Peak Gold, Easier to Model than Peak Oil? - Part II

Posted by Luis de Sousa on December 2, 2009 - 2:13pm in The Oil Drum: Europe
Topic: Geology/Exploration
Tags: gold, jean laherrère, peak minerals [list all tags]

This is the second installment of a guest post by Jean Laherrére on peak gold. The first part can be read here. This time Jean takes a macroscopic perspective on gold mining for the world as whole.

Note: This post contains 33 images amounting to **1.5 Mbytes** of data.

World gold production

In Part I, we mentioned how uncertain past data is, in particular for the countries of the Former Soviet Union. Furthermore, gold producers try to inflate their discoveries to get higher stock markets values, even to the extent of fraud. A series of high profile resource stock scams took place in the 1990s, which culminated in the huge Bre-X scandal in 1995. Bre-X's stock collapsed after its much-touted Busang gold project – thought at the time to contain more than 70-million ounces (2.1 kt) of gold - turned out to be a fraud; core samples from the drills had been tampered with and expertly "salted" with gold dust.

The world cumulative gold production has reached about 150 kt at the end of 2008 (151 kt according to Gavin Mudd and 161 kt according to USGS, which had too high an amount for FSU). USGS estimates remaining reserves at 50 kt and resources at 100 kt. We model the future for an ultimate of 250 kt.

The world population is also plotted and displays a good correlation with cumulative gold production.

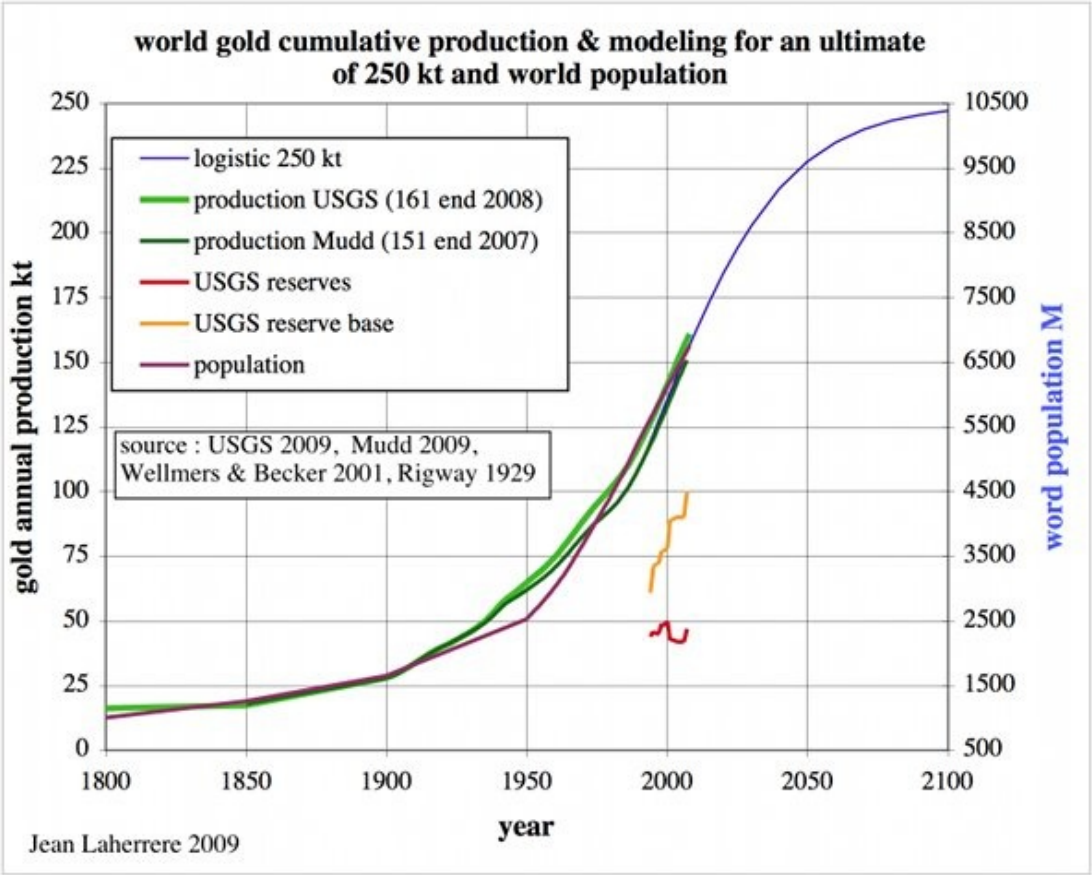


Figure 50: World cumulative gold production & modelling for an ultimate of 250 kt

Gold production is reported to have started about 6000 years ago, but industrial production started around 1900. Gold cumulative production displays a real hockey stick!

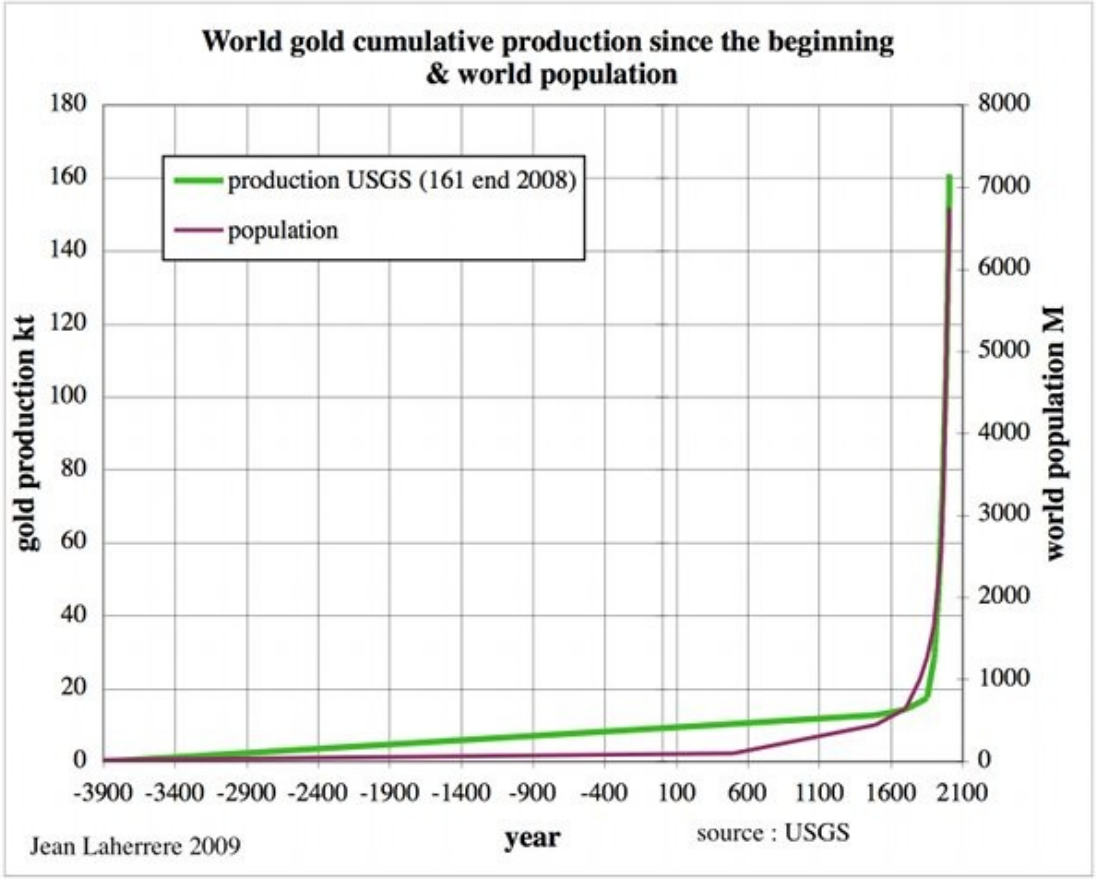


Figure 51: World cumulative gold production since the beginning of gold discovery in -3900 and world population

Hubbert linearization (annual production over cumulative production percentage versus cumulative production) is often used to estimate the ultimate with a linear extrapolation, but this procedure only works if cumulative production follows a logistic curve (called the S curve). The world linearization graph is useless; no reliable linear extrapolation can be drawn, except that the last 10 years since 1998 could be extrapolated towards 240 kt.

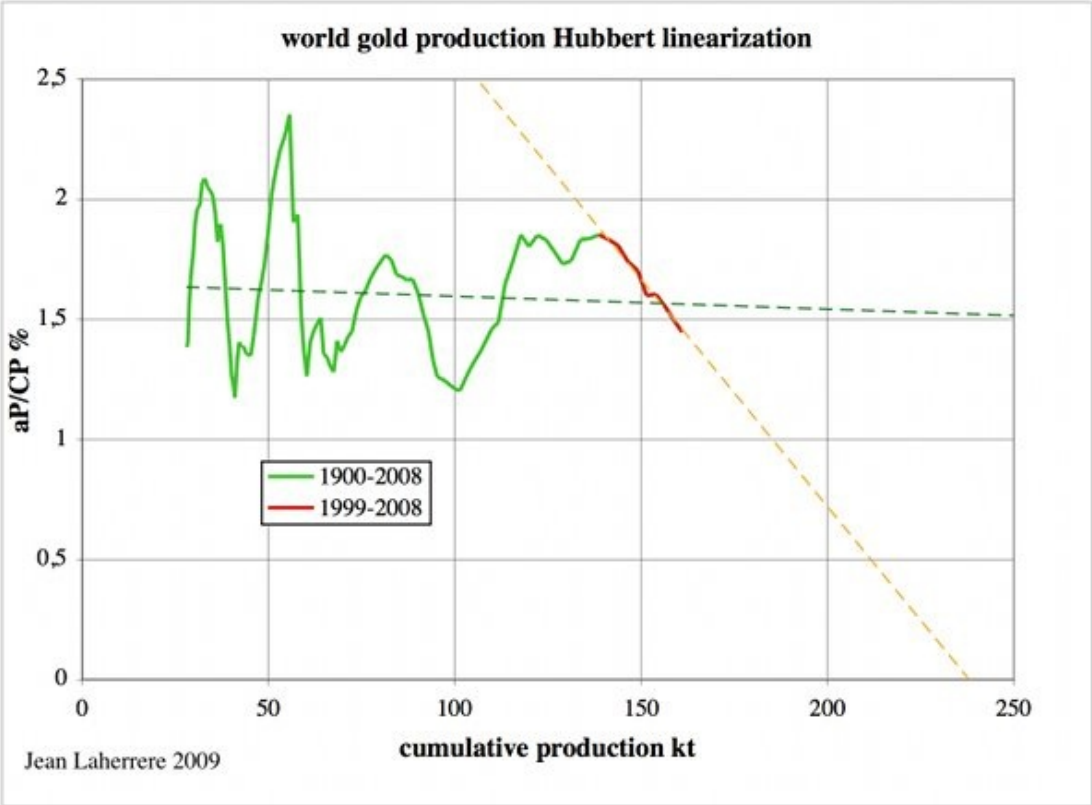


Figure 52: World gold production Hubbert linearization

World gold annual production is plotted from different sources: USGS, Gavin Mudd, and goldsheetlinks. There is a large discrepancy during WWII and the cold war because of the overestimates by the CIA for the FSU. Gold price is also plotted with the drastic increases of 1980 and 2008.

Gold annual production peaked in 2000, and the decline is as steep as the increase despite the increase in gold price.

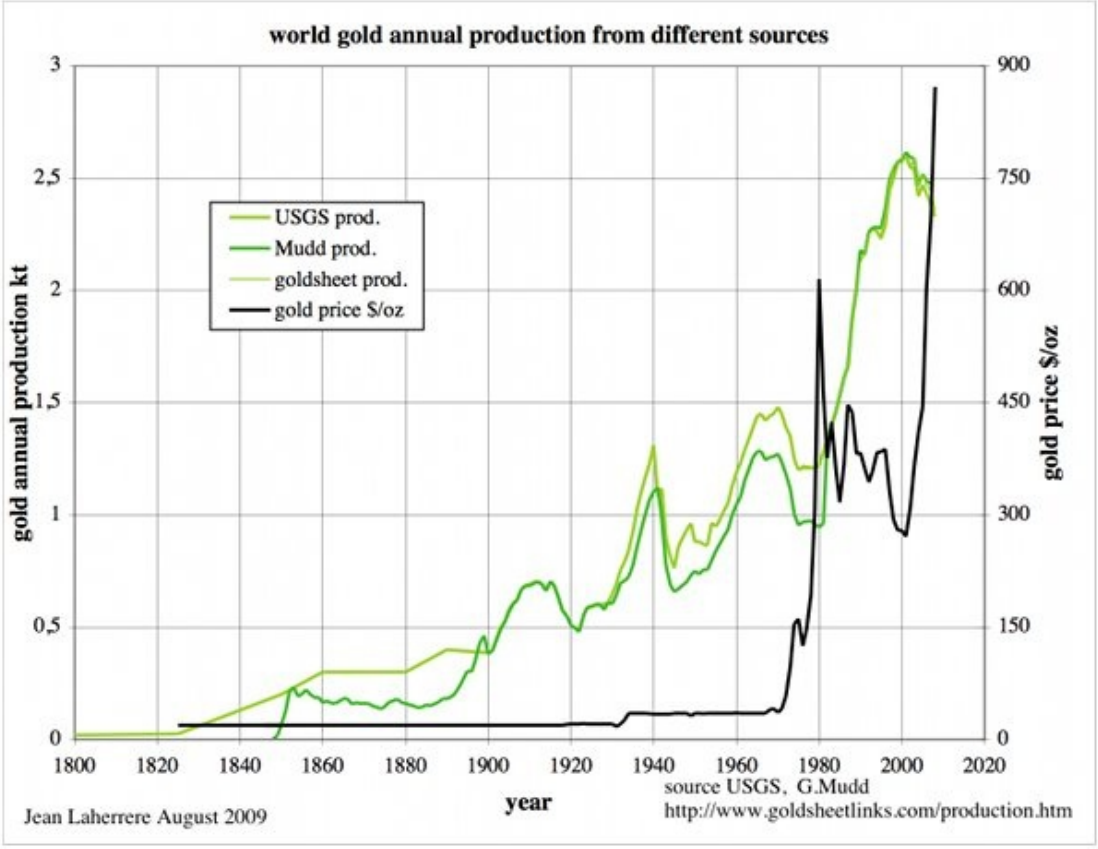
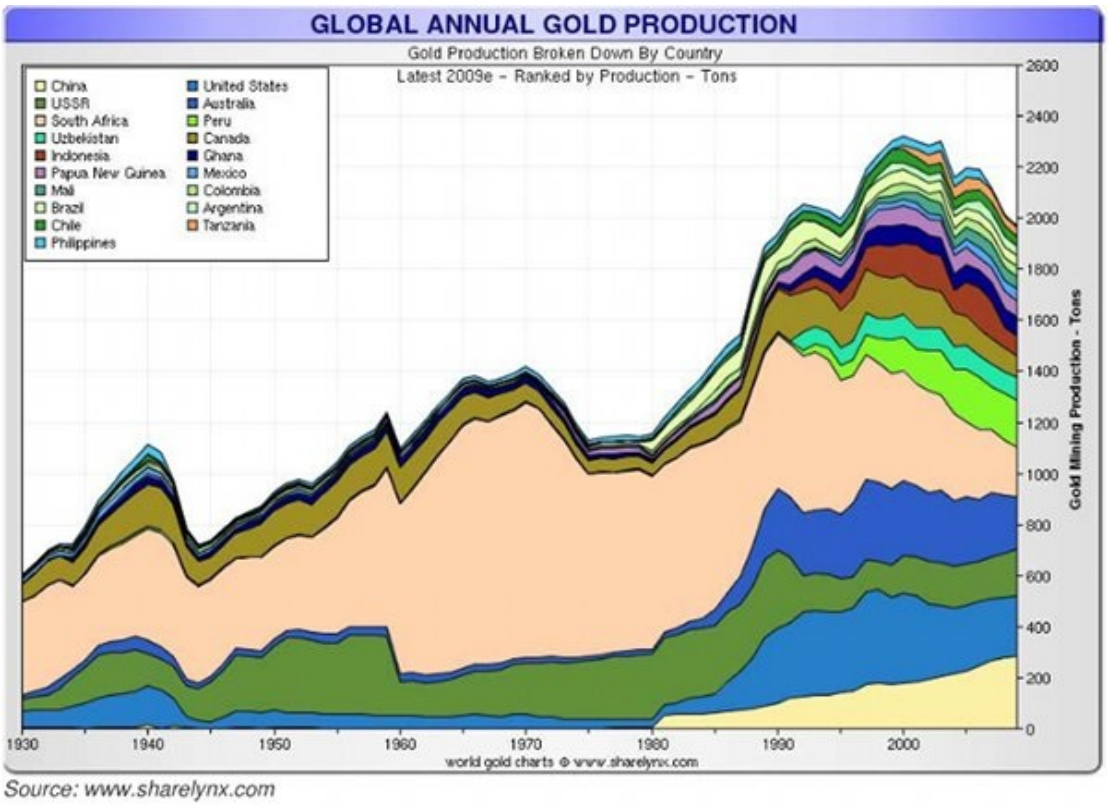


Figure 53: World gold annual production from different sources

The breakdown country by country can be seen clearly on the graph from the 2009 Erste Bank Special Report Gold, despite of the USSR collapse in 1960 being wrong, as previously described.



Source: www.sharelynx.com

Figure 54: World gold annual production breakdown by country 1930-2008

Moorhead 2009 Newcrest has a similar graph for 1980-2008:

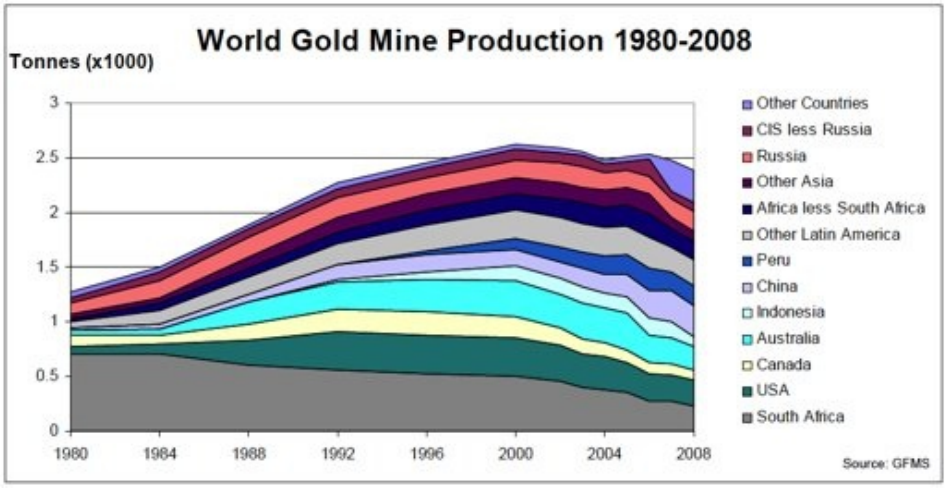


Figure 55: World gold annual production breakdown by country 1980-2008

World annual gold production is modelled with 7 cycles, but from 1800 (close to zero) to the 2000 peak the pattern looks like a simple bell-shape curve, despite several short bumps.

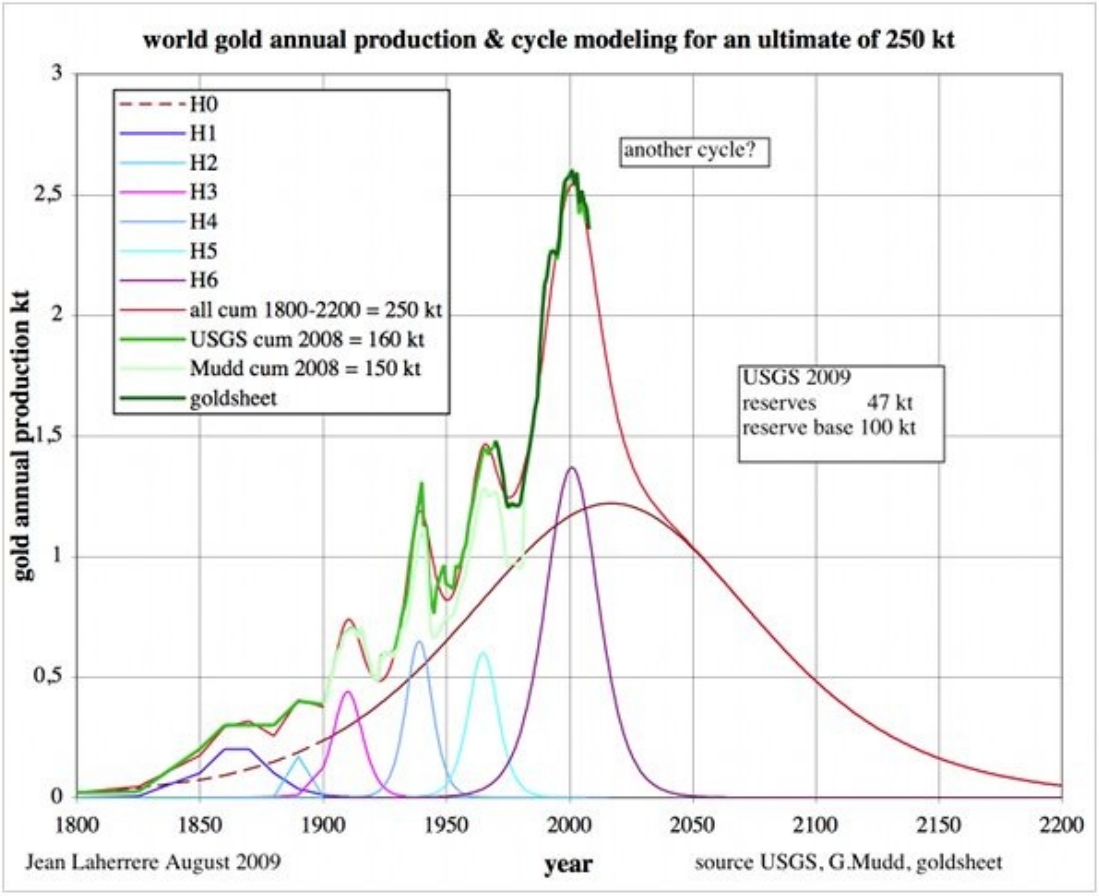


Figure 56: World gold annual production & modelling for an ultimate of 250 kt

Gold annual production and forecasts of the main producers are compared. If China is now the largest producer, South Africa could be back to that position in 2030 if its 58 kt ultimate is right. New producers will arrive if the world ultimate at 250 kt is right.

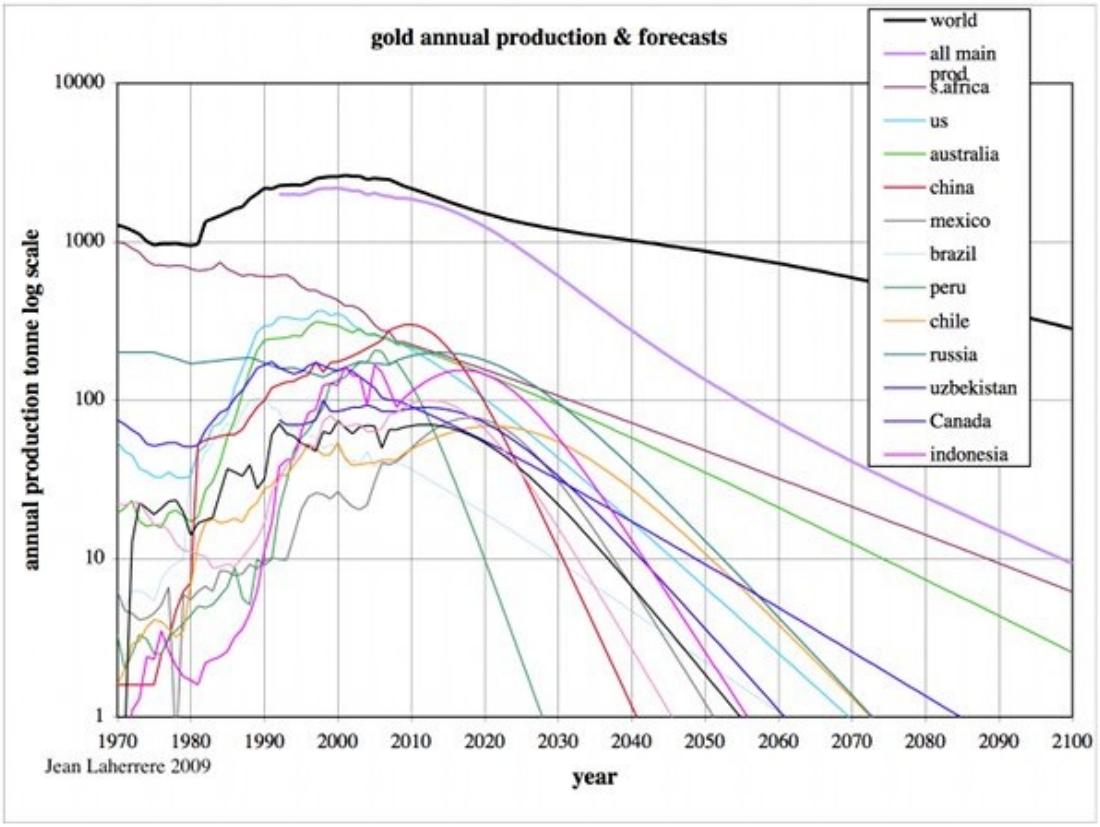


Figure 57: Gold annual production of the main producers in log scale

The same graph in normal scale:

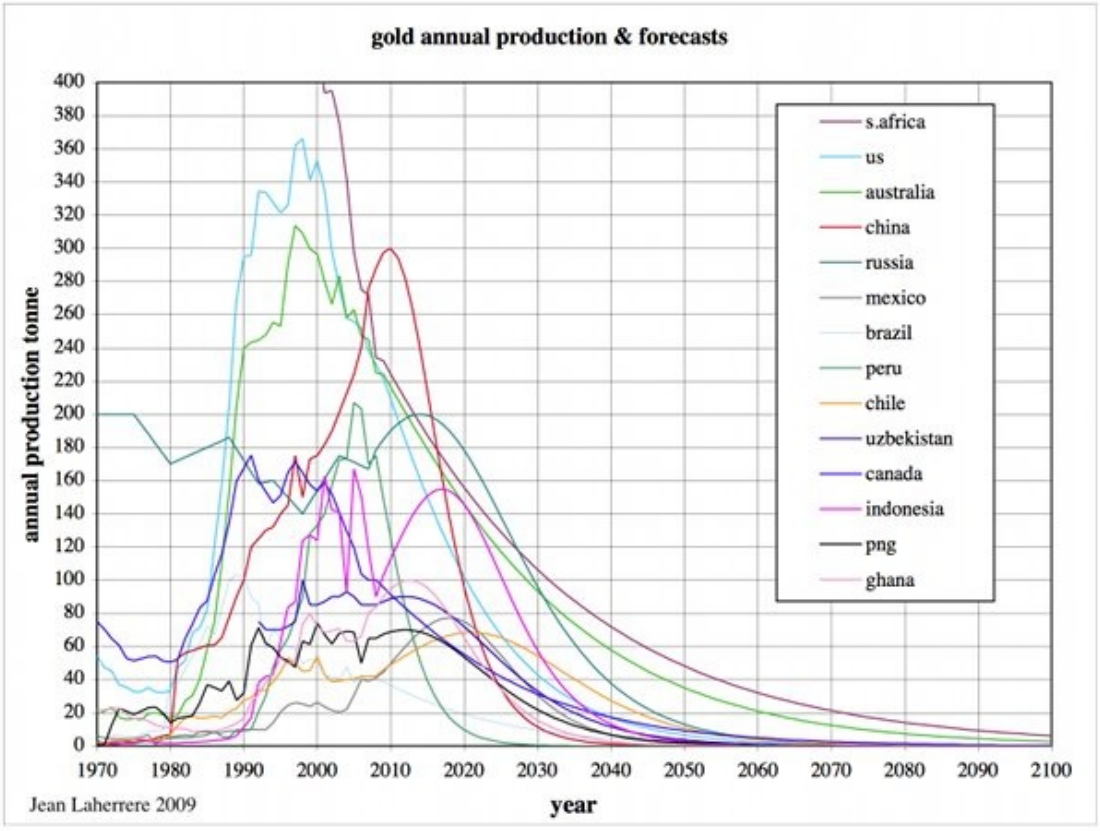


Figure 58: Gold annual production of the main producers

World gold grade

It is very hard to find historical data on world gold mine grade. The best one I found is from 2009-07-02: Erste Bank Special Report GOLD. The graph starts in 2000 at 2.2 g/t and declines down to 1.1 g/t in the first quarter of 2009. It is confirmed by data from CIBC World Markets.

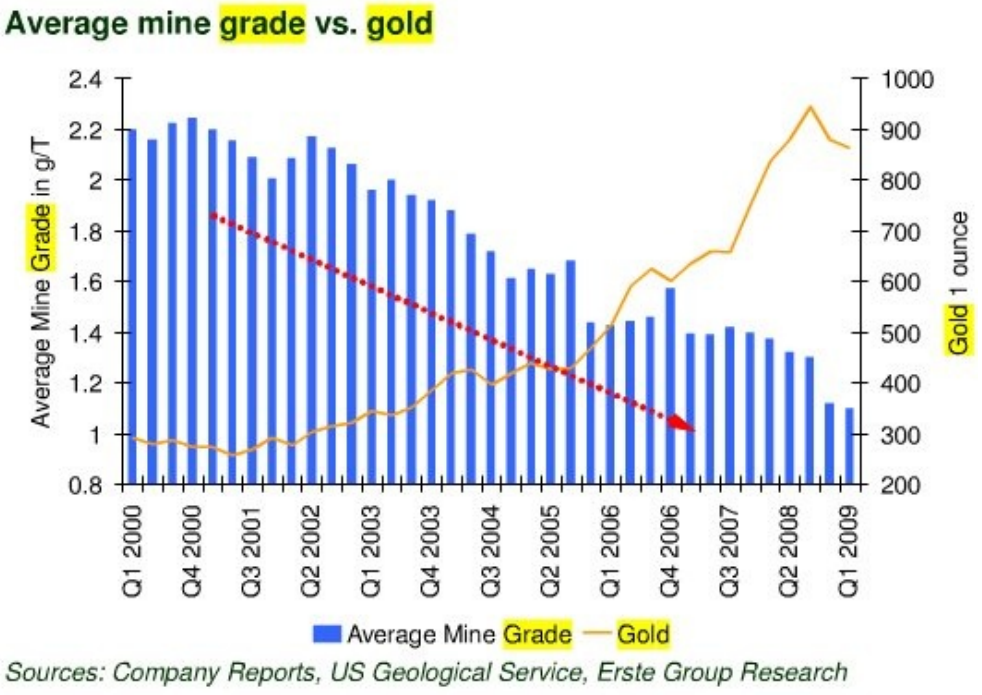


Figure 59: World gold mine grade 2000-2009

Estimation of reserves needs to assume an economic cutoff, which depends mainly upon the gold price and the mine set up (surface or deep mine). The gold cutoff was taken as 1 g/t a few years ago, but with the recent gold price increase it went down to 0.7 g/7 and now to 0.5 g/t. But in fact there is a little difference in reserve volume between cutoff at 0.5 g/t or 1 g/t, because the frequency of gold grade displays a pattern where 1-2 g/t seems more frequent than 0-1 g/t , as shown in this graph by Andean Resources Ltd [pdf!].

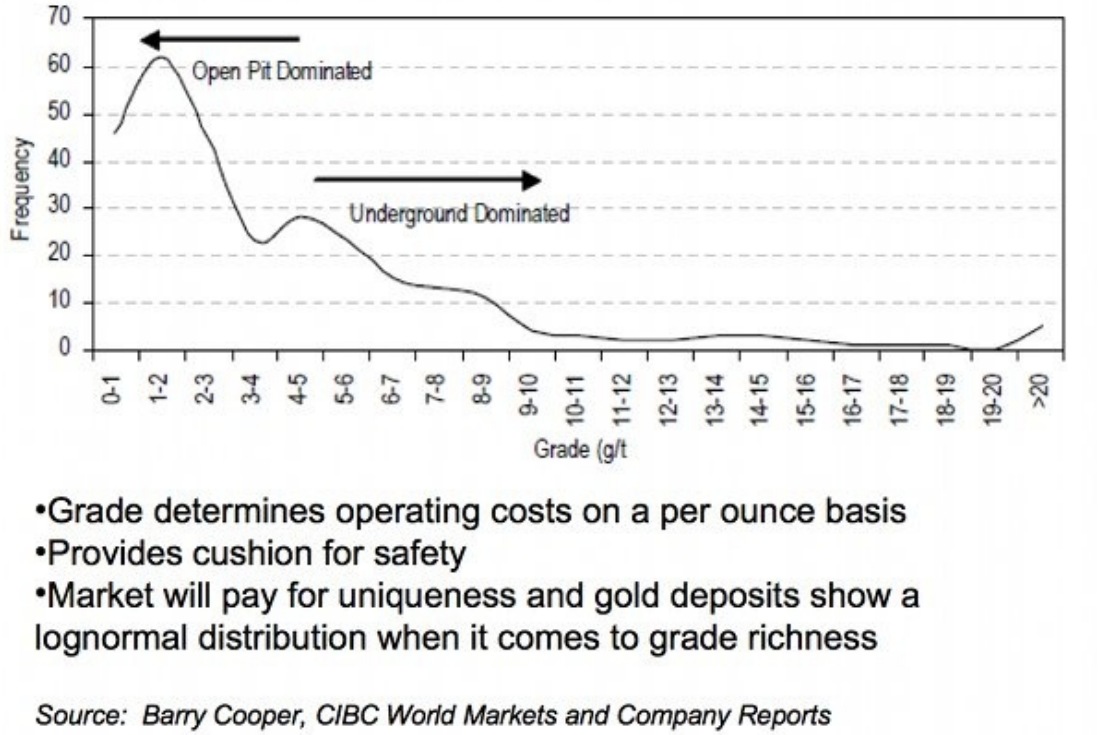


Figure 60: Gold grade frequency by Andean Resources Ltd

This graph surprises me because it disagrees with most fractal distributions I have seen. The frequency must be computed with the number of deposits and not by volume, and, of course, low-grade deposits are ignored; as well as gold in seawater.

Vann et al. in the 1995 article entitled *Global resource estimation [pdf!]* estimated reserves for a particular dseposit, where the difference between 1 g/t and 0 g/t is small.

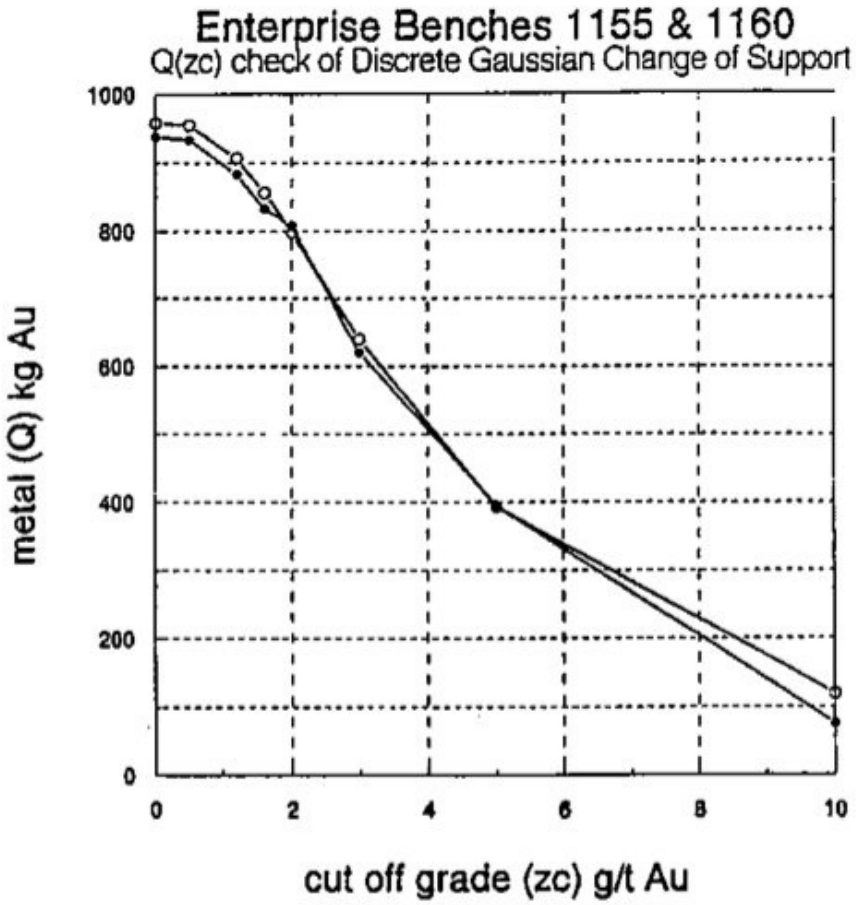


Figure 61: Gold volume estimate versus gold grade frequency (Vann 1995)

Gold in seawater

Everyone agrees that gold in seawater represents a huge volume, but it is hard to get a consensus on the concentration (grade) and volume. The volume of the oceans is 1.3-1.5 billion km3 (10E18). Some attempts have been made to assess these figures:

> The famous chemist Fritz Haber had heard that a ton of seawater contained 5/1000ths of a gram of gold or even more which meant the oceans could contain something like 8 million tons of it. Early sample tests were encouraging but not conclusive, so Haber and his assistants took about 5000 samples back to his Berlin laboratory. Alas the final result was that a ton of seawater only contained about 1/5000th of a gram. This was way too low to make it economically feasible to extract the gold. It was a crushing blow for Haber.

	Concentration (10E-12)	Volume (kt)	Reserves (kt)
Haber	200	320	
Bardi & Pagani 2007	11	14 300	42
Dartmouth University	600	8 000	
Encarta	50 000	9 000 000	

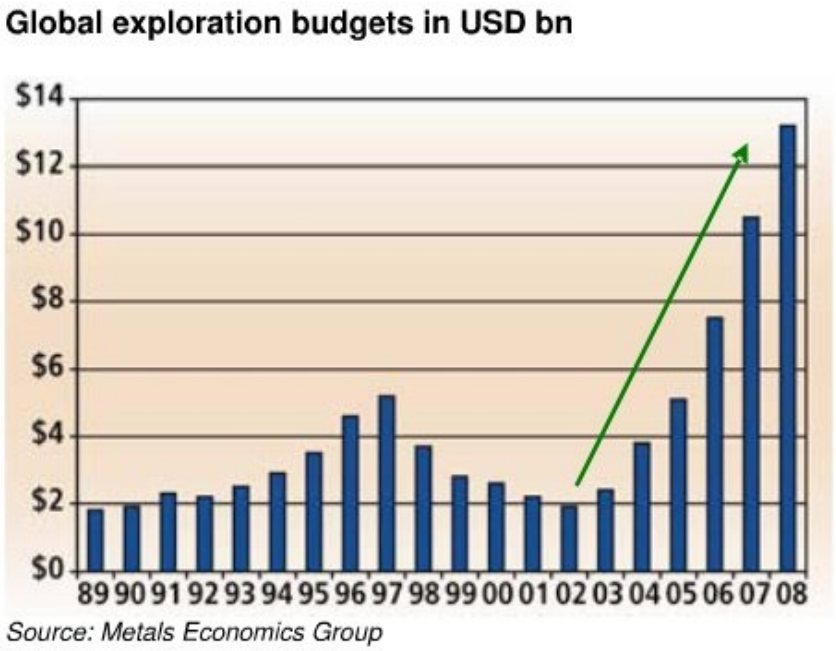
GoldFever	10	750	

It is a mess!

However, recently, a high concentration of gold (15 g/t) was found in oceanic deposits close to black smokers. Production with copper is planned by a company (Nautilus). In this case it is difficult to estimate the total volume at this stage.

World gold exploration and budgets

In the Erste 2009 report, it is interesting to see that gold exploration budgets have sharply increased since 2003, but exploration budgets for 2009 are estimated to be down by 40%!



[6] http://www.metalseconomics.com/pdf/Strategies_for_Gold_Reserves_Replacement_2009.pdf

Figure 62: Gold exploration budgets from the Erste report

The discoveries in the western world (Owen Hegarty CEO G-Resources «Gold: the perfect metal» June 2009) peaked around the 1980s, but low discoveries around 2000 may be due to low exploration investments.

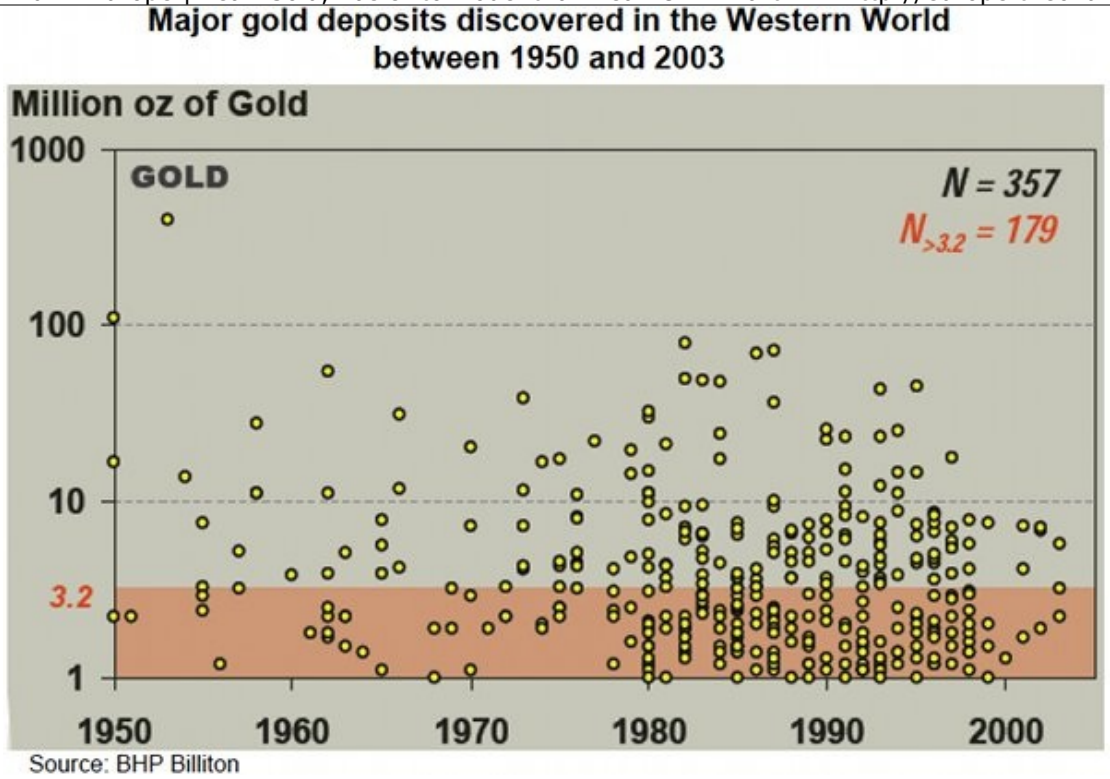


Figure 63: Gold discoveries in the western world 1950-2003

The Metals Economic Group says there were only been four world-class gold discoveries in the last 15 years. In fact, of all new discoveries, 75 % are made by the juniors.

Newcrest states that Gold discoveries are becoming rarer [pdf!]:

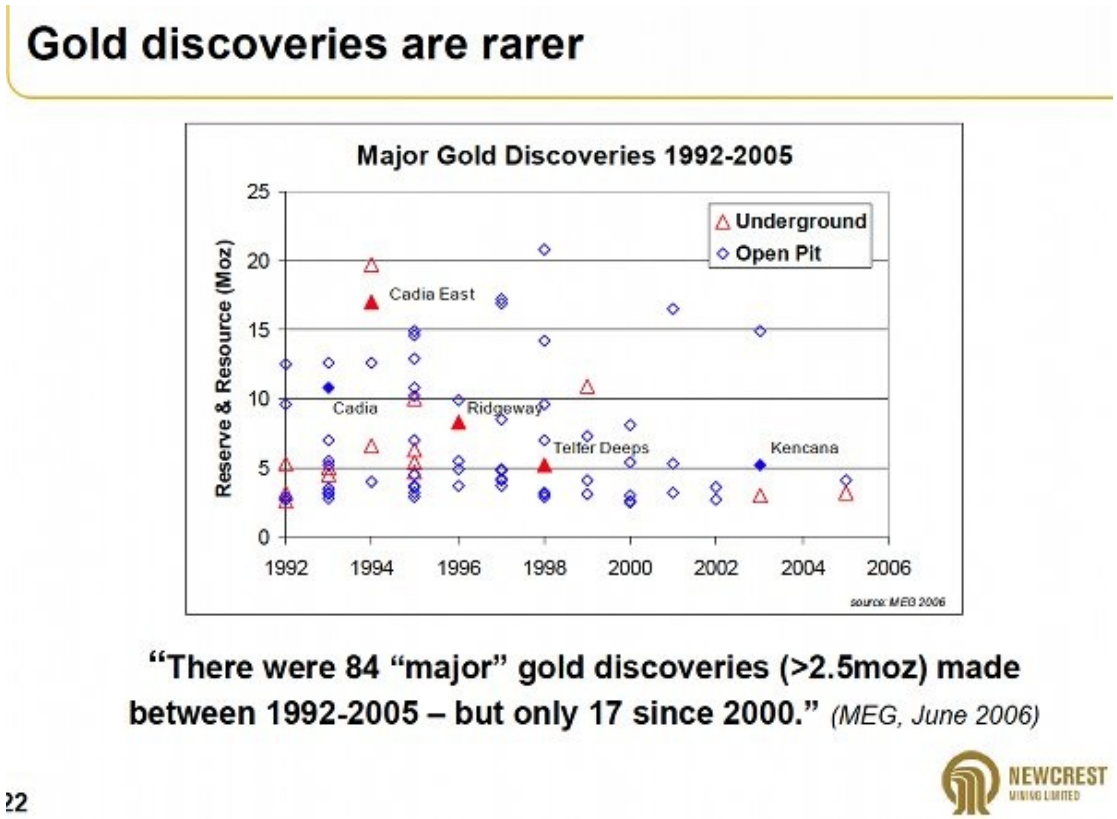


Figure 64: Gold discoveries 1992-2005 from Newcrest

Distribution of gold deposits

Peter Laznicka, 1999, *Quantitative relationships among giant deposits of metals*, Economic Geology V94 n04 gives the gold distribution from geological ages:

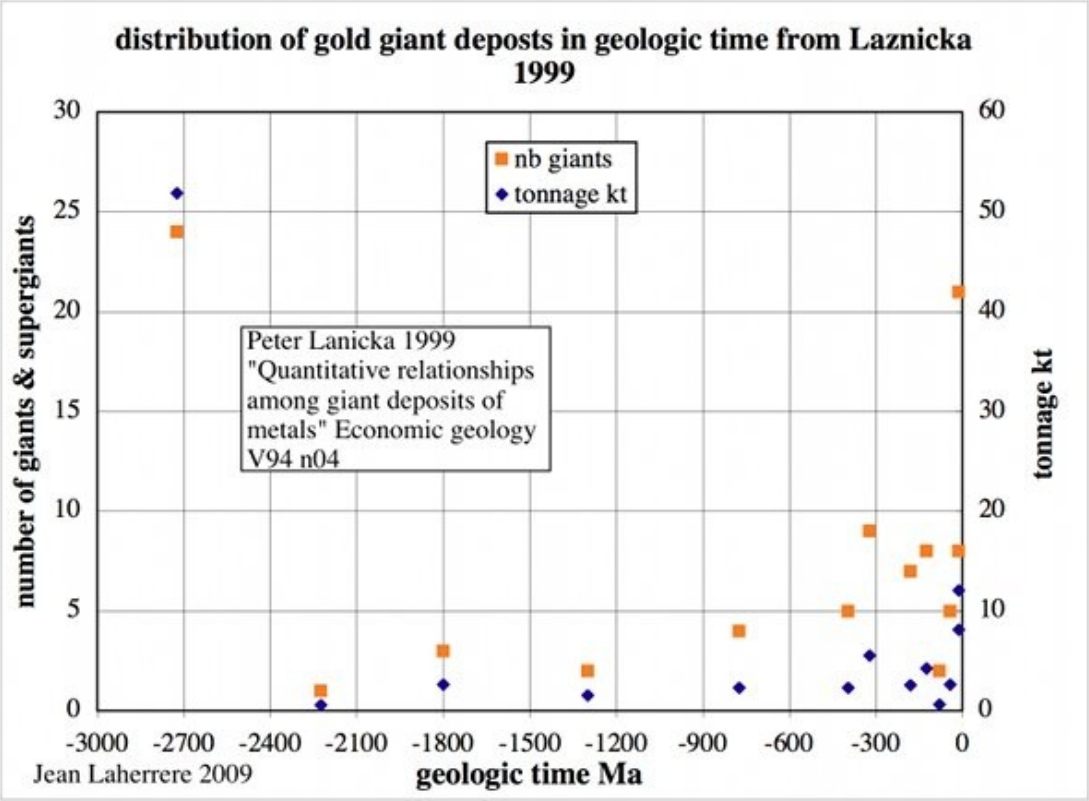


Figure 65: Gold giant deposits (number & tonnage) in geologic time from Laznicka

Laznicka has listed over 500 giant metal accumulations in a database called GIANTDEP that is not available on the web.

Robinson, 2007, *The Spatial and Temporal Distribution of the Metal Mineralisation in Eastern Australia and the Relationship of the Observed Patterns to Giant Ore Deposits* [pdf!] has a graph that is similar but slightly different despite being from the same source.

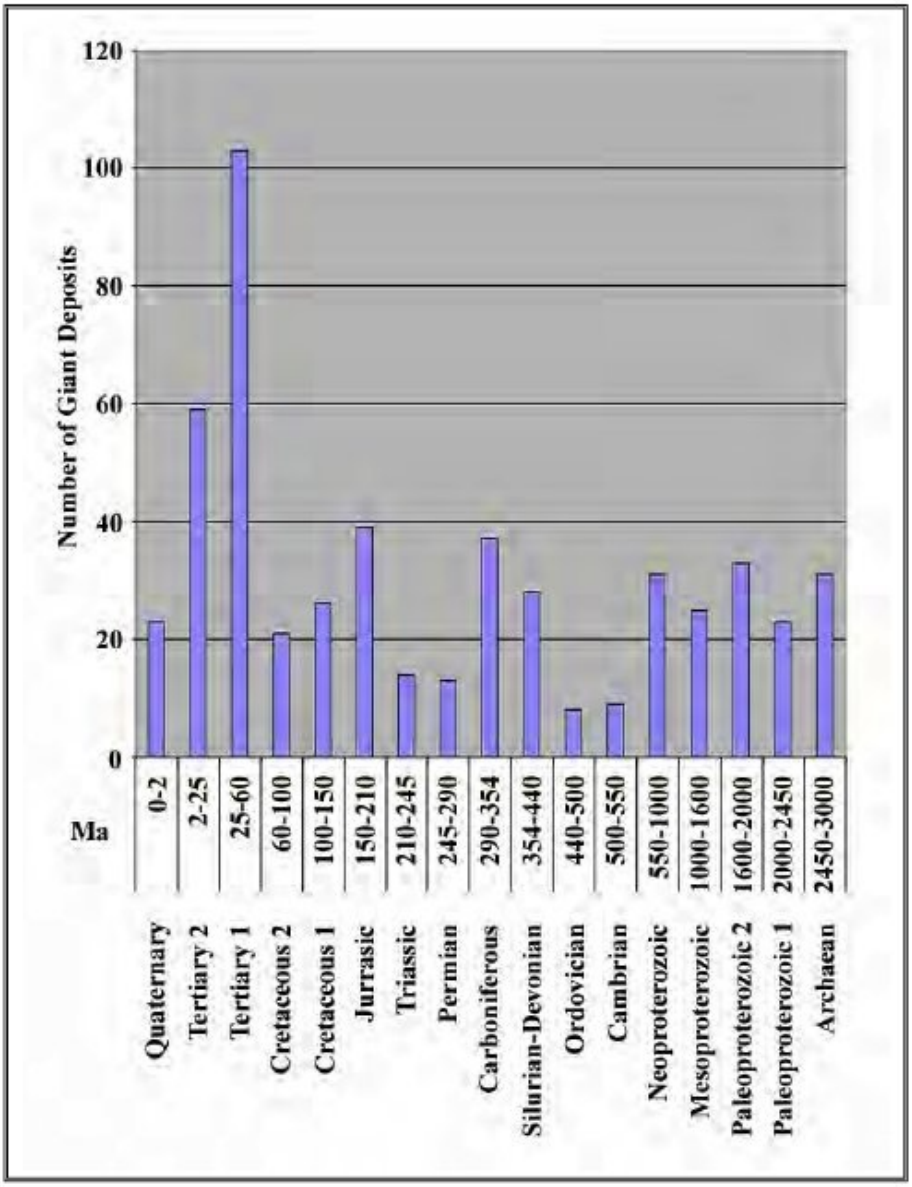


Figure 6-29 Giant Ore Deposits in Geological Time

Figure 66: Number of gold giant deposits in geologic time from Robinson page 220

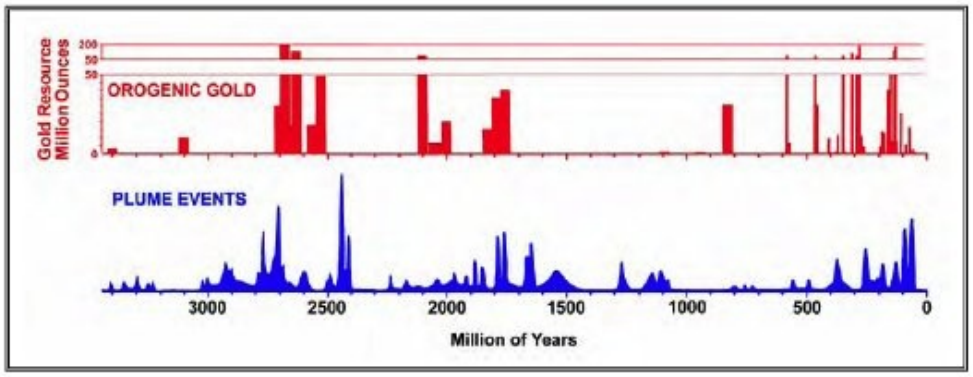


Figure 6-30 Temporal Distribution of Orogenic Gold Deposits and Plume Events
After Groves (2005), Abbott and Isley (2002b) and Goldfarb et al., 2001

Figure 67: Number of gold giant deposits in geologic time from Robinson page 221

Laznicka's classification is 4 kt for a supergiant, 400 t for giant and 40 t for large deposit.

Table 3-1 Classification Scheme for Large, Giant and Supergiant Deposits

After Laznicka (1998)

		Minimum Tonnage of Metal		
Metal	Clarke (ppm)	Large Deposits	Giant Deposits	Supergiant
Zn	70	700,000 t	7 Mt	70 Mt
Cu	55	550, 000 t	5.5 Mt	55 Mt
Pb	12.5	125, 000 t	1.25 Mt	12.5 Mt
U	2.7	27,000 t	270,000 t	2.7 Mt
Ag	70 ppb	700 t	7, 000 t	70,000 t
Au	4 ppb	40 t	400 t	4000 t

Figure 68: Classification of gold deposits, Robinson page 89

Unfortunately, no complete list of world gold deposit reserves is available on the web. We have to restrict our analysis to deposit production.

The fractal distribution of gold deposits annual production (deposit size versus rank of deposit in decreasing size order) is plotted from USGS 0FR 02 303 (table 11), world's largest mines in 2001 and gold producers from gooldsheetlinks. The fractal distribution is parabolic like all natural objects (Laherrere 1996, Laherrere & Sornette 1998).

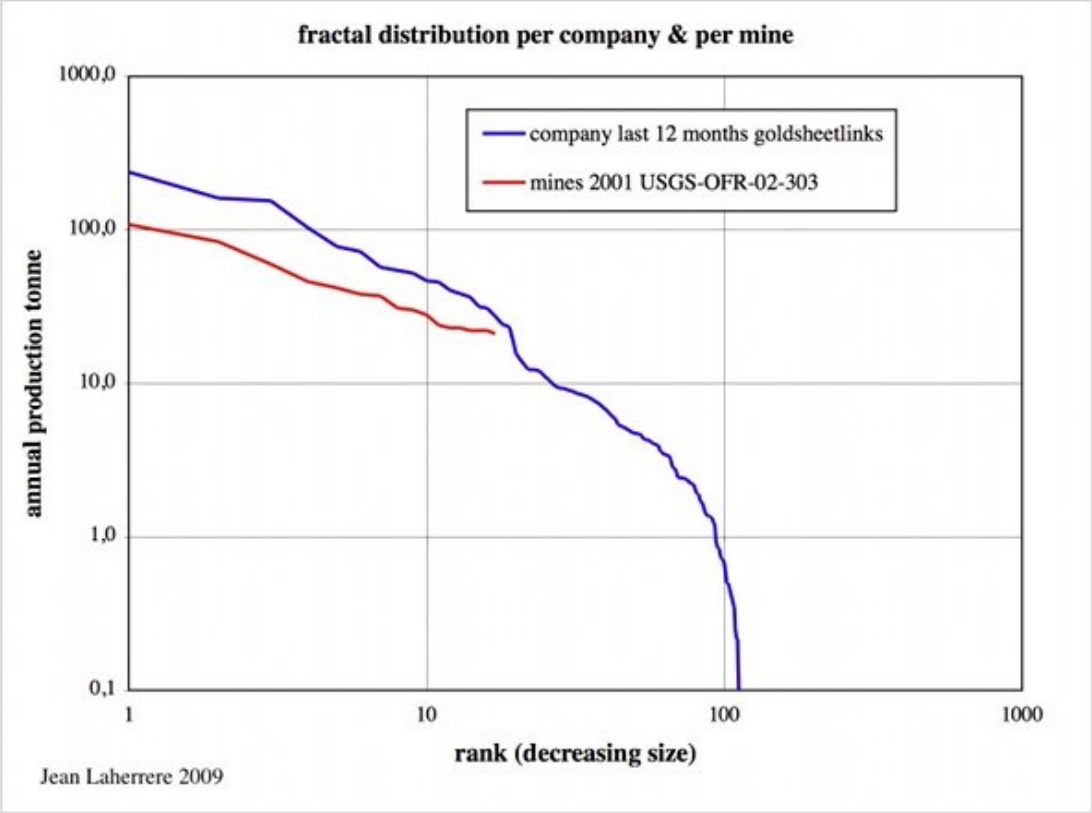


Figure 69: Fractal distribution of annual production per company & per mine

Fractal distribution is related to Pareto's law: 80/20 (80% of the production comes from 20% of producers). The production of the 15 largest producers represents 51% of the world's production (goldsheetlinks rank per company for the last 12-month trailing production, August 2009).

World gold demand

Unlike oil, gold is mostly conserved, and demand can be much larger than mine production. The demand is mainly jewelry.

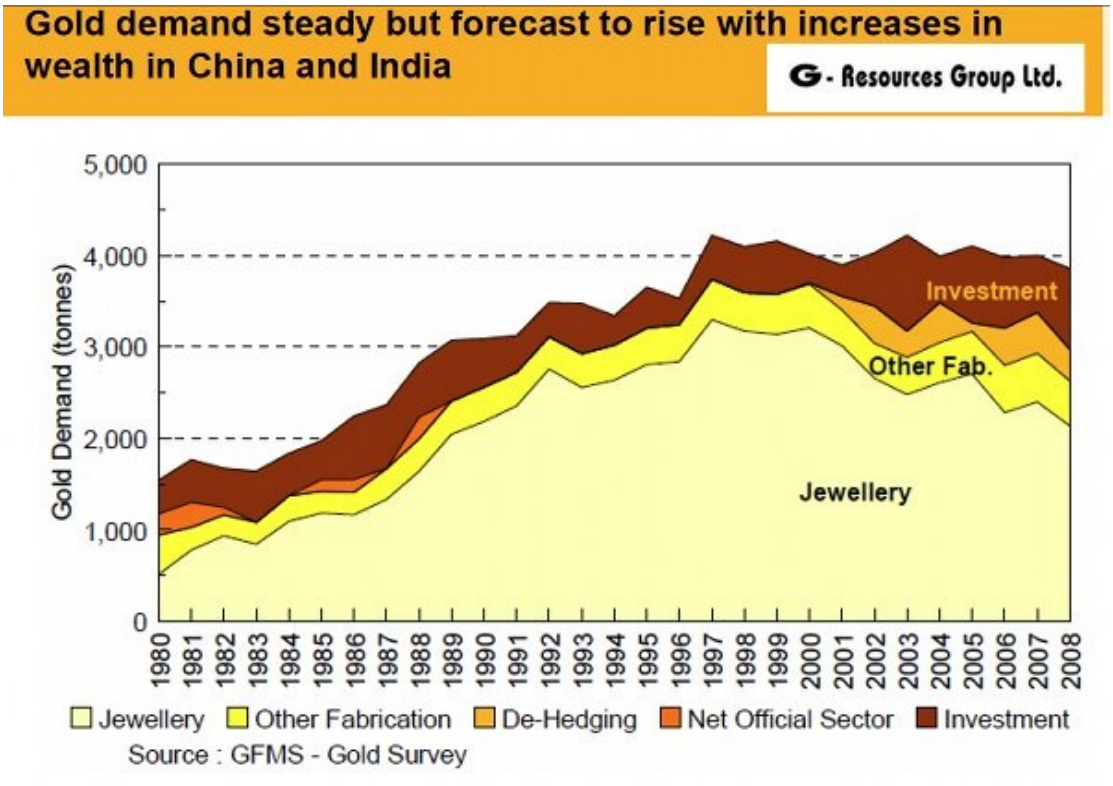


Figure 70: Gold demand from Erste report

The gold consumption pattern in 1999 (USGS –OFR-02-303-gold) shows that jewelry is the largest use, followed by electronics, then coins.

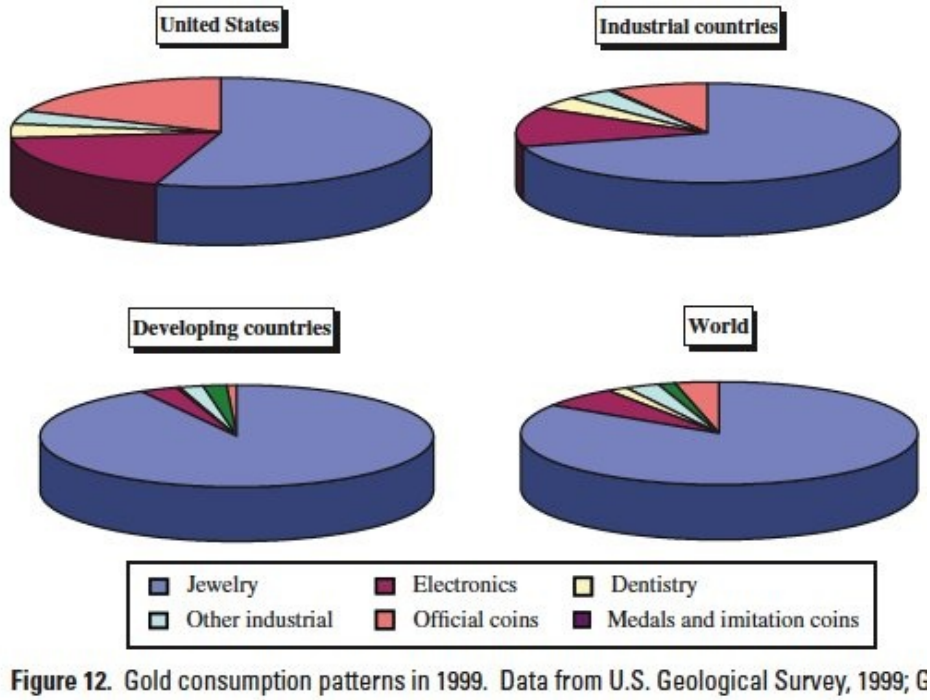


Figure 12. Gold consumption patterns in 1999. Data from U.S. Geological Survey, 1999; G

Figure 71: Gold consumption pattern in 1999

Mine supply provides the majority of the gold supply, followed by gold scrap and sales.

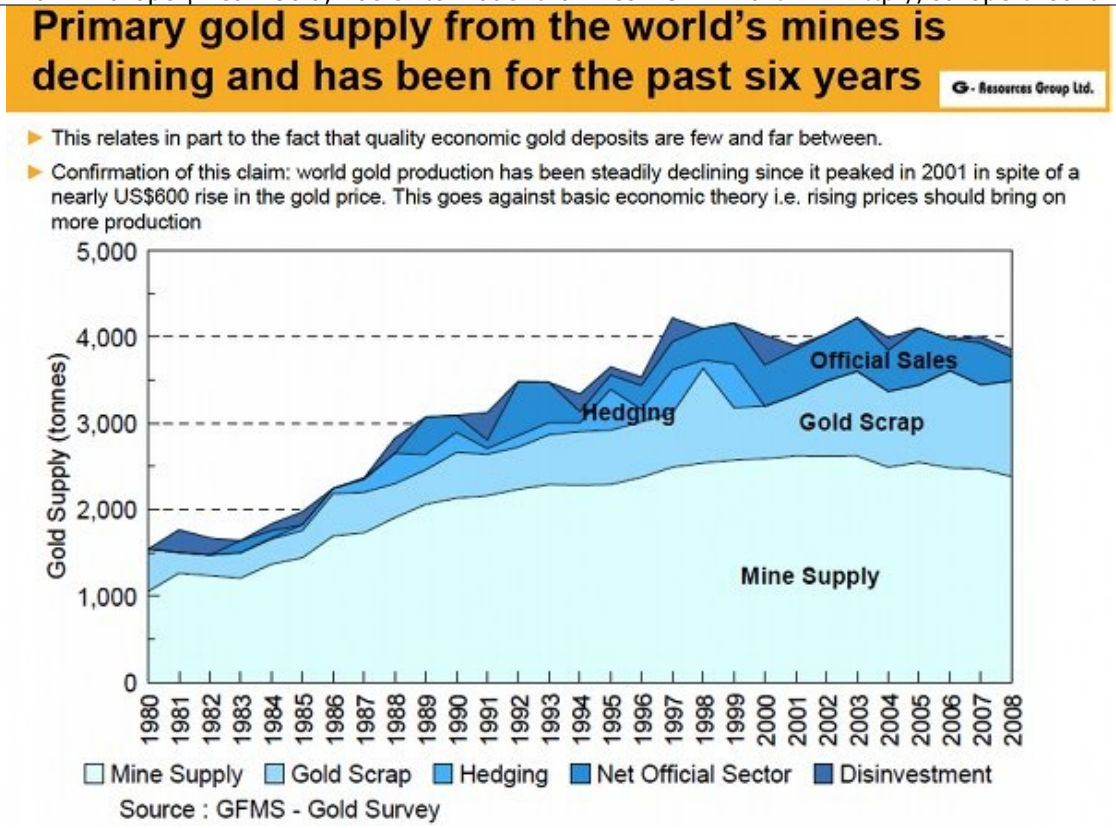


Figure 72: Gold supply 1980-2008

Official gold reserves

Gold reserves can either correspond to what is expected, from geological estimates, to be produced in mines, or the amount of gold in banks.

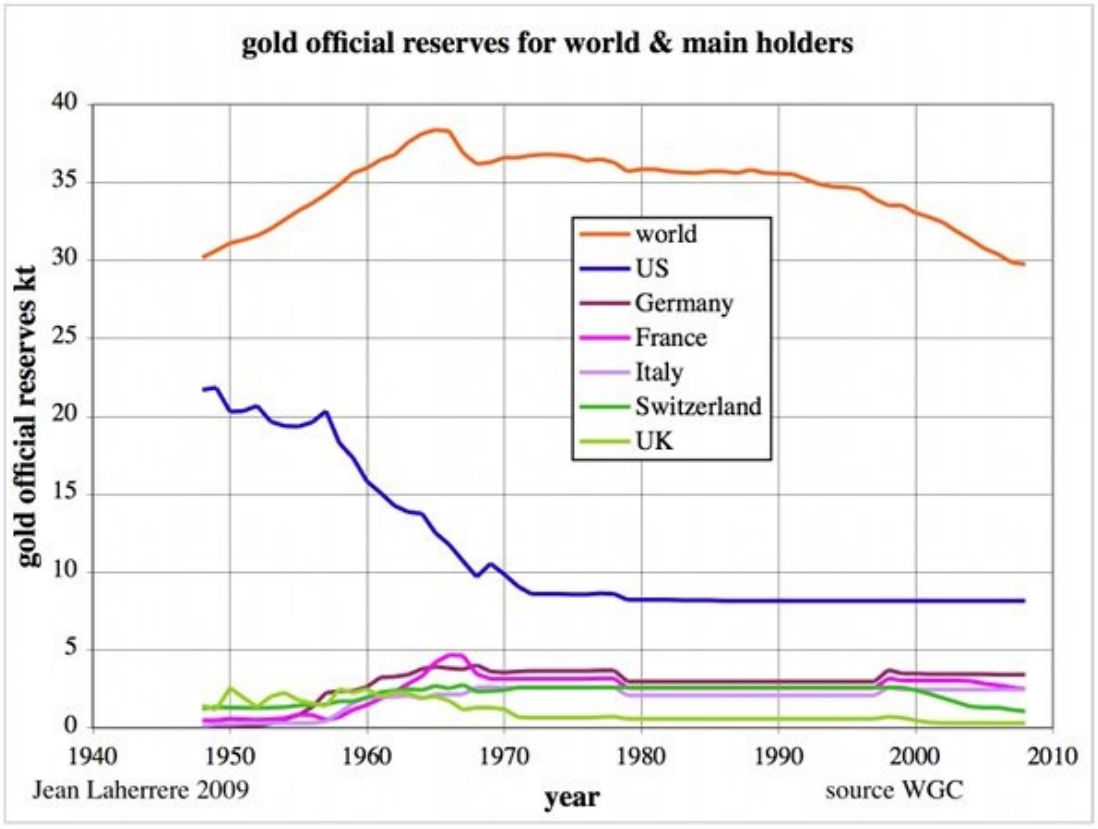


Figure 73: Official world gold « reserves » and main holders

Gold price

The price (London pm fix) of gold is displayed monthly in different currencies.

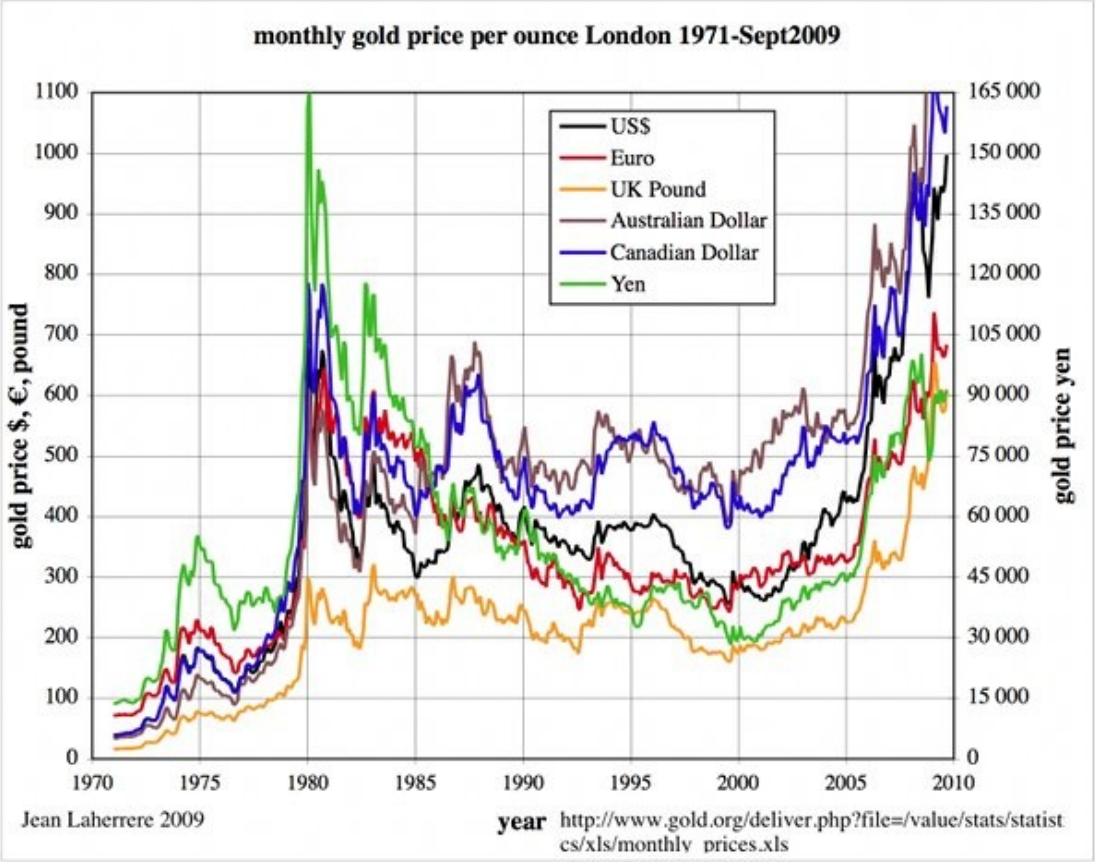


Figure 74: Monthly gold price in different currencies 1971-2009

The gold price is compared to the oil price and the wheat price in nominal dollars. Gold price tends to follow oil prices, whereas the wheat price (which depends on oil for fertilizers, pesticides and machinery), was very close to oil until 1973, but afterwards has become much less connected.

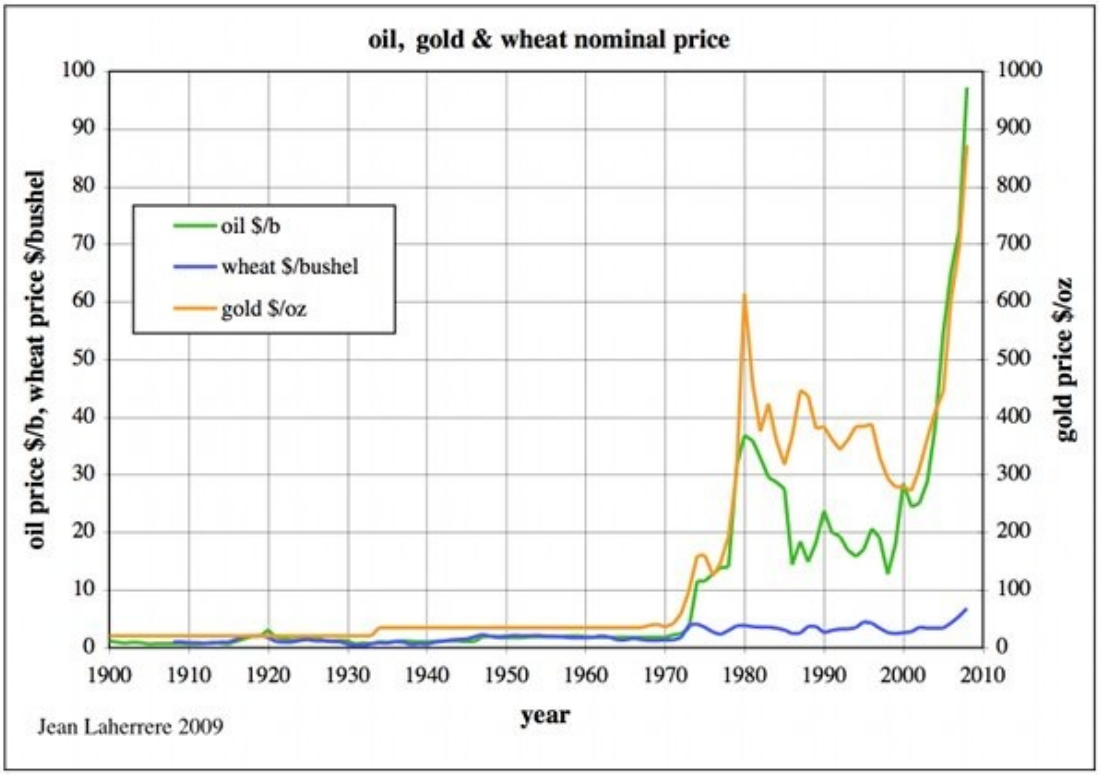


Figure 75: Gold, oil and wheat nominal price 1900-2008

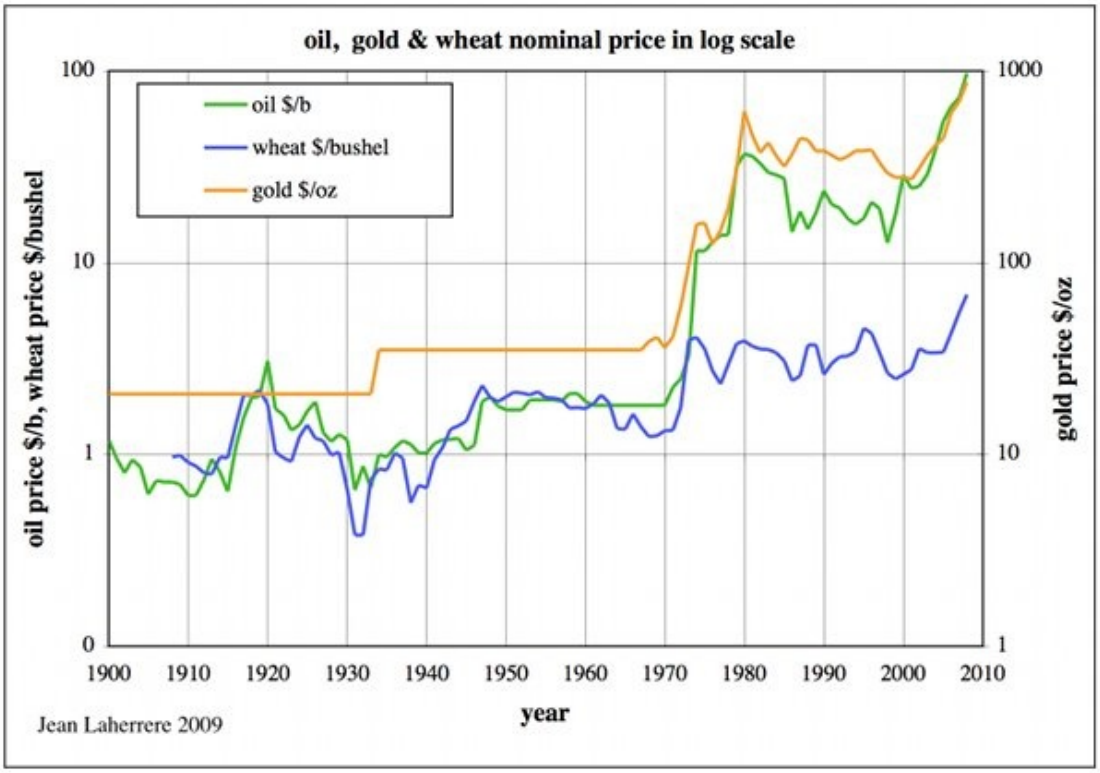


Figure 76: Gold, oil and wheat nominal price 1900-2008 in log scale

Since 2007, the price of oil seems to depend upon the value of the dollar:

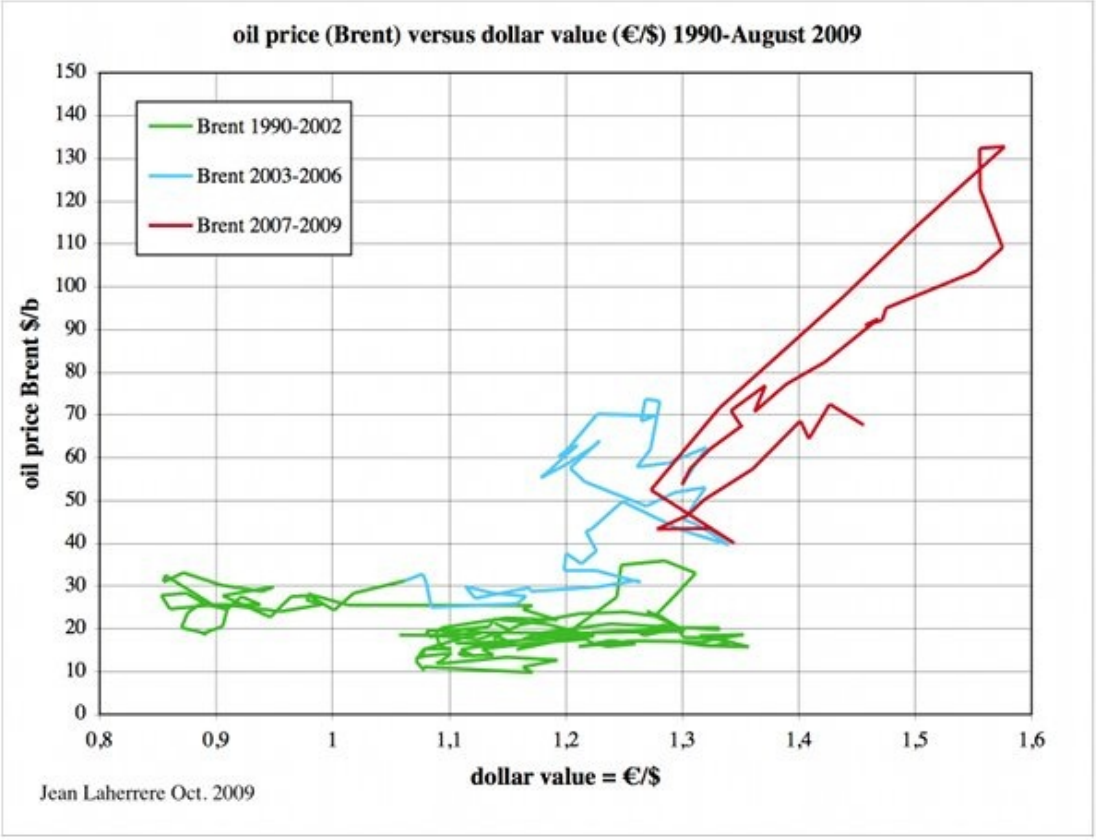


Figure 77: Oil price versus dollar value

The oil price seems to be correlated with the gold price since 1900, except during the 1979-2000 period:

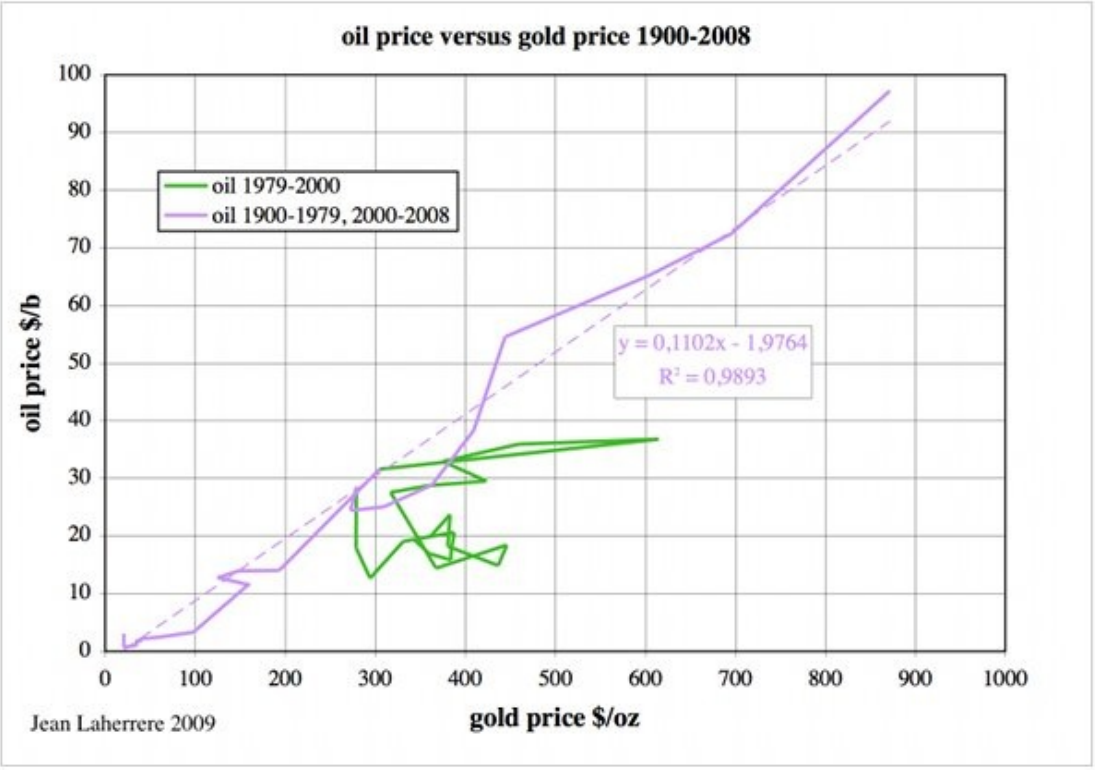


Figure 78: Annual oil price versus gold price 1900-2008

But the monthly values for 2009 seems to depart from the previous trend: is it going to return?

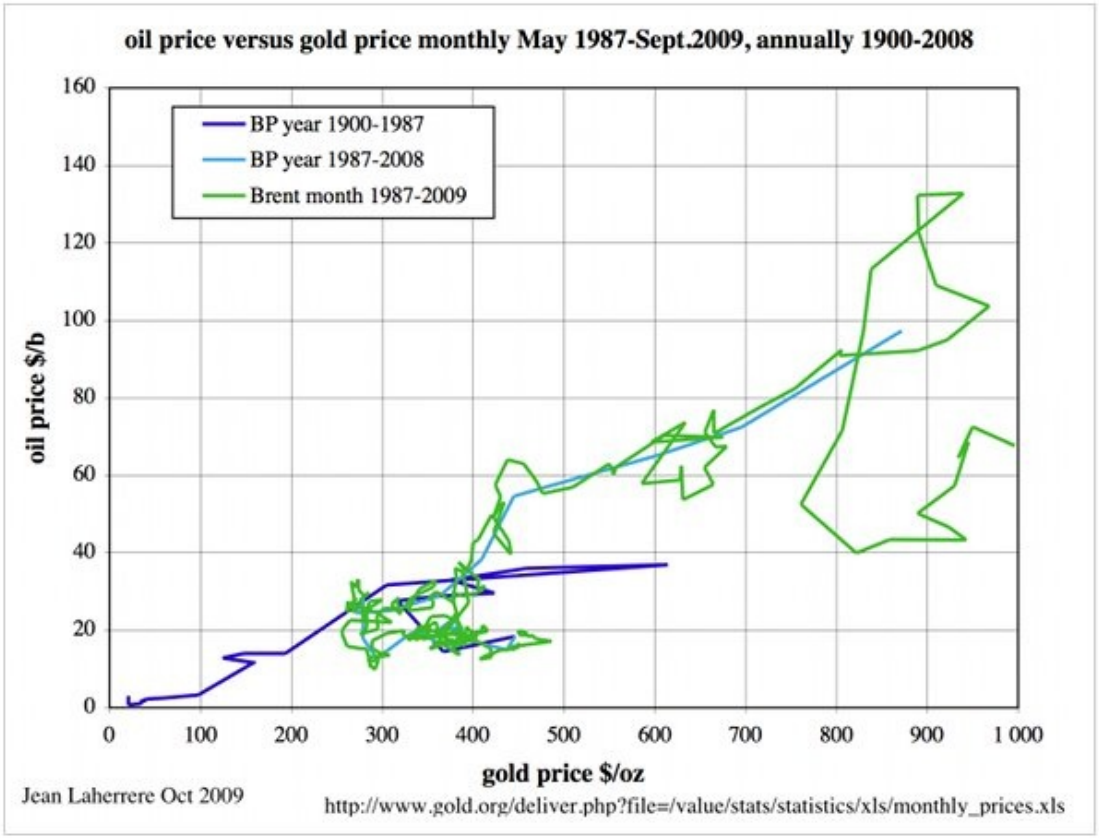


Figure 79: Annual oil price versus gold price 1900-2008, and monthly May1978-September 2009

Erste Bank displays the gold over Dow ratio since 1900, with bursts and back to earth runs.

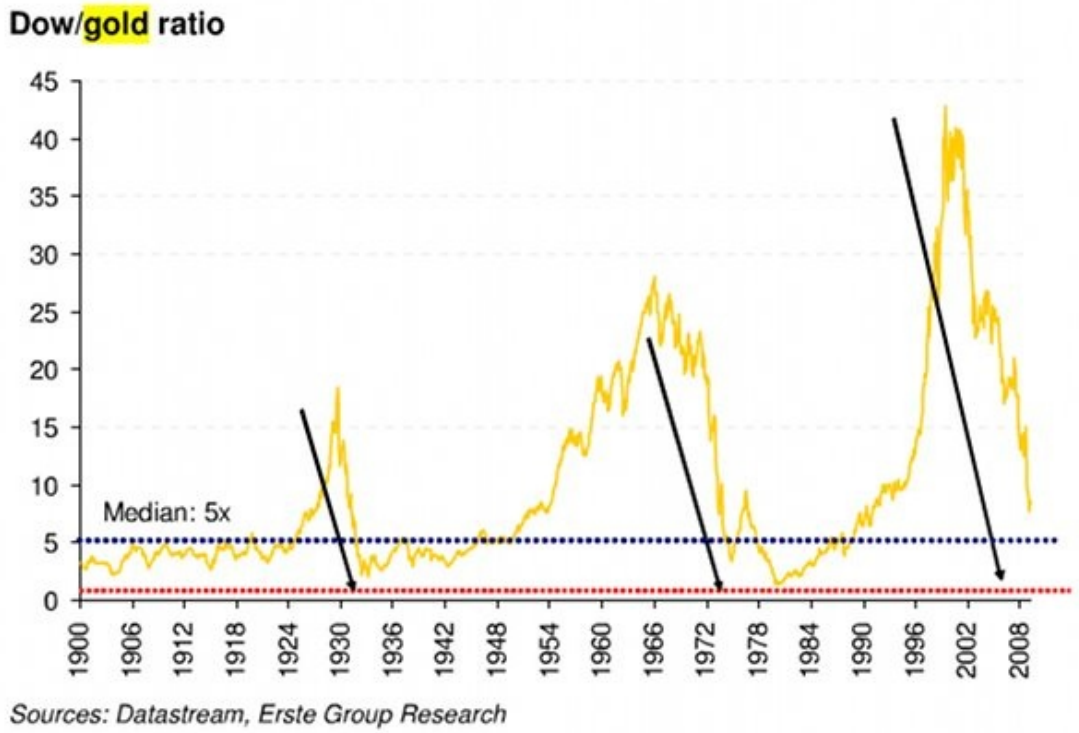


Figure 80: Dow Jones value over gold price ratio 1900-2008

Gold and oil annual production & forecast

The display of gold production and forecast for an ultimate of 250 kt is compared to oil (liquids) production and ultimates of 3 & 4 Tb.

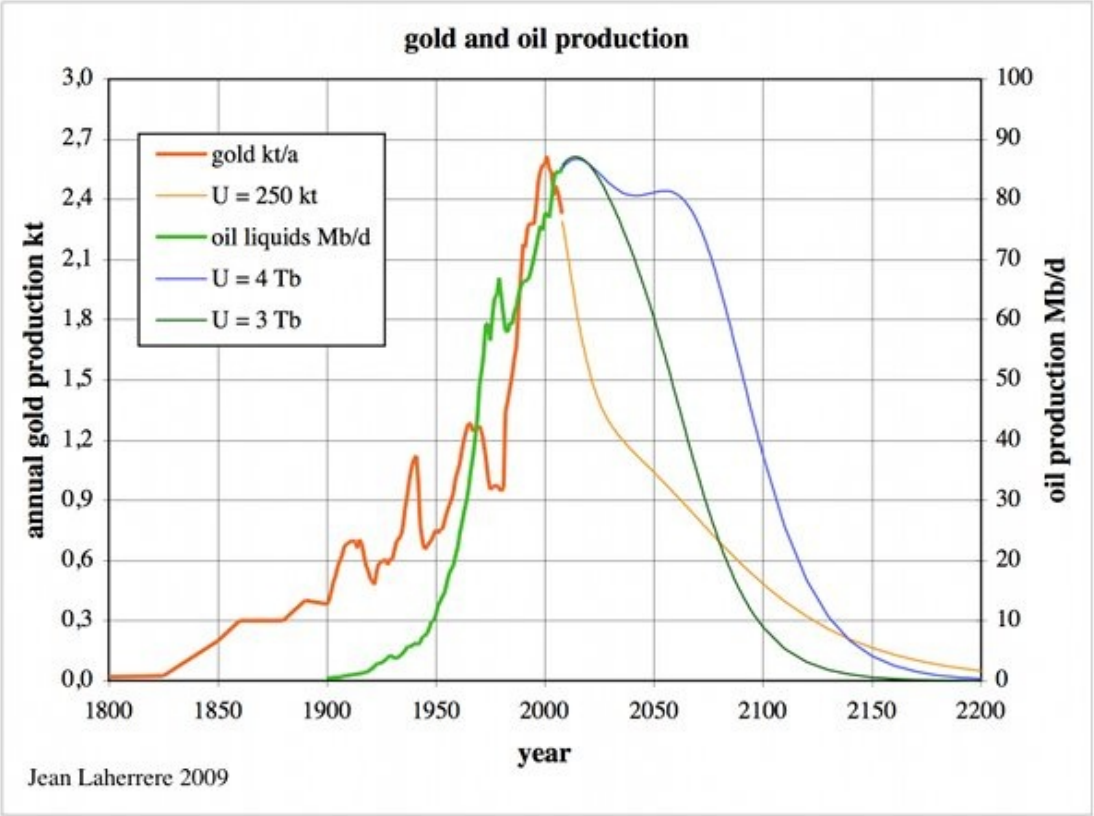


Figure 81: Gold and oil (liquids) production & forecasts 1800-2200

Conclusions

Gold production has a longer history than oil production, but both are likely to reach a peak during this decade: 2001 for gold and 2008 for oil (in fact, it is going to be a bumpy plateau instead of a peak), and both will cease to be extracted before 2200. Yet oil will be gone, converted into heat and ashes, while gold will remain as jewelry and bullion.

Excluding soil and water, which allows us to grow our food, oil and gold must be the two most important minerals of our present civilization. Their production will span for only a few centuries, much less than the western civilisation's lifetime.

It is amazing to think that we are presently at a key epoch (peak or plateau) of our civilisation in terms of supply and we do not realize it. Paul Valery wrote in 1931 “the time of a limited world begins”, but many do not accept this fact, always wanting to consume more.

It is time to change our way of life.

The first part of this work can be found here.