



Gemstones

Diamond prices



Prices are for brilliant cut diamonds. Calculated with <http://findmyrock.com/diamond-calculator/>

Carat:
 Base: Diamond of G color and VS1 Clarity will be:
 0.50 carats: 4'000 to 5000\$/ct
 1.0 carat : 9'000 to 11'000\$/ct
 2.0 carats: 18'000 to 20'000\$/ct
 3.0 carats: 90'000 to 110'000\$/ct

Color (yellow hues up to light yellow):	1carat	2carat	3carat
Diamond VS1 Clarity	9'000 to 11'000\$/ct	18'000 to 20'000\$/ct	31'000 to 33'000\$/ct
G color:	14'000 to 16'000\$/ct	30'000 to 32'000\$/ct	50'000 to 52'000\$/ct
D color:	5'000 to 7'000\$/ct	8'000 to 10'000\$/ct	13'000 to 15'000\$/ct
K color:			

Clarity	1 carat	2carat	3 carat
Diamond G color	9'000 to 11'000\$/ct	18'000 to 20'000\$/ct	31'000 to 33'000\$/ct
VS1 clarity:	14'000 to 16'000 \$/ct	28'000 to 30'000\$/ct	47'000 to 49'000\$/ct
IF clarity:	2'000 to 3'000 \$/ct	2'500 to 3'500\$/ct	3'000 to 5'000\$/ct
I2 clarity:			

Worst one carat diamond M I3: 800 to 1'500\$/ct
 Best one carat diamond D IF: 28'000 to 30'000 \$/ct
 Worst three carat diamond M I3: 1'500 to 1'700\$/ct
 Best 3carat diamond D IF: 110'000 to 112'000\$/ct
 Synthetic diamonds: 500 – 1000\$/ct

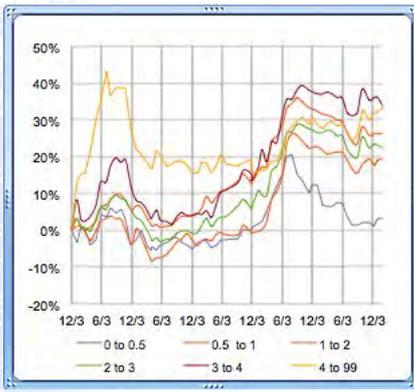
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Gemstones

Diamond price evolution





The diamond price chart to the left shows price changes in percent of 2007 prices for loose diamonds since 2007 for D-I color VVS2-SI2 clarity in several carat ranges

<http://www.pricerscope.com/diamond-search-results>

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Gemstones

Most expensive colorless diamond I



A rare flawless white diamond was sold at Sotheby's in Geneva and fetched a whopping cost of \$16.2 million. Brilliant-cut diamond, weighing 84.37 carats, was bought by Georges Marciano, the founder of clothing company Guess? Inc. It is the priciest colorless diamond sold in the last 20 years.

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Gemstones

Most valuable colorless diamonds




India's most famous diamond, Koh-I-Noor, discovered in Andhra Pradesh state, passed from one to ruler to another is now a part of British crown jewel. British East India Company seized this largest diamond ever before the Indian independence. This of course is the most expensive diamond along with the Sancy Diamond. The diamond is currently set into the Crown of Queen Elizabeth and is on display at the Tower of London. The 105.6 carat stone has no estimation

The Cullinan diamond is the largest gem-quality diamond ever found, at 3106.75 carat rough weight., It was found January 26, 1905, in the Premier No. 2 mine, near Pretoria, South Africa.

The largest polished gem from the stone is named Cullinan I or the Great Star of Africa, and at 530.4 carats (106.1 g) was the largest polished diamond in the world until the 1985 discovery of the Golden Jubilee Diamond, 545.67 carats (109.13 g, rough weight 755.5ct), also from the Premier Mine. Cullinan I is now mounted in the head of the Sceptre with the Cross., which is part of the British crown jewels. Price estimation: 400Mio\$

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Fancy diamond prices





Fancy (all colors but light yellow hues) and historic diamonds may reach much higher price levels than indicated in the previous list. Christie's sold the Wittelsbach diamond (Bavarian crown jewel) for \$24,311,191 in 2008. The fancy deep grayish blue diamond with VS2 clarity weighs 35.56-carat i.e. the carat price is 683'000\$/ct

A "vivid pink", near perfect SA mined 5 carat diamond fetched a 10.8 million \$ price tag at an auction in Honkong last february. This puts the world record carat price at 2.2 million\$

<http://www.bornrich.com/entry/expensive-diamonds-sold-auction/>

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Hope diamond





The Hope diamond is a deep blue diamond, which is owned by the Natural History Museum at the Smithsonian (Government owned) The 45.5 carat stone has a very tormented history full of sex and crime, which started in India in the 17th century. The Hope diamond was probably possession of the French court (Louis IX – XVI) and English court (George before going into private ownership. The name comes from the jeweller James Hope, who owned it from 1839 to 1861. In the twentieth century the stone was owned by the McLean family first and than by the famous jewellers, Harry Winston, who offered it to the Smithsonian. The Hope Diamond is valued 250 Mio\$, which makes it the diamond with the highest per carat value!

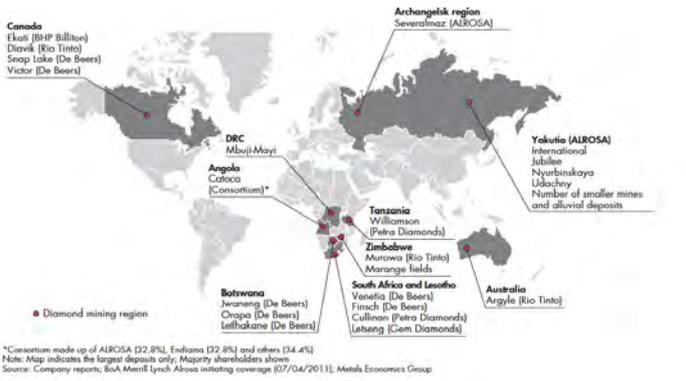
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Diamond deposits

Main gem diamond producing countries are South Africa, Botswana, Zaire, Australia, Russia

Main diamond deposits, in yellow producer countries. The mining areas correspond to regions with old cratons. 90% of the production comes from 20 mines.



* Consortium made up of ALROSA (12.8%), De Beers (12.8%) and others (14.4%)
Note: Map indicates the largest deposits only. Majority shareholders shown.
Source: Company reports, B&W Merrill Lynch, Alrosa initiating coverage (07/04/2011); Metals Economics Group

Approximately 120 -180 million carats of diamonds were mined annually in the past , with a total value of nearly US\$9 billion, and about 100'000kg are synthesized annually.
Blood diamonds: Diamonds from conflict areas, the Kimberley treaty (2002) bans these diamonds from the official distribution channels

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Evaluation of diamond deposits

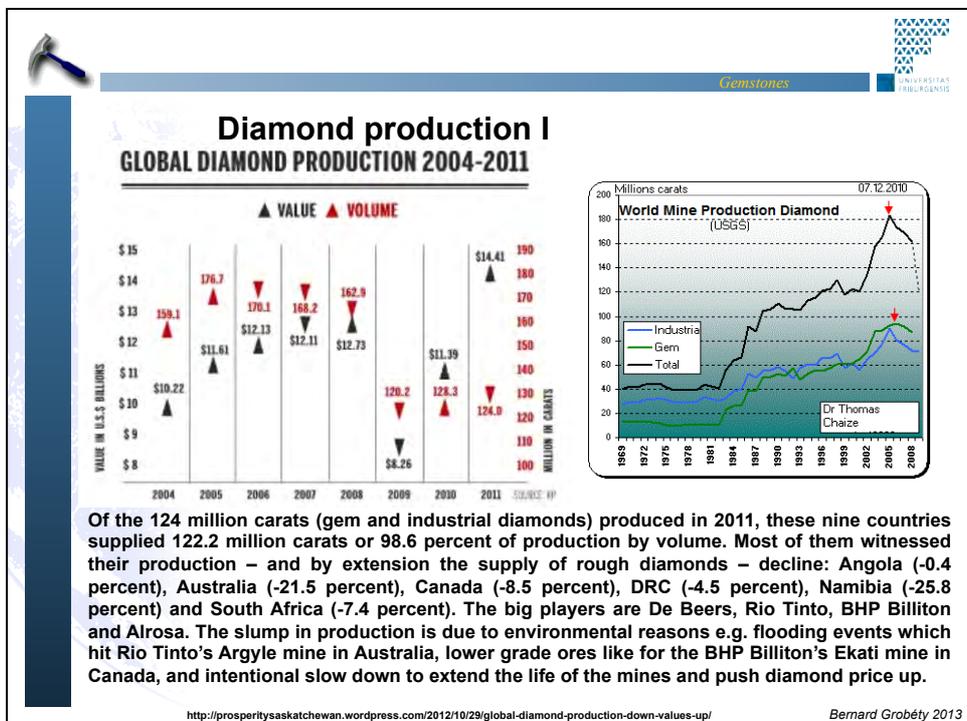
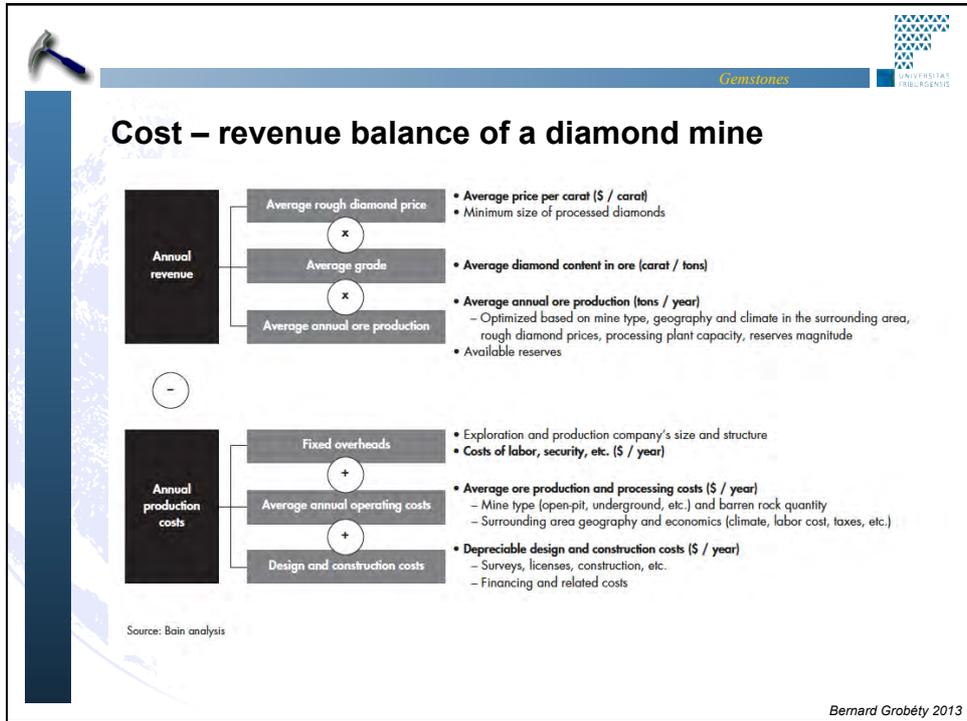
Exploration → Surveys → Economic appraisal → Licensing → Design and construction

Description:	Surveys	Economic appraisal	Licensing	Design and construction
<ul style="list-style-type: none"> Initial exploration Surveys to guide a decision on more detailed exploration Probability of success ~1.3%* 	<ul style="list-style-type: none"> Structural drilling to assess diamond content Identification of indicator materials Probability of success ~10%* 	<ul style="list-style-type: none"> Multi-step economic appraisal of the ore body Evaluation of environmental impact Probability of success ~25%* 	<ul style="list-style-type: none"> Obtaining construction and operation permits Environmental requirements compliance 	<ul style="list-style-type: none"> Mine facilities construction Infrastructure development Overburden removal Beneficiation plant construction
Time: ←———— 3.5 years overall —————→				~3.5 years
				

*Probability that the discovered deposit will go on to become a world-class operating mine
 Source: Expert interviews; Diamonds: the Diamond Exploration Cycle – Kaiser Research Online (2002)

The development of a diamond mine project takes between 5 and 10 years between discovery and production. Only 1 to 2 % of the discoveries (mainly hosted in Kimberlites or Lamproites) survive the first exploration step.

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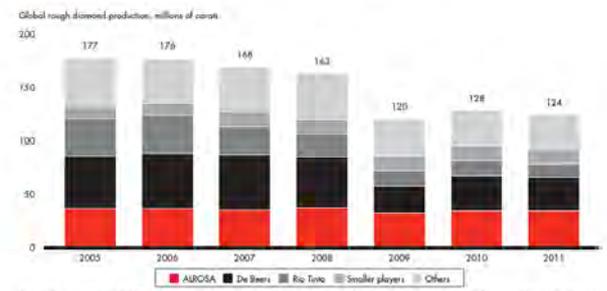





Diamond production II

Anglo American (De Beers): Southern Africa, Canada <http://www.debeersgroup.com/>
Rio Tinto: Australia, Canada, Zimbabwe, India, tried to sell its diamond mining division in 2012 <http://www.riotintodiamonds.com>
BHP Billiton: Canada Ekati mine has been sold to Harry Winston, famous jewellery maker <http://www.bhpbilliton.com/home/businesses/diamonds/>
Alrosa: Russia <http://eng.alrosa.ru/> government owned, will open its business to private investors in the next years, offered 10% of shares

Figure 7.6: Supply of rough diamonds contracted slightly in 2011



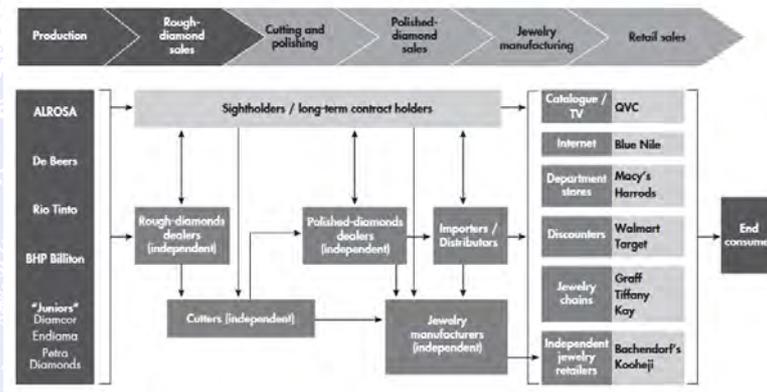
Year	Alrosa	De Beers	Rio Tinto	Smaller players	Others	Total
2005	35	45	25	10	6	177
2006	35	45	25	10	6	176
2007	35	45	25	10	6	168
2008	35	45	25	10	6	163
2009	35	45	25	10	6	125
2010	35	45	25	10	6	128
2011	35	45	25	10	6	124

Note: Smaller players include BHP Billiton, Catoca mine, Harry Winston, Petra Diamonds. Others include DRC, Angola, Zimbabwe, Assatek, Botswana, Canada, Russia, South Africa, Brazil, China, Congo, Central African Republic, Ghana, Guyana, Guinea, India, Indonesia, Lesotho, Liberia, Namibia, Sierra Leone, Tanzania, Egipt, Venezuela. Source: Kimberley Process Statistics

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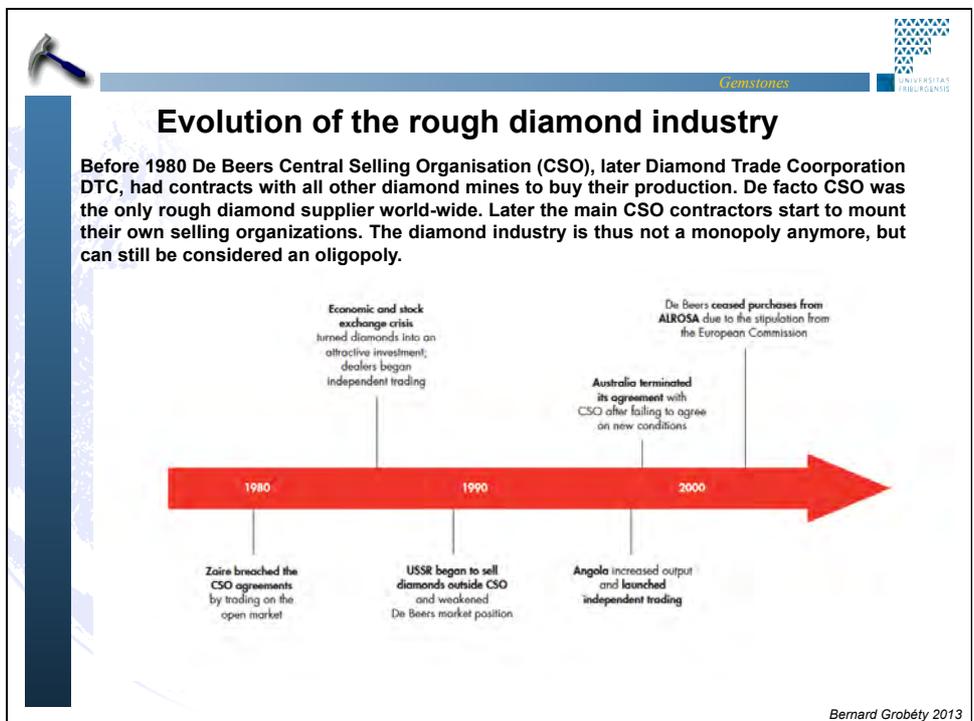
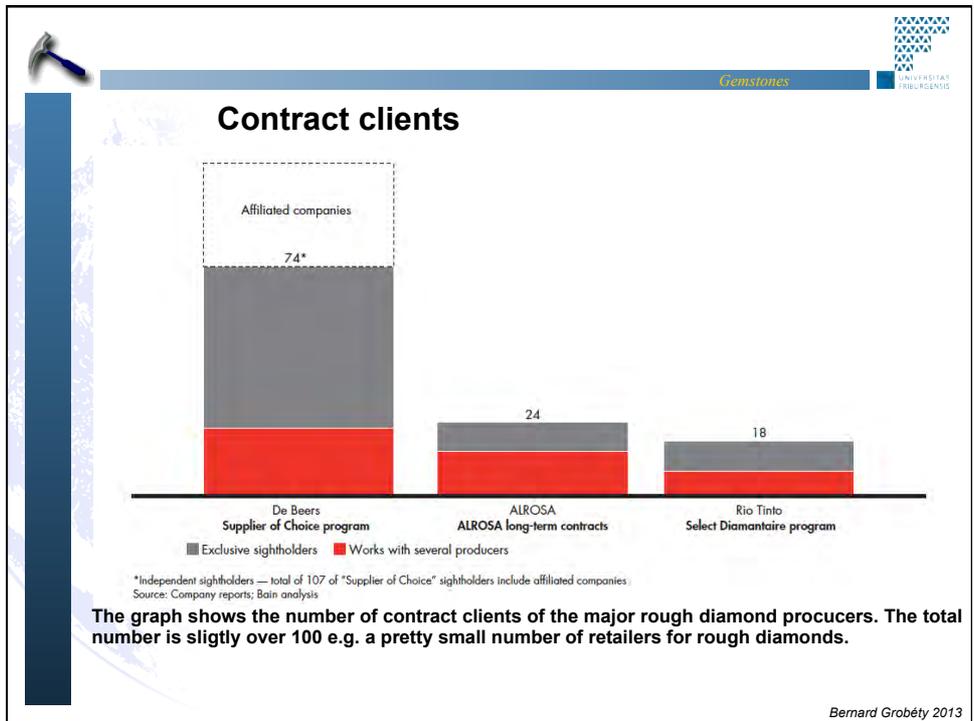

Rough diamond market

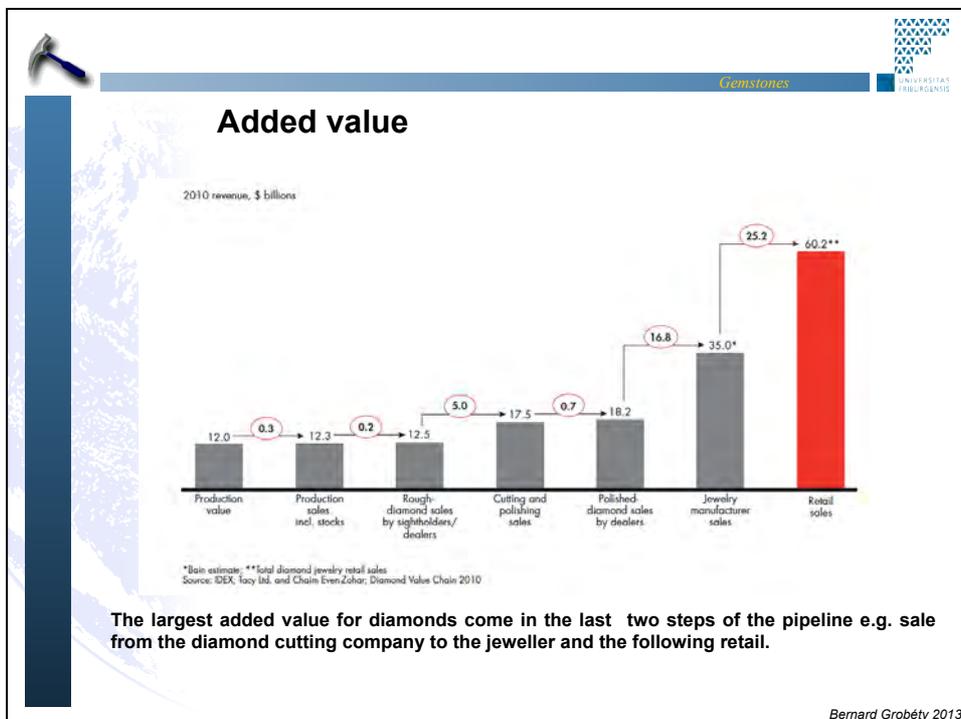
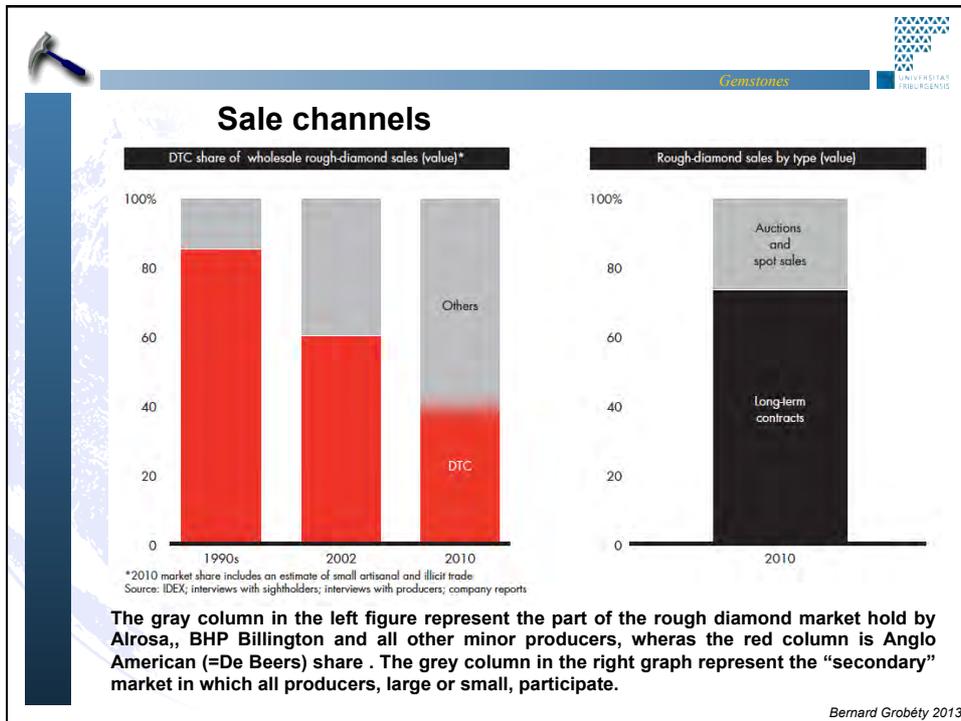


Source: Company reports, expert interviews, Bain analysis

The mining companies sort and grade the rough diamonds (12'000 grades at De Beers!). Contract clients (CC) also called sight holders (De Beers), select diamanteers (Rio Tinto) or term and port market clients (BHP Billiton) can evaluate the lots allocated to them (10 "sights" per year for DeBeers) and decide to buy or not. The CC sells to their contracted clients or process the diamonds themselves. The major and minor mines as well as the CC sell a part of the rough diamonds also in the secondary (wild) market.

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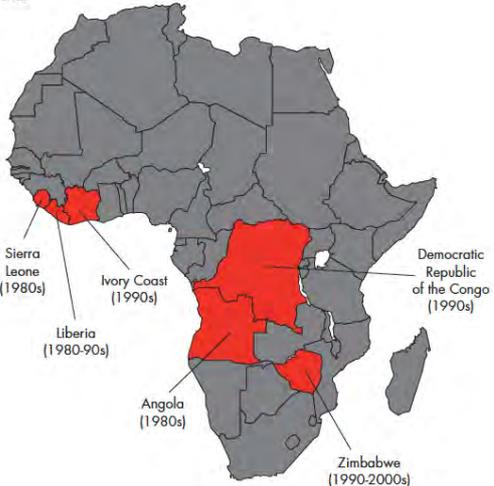


Gemstones 

„Blood“ diamonds

Source countries of conflict diamonds

“Blood” or conflict diamonds are used to sponsor rebel and revolutionary activities against legitimate and internationally recognized governments. In the 1990ties paramilitary or rebel groups in various politically unstable African countries had taken control of the diamond mines and were using the proceeds from diamond sales to finance their operations. Although these diamonds ended up in legitimate channels, they were either directly or indirectly funding violent conflict. Not surprisingly the Western media’s widespread coverage of the atrocities in these conflict zones—Angola, Sierra Leone, Liberia, the Democratic Republic of the Congo—began to damage the reputation of the diamond industry.

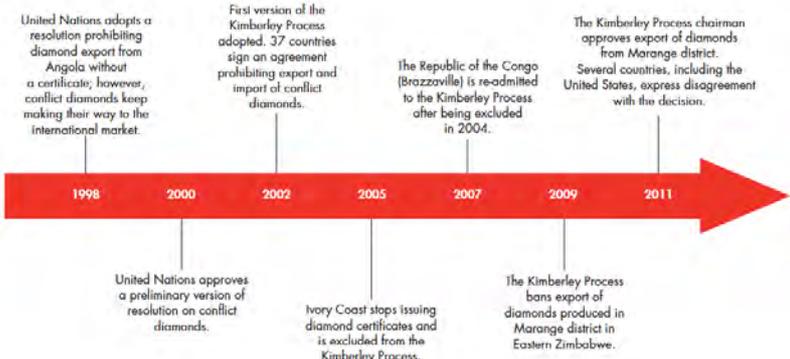


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Gemstones 

Kimberly Process



1998: United Nations adopts a resolution prohibiting diamond export from Angola without a certificate; however, conflict diamonds keep making their way to the international market.

2000: United Nations approves a preliminary version of resolution on conflict diamonds.

2002: First version of the Kimberly Process adopted. 37 countries sign an agreement prohibiting export and import of conflict diamonds.

2005: Ivory Coast stops issuing diamond certificates and is excluded from the Kimberly Process.

2007: The Republic of the Congo (Brazzaville) is re-admitted to the Kimberly Process after being excluded in 2004.

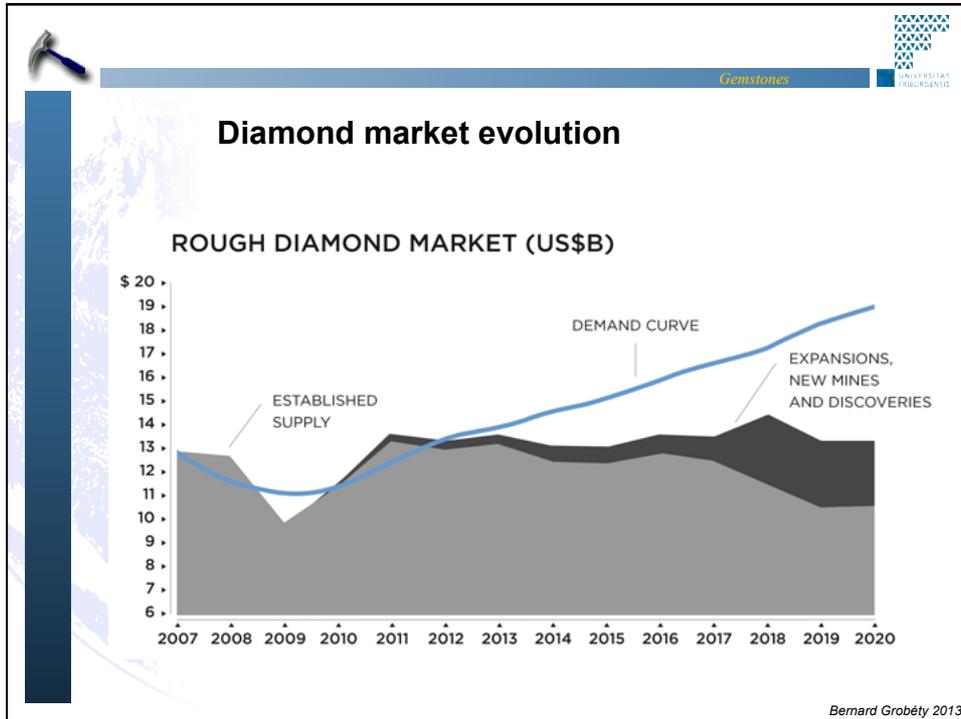
2009: The Kimberly Process bans export of diamonds produced in Marange district in Eastern Zimbabwe.

2011: The Kimberly Process chairman approves export of diamonds from Marange district. Several countries, including the United States, express disagreement with the decision.

In response the Kimberly Process was established in 2002 under the auspices of the United Nations, it requires certification of all rough diamonds to guarantee that their trade does not finance rebel activities. The Kimberly Process Certification Scheme (KPCS) outlines the set of rules each participating country must meet. These rules include an agreement to restrict trade to participants, to refrain from assisting others in trading conflict diamonds and to provide auditable statistical data on mining, exports and imports of diamonds. On 5th December 2011 Global Witness, an initiator NGO of the Kimberly Process, announced its departure from the Kimberly Process,

<http://www.globalwitness.org/conflict-diamonds>

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Diamond cutting centers

Gem quality diamonds are usually distributed to one of the main diamond cutting and trading centres. Almost all small stones are cut in India (Gujarat), Thailand and China. Antwerp, Tel Aviv and New York are the centers for large stones. Once they arrive at the diamond centres, experts (known as 'diamantaires') cut and polish the rough diamonds into shape.

<http://www.private-diamond-club.com/the-cutting-centres-around-the-world>

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Gemstones 

Cut diamond market

Channel share in wholesale structure

Exhibitions 30-40%	 Hong Kong	 Las Vegas	 Basel
Central and regional offices 60-70%	 Antwerp	 New York	 Tel Aviv

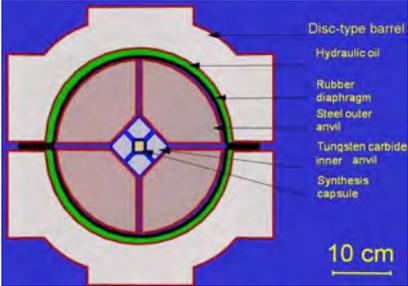
Wholesale channels

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Gemstones 

Natural vs. synthetic

Diamond and corundum, among other gemstones, may be manufactured synthetically. Synthetic diamonds are mainly produced by the HPHT and CVD techniques. Carat price for synthetic diamonds are about one third of natural carat price.



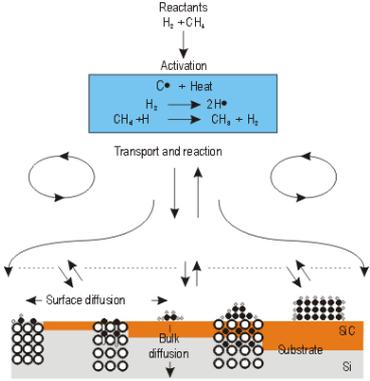
Diamond anvil cell used for the synthesis of diamonds

Reactants
 $H_2 + CH_4$

Activation

$C + Heat \rightarrow C^{\bullet}$
 $H_2 \rightarrow 2H^{\bullet}$
 $CH_4 + H^{\bullet} \rightarrow CH_3 + H_2$

Transport and reaction



Surface diffusion

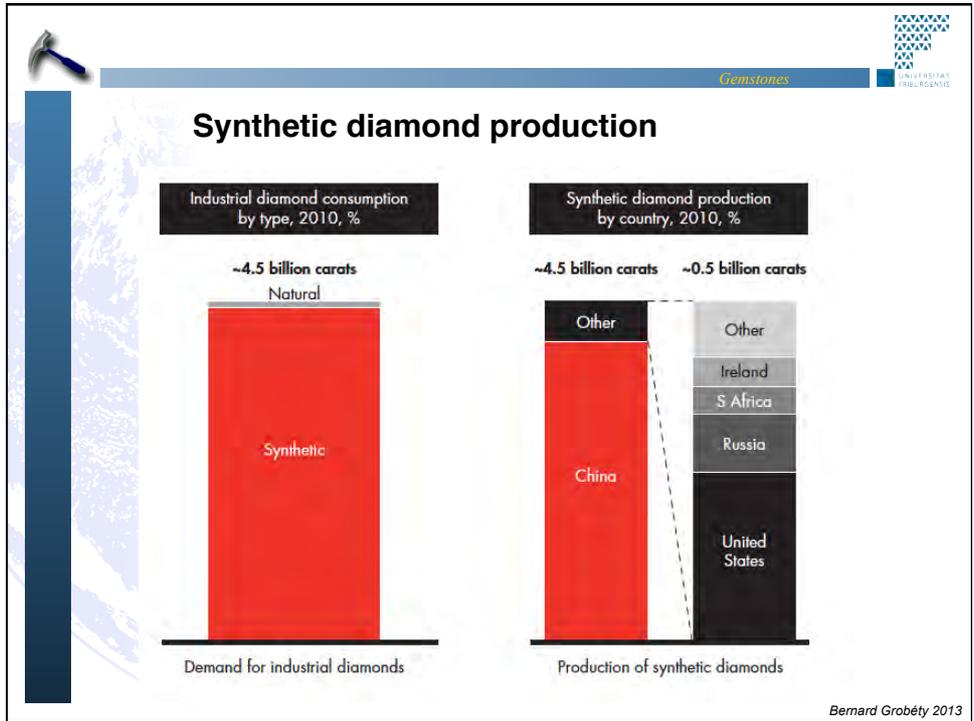
Bulk diffusion

Substrate

SiC
Si

CVD process *Azomam™*

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Diamond substitutes

	Diamond	Zirconia	Sapphire	Moissanite
Composition	C	ZrO ₂	Al ₂ O ₃	SiC
Crystal system	cubic	cubic	trigonal	hexagonal cubic
Hardness (Mohs)	10	8.25	9	9-9.5
Cleavage	excellent on (111)	none	none	none
Density	3.515	6.0	4.0	3.2
Refractive index (sodium light)	2.42	2.15-2.18	1.77	2.65
Dispersion	0.044	0.058-0.066	0.018	>0.08
Thermal conductivity (Wcm⁻¹K⁻¹)	5-25	0.1	0.4	0.9

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Recognizing natural diamonds

Although they lower the carat price, inclusions and certain optical properties are the best way to assert the natural origin of a diamond. Synthetic diamond producers (De Beers, Apollo Inc.) fingerprint often chemically their products.



Pyrope and Cr-diopside inclusions in natural diamonds



Metal inclusion in synthetic diamond



"Brown" deformation bands in natural diamond

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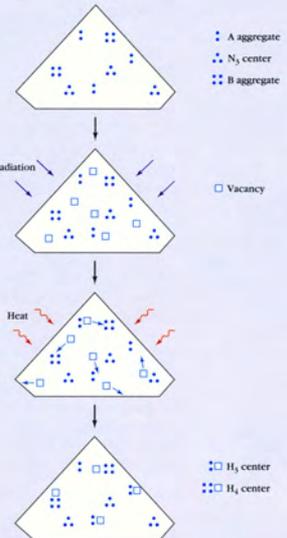

Diamond treatment I

Before treatment
Light yellow
(a few N₃ centers)

Irradiation
Creation of vacancies

Heat-treatment
The vacancies move and get trapped at aggregates

After treatment
Darker yellow, a few N₃ centers + newly created H₃ and H₄ centers



■ A aggregate
■ N₃ center
■ B aggregate
□ Vacancy
■ H₃ center
■ H₄ center

Irradiation and heat treatments may alter the defect concentration/distribution of color giving defects in diamonds. A light yellow diamond (color grade K) can be turned into a deep yellow, fancy diamond thereby increasing the value severalfold. Treatments have to be indicated in a gemstone report and may have an influence on the price.

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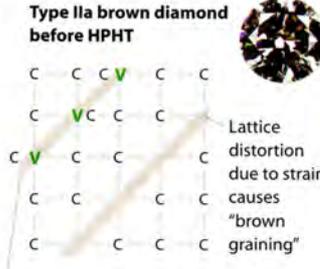


Gemstones



Diamond treatment II

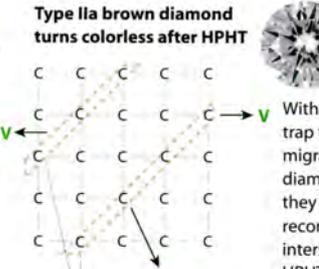
Type IIa brown diamond before HPHT



Lattice distortion due to strain causes "brown graining"

Plastic deformation results in abundant distorted and broken carbon bonds (and associated vacant lattice sites) concentrated along bands of brown color known by gemologists as "brown graining."

Type IIa brown diamond turns colorless after HPHT



With no impurities to trap them, vacancies migrate through the diamond lattice until they are eliminated by recombination with an interstitial C atom during HPHT annealing. No new color centers are formed.

HPHT treatment heals lattice distortions and broken bonds, releases vacancies, and thus removes brown color in graining, leaving only remnant colorless internal graining that is common in HPHT-treated diamonds.

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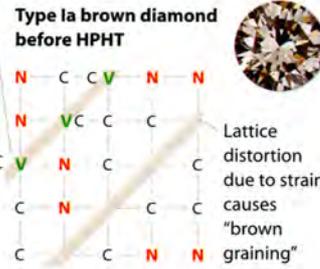


Gemstones



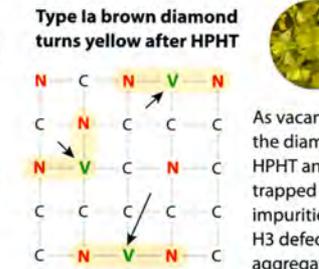
Diamond treatment III

Type Ia brown diamond before HPHT



Lattice distortion due to strain causes "brown graining"

Type Ia brown diamond turns yellow after HPHT



As vacancies migrate through the diamond lattice during HPHT annealing, they are trapped by aggregated N impurities (A centers) to form H3 defects [N-V-N]⁰. Some aggregated N also breaks down to release isolated N atoms at high temperatures. The combination of H3 defects and isolated nitrogen imparts a yellow color to the diamond. If abundant N occurs adjacent to the original brown graining, H3 defects will become concentrated along the formerly brown grainlines and will appear as treated yellow graining.

C = carbon atom
 N = nitrogen atom
 V = lattice vacancy

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