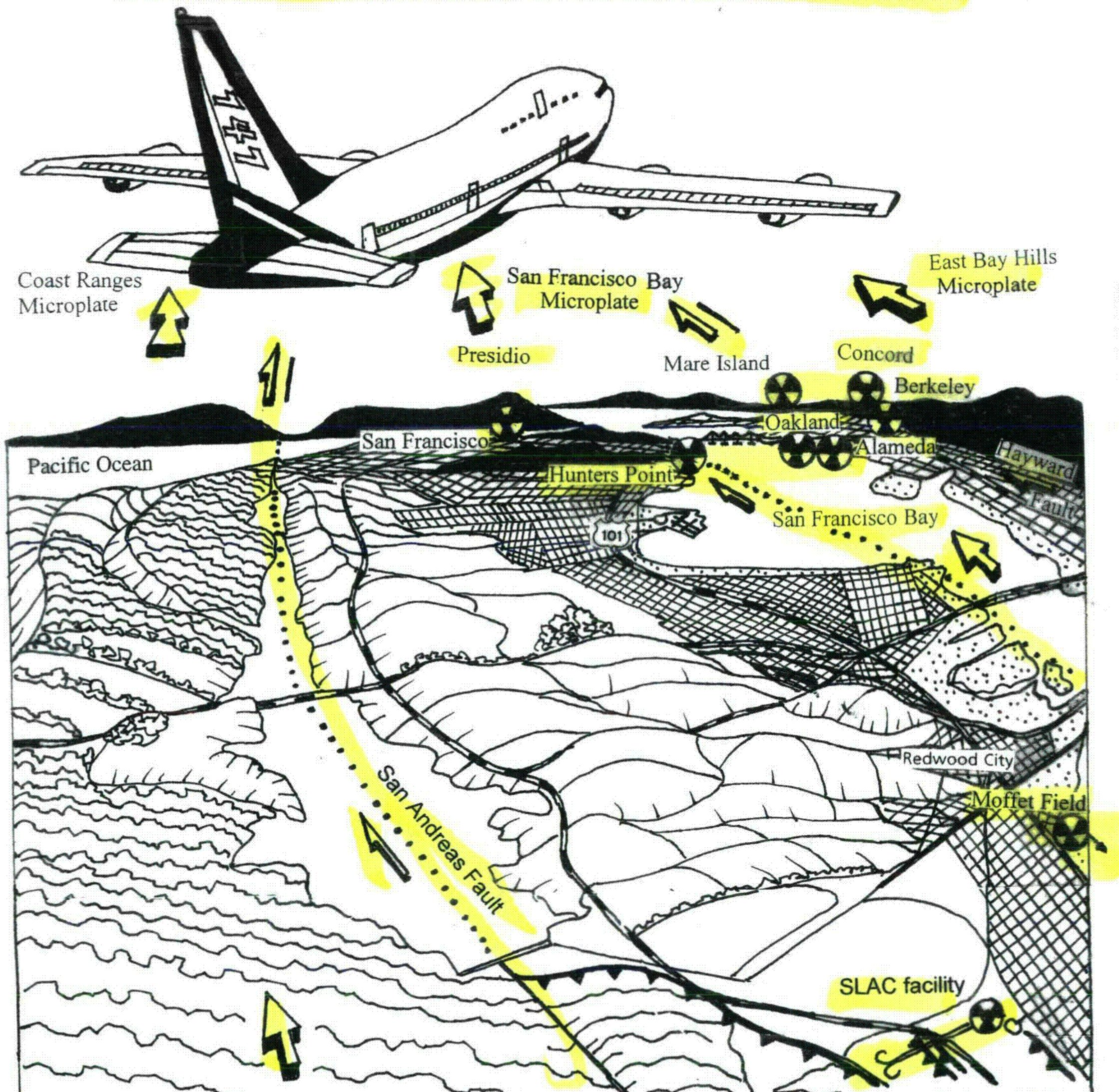


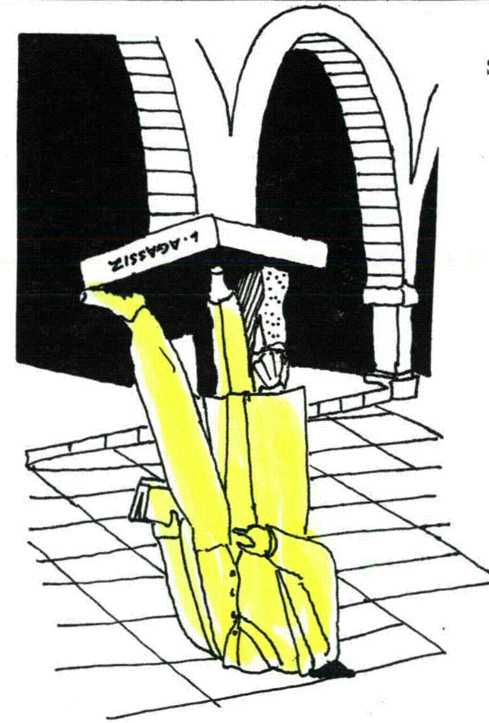
landslides bordering and undercutting the LBNL nuclear accelerator building just up-slope from the 8 M+ -capable Hayward Fault trace. Notably, the Hayward Fault trace was also actively offsetting the U.C. – Berkeley football stadium which sat immediately between LBNL and the U.C. – Berkeley campus.



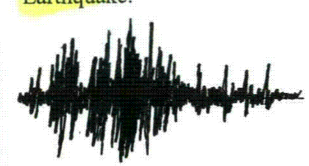


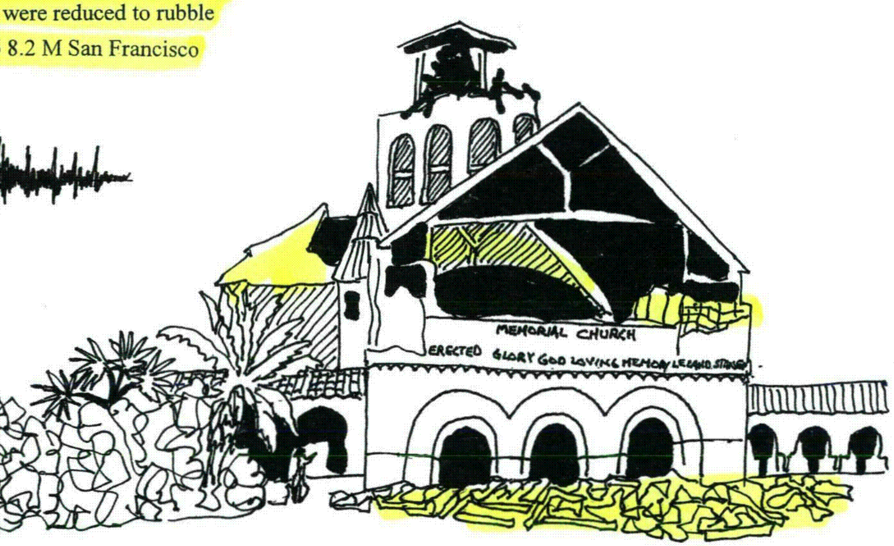
To me, it seemed totally absurd that both the SLAC and LBNL nuclear facilities were located and constructed in such active tectonic terrain, especially with major universities sited directly beside them. Ben Page was also obviously concerned enough about the situation to investigate and publish articles addressing the drawbacks of having the nuclear research facilities endangered by shifting earth. Even when he did not think that the thrust fault splays running under the SLAC facility would generate large quakes on their own, it was impossible to ignore that buildings





The Stanford Linear Accelerator straddles two fault traces, and sits in an area where whole buildings were reduced to rubble during the 1906 8.2 M San Francisco Earthquake.

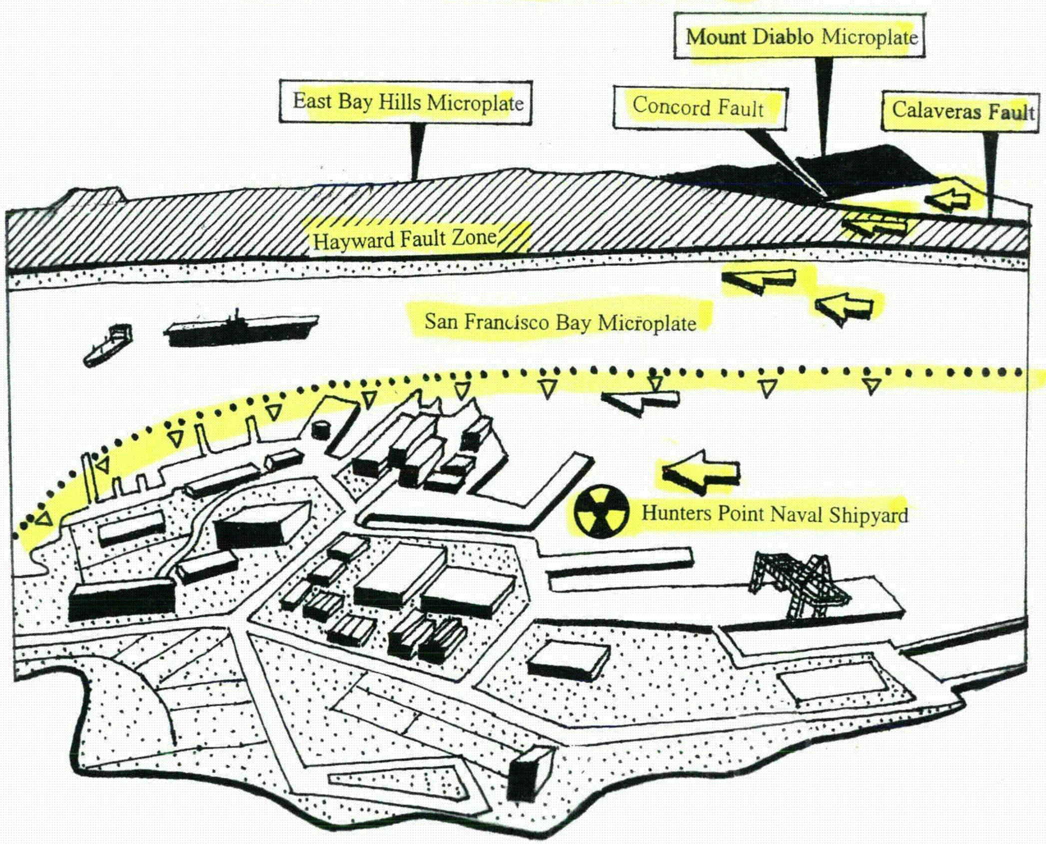


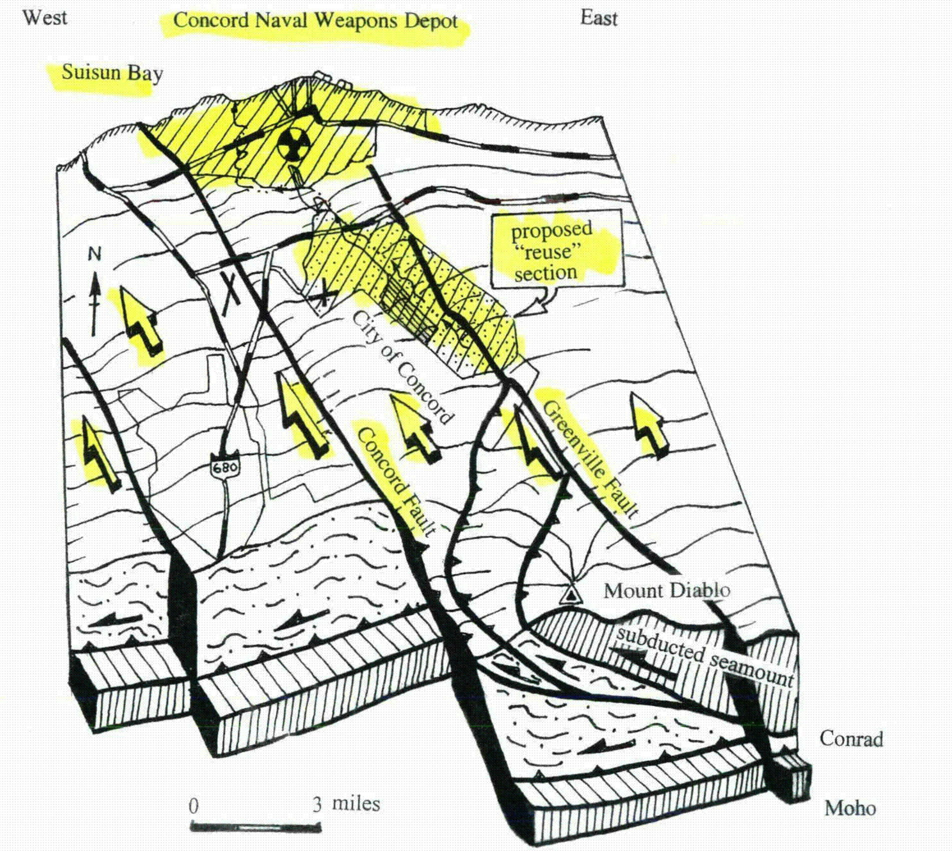


had already been leveled at Stanford by large quakes in recorded time, all tied directly to movements along the nearby San Andreas Fault that was also giving form to sag ponds in Portola Valley parks and more!

More to be expected, but still worrisome, if not even endangering to all, were most of the U. S. Military nuclear installations in the Bay Area. Sited poorly atop active fault traces, the facilities were also contaminating soils and shallow aquifers under and around them.

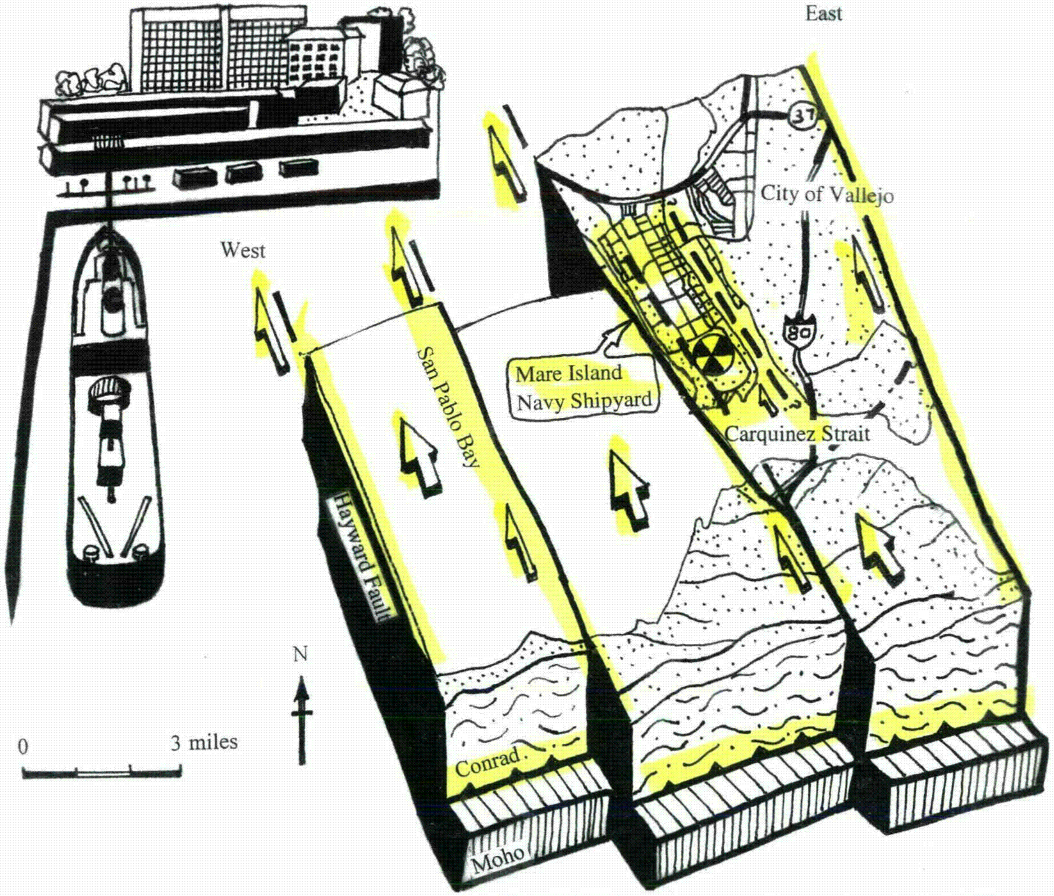
Hunters Point Navy Shipyard on the splintering San Francisco Microplate, for example, was flanked by a bayside thrust between the Hayward and San Andreas Fault Systems per my own interpretation of its geotectonic setting. Built partly on serpentine bedrock and partly on bay sediments and fill, the site's soils and groundwater were contaminated not only with radionuclides from the Navy's on-site Radiological Defense Lab, but with a variety of industrial chemicals, including solvents, metals and PCBs. Also significant was the fact that neighborhoods surrounding the facility would prove to soon have the highest incidences of infant mortality and cancer in California. Rocked regularly by earthquakes, the nuclear facility was a hazard to all in "full bloom", not one "in the making".





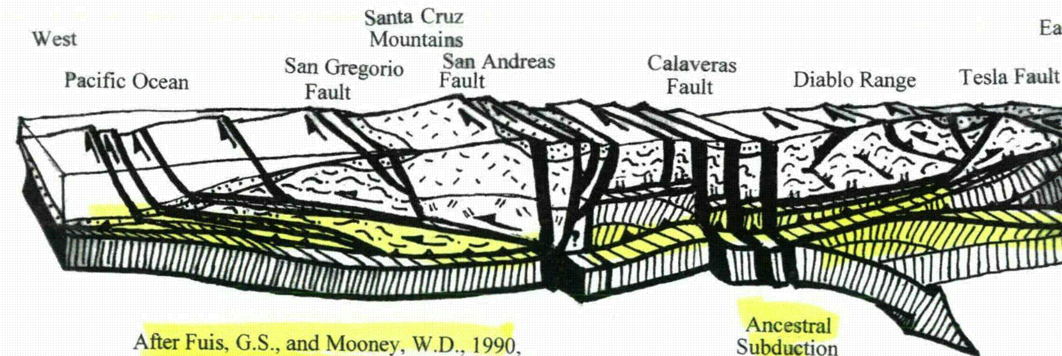
Concord Naval Weapons Depot 35-miles northeast of San Francisco fronted Suisun Bay astride northern extensions of the Concord and Greenville Faults. The compound was rumored to have housed up to 300 nuclear war heads during the height of the Viet Nam Conflict in the late 1960s, or easily enough explosive power to level the entire San Francisco Bay Area for decades. Contaminated with munition compounds, metals, solvents and other chemicals, the Depot had already shipped thousands of tons of both nuclear and conventional munitions across the Pacific to various Post-World Way II conflicts when I assessed its geotectonic setting in 1974.

Mare Island Navy Shipyard fronted Carquinez Strait between Suisun and San Pablo Bays just north of the splintering East Bay Hills Microplate. Bounded by a number of active, fault traces in the Greater San Andreas System, the Shipyard was shaken regularly by earthquakes as it constructed and serviced nuclear-powered submarines as well as numerous other naval vessels. The facility had been in use for



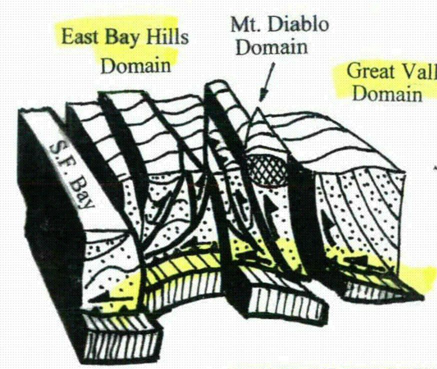
more than 120 years when I investigated its geotectonic setting and the site had a long history already of fuel oil spills and industrial accidents as well as other environmental contamination by acids, solvents, metals, munition compounds and even landfill products.

Notably, the early, schematic, geotectonic, block diagrams that I drafted for my study of selected nuclear sites in the San Francisco Bay Area drew not only from others' (e.g., Ben Page and Dick Jahns at Stanford University) and my work but also stood to be improved upon by later researchers at the USGS-Menlo Park, U.C. – Berkeley and elsewhere. Indeed, by the 1990s, numerous cross sections and block diagrams of tectonic domains/blocks/microplates/microplate slivers began to appear in the literature. For example, G.S. Fuis and W.D. Mooney at the USGS-Menlo Park published a very detailed cross section of the Greater San Andreas Fault System in the San Francisco Bay Area that could be adapted quite readily to block diagram form in USGS Professional Paper 1515. David Jones and others at U.C.- Berkeley

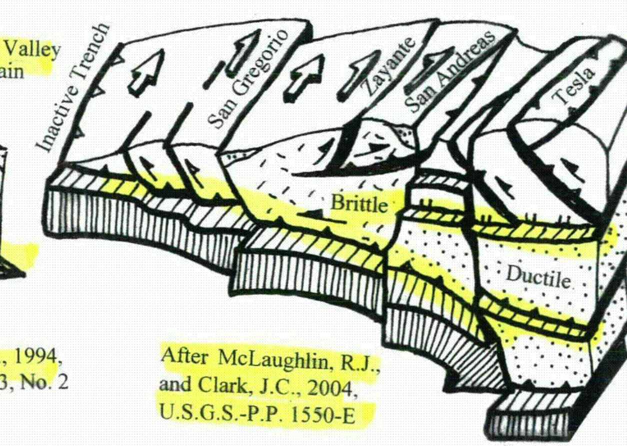


After Fuis, G.S., and Mooney, W.D., 1990,
U.S.G.S.-PP 1515 (Wallace, R.W., Editor)

followed with an even more detailed interpretation of East Bay deformation below and around the University in a 1994 issue of "Tectonics". Then C. Teyssier and B. Ticoff addressed seismic anisotropy in the upper mantle below the San Andreas System around the Bay Area in the 1998 "Geological Society of London Special Paper Number 135". More recently, R. J. McLaughlin and J. C. Clark publish a block



After Jones, D., et al., 1994,
Tectonics, Volume 13, No. 2



After McLaughlin, R.J.,
and Clark, J.C., 2004,
U.S.G.S.-P.P. 1550-E

Selected Geotectonic Block Diagrams of the Greater San Andreas Transform Fault System in the San Francisco Bay Area

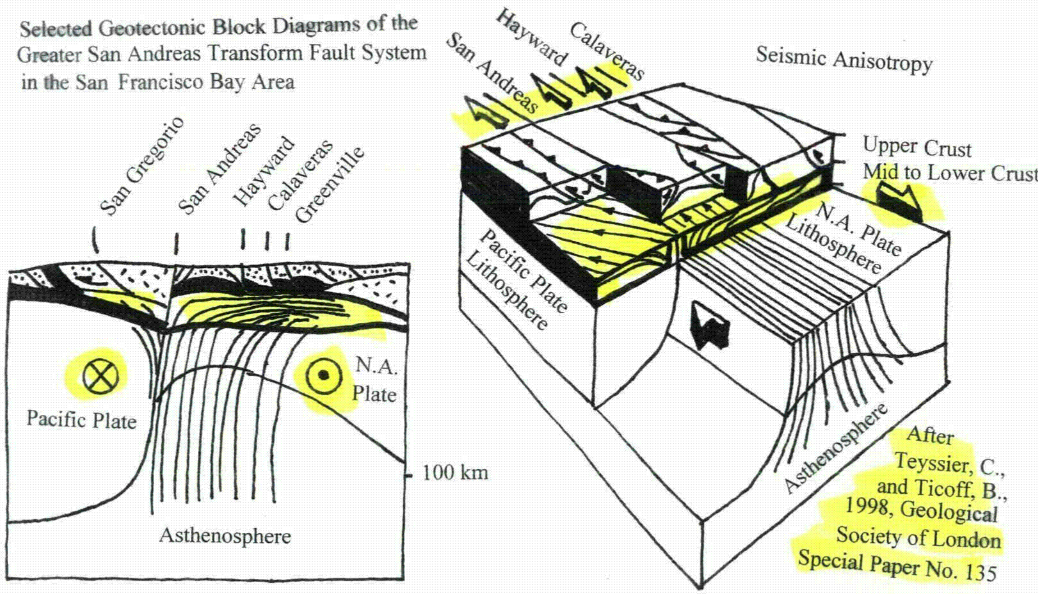
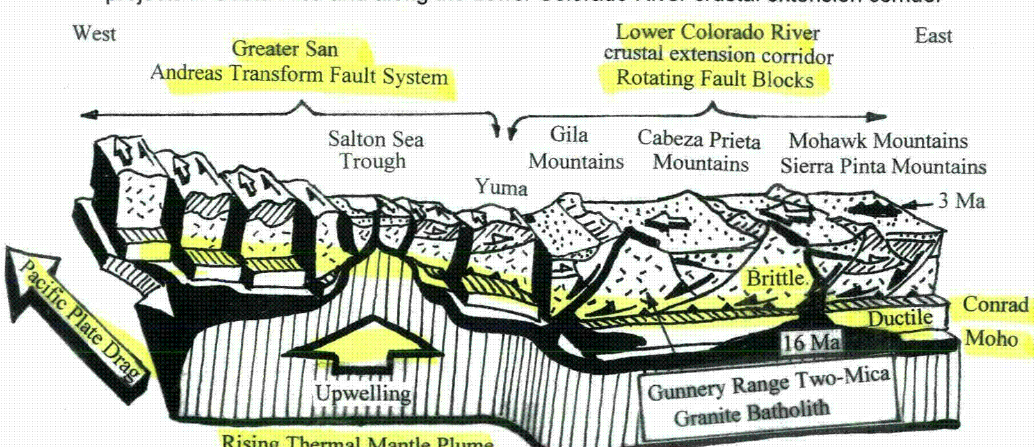
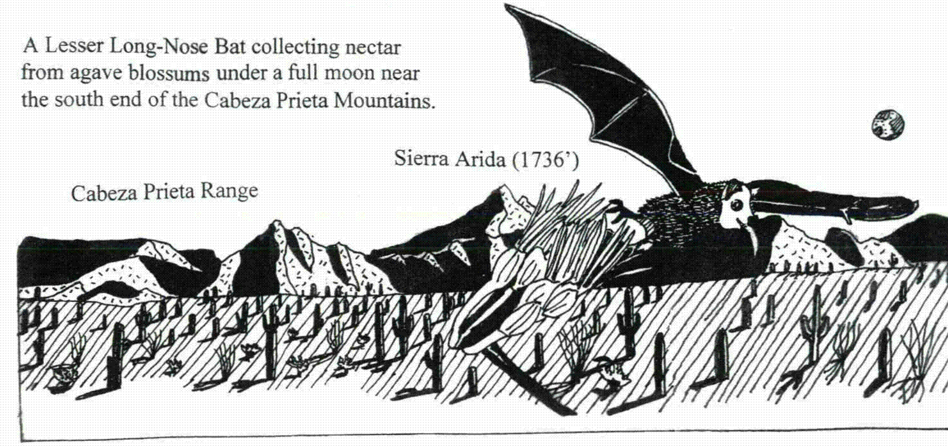


diagram of the San Andreas System in USGS Professional Paper 1550-E showing their own interpretation of tectonic blocks or microplates around the 1989 Loma Prieta Earthquake focus and epicenter area. Unspoken or written, but known by all, is the fact that the evolving transform crustal system is far more complex than any of us have shown it to date. Still, we are in relatively close agreement in our concepts of how the system is structured and, to some degree, how it operates. Such is the current nature of "The Plate Tectonic Revolution".

My last big field investigation with FUGRO after minor involvement with projects in Costa Rica and along the Lower Colorado River crustal extension corridor

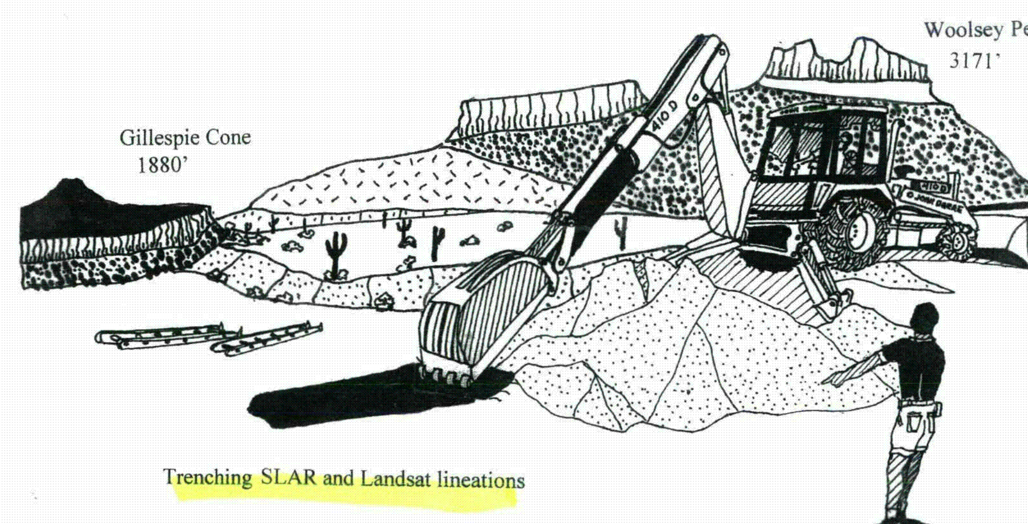


A Lesser Long-Nose Bat collecting nectar from agave blossums under a full moon near the south end of the Cabeza Prieta Mountains.

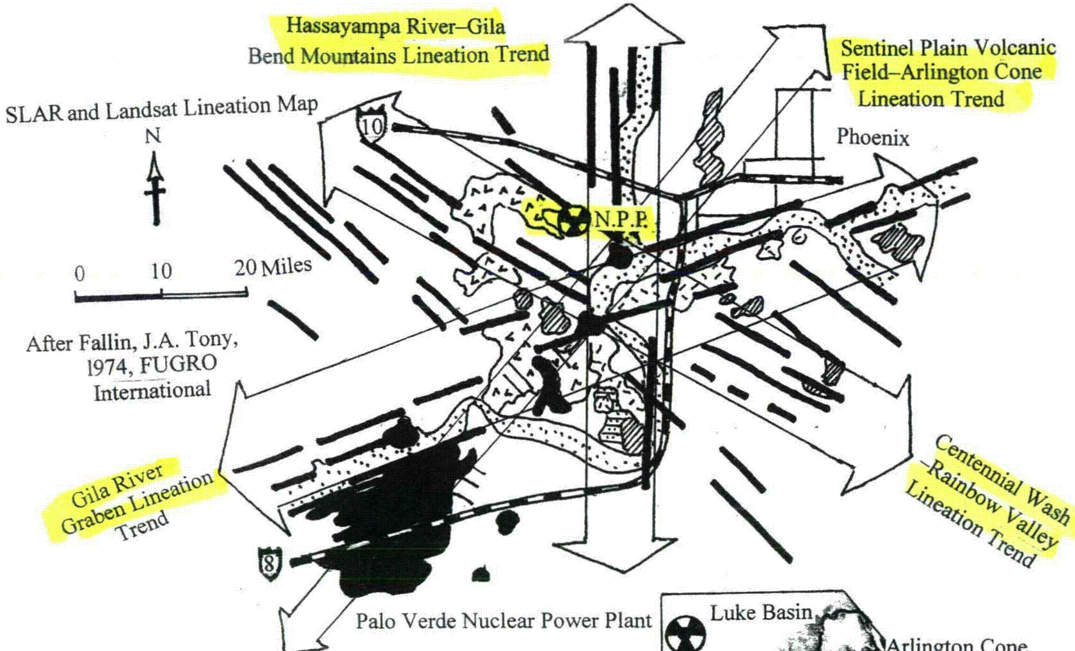


around Blythe in Southern California, was just southwest of Phoenix, Arizona. Arizona Public Service (APS) was providing the funds for a full-scale PSAR involving literature searches; Earthsat and aerial photo lineation studies; Shelby tube and oriented-core sampling during rotary drilling; backhoe trenching; geologic field mapping; outcrop K-Ar age-dating; soil testing and sampling; aquifer characterization and water-quality analyses; paleo-magnetic surveys; interim and final report writing; and in-house presentations to both clients and Federal NRC review boards.

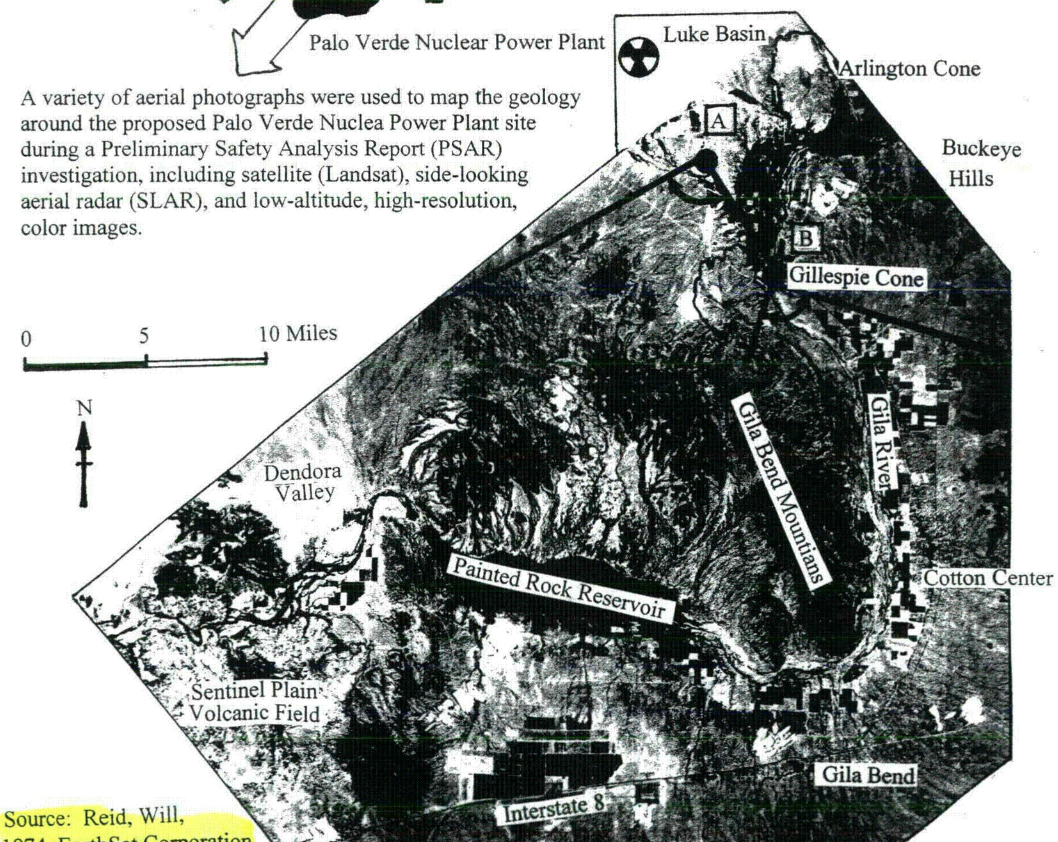
When not scanning side-looking aerial radar (SLAR), Earthsat and air photo imagery or supervising drilling and trenching operations, I managed to map the



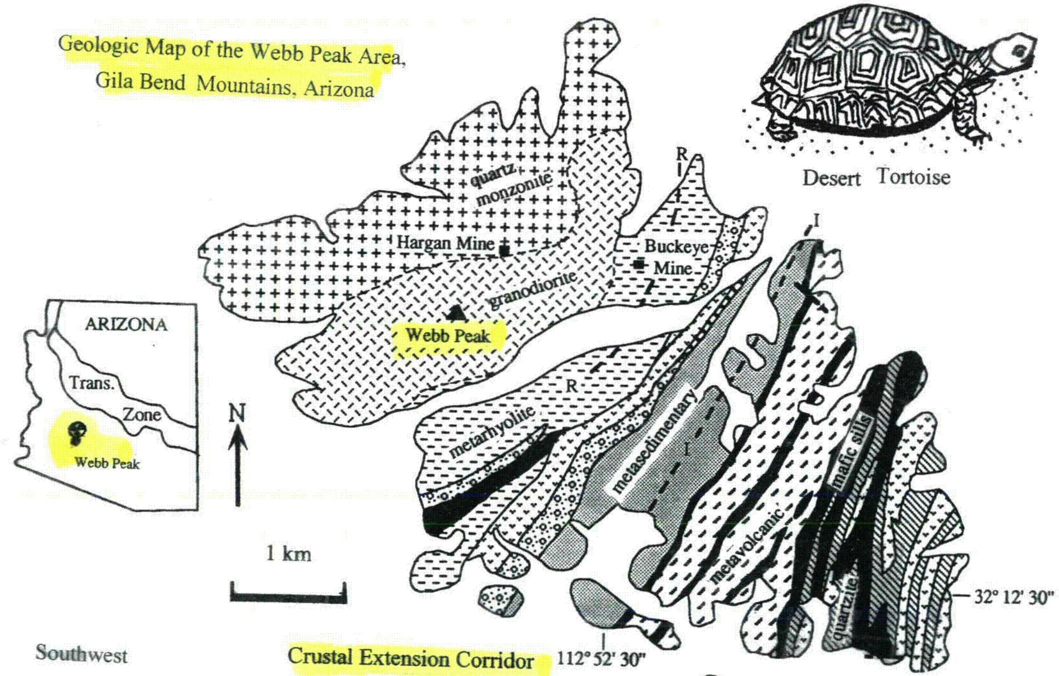
Trenching SLAR and Landsat lineations

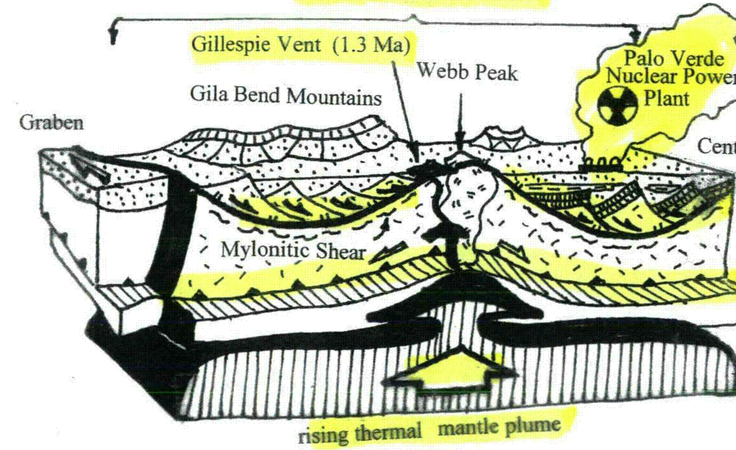


A variety of aerial photographs were used to map the geology around the proposed Palo Verde Nuclea Power Plant site during a Preliminary Safety Analysis Report (PSAR) investigation, including satellite (Landsat), side-looking aerial radar (SLAR), and low-altitude, high-resolution, color images.



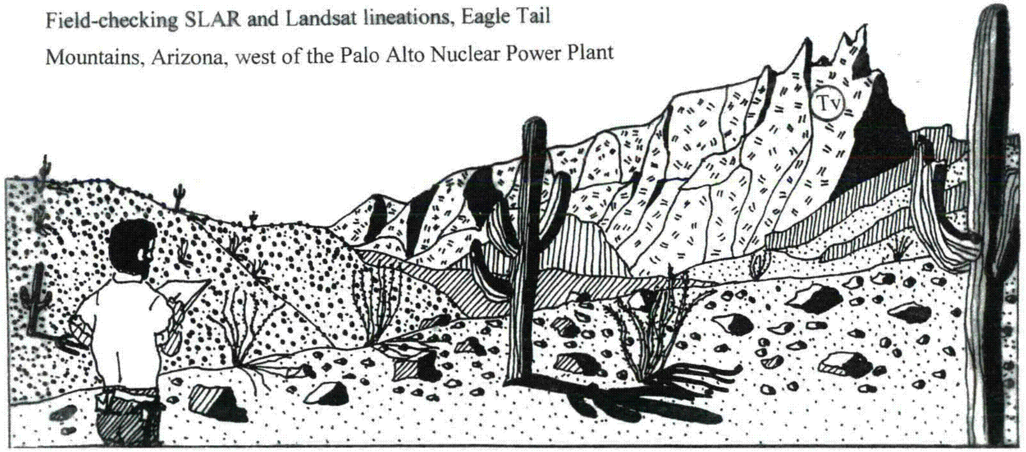
geology of several hundred square miles of harsh, desert terrain in and around the Gila Bend Mountains over a four-month period, helping with a host of other professionals to characterize what would become the Palo Verde Nuclear Power Plant site. It was a record hot summer, with temperatures reaching or breaking 100° F over one hundred days in a row.





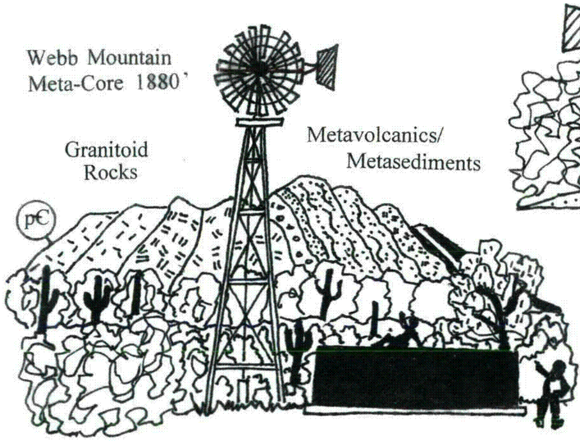
Schematic Block Diagram of the Palo Verde Nuclear Power Plant Area, Arizona

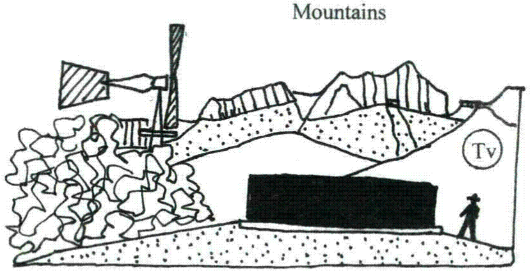
Field-checking SLAR and Landsat lineations, Eagle Tail Mountains, Arizona, west of the Palo Alto Nuclear Power Plant



We set up our field base at a motel in Goodyear, Arizona, just west of Phoenix and rented a small fleet of four-wheel drive vehicles to use during our field studies. Many of us would head to the field before sunrise and return around noon just to beat the thermal nuclear blast of afternoon, desert heat. Still, I visited “Tony’s Oasis Retreat” more than once even before mid-day for a quick, cool-off dip in a windmill stock tank surrounded by saguaros and other desert cacti. The windmill and stock tank were miles off the beaten-path, in the middle of what some Aussie friends call “The Great Fuck-All” after their own experiences in the Australian Outback, and I am sure the well and tank had another name. Still, my name stuck for the time that we used them and was even put on maps that we generated for APS.

Tony’s Oasis Retreat

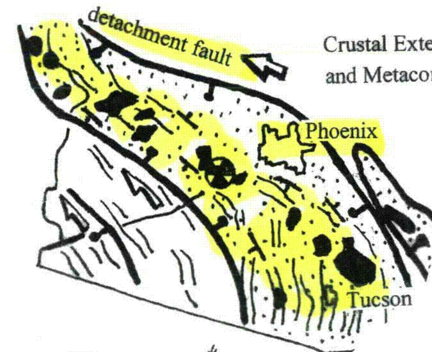




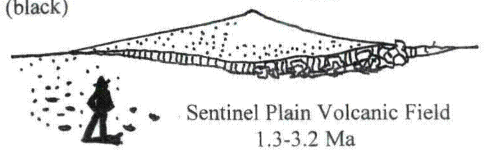
Water, Life in the Desert

The Spanish Soul

Quite often, I would join other members of the field survey team for a 40-mile drive to restaurants around the ASU campus for evening meals. But then a “Come Hither” letter from Helen would arrive and my focus would shift immediately from local talent to my next return trip to her and the kids in Palo Alto, CA, even when I wanted us all out of the congested Bay Area and away from the San Andreas Fault.

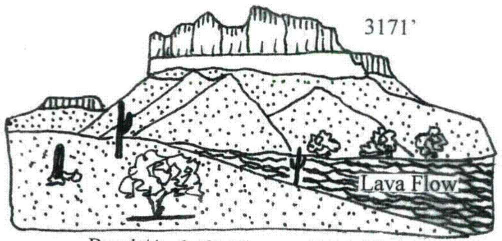


Crustal Extension Corridor and Metacore Complexes (black)

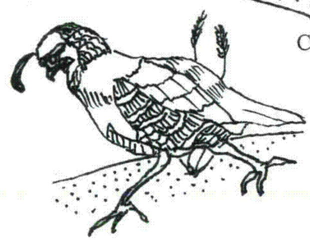


Sentinel Plain Volcanic Field
1.3-3.2 Ma

Woolsey Peak

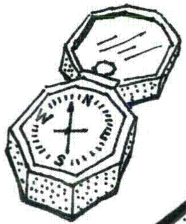


Basalt/Andesite Flows (15-30 Ma)



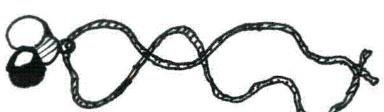
California Quail

Silky Flycatcher

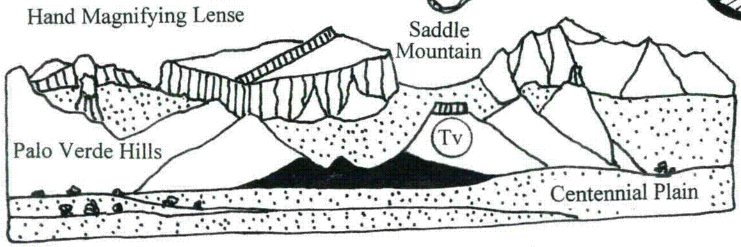


Brunton Compass

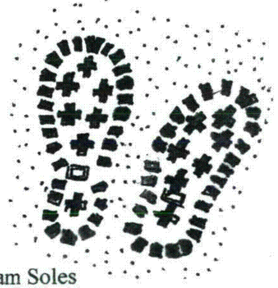
Rock Hammer



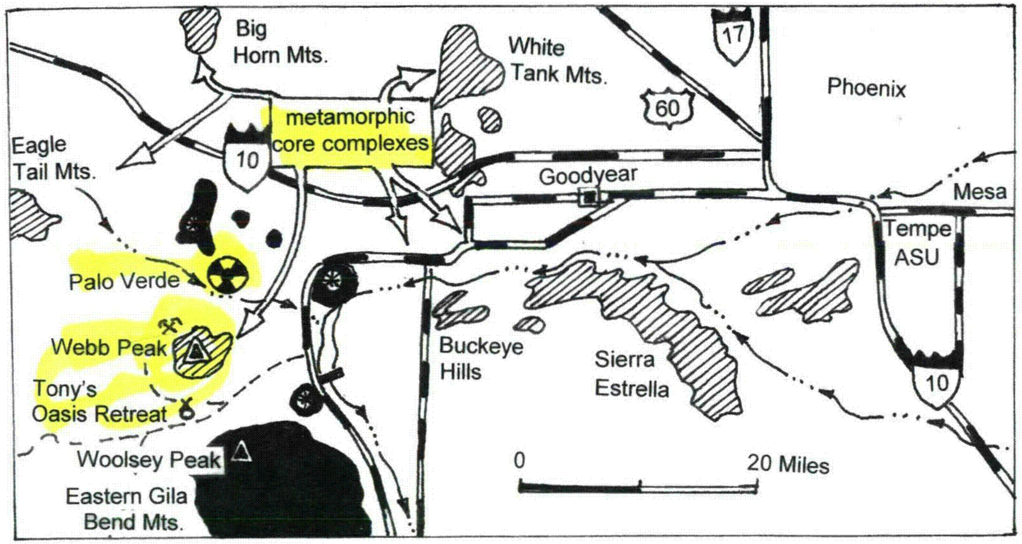
Hand Magnifying Lense



Field Sketches

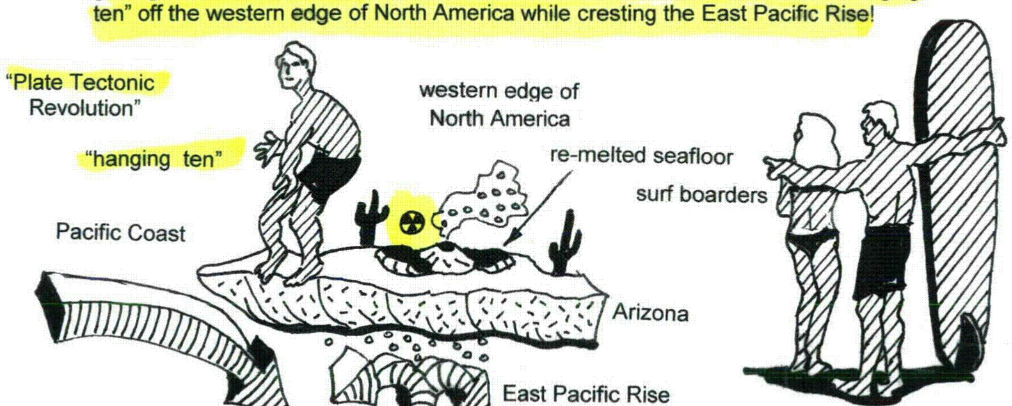


Vibram Soles

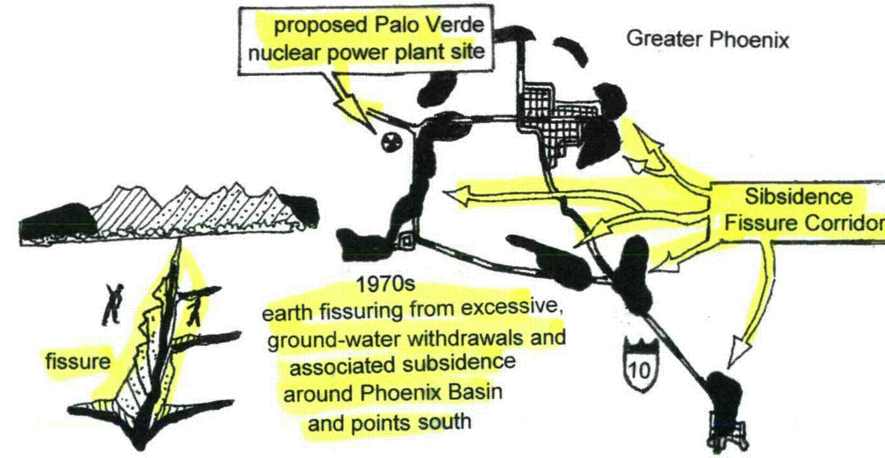


After enjoying personal time with Helen and the kids, clear of job duties and other distractions, I would return to Arizona feeling restored and up to being a designated driver again. First would come the air conditioned concourses at San Francisco and Phoenix International Airports, plus a pressurized jet cabin while in the air. Only after landing and debarking would I pass outdoors into blast-furnace, desert heat to load my serviced, field vehicle on melting asphalt. The "Monster out the Backdoor" was gone, replaced by the thermo-nuclear blast of a Southwestern SUN!

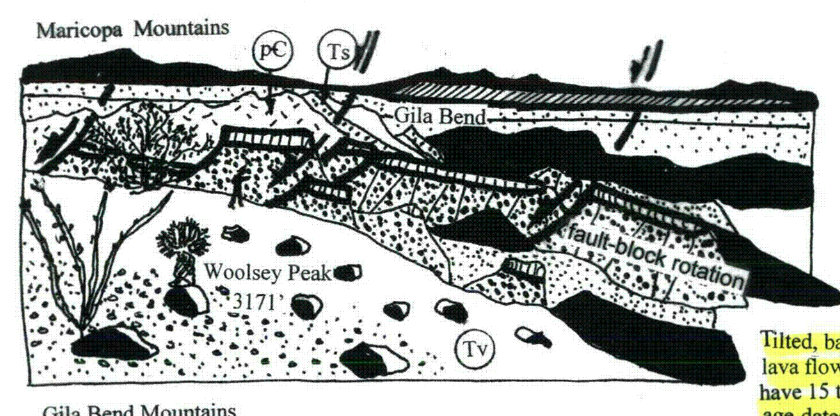
As on other, large-budget projects across the West, new discoveries were made daily on FUGRO's Arizona field investigation for Arizona Public Service. For example, fellow professional and colleague Gaylon Lee found tholeiitic feldspar while looking through a microscope with diffracted light shining through thin sections of lava flows we were mapping, suggesting the volcanic extrusions were of re-melted seafloor origin. Muhammed Shafiqullah at ASU in Tempe then added that his potassium-argon age-dating showed the flows had been extruded between 30 Ma and 15 Ma, or during Miocene time, after being subducted off the Pacific Coast. And suddenly, even as field geologists in a "Plate Tectonic Revolution", we could also be surf boarders "hanging ten" off the western edge of North America while cresting the East Pacific Rise!



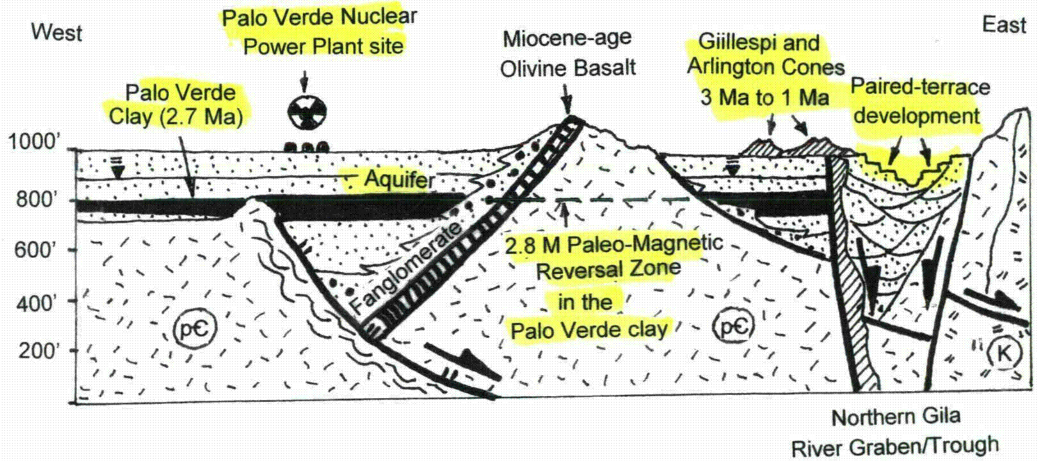
Looking for signs of other earth movements, Neotectonics Consultant and FUGRO advisor Roy Shlemon discovered open fissures around Phoenix Basin and points south. The fissures were forming as large, municipal, ground-water withdrawals led to sediment compaction and subsidence in the region. If the Palo Verde Nuclear Power Plant was going to use groundwater below it to cool its reactors, its building foundations and underground-containment vessels might also be affected adversely by similar, earth fissuring.



Further southwest, there was also evidence of recent, large-scale, fault-block rotation along the Lower Colorado River crustal extension corridor. Indeed, fresh fault scarps were in evidence along the edges of a number of mountain ranges in the Cabeza Prieta Wildlife Refuge, suggesting active, thermal, mantle upwelling at depth. Similar fault-block rotation had also occurred in the Gila Bend Mountains and Palo



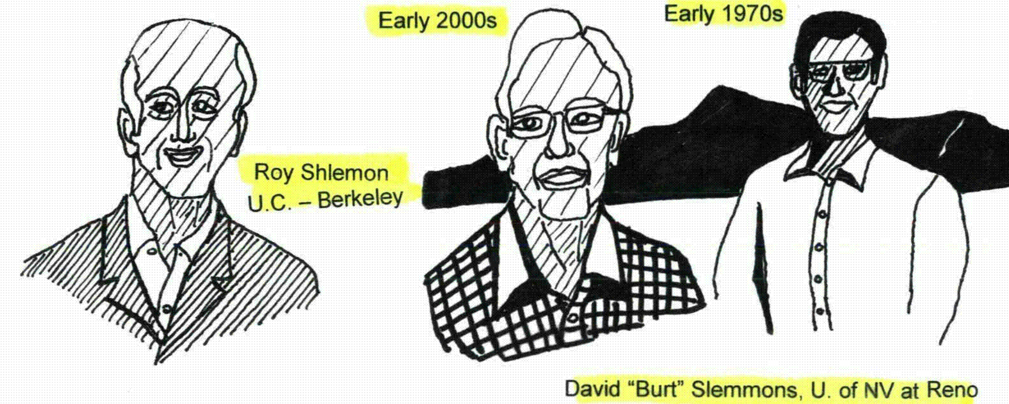
Schematic Geotectonic Cross Section of the Proposed Palo Verde Nuclear Power Plant Site



Verde area, but most of the offsets appeared to have been generated during periods of peak volcanism 30 Ma to 15 Ma per others and my findings during our own field investigations. Nonetheless, we would trench any fault traces we came across and look for signs of more recent movements.

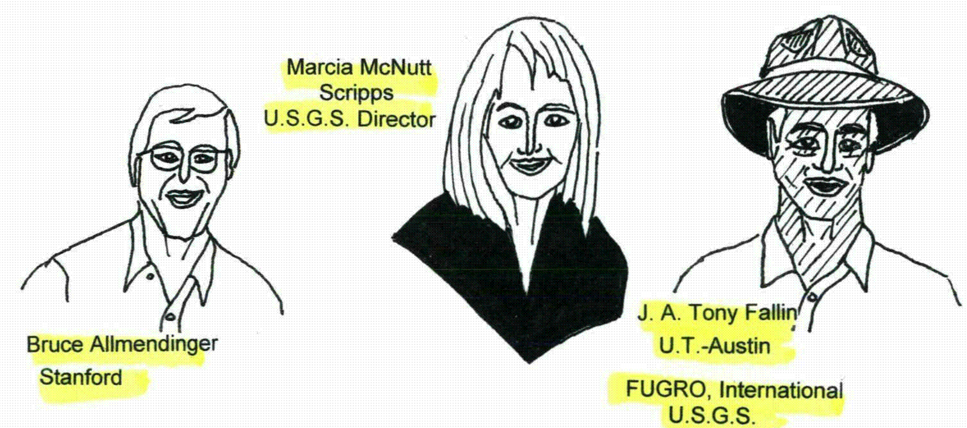
Some of the most recent signs of tectonism around the proposed Palo Verde nuclear power plant site were nearby volcanic cones along a north-trending, Gila River rift zone and paired terraces along the Gila River near Gillespi Dam. Potassium-argon age-dating showed the volcanic cones and associated lava flows to have been extruded between 3 Ma and 1 Ma, or old enough to not preclude nuclear power plant construction on the Palo Verde site. Notably one of the 2 Ma lava flows overlay a blanket, lakebed clay deposit that passed 200-feet below the proposed nuclear power plant site and that FUGRO found to be un-deformed in numerous rotary boreholes drilled throughout the study area. Paleo-magnetic analyses of oriented-cores and Shelby-tube samples taken in the Palo Verde clay interval would show the top of the deposit to be approximately 2.7 Ma in age.

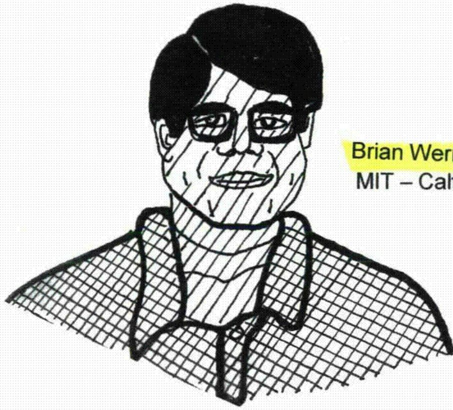
With the mile-deep Grand Canyon located north of our study area having formed since 6 Ma by most investigators estimates, crustal uplift of the Palo Verde site had to also be considered. Paired-terrace development along the Gila River could be explained by periodic, elevation rises around the site, but also to be considered were the effects of eustatic sealevel changes during past Ice Ages. Gaylon Lee and I both studied the terraces on high-resolution, 1:24,000, color, aerial photos, before making a number of field traverses across them looking for fault offsets that could be dated by the fluvial deposits. But all we found were signs of Paleo-Indian sites at upper, terrace levels, selected more to stay "high and dry" during flood seasons, undoubtedly, than to avoid much more discrete, crustal uplift and extension in the region.



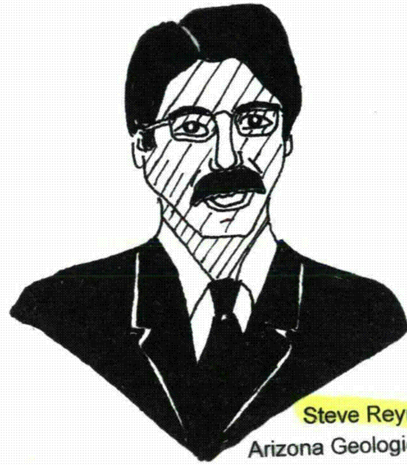
My experiences with extensional terrain, in general, were limited and recognition of its extent and effects across the Basin and Range of Western North America amongst others was also in its infancy for most during the mid-1970s. I had taken the opportunity to sit in on a talk by Bob Compton at Stanford addressing extensional terrain around a metamorphic core complex in the northern Basin and Range. And I had followed published accounts by other investigators on the topic after researching FUGRO's project site near Blythe in Southern California. This included the works of USGS professionals Bernie Troxell and John Stewart, as well as University of Nevada at Reno's David "Burt" Slemmons.

By the late 1970s and early 1980s, Stanford's Bruce Allmendinger and Bill Dickinson would also join the fun after moving to MIT and the University of Arizona, respectively, along with Steve Reynolds at the Arizona Geological Survey and Brian Wernicke at Caltech. Indeed, even Scripp's Marcia McNutt, would organize seismic investigations of extensional terrain below Lake Mead, before moving on to become the first woman to direct the U. S. Geological Survey. But until the others could join us … and correct some of our mistakes … just a handful of others and I had extensional terrain to ourselves.





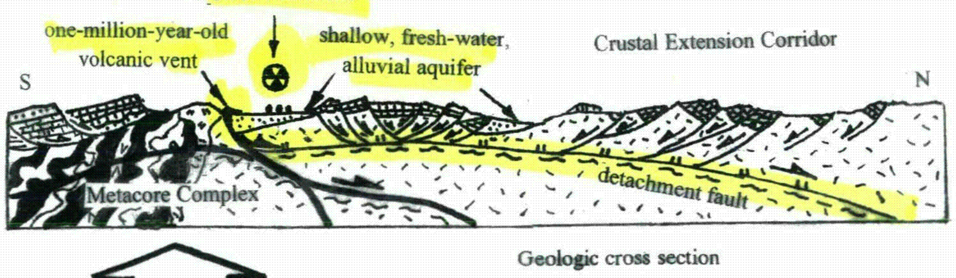
Brian Wernicke
MIT – Caltech



Steve Reynolds
Arizona Geological Survey

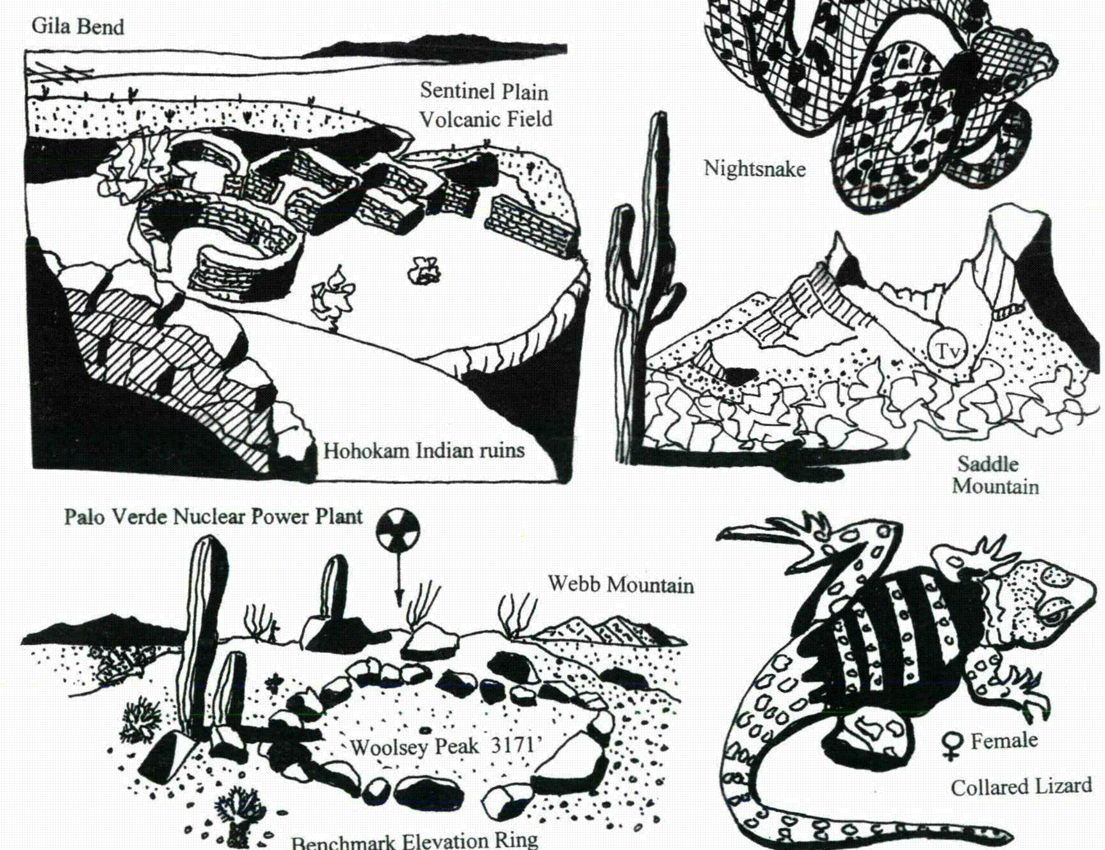
Here, I would play Devil's Advocate and propose that the Palo Verde site was located over an inactive detachment fault in extensional terrain beside a number of metamorphic core complexes, including outcrops around nearby Webb Peak at the north end of the Gila Bend Mountains. Detached from the older, Precambrian-age, core complexes were rotated fault blocks capped with tilted basalt and andesitic lava flows, plus bounding and over-lying, basin-fill deposits. More recent volcanism between 3 Ma and 1 Ma could easily be associated with crustal rifting in response to Pacific Plate drag!

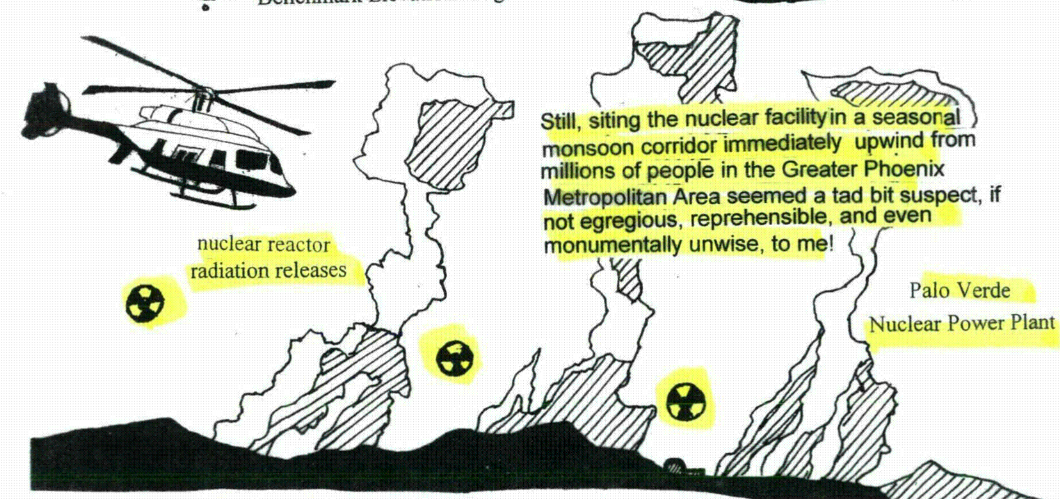
Of course, my conjured cross section showing a detachment fault running boldly at depth directly below the proposed nuclear power plant site never made it to print in FUGRO's PSAR. For even when deemed "inactive", the detachment fault was far more than what APS wanted to speculate about, much less accept and investigate further, while seeking an operating license from a pro-nuclear Nuclear Regulatory Commission. Perhaps unsurprisingly, the "Powers That Be" at FUGRO also agreed with their client, even with one Vice President supporting me on the side. I had had my fun and it was time to move on, perhaps one day yet to even be proven right!



Geologic cross section

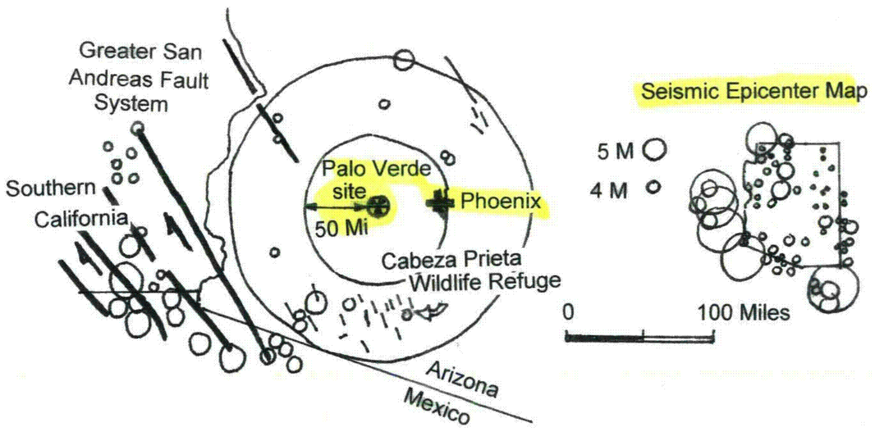
Field Sketches





Still, siting the nuclear facility in a seasonal monsoon corridor immediately upwind from millions of people in the Greater Phoenix Metropolitan Area seemed a tad bit suspect, if not egregious, reprehensible, and even monumentally unwise, to me!

In the end, FUGRO's PSAR would focus strongly on the Palo Verde Nuclear Power Plant site being located in a rare, aseismic or tectonically-quiet zone in the southern Basin and Range Province. The nearest recorded earthquake epicenters to the site were located more than 50 miles away and were of only 4 M-magnitude or less. Larger earthquake waves from the more distant Greater San Andreas Fault System to the west, or from Mexico to the south, could be accommodated simply by pouring a little more cement over rods of rebar. Wastewater from Phoenix would be



used to cool the reactors, precluding earth fissuring from excessive, ground-water withdrawals and associated subsidence around the plant. Vertical uplift of the site, if occurring at all, would be too slow to be a concern by all educated estimates and most certainly had to be deemed less than a fatal flaw. It was the only site I would ever work on with FUGRO that did not have an active fault running beside it or under it, endangering ALL!

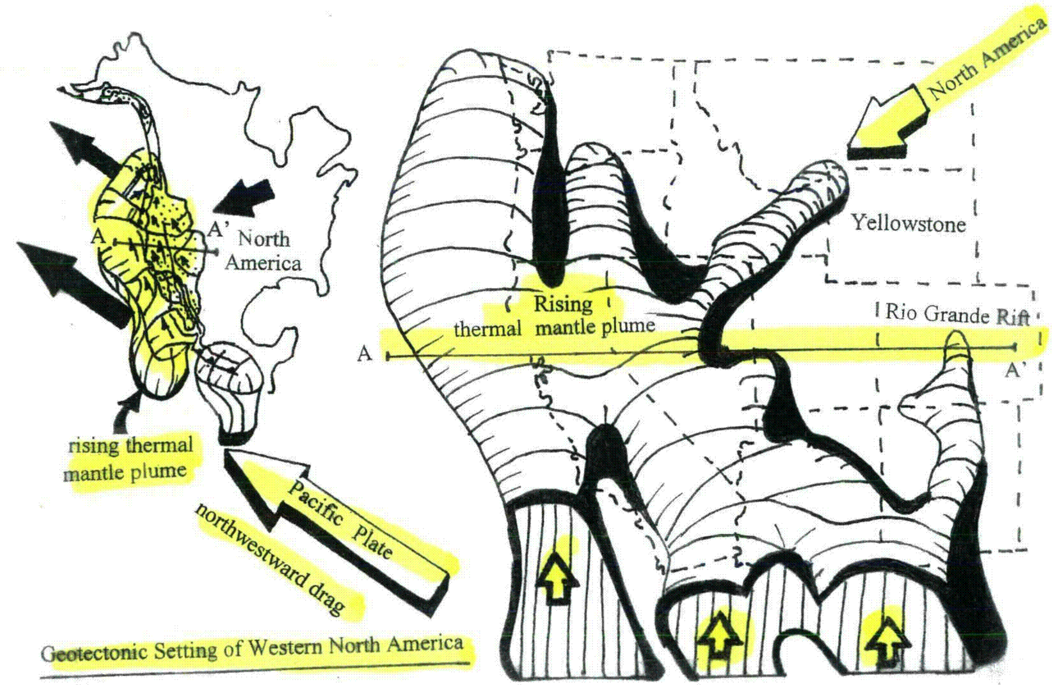
Still, siting the nuclear facility in a seasonal, monsoon corridor immediately upwind from millions of people in the Greater Phoenix Metropolitan Area, all on land purchased from an ex-Arizona Public Service Director, seemed a tad bit suspect, if not egregious, reprehensible, and even monumentally unwise, to me! It was time for me to take my leave. Working with death-wish clients and pro-nuclear Federal review boards prone to ignore their own safety rules, was getting old.

As for the "Plate Tectonics Revolution", it would go deeper underground for awhile. Entire books would be written on the subject as more and more data surfaced from various investigations around the world, with some focusing almost entirely on seismic and other studies of the Earth's interior. As is always the case, some of the publications were better than others, but all kept the topic of continental drift alive and well.

At U.T.- Austin, Bill Muehlberger drafted the Second Edition of the "Tectonic Map of North America", up-dating Phil King's 1969 classic First Edition, while also adding some of Tanya Atwater's, Peter Molnar's and others' seafloor data to the continental margins and placing "tectonosynthem" in the geologic lexicon. Around the same time, still brushing his teeth and putting his pants on one leg at a time, Peter Molnar returned from Asia, eventually to investigate microplate rotations immediately south of the Diablo Canyon Nuclear Power Plant in the Greater San Andreas Fault System of Southern California. Next, John Dewey would move to U.C.- Davis to "...bash his roks gain mad t'see how the world be built", too!

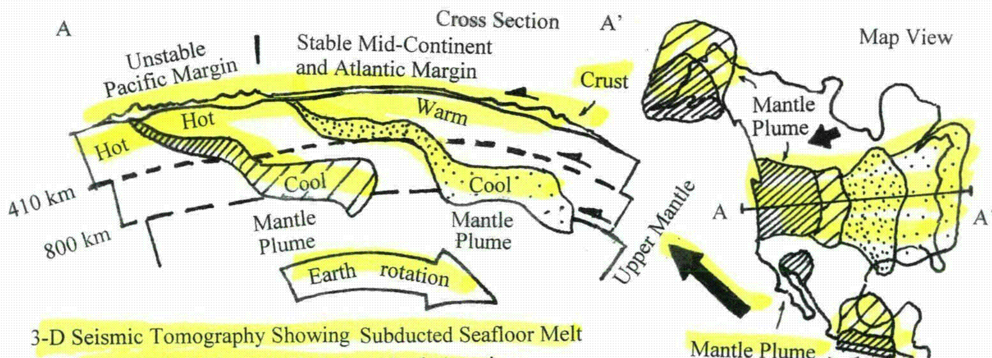
Elsewhere, Marcia McNutt focused on seafloor studies, discovering deep-trench volcanism during 15 or so oceanic expeditions, as Don Anderson "served time" as Director of Caltech's Seismological Lab, when both were not lecturing at MIT, Stanford, Caltech and elsewhere. Marcia even took time to give birth to twin girls, plus another daughter, while Don accepted the President's Medal for his contributions to earth science, before compiling a new, tectonic map of the South Pacific Ocean Basin.

By 2005, Kent Condie's 10th Edition of Plate Tectonics and Crustal Evolution was coming off the presses, unique and up-dated like each, previous Edition. In it were "new generation", 3-D seismic, tomographic images, giving readers better views of rising, thermal mantle plumes below Western North America and elsewhere.



Geotectonic Setting of Western North America

Already, some of us had tracked subducted seafloor movement in the mantle below the continent and under the Atlantic seafloor on seismic tomography while working with the USGS and even in the private sector as consultants. If nothing else, the tomography supported the view of a dynamic, evolving planet deserving more respect in spots when siting nuclear facilities atop "putty and Graham crackers" crust in severe, deformation zones.

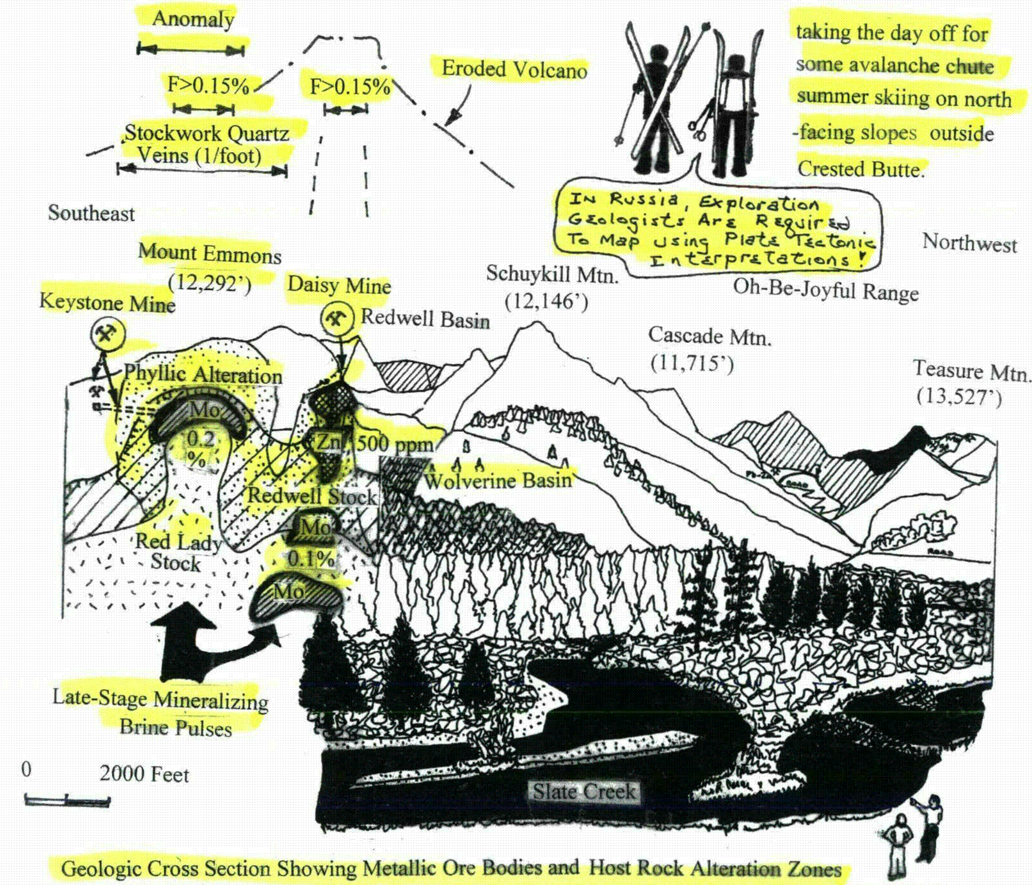


3-D Seismic Tomography Showing Subducted Seafloor Melt Plumes in the Upper Mantle below North America

Meanwhile, Pacific "hot spot" interpretations were being challenged by some "Old School" veterans, with both Caltech's Don Anderson and Colorado School of Mines' Warren Hamilton suggesting the Hawaii and other Pacific seamounts might actually be rising up through the spreading end of seafloor, tension fractures, rather than just over some mantle plume. And still, discoveries continue to be made, keeping the "Plate Tectonic Revolution" alive and well!

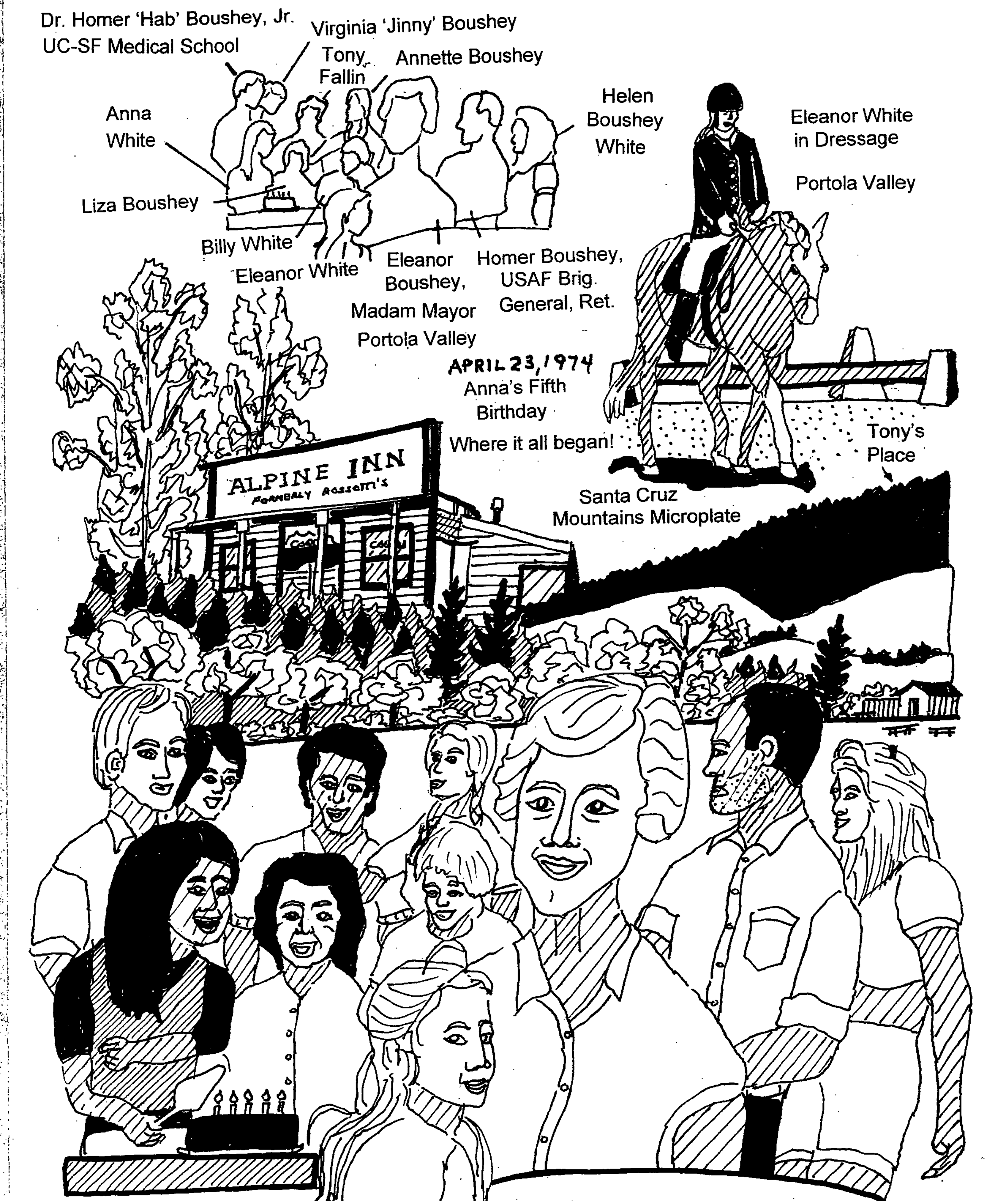
After leaving FUGRO in the mid-1970s, I re-located to Boulder, Colorado; hired on with the USGS; and was given career-tenure within two years while inventorying mineral resources across the West with a Wilderness Studies Group. One of my first projects was in the Maroon Bells-Snowmass Wilderness Area of the Central Colorado Rocky Mountains around Aspen. As I looked at mining prospects, Warren Hamilton was just over the hill, finding anomalous concentrations of pyrite or iron sulfide in the White Rock Pluton. Later, we would both discover evidence of molybdenum mineralization in the region, Warren in the Maroon Bells, me around Mount Emmons with others in the Oh-Be-Joyful Wilderness just south of Warren.

Addressing our discoveries with others from a plate tectonic perspective, speculating about the surfacing of re-melted crust above subducted seafloor plates and the origin(s), plus dynamics of the intrusive systems, in general, we may have just as well have been talking in tongues and writing in Sanskrit to the uninitiated. On my end, papers were "lost" intentionally in review.



Geologic Cross Section Showing Metallic Ore Bodies and Host Rock Alteration Zones Associated With the World-Class Mount Emmons Molybdenum Deposit, Mount Emmons, Colorado

Elsewhere in the Survey, Ogden Tweto was also being pressured to print his 2-degree, geologic maps of Colorado in "hard-to-read-and-use-in-the-field" black and white, rather in "easy-to-use" color. In addition, all ducks were supposed to get "in a row" doing wilderness studies, using one person's, subjective, classification scheme to estimate mineral resource potential, rather than allowing professionals to treat each area as unique or daring to venture into plate tectonic interpretations. Tiring of the sabotage and childish, over-stepping ignorance of others in the system, not to mention hold ups from field work and doing the job I had signed on to do, I would soon take a break, branching out to travel and do other things for a bit.



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ALLISON - ON THE RESPONSIBLE
END, HERE'S A COPY OF A
LETTER TO ONE OF MY CHARGES,
ANNA BANANA, et al. ANNA
IS MULATO AND ADOPTED; I
HOPE YOU WON'T HOLD IT AGAINST
HER. SHE TELLS ME I TALK
FUNNY SOMETIMES WHEN I
LAPSE INTO "GEOTECTONIC"
DISSERTATIONS: HENCE MY

J.A. Tony Fallin
P.O. Box 1624
Boulder, CO 80306

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Lest I overlooked sending this perspective to you earlier...

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