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Diamond – A Driller's Best Friend

Terry Matthias

NATIONAL OILWELL VARCO

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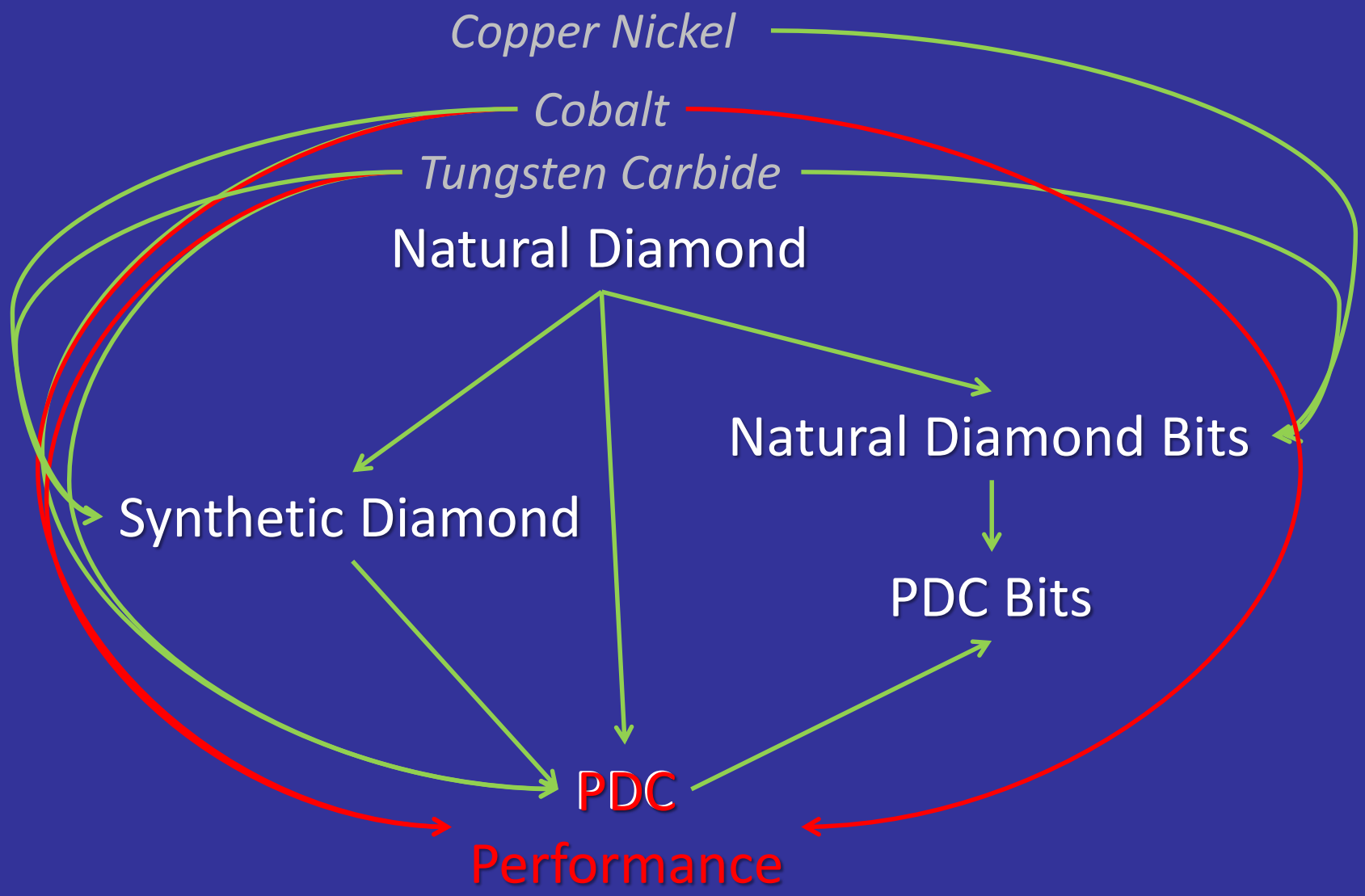
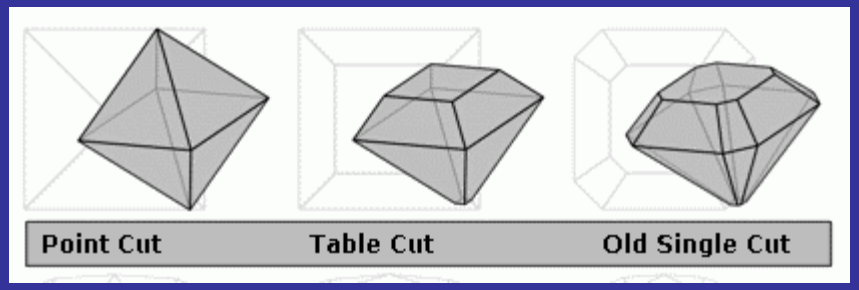
Overview


Copper Nickel
Cobalt
Tungsten Carbide
Natural Diamond
Natural Diamond Bits
Synthetic Diamond
PDC Bits
PDC
Performance

Early Use of Diamond

- Mists of Time
  - ~~Adornment~~
  - Stoneworkers
  - Talisman (Lucky Charm)

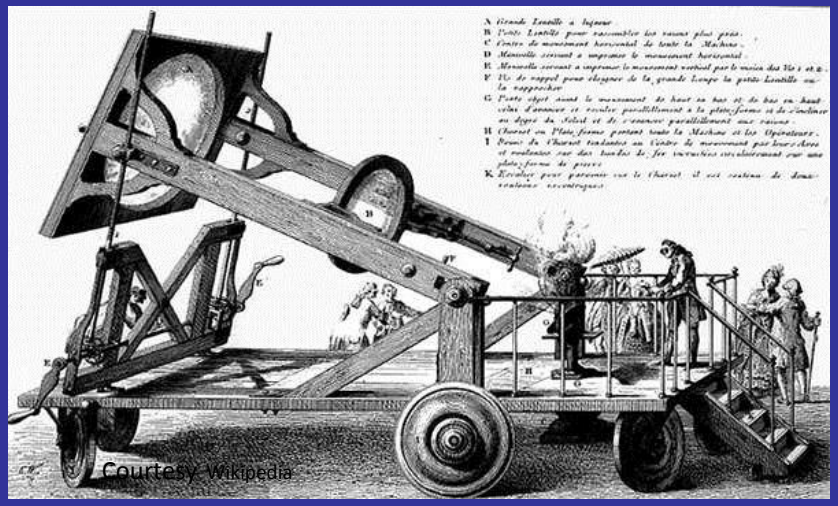
- From 1000 A.D.
  - Cleave & later polish diamonds



What is diamond?

- 1700's New science of chemistry
  - Break down materials with fire – couldn't with diamond
- 1772 Antoine Laurent Lavoisier
  - Magnifying glass to burn diamond
- 1797 Smithson Tennant
  - Diamond = Graphite


Courtesy Metropolitan Museum of Art


Courtesy Wikipedia

Early attempts to make diamond

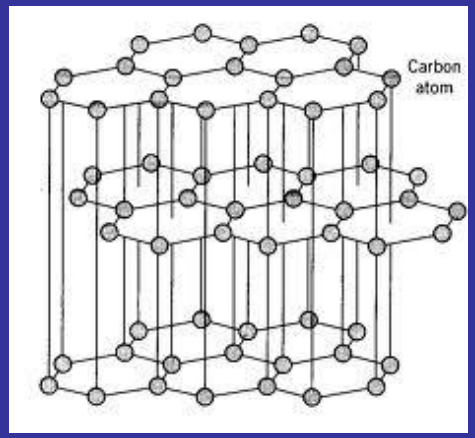
- 1772 – 1870 Temperature
  - Attempts to grow diamond crystals by evaporation of carbon rich solutions
- 1870 Diamonds found South Africa
- 1870 – 1910 Temperature and Pressure
  - Iron tubes, electric arcs, explosives, high velocities

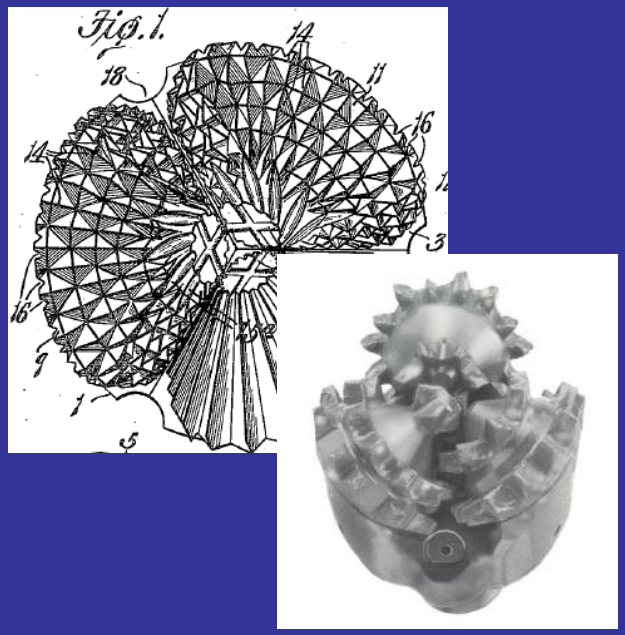
All Failed

Structure

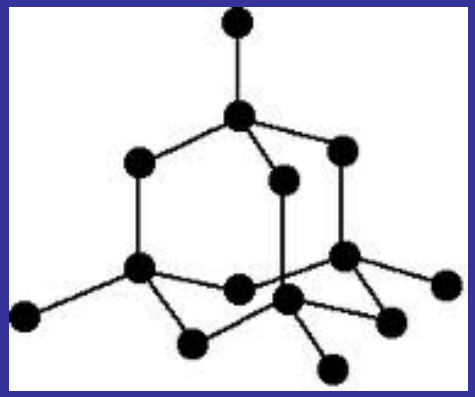
- 1912 Crystallography

Graphite



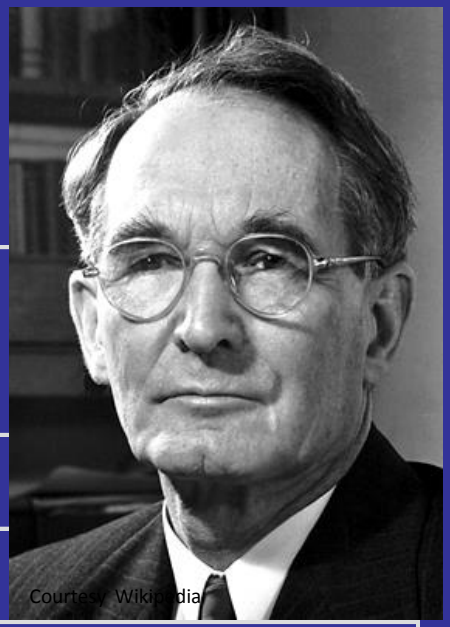


Diamond



High Pressure

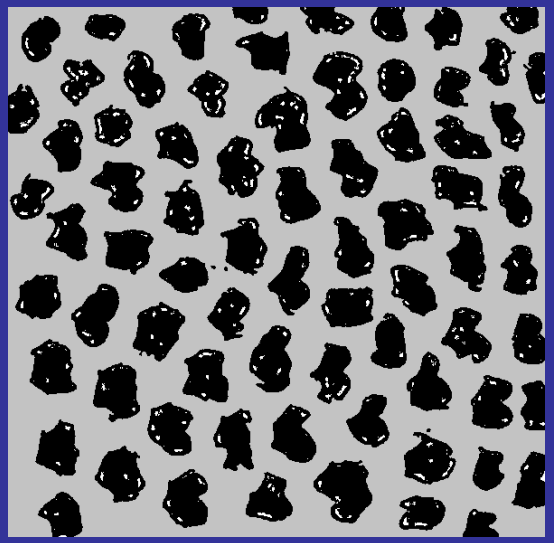
- Percy Bridgman



Year	Pressure (atm)	
1900	2,500	Cell leakage
1905	7,000	Screw press
1910	20,000	Hydraulic press
1935	50,000	Opposed tapered steel anvils
1940	70,000	Opposed tapered carbide anvils

High Pressure

Carbide

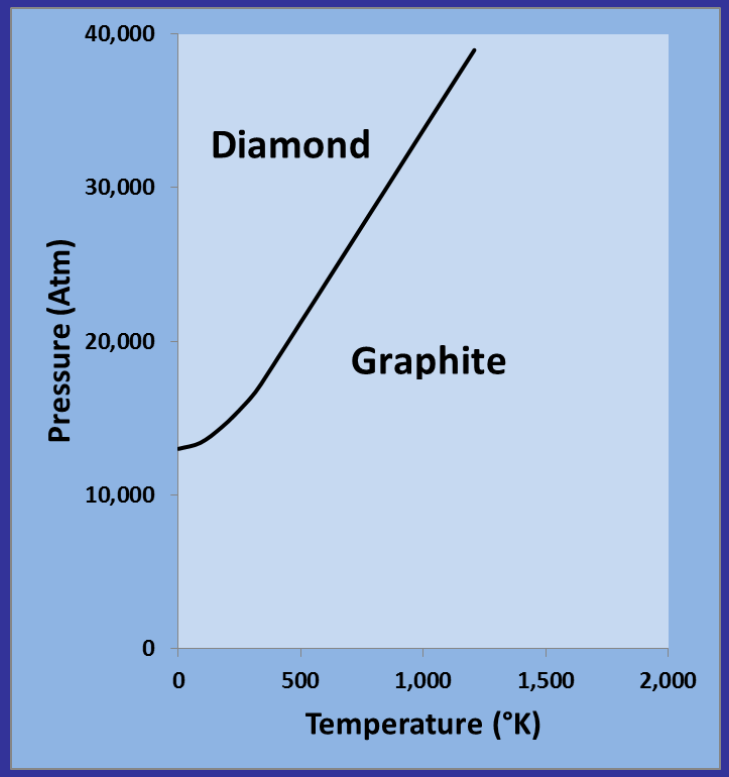


Cobalt Cemented Tungsten Carbide

Energy

1938

Thermodynamics predicts Phase Diagram



High Pressure & High Temperature

Early 1940's GE & Norton engage Bridgman

High pressure & high temperature tests to establish conditions diamond not destroyed

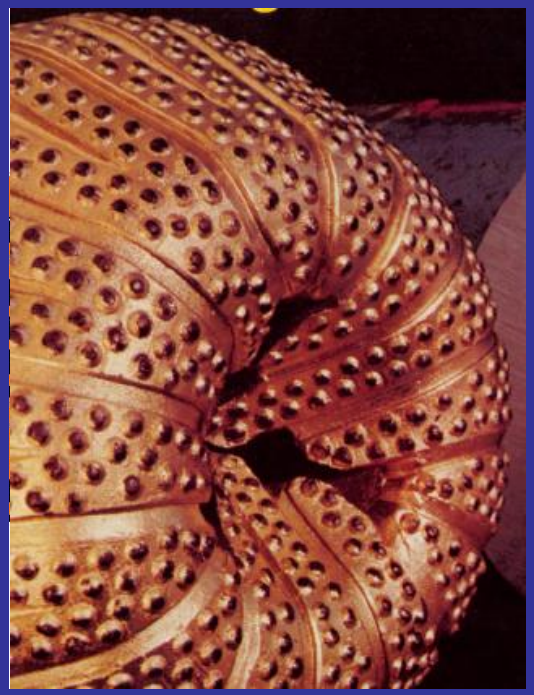
Conclusion

>1,000°C & >50,000 atm

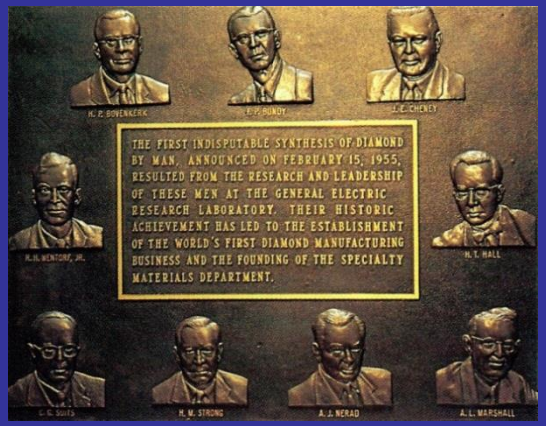
to make diamond

Natural Diamond Bits

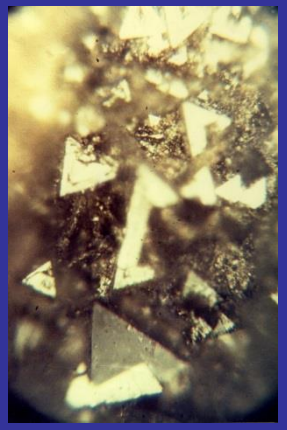
- Diamond retention
  - Cannot wet
  - Mechanically lock



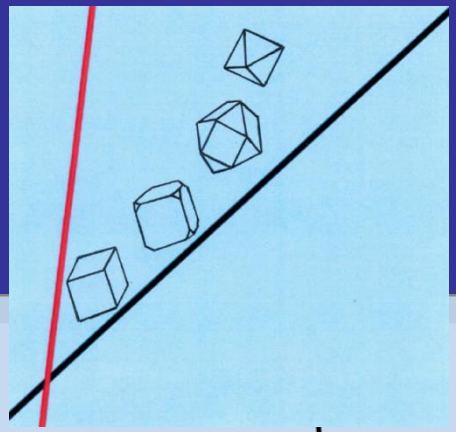
Synthetic Diamond



- 1951
  - Project Superpressure at General Electric
- 1954
  - 16th December First diamond made
    - Repeated 20 times in next 2 weeks



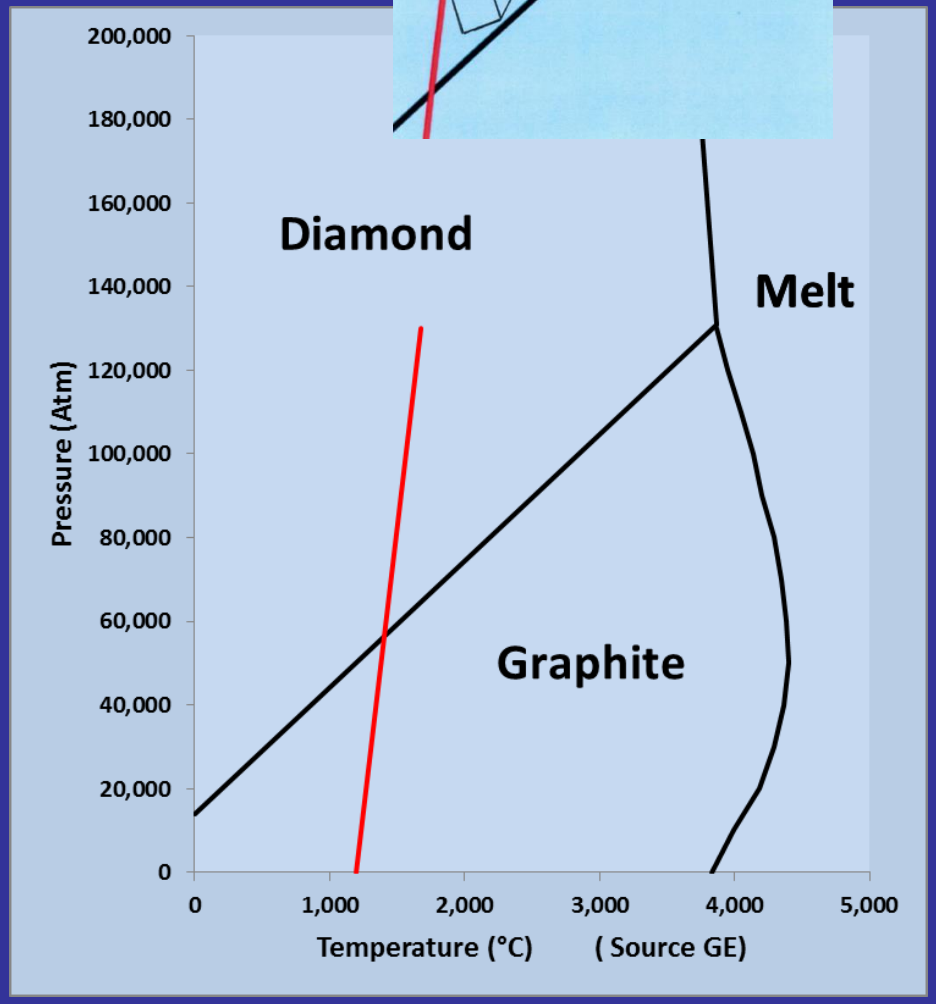
Man-Made® Diamond



1957 – 1977

Synthetic Diamond Grit

- Improving control of process for shape & properties
- Averaged a new product every year
- Grinding, sawing, drilling, lapping & polishing non ferrous materials



® GE registered trademark

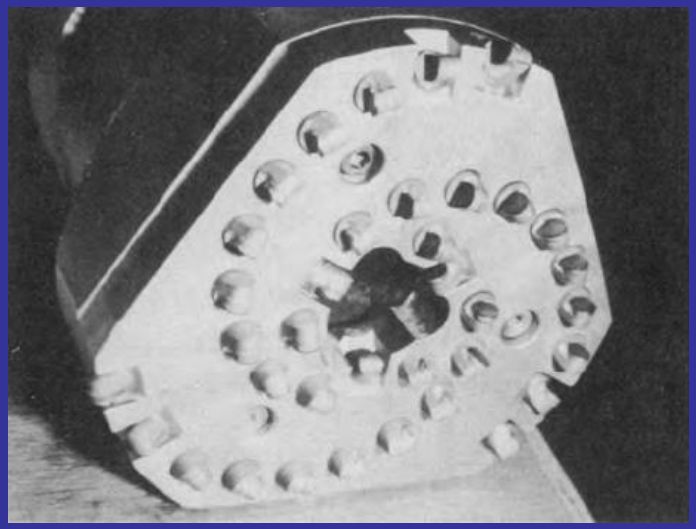
PCD

- Large single diamond crystals cleave
- Carbonado
  - Grains of diamond, diamond-to-diamond bonded together, a natural polycrystalline diamond
- 1973 Compax® ϕ8mm x 3.5mm
  - GE mix cobalt & fine diamond
  - Press at 60,000 atm & 1400°C

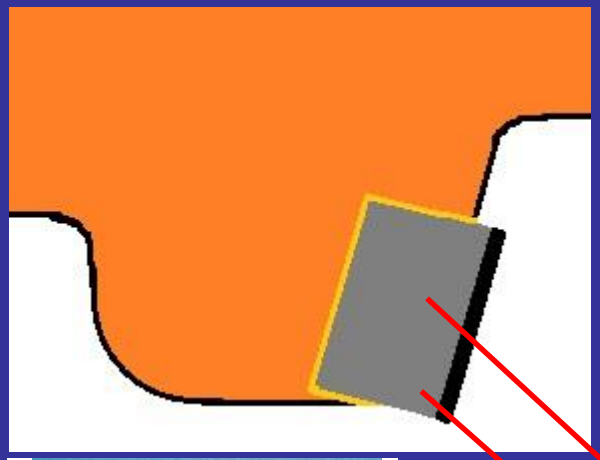
®GE registered trademark

First PDC Bits

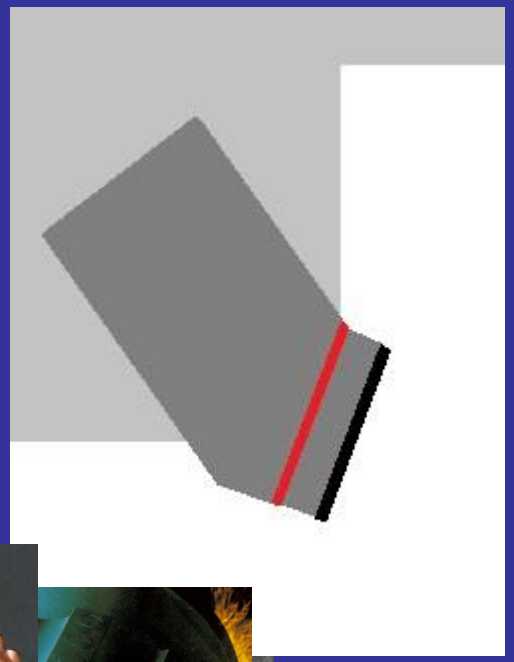
- 1974 - 1st Bit runs
  - USA
  - Isle of Wight, England

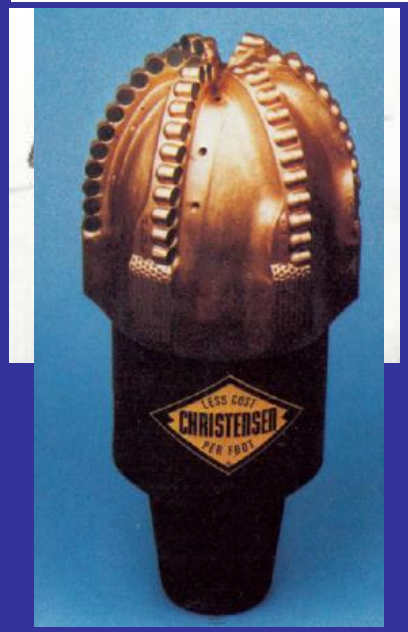


Cutter & Bit Development



1973
1976
1978
1979
1980
1982
1986





PDC Development for Drill Bits

Compromise Between

Hardness & Durability

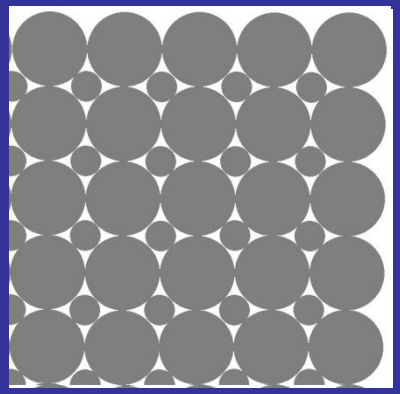
Hard – Wear resistant but brittle

Durable – Tough but soft

PDC Development for Drill Bits

- Micron diamond size
  - Mono modal - Single size of diamond
    - Diamond bonds/unit volume
  - Multi modal - Mix of 2, 3 or 4 sizes
    - Diamond bonds/unit volume

      &
    - Diamond volume



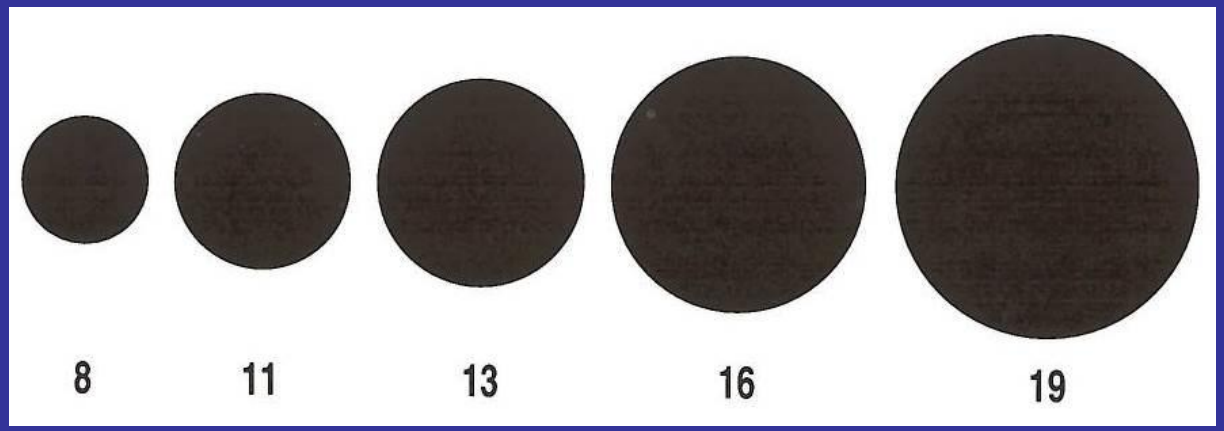
Medium

Medium

GE2500

PDC Development for Drill Bits

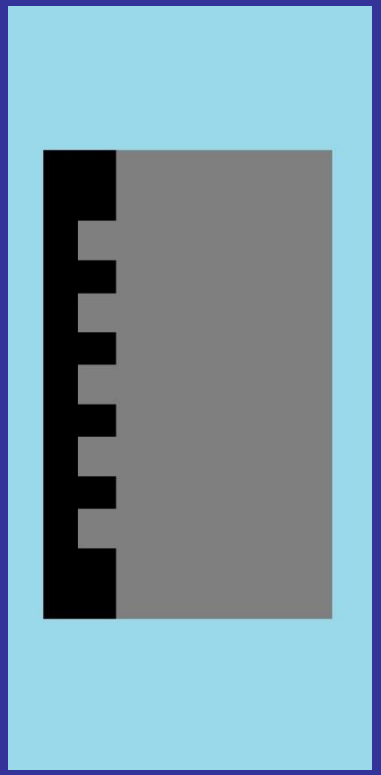
- Diameters



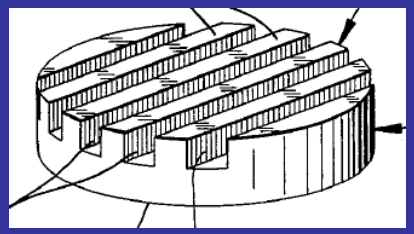
- Polished diamond faces

PDC Development for Drill Bits

- Diamond layer thickness
  - From ½ mm to 2-4mm
- Chamfered/Bevelled Edge
- Internal stresses - Interfaces
  - Flat to shaped – Claw, Star, Iris etc.



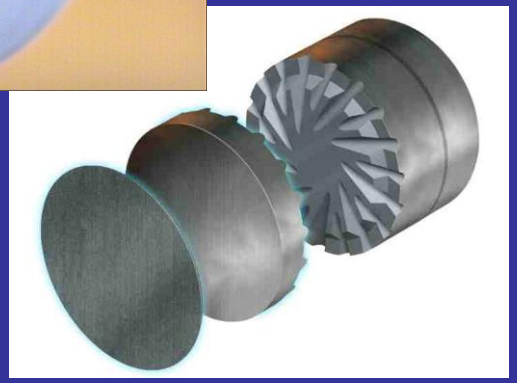
Bit Design

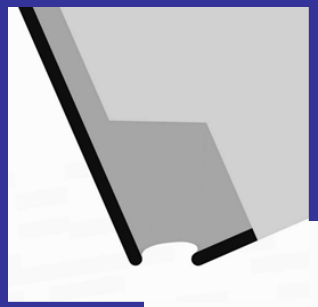


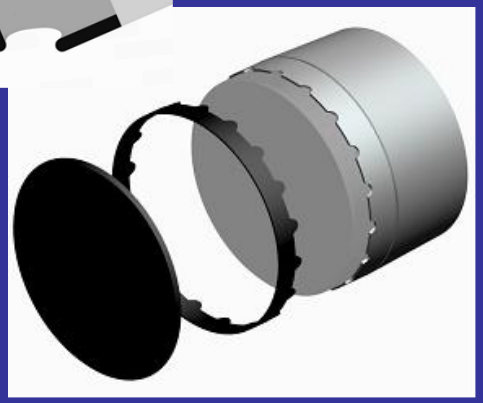
Thermal Stability

Removal of catalyst from surface of PCD

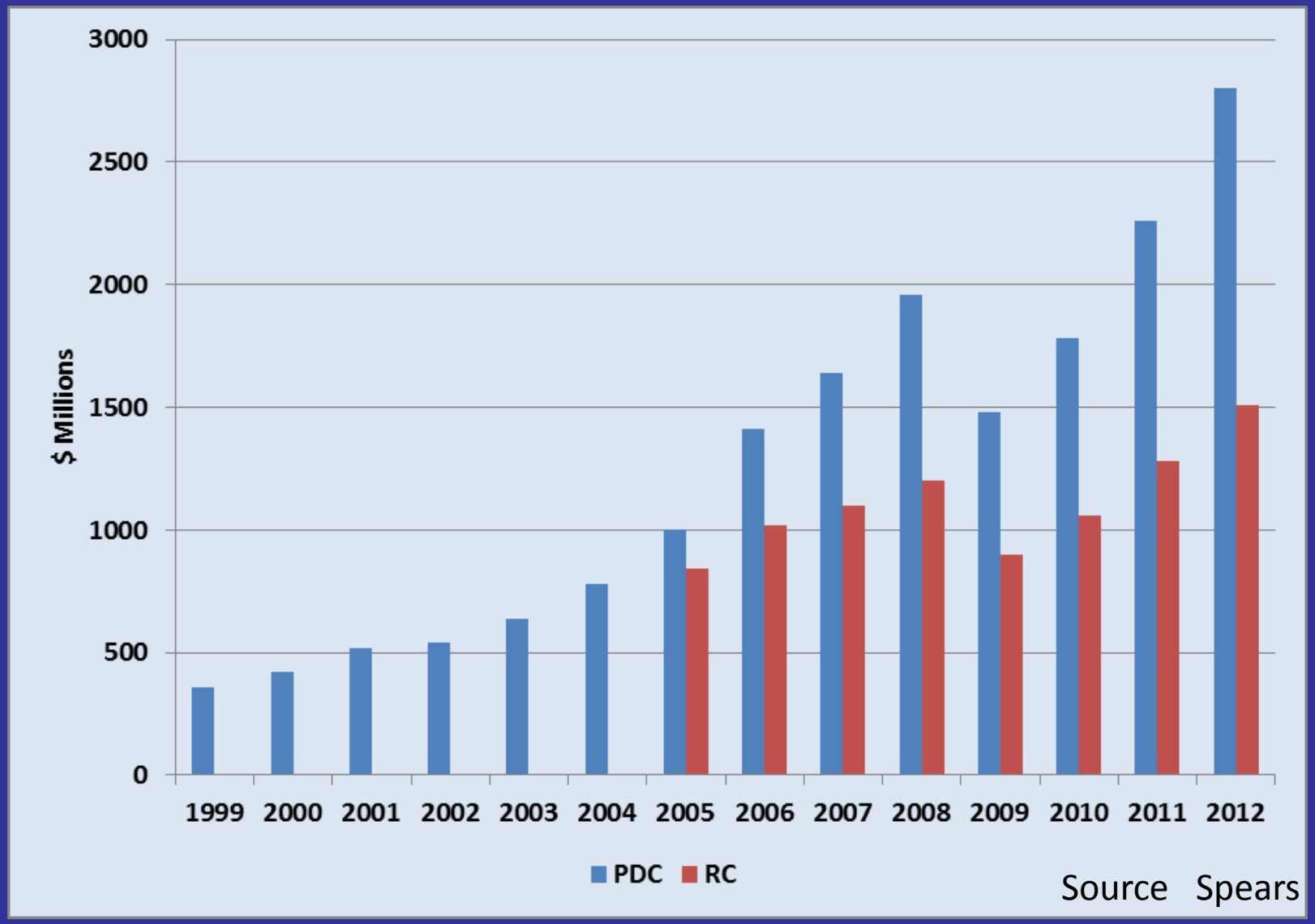
- 1st Generation (SPE 79797)
  - +40% footage
  - +40% rate of penetration
- 2nd Generation (SPE 102067)
  - +43% footage
  - +26% rate of penetration







Drill Bit Market

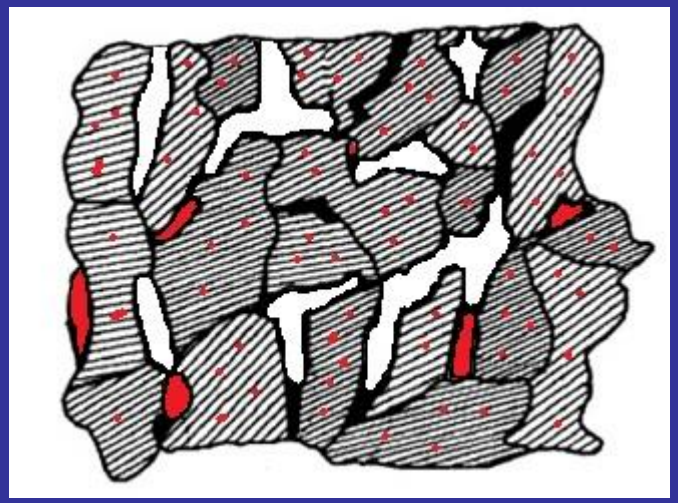


The Future for PDC and PDC Bits

- Diamond Sizes
  - Sub-micron 250nm – 1000nm
  - Nano 1nm – 250nm
- Diamond Mixes
  - Mono or multi modal sub-micron and/or nano
  - Multimodal with micron

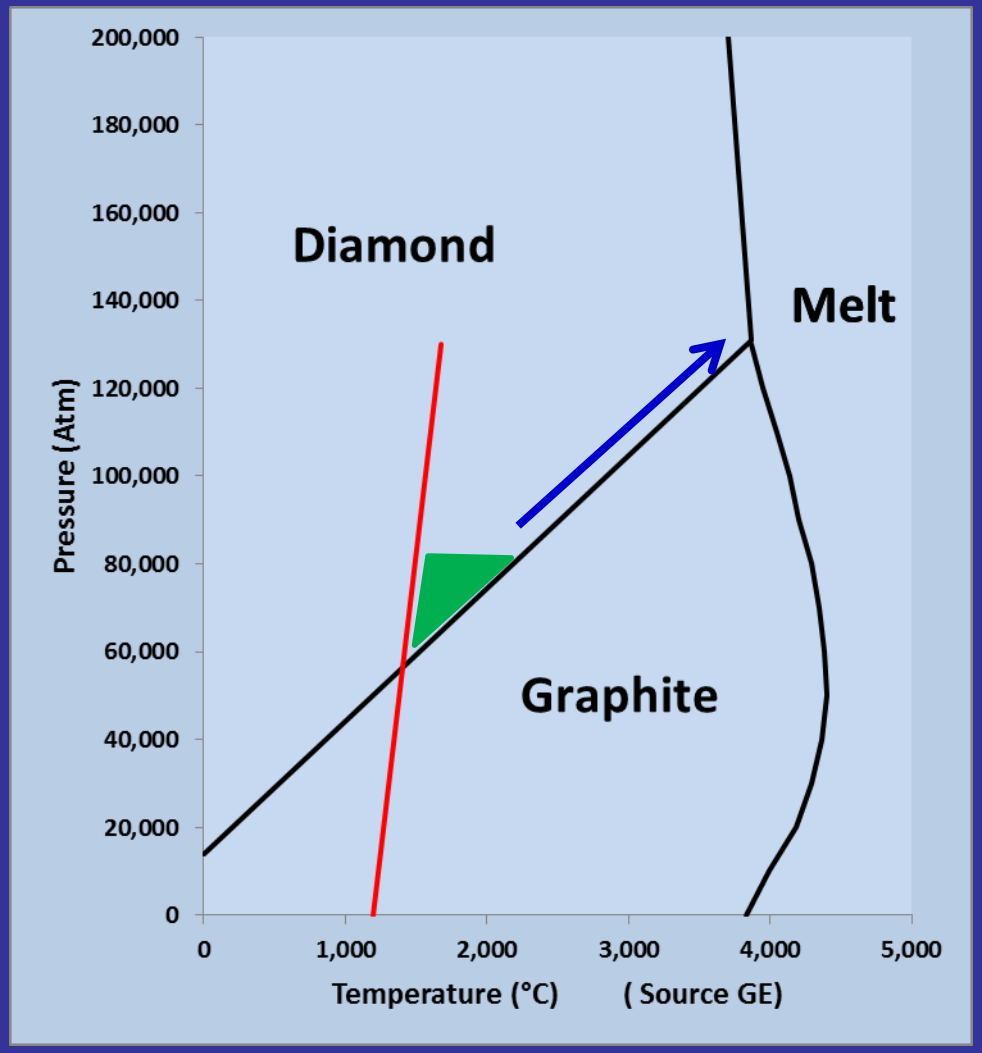
The Future for PDC and PDC Bits

- Challenges of Catalyst Removal
  - Islands
  - Dissolved
- Future Direction
  - Deeper
  - Smaller pathways
  - Implications on time to leach



The Future for PDC and PDC Bits

- Other catalysts
  - Rare earth elements
- Catalyst free



The Future for PDC and PDC Bits

- Pressing Equipment
  - Higher pressures and/or temperatures
  - Pressing volume
  - Cycle time

Implications for PDC costs

Conclusions

- PDC is a very reliable, high performance cutting tool.
- Thermally stable PDC was the biggest drilling cost reducer
- The PDC bit is now the predominant drilling product.
- With your help
  - New generations of PDC for even higher bit performance

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