LECTURE # 6

Sodium
From Latin Natrium (Na)

SODIUM

Soft, silvery metal. 2.27% of Earth's crust.

Highly reactive. Not found as free metal.

Found as minerals: feldspars, sodalite, rock salt and chemically as table salt, soda ash, baking soda, caustic soda, phosphates, and borax.

Readily donates single electron on outer shell ⇨ Na^+ cation

Sodium - History

Egyptian *Natron* ⇨ Arabic *soda (headache)*

1814 – Scientific name of *Natrium*

SALT (NaCl) =

Sodium (Na) + Chloride (Cl)

SALT

Crystalline mineral of **sodium chloride (NaCl)**

Vast amounts in sea water (3.5%) and in mines

Saltiness = basic human taste

Essential to human health

Processed from sea water and from salt mines

Taxation and active commerce

Trade and **War**

Salt - Timeline

~ 8000 BC – First evidence of processing salt from sea - Romania - boiling spring water

Human habitation around **water and salt**

The name “salt” from Latin “sal” ⇨“*salarium*” = soldier’s wage

Salt present in meat, less in plants - nomads do not eat salt. Farmers do.

Main trading: Chinese, Hittites, Hebrews, Egyptians, Indians, Greeks, Romans, Byzantines

“Salting the Earth”

Salt for barter

Salt trading routes – Via Salaria = Ostia-Rome

Salt – Timeline (cont'd)

2,800 BC – Active exchange - Egypt and Phoenicians.

Tuaregs (Africa) made caravan routes through Sahara.

800 BC – Salzburg on river Salzach - salt deposits (*Salz = salt German)*

Celtic people traded salt and salted meat to Greece and Rome.

War of Venice and Genoa over salt transport

Liverpool became rich exporting salt from mines of Cheshire

Columbus' voyages financed by selling salt from S. Spain

Oppressive salt tax in S. France ⇨ cause for French Revolution

1930 – Gandhi "Salt Satyagraha" ("Insistence on truth") – making own salt boycotting the British raj.

Seawater - Salinity

Contains salts 3.5% on average, dissolved sodium chloride ⇨ 35 gm/Liter of sea water with density = 1.025kg/L

Freezing point = -2.0°C

The Red Sea – 5.0% salt. The Dead Sea – 34% salt ⇨ Human body floats

The Caspian Sea - 35% salt

The most abundant, dissolved ions in seawater are: sodium, chloride, magnesium, sulfate, and calcium

Salt Deposits at the Dead Sea

Red Rock Salt, Pakistan

Salt Mounds, Bolivia

Salt – Brine from Sea Water Being Boiled Thailand

Salt - Economics

~200 Million tonnes produced

Producers: China, USA, India, Germany, Canada

Production:

- Sea water evaporation in ponds
- Mines (rock salt) followed by refining

Huge reserves of salt

Uses: 6%-17% - Human consumption

6% - Food processing

12% - Water conditioning process

6% - Agriculture

SALT and HEALTH

Salt = 40% **sodium** by weight

1 tsp (6g) = 2,300 mg of sodium

Sodium is an electrolyte necessary for the normal function of almost all organs. **Minimum requirement = 500 mg/day**

Necessary for **water regulation** in the body, blood volume, and blood pressure

Western countries: Salt intake = 10 g/day ⇨ High blood pressure and stroke incidence. Lowering salt intake ⇨ 9-17% reduction in HBP

WHO recommends: Sodium <2,000 mg/day (5,000 mg salt/day)

American Heart Assoc. - No more than 1.5 g of Na/day; less than 1,200 mg/day (3,000 mg salt/day) is not recommended

The World, its Resources, and Humankind

MINERALS

COAL
[(Carbon (C)]

Coal Formation and Uses

Volcanic activity ⇨ dead forests in wetlands ⇨
buried under soil ⇨
pressure of soil ⇨
carbonization ⇨ peat ⇨ lignite ⇨
sub-bituminous coal ⇨
bituminous coal ⇨
anthracite &
graphite

Uses: - Heating

- Fuel for generation of electric power (40% made with coal)

Bituminous Coal

Anthracite

COAL

Old English = "*mineral of fossilized carbon*"

Combustible sedimentary rock – coal beds or coal seams

Chiefly carbon with some sulfur, oxygen, hydrogen, and nitrogen

Coal Timeline

1,000 BC - Used for smelting copper in China

300 BC - Theophrastus - *"On Stones" - anthrakes*

200-400 CE - Roman Britain – Coal was known (uses?)

1,000 CE - Rhineland - Coal use for smelting iron ore

~1,300 CE - Marco Polo – *"black stones which burn like logs"*

1,300 CE - "Seacoal Lane" in London – unloading coal from Newcastle-upon-Tyne ⇨ for smiths at Westminster Abbey

13th Cent. - Underground extraction - "pitcoal" = open mining

18th Cent. - Industrial revolution started in England - steam engine

Coal Mining

Since 1880s England, N. America, Australia, S. Africa

- Surface open mines
- Underground mines (“colliery”)

Mine extraction - accidents, environmental hazards, disease

Made possible the **Industrial Revolution**

Coal mining in United States

Coal mine in Wyoming

Coal miner in Britain - 1942

Miners Leaving their Mine Shift

“Black Lung” Disease

Pneumoconioses = Occupational diseases due to the inhalation of foreign particles and their deposition into the respiratory tract

Anthracosis = “Black lung” disease of the miners

Coal particles are inhaled and deposited into the bronchi (wind pipes) lining and into the lungs, causing a **fibrotic (scar tissue**) reaction and **restriction of gas exchanges**

Severe chronic lung disease ⇨ Death

ANTHRACOSIS – Lung mass

Normal and “Black Lung” in Anthracosis

Anthracosis
[Coal Workers Pneumoconiosis (CWP) or Black Lung Disease]

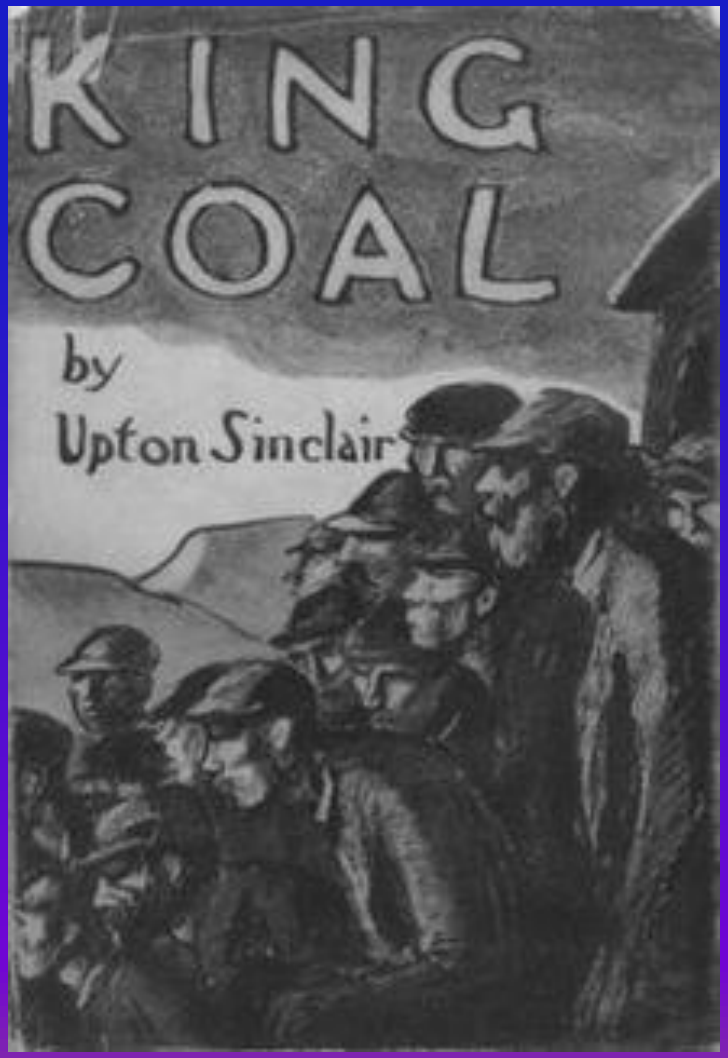
Federal Coal Mine Health and Safety Act of 1969 ⇨

“Black Lung Disability Trust”

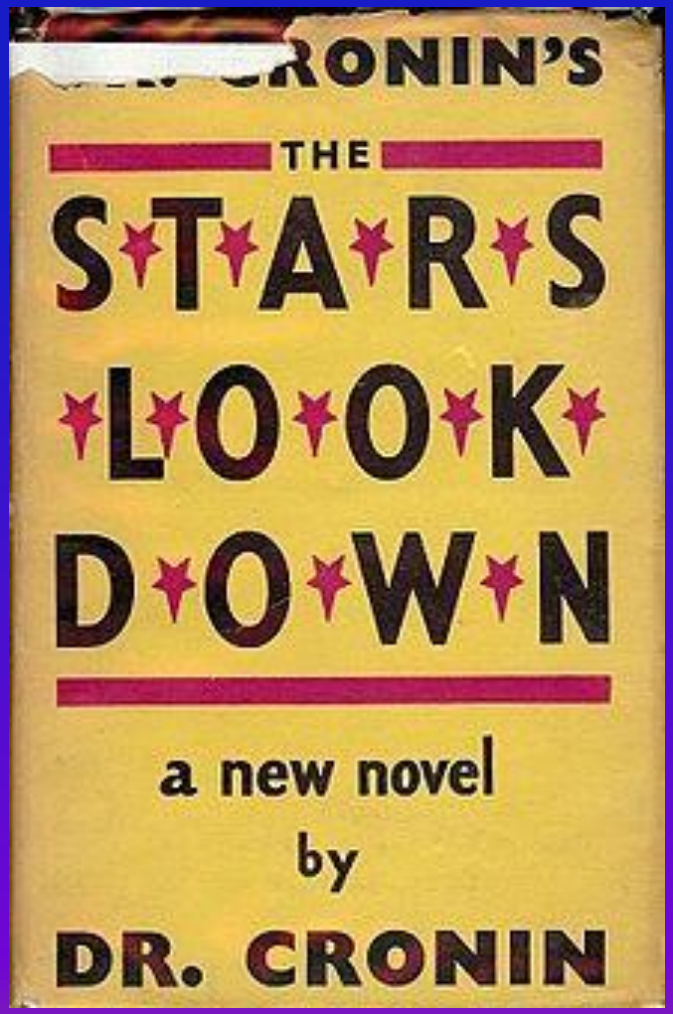
Anthracosis reduced by 90%, but recent increase reported

New data - 2% of surface miners (48% of workforce) develop CWP after one year of work

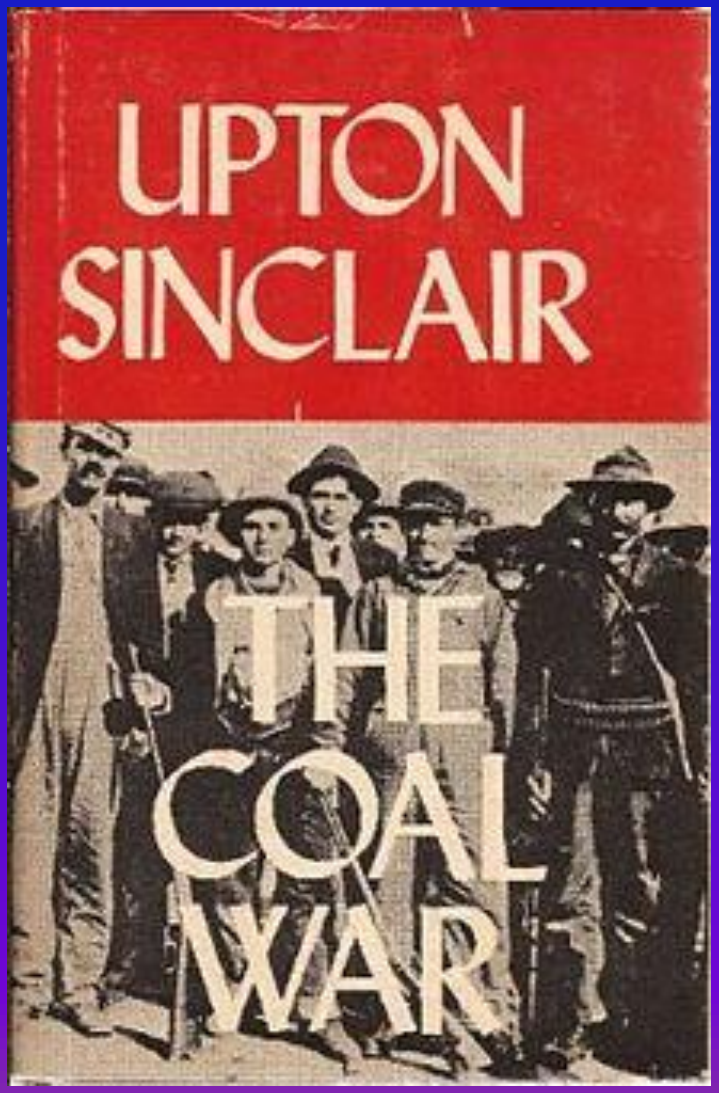
Upton Sinclair's "King Coal", 1917



A. J. Cronin, MD, 1935



Published posthumously, 1976



Environmental activists blocking access to a mine

Coal – Production and Uses

1947 – 750,000 miners in Britain, 2004 - only 5000

2001 – **China - 50% of world production**

USA, India, EU, Australia

Largest importer – Japan

Uses: **Heat,**

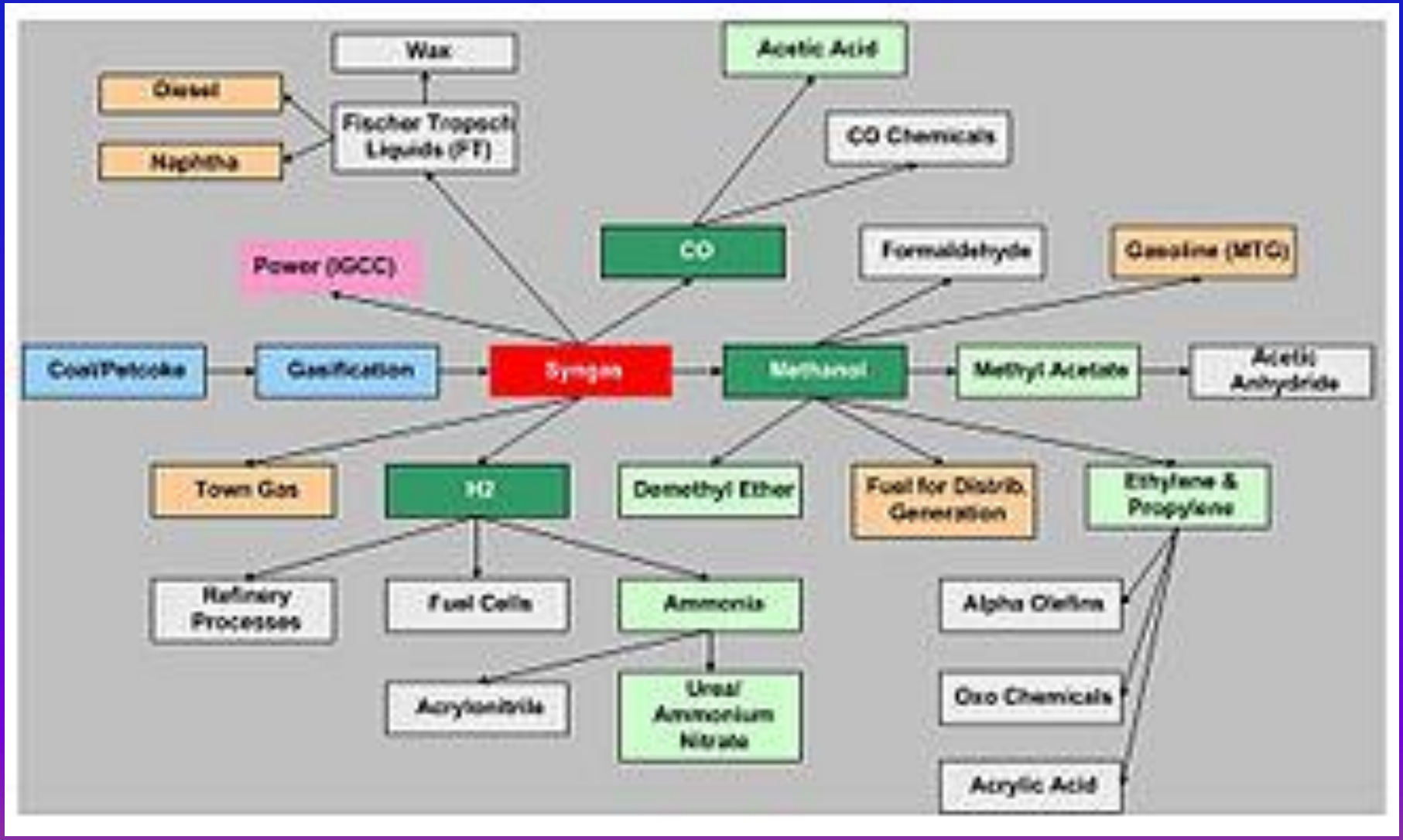
Electricity – 40% world's electricity.

USA coal use is declining since 2012

Petro-Chemicals – increasing output due to

gasification ⇨ syngas ⇨ electricity

Production of Chemicals from Coal



Gasification and Petrochemicals

Coal + oxygen + steam - Heated under pressure

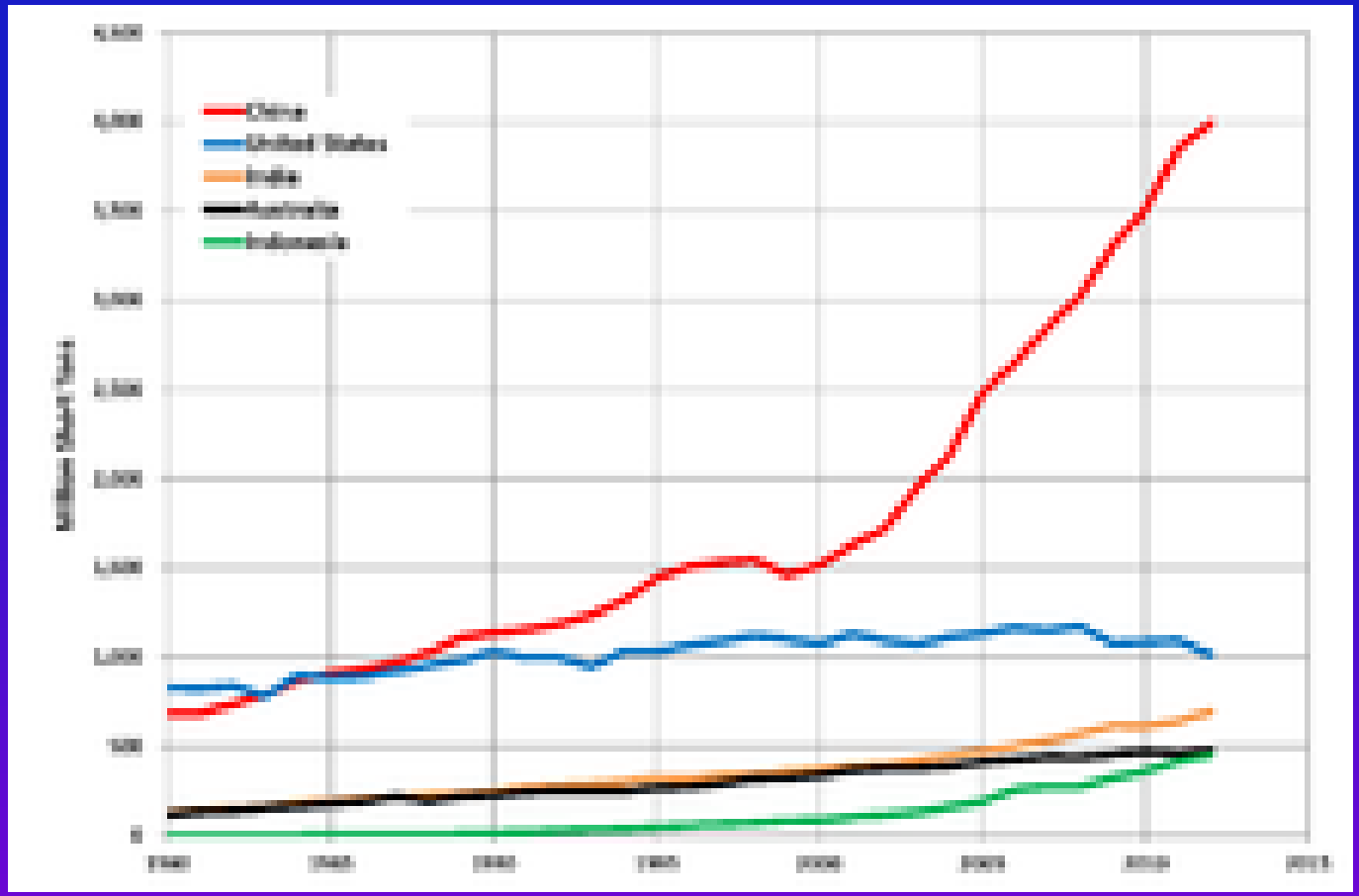
Oxygen and water molecules oxidize coal ⇨ CO + H_2 = "**SYNGAS**" used to fire engines ⇨ **electricity**

Syngas ⇨ **gasoline and diesel**

Syngas ⇨ **methanol ⇨ gasoline**

Since 1950s - **Petrochemicals: Olefins, acetic acid, formaldehyde, ammonia, urea, etc.**

World Coal Production - 1980-2012



China

USA

India

Australia

Indonesia

DIAMONDS

DIAMONDS

What are the diamonds?

Internet: *“Metastable allotrope of carbon”*

A mineral made of **pure carbon** with the atoms in a strong bond and arranged in a particular structure (**lattice**)

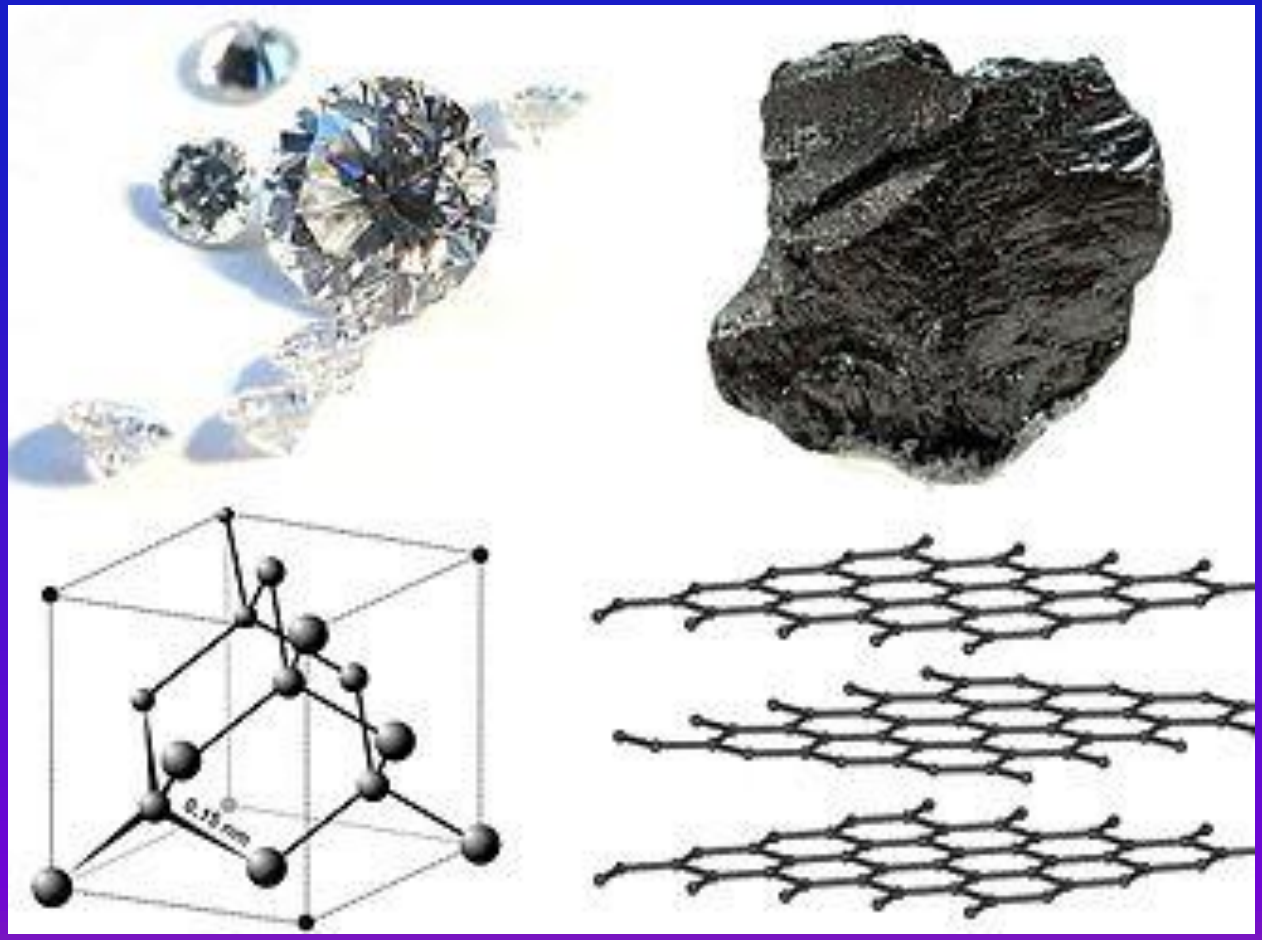
Highest hardness (grade 10)

Highest optical dispersion

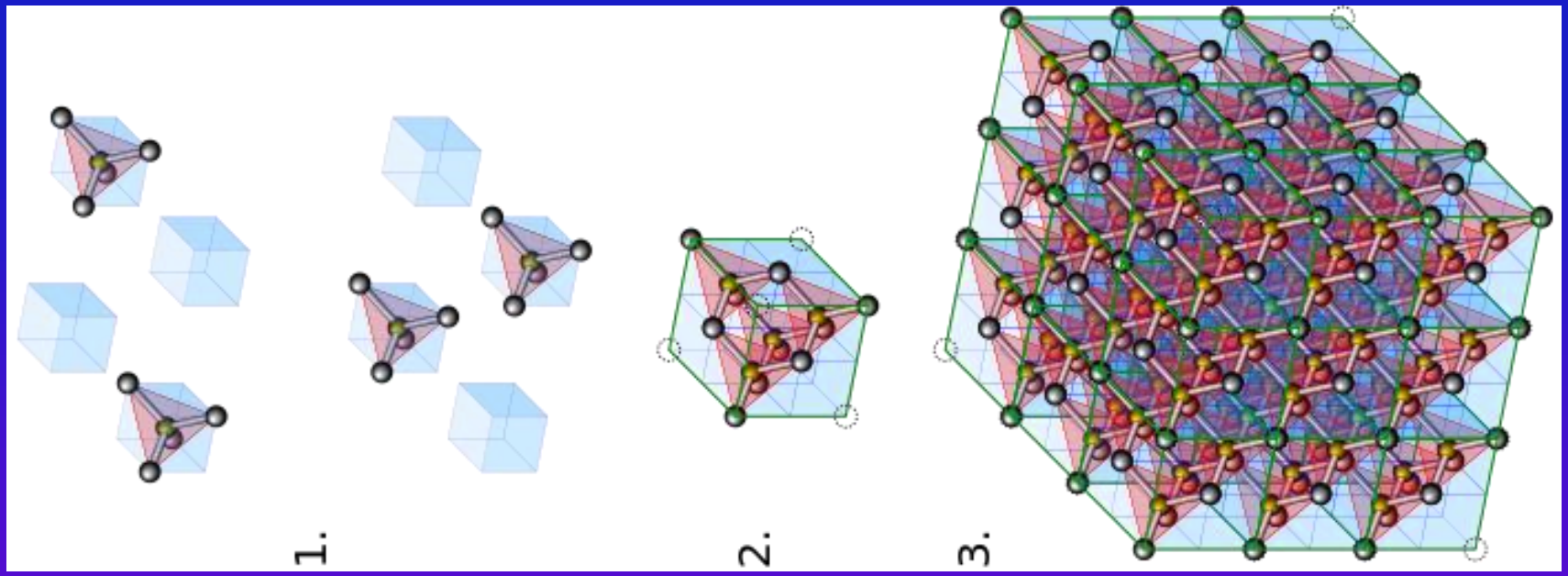
Colorless, but impurities may color:

Blue – boron, yellow – nitrogen, brown – lattice defects, green – radiation exposure

Lattice of Diamond (left) and of Graphite (right)



Lattice of Carbon Atoms in Diamond



Diamonds Formation

1 - 3 Billion years (25% - 75% of Earth's age)

Depth of 87 - 118 Mi. in the Earth's mantle

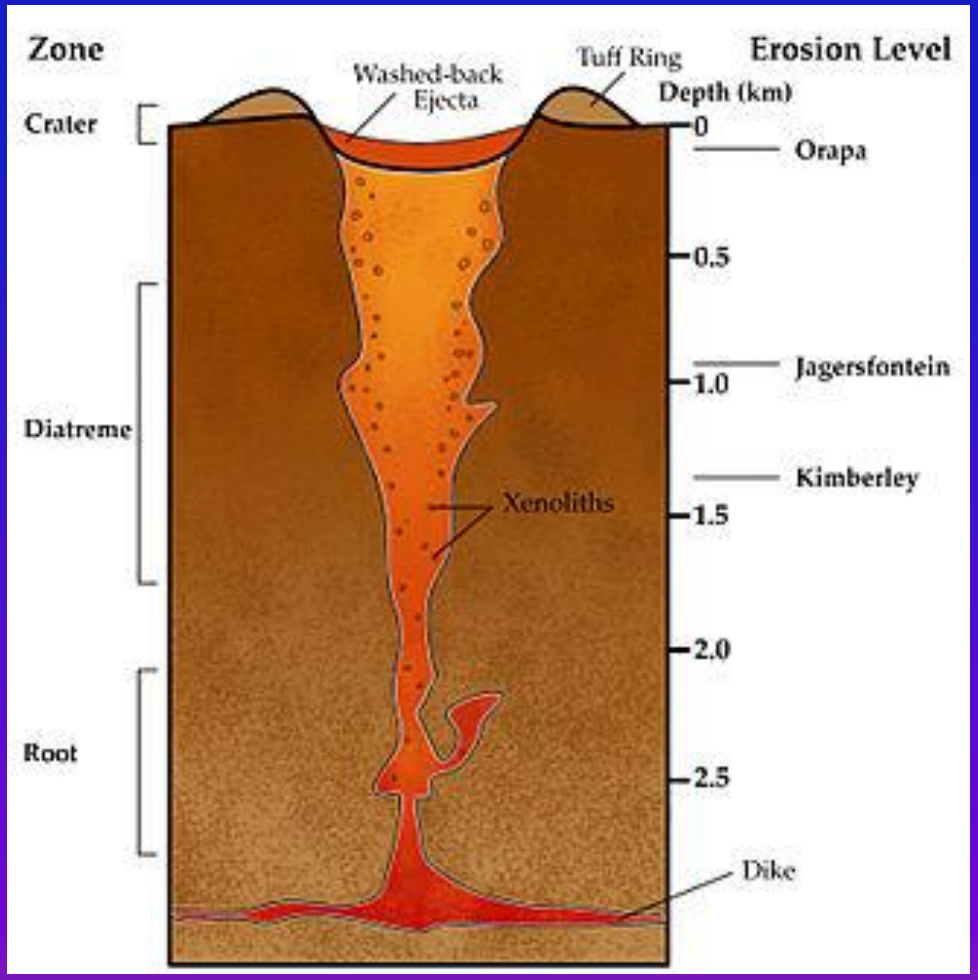
Temp of 1650° - 2370°F

Pressure 45 - 60 kbars (~1,000 atm. pressure)

May be produced synthetically (HPHT method)

"Diamond simulants" zirconium, germanium

Schematic Diagram of a Volcanic "Pipe"



Panning for Diamonds in Sierra Leone

Diamond Cutting

Cutting and polishing are done with scientific knowledge, tools, and experience

Centers: Johannesburg, Antwerp, Amsterdam, New York, Tel Aviv

Diamond - cut & polished = **brilliant**

~ 50% Weight reduction upon cutting

1 carat = 200 mg.

Uses: Industry - 80% of mined diamonds

Jewelry

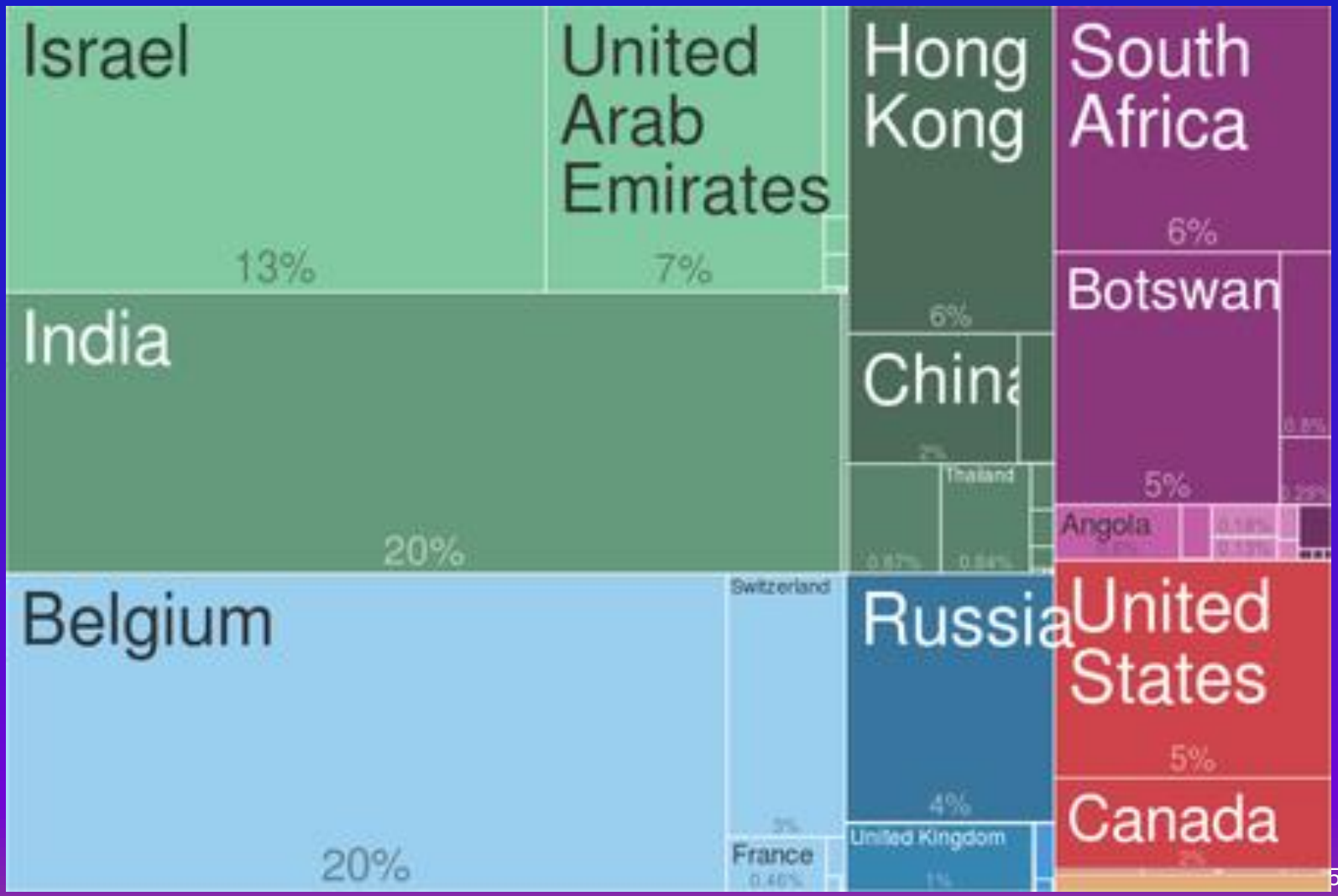
“Bleu de France” Diamond
In 1669 Louis XIV had the Indian 115 carat diamond recut

The “Hope Diamond” 45.52 carat
National Museum of Natural History, Washington, DC

CUT FROM “BLEU DE FRANCE” GIVEN TO LOUIS XIV - 1669

Brilliant set in a ring

Diamond Exports by Country - 2014



Diamonds – Production and Politics

Approx. 130,000,000 carat mined/year = US $9 Billion

9th cent. BC -18th cent. CE – **India was major producer**

18th cent. – Brazil, Canada, Zimbabwe, Angola, Russia

US – Arkansas, Colorado, Wyoming, **Montana**

Recent mines: Russia, Botswana, W. Australia, D.R. Congo

The World Looked on and Did Nothing

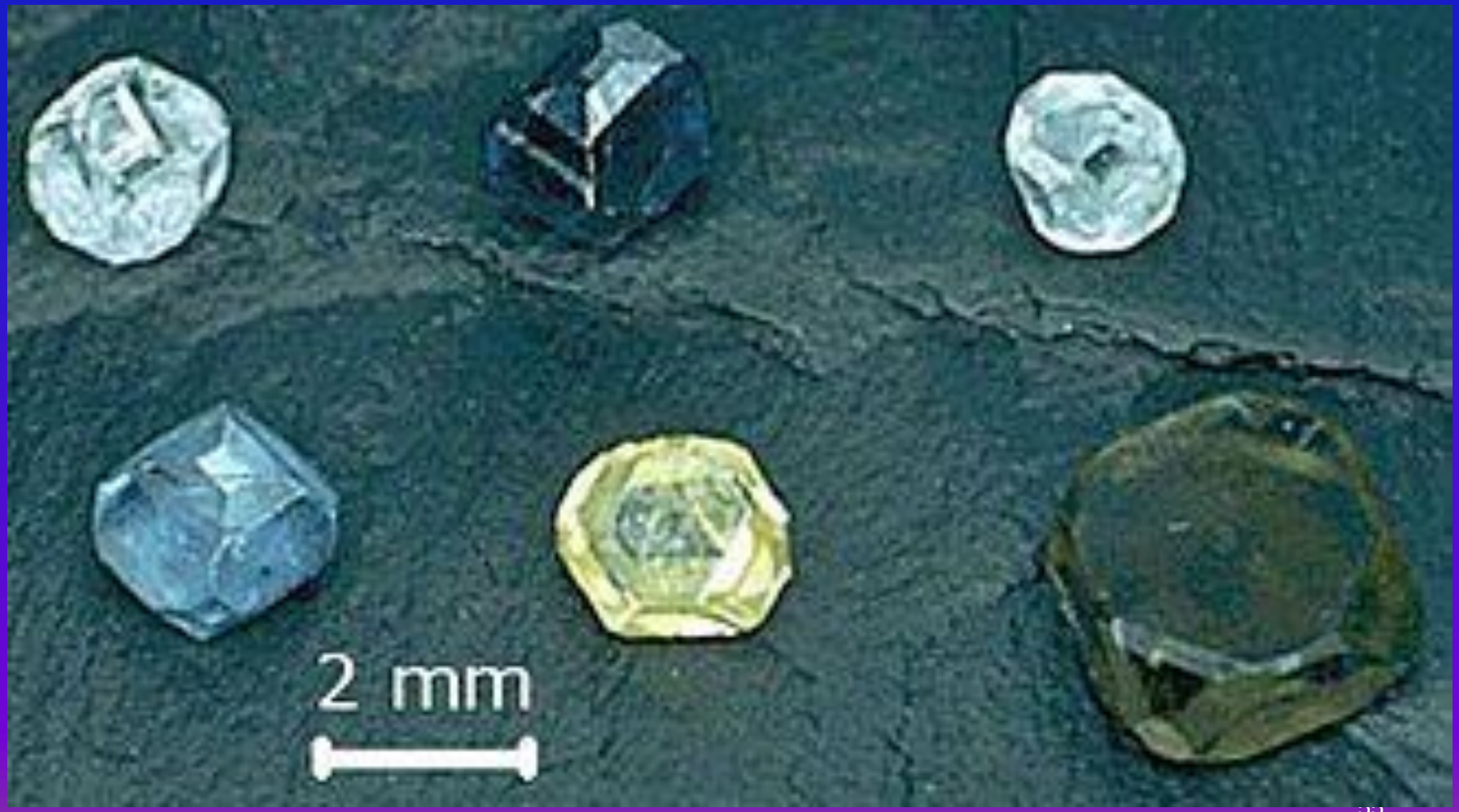
Political issues: D.R. Congo - 1998 - Revolutionary groups ➢ ***"Conflict and Blood Diamonds"***

Diamonds stolen by rebels and sold on the black market for own profit.

2000 - **UN Kimberley Process Certification** to block sales of conflict diamonds

What did United Nations do?

Synthetic Diamonds Grown by the High-Pressure High-Temperature Technique (HPHT)



Colorless Gem Cut From Diamond Grown by Chemical Vapor Deposition

SULFUR (S)

SULFUR

Solid yellow crystalline mineral abundant in Earth's crust

Occurs as native or as sulfide or sulfate minerals

Essential to life: Amino-acids (methionine, cysteine) and vitamins

Found in volcanic regions and hot springs

Mined in Sicily, Indonesia, Chile, Japan

Sulphur in fumarole – Volcano, Italy

Sulfur Timeline

Old Testament - “brimstone” ⇨ “fire-and brimstone” =
eternal damnation of unbelievers

Known in antiquity

6th cent. BC - Chinese medicine

1,044 CE - Chinese black gunpowder

Alchemists used it for skin conditions

18th cent. - Sicilian mines - horrible conditions -
Booker T. Washington:

“Sicily mine is the nearest thing to hell that I expect to see in this life.”

Sulfur – Production and Uses

Mining declined after 2002

Side product of oil refining

Uses: Sulfuric acid very important in oil refining and mineral extraction

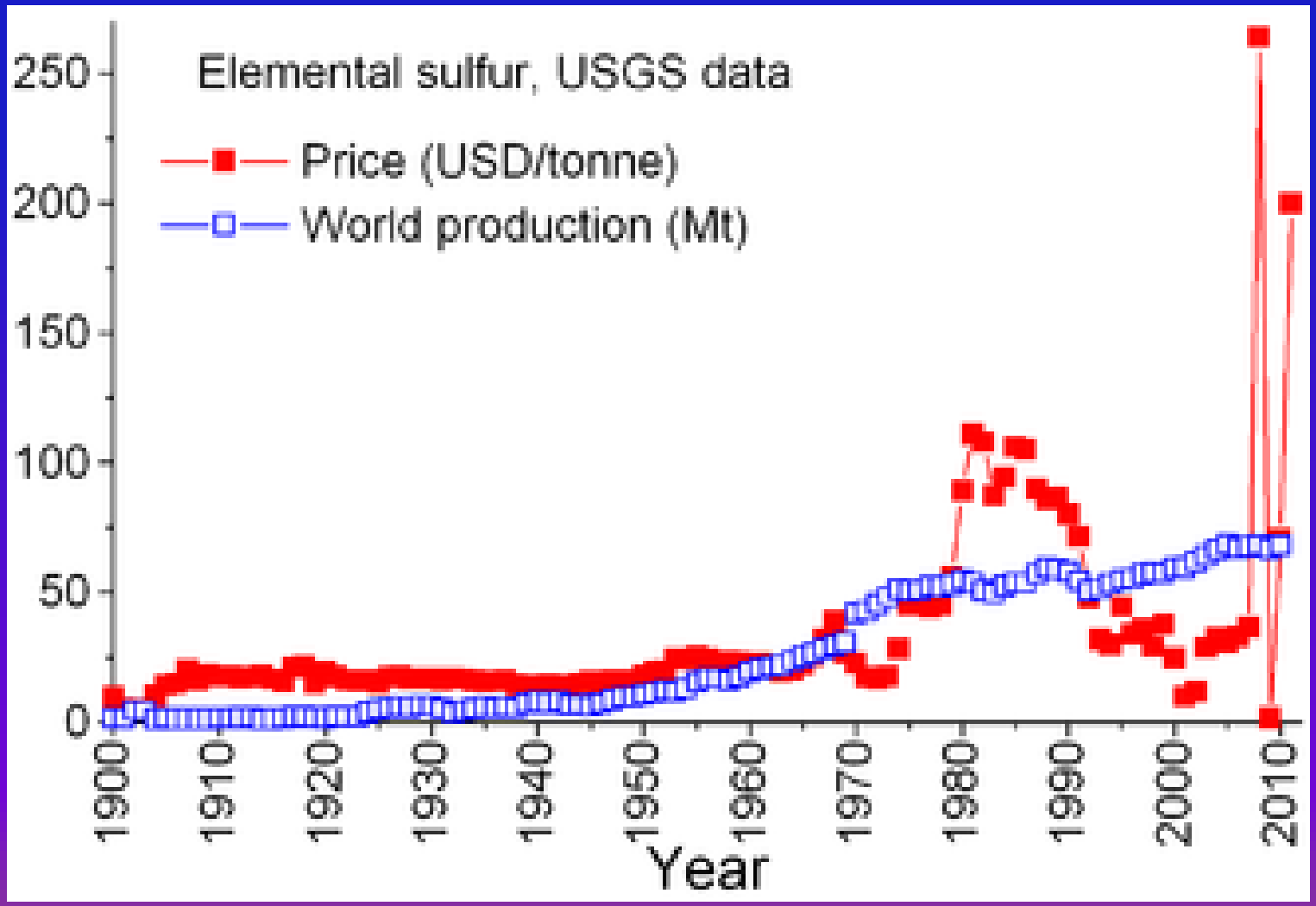
Fertilizers

Fungicides, pesticides

Sulfa drugs (antibacterial sulfonamides)

Winemaking (sulfites inhibit aerobic bacterial growth)

Production and Price (US market)
Price is in Red



Burning of coal in industry ⇨ sulfuric dioxide in air + water + oxygen = sulfuric acid ⇨ acid rain

Effects of Acid Rain on a Forest in the Czech Republic

SILICON [Silica (Si)]
(Silicon dioxide SiO_2)
(from Lat. silex)

SILICA

Second most abundant in the Earth's crust

Known since old times

Major constituent of **sand**

Wide use in industry

Silica

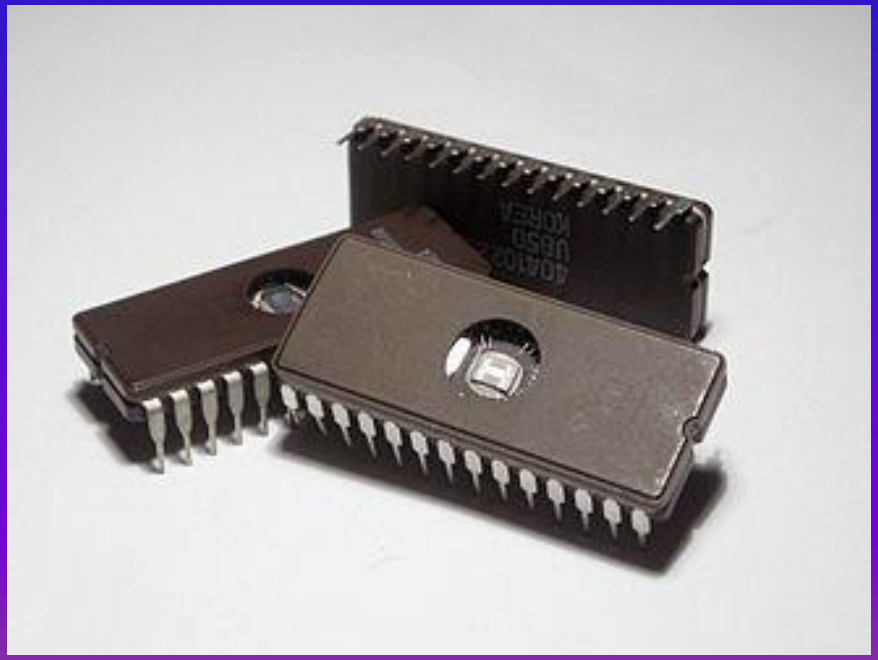
Uses:

- **Portland cement**
- Production of **glass**
- Production of **ceramics: Earthenware**
  Stoneware
  Porcelain
- Production of **microchips**

Health hazards: Silicosis – a lung disease due to inhalation of sand particles

Microchips = Integrated Circuits

Integrated circuits are used in virtually all electronic equipment today: **electronics, computers, mobile phones**, and other **digital home appliances**



QUARTZ

QUARTZ

Name is from German "*Quarz.*" The name *crystal* is from Greek *"kristalos"*

It is a **crystalized** form of **silicon dioxide**

A six-sided prism with a six-sided pyramid at one end and embedded into a matrix at the other end.

Many varieties due to impurities and the structure macro- or micro-crystalline structure

Rock crystal is the purest

A Cluster of Natural Quartz Crystals

Quartz crystal cluster from Tibet

Clear Rock Crystal

Amethyst crystals on matrix

IRON IS THE IMPURITY

Rose quartz cluster

Smoky Crystal from the Alps

Quartz Timeline

Known from antiquity

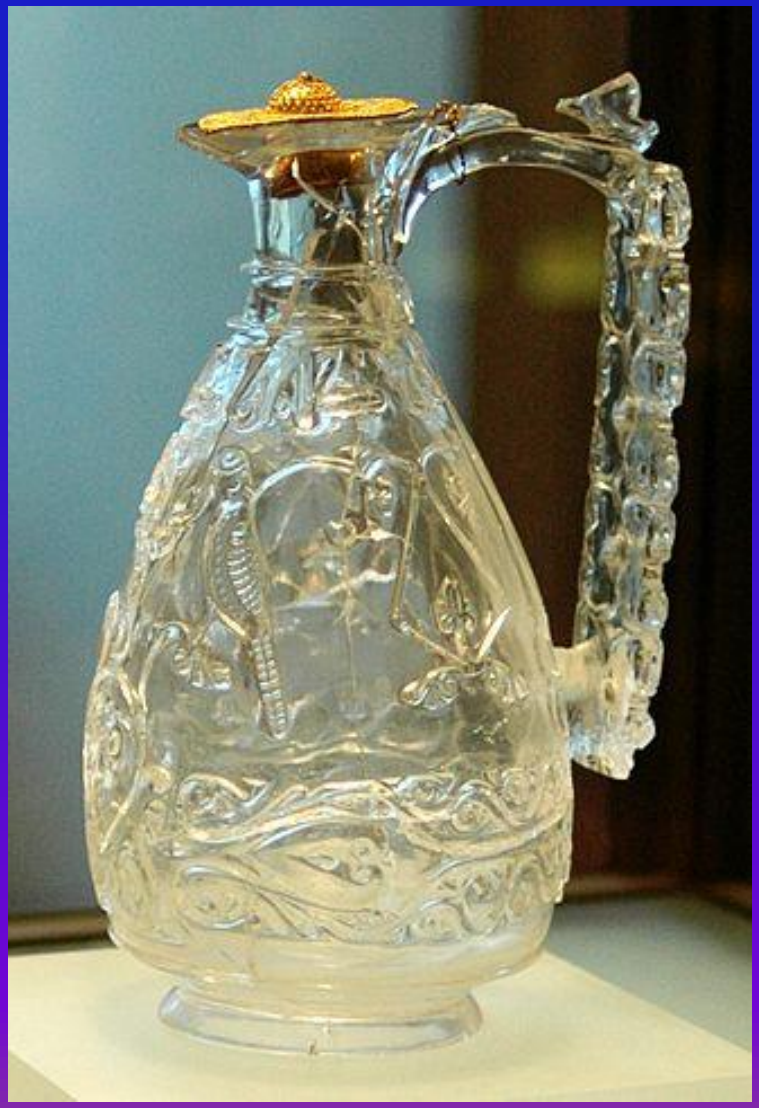
Associated with funeral ritual in many countries

Semi-precious in Europe and in Middle East as jade was in Asia. Many gems, vases, decorative.

17th cent. Nicolas Steno – **modern crystallography**

1930 – Electronic industry used quartz crystals

Persian Ewer in Rock Crystal – c. 1000



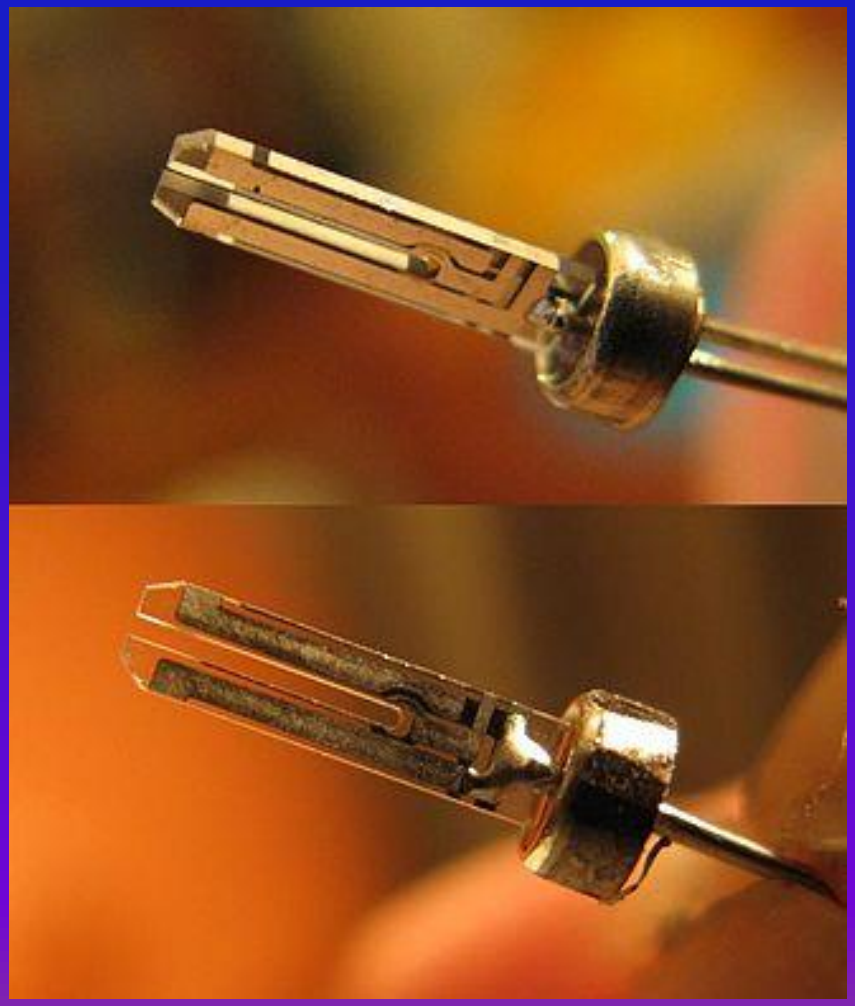
Cornucopia in rock crystal (pure quartz) – Austria, 1890

Piezoelectric Effect

Piezoelectric properties – 1880 - Jacques and Pierre Curie discovered that quartz crystals develop an **electric potential** upon application of **mechanical stress** (pressure)

Crystal oscillator used in the production of very accurate measurements like time – Quartz watch

Tuning-fork crystal used in a modern quartz watch



A Quartz Clock

CLAY

CLAY

Formation: Chemical weathering of rocks by carbonic acid and water

Natural soil material - Minerals + traces of metal oxides + organic matter

Absorbs water ⇨ swells and becomes plastic

Upon drying or being fired ⇨ becomes hard

Importance in building - foundations

Geologic clay deposits in layers of various colors

Firing in kilns ⇨ **ceramics: Earthenware,**
Stoneware
Porcelain

Clay Cliffs in Martha's Vineyards

Clay - Timeline and Uses

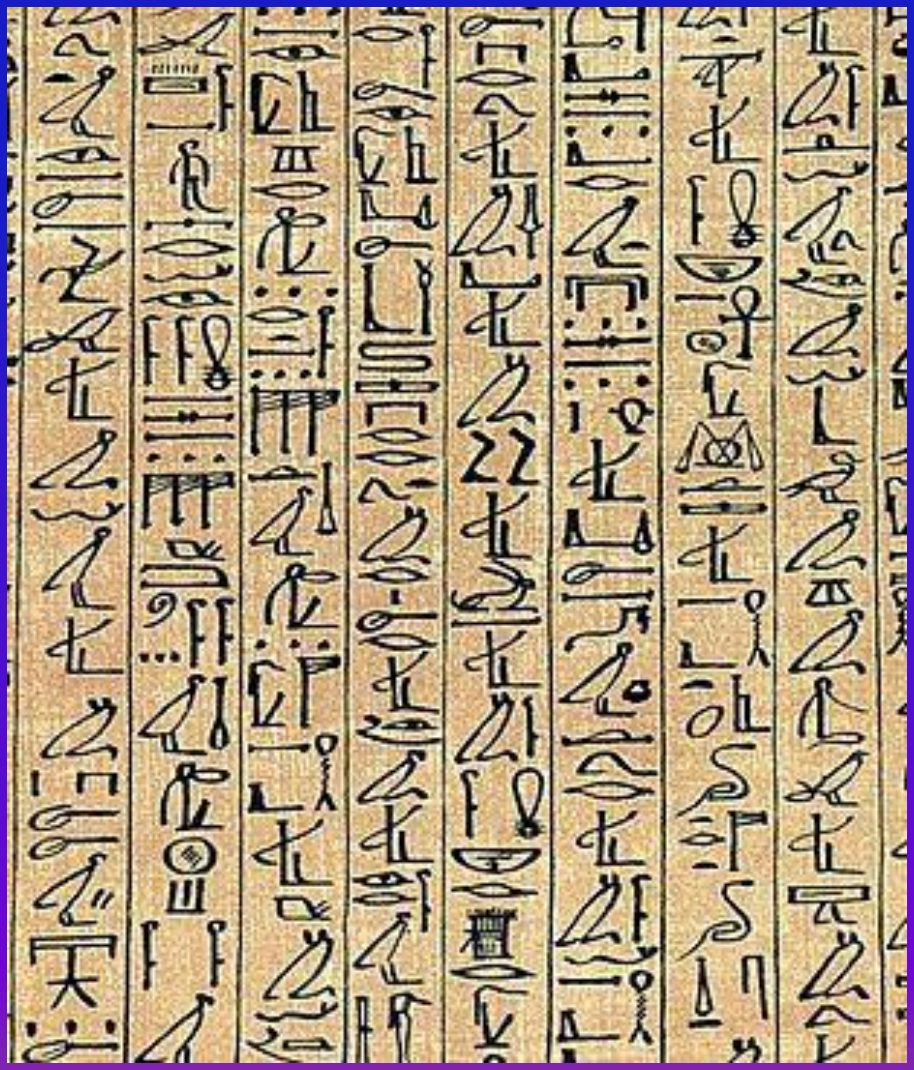
14,000 BC – Used in Japan - Jomon period 14,000-1,000 BC
Man discovered the clay properties upon heating – firing.
Clay tablets used for writing with a reed
3,500 BC - **Cuneiform writing and the hieroglyphs**

USES: Oldest **building material**, bricks - adobe
Wall and floor **tiles**
Pottery, dishware, cooking pots
Domestic appliances, musical instruments, art

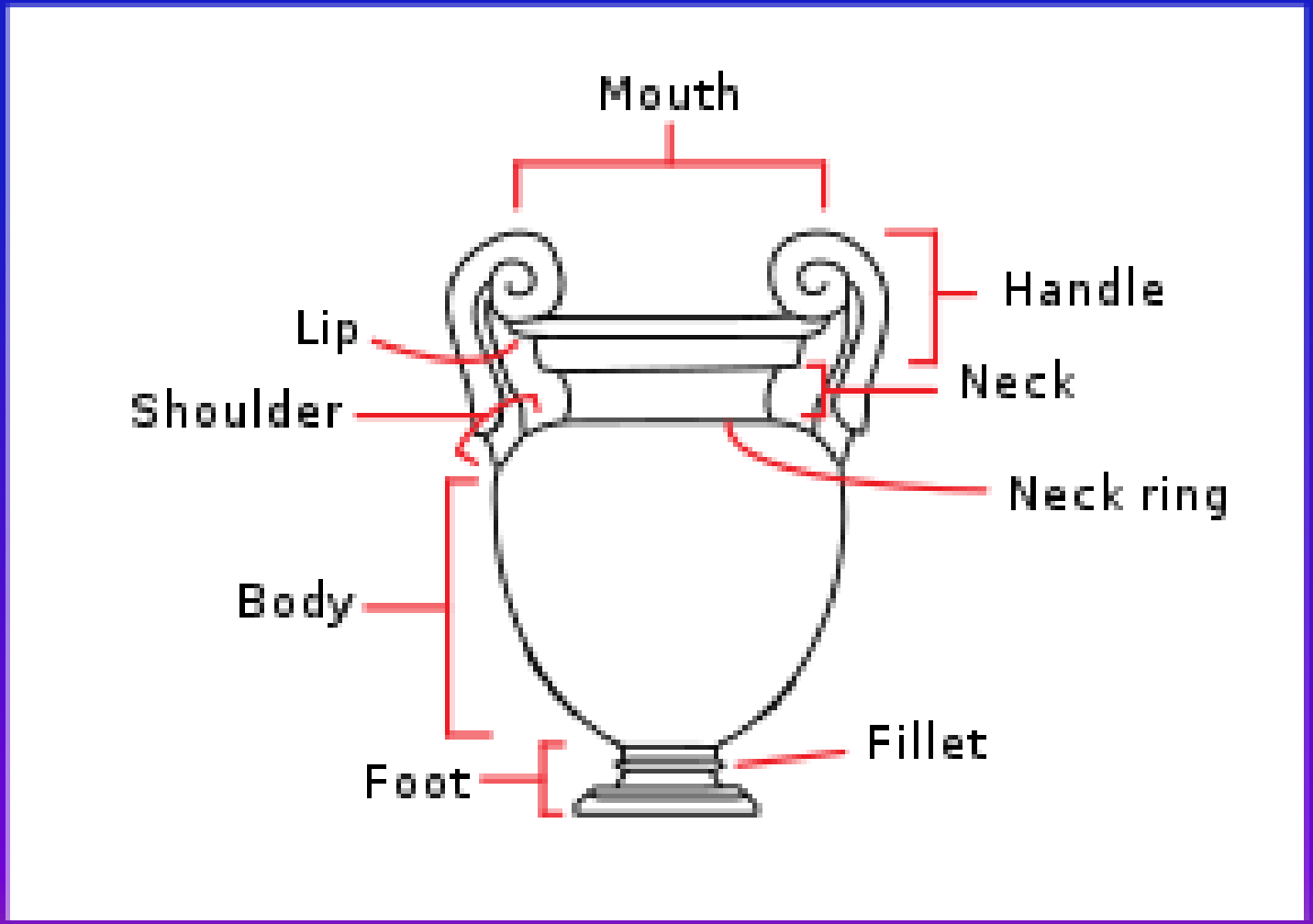
Ceramic Vessel from Mesopotamia
4,500 – 4,000 BC

Cuneiform Writing
Sumerian (Mesopotamia) 3,500-3,000 BC

Egyptian Hieroglyphs
3,300 BC



Greek vessels



Greek amphora 1,500 - 900 BC

Protocorinthian skyphos – 7th Cent. – The Louvre

Protocorinthian Olpe – 7th Cent.

Greek pottery – A Rhyton for Drinking Wine – 5th Cent. BC

Pueblo in Taos, NM
1000 years old

Tile Stove – Empress Catherina Palace St. Petersburg - 18th century

COLTAN

COLTAN

A metallic ore discovered ~1990

Name is short for ***columbite-tantalite***

The Niobium-dominant mineral in coltan is Columbite

The Tantalum-dominant mineral in coltan is Tantalite

x 80 better conductor than copper

Resists high temperatures

Resists oxidation

A Piece of Coltan

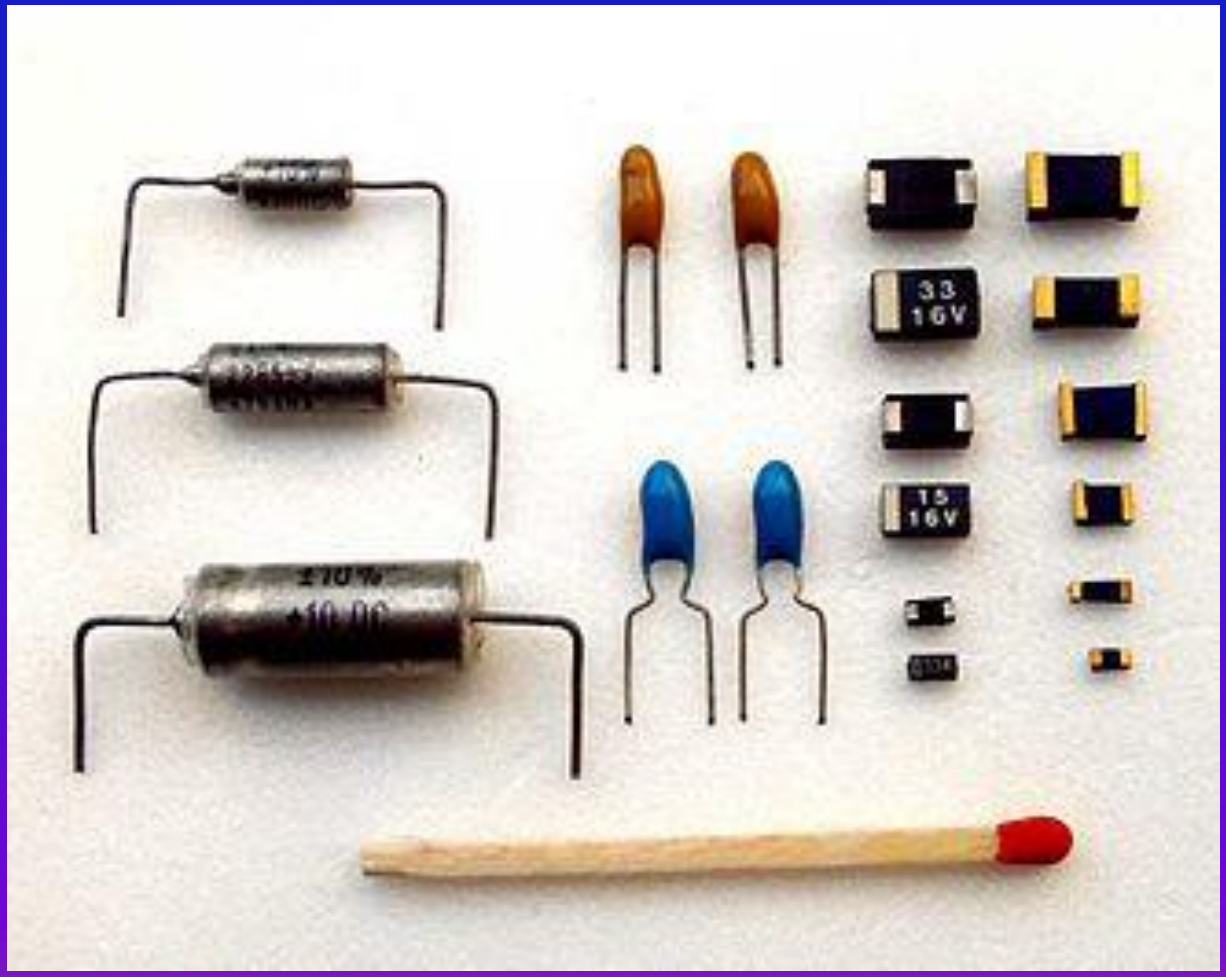
Coltan - Uses

60 - 89% of world production used for:

Mobile phones, flat TV, video games, MP3, batteries, laptops, GPS, airplane industry, optic fiber, tele-guided weapons, artificial satellites digital cameras, medical appliances

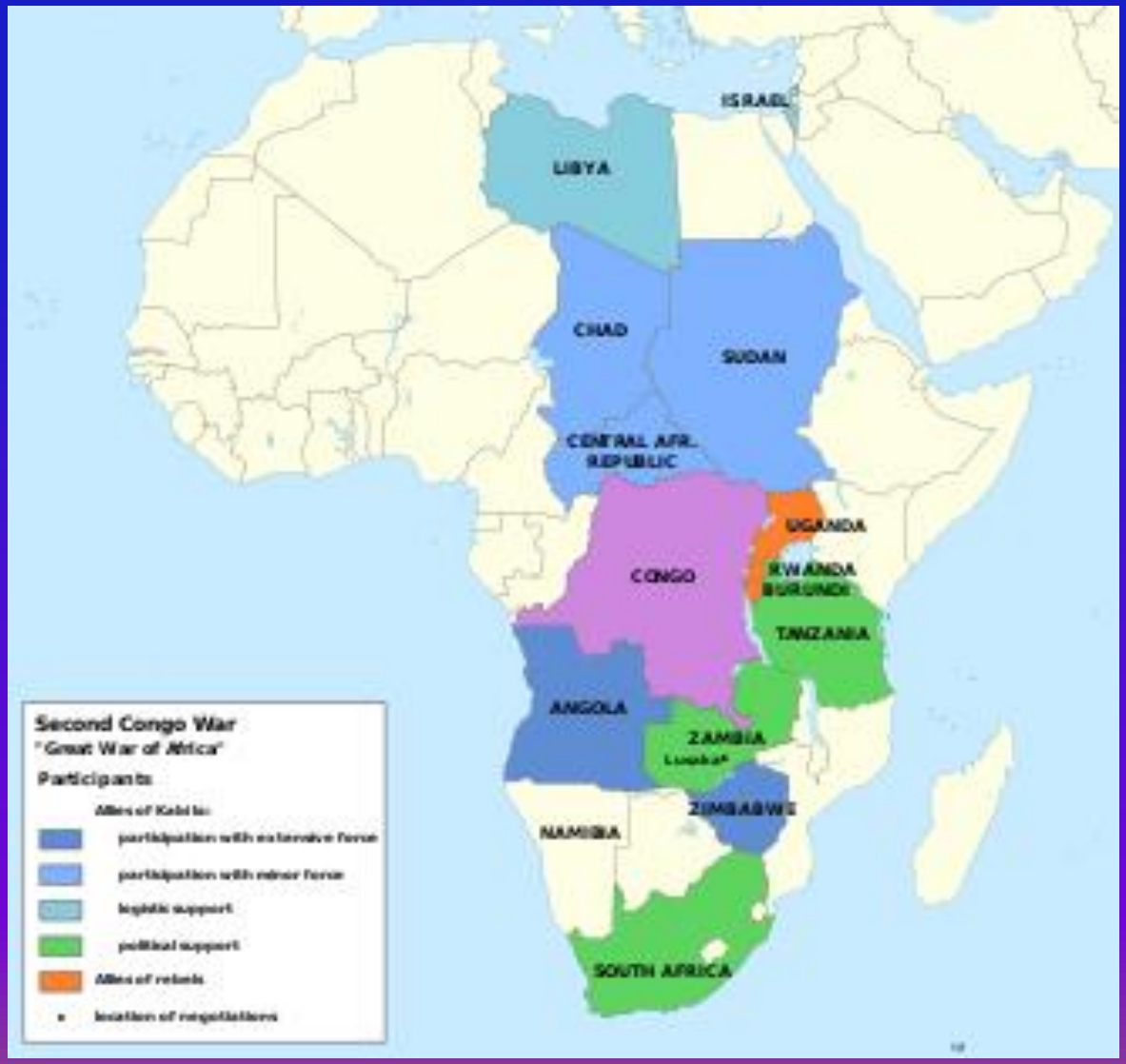
Late 2,000 – Great demand for *PlayStation 2* ⇨ Coltan price increased temporarily

Tantalum Capacitor



Map of Colonial Africa in 1910

Africa after the Second Congo War (1998-2003)



Coltan – Resources - Economy

71% mined in D.R.Congo; 20% recycled

Australia - 10%

Thailand – 5%

Brazil – 5%

Major explorations. High global demand - still met

Major international theft, aggression, and war

United Nations: Plunder of gems and minerals by militia and 125 companies

Coltan smuggled through Eastern Europe ⇨ Russia

Coltan – Social and Political Issues

"Resource Curse" = Countries rich in resources have worse economic development

Children used in the extraction; paid 1-2 US$/day

Corruption, exploitation ⇨ Political instability ⇨ paid militia ⇨ civil war

- **90% of young men – Leaving farms for mining**
- **30% of youth are illiterate**
- **60% do not have potable water**
- **30% - undernourished**
- **1 Million refugees**

Eastern Congo invasion from Rwanda, selling coltan

The World Looked on and Did Nothing

D.R. Congo – "Conflict diamonds" and "Blood diamonds" – Stolen by rebels and sold on the black market for own profit.

D.R. Congo – "Resource Curse" – Coltan

Stolen by insurgent armies and sold to pay mercenaries.

<u>What did United Nations do</u>?

RARE EARTH ELEMENTS

RARE EARTH ELEMENTS

- Cerium (Ce)
- Dysprosium (Dy)
- Erbium (Er)
- Europium (Eu)
- Gadolinium (Gd)
- Holmium (Ho)
- Lanthanum (La)
- Lutetium (Lu)
- Neodymium (Nd)
- Praseodymium (Pr)
- Promethium (Pm)
- Samarium (Sm)
- Scandium (Sc)
- Terbium (Tb)
- Thulium (Tm)
- Ytterbium (Yb)
- Yttrium (Y)

Rare Earth Elements

1787-1901 - Discovered in the soil of Ytterby, Sweden

17 elements found in the earth as oxides

Earth crust – 68 ppm (like Cu) - NOT SO RARE

Pacific Ocean seabed mud (?)

Isolation is difficult. Using difference in solubility and other modern techniques

Used in high-tech. **Reserves are dwindling.**

Environment concerns: Radioactive slurry, toxic acids in the refining process

Rare Earth Elements (1)

Scandium - Light aluminum-scandium alloys for aerospace, additive in metal-halide lamps, radioactive tracing agents.

Yttrium - Yttrium-aluminum garnet laser (YAG), TV, microwave filters, energy-efficient light bulbs, additive to steel.

Lanthanum - High refractive glass, hydrogen storage, camera lenses, catalyst for oil refineries.

Cerium - Oxidizing agent, catalyst for self-cleaning ovens and for oil refineries

Praseodymium - Magnets, lasers, carbon arc lighting

Rare Earth Elements (2)

Neodymium - Magnets, lasers, didymium glass, ceramic capacitors.

Promethium – Nuclear batteries, luminous paint.

Samarium - Magnets, lasers, neutron capture.

Europium - Lasers, mercury-vapor lamps, fluorescent lamps, NMR.

Gadolinium - Lasers, X-ray tubes, computer memory, MRI contrast agent, NMR, steel additive.

Terbium - Lasers, magnets, fluorescent lamps.

Dysprosium – Magnets, lasers.

Rare Earth Elements (3)

Holmium - Lasers, magnets, optical spectrophotometers.

Erbium - Infrared lasers, vanadium steel, fiber-optic technology.

Thulium - Lasers, portable X-ray machines, metal-halide lamps.

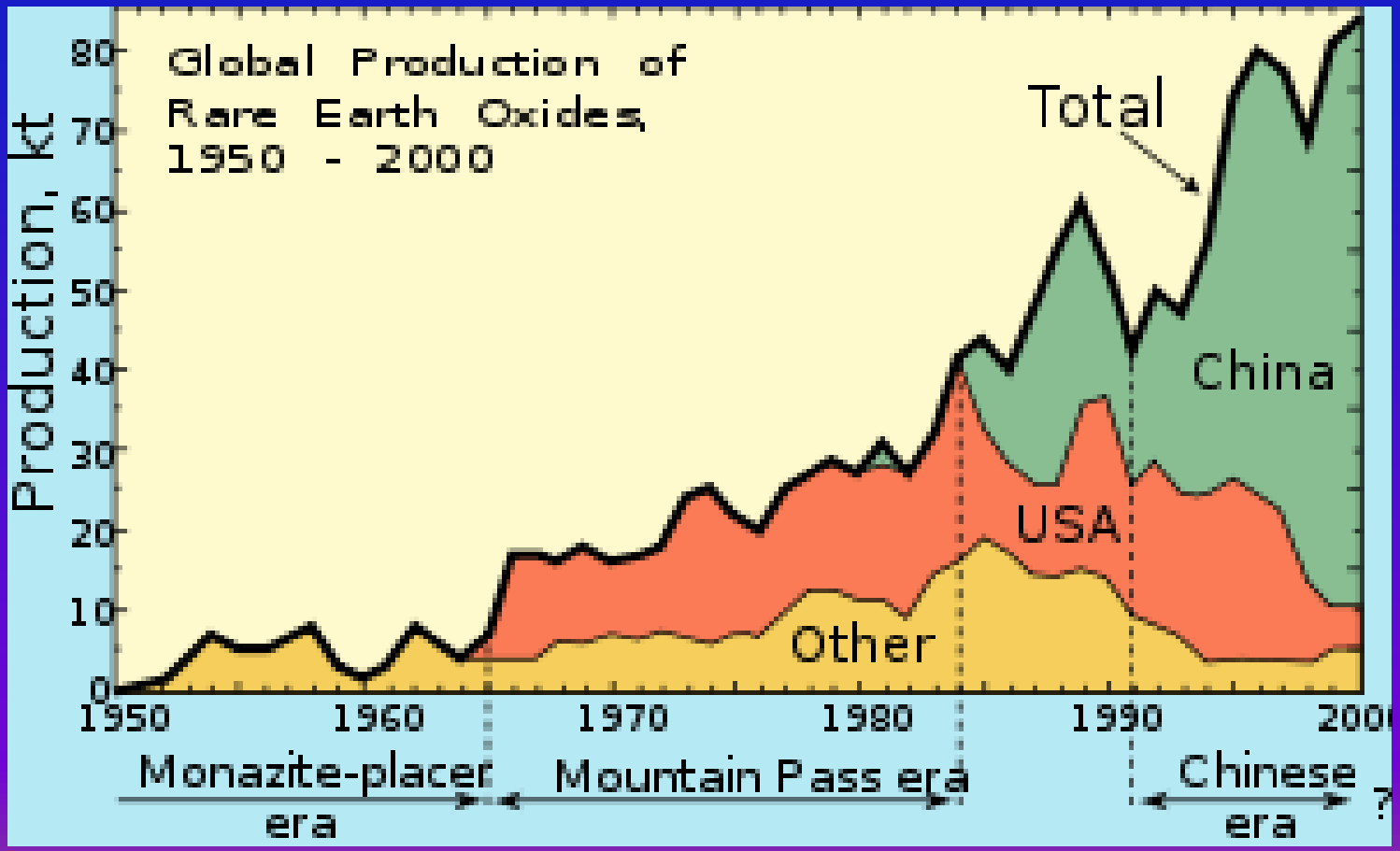
Ytterbium - Infrared lasers, stainless steel, nuclear medicine.

Lutetium - Positron emission tomography (PET scan), high-refractive-index glass.

RARE EARTH ELEMENTS

1950 – 1965 - India, Brazil; 1950s - S. Africa;

1965 -1985 - Mountain Pass, CA; 1985 - China



Rare Earth Elements
Economics and China

China – 90% of world production and exporter

Since 2009 China gradually reduced the export quotas

China forced small independent miners to merge into state-owned corporations

2012 – USA, EU, and Japan confronted China at WTO

2014 – WTO: China had broken free trade agreements

2015 – China lifted all quotas

Rare Earth Elements
World Economics

Searches for alternative sources

Canada, Australia, Vietnam, Greenland –

new sources of REE

North Korea = 2nd largest reserve. Selling to China

Recycling started in Japan, France, Malaysia

Pricing:
- Not exchange-traded
- Not sold in pure form
- Price dictated by demand

Rare Earth Elements Geopolitics

China: Reason for reducing quotas

- Depletion of resource
- Environmental concerns

USA: Dysprosium import “most critical”

- World production of REE = 132,000 metric tons.
- China production of REE = 129,000 metric tons

Solution: 1. New sources

2. Changing production policy

USGS - REE in So. Afghanistan’s Helmand province

1.3 Mil. tons - US$ 7.4 Billion

The World Looked on and Did Nothing

D.R. Congo – "Conflict diamonds" and "Blood diamonds"

Stolen by rebels and sold on the black market for own profit.

D.R. Congo – "Resource Curse" – Coltan

Stolen by insurgent armies and sold to pay mercenaries.

China – Quotas for the Rare Earth Elements

Limiting progress of other countries

What did United Nations do?

"The only thing necessary for the triumph of evil is for good men to do nothing"

E. Burke, 1770

END OF LECTURE # 6