The Necessity for Permanence: Making a Nuclear Waste Storage Facility

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Submitted to the Department of Architecture in partial fulfillment of the requirements of the degree Master of Architecture at the Massachusetts Institute of Technology

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Abstract

The United States Department of Energy is proposing to build a nuclear waste storage facility in southern Nevada. This facility will be designed to last 10,000 years. It must prevent the waste from contaminating the environment by either natural causes or by human intervention. This thesis investigates techniques of preventing curious or oblivious people from breaking into this highly toxic repository. It is a situation where the form must communicate meaning over many millennia in the absence of a cultural context.

Thesis Supervisor: Frank Miller
Title: Assistant Professor

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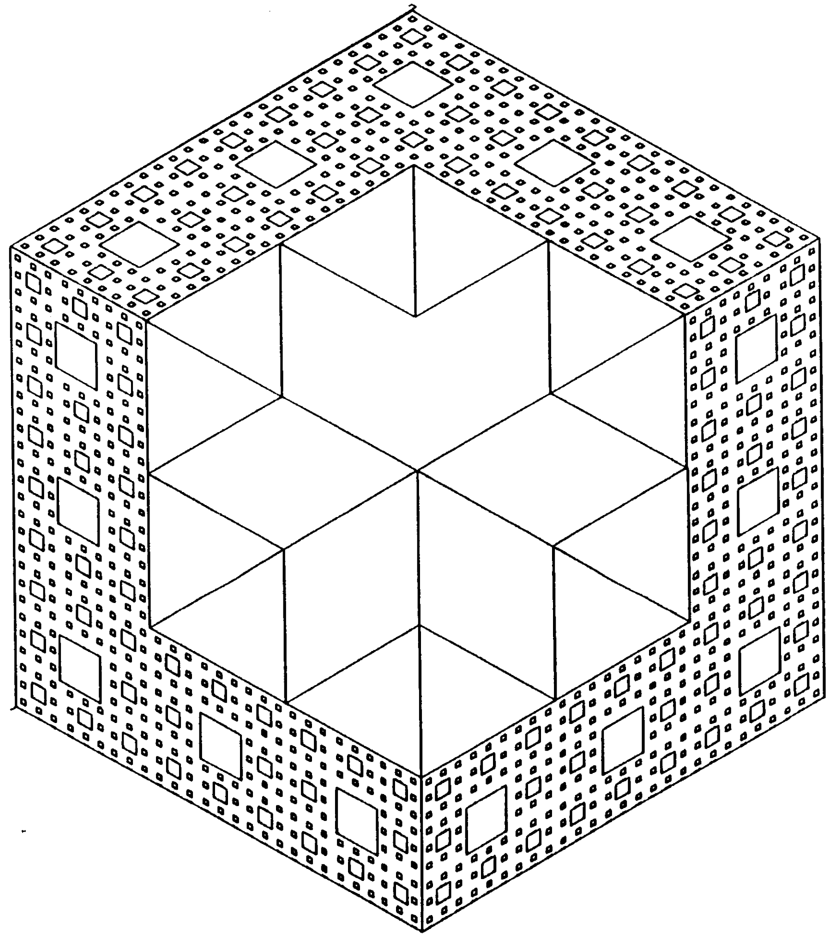


1. Origins of the Problem

1.1Radiation

The uranium used in nuclear reactors takes 100 million years to decompose. At the present time, there is no place to put the spent fuel. The Department of Energy (DOE) is proposing to bury it on the Nevada Test Site in southern Nevada. This site will need to be marked so that future generations will know the area's hazards. In order to understand the implications of using this site, one must first understand radiation.

Radioactive materials are substances that continually emit atomic particles. As Konrad Krauskopf points out in his book, Radioactive Waste and Disposal, "Our normal senses do not respond to radiation; a piece of high grade Uranium ore, for example, is not distinguishable from other kinds of heavy black rocks."[1]

A substance emits radiations when it loses, small particles from the nuclei of its atoms. By losing these charged particles, the atom is transformed into another atom. This substance may be also be radioactive. The chain of alchemy is a degenerative process that continues until a nucleus is formed that is stable and less energetic.[2]

The time required for half of any given mass to decay is called the half life of the isotope. Another property of radiation is that it is thermally hot; the energy that it is giving off is converted into heat as it moves through matter.

Fig. 1. Man with canister of high-level waste Krauskopf 1988

1.2 Longevity

How long is the material toxic for? This is a question without a straightforward answer. Krauskopf describes the situation:

> "If one imagines that all the waste in a repository could be readily accessible to the nearby populace, the waste will remain a hazard for more than 100 million years - a period equivalent to geologic time since the early Cretaceous. With a more reasonable guess as to how the escape of waste might occur - say by gradual leakage into ground water moving slowly along a fracture - the time over which functioning of the barriers would be important is more like 10,000 or 100,000 years, since after this the natural environment could probably be trusted to control the greatly reduced radioactivity. Thus a specification of the required isolation time can be set with good reason anywhere between 10^4 and 10^8 years. A possible compromise is to say that a repository should provide assurance of isolation for 10,000 years, with a strong probability that its barriers will continue to function for several hundreds of thousands of years longer. (In talking about times of this magnitude, it is well to keep in mind that recorded history goes back only some 6000 years, and the people with ten millennia more of technological experience behind them."[3]

Still, the margin of error Krauskopf offers himself is 9,990,000 years; he states the ,"specification of the required isolation time can be set with good reason anywhere between 10^4 and 10^8 years." More to the point, Krauskopf is trying to establish a time frame to take responsibility for. His answer is that the statute of limitation is roughly equivalent to the time of recorded history. This is to say that we are liable for a time

Isotope	*Symbol*	*Emitted particle*	*Half-life*
americium-241	^{241}Am	alpha	433 yr
americium-243	^{243}Am	alpha	7 370 yr
bismuth-210	^{210}Bi	beta	5.0 da
radiocarbon	^{14}C	beta	5 730 yr
curium-245	^{245}Cm	alpha	8 500 yr
cobalt-60	^{60}Co	beta	5.27 yr
cesium-135	^{135}Cs	beta	3×10^6 yr
cesium-137	^{137}Cs	beta	30.17 yr
tritium	^{3}H	beta	12.33 yr
iodine-129	^{129}I	beta	1.6×10^7 yr
krypton-85	^{85}Kr	beta	10.7 yr
neptunium-237	^{237}Np	alpha	2.14×10^6 yr
protoactinium-234	^{234}Pa	beta	6.8 hr
lead-210	^{210}Pb	beta	22.3 yr
polonium-210	^{210}Po	alpha	138.4 da
plutonium-239	^{239}Pu	alpha	24 000 yr
plutonium-240	^{240}Pu	alpha	6 570 yr
radium-226	^{226}Ra	alpha	1 630 yr
radon-222	^{222}Rn	alpha	3.82 da
tin-126	^{126}Sn	beta	ca. 10^5 yr
strontium-90	^{90}Sr	beta	28.8 yr
technetium-99	^{99}Tc	beta	2.14×10^5 yr
thorium-230	^{230}Th	beta	80 000 yr
uranium-234	^{234}U	alpha	2.45×10^5 yr
uranium-235	^{235}U	alpha	7.04×10^8 yr
uranium-238	^{238}U	alpha	4.47×10^9 yr
xenon-133	^{133}Xe	beta	5.25 da

Fig. 2. Glossary of radio isotopes Krauskopf 1988

period equivalent to our oldest collective memory. Nevertheless, the Department of Energy has decided that engineering for ten thousand years is appropriate. Admitting this is quite extraordinary. If one puts into consideration that a DOE study stated that the continuity of this culture can only be expected to last for 200 years. A governmental body taking responsibility for a period far longer than its civilization is likely to last is extraordinary.

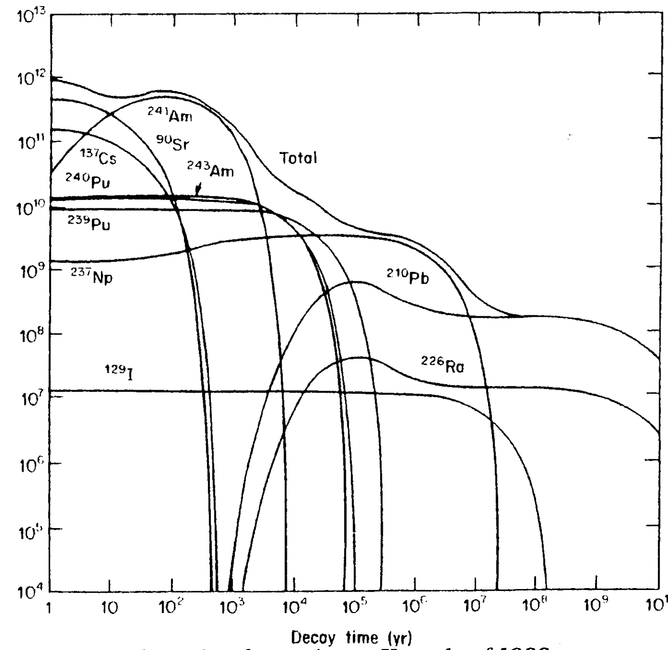


Fig. 3. Radioactive decay time Krauskopf 1988

1.3Toxicity

One of the major ways that radiation effects living cells is by ionizing the water in the cells thus creating free hydrogen and oxygen molecules. These charged molecules break the relatively weak bonds in the DNA. As the bonds break, the DNA's code is damaged and the cell consequently cannot regulate itself.

2. *High Level Nuclear Waste*

2.1 Fission

The fissionable Uranium, ^{235}U, only makes up 0.7% of natural Uranium. In fact, it only makes up a part of the Uranium rods used as reactor fuel. When ^{235}U is put through the fission process it breaks down into elements in the middle of the periodic chart, like selenium, cobalt, strontium, and cesium. The ^{238}U which makes up the bulk of the fuel rods becomes heavier after the fission process and turns into the transuranic element: neptunium, plutonium, americium, curium, and minor amounts of several others.[4]

The reactor rods last for about a year. The spent fuel rods are both radioactive and thermally hot. The rods are temporarily stored in large tanks of circulating water.5

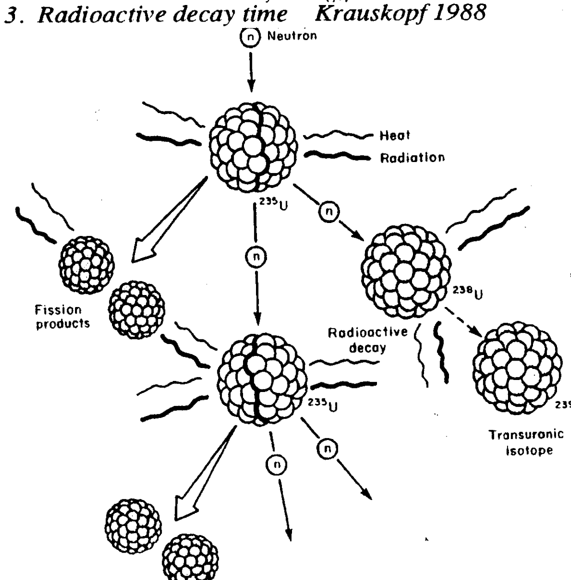


Fig. 4. The fission of Uranioum Krauskopf 1988

By bathing the spent fuel in nitric acid, it is possible to recover the plutonium. This plutonium is fissionable; it can be used for both reactor fuel and for the fabrication of bombs. But because it can be used for bombs, it is a security problem. Another problem with reprocessing is that the biproducts are hazardous. Large tank farms of the radioactive nitric acid have grown at the DOD reprocessing plants at Hanford, Washington and on the Savannah River in South Carolina (fig. 5).

Krauskopf makes the case that permanent disposal of radioactive waste from reactor, (known as high level waste or HLW), may not be the best course. The possible recovery of fissible plutonium and uranium is one reason to have accessible storage. Another reason is that the material is metallurgically rich since it contains large amounts of rare metals like cesium, zirconium, and technetium. But there is no way to predict when we will be better equipped to handle this radioactive material.[6] An accessible, recoverable storage facility would entomb the waste in a monolithic structure similar to the Egyptian pyramids or at the end of a horizontal tunnel driven into a mountainside.

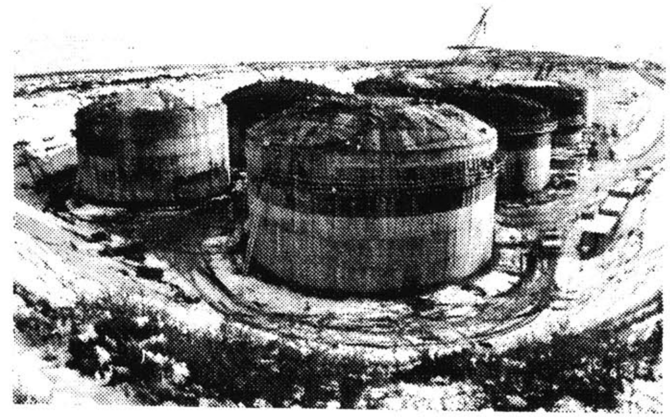


Fig. 5. Tanks for reprocessing waste at Hanford, WA.

Krauskopf 1988

2.3 Long Term Storage

Nevertheless the Department of Energy (DOE) has planned to put the HLW into a permanent storage facility. According to Krauskopf there is enough HLW in the United States to fill a college football stadium to a depth of 8 to 10 meters. But when stored in a permanent facility, the material will take up 3,000 underground acres.

There are other alternatives for permanent disposal. The waste could be put on a rocket and shot into space but the dangers of rocket launching make this a problematic option. The waste could also be placed in the thick ice sheet covering Greenland or Antarctica. Even though these areas are far away from the inhabited world, the effects of a thermally hot mass on the ice sheet could be disastrous. Finally, it could be placed in a deep hole and back filled. This is the method with the most consensus.[7]

A geologic repository has three main dangers: the radionucleotides leaking or washing into the water table, earthquakes or other major geologic events, and tampering by humans. Consequently, the waste repository must be situated in a rock formation with a stable history and which is located in an arid, remote region. Furthermore, the area must be well marked. The facility would be a mined series of tunnels that would be drilled without the aid of water. The HLW will be placed in specially designed cannisters. These containers are only designed to last for only 300 to 1,000 years because the HLW degrades whatever material that it is packed in. For the remainder of the time, indeed the majority of the time, the surrounding rock will be its host. As a result this rock should be resistant to the heat of the waste and should inhibit the flow of radiation.

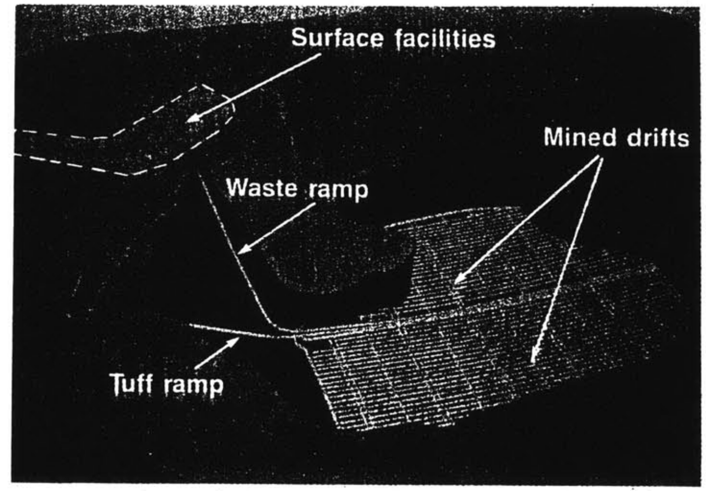


Fig. 6. Diagram of mined repository   Department of Energy

Yucca Mountain

3.1 Geology

The siting of the repository has been as much a geological problem as a political one. Because no one wants to live next to a nuclear waste dump, the government had to choose a site on its own land. The site chosen for this mined storage is in a formation of volcanic tuff on the Nevada Test Site outside Las Vegas, Nevada.

Fig. 7. A view inside a repository tunnel   Department of Energy

Geologically, this site is suited for the repository. The area has low rainfall and a very deep water table. The water is at a depth of 1,500 feet and is flowing to the North, away from Las Vegas.

The major features of this landscape were developed during a period between 40 to 10 million years ago. At this time, the Timber Mountain Caldera was active. This volcano is just to the north of the site. It laid down a layer of volcanic ash more than 200 meters thick. The eruption that formed the layer of the proposed repository, called Paintbrush Tuff, was produced in an eruption of 12,000 cubic kilometers of material. The ash was still molten as it was deposited and consequently became a cohesive mass. This mass is called Welded Tuff. There are also layers of Nonwelded Tuff which occured when the ash did not coalesce so strongly. Yucca Mountain itself was formed from a series of major faults which occurred roughly 10 million years ago. There has not been any major activity since that time. But, there have been some minor events; for example, earthquakes measuring 4.0 on the Richter Scale, have been recorded, and there may have been an eruption in the past 10,000 years from the Lathrop Wells Cone. This volcano is to the south of the site. The area's geologic prognosis is based on its history. The prediction for the next 10,000 years is that there will be no major geologic shifts and a possibility of a small volcanic eruptions from the Lathrop Wells Cone.[8]

The topologic changes in the area over the past 1,000 years have been minimal. The valleys have become slightly deeper but the climate has stayed stable. The topographic prediction, according to Adyth Simmons, a geologist at the DOE, is that in the next 1,000 years the canyons will deepen and the principle method of erosion will be due to flash floods. If one looks back 10,000 years, during the last major ice age, one finds that the site was semi-arid and covered by Juniper Trees. If one looks back further into the known geologic record, one finds that the site was never under water. But because climatic shifts are not well understood, it is impossible to make very convincing predictions. As a result, how the topography will change over the long term future is anyone's guess. But according to Simmons, within 10,000 years the climate probably will be different. With a greater rainfall, for example, the site could be covered with plants. This would flatten the area and could make it look like Vermont. Over the long term, it is possible that the site could be covered by a glacier or it could be underwater. Equally open for speculation is how society will change, indeed how man and the rest of the plant and animal world will evolve over the site's toxic lifetime.

REPOSITORY OBJECTIVE IS TO ISOLATE RADIOACTIVE MATERALS USING NATURAL AND ENGINEERED BARRIERS

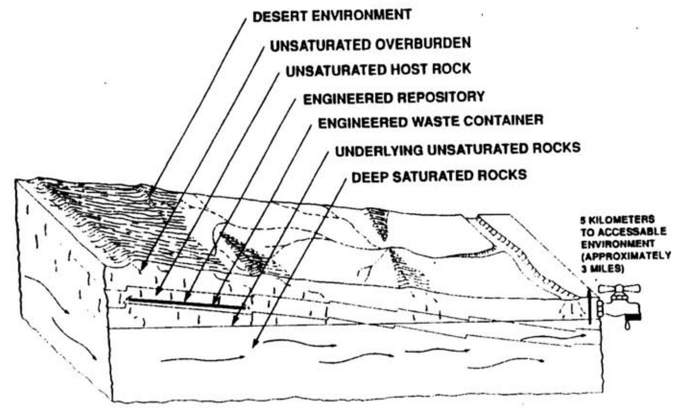


Fig. 8. Department of Energy

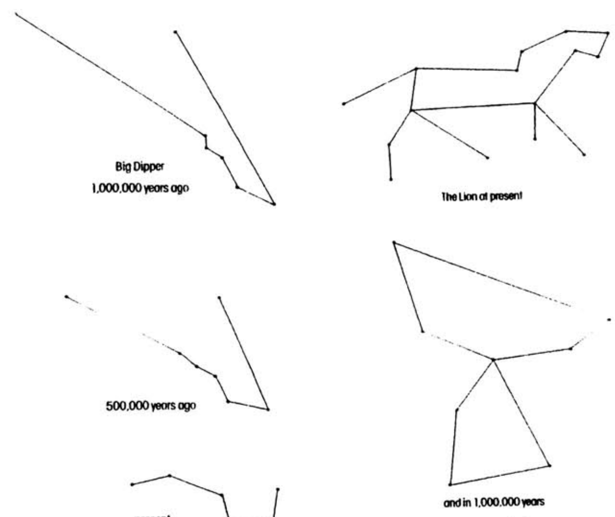


Fig. 9. The movement of the stars Sagan 1980

3.2 Context

The proposed repository location is on the grounds of the Nevada Test Site. This is the land set aside for nuclear bomb testing. Krauskopf points out that this,"location is already contaminated by radioactive debris released by underground (and overground) nuclear weapons testing, so that minor additions from a remotely possible malfunctioning of a repository would be less serious here than at most sites elsewhere."[9] This area of weapons testing is called Yucca Flat. It is approximately 40 miles north-east of Yucca Mountain. Yucca mountain is on the south-western side of the Nevada Test Site. It is located 80 miles from Las Vegas. The closest town is Lathrop Wells to the south and Mercury to the east, a town inside the Test Site.

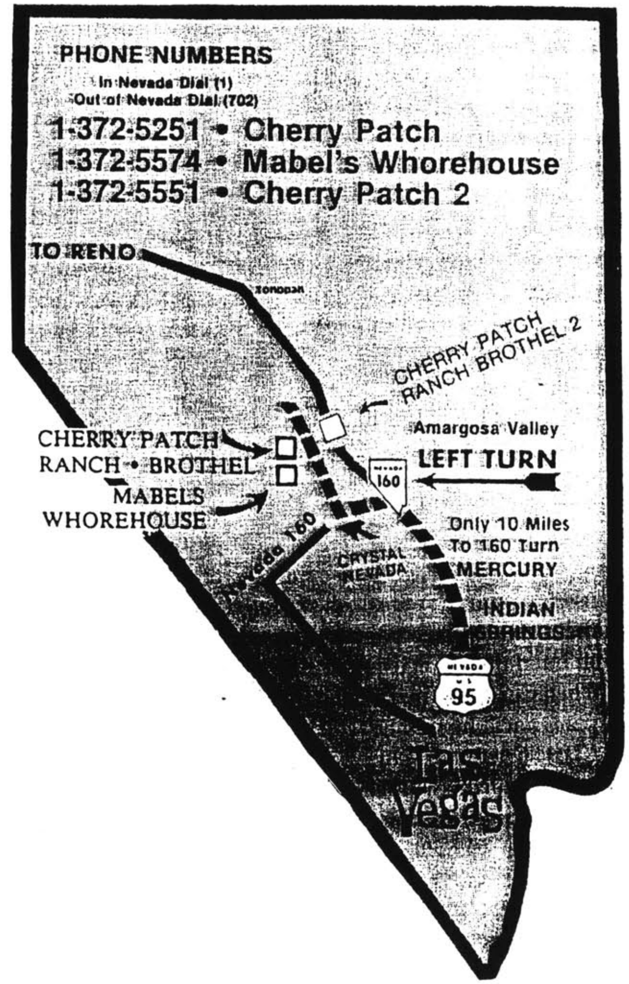


Fig. 10. Map of Nevada brothels

Security is a major concern at the Test Site. It is a 10,000 square mile fenced in area that belongs to the Federal Government's Department of Energy and Department of Defense. It seem inconceivable to me that any one group, even the Government could cordon off that much land. But as it turns out, only 17% of Nevada is privately held land. Moreover, the Test Site is bordered on three sides by Nellis Air Force Range; an even larger zone.

The Test Site area is a vast mountainous desert with high security research labs scattered throughout it. There are 6,000 people who work here. Even though it is a security conscious place, tours are given. A secretary at the Office of Civilian Radio Active Waste Management said that the tour of the Nevada Test Site, including the Yucca Mountain Long Term Storage Facility and Frenchman Flat the underground Atomic Bomb Test Facility would be leaving from the Meadow Mall parking lot next to Sears in Las Vegas. A box lunch would be provided.

The land of the Test Site can be viewed from opposing conceptions of landscape. The desert can be seen as a beautiful and delicate ecosystem. From another viewpoint, this land is not fit for most economic activities, consequently making for excellent bombing ranges. These opposing ways of looking at this place have clashed over the issue of an endangered species of tortoises that live on the site. Advocates for these animals have won a court case against the Department of Energy, so that the Test Site employees cannot drive their trucks off the road to insure that they do not run over a turtle. The employees had to go to a turtle handling seminar to learn what to do if they find a turtle crossing the road. The procedure is to push the turtles tail in (so that it will not urinate and thus dehydrate) and carry it across the road so it can continue its journey.

Yucca Mountain is also viewed as part of the ancestral land of the Pahute Indians. It is also viewed as a political nightmare for the Governor of Nevada. Both the Pahutes and the Governor are trying to stop the repository from becoming approved. The Indians have land claims throughout the Test Site and the Governor attempted to make Yucca Mountain its own county. Inside the fence, where no one lives, the Governor tried to make a political boundary. I think this would be the first county created for a toxic zone.

It is ironic that the same piece of land can be considered both a radioactive area and a delicate ecosystem. I witnessed a clash of these views when I was told that acres of the Test Site are scoured by ecology students documenting plants and animals. Each find is marked by a fluorescent plastic ribbon. The environmentalists paint the desert with these ribbons. This image is in contrast to the engineer who took me around the site. He did not like to touch the ground because of the atmospheric weapons testing conducted at the site from 1951 to 1959.

If the area is seen as a toxic wasteland, then who gets the Nevada Test Site when the Government ceases to exist? Who will want a radioactive waste dump? If no one else clams it, our government will own this land as long as it is harmful. It could be our oldest possession.

The Government's control of this property is strong. Boundaries are indicated by discrete fences, by motion detectors and by encouraging a code of behavior to inhibit curiosity and dissent.

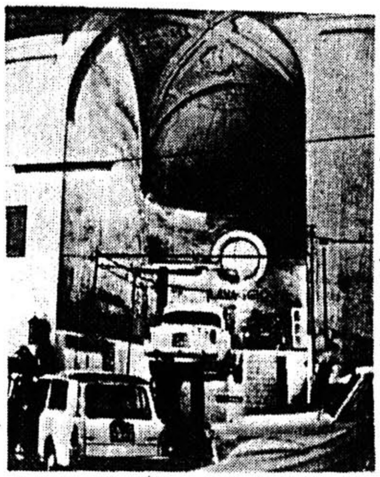


Fig. 11. Car repair shop in the altar of former church

Lynch 1972

The Test Site's outer gate is 200 yards from the highway and 1 mile from the second gate. The first gate has no door. It is merely a break in the fence with a 20' x 20' holding pen. Here the Nye county Sheriff's Department holds the protesters who occasionally visit the site. The protesters want an end to the testing of nuclear weapons. The site of the weapons testing is 80 miles north; but the first gate is the closest they can get to it. The Sheriff's Department. picks up the protesters who are yelling in the middle of the desert and carries them 10 feet into the pen. There is not even a guard house at the first gate, not even a sign; just a break in the fence and a holding pen. The second gate has a more formal entrance with guard houses, security buildings, and a very big sign that says "Nevada Test Site." It is a sign the protesters never get to see.

Another interesting delineation of a boundary occurs in Area 25. The engineer who was taking me around said, "If we go down that road they will come out with their guns drawn." There was no warning sign or gate; it is just a known fact among the workers not to go there. But the intersection is proudly marked. There is a billboard with all the names and logos of the firms who work at this lab. Status and power is announced while refusal and warning are implicit.

Test Site mentality is more than just a code for work behavior. This is obvious in Mercury, a town inside the Test Site. As one looks around the town, one sees a lab with a fence and motion detectors next to a cafeteria, next to another secure lab, next to a pile of pipes, next to a parking lot full of campers where a hook-up runs $6 per week next to another secure lab next to a bowling alley. There are no trees or plants. Mercury is a larger version of a town that will be built at the site of the repository during construction.

The bizarre qualities of the Test Site have inspired an amazing mythology. One of my hosts in Las Vegas told me that he heard the Government keeps Flying Saucers at the Test Site in Area 5. The next day my guide corroborated the story, "I suppose it is all right to tell you

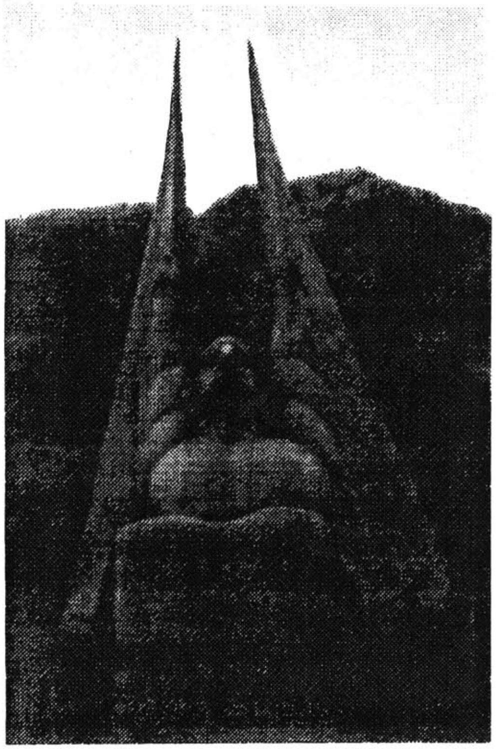


Fig. 12. The guardian angel of the Hoover Dam

this because it is in the public record. There was a major scientist here, one of the most important on the site, who got pissed off with something and quit. He went on television saying that the Government is flying Flying Saucers around the site. The aliens are dead but their crafts still work. Then the Government put a silencing campaign on him. When he went to get another job and tried to show his prospective employer his degree, the school he went to said he was never a student there. Everyone denied he existed." The power of the Government is mythologized and respected. It fits with the myth that, if one transgresses the Government, one effectively gets cursed.

Rayner Banham writes a similar mythology of the desert. "That merciless old time religion on which I had been raised was crammed with desert imagery."[10] It is,"a place of secrets where the customary restraints of law and habit are suspended. Never forget that it was in the Mojave that the first claimed UFO sightings took place and the pioneer conversations with little green men from Venus. In a landscape where nothing officially exists (otherwise it would not be 'desert') absolutely anything becomes thinkable and may consequentially happen."[11]

It is in this context that one comes upon Las Vegas. My first view of Las Vegas, for example, was at night from an airplane. The desert was black and 33,000 feet below. Then ahead it looked as if someone had turned on a desk lamp in a den of a house. The scale of the plane and the vast landscape had completely flipped. The entire scene of the city , the desert the sky and the night looked completely domestic.

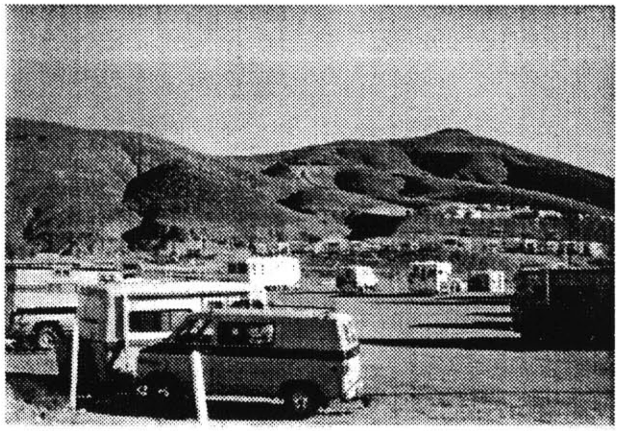


Fig. 13. The inhabitation of a barren landscape

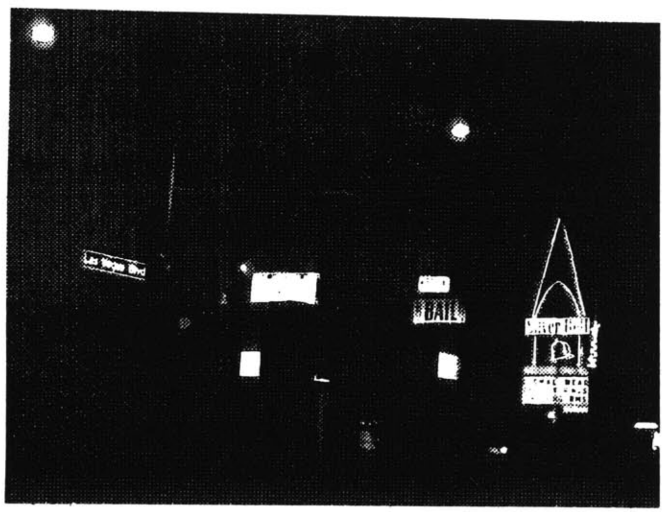


Fig. 14. A Las Vegas marriage parlor and bail bond

Fig. 15. Yucca Mountain looking South

Fig. 16. Yucca Mountain looking Southwest

Fig. 17. Road map of Nevada

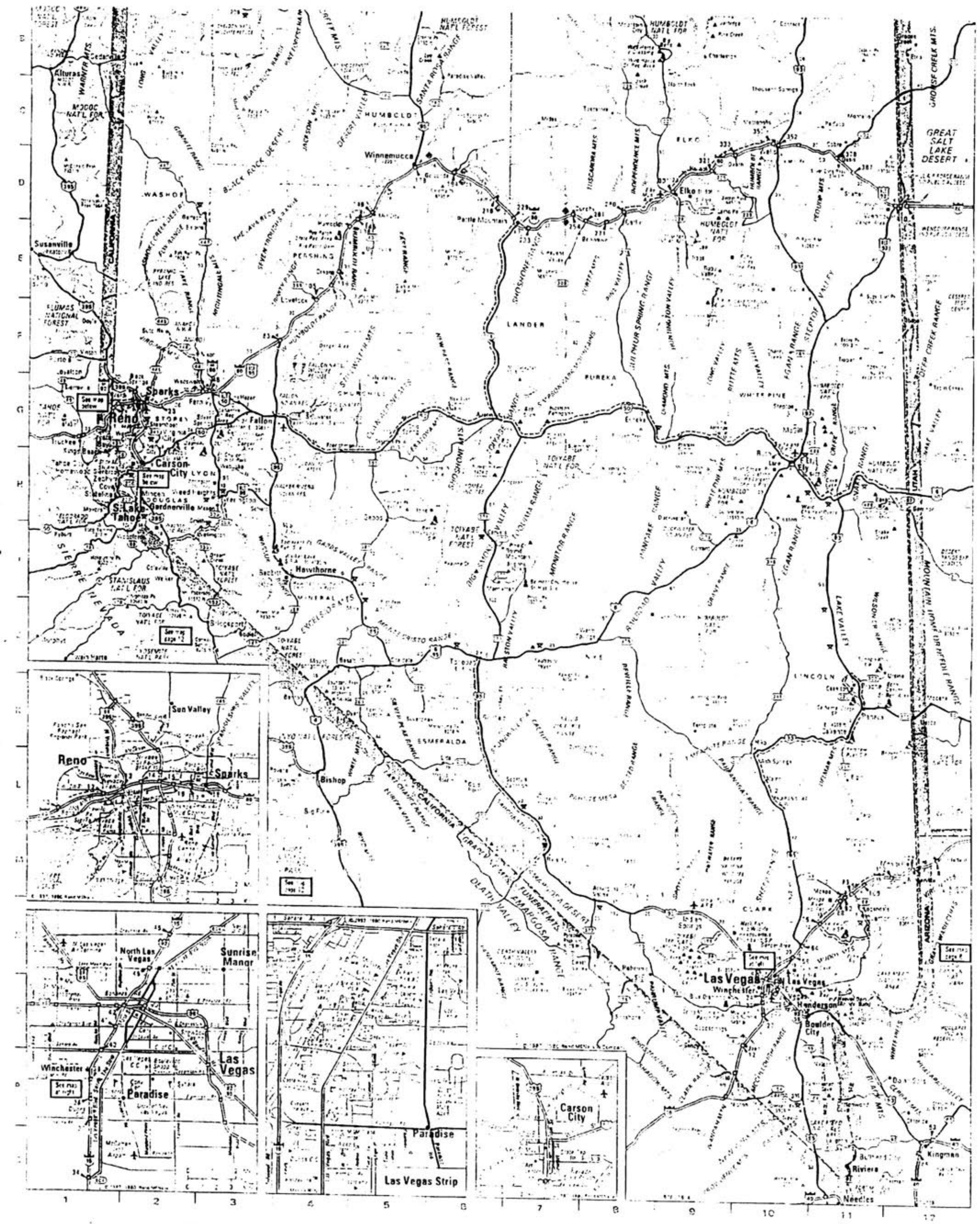


Fig. 18. Department of Energy

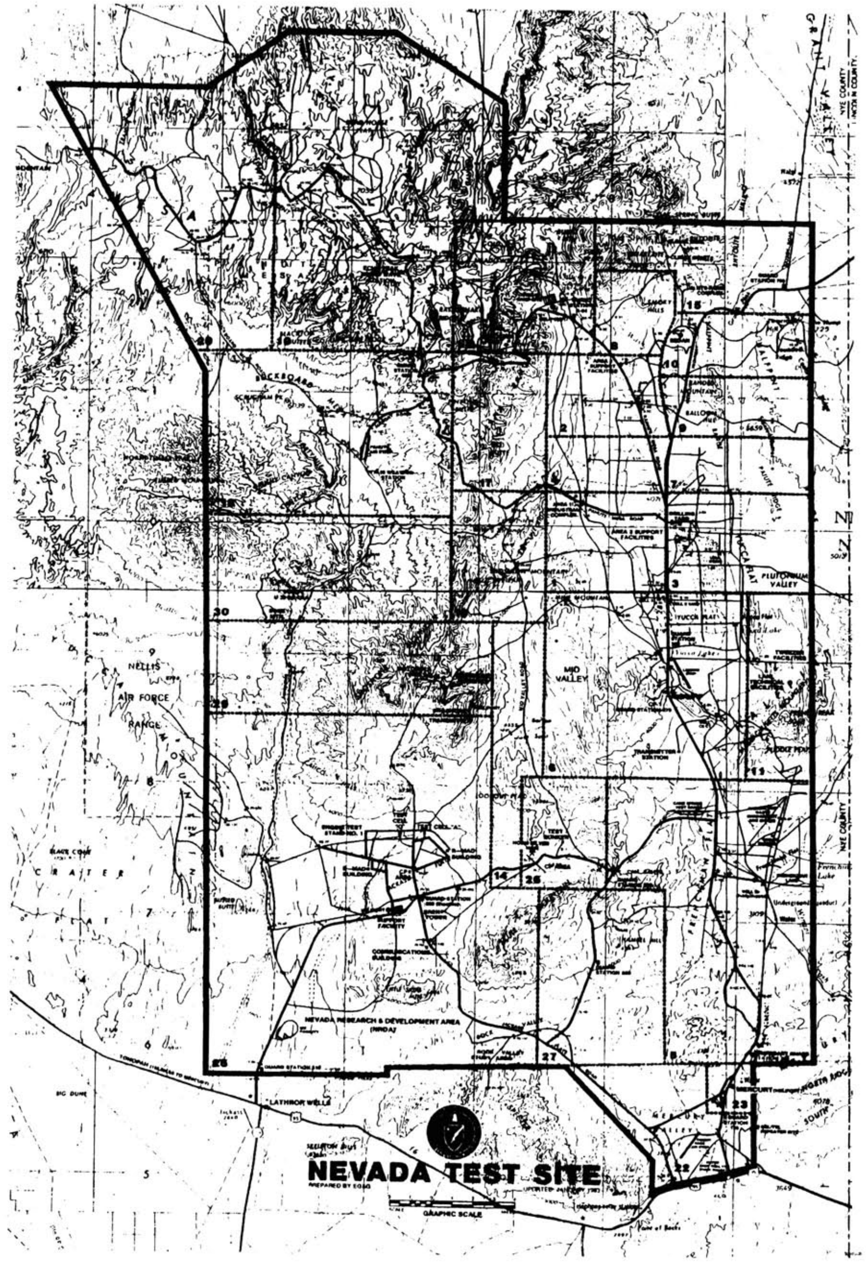
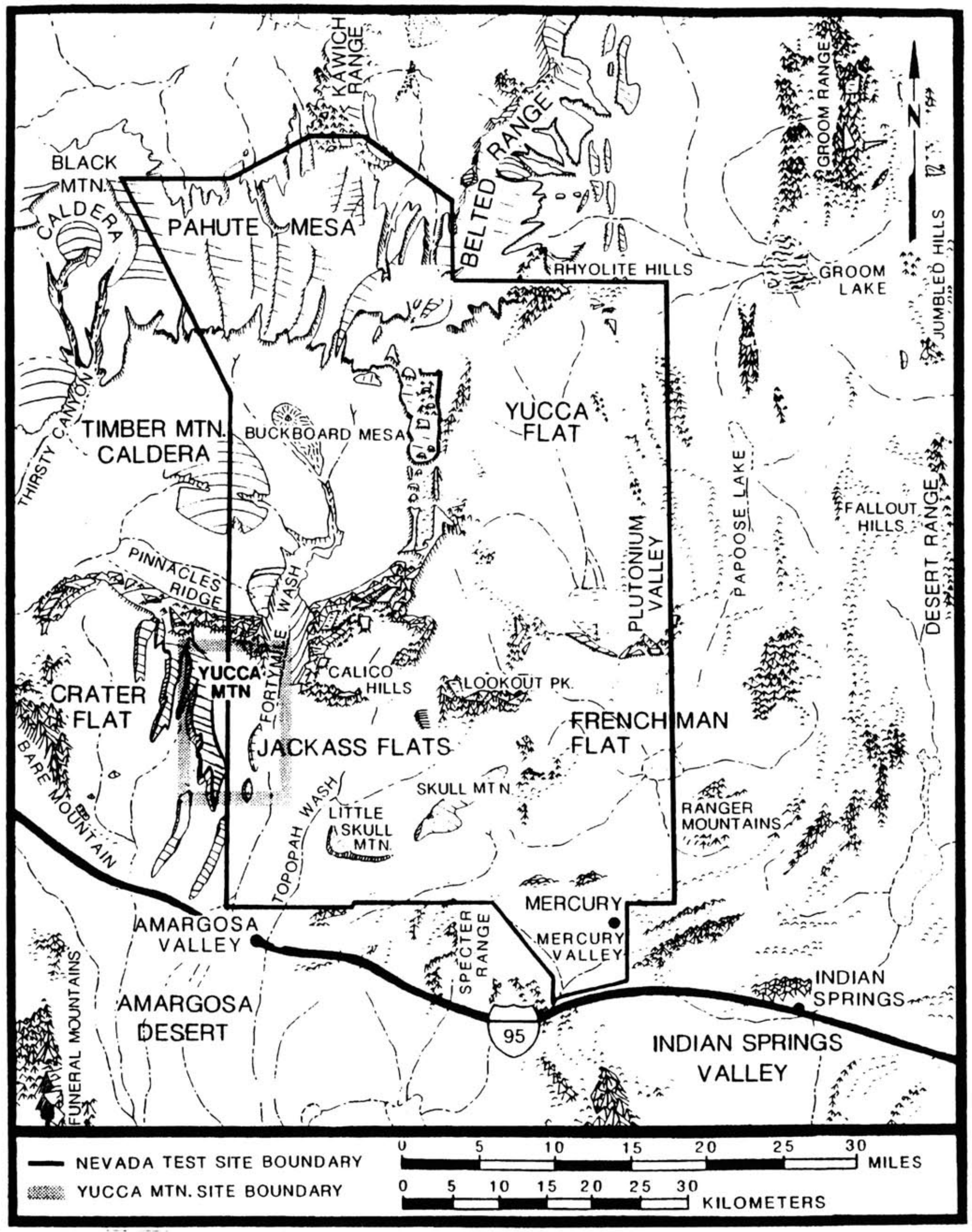
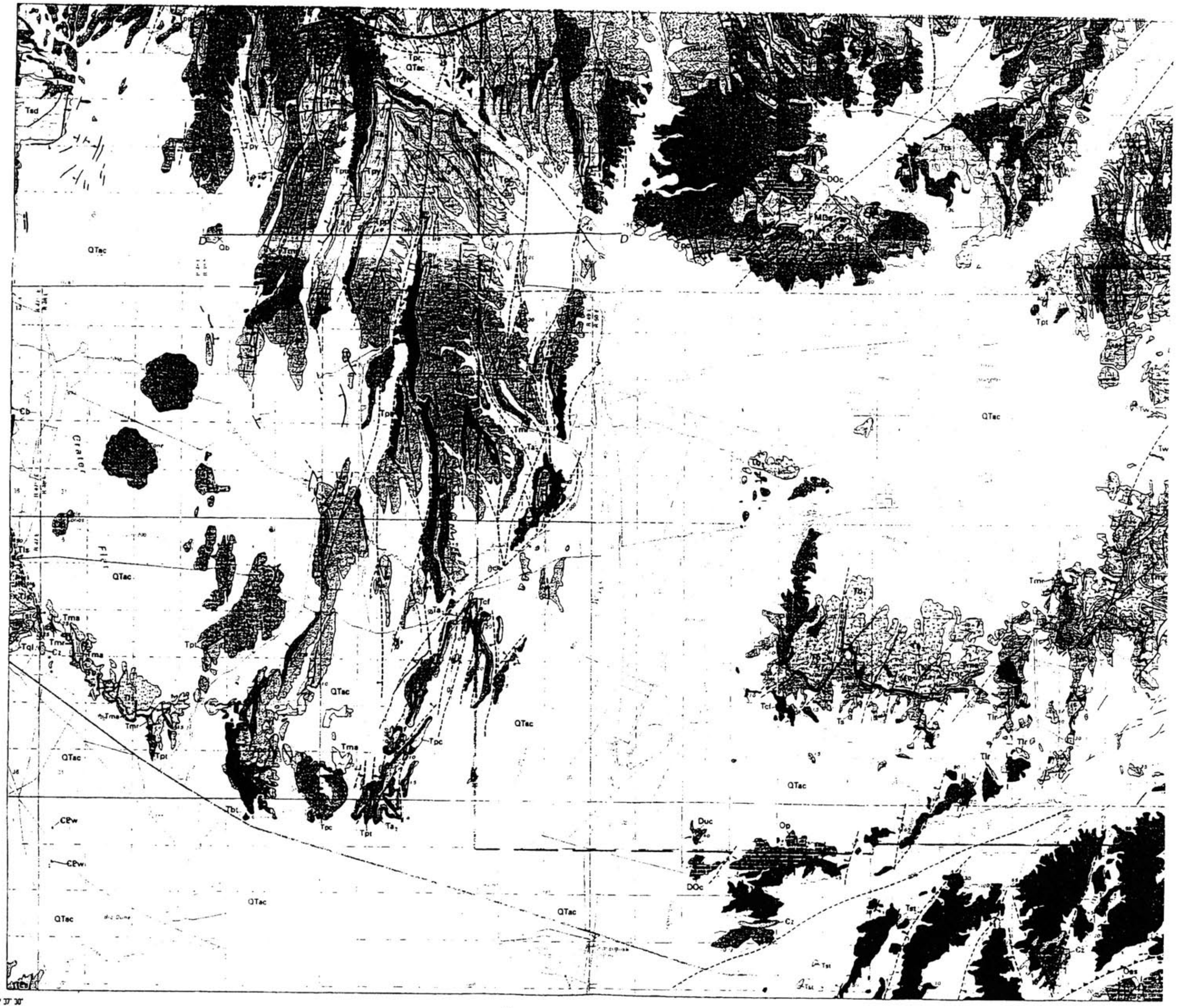


Fig. 19. Department of Energy





36° 37' 30"
116° 37' 30"

Base from U.S. Geological Survey
Beatty 1986, Pahranagat Range 1985, Indian Springs 1978
and Pahute Mesa 1979.

Fig. 20. Yucca Mountain

SCALE 1:100 000

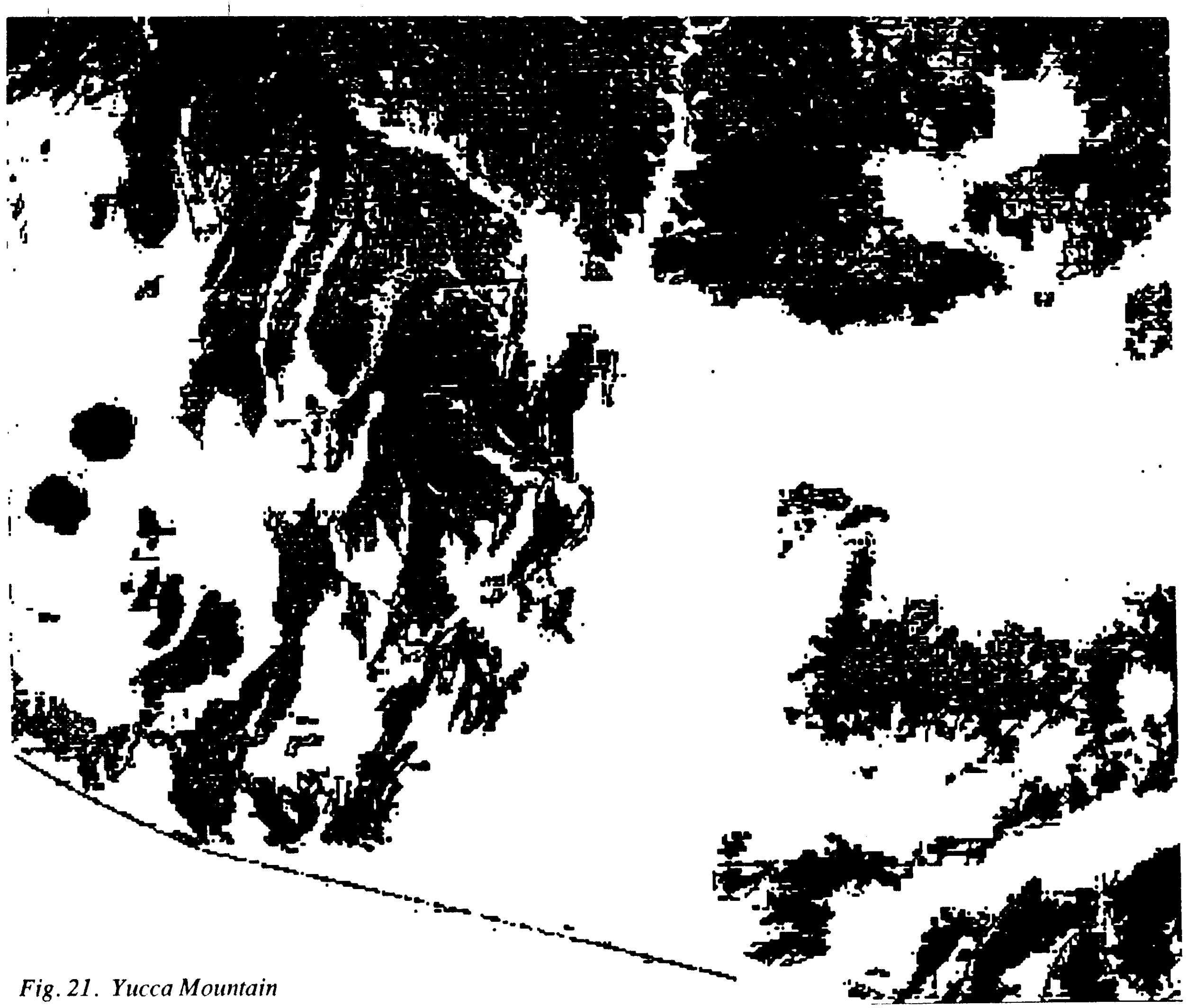


Fig. 21. Yucca Mountain

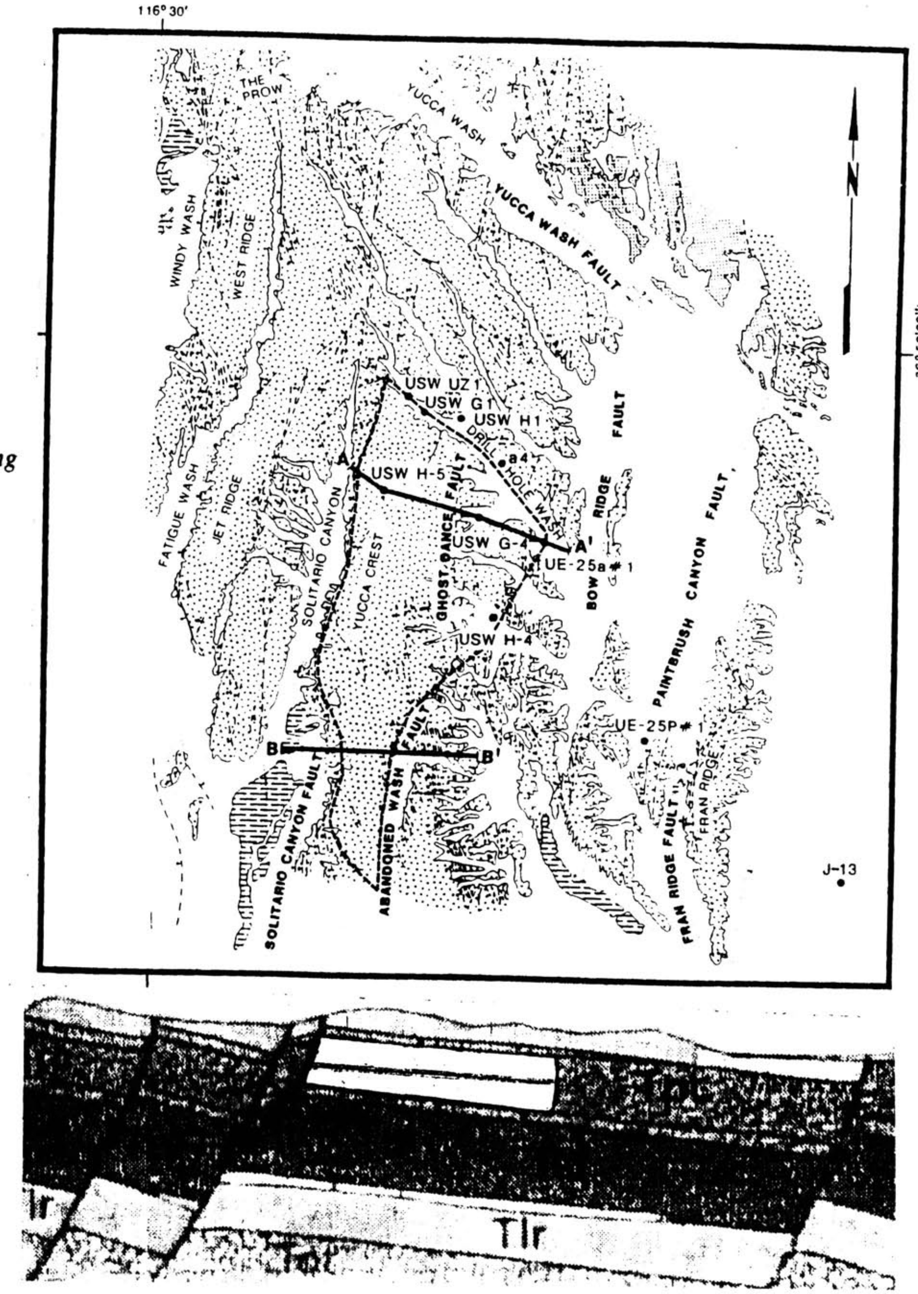


Fig. 22. Section through Yucca Mountain showing the placement of the repository

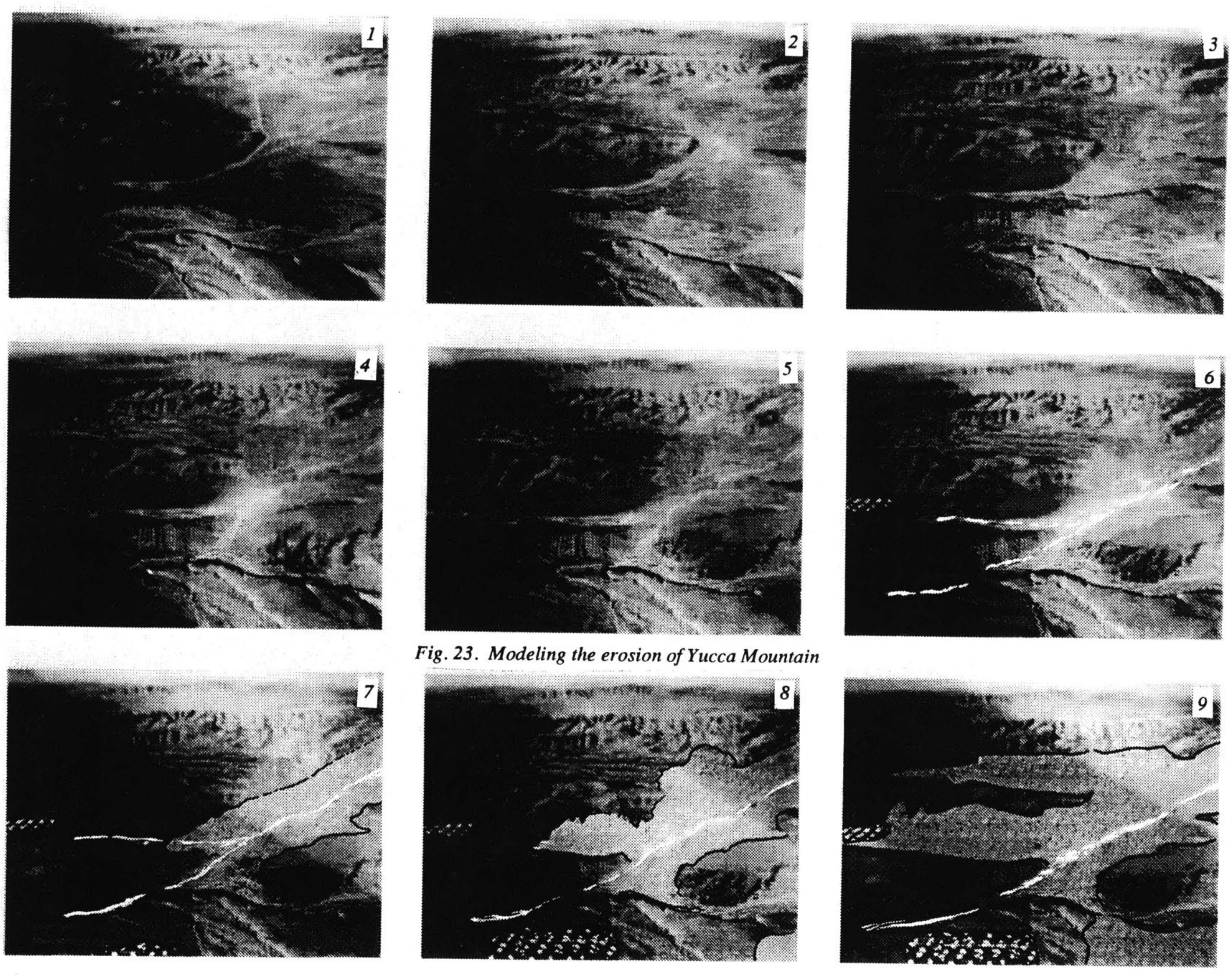


Fig. 23. Modeling the erosion of Yucca Mountain

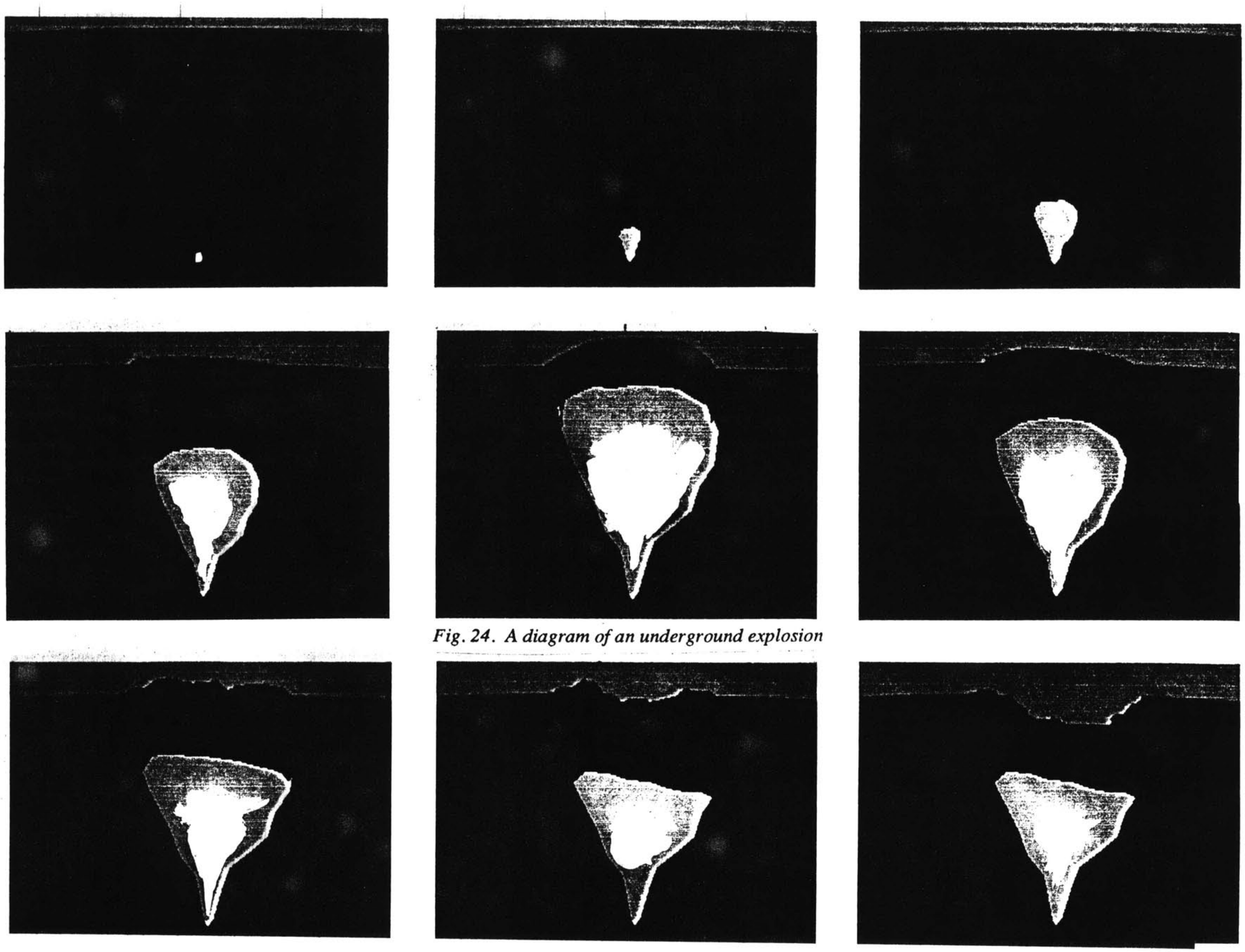


Fig. 24. A diagram of an underground explosion

Fig. 25. Yucca Flat, the underground nuclear weapons testing facility
Department of Energy

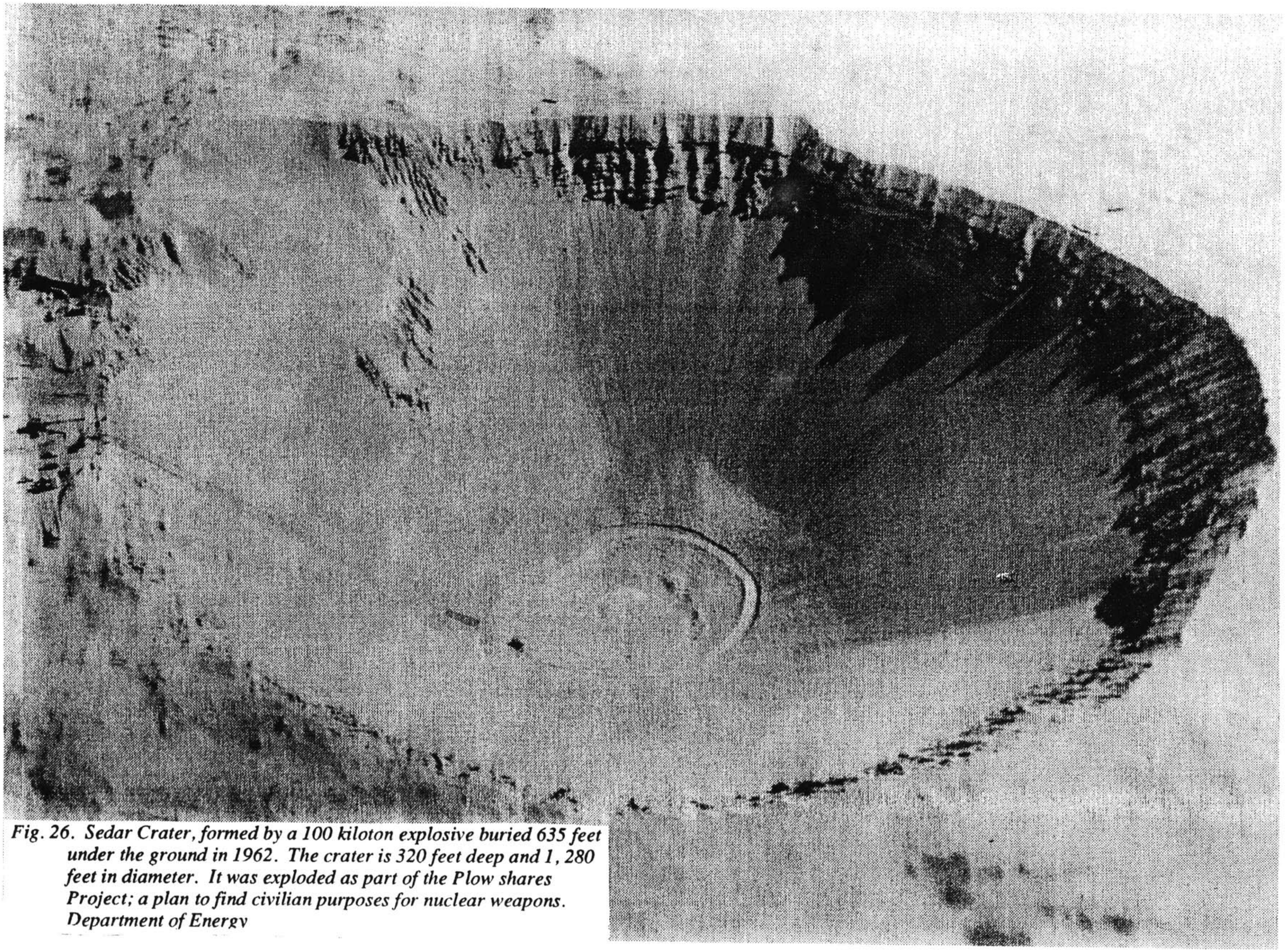


Fig. 26. Sedar Crater, formed by a 100 kiloton explosive buried 635 feet under the ground in 1962. The crater is 320 feet deep and 1, 280 feet in diameter. It was exploded as part of the Plow shares Project; a plan to find civilian purposes for nuclear weapons. Department of Energy

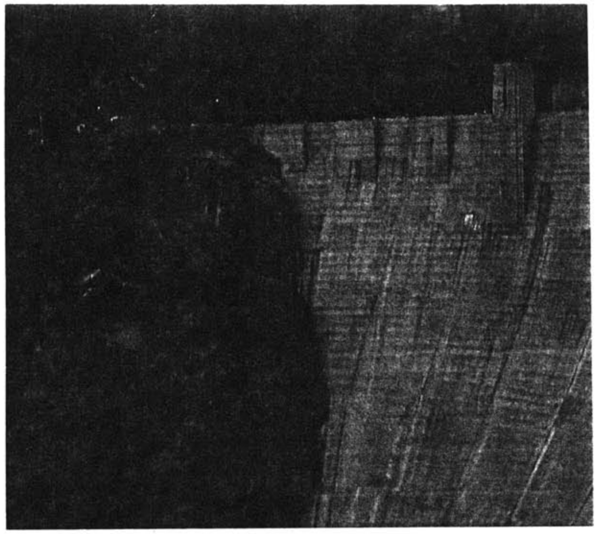


Fig. 27. Detail of the Hoover Dam

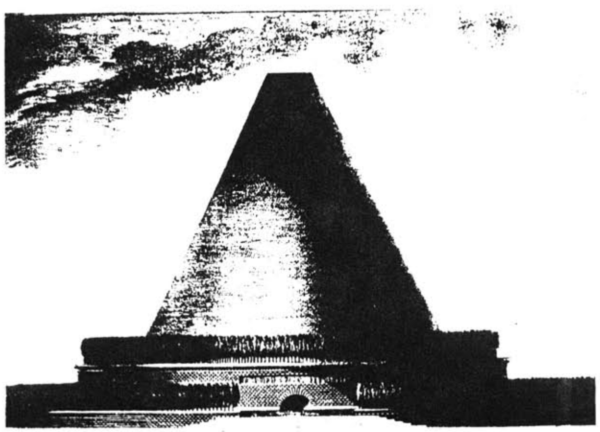


Fig. 28. Cenotaph by Boulle

4. Warnings

4.1 Looking into the Future

The time machine, in H.G. Wells' story The Time Machine, moves in time but does not move in location. On his first voyage the inventor gets into the machine, which is sitting in his workshop and travels 300,000 years into the future. Upon arrival he sees that his workshop has become a grassy knoll with a golden sphinx on it. Later in the story, he goes several million years into the future and on the same spot as his workshop and as the golden sphinx, he is attacked by giant spiders.[16]

"We now prefer what is light ephemeral , quick,... Our houses will not outlive their tenants. Every generation will build its own city."
-Saint 'Elia, the Futurist architect[14]

Instead of seeing our lives and environments on a continuum between past and future, our culture has focused on the present. Although having stated this, in the southern Nevada area, there is a structure engineered to last for 1,000 years. It is the Hoover Dam. The Dam is built complete with guardian angels and with detailing that makes it look like it existed before the rock. In fig. 27, the rock looks like it has been cut into the smooth dam concrete; instead of the other way around. The dam is a testament to man's power over nature.

The warning marker for a nuclear waste facility must last far longer than 1,000 years. Consequently it should not attempt to subdue nature, but should make it work to its advantage. The forces of erosion could be harnessed for its sculpting power. Sostaratus, the architect who designed the Alexandrian Lighthouse, understood this. His structure was 450 feet high and stood for 1,500 years. He had his name carved in hard stone and put on all the sides of the lighthouse. Then he had the stone cemented over with the pharo's name. In several hundred years the cement crumbled off and revealed his name.

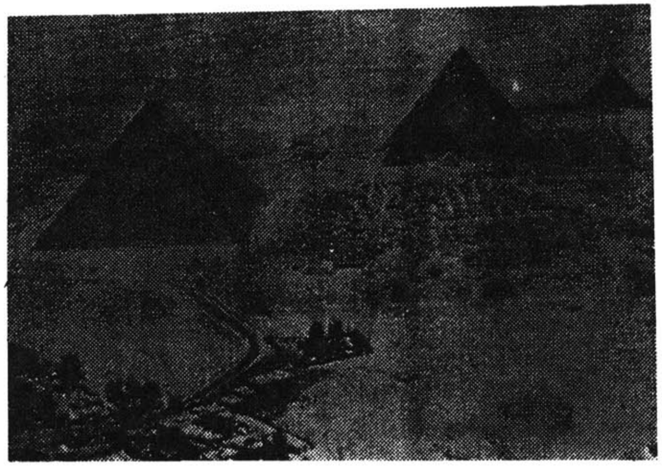


Fig. 29. Pyramids of Giza

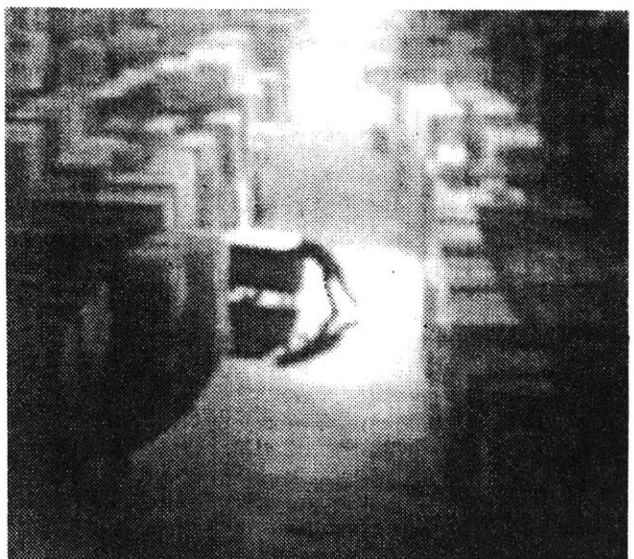


Fig. 30. Ark of the Covenent being stored in a warehouse in Raiders Of the Lost Ark 1984

4.2 Permanent Storage

For effective permanent storage, the inhibition of the corrosive forces of nature and the protection against looting is necessary. The ancient Egyptians used several storage techniques. One technique was to built massive structures. These structures usually had labyrinths in them to make their storage area less accessible. The pyramid's long term storage success can be considered minimal. All the large tombs have been thoroughly cleaned out. But an effective method the Egyptians used was to create a diversion, so that the tomb would not be noticed. This method protected King Tut's crypt from being discovered for thousands of years.

The ancient Chinese of the Ming Dynasty built a series of tombs that still have not been excavated. These tombs are protected by a long processional of statues that supposedly will put a curse on anyone who disrupts the them. The protection of this place relies on the propagation of this belief. Could a modern equivalent of a curse be used at Yucca Mountain to protect the waste? A gargoyle or a pyramid could be built (see fig40 &41). If they were large enough these markers could last the requisite time.

4.3 Communication

A nuclear waste storage facility must do far more than last for a long time, it must communicate to future civilizations the danger of this place. This project presents a situation where the form must communicate the message in the absence of a cultural context. A somewhat analogous situation occurred in the movie, 2001: A Space Odyssey. The wall, in the movie, sent a message many millions of years after it was buried. A similar demand is made of a marker in a nuclear waste storage facility.

4.4 Death

Because the time frame is unclear, a nuclear waste marker does not need to act like an alarm clock. Instead, it could function as a barrier like the wall of the castle in Edgar Allen Poe's "Mask of the Red Death," that is used to keep out the evil disease.

If the place is considered like a modern hell then an appropriate warning message would be an updated version of the message on the gate to the hell that Dante Encountered:

"Through me the way into the suffering city,
Through me the way to the eternal pain,
Through me the way that runs among the lost.
Justice urged on my high artificer;
My maker was define Authority,
The highest wisdom, and the primal love.
Before me nothing but eternal things were made,
And I endure eternally
abandon every hope, Who enter here."[15]

4.5 An Object Out of Context

Another method of signalling a warning is to take an object out of its context. If an old New York City hotel is copied, and put out in the desert, it would become a building where the stay is not over night but for 10,000 years (see fig. 30). Moreover, if a building is used that already has a cultural importance, then the respect offered to this building in its new use might be greater. For example, if a copy of the Washington monument is used to mark a site of waste burial then Yucca Mountain could be offered the same respect that the Mall in Washington is given. This respect could be conceivably transfered from culture to successive culture. If, at some point in the future, the Mall in Washington were destroyed then the copy of monument in Nevada would become the culturally important icon.

An impressionistic version of this changing of context would be to take a figure of cultural importance from this specific region and to cut his likeness into the stone of the mountain. Don Rickles face, for example could make an excellent warning. Another impressionistic version is to

Fig. 31. The well preserved corpse of Remeses II   Gore 1991

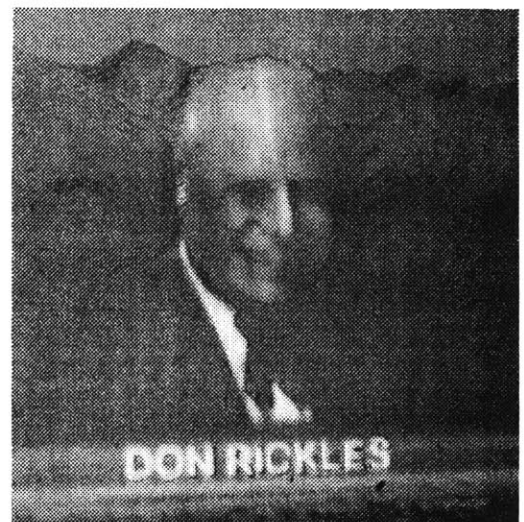


Fig. 32. Don Rickles' face as a warning for nuclear waste storage

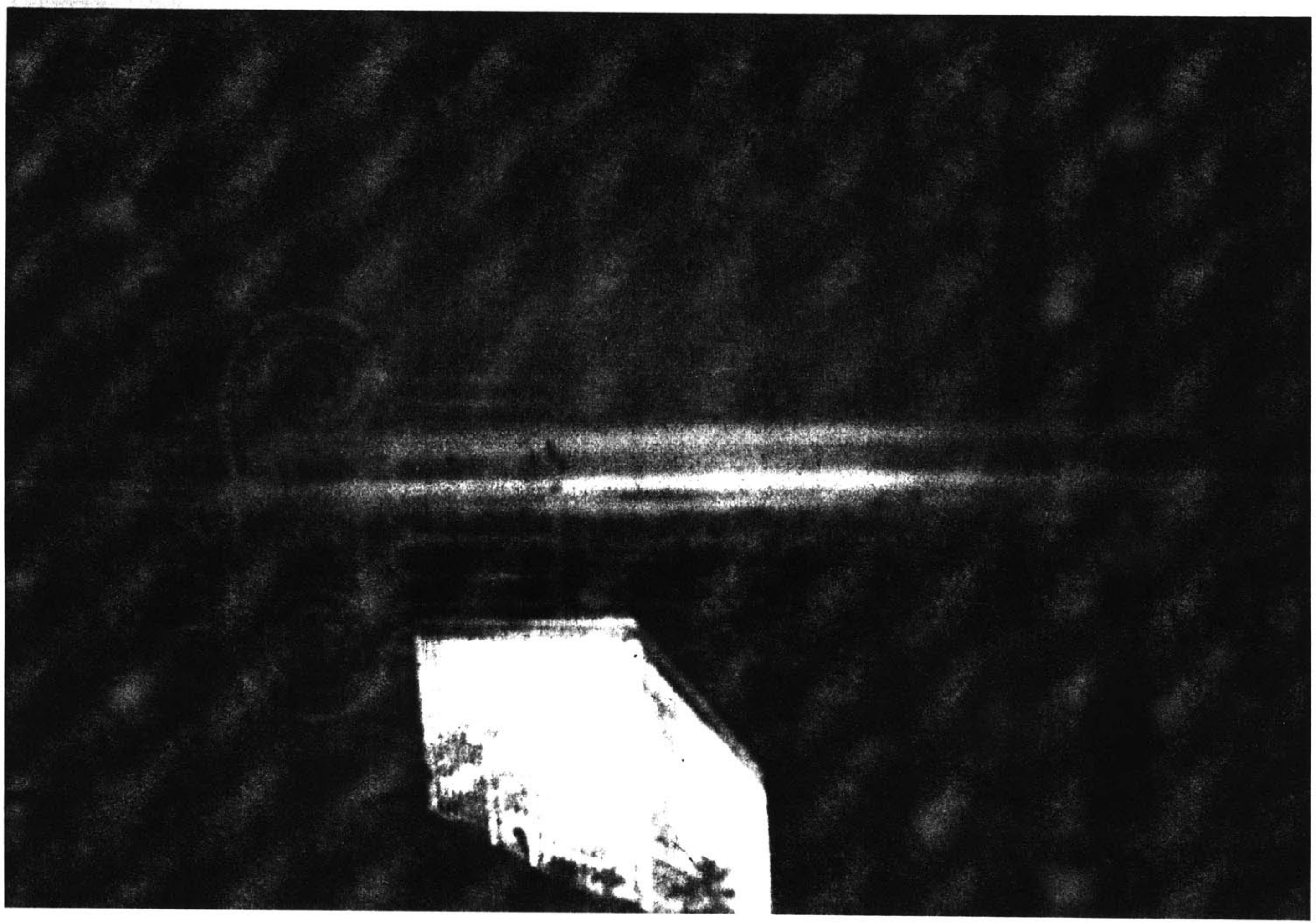


Fig. 33. A hotel for the millenia

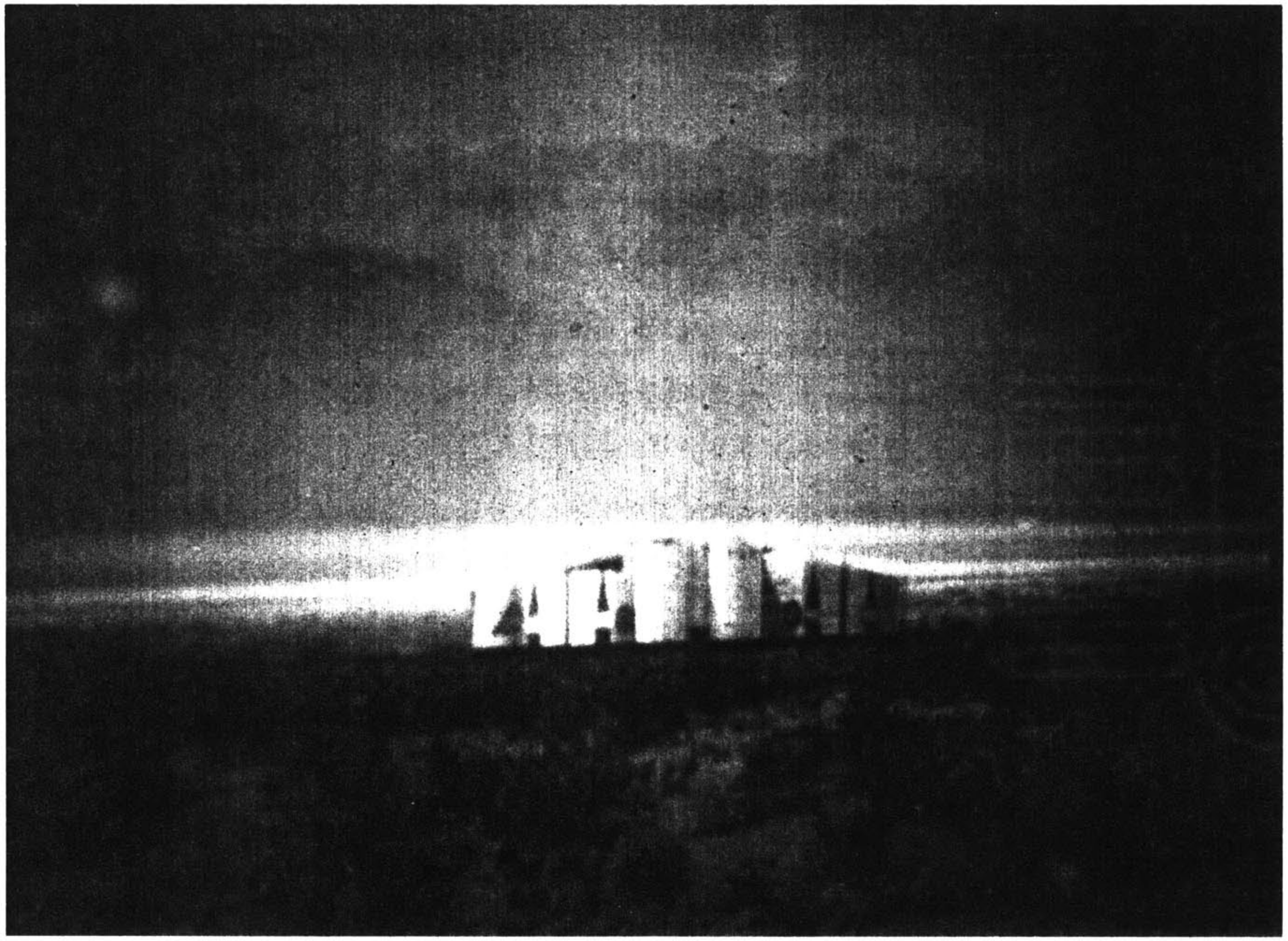


Fig. 34. A reconstruction of Kahn's National Assembly Hall as a building to last forever.

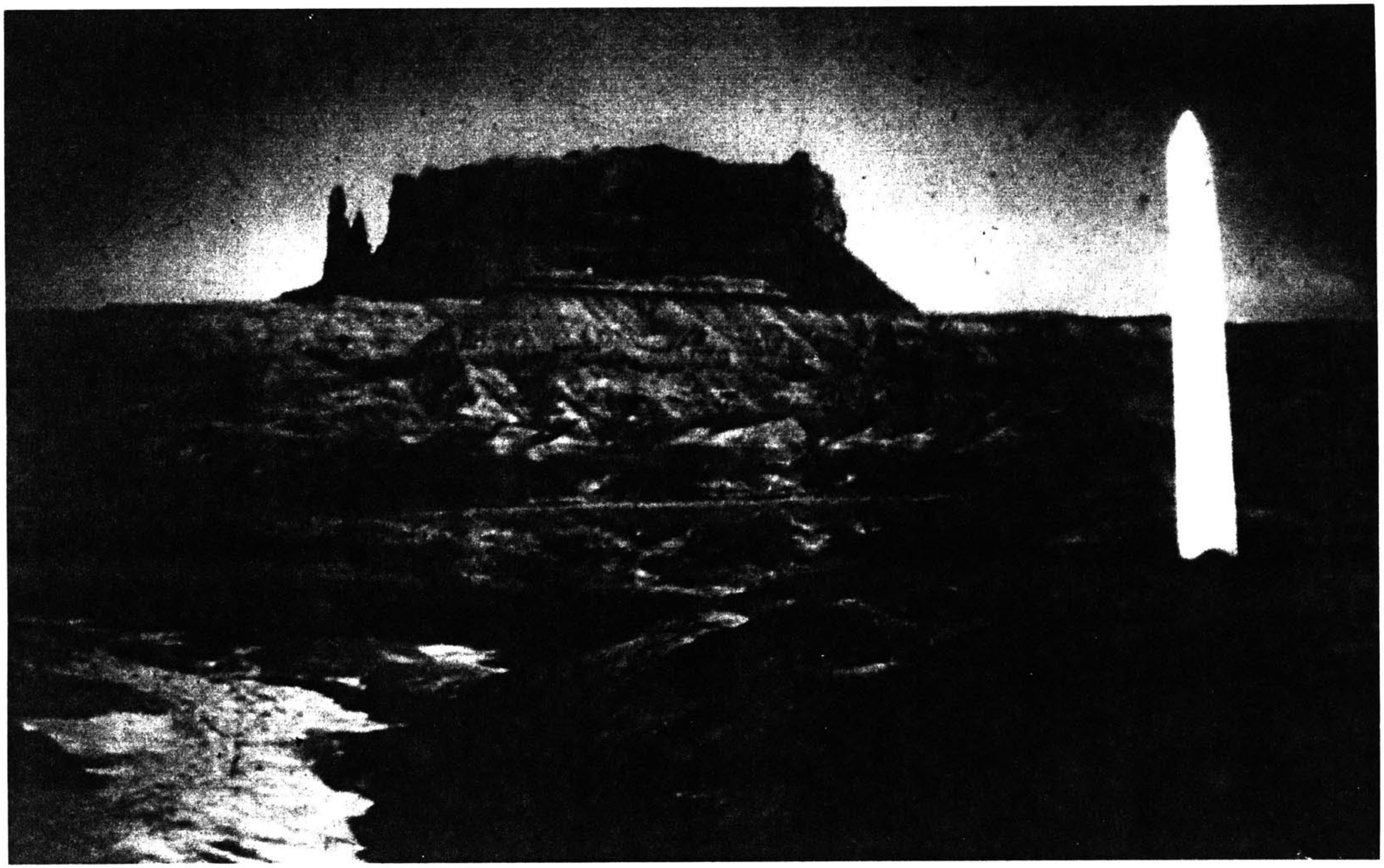


Fig. 35. Washington monument as nuclear waste marker

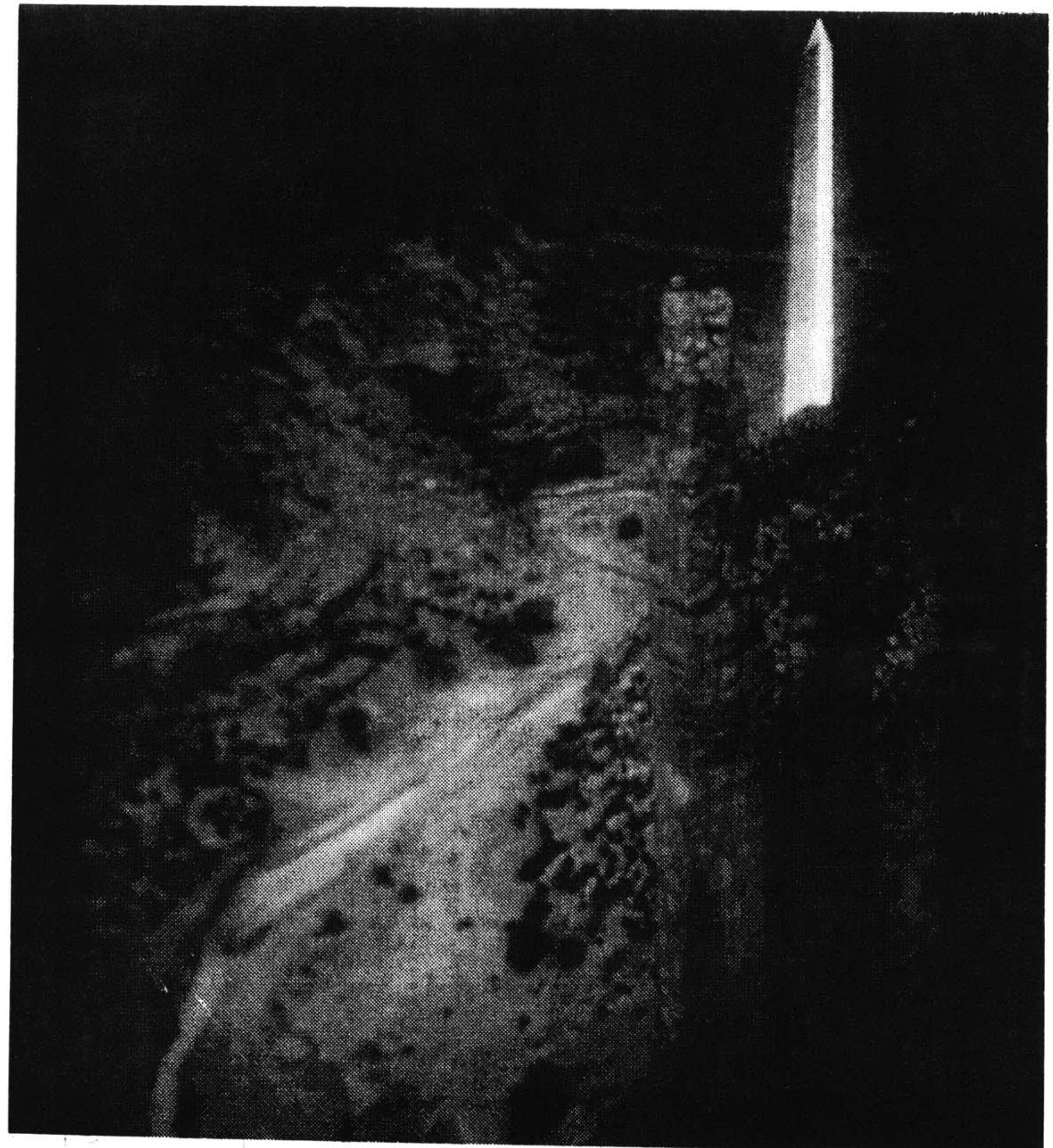


Fig. 36. Washington monument as nuclear waste marker

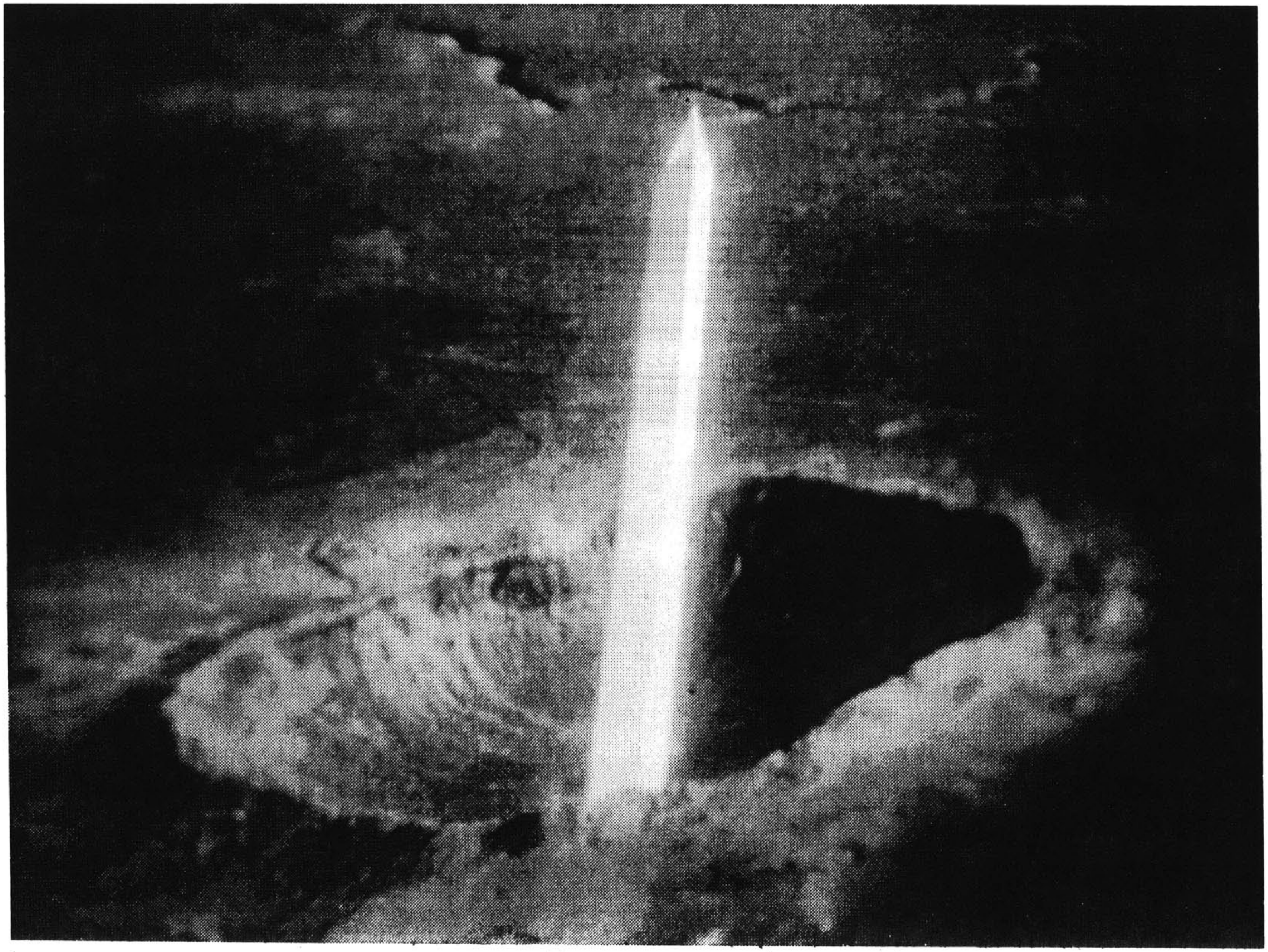
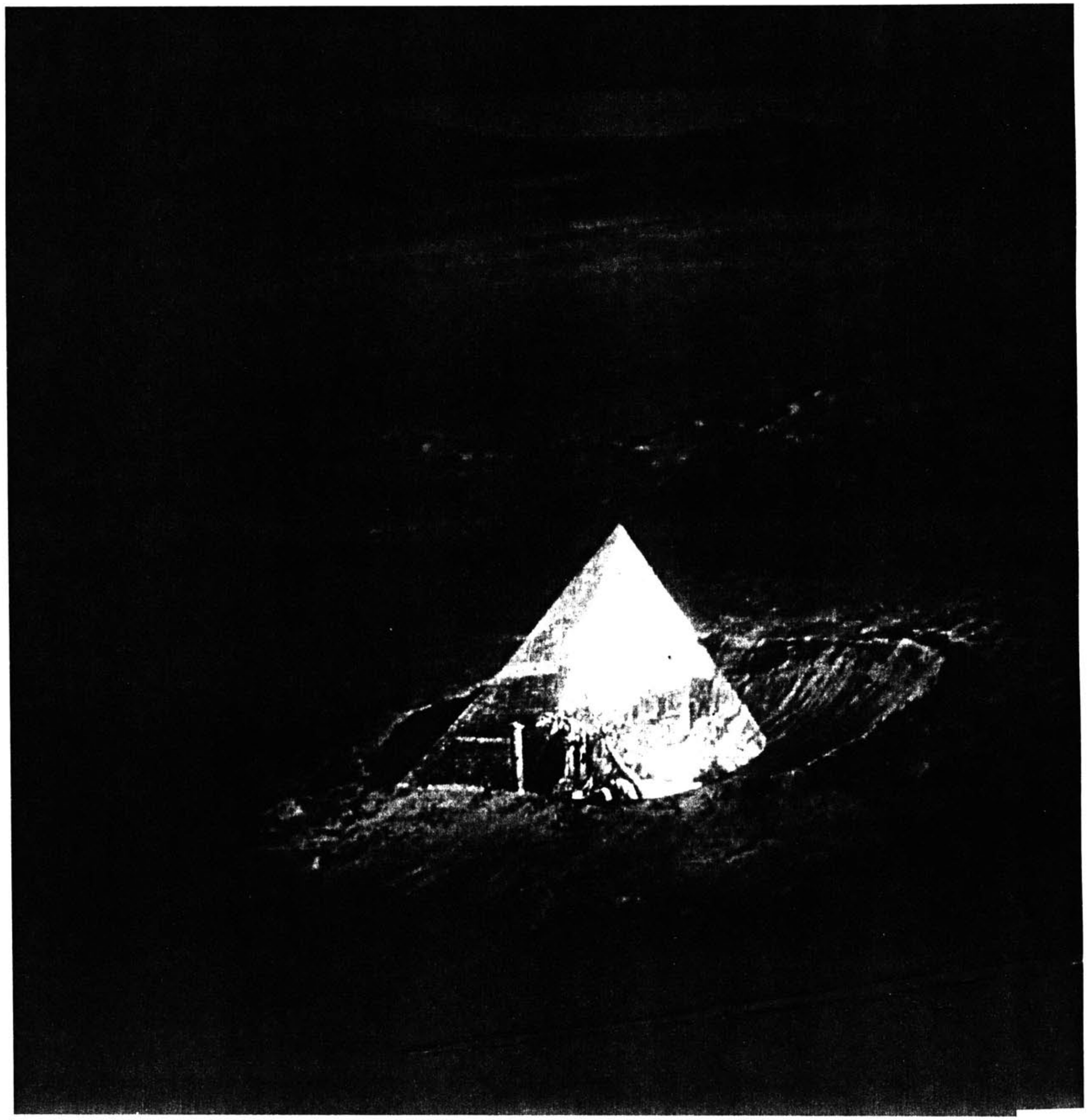


Fig. 37. Washington monument as nuclear waste marker

Fig. 38. A pyramid in a meteor crater



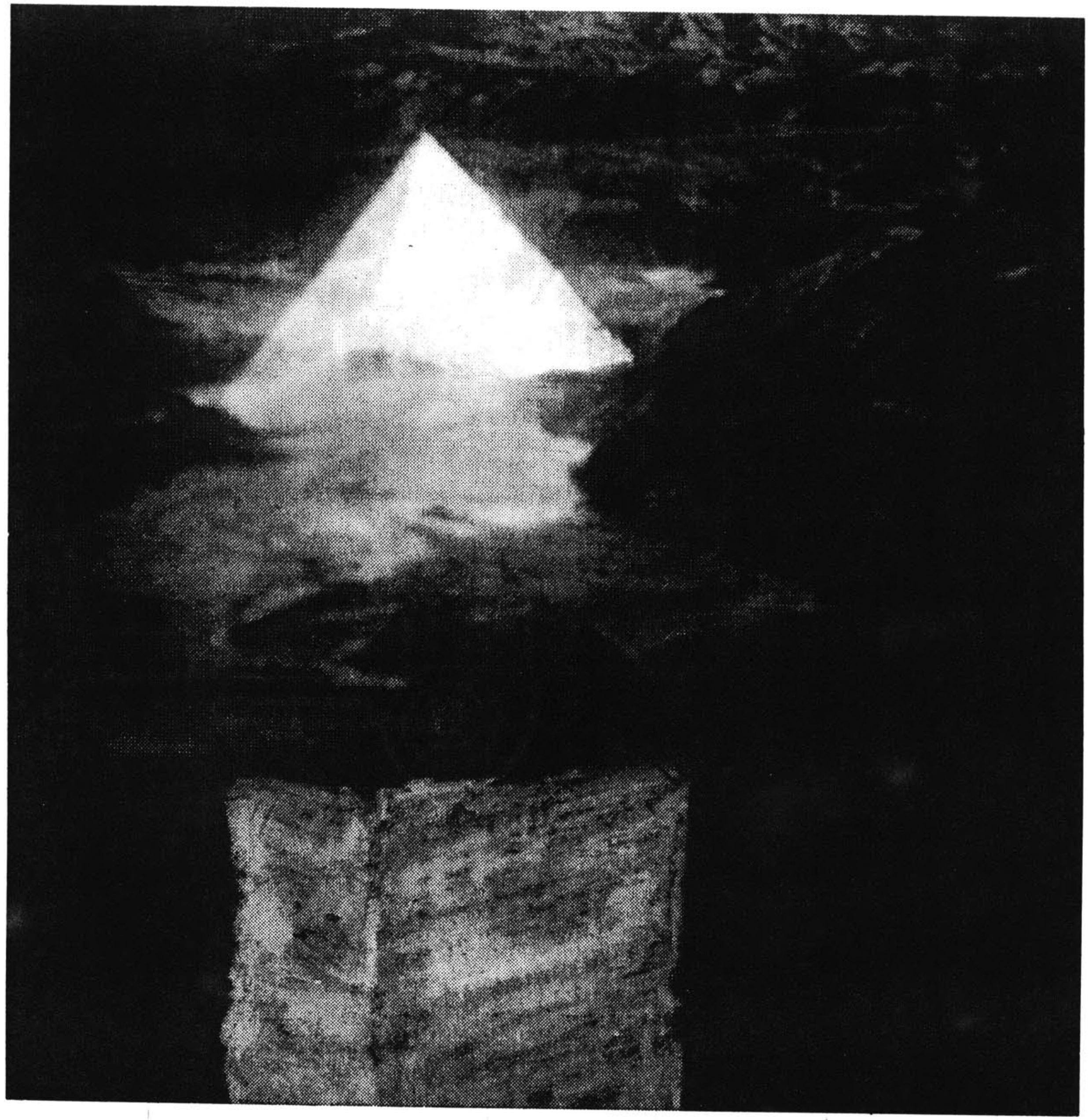


Fig. 39. A pyramid that is "just the tip of the iceberg"

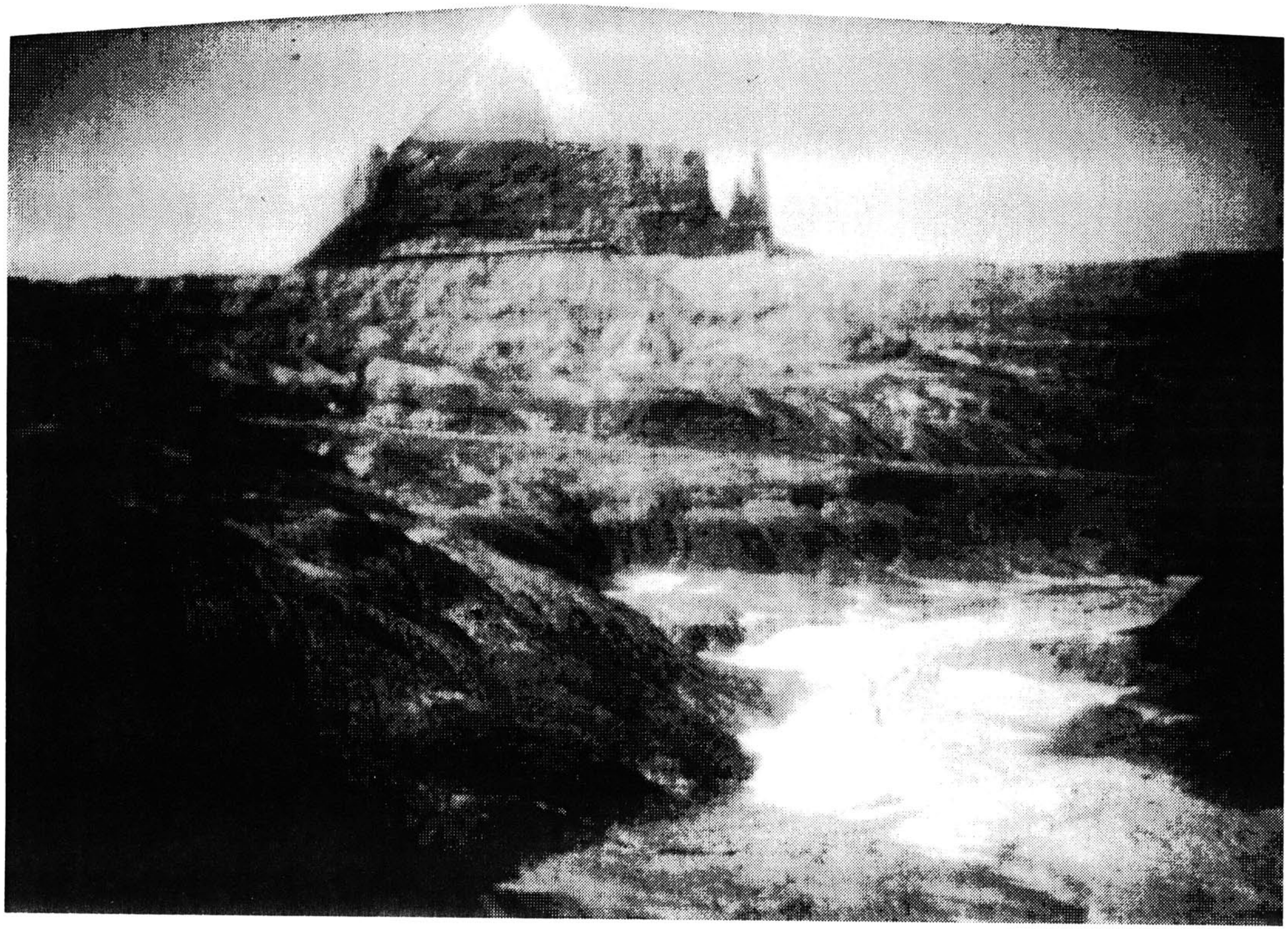


Fig. 40. A pyramid built on a butte

Fig. 41. A gargoyle

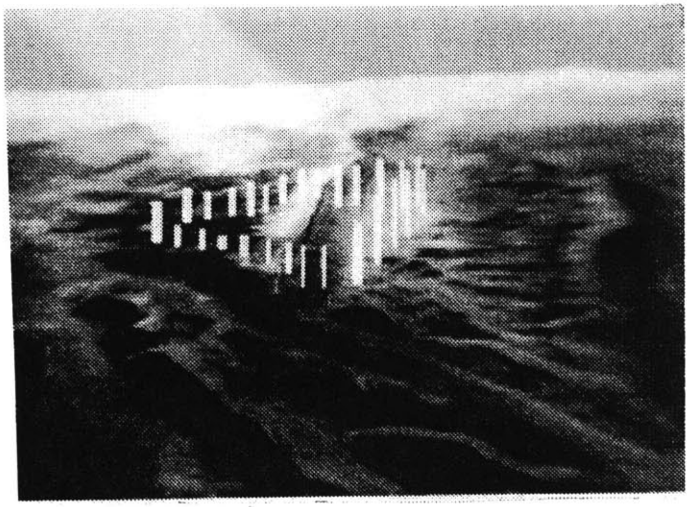
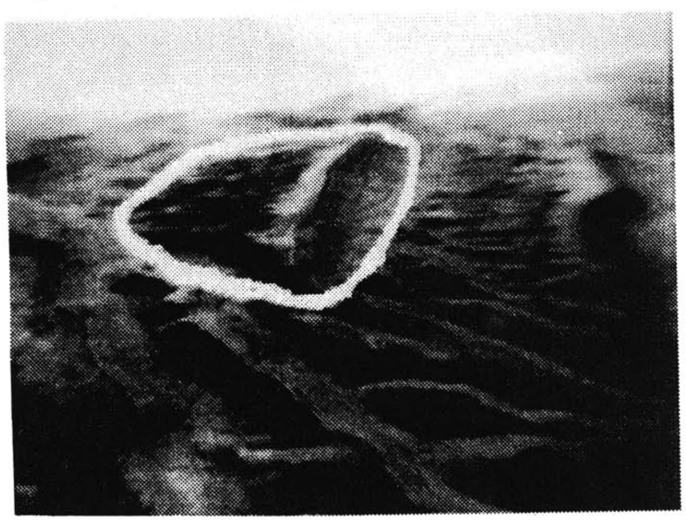


Fig. 42. Marking the perimeter of a waste depository

Fig. 43. The Great Wall of Nevada



show the feelings of desolation of the place by recreating a late Rothko painting in the mountain.

A recreation of the forms of natural or man made disaster could be an effective warning. For example, volcanos or meteor craters could be recreated. Similarly, copies the Chernobyl power plant or craters at Yucca Flat could be built.

4.6 Possible Misunderstandings

If the warning device is not clear, the site will probably be used for other purposes. If the site is encircled with a wall, it could be used as a military barricade. If the site has towers marking the perimeter of the waste tunnels, these could become radio towers or religious icons.

5. Large Toxic Sites

The design of our large toxic landscapes generally gives little consideration to their future use. Reyner Banham describes several of these places . "If there is a point on the earth's surface, that, for me, brings to a pustular head all the insults done upon the desert by the extractive industries, it is at Bairoil.." He compares the Bairoil site with another toxic site, "At the generating station on Navajo land...."Those enormous isolated power plants with their geologically sized open cast coal pits do have grand Miltonic scale and manifest bloody-mindedness. However ecologically evil they may be, they do , at least have the style of the devil, but Bairoil has no style."[17]

5.1 Reusable Sites

In order to equip ourselves for our ever more common toxic landscapes, we must alter our conception of waste. Lynch writes about the changes we need to make,"The road is part of the destination. Death, waste,and decay are an integral part of that becoming. Dying then must not be papered over nor should trash dumps be hidden sores. We need new rituals of death or of waste disposal to complement the gift giving and the bright wrappers associated with new things."[18]

New York City's Fresh Kills Landfill is a large "toxic-scape." The landfill is the size of three Central Parks. The process of dumping solid waste in this scale can be seen as mountain building. The New York City Sanitation Department is deciding how to cover and use the landfill when it is no longer a dump. Since the fifties the residents of Staten Island were told that the landfill could be turned into a park with baseball fields. But the landfill never closed. When it does close it will not be used for baseball fields because the garbage settles at varying rates. It is likely that people believing that the landfill would be converted into a park bought homes next to it. Indeed Staten Islands largest shopping center is across the street from the landfill. Fresh Kills may become a recreation area, but it will be a bizarre environment that has methane ventilation pipes poking through the manicured plantings.

Fig. 44. An open pit copper mine in Arizona

Stoke on Trent in England is another case. The pottery industry is located here. Kevin Lynch describes the situation,"Waste in the pottery industry is particularly voluminous; much of the total mass of the materials processed is left on the land, partly as waste sand, partly as broken or defective china ware."[20] Cedric Price proposed using the area's abandoned rail lines and stations as a university.[21]

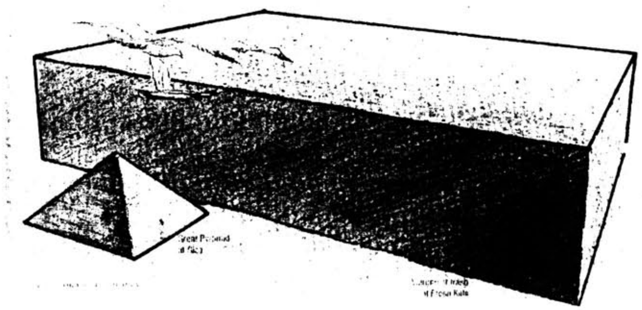


Fig. 45
A comparison between the largest pyramid at Giza and the New York City landfill Rathje 1991

5.2 Permanently Hazardous Places

There are sites where the reuse (with the current understanding) is hazardous. These places should be marked with signs designed to last a very long time. For example, the reuse of nuclear weapons testing area of the Test Site at Yucca Flat is inconceivable. But the demonic look of this place may be its own best warning.

It is more important to mark areas where the toxicity is invisible. How will a culture a thousand years from now know that Times Beach, Missouri, the town polluted by Dioxin, is poisonous? Archeology in the future may be a very hazardous profession. Generally, these toxic places have short term signs. The road to Times Beach has a relatively small barricade across it. As a result of the Chernobyl Accident, the radiation zone has a fence around it. "The village of Nozdrishche is already empty . On the outskirts, authorities have built a barbed wire fence. It curves between an apple orchard and a hay field. A sign at the gate warns,'Danger -Radioactive Zone.' The fence offers a pretense of demarkation ; the apples on one side are be, the hay on the other is good. But the fence is rusted , the lock broken, The gate hangs open. Through it headed towards the distant reactor, a stream of foot prints is etched in wet and muddy snow."[22]

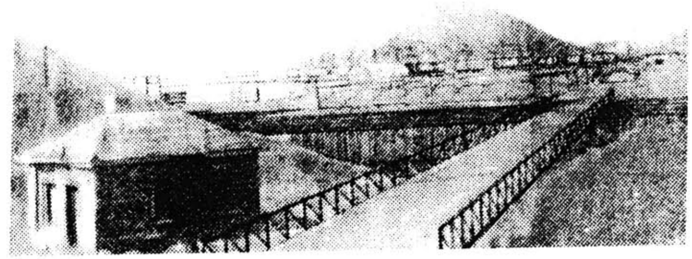


Fig. 46. Cedric Price's Pottery Thinkbelt Price 1984

6. Problems with Warning Icons

The evacuated zone around the Chernobyl plant was immediately looted. "One week after the accident, you could buy a radioactive television at the market in Gomel for a bottle of vodka."[23] In this context, it seems difficult to believe that any warning symbol could be effective. Yet, the DOE sponsored the study "Communicating Across 300 Generations" in an attempt to develop such a symbol. The most important aspect of marking a toxic site is that it must be clearly distinguished from the places which contain valuable objects. This is to say that Yucca Mountain must never be confused with the bunkers of gold at Fort Knox. We should make signs that say"Poison Here" and "Treasure Here." How we mark toxins inevitably has an impact on how we mark valuable goods. But if the ultimate symbol toxicity were developed, it would likely be used on locations without a hazard as a "No Trespassing" sign. Once the "bluff is called," the symbol's meaning will be gone.

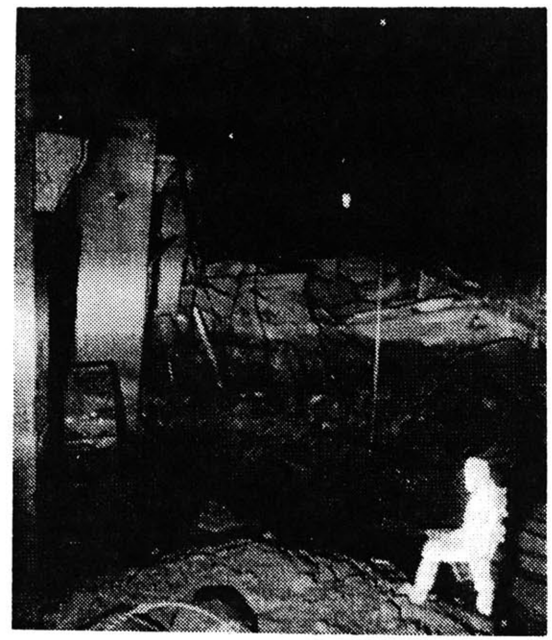


Fig. 47 A view from the core of the Chernobyl Power Plant

(Barringer, 1991)

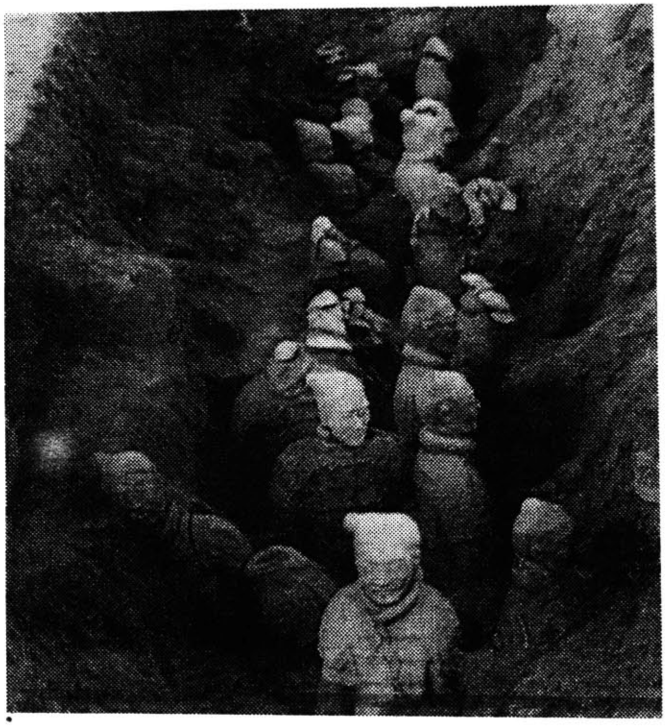


Fig 49 Clay body guards of the first Chinese Emporor, Qin (Hearn, 1979)

Fig50 Amateur archiologists at work (Lynch 1972)

7. Landscape of Permanence

Over its toxic lifetime, the waste will be the one piece of this landscape which will not change. The topography, and the plant and animal life will evolve continually. The longevity of the waste should be harnessed in considering how to mark the site. Whatever marking is put on the site should have at its root a desire to "tag along" with the waste for its "ride through time." Therefore information which we want to protect for the far future should be kept here. This body of knowledge will teach its readers about the dangers, the history, and the context in which the waste was produced.

7.1 Preservation vs. Conservation

This information must be stored so that it does not deteriorate. According to Kevin Lynch,"Preservation is keeping something in a state impervious to change. Conservation is the maintenance of a resource over time."[24] The ultimate example of "conservation" is the Japanese Shinto Temple at Ise. It has been rebuilt every twenty years for the last thousand years. This building is ancient because its original design is ancient and at the same time it is living in the present by being rebuilt so often. Nuclear waste storage needs to have a degree of "preservation" in its design. The radioactive waste decomposes at such a slow rate that, from a human time frame, it is effectively permanent. Because the waste does not change, the rock that surrounds it must be "preserved" so that the larger environment is protected. Information associated with the site must be "conserved" so that it will last a long period of time and can be used by future civilizations. Lynch discusses the amount of effort we should put into saving and documenting our resources." The criteria for inclusion in this set of things to be conserved are that the resources must be ones that are likely to remain important for generations to come and that if used properly they do not waste away. In that case, a very high present cost for preserving them can be justified, even though we are unable to foresee the far future with any precision and so cannot compute the present value of the conservation."[25]

7.2 Repository and Library

As we need to transform how we think of waste we must see HLW as part of a process. It begins with mining the uranium, enriching it, using it for fission, burying it, and waiting for its decay to complete. Warning and information are an integral part of the waiting and thus an integral part of using uranium. While the waste will be a liability to our progeny, the information, kept near the waste should be seen as a gift.

This Library of information should include: medical information, so that if contamination occurs we can offer some assistance; cultural information, to understand the context that the radioactive material was produced; and genetic and biological databases, like a modern Noah's Ark to help maintain the genetic diversity of the planet. We need a body like the ancient Chinese who are "reputed to have had an official tribunal whose duty it was to decide what events were worth remembering and therefore worthy to be passed down to future generations."[26]

The information that we deposit in this library will be in code. This code will be at least the six official languages of the United Nations and in a pictorial code. According to David Givends of the American Anthropological Association,"Lexicostatistics studies shows that 19% of a language's basic words change every 1,000 years."[27] As a result, within 12,000 years English will be unintelligible. The library will therefore need to include a series of Rosetta stones.

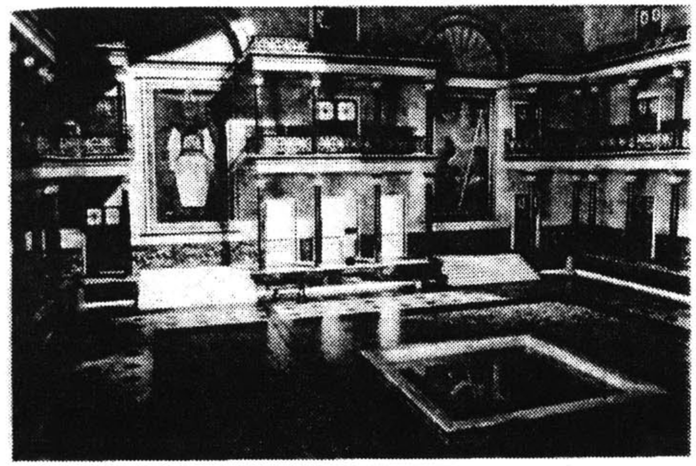


Fig. 51 A model of the Library at Alexandria (Sagan 1980)

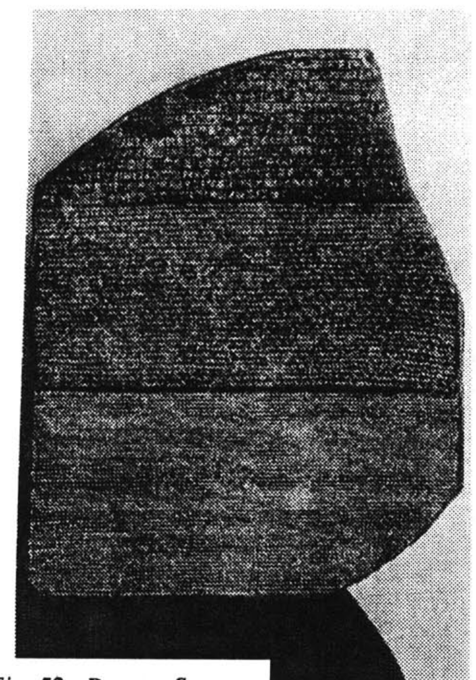


Fig. 52. Rosetta Stone

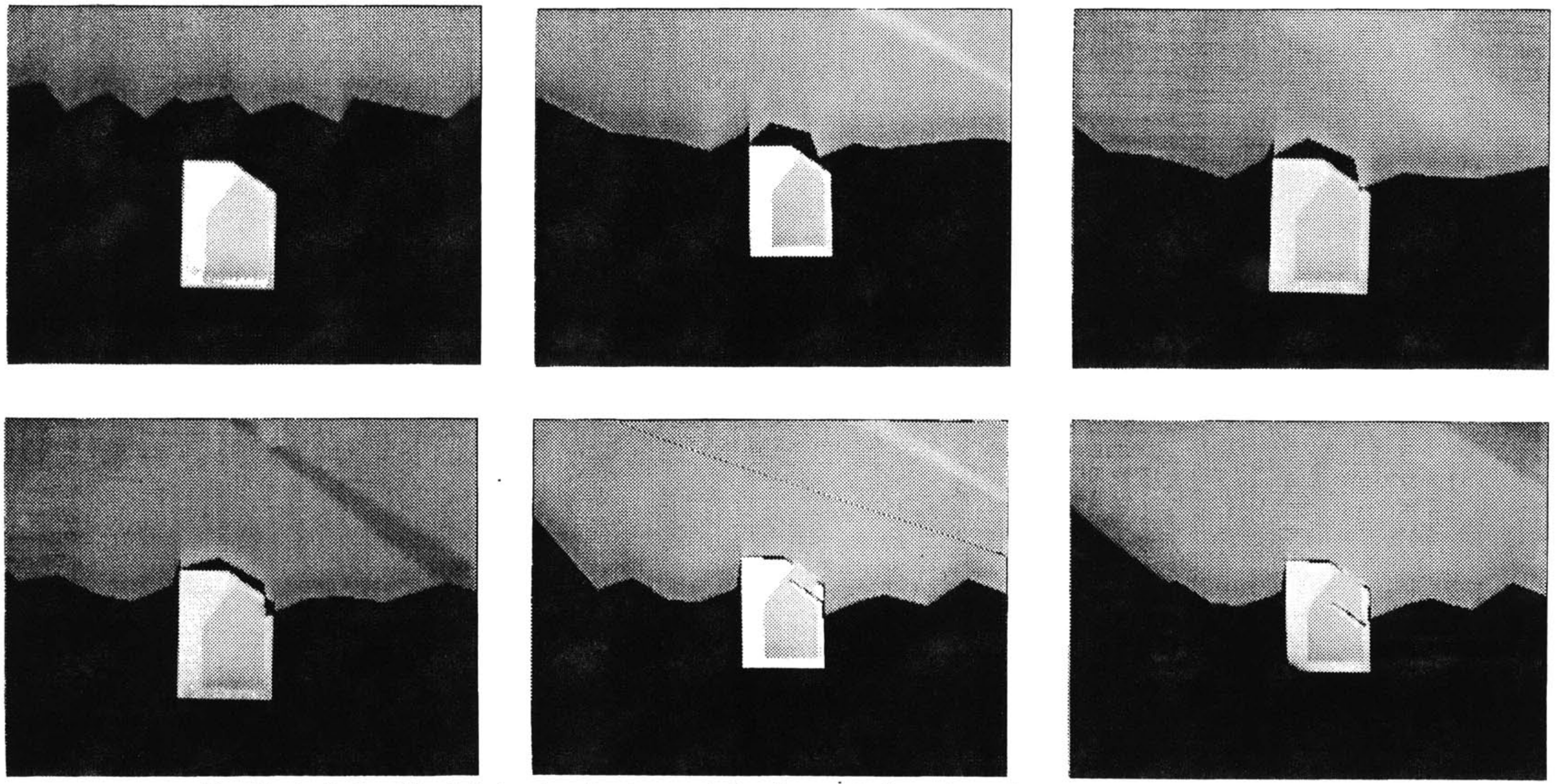
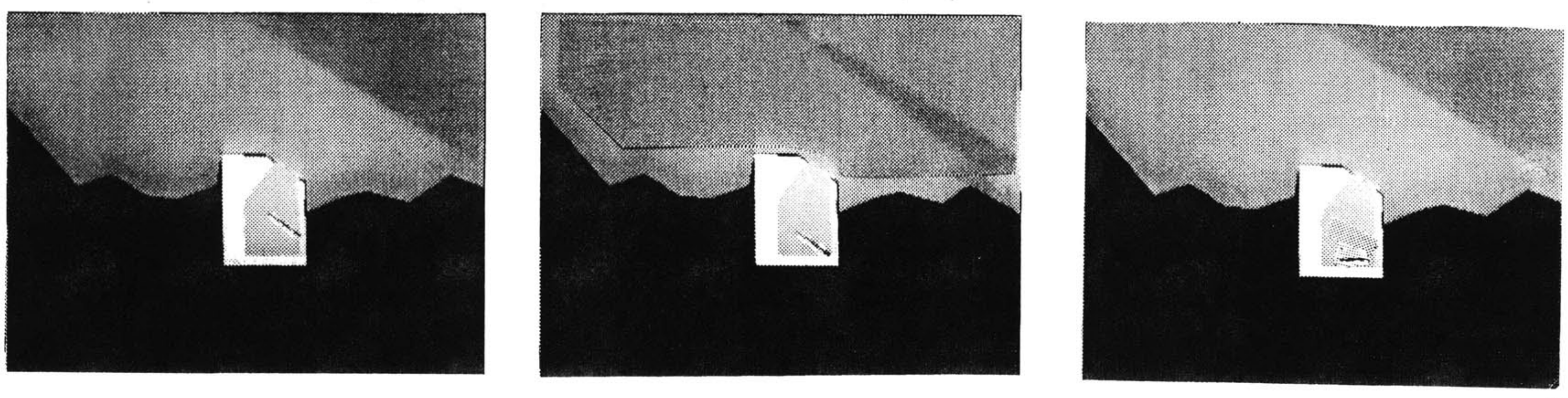
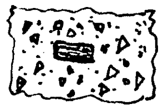


Fig. 53. An isolated buried chamber that is revealed and opened through erosion

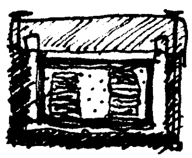


7.3 Storage Methods

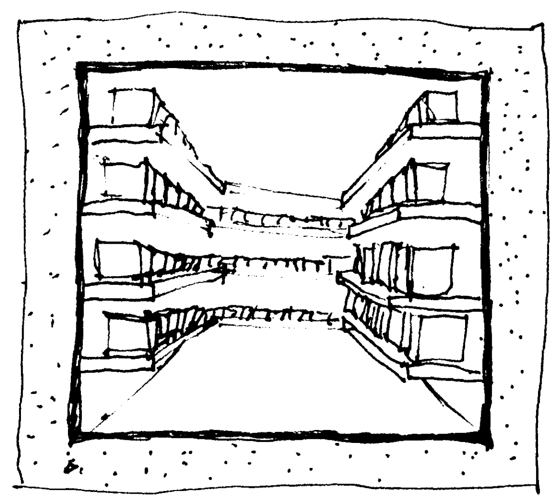
The storage of information for millennia requires very secure casework. Information could be stored inside a brick. The brick would protects its contents even after the library fell apart. As the library is lying in ruins the bricks might be hauled off the site and used for building material. Eventually they would break open and reveal their message.



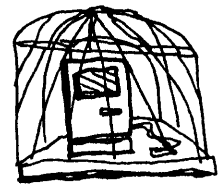
Information could be put in a box that is air tight and filled with an inert gas.



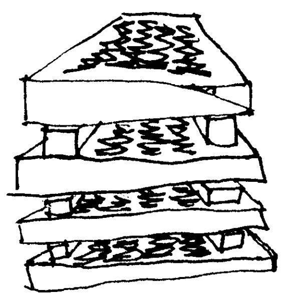
Information could be put on shelves in a room that is air tight and filled with an inert gas.



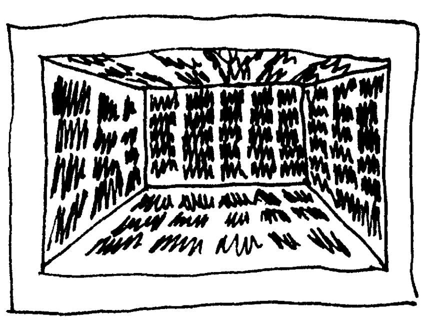
Information could be put in a computer and the computer stored using a yet unknown technique that would inhibit its circuit boards from breaking down.



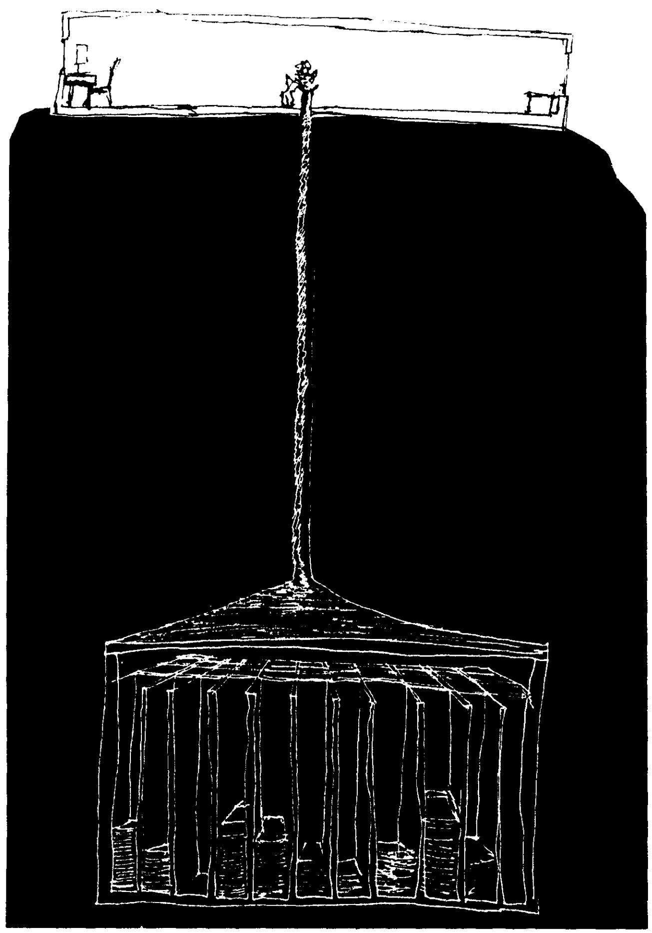
Information could be etched on stone tablets and stacked.



Information could be etched on a wall.



In order to keep the information secure, the doors of the library would need to be sealed upon its completion. This makes adding material problematic. But using the storage method shown below, information could be compiled over time while still keeping the repository inaccessible. In this scenario, as discoveries are documented, they are dropped down a shaft and mechanically sorted by subject.



7.4 Cryptological Framework

The entire project can be looked at as a cryptological problem. The waste is dangerous because it destroys genetic codes. The library teaches and preserves codes. In order to complete this conceptual picture institute of genetic codes should go on the top of the mountain. In this scenario, there is the active scrambler, the steady state code repository, and the active decoder. The scheme in fig. 54, is sited above the waste repository. It has a genetics lab on its top and an inaccessible storage of information on the bottom (the waste repository is well below this level). Large monoliths etched with crude information connect the lab with the storage. A spiral ramp is dug to access isolated rooms for sealed storage. These rooms will be uncovered through erosion as illustrated in fig. 53, which is taken from an animation sequence.

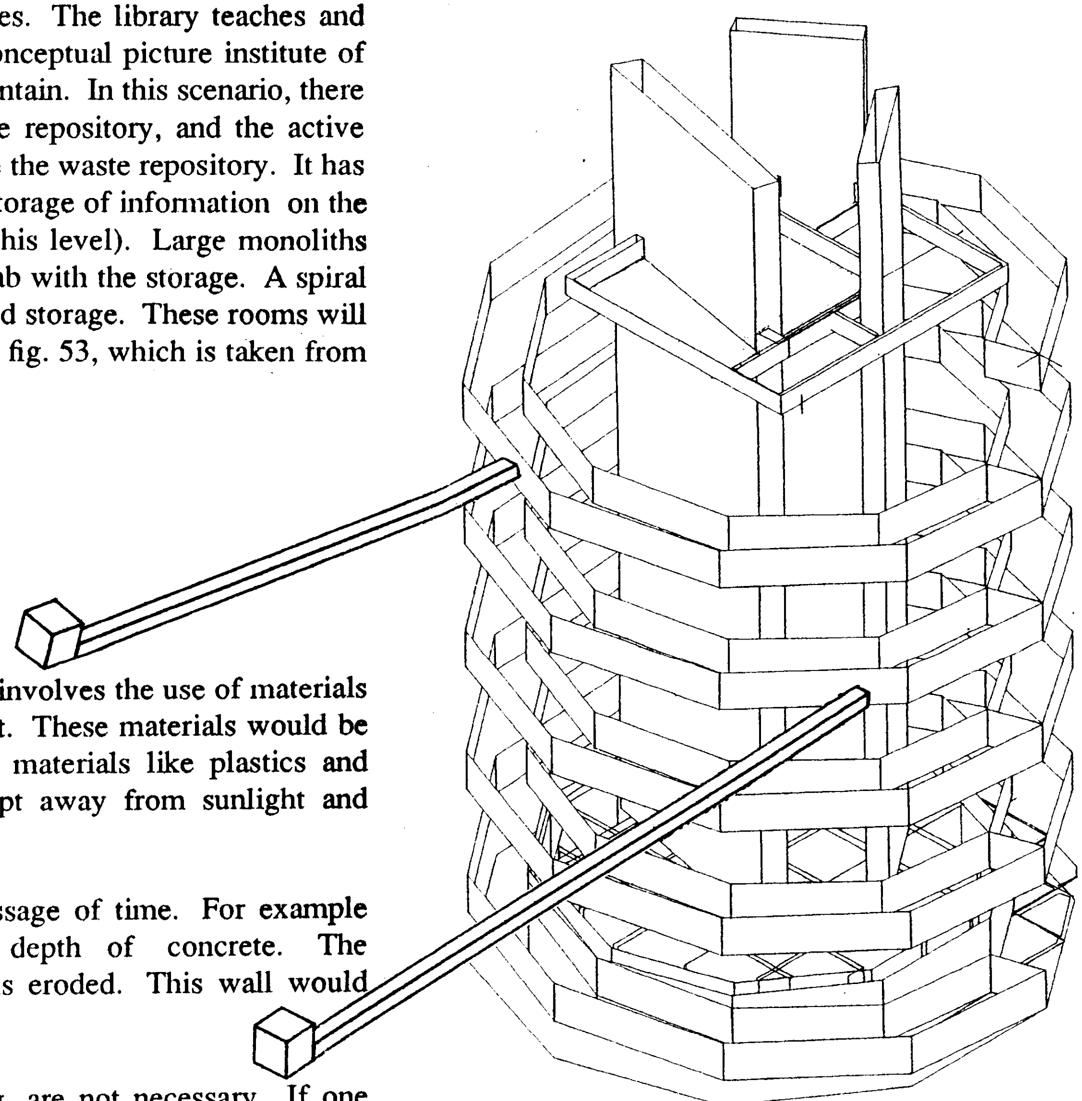


Fig. 54. A genetics lab with an information repository below it and isolated chambers around it

7.5 Materials

Housing information associated with the site involves the use of materials that can last for the time frame of the project. These materials would be reinforced concrete, glass, and stone. Also materials like plastics and pressure treated wood could be used if kept away from sunlight and oxygen.

The use of materials can accentuate the passage of time. For example hieroglyphics can be embedded in the depth of concrete. The hieroglyphics can be revealed as the wall is eroded. This wall would unpeel like an onion.

The mechanical systems in this the building are not necessary. If one considers how much effort future civilizations will have to put into investigating this place, then it is fair to assume that they can provide their own power, and heat.

8. The Library of Yucca Mountain

"The universe (which others call the Library) is composed of an indefinite, perhaps an infinite, number of hexagonal galleries, with enormous ventilation shafts in the middle, encircled by very low railings. From any hexagon the upper or lower stories are visible, interminably. The distribution of the galleries is invariable. Twenty shelves--five long shelves per side--cover all sides except two; their height, which is that of each floor, scarcely exceeds that of an average librarian. One of the free sides gives upon a narrow entrance way, which leads to another gallery, identical to the first and to all the others. To the left and to the right of the entrance way are two miniature rooms. One allows standing room for sleeping; the other, the satisfaction of fecal necessities. Through this section passes the spiral staircase, which plunges down into the abyss and rises up to the heights. In the entrance way hangs a mirror, which faithfully duplicates appearances. People are in the habit of inferring from this mirror that the Library is not infinite (if it really were, why this illusory duplication?); I prefer to dream that the polished surfaces feign and promise infinity... "

from the Library of Babel
by Jorge Louis Borges

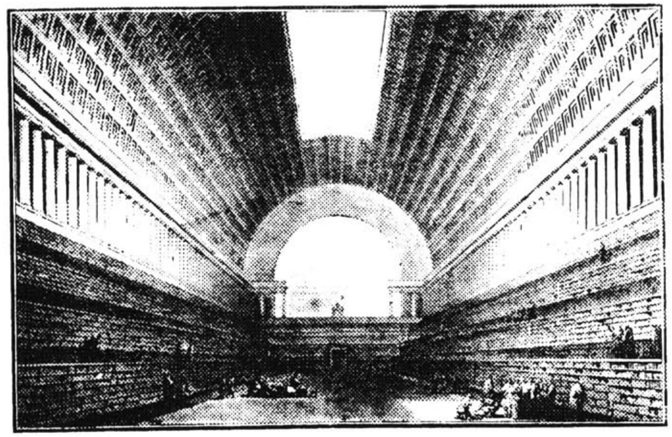


Fig. 55. Boulee's Bibliotheque Nationale

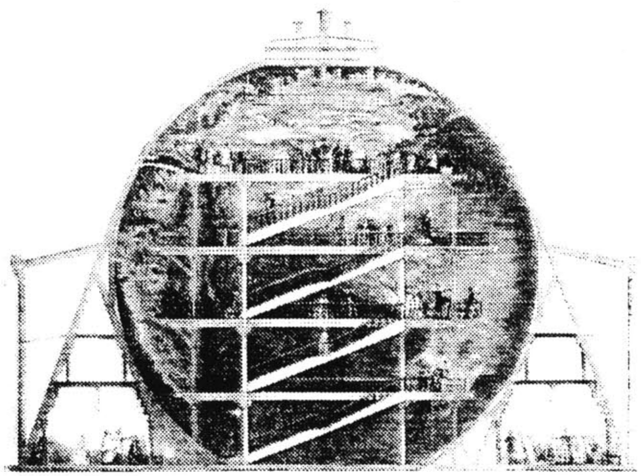


Fig. 56. James Wyld's geographic globe Leicester Square, London 1851-1861

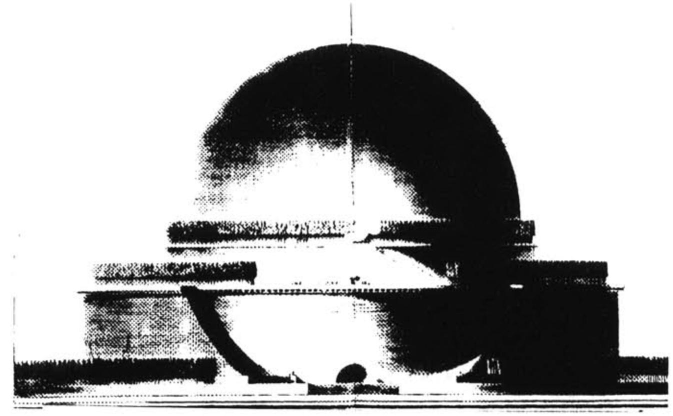


Fig. 57. Boulee Cenotaph for Newton

Fig. 58. An archeologist Gore 1991

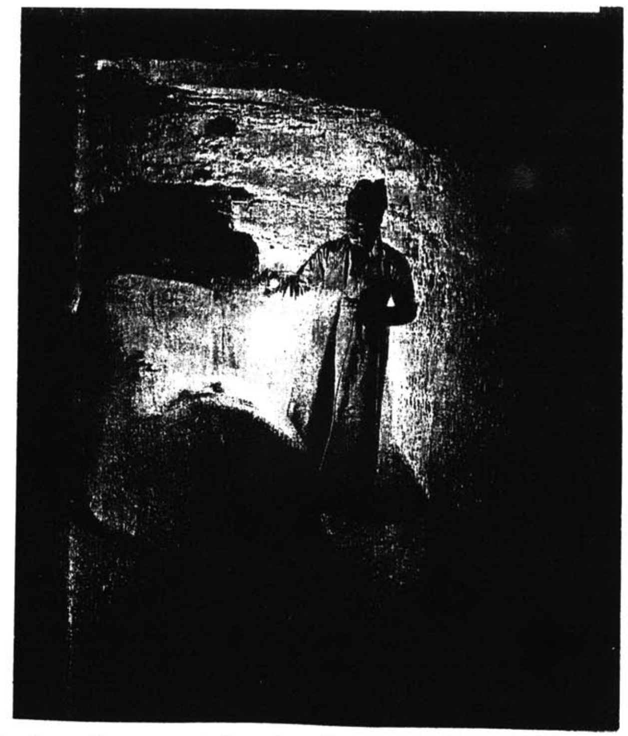
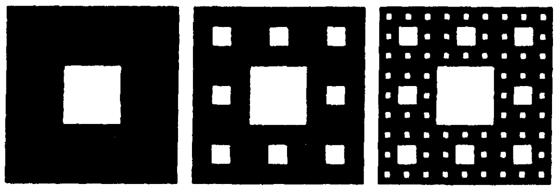


Fig. 59. A newly excavated tomb at Saqqara Gore 1991

8.1 Description

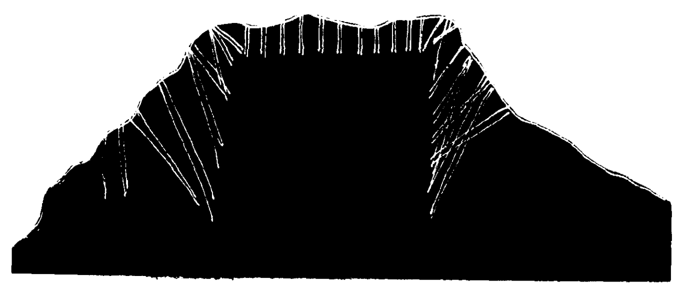
The Yucca Mountain Library will be a space which will look highly logical. It is essentially the inverse of a menger sponge. A menger sponge is a square with a square one third its size in its center and with eight squares 1/9 its size around it. This pattern recurs adinfinitum.



In the design of the Library, instead of putting a square inside a larger square, I put a cube projecting out of the center of a square and then surrounded this cube with eight smaller cubes. The square is 300 feet high. The cube projecting from the center is 100 feet on a side. The next smaller cube is 33.3 feet and the next smaller cube is 11.1 feet and the smallest is 3.7 feet.

The largest cubes are solid except of a small tunnel running through their center. The 33.3 foot cubes are auditoria and study areas . The 11.1 foot cubes are sealed stacks and the 3.7 foot cubes are cabinets for more sealed storage. The smallest cubes on the walls are the back side of draws which are accessible from corridors which encircle the building. All the cubes except for the largest will be made from reinforced concrete. The tunnels that encircle the cube will be carved from the rock. The rock that surrounds the library will be drilled and thus weaken so that as it erodes it will form a cube. As the ground erodes the skylights are uncovered and the library will be lit.

Fig. 60. How to make a cube from a butte



The amount of erosion determines where one can enter the cube; before the ground erodes one would enter from the top . As the ground erodes away entering from the side is possible.

At some time in the future an explorer will probably come upon the cube. He or she or it (or whatever the gender) will see an inset in the center of its sides. The inset is a stone that can be pry out of the way. Moving this stone the explorer will find a passage . The passageway will take him to the middle of a wall in a 90 foot cube space. Drawn on the wall will be warnings about the site. The explorer must climb down to the floor of the chamber. The paintings on the wall are fit into frames 11.1 feet square.

The explorer sees five passageways on all the four sides and on the roof of the room . They are like the hallway that he took. But he thinks it might be possible that there could be a passageway that goes down from the center panel of the floor. By prying up the floor panel the explorer finds a spiral staircase.

Climbing down 100 feet he emerges in an enormous three hundred foot high space with a massive three dimensional cross in it.

There are recursively smaller cubes projecting out of the wall, the floor, and the ceiling. Here he realizes that the room with the paintings was in the center of the entire space. He gaspes with wonder.

To get to the upper floors of the structure, the explorer goes to the corners where the stairs are. The stairs surround an elevator shaft. The elevator has probably ceased working millennia ago. (even if it still worked there would be no power for it.) The smallest cubes on the wall are the back end of drawers which are approached by a ladder on a roller. After this building has eroded away another will begin to emerge from the soil.

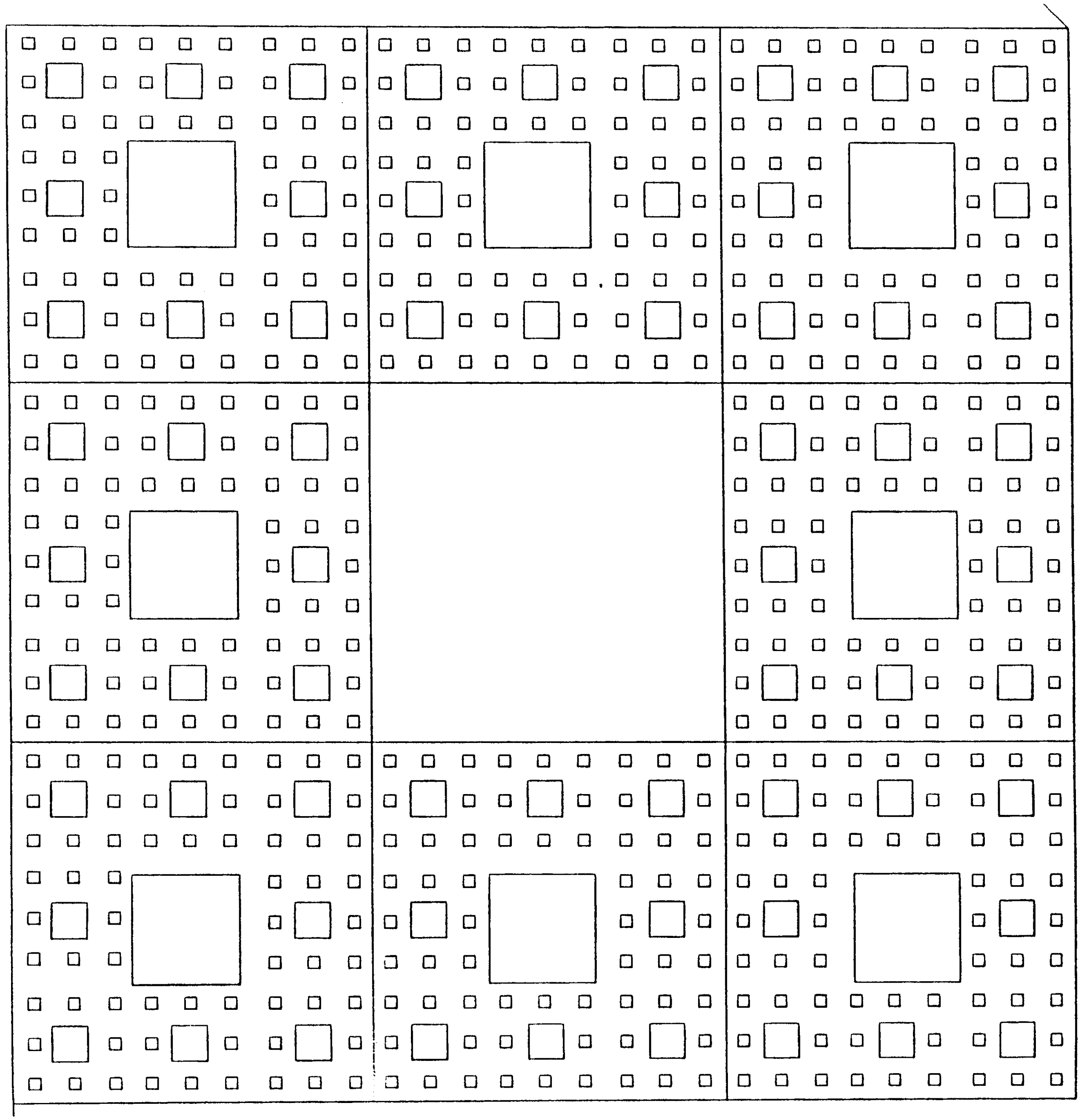


Fig. 61. A two dimensional Menger Sponge better known as a Sierpinski Carpet

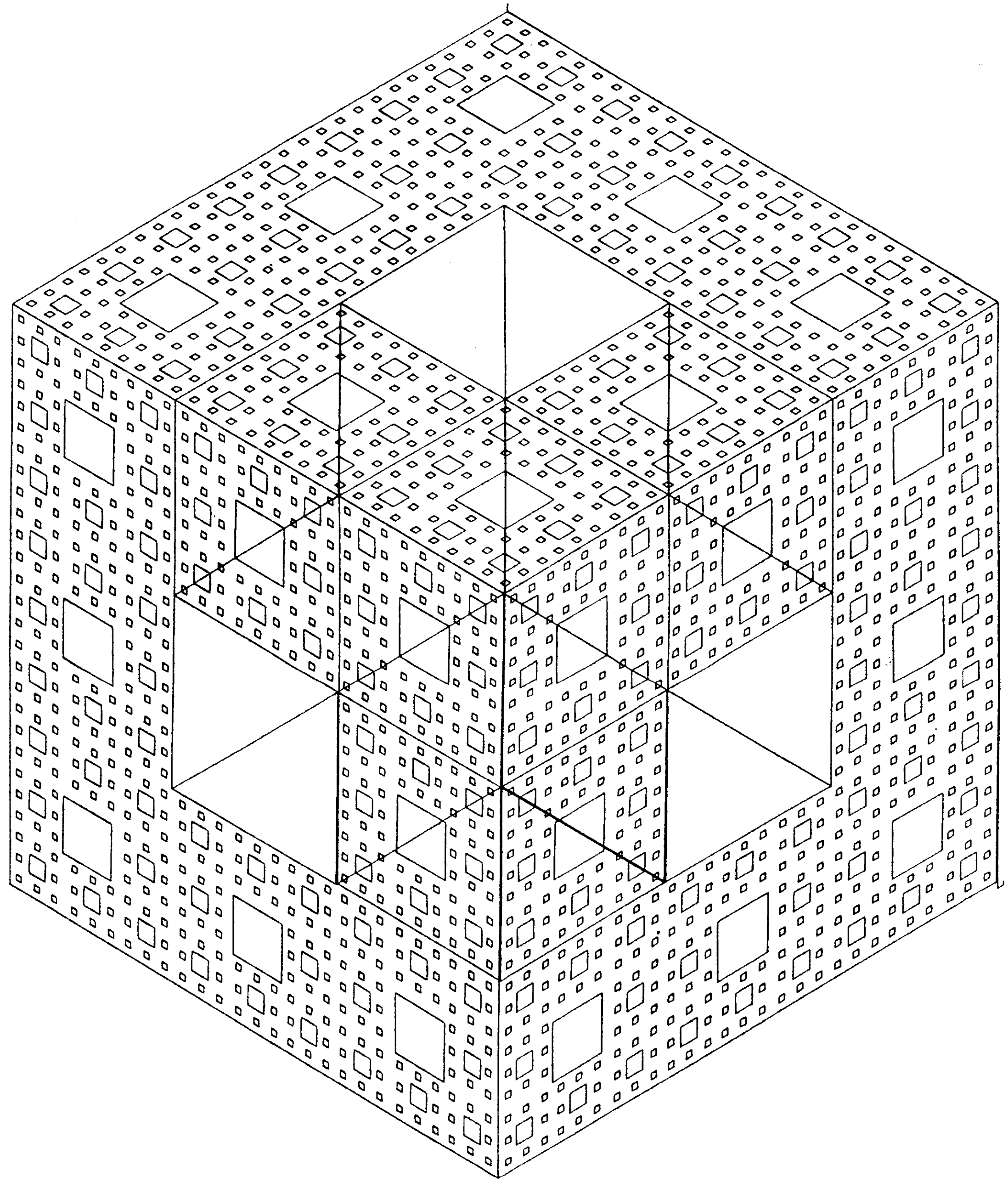


Fig. 62. A Menger Sponge

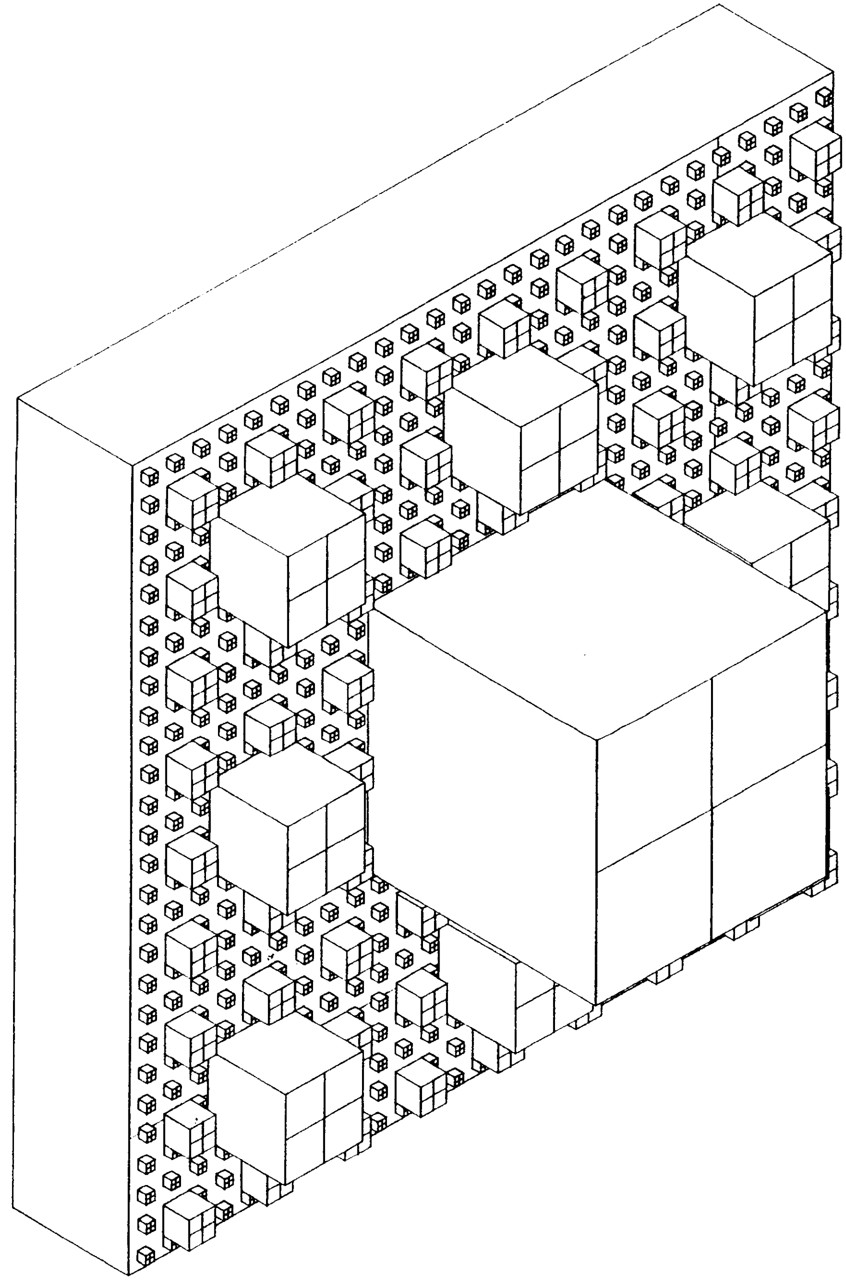


Fig. 63. The first wall

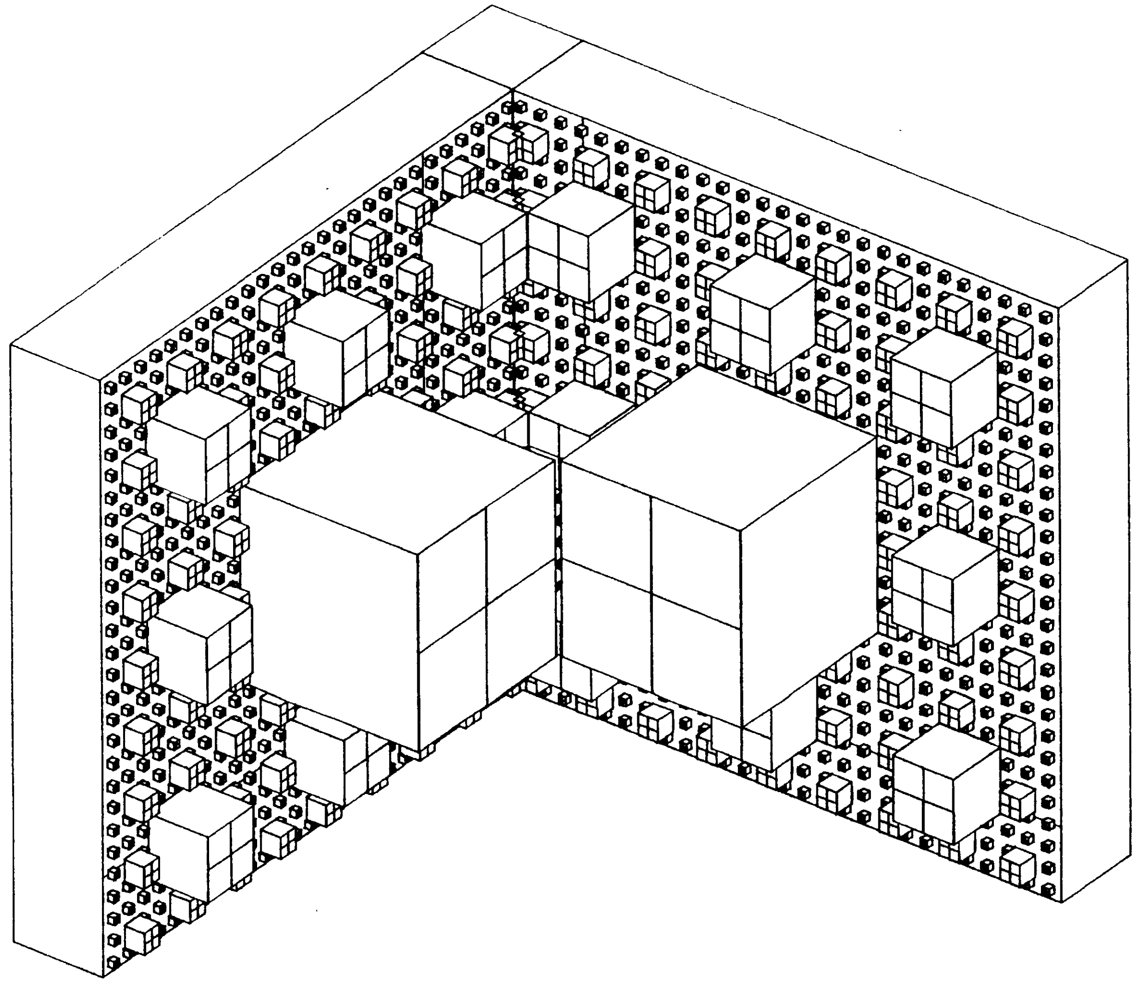


Fig. 64. Two walls

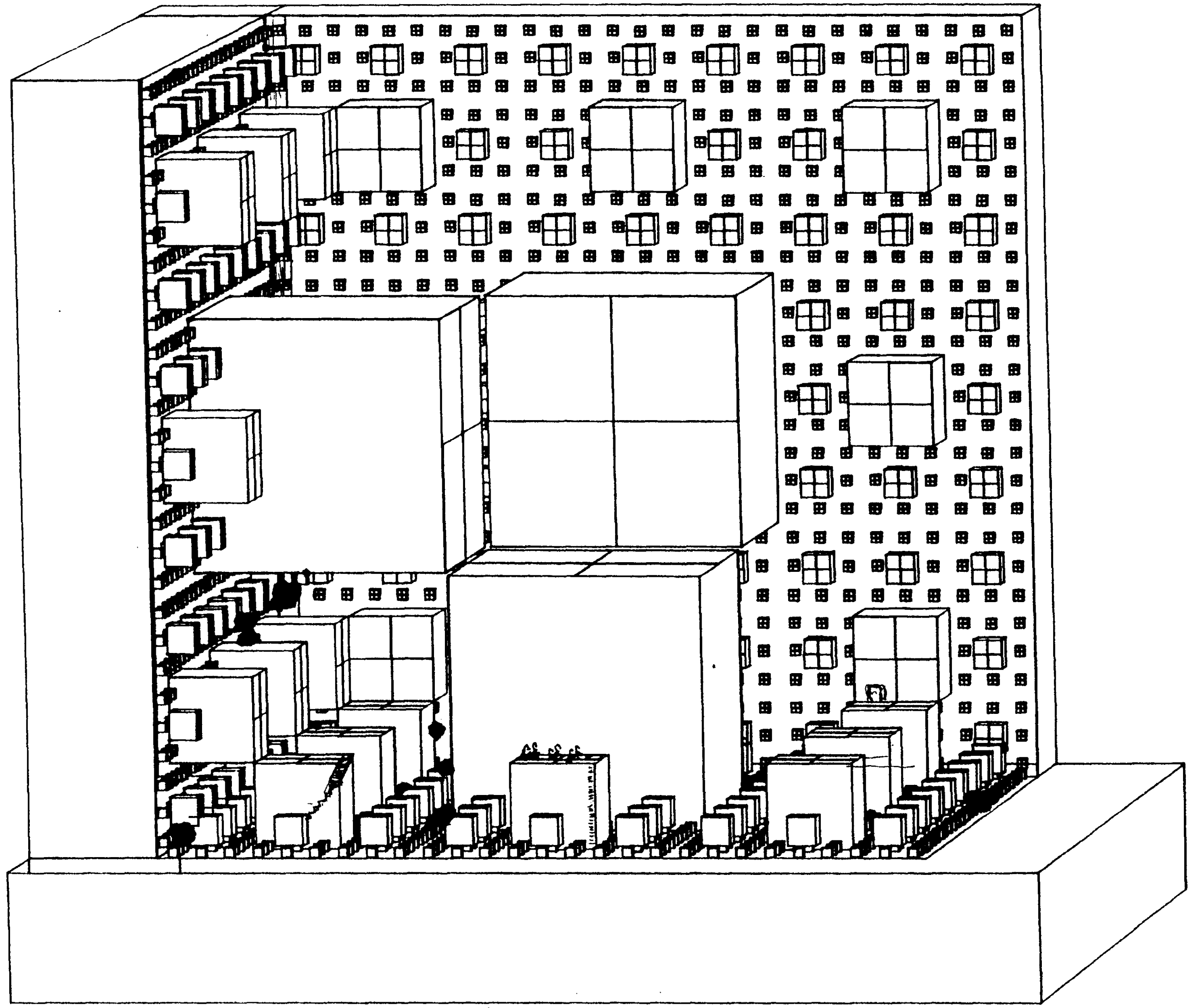


Fig. 65. Three walls

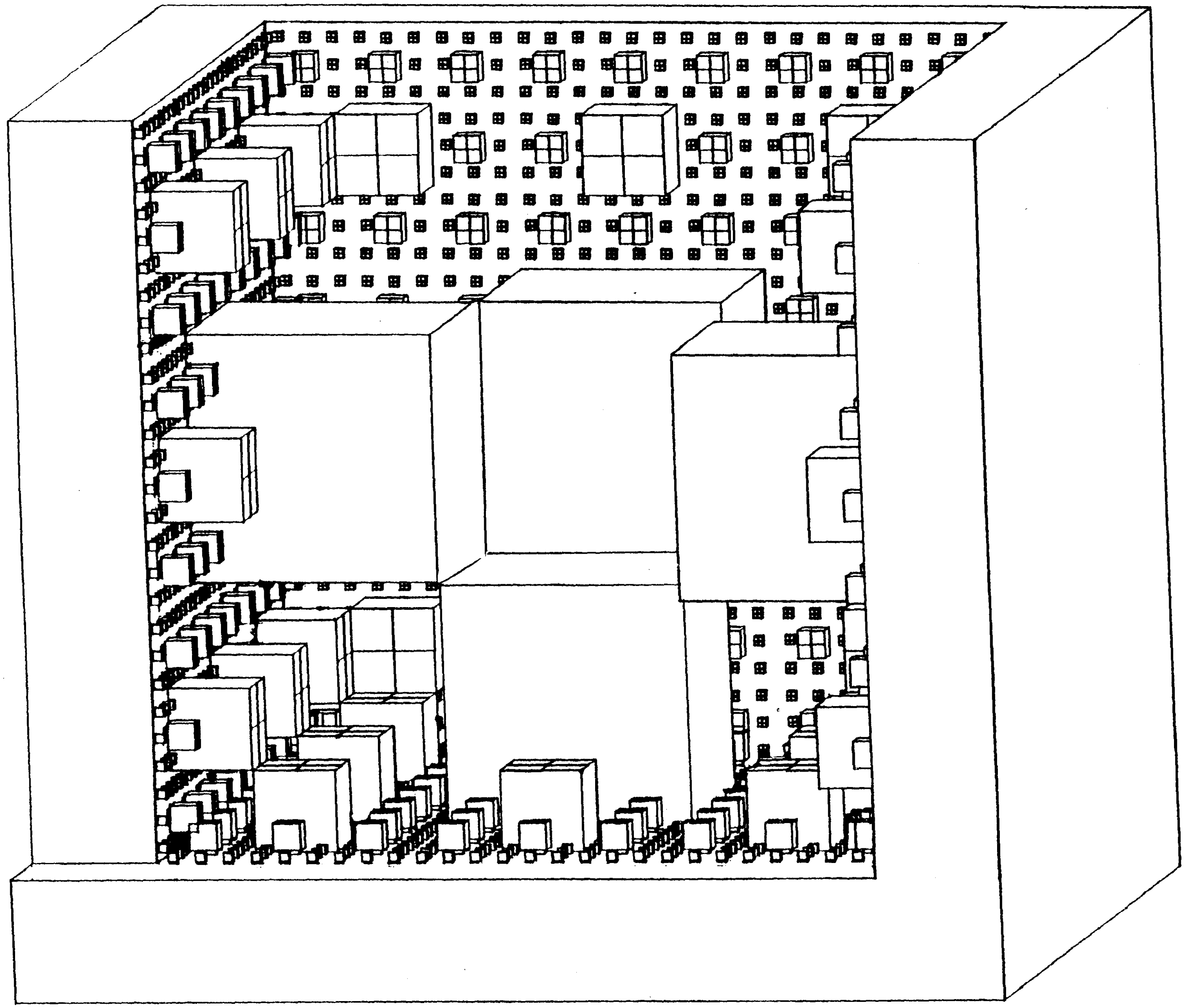


Fig. 66.

Four walls

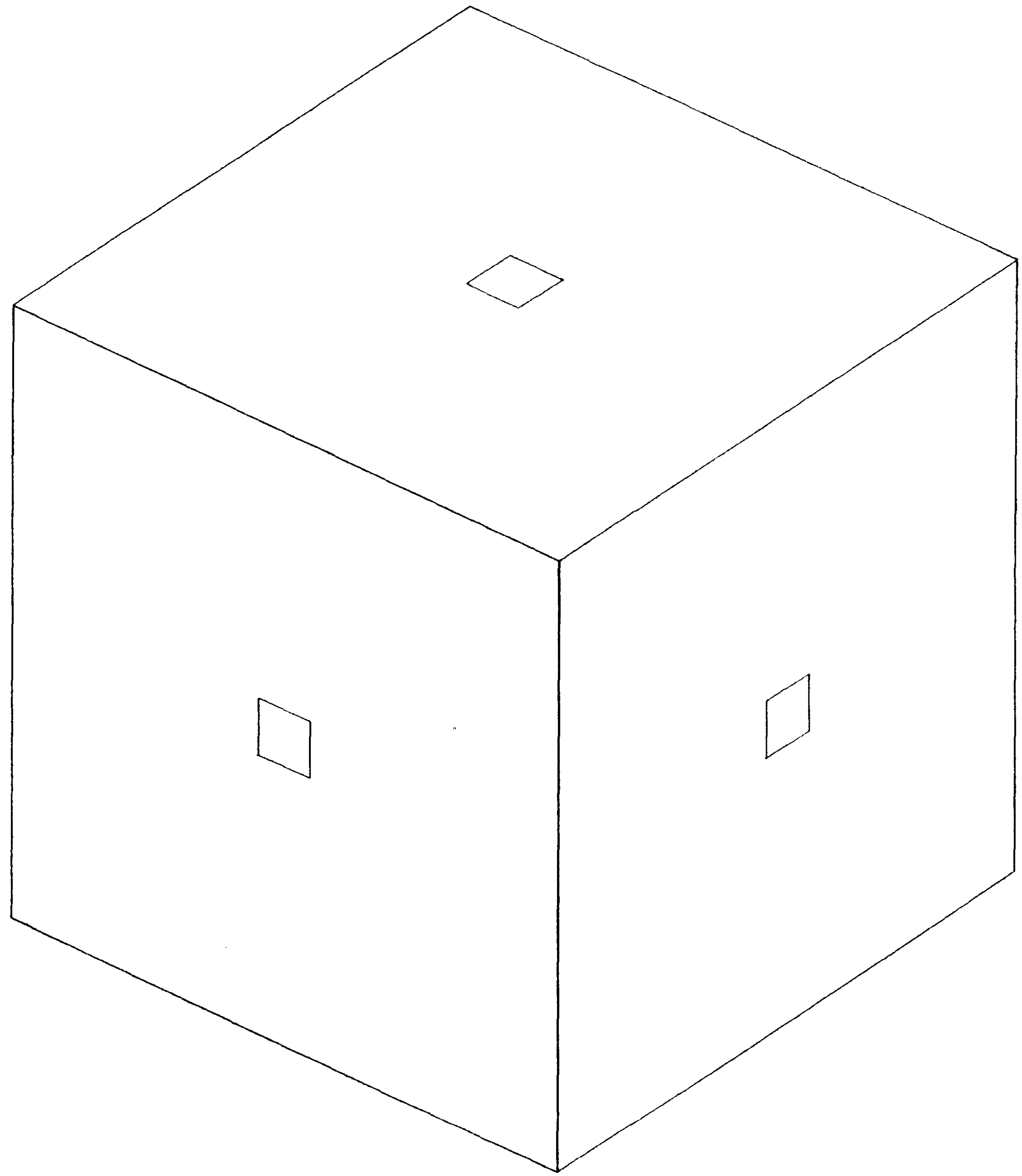


Fig. 67. The library from the outside

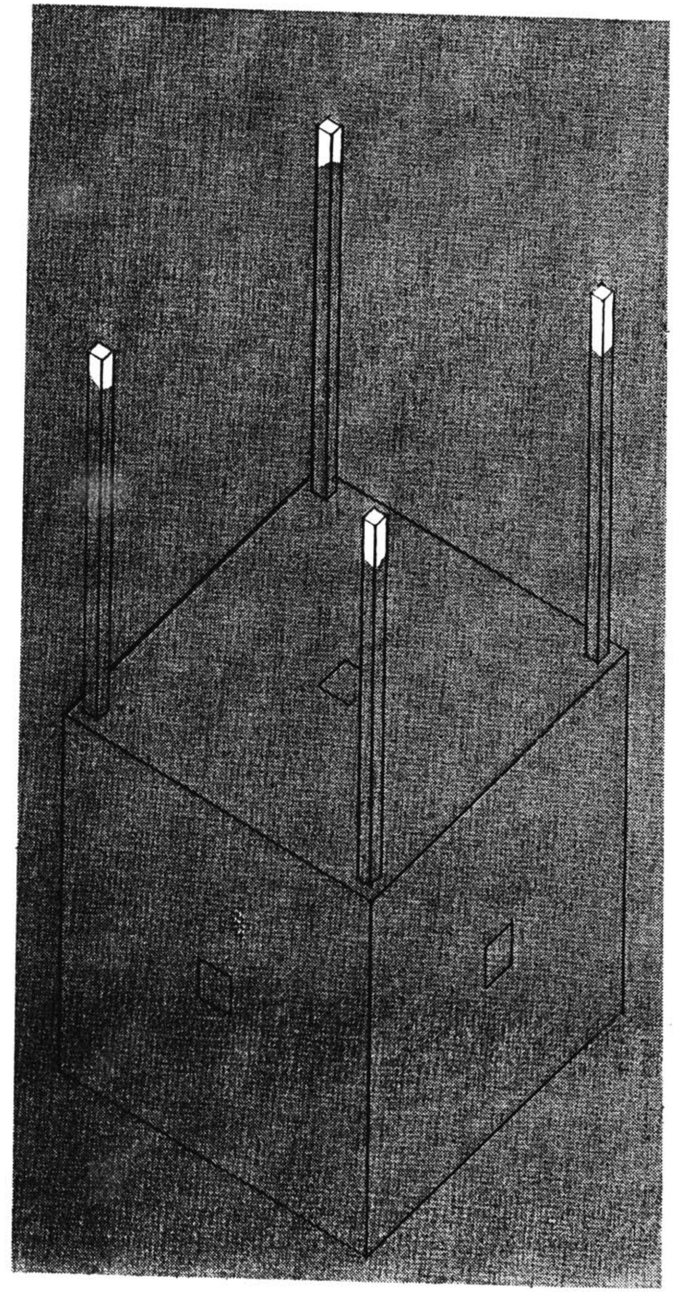


Fig. 68. The library underground with its elevated shafts revealed

33.3'

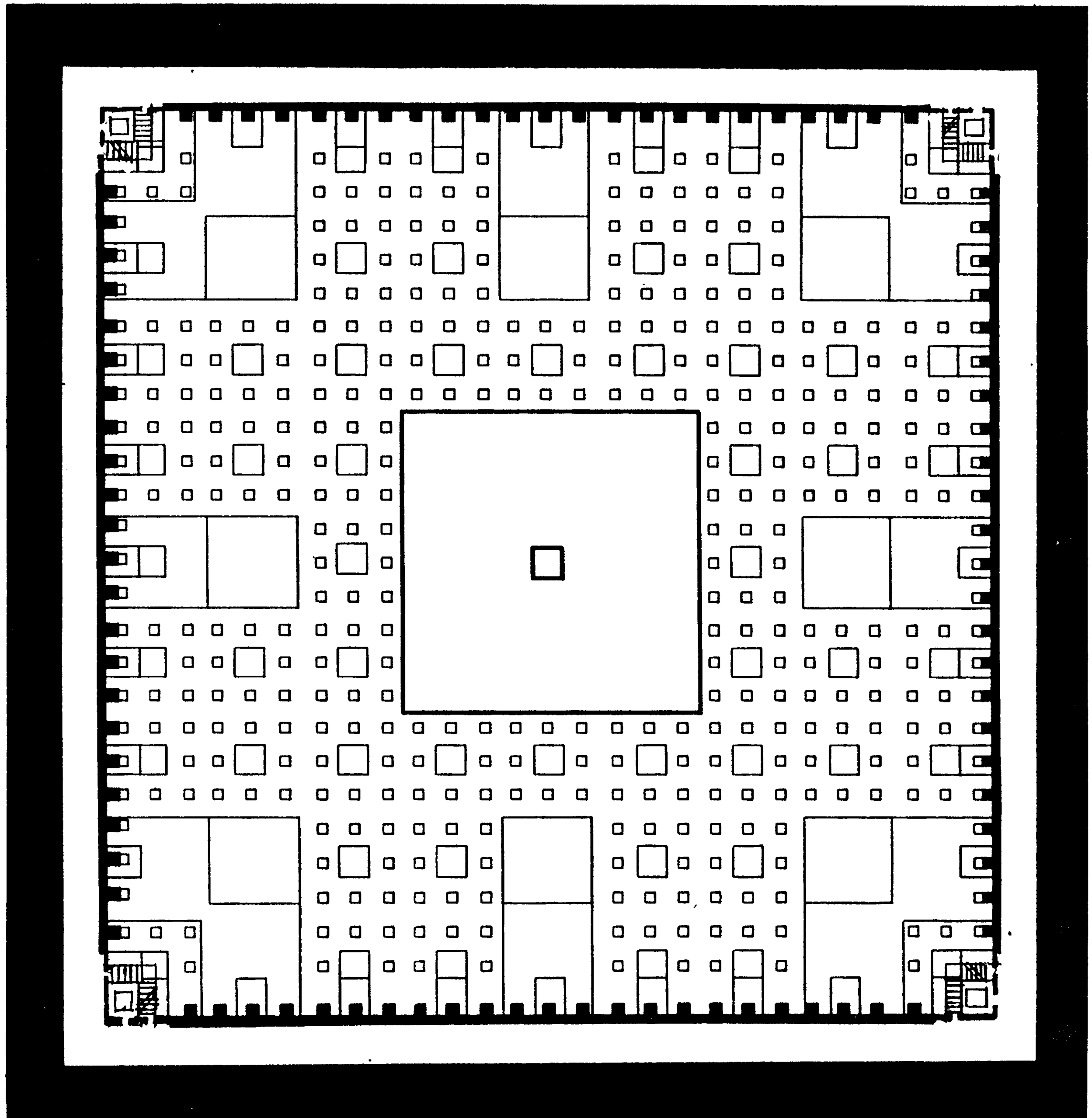


Fig. 69. Plan

-415.00'

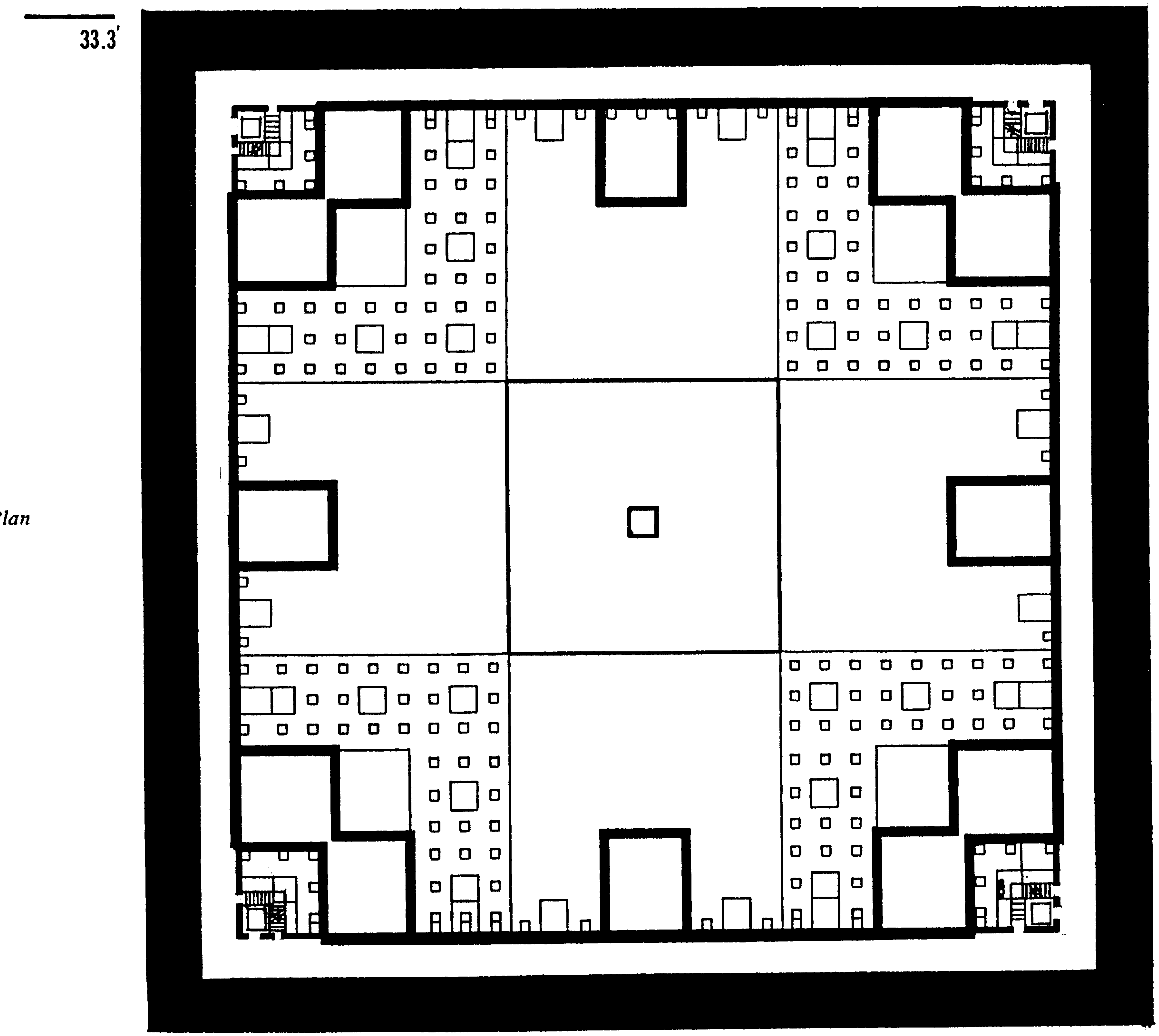


Fig. 70. Plan

-382.00'

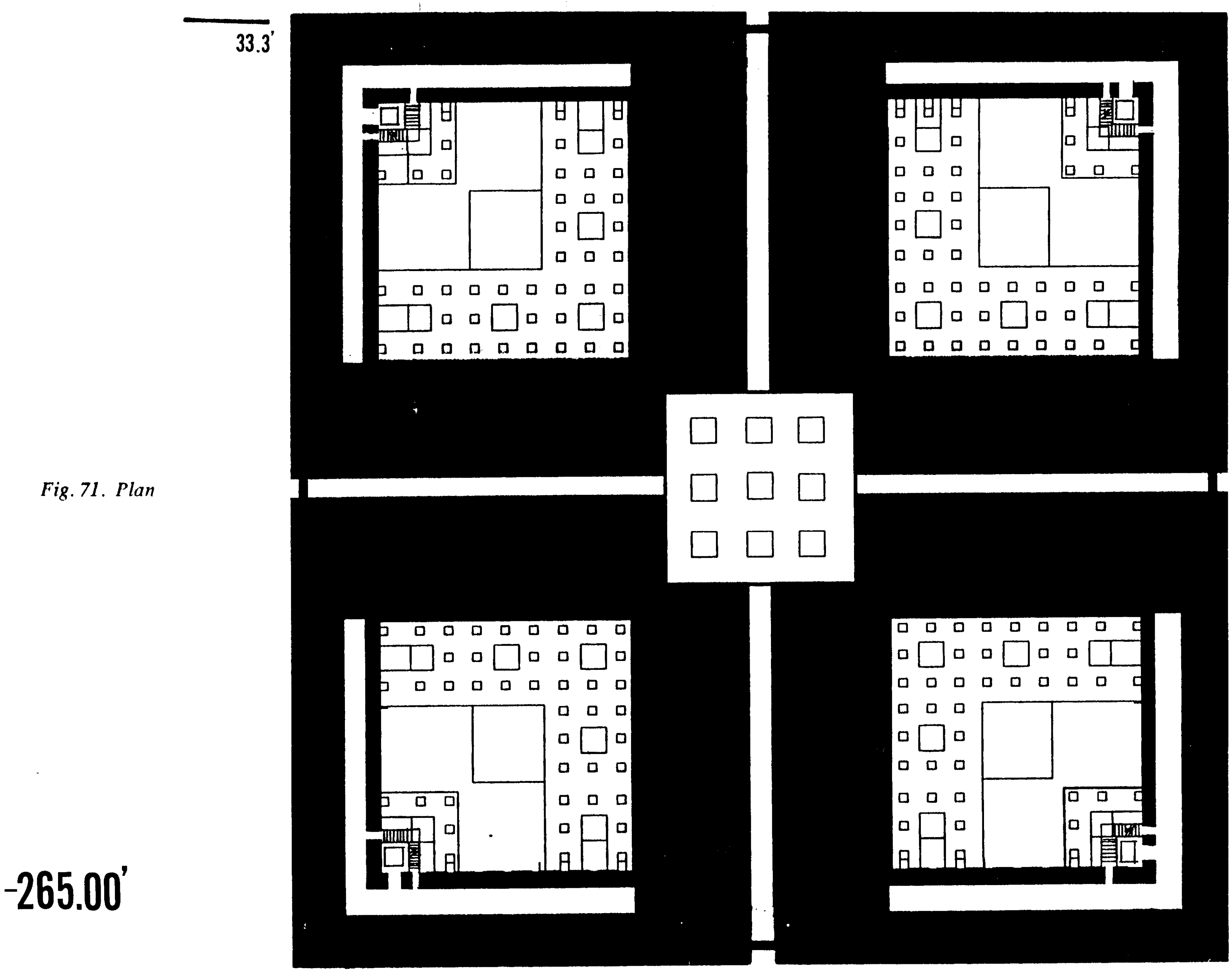


Fig. 71. Plan

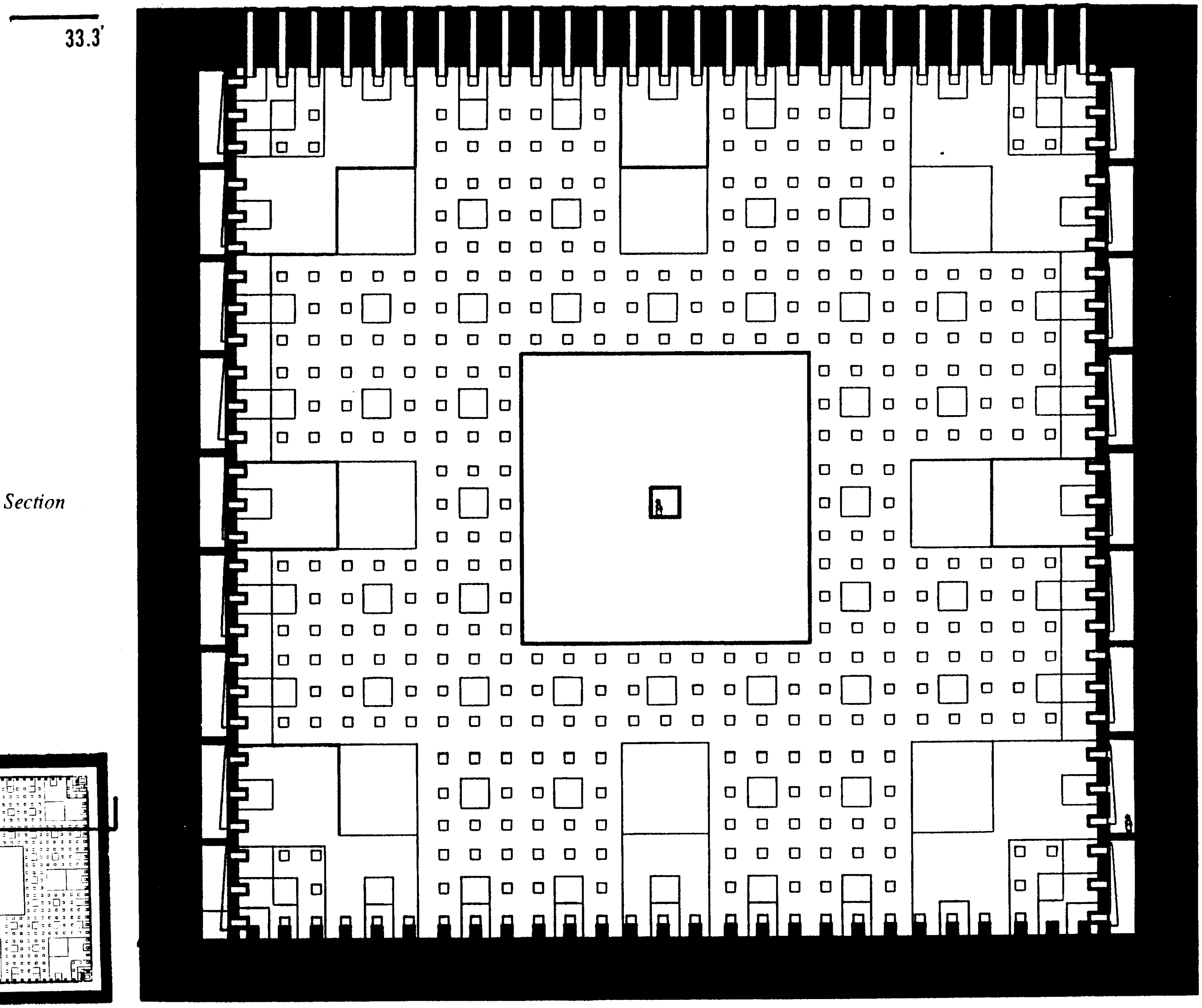
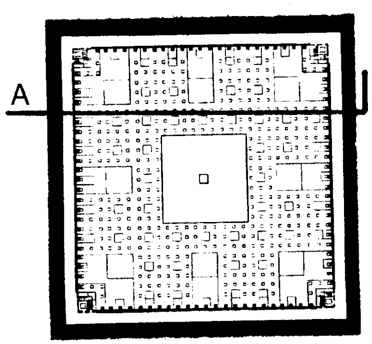


Fig. 72. Section



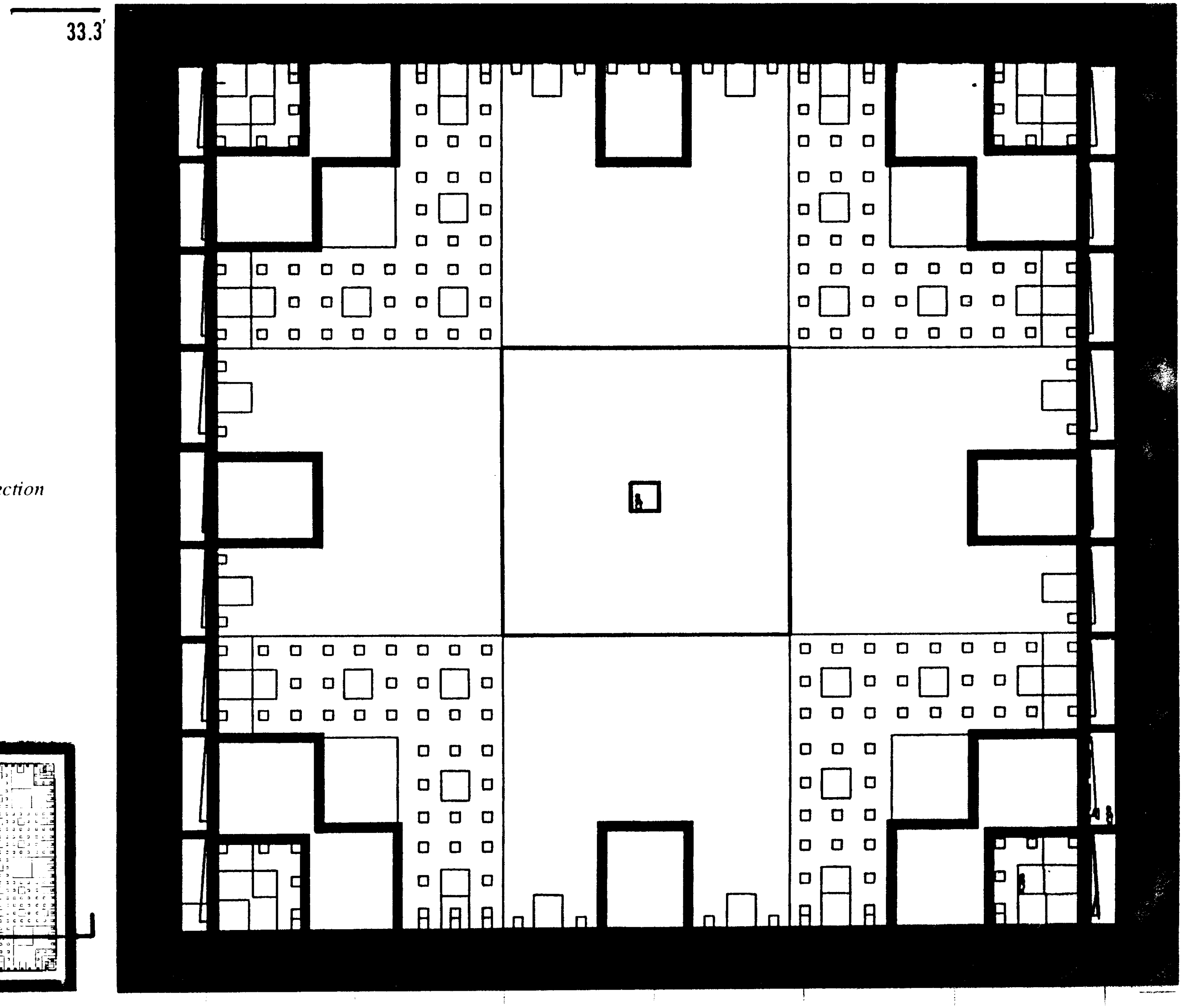
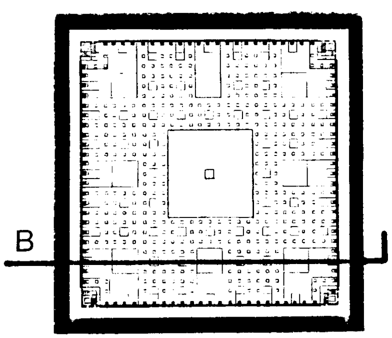


Fig. 73. Section



33.3'

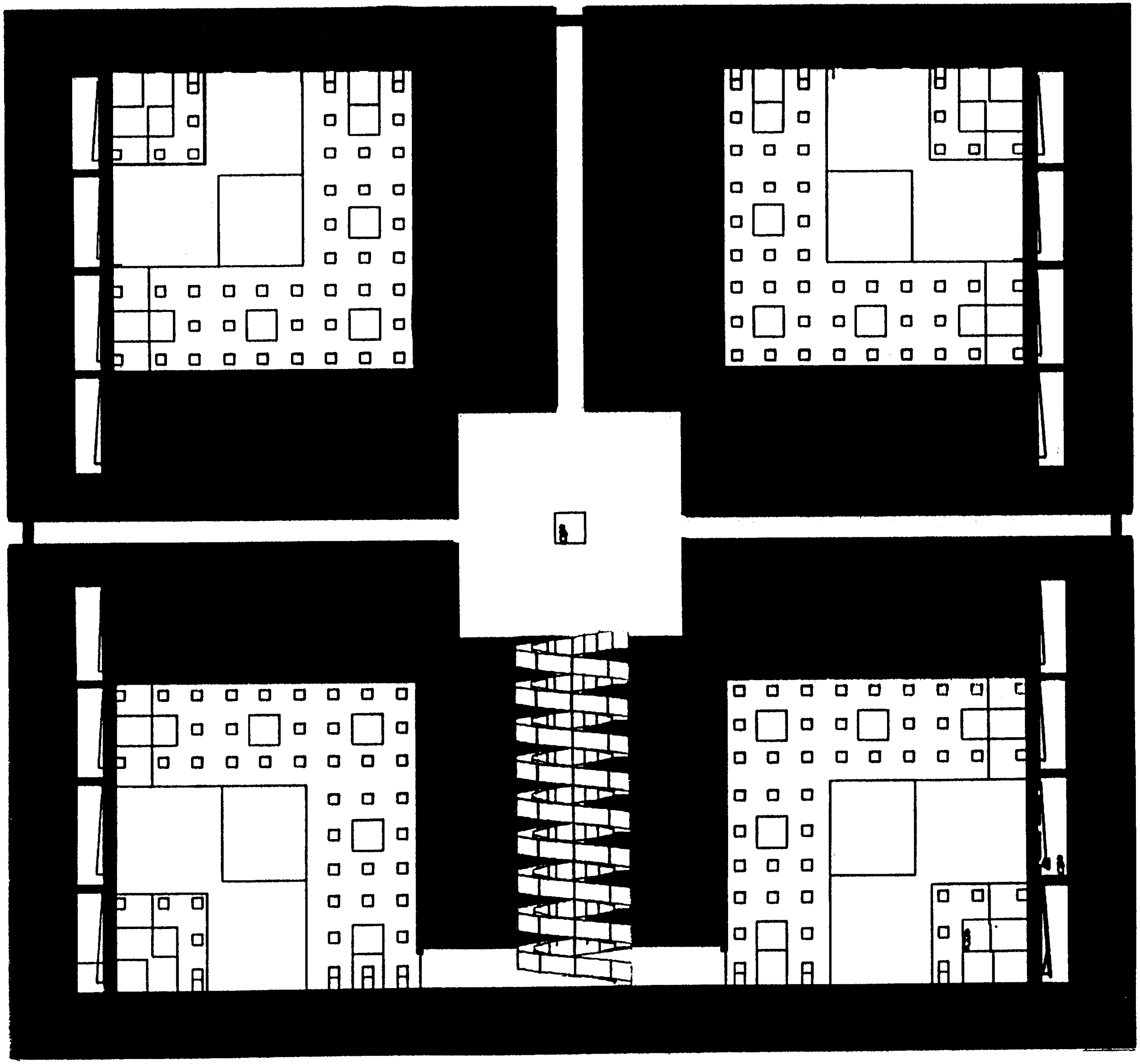
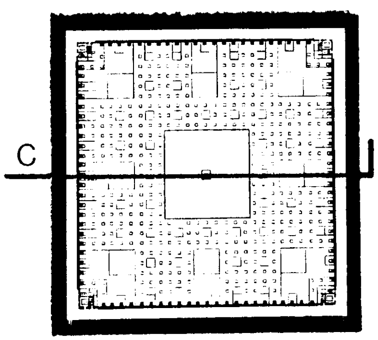


Fig. 74. Section



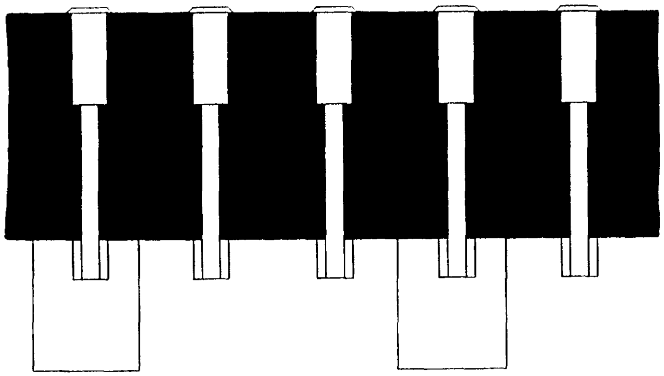


Fig. 75. Detail of skylights to stay leakproof for 100,000 years

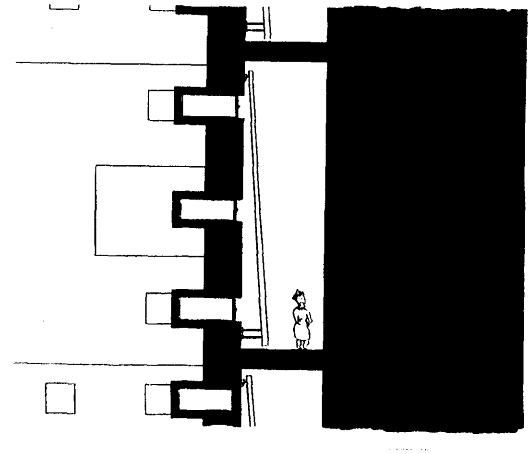


Fig. 76. Detail of hallway with drawers

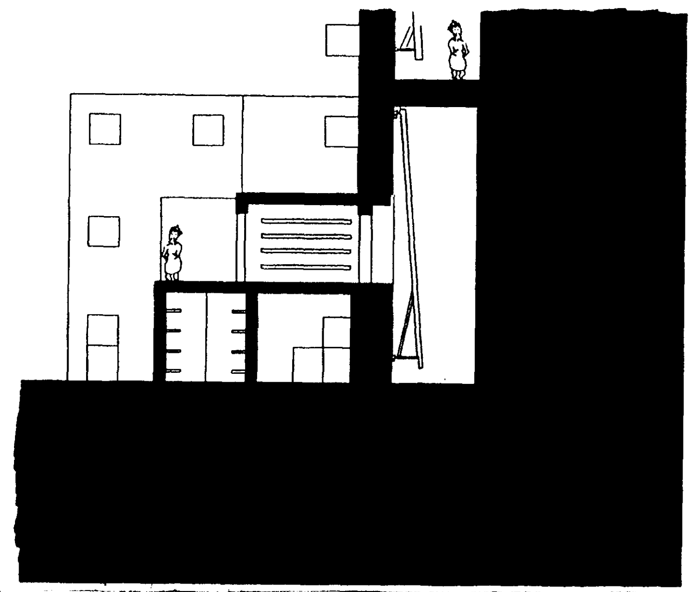


Fig. 77. Detail of hallway and 1,331 cubic feet storage rooms

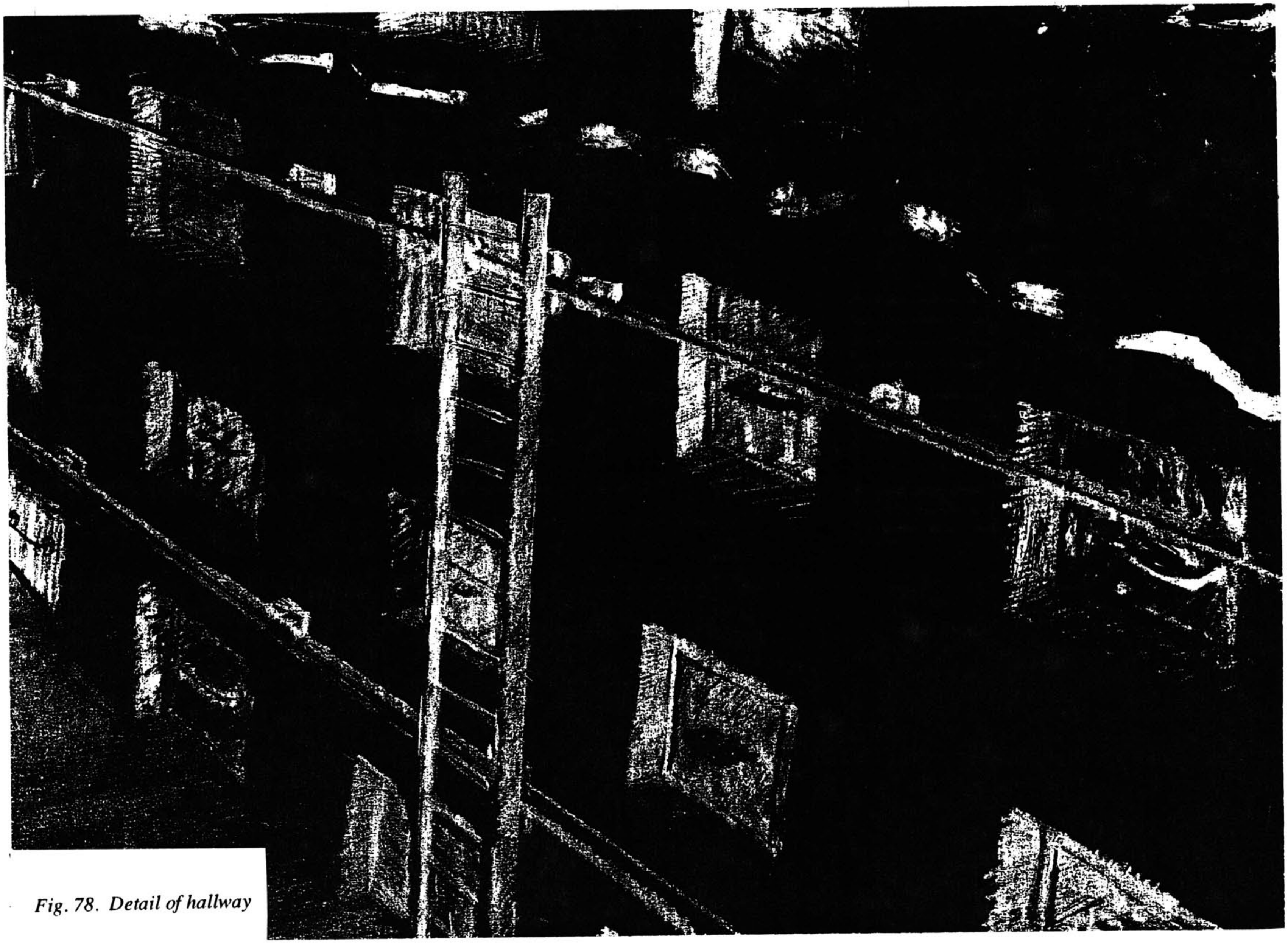


Fig. 78. Detail of hallway

Fig. 79. A single library revealed by eroding landscape

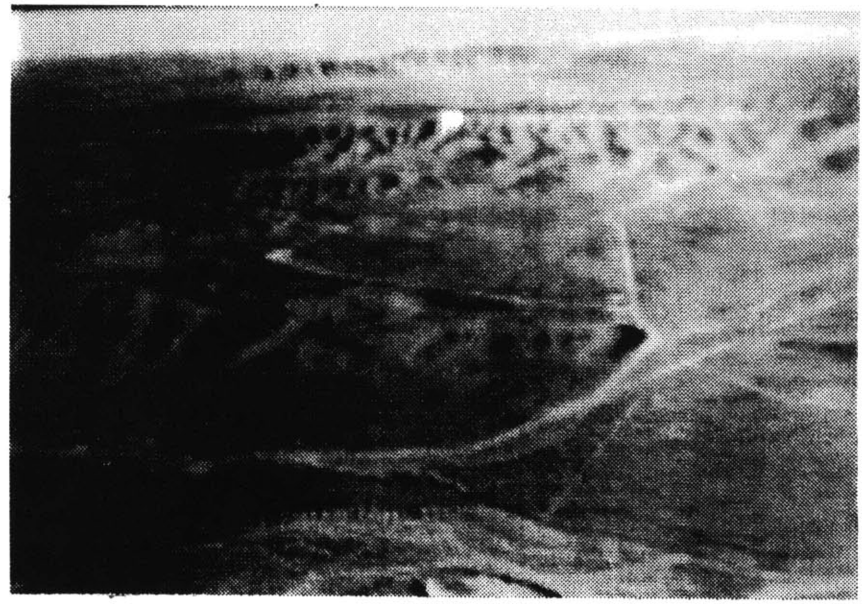
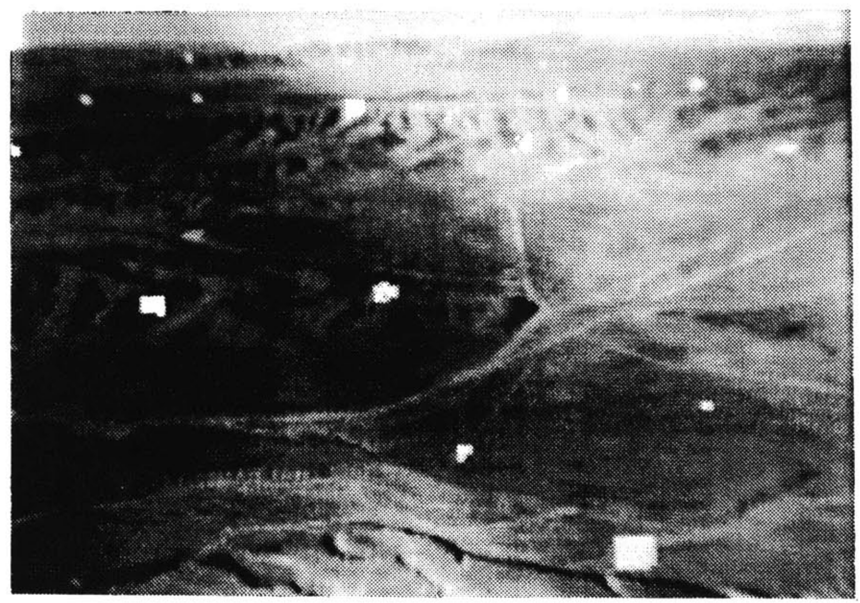


Fig. 80. Successive libraries revealed by eroding landscape



Endnotes

[1] Konrad Krauskopf, Radioactive Waste Disposal and Geology (London:Chapman and Hall, 1988)p.3.

[2] Krauskopf, p.3.

[3] Krauskopf, p.46.

[4] Krauskopf,p.13.

[5] Krauskopf, p.16

[6] Krauskopf p.22.

[7] Krauskopf p.32.

[8] Adryth Simmons, interview held, March 18, 1991.

[9] Krauskopf p23.

[10] Rayner Banham, Scenes in America Deserta (Sayton, Utah:Peregrine Smith, 1982),p.16.

[11] Banham, p. 50.

[12] Banham p.41.

[13] Banham, p.87.

[14] Kevin Lynch , What Time is This Place (Cambridge, MA: MIT Press, 1972) p.87.

[15] Dante Alighieri, Inferno (Berkley: Banham Books, 1980) p.21.

[16] H.G. Wells, Time Machine(Bloomington: University of Indiana, 1987).

[17] Banham, p.65.

[18] Lynch, p.113.

[20] Lynch p.14.

[21] Lynch p.15.

[22] Felicity Barringer, "Outside the Day Still Persists," The New York Times Magazine, April 11, 1991, p.29.

[23] Barringer, p. 32.

[24] Lynch p63.

[25] Lynch, p.104.

[26] Lynch. p.125.

[27] Carol Douglas, "Stone Sentry," Omni, June 1985, p63- 65.

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