When a Radical Experiment Goes Bust

A $40-million gas well drilled in Sweden has come up dry, but that doesn't discourage the maverick American scientist who sold the Swedes on prospecting in a most unlikely place

AFTER 3 YEARS of punching more than 6 kilometers down into the tough granite of central Sweden, drilling crews gave up last September. Swedish investors had hoped the well, called Gravberg-1, would produce a gusher right there in the midst of the scenic Siljan lake district. But the hole was dry, devoid of exploitable oil or natural gas. Not that investors could blame geologists. From the start, the world's authorities on petroleum exploration thought the Siljan deep-gas project a folly and the theory that gave birth to it a naïve self-deception. One prominent scientist who did not: Thomas Gold.

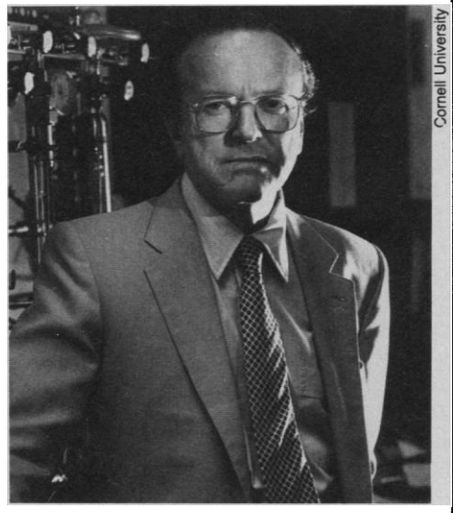
Even today, Gold, and a very few others, view the Siljan failure with equanimity. An emeritus professor of astronomy at Cornell University, Gold promoted the unconventional theory of the origin of oil and gas that prompted the Swedish State Power Board to drill at Siljan. A bit like Moses bringing forth water in the desert, Gold wanted to tap into the enormous reserves of gas that he expected to find locked in the Swedish granite—despite the conventional geological wisdom that says there could not possibly be any usable gas there.

By conventional thinking, the organic remains of marine life yield oil and gas, and those remains occur only in sedimentary rock, certainly not in the crystalline rock of Sweden. But astrophysicist Gold has long insisted that oil and gas drillers are hitting hydrocarbons that have seeped up 40 kilometers and more from Earth's mantle, where they were deposited as the planet formed. "I never believed that oil and gas had principally a biological origin," Gold has said.

Gold's belief in the existence of massive amounts of abiogenic oil and gas might place him on the scientific fringe, but the Swedes could not dismiss him out of hand. His astrophysics accomplishments have earned him membership in the Royal Society and the U.S. National Academy of Sciences, and he is a recipient of the prestigious Gold Medal of the Royal Astronomical Society.

Were Gold proven right, the world's oil and gas reserves would be far larger than now thought, enough to last centuries rather than decades. And the energy supply would be more democratically distributed. In the Gold theory, mantle gas is trapped deep in the earth, just beyond the usual reach of drilling. And not only under geologic structures formed in sedimentary rock, but in places never probed by an oil industry guided by fundamentally false premises. Those premises have kept industry away from Sweden, a land of largely bare granite only thinly draped with sediments or sedimentary rock.

As unlikely a place as Sweden seemed to geologists, Gold's theory touched off a search for deep gas that drew money not only from the Swedish government but also from Swedish industry, municipalities, and any private individuals willing to ante up for a chance to play the game. Even some Americans bought in—the Gas Research Institute (GRI) in Chicago, an entity funded by gas consumers, supplied more than $4 million to support the scientific analyses involved in testing Gold's theory.



Iconoclast Thomas Gold. *His theory launched 6 kilometers of controversial drilling.*

If it had been left to Gold's theory alone to attract the $40 million that eventually went into drilling the Siljan hole, things would hardly have gone as far as they did. As early as 1979, a couple of years after Gold began actively promoting the deep gas hypothesis, a committee of the U.S. National Academy of Sciences advised against any U.S. drilling for abiogenic gas and questioned whether deep gas, even if it existed, could ever be extracted economically.

The Swedish State Power Board, also called Vattenfall, got much the same response 5 years later when it assembled an independent group consisting of three U.S. experts in oil exploration and two Swedes familiar with local geology. First the group went to inspect Gold's proposed drilling area. In selecting a drilling target, Gold had reasoned that the best way to convince a skeptical world that deep gas exists would be to find commercial quantities of gas where no self-respecting petroleum geologist would ever look.

So Gold avoided sedimentary rock and looked instead to the once-molten granites of central Sweden. To make the drilling easier, he picked a spot, a meteorite impact crater, where substantial amounts of mantle gas should have collected within easy reach of current drilling technology, according to his theory.

Gold saw several advantages in the Siljan impact crater. When an asteroid or comet formed the 52-kilometer crater 368 million years ago, it shattered the crust, possibly all the way to the mantle 40 kilometers down. That would open cracks for mantle gas to rise toward the surface, he reasoned. The fractures within a few kilometers of the surface might also provide open space to form a reservoir to store the gas. The only other requirement would be some sort of seal to keep the gas from leaking out the top of the reservoir rock. Gold saw signs of such a seal in calcium carbonate deposits in the shallowest cracks. To top it all off, gas and oil were seeping from the ground around the edge of the Siljan crater.

"If I was a gambling man," Gold told the BBC as the drilling of Gravberg-1 started, "I'd give better than 80% odds the first hole will already find commercial quantities. I'd give it a 90% chance of discovering amounts that would be enough to make people look up and drill more holes."

After due study, Vattenfall's panel of experts agreed with Gold on one point—that Siljan was indeed an impact crater—but adamantly disputed the rest of his contentions. The seven shallow exploratory holes

Is the Siljan Hole Completely Dry?

Astrophysicist Thomas Gold says there is natural gas down there in the mantle, just below the bottom of the 6.8-kilometer-deep well recently drilled to search for the stuff in the Siljan lake district of Sweden. The experts see no sign of it in the hole, but Gold does. So goes the life of an iconoclast.

The Swedish drillers have found an assortment of hydrocarbons that Gold interprets as indicators of gas oozing up, just as he predicted over a decade ago. But that is not what chemical analysis of the hydrocarbons shows, says organic geochemist Isaac Kaplan of Global Geochemistry Corporation in Canoga Park, California, where much of the work was done. "We concluded we were not dealing with a natural situation," he says, "but with a man-imposed one." Drillers pump all sorts of things down wells to keep the drilling going smoothly—at Siljan, they even used diesel oil—and Kaplan believes that all Gold is seeing is the diesel oil as well as other hydrocarbons produced by additives that were altered by the frictional heat of the drill bit. Not surprisingly, Gold disagrees with this conclusion.

Whom to believe? Geochemists would resolve this dispute by determining the isotopic composition of helium in the gases. Crustal rock produces only the isotope helium-4 by the radioactive decay of uranium and thorium, whereas mantle gases should carry helium-3, a stable isotope trapped in Earth's deep interior when the planet formed. Indeed, researchers looked for an enrichment of helium-3 in the gases and found none. Harmon Craig, a geochemist at Scripps Institution of Oceanography in La Jolla, found that at least 99.85% of the helium is crustal.

But Gold is no conventional thinker, and as usual, he has an unconventional riposte. He explains away this apparent disappointment by suggesting that a mixture of gases had already flushed out all the mantle helium that can be removed through existing passageways. With the passageways freed of mantle helium, the remaining gases, including hydrocarbons, continued rising toward the surface.

And then there's Gold's other evidence—again unorthodox. The drilling fluid that was circulated through the hole brought up tons of micrometer-size grains of the mineral magnetite. Gold believes that the magnetite was produced by bacteria living off mantle hydrocarbons an extraordinary 6 kilometers below the surface of the earth.

Specialists have a hard time accepting the idea that bacteria can live that far down, however. John Castaño is an oil and gas consultant in Houston who was at the Siljan hole during much of the drilling and has had occasion to ponder the possibilities for subterranean life. It's "very, very farfetched," he says of Gold's proposal.

But even if these nay-saying experts are right, the theory that oil and gas exist deep in Earth's mantle is taken seriously east of Sweden. Soviet scientists have reported the detection of "circulating fluids" at great depths in their 12-kilometer hole on the Kola Peninsula near Murmansk. American researchers are intrigued but frustrated. They have yet to see any hard evidence that the deep gases are not simply contamination from the surface.

The helium evidence that is available in the West has been negative. American scientists sniffing around the 10- to 15-kilometer-deep faults of southern California have failed to find any mantle helium leaking upward. Even a test of the 3.5-kilometer-deep well just 4 kilometers off the San Andreas at Cajon Pass showed no mantle helium.

More chances to probe the deep crust are likely. These scientific holes may not be drilled just to test Gold's hypothesis, but you can bet that any wisp of gas found down there will be checked for a whiff of his mantle gas. ■ **R.A.K.**

drilled earlier by Vattenfall showed that the rock was not porous enough to act as much of a gas reservoir, the panel's report said. On the other hand, it was not impermeable enough to provide the needed seal either. Interpretations of deeper features, which were revealed by geophysical surveys as possible sealed reservoirs, were "speculative."

And, the report went on, Gold's claim that the oil and gas seeping out around the crater came from the mantle was "without merit." The seeps showed every sign of coming from organic matter in nearby sediments. Finally, even if Gold's mantle gas was seeping into a usable reservoir at Siljan, getting it out would probably prove uneconomic. "We are led to conclude that the chances for commercial gas production are remote," the five experts told Vattenfall in November 1984.

Even though it asked for this advice, Vattenfall wasn't listening. It issued its own report, citing the experts' study while toning down and largely discounting their negative conclusions on the basis of last minute results from the field. The next step, Vattenfall's report concluded, should be a hole drilled 3 to 5 kilometers into the crater in search of commercial quantities of gas. The payoff could be huge, Vattenfall said. Siljan could hold a world-class giant deposit that could conceivably reach 100 billion cubic meters of gas. If most of that could be recovered, it would rival the gas thought to be awaiting discovery offshore of Alaska.

Vattenfall's decision dismayed the experts, but Sweden's major power generator was undoubtedly swayed by other considerations. One may well have been Gold's effectiveness as an advocate for deep gas. "He's a good salesman," says Joseph Riva, who analyzes oil and gas resources for the Congressional Research Service.

In fact, Riva recalls that Gold learned on the job: "When he first started, he . . . made all kinds of geologic mistakes. That's what upset geologists; he can be kind of infuriating. But then he refined his story. The central premise was still cockeyed, but the rest got better and better." In 1982 it was good enough to sway Vattenfall. "My first meeting there was enormously successful," recalls Gold. "I really got them hooked."

But it wasn't pure salesmanship. Gold combines a good spiel with international stature in astrophysics. In 1968, Gold announced that he had identified a flickering source of pulsar signals as a rotating neutron star. The mainstream astrophysics community balked. But after much skepticism, astronomers recognized that Gold was right.

Moreover, the leap from flickering neutron stars to deep mantle gas is not quite as great as it sounds. Gold got part of the idea from astrophysical studies that suggested to him that hydrocarbons synthesized between the stars could become incorporated in the newly formed Earth. Indeed, Gold is known for his penchant for hurdling normal disciplinary boundaries. He has delved into everything from the origin of the universe and the nature of time to moon dust, earthquake prediction, and the workings of the human ear. Wrote *Newsweek*, he's an "irrepressible iconoclast."

But beyond Gold's stature and persuasiveness, Vattenfall may have succumbed to its desperate need to find new sources of energy. Swedish voters had declared in a 1980 referendum that the country's 12 nuclear power plants should be closed down by 2010. Nor is the populace disposed to increasing the number of hydroelectric plants, which already supply much of Sweden's

energy needs. And the country's known oil and gas resources are negligible. Thus the appeal of homegrown deep gas.

More cynical observers, outside Vattenfall, see another possible motive. If the search for alternatives to nuclear power were a highly public, exhaustive one, the argument goes, Vattenfall could go back to the voters with proof that the nuclear route is their only choice.

With the odds long but the potential payoff high, Vattenfall bit. But the Swedish government wasn't willing to go it alone. It required that Vattenfall get outside financial help. The agency then formed a company, called Dala Deep Gas, to do the drilling and sold 49% of it in large chunks to industrial firms, municipalities, and private consortia. Swedish entrepreneurship even made it possible for the little guy to invest in the testing of this maverick American scientist's theory. Two holding companies bought some of the large shares and subdivided them, bringing the cost per share down to about $1500—well within the reach of small investors.

And then there was the enticing tax angle. Swedish income tax rates are high, and investors in risky ventures such as the Siljan drilling were able to quickly deduct most of their investment. If there were losses, more deductions could be made. "You don't risk anywhere near as much as you would" in the United States, says oil and gas consultant John Castaño of Houston, who represented GRI at the drill site. Of course, the burden then falls on the government and thus all taxpayers.

Finally, there was the gambler's enticement: the ever increasing size of the speculative carrot being dangled before investors. By the start of drilling in July 1986, Vattenfall's estimate of the amount of gas that might lie beneath Siljan had jumped from 100 billion to 800 billion cubic meters, according to a prospectus for Anathema Oil, one of the two holding companies marketing public shares. That volume of gas would have been worth upwards of $40 billion or $5000 per Swede. By the fall of 1986, Anathema Oil boasted in its prospectus that a Norwegian oil firm had an estimate of 4000 billion cubic meters, or more than all the gas ever produced in the entire world. Says Castaño, such claims "in this country would bring the Securities and Exchange Commission down on you with both feet." Things are obviously different in Sweden.

With expectations running so high, investors may not have noticed that the first 5 kilometers of drilling, all that was initially planned, failed to support Vattenfall's justifications for the project. The first 5 kilometers of fractured granite made a poor reservoir rock, if sufficient pore space existed at all. The possible reservoir seals turned out to be solidified magma intrusions, not carbonate deposits. And there was no sign of mantle gas.

But investors were now told of a possible reservoir with a seal at 7.4 kilometers, and drilling was going smoothly. Indeed, the hole had become the second deepest ever drilled in crystalline rock. At one point, the stock actually soared to ten times its initial value.

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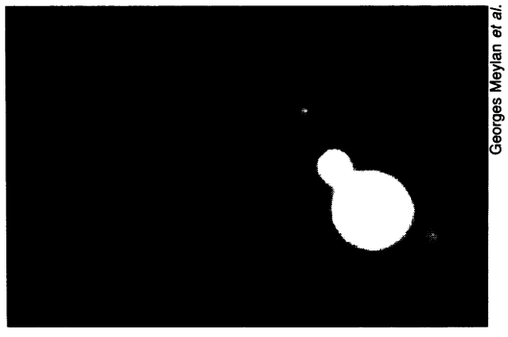
But then came the disasters. The worst of these involved wayward drill bits. Drillers could not keep the hole from bending away from the vertical until the drill bit and the increasingly bent pipe connecting it to the surface became stuck. Drilling finally stopped last September at a depth of 6800 meters.

Most oil and gas professionals see little reason to try to resume drilling (see box). Sure, they say, the Siljan granite contained about 100 parts per million of methane (the principal component of natural gas), but that is less than the amounts found in dry holes at conventional exploration sites. And the isotopic composition of the accompanying helium demonstrates, by conventional reasoning at least, that none of the gas is seeping up from the mantle. "The amount of gas we saw in the more interesting zones still makes any future prospecting very speculative," says Castaño, "just as speculative, if not more so, than when we started."

"The results on the Siljan hole show that it's highly unlikely that there are commercial quantities of gas there," says Gordon MacDonald of the Mitre Corporation in McLean, Virginia. Once the chairman of GRI's advisory committee on the Siljan drilling, he had strongly supported Gold in the early 1980s in Gold's bid for serious consideration of his theory in the United States.

Despite such apparent setbacks, Gold remains adamant. "The drilling has been done in an atmosphere of extreme passion pro and con with hardly anyone with an open mind in between," he says. "Some people are totally unwilling to give up their views in a field that has been their livelihood." Gold still argues that gas is seeping up from the mantle and probably being trapped just a few hundred meters below the bottom of the hole. "I would expect we would see the free gas below" 7.4 kilometers, he says.

As incredible as it seems to most U.S. experts, Swedish investors, some of whom contributed to the $40-million dry hole, may be willing to back Gold up on his latest prediction. Vattenfall is out of the deep gas business, having just sold its share in Dala Deep Gas. But the man at Vattenfall whom Gold initially had to convince, engineer Tord Lindbo, now heads Dala and is gathering funding for another Siljan hole. Gold is on the board of directors. As he once told the *Wall Street Journal*, "In choosing a hypothesis, there isn't any virtue in being timid." ■ **RICHARD A. KERR**



Georges Meylan *et al.*

Twin Quasars Found. If a galaxy happens to have an ultramassive black hole at its core, the theory goes, and if another galaxy happens to come close enough for gravitational tidal effects to push gasses and other matter into the hole, then the result will be a violent spasm of activity known as a quasar. The recent discovery of twin quasars—the closest such pair ever observed—has given a big boost to the theory; they formed, presumably, when two galaxies, both with central black holes, got together. The discovery, which was announced in January at the Washington, D.C., meeting of the American Astronomical Society, is the result of a joint effort by four astronomers: Georges Meylan of the Space Telescope Science Institute of Baltimore; S. George Djorgovski and his graduate student Nicholas Weir, both of the California Institute of Technology; and Peter Shaver of the European Southern Observatory in Garching, West Germany.

Djorgovski and Weir first thought the quasar pair might be a single quasar exemplifying the gravitational lens phenomenon, that is, the bending of light that can produce a double image. But even though the two astronomers were looking for evidence of gravitational lenses, they have no question that the two quasars are distinct bodies. Explains Djorgovski: they have different spectra. ■ **SARAH WILLIAMS**