MINERAL RESOURCES

Is the World Tottering on The Precipice of Peak Gold?

Seventeen-hundred-dollar-an-ounce gold is driving a mining frenzy, but analysts are concerned that miners can't extract gold any faster than they have the past decade

Gold miners are worried. In the past 40 years, they've seen a slew of developments favoring their business. Gold's price has risen so that on average it's been worth several times what it was. Investment in the search for new gold deposits doubled and then doubled again, making gold more intensively sought after than any other metal or mineral group. Technologists have come up with better and cheaper ways to find and extract gold. And gold mining has spread throughout the planet.

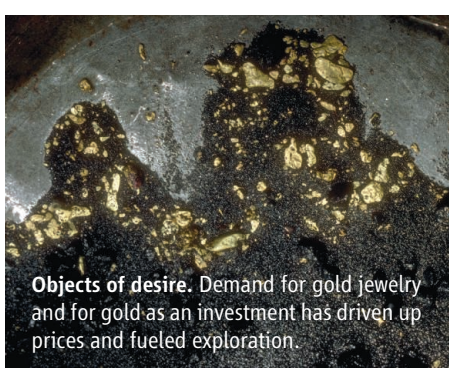
And yet worldwide, production of the glittering element has hardly budged in the past decade. It's not for lack of demand. Gold may not fuel economies the way oil does, but gold for jewelry—its primary use—has been much in demand, and that demand will likely increase. Investors' interest could be intense for years longer. But to judge by the mining industry's modest success of late in finding new deposits of gold, production will not be much higher in the next decade.

Miners and analysts agree that most of the easy-to-find, easy-to-develop gold has been found. To discover still-hidden deposits and at least maintain production, let alone increase it, miners will need continued high or even higher gold prices, revolutionary new technology, and the cooperation of often reluctant host countries.

"It's a huge amount of new [gold] deposits that has to be found," says resource geochemist Stephen Kesler of the University of Michigan, Ann Arbor. "That is an issue of considerable concern" because no one wants to see the world's first mineral resource peak anytime soon.

A golden age

The times may be challenging in gold mining, but you don't have to go back to California's '49ers to find an exuberant heyday for gold. In a 2010 article, three experts—Tommy D. McKeith, vice president for exploration and development for Gold Fields Ltd. in Perth, Australia; Richard Schodde, managing director of MinEx Consulting Pty. Ltd. in Melbourne, Australia; and Ed Baltis of Gold Fields, Perth—pointed to a confluence of forces in the 1970s and '80s that drove an eventual doubling of production.



Objects of desire. Demand for gold jewelry and for gold as an investment has driven up prices and fueled exploration.

First of all, in 1971, governments stopped fixing their currencies to gold at a price of $35 an ounce ($185 in 2009 dollars). As the unleashed gold price rose through the 1970s toward a 1980 peak above $1500 an ounce, so too did investment in exploration for gold. Exploration expenditures soared in the 1980s by an order of magnitude, never again falling below double the spending of the 1970s.

Technical and scientific breakthroughs fed gold mining fever as well. Recognition of new types of gold deposits—such as the Carlin deposits of Nevada, which have no visible gold grains—aided exploration. So did new technology, from more-sensitive sample analyses that detect low levels of gold to orbiting satellites that use spectra to map promising mineral terrains. New, cheaper gold-extraction techniques—such as leaching gold from heaps of ore with a cyanide solution—made ores worth mining even when they contained less than a gram of gold per ton of rock.

By the 1980s and especially in the 1990s, those changes greatly broadened the gold mining club. They made the United States, Australia, and China major producers in a business previously dominated by South Africa. They also drew in more than a dozen new countries. And production soared. From a low of 1200 metric tons of gold in 1975, the industry's output more than doubled to 2600 tons in 2001.

End of an age

The exuberance of the 1980s and '90s has definitely cooled, and now it is tinged with anxiety. Production immediately began dropping from its 2001 record high to a low of

CREDITS (TOP TO BOTTOM): BARRICK GOLD CORP; PHIL SCHERMEISTER/CORBIS

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Big mining. Part-per-million gold ores require large-scale operations (note people in red, *center*).

2260 tons in 2008. Miners have since clawed their way back to record-equaling production, spurred by gold prices rocketing to the (inflation-adjusted) levels of 1980.

That resurgence isn't heartening gold miners much, though, because their best indicator of future production—the amount of gold discovered in the past 10 years or so—is showing no signs of life. As he reported at the 2011 NewGenGold Conference in Perth last November (http://www.minexconsulting.com/publications/nov2011b.html), Schodde has compiled reports of the amounts of gold discovered per year from 1950 to 2010 (see figure). Using history as a guide, he increased the size of recent discoveries to account for the inevitable growth in the apparent size of a newly discovered deposit as geologists explore it.

By Schodde's reckoning, gold discoveries peaked in the 1980s. That presumably led to the 2001 production peak. Since the 1980s, discoveries have been something like 20% lower. Is that enough to sustain production over the next decade or two? "Yes," Schodde says, "but it's a struggle, it really is." A bolstered exploration effort has been yielding meager returns; the average gold content of ore mined has steadily fallen by a factor of 4 since 1979. So to produce an ounce of gold, four times the tonnage of rock has to be moved and processed.

The golden age seems to be over. "It's becoming harder and harder to find" gold, concludes minerals analyst Michael Chender, CEO of Metals Economics Group in Halifax, Canada. "There's a general sense that most of what's easily available has been found and picked up." Andrew Lloyd agrees; the industry "has increased exploration, but they're not finding a lot of new deposits, especially the large ones," says the spokesperson for the world's largest gold mining company, Barrick Gold Corp., headquartered in Toronto, Canada. "The industry as a whole is really struggling to keep up with demand."

Online

sciencemag.org

Podcast interview (http://scim.ag/pod_6072) with author Richard A. Kerr.

Pause or peak?

How the struggles of the gold mining industry will play out depends on whose crystal ball you are consulting. Those who have been predicting that the world's production of oil will shortly peak, if it hasn't already done so, are pessimistic about gold's prospects as well. Applying a standard peaking analysis to the history of gold production, retired oil geologist Jean Laherrère concluded in 2009 that 2001 was the peak and that production would soon plummet.

Some analysts and explorationists are considerably more optimistic. They point to the three production peaks in the 20th century, each of which was followed by a higher peak. Each time, the gold price went up, new territory opened to mining, or new technology made it easier to find or process gold ore. "I'm sure we'll discover something in the next 10 years that will change the picture," Kesler says. A can-do spirit goes with the turf, says resource geochemist Gavin Mudd of Monash University, Clayton, in Australia. "It's never say never" in the mining industry, he notes. "Part of this business is the business of hope."

Others come down on a middle ground. "Our view is that mine supply is not likely to increase from present levels," Barrick's Lloyd says. Schodde, too, sees another decade, at least, of more or less unchanging gold production. That would be reminiscent of the "undulating plateau" of recent world oil production (*Science*, 3 February, p. 522). Shifts in price or demand or the politics in a producing country might swing annual production up or down for a few years, but over a decade or so the supply would be little changed.

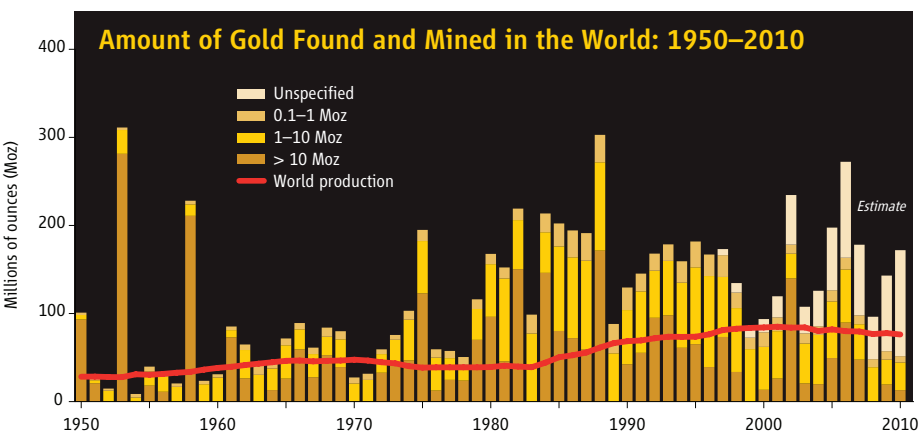
Gold plateauists tend to see greater challenges in gold production now than ever before, but no good solutions in the offing. For example, all the exploration innovations of the past 50 years have not let geologists find deposits any deeper in Earth's crust. Hot, briny solutions deposited gold not at the surface but several kilometers below it. But Schodde finds that the depth to gold deposits discovered in virgin territory has averaged a mere 30 meters in each of the past 5 decades. In every decade, almost half of those discoveries were deposits now exposed at the surface by erosion. Even the generally optimistic Kesler "cannot think of any major processing, mining, or exploration method that is very recent in appearance" that could help out anytime soon.

While these "belowground" issues loom large, the aboveground ones are looking equally daunting. Getting all the required permits for a new mine is taking longer, miners say. Resource economist Keith Long of the U.S. Geological Survey in Tucson, Arizona, has found that in the United States it has taken on average 7 years from requesting a permit to opening a mine. Remote sites in Alaska or deposits in a country new to large-scale mining can take much longer. And overseas, the big global mining companies must delicately, and slowly, navigate the tricky political and social waters of the countries holding the remaining gold.

Litigation further stretches out the development process and increases costs. The gold mining industry produces hundreds of millions of tons of waste rock a year and uses tons of cyanide, Mudd notes. The mass of potential pollution is already increasing as the grade of gold ores has declined, he has found. "The big constraints [on gold production] will be environmental and social," Mudd believes, "not so much discoveries."

Gold, mined as it has been for 6000 years, may be a harbinger of production challenges in other metal industries. Analysts often mention economically essential copper as another element encountering mining constraints. But trends in mineral discovery in general suggest to Kesler that "we are approaching some sort of wall in materials to support our way of life." So watch gold's price and production figures for clues to how close the world may be to the first such wall.

–RICHARD A. KERR



Up, up, and level. Record amounts of gold found in the 1980s let world production rise until 2001. Since then, production has been essentially flat. ("Unspecified" is an estimate.)

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