GEOLOGY

To pump or un-pump

The Army's Colorado waste disposal may be causing earthquakes, but a number of concerned investigators are no longer so sure

by Jonathan Eberhart

There hasn't been such controversy over a hole in the ground since the Mohole. This time the center of attraction is nothing but a garbage disposal. It was drilled by the Army at its Rocky Mountain Arsenal near Denver, Colo., in 1961, a 12,000-foot-deep well to be used for getting rid of poisonous chemical wastes.

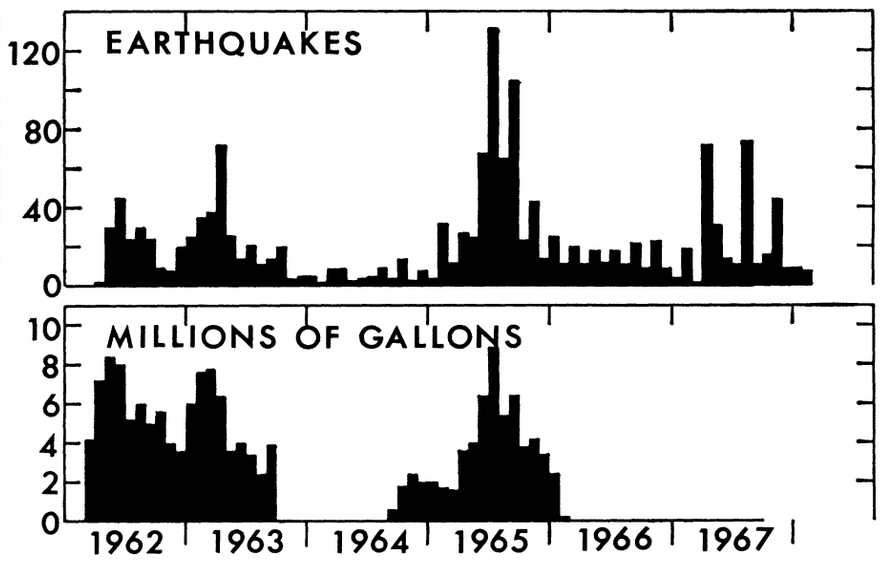
The well opens into a vast reservoir, apparently some 20 miles long and extending eight miles below the surface. The reservoir is not an empty cavern; it is filled with crack-ridden rock of about the density of a subterranean oil field. The Army's fluid would simply seep and ooze its way down and outward, filling the myriad fissures as it went.

The pumping began in March 1962. The next month, after only 4 million gallons had been poured down, Denver had its first earthquake in 80 years. More material was pumped down the well, reaching a peak in May, and the number of quakes increased to a peak one month later. The pumping declined toward the end of the year, then rose again to another high in March of 1963. The quakes followed in phase.

When the pumping rate fell off late in 1963, then rose again toward the end of 1964, finally climbing to new heights the following summer, the earth tremors obligingly waned and waxed.

Until then, says Dr. Maurice Major of the Colorado School of Mines in Golden, no one had made a connection between the quakes and the Army's hole in the ground. Eventually, however, a consulting engineer named David Evans noticed the strange correlation, drew a graph of his findings on a piece of cardboard and took it down to the local television station. The Army stopped pumping in February 1966, after 163 million gallons of liquid had been laid away in the ground.

Here was a nice, open-and-shut case. There was even a ready-made geological principle, called the Hubbert-Rubey effect, to explain it. The Army's fluid had apparently just worked its way among the rocks at the foot of the well, moving them apart enough that they could slide about. The correlation between pumpings and quakings was so perfect, says Dr. Major, that the probability of its being due to coincidence



Colorado School of Mines

As pumping volume rose and fell, so did the number of quakes—until 1966.

was only two or three chances in 1,000.

When the pumping stopped, however, the quakes didn't. Hundreds of tremors have occurred since the Army stopped sending liquid down its well. The three most violent quakes since the incident began, in fact, have all taken place more than a year after the pumping was discontinued. These were so strong that they shook houses and broke windows —including Dr. Major's—more than 20 miles from their centers. Since December, tremors have been coming at the rate of about eight per month.

Where did the correlation go? For four years it was perfect; now it's nonexistent. "It's our chief embarrassment," Dr. Major says.

In the public eye, however, the well is still the front-runner as the candidate for guilt, largely because of those four incriminating years and partly because of the difficulty in establishing that Colorado has any pronounced natural seismic tendencies. The only quake records going back any length of time are "felt reports," as geologists call newspaper accounts and other subjective evidence. "If you take newspaper reports and try to make a map," Dr. Major says, "you come up with garbage."

The quakes center in a curved zone some 10 to 15 miles long and 4 miles wide, running directly beneath the arsenal. The zone is about six or seven miles below the surface, which means that it is shallow enough to pass through the reservoir.

On the other hand, there are an estimated 90 other waste disposal wells around the country, and none of them have ever been accused of starting quakes. "This is a completely new thing," says Dr. Walter Baer, who is keeping track of the quake machinations for President Johnson's science adviser, Dr. Donald F. Hornig.

Dr. Hornig, together with the state of Colorado, the Army and the U.S. Geological Survey, is considering the possibility of trying to pump out the well in hopes that the rocks will settle back into a stable mass. But this idea has its violent opponents, including many area residents who fear what might happen if the Army meddles again with what it apparently failed to control in the past; also, it has been estimated that the well will return to equilibrium pressure (so that it is exerting no abnormal pressure on the rocks) by itself within 18 months.

"If pumping wastes into the well did indeed trigger the earthquakes, are we justified in saying we can now untrigger them?" asks Ruth B. Simon, a research associate at the School of Mines. "Might not pumping out what was put in during those years be effectively re-loading the gun and pulling the trigger again?"

Waiting it out for 18 months, how-

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ever, may be an unavailable luxury. There are predictions that a major quake of magnitude 6.2—the largest so far has been 5.3—will rock Colorado this year. Though some geologists discount this likelihood, there is the chance that pumping the waste materials back out of the ground could suddenly change the subterranean pressures and bring on a large tremor anyway.

Even if pumping out the well seems necessary, a test run will almost certainly have to be made to see if it is possible. There are indications, according to Dr. Major, that it may be impossible to pump out more than about 300 gallons a day. At this rate, recovering all 163 million gallons in the well would take 1,488 years.

As if quakes were not enough of a headache, there may be another, more serious problem. The Rocky Mountain Arsenal, according to some reports, is still being used, as it was during World War II, for the production of nerve chemicals such as GB, or Sarin. The Army denies this, although such agents are still stored there.

If nerve gases and the like are indeed being produced there, they may well be among the wastes of which the Army wishes to dispose down the well. There has been some concern that if this is being done, longlasting GB might find its way into water supplies.

This is virtually impossible, according to Dr. Baer. "There is no evidence or conjecture" of contamination, he says. Furthermore, he adds, the well is some 12,000 feet deep, while the water-containing aquifers are only from a few hundred to 1,000 feet deep. The well itself is a double-walled steel tube, encased in a concrete jacket, with a liquid-filled center section that serves as a pressure indicator to warn of any leak.

According to the Army, the main component of the fluid in the ground is water. Most of the rest is waste material produced by the Shell Chemical Co., which has leased space on the arsenal grounds, in the manufacture of pesticides and insecticides. The Army has already pointed out, however, in the case of the mysteriously dead sheep in Utah (SN: 4/6 p. 327), that insecticides and pesticides contain chemicals very like those in some nerve agents.

But the main concern is over the quakes. And several of the School of Mines geologists feel that the Army is not entirely, if at all, to blame. "The Rockies are a young mountain range," says one, "and may well have some kicks left." The leading possibility seems to be that the pumped fluid may have acted as a trigger, nudging the underground rocks into a less stable position, but that the actual force causing the quakes came from elsewhere.

TRANSPLANTATION

Pancreas joins the list

Transplant of the insulin-producing organ is now technically possible; new hope seen for diabetics

by Faye Marley

With the first transplants of the pancreas in humans now achieved, there is hope for severe diabetics who no longer respond to insulin.

Dr. Richard C. Lillehei, head of the surgical team at the University of Minnesota, Minneapolis, which did the work, was not jubilant over the feat, but said the four cases (one person survived) prove the transplant technically possible.

An earlier report of pancreas transplant, or implant, in the cheek pouch of golden hamsters in which diabetes had been induced, was made by three Boston University scientists.

Dr. Alden Macchi, professor of biology at Boston University, said Dr. Lillehei's achievement is a sign of progress. His own team, headed by Dr. Samuel B. Beaser, has been considering human transplant of the pancreas but has felt the need of further animal work.

The technical difficulty in transplanting an entire pancreas lies in tieing the substitute organ into the blood stream, because the blood vessels derive from the main gastrointestinal artery.

Dr. Macchi explains that the work with hamsters involved, not the entire pancreas, but implants of pancreas tissue, which did grow and produce both veins and arteries. His group would not say definitely that the resulting enzyme production was insulin but believed that it was.

Previously, the pancreas has been removed when it was cancerous, but patients do not live normally after losing the organ. It is necessary to restrict their diet and give them heavy medication.

Dr. Lillehei says now that it has been shown possible to transplant the organ, the operation should become more common within five years, at least among the severe diabetics who cannot continue to respond to insulin. He used glands from cadavers.

The pancreas is one of the body's independent organs; that is, there is only one. The liver, the spleen and the heart are other unduplicated organs that have been replaced with some small success, and cautious attempts continue to be made to transplant them more effectively.

In the case of the heart, only one of six patients, Dr. Philip Blaiberg, of Capetown, South Africa, still lives with a transplanted organ. Dr. Richard R. Lower of the Medical College of Virginia, Richmond, writes in the April issue of SURGERY, GYNECOLOGY & OBSTETRICS, the official journal of the American College of Surgeons, that the procedure "should probably be undertaken in man only if death of the recipient is otherwise imminent."

This might also be the criterion in other cases of single organs. The liver, for example, has been transplanted—unsuccessfully in most cases. No one can live without a liver, for this complex organ secretes bile for digestion, breaks down protein into simpler compounds, stores blood sugar and fat, maintains chemical levels within the blood and cleanses the blood of foreign matter.

Five liver transplants have been done in Denver, Colo., two in early 1968, by Dr. Thomas Starzl's team. Three patients remain alive with foreign livers. Only one of the small girls who received new livers last July remains alive: Julie Rodriguez of Pueblo, Colo. One of the more recently transplanted patients is a teenage girl; the other is an infant.

Dr. John C. Norman of Harvard University, who has done extensive animal research on spleen transplants, expects to report human transplants soon. His work is aimed at helping hemophiliacs, or bleeders. He believes the source of their blood problem is in the spleen and that if a defective organ can be replaced, their blood will coagulate normally.

The fact that kidney transplants are far ahead of the single organs does not mean that the surgery is easy. Heart transplants are said to be technically easier to do than kidneys. But there are two kidneys, and so it is possible to get an organ from a live donor, preferably a close relative or, best of all, an identical twin. It is also possible to redo a kidney transplant if the first does not work.

Kidney machines and heart-lung bypass machines help to make these operations technically simpler than the ones involving liver, pancreas and spleen.