

DIAMONDS

in picture

鑽石淺談



VW2021

Prologue

“Diamonds are a girl’s best friend” as they are not only naturally beautiful but also romantic, symbolize eternal love, hold memories and last but not least possess high value. However the traditional market is now being seriously challenged by new comers as well as the very successful entry of man made-diamond and diamond look-alikes. As a result the price and sales of natural diamond is under pressure & consumers are also finding it most difficult to differentiate what is natural and what is not ! The following presentation will try to explain these issues

Content

- Natural/Mined diamond 天然鑽
- Synthetic diamond 人造鑽
- Diamond lookalikes 仿鑽
- Quality classification/certification 品質分類/認證
- Source and production 主要產地
- Industry update 業務概況
- Famous diamonds 世界名鑽

Natural/Mined Diamond

天然鑽

Diamond in Greek "Adamas" means "Unbreakable". In fact it has the highest hardness of any natural material (Mohs scale 10), highest optical dispersion (refract and reflect light 折射/反射) highest thermal conductivity & highest sound propagation velocity but poor in electrical conductivity. When properly cut and polished diamond is the most sort after gemstone. Diamond is always in great demand from both the industrial and commercial markets because of the above properties



Diamond is 5 times harder than No.2 Corundum

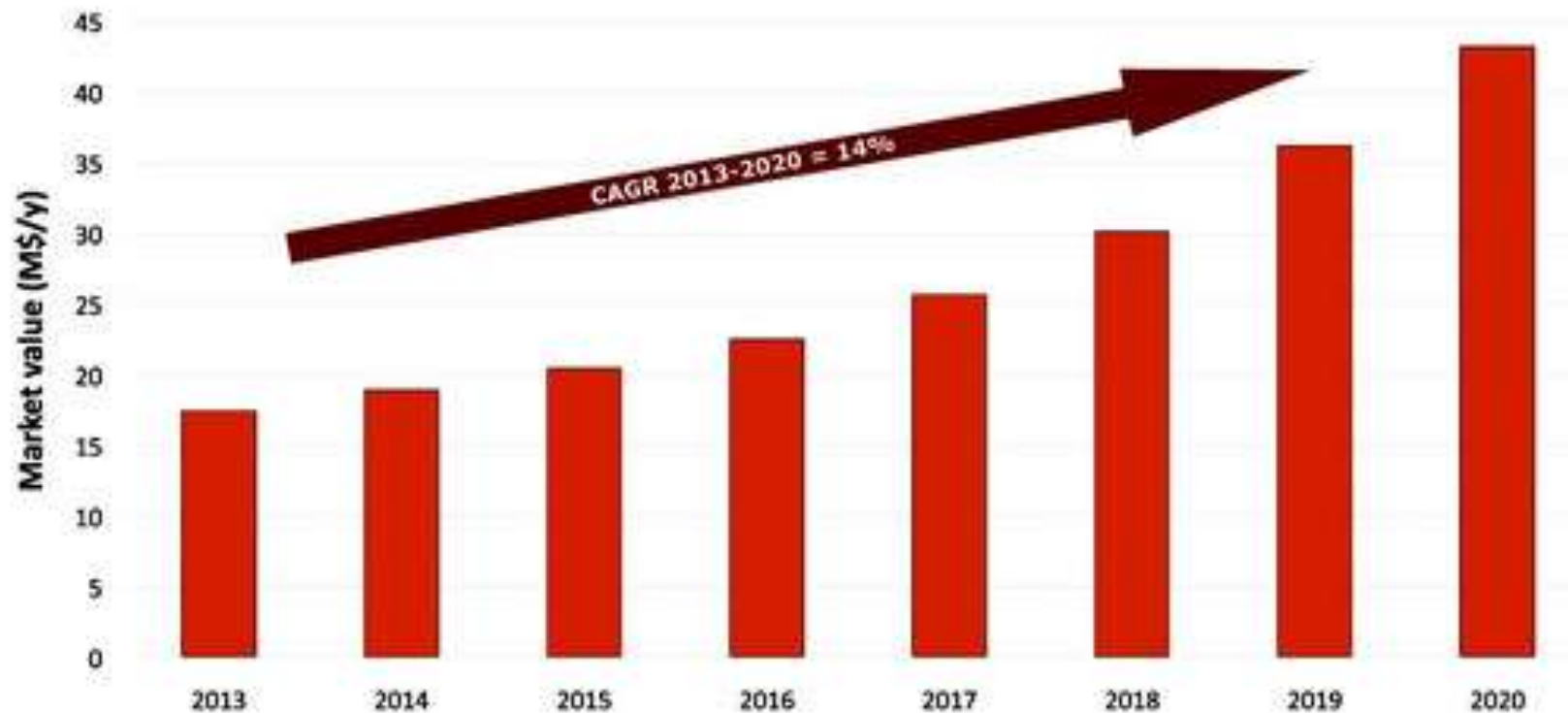


In 2019 142 million carats of rough diamonds were produced of which 42 million carats are gem diamonds and the balance 100 million carats are industrial diamonds used in cutting, grinding, drilling, polishing, speaker domes and heat sink. Their total value is estimated to be around US\$25 billion after polishing and US\$82 billion when reaching the jewellery market. Compared to 2018, production is down 4.8% in volume and 9.7% by value



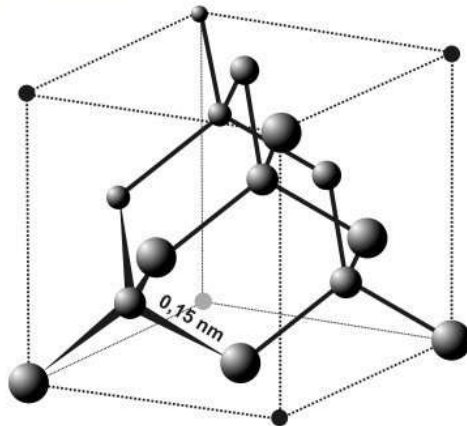
Diamond material market 2013-2020 – Base scenario

Report includes detailed breakdown: R&D and other, diamond DUV LED, heat spreaders (power devices, LD, RF devices, LEDs), diamond power devices, diamond high-frequency devices

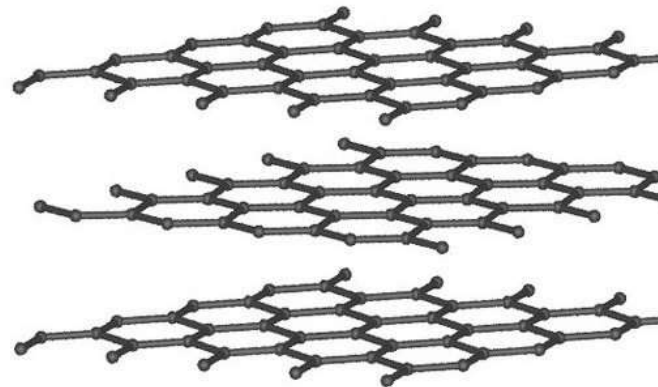


Diamond is a solid form of pure carbon 固體炭. In nature pure carbon also exist in another solid form called graphite. Their properties however differ very drastically mainly due to their difference in their molecular structure

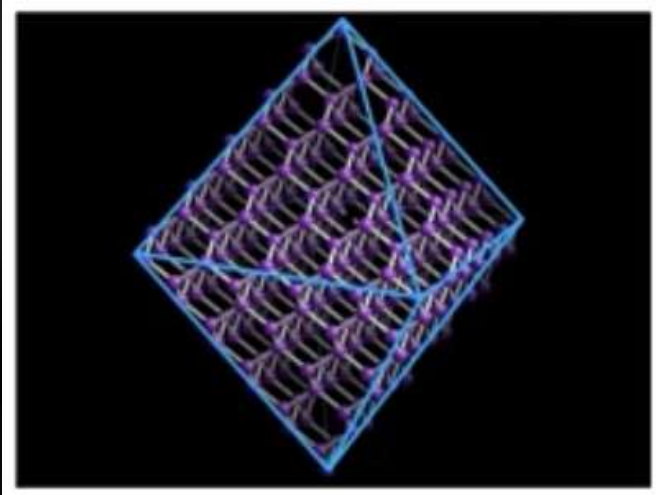
Diamond 鑽石/金剛石



Graphite 石墨



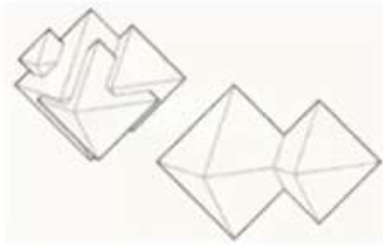
Diamond Crystal Forms – basically octahedron



Tappert and Tappert, 2011

Diamond Crystal Forms

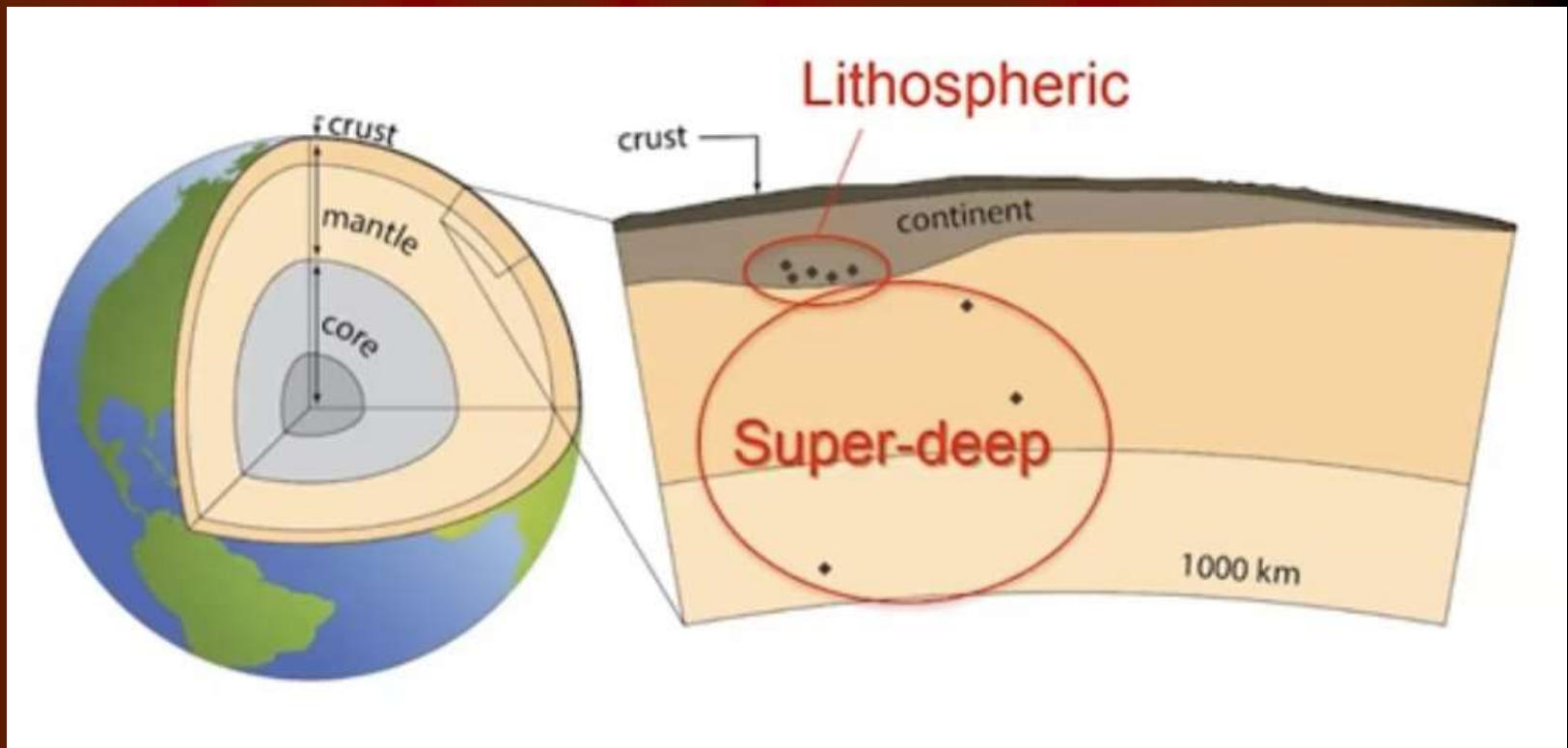
- ◆ Intergrown, parallel twins, or non-parallel polycrystals



- ◆ Macle (spinel-law twin)



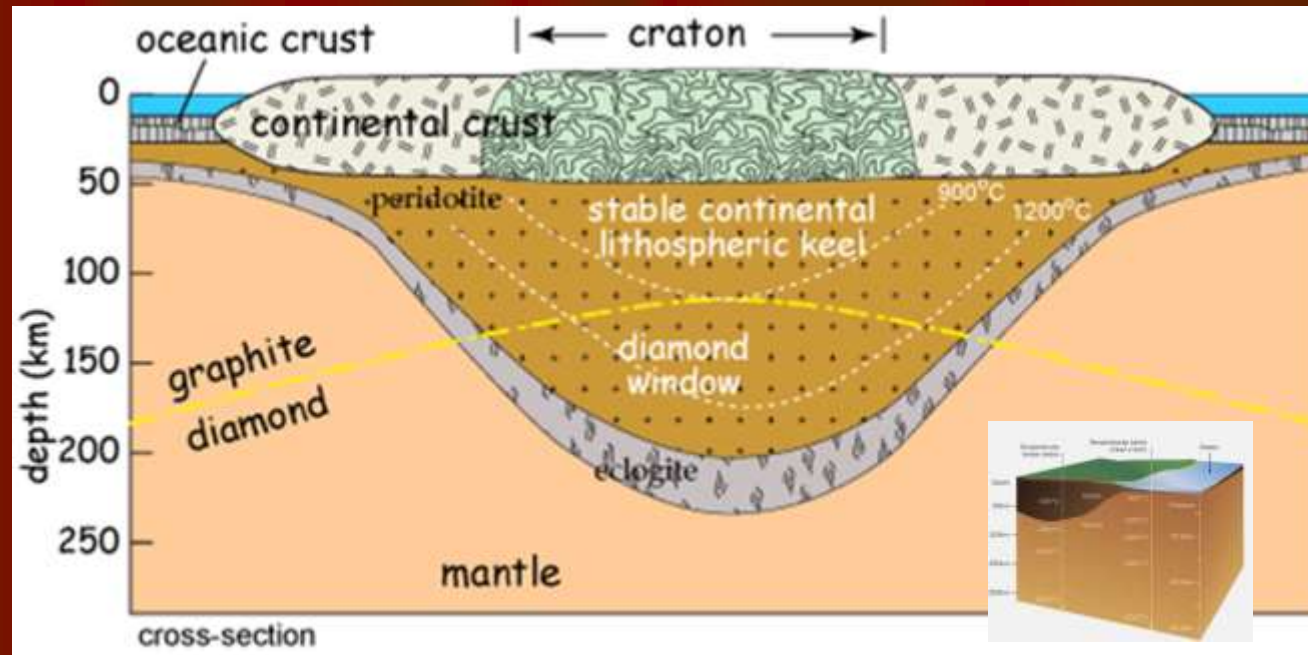
Basis on their “birth place”, natural diamonds can be classified into Lithospheric diamond 岩石圈鑽石 & Super-deep diamond 超深層鑽石. The former is formed at the boundary of the Earth’s upper mantle 上地函/幔邊沿. The latter is actually formed inside the Earth’s upper mantle 上地幔. Most of the diamonds we see today are lithospheric



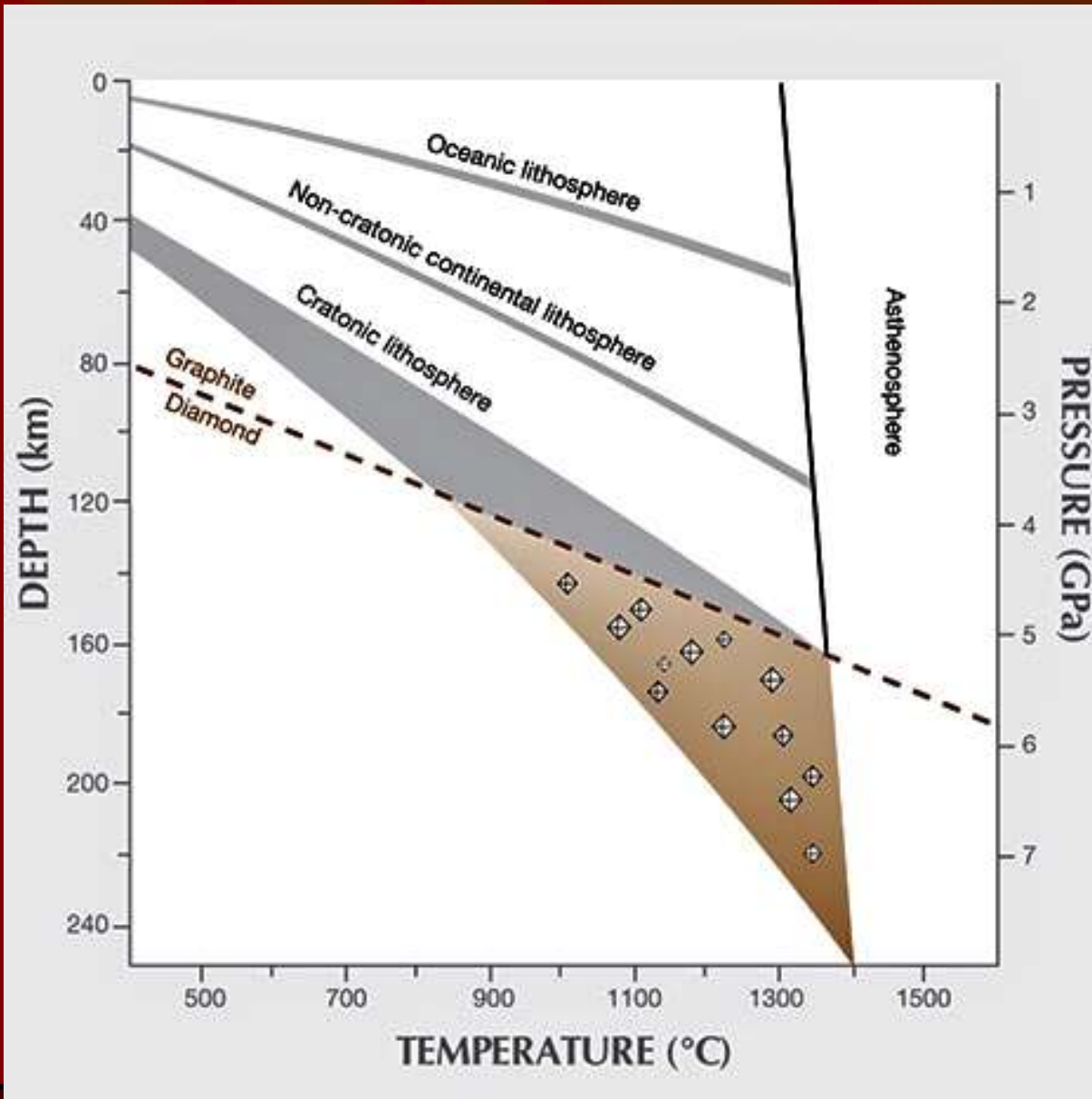
Lithospheric Diamond

It can only be formed at an optimum environment with temperature between 900-1200 C & pressure between 45-60 kilobar. These conditions can only be met at depths of 150-200 kilometers in the Earth's mantle rim beneath the relatively stable *Cratons 地台 known as the "Diamond Stability Zone". Carbon containing minerals both organic and inorganic provide the carbon source & the growth occurs over periods from 1 billion to 3.3 billion years which is 25% to 75% of the age of the Earth !

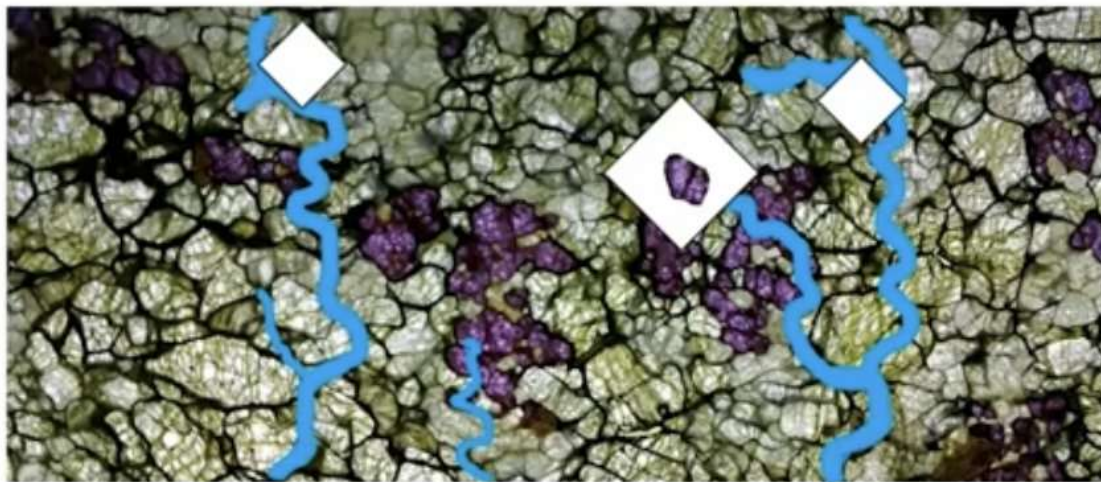
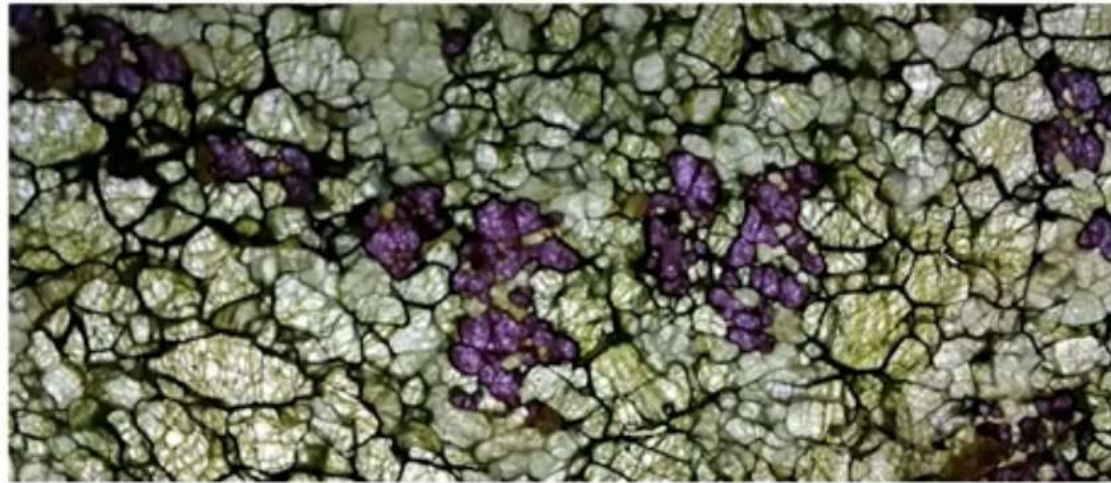
Ideal conditions for diamond to form under craton



- Most natural diamonds are of lithospheric origin



- ◆ There are multiple ways diamonds can form
- ◆ Diamonds form by carbon crystallizing out of a fluid
 - Different kinds of carbon-bearing fluids
 - Different kinds of rocks



- A craton is an old and stable block of the earth's crust which had survived cycles of merging and rifting of the earth's continents now generally found in the interior of tectonic plates. Exposed craton is called shield 地盾 (e.g. the Canadian Shield)

Ancient super continents – Columbia/Nuna, Rodinia and Pangea

Columbia/Nuna (2.5 Ba)



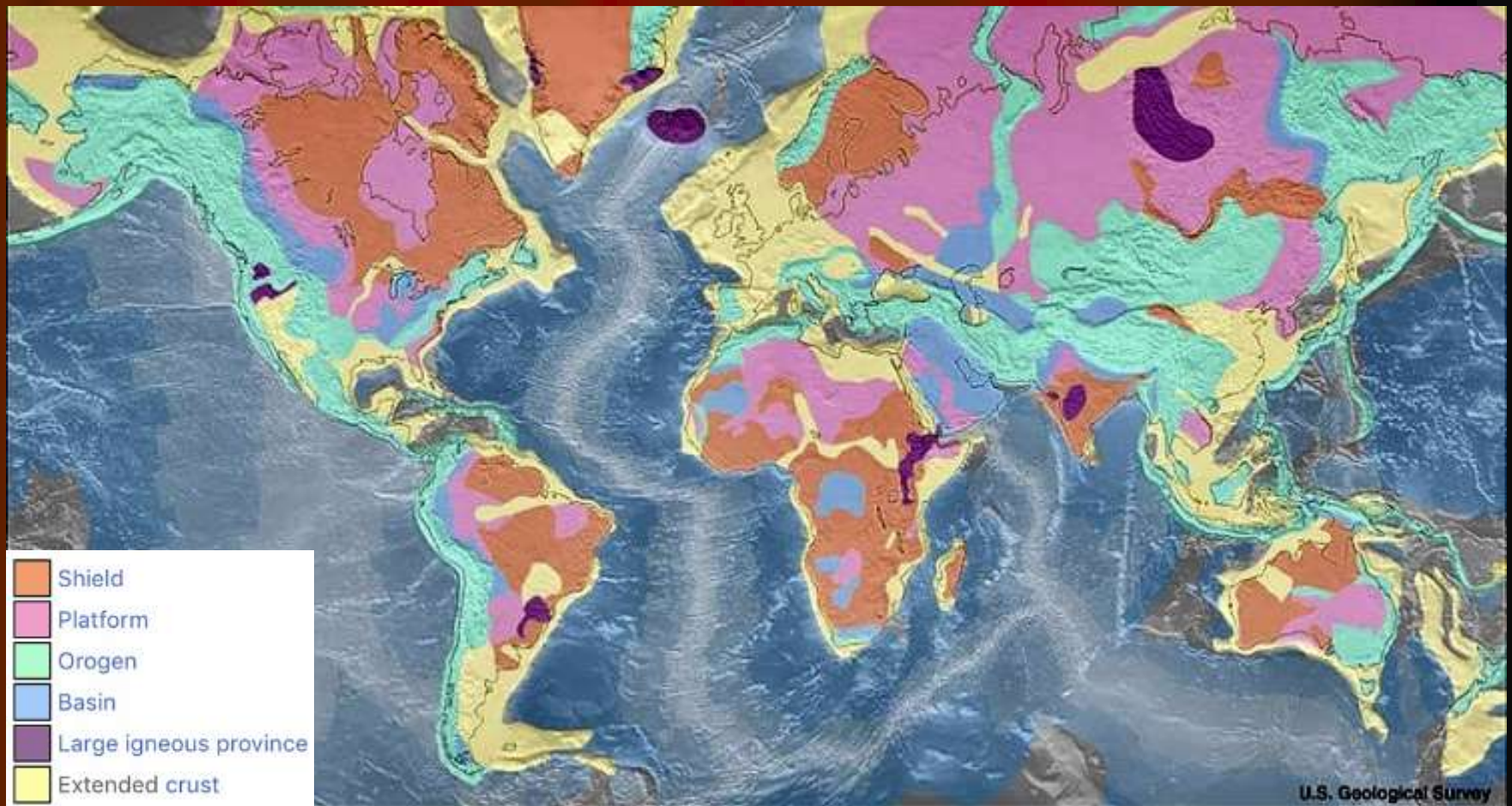
Rodinia (1.1 Ba -750Ma)



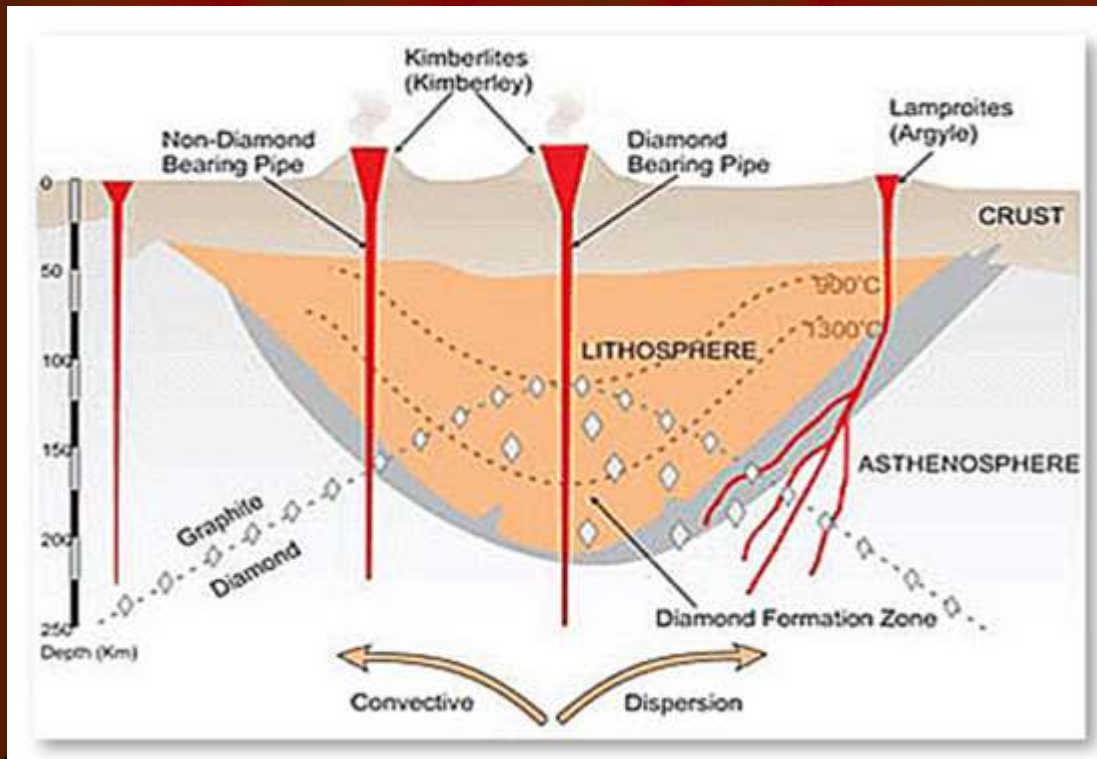
Pangaea (335-180



Present locations of cratons/shields



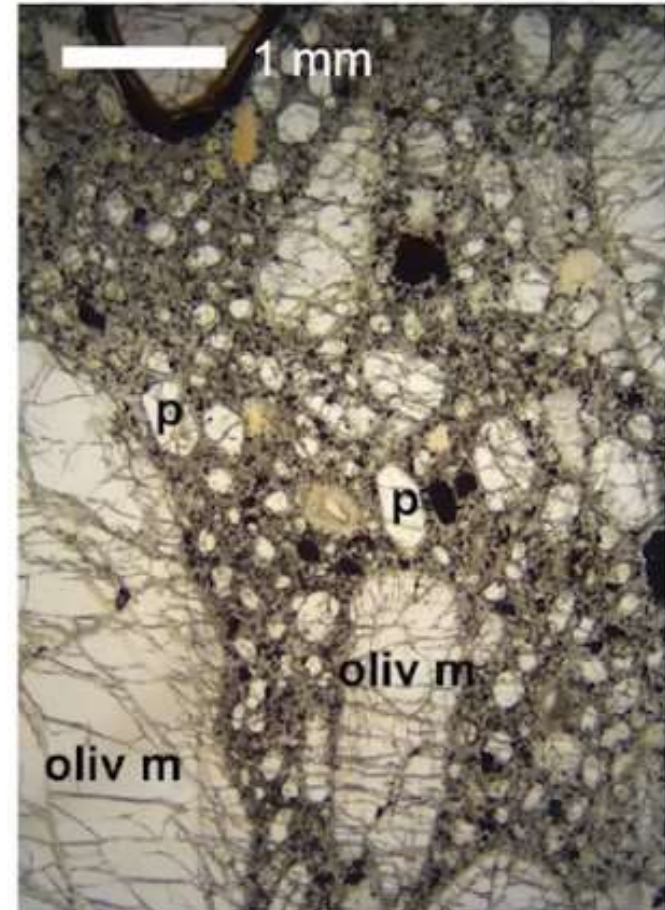
- The diamonds so formed are then brought close to the Earth's surface through Deep-source volcanic eruptions by ultramafic magma 鎂鐵質岩漿 via fault lines forming volcanic pipes 岩管 which cooled off as diamond bearing mantle rock called Kimberlite 金巴利岩 or Blue ground and also rarely in Lamproite pipes. Of the 6,400 kimberlite pipes being identified 900 are classified diamondiferous but only 50 are economic enough for mining



Kimberlite

Kimberlite explosion is very violent and also very rare. The magma can travel 200 km upward just in hours and the last eruption that became a diamond mine occurred 20 Ma in Ellendale Australia

- ◆ Mantle derived magma
- ◆ High CO₂ and H₂O content
- ◆ Olivine rich (typically >25%)
 - ◆ Olivine macrocrysts
 - ◆ Olivine phenocrysts
- ◆ Highly variable
- ◆ One pipe can have multiple eruption episodes
- ◆ Clusters of 10's or 100's of kimberlites



Mitchell et al., 2019

Lamproite

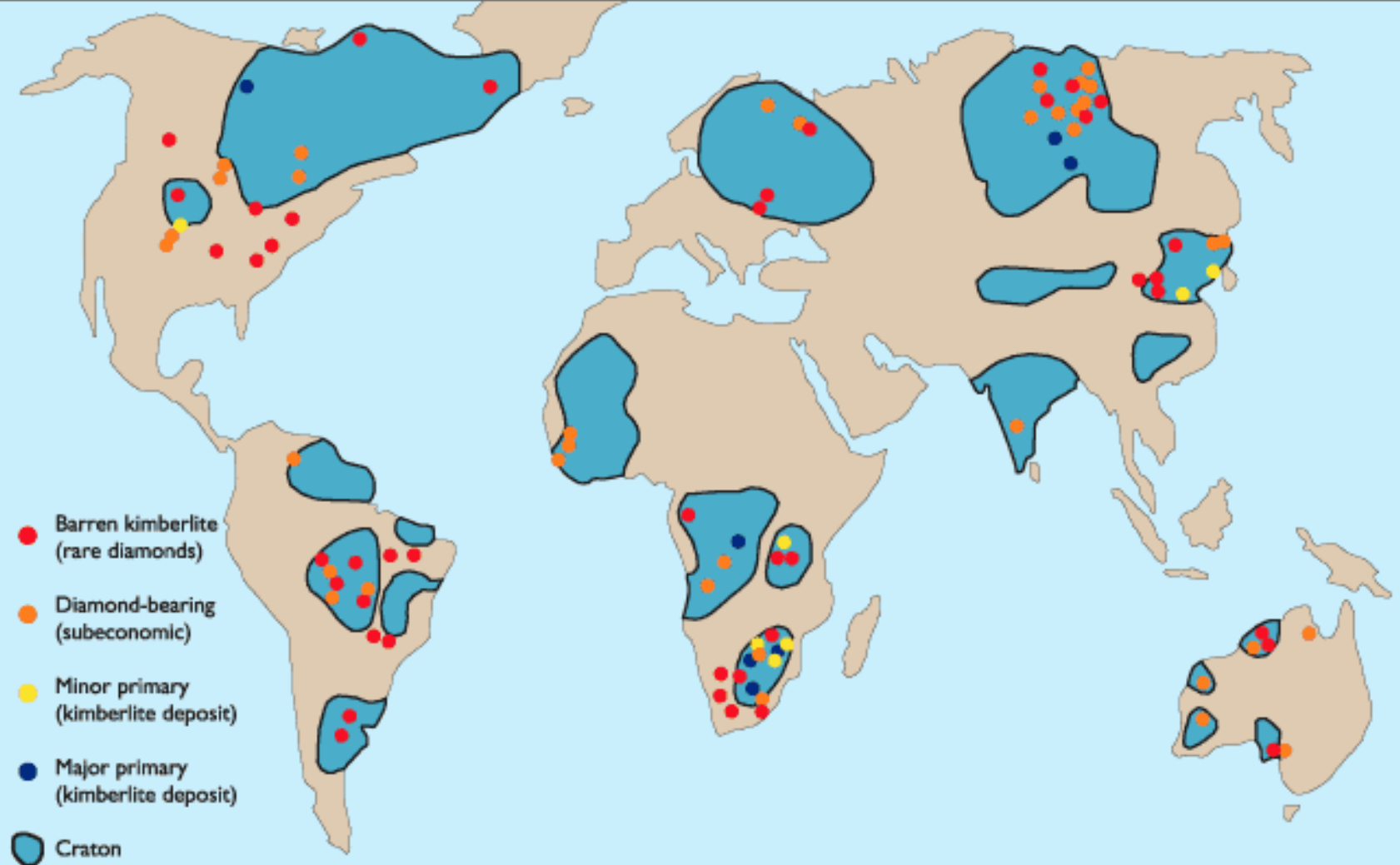
Lamproites 鉀鎂煌斑岩 are geographically widespread yet volumetrically insignificant. They are found in terrains of varying age from Archaean in Western Australia to Paleozoic and Mesozoic in Spain with the youngest being 56,000 years old. They were formed from partially melted mantle in depths exceeding 150 km and unlike kimberlite lamproite pipes are not related to craton. The Argyle diamond mine is the only economically viable source of lamproite diamond and also the main source of pink diamonds



Clifford's Rule

Kimberlite & diamonds are associated to cratons

Distribution of kimberlites worldwide



Other indicators for locating diamonds

Mineral Grains (garnet, chromite, dioside) 伴生礦石 & Xenoliths 苯石

◆ Minerals grains related to diamond formation

- Transported up to surface along with diamonds
- Where we find these indicator minerals, we might find diamonds
- More abundant than the diamonds themselves



“foreign material” contained in kimberlite:

Xenoliths (*rocks*)

Xenocrysts (*disaggregated rocks = minerals*)

Diamonds

Super-deep diamond

Diamond can also be formed as deep as 660 km within the Earth's upper mantle. For many years it is believed that they are not only extremely rare but also small and lack clarity and therefore not suitable for industrial or commercial use. However in the past years scientists have discovered that in fact many top quality diamonds are super-deep Clippir diamonds (type IIA) or type IIB diamonds(see Appendix 1 on Cullinan diamond)

CLIPPIR diamonds

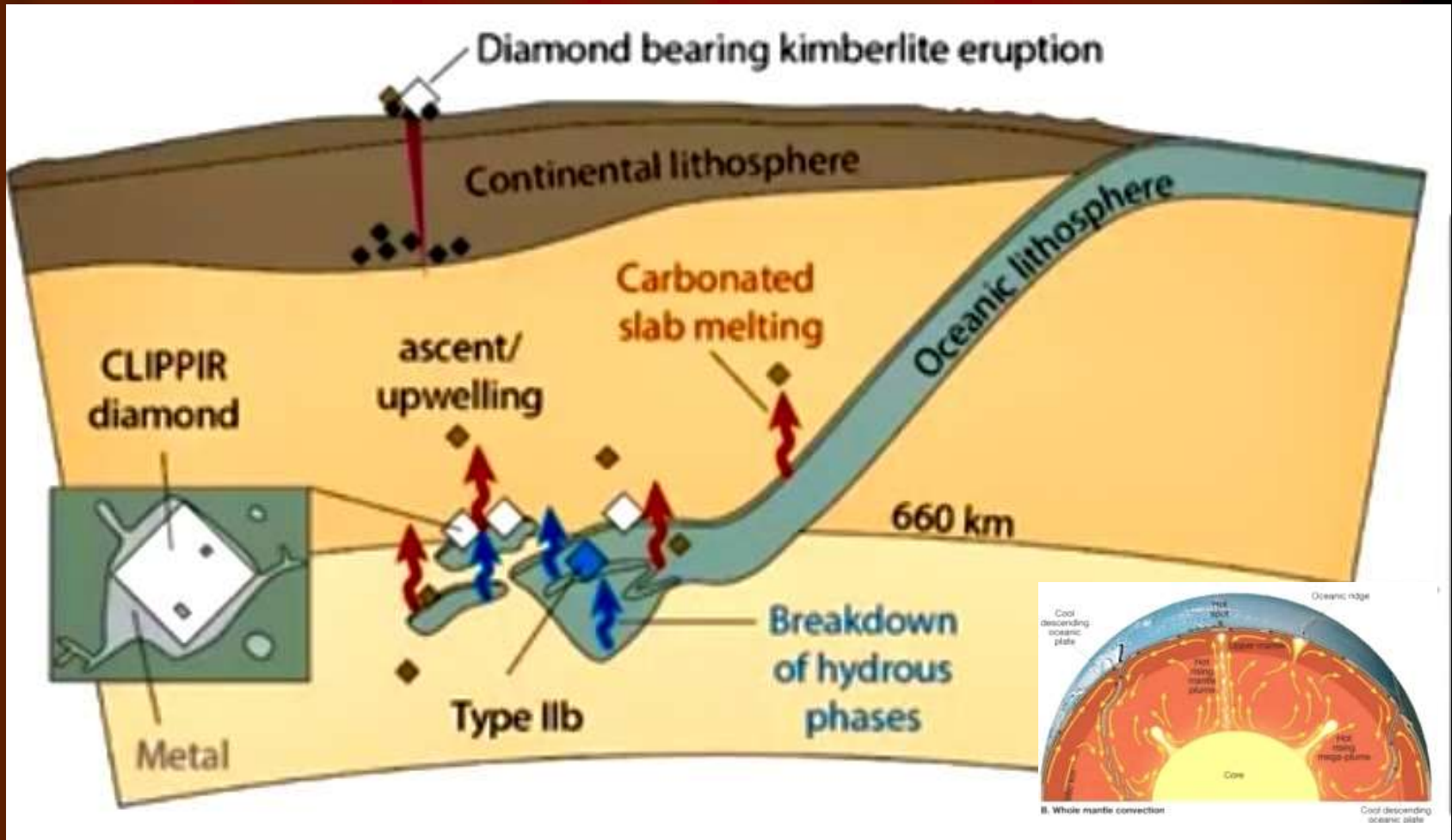


- ◆ Cullinan-like
 - ◆ Large
 - ◆ Inclusion **P**oor
 - ◆ **P**ure (Type II, low nitrogen)
 - ◆ Irregular
 - ◆ Resorbed
-
- ◆ How they form has long remained unknown
 - ◆ Strikingly different from other diamonds
 - ◆ New insight into the Earth's mantle



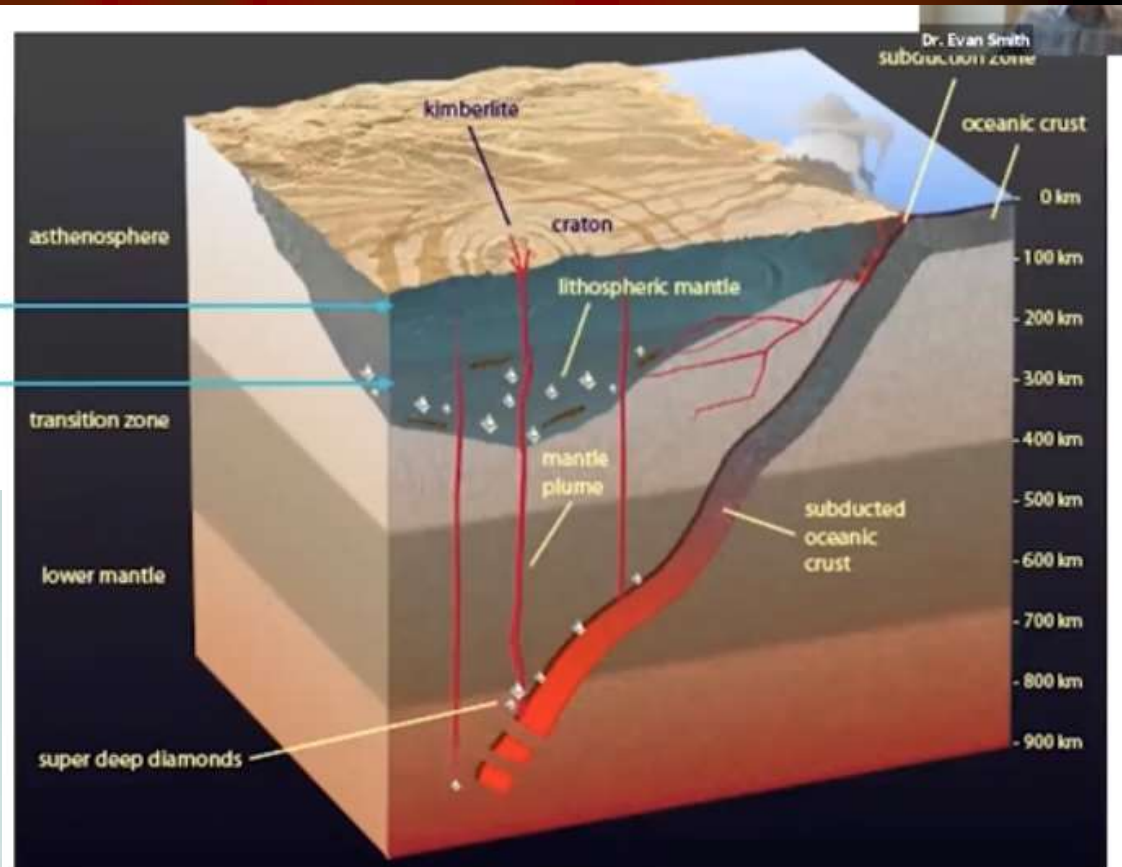
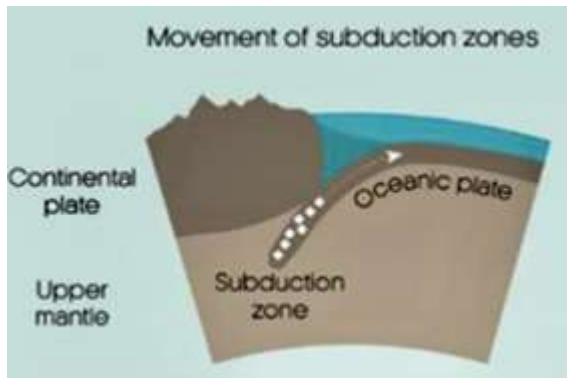
(Wodiska, 1909)

Super-deep Diamond in fact is likely to be formed by the Subduction of an Ocean Plate against the Continental Plate due to plate tectonic 地殼俯冲帶



- The Super-deep diamonds are brought to the surface through deep-source volcanic eruption as well as by the subduction itself

Graphite stability field
Diamond stability field

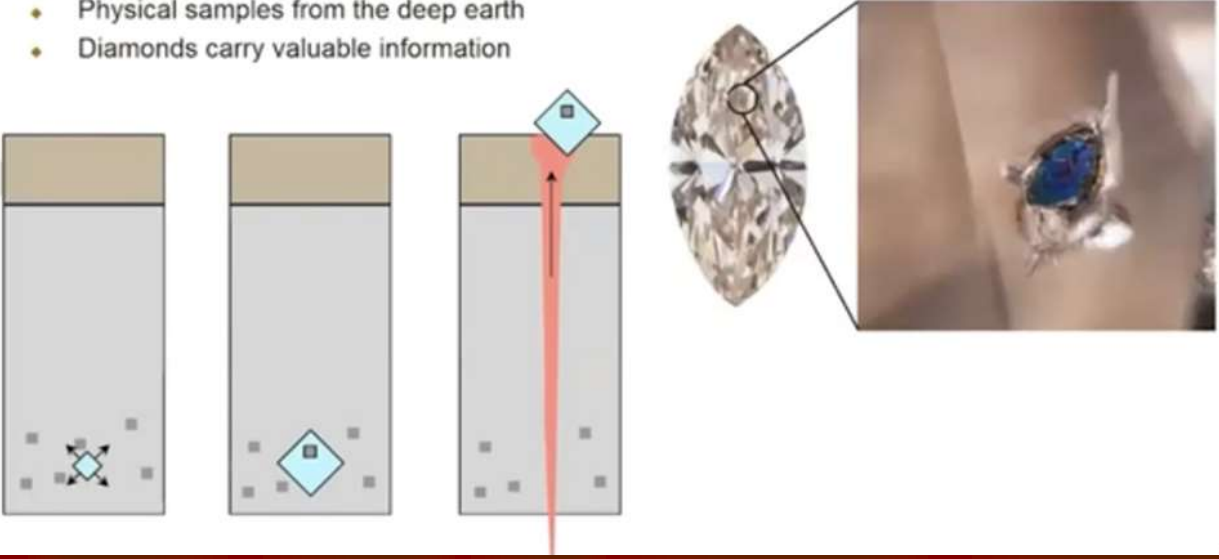


The Magic of Inclusions

- Inclusions 内含物 in Super-deep diamond tell a lot of stories including how the diamond was formed as well as where and when it was formed

◆ We have learned from studying inclusions in diamond

- ◆ Physical samples from the deep earth
- ◆ Diamonds carry valuable information

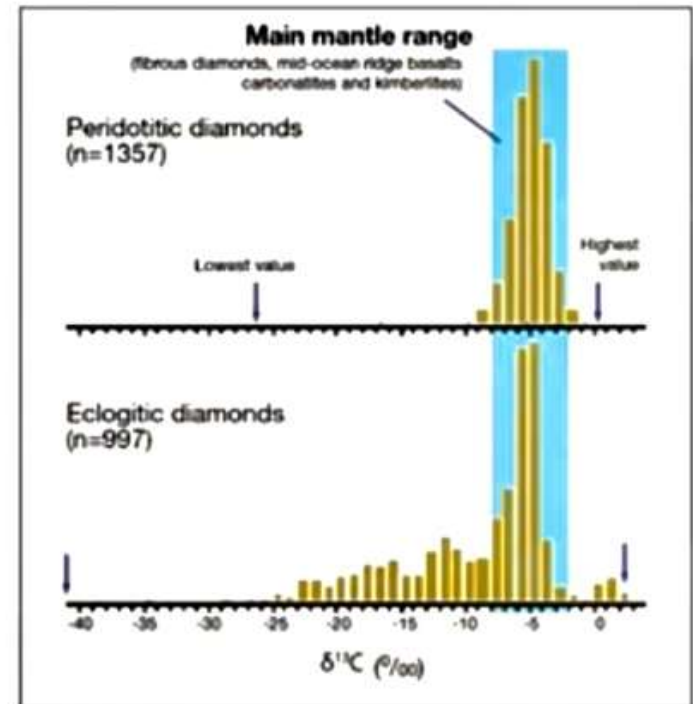


Geologists study inclusions and defects in natural diamonds to understand processes deep in the Earth

Evidence of Subduction

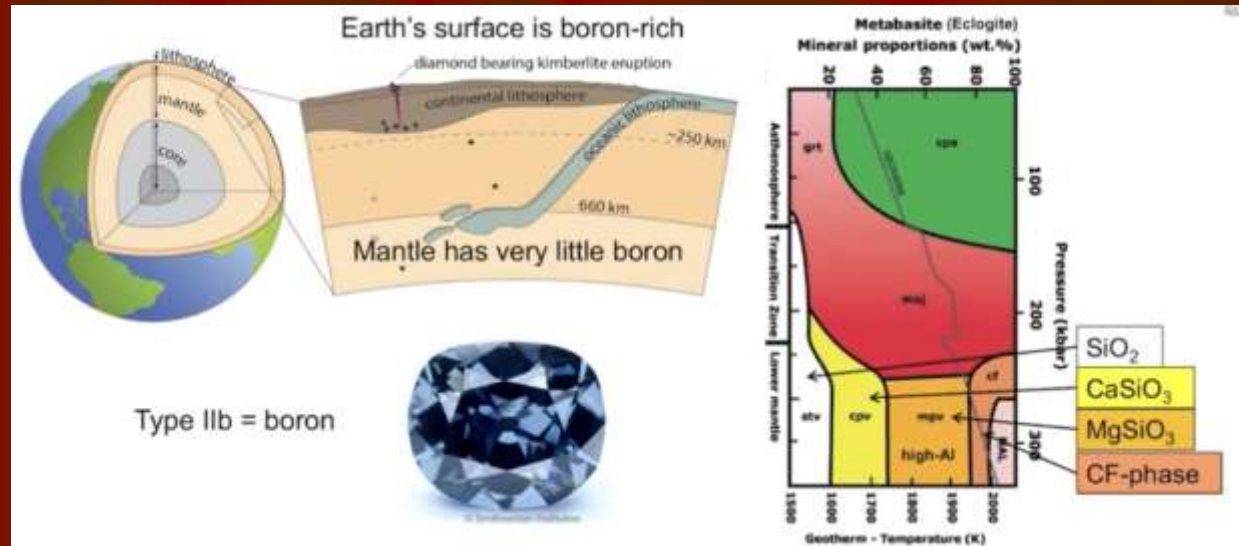
Presence of Carbon 12 and 13 which are of biogenic origin

- ◆ Some diamonds can be linked to subducted oceanic tectonic plates
- ◆ Diamonds show evidence of materials being carried from Earth's surface down into the mantle
- ◆ Diamond is made of carbon
 - Carbon-12
 - Carbon-13
- ◆ Isotopes suggest multiple different sources of carbon may be involved
- ◆ Isotopically "light" carbon is thought to be subducted down to the mantle from Earth's surface



(Shrey et al. 2011)

Presence of Boron which is rich on the Earth's surface but not in the mantle



- ◆ Characterized by presence of boron
 - ◆ 0.01–10 ppm B
 - ◆ Often blue in color
- ◆ B is very enriched at Earth's surface
- ◆ Very little B in the mantle

Hope diamond – 45.5 ct

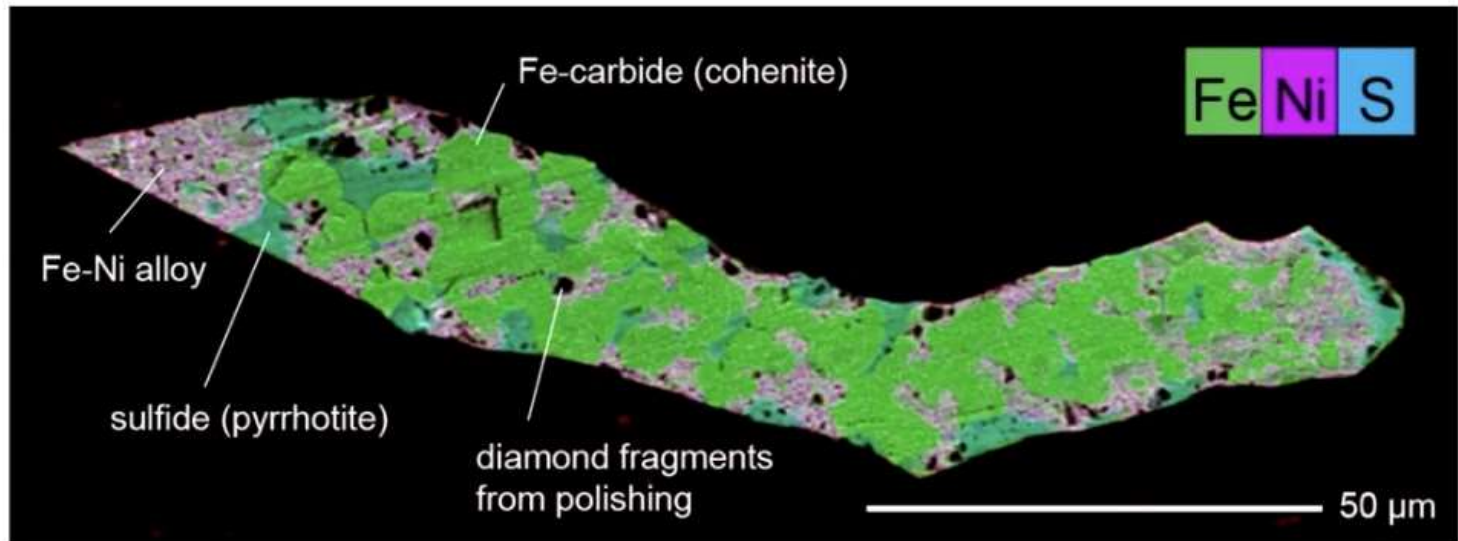


Evidence of Formation Location

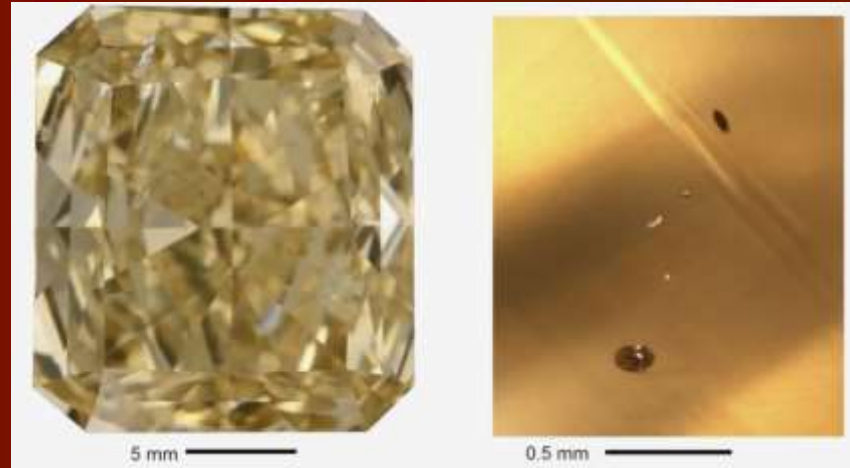
- Iron-nickel metal inclusion confirmed the diamond was formed in the mantle



- ◆ Mixture of iron-nickel-carbon-sulfur
- ◆ Originally trapped as liquid (molten metal)



- Another 30.13 ct diamond with metallic inclusions which is magnetic

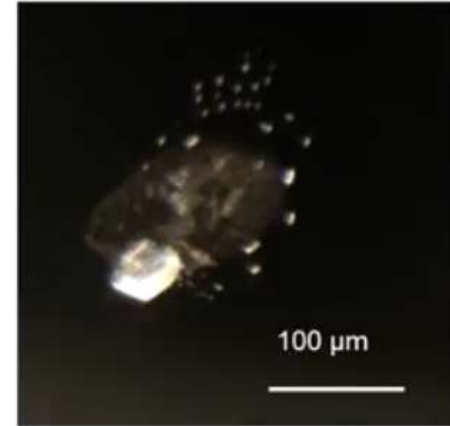
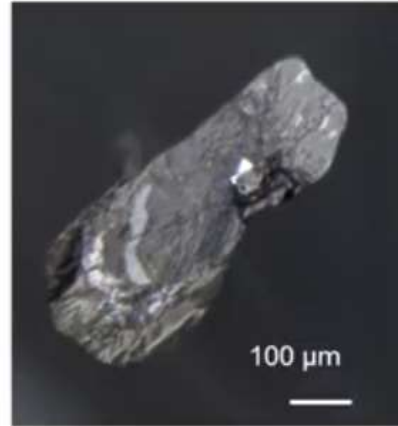
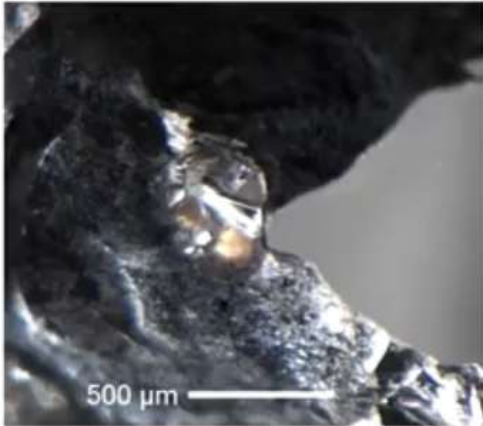


- Similarly presence of Harzburgite inclusions which is formed in peridotite rock which is ultramafic indicates a mantle origin

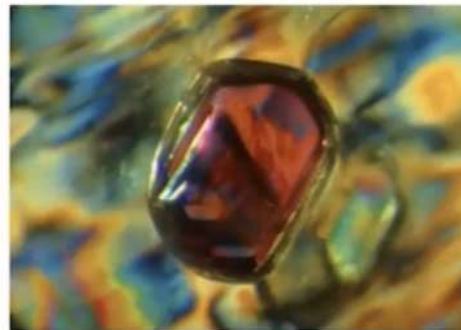


- The presence of special garnet and calcium silicates also indicate the diamond was formed under extreme pressure at the mantle

- ◆ 15 of 53 diamonds special garnets and calcium-silicates
- ◆ These minerals only form at extreme pressure
- ◆ Derived from 220–460 miles deep



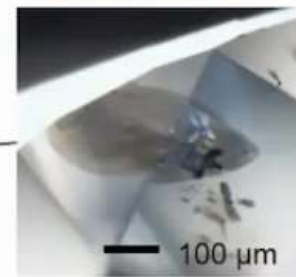
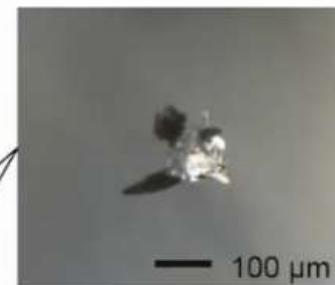
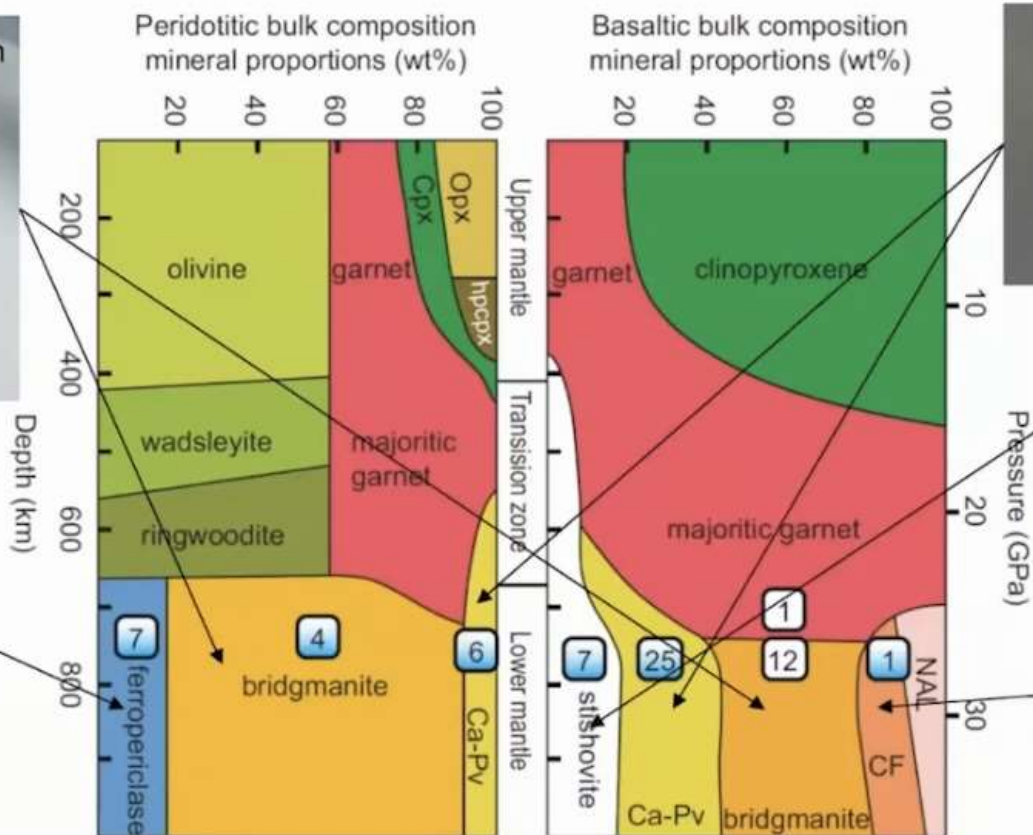
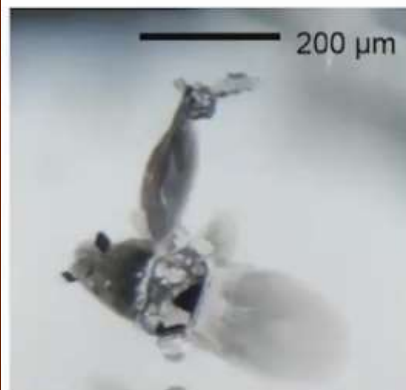
Eclogitic
almandine garnet



Peridotitic
pyrope garnet



Peridotitic
clinopyroxene



Indication of Age

- Sulphide inclusion allow us to determine the age of the diamond. It is done by studying the radioactive isotope of rare mineral inside such as rhenuim (Re) which decays very slowly into osmium (Os) with a half life of 41 Ga. Dating diamond itself is not possible because it has no radioactive element. Standard carbon dating cannot be used as the Half live of C14 is only 5700 years !



Sulphides

Silver-grey appearance

Expand more than diamond during kimberlite ascent and fracture the diamond

Fractures filled mostly with graphite (gives blackish color)

Analyses of these inclusions allows us to determine the age of the diamond



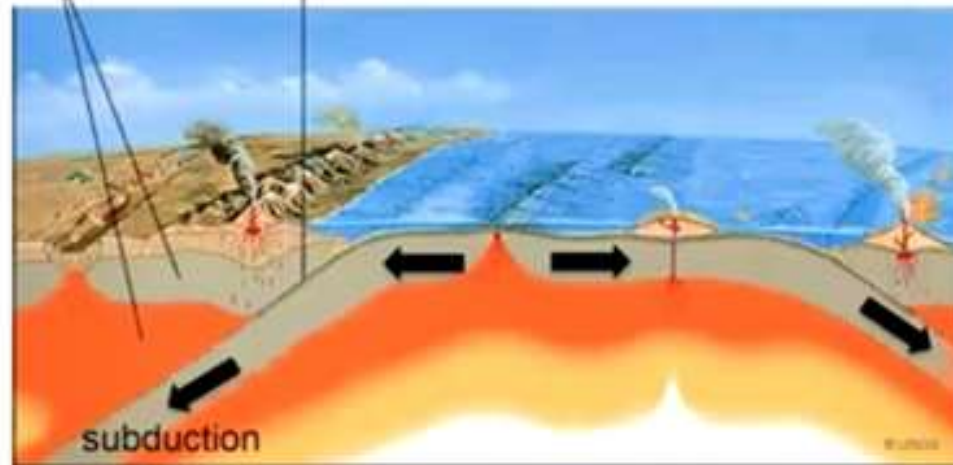
Re-Os has always allowed single sulphides to be used for dating (depending on size and Os concentration)

- Kyanite was formed under extreme pressure as a result of the two landmasses that formed supercontinent Pangea 3.35 By. Its presence in the diamond serves as a good index mineral for age, temp & pressure



Peridotite

Ocean crust, basalt → eclogite



Subducted ocean crust appears in diamond record after 3 Ga

Garnet and kyanite

Host rock type: eclogite



(3.57 mm field of view)

Olivine

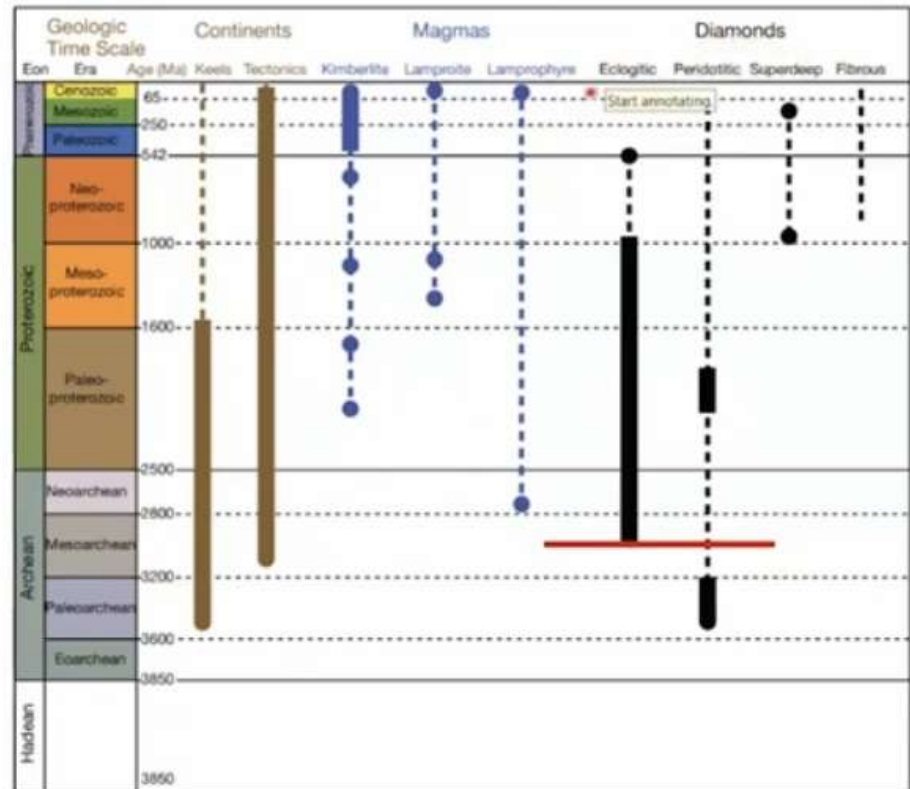
Host rock type: peridotite



(1.42 mm field of view)

- The oldest age of the super-deep diamond tested was 3 Ga which indicates plate tectonics may have started then pushing the ocean crust down into the mantle

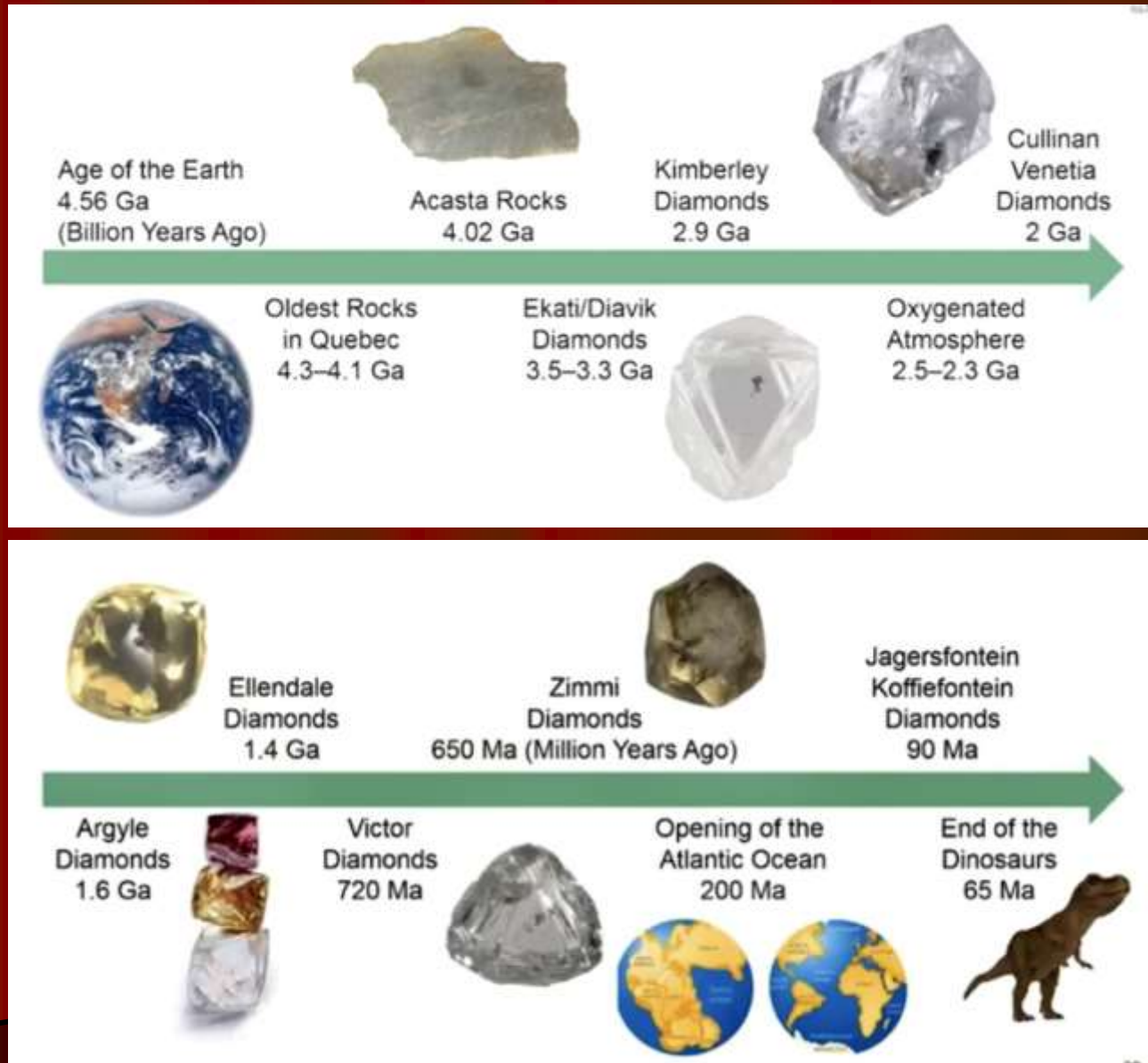
- ◆ Diamonds tie into our ideas of when plate tectonics *started*
- ◆ Examination of inclusions in many diamonds
 - ◆ Identification of mineral inclusions
 - ◆ Eclogite and peridotite host rocks
 - ◆ Determination of ages
- ◆ Eclogitic diamonds only appear after 3 billion years ago
- ◆ Plate tectonics may have started around 3 billion years ago and carried ocean crust down into the mantle



(Shirey et al., 2013)

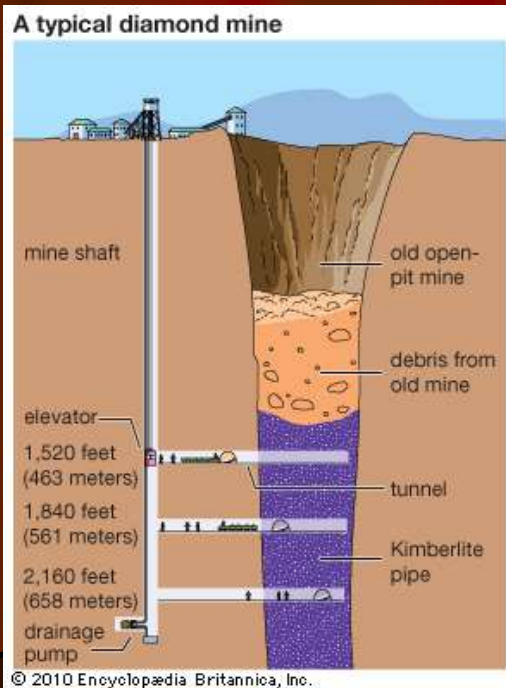
The Age of Diamond

See age of all diamonds tested in appendix 2

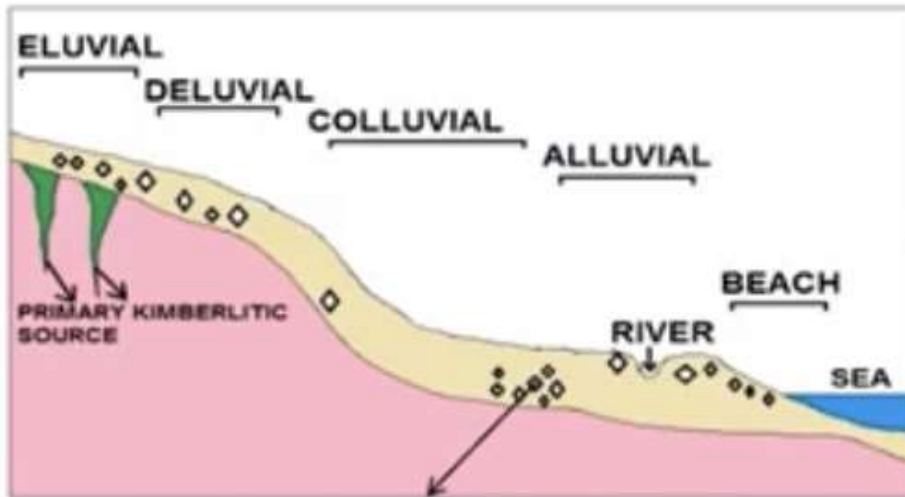


Mining methods

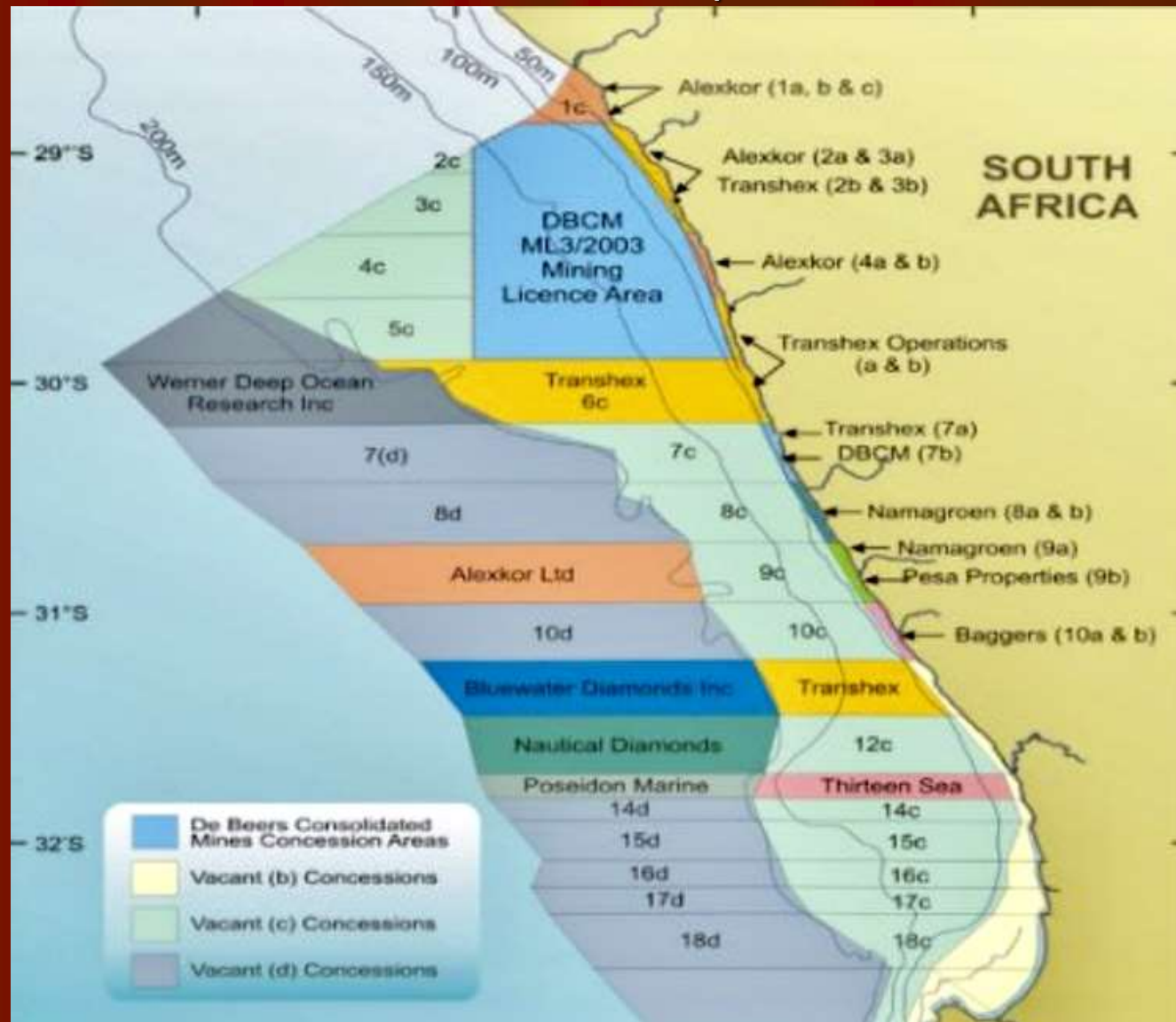
- I. Primary deposit - Mining the kimberlite pipes – open pit and/or underground tunnels. Low concentration, all quality grades
- II. Secondary deposit - Mining alluvial deposit formed through weathering and transport by water: Alluvial/Placer Diamond 冲積鑽石
- III. Mining marine deposit – Marine Diamond 海洋鑽石



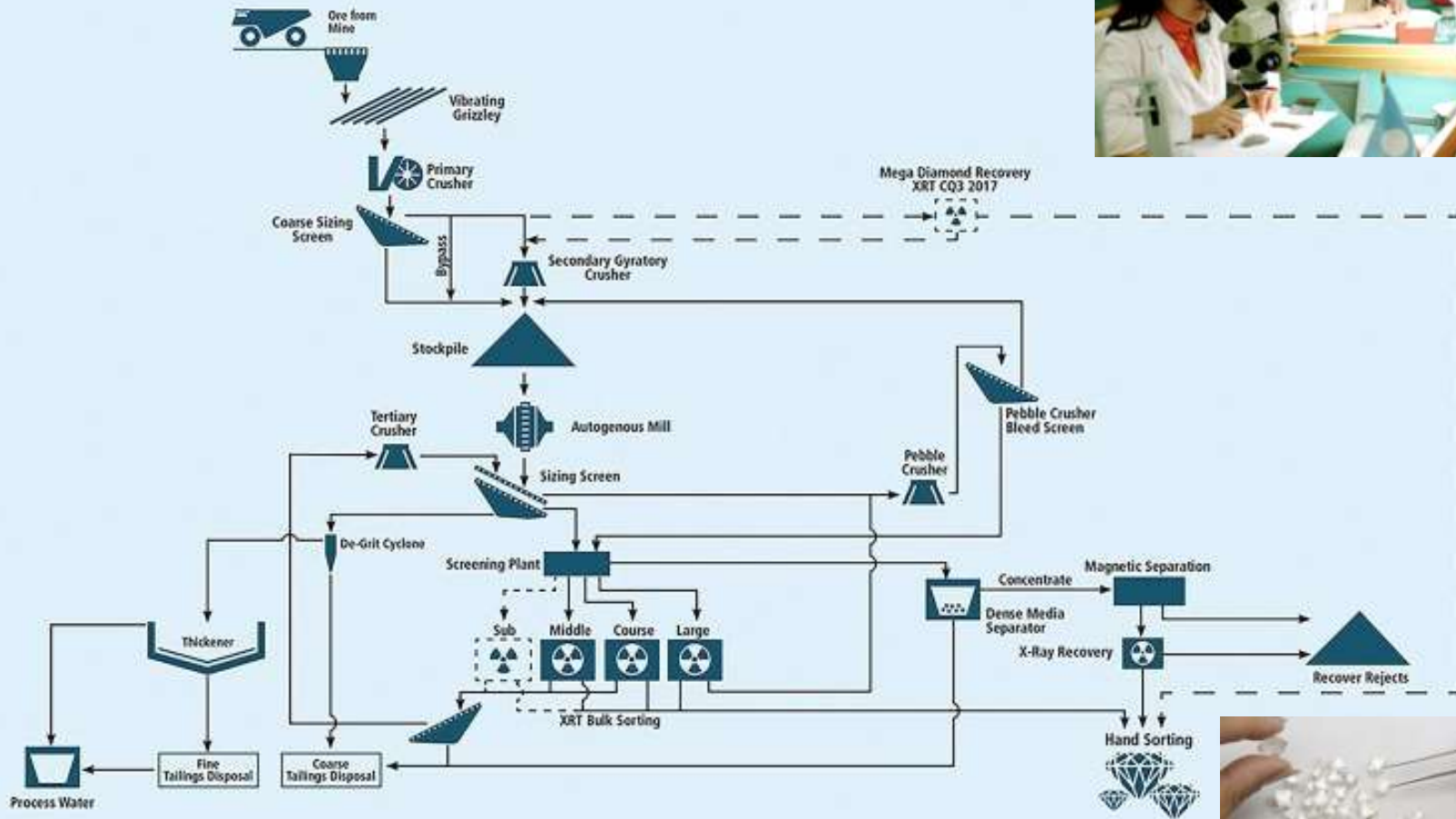
Secondary deposit is the result of weathering and erosion on the primary deposit. Diamonds are transported by water or gravity and deposited down stream as placer when the transportation energy weakens. The gems are of higher grade and being concentrated because fractured goods are broken during transportation – Nature Sorting



Marine diamond mining takes place primarily along the 1,400 km coastline of southern Namibia at a depth from 90 to 140 meters



Crushing, Scrubbing, Separation, Recovery, Clean/weighed/package



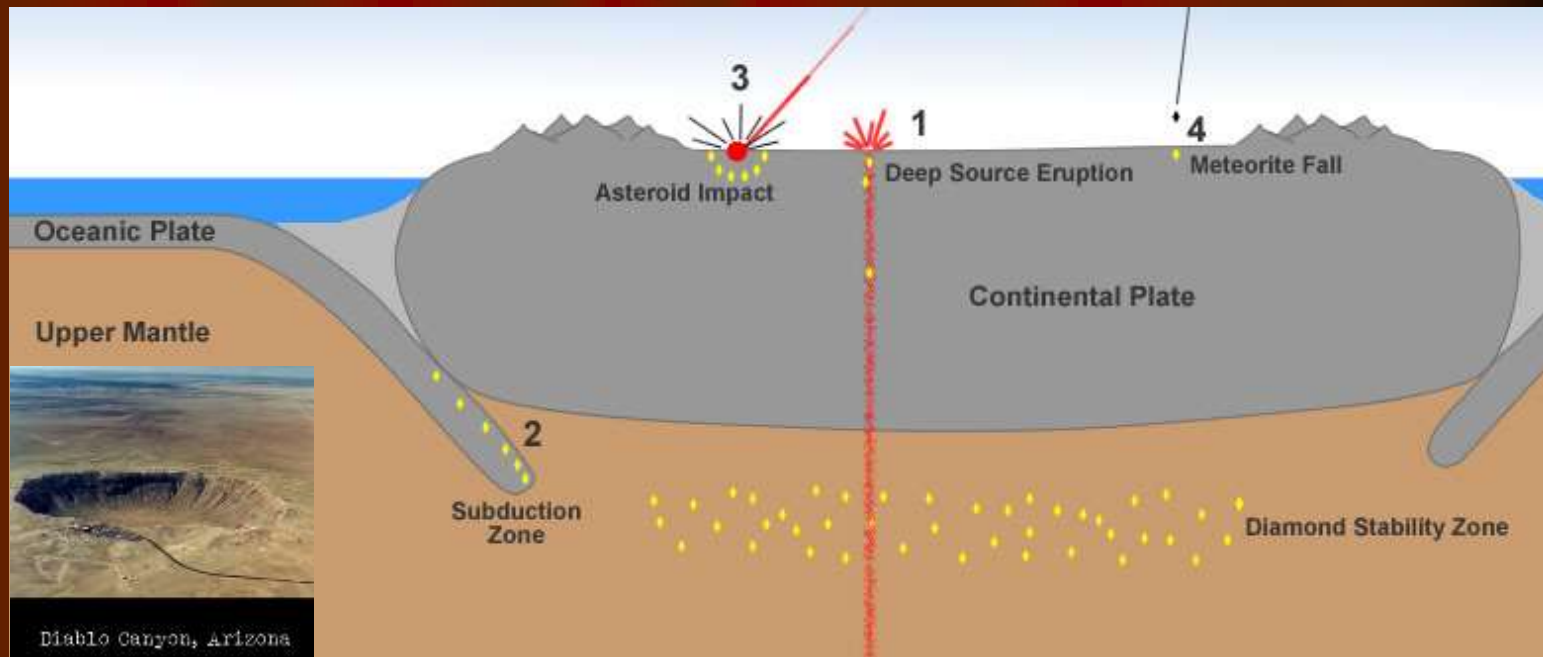
Samples of rough stones





Other origin :

I. Asteroid Impact Diamond 小行星撞激



Impact diamonds

Canyon Diablo, iron meteorite (IAB). Found 1891, Arizona, USA.

Around 50,000 years ago a massive meteorite struck Arizona carving out a crater 1.2 kilometres wide and 180 metres deep. The impact was so strong that most of the meteorite vaporised. The tremendous pressure generated caused the carbon in some of the remaining fragments to transform into tiny diamonds. You can see a black lump on the surface. This is where the cutter's wheel has been interrupted by a nodule containing these hard diamonds, not much bigger than grains of sand.



II. Meteoric diamond 天外來客

About 3 percent of the carbon in meteorite is in the form of Nano diamond
納米鑽石 with size below one micrometer 10-9

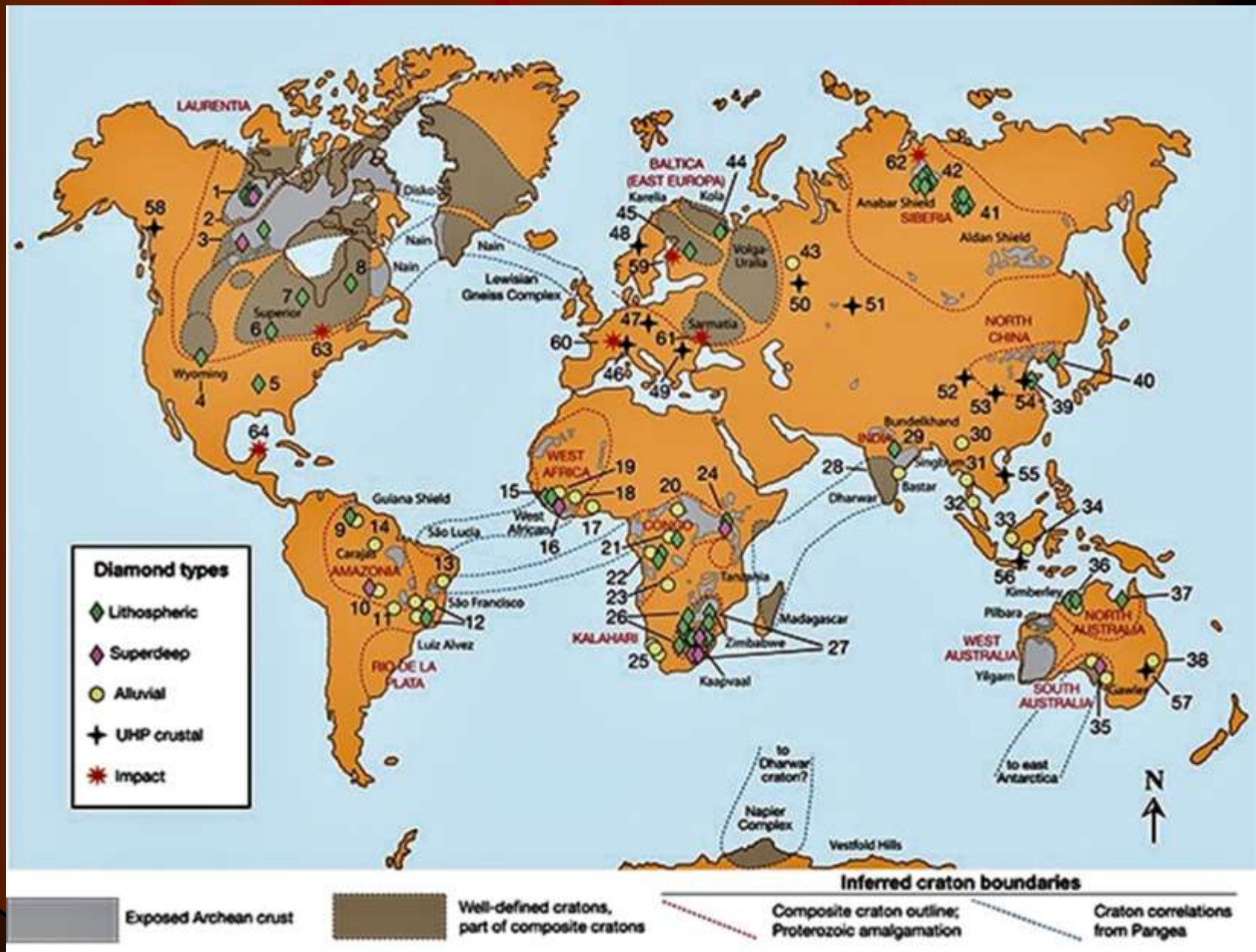
Diamonds from star dust

Cold Bokkeveld, stony meteorite (CM2 chondrite).
Fell 1838, Cold Bokkeveld, South Africa.

If you look carefully in the bottom of this little tube you can see a white smudge of powder. This smudge is made up of millions of microscopic diamonds. These are the oldest things you will ever see. They formed in the dust around dying stars billions of years ago, before our solar system existed. The diamonds dispersed in space and eventually became part of the material that formed our solar system. Ultimately, some of them fell to Earth in meteorites, like the ones you see here.



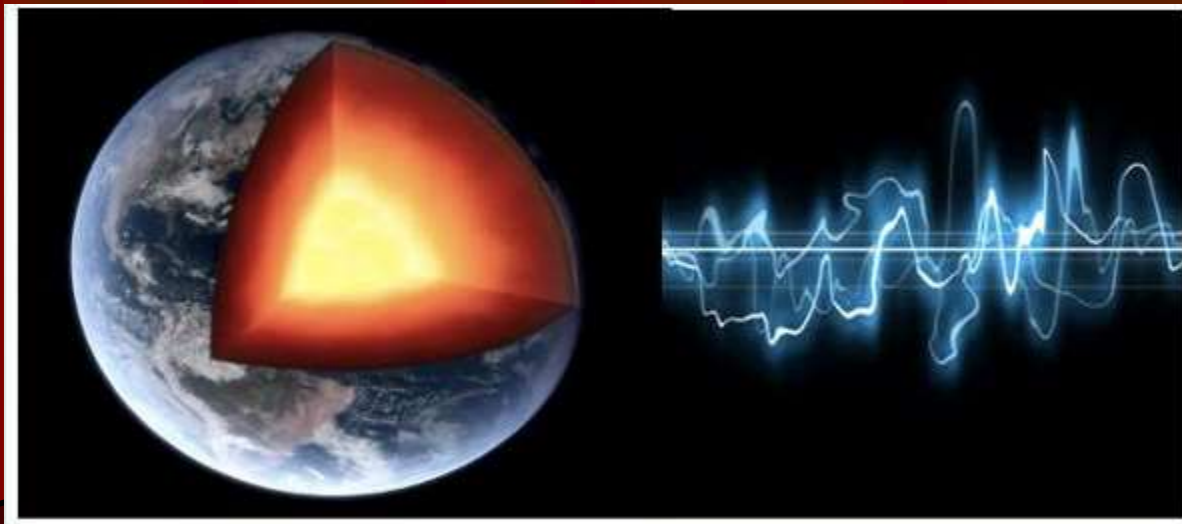
Location of diamond mines by type



How much diamond is there on Earth ?

A total of 600 tons of diamonds have been mined & traded since 1900. A recent MIT study with sound waves reviewed that 1 to 2% of the world's oldest mantle rocks are made from diamond. This is equivalent to more than a quadrillion (10^{16}) tons of diamond. However they are hidden in the Earth's interior buried more than 140 km below in the cratonic roots which is deeper than any drilling expedition can reach ! Current declared accessible global diamond reserve is estimated to be only 240 tons (1 billion carats)

Sound waves reveal diamond deep in the Earth's interior - its sound velocity is more than twice as fast as in the dominant mineral in the mantle rock olivine



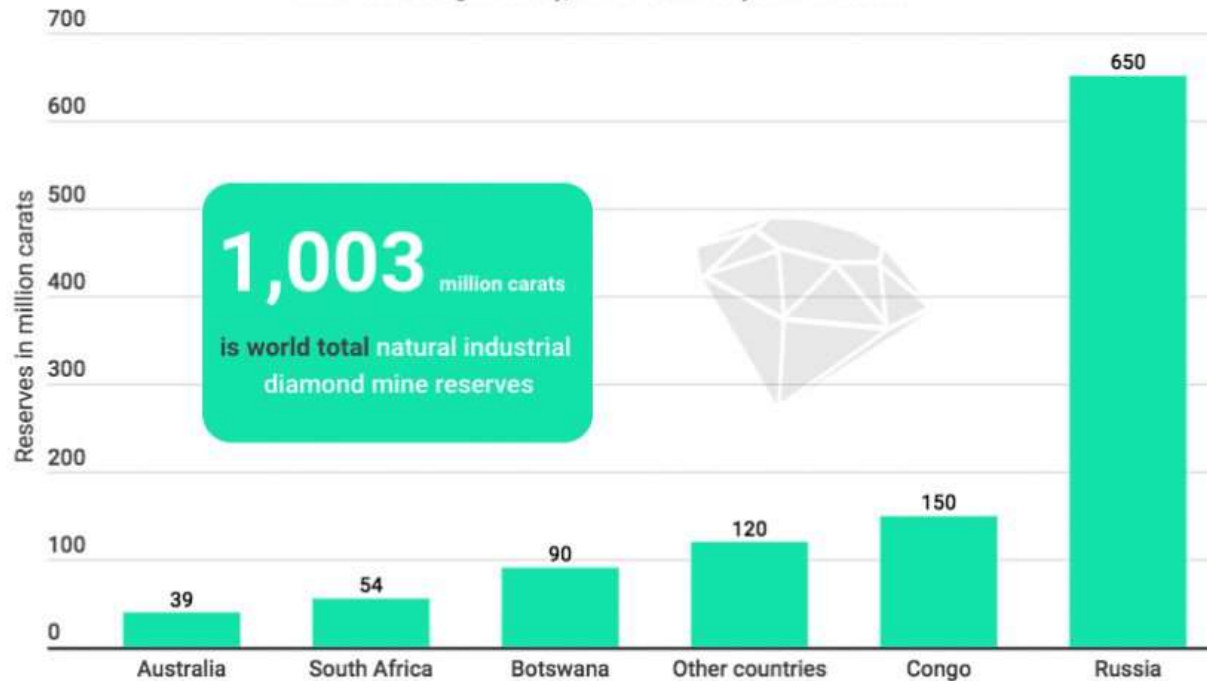
Countries with the largest diamond reserves in 2018

Total global reserve 240 tons/1 billion carats

World natural industrial diamond mine reserves, by country

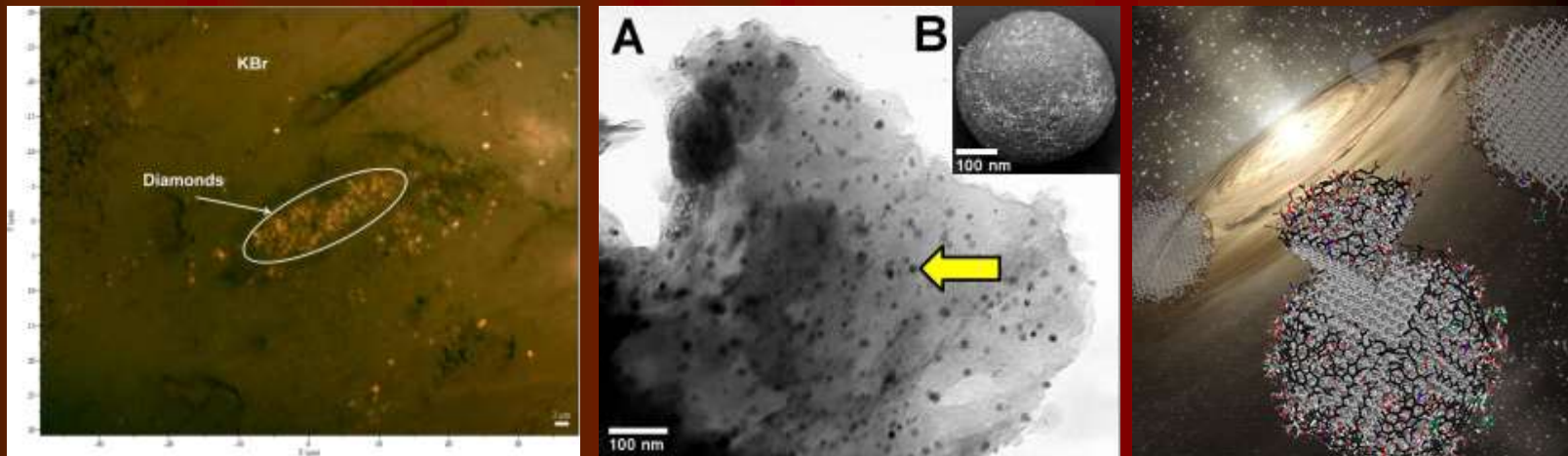
Details: Worldwide; in million carats; summaries for 2019 released in 2020

Source: U.S. Geological Survey, Mineral Commodity Summaries 2020



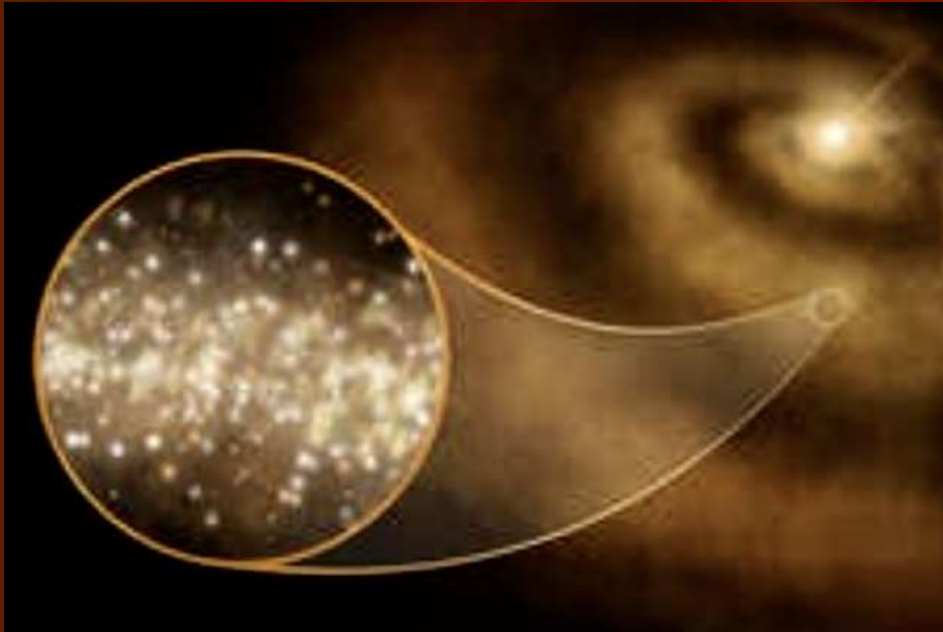
Cosmic Diamond

Diamonds may be rare on Earth but surprisingly common in space. Studies of meteorites that crashed into Earth revealed lots of tiny *nanometer-sized diamonds 纳米鑽石. Astronomers estimated that just a gram of dust & gas in a cosmic cloud could contain as many as 10,000 trillion nano diamonds ! These diamonds are thought to have formed in space through high-speed collisions of up to 10,000 miles per hour. The process is similar to how diamonds were formed on Earth at meteor impact sites but without the high pressure high temperature environment which do not exist in space



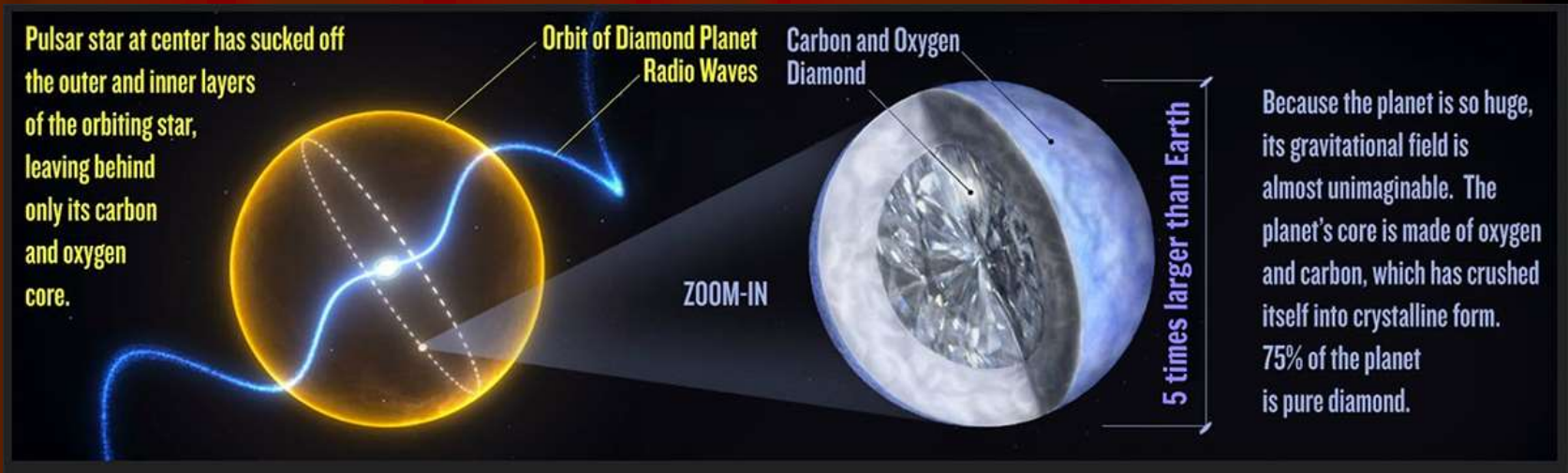
* Nanometer = billionths of a meter in diameter (micrometer)

Scientists believed the previously unexplained glow in space is caused by the existence of nano diamonds



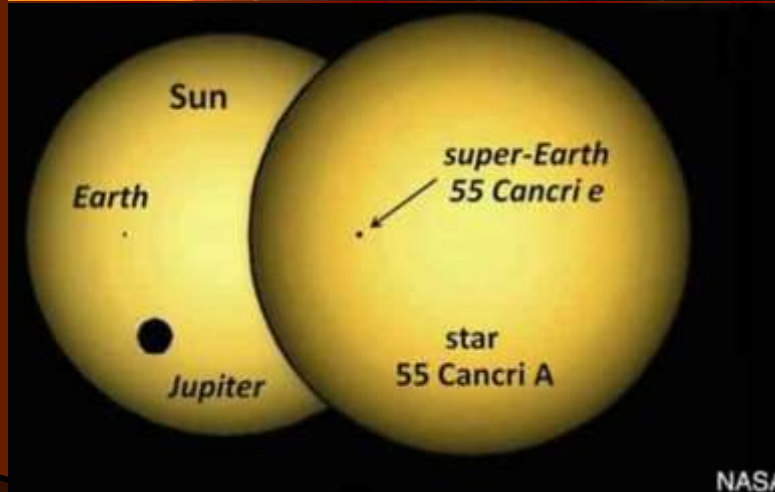
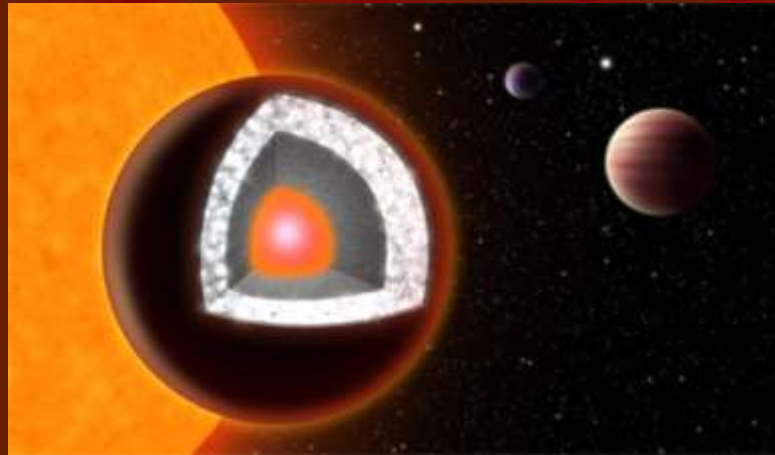
BPM37093 LUCY

Discovered in 2004 at 40 light-years away it is a white dwarf 白矮星 75% of which is pure diamond weighing 10 billion, trillion, trillion carats



55 Cancri e

Located 50 light years away it has a radius twice earth's and a mass eight times greater making it called a "super-Earth". It is extremely hot (2148C) and its year just last 18 hours. The surface of the planet is likely covered by graphite and diamond rather than water and granite !

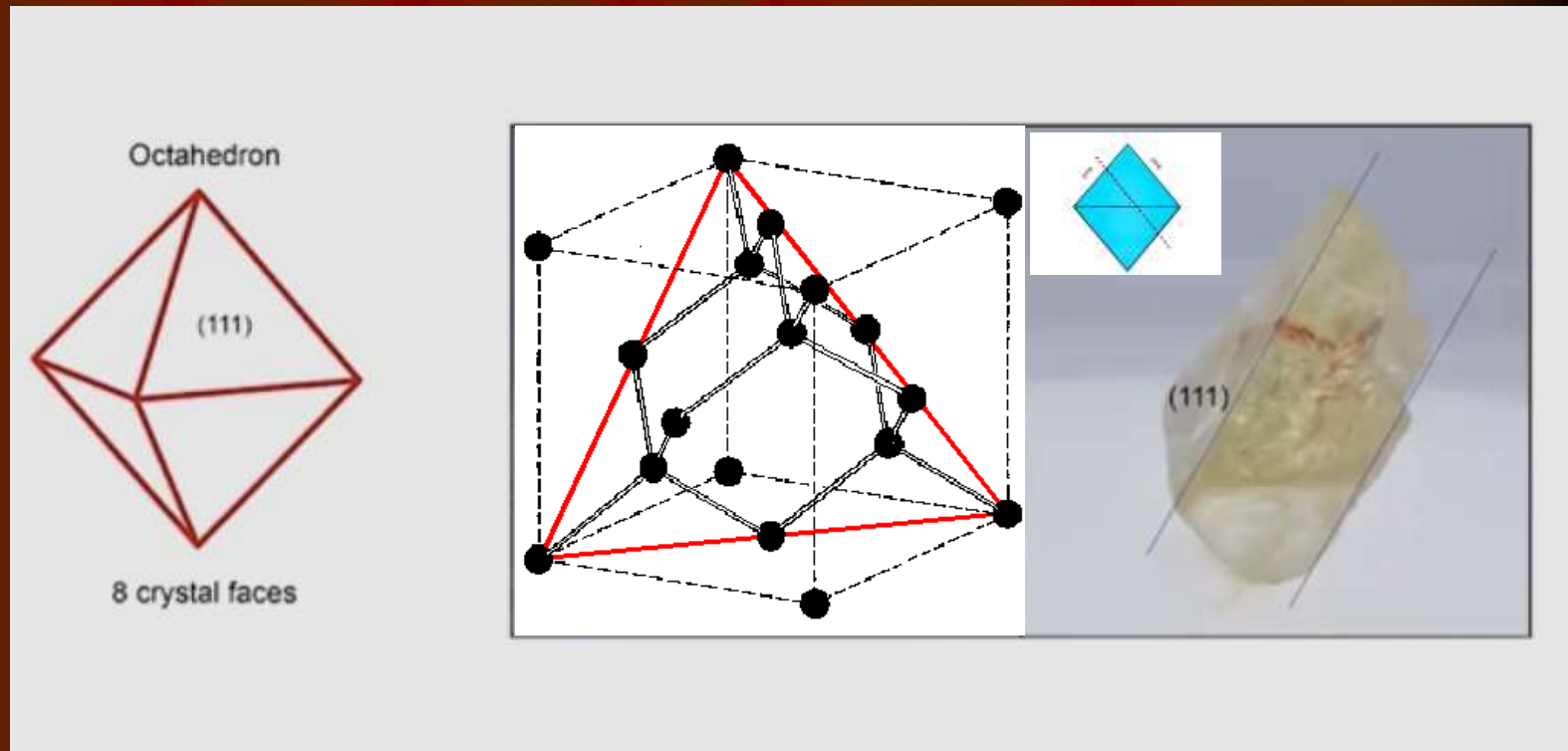


Are Diamonds really “forever” ? 鑽石恒久遠 ?



The answer is **NO**

Although diamond is very hard it is brittle 脆性. Breakage can occur by external forces along its natural cleavage 111 plane 裂解平面/解理 which is parallel to the octahedral crystal plane. It can also be worn down by dissolution 溶解 when being transported around



The diamond morphology we see is a function of the atomic-scale lattice

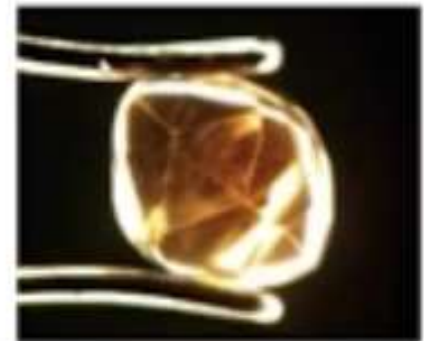
- ◆ Processes during growth
 - ◆ How atoms are added to the surface of a growing crystal
- ◆ Processes after growth
 - ◆ Deformation
 - ◆ Resorption
 - ◆ Abrasion/breakage

Morphology is a physical record of these geological processes

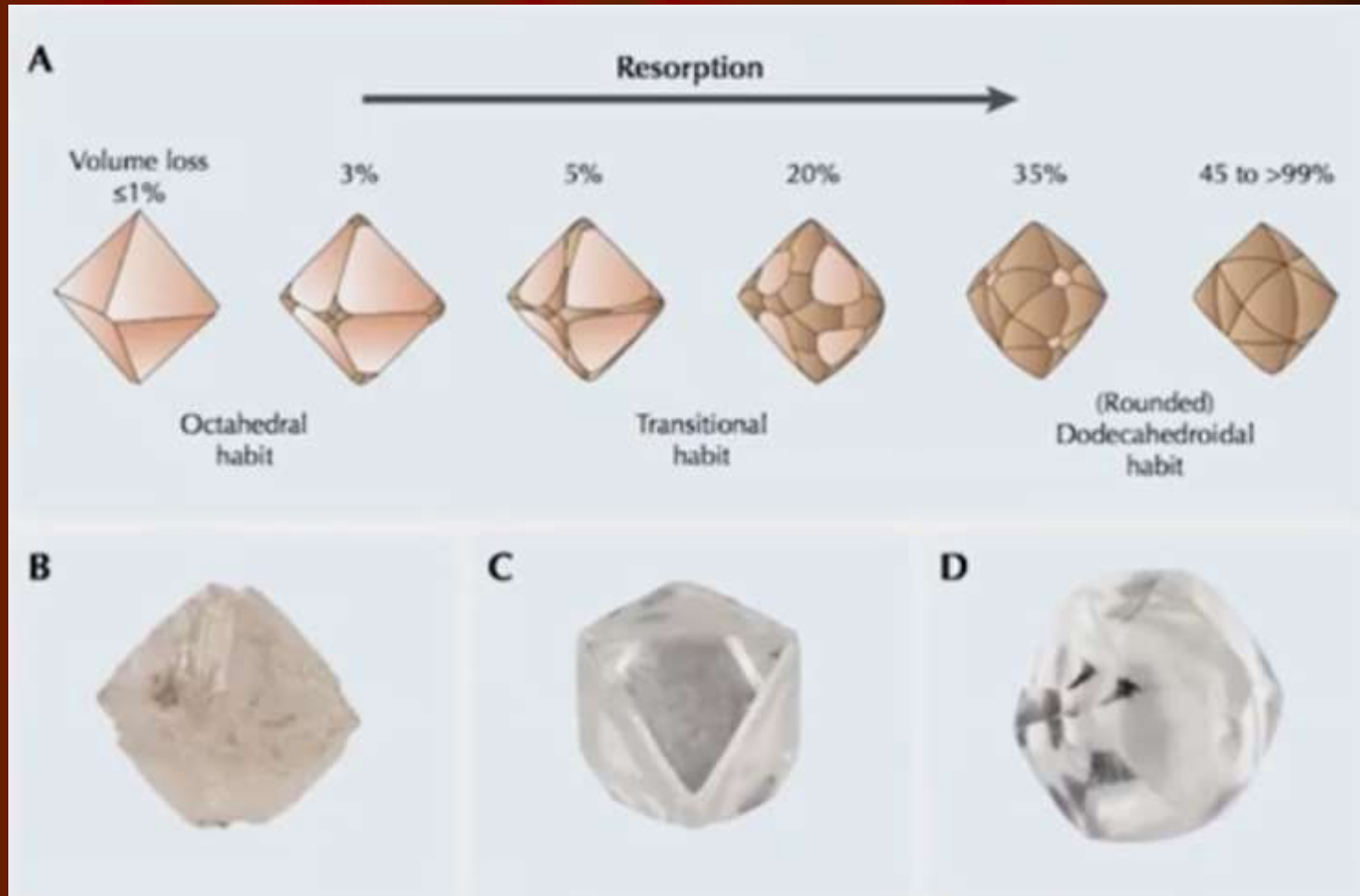
- ◆ Processes during growth



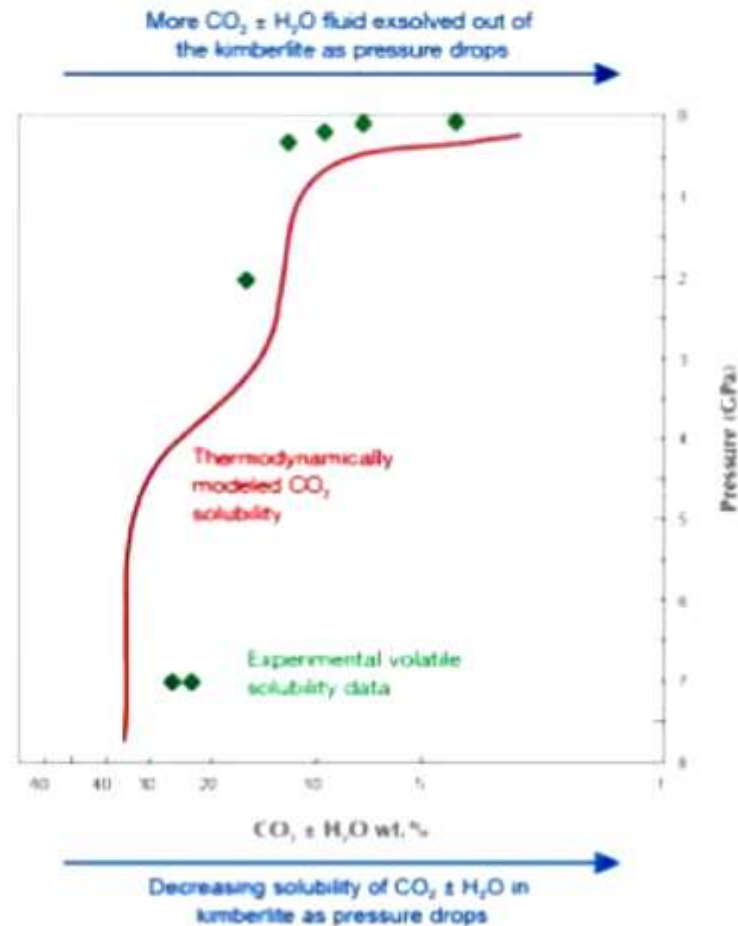
- ◆ Modification after growth

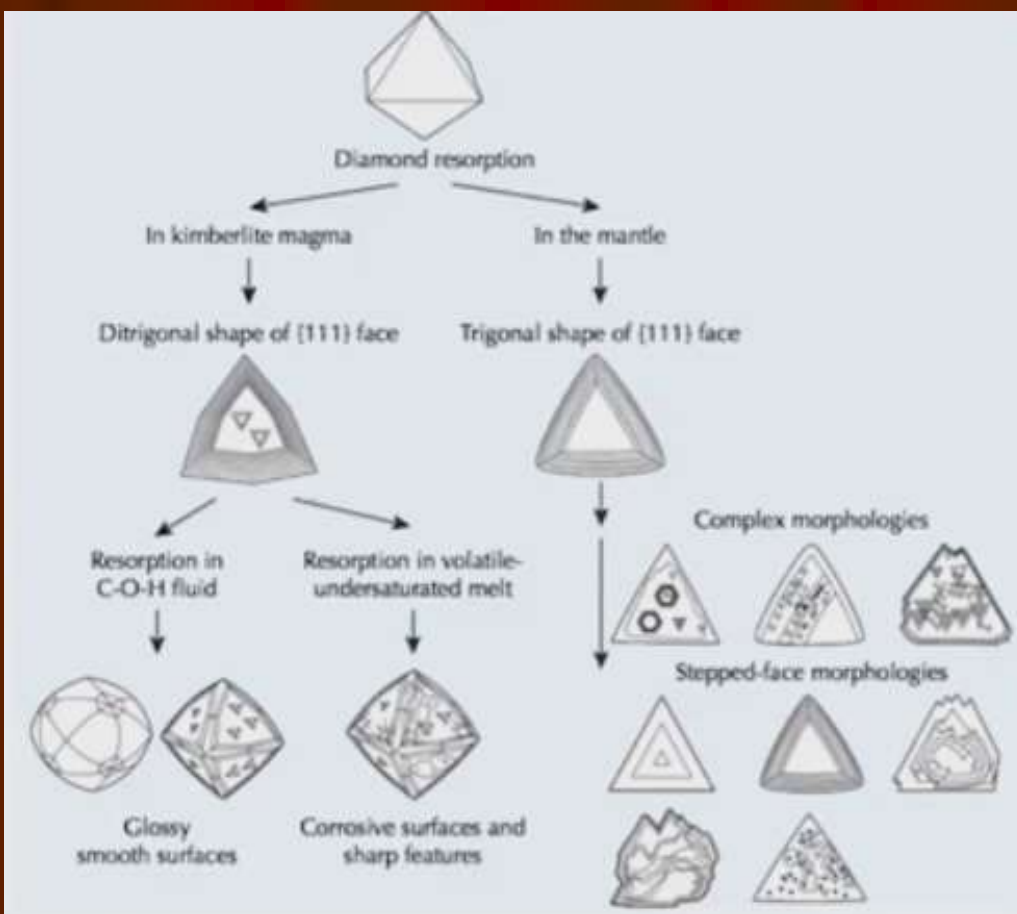


- Resorption (dissolution/corrosion) by fluid or melt can lead to Rounded Dodecahedroidal shape. Resorption can occur in the mantle or during volcanic transport by kimberlite



As kimberlite magma reached the surface the reduction of pressure released volatiles 揮發物 which can etch and dissolve diamonds





© Van King (mindat.org/photo-85485)



© johnbetta-flickr/istockphoto.com

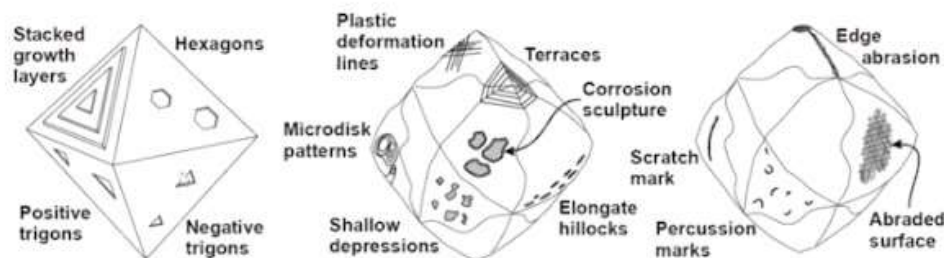
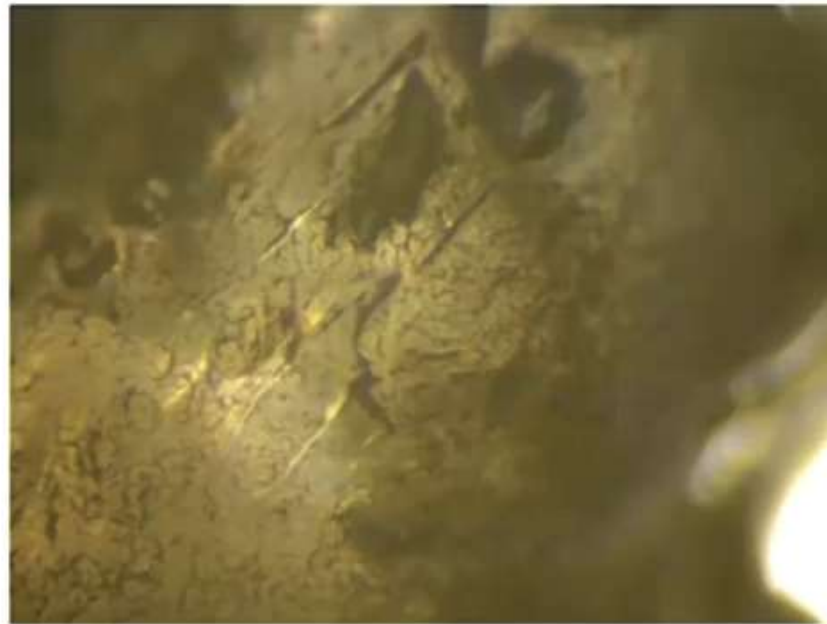
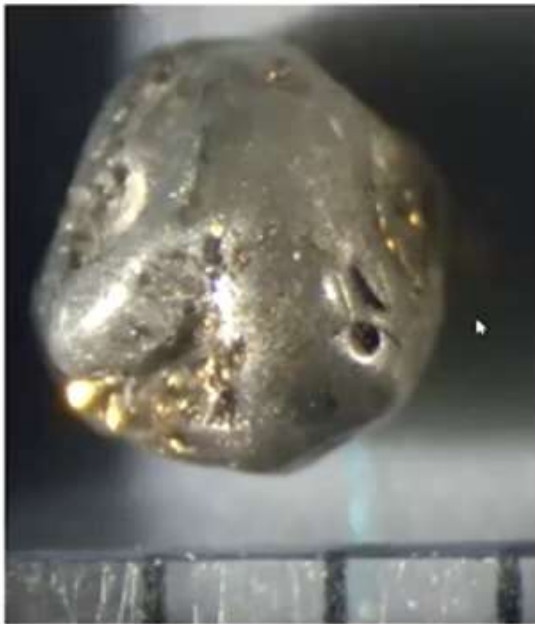


FIG. 1-5. Surface features on diamond. Left: surface features on octahedral faces. Center: surface features on rounded dodecahedral faces. Right: surface features typically associated with diamond from alluvial deposits (unrestricted to a particular type of face).





- ◆ Chipping, scratching, and grinding due to mechanical abrasion during alluvial transport, or washing back and forth in a beach
- ◆ Resembles texture of ground glass, like at a beach



Different morphology of the rough stones resulted from processes during growth as well as after growth



Diamond also burns releasing CO_2 although the ignition temperature is very high (690-840 C in pure oxygen). Tomas Weller of the ISIS Neutron Facility in England has shown that with the right kind of laser pulse industrial diamond can be converted into graphite. Researchers from SLAC National Accelerator Laboratory in the US also able to induce graphitization by using ultra-short flashes of X-ray laser. Recent experiment also show that small amount of synthetic diamonds were transformed into graphite by heated oxygen torch up to 1400-1500 C. Having said the above, diamonds are very stable within the Earth's surface ambient environment



Synthetic Diamond

人造鑽

Revolution !

Forbes

Natural Mined Diamonds Can't Deliver This:
Personalized Diamonds Made From Memories

Jan 21, 2018

Diamonds Disrupted: How Man-Made
Diamonds Will Disrupt The Mined-Diamond
Industry

Sep 2, 2017

The New York Times

Is That Rock for Real?

Nov. 17, 2014

Clarifying What Makes a Diamond

Dec. 6, 2017

WIRED

09.01.18

THE NEW DIAMOND AGE

PEAK Will we finally say "I do" to lab-grown diamonds in 2018?

JANUARY 12, 2018

FINANCIAL TIMES

Spot the difference: why lab-grown diamonds
pose a threat to big miners

OCTOBER 31, 2017

Producers of natural gems are unnerved by cheaper, cleaner synthetic jewels

The Business of Fashion

BOF : *Business of Fashion*

Will Lab-Grown Stones Save or Sink the Troubled
Diamond Market?

March 6, 2017

Man-made diamond aka synthetic diamond or Lab-grown diamond or cultured diamond are real diamonds which has the same optical, physical & chemical properties of a natural diamond. It is extremely difficult and costly to distinguish from natural diamonds not to mention some synthetic diamonds have properties such as thermal conductivity and electron mobility that are superior to natural diamond. That synthetic diamonds are like test tube babies vs natural born babies is a good analogy

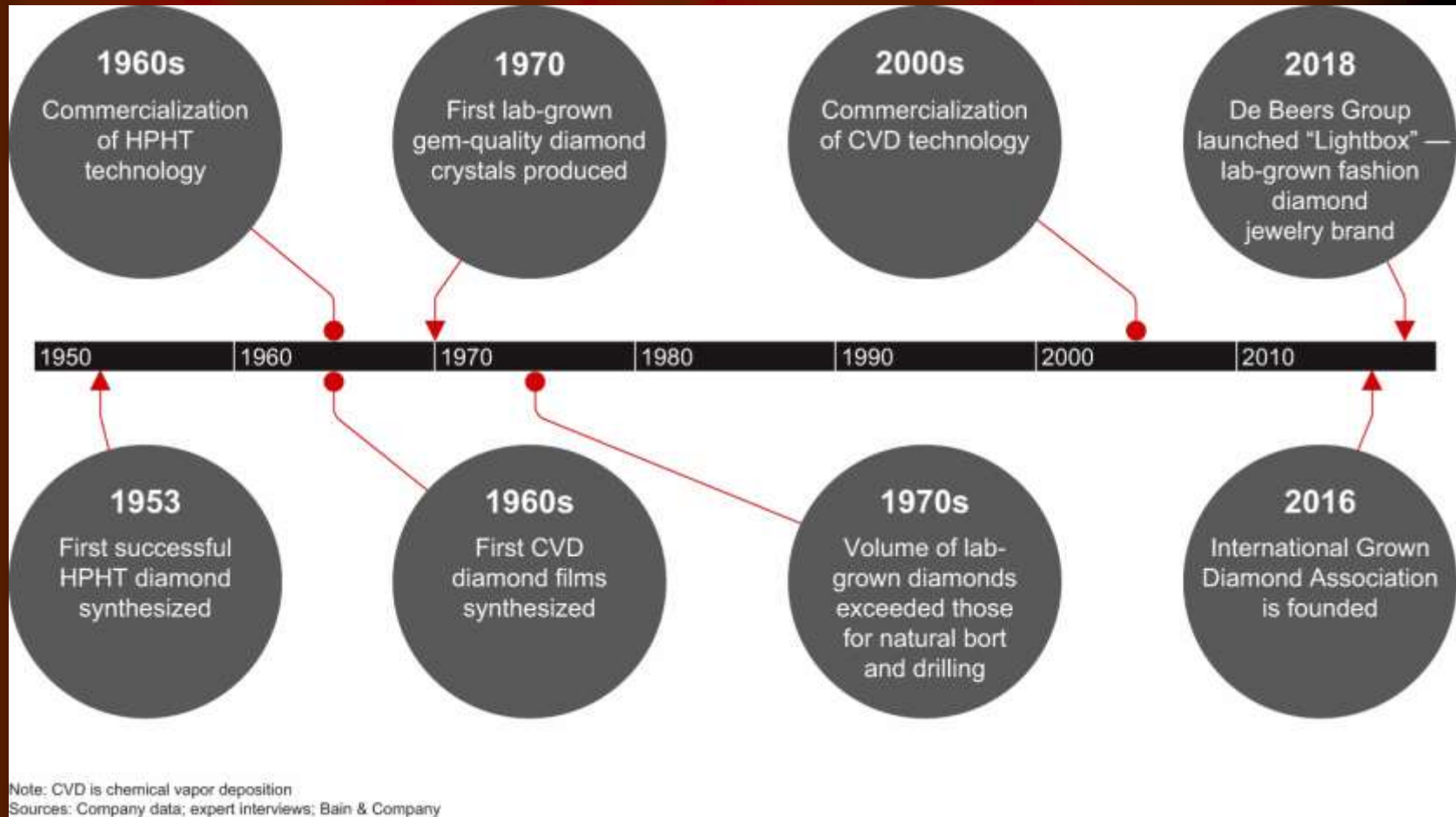
Grown vs Mined			IS IT A DIAMOND?	
Diamonds	Grown	Mined	LAB-GROWN	EARTH MINED
Chemical Composition	C	C		
Crystalline Structure	Cubic	Cubic		
Refractive Index	2.42	2.42		
Dispersion	0.044	0.044		
Hardness	10	10		
Density	3.52	3.52		
			✓ Yes	✓ Yes

Diamond can be grown from high purity carbon under high pressure and temperature (HPHT) or from hydrocarbon gas by chemical vapor deposition (CVD). Lab diamond's chemical, physical and gemological properties are the same as natural diamond but their price is around 30 - 40% less than natural diamond. As they can only be distinguished from natural diamond by trained gemologists using special spectroscopic devices they are a threat to the natural diamond industry



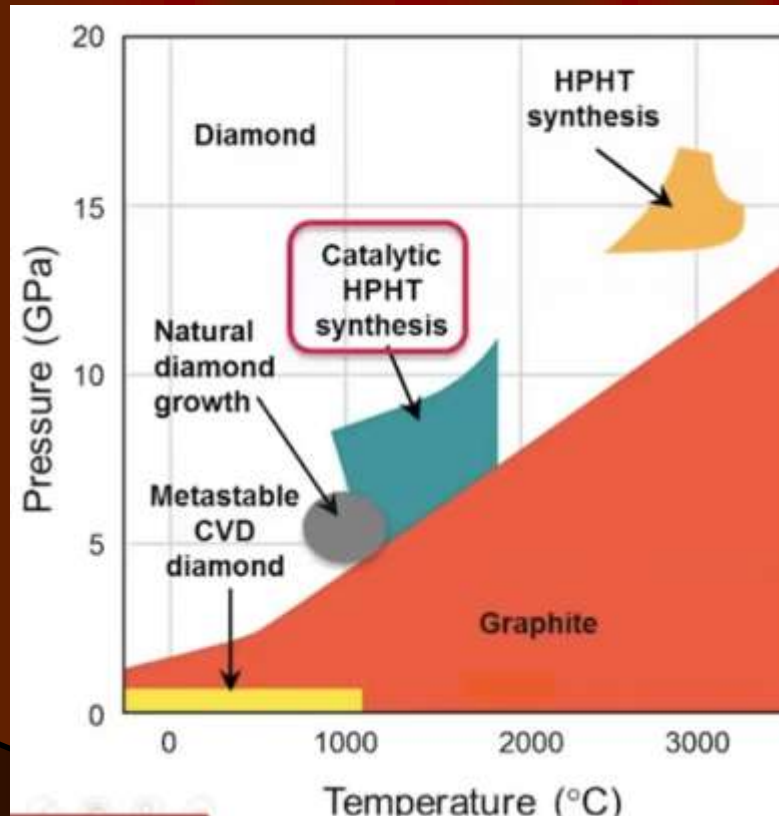
History of synthetic diamond manufacturing

It is estimated that 98% of industrial grade diamond is supplied with synthetic diamonds
For detail history of development please refer to the appendix



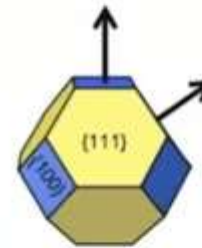
HPHT 高壓高溫法

Have 99% share of lab-grown diamond market. There are 4 manufacturing processes all basis on mimicking nature with high pressure & high temperature. They include the Belt Press, the Cubic Press, the BARS Press and the Toroid Press. Each process starts with a small diamond seed 晶種 which is placed in carbon source and put under very high pressure of 5-6 GPa and temperature of 1300-1600 C to “grow” the diamond within days - weeks



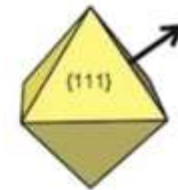
Differences in Growth Shape

Lab Grown HPHT
Cuboctahedron



14 directions

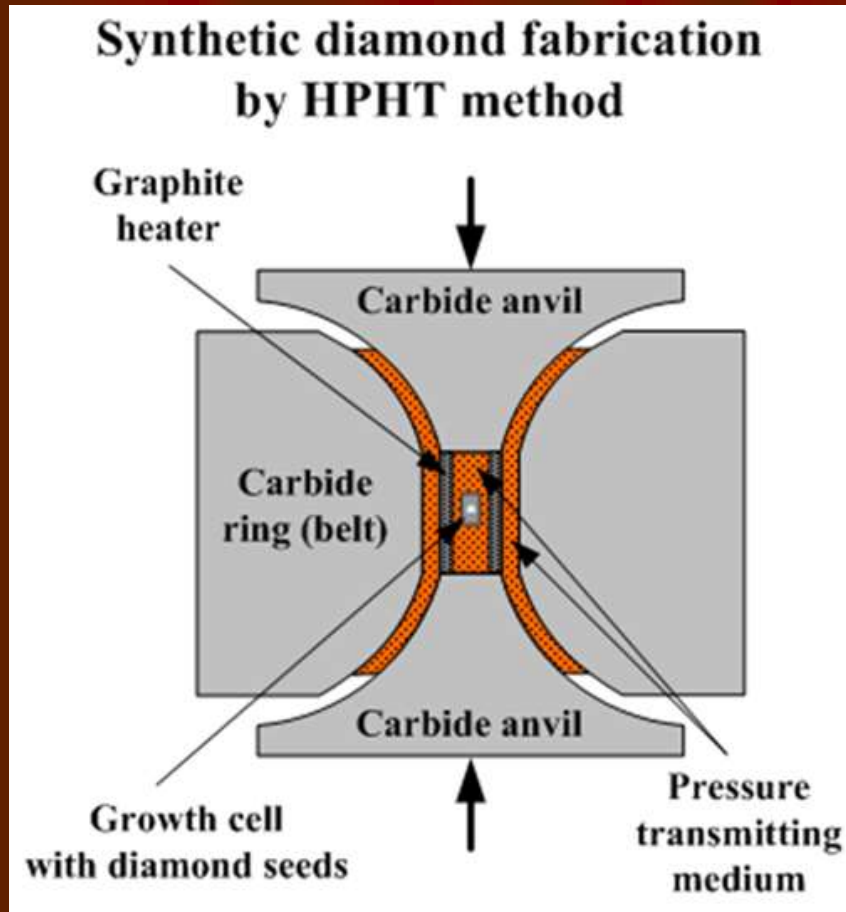
Natural
Octahedron



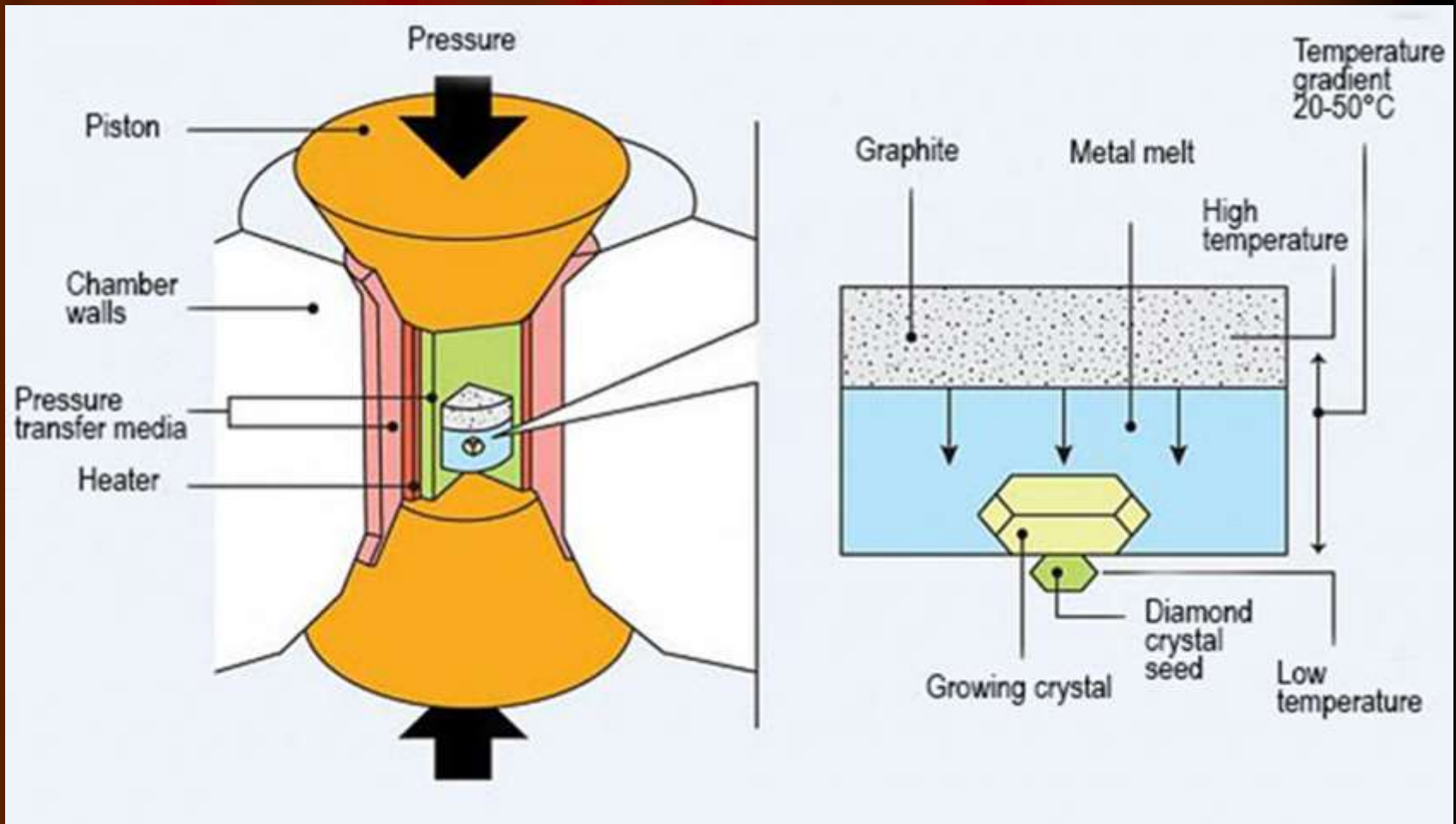
8 directions

1. The Belt Press

It was developed by GE with the first product made in Dec 16, 1954



- This design has 2 anvils that press together from opposite direction around cylindrical inner cell. It can grow many diamonds in one cycle and is mainly used for making industrial diamond



1 Capsule preparation

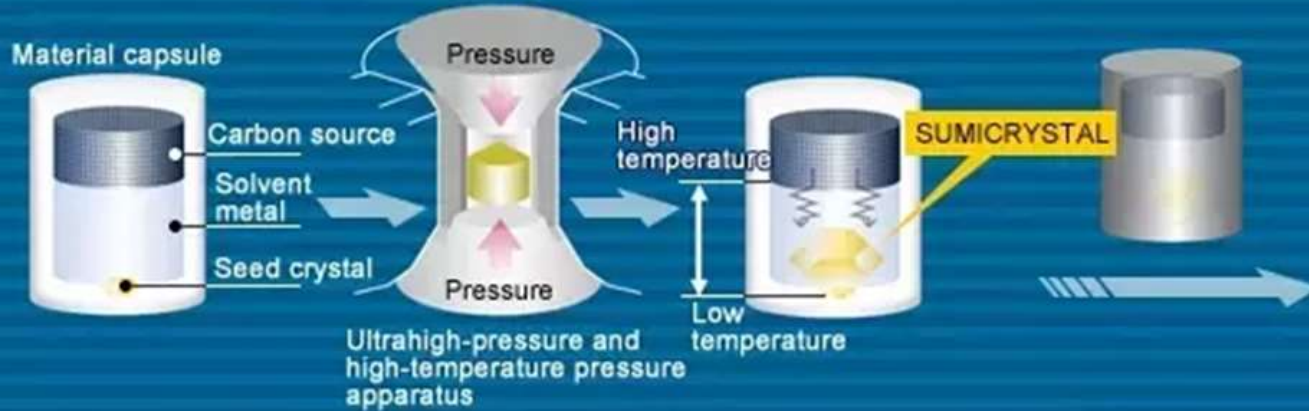
A material capsule is prepared that contains seed crystal, solvent metal and carbon source.

2 Compressed under ultrahigh-pressure and high-temperature

The capsule is placed in an ultrahigh-pressure apparatus, which reproduces an environment equivalent to that in which natural diamonds are produced (extremely high-pressure and high-temperature conditions present within the interior of the Earth). A temperature gradient, created inside the heater, is used to melt the carbon source into a molten solvent metal. This enables the diamond to grow on a seed crystal.

3 Removal of capsule

After the synthesis conditions shown at left have been maintained over an extended period of time, the capsule is removed.

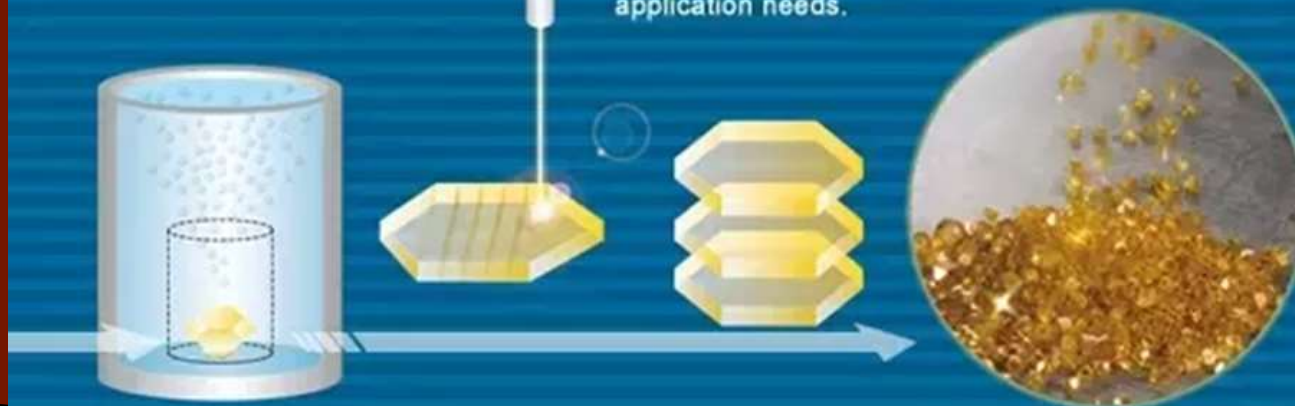


4 Acid treatment

5 Laser cutting

Crystals are cut with a laser to meet specific application needs.

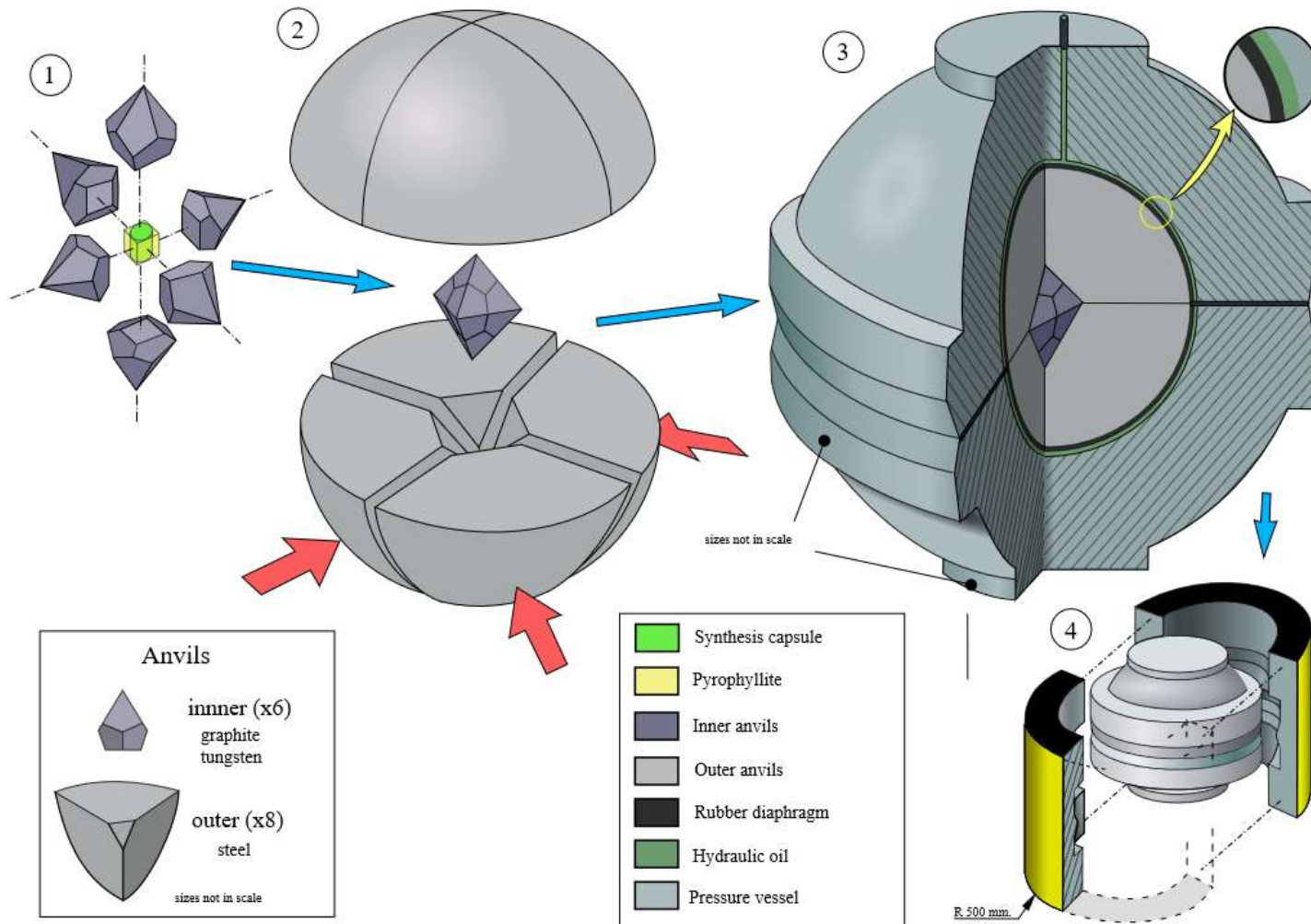
6 Finished!





2. The BARS (Split Sphere) Press

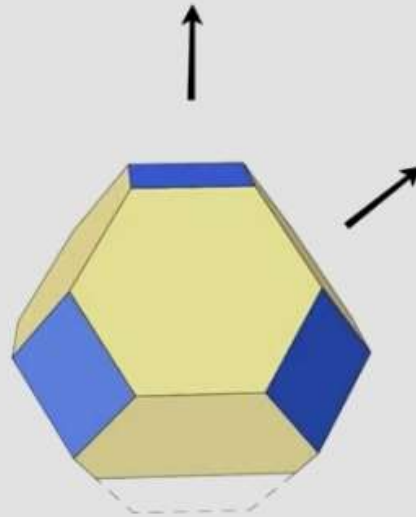
It uses 6 inner anvils and 8 spherical outer anvils to apply hydraulic pressure to the growth cell. One cycle of a BARS produces only one diamond crystal





HPHT Synthetic Diamond growth

Growth at high pressures and temperatures



Growth along cube
(blue) and octahedral
(yellow) directions



- The BARS Press was developed by Russian scientists and is to date considered the most effective process for growing comparatively large gem-quality diamond

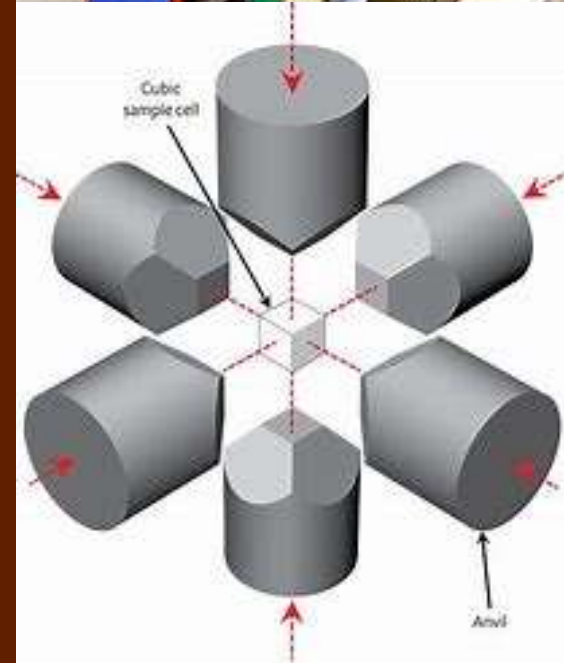
BARS presses for growing diamonds



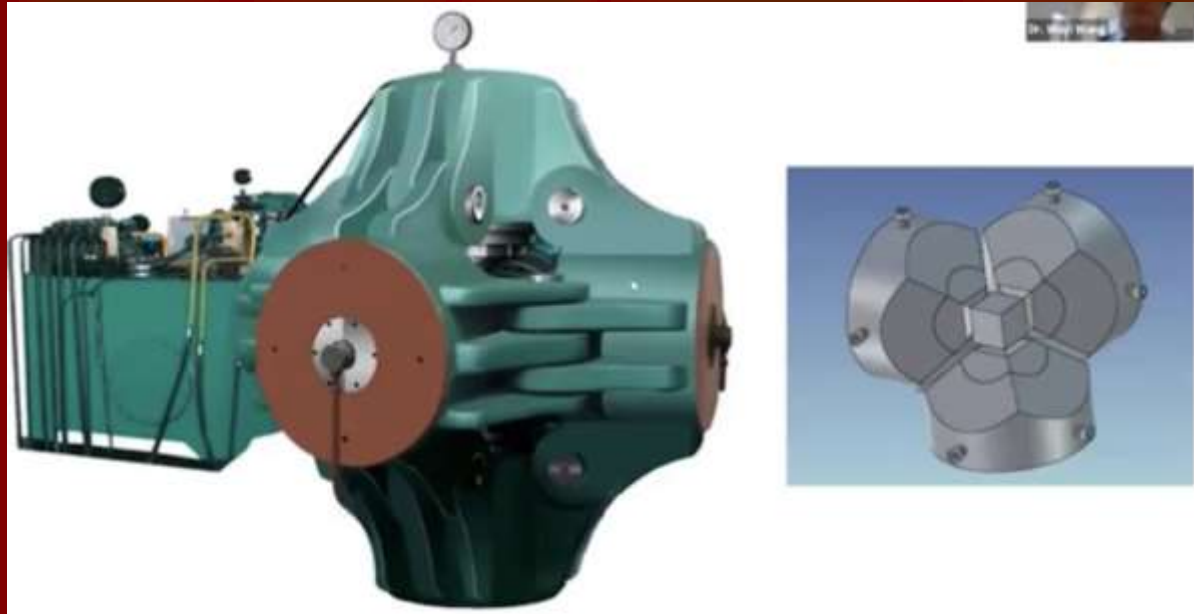


3. The Cubic Press

It uses 6 different anvils pressing onto a cube. This is the most commonly used HPHT machine mainly for producing melee



- The cubic press was actually designed in China in 1965



Features of cubic-press

- Six independent anvils
- Very durable, long life-time, easy maintenance
- Pressure generated in cubic form, dynamically symmetrical
- Highly reliable and controllable
- Quick increase and decrease of pressure
- Easy operation
- Low cost

4. The Toroid Press

A Russia made HPHT machine

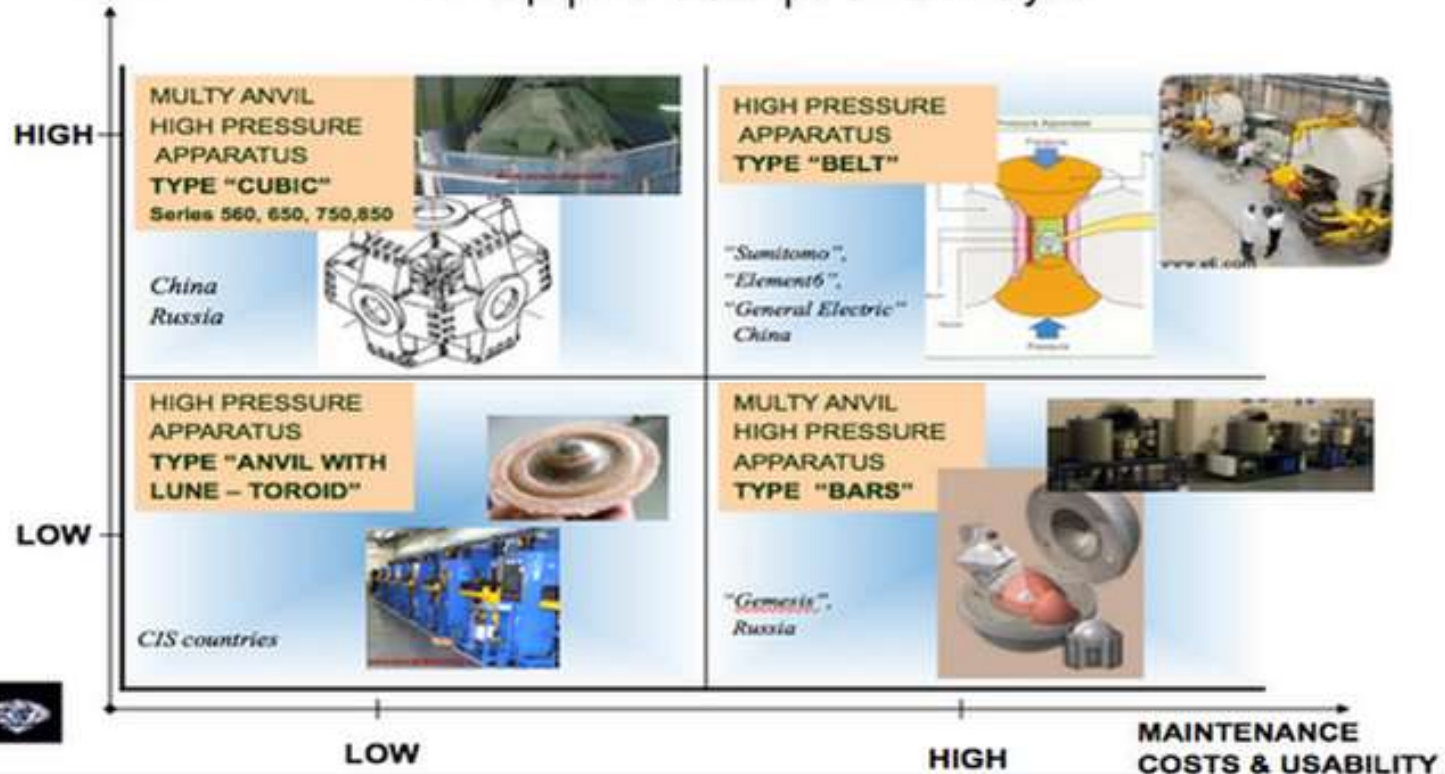


HPHT equipment Comparative Analysis

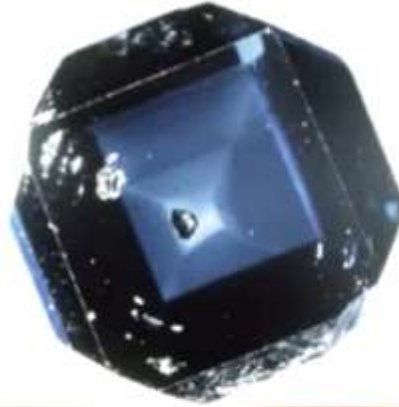
NEW
DINAMIC
TECHNOLOGY

**INVESTMENT
COSTS**

Production High Pressure Techniques HP Equipment Comparative Analysis



HPHT produced crystals



HPHT Products

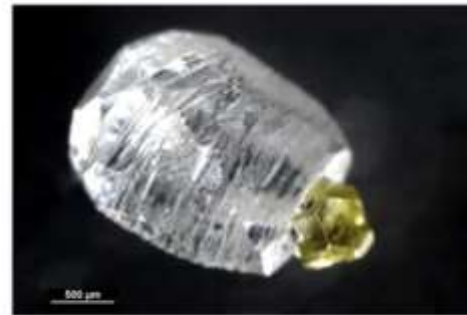
Multiple industrial usage – automotive, photographic, electronic, drilling



Gem stone - HPHT Synthetic Diamond MELEE (伴石) <0.2 carat



Colorless type IIa crystals grown on yellow type Ib seeds



HPHT facilities in China produce tens of thousands of carats of gem-quality melee diamond crystals each month



From melee to large gem quality Diamonds



10.02 ct, "E"
color, VS1



5.06 ct, "D"
color, VS2



5.05 ct, "D"
color, VS2



5.03 ct,
FDP B



5.26 ct, FDP B,
VVS2



5.27 ct, FDP
B, VS1



◆ 4.09 ct
◆ Fancy Vivid Yellow – Orange
◆ VS₁

2005



◆ 10.07 ct
◆ Fancy Intense Yellow
◆ SI₁

2018



◆ 20.23 ct
◆ Fancy Vivid Yellowish Orange
◆ VS₂

2019

From large to largest

103.50 CT



Largest Lab Grown HPHT diamond

- Grown by NDT (New Diamond Technology) in Saint Petersburg, Russia
- Grown in 14 days in December 2018



109.81 ct



115.81 ct

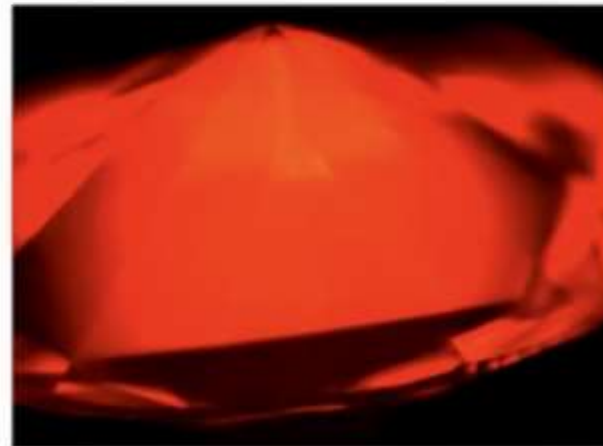
A3.02 ct Vivid Pink HPHT lab-grown gem quality Diamond



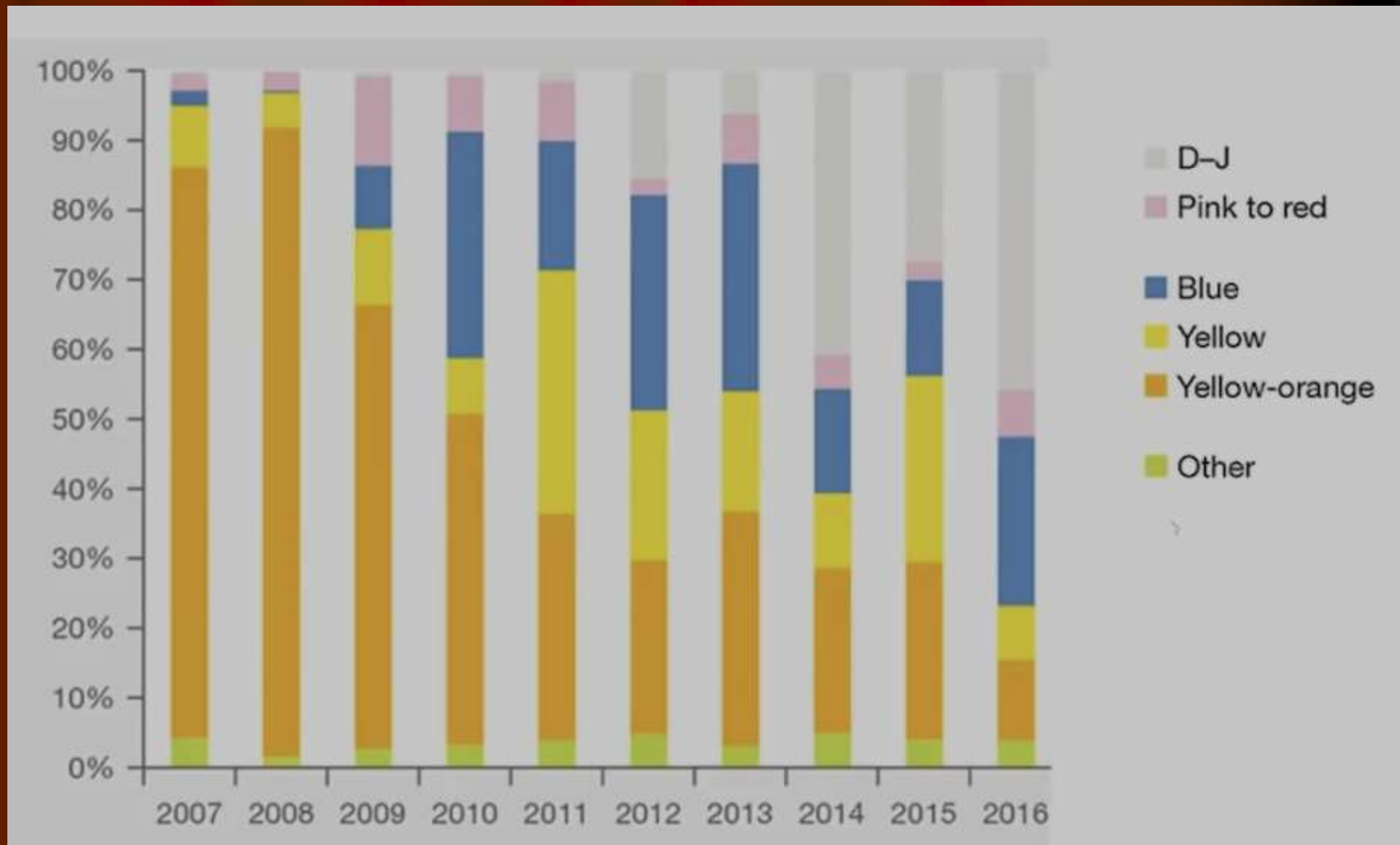
Vivid Pink
3.02 ct
HPHT lab-grown

Summer 2020 Lab Notes: "HPHT Laboratory-Grown
Pink Diamond with Unstable Color"
(Kaitlyn Mack and Paul Johnson)

Dr. Kelly Magala



Colour Distribution of HPHT Grown Diamonds – towards gemstones



Ultrahard polycrystalline diamond (PCD) from graphite

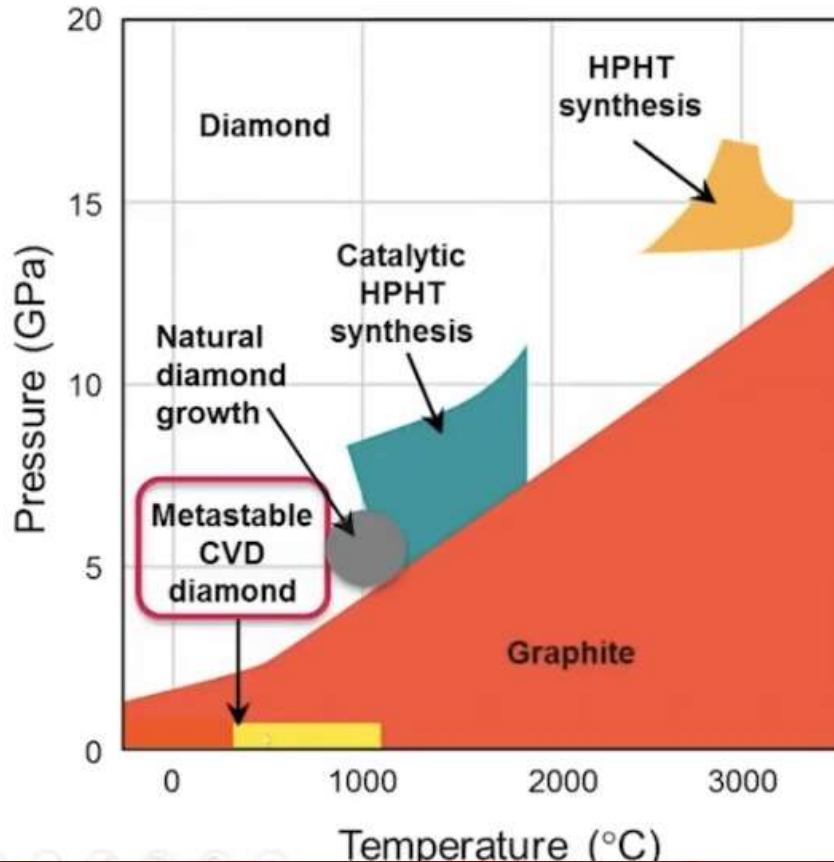
It is harder than single crystal diamond and very valuable for cutting and polishing other material and used in making scientific and industrial tools.

	Conventional Artificial Diamond	Super Diamond
Pressure	55,000 Atmospheres	250,000 Atmospheres
Temperature	1300°C ~ 1400°C	2500°C ~ 2700°C

 MONOCRYSTALLINE	 POLYCRYSTALLINE
---	--

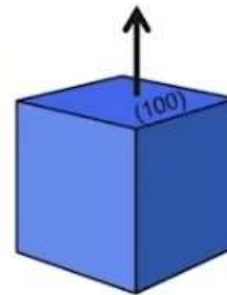
CVD 化學氣相沉積法

Chemical Vapor Deposition Diamond (CVD) production environment



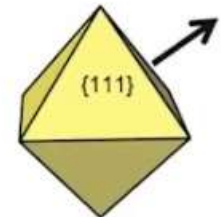
Differences in Growth Shape

Lab Grown CVD
Cube



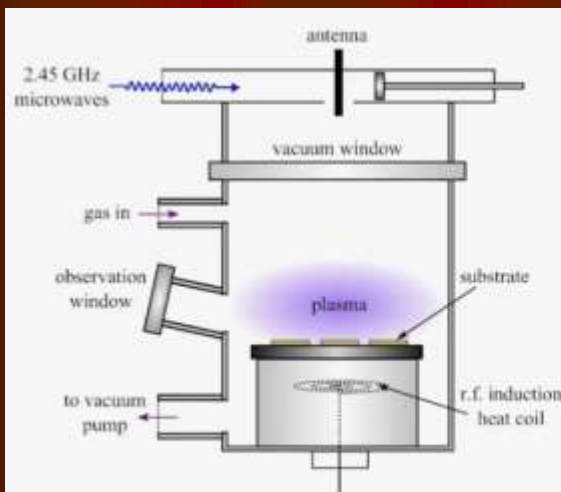
1 direction

Natural
Octahedron



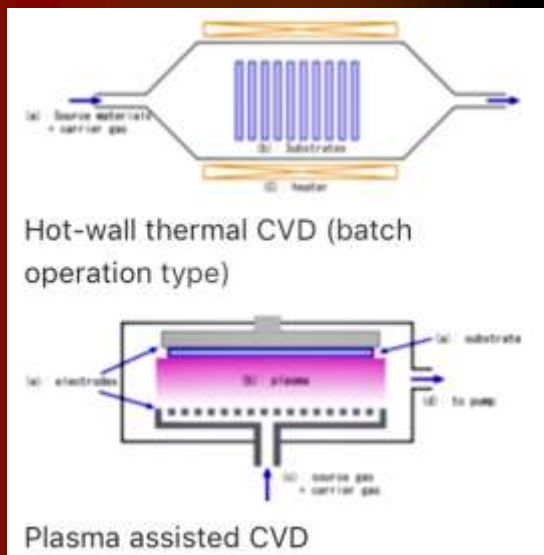
8 directions

Have 1% share of the lab-grown diamond market but mainly used for producing gem quality diamond and high tech use (sensor, laser, semiconductor, medical tools). It is done by heating a mixture of hydrocarbon gas (mainly hydrogen H_2 and methane CH_4) in a vacuum chamber at 700-1000 C but high pressure is not required. The gas breaks apart and releases the carbon atoms which rains down onto a diamond substrate 基体 (silicon carbide, tungsten, molybdenum) and grow in layers as a crystal. Current cost to produce 1 carat has reduced from US\$4,000 in 2008 to US\$300/500 in 2019 resulting in a 50% drop in retail price



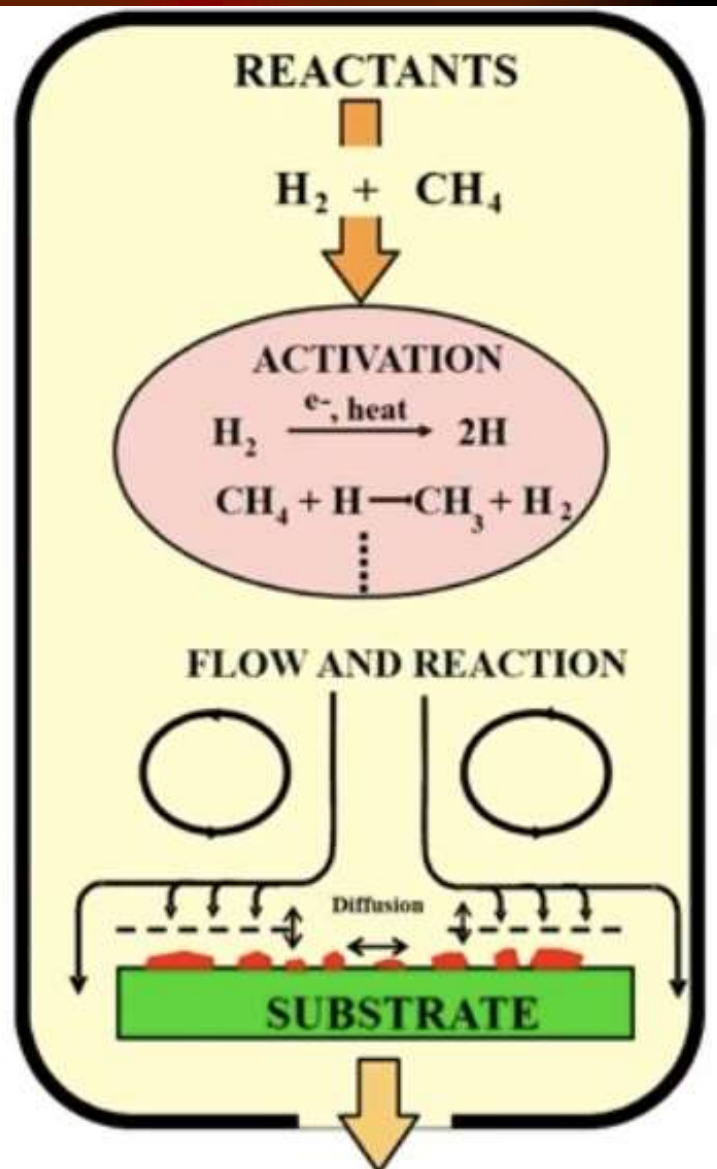
Chemical Vapor Deposition (CVD)

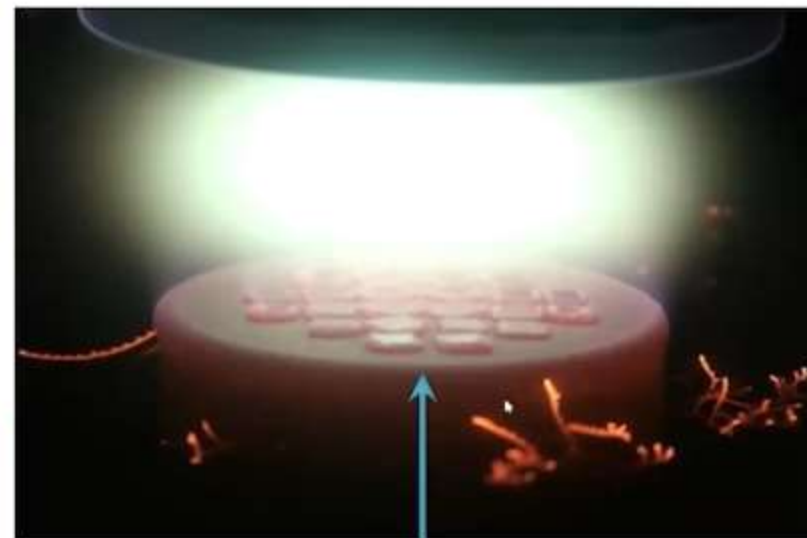
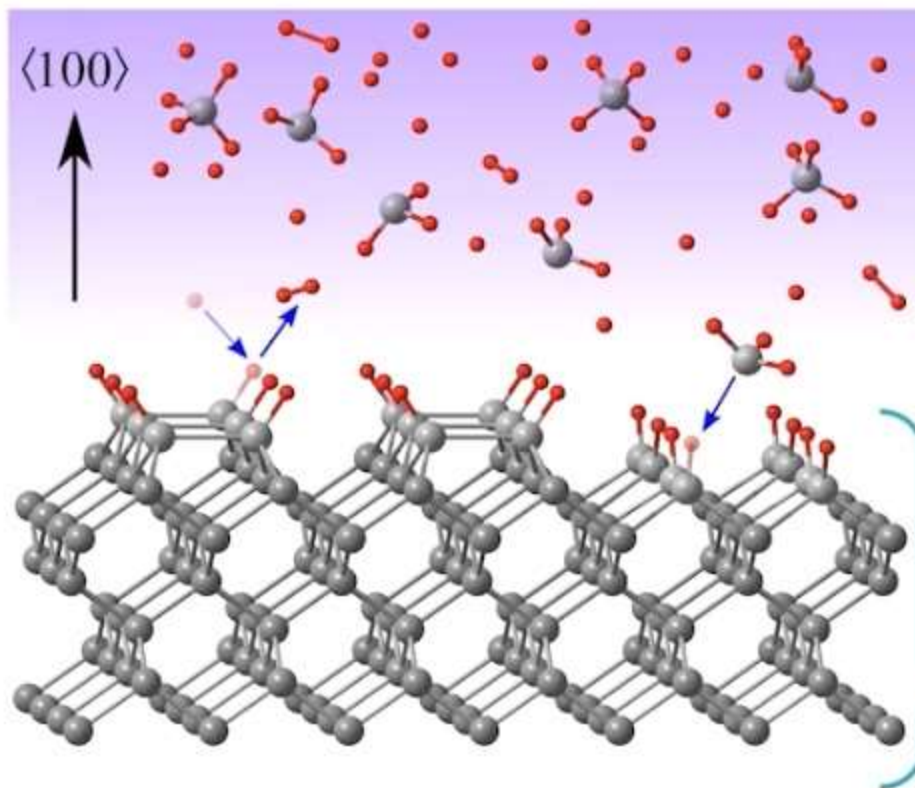
- ◆ Gas-phase chemical reaction
 - ◆ Hydrocarbon gas (methane) in hydrogen gas above diamond substrate
 - ◆ Pressure ~10–200 torr (1/20–1/4 atm)
 - ◆ Temperature ~700–1000 °C
 - ◆ Duration ~days–week





From Seki Instrument, Japan

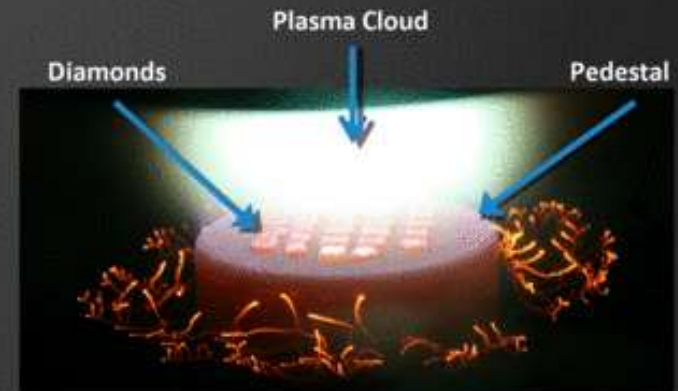




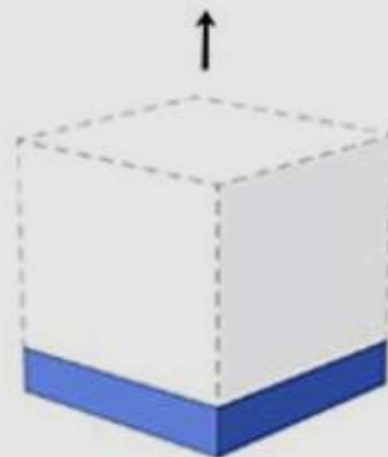
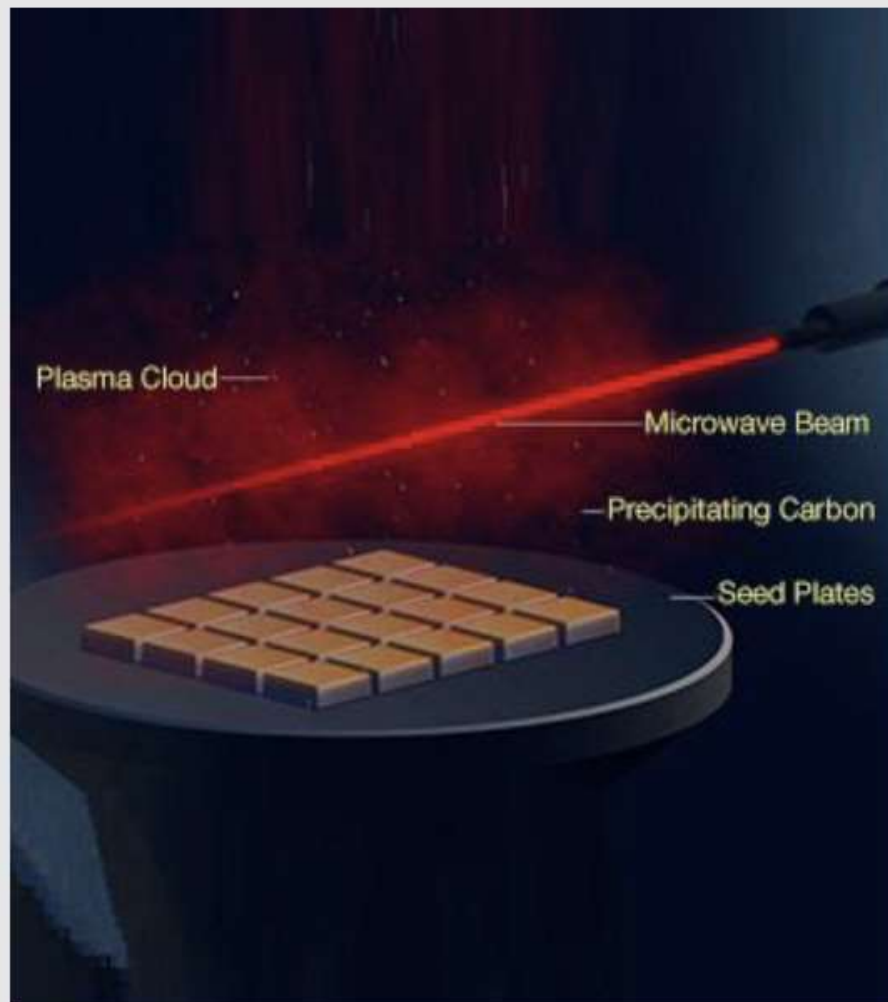
Substrate
+
CVD Lab-grown Diamond

CVD Diamond Growing Process

- Step 1 - Place diamond seeds on pedestal - depressurize chamber
- Step 2 - Inject starting gases into chamber - heat until electrons separate from nuclei, forming plasma
- Step 3 - Freed carbon precipitates out of plasma cloud and is deposited on wafer seeds
- Step 4 - Wafer seeds gradually become diamond crystals
- Step 5 - Remove diamond crystals. Slice and shape for use in commercial and gemstone applications



CVD Synthetic Diamond Growth. Next step remove edges and facet



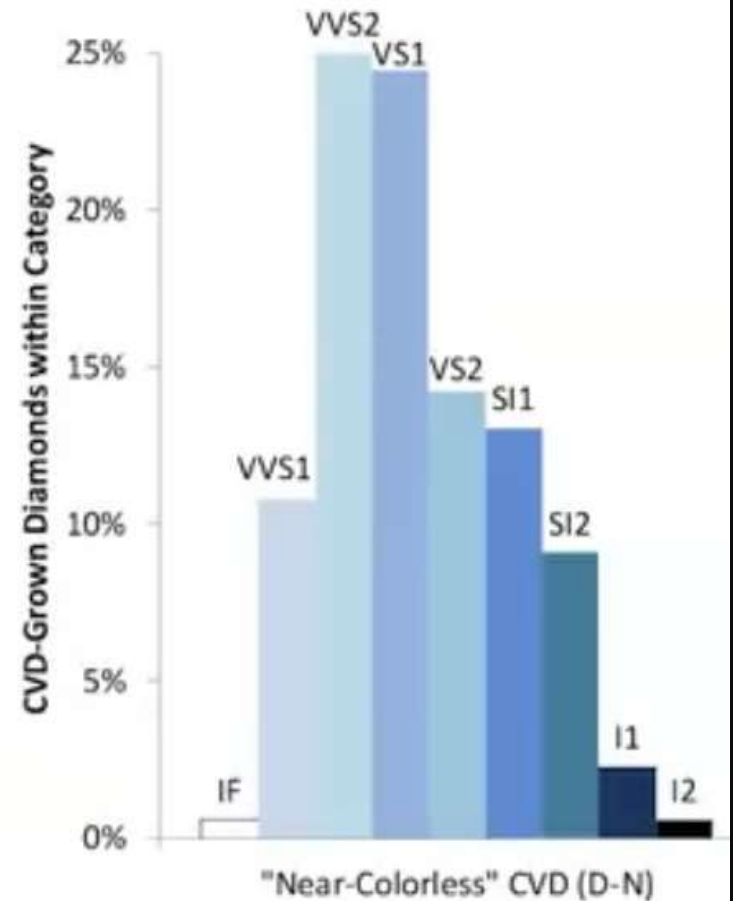
CVD crystals exhibit a flat tabular shape and a dark edge of graphite

GIA.edu

CVD diamonds have low inclusion and therefore possess high clarity

Often High Clarity

- ◆ Up to IF
- ◆ Non-diamond carbon inclusions
 - ◆ < 50 μm in size; pinpoints, clouds



CVD produced crystals

CVD Crystal Habits



Element Six



Apollo



Decoloring by HPHT Treatment on CVD Diamonds

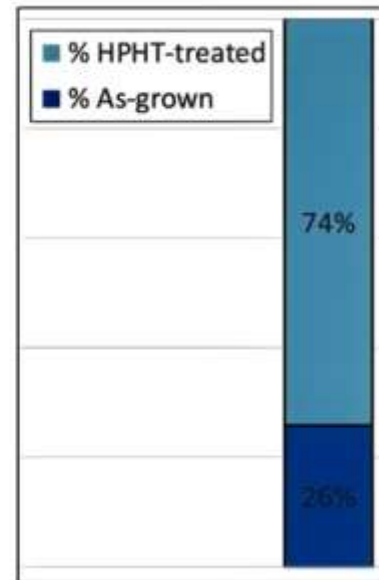
As-grown CVD diamond



HPHT-processed CVD diamond



2 distinct sets of properties for identification



As-grown CVD diamond



After HPHT Annealing

HPHT treatment can remove the brown color, and turn a brown CVD diamond to colorless or near colorless

Most CVD Diamonds are treated after growth

As-grown



Yellow: Ib



Brown: IIa



Brown-pink to pink: Very low Ib; Silicon doping



Grayish blue: IIa; Silicon doping

Treated



Colorless to near-colorless: IIa; HPHT processed



Gray: IIa; HPHT processed

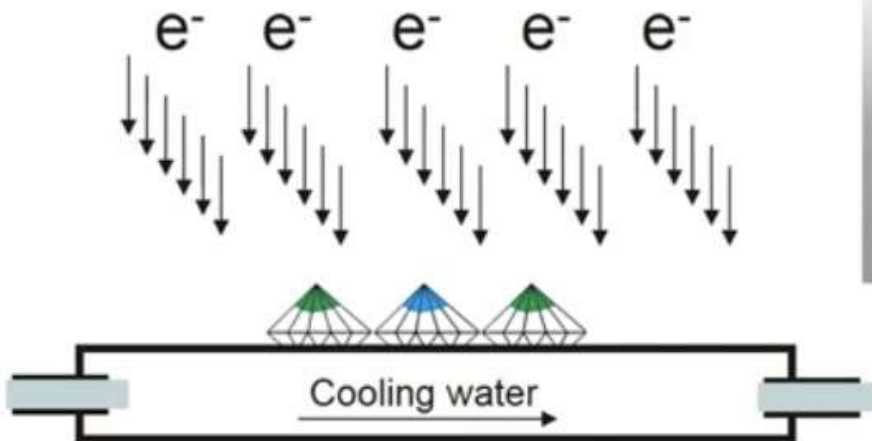


Blue to Green: IIa or Ib; Irradiated

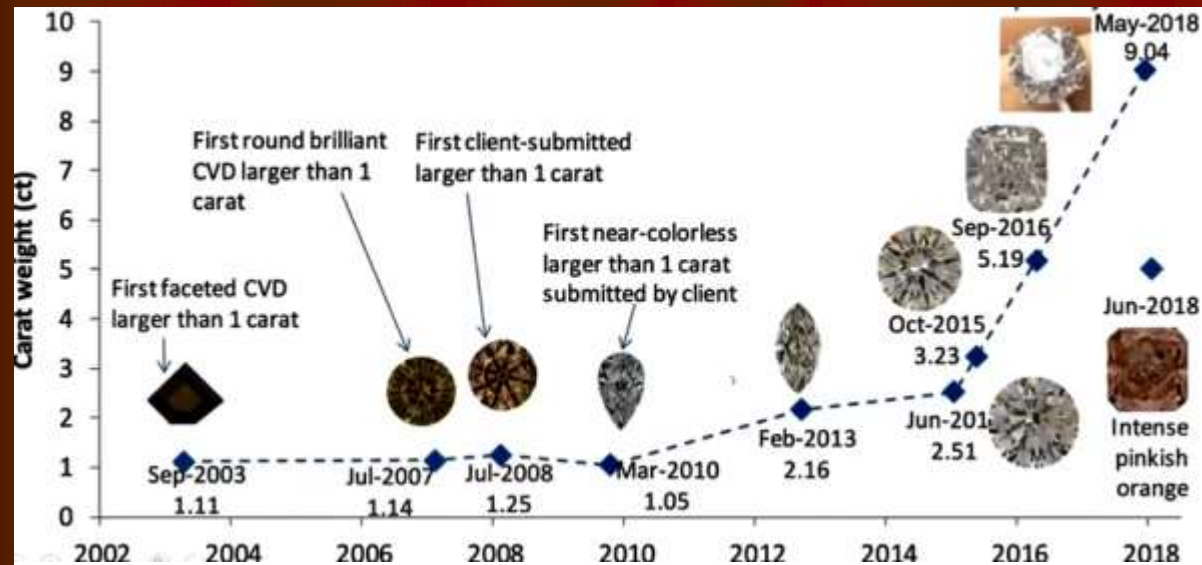


Pink: Very low Ib; Multiple treatments

CVD post-growth treatment by electricity



CVD method is more commonly used today for making gem quality diamond. The largest one ever made is at 155 carats by the University of Augsburg Gr



合成出了一块直径 92mm、155 克拉的钻石



5.19 ct, J, VS



5.01 ct, Fancy
Intense pinkish
Orange, SI



6.21 ct, D, VS



9.04 ct, I, VS

Visual Features Comparison

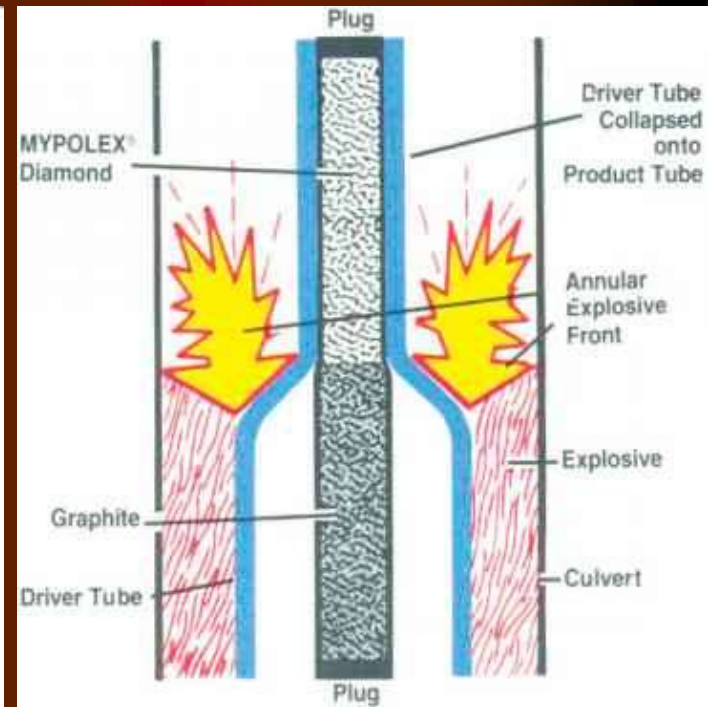
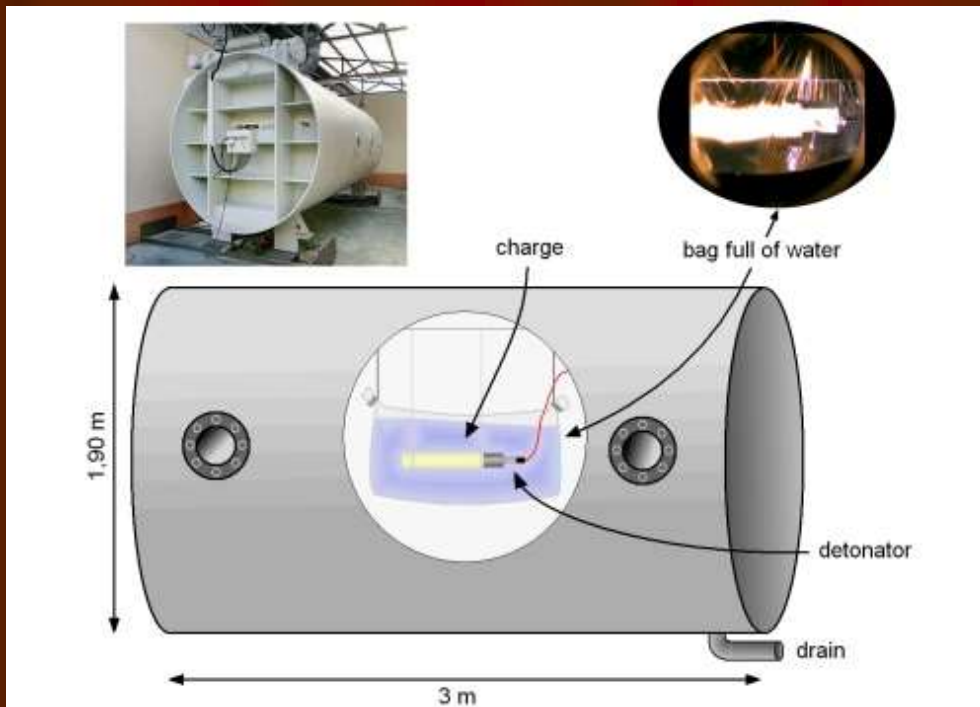
Comparison of Visual Features

HPHT Synthetic	CVD Synthetic
Uneven color distribution	Even color distribution
Graining patterns	No graining patterns
Unusual fluorescence colors	Unusual fluorescence colors
Fluorescence color patterns	Fluorescence color patterns
Occasional phosphorescence	Occasional phosphorescence
Metallic flux inclusions	Occasional dark pinpoint inclusions
No strain patterns	Banded strain patterns
Possible inscription on girdle	Possible inscription on girdle

Two other manufacturing methods

1. Detonation of explosives

Diamond nanocrystals (5nm in diameter) can be formed by detonating certain carbon containing explosives inside a metal chamber. The Detonation Nano Diamond (DND) powder so produced is used primarily in polishing applications. This product is also called Ultra dispersed diamond (UDD). This method was introduced in 1990

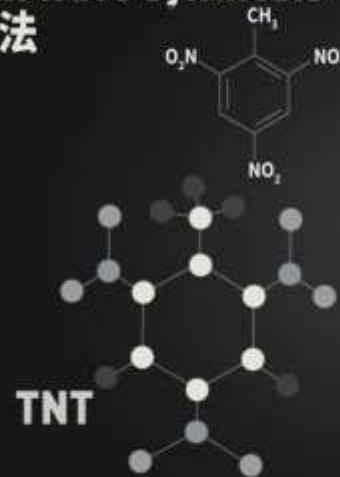


RDX ($\text{O}_2\text{N}_2\text{CH}_2$)₃ is a very powerful military explosive

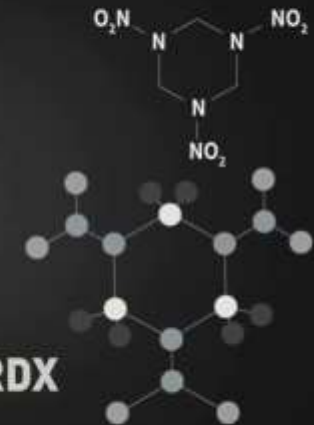


Shock wave synthesis

爆炸法



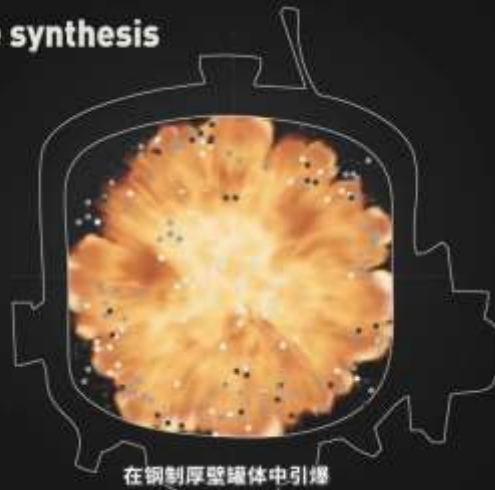
TNT



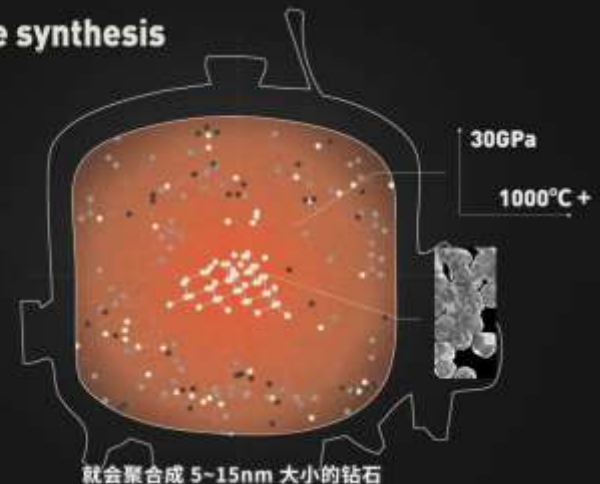
RDX

和轰爆压力非常高的 RDX 两种炸药混合

Shock wave synthesis
爆炸法

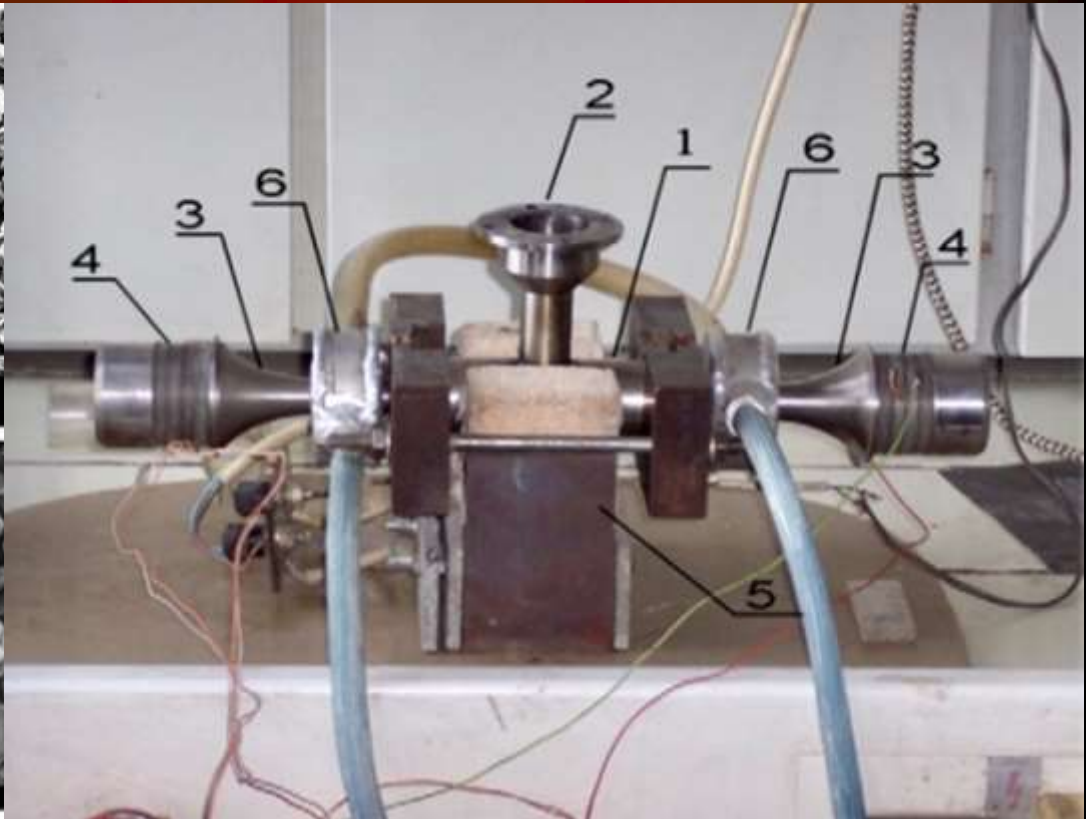
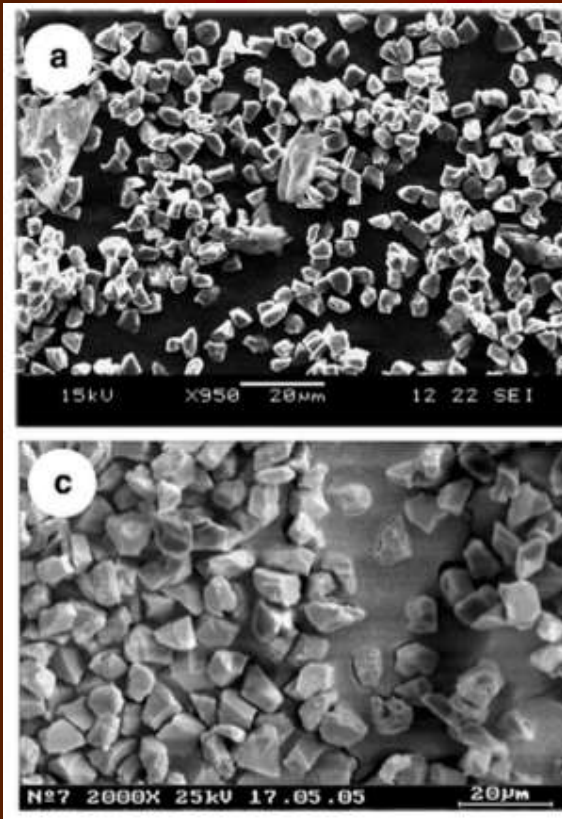


Shock wave synthesis
爆炸法



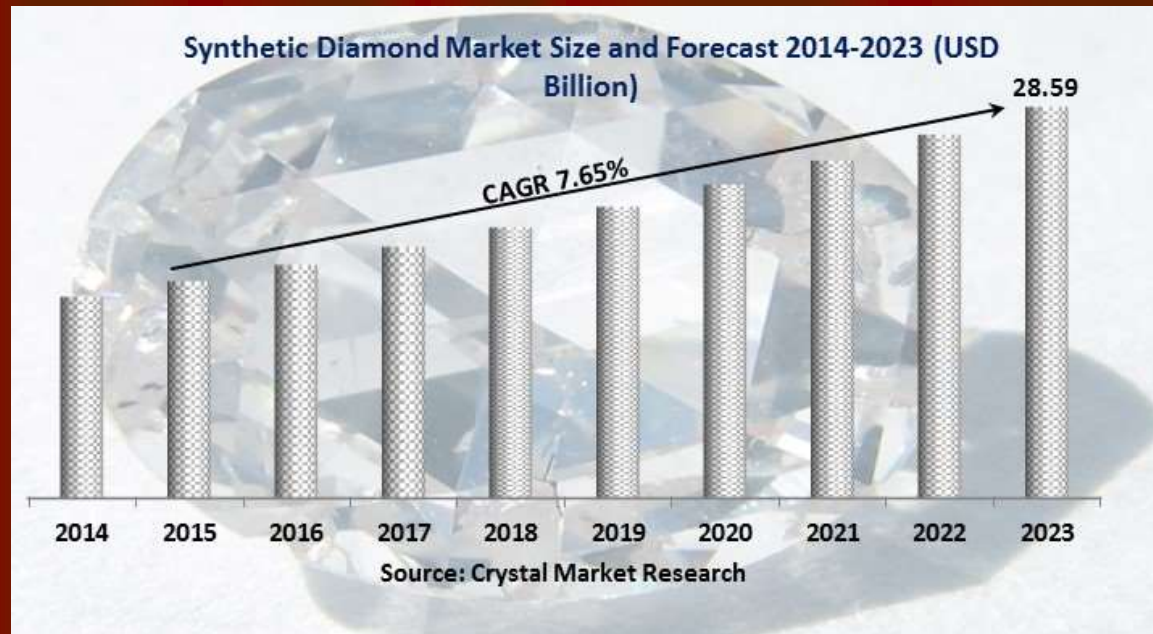
2. Ultrasound cavitation

Micron sized diamond crystals can be synthesized from a suspension of graphite in organic liquid at atmospheric pressure and temperature of 120 C using ultrasound cavitation. No industrial use as yet



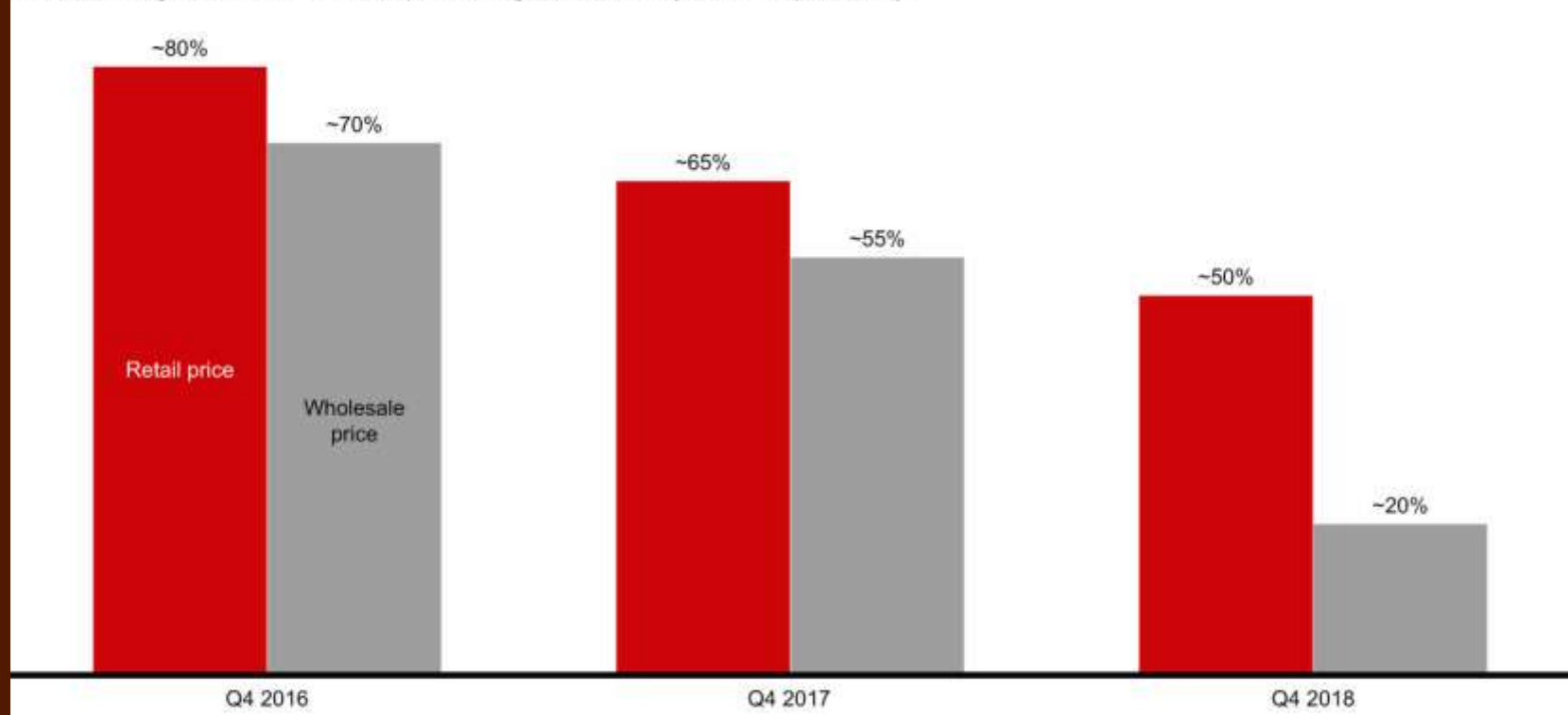
Growing global synthetic diamond market size 2014-2023

Limitation is more on investment in capacity



Price of lab-grown diamond as a percentage of natural diamond

Price of lab-grown diamond as a percentage of natural (1ct G VS polished)



Note: Values calculated with the average discount and price for the given period
Sources: Thomson Reuters; expert interviews; online retailers' websites; Bain & Company

The price of man-made diamonds is expected to fall further as there is no physical limit to their production. As such they may have little to zero resale value while natural diamonds usually have 100% trade-in-value

Synthetic Diamond Market Revenue

By Region, 2017 (US\$ Mn)

CAGR 7.0% (2017-2025)

**North
America**

3,525.7
(US\$ Mn)

Europe

XX.X

**Asia
Pacific**

XX.X

**Latin
America**

XX.X

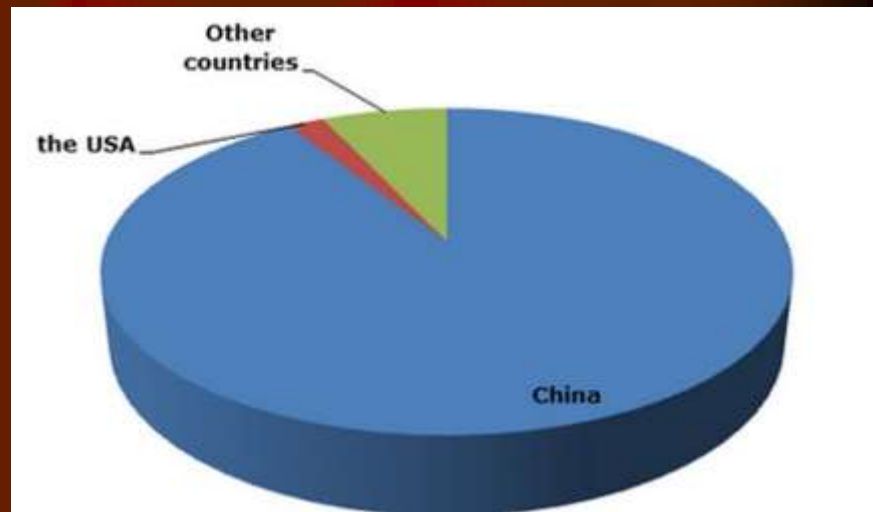
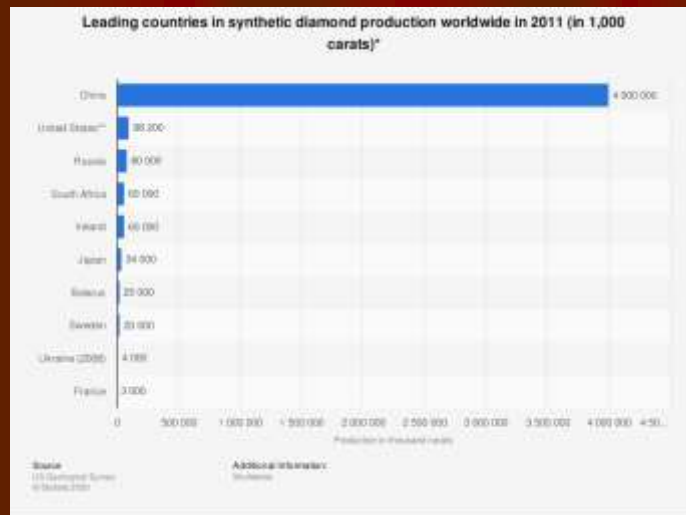
**Middle East
and Africa**

XX.X

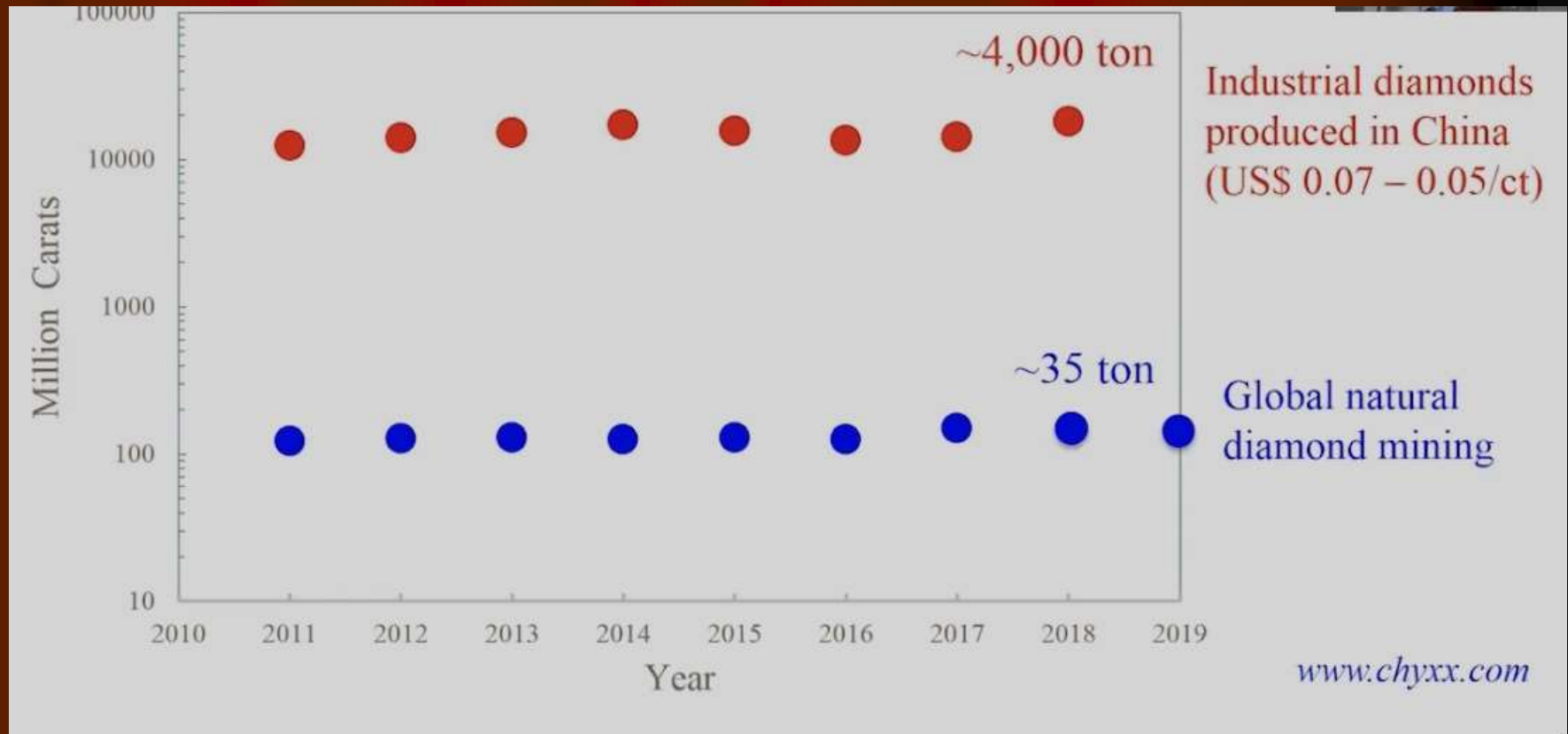
Source: Transparency Market Research Analysis, 2017

Key manufacturers of synthetic diamond

- Nowadays synthetic diamonds are produced in significant quantities in China (e.g. Zhongnan Diamond & Henan Huanghe Whirlwind), USA (e.g. Diamond Foundry, DeBeers), Russia, India, S. Africa, Ireland and Japan. Started only in 1960, China is now taking the lead by producing 15.4 billion carats in 2019 which is 90% of world market and to reach 17.4 billion carats by 2026 mainly for industrial use. USA are more focusing on gem quality diamond



China's industrial diamonds production 2010-2019



- China initially focused in industrial use melee diamond but now also in gem diamond. The first diamond was produced in Henan Zheng Zhou 鄭州 in 1963 and it is now the HPHT diamond capital

Major Diamond Producers in China: (total ~600 factories)

- Zhongnan (<http://cn.diamond-zn.com/>)
- Huanghe Whirl Wind (<http://www.huanghewhirlwind.com/>)
- Sino-Crystal (<http://www.sinocrystal.com.cn/cn/>)



HUANGHE WHIRLWIND



Quote prices of HPHT synthetic gem diamonds from China

Size (ct/piece)	Color	Clarity	Price (US\$/ct)
0.02	DEF	VS+	160
0.05	DEF	VS+	180
0.10	DEF	VS+	280
0.20	DEF	VS+	380
0.30	DEF	VS+	420
0.40	DEF	VS+	560
0.50	DEF	VS+	630

Factories in China producing HPHT diamonds







CVD in China

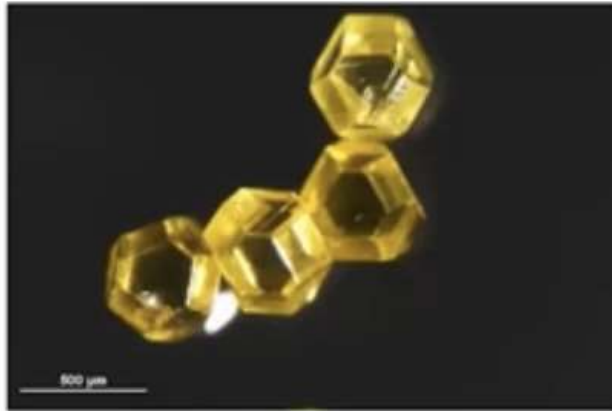


Main Producer

- Shanghai ZHENGSHE
- Ningbo CRYSDIAM
- Xi'an C-STAR



● Growth of Melee diamond production



- 1965: 10,000 carats
- 1970: 0.5 million carats
- 1980: 4.5 million carats
- 1985: 5.5 million carats



- China started growing large single crystal diamond in the 1980s but only successful in the 1990s. Now producing gem class diamonds both by HPHT & CDV with melee white diamond exceeding 200,000 ct per month



0.9 – 1.2 ct each



0.5 – 0.7 ct each

Diamonds produced in
China (2018)



5.12 ct, G, VS₂



5.03 ct, F, VVS₂

Gem Diamonds produced in China (2018)

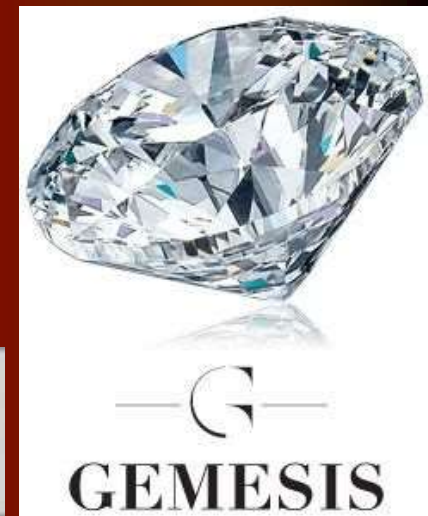
Factory	Total No. of Press	Piston Diameter (mm)	No. of press for gem diamond	Products in Market	Products Under Developing	Crystal quality
Zhongnan	3600	Ø600	1300	3 - 5 ct	>10 ct	*****
Huanghe	2500	Ø500	200	2 - 3 ct	3 - 5 ct	***
Sino Crystal	800	Ø700	400	0.8 - 1.5 ct	2 - 3 ct	**



Western Players

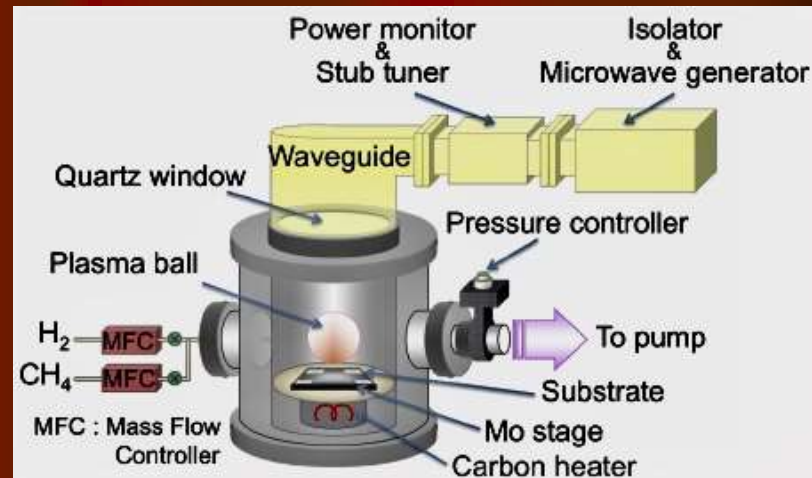


DIAMOND
FOUNDRY

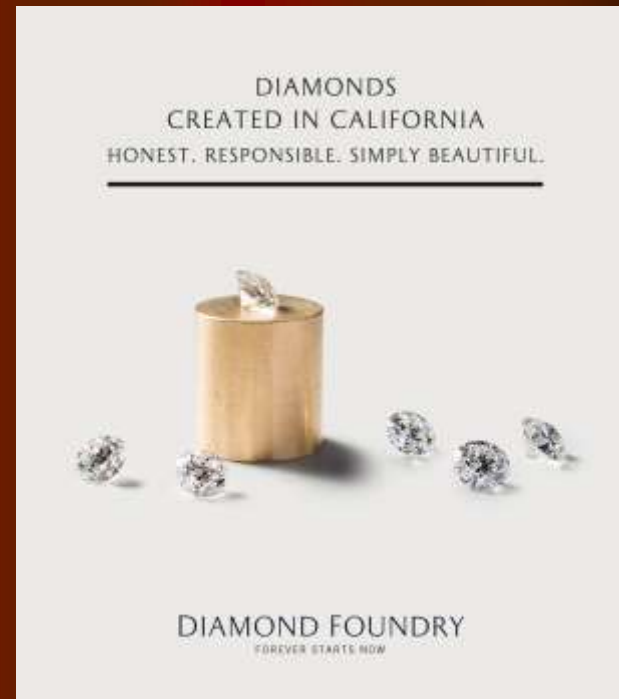
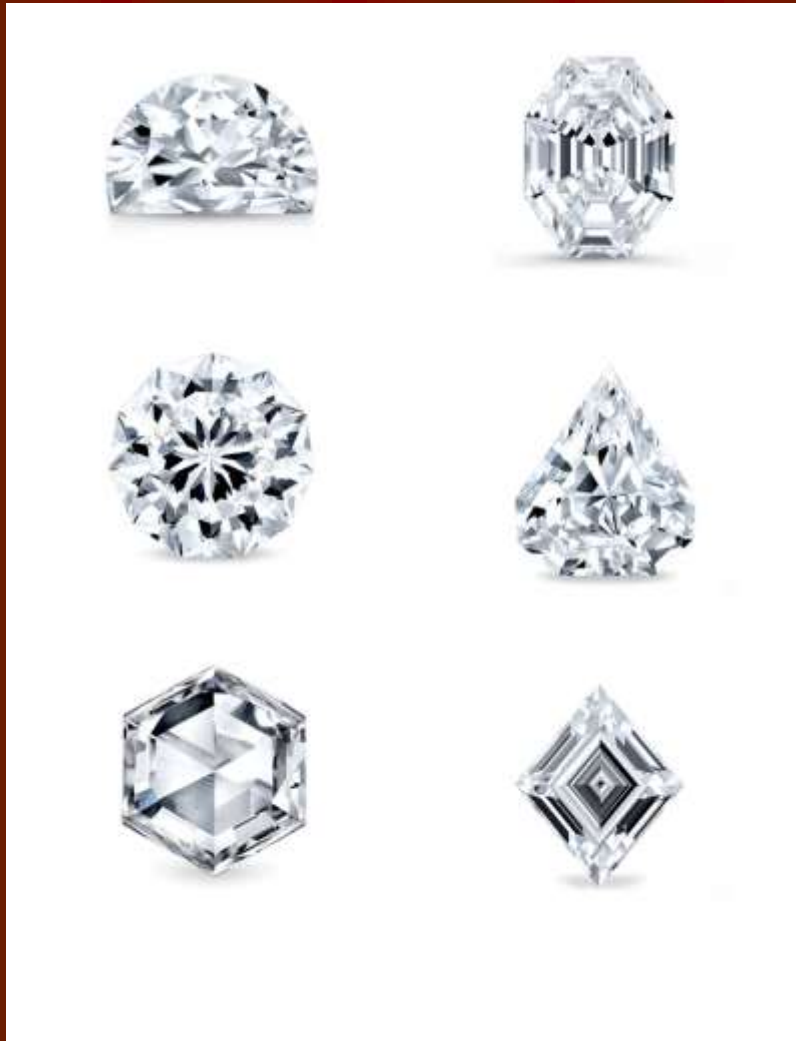
The text "DIAMOND FOUNDRY" is displayed in a dark blue, serif font, centered on a light pink rectangular background.

Diamond Foundry

Founded in San Francisco in 2012 it is America's leading diamond manufacturer using the CVD method. Since 2018 the company is producing 1 million carats of artificial diamond every year using a new hydro-powered plasma reactor. This is enough for 0.5 million engagement ring and cost between a few hundred dollars !

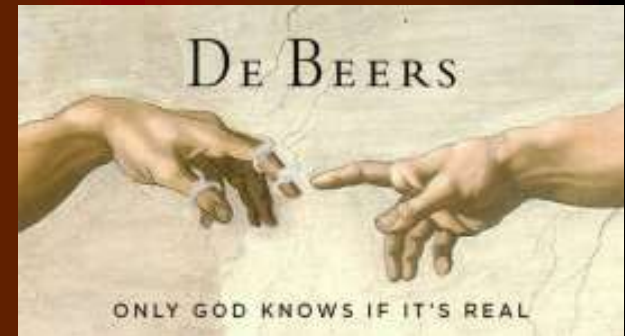


- Some of the 29 new diamond cuts on Diamond Foundry



De Beers

De Beers announced in September 2018 they have a new line of jewelry selling synthetic diamond or MMDs (Man made diamond) called "Lightbox" around US\$200 for quarter carat, \$400 for half carat and \$800 per carat set. There is no grading on the stones which are white, yellow, blue or pink. It is for "moments" not "milestones" (wedding). They are producing synthetic diamonds at Ascot and in a new 60,000 ft US\$94 m dollar CVD factory in Portland Oregon which can produce 500,000 carats per year

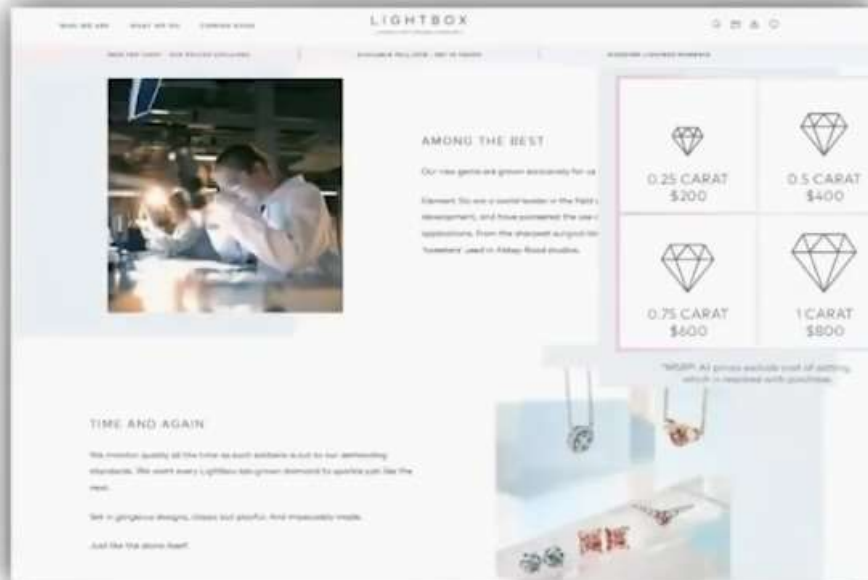


“LIGHTBOX”

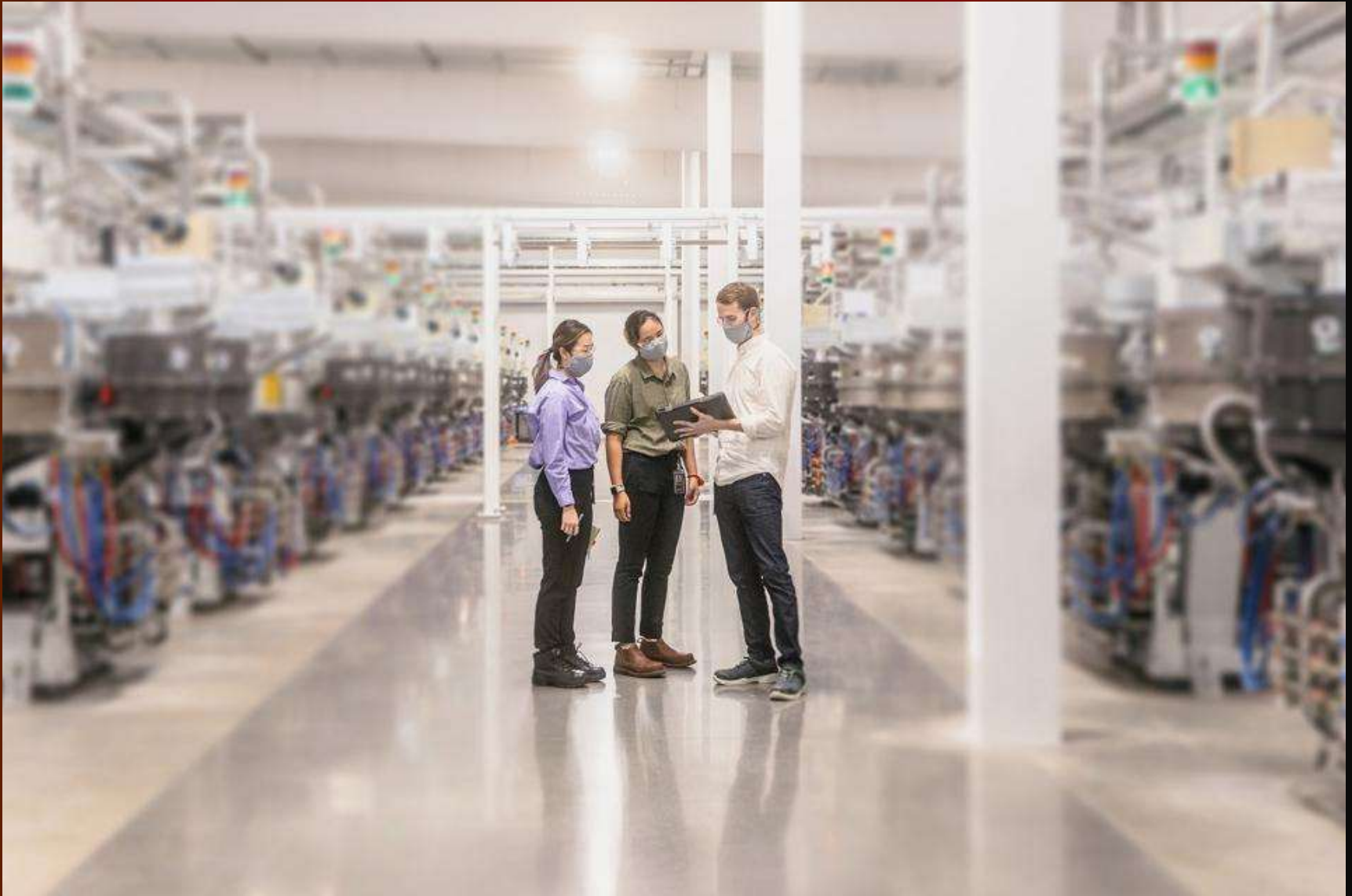
CVD gem diamonds from Element Six, owned by De Beers
2 samples were examined at GIA at launch;
near colorless (~ G), EX/VG Cut, VS clarity

Lightbox logo

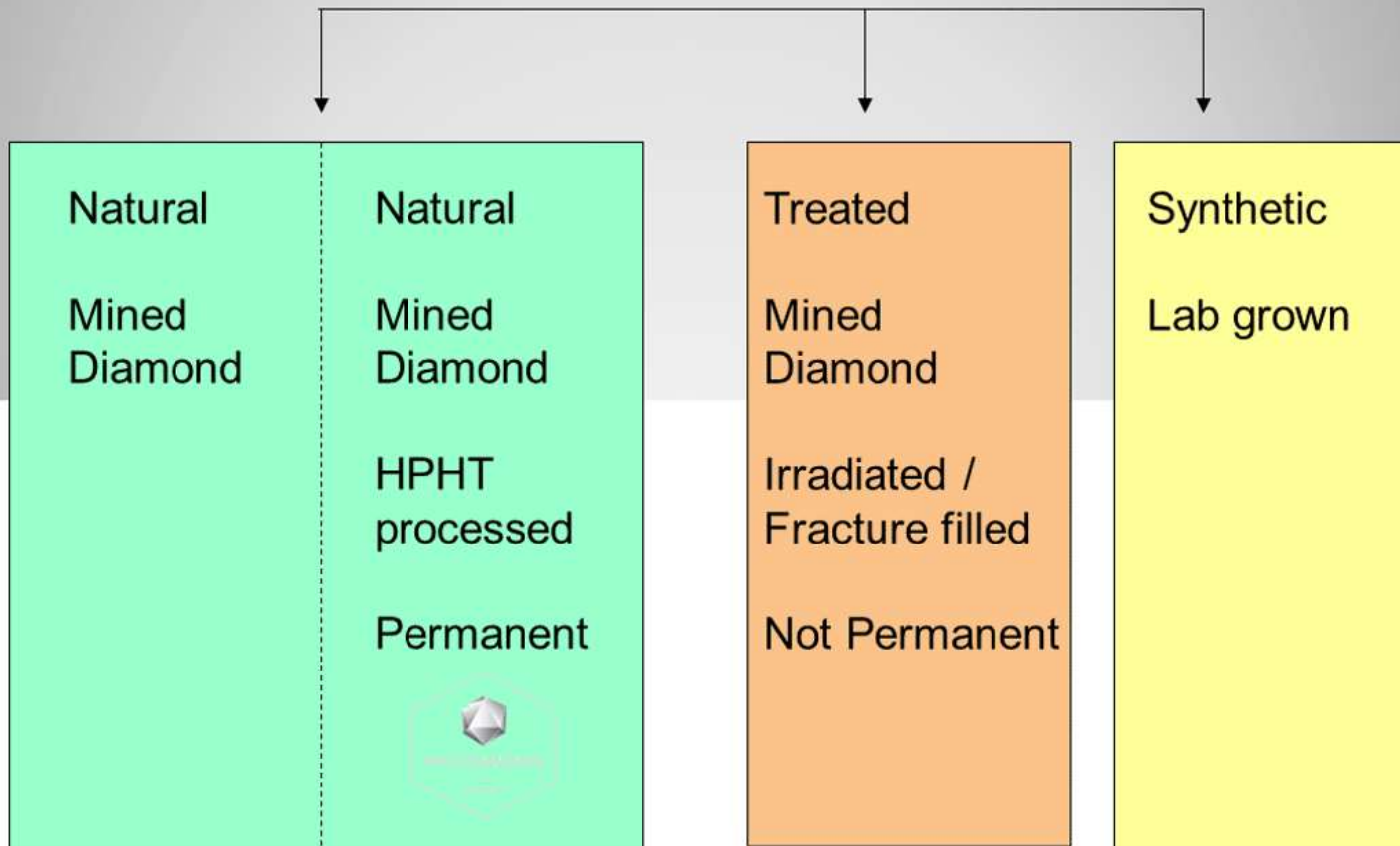
(positioned center of table; ~200 microns beneath surface)



- Workers on the manufacturing floor



Diamond



- HPHT Processed allows manufacturers to select flawed or discoloured diamonds and alter into more desirable colourless, pink, blue or yellow diamonds

Before & After: HPHT Process of GIA Certified Diamonds

HPHT PROCESS



Can Hadar Diamonds finish what Mother Nature started? YES. Nature creates varieties of off-color diamonds. They can be processed (not treated) by HPHT. By applying the right amount of heat and pressure, these ultra high clarity diamonds will reach a new permanent, colorless state.

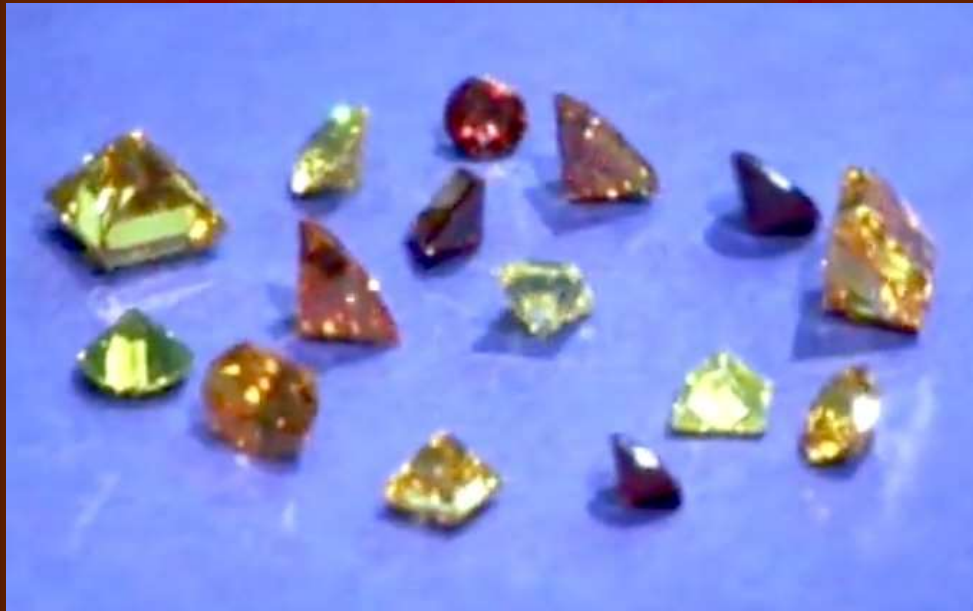
Memorial Diamond 懷念鑽

- Also known as burial diamond, cremation diamond, memorial gem, they are synthetic diamonds created from the carbon extracted from cremated ashes, hair or a combination of both. They possess similar optical, chemical and physical properties as natural diamonds but contains only 1 to 5% of the memorial carbon



**Your Cremated Remains...
turned into a diamond.**





Diamond look alike stones
or “Simulants”

仿鑽

Diamond Simulants or “Diamante”

1. Lead glass/crystal (18-40% lead oxide) used since 1500 水鑽
2. Synthetic Cubic Zirconia (Zirconium dioxide ZrO_2) 立方氧化鋯
3. Synthetic Moissanite (silicon carbide SiC) 莫桑石



4. YAG (yttrium aluminium garnet YAG $\text{Y}_3\text{Al}_5\text{O}_{12}$) 鈮鋁石榴石
5. Strontium titanate (SrTiO_3) 鈦酸鈦
6. Gadolinium Gallium Garnet (GGG) $\text{Gd}_3\text{Ca}_5\text{O}_{12}$
7. Corundum 剛玉

Cubic Zirconia (CZ) 蘇聯鑽/蘇聯石/碳鑽

It is the synthetic cubic crystalline form of zirconium dioxide (ZrO_2) made by melting powdered zirconium and zirconium oxide together at 2,750 C. It has the optical properties highly similar to that of diamonds but chips and breaks more easily (Mohs scale only 8.5 vs 10 in diamond). It is a thermal insulator with its density 1.7 times that of diamond & refractive index 2.2 vs diamond's 2.42. Tends to turn cloudy & less brilliant over time. Popular since the 70s



- Swarovski Zirconia are cut and polished in its own factory in Austria and each is marked with a microscopic laser engraving that is invisible to the naked eye. It can withstand very high temperature and follow GIA cut quality standard

SWAROVSKI ZIRCONIA



COMPARABLE MATERIALS

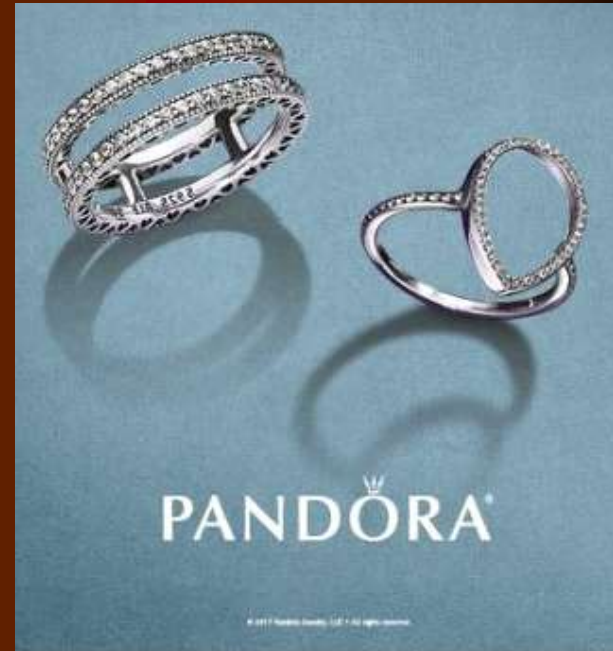
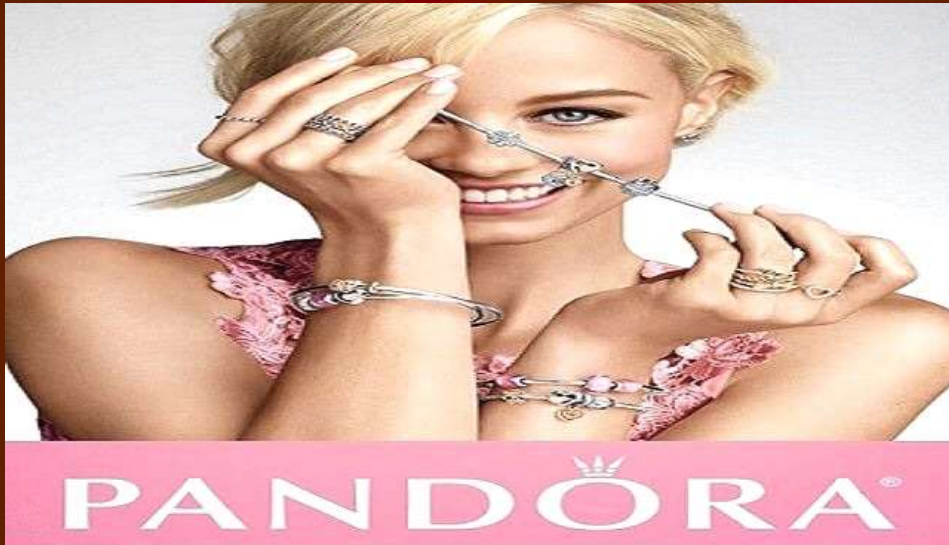
	Zirconia	Diamond	Crystal
Origin	Created	Natural	Created
Mohs Scale	8.5	10	6
Refractive index	2.20	2.42	1.56

STONE SIZES



Carat Weight	0.10	0.25	0.33	0.50	0.75	1.0	1.25	1.50	2.0
Diameter mm	2.8	4.0	4.25	5.0	5.75	6.25	6.75	7.25	8.0

- According to Pandora the environmental cost of cubic zirconia sold by them is only 0.001% that of natural diamond due to the largely smaller quantity of energy required to produce cubic zirconia





Moissanite (SiC) 莫桑石/摩星石

Composed of Silicon carbide which is mainly found in meteorites. Now man made created by Charles & Colvard and held the patent which already expired in 2018. It's hardness at 9.25 is close to diamond and its refractive index at 2.65 is higher than diamond's 2.42. Popular from the 90s till now and the price is only 1/10 that of natural diamond



Moissanite color chart

 Clear White	 White	 Light Yellow
 Champagne	 Light Blue	 Light Green

Moissanite vs Diamond

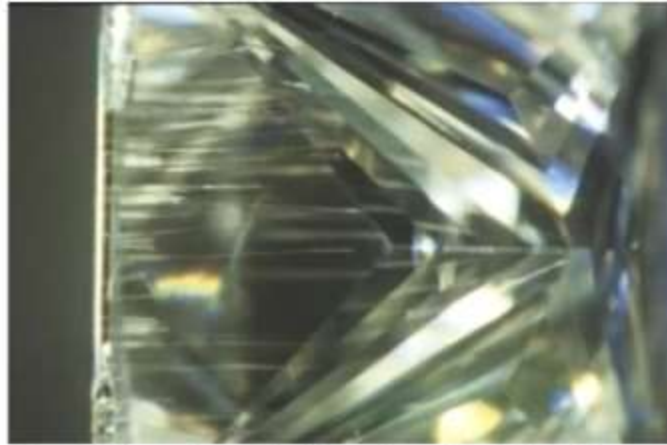
	Diamond	Moissanite	
Atomic Composition	C	SiC	
<u>R.I. (Brilliance)</u>	2.42	2.69	
<u>Fire (dispersion)</u>	0.044	0.104	
<u>Luster</u>	17.20%	20.40%	
<u>Hardness</u>	10	9.25	
<u>Toughness</u>	Good	Excellent	
<u>Clarity</u>	I3 - Flawless	VS	
<u>Quality of Cut</u>	Varies (Poor to Excellent)	Excellent	
Attraction to Dirt/Oil	Moderate	Low	
<u>Heat Resistance</u>	High	Very High	
Price	\$3000-\$8000/ct	~ \$300 / ct	

- Moissanite posts the biggest challenge to natural diamond as it is better than diamond in brilliant, luster, toughness as well as heat resistant



- Moissanite identification include growth lines and strong doubling 雙折光

Synthetic Moissanite



Growth lines in synthetic moissanite © DTC Research

Synthetic Moissanite has strong 'doubling' of the back facets. A diamond will never show doubling.



No doubling seen in diamond © Gem-A



Strong doubling seen in synthetic moissanite © Gem-A

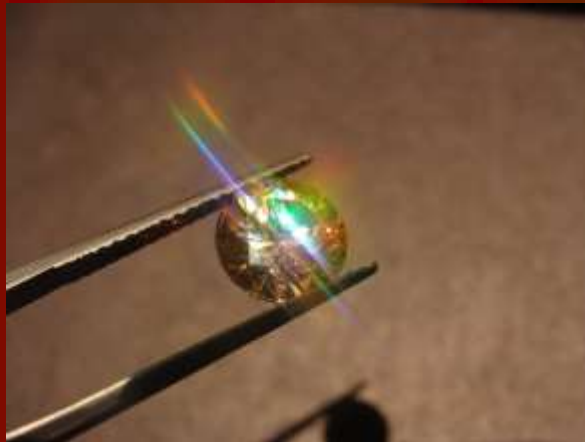
YAG – Yttrium aluminum garnet (YAlO₂) 鉍鋁石榴石

YAG in the 1970s was used in jewelry as a diamond and other gemstone simulant but lacks fire and luster of a diamond. Colored variants include green, yellow, purple, pink and orange. YAG has numerous trade names such as diamonite and diamonte



Strontium titanate (SrTiO_3) 鈦酸鈦

Sold under many different trade names such as Diagem, Fabulite and Marvelite, it has a very similar luster and brilliance like a natural diamond but its “fire” greatly exceeded that of natural diamond and it only has a Mohs hardness of 5.5 making it more brittle. Popular between 1950-70s



Gadolinium gallium garnet (GGG) $\text{Gd}_3\text{Ca}_5\text{O}_{12}$

It is a synthetic crystalline material of the garnet group with good thermal and optical properties. Usually colorless but is available in a variety of colors. Mohs hardness of 6.5 /7.5 making it more brittle. Popular between 1950 - 70s



Corundum – Ruby & Sapphire (Al_2O_3)

Particularly white sapphire . Although it has a Mohs value of 9, white sapphire tends to scratch relatively more easily and also less brilliant. White sapphire can also be lab grown (Chatham lab grown sapphire)



Owing to their greater **light refracting capability**, **Daimonds** shine more brilliantly than white **sapphires**.



Natural White Sapphire



DIAMOND PROPERTIES COMPARISON

DIAMONDS:	CHEMICAL COMPOSITION	CRYSTALLINE STRUCTURE	REFRACTIVE INDEX	DISPERSION	HARDNESS	DENSITY
Synthetic Diamond	C	Cubic	2.42	0.044	10	3.52
Natural Diamond	C	Cubic	2.42	0.044	10	3.52
SIMULANTS:						
Cubic Zirconia (CZ)	ZrO ₂	Cubic	2.20	0.066	8.25	5.70
Moissanite	SiC	Hexagonal	2.65	0.104	9.25	3.21
White Sapphire	Al ₂ O ₃	Hexagonal	1.77	0.018	9	3.97
YAG	Y ₃ Al ₅ O ₁₂	Cubic	1.83	0.028	8.25	4.60

Comparison of Diamond and Diamond Simulants

Material	Refractive Index	Dispersion	Hardness	Popular During
Diamond	2.417	0.044	10	1500s to present
Strontium Titanate	2.41	0.190	5.5	1950s to 1970s
YAG	1.83	0.028	8.3	1970s
GGG	1.97	0.045	7	1970s
CZ	2.2	0.06	8.3	1970s to present
Moissanite	2.66	0.104	8.5 - 9	1990s to present

Identification



**Diamond
Exploration**

Mining

**Lab
Development**

**Factory
Growth**



I. Simple Tests to identify real diamond from look-alikes



Breath Test:
The diamond should look transparent.



Loupe Test:
Inspect your stone under magnification in good light.



Newspaper Test:
You shouldn't be able to read the print through the diamond.



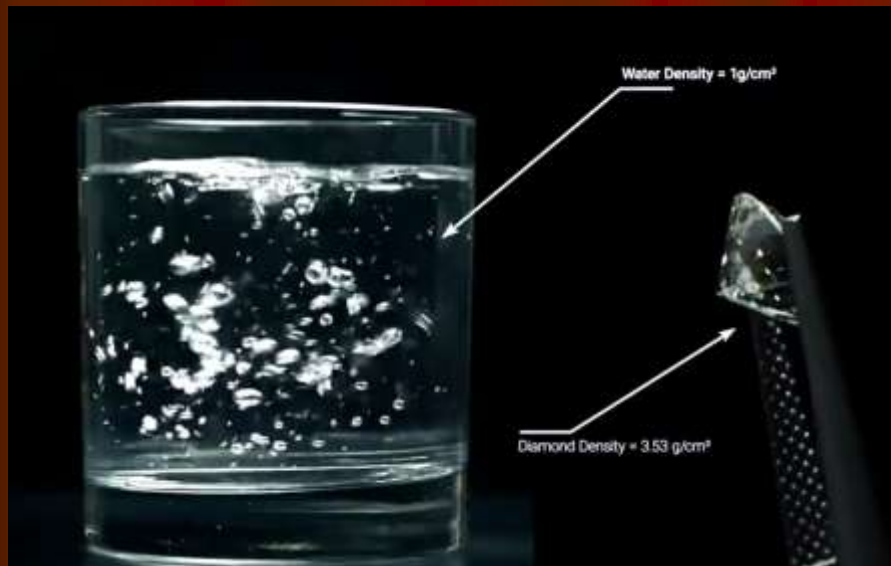
Scratch Test:
scratch a piece of glass with the stone.



Water Test:
A real diamond will sink to the bottom of the glass.

Water Test

Real diamond will sink but so are others like glass & Cubic Zirconia



Newspaper/Read through Test

To identify real diamond from lookalikes such as Cubic Zirconia (CZ)
Cannot read the letters through a real diamond due to high reflection

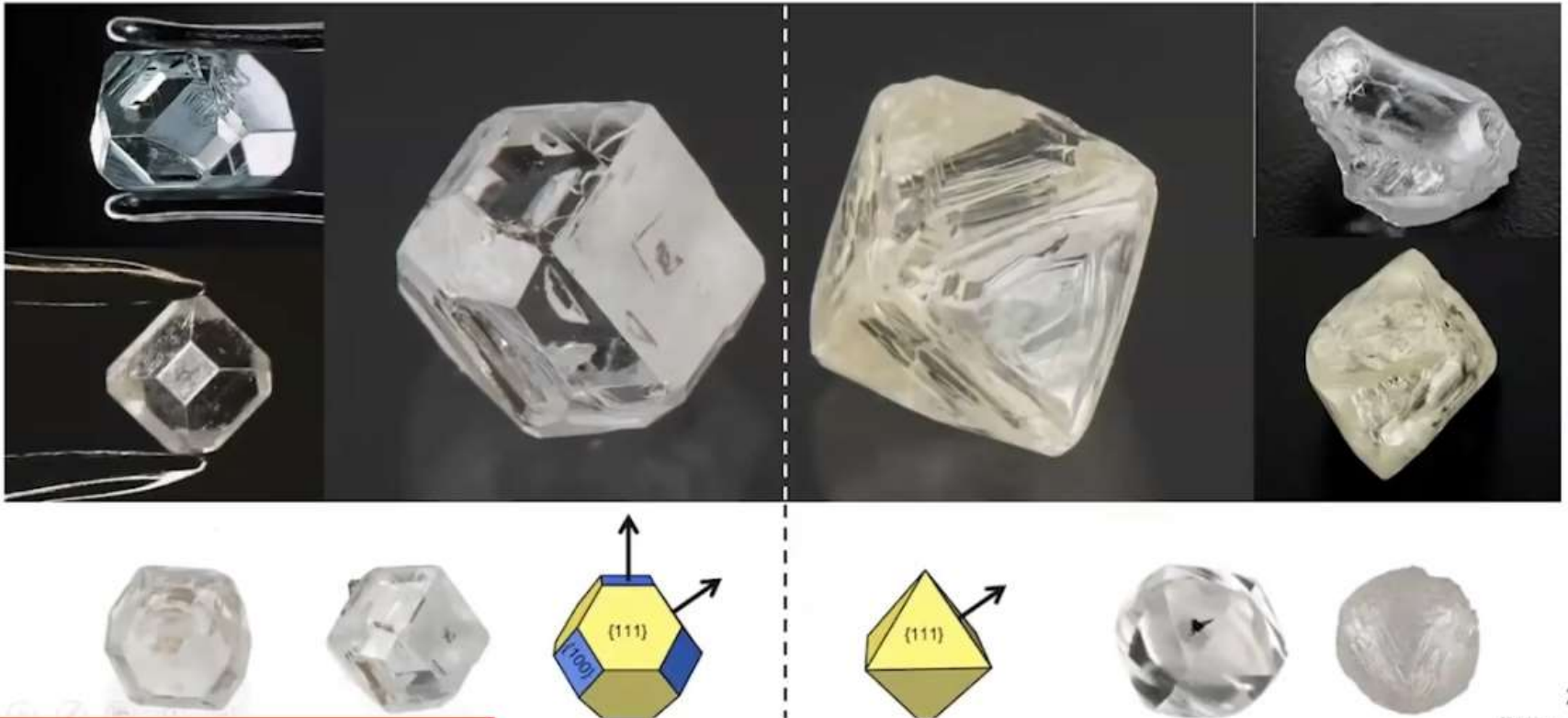


Loupe Test 放大鏡

Morphological comparison between Lab-grown & Natural diamond before polishing

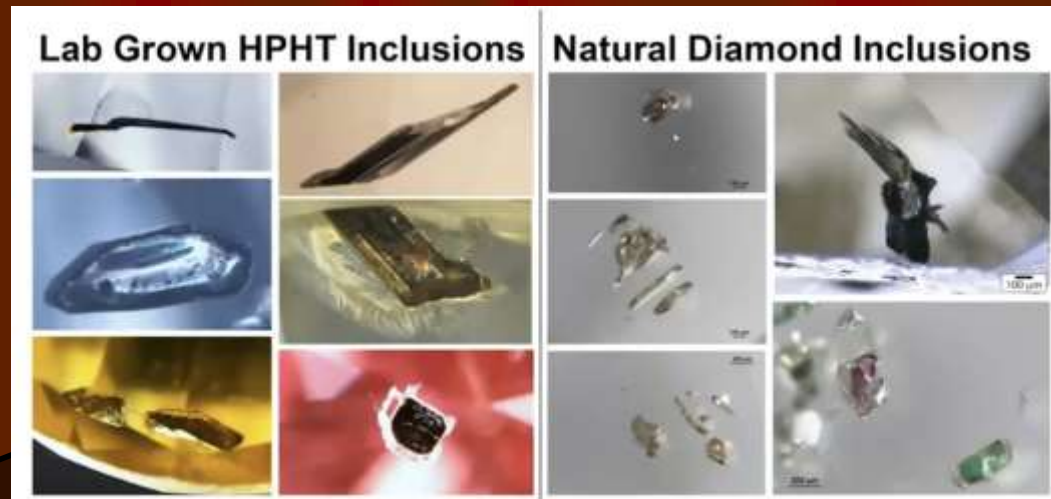
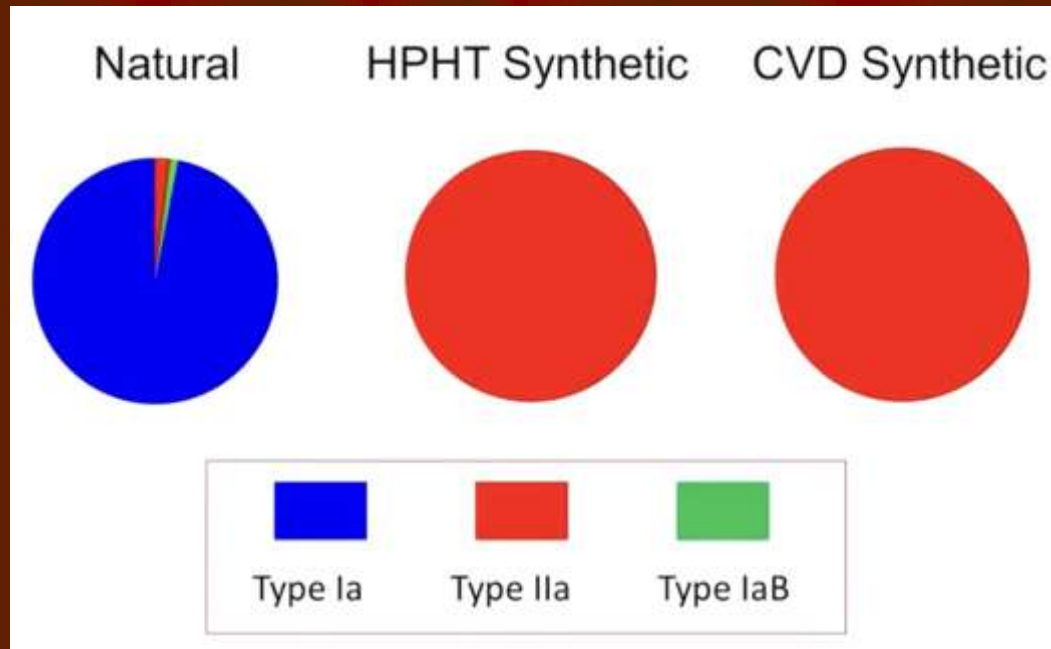
Lab Grown HPHT Morphology

Natural Diamond Morphology



Inclusions & defects

They are usually absent in Lab diamonds



Natural diamond does not have metal inclusions. Those present in lab grown diamond can also turn it magnetic !

Metal solvent/catalyst

- ◆ Traces may get trapped in HPHT lab grown diamond
- ◆ Dark and metallic
- ◆ Irregular/rod shaped

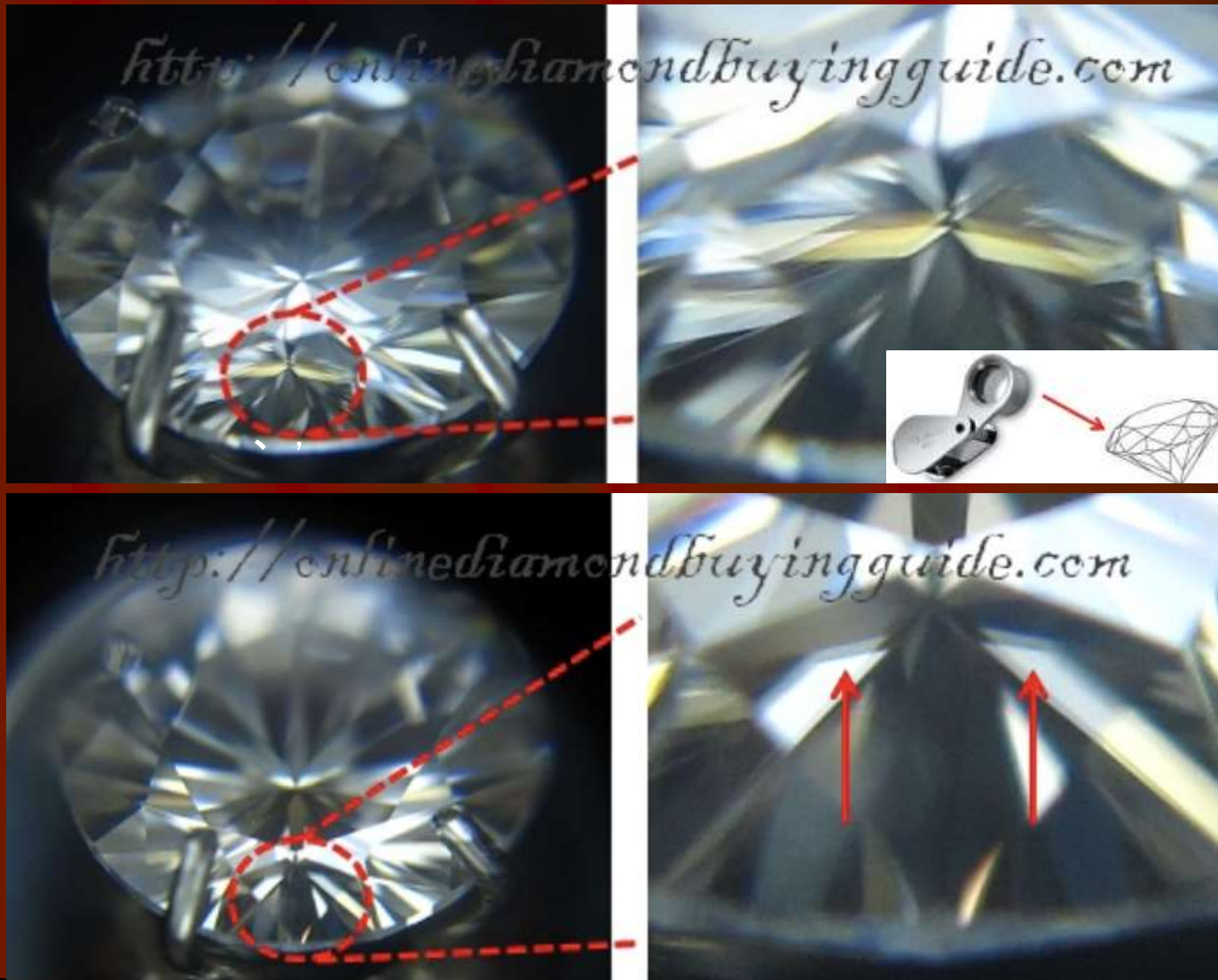


20



HPHT lab-grown diamond with significant metallic inclusions may be attracted to a strong magnet

Identifying moissanite by observing “doubling view” 雙棱影 caused by its refraction property which does not appear in diamond



Flame Test

Identify real diamond from Cubic Zirconia



BEFORE HEAT & WATER



AFTER HEAT & WATER



DIAMOND VS CUBIC

Magnetism Test



Man-made diamond with significant metallic inclusions may be attracted to a strong magnet.

(Generally clarities of SI and lower)



II. Using diamond testing devices



II. Using diamond testing devices

Several commercially available testing devices are based on various techniques

- ◆ Ultraviolet transparency
- ◆ Ultraviolet-Visible absorption (spectroscopy)
- ◆ Infrared absorption (spectroscopy)
- ◆ Phosphorescence
- ◆ Phosphorescence emission (spectroscopy)

Before purchasing, it is important to understand how the device works, any restrictions on its use, and the possibility of it giving false results

Gemological Observations

- ◆ Inclusions
- ◆ Growth-related color zoning, graining, or fluorescence
- ◆ Strain
- ◆ Fluorescence and phosphorescence

Spectroscopic Analysis

- ◆ Infrared absorption spectroscopy
- ◆ UV-Vis absorption spectroscopy
- ◆ Photoluminescence spectroscopy with varying laser excitations from UV to IR
- ◆ Phosphorescence spectroscopy
- ◆ Fluorescence spectroscopy
- ◆ CL image and spectroscopy
- ◆ Fluorescence image
- ◆ EPR (Electron Paramagnetic Resonance)

Thermal/Electrical Conductivity Testers



Diamond Inspector



ALROSA DIAMOND INSPECTOR

ALROSA
ASSURE ID: 64815

ALROSA DIAMOND INSPECTOR is a portable diamond verification instrument for loose and mounted diamonds. ALROSA DIAMOND INSPECTOR is designed to separate natural diamonds from synthetic diamonds and loose simulants. ALROSA DIAMOND INSPECTOR is currently approved but gives an automatic test result. ALROSA DIAMOND INSPECTOR is suitable for use in the environment where you need to test both mounted and loose diamonds e.g. dealers, diamond and jewellery manufacturers, retailers, buyers and gemological laboratories.

5,799 USD (August 2019)
www.alrosa-inspector.com
info@alrosa-inspector.com
+7 (495) 106-52-58

How does the instrument operate?

The user manually places the loose or mounted stones inside the test chamber of the instrument. To start the testing, the user closes the test chamber and presses the start button.

ALROSA DIAMOND INSPECTOR automatically makes a measurement and displays one of the following results:

- ◊ "Natural"
- ◊ "Type I(a) Refer to Lab."
- ◊ "Treated"
- ◊ "Need investigation"
- ◊ "Simulant"
- ◊ "Check stone"

The TYPE I(a) Refer to lab" and "Need investigation" results could contain potential synthetic diamonds and diamonds. These results shall be tested further for full verification. ALROSA recommends further testing of referred stones by a gemological laboratory.



110mm 110mm (w) x 33mm (d) x 110mm (h)

1.8/2.1kg

Stone Capabilities

Weight of stones: 0.02 ct - 10 ct
Size of stones: 2mm - 14.4mm
Colour of stones: D-J
Shape of stones: ALL
Diamond simulants: YES
Jewellery: YES

Instrument Capabilities

Automatically load the stones: NO
Automatically interpret the result: YES
Automatically dispense the stones: NO
Detect or refer synthetic diamonds: REFUSE
Detect or refer diamond simulants: DETECT
Multiple stones at one time: NO
Timing: NO

ACCORDING TO ALROSA

Test Procedure

ALROSA DIAMOND INSPECTOR was tested in accordance with the Diamond Verification Instrument Standard with the test protocol for instruments that separate diamonds, synthetic diamonds and diamond simulants (Operation Category 3).

The tests took place at the Independent Laboratory ILI in Canton, Massachusetts, United States. ALROSA DIAMOND INSPECTOR does not require manual interpretation and the instrument was tested both with a service operator. The detailed test results can be found in the summary report issued by ILI.

ALROSA DIAMOND INSPECTOR was tested with the ASSURE Core Sample.

ASSURE Core Sample

The ASSURE Core Sample consists of 1,000 diamonds, 200 synthetic diamonds and 200 diamond simulants. The stones are 0.02 ct to 0.20 ct in D-J colour. The below results are from the test with the ASSURE Core Sample.

Test Results

	CORE
DETECTED NATURAL PERCENT RATE	0%
DETECTED SYNTHETIC DAYS	3.6%
DETECTED ACCURACY	96.4%
1000	24

This test report including more detailed test results can be found here.
This report was issued 07/2019.

Safety Credentials

The most important measurement when selecting a Diamond Verification Instrument is that the instrument meets the safety requirements of your local jurisdiction. Before purchasing an instrument, request that the manufacturer provides that their instrument complies with all regulatory requirements. Click here to download the safety testing conducted by ALROSA DIAMOND INSPECTOR submitted by ALROSA. Please note that the safety testing credentials have not been released through the ASSURE Program.

Long Wave/Short Wave Ultra Violet Diamond Testing Device

UV Fluorescence

◆ Gem testing lamp:

Shortwave UV = 254 nm

Longwave UV = 365 nm



◆ DiamondView:

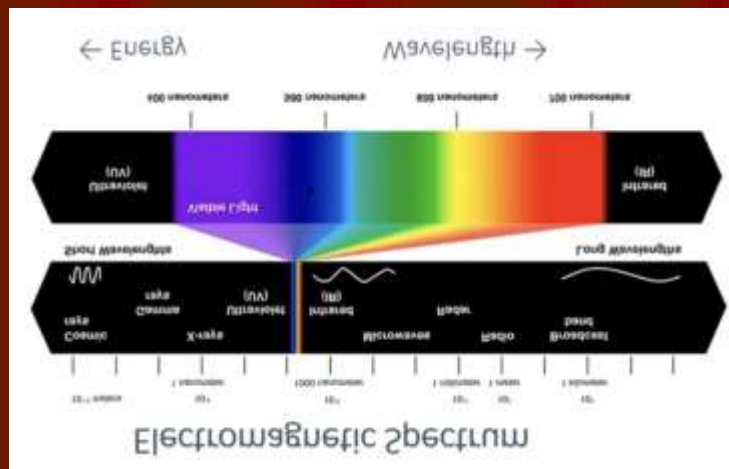
Deep (ultra-shortwave) UV < 225 nm

- ◆ High energy
- ◆ Excites fluorescence in nearly all diamonds
- ◆ Sharp, surface specific images under magnification



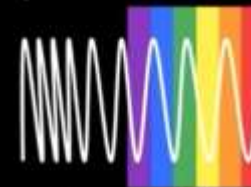
© De Beers Technology

7



Ultraviolet light

Most common source for testing fluorescence

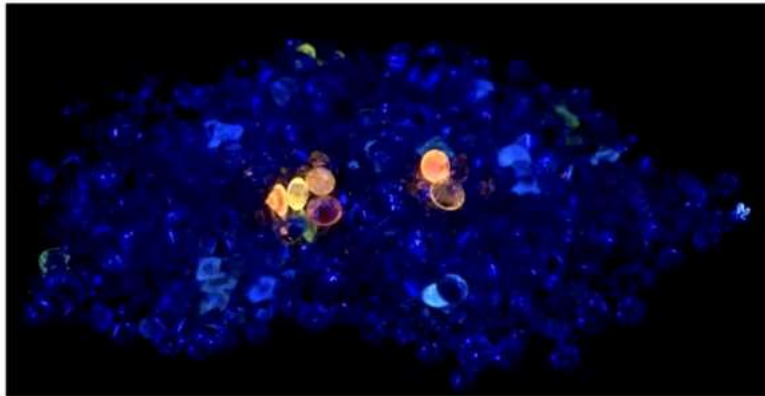


UV: 10 – 400nm
Visible: 400 – 700nm

SWUV:
10nm – 300nm
254nm

LWUV:
300nm – 400nm
365nm

Mounted Diamond Testing Device GIA iD100 based on fluorescence spectroscopy



GIA has developed and plans to sell a new device, based on fluorescence spectroscopy, for testing diamonds mounted in jewelry



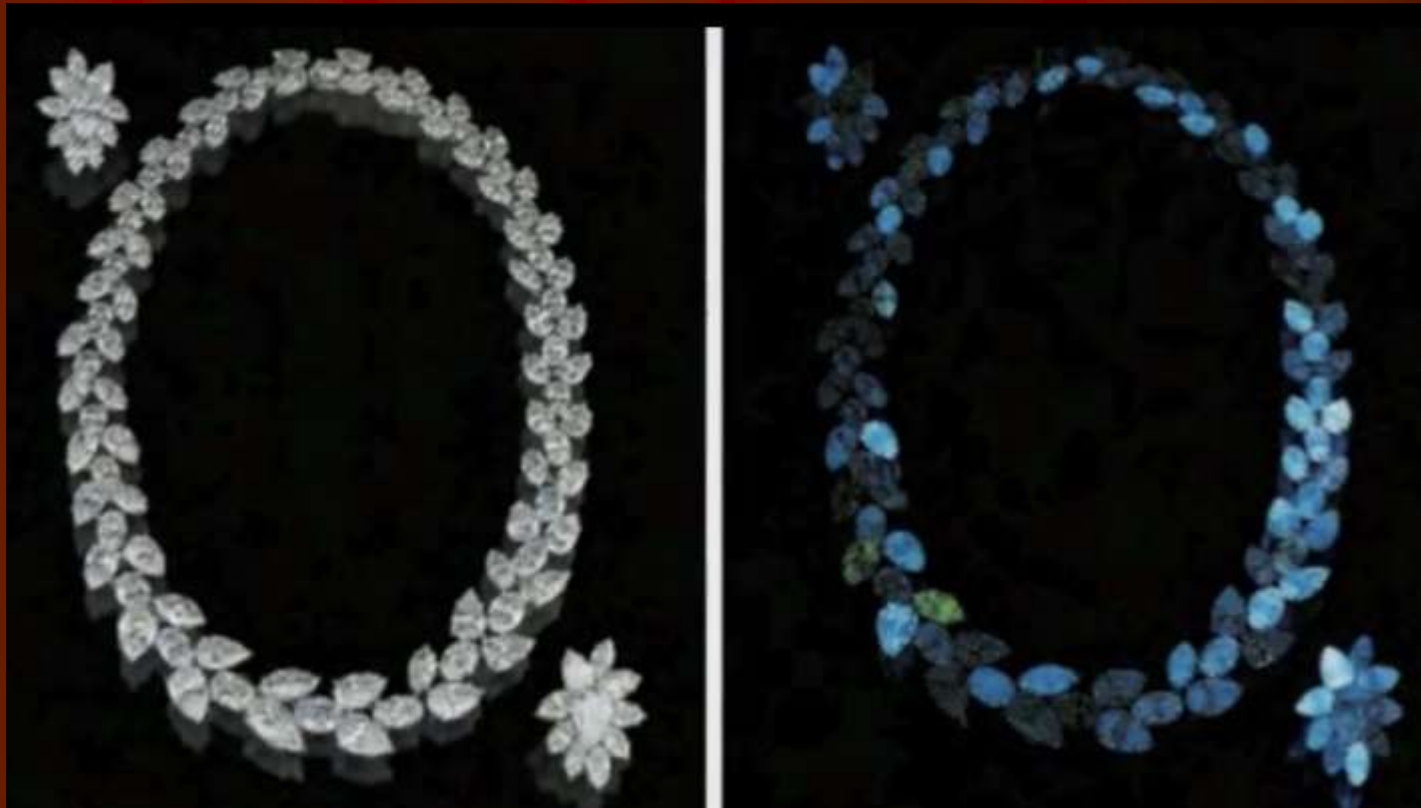
- ◆ Refers all synthetic diamonds and diamond simulants
- ◆ High pass rate for natural diamonds (> 97% for "D-Z" colors)
- ◆ All sizes (0.005 ct or larger) and all shapes
- ◆ Loose or mounted, and rough or polished diamonds
- ◆ Hold probe near stone – response in less than two seconds
- ◆ Avoid use near fluorescence materials (i.e., paper)



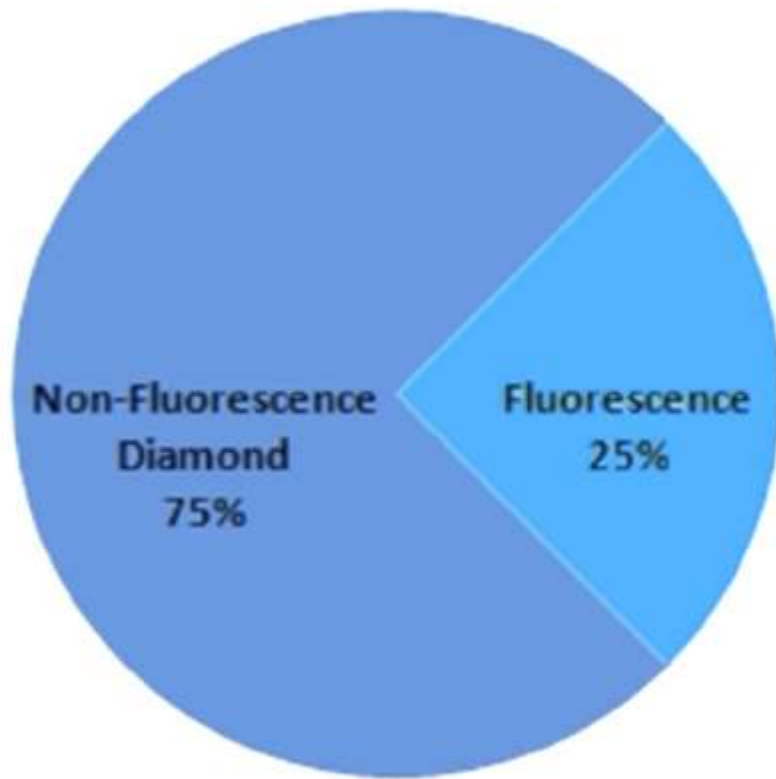
		GIA ID100
Test	ASSURE test number	75549
	Date of test report	05/2019
Manufacturer	Manufacturer	GIA
	ASSURE Partner	ASSURE Partner
Dimensions	Dimensions (cm)	W16.5 x D20 x H8
	Weight (kg)	1.02
	Portability	Portable
Functionality	Feed of stones	Manual
	Interpretation of results	Automatic
	Dispensation of stones	Manual
	Multiple stones?	No
Operation Category	Synthetic diamonds	Refer
	Diamond simulants	Refer
	Operation Category	2
Stone Capabilities (manufacturer claimed)	Weight (ct)	0.005+
	Colour	D-I
	Shape	All
Jewellery	Jewellery?	Yes
Operator	Tests performed by novice or expert?	Novice operator
Test Results ASSURE Core Sample	Diamond False Positive Rate (%)	0%
	Diamond Referral Rate (%)	3.3%
	Diamond Accuracy (%)	96.7%
	Synthetic Diamond False Positive Rate (%)	0%
	Synthetic Diamond Referral Rate (%)	100%
	Synthetic Diamond Accuracy (%)	n/a
	Diamond Simulant False Positive Rate (%)	0%
	Diamond Simulant Referral Rate (%)	100%
	Diamond Simulant Accuracy (%)	n/a

Fluoresces Test 螢光測試

Fluorescence is the emission of light by a substance that has absorbed light or other electromagnetic radiation such as ultra violet light. Phosphorescence is the emission of light by a substance exposed to radiation which persisted as an afterglow after the source of the radiation has been removed



About 25% of all natural diamond will turn strong fluorescent under long wave ultra violet Light (LWUV). Some 95% of them will display blue colour mainly due to the existence of boron. The balance can display many different colours. Out of the 95% about 0.3 to 0.6% of fluorescence diamond can appear milky



**THE world FAMOUS Hope Diamond
FLUORESCES' A VERY STRONG RED!**





Effects on Diamonds:

- In colourless diamonds (D – F) strong fluorescence may have negative effect in daylight.
- In more yellowish coloured diamonds (G – L) strong fluorescence has a positive effect in daylight.



Diamonds which fluoresce strongly are generally *less* valuable

White diamond with strong fluorescence is called Greasy Blue 火油鑽

Top View



Before the UV Light is Turned On



After the UV Light is Turned On



GIA Fluorescence Classification



无荧 弱荧 中荧 强荧 超荧

IGI Florescence Classification

IGI

1. None

4. Medium

2. Very Slight

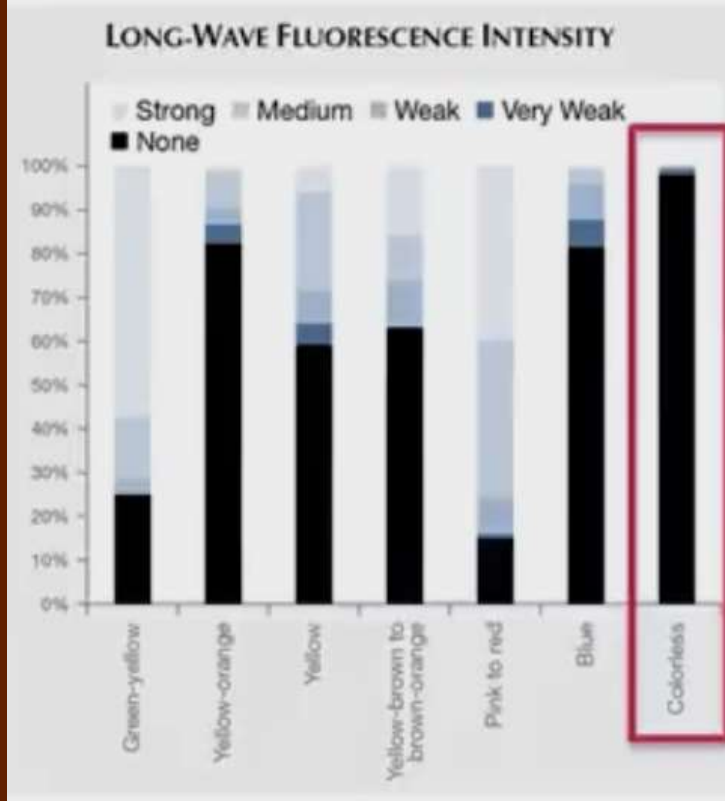
5. Strong

3. Slight

6. Very Strong



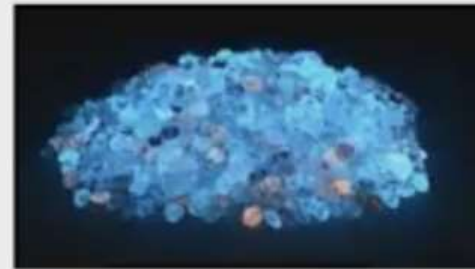
Identification by handheld UV Florescence



2%

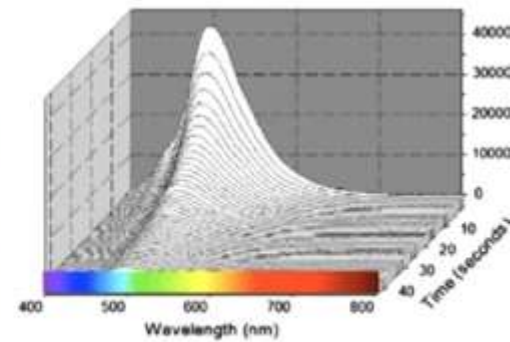
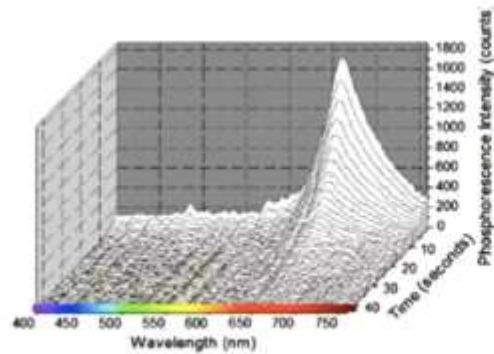
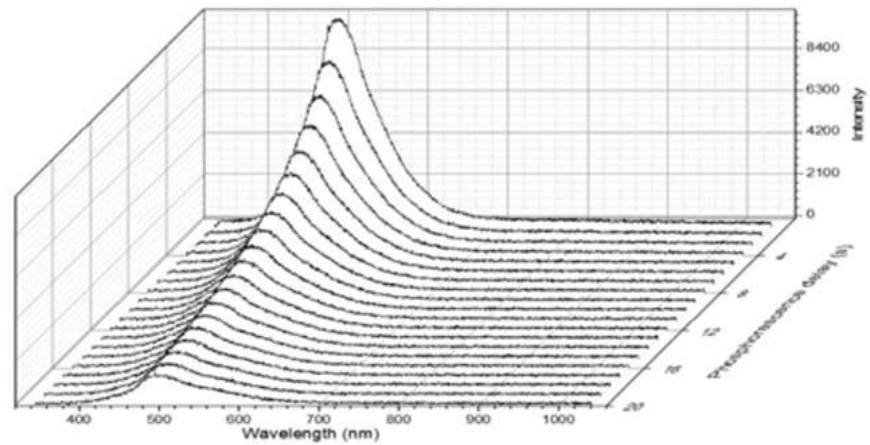
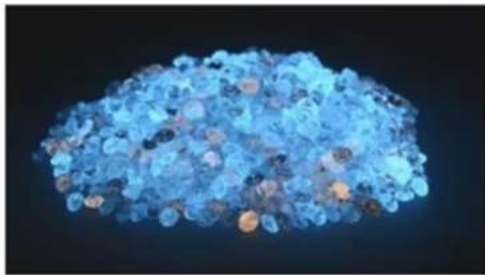
SWUV > LWUV

= Likely Lab Grown



**Phosphorescence to SWUV,
Strong sign of Lab Grown**

Phosphorescence HPHT lab-grown diamonds to SWUV

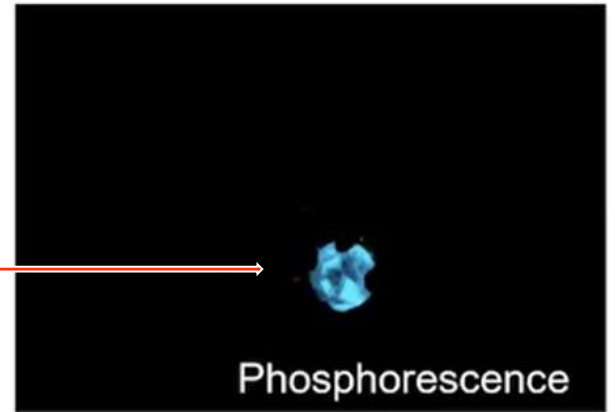
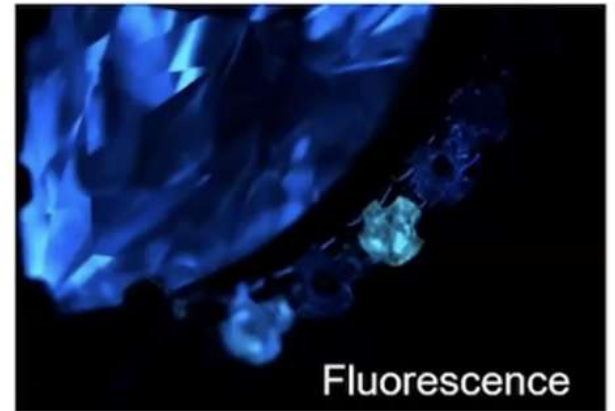


- The HPHT Lab grown melee diamond exhibits Phosphorescence after the UV light is turned off

One of the 70 melee diamonds in this ring is HPHT lab grown



HPHT lab
grown



Synthetic and natural diamonds vary in fluorescence.

Natural Diamond	Synthetic Diamond
Fluoresce strongest in LWUV	Fluoresce strongest in SWUV
Mainly fluoresce Blue	Mainly fluoresce Orange - Yellow
Phosphorescence – after LW	Phosphorescence – after SW

Gemstone	LWUV	SWUV
Diamond	Blue (Strongest)	Blue (Weaker)
Cubic Zirconia	Dull Yellow/Orange	Dull Yellow/Orange (weaker) or inert
Paste	Inert	Chalky White
Synthetic Moissanite	Yellow – Orange or inert	Yellow – Orange or inert
Synthetic Spinel	Inert	Chalky blue/green
Zircon	Brown - Yellow	Inert

Effect of irradiation on HPHT diamonds



DIAMOND SERVICES

PRESS RELEASE

CONTACT

Email: info@diamondservices.com.hk

Tel: +852 2536 4555

LAB ALERT

**HPHT-grown diamonds might escape detection as synthetics,
once they are treated with irradiation**

HONG KONG: APRIL 17, 2018 - Diamond Services, the Hong Kong-headquartered developer of technological systems and services for detecting synthetic, imitation and treated diamonds, has issued a worldwide alert to the jewellery and gemstone trades stating that research it has conducted indicates that synthetic diamonds, which have created under conditions of High Pressure-High Temperature (HPHT) and then subject to irradiation treatment, may be escaping detection by many of the screening devices available in the market that are testing diamonds at room temperature.

April 17, 2018

“Research conducted by Diamond Services has revealed that once an HPHT-grown synthetic diamond has been subject to irradiation, the diamond **no longer will phosphoresce at room temperatures**, meaning

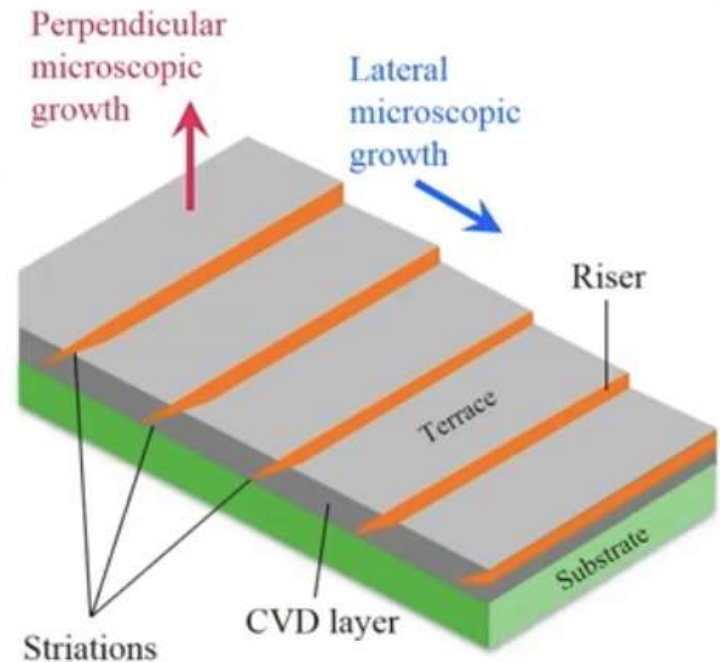
Irradiation is typically used to alter the colour of a stone, and Diamond Services reports that this masking of the phosphorescence effect has been witnessed both in diamonds that are colour-altered and diamonds in the standard colour ranges.”

Striations

CVD diamond display very distinct striations

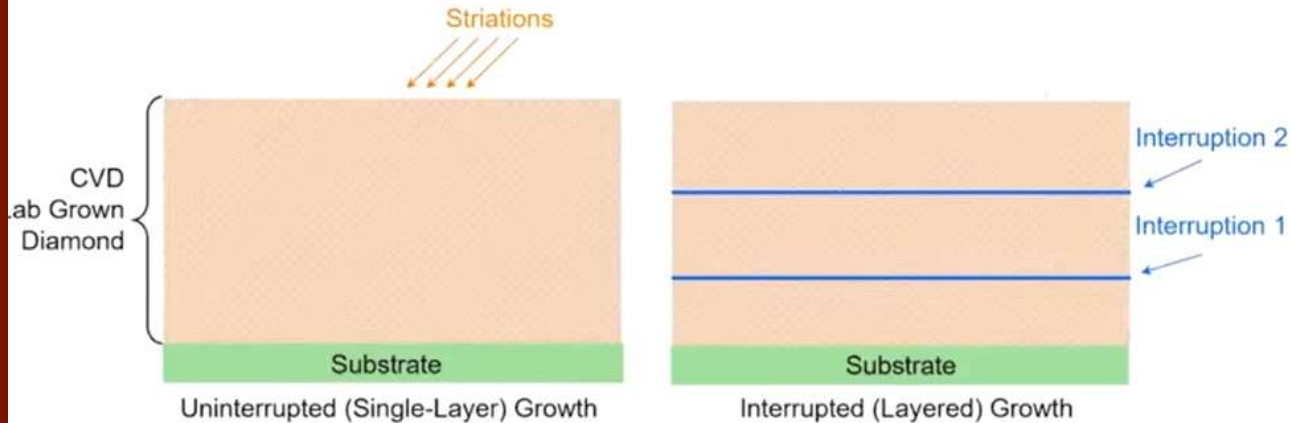
CVD Diamond Growth

- ◆ Deposits by step-flow growth
 - ◆ Microscopic perpendicular and lateral growth on substrate
 - ◆ Growing surface elevation varies
- ◆ Impurity and defect uptake differs for risers and terraces
 - ◆ Fluorescence contrast variations and striations
- ◆ Most CVD synthetics show striations
 - ◆ Clusters of lines rare in natural diamond



Growth lines 生長紋

Multilayer “stop-start” growth may produce bigger crystals more easily than a single thick layer

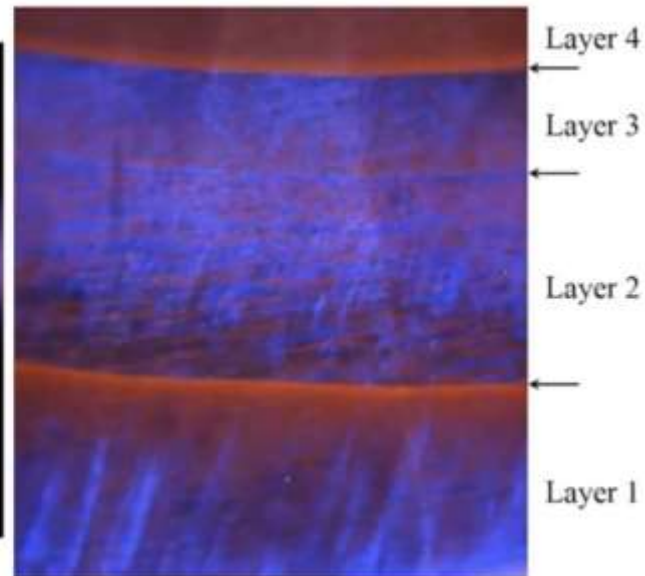


39

Multiple-Layer CVD Growth



Dislocation bundles →

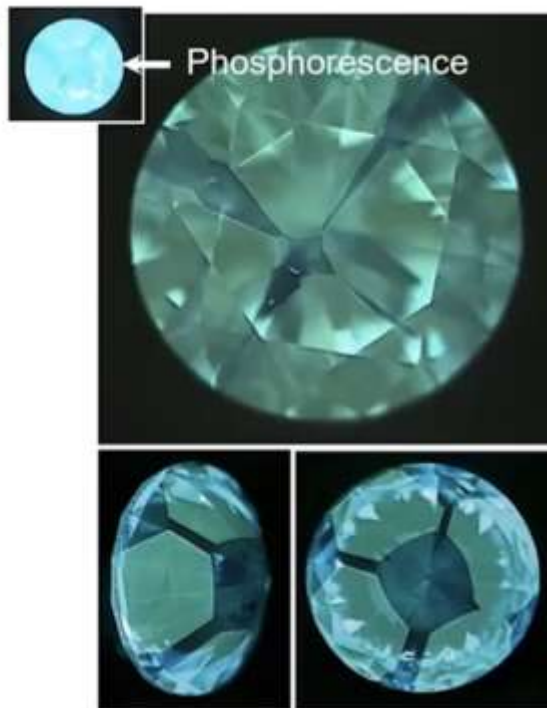


3

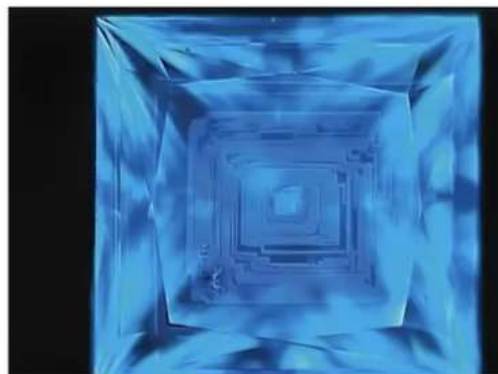
Identification through Deep UV Fluorescence

Deep UV fluorescence (e.g., DiamondView)
($\lambda_{\text{ext}} < 230 \text{ nm}$)

- ◆ Impurity uptake differs for different growth sectors
- ◆ Colorless Lab Grown HPHT Diamonds
 - ◆ Green or green-blue fluorescence
 - ◆ Strong, long-lived green-blue phosphoresce



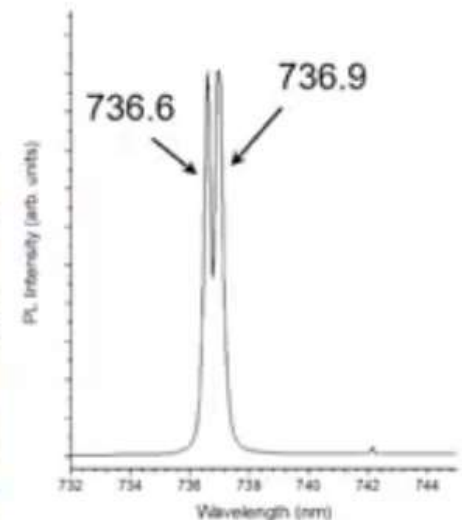
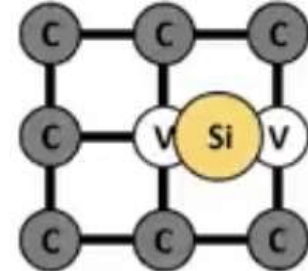
Most
Natural
Diamond



Natural
Growth
Zones

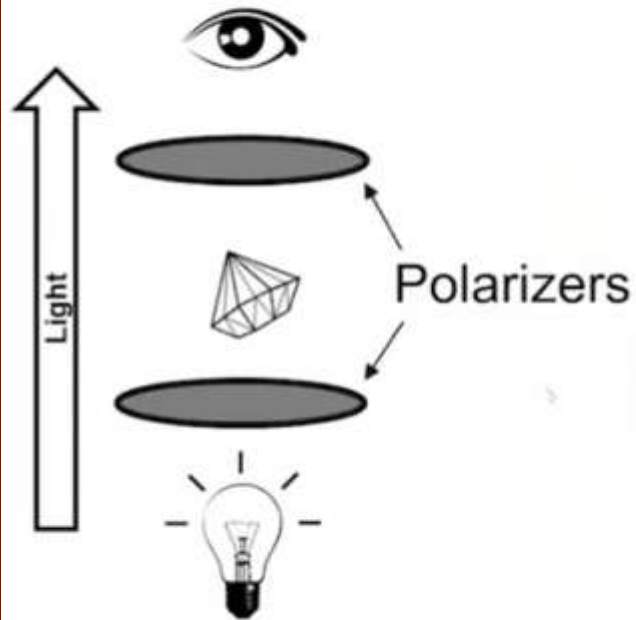
Presence of Silicon in CVD lab-grown diamonds

- ◆ SiV⁻ defect commonly detected (“737”) by photoluminescence
- ◆ Often introduced unintentionally (silicon-containing reactor components)
- ◆ Sometimes doped by adding silane to growth gases
- ◆ *Extremely rare* for natural diamonds



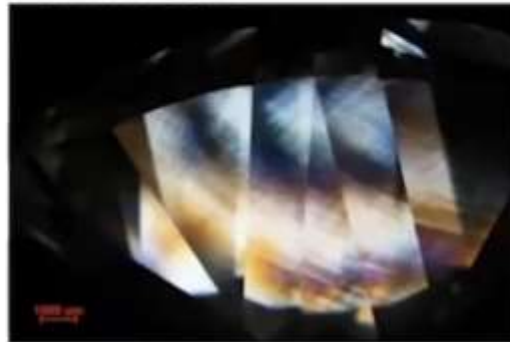
Strain Pattern (Birefringence)

Strain pattern under the microscope with polarizers



Strain Pattern

Natural, treated, or Lab
Grown CVD



No Strain Pattern

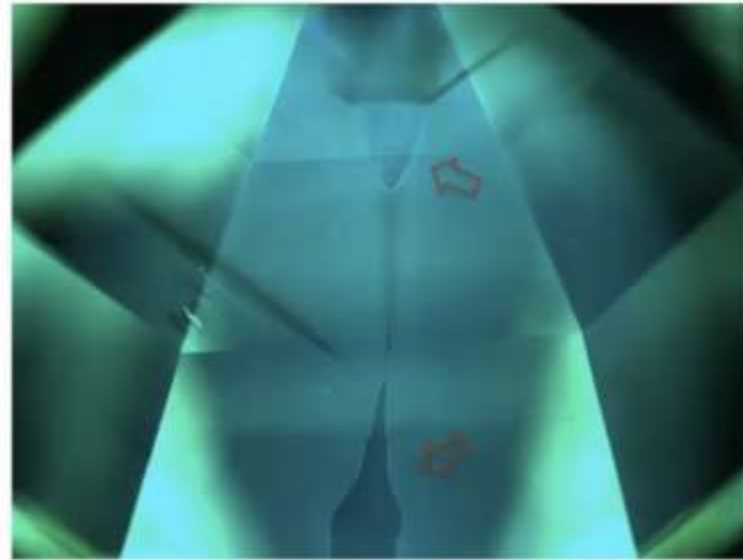
Lab Grown HPHT



HPHT lab-grown diamond



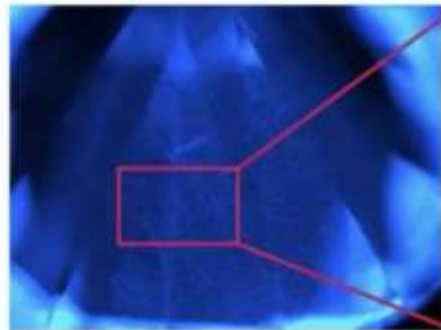
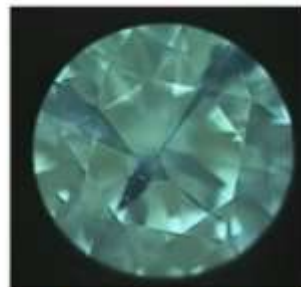
Fluorescence image



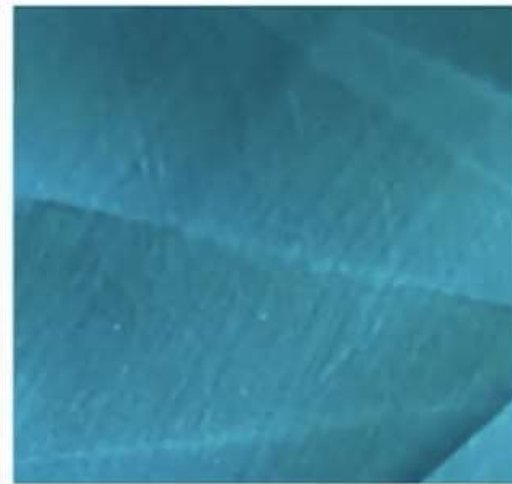
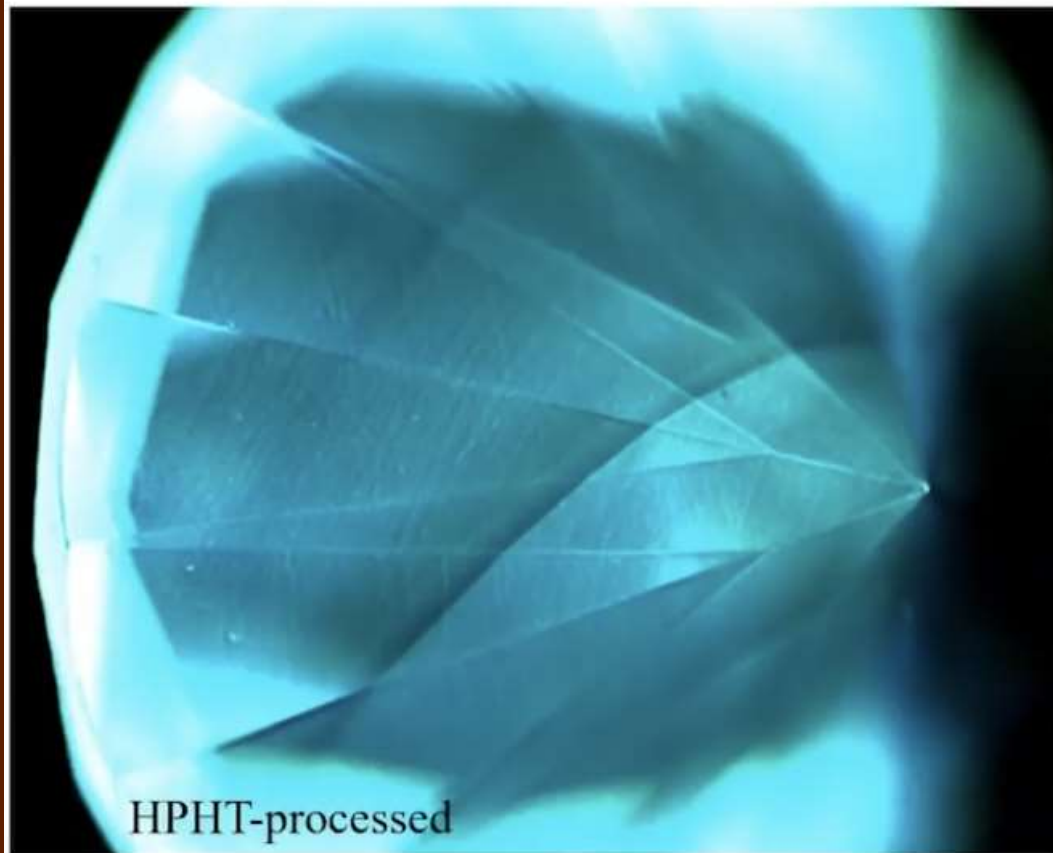
HPHT
Lab-grown
Type IIa



Natural
Type IIa



Natural
dislocation
network



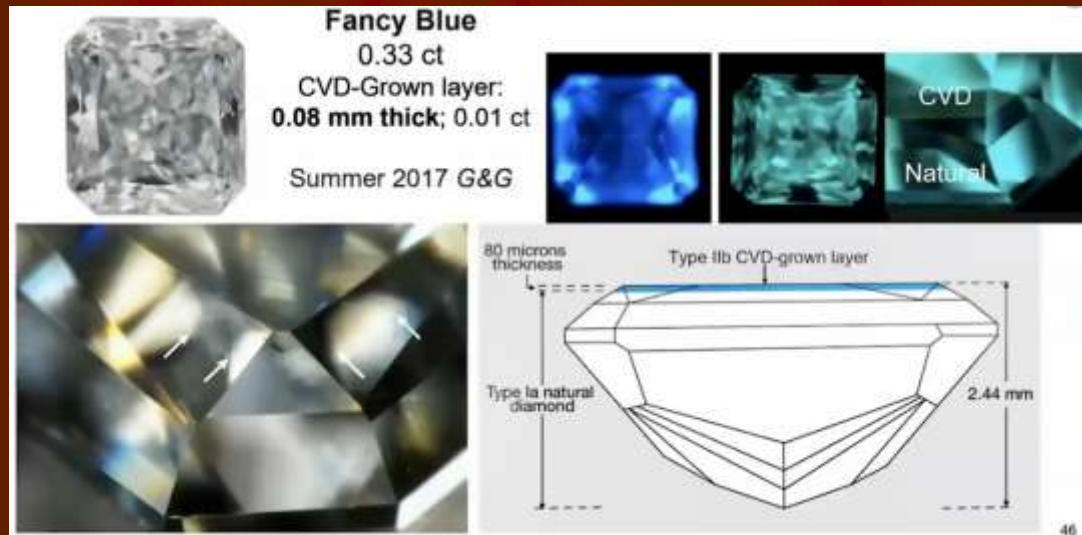
Striations



Layer interface

Identify composite diamonds

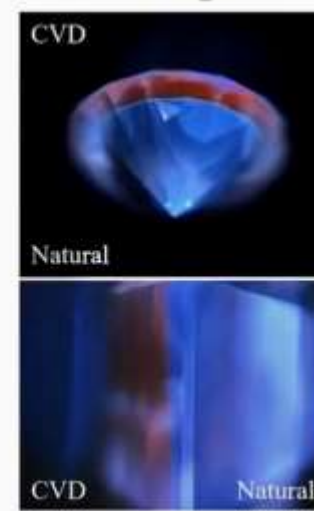
From white to Fancy Blue through adding a CVD grown substrate



CVD layer on natural diamond to increase weight

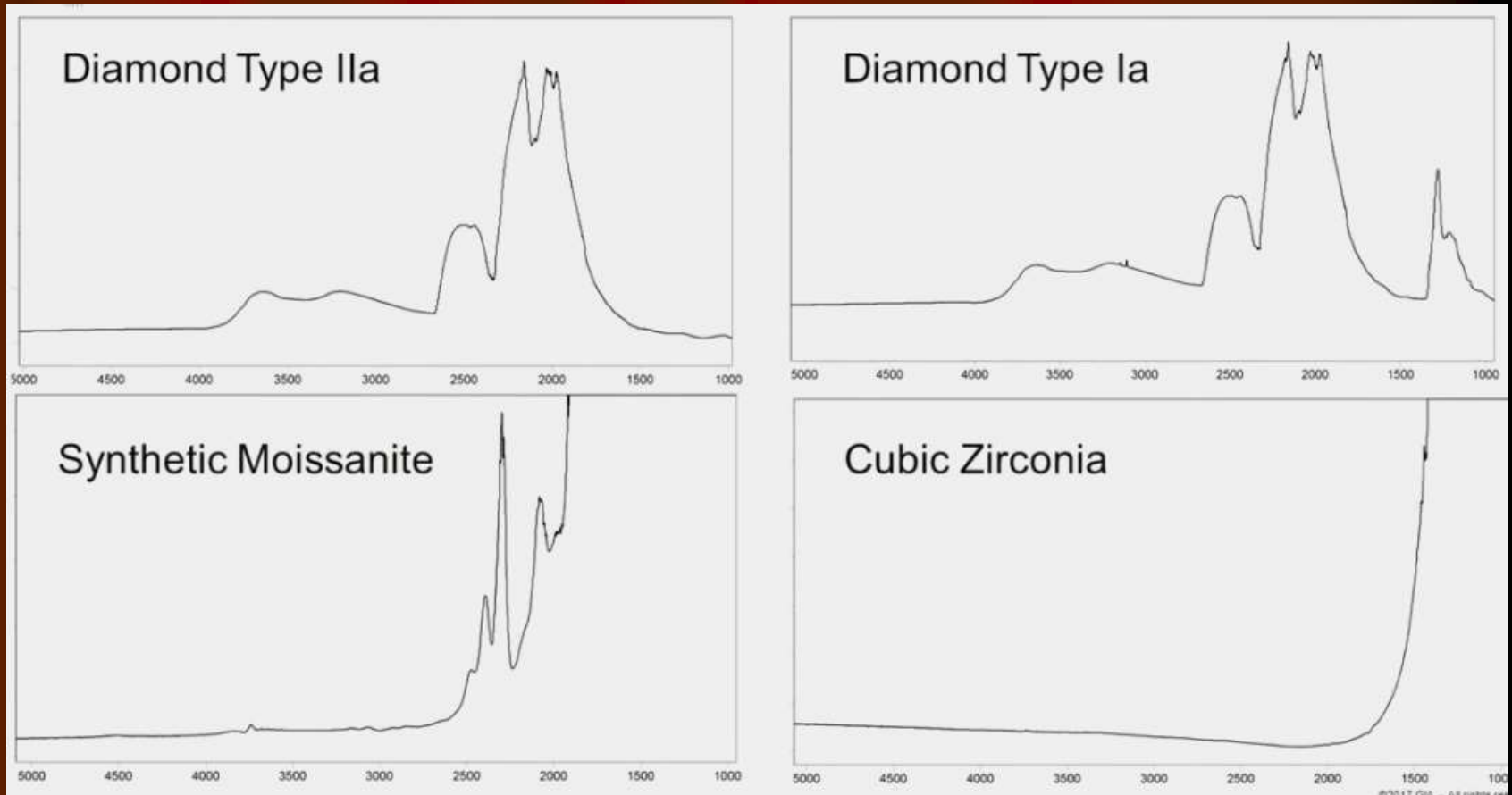
Natural Diamond Substrate

- CVD grown on natural substrates or gemstones to increase weight
- Deep UV fluorescence reveals layers
 - Natural diamond fluoresces blue
 - CVD layer fluoresces orange, pink, or red



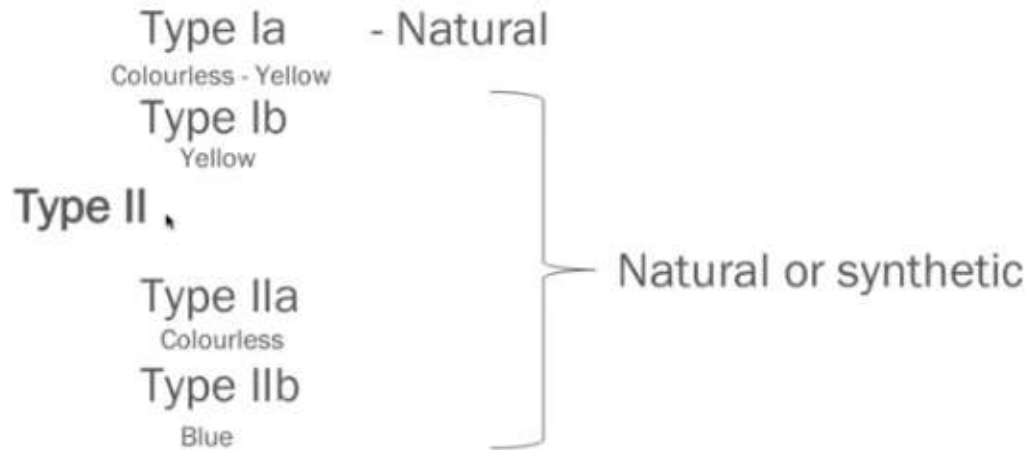
Infrared signatures

Comparison of Infrared Spectra between natural diamond, Moissanite and Cubic Zirconia



Screen Testing

Type I



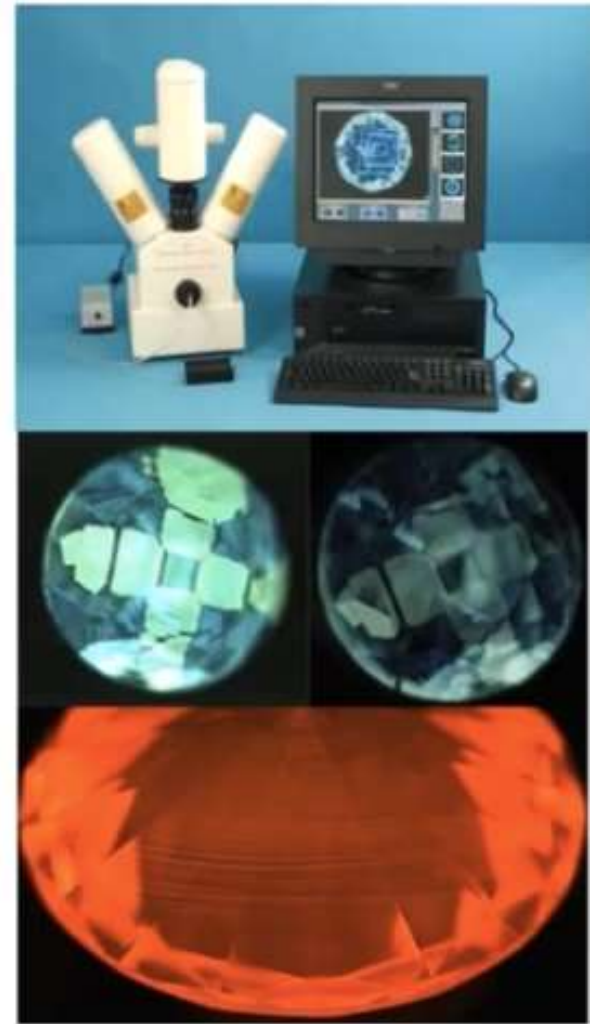
- DTC DiamondSure – detects 415.2nm line in natural Type 1a
 - HRD 'D' Screen
 - Presidium Synth. Diamond Screener
 - SSEF Diamond Spotter
- Separates
Type I and Type II
- Magilabs EXA - phosphorescence

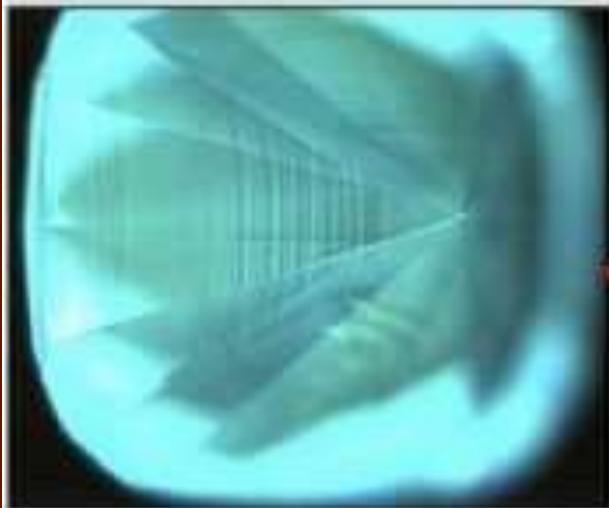
Advance Testing



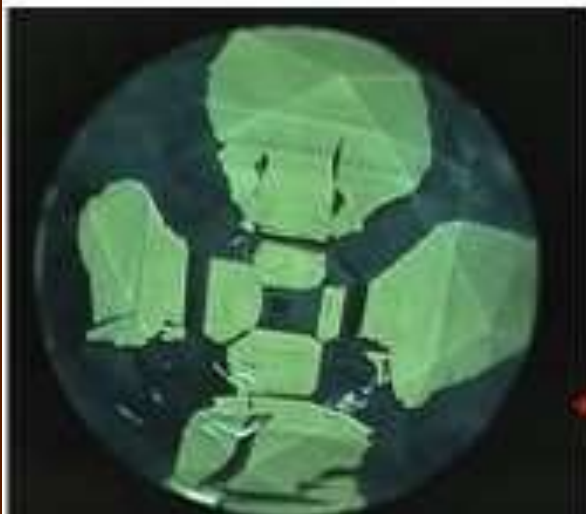
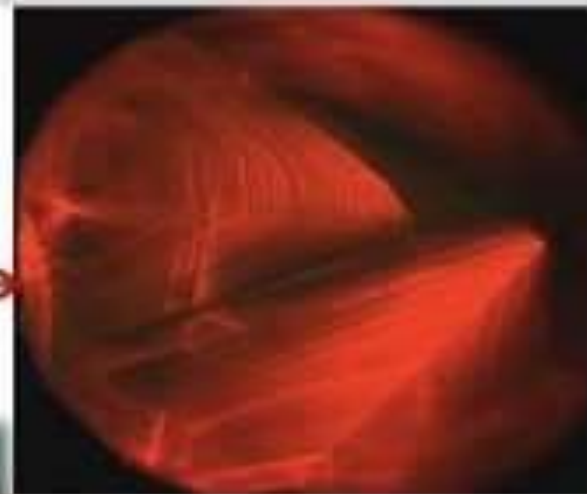
Synthetic Diamond Identification: Advanced Tests

- DTC DiamondView/Cathodoluminescence
 - Growth patterns
 - DeBeers SYNTH Detect
 - DTC Diamond PPlus
 - Yehuda Sherlock Holmes Detector
 - Magilabs EXA
 - IIDGR PhosView
- photoluminescence
- phosphorescence





**CVD
Grown
Diamond**



**HPHT
Grown
Diamond**

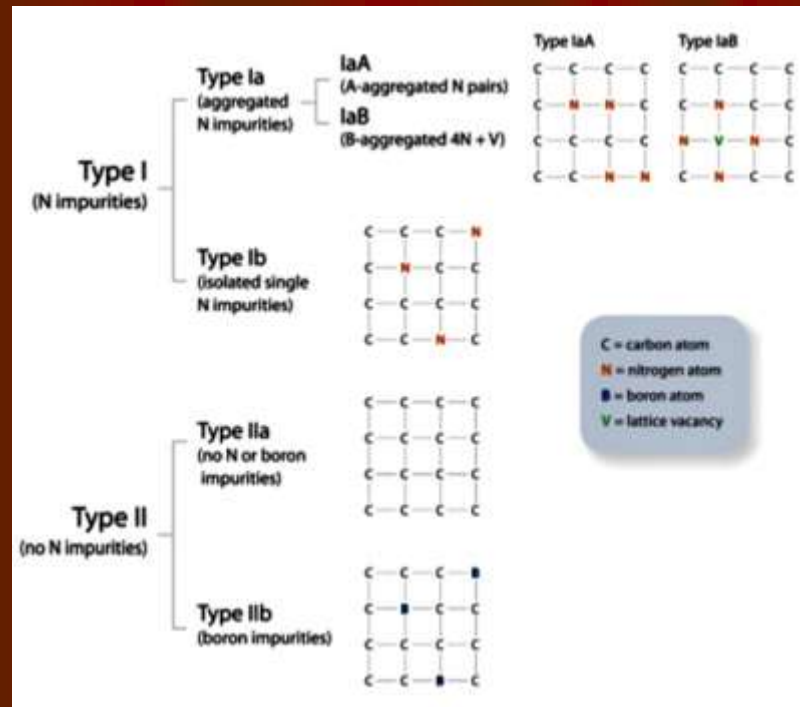


NATURAL DIAMOND CLASSIFICATION

品質分類

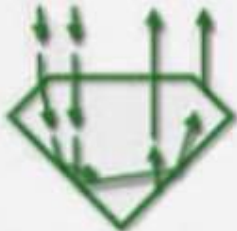
Diamonds are separated into four types Type Ia, Ib, IIa and IIb basis on the impurities (mainly nitrogen 氮 and boron 硼) measured at the atomic level within the crystal lattice of carbon atoms which can be detected by an infrared spectrometer 光譜儀

98% of gem diamonds are type Ia, Ib 1%, IIa 0.8%, IIb 0.2%



The 4 C standard

Introduced by Gemological Institute of America (GIA) in 1953

Cut	Color	Clarity	Carat
 Well Cut	 Colorless (D, E, F)	 <i>Flawless</i>	 2 <i>ct</i>
	 Near Colorless (G, H, I, J)	 <i>Very, Very Slightly Included</i>	 1 3/4 <i>ct</i>
 Too Shallow	 Faint Yellow (K, L, M)	 <i>Very Slightly Included</i>	 1 1/2 <i>ct</i>
	 Very Light Yellow (N, O, P, Q, R)	 <i>Slightly Included</i>	 1 1/4 <i>ct</i>
 Too Deep	 Light Yellow (S through Z)	 <i>Included</i> ₁	 1 <i>ct</i>
		 <i>Included</i> ₂	 3/4 <i>ct</i>
		 <i>Included</i> ₃	 1/2 <i>ct</i>
			 1/4 <i>ct</i>

1 ct = 1 carat = 0.2 gram

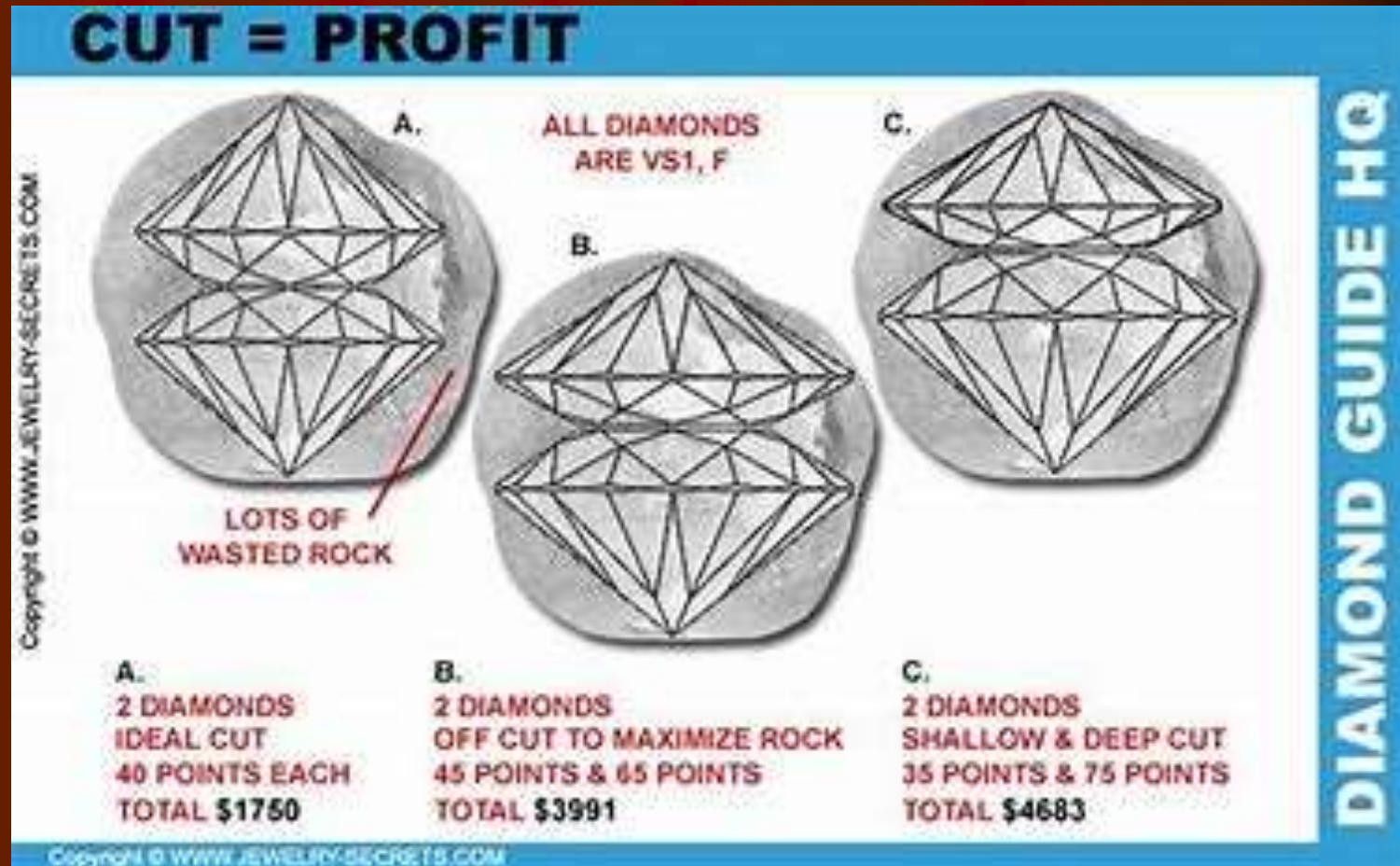
Cut 車工

Diamond cutting is the practice of changing a diamond from a rough stone into a faceted gem. This process requires specialized knowledge, tools, equipment and techniques including cleaving, bruting (shaping) & polishing



Diamond cutting has the following objectives

1. Maximise return on investment by finding the optimum way to cut the stone noting the importance of weight retention (carat value)



Three dimensional computer modeling used for cutting



7.02

Received:

56.8%



AGL

EXCELLENT

Scanox

Shape	Round
Grade	Ex
Weight	Ct 3.20
Diam.	mm 9.45
Length	mm
T.Depth	mm 5.90
T.Depth	% 62.4
L/W	
Cr.Angle	° 35.0
Cr.Depth	% 15.6
Pv.Angle	° 41.1
Pv.Depth	% 43.6
Table	% 55.3
Girdle	% 3.2
Rm.Angle	° 35.0

Result

	0.03(0.21) 14% AGL
	D I2 12 Ex
	0.04(0.12) 33% AGL
	D I2 16 Ex
	0.05(0.16) 31% AGL
	D I2 20 Ex
	0.07(0.43) 16% AGL
	D I2 27 Ex
	3.20(5.58) 46% AGL
	D I2 12800 Ex

3.20(4.24) 75.5%

8.40 x 10.51 - 6.78 / 80.7%

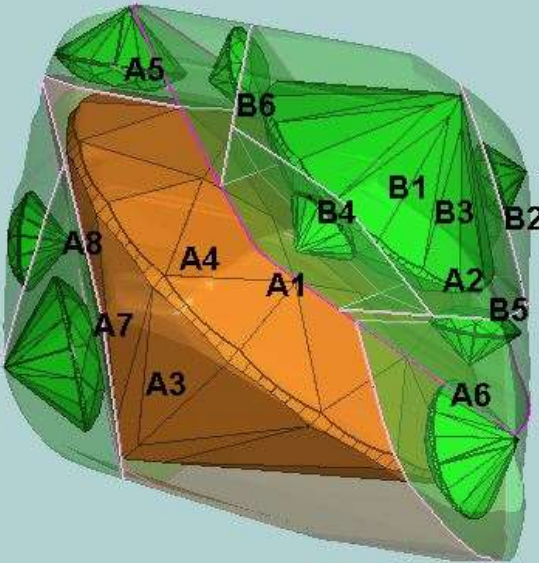
AGL Ex

12800\$ (4000\$)

rough

D I2

-0%



13507\$

1924\$







History

Viewer

CTIC ROUG

Whole

Cut

Video

Measure

Saw

Label

Control Panel

Exit

OGI Systems

15:39:43

F1

F2

F3

F4



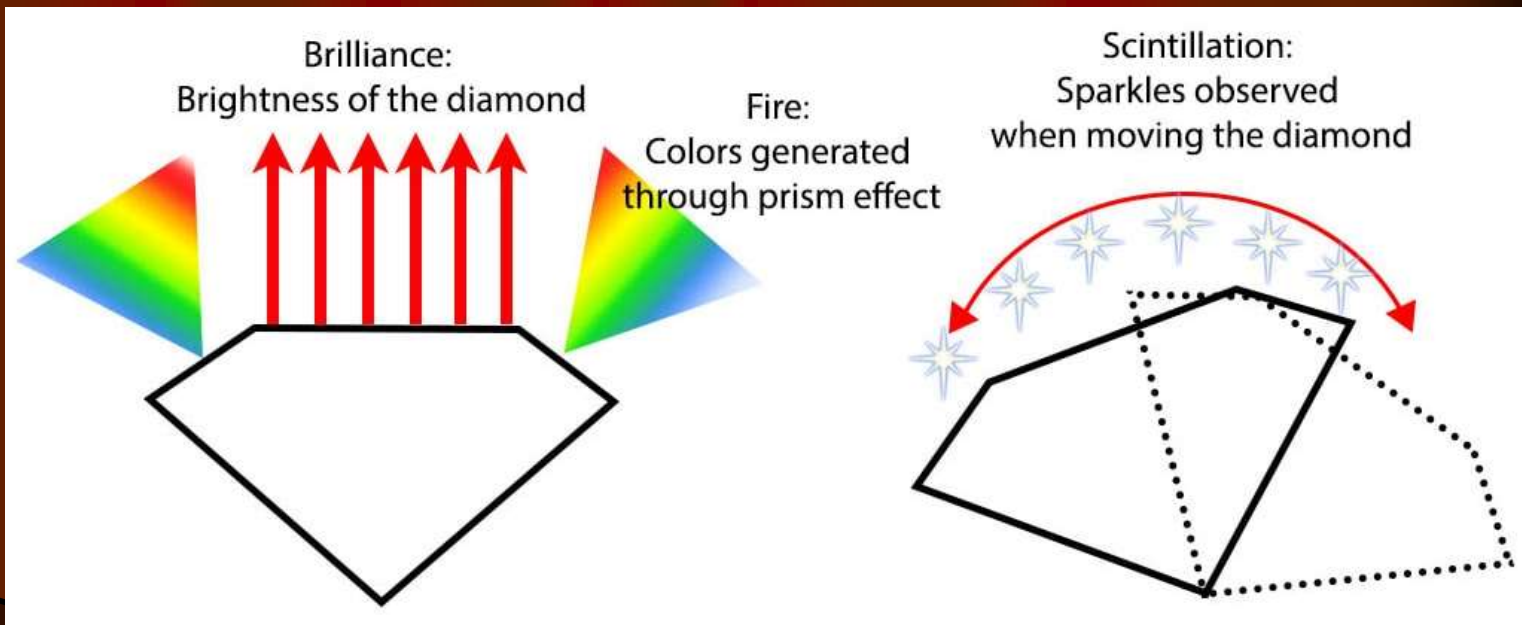
Limitations

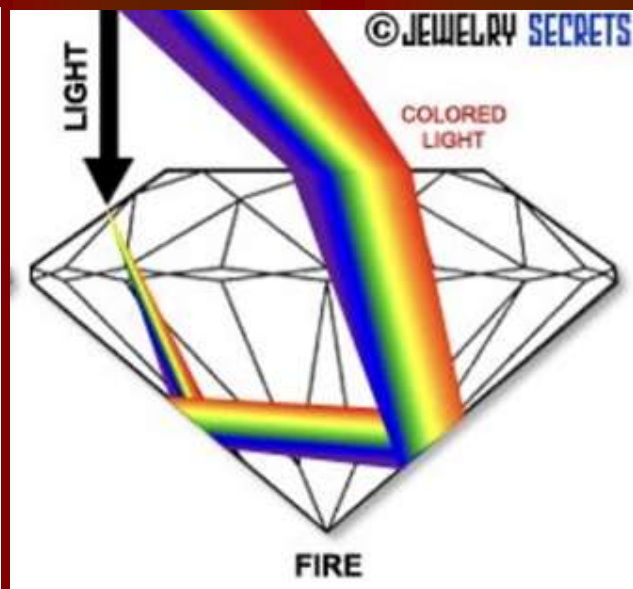
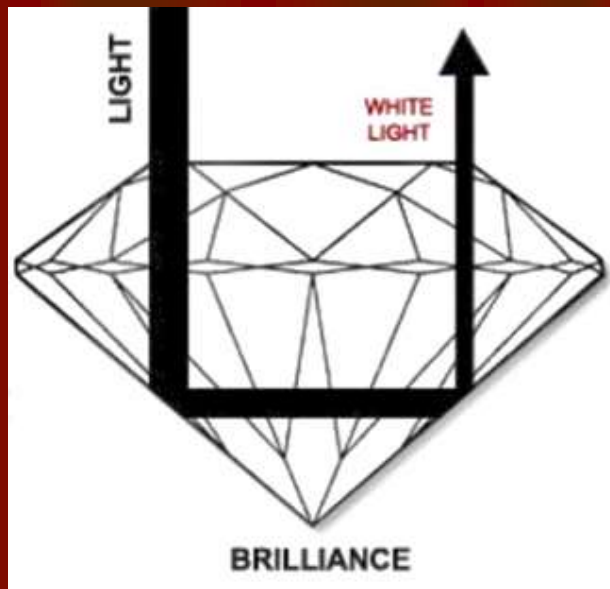
2. Create the most desirable shape. The round brilliant cut is most referred for octahedron crystals. All the others are called Fancy Cuts 雜形石



3. Create the most desirable visual effects including :

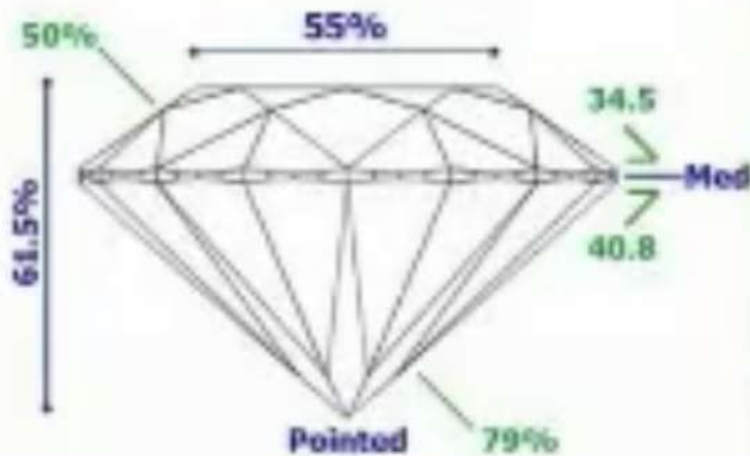
- a. Brilliance 光 – the internal and external white light reflected from a diamond
- b. Fire 火 – the scattering of white light into all colours of the rainbow through refraction
- c. Scintillation 閃 – the amount of sparkle a diamond produces as it moves





CUT ASSESSMENT

PROPORTIONS and PERFORMANCE



PROPORTIONS

Takes Outer Measurements
To Predict Appearance

Looks at 'CONTAINER'



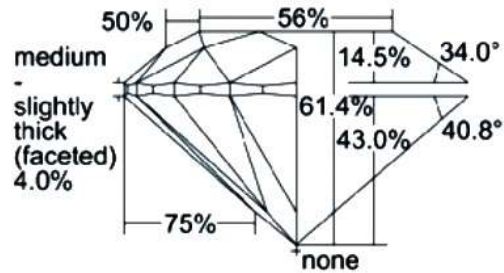
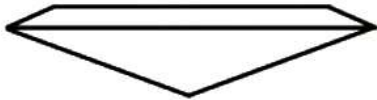
PERFORMANCE

Takes Actual Diamond
And Measures Light Output

Looks at 'CONTENTS'

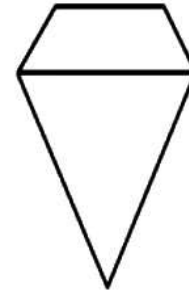
PROPORTIONS

Brighter & Bigger



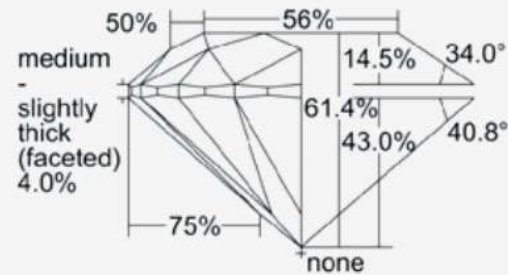
Profile to actual proportions

Higher Fire & Scintillation



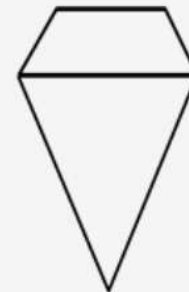
PROPORTIONS

light leakage

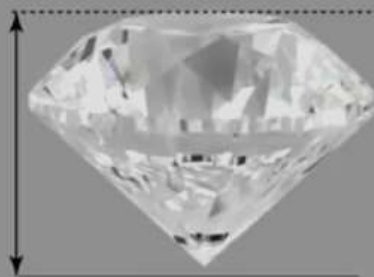


Profile to actual proportions

appear smaller



Same carat weight (0.72 Ct)



steep / deep cut



Ideal cut



shallow cut



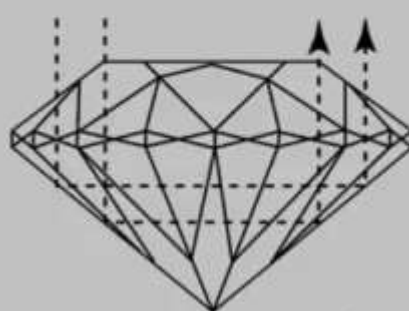
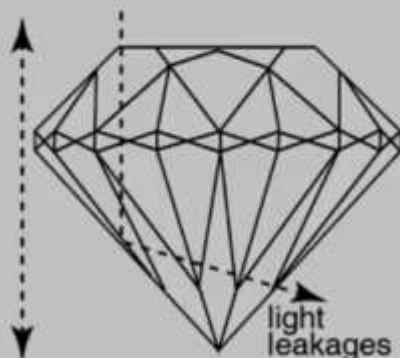
steep / deep cut



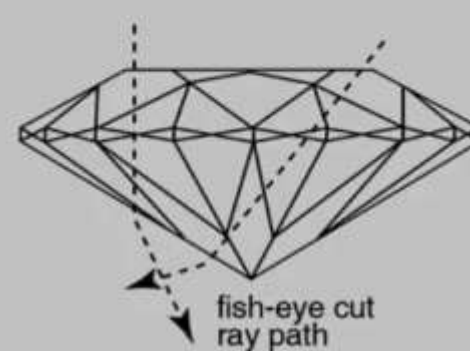
Ideal cut



shallow cut



maximise carat weight
& light performance



PROPORTIONS



IDEAL



SHALLOW



DEEP



VERY SHALLOW



VERY DEEP



EXCELLENT



GOOD



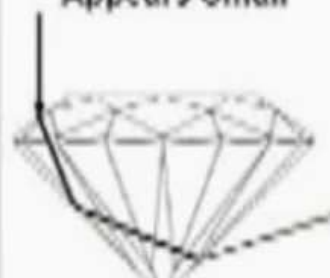
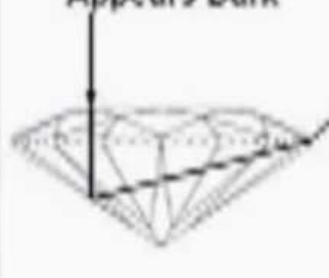
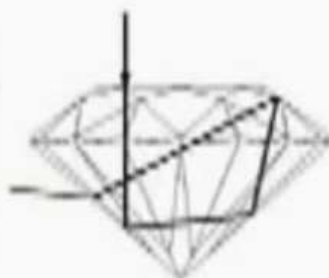
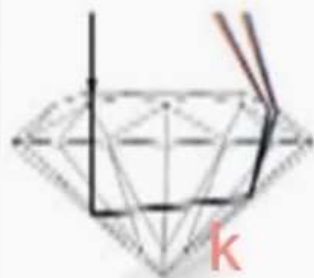
POOR



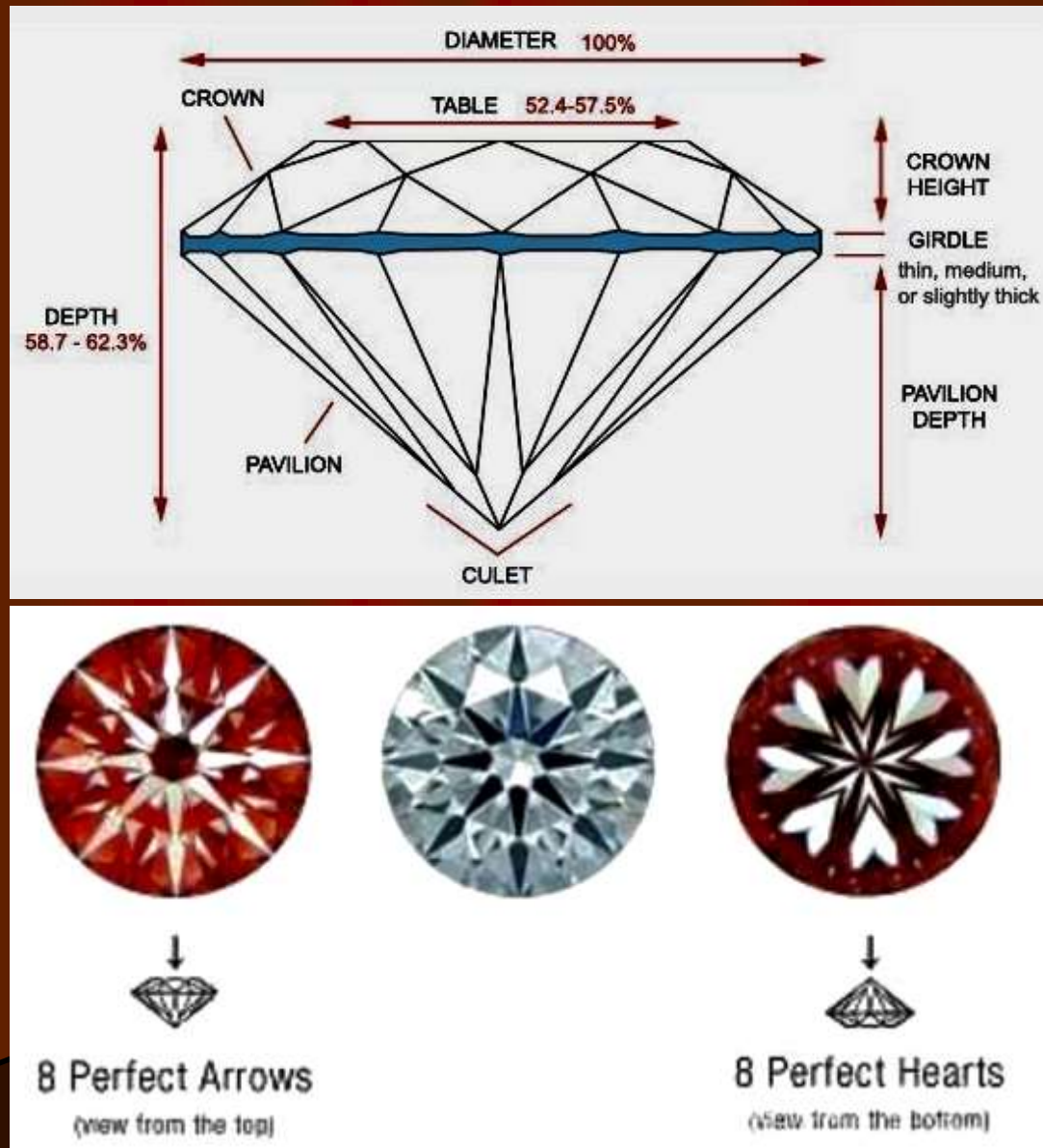
POOR
Appears Dark

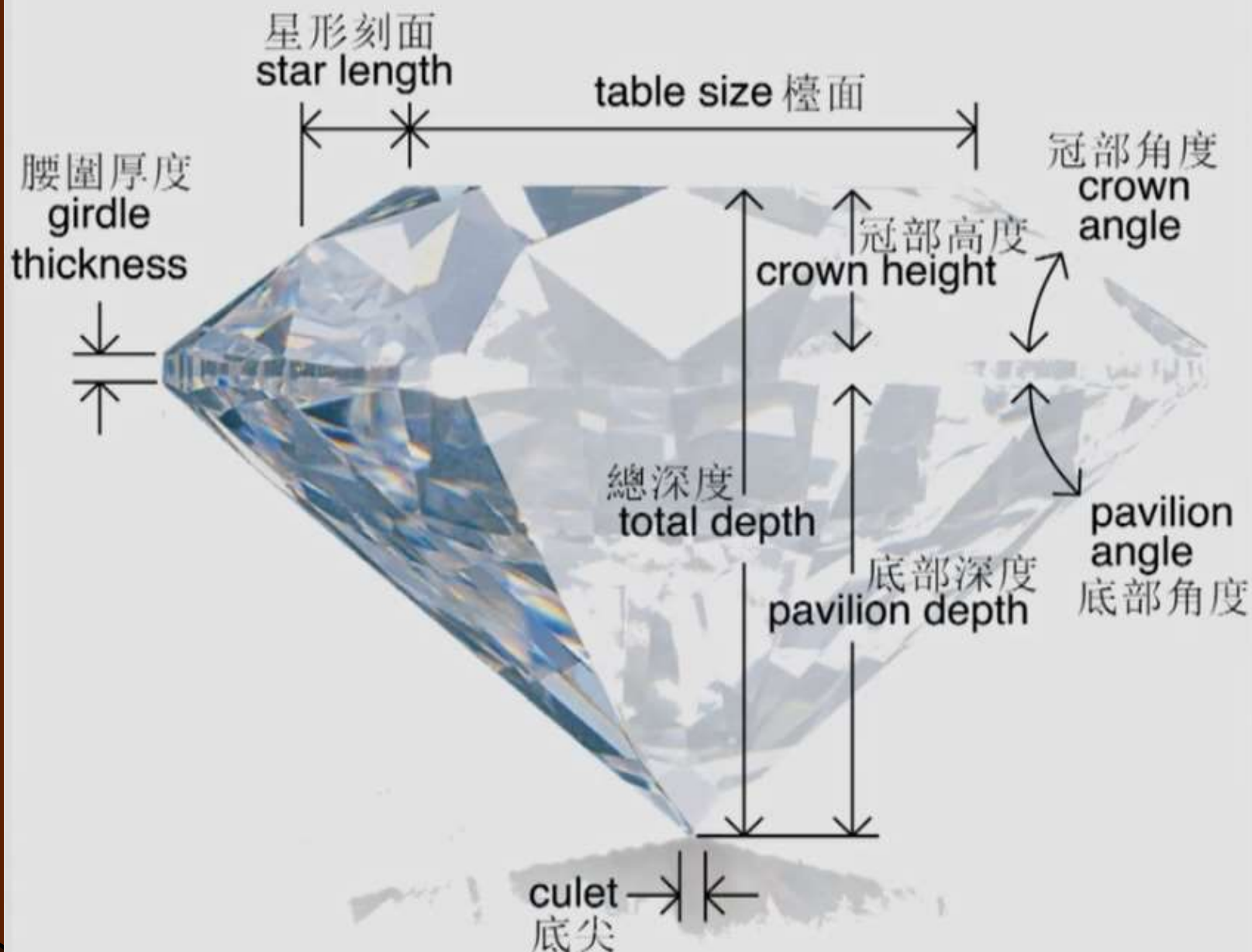


VERY POOR
Appears Small



An Ideal Brilliant-cut round diamond has 58 facets & displace 8 Perfect Arrows 8 Perfect Hearts 八心八箭



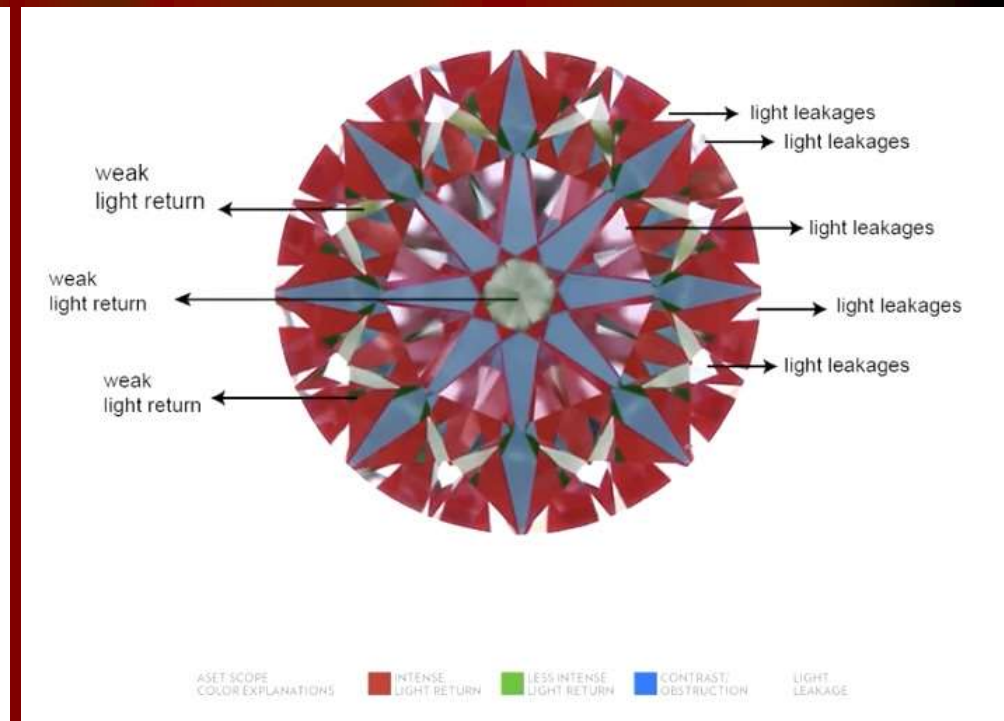
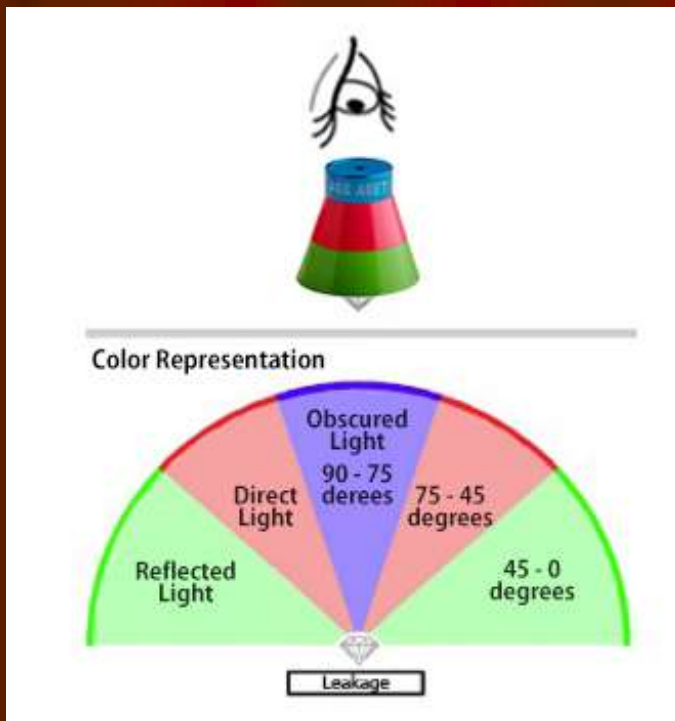


Angular Spectrum Evaluation Tool - Aset Scope

An asset scope is used to analyze the diamond's light performance

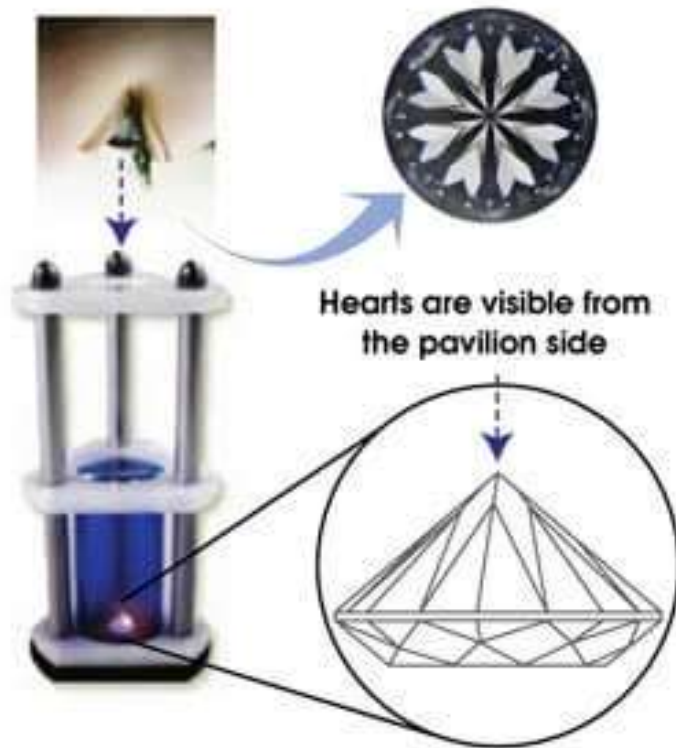
Pink/Black = facets reflecting like a mirror

Clear/white = facets leaking light like a window

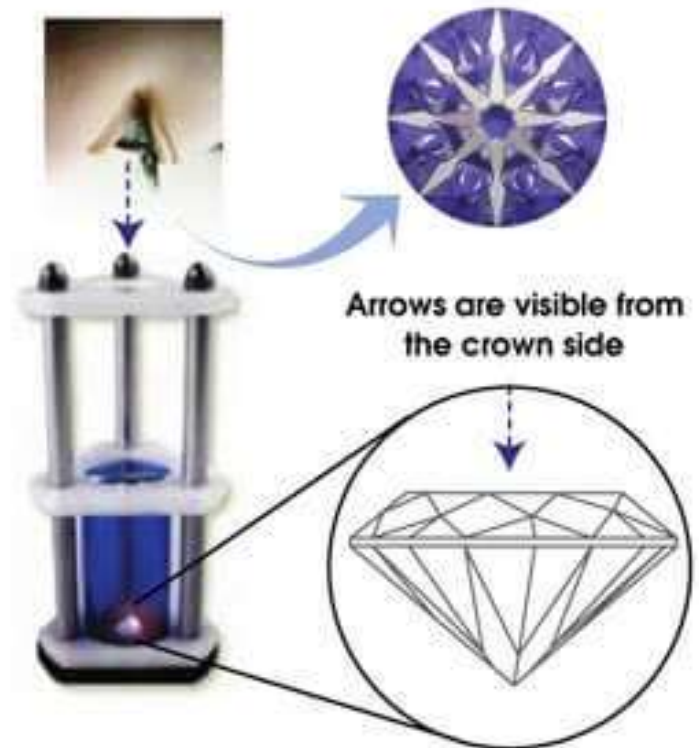


An Ideal Scope Viewer is used to measure optical symmetry

Pavillion



Crown



IDEAL-SCOPE



ASET



Ideal-Scope Use



Structured Light Environment

Ideal-Scope reveals overall light return



IDEAL



AVERAGE



POOR



Interpreting Ideal-Scope Images

FINE CUT



AVERAGE CUT



POORLY CUT



Black Areas = High Angle Light Return (+)

Red Areas = Optimum Light Return (+)

Pink Areas = Low Angle Light Return

White Areas = Light Escape or 'Leakage' (-)

High Performance

Above Average

Common

Poor

AGS ASET Scope ® Images



Ideal-Scope ® Images



Substandard cutting

Symmetry factors

- Uneven outline
- Table off centre
- Culet off centre
- Wavy Girdle
- Misaligned facets
- Facets not pointed properly



Polish quality-need smooth mirror like finish

Polish Lines



Polishing lines on diamond © Gem-A

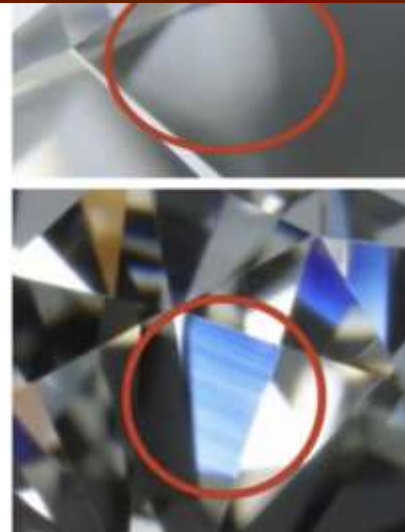


Image courtesy of the Russian Gemmological Center

Grading of Cut

All cuts should be well proportioned, with good symmetry & nicely polished
Cut grading only applies to round diamond and not for fancy cut

GIA Cut Grade (Evaluation based on girdle thickness, finish and culet size)

Excellent	Very Good	Good	Fair	Poor
-----------	-----------	------	------	------

AGS Cut Scale (Evaluation based on light quality, proportion, and finish)

Ideal	1 2	3 4	5 6 7	8 9 10
-------	-----	-----	-------	--------

* Diamonds graded excellent to good on the GIA scale, and Ideal - 4 on the AGS scale, look very similar to the untrained eye. Diamonds below these values have decreasing brilliance and fire and increasing threats to durability and strength qualities of the diamond.

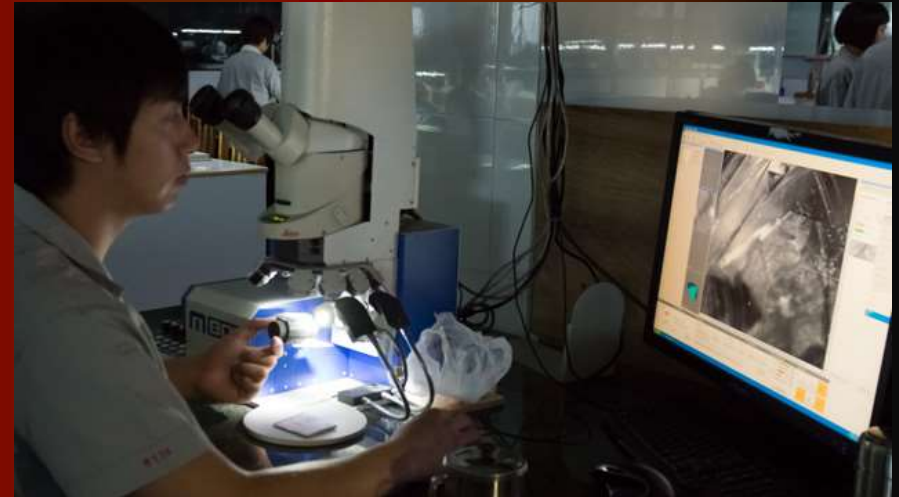
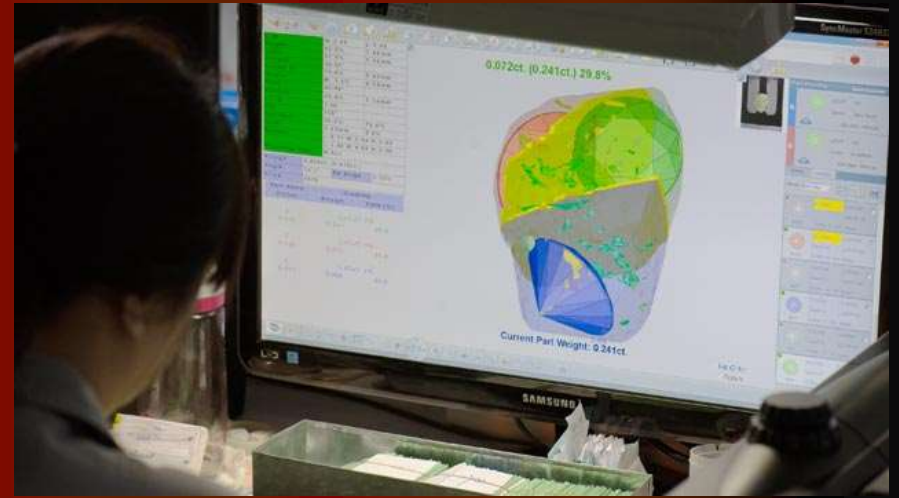
- World's leading Cut/Polishing Centres are India (Mumbai/Surat), Israel (Ramat Gan), Russia, South Africa (Johannesburg), Belgium (Antwerp), USA (New York), Holland (Amsterdam) & China (Guangzhou/Shenzhen). 90% of all polished stones are cut and polished in India due to low labour cost (India US\$10 per hour vs US\$100 per hour in USA). China only started 20 years ago but is growing fast to become one of the biggest players. However top end stones are usually polished in New York, Antwerp and Rotterdam



- The diamond cutting and polishing business in India created 500,000 jobs in Surat alone. China has over 100,000. 周大福 Chow Tai Fook has a center in 佛山倫教. Israel & Belgium have lost much of their business. Israel now employs 1,000 people & only a few hundred in Antwerp handling mainly expensive stones

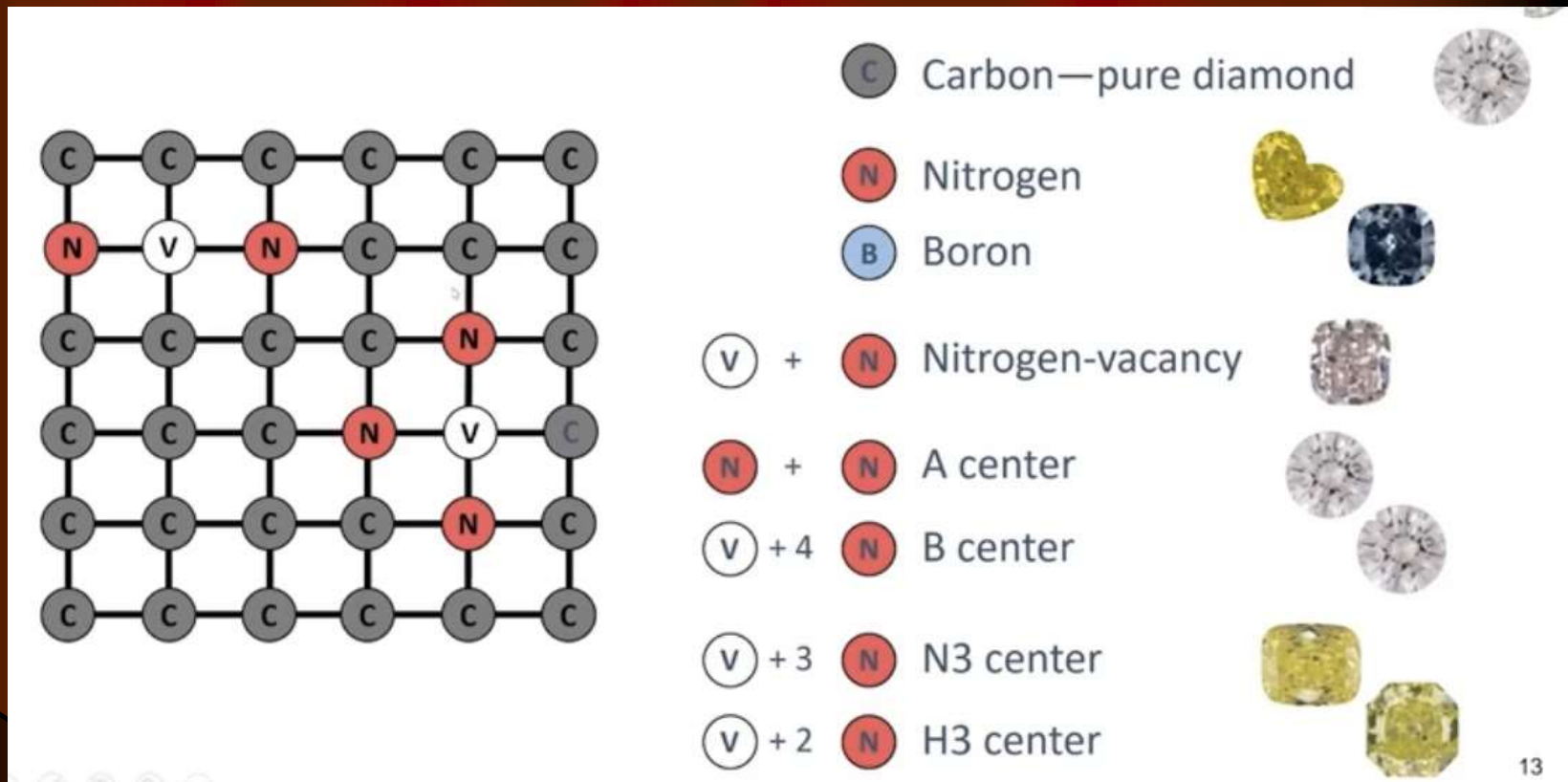
Chow Tai Fook diamond cutting factory



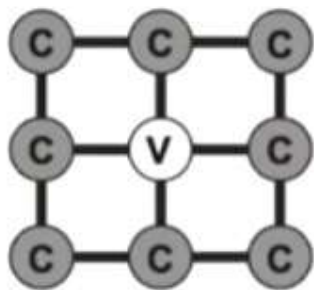


Color 成色

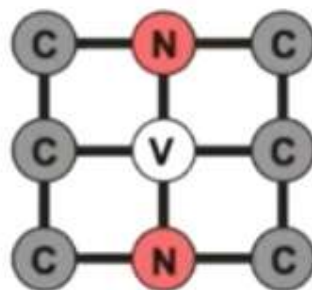
A perfect diamond has no color. The color of diamond is the result of chemical impurities or structural defects in the crystal lattice including vacancy, vacancy cluster, interstitial, deformation & their combinations. Some defects selectively absorb visible light. When their concentrations are suitable, diamonds will show fancy colors



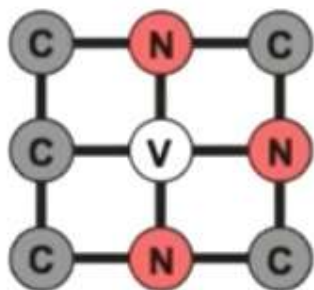
GR1 (V^0)



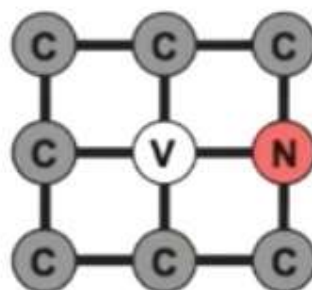
H3 (NVN^0)



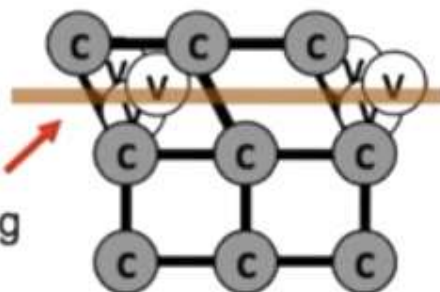
N3 (VN_3)



$NV^{0/-}$



Vacancy Clusters



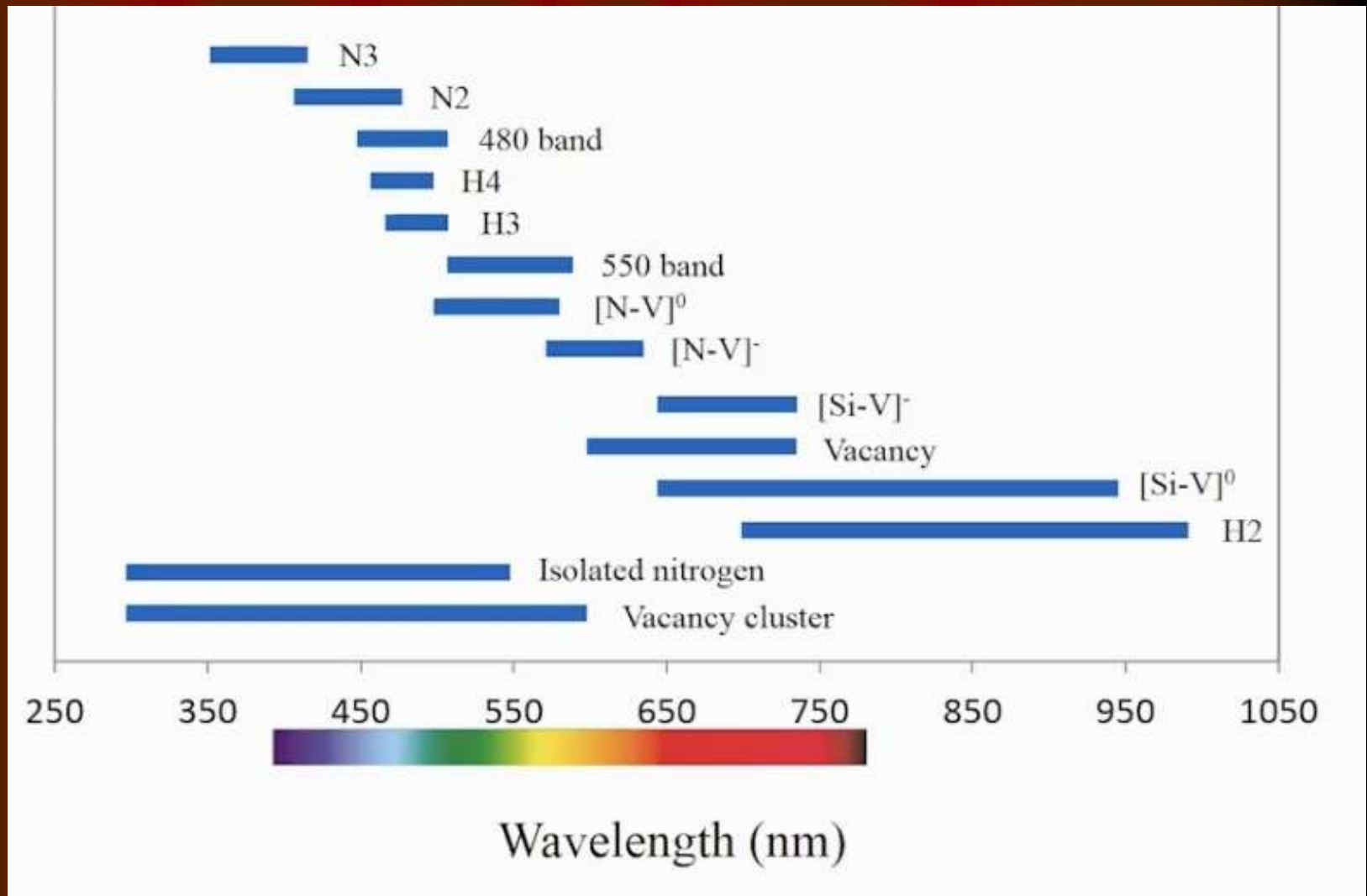
Brown Graining

Develops due to plastic deformation

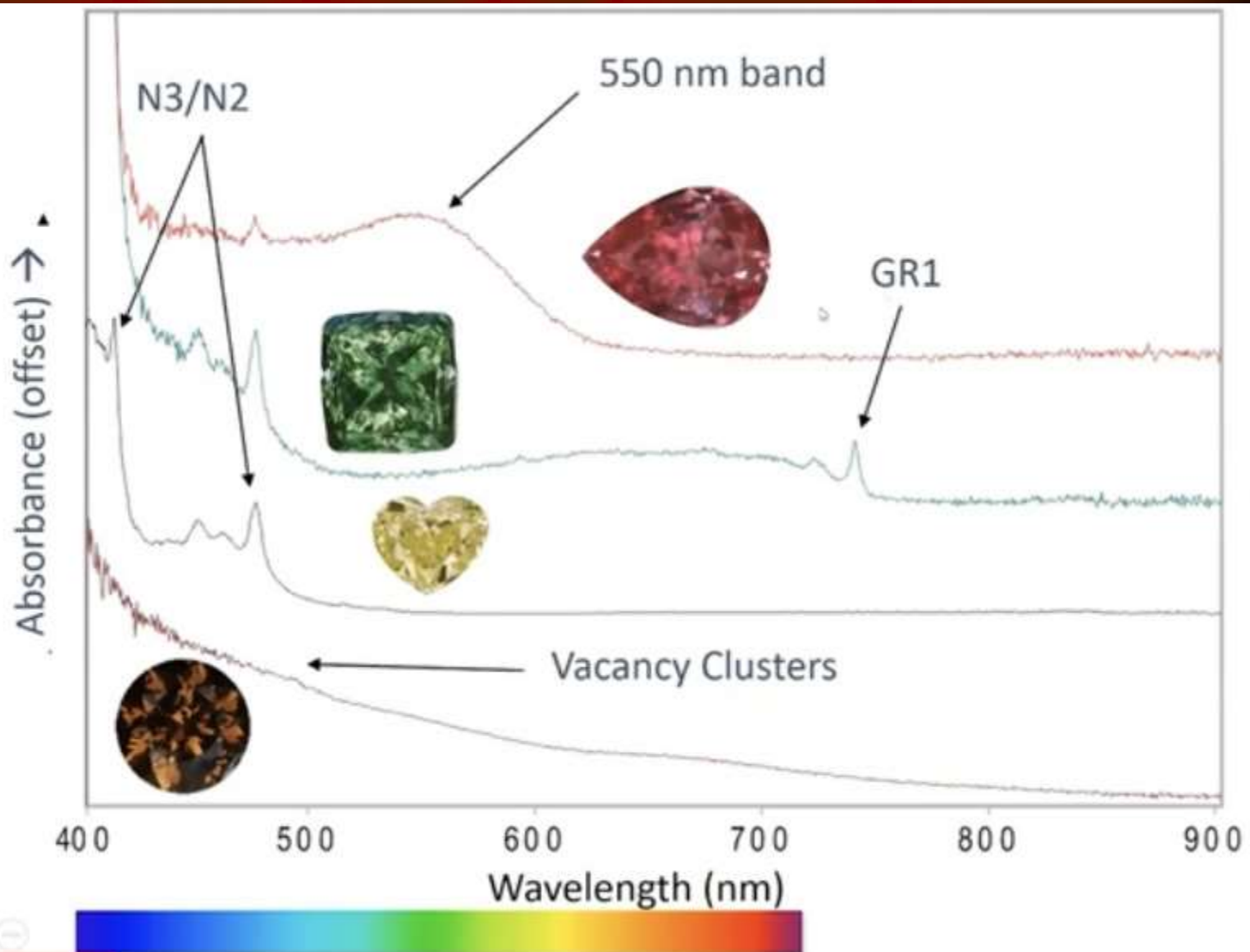


700

Relationship between observable color, impurities and lattice defects



Visible Absorption and Color



Two Scales

I. Colorless diamond/white diamond

It is divided into 23 grades from D to Z by GIA from Colorless to Near Colorless to Faint Yellow to Very Light Yellow to Light Yellow. Fancy color diamonds such as yellow, red, pink and blue are graded on a separate color scale

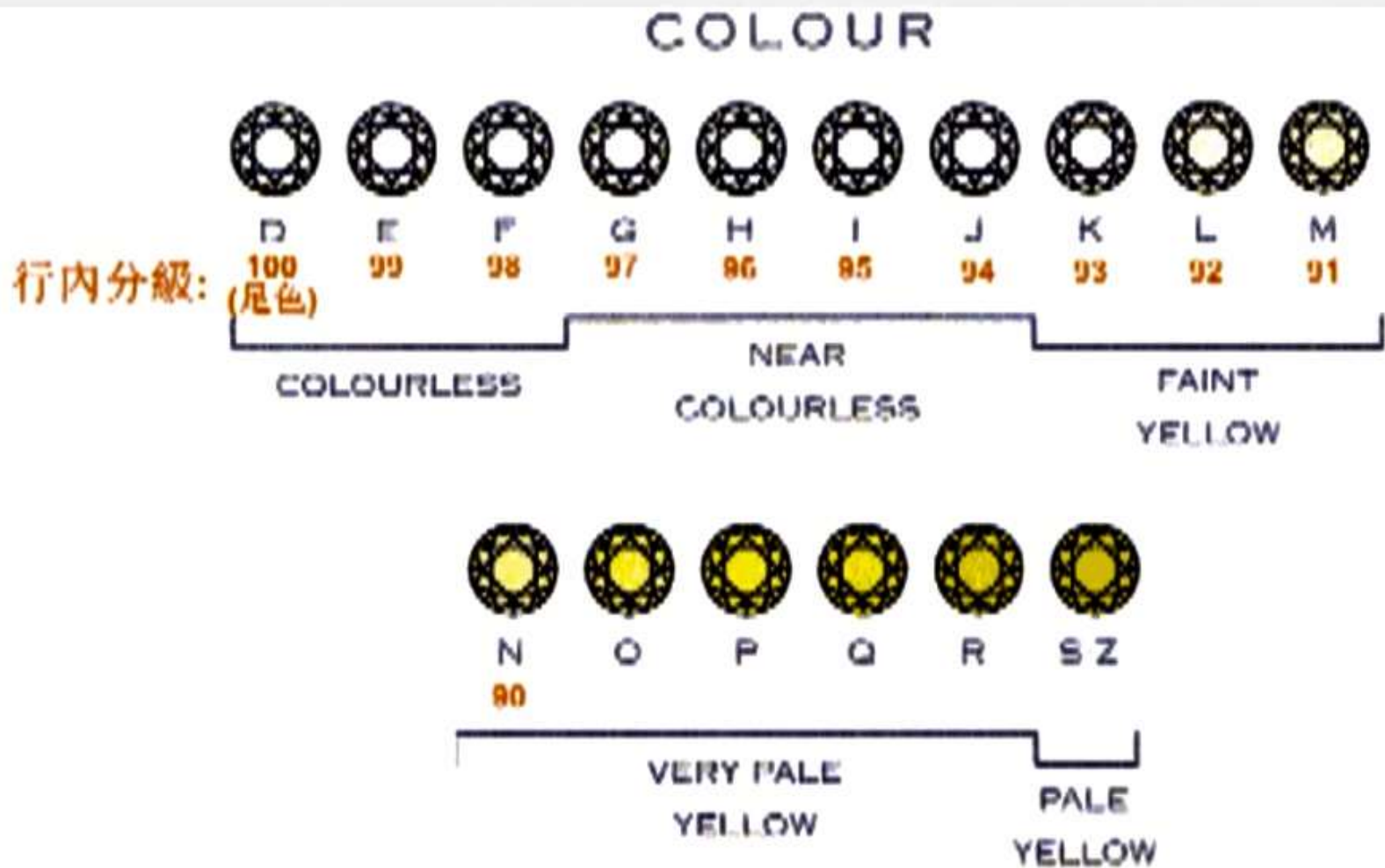


Color is best be observed & compared sideways



GIA	CIBJO	AGS	General Appearance
D	Exceptional White +	0	Table up colourless, table down colourless
E	Exceptional White	0.5	
F	Rare White +	1	Table up colourless, table down colourless but not as bright as above
G	Rare White	1.5	
H	White	2	Table up colourless, table down very slightly tinted
I	Slightly Tinted White	2.5	Table up slightly tinted
J	Slightly Tinted White	3	Table down very slightly tinted
K	Tinted White	3.5	Table up slightly tinted
L	Tinted White	4	Table down obviously tinted
M-Z (Tinted)	Tinted Colour	4.5 -10	Table up obviously tinted, table down very obviously tinted
Fancy	Fancy Colour		Table up definite colour

Color Grading System for white diamond used by jewelers in Hong Kong



II. Fancy Color Diamonds 彩鑽

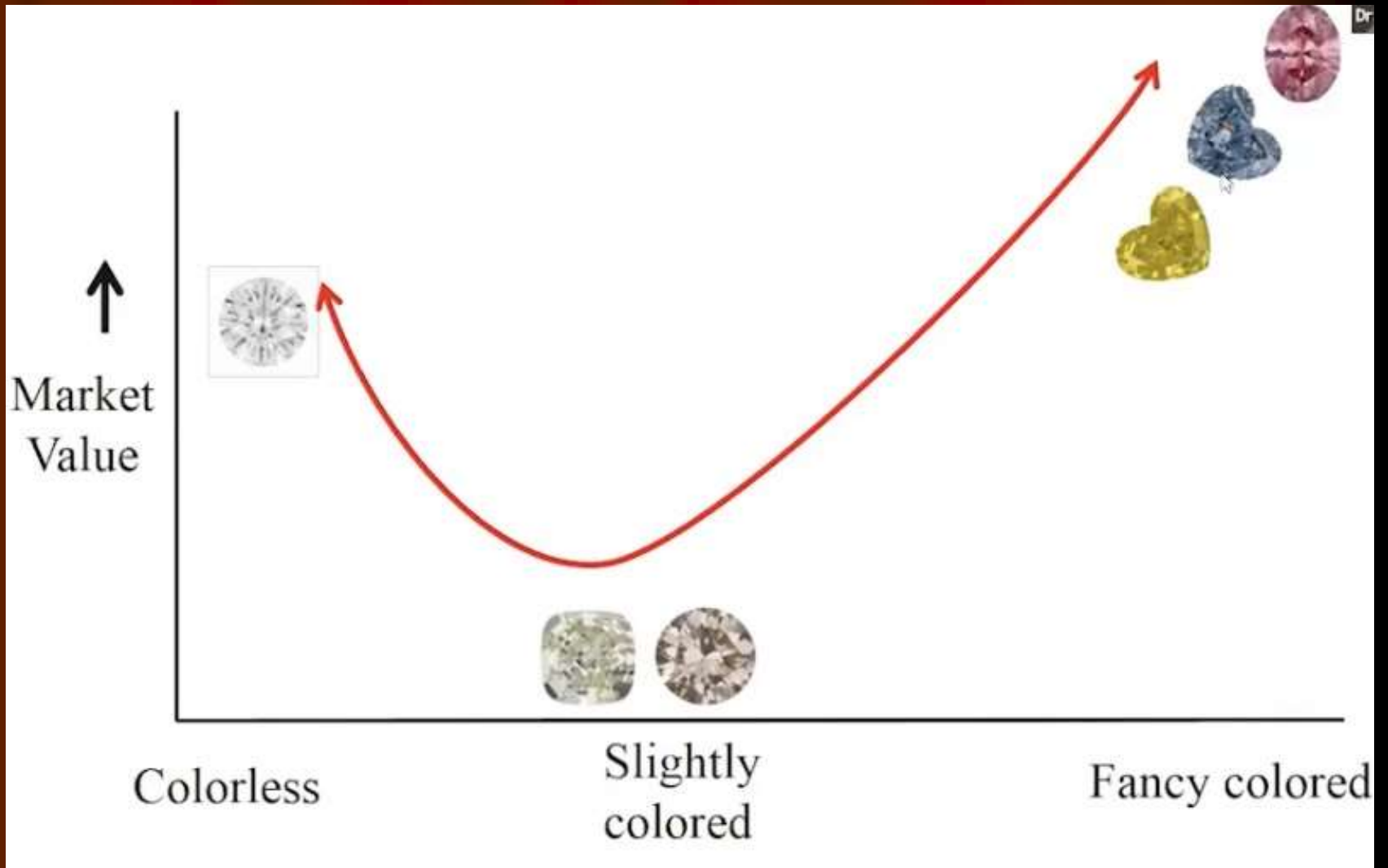
Diamonds beyond the color grade "Z" are called fancy color diamonds.

Here the opposite is true: The value usually **increases** the more obvious the color becomes

Only 1 in 10,000 diamonds has a fancy color!



Relationship between color & market value



Fancy colored diamonds are found in nature by lattice defects or due to contamination by chemical impurities e.g. yellow by nitrogen; brown by nickel; blue by boron; green by radiation exposure; red and pink diamond due to the change of the electron structure during its journey to the surface and they are rare



Similar colors could be attributed to entirely different lattice defects



550 nm band



N-V Centers

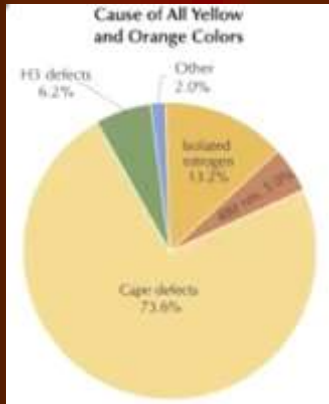


- Color darkness is proportional to the concentration of defects
- When defect concentration is very high, diamond turns black
- Brown is the most common color in natural diamonds. It is attributed to defect of "vacancy cluster"

- Four major causes for blue/grey colored diamonds – Boron, Hydrogen impurities, Irradiation (GR1) and Inclusions



- Yellow is the most common fancy diamonds and its close relative orange is the rarest. Majority of the yellow and orange colors are caused by Cape defects (N3 and associated absorption)





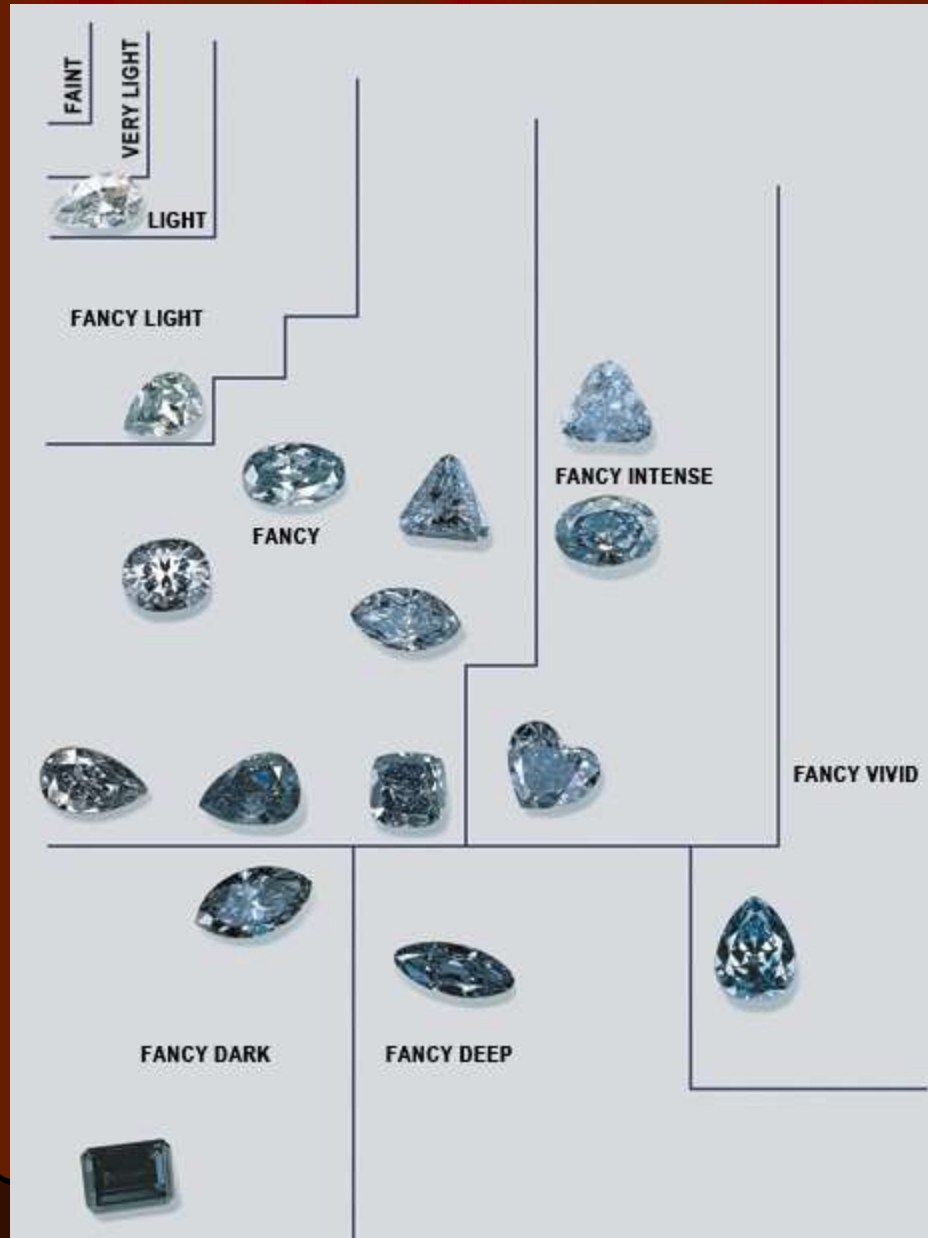
- Unlike colorless diamond fancy color diamonds are evaluated less for brilliance or fire and more for color intensity. Shades that are deep and distinct are rated higher than weak or pale shades. There are 27 hues 色譜 then tone and saturation 色調/深度 is described by terms starting from “Faint” to “Fancy Deep”



Tone and Saturation



Fancy blue colour grading



Fancy pink colour grading

Purple Pink Diamonds	Pink Diamonds	Brownish Pink	Pink Champagne	Champagne
 1PP	 1P	 1BP		 Fancy Cognac
 2PP	 2P	 2BP	 PC3	 C7
 3PP	 3P	 3BP		 C6
 4PP	 4P	 4BP	 PC2	 C5
 5PP	 5P	 5BP		 C4
 6PP	 6P	 6BP	 PC1	 C3
 7PP	 7P	 7BP		 C2
 8PP	 8P	 8BP		 C1

1PP is the most expensive; prices and intensity reduce down the chart and across to the right. PC1 is light champagne with a secondary pink colour.

Every thing equal, pink diamond is more expensive than white diamond



\$116,000



\$21,000



\$500,000+



\$23,500



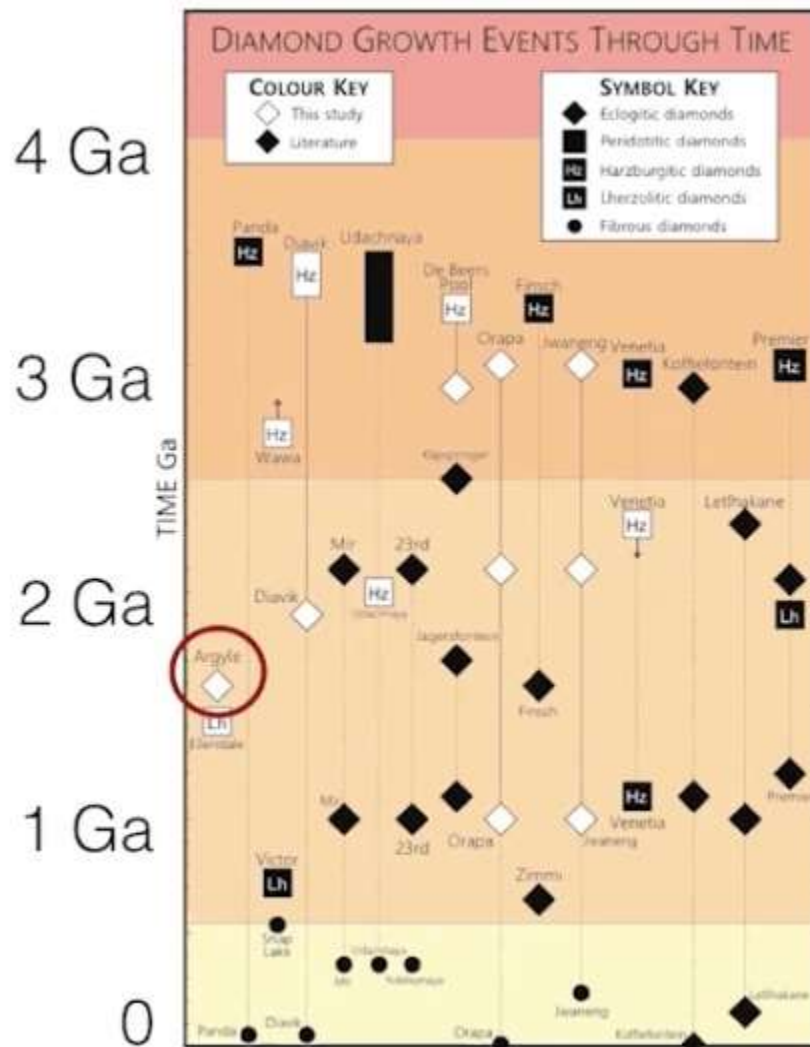
\$650,000



\$4,000

- The only known significant pink and red diamonds are from the Argyle diamond mine in Western Australia. Only 0.01% is pink. These as well as other naturally coloured diamonds including champagne, cognac and rare blue diamond are mined from a lamproite pipe rather than kimberlite & not necessarily associated with craton. The mine stop production at 2020





Argyle diamonds

Eclogitic diamonds,
some of which are pink
formed around 1.6 Ga

Richardson, 1986



Copyright © 2018 Rio Tinto
Argyle mine, Kimberley Craton, Australia



Copyright © 2018 Rio Tinto



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"Black diamond" or Carbonado diamond

It is the toughest form of natural diamond which is only found in Brazil and Central Africa Republic & unassociated with mantle rocks. They are aggregates of a bunch of randomly arranged microcrystals with pores. Their origin is controversial which includes simply impure diamond consisting of diamond, graphite and amorphous carbon to direct conversion of organic carbon under high pressure; radiation induced formation; shock metamorphism; explosion of a giant star (supernova) near earth and impact of an asteroid 2.6 to 3.8 billion years ago



Black diamond owe their colour to the inclusion of graphite & random clustering throughout the diamond. It has only one colour intensity Fancy Black. Brilliant is not their strong side

Evaluating Black Diamonds

Cut Variables



Rose Cut



Small Table



Large Table

Surface Reaching Inclusions



Major



Minor



Insignificant

Internal Characteristics



Opaque



Smoky



Minor visible
characteristics



Unique internal
characteristic

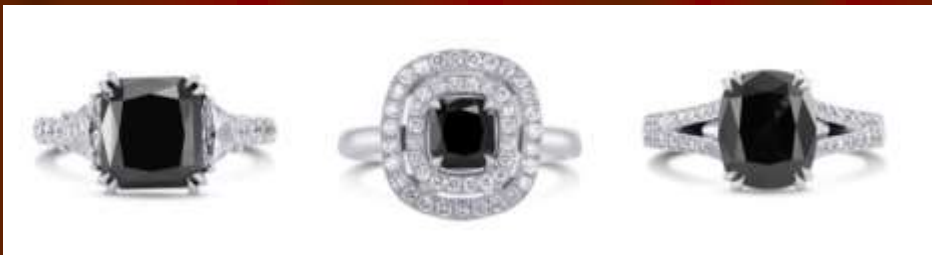


Significant
characteristics



Extreme
characteristics
with transparency

The demand of black diamonds has gone up substantially in recent years and became an amazingly desired fashion items. The price can easily be US\$3,000-5,000 per carat for diamonds weighing 1 to 3 carat. But do beware as most of the black diamonds in the market are not natural or natural but treated ones



Artificial Color

Color is strongly influenced by impurities/defects as well as artificial treatments such as irradiation, high temperature and high pressure

Type	Colors of Natural Diamonds	Colors of Treated Natural Diamonds	Colors of Synthetic and Treated Synthetic Diamonds
Ia			
Ib			
IIa			
IIb			

						
Vacancy	H3, H4		H2	N-V Centers		

Major Techniques for Diamond Color Treatments

- Irradiation with or without annealing
- Annealing under high-pressure and high-temperature (HPHT)
- Multiple treatment

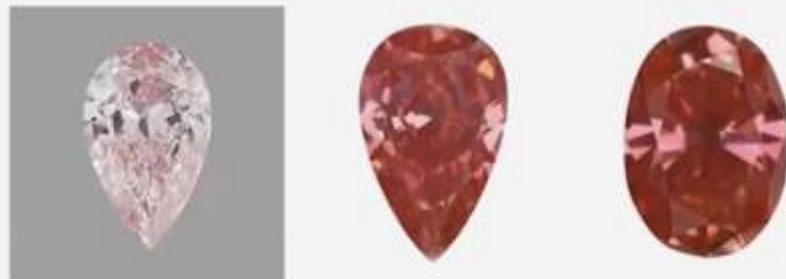
Natural brown diamond

↓ *HPHT*

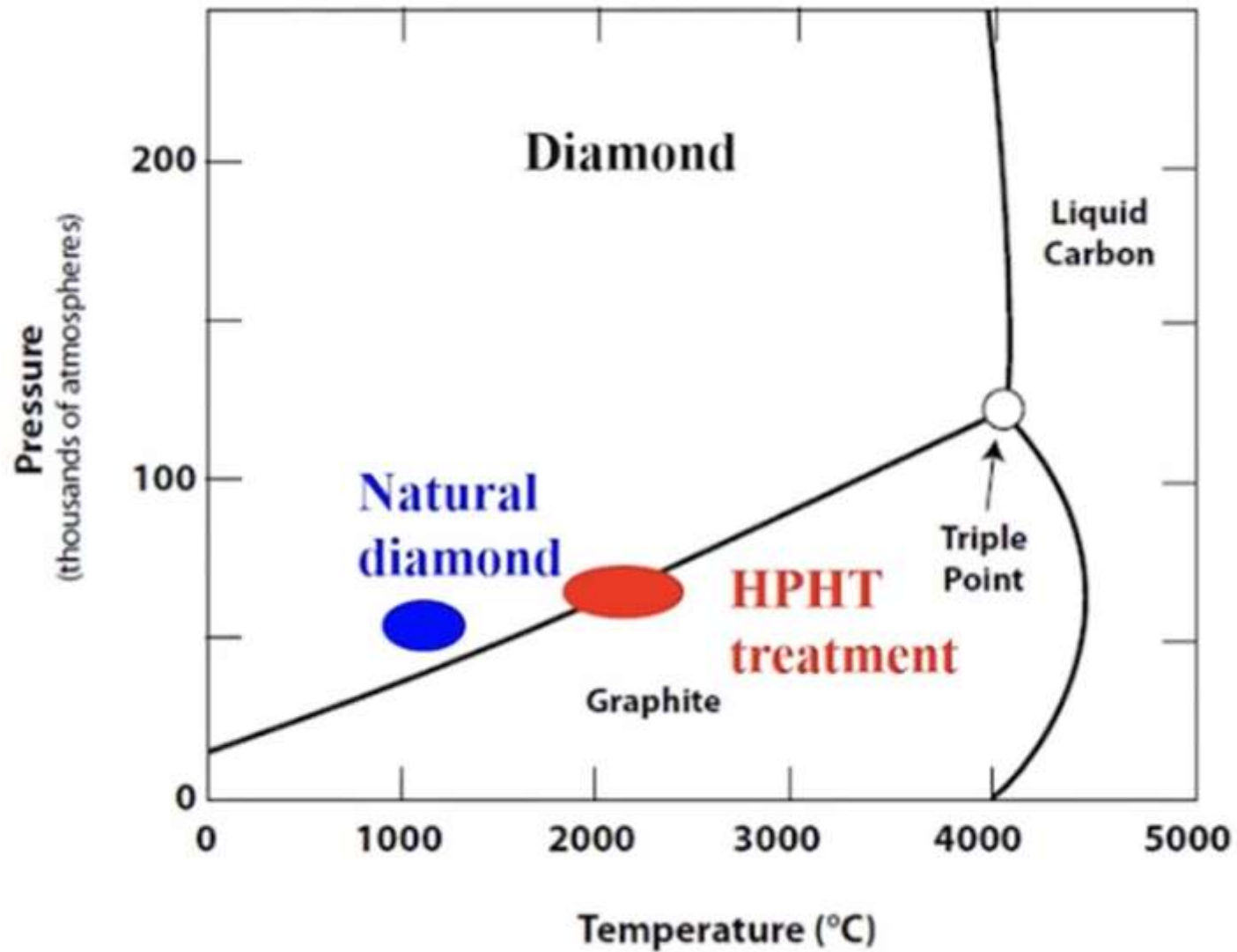
Remove brown color
Create isolated nitrogen

↓ *Irradiation
& Annealing*

Create vacancy
Create N-V centers



HPHT treatment comfort zone



Effect of HPHT treatment

Type Ia

Before



After



Effect of HPHT treatment

Type II

Before



After



Natural Iia Brown



3.72 ct



2.63 ct
FAN brY



2.63 ct
(HPHT)



2.55 ct
"F" color



1.67 ct
FAN brY



1.66 ct
(HPHT)



1.57 ct
"F" color

Clarity 淨度

This is for evaluating the number, size, relief, nature and position of internal Inclusions 包含物 and External Blemishes 瑕疵 that will spoil the appearance of the stone. The diamond is graded basis on 10 times magnification. Natural inclusion free diamonds are called "glassies"

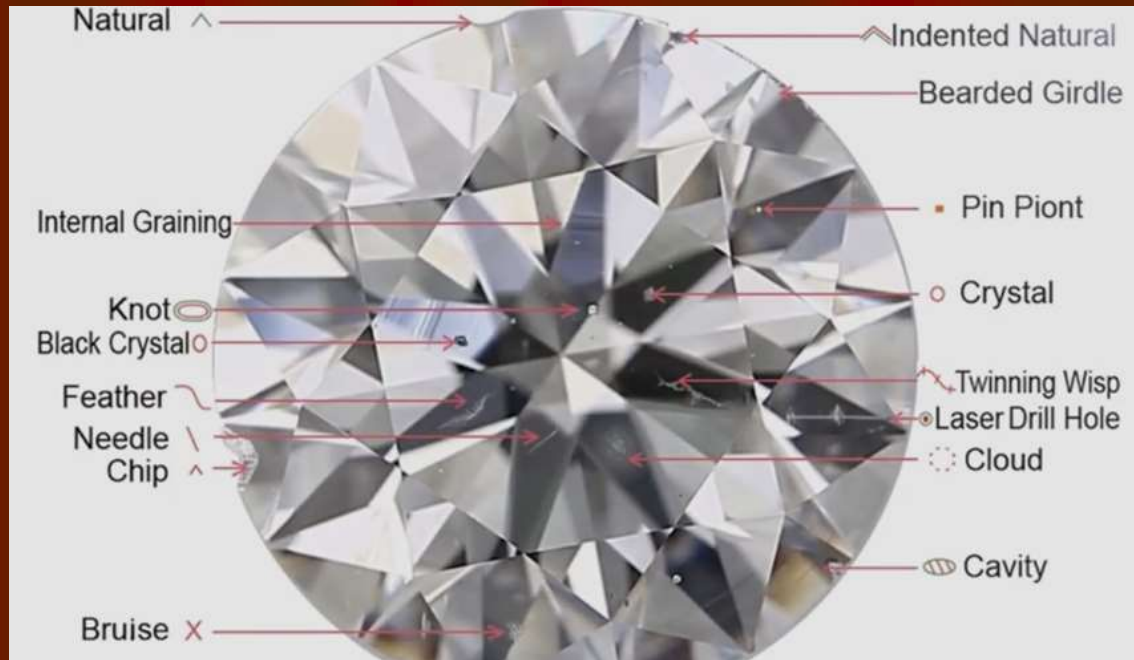
DIAMOND CLARITY CHART								
GRADE	FL	IF	VVS1, VVS2	VS1, VS2	SI1	SI2, SI3	I1, I2	I3
								
CATEGORY	FLAWLESS	INTERNALLY FLAWLESS	VERY VERY SLIGHTLY INCLUDED	VERY SLIGHTLY INCLUDED	SLIGHTLY INCLUDED		INCLUDED	



Clarity classification in Chinese



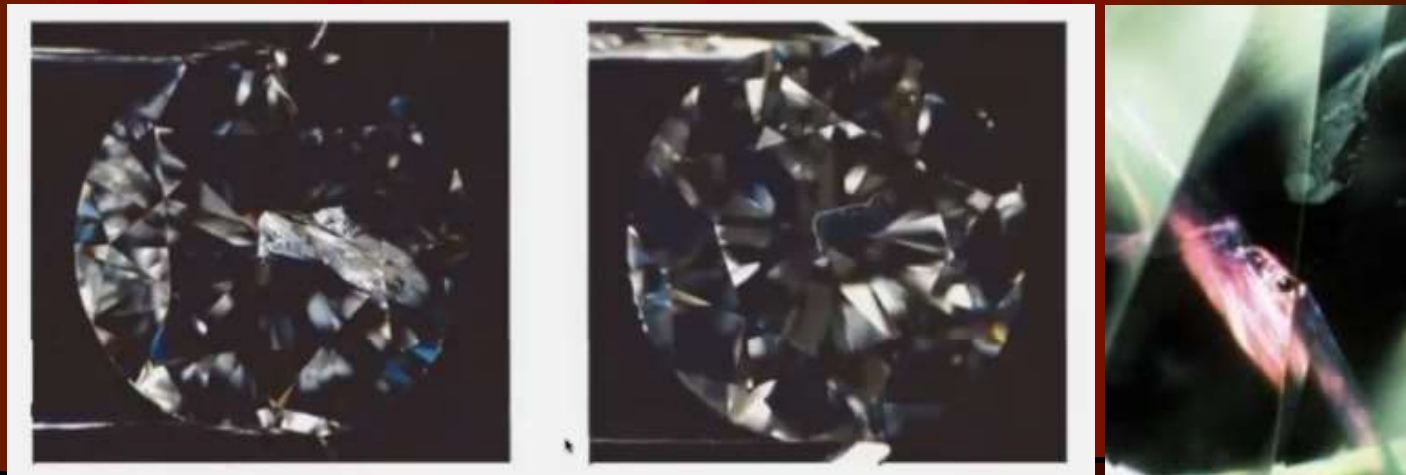
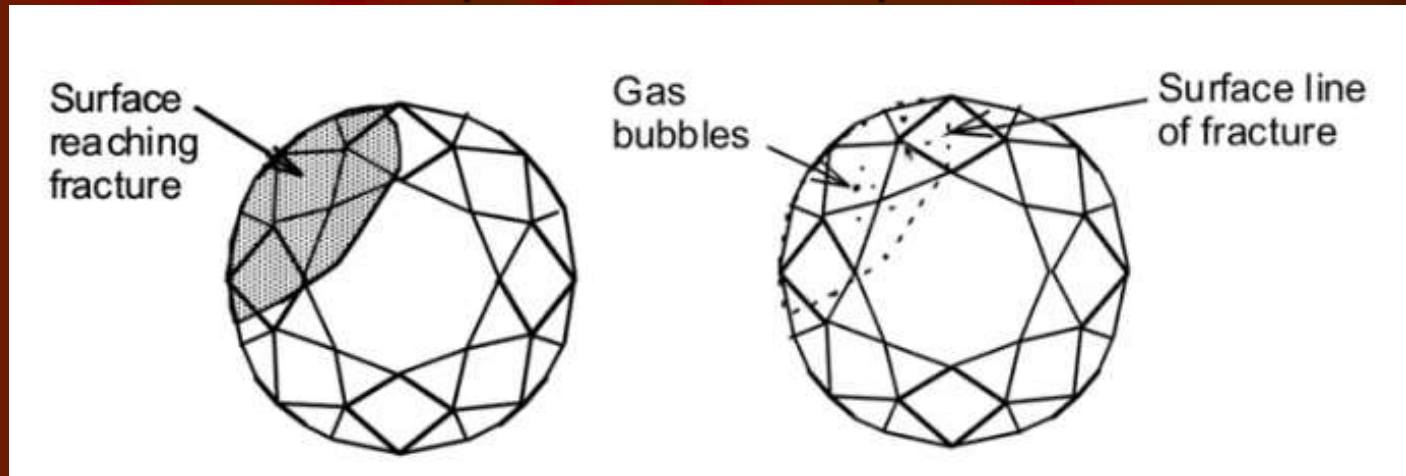
GIA Inclusion Symbols



INCLUSIONS - Imperfections or flaws inside of the diamond

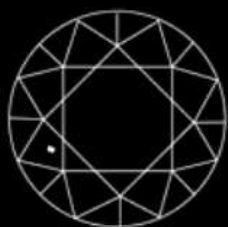


- Inclusions can be natural or man made the latter includes fracture fillings. In diamond the filling is High lead-content glass which sometimes may consist gas bubbles and “color flashes” caused by difference in dispersion

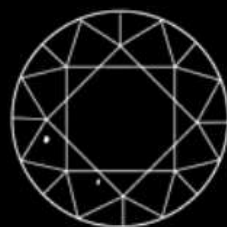
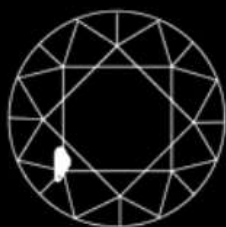


Factors to consider when grading clarity

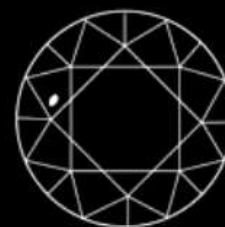
SEVERAL FACTORS TO BE CONSIDERED WHEN GRADING CLARITY



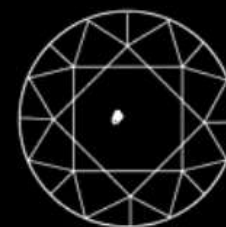
size



number



position / location



INTERNAL



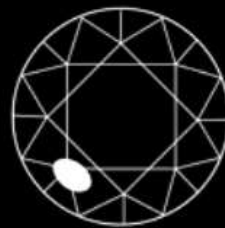
EXTERNAL



nature



color



Modern GIA grading system

GIA diamond clarity grading scale

Cate gory	Flawl ess	Inter nally Flawl ess	Very Very Slightly Included		Very Slightly Included		Slightly Included		Included		
Grad e	FL	IF	VVS 1	VVS 2	VS₁	VS₂	SI₁	SI₂	I₁	I₂	I₃

American Gem Society



AGS diamond clarity grading scale

GI A	FL	IF	VVS ₁	VVS ₂	VS ₁	VS ₂	SI ₁	SI ₂	I ₁	I ₂	I ₃
AG S	0	1	2	3	4	5	6	7	8	9	10

International Diamond Council



IDC diamond clarity grading scale

GIA	FL	IF	VVS ₁	VVS ₂	VS ₁	VS ₂	SI ₁	SI ₂	I ₁	I ₂	I ₃
IDC	Loupe clean	Loupe clean	VVS ₁	VVS ₂	VS ₁	VS ₂	SI ₁	SI ₂	P _I	P _{II}	P _{III}

European Gemological Laboratory



EGL diamond clarity grading scales

GIA	FL	IF	VVS ₁	VVS ₂	VS ₁	VS ₂	SI ₁	SI ₂	I ₁	I ₂	I ₃	
EGL USA ^[8]	IF		VVS ₁	VVS ₂	VS ₁	VS ₂	SI ₁	SI ₂	SI ₃ ^[9]	I ₁	I ₂	I ₃
EGL India ^[10]	FL	IF	VVS ₁	VVS ₂	VS ₁	VS ₂	SI ₁	SI ₂	SI ₃	P ₁	P ₂	P ₃

GIA		Definition	CIBJO	
FL	Flawless	No inclusions or blemishes	LC	Loupe Clean
IF	Internally Flawless	No inclusions, insignificant blemishes		
VVS1	Very very slightly included	Minute inclusions: Extremely difficult to see	VVS1	Very very small inclusions
VVS2		Minute inclusions: Very difficult to see	VVS2	
VS1	Very slightly included	Minor inclusions: Difficult to see	VS1	Very small inclusions
VS2		Minor inclusions: Hard to see	VS2	
Si1	Slightly included	Noticeable inclusions: Moderately hard to see	Si1	Small inclusion
Si2		Noticeable inclusions: Easy to see	Si2	
I1	Included	Obvious Inclusions: Beauty or Durability affected	P1	Pique
I2		Obvious Inclusions: Beauty or Durability seriously affected	P2	
I3		Obvious Inclusions: Beauty and Durability seriously affected	P3	

Carat 卡拉重量

Carat is the unit weight used in India for diamond which was first mined there around 2000 years ago and is based on the weight of one fruit of the carod plant 角豆 which was around 200 milligrams. It was adopted universally since 1907 with one carat equals to 200 milligrams (0.2 gram or 0.007055 oz) & subdivided into 100 points 分

Oval Diamond

.50 carat (6.0mm)

.75 carat (7.0mm)

1 carat (7.7mm)

1.5 carat (8.5mm)

2 carat (9.0mm)

3 carat (12.0mm)

1 Carat = 200mg



1/2  0.50ct = 50 Points

1/4  0.25ct = 25 Points

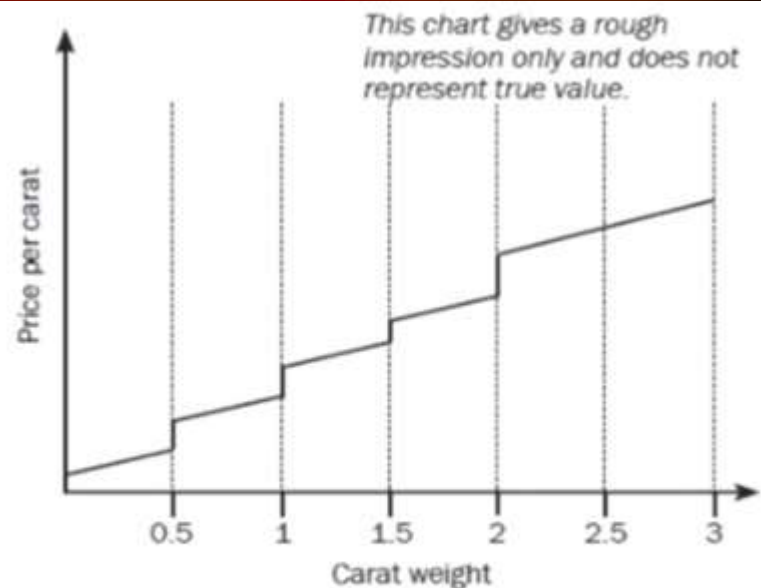
1/100  0.01ct = 1 Point



- Everything equal a one carat diamond is much more expensive than 4 X 0.25 carat diamonds

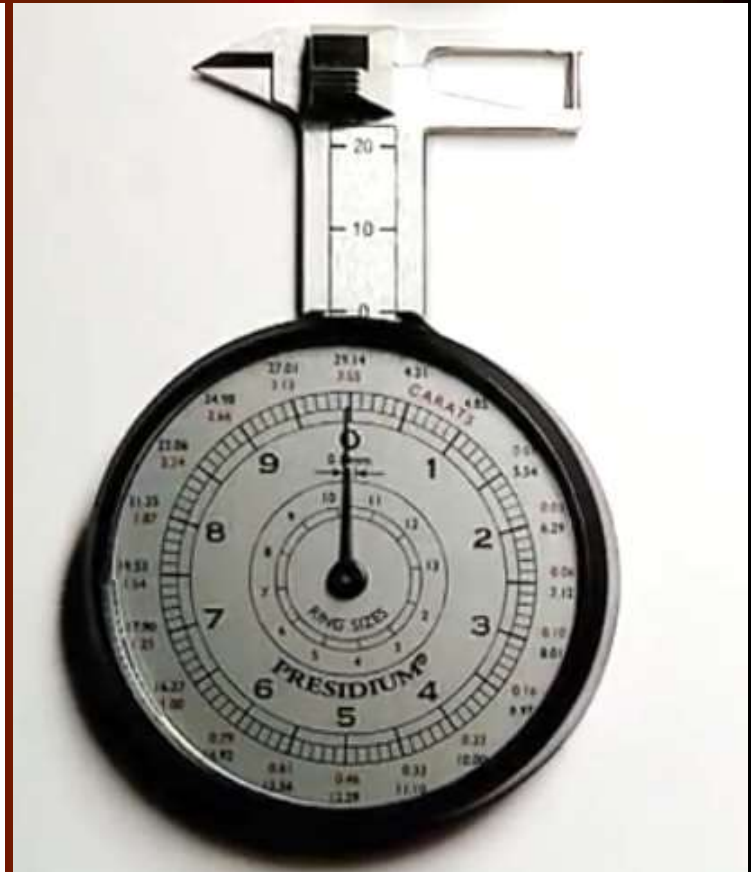


- All other factors equal the diamonds are sold on carat weight
- 1 carat equals 0.2g
- Pricing of diamonds is experiential and prices increase most around whole numbers e.g. 0.5cts, 0.7cts, 1ct, 1.5cts



Price increments of cut diamonds according to size © Gem-A

- Weighing equipment



- Melee diamonds are small diamonds used for jewelry setting used to accentuate a center stone. They are less than 0.2 carat and can be as small as 0.001 carats

“Large”



“Commercial”



“Melee”



Certification

A number of third party international institutions inspect & issue grading certificates for valuation. Only unmounted stones are graded precisely. Some are less strict and consistent than others



GIA®



E.G.L.
INTERNATIONAL

**IN-HOUSE
CERTIFICATE**



IDC

ISRAEL DIAMOND CENTER

SSEF 

SCHWEIZERISCHES GEMMOLOGISCHES INSTITUT
SWISS GEMMOLOGICAL INSTITUTE
INSTITUT SUISSE DE GEMMOLOGIE

國際寶石鑑定



- 美國寶石學院 (**Gemological Institute Of America**)
- 歐洲寶石學院 (**European Gemological Laboratory, EGL** [<http://www.egltw.asia/> 歐洲寶石鑑定所在台灣])
- 比利時鑽石高等評議會 (**HRD**)
- 美國寶石協會 (**AGS**)
- 國際寶石學院 (**International Gemological Institute**)
- 自然資源部珠寶玉石首飾管理中心 (**National Gemological Training Center**)

The GEMOLOGICAL INSTITUTE OF AMERICA (GIA)

Issues two types of certificates - the GIA Diamond Dossier for stone under 1 carat & GIA Diamond Grading Report for stones at or above 1 carat



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FACSIMILE

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GIA DIAMOND DOSSIER®

July 18, 2014
 GIA Report Number 1179759858
 Shape and Cutting Style Round Brilliant
 Measurements 5.63 - 5.68 x 3.56 mm

GRADING RESULTS

Carat Weight 0.70 carat
 Color Grade D
 Clarity Grade VVS2
 Cut Grade Very Good

ADDITIONAL GRADING INFORMATION

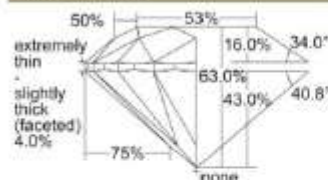
Polish Excellent
 Symmetry Very Good
 Fluorescence None
 Clarity Characteristics Pinpoint, Needle, Indented Natural
 Inscription(s): GIA 1179759858

www.gia.edu

GIA REPORT
 1179759858

Verify this report at gia.edu

PROPORTIONS



Profile to actual proportions



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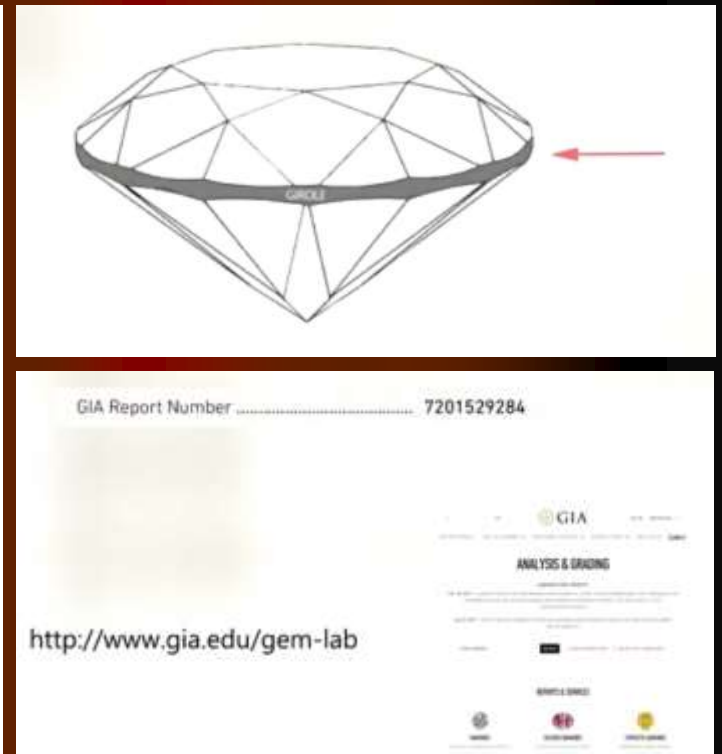
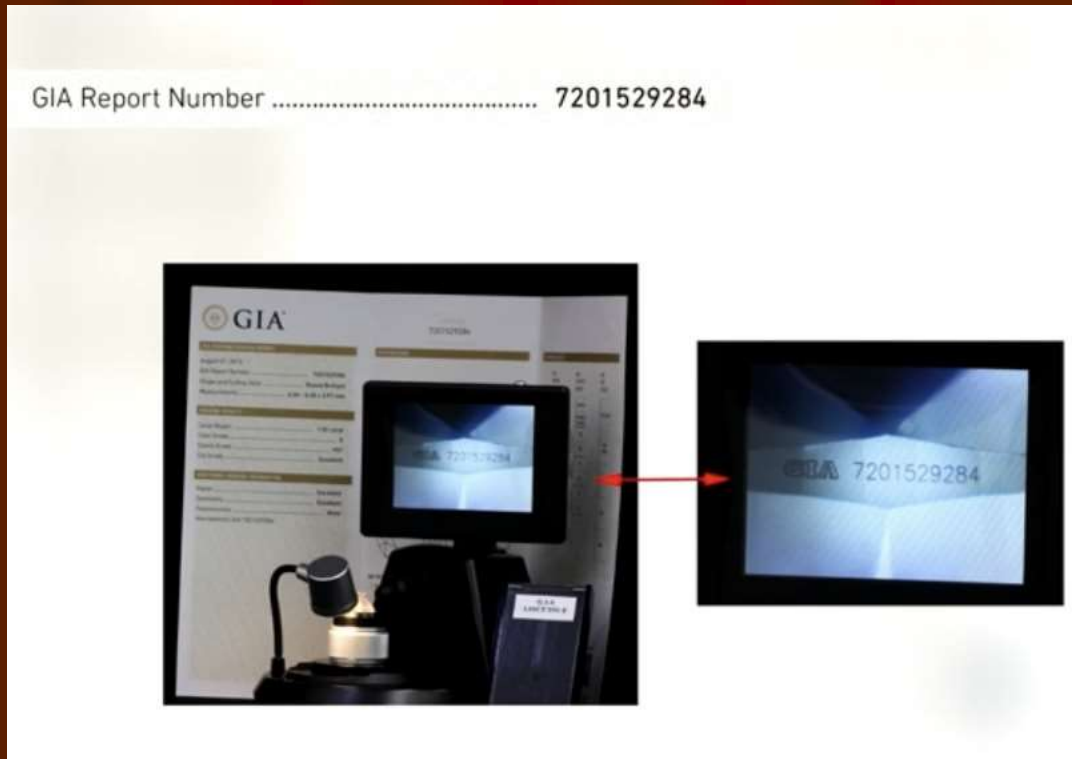
GRADING SCALES

GIA COLOR SCALE	GIA CLARITY SCALE	GIA CUT SCALE
D E F G H I J K L M N O P Q R S T U V W X Y Z	FLAWLESS INTERIALLY FLAWLESS VVS ₁ VVS ₂ VS ₁ VS ₂ SI ₁ SI ₂ I ₁ I ₂ PDR	EXCELLENT VERY GOOD GOOD FAIR POOR

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- Each GIA certified diamond has a unique number which will be lasered on the girdle of the diamond and the GIA report can be authenticated through the GIS website



GIA DIAMOND GRADING REPORT

DATA AND RESULTS

ADDITIONAL GRADING INFORMATION

Inscription(s): NPHT PROCESSED

www.sagepub.com

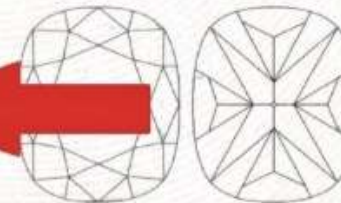
◎ 臨終前「最後的叮嚀」

[Verify this report at gov.uk](#)

PROPORTIONS

are not to actual proportions

CLARITY CHARACTERISTICS



KEY TO SYMBOLS*

- Feather
- Pinpoint
- Indented Natural
- Natural

* Spot symbols denote internal characteristics (inclusions). Grey or black symbols denote external characteristics (blemishes). Diagram is an approximate representation of the diamond, and symbols shown indicate type, position, and approximate size of clarity characteristics. All clarity characteristics may not be shown. Details of finish are not shown.



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GIA NATURAL DIAMOND GRADING REPORT

2019
 GIA Report Number
 Shape and Cutting Style
 Measurements 11.20 x 8.18 x 3.67 mm

GRADING RESULTS

Carat Weight carat
 Color Grade D*
 Clarity Grade VVS1

ADDITIONAL GRADING INFORMATION

Polish Excellent
 Symmetry Good
 Fluorescence None
 Inscription(s): TREATED COLOR
 Comments: Clarity grade is based on internal graining that is not shown.

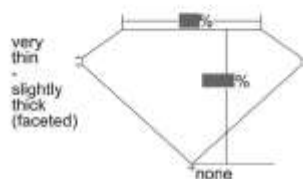
* This diamond has been treated by one or more processes to change its color.

GIA.edu

GIA REPORT

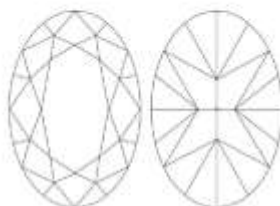
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PROPORTIONS



Profile not to actual proportions

CLARITY CHARACTERISTICS



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GRADING SCALES

GIA COLOR SCALE

FLAWLESS	D
	E
	F
	G
	H
	I
	J
	K
	L
	M
	N
	O
	P
	Q
	R
	S
	T
	U
	V
	W
	X
	Y
	Z

GIA CLARITY SCALE

FLAWLESS	
INTERNALLY FLAWLESS	
VVS ₁	
VVS ₂	
VS ₁	
VS ₂	
S ₁	
S ₂	
I ₁	
I ₂	



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- GIA also test man-made diamond and offer Synthetic Diamond Grading Reports which are distinct from GIA grading reports for natural diamonds both in appearance and the information provided. They clearly identify that the diamond is man-made or laboratory-grown and evaluate color and clarity using descriptive ranges rather than the specific grades of the color and clarity scales. In addition the man-made diamond's girdle is laser inscribed with its report number and a statement that the stone is laboratory-grown

natural diamond report		synthetic diamond report	
COLORED DIAMOND GRADING REPORT		SYNTHETIC COLORED DIAMOND GRADING REPORT	
January 1, 2006		January 1, 2007	
Laser Inscription Registry	GIA 10958099	Laser Inscription Registry	GIA 12345678
Shape and Cutting Style	Cut-Cornered	Identification	LABORATORY GROWN
	Rectangular Modified Brilliant	Shape and Cutting Style	Cushion Modified Brilliant
Measurements	6.59 x 5.90 x 3.75 mm	Measurements	10.0 x 5.02 x 4.07 mm
Carat Weight 1.18 carat		Carat Weight 2.04 carat	
Color		Color	
Origin	NATURAL	Grade	INTENSE
Grade	FANCY		ORANGY YELLOW
Distribution	Even	Distribution	Even
Clarity Grade	VS1	Clarity Grade	VERY SLIGHTLY INCLUDED
Finish		Finish	
Polish	Very Good	Polish	Good
Symmetry	Very Good	Symmetry	Good
Fluorescence	None	Fluorescence	Medium Yellow
Comments:		Comments:	
Additional Inscription:		"LABORATORY GROWN" has been inscribed on	



Synthetic diamond with natural diamond's GIA number !



CVD Synthetic Diamond

- 6.57 x 6.53 x 3.98 mm
- 1.03 ct; F color
- Stone was taken in for “update” service with inscription of “GIA 5263846282”

This report number was issued for a natural diamond

- 6.45 x 6.41 x 4.03 mm
- 1.03 ct; F color

- Current Lab-grown diamond Report

GIA LAB-GROWN DIAMOND REPORTS

2019

GIA REPORT
S202397873

Issued September 01, 2019

GIA LABORATORY-GROWN DIAMOND REPORT

IDENTIFICATION INFORMATION

REPORT DATE

GIA	INSTRUMENT	INSTRUMENT	INSTRUMENT
TABLE	55.0%	55.0%	55.0%
CROWN ANGLE	34.0°	34.0°	34.0°
CROWN HEIGHT	16.1%	16.1%	16.1%
GIRDLE	1.1 mm	1.1 mm	1.1 mm
PAVILION ANGLE	40.7°	40.7°	40.7°
PAVILION DEPTH	43.2%	43.2%	43.2%
DEPTH	7.07 mm	7.07 mm	7.07 mm

September 01, 2019

Report Type Grading Report

GIA Report Number S202397873

Identification Laboratory-Grown*

Shape and Cutting Style Round Brilliant

Measurements 7.03 - 7.07 x 4.35 mm

Carat Weight 1.32 carat

Color Grade Colorless

Clarity Grade Very Slightly Included

Cut Grade Excellent

Polish Excellent

Symmetry Excellent

Fluorescence None

Inscriptions: GIA S202397873, LABORATORY-GROWN

Comments: "SAMPLE""SAMPLE""SAMPLE""SAMPLE"

*This is a man-made diamond (Chemical Vapor Deposition or HPHT High Pressure High Temperature) growth processes and may include post-growth treatments to change the color.

GIA LAB-GROWN DIAMOND REPORTS

GIA LABORATORY-GROWN DIAMOND REPORT

September 01, 2019

Report Type Grading Report

GIA Report Number S202397873

Identification **Laboratory-Grown***

Shape and Cutting Style Round Brilliant

Measurements 7.03 - 7.07 x 4.35 mm

Carat Weight 1.32 carat

Color Grade **Colorless**

Clarity Grade **Very Slightly Included**

Cut Grade Excellent

Polish Excellent

Symmetry Excellent

Fluorescence None

Inscriptions: GIA S202397873, LABORATORY-GROWN

Comments: "SAMPLE""SAMPLE""SAMPLE""SAMPLE"

*This is a man-made diamond produced by CVD (Chemical Vapor Deposition) or HPHT (High Pressure High Temperature) growth processes and may include post-growth treatments to change the color.

34

- New Certificate for Lab-grown diamond replacing the currently used descriptive terms and ranges

**GIA**

GIA'S NEW LAB-GROWN DIAMOND REPORTS





All New Laboratory-Grown Diamond Reports by GIA

- Redesign and Digital-Only format
- Dossier format available
- Full 4Cs assessment
- Added letter specifications for Color & Clarity
- Custom landing page for each report with enhanced educational information

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36

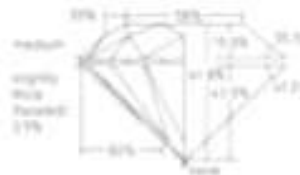
LGDR



LABORATORY-GROWN DIAMOND REPORT

Order # 12 3000
 GIA Report Number 6202241974
 Identification Laboratory-Grown Diamond
 Weight & Tinting Data Round Brilliant
 Measurements 1.00 - 7.07 x 5.25 mm

FEATURES



Proportions are approximate

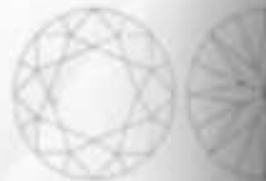
LABORATORY-GROWN DIAMOND IDENTIFICATION

Carat Weight 1.02 carat
 Color G Green
 Clarity Very Slightly Included
 Cut Excellent

ADDITIONAL INFORMATION

Finish Excellent
 Symmetry Excellent
 Fluorescence None
 Annotations GIA 6202241974 Laboratory notes
 Comments "Growth" "Growth" "Growth" "Growth" "Growth"
 This is a machine-made diamond produced by CVD
 (Chemical Vapor Deposition) growth process

CLARITY CHARACTERISTICS



GRADING

Color: G, Clarity: VS1, Cut: Excellent

Measurements: 1.00 - 7.07 x 5.25 mm
 Weight: 1.02 carat
 Identification: 6202241974

With GIA online app available

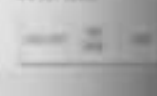
GG DRIFT SCALE



AK CLARITY SCALE



AK CUT SCALE



LABORATORY-GROWN DIAMOND REPORT
 6202241974

Order # 12 3000
 Date: 12 2020

LGDR



IDENT

Color: G Green
 Clarity: VS1

PROPERTIES

Clarity: VS1

CLARITY CHARACTERISTICS

Measurements: 1.00 - 7.07 x 5.25 mm
 Weight: 1.02 carat
 Identification: 6202241974

COMMENTS

This is a machine-made diamond produced by CVD (Chemical Vapor Deposition) growth process. It is a machine-made diamond produced by CVD (Chemical Vapor Deposition) growth process.

For more information, please visit www.gia.edu

Print

- Testing/grading Melee

- ◆ D-to-Z color grades and 0.005-0.25 carat weights Automated processing (up to 2000 stones per hour)
- ◆ Cost \$0.08 to \$0.40 per stone based on diameter
- ◆ Separation of natural untreated diamonds from simulants, and from potentially synthetic or treated diamonds
- ◆ Tested natural diamonds grouped by color grade ranges
- ◆ Tested stones sealed in parcels for return shipment





NUMBER	310868687 ANTWERP, May 8, 2018
DESCRIPTION	NATURAL DIAMOND
SHAPE AND CUT	ROUND BRILLIANT
CARAT WEIGHT	0.53 CARAT
COLOR GRADE	K
CLARITY GRADE	VS 2
CUT GRADE	EXCELLENT
POLISH	EXCELLENT
SYMMETRY	EXCELLENT
Measurements	5.17 - 5.19 x 3.22 mm
Table Size	54.5%
Crown Height - Angle	16% - 34.9°
Pavilion Depth - Angle	42.5% - 40.6°
Girdle Thickness	MEDIUM (FACETED)
Culet	POINTED
Total Depth	62.2%
FLUORESCENCE	VERY SLIGHT
COMMENTS	IDEAL CUT ROUND BRILLIANT
LASERSCRIBE	IGI 310868687

SSEF 
 CHAMBER OF COMMERCE AND INDUSTRY
 OF THE CANTON OF BASEL ST. CITY
 BASEL ST. CITY

The SC grades

Case Weight:	1.000 ct
Colour:	rain-white + (F)
Clarity:	VSI2
Cut:	very good

Further characteristics

Shape, cut style	round brilliant
Measurements	6.08 × 6.72 × 3.05 mm
Symmetry	good
Polish	good
Proportions	depth: 55% table: 95%
Girdle	medium to thin, regular
UV fluorescence	none
Comments	showing characteristics indicated in green



Students select the appropriate value of α based on the value of β . For example, if $\beta = 0.05$, then students will choose $\alpha = 0.05$ for the first test, $\alpha = 0.01$ for the second test, and $\alpha = 0.001$ for the third test. These values correspond to values of α given by

[illegible]

SWISS LINGUISTICAL INSTITUTE - SLI

Received 10 March 2013; in final form 12 April 2013

Received 22 November 2005; accepted 12 January 2006



World Bank

- Sample certificates issued by AGS



Setting
the
Highest
Standard
for
Diamond
GradingSM

AMERICAN GEM SOCIETY LABORATORIES®

AGS 0008638005

June 13, 2007

Shape and Style Round Brilliant
Measurements: 8.21 x 8.26 x 5.05 mm

Cut Grade AGS Excellent 1

Color Grade AGS 0 (D)

Clarity Grade AGS 5 (SI1)

Carat Weight 2.126 cts.

Comments

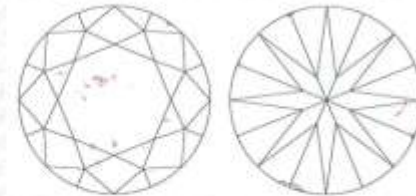
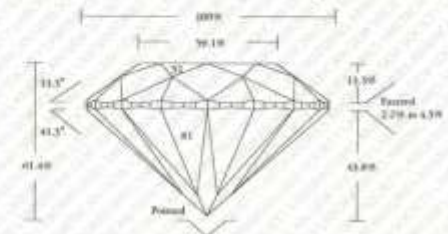
Fluorescence: Negligible
Additional clouds are not shown.

IMPORTANT NOTICE:
All three quality factors of Cut, Color, and Clarity can dramatically affect the beauty and value of a diamond. Because of cutting, diamonds with the same color and clarity grades can vary in value by as much as 50% or more. Therefore, it is advisable to consult a Certified Gemologist® or other credentialed gemologist, before purchasing this Diamond.

THIS DOCUMENT IS
NOT A WARRANTY,
GUARANTEE, OR
APPRAISAL OF VALUE.

Diamond Quality™ Document

Performance-Based



Key to Symbols

Crystal
Feather
Indented Natural
Natural
Extra Facet

PLOT INFORMATION: The Clarity grade is diagrammed using the clarity symbols contained in the AGS Diamond Standards Manual. Red marks indicate inclusions; green marks indicate external characteristics.

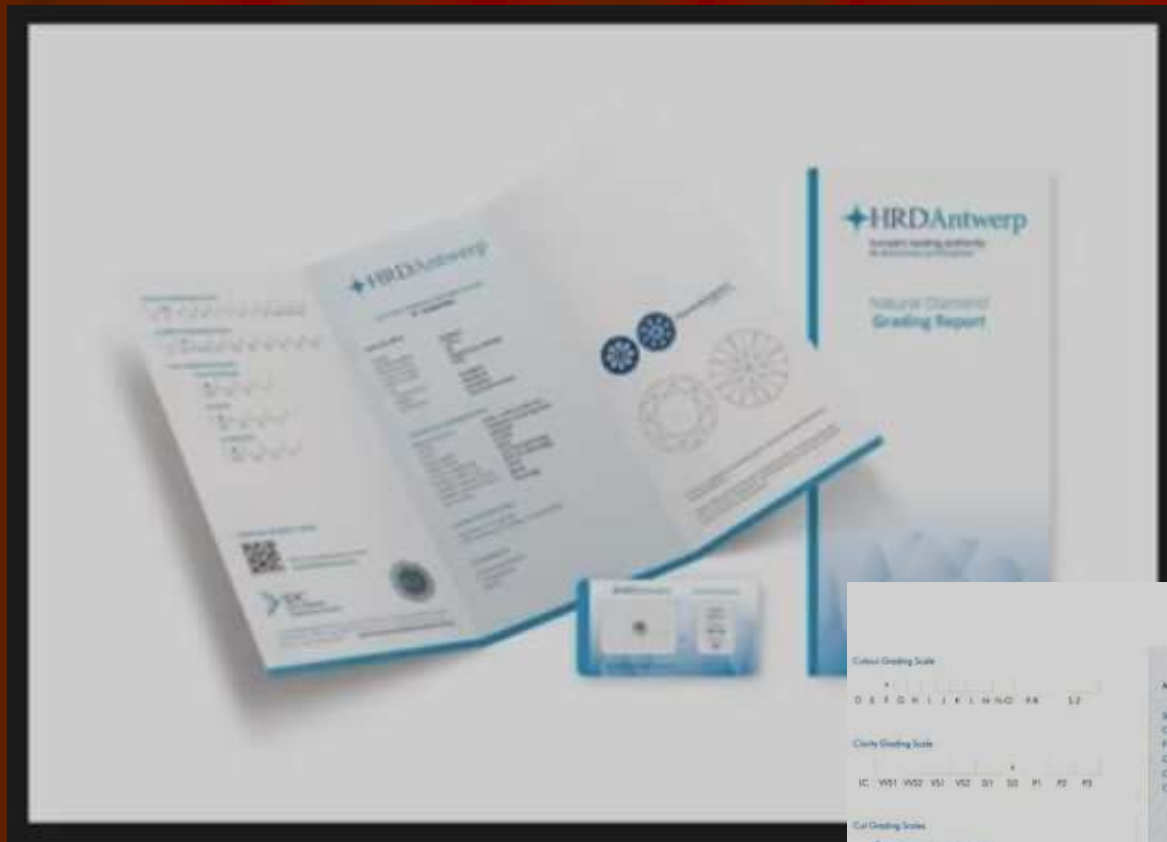
Cut Scale	0	1	2	3	4	5	6	7	8	9	10														
	AGS Ideal	AGS Excellent	AGS Very Good	AGS Good		AGS Fair			AGS Poor																
Color Scale	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	Fancy Yellow	
	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z		Fancy Yellow
	COLORLESS			NEAR COLORLESS			FAINT			VERY LIGHT					LIGHT										
Clarity Scale	0	1	2	3	4	5	6	7	8	9	10														
	FLAWLESS / IF	VVS1	VVS2	VS1	VS2	S1	S12	I1		I2	I3														

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NOTICE: Important Limitations On Reverse

ORIGINAL

- Sample certificates issued by HRD Antwerp



HRD Antwerp
Institute of Gemmology

Certificate N° 10011956014

Antwerp, May 25, 2010

Shape	brilliant
Carat (weight)	1.88 ct
Fluorescence	medium
Colour Grade	none visible (F)
Clarity Grade	S2
Cut	
Proportions	very good
Finish	excellent
Symmetry	excellent

Technical Information

Measurements	7.26 x 7.41 mm x 4.83 mm
Grafs	medium 3.0% faceted
Color	graded
Total Depth	62.8 %
Table Width	55. %
Crown Height (°)	16.8 % (38.0 deg)
Pavilion Height (°)	43.0 % (41.1 deg)
Length-Hollow Crown	85. %
Length-Hollow Pavilion	75. %
Sum	in 6.8 77.5 deg

BE LAC NEN EN ISO/IEC 17025

The HRD Antwerp Diamond Lab is a BEAC accredited for the quality examination of polished diamonds under the ISO 15875. This Certificate is conforming to the BEAC Rules for grading polished diamonds, approved by NEN and ISO and may not be reproduced by any means except in its complete form.

Gemmologist

The stone in accordance with the mentioned number has been identified as a natural gem diamond.

Selective characteristics have been indicated in order to certify the description and for further identification. Symbols do not usually reflect the exact shape or size of the characteristics.

鑽石分級報告 Diamond Grading Report

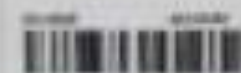
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 客戶名稱: NGTC
 客戶地址: 香港灣仔
 客戶電話: 2612 2222
 客戶傳真: 2612 2222
 客戶電郵: info@ngtc.org.hk
 客戶網址: www.ngtc.org.hk
 客戶地址: 香港灣仔
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鑽石分級報告 Diamond Grading Report

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珠寶國檢 真質鑒證
 買珠寶 要認準 認準NGTC

珠寶業與標準化新發展

Industry and Standardisation
 for Mutual Success

時間 Time: 20170401 (Thursday 星期四) 下午2:30 pm - 5:00 pm
 地點 Venue: 香港會議展覽中心 S226-227會議室
 Meeting Room S226-T, L2, Hong Kong Convention and Exhibition Centre

國家珠寶玉石質量監督檢驗中心
 NATIONAL GEMSTONE TESTING CENTER

北京|深圳|上海|廣州|平洲|雲南|沈陽|中國香港 等地實驗室

NGTC中國香港實驗室 NGTC CHINA HONG KONG LAB
 地址 Add: 香港九龍紅磡彌敦道333號 萬安中心702室
 Unit 702, Guardian Centre, 333 Hoi Yuen Street East,
 Hungfai, Kowloon, Hong Kong
 電話 Tel: + 852 2121 8817 傳真 Fax: + 852 3691 8898



NGTC主網 中國珠寶玉石網

Inhouse certification

Example : The 4 T classification by Chow Tai Fook - Buying & coding, cutting, polishing, marking, authentication, design, inlaying

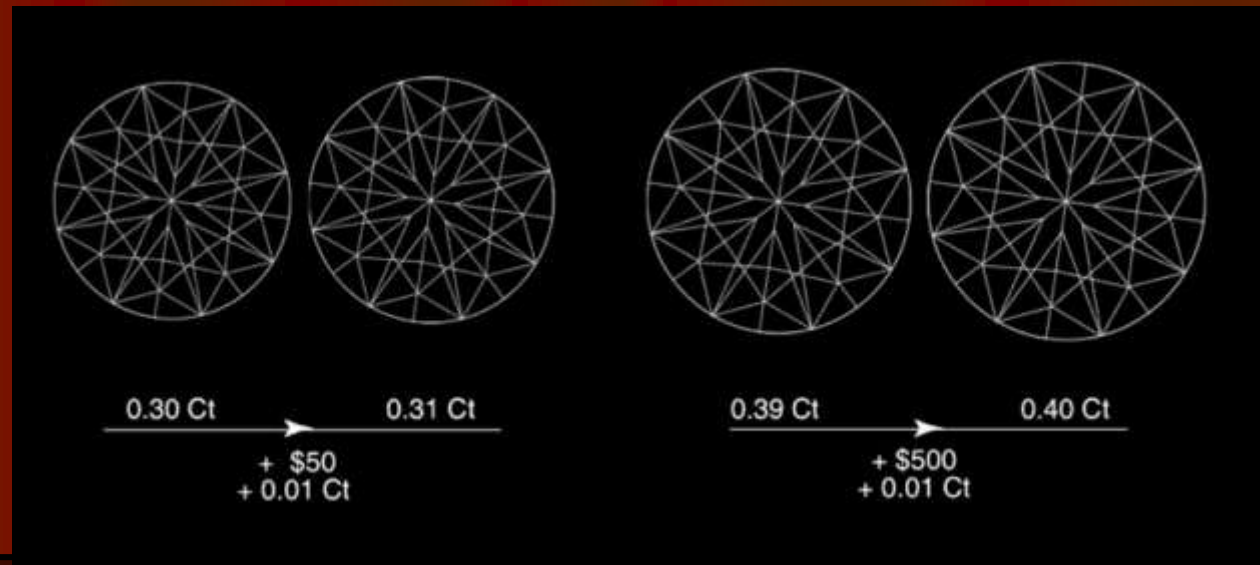
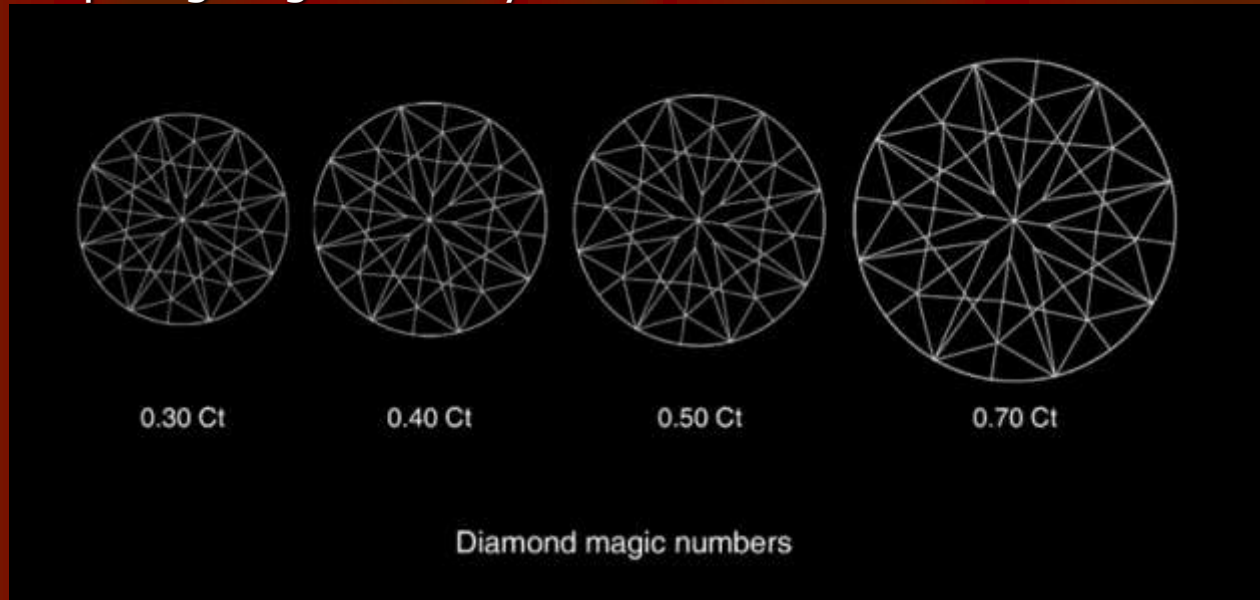




The more sophisticated technology that has sprung up in recent years

Pricing

- The process of calculating natural diamond prices is extremely complex giving the many factors that need to be considered



If all other Cs are equal



>



+



1.50ct

1ct + 1ct



>



+



+



+



2.0ct

1ct + 1ct + 1ct + 1ct



>

3.0ct > 10 x 1ct



>

5.0ct > 26 x 1ct

The Rapaport Price List

- It is an international benchmark used by the dealers to establish diamond prices in all the major markets since the 1970s
- For well-shaped fine cut white diamonds from 1-10 carats both round and pear shape the latter as an indication for all fancy shapes
- Represent High Cash Asking Prices in USD cash. HCAP is the asking price that a seller would always be prepared to accept
- Issues 3 lists namely Round Price List, Pear Price List and Parcel Price list
- The lists are updated every Thursday midnight New York Time

RAPAPORT DIAMOND REPORT

Tel: 877-987-3400

www.RAPAPORT.com

info@RAPAPORT.com



May 27, 2011 - Volume 34 - No. 20: APPROXIMATE HIGH CASH ASKING PRICE INDICATIONS - Page 97
NEW YORK ASKING PRICES: Round Brilliant Cut Diamonds per "Rapaport Spec 2" in hundreds US\$ per carat.

News: Rapaport launches Rupee Price List. Goods are tight and seller's market prevails ahead of next week's JCK Vegas show as U.S. retailers experience strong 1Q signal sales +10% to \$887m, profits +50% to \$75m. Tiffany sales +20% to \$761m, profits +26% to \$61m. Zale Corp sales +14% to \$412m, net loss of \$9m vs. loss of \$12m a year earlier. Harry Winston to source diamonds for \$250m investment fund. Botswana 1Q diamond exports +36% to \$1b. Gold jewelry demand +34% to \$24.8b in 1Q. RAPAPORT BREAKFAST at JCK Vegas Show - 8 am Sunday June 5 - moved to South Seas Ballroom after 650 people register. Registration reopened. Reserve now conference@diamonds.net

RAPAPORT : (.01 - .03 CT.) : 05/27/11										ROUNDS RAPAPORT : (.04 - .07 CT.) : 05/27/11									
	R-VVS	Vs	S1	S2	S3	I1	I2	I3		R-VVS	Vs	S1	S2	S3	I1	I2	I3		
D-F	11.0	9.5	7.3	6.0	5.2	4.7	4.0	3.2	D-F	11.0	9.5	7.3	6.0	5.4	4.8	4.2	3.4	D-F	
G-H	9.5	8.5	6.5	5.5	4.8	4.5	3.8	3.0	G-H	9.5	8.5	6.5	5.5	5.0	4.6	4.0	3.2	G-H	
I-J	7.5	6.8	5.8	5.0	4.4	4.2	3.5	2.7	I-J	7.5	6.9	5.8	5.0	4.6	4.4	3.7	3.0	I-J	
K-L	4.9	4.2	3.9	3.5	3.1	2.9	2.2	1.6	K-L	5.3	4.8	4.4	3.8	3.4	3.1	2.5	2.0	K-L	
M-N	3.6	3.0	2.4	2.1	1.8	1.5	1.3	1.0	M-N	4.0	3.5	2.7	2.4	2.0	1.8	1.5	1.2	M-N	

RAPAPORT : (.08 - .14 CT.) : 05/27/11										ROUNDS										RAPAPORT : (.15 - .17 CT.) : 05/27/11									
	#	VVS1	VVS2	VSI	VSI2	S1	S2	S3	I1	I2	I3		#	VVS1	VVS2	VSI	VSI2	S1	S2	S3	I1	I2	I3						
D-F	11.3	10.2	8.6	7.6	6.7	5.5	4.7	4.0				D-F	15.3	13.2	10.1	8.6	7.3	5.9	4.9	4.1									
G-H	10.2	9.1	7.7	6.7	6.0	4.9	4.2	3.6				G-H	13.2	11.5	9.1	7.4	6.5	5.2	4.4	3.7									
I-J	9.0	8.1	6.9	6.0	5.3	4.5	3.9	3.3				I-J	11.2	10.0	7.8	6.5	5.5	4.6	4.1	3.4									
K-L	6.8	6.2	5.3	4.5	3.8	3.3	2.8	2.3				K-L	8.2	7.3	5.8	5.1	4.1	3.5	2.9	2.4									
M-N	4.6	4.1	3.5	3.1	2.8	2.3	1.8	1.4				M-N	5.5	4.6	3.9	3.4	3.1	2.4	1.9	1.7									

*It is illegal and unethical to reproduce this price sheet. Please do not make copies. © 2011

RAPAPORT : (.18 - .22 CT.) : 05/27/11										ROUNDS RAPAPORT : (.23 - .29 CT.) : 05/27/11									
	#	VVS	VSI	S1	S2	S3	I1	I2	I3		#	VVS	VSI	S1	S2	S3	I1	I2	I3
D-F	16.0	13.6	11.0	9.6	8.3	6.6	5.4	4.3		D-F	22.0	17.5	13.0	10.7	9.4	7.7	6.2	4.8	
G-H	14.6	12.5	10.1	8.7	7.5	5.9	5.0	4.0		G-H	18.1	14.8	11.5	10.0	8.5	6.9	5.4	4.5	
I-J	12.4	10.8	8.7	7.5	6.4	5.1	4.5	3.6		I-J	15.0	12.1	9.5	8.5	7.3	5.8	4.8	4.0	
K-L	9.5	8.0	6.8	5.8	4.9	4.3	3.3	2.6		K-L	11.5	10.0	7.7	7.0	6.2	4.7	3.7	2.9	
M-N	8.0	6.6	5.7	4.6	4.0	3.0	2.2	1.8		M-N	9.6	8.5	6.7	5.8	5.1	3.6	2.7	2.1	

Very fine Ideal and Excellent Cuts in 0.30 and larger sizes may trade at 10% to 20% premiums over normal cuts.

RAPAPORT : [.30 - .39 CT.] : 05/27/11											ROUNDS	RAPAPORT : [.40 - .49 CT.] : 05/27/11											
	#	VVS1	VVS2	VSI	VSI2	S1	S2	S3	I1	I2	I3		#	VVS1	VVS2	VSI	VSI2	S1	S2	S3	I1	I2	I3
D	47	40	35	31	28	21	18	15	14	11	7	D	55	47	42	38	30	23	21	19	15	12	8
E	40	37	32	28	26	20	17	16	14	10	6	E	47	43	39	36	28	22	19	18	15	11	7
F	37	34	29	26	24	19	16	15	13	9	5	F	43	40	35	31	26	21	18	17	14	11	7
G	34	30	27	24	21	17	15	14	12	8	5	G	40	35	31	28	24	20	17	16	13	10	6
H	31	27	24	21	19	16	14	13	11	8	5	H	35	32	28	25	22	19	16	15	12	9	6
I	26	23	21	19	16	15	13	12	11	7	5	I	30	27	25	22	20	18	15	14	12	8	6
J	20	19	17	15	14	13	12	11	9	7	4	J	25	23	21	19	17	15	14	13	11	8	5
K	18	17	15	14	13	12	11	9	8	6	4	K	23	21	19	17	16	14	12	11	9	7	5
L	15	14	14	13	12	11	9	7	6	5	3	L	20	19	18	16	15	13	11	9	7	6	4
M	13	12	12	11	11	10	8	7	5	4	3	M	17	16	15	14	13	12	9	8	6	5	4

W: 30.08 ± 0.00% Q: Q: Q: 1: 16.16 ± 0.00%

0.60-0.69 may trade at 7% to 10% premiums over 0.50

W: 35.16 ± 0.00% Q: Q: Q: 1: 19.05 ± 0.00%

0.80-0.89 may trade at 7% to 10% premiums over 0.70

RAPAPORT : (.50 - .69 CT.) : 05/27/11											ROUNDS											RAPAPORT : (.70 - .89 CT.) : 05/27/11										
	#	VVS1	VVS2	VSI	VSI2	S1	S2	S3	I1	I2	I3		#	VVS1	VVS2	VSI	VSI2	S1	S2	S3	I1	I2	I3									
D	90	70	60	50	45	37	29	26	22	19	12	D	115	85	75	65	60	50	45	38	30	21	13									
E	70	60	55	47	41	34	27	24	21	18	11	E	85	75	66	62	55	48	43	36	29	20	12									
F	60	55	50	45	39	30	25	22	20	17	11	F	75	68	62	57	50	45	40	34	28	19	12									
G	55	50	45	40	34	27	22	20	19	16	10	G	68	62	57	50	45	41	37	32	27	18	11									
H	49	45	40	34	30	25	21	19	18	15	9	H	62	57	50	45	41	38	34	30	25	17	11									
I	41	38	34	29	26	22	20	18	17	14	9	I	50	47	45	41	38	34	29	27	24	16	11									
J	32	30	28	25	22	20	19	17	16	13	8	J	37	36	35	32	30	29	27	24	22	15	10									
K	27	26	25	21	20	19	18	16	15	13	8	K	33	32	31	27	26	24	22	21	18	14	10									
L	25	22	21	20	19	17	16	14	13	11	7	L	29	27	26	24	23	22	20	19	16	12	9									
M	21	19	18	17	17	16	15	13	12	9	6	M	27	25	24	22	21	20	19	17	14	11	7									
W:50.36 = 0.00% C:0 G:0 T:26.72 = 0.00%											W:63.76 = 0.00% C:0 G:0 T:34.81 = 0.00%																					

W: 50.36 ± 0.00% Q: Q: Q: 1: 28.72 ± 0.00%

W: 63.76 ± 0.00% Q: Q: Q: 1: 34.81 ± 0.00%

Prices in this report reflect our opinion of HIGH CASH NEW YORK ASKING PRICES. These prices may be substantially higher than actual transaction prices. No guarantee is made and no liability is assumed as to the accuracy or validity of the information in this report. © 2011 by Martin Rapaport. All rights reserved. Reproduction in any form is strictly prohibited.

Natural Diamond Production

Early history of production

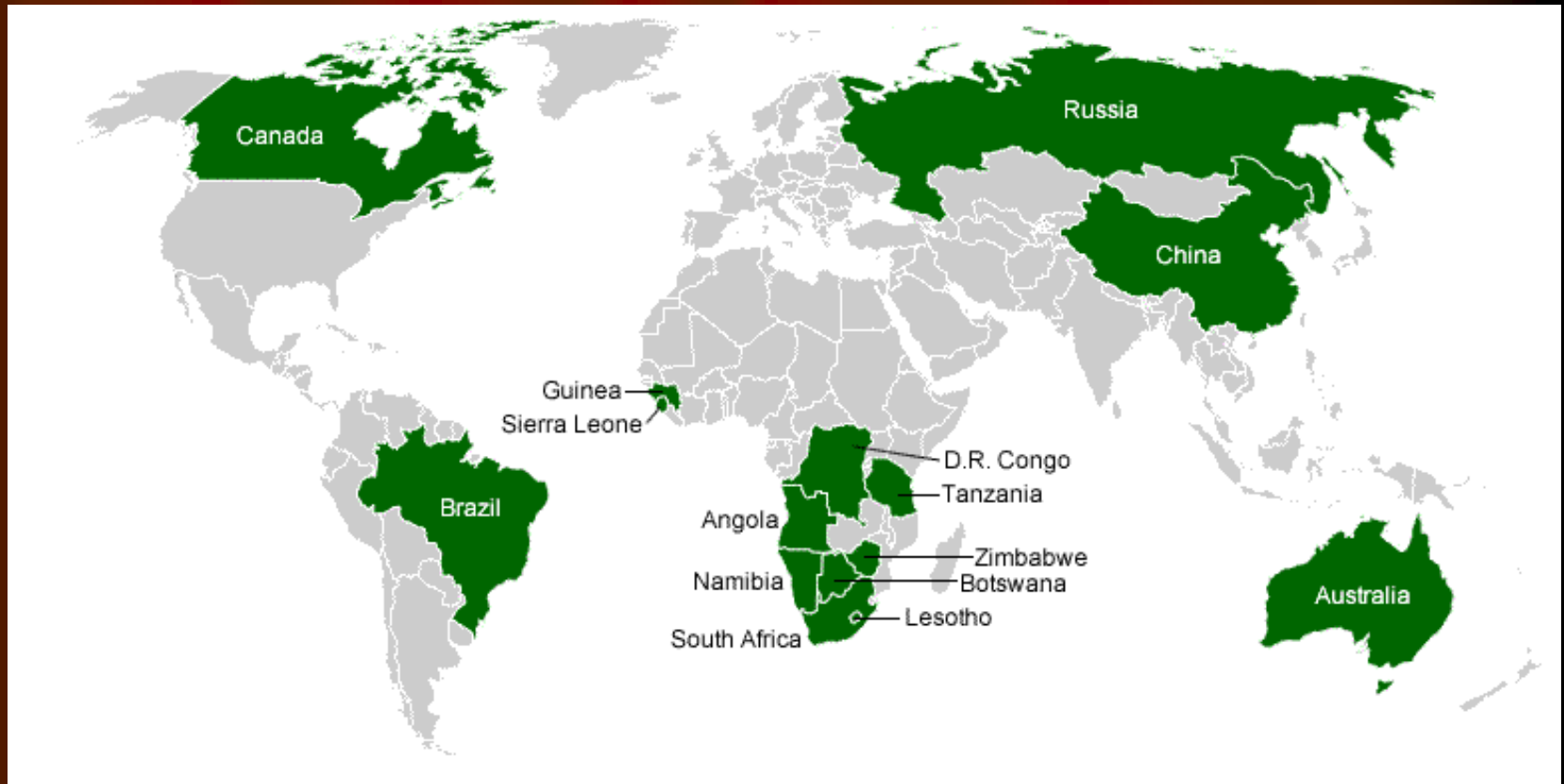
Dr. Evan Smith

- ◆ Alluvial diamonds in India
 - ◆ Over 2000 years ago
 - ◆ Only known source for centuries
 - ◆ Many famous historic diamonds
- ◆ Alluvial diamonds of Kalimantan, Borneo
 - ◆ 1500's or earlier (600 A.D.?)
- ◆ Diamonds found in Brazil
 - ◆ First diamonds found in 1725
 - ◆ Crystals encountered while gold panning
- ◆ Chance discoveries

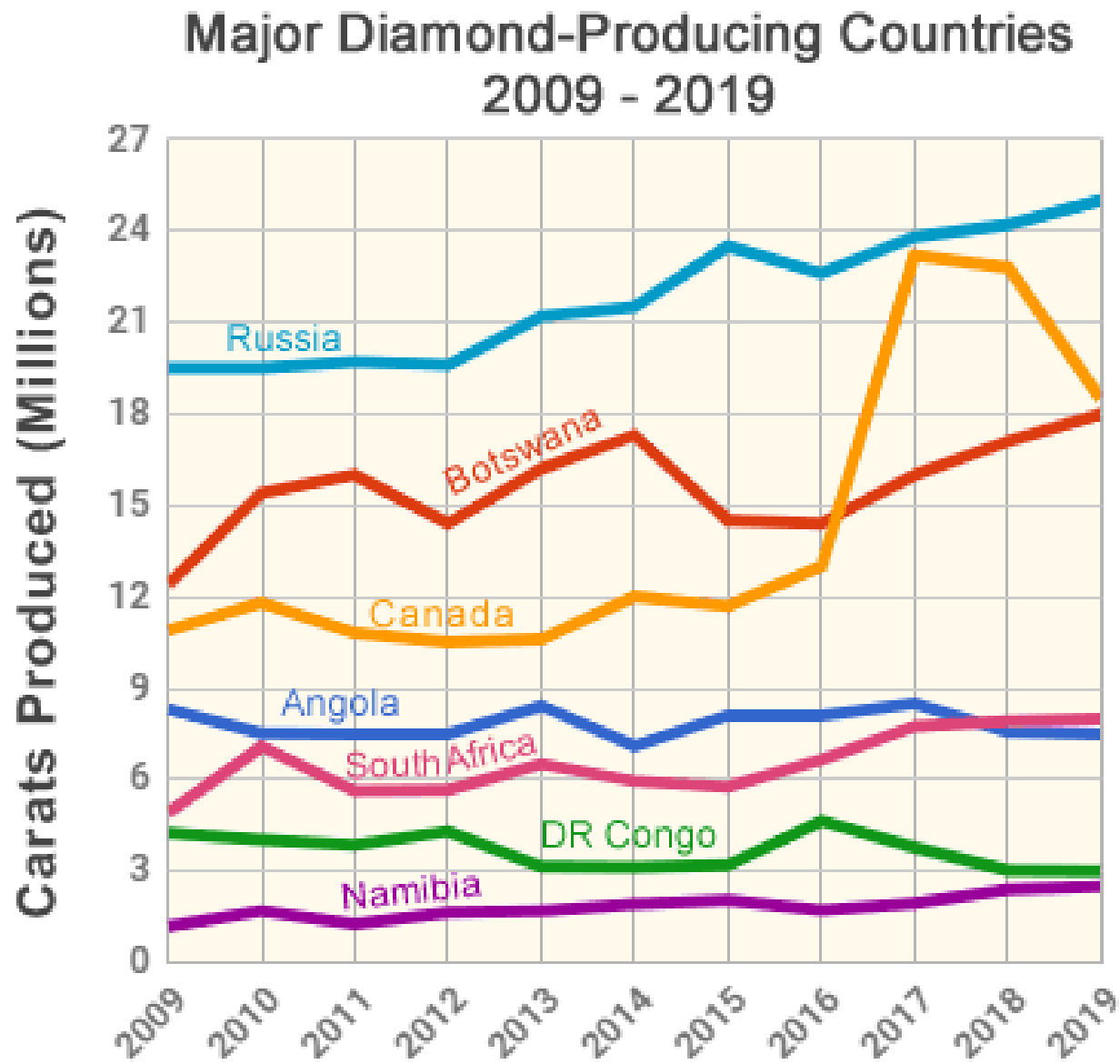


Location of diamond producing countries

Approximately 140 million carats of diamonds are mined annually at a total value of US\$ 9 billion. This map shows countries which produced at least 50,000 carats of natural diamond in 2019. Note China is included for the first time

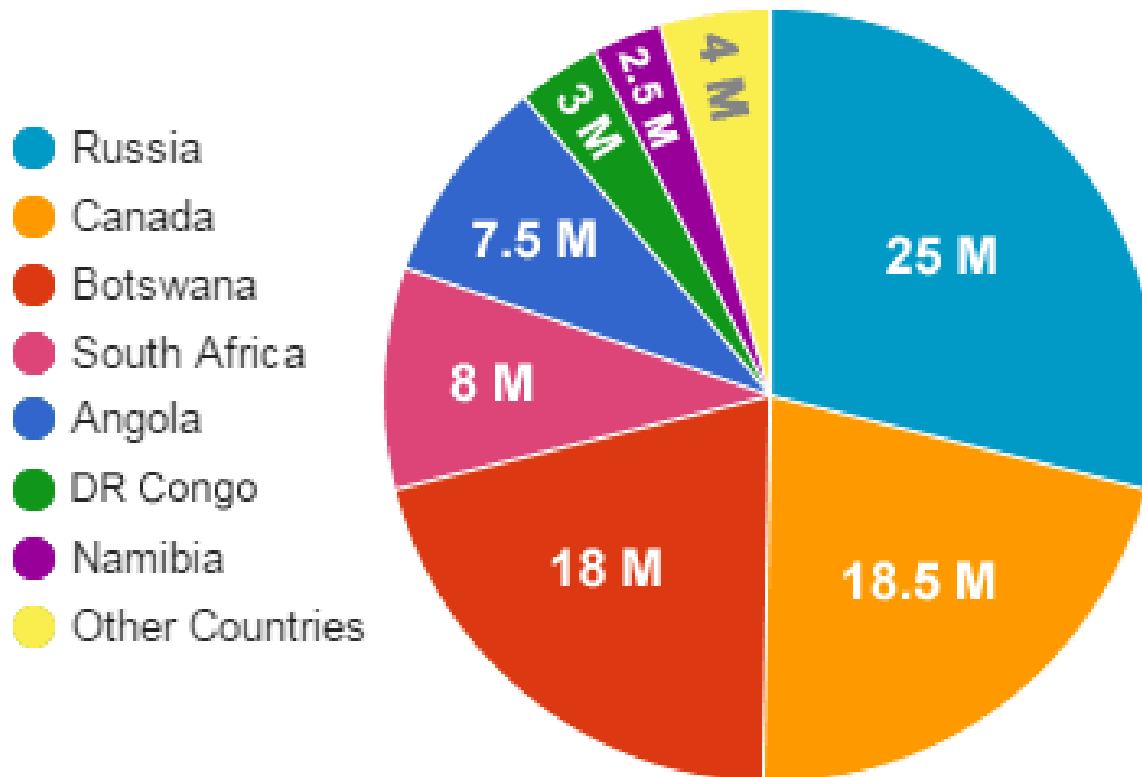


Performance of major gem-diamond Producing Countries 2009-2019



Top Gem Diamond Producers

Millions of carats – 2019 Data from USGS



Country	2019
Russia	25,000
Canada	18,500
Botswana	18,000
South Africa	8,000
Angola	7,500
DR Congo	3,000
Namibia	2,500
Lesotho	1,300
Sierra Leone	600
Tanzania	400
Zimbabwe	400
Australia	280
Brazil	250
Guinea	240
China	100
Other Countries	400

Quality of diamonds in 19 producing countries

Sort alphabetically



• Angola	00000
• Australia	00
• Botswana	0000
• Brazil	00
• Canada	000
• Central African Rep.	000
• China	0000
• Dem. rep. of Congo	000
• Ghana	000
• Guinea	000
• Guyana	00
• Lesotho	000
• Liberia	0
• Namibia	00000
• Russia	00000
• Sierra Leone	0000
• South Africa	0000
• Tanzania	000
• Venezuela	000

Sort by better quality



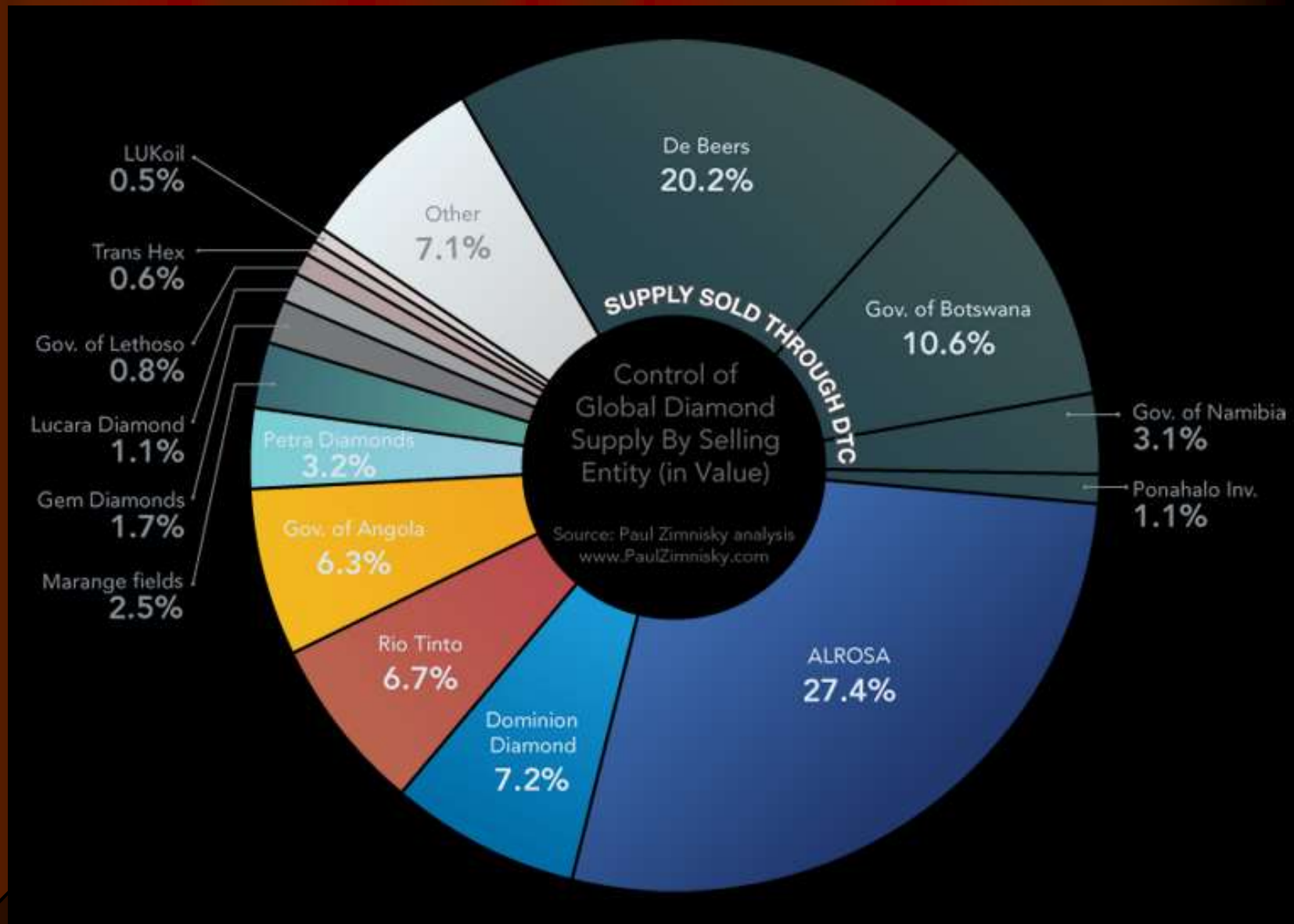
• Angola	00000
• Namibia	00000
• Russia	00000
• South Africa	0000
• Botswana	0000
• China	0000
• Sierra Leone	0000
• Canada	000
• Central African Rep.	000
• Guinea	000
• Lesotho	000
• Dem. Rep. of Congo	000
• Tanzania	000
• Venezuela	000
• Australia	00
• Brazil	00
• Ghana	00
• Guyana	00
• Liberia	0

World's Big 5 Diamond miners performance 2015-2019

On average they provided 75% of global production and 85% of product sales

	2015		2016		2017		2018		2019***	
	Ct M	US\$ M	Ct M	US\$ M	Ct M	US\$ M	Ct M	US\$ M	Ct M	US\$ M
De Beers Group*	28.7	4671	27.3	5587	33.5	5841	35.3	5389	30.8	4605
ALROSA Group (Russia)*	38.3	3286.7	37.4	4392.1	39.6	4266.8	36.7	4500	38.5	3338
ALROSA Group with Catoca*	44.73	3788.3	44.4	4986.1	47.0	4866.8	43.3	5100	46.3	4038
Rio Tinto	16.03	698	17.95	613	21.63	706	18.43	600	17.0	510
Dominion Diamond Mines	5.18	915.8	6.6	570.9	7.35	925	9.55	975	8.15	830
Petra Diamonds	3.2	425.0	3.7	431	4.0	477	3.8	495.3	3.7	463.6
Total: 5 major companies	97.84	10498.1	99.95	12188	113.48	12815.8	110.38	12559.3	105.95	10446.6
Share of 5 major companies, %	76.8	75.6	79.1	99.3	75.2	80.7	74.4	86.8	75	80
Global diamond production **	127.4	13881.6	126.4	12268.7	150.9	15870	148.4	14465.9	141.3	13058.2

- Chart showing control of global rough diamond supply by selling entity



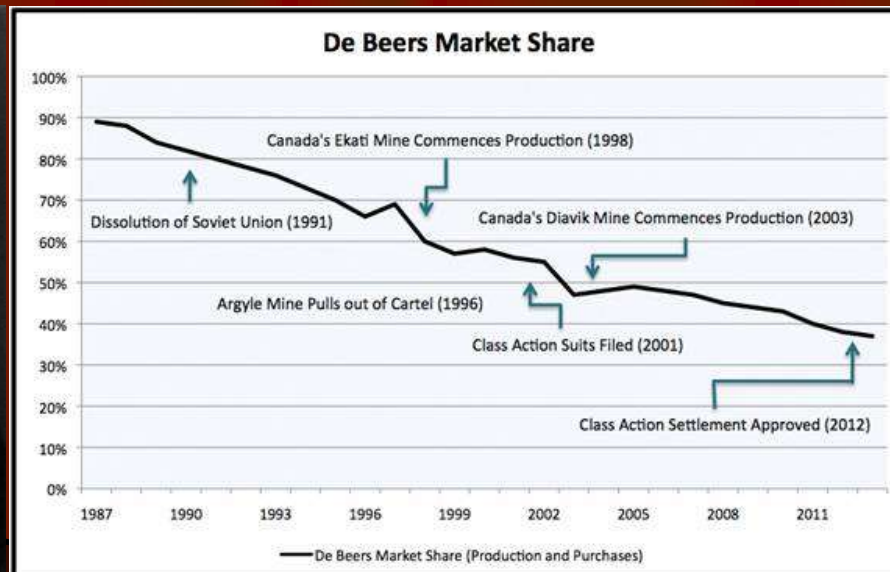
De Beers

Founded by Cecil Rhodes in South Africa in 1888, De Beers Consolidated Mines is involved in the exploration, mining, processing, retail and trading of both industrial and commercial diamond as well as artificial diamond production. Controlled by the Rothchild Bank in England, the company had a virtual monopoly of the global diamond market controlling as much as 90% of rough diamond distribution. This business model changed in the 21st Century as countries like Canada and Australia decided to distribute outside the De Beers channel; rising awareness of Blood diamond limiting the country of supply and Class Action against Cartel. As a result their control was reduced to 20.2% & they are now also operating in Botswana, Namibia and Canada. 2018 revenue US\$ 6b

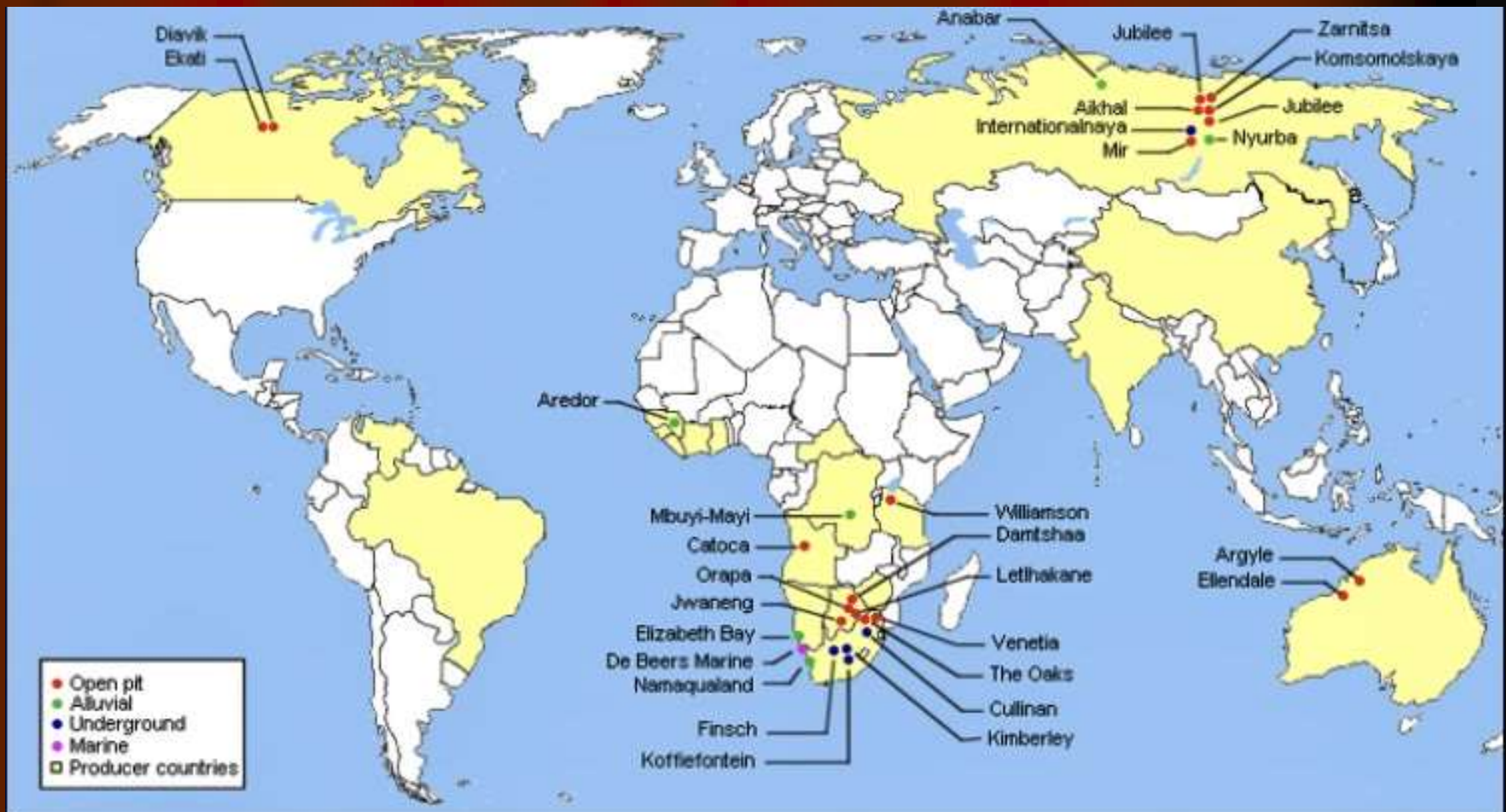
Cecil Rhodes



Nathan Rothchild



Key diamond mines in the World



Appendix - 2017E Global Diamond Production by Mine

© PaulZimnisky.com, 2017

Rank	Mine	Country	LOM	2017E Diamond Production	
				Volume (in carats)	Value (in M US\$)
1	Jwaneng	Botswana	>20	12,000,000	\$2,340
2	Jubilee	Russia	12	9,200,000	\$1,426
3	Orapa	Botswana	>15	9,800,000	\$882
4	International	Russia	11	4,000,000	\$880
5	Diavik	Canada	17	7,400,000	\$740
6	Debmairine (A - marine)	Namibia (Offshore)	>20	1,250,000	\$656
7	Catoca	Angola	>15	6,500,000	\$618
8	Nyurbinskaya	Russia	10	5,000,000	\$575
9	Gahcho Kué	Canada	16	4,200,000	\$525
10	Mir	Russia	>40	3,200,000	\$464
11	Udachnaya (OP & UG)	Russia	>50	3,800,000	\$456
12	Ekati	Canada	15	6,500,000	\$455
13	Argyle	Australia	4	17,000,000	\$425
14	Venetia	South Africa	>30	3,500,000	\$403
15	Grib	Russia	13	4,200,000	\$357
16	Finsch	South Africa	>25	2,500,000	\$255
17	Almazay-Anabara placers (A)	Russia	9	3,500,000	\$245
18	Nizhne-Lenskoye placers (A)	Russia	4	1,750,000	\$236
19	Victor	Canada	2	600,000	\$225
20	Karowe	Botswana	>10	300,000	\$207
21	Renard	Canada	12	1,700,000	\$204
22	Namdeb (A)	Namibia	20	400,000	\$200
23	Letšeng	Lesotho	19	105,000	\$189
24	Arkangel'skaya/Karpinskogo-1	Russia	>50	2,400,000	\$144
25	Zarnitsa	Russia	10	750,000	\$139
26	Nyurba placers (A)	Russia	21	1,200,000	\$138
27	Mirny placers (A)	Russia	9	670,000	\$134
28	Aikhal	Russia	13	2,600,000	\$130
29	Kimberly	South Africa	>20	900,000	\$113
30	Komsomoiskaya	Russia	5	400,000	\$108
31	Cullinan	South Africa	>50	950,000	\$105
32	Koidu	Sierra Leone	23	300,000	\$90
33	Botuobinskaya	Russia	>50	700,000	\$81
34	Voorspoed	South Africa	11	650,000	\$75
35	Somilana (A)	Angola	>15	130,000	\$62
36	Letihakane	Botswana	25	600,000	\$57
37	Luilo (A)	Angola	4	20,000	\$48
38	Williamson	Tanzania	>50	210,000	\$47
39	Murowa	Zimbabwe	5	500,000	\$45
40	Baken + Bloeddrif (A)	South Africa	<5	41,000	\$43
41	Brauna	Brazil	9	220,000	\$39
42	Kao	Lesotho	>25	75,000	\$37
43	Koffiefontein	South Africa	>20	60,000	\$32
44	Marange (A)	Zimbabwe	5	1,100,000	\$28
45	Liqhobong	Lesotho	15	250,000	\$28
46	Udachny placers (A)	Russia	4	250,000	\$25
47	Namaqualand (A)	South Africa	>10	90,000	\$15
48	Merlin	Australia	10	35,000	\$11
49	Saxendrift + other MOR (A)	South Africa	<10	5,000	\$7
50	Krone-Endora (A)	South Africa	37	35,000	\$4

Artisanal Production

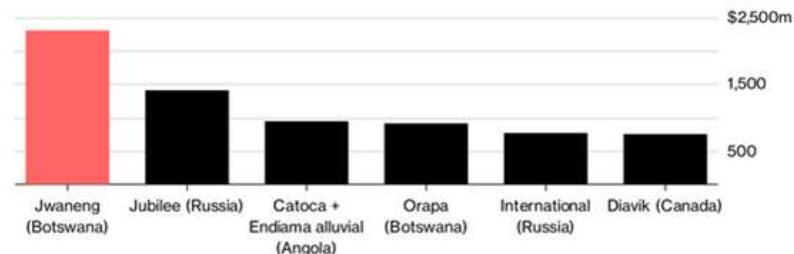
Angola	2,000,000	\$550
DRC (incl. MIBA)	16,000,000	\$128
All other global artisanal	750,000	\$188

Total Global Production 142,296,000 \$15,609

Average Price Per Carat \$110

Gem Giants

Jwaneng was the leader by production value in 2017



Source: Paul Zimnisky Diamond Analytics

Bloomberg



Russia diamond

Russia is the biggest producer in the world and believed to have the world's largest diamond resources exceeding 650 million carats or 54% of the world's reserve. Some 80% of this reserve is located in the Republic of Sakha and 18% in Arkhangelsk Oblast both situated in the northern part of the country. Most of the ore are above the average grade but mining condition is very tough and output is stagnant. Overall production is dominated by ALROSA which is 77% owned by Russian national and regional government balance by individuals

Deposit		Reserves (million ct)		Grade (ct/mt)	Prod. (million ct/y)
		ABC1	C2		
JSC ALROSA, Republic of Sakha (Yakutia)					
Tube Udachni	Primary	198.2	69.0	1.55	13.32
Tube Mir	Primary	146.5	3.3	3.63	0.00
Tube Anniversary	Primary	96.6	0.0	0.83	4.19
Tube International	Primary	44.9	13.9	8.52	3.69
Tube Aihal	Primary	32.6	10.1	4.93	0.40
Tube Zarnitsa	Primary	26.8	26.6	0.39	0.79
Watershed Pebbles	Alluvial	4.9	0.1	0.94	0.04
Placer Billyah	Alluvial	4.1	0.6	0.98	0.58
Mountain section	Alluvial	3.3	0.0	0.50	0.09
OJSC ALROSA-Nyurba, Republic of Sakha (Yakutia)					
Tube Nyurbinskaya	Primary	52.1	36.1	4.55	8.39
JSC Sevelalmaz, Arkhangelsk Region					
Lomonosov	Primary	199.4	8.4	0.44-1.21	0.64
AGD, Arkhangelsk Region					
Tube Griba	Primary	62.6	5.8	1.12	0.00
Unallocated fund, the Republic of Sakha (Yakutia)					
Placer Ebelyah	Alluvial	23.8	1.3	1.47	0.00

Source: Ministry of Subsurface Resources Management of Russia



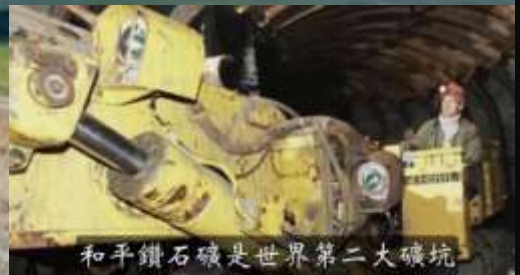


Autonomous republic

Autonomous oblast (AO)

Autonomous okrug (AOK)

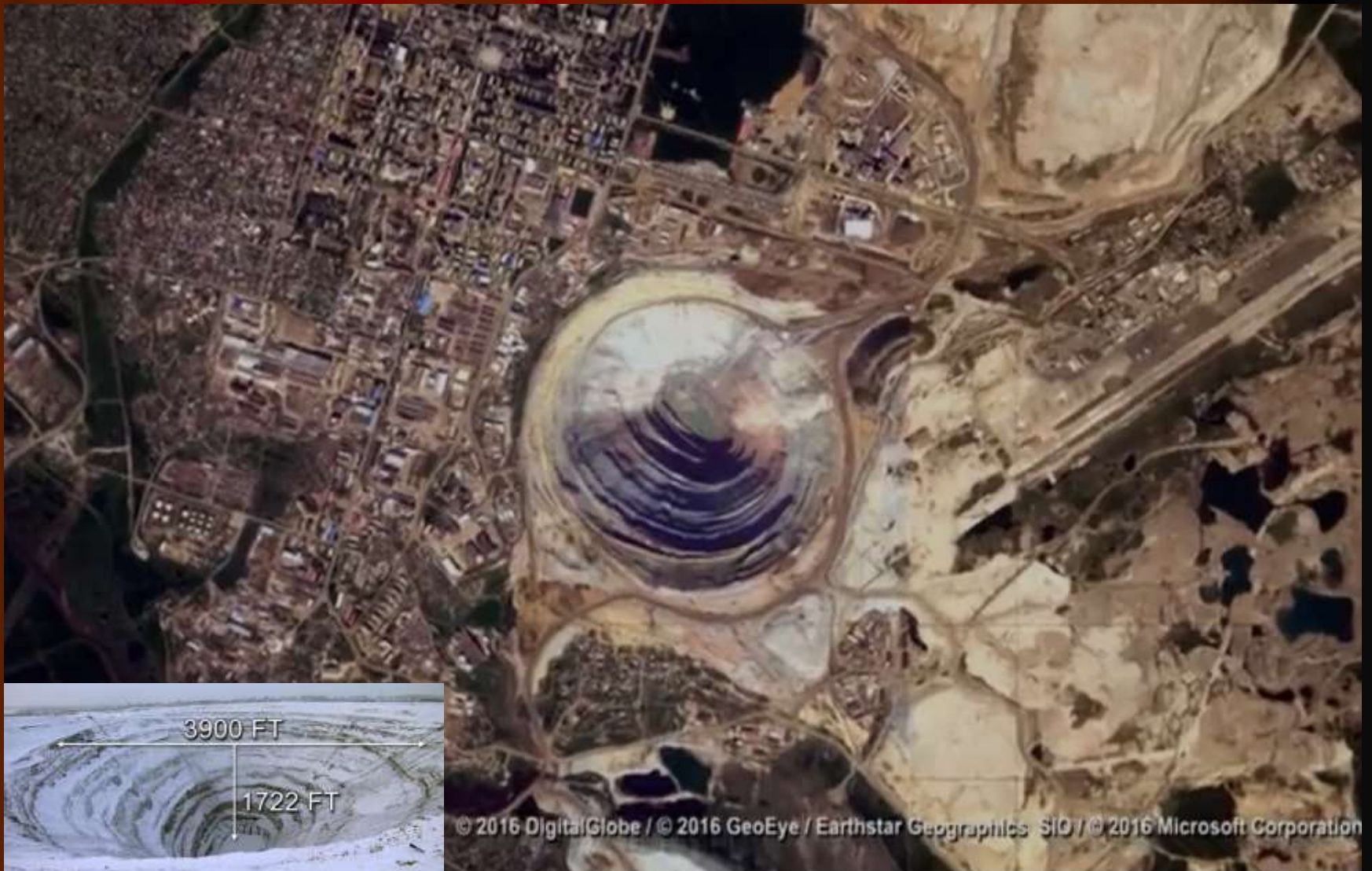
- The International Mine operated by Alrosa



The International mine in Russia. Source: ALROSA

- The Mir mine is huge. Originally open cast now mined underground





© 2016 DigitalGlobe / © 2016 GeoEye / Earthstar Geographics SIO / © 2016 Microsoft Corporation





- The Popigal crater in Russia's Siberia may have the world's largest diamond deposit, estimated at trillions of carats all formed by an asteroid impact changing graphite into diamond. The crater is 95 km in diameter and formed about 35.7 million years ago. The area is off limit and during Stalin's time was mined by the gulag prisoners. The diamonds are usually 0.5 to 2 mm in diameter good only for industrial use.



Botswana diamond

Diamond mining in Botswana is carried out under a 50/50 joint venture between De Beers and the Botswana government called Debswana (The Botswana government also owns 15% of the De Beers group)



The Jwaneng Mine is the richest diamond mine in the world producing 13 m carats/year value at US\$2.5 b making it world number one in 2017



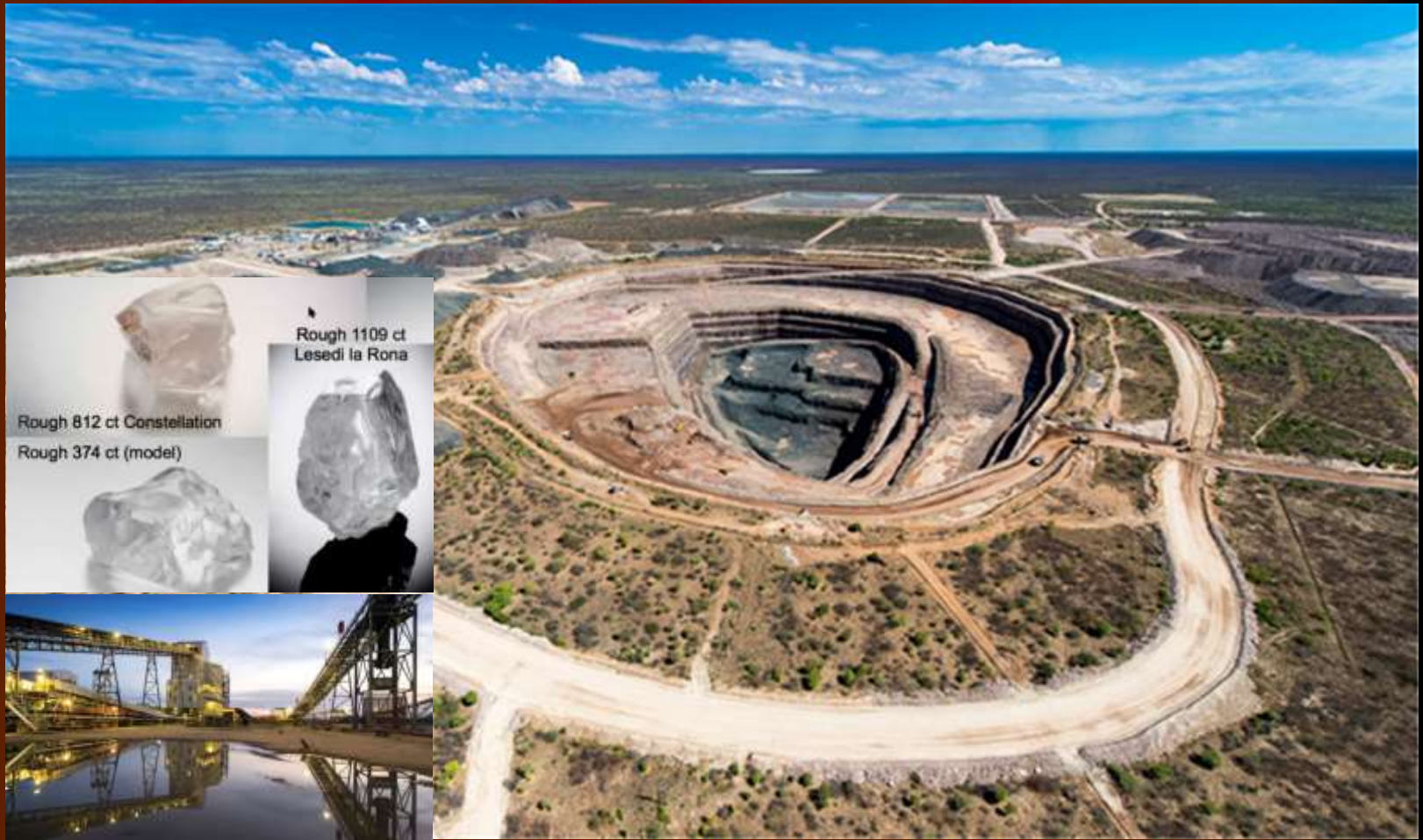
At 1.18 km², Orapa Mine is the world's largest open-pit diamond mine in by area and the 9th largest by reserve producing 12 m carats/year out of two volcanic pipes



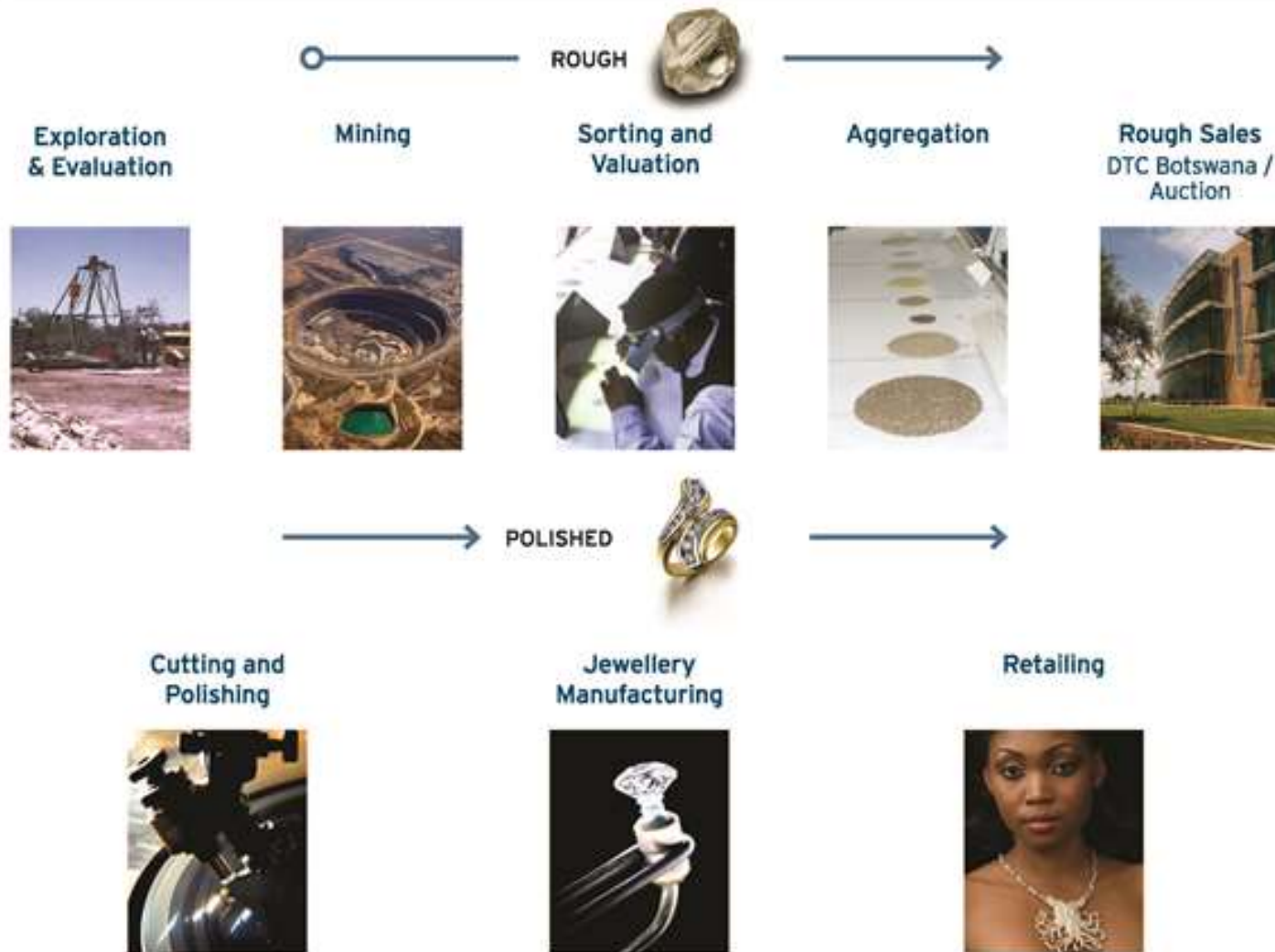
Aerial view of the Orapa Mine



The Karowe Mine is a state of the art mine fully commissioned in 2012 & is one of the world's foremost produce of type IIA diamonds in excess of 10.8 carats



The Journey of Botswana Diamonds



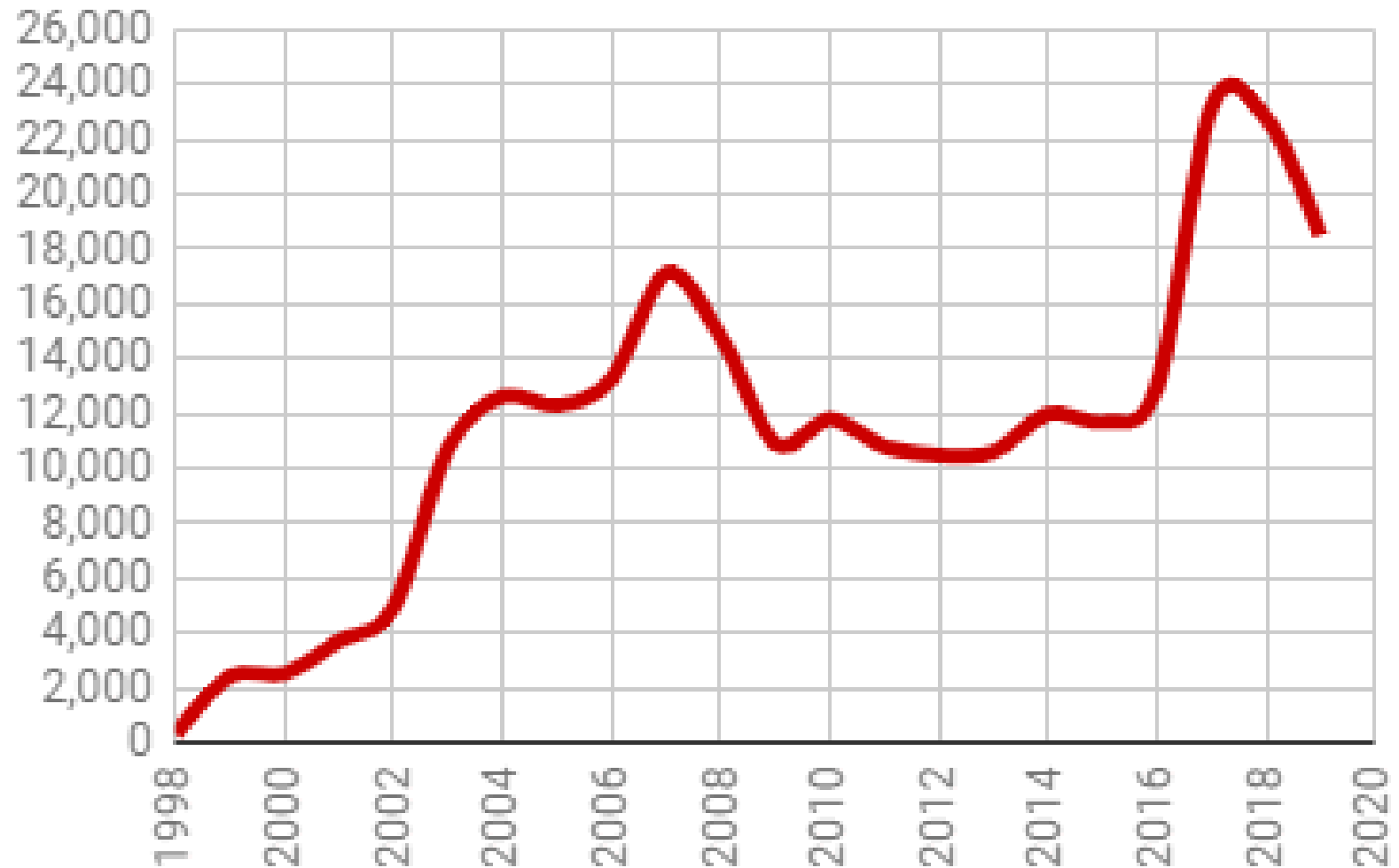
Canada Diamond

Diamond rich areas weren't discovered in Canada until the early 1990s. However within 10 years major diamond mines were unearthed and active mining began. Today Canada is the third largest diamond producing country in the world producing 13 million carats in 2018

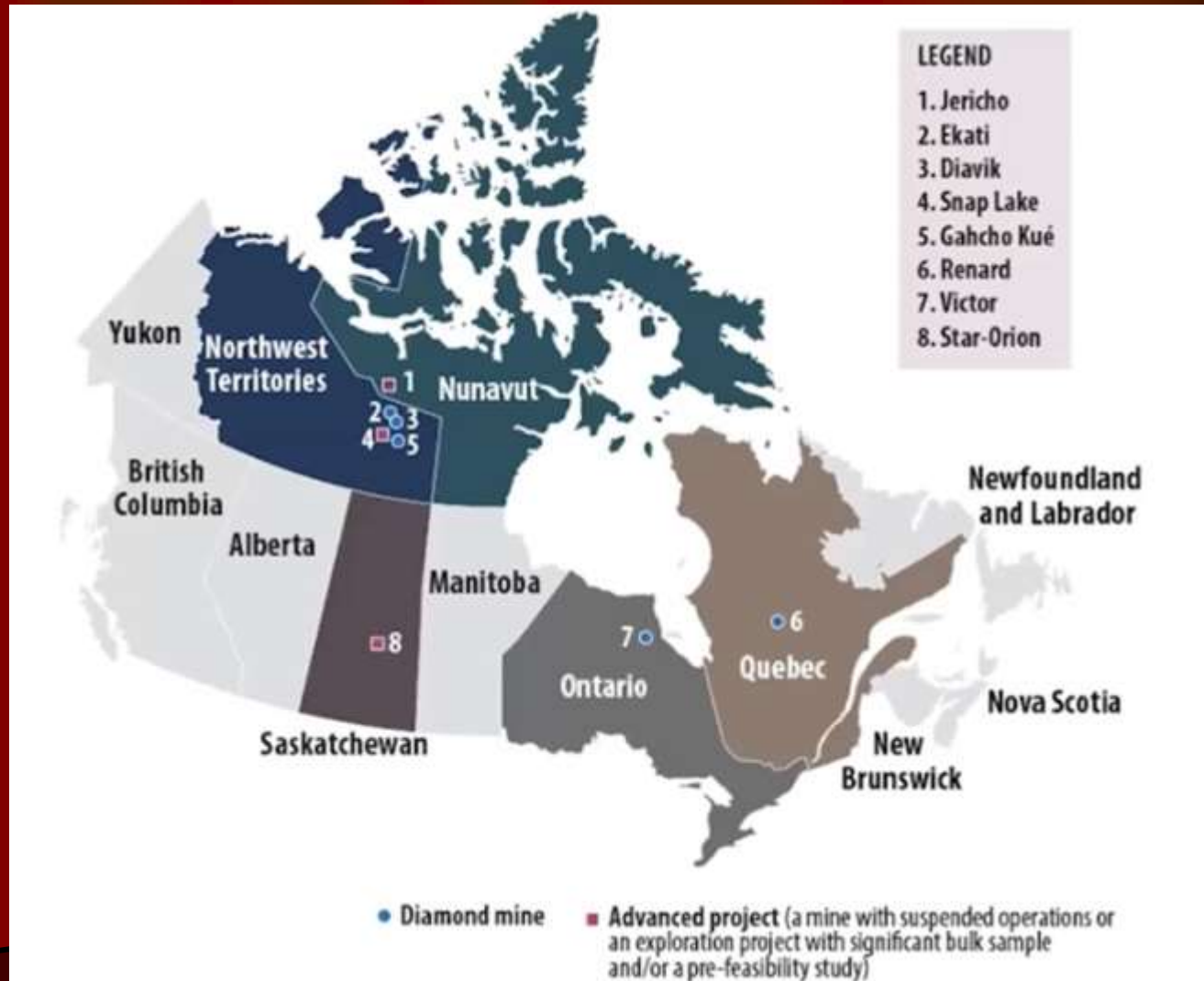


Canada Diamond Production

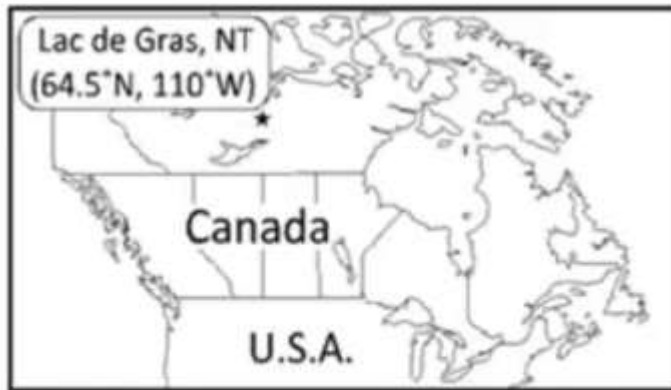
(thousands of carats per year)



- The country hosts 8 large scale diamond mines with state-of-the-art infrastructure which are operated by companies like De Beers, Rio Tinto, BHP and Dominion Diamond



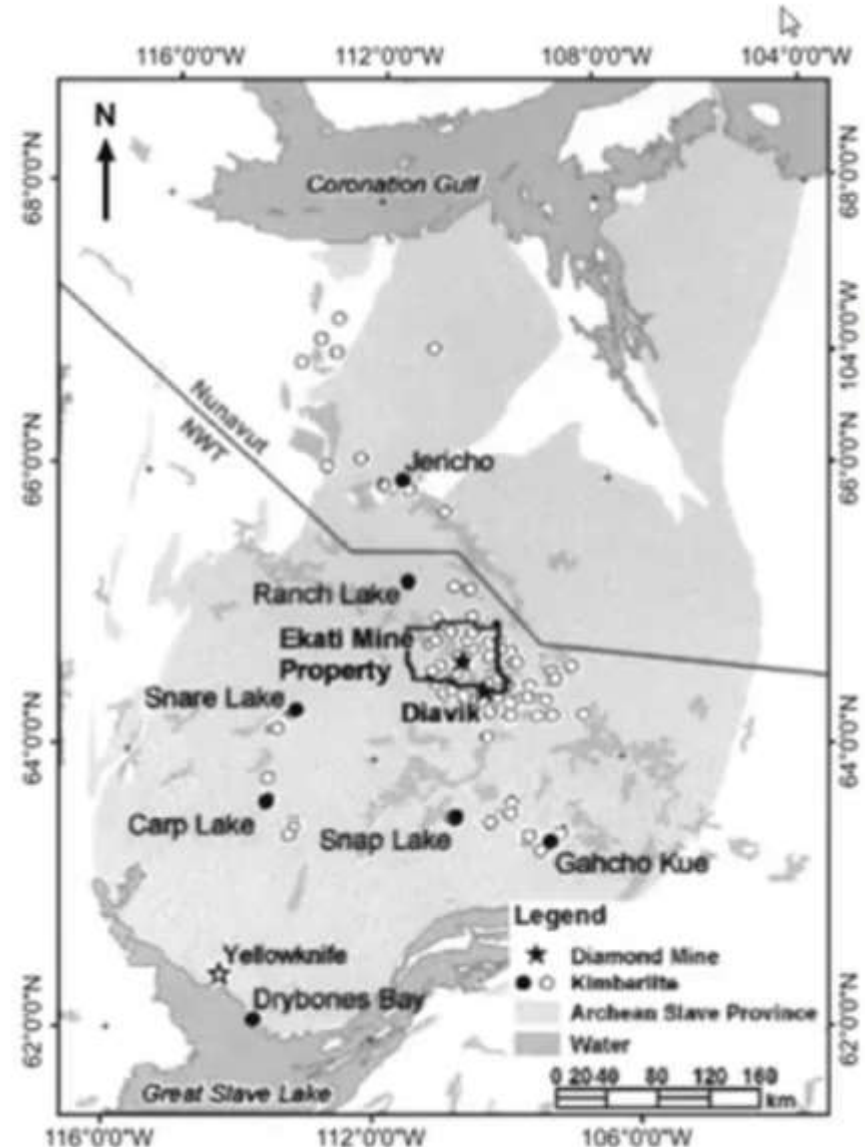
- BHP's Ekati Mine is Canada's first diamond mine open 1998



Hundreds of pipes are now known (~150 on the BHP Ekati property alone *now Harry Winston*), thousands are likely to exist

Economic diamond grades occur in a handful of these

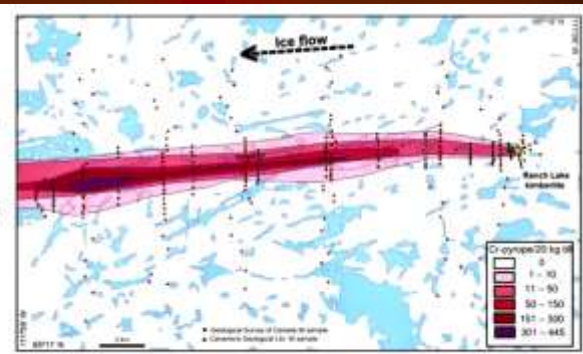
BHP obtained ~10 km of exploration core 1985-2005



- Glaciation features tells a story



- Glacial till sampling
- Geophysical surveys
 - Magnetism
 - Gravity
- Vegetation, topography
- Kimberlite
 - Drilling/characterization
 - Evaluate diamond content
 - Economic?

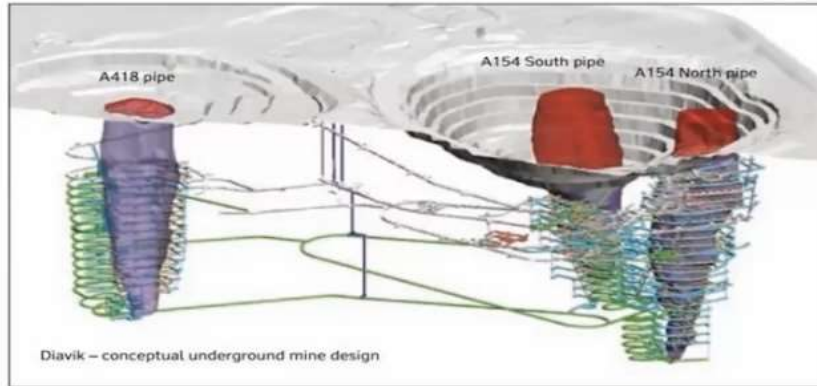


- Aerial view of BHP's Ekati Mine at Slave Craton, Canada



Copyright © Dominion Diamond Mines
Ekati Mine, Slave Craton, Canada

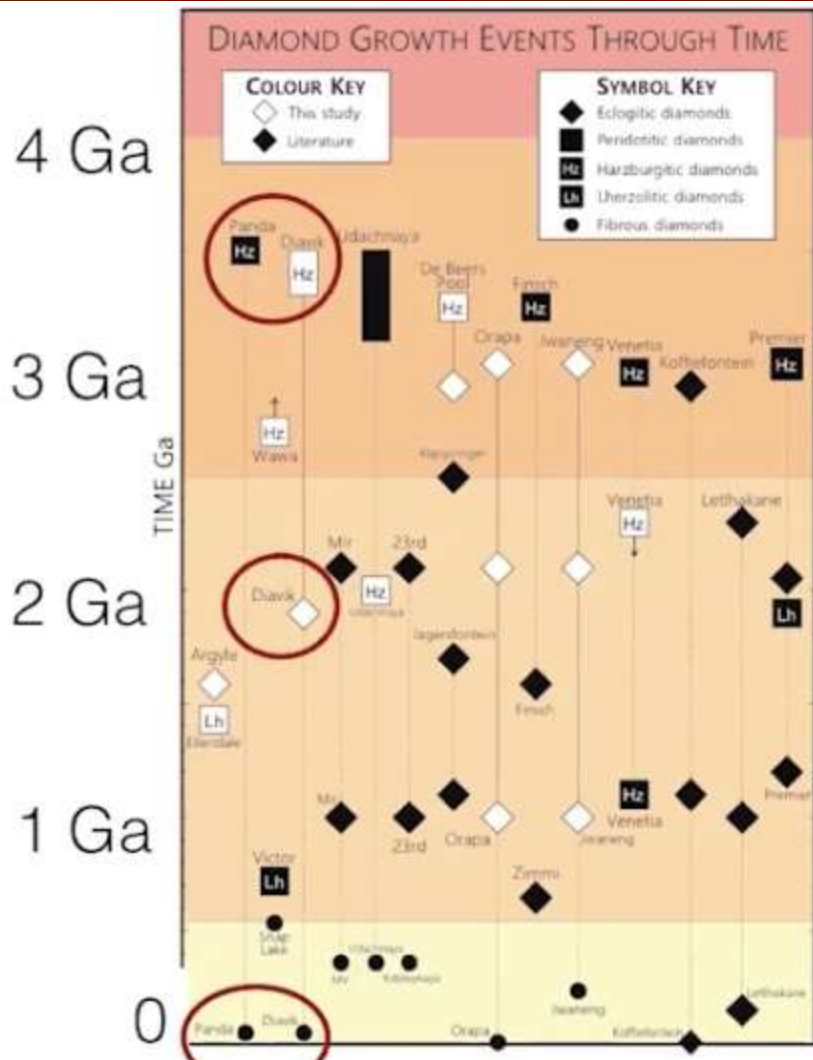
- Aerial view of the Diavik Diamond Mine with three kimberlite pipes



© Diavik Diamond Mines Ltd



552 ct rough diamond
Mined at Diavik in 2018



Ekati and Diavik
have the oldest
diamonds on Earth
3.5-3.3 Ga

Both these mines also have young diamonds

Westerlund et al., 2006
Aulbach et al., 2009

- The Gahcho Kué' Project



- The Star-Orion Diamond Project in Saskatchewan with 66 m carat potential

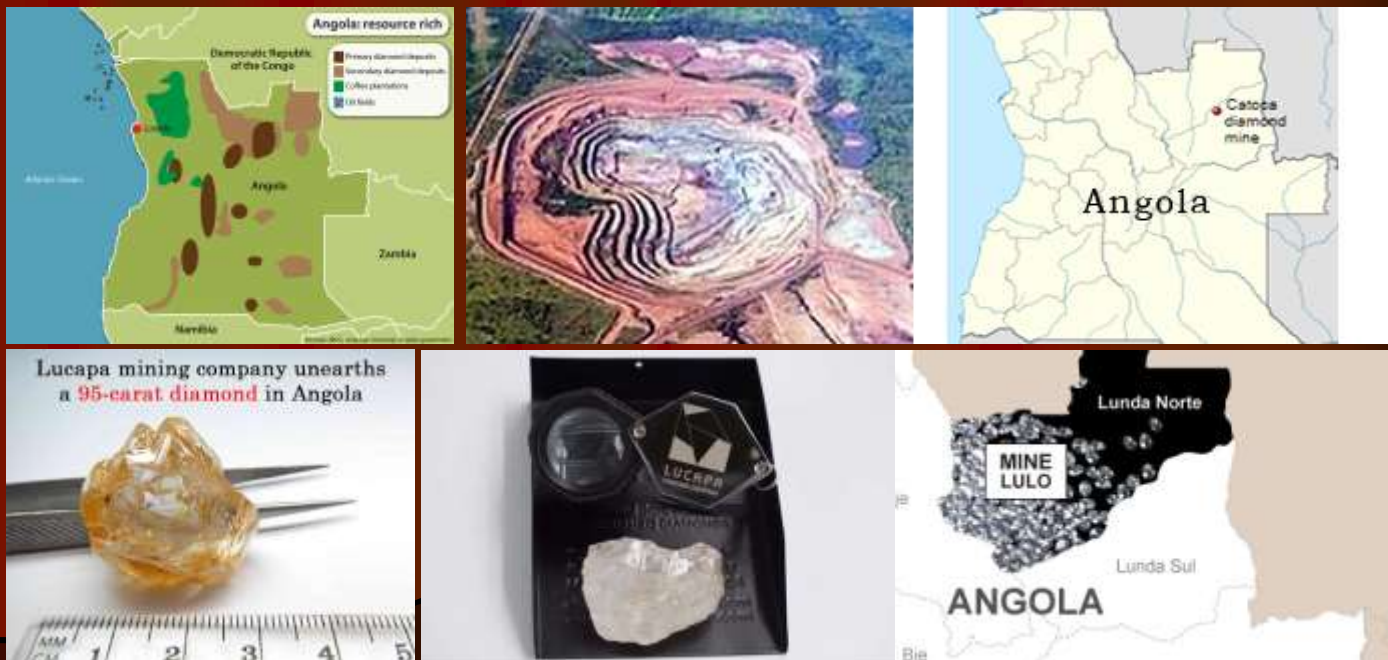


LDD-140-15-023-02	3.25ct		LDD-140-15-025-02	0.81ct	
LDD-141-15-019-07	1.15ct		LDD-140-15-027-06	0.78ct	
LDD-141-15-024-07	1.09ct		LDD-141-15-024-04	0.76ct	
LDD-141-15-020-05	1.04ct		LDD-141-15-023-04	0.75ct	
LDD-140-15-025-06	0.82ct		LDD-140-15-025-04	0.70ct	

Rough diamond sample from the Star-Orion South project in Canada. Source: Shore Gold

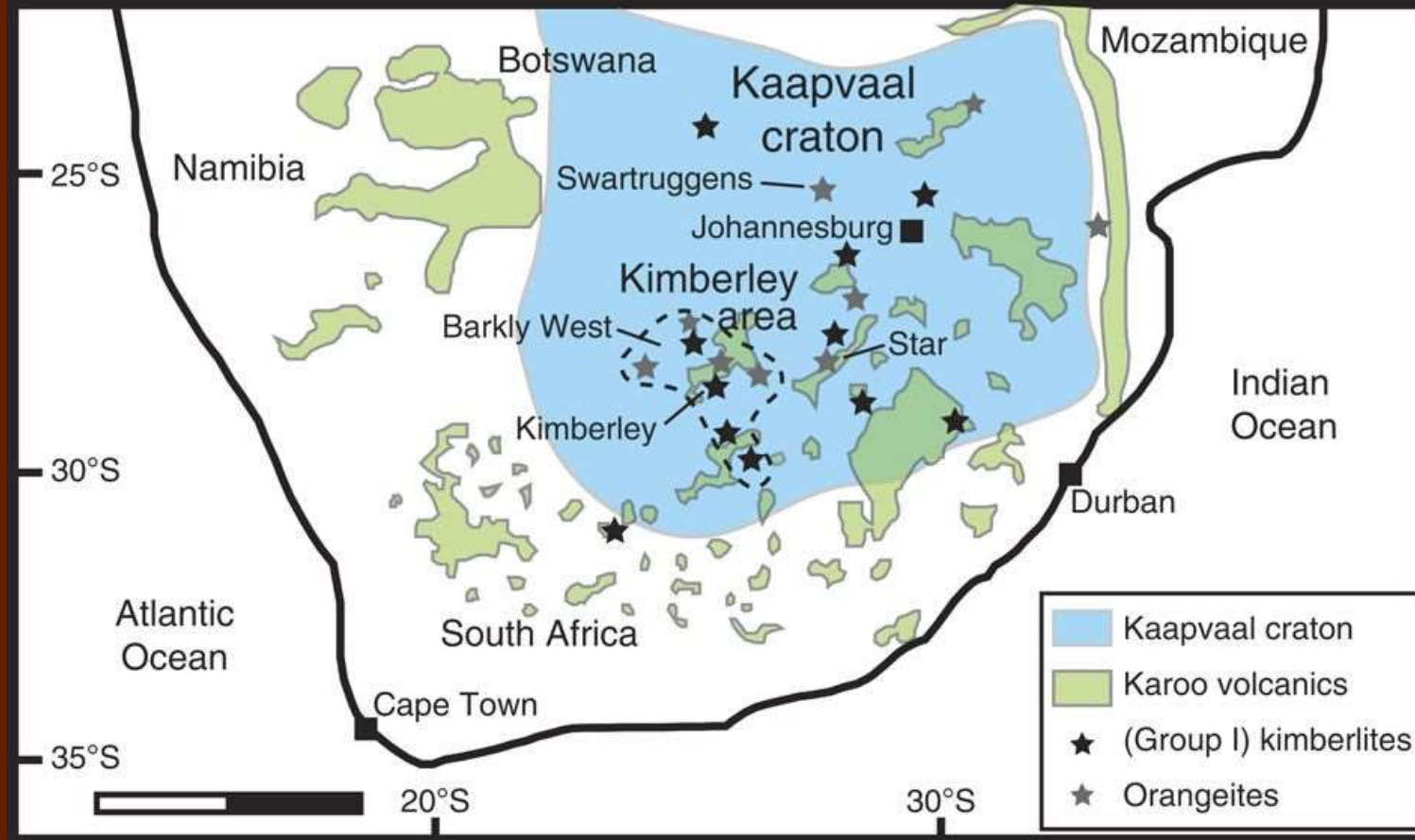
Angola diamond

It is the 4th largest diamond producer in the world by value with 75% of the nation's production coming from one mine, Catoca. The mine is owned by 4 entities primarily Endiama E. P. which is the Angolan-state diamond miner & ALROSA. The mine produce 6.5 m carats worth over US\$600 million. ALROSA is developing a new mine called Luaxe which can produce 10 million carats per year. Small Angolan alluvial miner Lucapa Diamonds has made headlines with exceptionally large finds including a 404 carats colorless diamond

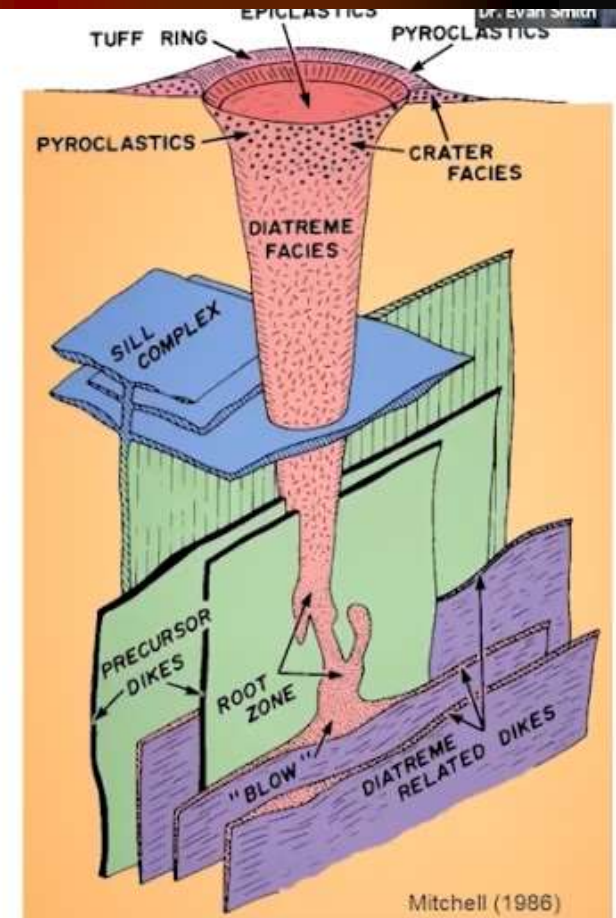


South Africa diamond

South Africa diamond including those originated from Botswana, South Africa Republic, Namibia and Zimbabwe all coming out from the Kaapvaal Craton which was formed 3.6 Ba ago



- ◆ South Africa's first diamond, Eureka, discovered 1866
- ◆ First kimberlite discoveries—1871
- ◆ De Beers Consolidated Mines Ltd. established in Kimberley—1888



The seven major mines in South Africa are controlled by DeBeers Consolidated Company. The most famous is the Kimberley Mine which started production in 1868. By 1880, 95% of the world's demand came from this country. Now the majority of its diamond has been mined & closed in 1915 having produced 2.9 m tons or 4.5 million carats. De Beers however still monopolized the world market until the beginning of the 21st century. Today over 60% of the production is from De Beer's Venetia and Petra

Kimberlites

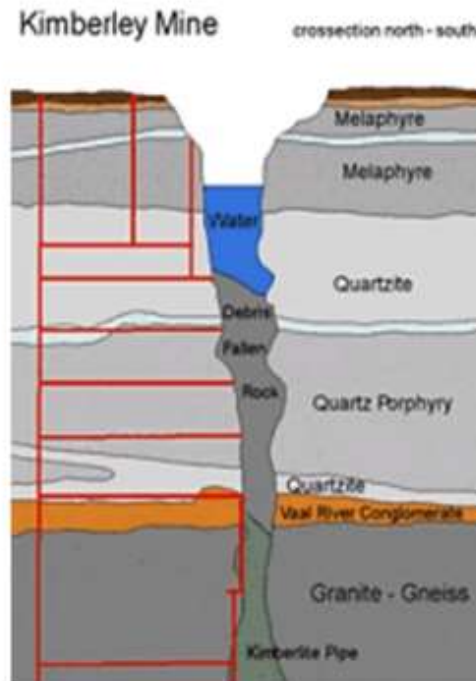
Kimberlite age: 2 billion yrs to recent.

Contained diamonds are usually 1.0 - 3.3 billion years old

Diamondiferous kimberlites almost always above Archaean cratons (>2.5bn yrs)

Massive degassing of CO₂ in rising magma leads to fluidizing

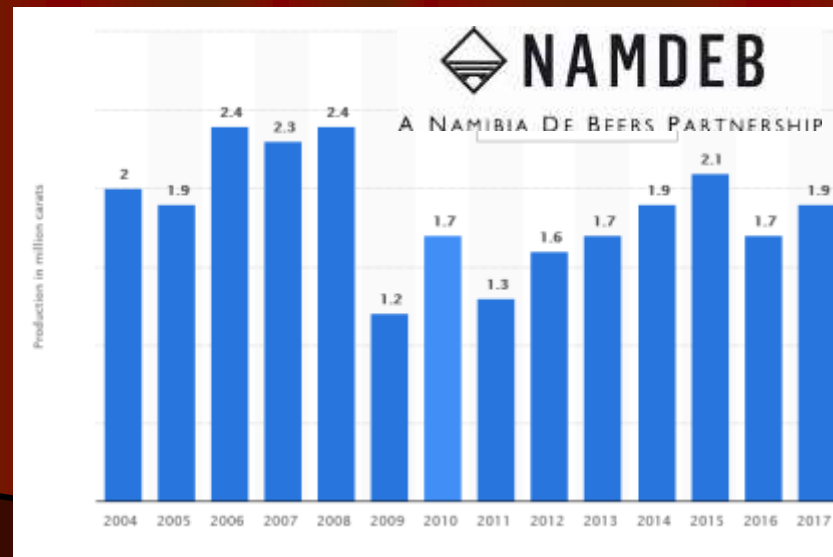
Drill through the crust as narrow pipe-like intrusions or dykes - erupt at high speed.



Namibia diamonds

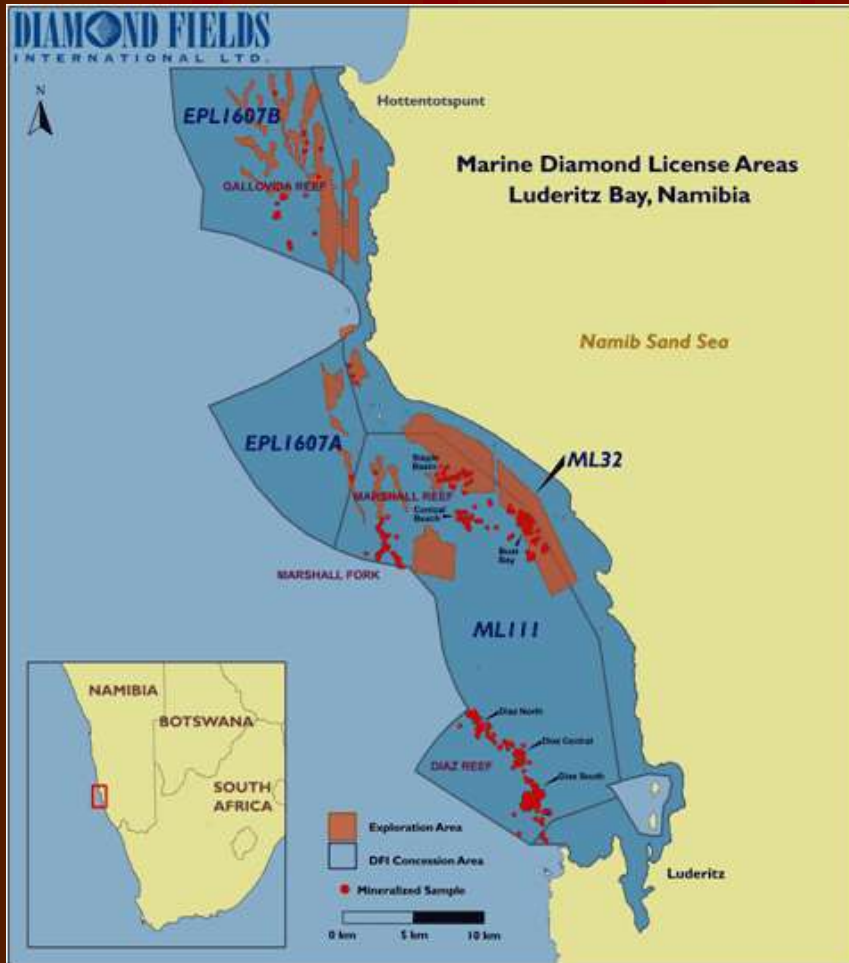
Namibia diamonds are secondary deposits which originated from the *Kaapvaal Craton located in South Africa. Over the past 90 million years, the diamonds were eroded out of the kimberlite pipes & transported to the east by rivers down a drainage basin & eventually reached the Atlantic Ocean. During this process imperfect stones are being destroyed. As a result up to 95% of the sea diamond in Namibia are of gem quality ! Russia diamond is the opposite with 95% industrial & only 5% gem. Under German rule some 7 million carats were extracted between 1908 & 1914. Today mining is under a DeBeer/Namibia government JV called NAMDEB

Production in Million carats

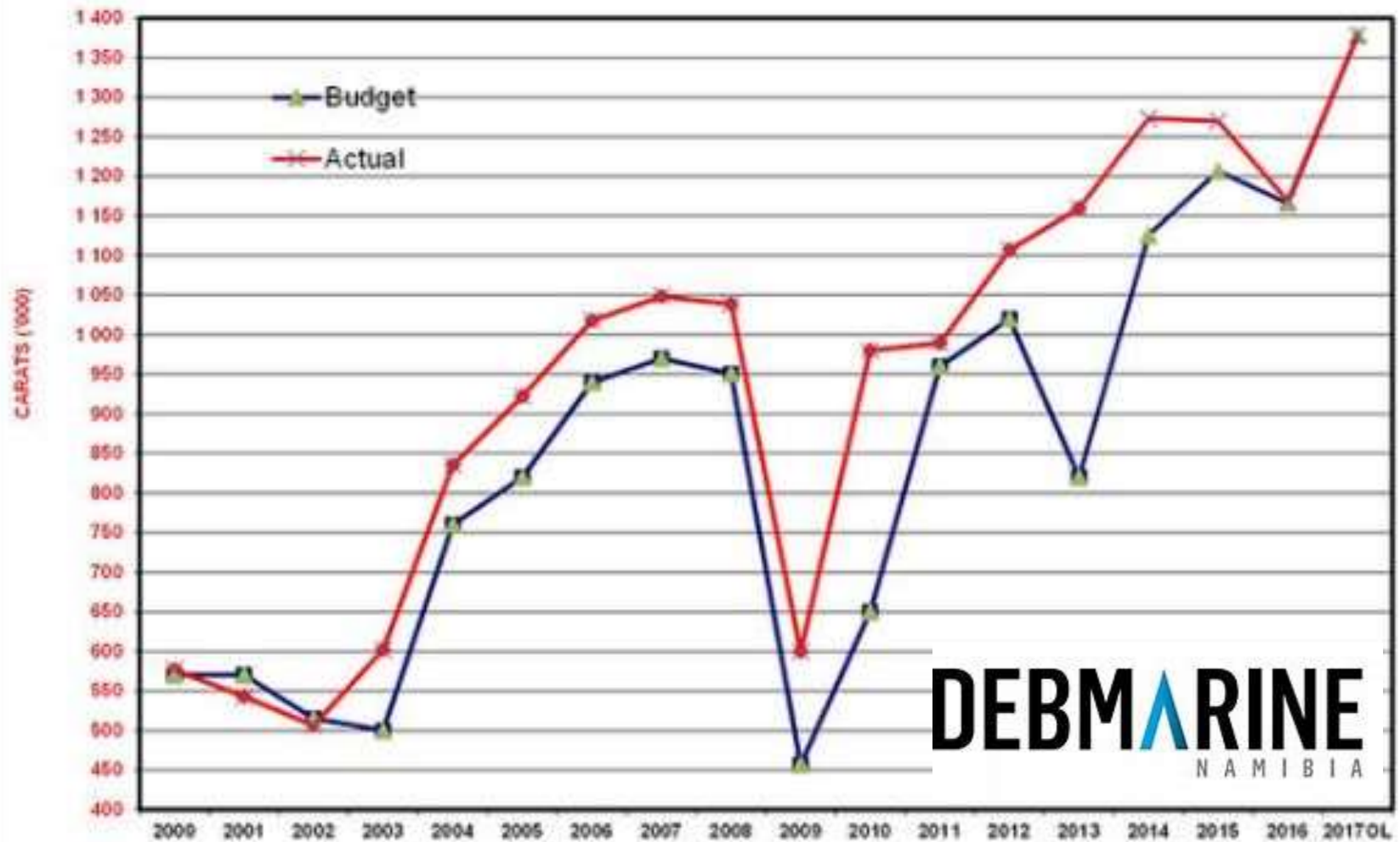




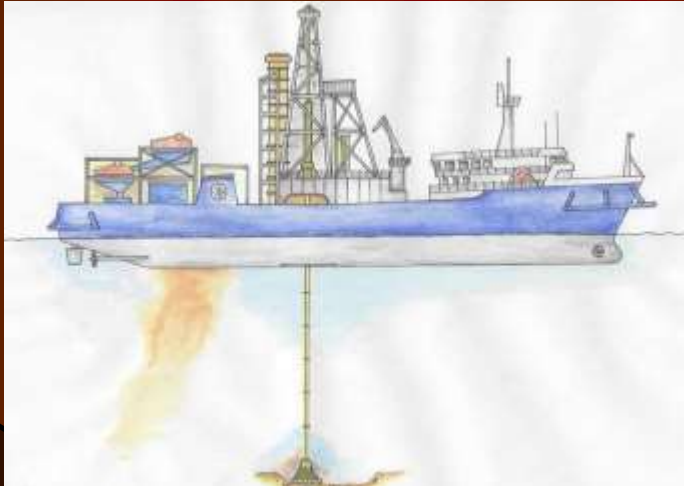
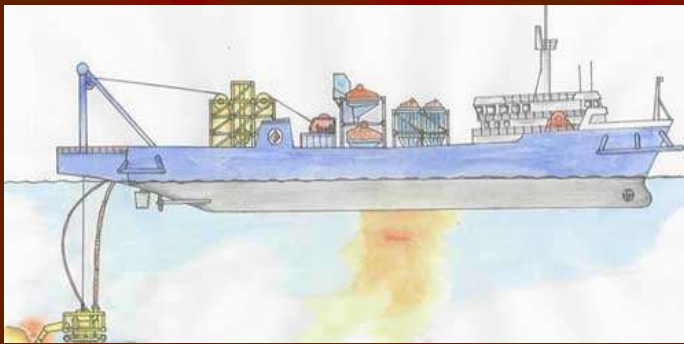
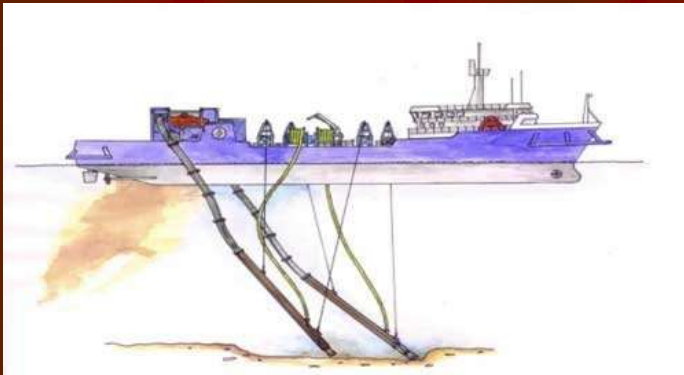
Mined since 1908, Namibia has the richest marine deposit in the world estimated to be more than 100 million carats. The “Diamond Coast” is now mined by DEBMARINE, a JV between De Beers & the Namibia Government company Namdeb Corporation with annual production around 1.4 to 1.6 million carats accounting for 70% of total production

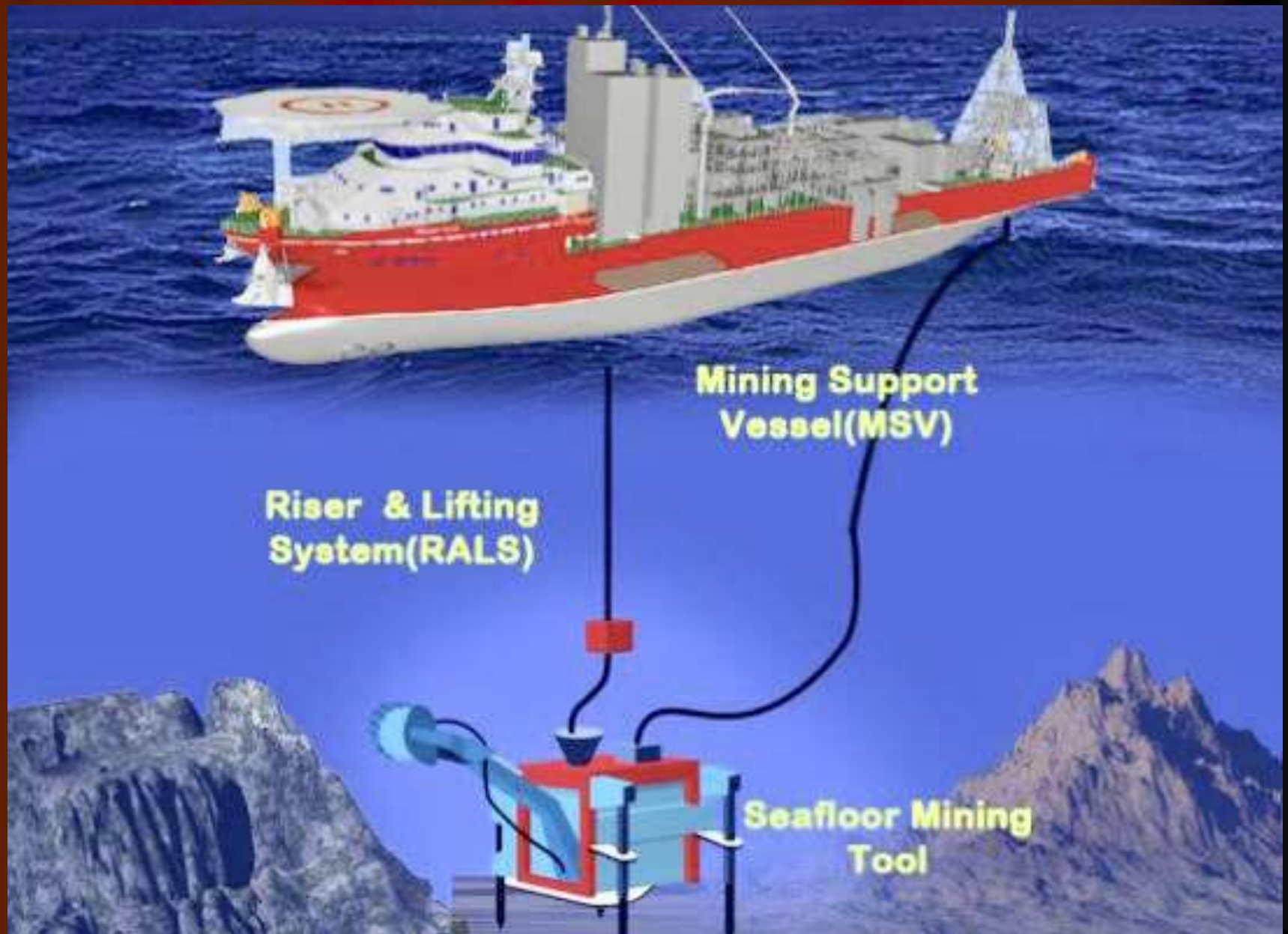


Debmarmine Namibia Production



- Marine diamonds are mined by suction, dredging or drilling







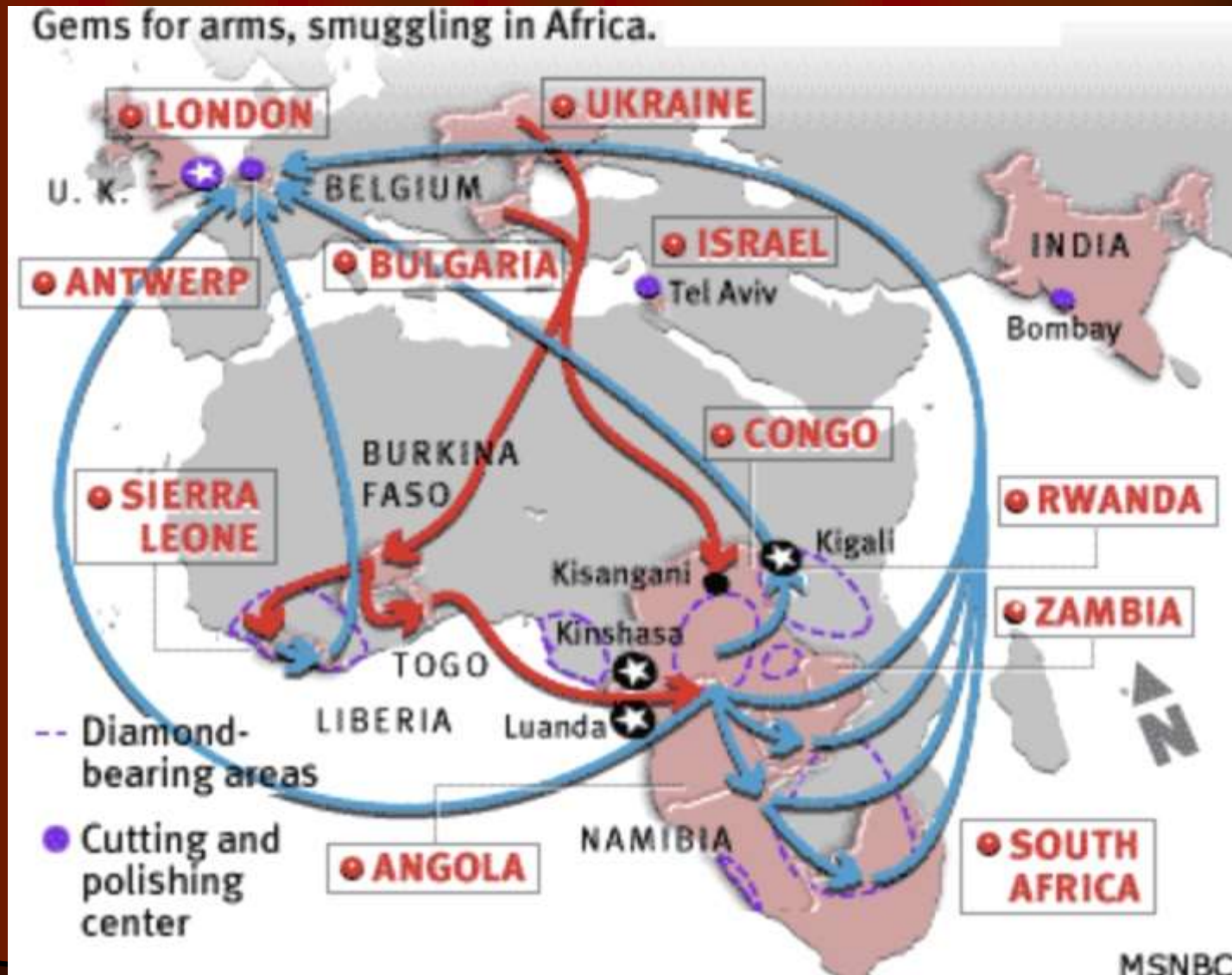
One of Nautilus Mineral's seafloor production tools for mining precious and base metals. Source: Nautilus Minerals

Blood Diamonds 血鑽

Also called conflict diamonds/ war diamonds/ hot diamonds/ red diamonds is a term used for a diamond mined in a war zone and sold to finance an insurgency, an invading army's war effort or a warlord's activity e.g. those mined in Angola, Ivory Coast, Sierra Leone, Liberia, Nigeria, Guinea and Guinea Bissau. In Sierra Leone 300,000 to 400,000 people are involved generating US\$250 million per year but very little returns to the areas due to poor governance & widespread corruption

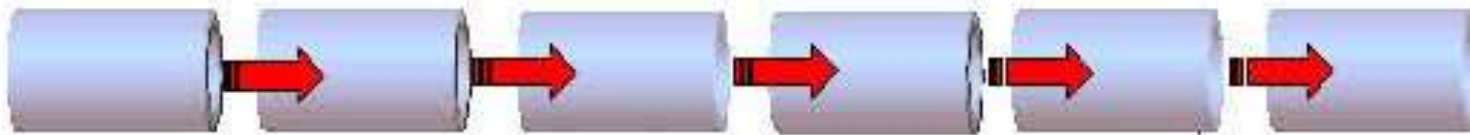


- It was estimated that at the peak 1 out of 4 diamond in the market is a blood diamond operating in a very sophisticated network



Blood diamonds already left more than 50,000 people dead, half a million people homeless and thousands of amputees. To curtail the flow of such products, the Kimberley Process Certificate Scheme (KPCS) was approved and activated in January 2003





Mining

Export

Import

Polishing

Manufacturing

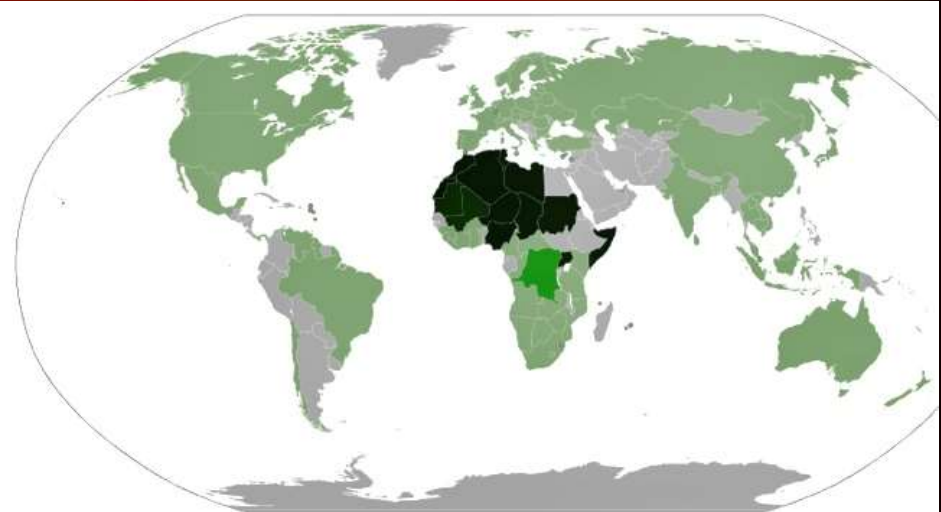
Retail

Kimberley Process
Certification Scheme

System of Warranties



75 countries have joined the KPCS to prevent “conflict diamonds” from entering the mainstream market. It endorsed an Invoice Warranty System created by the World Diamond Council covering the trade and successfully reduced the circulation from 15% to only 1%



-  Countries who are participants and official applicants
-  Participant ongoing conflict
-  Official applicants ongoing conflict
-  Ongoing conflicts in Africa

China Diamond

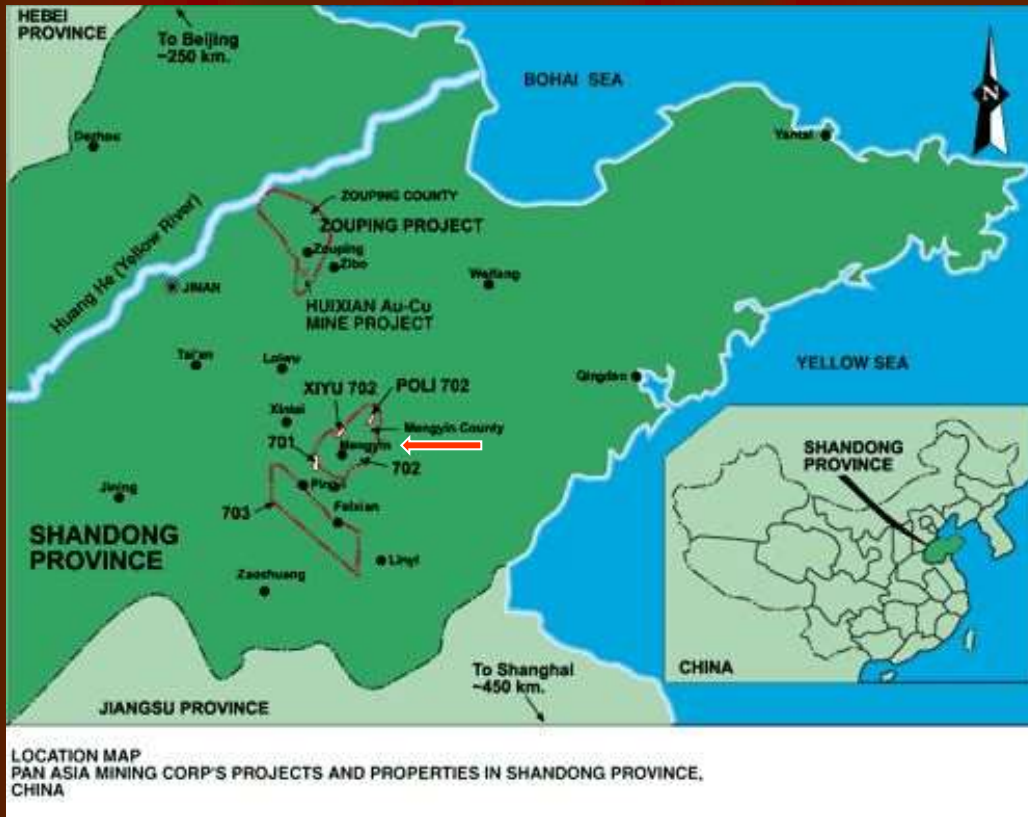
Exploration only started in 1952 with first kimberlite found in 1965. Over the past 50 years China discovered more than 20 kimberlite pipes and over 100 diamond placers. Current reserve estimate is at 23 million carats. About 50% or 11 million carats of proven reserves are concentrated in Liaoning Province. The balance is in Shandong (9 million carats) with much smaller amount in Hunan and Jiangsu Province. Current annual production 150,000 carats



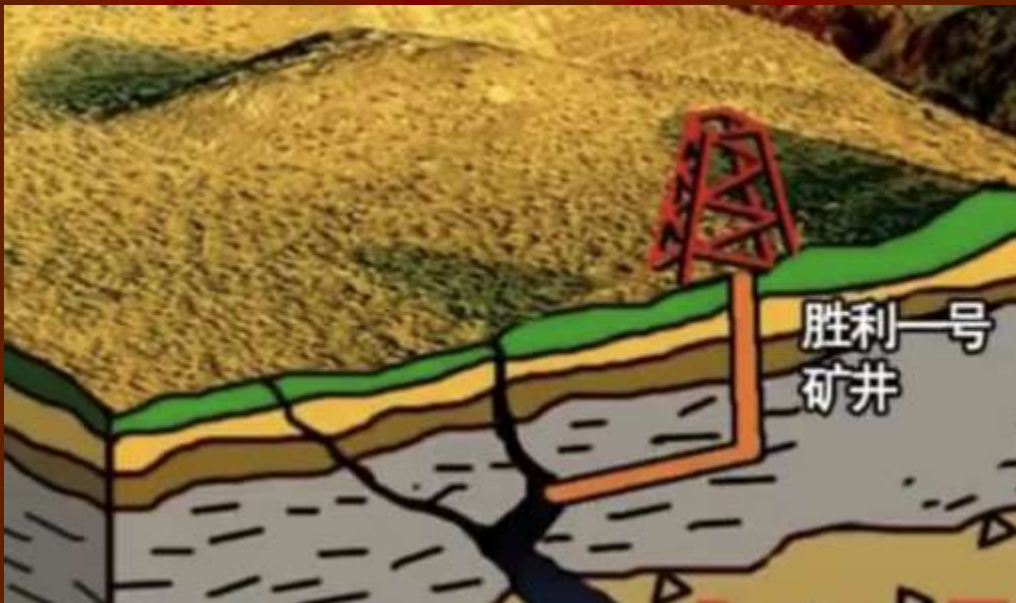
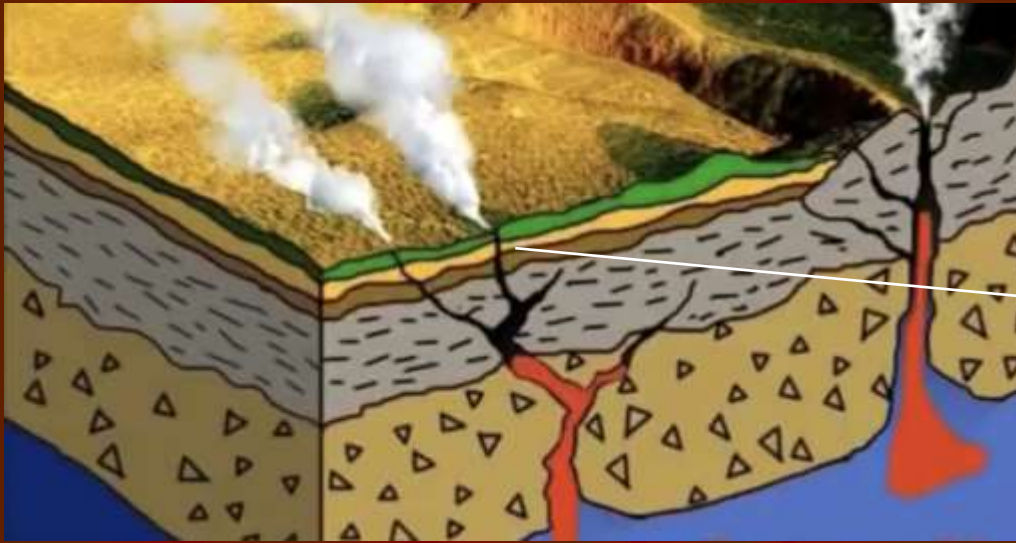
10 Years of Diamond mining in China						
Year	Diamond Production			YoY % Change		
	Carats	Value	Avg p/c	Carats	Value	Avg p/c
2005	71,764	\$1,000,000	\$13.93			
2006	74,080	\$1,240,000	\$16.74	3%	24%	20%
2007	61,373	\$1,110,000	\$18.09	(17%)	(10%)	8%
2008	69,480	\$1,370,000	\$19.72	13%	23%	9%
2009	45,932	\$480,000	\$10.45	(34%)	(65%)	(47%)
2010	17,227	\$280,000	\$16.25	(62%)	(42%)	56%
2011	201	\$50,000	\$248.76	(99%)	(82%)	1430%
2012	1,855	\$43,500	\$23.45	823%	(13%)	(91%)
2013	1,050	\$33,000	\$31.43	(43%)	(24%)	34%
2014	0	\$0	\$0.00	(100%)	(100%)	(100%)

Source: KP

The most notable mine in Shandong Province is mine number 701 Changme 沂蒙 located in Mengyin 蒙陽 with annual production capacity estimated to be around 50,000 carats. The Diamond market is young in China with the Shanghai Diamond Exchange only established in 2000. Photo on the lower right is the 158.7 carat 常林鑽石 discovered in 1977

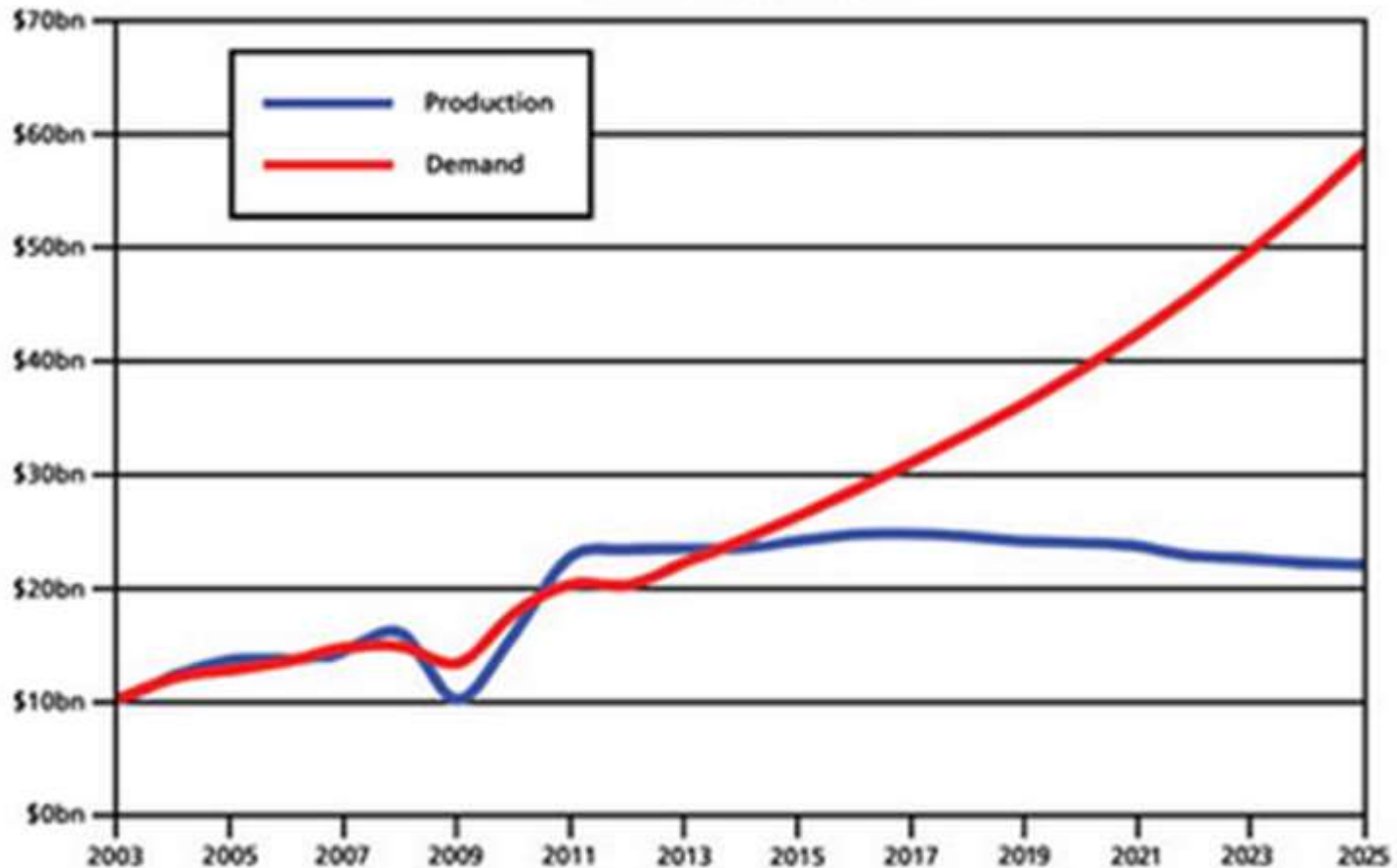


Kimberlite pipe 岩管/筒
formed 500 Ma

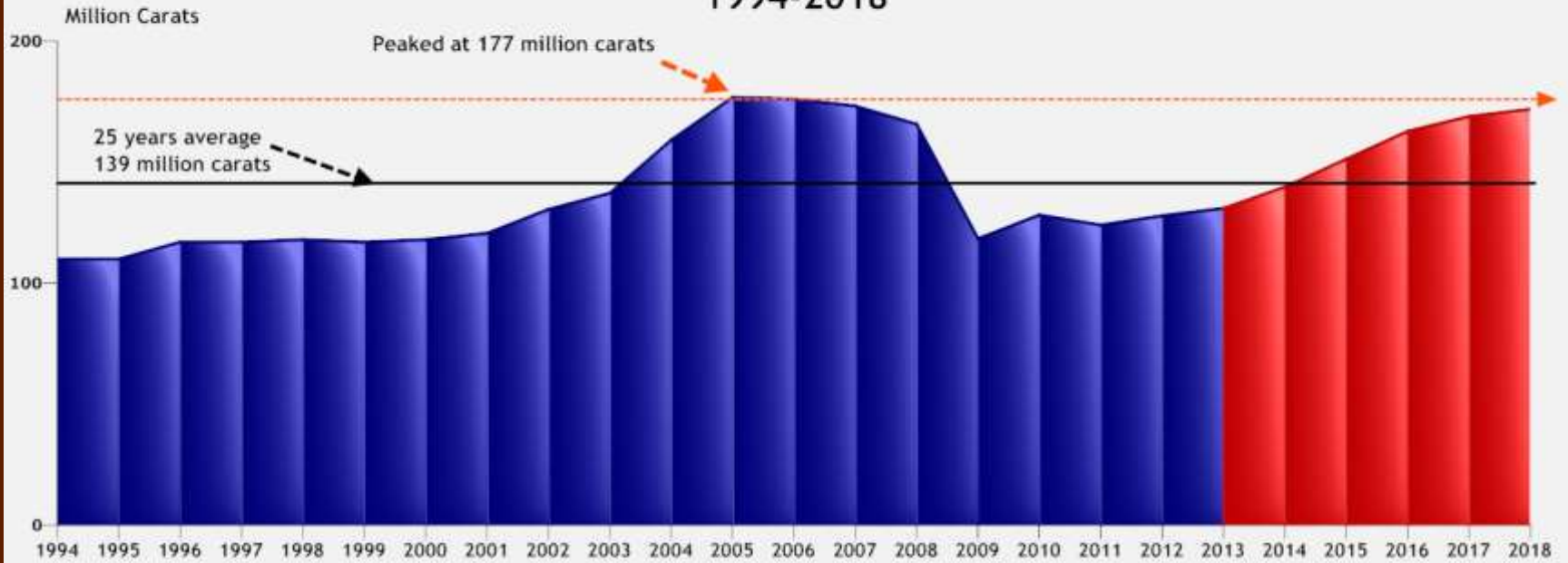


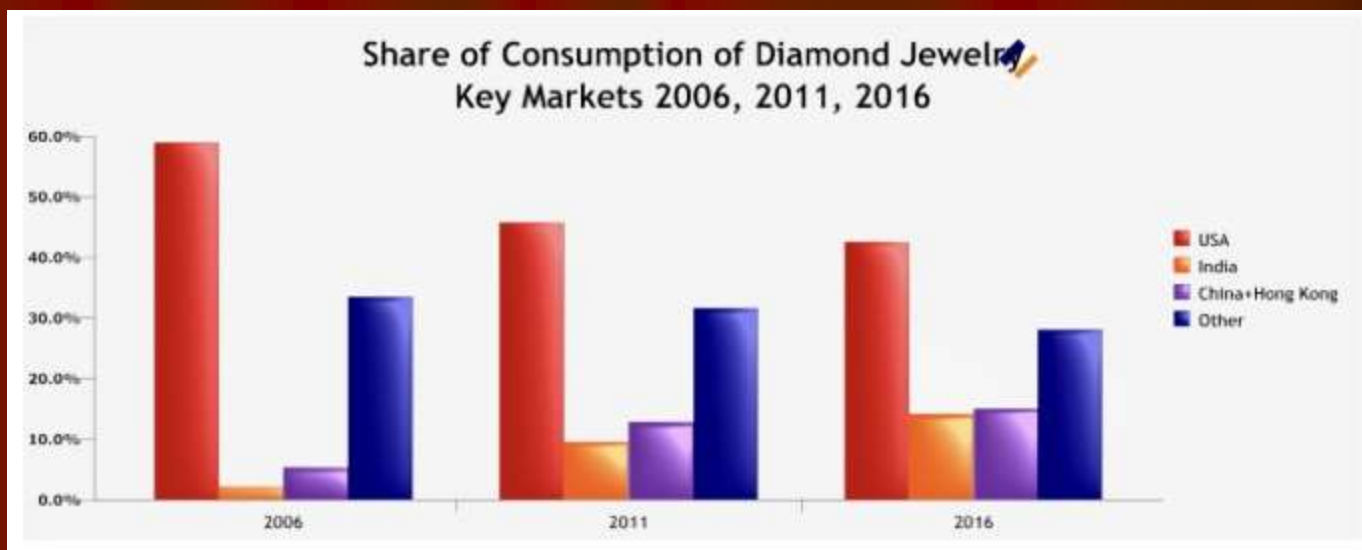
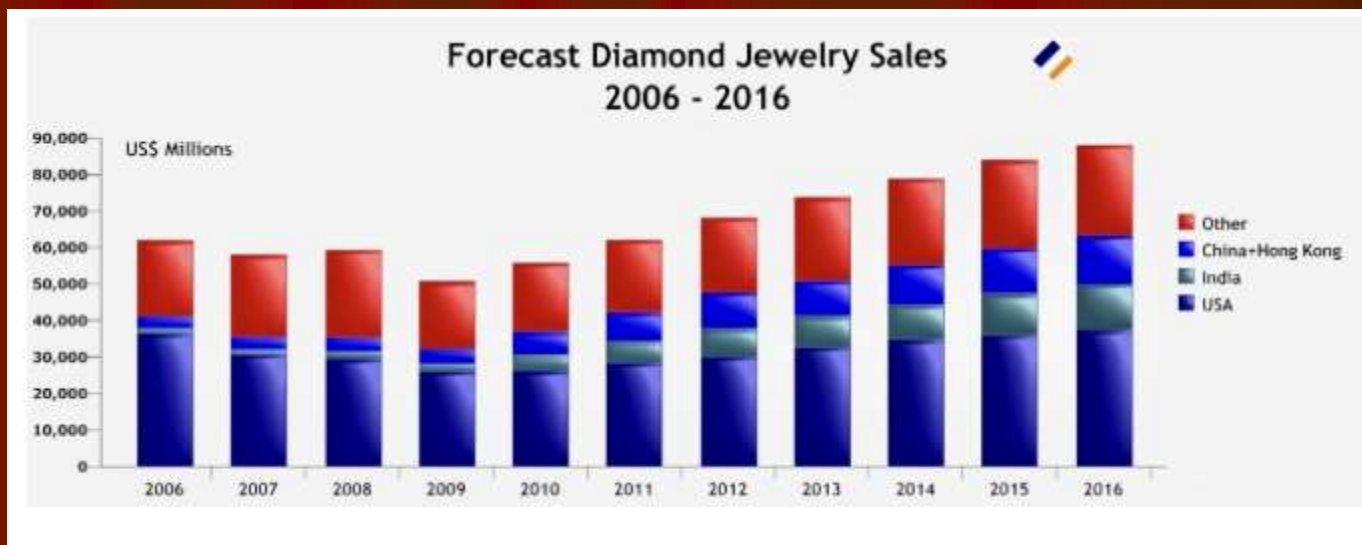
Industry Update

Production and Demand in Rough Terms (May 2011 values)



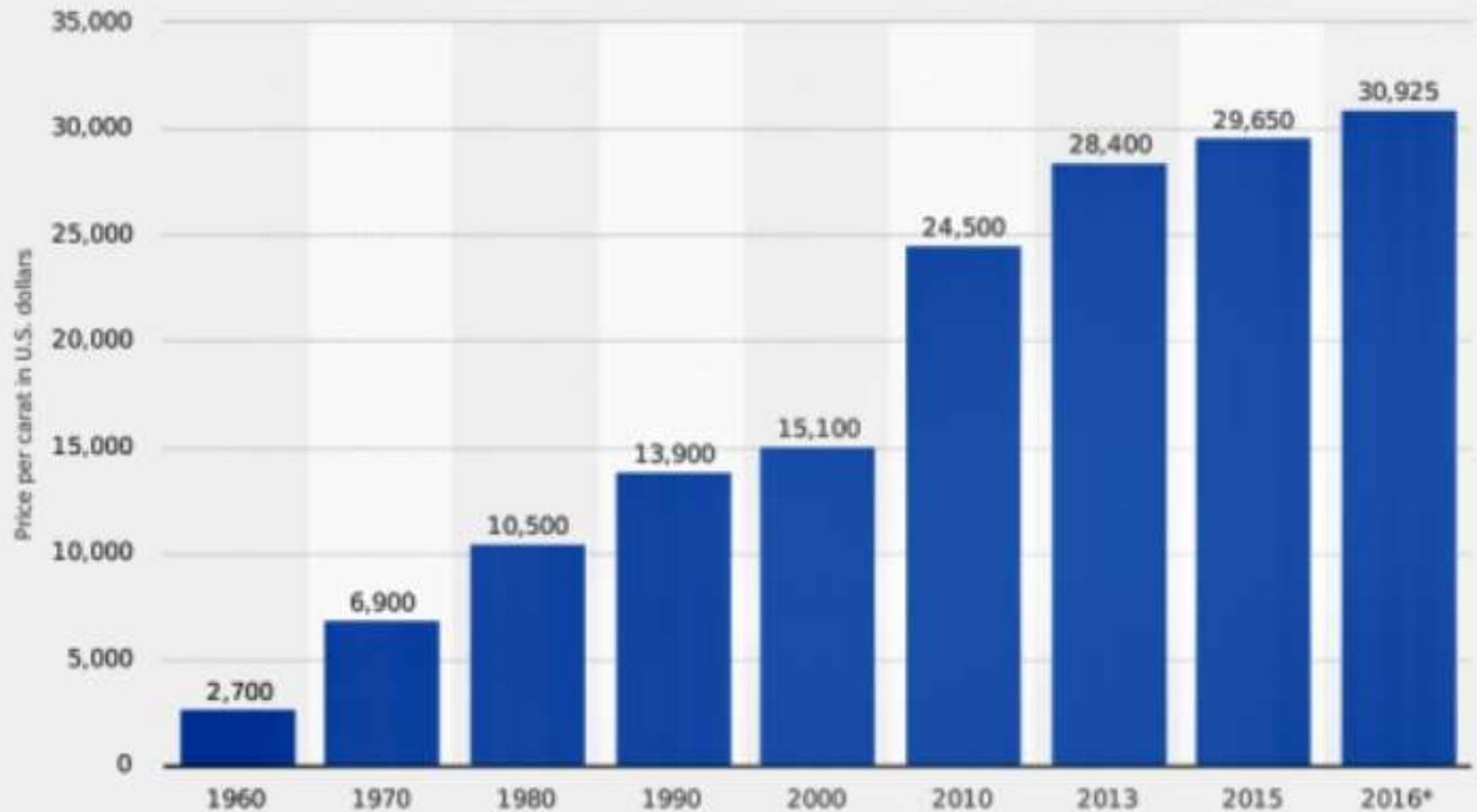
World Diamond Production 1994-2018





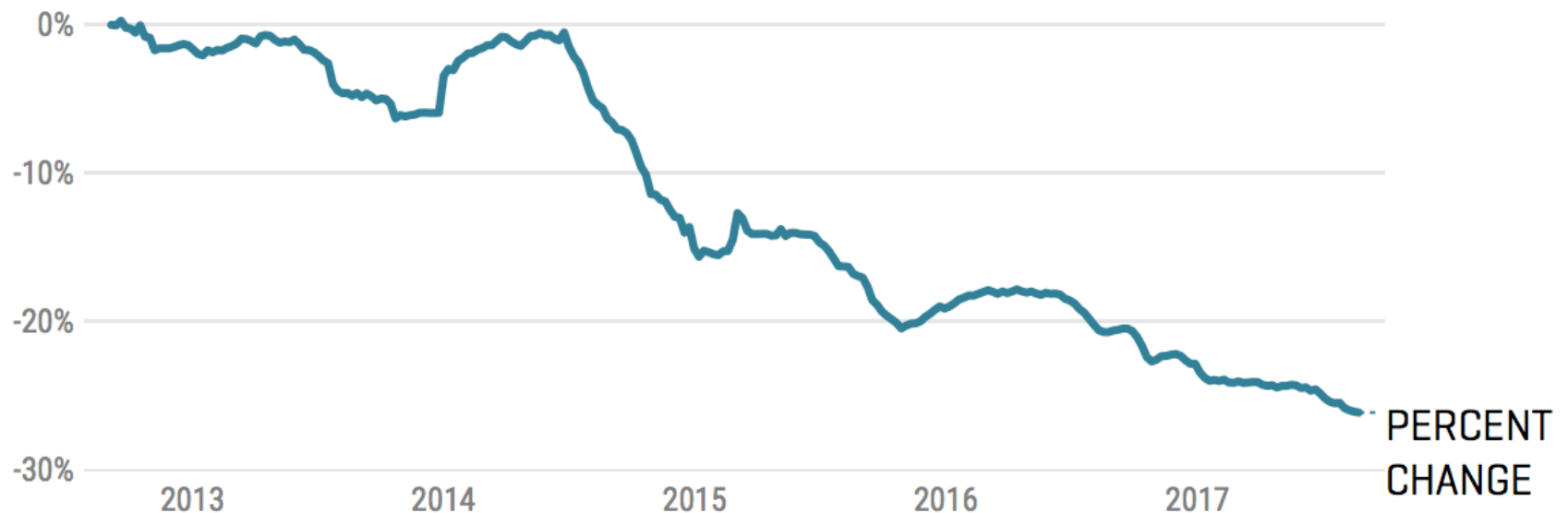
2018 USA accounted for 35% of the world's diamond value at US\$26 billion making it the largest in the world and still way ahead of India and HK/China which still lack the western "diamond culture"

Diamond prices per carat from 1960 to 2015 (in U.S. dollars)*



The Price of Diamonds is Falling

Diamonds prices are in decline due to low demand in China and India along with changing traditions in the United States.



SOURCE: Bloomberg

FORTUNE

Prices of Lab-Created Diamonds Versus Natural 人造钻石与天然钻石价格对比

2017.03

克拉重量	人造钻石价格	天然钻石价格	价格差
0.5	\$1,315	\$1,480	11%
1.0	\$4,850	\$5,850	17%
1.5	\$9,500	\$11,875	20%

2018.03

克拉重量	人造钻石价格	天然钻石价格	价格比
0.5	\$1,090	\$1,505	28%
1.0	\$4,350	\$6,150	29%
1.5	\$7,275	\$12,125	40%

“以上数据对应钻石样本为净度等级VS,颜色等级F-H,切工等级为优良,荧光等级无或较弱”

这个差距已经拉开到 30~40%

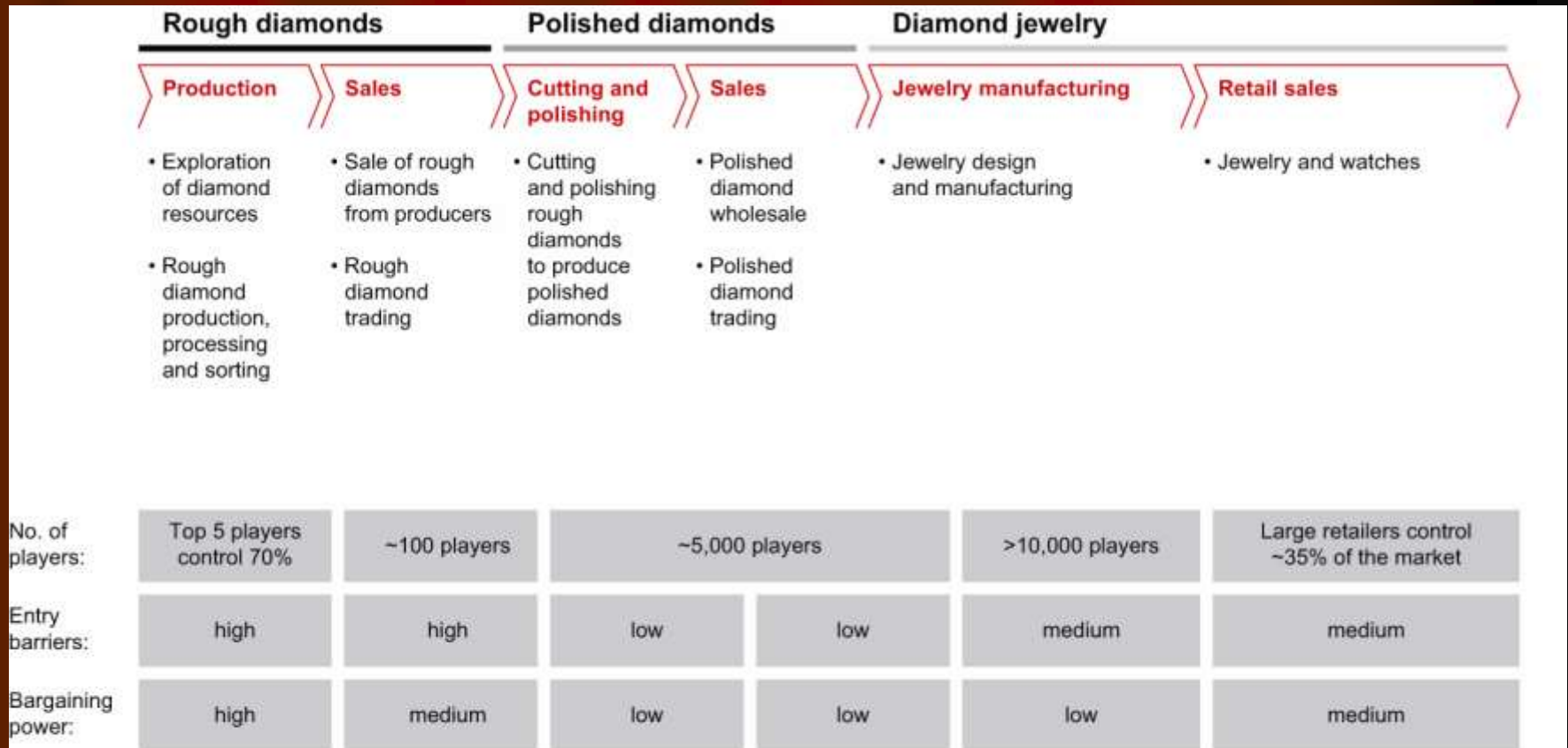
Lab-grown diamond is becoming more popular as many believe it is not related to conflict and also much more environmental friendly than mining natural diamonds – to obtain 1 carat of diamond must remove 250 tons of earth. The Ethical and ECO cost !



Man-made diamond now represents 2% of market but growing at 20% per year. 2018 total value 1.9 b expect to reach 5.2b by 2023 & 14.9 b by 2035. Natural diamonds 3 Ds strategy - Detection, Disclosure, Differentiate



Natural diamond market value chain



Source: Bain & Company

Diamond Industry Revenue Pipeline



Some strategic questions for the different players

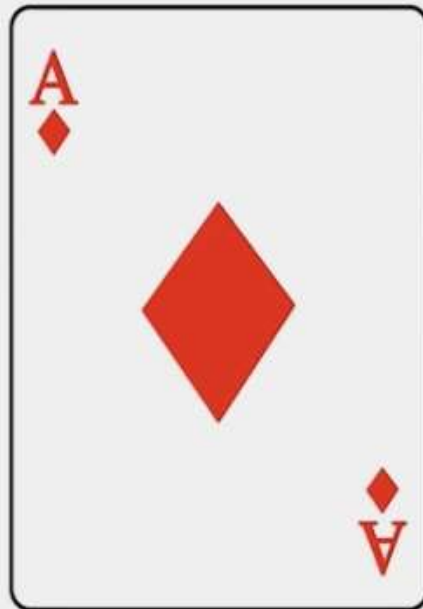
Mining companies	Cutters and polishers	Retailers	Lab-grown producers
• How can we use digital to improve our operations?	• How can we use digital to further optimize yields and shorten cutting and polishing cycles?	• How can we make use of social influencers and ensure readiness for social media shopping?	• What changes are required to the business model of the future with increased competition and rapid price decrease?
• What assortment will be affected by lab-grown diamonds? What does it mean for our asset portfolio?	• What opportunities can an automated process offer?	• Should lab-grown diamonds be introduced into portfolio? How could this affect our brand and reputation?	• Should the bet be on industrial or jewelry segment?
• What should the approach to marketing strategy be? How can we build a successful brand around our supply?	• How can we redesign our distribution system to ensure confidence from retailers?	• How should we adjust footprint, product design, assortment and marketing messages to remain competitive with other products?	• How can we achieve cost leadership?
	• How do we ensure profitable growth of our business?		• Is it necessary, and if so, how do we build a successful consumer brand?

FAMOUS DIAMONDS

- Diamonds have been used in jewellery and adornment for centuries.
- Believed to be indestructible and to provide protection from various ills.



Archduke Maximillian of Austria proposed to Mary of Burgundy with the first known diamond engagement ring in 1477 with the inscription 'My Love will run out at the hoop's end'.



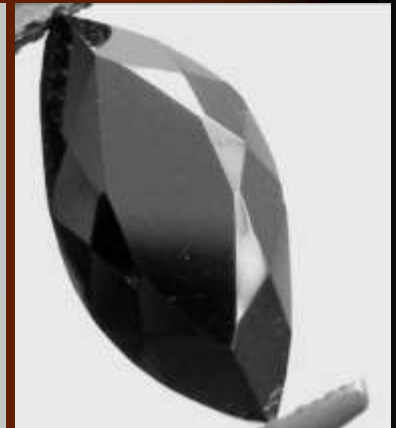
© The Metropolitan Museum of Art

Top 10 largest rough diamonds ever discovered

- 1. Sergio : 3167 carats from Brazil (non gem black)
- 2. Cullinan : 3106.75 carats from South Africa
- 3. Lesedi La Rona : 1109 carats from Botswana
- 4. Excelsior : 995.2 carats from South Africa
- 5. Star of Sierra Leone : 969 carats from Sierra Leone
- 6. Incomparable : 890 carats from Congo
- 7. Constellation : 813 carats from Botswana
- 8. Millennium Star : 777 carats from Congo
- 9. The Woyie River : 770 carats from Sierra Leone
- 10. The Golden Jubilee : 755 carats from South Africa

1. Sergio Diamond

Sergio or Carbonado de Sergio is the world's largest rough diamond which is black. At 3,167 carats it was found in 1895 in Brazil. There has been a lot of debate over the years as to how it was formed. Some believed it was the result of ancient meteors that have made their way into the earth's crust. Other theories include impact of asteroids in space or the result of supernova explosion. The stone was sold at only US\$25,000 and eventually broken up into small 3-6 carat pieces mainly as industrial diamond drills



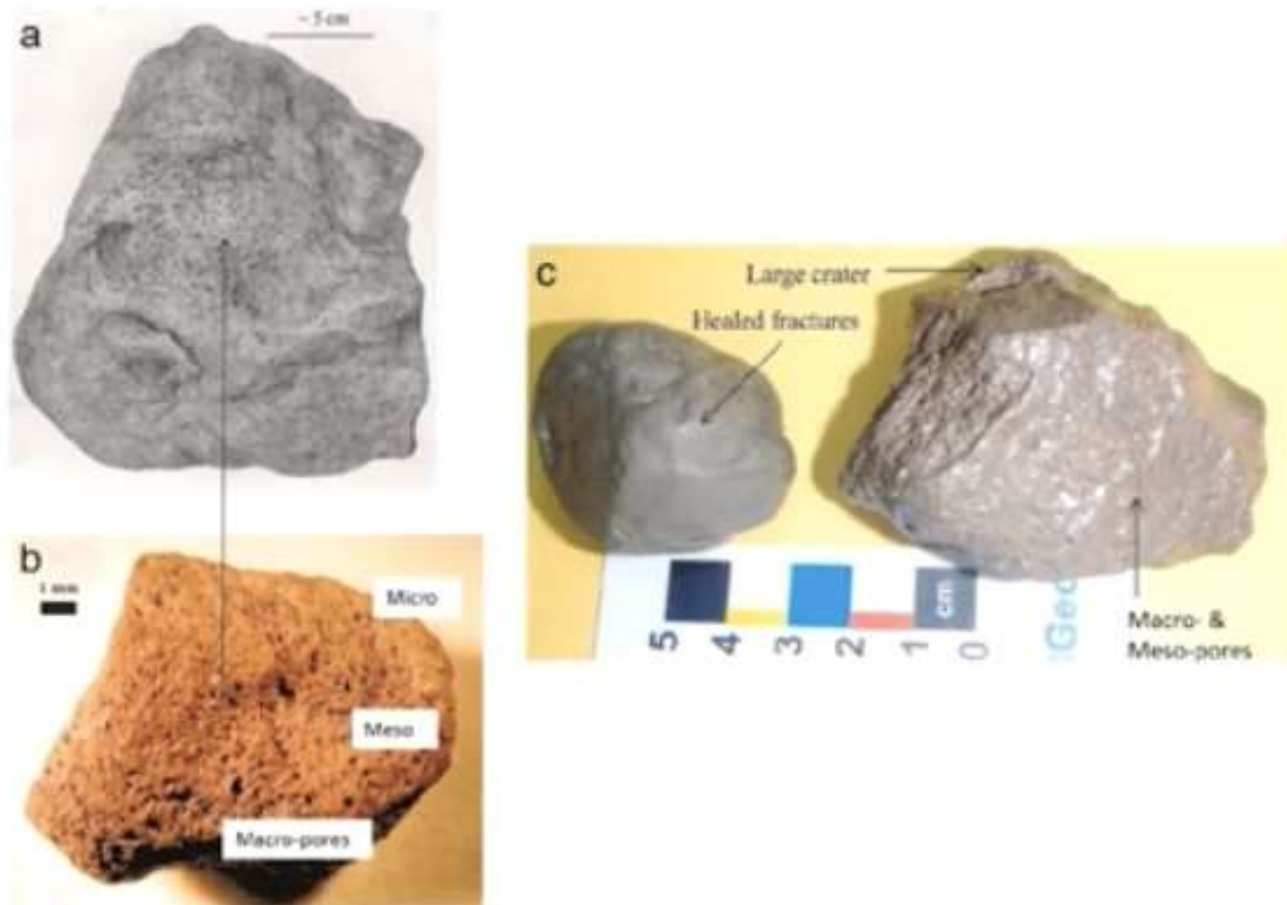


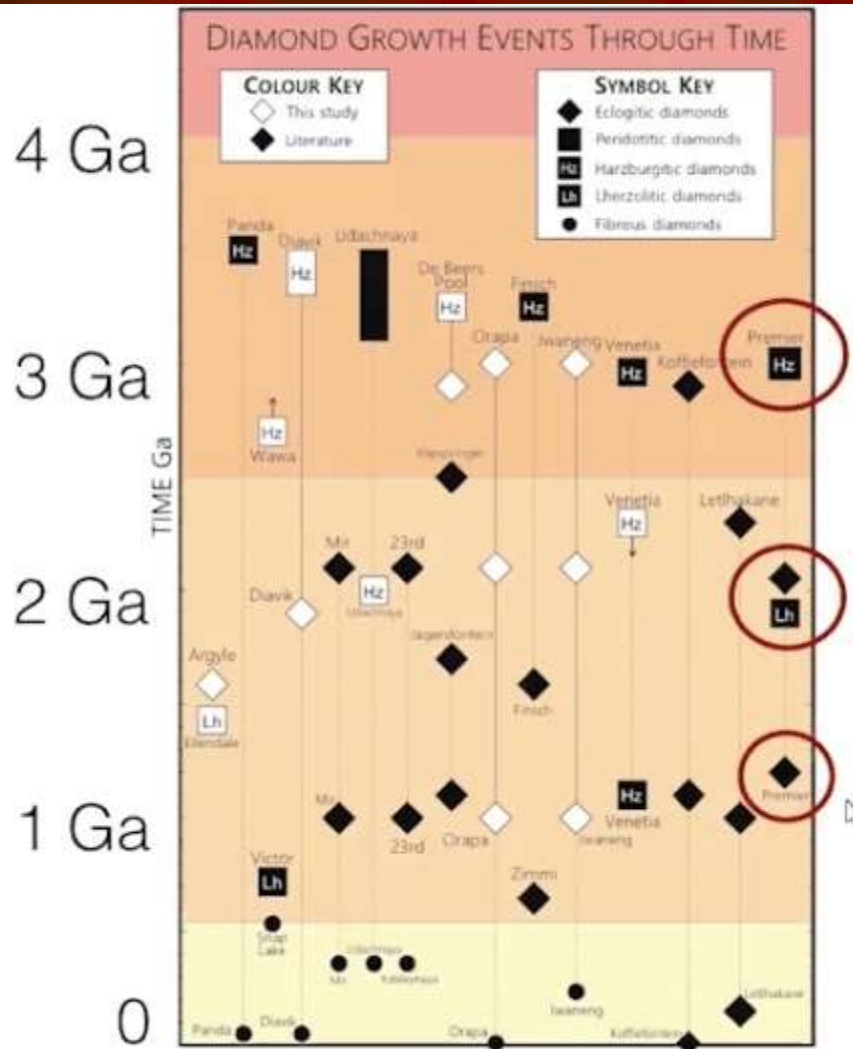
Fig. 6. (a) "Sergio" (Lencois, Brazil), discovered by an artisanal miner in 1905, weighs 3167 ct and is the largest (albeit polycrystalline) diamond ever reported. (b) Note the reticulate porous interior which is very similar to "Sergio" in a much smaller sample of carbonado (8.6 ct). (c) Left is a massive, putty colored 350 ct carbonado from the CAR – the ridges are sealed and healed fractures; right is a 730 ct brown macro- and micro-porous carbonado from Brazil.

2. The Cullinan

It is perhaps the most famous of all gem-quality diamonds. Found in the Premier Mine in Transvaal, Pretoria of South Africa in 1906 the 3,106.75 carats stone was named after the mine owner Sir Thomas Cullinan. He sold the diamond to the Transvaal government at 150,000 Pounds on condition that it will be given to King Edward VII in order to restore goodwill between Transvaal & Great Britain after the Boer War



The Cullinan Diamond: A photograph of the Cullinan Diamond being held by Frederick Wells, who discovered it while working as the surface manager of the Premier Mine. This photo was taken in 1905 by an unknown photographer.



Cullinan diamonds

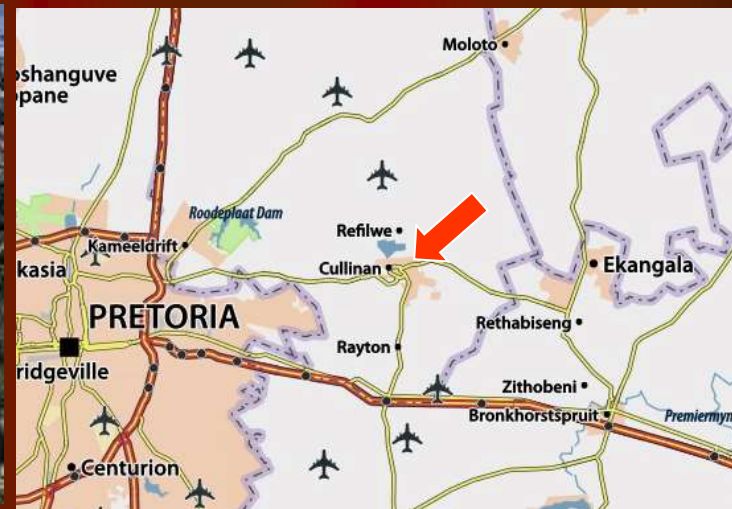
Don't know how old the super large super deep diamonds are

Lithospheric diamonds have range in ages

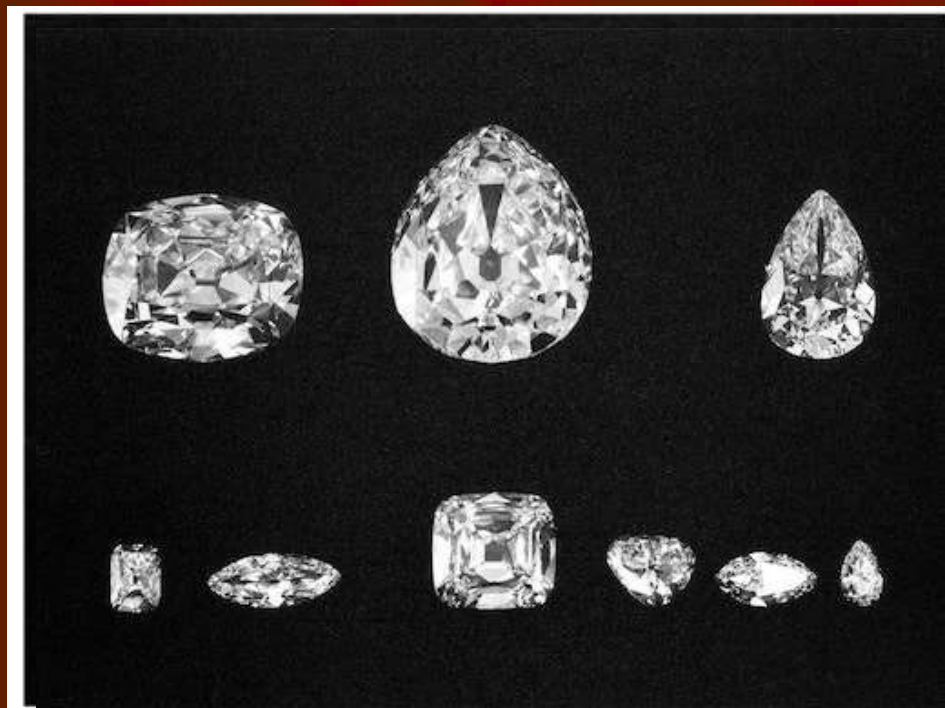
Richardson, 1986

Richardson & Shirey, 2008

The Primer Mine located in Pretoria, South Africa was established 1902 now renamed the Cullinan Diamond Mine. It has produced 750 stones larger than 100 carats !



The stone was cut into 9 major pieces & 96 smaller pieces. Cullinan I became The Great Star of Africa (530.4 carats now in Sovereign's Scepter with cross); Cullinan II The Star of Africa II (317.4 carats now the front cross on the crown); Cullinan III to VIII (brooches) and Cullinan IX (a ring). Cullinan I estimated value US\$400 million



The nine major stones. Top: Cullinans II, I, and III. Bottom: Cullinans VIII, VI, IV, V, VII and IX.

530.2 carats

317.4 carats

94.4 carats



The Finished Stones

63.6 carats

6.8

11.5



18.8



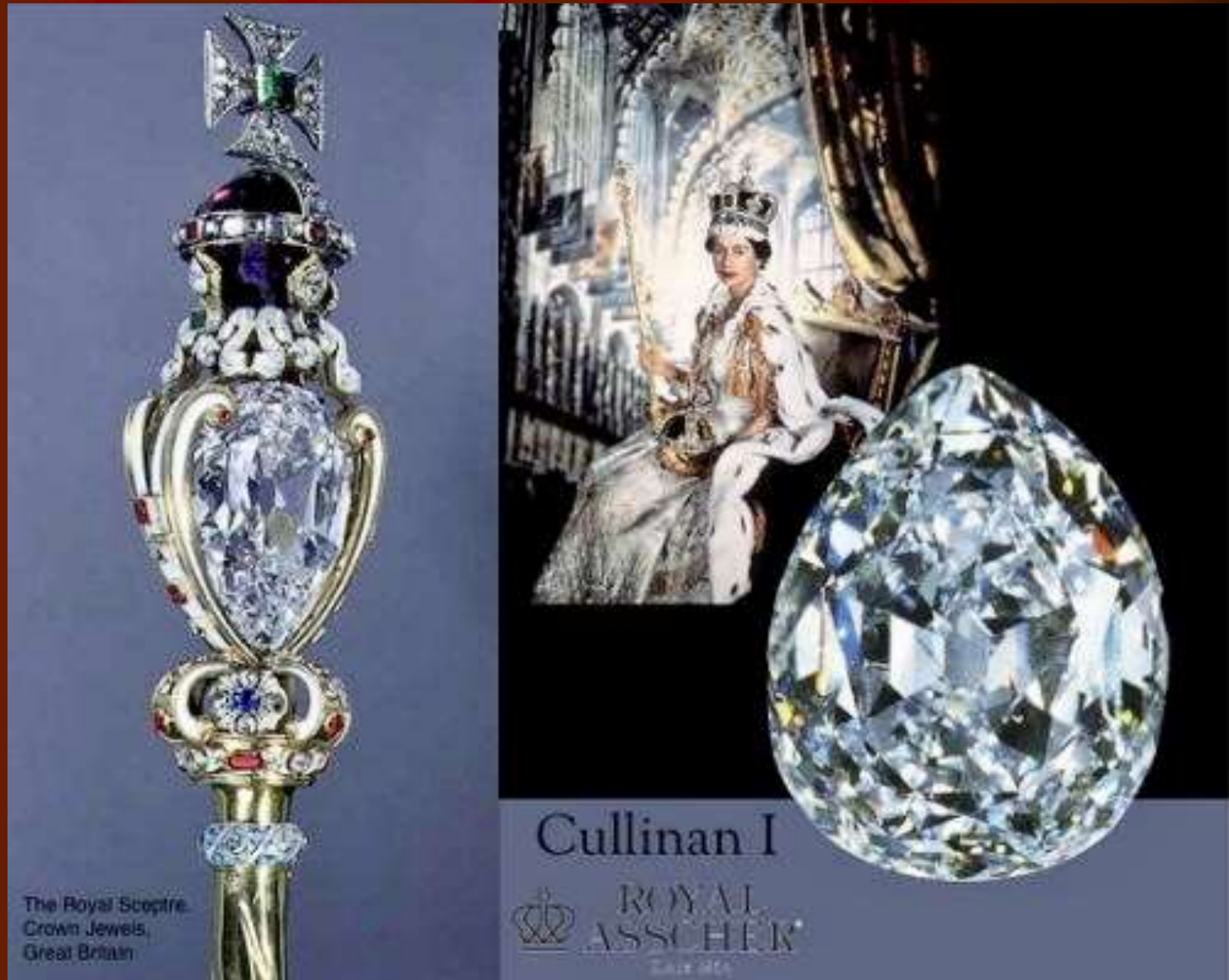
8.8



4.4



Estimated value US\$400 million



Cullinan II
ROYAL
ASSCHER



The Imperial State Crown.
Crown Jewels, Great Britain





Cullinan IX the ring



3. Lesedi La Rona

Discovered in Botswana in 2015, the name in Tswana language means “Our Light”. Weighing 1,109 carats it is the second largest gem quality uncut diamond after Cullinan and the largest to be discovered in a century. Expert believes once cut it will knock down the 530.4 carats Great Star of Africa. It was expected to fetch more than US\$70 million at Sotheby's London auction in 2016 but failed to sell ! London jeweler Laurence Graff bought it in 2017 at US\$53 million



- Laurence Graff recently unveiled the first diamonds polished from the Lesedi La Rona which is expected to yield some 60 stones ranging from 1 to 100 carats



4. The Excelsior Diamond

Found in South Africa in 1893 this 995.2 carats stone was picked up from a pile of gravel by a worker. It was later cut up to 11 pieces named as Excelsior I to XI most of them in pear shape with sizes ranging from 69.68 to 9.82 carats plus a further 11 smaller ones



Excelsior I	69.68 carats	pear shape
Excelsior II	47.03 carats	pear shape
Excelsior III	46.90 carats	marquise (the Rovensky?)
Excelsior IV	40.23 carats	pear shape
Excelsior V	34.91 carats	marquise
Excelsior VI	28.61 carats	marquise
Excelsior VII	26.30 carats	pear shape
Excelsior VIII	24.31 carats	pear shape
Excelsior IX	16.78 carats	pear shape
Excelsior X	13.86 carats	pear shape
Excelsior XI	9.82 carats	pear shape



5. Star of Sierra Leone

Found in 1972 at 969 carats the Star of Sierra Leone ranks as the fourth largest gemstone quality diamond and the largest alluvial diamond ever discovered. It was sold to a New York jeweler at US\$2.5 million and eventually cut into 17 different stones 13 being flawless with 6 of them turned into a beautiful brooch as shown below



6. The Incomparable Diamond

This rare yellow diamond found in a rubble pile in the Democratic Republic of Congo (formerly Zaire) in 1968 ! Before it was cut into 15 stones the rough diamond weighed 890 carats making it the 6th largest rough diamond and also the largest brown diamond ever discovered. In 1988 the 407.48 carat diamond was auctioned at a reserved price of US\$12 million but not sold. In 2002 it was placed on eBay at US\$15 m but still not buyer. Till now the whereabouts of this diamond remains unknown



7. Constellation Diamond

A 813 carats diamond found in the same mine as the Lesedi la Rona in Botswana. The rough stone was sold in 2016 by Canadian miner Lucara Diamond to a Dubai based firm for a record breaking US\$68 million or \$77,500 per carat making it the world's most expensive diamond



8. The Millennium Star

The 777 carat stone was discovered in the Republic of Congo in 1990. After cutting the 203 carat diamond is the world's second largest known top color (grade D colorless), internally and externally flawless pear shaped diamond displayed in 1999 as the centerpiece of the De Beer's Millennium diamond collection in London. Valued at US\$160m there was an attempt to steal the stone but the plot was discovered and the robbers were arrested. Crime Journalist Kris Hollington wrote a book called "Diamond Geezers" covering this attempt



9. Woyie River Diamond

This diamond was named after the Woyie River in Sierra Leone where it was found in 1945. Weighing 770 carats it was another very large alluvial diamond ever found. It ended up being cut and polished into thirty colorless diamond in London in 1947. At 31.35 carats the largest piece is named the Victory Diamond and sold at Sotheby for US\$4.3 m

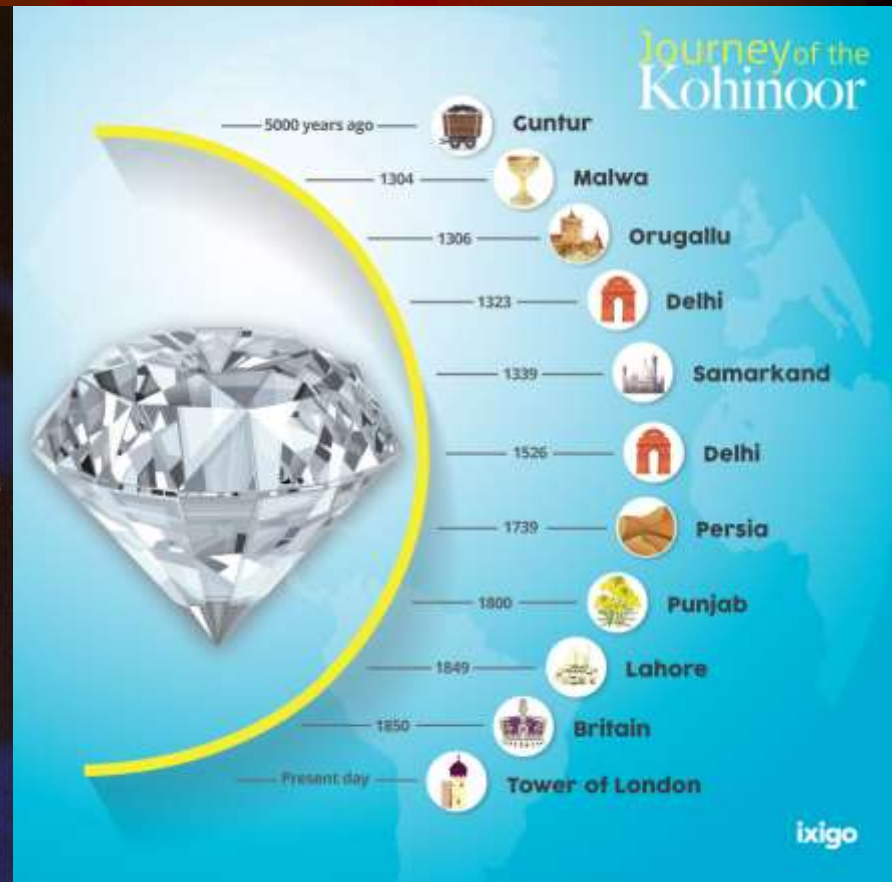


10. Golden Jubilee the world's largest cut diamond

The Golden Jubilee is the largest cut and faceted diamond in the world weighing 545.67 carats cut from a large 755 carat brown diamond which was discovered in the Premier Mine in 1985 which is also the origin of the Cullinan Diamond and the Taylor-Burton Diamond. The original owner was a group of Thailand businessman led by Henry Ho and they presented it to King Bhumibol the King of Thailand in year 2000 to celebrate his 50th anniversary to the throne hence the name "Golden Jubilee". The estimated price is around US\$4 to 12 million



The 5,000 years Long Journey of the Koh-i-Noor 光明之山
Meaning a mountain of light in Persian, it is a 186 carat white diamond originally owned by the Mongol ruler Rajah Malwa in 1304. Changing hands many times the stone was sent to queen Victoria in 1849 and cut once more to 108.93 carats and set in Queen Elizabeth's crown



Elizabeth Taylors diamond

Formerly known as the Krupp diamond it is a 33.19 carats Asscher cut diamond ring bought by Richard Burton at US\$307,000 from the wife of the German industrialist Vera Krupp for his wife in 1968. The diamond probably was originated from Golconda India and cut in the 1920s. It was renamed after her when she passed away in 2011 and sold by her estate at US\$8.8 million to the South Korea conglomerate E-Land



Elizabeth Taylor loved white diamond. Her collection also include a 68 carats Taylor-Burton Diamond bought at US\$1.1 million. It was insured with Lloyd at on condition it could only be worn for thirty days in any given year with armed guards & be stored in a vault. She later made a replica that cost US\$2,800. The stone was sold at an auction after the two divorced for US\$8.8 million with the proceed donated to build a hospital in Botswana Africa. The diamond is now with Robert Mouawad of the jewellers Mouawad



From Shah to Tsar

The Shah Diamond is a 88,7 carats elongated octahedron diamond with a yellowish tinge due to the presence of a little iron oxide. It was found at the Golconda mine in Central India in 1450. Its most unusual feature is that on three of its faces the names of three of the Persian rulers who owned it have been engraved in Persian along with the Hijri year. They are respectively Nizam Shah, Jahan Shah and Fath 'Ali Shah. Originally Indian, the Persian took it away in 1738. In 1829 a Russian diplomat was murdered in Tehran and Russian demanded severe punishment. As a result the diamond was given to Tsar Nicolas I as compensation. It became part of the kremlin Diamond Fund after the Revolution and is now held in the Kremlin in Moscow



The Tiffany Diamond

It is one of the world's largest and finest yellow diamonds discovered in Kimberley in 1877. The 287.42 carat stone was acquired by Charles Lewis Tiffany for US\$18,000 and cut into a cushion-shape brilliant weighing 128.54 carats with an unprecedented 82 facets, 24 more than the traditional 58 facet brilliant cut. Now kept at the 5th Avenue store



Is the Hope really cursed ?

The Hope Diamond is a 45.52 carats Grayish Blue Diamond found in India in 1642. It was set in the royal crown of Louis the XIV in 1668 but was stolen during the French revolution. In 1830 a blue diamond was bought by a diamond dealer called Thomas Hope. It was believed that this is part of the hope diamond. It has long be rumored that the Hope carry a curse as Louis XIV and Marie Antoinette were both beheaded. It is now being exhibited in the Smithsonian in Washington DC and reported to be insured for as much as US\$350 million



HOPE DIAMOND, "BAD LUCK" GEM, CHANGES HANDS

Commentary by JAY SIMS

Same applied to the Tereshchenko Blue ?

It is a 42.92 carats diamond of blue color cut in the pear shape by Cartier in 1673 after being bought by the Tereshchenko family. Believed to be from Golconda India, it is the second biggest blue diamond in the world after "Hope". After the French Revolution, the diamond went to England and then to the United States. According to legend this diamond is also cursed together with Hope because both were alleged to be stolen from eyes of the statue of the Hindu goddess Sita from India during the late 19th century



The Heart of Eternity Diamond

It is a diamond measuring 27.64 carats rated as "Fancy Vivid Blue" found in the Premier Diamond Mine in South Africa which is the only mine in the world with an appreciable production of blue diamond. Rough stone was at 777 carats. Owned by De Beers it was unveiled in 2000 as part of its Millennium jeweler collection. Estimated value US\$16m. The current owner is unknown



The Oppenheimer Blue Diamond

It is a vivid blue diamond measuring 14.62 carats. Clarity is graded as one step below internally flawless. Estimated value US\$57.5m



The Moussaieff, largest Red Diamond in the world

Red diamond is the rarest & most expensive of all diamond & they are mostly found in size less than one carat. At 5.11 carats this one which is also called the "Red Shield Diamond" is the largest known found in Brazil by a farmer around 1990. It was purchased in 2001 by Shiomou Moussaieff, an Israel born Jewelry dealer in London and exhibited in 2003 as part of the Smithsonian Institution's "The Splendor of Diamond" exhibit. Estimated value US\$20 million



Noor-ul-Ain Diamond Tiara

This 60 carats pink diamond was believed to be looted from India in the 18th century by the Persian king Nader Shah Afshar. It was given to Empress Farah Diba as a center piece in the tiara when she married Mohammad Reza Shah Pahlavi, the last Shah of Iran. The tiara was surrounded by hundreds of colored diamonds and centuries of royal history making it irreplaceable



CTF Pink Star

Mined by DeBeers in south Africa in 1999, Sotheby sold a 59.6 carat Vivid Pink Internally Flawless, Type IIA diamond "Pink Star" in HK in April 2017 at a record high of US\$71.2 million to Chow Tai Fook Company making it the most expensive gem stone in the world

Up for Auction 59.6 Carat "Pink Star", Diamond by Sotheby's



周大福

CHOW TAI FOOK



The Perfect Pink

Sotheby selling a 10.64 carat Vivid Purplish pink internally Flawless diamond and diamond ring in HK in October 3-7,2019 price US\$23 million





The Ai Diamond,
Rare and Important Fancy Vivid Blue
Diamond and Diamond Ring

EST. HK\$98,000,000 - 120,000,000

SOHOKU



A Rare Fancy Vivid
Green Diamond and Diamond Ring

EST. HK\$12,000,000 - 15,000,000



A Fancy Intense
Purplish Pink Diamond and Diamond Ring

EST. HK\$8,700,000 - 10,000,000

SOHOKU



A Fancy Vivid
Bluish Green Diamond and Diamond Ring

EST. HK\$5,600,000 - 7,200,000

SOHOKU

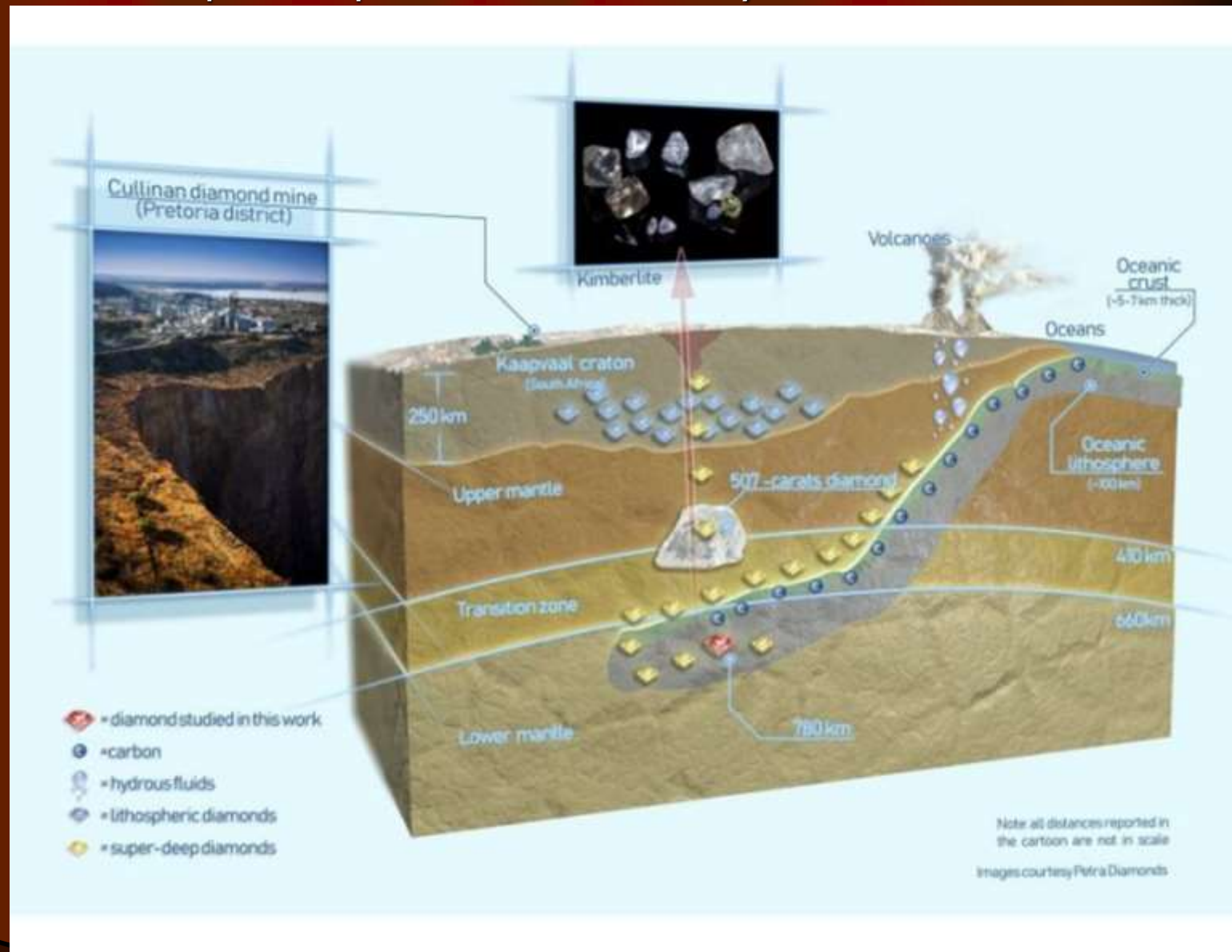
The Black Orlov Diamond

Weights 67.5 carats cushion cut. Shaped like a chicken's heart it was found in India which served as the eye of a deity. Stolen by a French soldier in 1747. Bought by Count Orlov who gave it to Catherine the Great. Now in the Kremlin Armoury in Moscow



THE END

A 1 : Super Deep-diamond formed by Subduction



A 2 : History of development for synthetic diamond

1952

William Eversole at Union Carbide creates tiny CVD diamond

1954

GE produces small-grit HPHT diamond for industrial use



HISTORICAL EVOLUTION

1953

Swedish company, ASEA, grows HPHT diamond

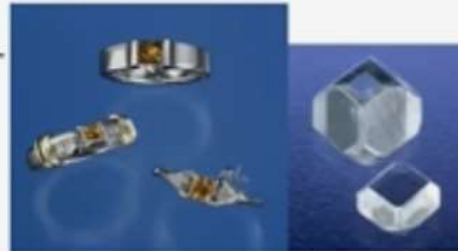
1970

GE produces 1st experimental gem-quality HPHT lab-grown diamond



1990s

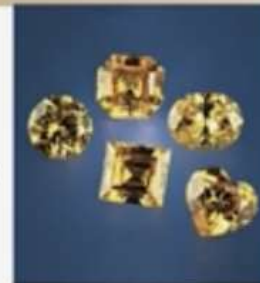
Russian firms produce first HPHT lab-grown diamonds for commercial use; GE, De Beers, and Sumitomo grow experimental near-colorless HPHT diamonds



HISTORICAL EVOLUTION

2002

Gemesis begins producing commercial quantities of HPHT diamonds for jewelry



2003

Apollo Diamond
produces CVD
diamonds



HISTORICAL EVOLUTION

2008

WD Lab Grown
Diamonds licenses
CVD technology from
Carnegie Institute

2004

Chatham offers HPHT
lab-grown diamonds in a
variety of colors



2010

Gemesis announces
plans to market
colorless and near-
colorless CVD
diamonds



HISTORICAL EVOLUTION

2012

AOTC starts producing
colorless to near-colorless
HPHT-grown diamonds up
to 0.8 ct in size



HISTORICAL EVOLUTION

2014

New Diamond Technology (NDT) starts producing large colorless HPHT-grown diamonds up to 5.11 ct



2015

NDT makes first colorless faceted lab-grown stone surpassing 10 ct (HPHT-grown, 10.02 ct, E, VS₁)



2016

GIA reports largest near-colorless faceted CVD graded, 5.19 ct (J, VS₂)



HISTORICAL EVOLUTION

Largest near-colorless faceted HPHT-grown diamond graded, 15.32 ct, (H, I₁)



2017

HPHT melee gem diamond growth in China reportedly ~200,000 carats per month



2018

6.21 ct (D, VS₂)
CVD diamond
seen at trade
show



HISTORICAL EVOLUTION



5.01 ct INT pk-O
CVD diamond



New Diamond
Technology (NDT)
grows largest known
HPHT lab-grown
diamond
(103.5 ct)

De Beers launches
Lightbox, selling white,
blue and pink lab-grown
diamond jewelry priced
at \$800 /carat



World's first Gemological description of synthetic diamonds by GE



First gemological description of synthetic diamonds



"General Electric's Cuttable Synthetic Diamonds" by Robert Crowningshield

GENERAL ELECTRIC'S CUTTABLE SYNTHETIC DIAMONDS

By Robert Crowningshield
Gemological Institute of America
New York, N. Y.

Description of the first commercially available synthetic diamonds from Sumitomo Electric Industries

THE GEMOLOGICAL PROPERTIES OF THE SUMITOMO GEM-QUALITY SYNTHETIC YELLOW DIAMONDS

By James E. Shigley, Emmanuel Jirassak, Carol M. Stockton, John I. Kovoda,
Charles W. Frey, and Robert E. Rose

The distinctive gemological properties of the gem-quality synthetic yellow diamonds grown by Sumitomo Electric Industries are described. These synthetic diamonds, produced in a commercial form, are grown as thin yellow single crystals in sizes up to 1 ct. The material is currently marketed for industrial applications only, at prices up to about \$140/ct. The synthetic diamonds can be distinguished by their diamond fluorescence (most to long-wave, sporadic yellow to blue-white), their unusual girdling, cleaving, and other features under magnification, and the absence of distinct cleavage facets in their spectra.

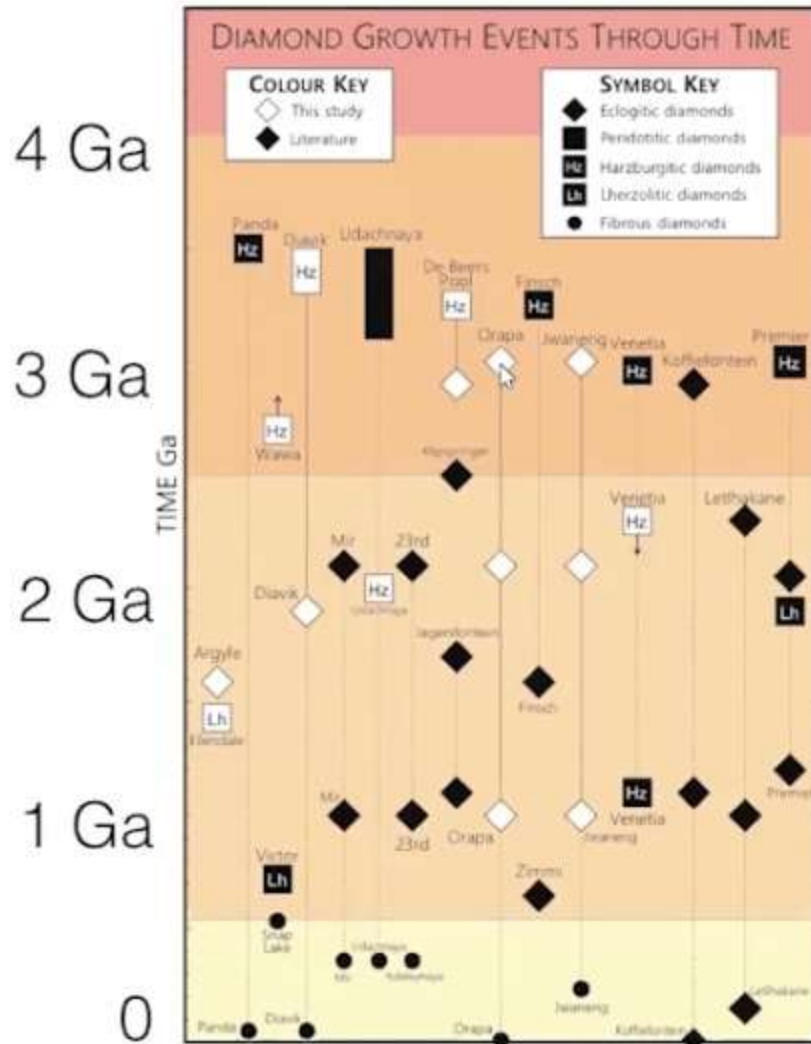
The first synthetic diamond crystals of a quality and size suitable for gem use were produced by the General Electric Company in 1955. These crystals were reported to range up to slightly more than 1 ct and to be colorless, yellow, or blue. Although the crystals were of very good gem quality, technical difficulties and high costs prevented the production of these synthetic diamonds from proceeding beyond an experimental stage. It has been widely believed in the jewelry trade since then that such problems would render the commercial production of gem-quality synthetic diamonds economically impractical for some time. Even so, the success of the G.E. scientists in growing gem diamonds in the laboratory prompted considerable interest within the jewelry industry.

The situation has now changed. In April 1965, Sumitomo Electric Industries of Japan, Japan, announced that they had accomplished the long-sought production of syn-



Gems & Gemology, Vol. 22, No. 4, pp. 192-208, (1986)

- A3 : Age of all diamonds tested



All diamonds that
have ever been
dated

Howell et al., 2022



GIA®

Tangent: Naming of optical centers in diamond

Unraveling the confusing compendium of defect centers in diamond

- Names of diamond defects are a confusing mix of historical designations and those based on their atomic configurations
 - The **N** in **N3** (and **N2**, etc) stands for “**Natural**” (not nitrogen)
 - It’s coincidence that **N3** has 3 nitrogens and a vacancy
 - The **H** in **H3** (and **H2**, **H4**, etc) stands for “**Heated**” (not hydrogen); its composition is [nitrogen-vacancy-nitrogen]
 - Meanwhile, the **N** in ‘**NV**’ does stand for **nitrogen** and **GR1** stands for **General Radiation 1**.
- Decades ago, many centers were seen in the absorption spectra of **natural** and **heated** diamonds, and researchers designated the peaks across the spectra as ‘1, 2, 3, etc’.
- These defects are now identified and “**heated**” centers such as **H3** are also detected in natural, unheated diamonds.
- However...the defect nomenclature remains.

